UTAH GEOLOGICAL SURVEY
a division of the
UTAH DEPARTMENT OF NATURAL RESOURCES
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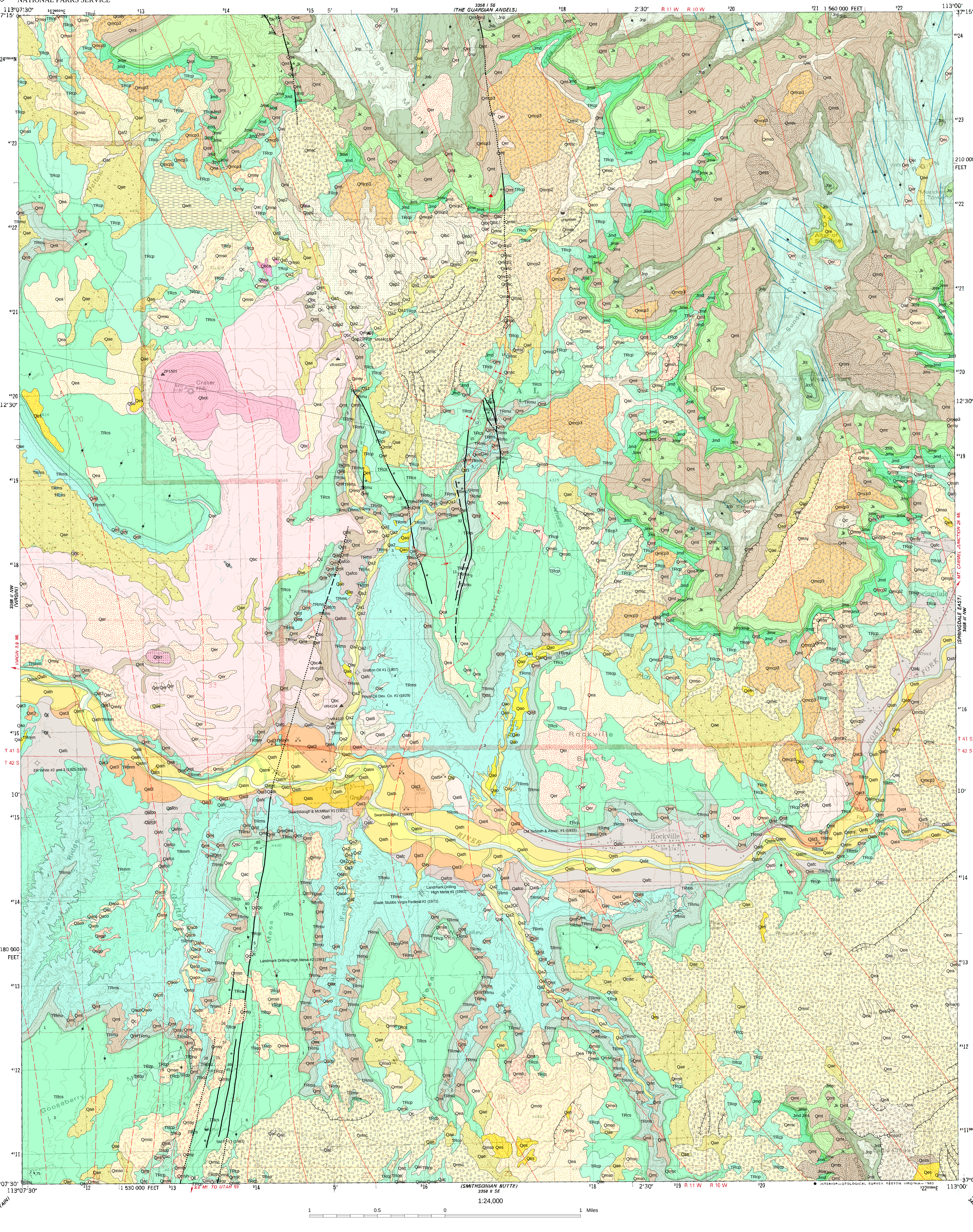
Plate 1
Utah Geological Survey Open-File Report 394
Interim Geologic Map of the Springdale West Quadrangle



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OPEN-FILE REPORT 394 **July 2002**
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Grant C. Willis[1], Hellmut H. Doelling[1], Barry J. Solomon[1], and Edward G. Sable[2]

[1]Utah Geological Survey, [2]U.S. Geological Survey,

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Digital and GIS cartography by:
Kent D. Brown

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6/14/02

Springdale West Quadrangle
Description of Map Units

QUATERNARY

Fill Deposits

Qf **Fill (Historical)** -- Fill in small dams and dikes; most road fill not shown; 0 to 30 feet (0-10 m) thick.

Alluvial Deposits

Low-level alluvial deposits of the Virgin River (upper Holocene) -- Moderately to well-sorted gravel, sand, silt, and clay in lenses and thin layers deposited by fluvial processes in larger, well-graded river valleys; generally reddish brown to pale brown; clasts are subrounded to well-rounded, mixed exotic (derived from sources many miles upstream) and locally derived (from within quadrangle area), and are mostly quartzite, sandstone, basalt, limestone, and chert; most clasts are pebble to small cobble sized; a few locally derived clasts are more than 3 feet (1 m) in diameter; differs from alluvial deposits in small side canyons in that clasts are significantly better sorted and a large percentage are exotic; forms river channels and terraces up to about 25 feet (8 m) above the modern river level; 0 to 30 feet (0-9 m) thick.

Working with low-level terrace deposits in the Springdale area, Hereford and others (1995) recognized four episodes of terrace construction that are distinguished by elevation above the active channel, development of soils and vegetation, dating of trees, and archeological artifacts. Terrace deposits shown on this map approximately correlate with Hereford and others' divisions, but are more generalized -- age and correlation of most terrace segments were determined from aerial photographs and only locally verified, and mapped terrace segments locally include segments from other fluvial episodes too small to map separately.

Qala **Level 1 (active channel) alluvial deposits (Historical)** -- Deposits in active river channel up to average annual high-water line about 4 feet (1.2 m) above modern river channel; deposited or reworked by the Virgin River mostly after A.D. 1980. Note: the river position shown on the gray topographic base map was based on 1973 aerial photographs; the position of the river channel shown on the geologic map (map unit Qala) was based on 1994 aerial photographs; during that time interval, the river channel has migrated significantly (unlike upstream in the Springdale East quadrangle [Doelling and others, 2002]).

Qatm **Level 2 ("modern") alluvial terrace deposits (Historical)** -- Deposits between about 4 feet (1.2 m) and 8 feet (2.4 m) above the active channel; generally vegetated with weeds and shrubs such as tamarisk; commonly covered every few years to decades by floods during unusually high spring runoff and following intense thunderstorms; Hereford and others (1995) referred to these sediments as the "modern" level and noted that they were deposited mostly between A.D. 1940 and 1980.

Qath **Level 3 ("historic") alluvial terrace deposits (Historical)** -- Deposits forming terraces 8 to 15 feet (2.4-4.6 m) above active channel; commonly mantled by fine-grained overbank silt, sand, and clay deposits; vegetated by cottonwood trees and mature shrubs; Hereford and others (1995) called these deposits the "historic" level; historic photographs show that the sediments of this level were deposited mostly between A.D. 1883 and 1926 (1926 to 1940 was a period of arroyo cutting) (Hereford and others, 1995).

Qats **Level 4 (“settlement and late prehistoric”) alluvial terrace deposits (upper Holocene)** -- Deposits forming terraces 15 to 25 feet (4.6-8 m) above the active channel; generally forms a broad terrace along the Virgin River and in side canyons; where not cultivated, surface is covered mostly by sagebrush and is above the zone of abundant cottonwood trees in the river flood plain; in many areas terraces of this level are mostly covered by Qafc deposits; Hereford and others (1995) named this surface the “settlement surface” because it was the main surface for houses and cultivation by earlier pioneer settlers in the middle to late 1800s; they noted that the pioneer fields and settlements on these surfaces were occasionally flooded during unusually high spring runoff; the settlement surface contains no Ancestral Puebloan (Anasazi) Indian artifacts, indicating that the sediment was deposited after about A.D. 1200; Hereford and others (1995) noted that river deposition on this surface ended by about A.D. 1880 as renewed river and arroyo cutting lowered the river channel; as generalized for this map, this unit locally includes surfaces between about 25 and 33 feet (8-10 m), but locally as low as 20 feet (6 m) above the active channel, that are part of what Hereford and others referred to as “prehistoric” and that may date to A.D. 800-1200.

Qat3, Qat4, Qat5, Qat6

High-level alluvial terrace deposits (middle Holocene to middle Pleistocene) -- Moderately to well sorted, pale-gray to pale-brownish-gray cobble gravel with sand, silt, and clay in lenses and matrix; clasts are mostly exotic and consist of quartzite, basalt, sandstone, limestone, and chert; form terrace remnants that cap hills and bluffs near the Virgin River; show moderate soil development; locally partially mantled by windblown sand, colluvium, and talus; as mapped, locally includes a thin apron of colluvium that sloughed downslope from the terraces; terraces of several different levels are grouped into four map units based on height above the nearby active river channel: Qat3 between 30 and 90 feet (9-27m) above the channel, Qat4 from 90 to 140 feet (27-43 m), Qat5 from 140 to 190 (43-58 m),and Qat6 from 190 to 250 feet (58-76 m); 0 to 80 feet (0-24 m) thick.

The age of river-terrace and other deposits that are graded to the Virgin River can be estimated using calculated long-term incision rates, combined with amount of soil development and lithification. Present height of remnants of well-dated basaltic lava that flowed into the ancestral river channel indicates about 1,300 feet (400 m) of incision in the last one million years, or 1.3 feet (0.4 m) per thousand years. Using this rate, Qat3 deposits are calculated between about 20,000 and 70,000 years old, Qat4 deposits between 70,000 and 110,000 years old, Qat5 deposits between 110,000 and 150,000 years old, and Qat6 deposits between 150,000 and 190,000 years old. However, these calculations do not take into account fluctuations in incision rates during this time, which could shift these age estimates significantly; in addition, low-level deposits show incision of 25 feet (8 m) or more in just the last few hundred years, though this type of variation probably reflects short-term cyclicity more than long-term incision rates; thus, Qat3 deposits, which would be affected most by short-term cyclicity, may be as young as middle Holocene.

Qa1 **Level 1 alluvial stream deposits (upper Holocene)** -- Stratified, fine- to coarse-grained, pale-orange to yellowish-brown sand with varying amounts of poorly to moderately sorted clay, silt, and subangular to subrounded pebble to small boulder gravel with sandstone, limestone, and basalt clasts; mapped along larger tributaries of the Virgin River; up to about 10 feet (3 m) above the active channel; less well sorted than Qala and Qatm deposits and does not include exotic clasts; generally less than 10 feet (3 m) thick.

Qa2 **Level 2 alluvial stream deposits (Holocene)** -- Same as Qa1deposits except forms incised terraces 10 to 30 feet (3-9 m) above the active channel and locally covered by windblown silt and fine-grained sand; as much as 20 feet (6 m) thick.

Qay **Younger alluvial deposits (upper Holocene)** -- Similar to and includes deposits equivalent to both Qa1 and Qa2 deposits, but correlation uncertain; includes deposits up to about 30 feet (9 m) above the stream channel.

Qao **Older alluvial deposits (Holocene to Upper Pleistocene)** -- Deeply incised and eroded remnants of older alluvial fan and stream channel deposits 20 to about 80 feet (6-24 m) above nearby washes; mapped in small side channels; 0 to 10 feet (0-3 m) thick.

Qam **Alluvial mud deposits (Holocene to upper Pleistocene)** -- Pale-yellowish-gray to reddish-gray clay and silt, with generally minor sand; locally includes lenses of pebble to cobble gravel; mantles broad gentle slopes on nonresistant units; derived primarily from weathering of Petrified Forest Member of Chinle Formation; 0 to 20 feet (0-6 m) thick.

Qagp **Alluvial gypsiferous deposits (Holocene to upper Pleistocene)** -- Pale- to medium-gray to reddish-gray gypsum, silt, clay, and, and pebble to cobble gravel; forms a moderately resistant punky gypsiferous soil cap over outcrops of Shnabkaib Member of Moenkopi Formation; caps surfaces 20 to 60 feet (6-18 m) above the local washes; 0 to 10 feet (0-3 m) thick.

Qaf2 **Level 2 alluvial-fan deposits (Holocene to upper Pleistocene)** -- Dissected remnants of pale-reddish-brown to reddish-gray, moderately to poorly sorted, boulder- to clay-sized sediment deposited on low to moderate slopes by debris flows and ephemeral streams; locally includes colluvial and talus deposits, and locally mantled by eolian sand; form mounds and erosional remnants up to about 50 feet (15 m) above washes; low-level (younger) alluvial fans are included in Qac and Qae deposits; 0 to 50 or more feet (0-15+ m) thick.

Qap2 **Alluvial pediment-mantle deposits (upper Pleistocene)** -- Dissected remnants of pale-reddish-brown to reddish-gray, moderately to poorly sorted, boulder- to clay-sized sediment that forms a planar cap over erosional remnants of Coal Pits Wash lacustrine and basin-fill deposits; these deposits probably developed after the basin filled with lacustrine and marginal lacustrine sediments, allowing ephemeral streams to reestablish across the surface; they were incised as the streams cut through the natural dam; 0 to 30 feet (0-9 m) thick.

Mixed Alluvial, Colluvial, and Eolian Deposits

Qafc **Young alluvial-fan and colluvial deposits (Holocene to upper Pleistocene)** -- Reddish-brown, poorly stratified, poorly sorted, coarse- to fine-grained sand and pebble to cobble gravel with silt and scattered boulders; clasts are angular to subangular and locally derived; deposited by debris flows and sheet wash at decrease in slopes and at mouths of small ephemeral channels that flow into Virgin River valley and major tributaries; mostly graded to and partially mantle Qath and Qats alluvial deposits, and commonly includes small secondary fans (not mapped separately) inset into main deposit that are graded to the active or modern channel; commonly interfingers with and covers alluvial stream deposits; forms most surfaces cultivated and built on by communities of Rockville and Springdale; in many areas debris flows have surged across these surfaces in historical times, sometimes causing considerable damage to buildings and roads; 0 to 30 feet (0-9 m) thick.

Qafco **Middle-level alluvial-fan and colluvial deposits (lower Holocene to upper Pleistocene)** -- Similar to Qafc deposits described above, except deposits are graded to older alluvial surfaces (Qat3 and Qat4), are incised by modern stream channels, and are no longer accumulating sediment; deposited by debris flows issuing from small side canyons; thickness probably less than 20 feet (6 m).

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 stream channels.

Qae **Mixed alluvial and eolian deposits (Holocene to upper Pleistocene)** -- Locally derived, moderately to moderately well-sorted, mostly silt, clay, and fine sand with scattered lenses of subangular to angular gravel; deposited in shallow topographic depressions and on broad gentle slopes by slope wash and wind; includes small fans and colluvium from adjacent slopes; 0 to 20 feet (0-6 m) thick.

Qea **Mixed eolian and alluvial deposits (Holocene to upper Pleistocene)** -- Well-sorted, pale-reddish-brown to pale-yellowish-gray, windblown sand locally redeposited by alluvial processes; locally includes minor alluvial gravel; covers broad, gently sloping surfaces; deposits are relatively old and stable and are isolated from most erosion, allowing eolian sediments to gradually accumulate; scattered incisions through the deposits reveal stage II to IV pedogenic carbonate soil; generally 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; occurs as sheets, mounds, and poorly formed dunes 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; one small exposure on Altar of Sacrifice in northeast part of quadrangle; 0 to 10 feet (0-3 m) thick.

Colluvial, Mass-Movement, and Related Deposits

Qc **Colluvium (Holocene to upper Pleistocene)** -- Poorly sorted, nonstratified sand and silt with subangular to angular mostly sandstone blocks; color and clast composition vary with parent material; deposited primarily by creep and slope wash on moderate slopes; locally includes talus and alluvial deposits; generally less than 20 feet (6 m) thick.

Qmt **Talus (Holocene to upper Pleistocene)** -- Primarily very poorly sorted, coarse, angular blocks on steep slopes; fine-grained interstitial component varies from abundant to absent; composed of blocks derived from immediately upslope ledges and cliffs; locally contains small landslide and slump masses 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.

Qmts **Talus sand (Holocene to upper Pleistocene)** -- Cone-shaped deposits of sand commonly mantling talus, colluvium, and other slope-forming units; locally contains small landslide and slump masses and boulders with diameters exceeding 30 feet (9 m); sand was mostly derived from eroding bare sandstone exposed upslope; locally concentrated by wind; up to 20 feet (6 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 bentonitic mudstone and claystone in the Petrified Forest Member of the Chinle Formation and the Kayenta 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 or human activity; vary greatly in thickness, but most are probably less than 50 feet (15 m) thick.

Qmso **Older undifferentiated mass-movement slide and slump deposits (lower Holocene to Pleistocene)** -- Similar to Qmsy deposits but forms isolated mounds and erosional remnants of once larger landslide masses; locally may be more than 300 feet (90 m) thick.

Qmsc, Qms(n)
Undifferentiated landslide complex (Holocene to Pleistocene) -- Large complex mass of slump, slide, and earthflow deposits; forms large hummocky mounds and hills; includes older, younger, and historical landslide deposits; locally reactivated with historical movement along and upslope from incised channels; large mostly intact blocks of Navajo Sandstone mapped as Qms(n); 0 to 200 feet (0-60 m) thick.

Qms(b) **Collapsed blocks of basalt (lower Holocene to upper Pleistocene?)** -- Large blocks of Crater Hill basalt flow that collapsed and slid after softer underlying sedimentary rocks were eroded out by streams; age poorly constrained.

Qmcp1, Qmcp2, Qmcp3
Older mass-movement, colluvial, and alluvial pediment-mantle deposits (lower Holocene to Pleistocene) -- Remnants of poorly sorted 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 angular and subangular, up to house-sized boulders to fine-grained sand, and lesser amounts of silt and clay derived from local cliffs and ledges; color is dependent on source formations; 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 the ancestral Virgin River, which, at the time of deposition, must have been up to several hundred feet above its present position or, are the remnants of sloping erosional surfaces mantled and protected from erosion by the coarse deposits and were not graded to the river; mapped deposits locally include aprons of colluvium derived from the pediment-mantle deposits; as much as 30 feet (9 m) thick; graded to several levels that project up to 700 feet (210 m) above the modern river channel; here divided into low-level

(Qmcp1, in which the inclined surface projects less than about 100 feet [30 m] above the river), middle-level (Qmcp2, about 100 to 200 feet [30-60 m]), and high-level (Qmcp3, 200 to 700 feet [60-180 m]) deposits.

Lacustrine and Basin-Fill Deposits

Qlbc **Lacustrine and basin-fill deposits of Coal Pits Wash (upper Pleistocene)** -- Well-sorted, pale-yellowish-brown, to pale-reddish-brown, thin-bedded to laminated, planar-bedded clay, silt, sand, and marl; locally with soft-sediment slump features; form remnants draped across older alluvial, mass-movement, and bedrock deposits; locally as much as 150 feet (45 m) thick; coarser grained in distal areas where grades into alluvial and colluvial deposits; deposits rest directly on a basaltic ash in some areas; lake formed by basalt flow that filled Coal Pits Wash (north-central part of quadrangle) and impinged against older landslide deposits; estimated at about 100,000 years old; 0 to 150 feet (0-45 m) thick.

Qlg **Lacustrine and basin-fill deposits of ancestral Lake Grafton (upper Pleistocene)** -- Pale-gray, pale-yellowish-brown, and medium-greenish-gray, planar, thin-bedded to laminated clay, silt, sand, and marl; deposited directly on a basaltic ash; deposited in a large lake that formed behind a basalt dam formed by flows from the Crater Hill eruption that dammed the Virgin River; the lake extended upriver into the southern part of Zion Canyon; only one small exposure in NE1/4 section 3, T. 42 S., R. 11W.; about 60 feet (20 m) thick, though base is poorly exposed; estimated at about 100,000 years old.

Qbc, Qbcc, Qbca, Qbcr

Basaltic flows, cinders, ash, and rafted block of Crater Hill (upper(?) Pleistocene) -- Medium-gray (fresh surfaces), weathering to dark-brownish-gray to dark-brownish-black, olivine basalt to trachybasalt (table 1); vesicular to dense; locally jointed; forms prominent cinder cone with a large mound of cinders (Qbcc) that may have been deposited by a directed plume eruption or wind drift; basaltic ash (Qbca) is preserved in several areas to the northeast of the cone, and one locality to the southeast; upper surface of flows (Qbc) generally has large arcuate flow ridges and locally a large rafted and tilted block (Qbcr) once considered a separate cinder cone and vent (Nielson, 1977); strongly weathered upper surface mostly covered by eolian and alluvial deposits; rubbly base where exposed; flow is typically 40 to 80 feet (12-24 m) thick, but locally up to 400 feet (120 m) thick where it ponded in Virgin River and ancestral Coal Pits Wash channels; base is about 125 feet (38 m) above modern river channel (appears higher along State Highway 9 because the cliff face exposes a higher level of the dish-shaped flow); caps broad sloping bench in north-central part of quadrangle; estimated at 100,000 years old.

JURASSIC

Carmel Formation

Jccl **Lower unit of Co-op Creek Limestone Member** -- In quadrangle, only lowermost part of lower unit is preserved as an inaccessible outcrop at the top of The West Temple; description is based on exposures in adjacent quadrangles. Mostly thinly laminated to thin-bedded, pale-yellowish-gray weathering, calcareous shale and platy limestone; local rip-up clast conglomerate at the base; 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; forms low, sloping, vegetated cap on top of the Temple Cap Formation; deposited in a marine (shallow sea) environment; probably less than 60 feet (18 m) preserved.

J-2 unconformity

Temple Cap Formation -- forms inaccessible outcrops capping Towers of the Virgin in northeast part of quadrangle; descriptions based on exposures in adjacent quadrangles.

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; upper contact is sharp and marked by a reddish zone at the base of the Co-op Creek Limestone Member of the Carmel Formation; estimated at 80 to 100 feet (24-30 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; estimated at 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 locally 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; 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 pale-gray, yellowish-gray, orangish-gray, to white because of alteration, remobilization, and bleaching of limonitic and hematitic (iron-bearing) cement; generally forms a massive cliff; includes upper 400 to 800 feet (120-240 m) of the formation in Zion National Park.

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 a 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 60 feet (0-18 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 pale-greeenish-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 to dark reddish-orange to pale-reddish-brown, thin-bedded siltstone, very fine-grained sandstone, and claystone; near the base, contains a minor amount of conglomerate similar to beds in underlying Petrifed Forest Member of 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 **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; weathers as badlands; prone to landsliding; 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.

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; 200 to 280 feet (60-85m) 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; total member is probably about 400 feet (120 m) thick.

TRmm **Middle red member of Moenkopi Formation** -- Interbedded, laminated to thin-bedded, moderate reddish-brown to moderate-reddish-orange siltstone, mudstone, and very fine-grained sandstone; white to greenish-gray gypsum beds and veins are common, especially in the lower part; upper contact is conformable and gradational and corresponds to the base of the first thick gypsum bed; deposited in tidal-flat environment; about 400 to 450 feet (120-140 m) thick.

unconformity

PERMIAN

P **Permian strata, undifferentiated** -- Shown in cross section only; includes Kaibab, Toroweap, and Queantoweap Formations; probably about 3,000 feet (600 m) thick beneath quadrangle.

REFERENCES

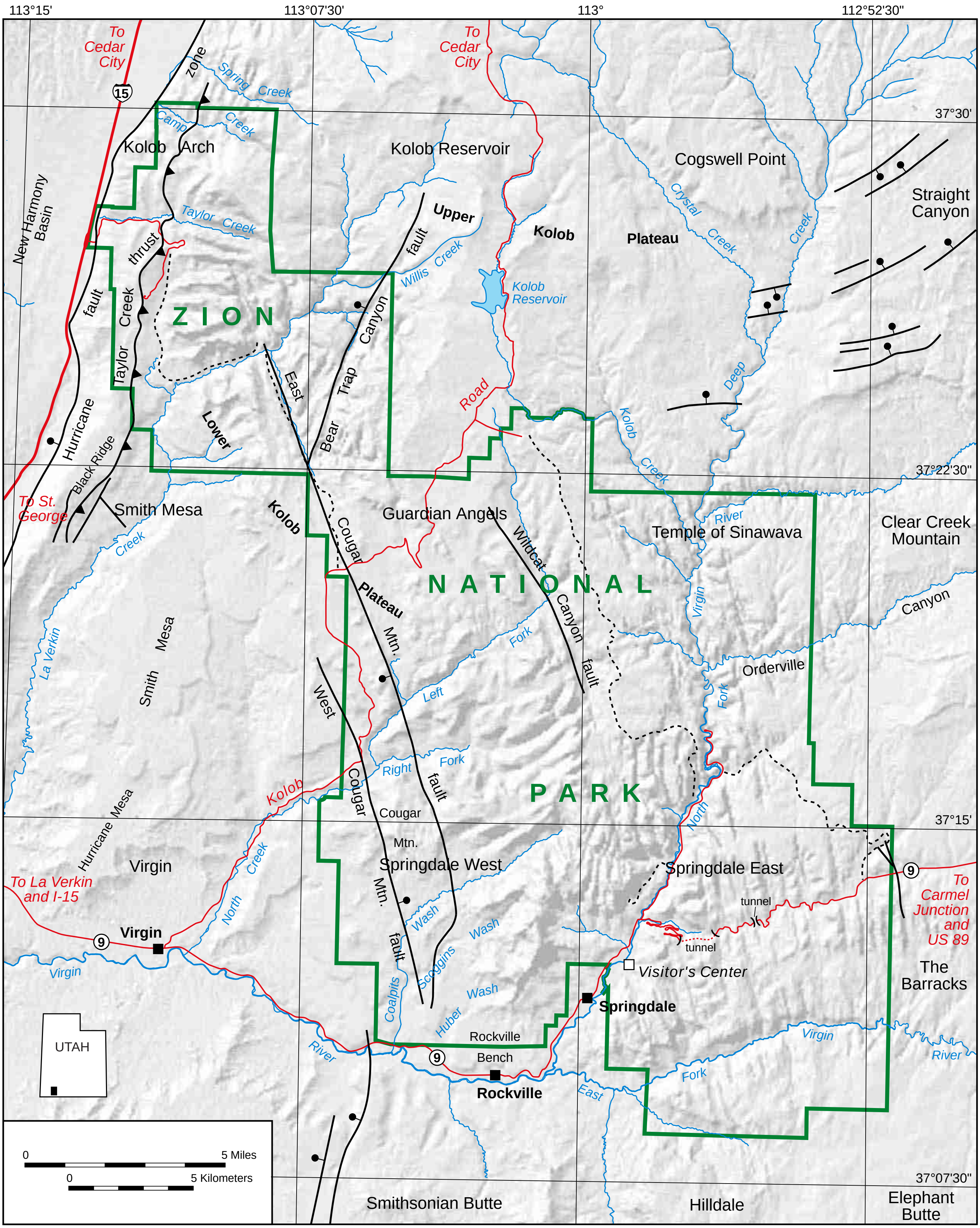
Doelling, H.H., Willis, G.C., Solomon, B.J., Sable, E.G., Hamilton, W.L., and Naylor, L.P., 2002, Interim geologic map of the Springdale East quadrangle, Washington County, Utah: Utah Geological Survey Open-File Report xxx, 1:24,000.

Hereford, R., Jacoby, G.C., and McCord, V.A.S., 1995, Geomorphic history of the Virgin River in the Zion National Park area, southwest Utah: U.S. Geological Survey Open-File Report 95-515, 75 p.

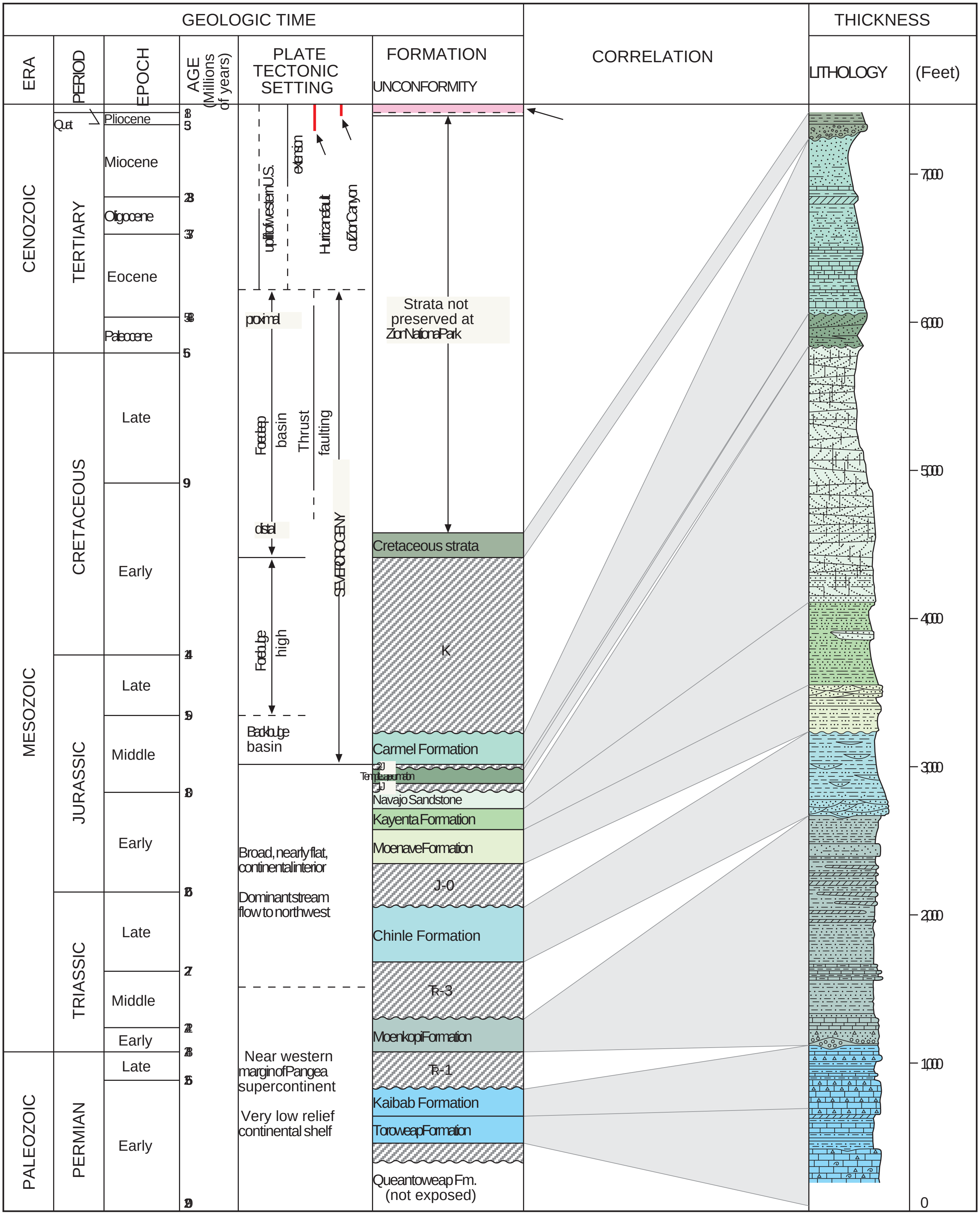
Nielson, R.L., 1977, The geomorphic evolution of the Crater Hill volcanic field of Zion National Park: Brigham Young University Geology Studies, v. 24, pt. 1, p. 55-70, map scale 1:47,000.

Caption for plate 2 index map:

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.



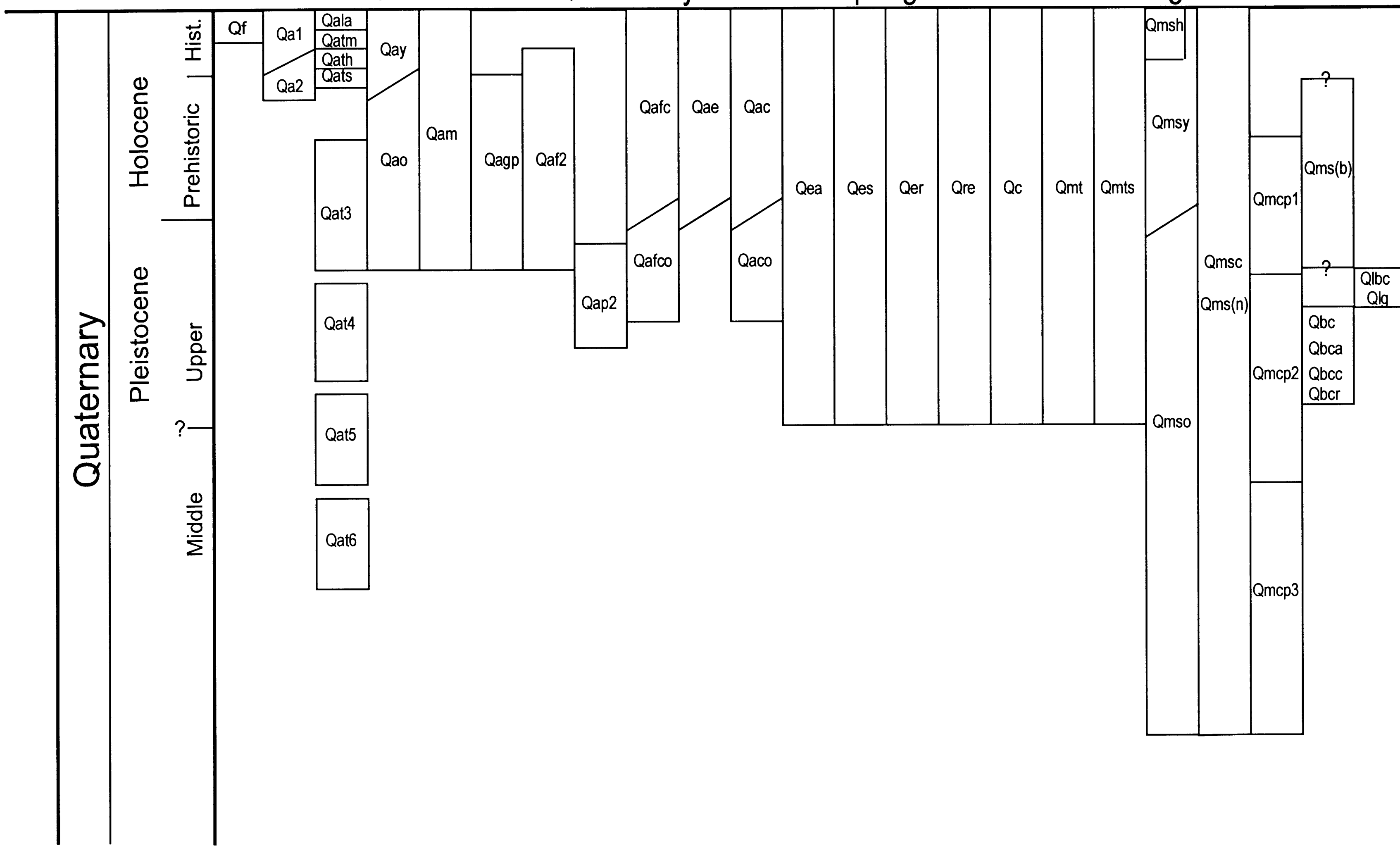
113°15'
113°07'30"
113°
112°52'30"
37°30'
37°22'30"
37°15'
37°07'30"
To Cedar City
To Cedar City
15
Kolob Arch
Kolob Reservoir
Cogswell Point
Straight Canyon
New Harmony Basin
Upper
Kolob
Plateau
Kolob Reservoir
Z I O N
N A T I O N A L
P A R K
Guardian Angels
Temple of Sinawava
Clear Creek Mountain
Smith Mesa
To St. George
Lower
Kolob
Plateau
Hurricane Mesa
Virgin
To La Verkin and I-15
Virgin
9
Springdale West
Springdale East
Cougar
Mtn.
Visitor's Center
Springdale
Rockville
Bench
Rockville
tunnel
tunnel
To Carmel Junction and US 89
The Barracks
9
UTAH
Smithsonian Butte
Hilldale
Elephant Butte
0
5 Miles
0
5 Kilometers
Hurricane
fault
thrust
zone
Taylor
Creek
Black Ridge
East
Cougar
Mtn.
fault
West
Cougar
Mtn.
fault
Wildcat
Canyon
fault
Bear
Trap
Canyon
fault
Spring Creek
Camp Creek
Taylor Creek
Willis Creek
Crystal Creek
Creek
Deep
Kolob Creek
River
Virgin
Orderville
Canyon
Fork
Left
Fork
Right
Fork
North
Fork
Kolob
Creek
North
Creek
La Verkin
Creek
Virgin
River
Wash
Scoggins
Wash
Coalpits
Wash
Huber
Virgin
River
East
Fork
Road



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

Correlation of Quaternary Units Springdale West Quadrangle

7/02



Geochemistry of samples collected from the Crater Hill basalt flow in the Springdale West quadrangle.

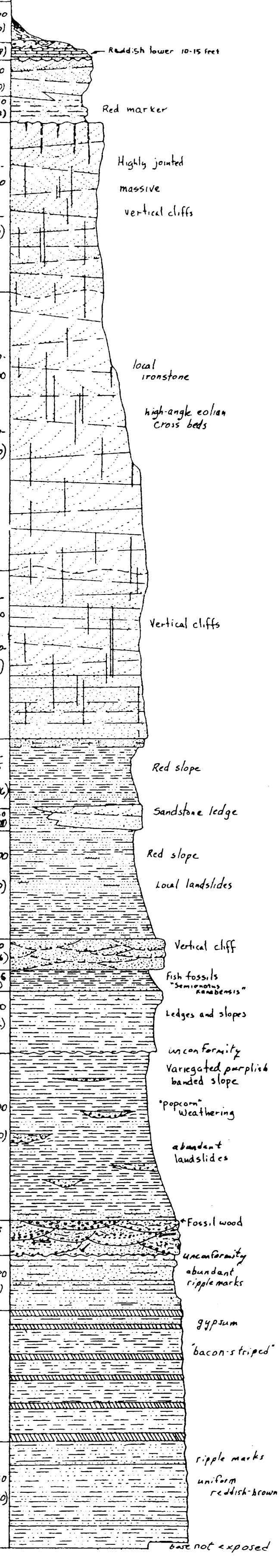
Sample No.	Latitude	Longitude	Collected	Ar-Ar Age	Al2O3	CaO	Cr2O3	Fe2O3	K2O	MgO	MnO	Na2O	P2O5	SiO2	TiO2	LOI	TOTAL
VR-4102	37.174	113.083	03/19/1997		13.43	8.92	0.02	11.2	1.64	9.34	0.15	2.98	0.46	48.54	1.61	0.01	98.3
VR-4103	37.18	113.085	03/19/1997		13.43	8.84	0.03	11.07	1.83	9.39	0.16	3.12	0.47	48.3	1.57	0.01	98.22
VR-4104	37.176	113.082	03/19/1997		13.33	8.94	0.03	11.09	1.72	9.93	0.16	3.02	0.5	47.67	1.72	0.01	98.12
VR-4401R	37.216	113.078	04/17/1997		14.21	8.86	0.04	10.82	1.48	8.75	0.15	3.03	0.43	49.58	1.44	0.01	98.8
VR-4402R	37.214	113.082	04/17/1997		12.37	9.59	0.03	11.45	1.83	10.2	0.16	2.93	0.55	46.52	1.91	0.41	97.95

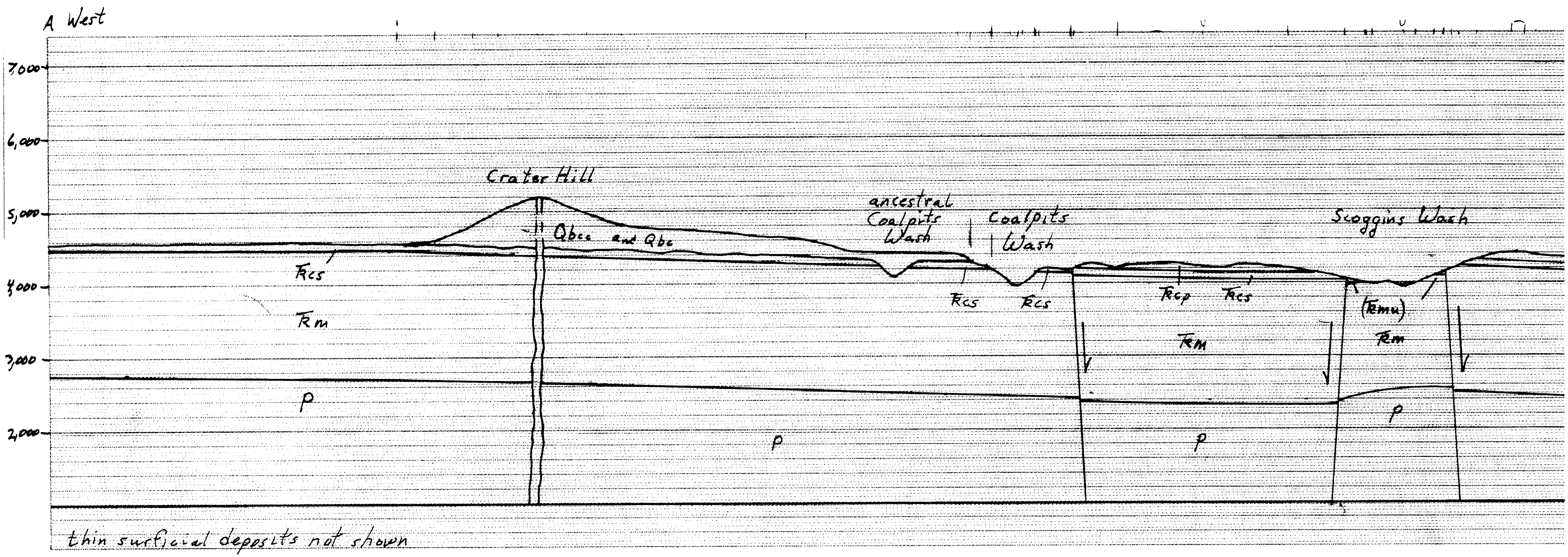
	Hf	La	Nb	Rb	Sr	Ta	Y	Zr
VR-4102	4	38	32	16	574	3	21	142
VR-R4103	3	38	31	17	573	3	21	139
VR-4104	4	41	36	16	621	3	21	152
VR-4401R	3	35	29	15	557	2	21	133
VR-4402R	3	43	42	19	642	3	21	161

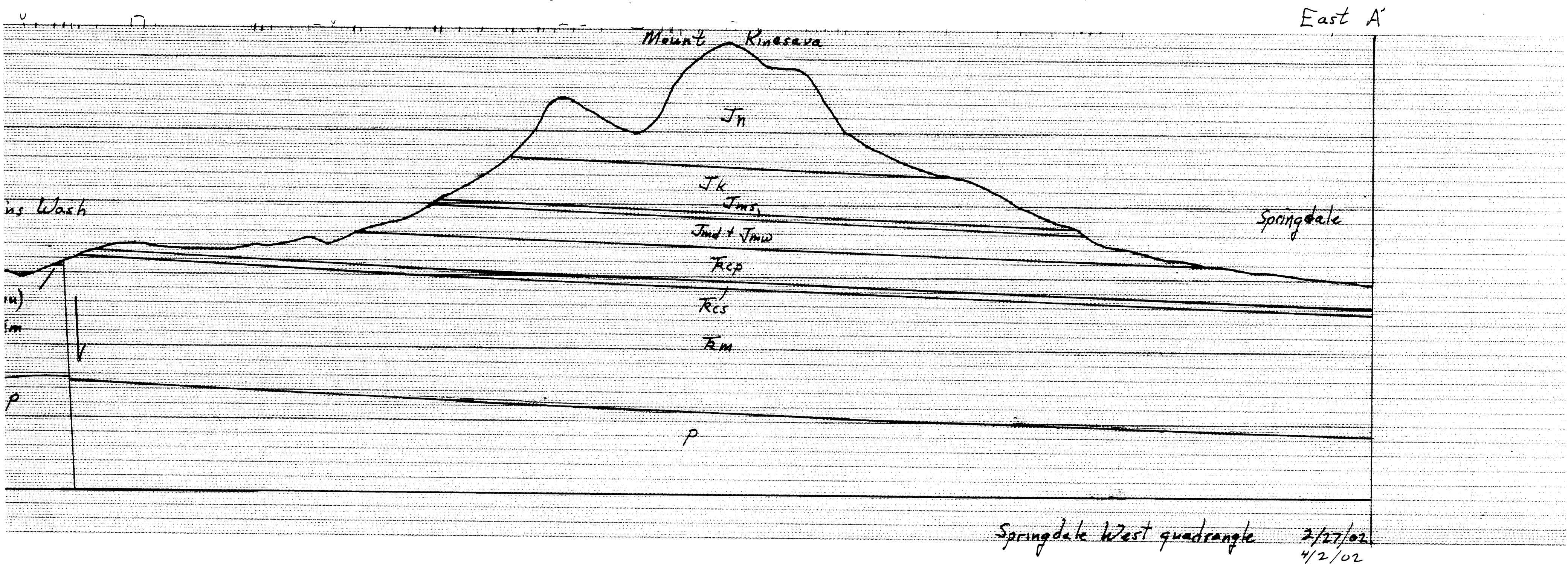
Springdale West Quadrangle 4/02

System	Series	Formations, members, & other units		Symbol	Thickness feet (meters)
Quaternary	Holocene & Pleistocene	Alluvial, mass-movement, eolian, basalt and other surficial deposits		Various Q	0-400 (0-120)
Jurassic	Middle	Carmel Formation	Co-op Creek Ls Member - Lower unit	Jccl	<60 (<18)
		Temple Cap Formation	White Throne Member	Jtw	80-100 (24-30)
			Sinawava Member	Jts	100-140 (30-42)
	Lower	Navajo Sandstone 1,800-2,200 (550-670)	white Navajo	Jnw	400-800 (120-240)
			pink Navajo	Jnp	400-1,000 (120-300)
			brown Navajo	Jnb	400-600 (120-180)
		Kayenta Formation 550-700 (170-210)	Tenney Canyon Member	JKt	140-315 (43-96)
			Lamb Point Tongue of Navajo Sandstone	Jnl	0-60 (0-18)
			main body	JK	290-400 (88-120)
		Moenave Fm.	Springdale Sandstone Mbr.	Jms	90-150 (27-46)
			Whitmore Point Mbr.	Jmw	60-86 (18-26)
			Dinosaur Canyon Member	Jmd	150-270 (46-82)
Triassic	Upper	Chinle Formation	Petrified Forest Member	₨cp	400-500 (120-150)
			Shinarump Conglomerate	₨s	60-135 (18-41)
	? Mid	Moenkopi Formation	upper red member	₨mu	200-280 (60-85)
	Lower		Shnabkaib Member	₨ms	400± (120±)
			middle red member	₨mm	400-450 (120-140)

LITHOLOGY




A West
7,000
6,000
5,000
4,000
3,000
2,000
Crater Hill
Qbcs and Qbc
ancestral Coalpits Wash
Coalpits Wash
Scoggins Wash
T̄Rcs
T̄Rm
T̄Rcp
(T̄Rmu)
P
thin surficial deposits not shown


East A'
Mount Kinesava
ns Wash
Jn
Jk
Jms
Jmd + Jmw
Springdale
Rcp
Rcs
Rm
P
u)
m
P
Springdale West quadrangle
2/27/02
4/2/02