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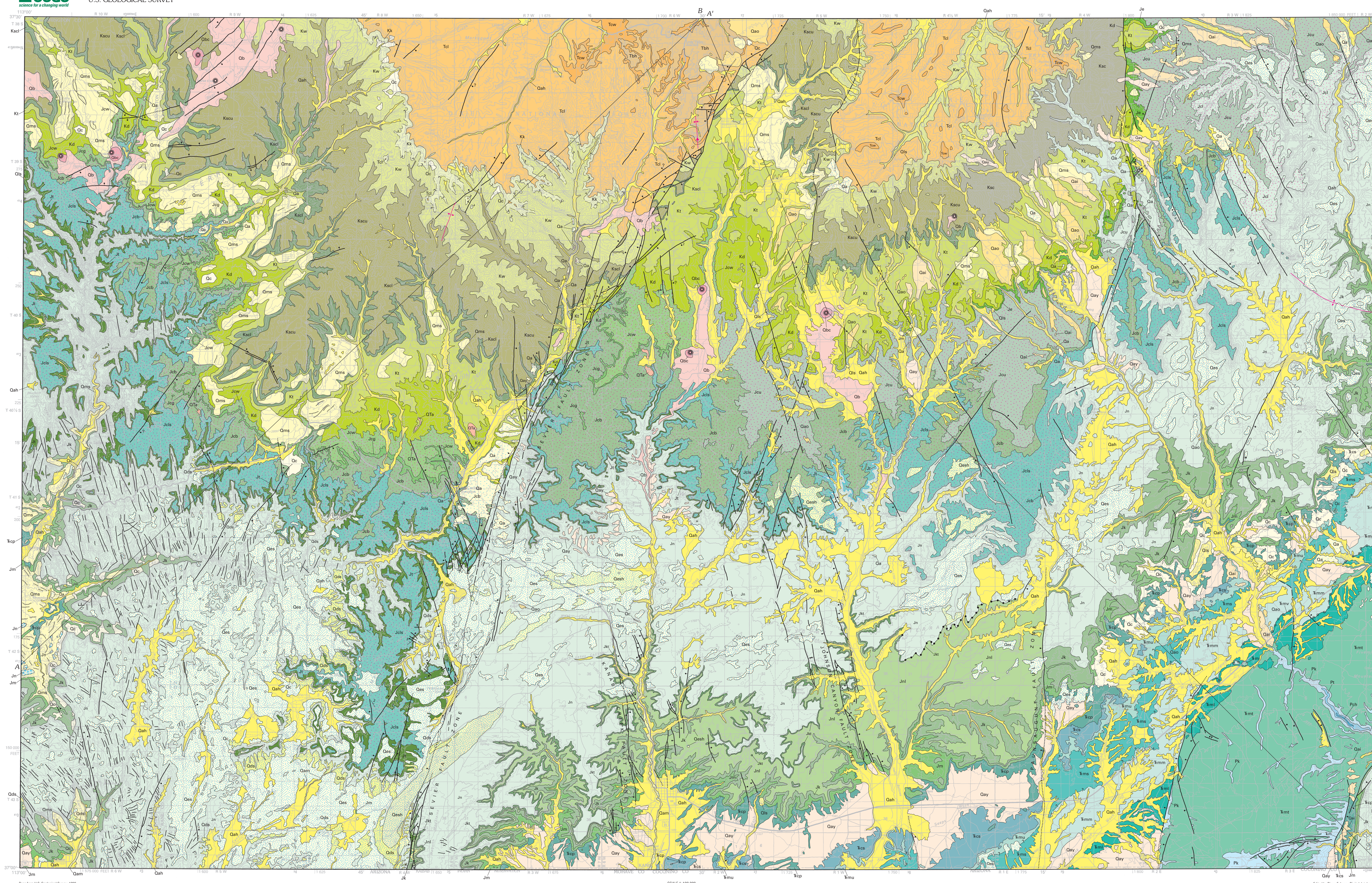
U.S. GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS SERIES I–2655



Base from U.S. Geological Survey, 1980
Projection and 10,000-meter grid, zone 12
Universal Transverse Mercator
25,000-foot grid ticks based on Utah coordinate system, south zone. 1927 North American datum

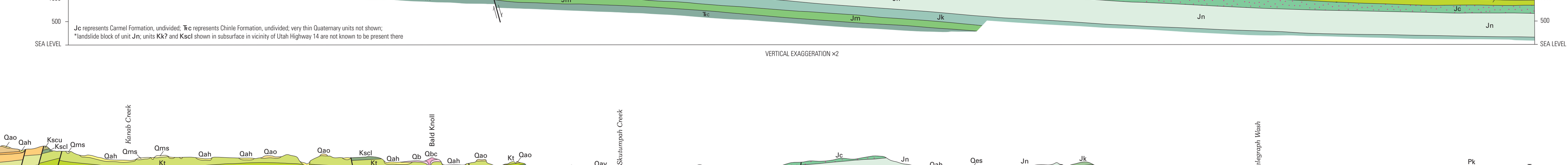
APPROXIMATE MEAN DECLINATION, 1980

SCALE 1:100 000

CONTOUR INTERVAL 50 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

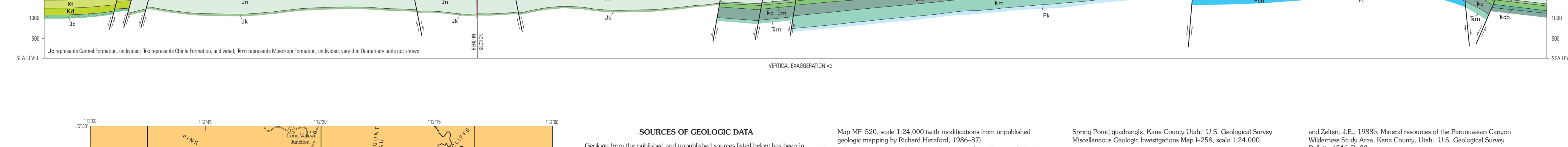
Edited by Diane E. Lane. Digital database by David Maxwell, Southern Utah University, and Jeremiah Workman. Graphics and digital cartography by Diane E. Lane, William Sowers, Dennis Welp, and Jeremiah Workman

Manuscript approved for publication July 23, 1998



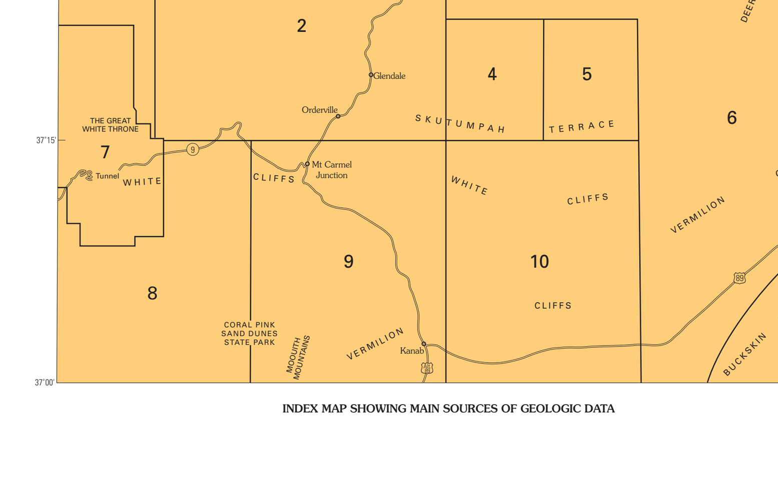
Jc represents Carmel Formation, undivided; TRc represents Chinle Formation, undivided; very thin Quaternary units not shown;
*landslide block of unit Jn; units Kk? and Kscl shown in subsurface in vicinity of Utah Highway 14 are not known to be present there

VERTICAL EXAGGERATION ×2



Jc represents Carmel Formation, undivided; TRc represents Chinle Formation, undivided; TRm represents Moenkopi Formation, undivided; very thin Quaternary units not shown

VERTICAL EXAGGERATION ×2



INDEX MAP SHOWING MAIN SOURCES OF GEOLOGIC DATA

SOURCES OF GEOLOGIC DATA

Geology from the published and unpublished sources listed below has been in part modified and adjusted to fit the topographic base. Principal sources are given first. Amount of data used from additional sources, including photogeologic maps, dissertations, and topical studies, varies widely. Sources are keyed by number to index map.

1. Geologic mapping (1985, 1986, 1989) and compilation by Sable in part published in Van Loenen and others (1988a,b;1989; see entry 8, below).
   Gustason, E.R., 1989, Stratigraphy and sedimentology of the middle Cretaceous (Albian-Cenomanian) Dakota Formation, southwestern Utah: Boulder, University of Colorado, Ph.D. dissertation, 376 p.
   Moir, G.J., 1974, Depositional environments and stratigraphy of the Cretaceous rocks, southwestern Utah: Los Angeles, University of California, Ph.D. dissertation, 316 p.
   Pillmore, C.L., 1956a, Photogeologic map of the Orderville Canyon NW [now Cogswell Point] quadrangle, Kane and Washington Counties, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–188, scale 1:24,000.
2. Cashion, W.B., 1967, Geologic map of the south flank of the Markagunt Plateau, northwest Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–494, scale 1:62,500 (with modifications from unpublished geologic mapping by Sable, 1989).
   Gustason, E.R., 1989, Stratigraphy and sedimentology of the middle Cretaceous (Albian-Cenomanian) Dakota Formation, southwestern Utah: Boulder, University of Colorado, Ph.D. dissertation, 376 p.
   Moir, G.J., 1974, Depositional environments and stratigraphy of the Cretaceous rocks, southwestern Utah: Los Angeles, University of California, Ph.D. dissertation, 316 p.
3. Bowers, W.E., 1990, Geologic Map of Bryce Canyon National Park and vicinity, southwestern Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I–2108, scale 1:24,000; text, 15 p.
4. Goode, H.D., 1973a, Preliminary geologic map of the Bald Knoll quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–520, scale 1:24,000 (with modifications from unpublished geologic mapping by Richard Hereford, 1986–87).
5. Goode, H.D., 1973b, Preliminary geologic map of the Skutumpah Creek quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF–521, scale 1:24,000 (with modifications from unpublished geologic mapping by Richard Hereford, 1986–87).
6. Geologic mapping and compilation by Richard Hereford, 1981–89, with minor additions from Doelling and Davis (1989, pls. 1 and 2).
   Bowers, W.E., 1975, Geologic map and coal resources of the Henrieville quadrangle, Garfield and Kane Counties, Utah: U.S. Geological Survey Coal Investigations Map C–74, scale 1:24,000.
   Bowers, W.E.,1990, Geologic map of Bryce Canyon National Park and vicinity, southwestern Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I–2108, scale 1:24,000; text, 15 p.
   Doelling, H.H., and Davis, F.D., 1989, The geology of Kane County, Utah—Geology, mineral resources, geologic hazards, *with sections on* Petroleum and carbon dioxide by C.J. Brandt: Utah Geological and Mineral Survey Bulletin 124, 192 p.; and Map 121 to accompany Bulletin 124, 10 pls., scale 1:100,000.
   Hackman, R.J., 1957a, Photogeologic map of the Buckskin Gulch NE [now Eight-Mile Pass] quadrangle, Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–259, scale 1:24,000.
   ———1957b, Photogeologic map of the Buckskin Gulch NW [now Nephi Point] quadrangle, Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–241, scale 1:24,000.
   ———1957c, Photogeologic map of the Buckskin Gulch SW [now Petrified Hollow] quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–244, scale 1:24,000.
   Hereford, Richard, 1988, Geology of the Cannonville quadrangle, Kane and Garfield Counties, Utah: Utah Geological and Mineral Survey Open-File Report OFR–142, 1 sheet and text, 17 p., scale 1:24,000.
   Orkild, P.P., 1957, Photogeologic map of the Rainbow Point SE [now Deer Spring Point] quadrangle, Kane County Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–258, scale 1:24,000.
   Tilton, Terry, 1991, Provisional geologic map of the Alton quadrangle, Kane County Utah: Utah Geological and Mineral Survey Contract Report 91–1, 2 sheets and text, 46 p., scale 1:24,000.
7. Hamilton, W.L., 1978, Geological map of Zion National Park, Utah: Springdale, Utah, Zion Natural History Association, scale 1:31,680 (with minor modifications from unpublished geologic mapping by E.G. Sable).
8. Geologic mapping and compilation by E.G. Sable in part published in Van Loenen and others (1988a,b; 1989) and Sable and Doelling (1990, 1993) (see below).
   Pillmore, C.L., 1956b, Photogeologic map of the Springdale NE [now The Barracks] quadrangle, Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–148, scale 1:24,000.
   ———1956c, Photogeologic map of the Springdale SE [now Elephant Butte] quadrangle, Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–131, scale 1:24,000.
   ———1956d, Photogeologic map of the Springdale SW [now Hildale] quadrangle, Kane and Washington County, Utah, and Mohave County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–132, scale 1:24,000.
   Sable, E.G., and Doelling, H.H., 1990, Geologic map of Elephant Butte quadrangle, Kane County, Utah, and Mohave County, Arizona: Utah Geological and Mineral Survey Map 126, 2 sheets and text, 10 p., scale 1:24,000.
   ———1993, Geologic map of the Barracks quadrangle, Kane County, Utah: Utah Geological and Mineral Survey Map 147, 2 sheets and text, 11 p., scale 1:24,000.
   Van Loenen, R.E., Sable, E.G., Blank, H.R., Jr., Turner, R.L., Kreidler, T.J., Zelten, J.E., and Cook, K.L., 1988a, Mineral resources of the Canaan Mountain and the Watchman Wilderness Study Areas, Washington and Kane Counties, Utah: U.S. Geological Survey Bulletin 1746–A, 26 p.
   Van Loenen, R.E., Sable, E.G., Blank, H.R., Jr., Barton, H.N., Cook, K.L., and Zelten, J.E., 1988b, Mineral resources of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah: U.S. Geological Survey Bulletin 1746–B, 22 p.
   Van Loenen, R.E., Sable, E.G., Blank, H.R., Jr., Barton, H.N., Briggs, P.H., Zelton, J.E., and Cook, K.L., 1989, Mineral resources of eight wilderness study areas bordering Zion National Park, Washington and Kane Counties, Utah: U.S. Geological Survey Bulletin 1746–E, 23 p.
9. Sargent, K.A., and Philpott, B.C., 1987, Geologic map of the Kanab quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Geologic Quadrangle Map GQ–1603, scale 1:62,500.
   Detterman, J.S., 1956, Photogeologic map of the Kanab SE [now Kanab 7½-minute] quadrangle, Kane County, Utah, and Mohave and Coconino Counties, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–137, scale 1:24,000.
   Pillmore, C.L., 1956e, Photogeologic map of the Kanab SW [now Yellow Jacket Canyon] quadrangle, Kane County, Utah, and Mohave County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–138, scale 1:24,000.
10. Sargent, K.A., and Philpott, B.C., 1985, Geologic map of the Johnson quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Geologic Quadrangle map GQ–1602, scale 1:62,500.
   Detterman, J.S., and Hackman, R.L., 1957, Photogeologic map of the Johnson SE [now Johnson Lakes] quadrangle, Kane County, Utah, and Coconino County Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–248, scale 1:24,000.
   Pomeroy, J.S., 1958, Photogeologic map of the Johnson NW [now Mount Carmel] quadrangle, Kane County, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–267, scale 1:24,000.
11. Unpublished geologic mapping by K.A. Sargent, 1979–80.
   Minard, J.P., 1957, Photogeologic map of the Buckskin Gulch SE [now Pine Hollow Canyon] quadrangle, Kane County, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–260, scale 1:24,000.

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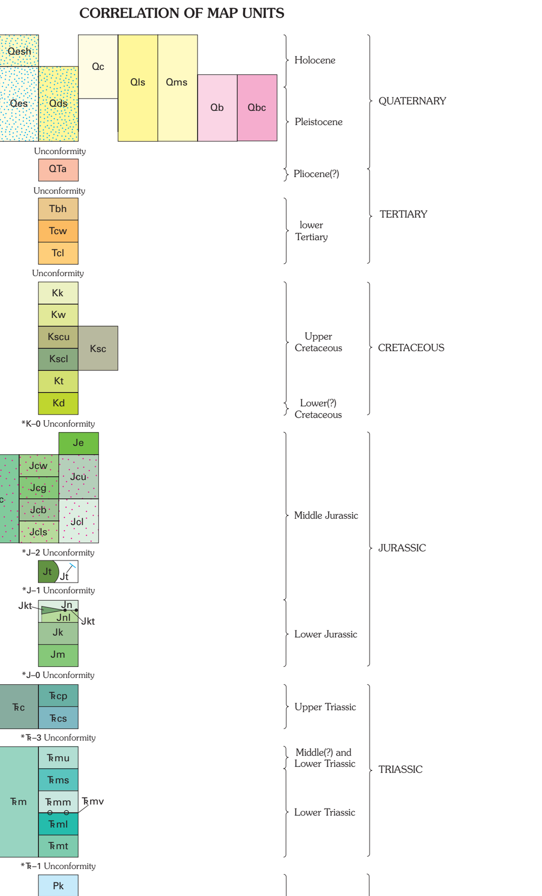
GEOLOGIC MAP OF THE KANAB 30´ × 60´ QUADRANGLE, UTAH AND ARIZONA

By
E.G. Sable and Richard Hereford
2004

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

ALLUVIAL DEPOSITS

Qam **Alluvium (Holocene)**—Very recent unconsolidated deposits of locally derived sand, silt, clay, and minor gravel of modern flood plains and stream channels that occupy post-1880 arroyo floors. Thickness generally less than 2 m

Qah **Alluvium (Holocene)**—Sand, silt, clay, and gravel of several cut-and-fill deposits, roughly 1 m higher than unit Qam, dissected by post-1880 arroyos. Includes eolian sand and residuum in places. Radiocarbon ages from deposits along Park Wash and Kitchen Corral Wash (east part of quadrangle north of U.S. Highway 89) indicate five depositional phases beginning at 6,320, 5,650, 5,390, 4,330, 2,145, and 340 yr B.P. Narrow belts of unit Qam are mapped with unit Qah in western part of map area

Qa **Alluvium, undivided (Holocene and Pleistocene)**—Sand, gravel, silt, and clay at various altitudes; not correlated with alluvial deposits described below

Qay **Younger alluvium (Holocene? and Pleistocene?)**—Weakly to moderately consolidated deposits of sand, gravel, and gravelly sand. Forms low terraces 5–10 m topographically higher than unit Qah. Thickness 5–20 m

Qai **Intermediate alluvium (Pleistocene)**—Moderately consolidated deposits of gravel, gravelly sand, and coarse sand. Forms a moderately dissected intermediate-height terrace as much as 25 m topographically higher than unit Qay. Thickness 5–40 m

Qao **Older alluvium (Pleistocene)**—Firmly consolidated deposits of gravel, sandy gravel, and coarse sand. Occurs in moderately dissected terraces and pediments higher than unit Qai; on larger streams terrace is roughly 50–70 m above stream channel. Highest deposits may be of late Tertiary age. Thickness 10–50 m

QTa **Alluvium (Pleistocene or Pliocene)**—Firmly consolidated gravel and sand deposits; contains pebbles and cobbles of mostly gray and red quartzite and silicified limestone. Preserved in stream terrace remnants west of Sevier fault zone at heights of 50–120 m above present streams. Age uncertain

EOLIAN DEPOSITS

Qesh **Eolian sand in active dunes (Holocene)**—Light-gray, yellowish-gray, and reddish-orange, fine to medium, well-sorted sand composed mostly of quartz; largely derived from Navajo Sandstone

Qes **Eolian sheet sand, alluvium, and residuum (Holocene and Pleistocene)**—Sand as in unit Qesh, in widespread, mostly stabilized sheets and as fillings of topographically low areas. Lacks dune morphology; locally includes small bedrock outcrops, slope-wash deposits on gently sloping surfaces, residuum, and locally derived sand and silt deposited by minor intermittent streams and washes

Qds **Eolian sand in mostly inactive dunes (Holocene and Pleistocene)**—Sand as in unit Qesh, but mostly reddish orange; in mostly vegetation-stabilized climbing and falling dunes (sand ramps and aprons) that flank buttes and mesas, and as small dune fields in canyons or in lowland areas; largely derived from Navajo Sandstone. May be as much as 15 m thick in places. Includes gently sloping areas modified by slope wash

MASS-WASTING DEPOSITS

Qc **Colluvium, undivided (Holocene and Pleistocene?)**—Poorly sorted debris flow, talus, and rockfall deposits of sand and angular to subangular blocks of rock as unsupported masses and as clasts in clayey matrix, and small landslide deposits. Includes clayey weathering residuum and slope wash in some areas, such as west of Meadow Creek, south of Utah State Highway 9

Qls **Landslide slump-block deposits (Holocene and Pleistocene)**—Essentially coherent, slumped and rotated blocks of bedrock, such as Toreva blocks, overlying incompetent units such as Petrified Forest Member of Chinle Formation, Entrada Sandstone, and Tropic Shale. Includes relatively small landslide sheet deposits in some areas

Qms **Mass landslide sheet deposits (Holocene and Pleistocene)**—Large coherent blocks of rock in a matrix of smaller clasts and clay, locally exhibiting landslide scarps, sag areas, and downslope creep surface textures. Thickness largely unknown due to poor exposures, but in part at least as much as 24 m thick. Originates in and mostly overlies incompetent units, notably the Tropic Shale, Dakota, and Chinle Formations. Includes small unmapped areas of alluvial, pond, and slope-wash deposits, and surface slump material

IGNEOUS ROCKS

Qb **Olivine basalt (Holocene and Pleistocene)**—Medium- to dark-gray, dense to vesicular basalt as blocky lava; includes downslope concentrations of blocks that may be flow margins or talus; contains phenocrysts and groundmass minerals of olivine, labradorite, titaniferous augite, and iron-titanium oxides. Minor basalt dikes as local features. Flows occur on topographic benches and in part along present stream valleys. Radiometric age of basalt along Tenny Creek (26 km east-northeast of Glendale) is 1.1 Ma; basalts in western part of quadrangle are 0.36, 0.56, and 0.8 Ma (Best and others, 1980). Maximum thickness of unit Qb probably about 20 m

Qbc **Cinder cones and vents**—Gray, black, and red cinders, scoria, and minor volcanic bombs

SEDIMENTARY ROCKS

Tbh **Brian Head Formation (sandstone and conglomerate unit as revised in Sable and Maldonado, 1997) (lower Tertiary)**—Sandstone, conglomerate, mudstone, and minor limestone, shale, and clay. Mostly slope forming; weathers drab gray and brown; includes pale-orange to yellowish gray conglomerate that contains moderately well rounded pebbles and cobbles of chert, quartzite, and limestone, and litharenite that is poorly sorted, strongly crossbedded, and poorly to moderately indurated. Lowermost beds are yellowish-orange-weathering clay and siltstone. Lower contact appears to be abrupt and may be an unconformity. Maximum exposed thickness of unit is about 120 m

Claron Formation (lower Tertiary)—Forms the Pink Cliffs. Consists of two mapped informal units described below. Previously referred to as Wasatch Formation (Cashion, 1967) or Cedar Breaks Formation (Hintze, 1973) within the quadrangle or in adjoining areas. Maximum thickness about 300 m. Base is a low-angle regional unconformity. Apparent sparsity of primary depositional features suggested to Mullet and others (1988) that pedogenic processes have largely altered the original strata of fluvial and lacustrine origin

Tcw **White limestone unit**—Limestone and minor limy shale and chalky clay that forms cliffs and steep slopes. Limestone is white to very light gray, massive, in part brecciated; calcite-filled solution cavities, vugs, calcite veins, and dolomitic patches are common. Thickness about 20–40 m

Tcl **Lower unit**—Largely limestone and limy mudstone, and lesser channel-form sandstone and conglomerate, siltstone, limestone breccia, and dolomite; mostly vivid to pale pink to orange and light to very light gray; bedding features are absent to poorly defined in carbonate rocks, which exhibit mottled to nodular textures and calcite veins and vug fillings; root casts and oncholites occur in some beds; locally contains very rare casts and molds of gastropods and pelecypods. Well-rounded pebbles and cobbles in conglomerate are abundant mostly in eastern parts of quadrangle, such as Bryce Canyon area. Locally weathers to spectacular cliffs, columns, and spires. Uppermost beds are about 15 m of reddish-orange claystone and siltstone underlain by about 30 m of light-gray limestone; in places west of the Sevier fault zone these beds were mapped by Cashion (1967) as the "uppermost prominent light-gray ledge-forming limestone," but elsewhere this unit name was applied to unit Tcw. Basal beds, 0 to about 30 m thick, consist of yellowish-orange-weathering shale, claystone, and siltstone, possibly equivalent to the Pine Hollow Formation (Bowers, 1972), underlain by gray, well-indurated quartzose conglomerate and sandstone that is possible equivalent of the Canaan Peak Formation (Bowers, 1972).

Elsewhere, basal beds in some places are pink to reddish-orange limestone breccia. Thickness of unit about 250 m; east of Sevier fault zone thickness is as little as 150 m

Kk **Kaiparowits(?) Formation (Upper Cretaceous)**—Sandstone, clay, mudstone, minor ironstone lenses and concretions and limestone-clast conglomerate. Sandstone; subarkose to litharenite; drab yellowish-gray to medium-gray, salt-and-pepper appearance, and clay matrix; weathers brownish gray with earthy bluish appearance; contains abundant small- to medium-scale trough crossbeds; contains lesser amounts of yellowish-orange-weathering, fine-grained sandstone lenses. Clay and mudstone are mostly medium to dark gray, in part carbonaceous, containing a few pale-red beds. Unit contains scattered vertebrate (probably dinosaur) bones, poorly preserved pelecypod shells, and plant fragments. Basal contact characteristics are vague; unit appears to interfinger with underlying Wahweap Formation. Estimated thickness 0 to about 75 m; absent or intermittently present in vicinity of, and east of, Sevier fault zone. Depositional environment: upper(?) alluvial plain. Palynology indicates that Kaiparowits(?) Formation in Markagunt Plateau is of mid-Coniacian through Santonian age, older than typical Kaiparowits Formation (Campanian) in southern Kaiparowits Plateau (Nichols, 1997)

Kw **Wahweap Formation (Upper Cretaceous)**—Slope- and ledge-forming shale, clay, siltstone, and sandstone; minor concretionary limonite, carbonaceous shale, siltstone, and clay-gall and limestone-clast conglomerate. Shale and clay are medium to light gray and pale red, having a relatively high clay mineral content. Sandstone constitutes about 10–25 percent of unit, mostly in lower part; is mostly fine to medium grained, subarkosic, trough crossbedded, calcareous; commonly weathers to vivid yellowish orange hues; is mostly well indurated but less indurated and coarser grained in upper part; occurs in beds mostly less than 5 m thick but as much as 15 m thick. Lenticular channel-fill sandstone is common and most abundant between Meadow Creek and East Fork of Virgin River. Formation contains sparse fresh-water pelecypods and gastropods and limonitic wood fragments. Formation thins eastward to feather edge. Basal contact drawn at top of quartzose sandstone and conglomerate (Drip Tank Member equivalent) at top of upper unit of Straight Cliffs Formation. Thickness about 100–200 m east of Sevier fault zone and about 245–305 m west of zone. Depositional environments: upper(?) alluvial plain, fluvial and lacustrine

Kscu **Straight Cliffs Formation, upper unit (Upper Cretaceous)**—Slope- and ledge-forming, interbedded claystone, mudstone, siltstone, sandstone, conglomerate, and minor ironstone, limestone-clast conglomerate, carbonaceous shale, and thin coal beds. Sandstone forms 10–30 percent of unit; is yellowish gray, subarkosic, fine-grained to very coarse grained, moderately to poorly sorted; moderately indurated; weathers to drab light-brown to pale-yellow tabular sets of beds having cavelike, fretted reentrants; has low- to moderate-angle trough crossbeds and commonly contorted, convolute bedding. Finer-grained lithologies are commonly light to medium gray and minor pale red and reddish brown. Upper unit consists of three subunits (not mapped separately): upper, middle, and lower. Upper subunit is distinctive interbedded gray quartzose sandstone and granule to pebble conglomerate that contains well-rounded, resistate clasts, is moderately indurated, weathers to low-angle slopes and saddles and is 15–30 m thick. This upper subunit is interpreted to be the Drip Tank Member of the Straight Cliffs Formation of the Kaiparowits Plateau (Peterson, 1969). Middle subunit forms steep slopes and ledges; contains sandstone cliffs as much as 25 m high, especially in area between Muddy Creek and East Fork of Virgin River, where sandstone is about 35 percent of subunit; sandstone is much less abundant in westernmost areas of quadrangle. Middle subunit, about 240–245 m thick, contains thin coal beds and is interpreted to be roughly equivalent to John Henry Member of Straight Cliffs Formation of Kaiparowits Plateau (Peterson, 1969). Lower subunit is slope forming, approximately 50- to 75-m thick, mostly poorly resistant mudstone and siltstone and minor Ostrea-bearing limestone and sandstone; interpreted to be an approximate correlative of the Smoky Hollow Member of the Straight Cliffs Formation of the Kaiparowits Plateau (Peterson, 1969). Basal contact of unit placed at top of uppermost cliff-forming sandstone of the lower unit of Straight Cliffs, believed to be generally coeval throughout map area. A distinctive sandstone and conglomerate about 15 m thick, similar to the Drip Tank Member equivalent, occurs in places in lower part of middle subunit; it is tentatively correlated with the Calico bed of Peterson (1969). Middle and lower subunits contain sparse mollusks, wood fragments, and plant impressions. Total thickness of unit about 300–380 m; thickest in areas of abundant sandstone. Depositional environment: lower coastal plain or lower alluvial plain; Drip Tank equivalent probably of braided stream system origin

Kscl **Straight Cliffs Formation, lower unit (Upper Cretaceous)**—Predominantly cliff-forming sandstone; fine to medium grained, well sorted, quartzose, calcareous, medium gray to grayish orange; weathers grayish orange and dark yellowish orange; in medium to very thick planar beds and low-angle crossbeds; interbedded with shale, mudstone, and silty to sandy limestone. Shale, in part carbonaceous, contains thin coaly lenses and lenses of coquinoid Ostrea-bearing organic limestone. Fossils include pelecypods, ammonoids, and trace fossils; bioturbation features are locally common. Unit is approximately equivalent to Tibbet Canyon Member of Straight Cliffs Formation of Kaiparowits Plateau (Peterson, 1969) east of the mapped area. Thickness varies from about 25 m to as much as 100 m; unit thickens westward mostly by intertonguing with underlying Tropic Shale from about 50 m to as much as 180 m. Depositional environments: mostly marine shoreface and foreshore with minor lagoon or bay influence

Ksc **Straight Cliffs Formation, undivided (Upper Cretaceous)**—Mapped in eastern part of quadrangle, east of Slide Canyon; includes both upper and lower units of Straight Cliffs where lower unit is too thin (generally less than 15 m) to portray at scale of map. Lithologies similar to those described above. Total thickness about 300–340 m; uppermost subunit (Drip Tank Member equivalent) is about 30–50 m thick

Kt **Tropic Shale (Upper Cretaceous)**—Slope-forming, drab, thin-bedded mudstone that weathers gray to olive gray and yellowish gray; dark upper part generally has higher organic content than lower part; bentonitic mudstone in lower part. Minor carbonaceous shale and coal occur in western part of quadrangle. Generally west of Muddy Creek (north of Mt. Carmel Junction), successions of cliff-forming, yellowish-gray quartzose sandstone as much as 50 m thick having planar beds to low-angle crossbeds occur in lower part and thinner successions are present in uppermost part. Limestone and calcitic septarian limestone concretions are locally present. Unit contains marine fossils ranging in age from upper Cenomanian to Turonian. The Tropic grades into, and interfingers with, overlying Straight Cliffs Formation mostly west of Muddy Creek; its basal contact is placed at top of an upper coal zone of Dakota Formation (Cashion, 1967). Thickness variable, but Tropic generally thickens eastward from about 90 m to more than 305 m. Depositional environments: mostly marine offshore, grading upwards to foreshore and shoreface

Kd **Dakota Formation (Upper and Lower? Cretaceous)**—Slope- to ledge-forming, interbedded mudstone and sandstone, and minor but distinctive bentonitic mudstone, coal, conglomerate, and ironstone. Mudstone is gray to very dark gray, brown, and olive gray; sandstone is mostly yellowish-gray to light-gray litharenite, moderately cemented, lenticular, trough crossbedded, and resistant. Two or three coal beds as much as 1.5 m thick occur in eastern part of quadrangle, and two persistent coal zones having coal beds as much as 5.5 m thick are present along the southern Markagunt and Paunsaugunt Plateaus (Cashion, 1961, 1967; Doelling, 1972). Conglomerate as much as 25 m thick is common as channel fills in basal part of formation; contains well-rounded clasts of resistate chert, quartzite, limestone, silicified logs, and organic "trash," some of which is uranium bearing. Diverse fossil pollen assemblage from lowermost part of formation suggests Barremian and Aptian ages, and pollen from middle part suggests late Albian to late Cenomanian age (Doelling and Davis, 1989, p. 73); marine pelecypods and scarce ammonoids occur in lower and upper parts of the Dakota. Base of formation corresponds to K–0 unconformity of Pipiringos and O'Sullivan (1978). Thickness east of Muddy Creek is about 60–75 m; thickens westward to about 230 m in northwest corner of quadrangle. Depositional environments are varied: fluvial, lagoonal, brackish to marine foreshore, foreshore and offshore(?) marine

Je **Entrada Sandstone (Middle Jurassic)**—Ledge-forming sandstone and minor interbedded siltstone and claystone, mostly light to medium light gray, fine to medium grained, quartzose, round to subround; moderately indurated, with calcareous, siliceous, and iron-oxide cement; in part containing medium- to large-scale, wedge-planar crossbeds. Thickness about 30 m in eastern part of exposure belt in northeastern part of quadrangle; thins westward as the result of pre-Dakota Formation erosion; not present west of Table Mountain. Depositional environments: probably alluvial coastal plain and eolian dune fields

Jc **Carmel Formation, undivided (Middle Jurassic)**—Consists of four members; contacts between members appear to be conformable; base of formation corresponds to J–2 unconformity of Pipiringos and O'Sullivan (1978). Member names are those of Cashion (1967). Shown undivided only on cross sections

Jcw **Winsor Member**—Mostly sandstone; fine to medium grained, friable; includes interbedded siltstone and mudstone in lower part. Upper part in western part of quadrangle is commonly light-gray to yellowish-gray sandstone, forming steep slopes and cliffs, crossbedded; lower part is reddish brown to light brown, forming slopes. Member thins westward, mostly resulting from pre-Dakota erosional bevelling, from about 100 m in northeastern part of quadrangle to less than 60 m near western boundary. Uppermost beds include about 13 m of interbedded gypsum and soft siltstone equivalent to the Wiggler Wash Member of Thompson and Stokes (1970) in extreme northeastern part of quadrangle. Depositional environments: lower coastal plain to tidal flat sabkha

Jcg **Gypsiferous member (Paria River Member of Thompson and Stokes, 1970)**—Gypsum and minor interbedded claystone, as prominent widespread basal unit of member; white, gray, pink, massive, and cliff forming; absent or represented by thin solution breccia in northeastern part of quadrangle; overlain by interbedded reddish-brown and gray sandstone, siltstone, mudstone, and gypsum; capped by light-gray sandstone, siltstone, mudstone, gypsum, and pelecypod-bearing limestone. Member thins eastward from about 15–33 m in western part of quadrangle to less than 10 m in northeastern part, where it is included in upper unit (Jcu) of Carmel Formation. Depositional environments: sabkha and lower coastal plain

Jcb **Banded member (Crystal Creek Member of Thompson and Stokes, 1970)**—Gypsiferous sandstone, siltstone, and mudstone; reddish brown, light brown, and light gray; interbedded with clay-gall conglomerate and gypsum. Thins eastward from about 55 m to 10–40 m. Depositional environments: lower alluvial plain and sabkha

Jcls **Limestone member (Co-op Creek Member of Doelling and Davis, 1989)**—Mostly limestone and calcareous shale, minor sandstone, dolomitic limestone, dolomite and local minor gypsum; yellowish gray, light olive gray, and tan; limestone mostly micritic to very finely crystalline, in part oolitic, arenaceous, and coquinoid. Minor sandstone is thin to medium bedded, flaggy to blocky. Member weathers to cliffs and ledges and to steep slopes. Basal beds are commonly vivid reddish-brown siltstone. Locally fossiliferous, containing pelecypods, gastropods, and crinoid columnals, including *Pentacrinus asteriscus*. Thickness about 10–60 m in eastern part of quadrangle, 76 m at Meadow Creek, and 90–120 m in westernmost part. Depositional environments: lagoon or bay and low tidal flat

Jcu **Carmel Formation, upper unit**—Mapped in northeastern part of quadrangle. Slope-forming, light-red, fine-grained, friable sandstone and siltstone. Includes equivalents of gypsiferous member and Winsor Member of Carmel Formation, which lose their individuality eastward. Basal part includes beds equivalent to Thousand Pockets Tongue of Page Sandstone (Peterson and Pipiringos, 1979), exposed in northeastern part of quadrangle, mostly cliff-forming, quartzose, variegated sandstone, fine to medium grained, having high-angle crossbeds; thickness about 0–9 m; pinches out west of Paunsaugunt fault zone. Total upper unit thickness about 80–140 m

Jcl **Carmel Formation, lower unit**—Mapped in northeastern part of quadrangle. Sandstone, siltstone, mudstone, and limestone. Includes equivalents of banded and limestone members of Carmel Formation, which thin eastward and become difficult to differentiate. Lower unit about 70 m thick

Jt **Temple Cap Sandstone (Middle Jurassic)**—Consists of White Throne and Sinawava Members, undivided. Cliff-forming White Throne Member is very light gray to grayish-pink, fine- to medium-grained sandstone having large-scale crossbed sets like those in underlying Navajo Sandstone, and minor interbedded, reddish-brown, tabular siltstone and silty sandstone; unit as much as 50 m thick. Underlying Sinawava Member is mostly thin-bedded, reddish-brown siltstone, silty sandstone, and mudstone as much as 15 m thick. Formation thins eastward to a thin sandstone bed between lower unit of Carmel Formation (Jcls) and Navajo Sandstone (unit Jn) northeast of Burnt Cedar Point (24 km east of Mt. Carmel Junction). There it thins eastward to a featheredge. Basal beds are locally conglomeratic; base of Temple Cap abrupt, interpreted to correspond with J–1 unconformity of Pipiringos and O'Sullivan (1978). Total thickness as much as 60 m in southwestern part of quadrangle. Depositional environments: eolian dune field to alluvial plain

Jn **Navajo Sandstone (Lower Jurassic)**—Sandstone; highly quartzose, very light to light gray, pale orange, yellowish gray, and reddish orange, fine to medium grained, and well sorted; contains prominent, large-scale tabular- to wedge-planar crossbeds in thick to very thick sets; locally contains contorted and convoluted beds; generally weakly cemented by ferruginous, siliceous, and calcareous cement; thin reddish-brown claystone and siltstone partings and rare thin limestone beds between some crossbed sets. Locally, the lower 20–100 m of the Navajo includes Kayenta-like sandstone beds. Navajo includes three gross color divisions in western part (descending): white, pink or vermilion, and brown. Forms the White Cliffs. Thickness ranges from about 440 m in eastern part to about 550 m along Parunuweap Canyon near western boundary of quadrangle. Depositional environment: eolian dune field "sand sea" with interdune ephemeral lakes, ponds, and small streams. Mapped unit includes local areas of weathered sand residuum and Quaternary eolian sand

Jkt **Tenny Canyon Tongue of Kayenta Formation (Lower Jurassic)**—Lithology similar to main body of the Kayenta Formation described below. Present west of Johnson Canyon, where it overlies Lamb Point Tongue of Navajo Sandstone. Thins eastward to a featheredge. Thickness about 35 m west of Johnson Canyon, about 185 m thick near Hildale

Jnl **Lamb Point Tongue of Navajo Sandstone (Lower Jurassic)**—Predominantly sandstone similar to that in Navajo Sandstone; conformably lies between Tenny Canyon Tongue and main part of Kayenta Formation; mapped only where overlain by unit Jkt; contact between unit Jnl and lower part of unit Jn is an artificial cutoff. Mapped from approximately west of Johnson Canyon to Moquith Mountains; thins westward from about 150 m to about 85 m; farther west, it is about 8 m thick in the vicinity of Hildale, where it is mapped with Kayenta Formation

Jk **Kayenta Formation, main unit (Lower Jurassic)**—Widespread unit that intertongues with Navajo Sandstone as Tenny Canyon Tongue (unit Jkt), upper part of the Kayenta, and underlies Lamb Point Tongue of Navajo as the main Kayenta body (unit Jk). Vivid reddish-orange to reddish-brown siltstone, mudstone, and very fine grained to fine-grained, quartzose sandstone having calcareous, ferruginous, and clay matrix; includes minor intraformational pebble conglomerate and thin beds of gray limestone. Sandstone percentage decreases westward. Unit contains sparse dinosaur tracks and bones. Padian (1989) identified scutes of dinosaur *Scelidosaurus* (Early Jurassic) from Kayenta Formation in Arizona. Main Kayenta unit is about 35–45 m thick in south-central part of quadrangle, and about 200 m thick in westernmost exposures. Depositional environment: alluvial plain

Jm **Moenave Formation (Lower Jurassic)**—In southwestern part of quadrangle consists of Springdale Sandstone, Whitmore Point, and Dinosaur Canyon Members; in south-central and southeastern parts consists of members not mapped separately in either area. Springdale Sandstone Member is cliff-forming, pale-reddish-brown to pale-red, fine-grained to very fine grained sandstone; blocky to massive, with trough crossbeds, ripple marks, and mud cracks; contains distinctive lenses of claystone- and siltstone-pebble conglomerate and minor thin siltstone and mudstone partings; locally intertongues with underlying Whitmore Point Member and, where that member is absent, with Dinosaur Canyon Member. Thickness of Springdale is about 50–65 m in southeastern and south-central areas and 30–35 m in southwestern part. Whitmore Point Member, present west of Johnson Canyon, is greenish-gray to grayish-red, thin-bedded siltstone, variegated claystone, and interbedded thin sandstone beds similar to those in the Springdale; contains fresh-water fish remains that have been considered to be of Triassic age and palynomorphs dated as Early Jurassic (Peterson and Pipiringos, 1979, p. B31). Whitmore Point is slope-forming and forms a reentrant below the Springdale; thickness is 0 to about 15 m, thickening westward. Dinosaur Canyon Member is largely steep-slope-forming, reddish-orange siltstone, variegated reddish-brown to green mudstone, and very fine grained, thin- to thick-bedded tabular sandstone and includes minor chert- and claystone-pebble conglomerate. Sandstone is quartzose, consisting of subangular to subround, well-sorted grains cemented by calcite; increases in abundance northeastward (Doelling and Davis, 1989, p. 42). Member thickness in eastern part about 80 m; appears to thicken westward to about 120 m. Base of Moenave is J–0 unconformity of Pipiringos and O'Sullivan (1978). A distal tongue of probable Wingate Sandstone (Lower Jurassic) less than 2 m thick has been reported at base of the Moenave at the Managanese King Mine, about 2 km west of the eastern quadrangle boundary (Doelling and Davis, 1989, p. 41). West of this, the Moenave Formation or intermittent, very thin Wingate, mapped with the Moenave, overlies Chinle Formation. Depositional environments: alluvial flood plain and lacustrine. Total Moenave thickness is about 150 m in southwestern part and about 100–130 m in south-central and eastern areas

TRc **Chinle Formation (Upper Triassic)**—Exposed in southeastern part and along southern boundary of quadrangle. Base is TR–3 unconformity of Pipiringos and O'Sullivan (1978). Shown undivided only in cross sections

TRcp **Petrified Forest Member**—Slope- and badland-forming, variegated purple, red, yellow, gray, and greenish-gray bentonitic mudstone and interbedded gray to nearly white sandstone and conglomeratic sandstone; mudstone firmly cemented, in part calcareous, locally containing limestone and manganese-rich nodules. Sandstone has clay matrix; contains silicified logs and log fragments. Rocks of member are extremely slippery and unstable when wet, forming unstable slopes prone to landsliding. Member ranges in thickness from about 130–240 m. Depositional environments: lacustrine and fluvial with volcanic influx

TRcs **Shinarump Sandstone Member**—Cliff- to ledge-forming, gray, yellowish-gray, and grayish-orange sandstone and conglomerate having low- to moderate-angle trough crossbedding; fills paleochannels in underlying beds and within unit; contains thin gray and green mudstone interbeds. Conglomerate clasts are well-rounded, gray, black, and red chert, limestone, and angular silicified wood. Thickness ranges from 0 to about 50 m ; averages about 17 m. Depositional environment: alluvial plain with braided streams

TRm **Moenkopi Formation (Middle? and Lower Triassic)**—Exposed in southeastern part of quadrangle. About 275–300 m thick in eastern areas; thickens westward. Base is TR–1 unconformity of Pipiringos and O'Sullivan (1978). Mapped as undivided Moenkopi in southeast corner of quadrangle because of narrow outcrop belts due to steep dips; there, however, the Timpoweap Member is mapped separately

TRmu **Upper red member (Middle? and Lower Triassic)**—Reddish-brown to light-brown siltstone and very fine grained to fine-grained sandstone having a clayey matrix; in part calcareous and micaceous; includes interbedded mudstone; thin bedded to massive, unit generally coarsens upwards and steepens from slope-forming to cliff-forming beds; locally contains variegated siltstone and mudstone in uppermost part. Thickness about 30–50 m; lower contact conformable and gradational. Depositional environments: alluvial floodplain and upper coastal plain

TRms **Shnabkaib Member (Lower Triassic)**—Interbedded reddish-brown, tan, and yellowish-gray, earthy-weathering sandstone and reddish-brown and greenish gray siltstone and mudstone, including characteristic very light gray to greenish-gray individual gypsiferous beds as thick as 2 m. Unit forms slopes, is about 50–65 m thick (Doelling and Davis, 1989, p. 35), thickens westward; lower contact is conformable and gradational. Depositional environments: lower coastal plain, tidal flat, sabkha

TRmm **Middle red member (Lower Triassic)**—Poorly resistant, slope-forming, medium-red to reddish-brown mudstone and siltstone containing veinlets and thin seams of gypsum and lesser fine-grained and silty sandstone; gypsum increases upwards. Thickness about 90–110 m (Doelling and Davis, 1989, p. 34). Lower contact apparently conformable. Depositional environment: similar to upper red member

TRmv **Virgin Limestone Member (Lower Triassic)**—Limestone, dolomite, sandstone, shale and mudstone; dolomitic limestone and dolomite are mostly yellowish gray, mostly micritic, in part oolitic; birdseye structure locally present; ledge forming. Sandstone is yellowish-gray with small-scale crossbedding. Shale, siltstone, and mudstone are brownish gray, generally calcareous. Member forms low hogbacks and caps low buttes; contains locally abundant pelecypods, gastropods, crinoid columnal fragments, and scarce Early Triassic ammonite *Tirolites*. Lower contact is apparently gradational. Member is about 4–10 m thick (Doelling and Davis, 1989, p. 34), thickening westward. Virgin Limestone Member is widespread but too thin to map as a separate unit; outcrop of this thin member along the vaguely exposed contact between units TRmm and TRml in southeastern part of map area is indicated by line decoration Depositional environment: very shallow, restricted, low-energy marine

TRml **Lower red member (Lower Triassic)**—Slope-forming, reddish-brown to grayish-red and grayish-brown siltstone and interbedded fine-grained, arkosic, micaceous, calcareous sandstone; ripple marks and small-scale crossbeds common; unit generally coarsens upwards. About 43–67 m thick (Doelling and Davis, 1989, p. 34), thickening westward. Depositional environment: similar to that of upper red member, probably coastal plain

TRmt **Timpoweap Member (Lower Triassic)**—Ledge- to cliff-forming, tan to yellowish-gray limestone, dolomitic limestone, dolomite, calcareous sandstone, siltstone, chert breccia, and chert granule- to pebble- conglomerate; minor yellow shale; thin to thick bedded; lower contact with underlying Kaibab Formation is a disconformity commonly marked by a 1- to 2-m-thick chert breccia and (or) conglomerate; contact locally difficult to recognize because lithologies of underlying and overlying beds are similar. Thickness of Timpoweap about 6–15 m (Doelling and Davis, 1989, p. 32). Base is TR–1 unconformity of Pipiringos and O'Sullivan (1978). Depositional environments: very shallow, restricted(?) marine shelf and lower coastal plain having low-energy stream input

Pk **Kaibab Formation (Lower Permian)**—Upper part is slope- and ledge-forming, gray to yellowish-gray limestone, dolomitic limestone, dolomite, sandstone, and banded chert; thickness about 24 m. Gypsum beds in western areas. Best exposed in Kaibab Gulch. This is the informal Alpha member of McKee (1938) and the Harrisburg Member of Nielson (1981). Underlain by about 60 m of cliff-forming, gray, cherty limestone (80 percent) and calcareous, tan to gray, fine- to coarse-grained sandstone; chert occurs as white and brown spherical nodules, irregular masses, and tabular layers in limestone and sandstone. Corals, brachiopods, bryozoans, and crinoids common in some limestone beds. This unit includes the informal Beta and Gamma members of McKee (1938) and is the Fossil Mountain Member of Nielson (1981). Depositional environments: upper part, marginal shallow restricted marine and bay or lagoon; lower part, open marine.

Pt **Toroweap Formation (Lower Permian)**—Upper part is slope-forming, yellowish-gray and reddish brown sandstone (70 percent), sandstone breccia (20 percent), gray arenaceous to crystalline limestone (less than 10 percent), and minor red shale and travertine interbedded or associated with breccia; bedding generally irregular, in part contorted; 46 m thick. Exposed in Kaibab Gulch. This is the Woods Ranch Member of Nielson (1986). Lower part is cliff-forming, gray to yellowish-gray limestone, siliceous to arenaceous, in part containing gray chert as nodules, irregular masses, and tabular bands; includes lesser amounts of calcareous sandstone. Fossils consist mostly of large brachiopods locally abundant in limestone; unit is 30 m thick. This is the Brady Canyon Member of Nielson (1981). Depositional environments: coastal plain, restricted marine, and open marine; breccias possibly post-depositional due to solution of evaporite beds. Upper and lower parts similar to upper and lower parts, respectively, of overlying Kaibab Formation

Pch **Coconino(?) Sandstone and Hermit Formation, undivided (Lower Permian)**—Coconino unit, 20 m thick, consists of buff, fine-grained, quartzose, in part crossbedded sandstone (60 percent) containing minor conglomerate lenses; gray to buff, crystalline to arenaceous limestone and calcareous sandstone (35 percent); and minor calcareous shale and chert. Hermit Formation, 17 m exposed, consists of red and green concretionary sandstone (65 percent) and red to buff sandy shale (35 percent). Exposed in Kaibab Gulch. For details of section see Doelling and Davis (1989, p. 27–28)

Contact—Includes approximately located and inferred contacts. Dashed and queried where location very uncertain

Fault—Dashed where approximately located or inferred; dotted where concealed; queried where sense of movement uncertain. Bar and ball on downthrown side

Anticline—Dotted where concealed

Syncline—Showing direction of plunge. Dotted where concealed

Strike and dip of beds

Local structural depression—Hachures point downdip

Prominent fracture—Probable joint or fault

Volcanic vent

Landslide scarp—Hachures point in direction of movement

Landslide block—Showing unit symbol of parent rock

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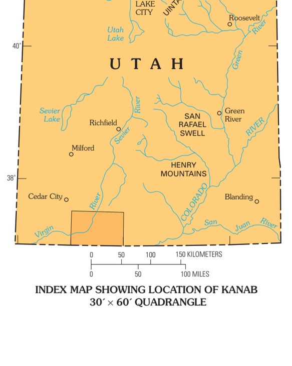

INDEX MAP SHOWING LOCATION OF KANAB 30´ × 60´ QUADRANGLE

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