U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE ST. THOMAS 7.5-MINUTE QUADRANGLE, CLARK COUNTY, NEVADA, AND MOHAVE COUNTY, ARIZONA

by

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS
[Differentiated chiefly by photogeologic techniques and then field-checked]

Qa_4 **Alluvial deposits (Holocene)**--Gray to tan or red-tan, unconsolidated, poorly sorted boulders, cobbles, sand, silt and clay. Clasts are typically sub-angular but in some deposits are subrounded. Clast types are dominantly Paleozoic carbonates, although Proterozoic clasts are usually present and locally abundant. Includes deposits in active washes, as well as undissected alluvial fan and alluvial plain deposits. Thickness ranges from 5 to more than 20 m

Qct **Colluvial, talus, and rockfall deposits (Holocene)**--Unconsolidated, very poorly sorted, locally derived slope wash, talus, and rockfall material. Thickness 0 to 10 m

Qs **Dune and sand sheet deposits (Holocene and Pleistocene?)**--Red-orange, unconsolidated, well-sorted eolian sand deposited as dunes and sand sheets. Deposits confined to west part of quadrangle. Sand derived mostly from nearby Navajo Sandstone outcrops. Thickness about 0 to 5 m

Qa_3 **Slightly dissected alluvial and pediment deposits (Holocene and Pleistocene)**--Unconsolidated, poorly-sorted material similar to unit Qa4, but slightly dissected and from 1-3m higher than nearby Qa_4 deposits. Clasts at surface of deposit have undercoatings of carbonate. Thickness about 0 to 30 m

Qoct **Older colluvial, talus and rockfall deposits (Holocene and Pleistocene)**--Isolated deposits of unconsolidated, very poorly sorted, locally derived slope-wash, talus, and rockfall material. Topographically higher or further from slopes than Qct deposits. Thickness 0 to 15 m

Qls **Landslide deposits (Pleistocene)**--slump blocks that rim mesa capped by Tertiary basalt in southeast corner of quadrangle. Failure occurs at contact of basalt with underlying Tertiary sediments (Thcs). Slump blocks are up to .5 km long parallel to the mesa

Qmd **Marl deposits (Middle Pleistocene)**--Dissected lake and spring deposits, exposed in washes between Pakoon and Whitney Ridges, composed of chalky white, silty carbonate and gysum marl containing gastropods and ostracods. Thin sandy channeled layers increase in abundance laterally toward the edges of the deposits. Local thin gray-green silt to clay layers contain charcoal fragments. Surface of deposit characterized by vuggy calcrete-cemented layers that drape surfaces of local valleys. Deposits fill drainages of probable Middle Pleistocene age. Locally overlain by Qa_2 and Qa3 alluvial deposits. Thickness 0 to 10 m

Qa_2 **Moderately dissected alluvial and pediment deposits (Middle Pleistocene)**--Slightly to moderately consolidated, discontinuous alluvial-plain deposits and pediment gravels that are lithologically similar to Qa_3 deposits, but dissected and 5-15 m higher than Qa_4. Surface typically has well-developed calcrete soil about half a meter thick. Deposit southeast of Greasewood Basin underlain by conglomerate and sandstone unit of Thumb member of Horse Spring Formation, as indicated by (Thc) symbol. Thickness from 0 to as much as 20 m

Qa_1 **Highly dissected alluvial and pediment deposits (Early Middle Pleistocene)**--Moderately consolidated, isolated, alluvial-plain and pediment deposits that are lithologically similar to Qa_3 and Qa_2 deposits, but highly dissected and 15-20 m higher than Qa_4. Well-developed calcrete on upper surface is as much as 1 m thick. Clasts completely embedded in calcrete and profile of calcrete deposit shows well-developed horizontal laminated structure. Thickness 0 to 10 m or more

Tg **Alluvial fan and pediment deposits (Pliocene)**--Sand, cobble and boulder deposits in east part of quadrangle, overlying Tertiary basalt where present and Miocene deposits elsewhere. Clasts are angular to subrounded and include basalt boulders south of basalt outcrop on west side of Pakoon Ridge. Derived from east side of Whitney Ridge and from Virgin Mountains north of quadrangle. Thickness 0 to 20 m or more

Tb **Basalt (Late Miocene or Early Pliocene)**--Dark gray vesicular olivine basalt, weathering dark brown or rusty black. Olivine phenocrysts, about 1-2 mm size, partly to mostly altered to iddingsite. Exposed in two locations in east half of quadrangle. Outcrops on west side of Pakoon Ridge consist of one thin (2-5 m) flow, intermittently exposed in washes between Whitney and Pakoon Ridges, that fills shallow channels cut into underlying Tertiary sedimentary deposits. Overlain by Pliocene alluvial fan and pediment gravels (Tg). Dated at 5.1 ±.85 Ma by H. Mehnert (1992, USGS Isotope Lab, Denver, Co)(K-Ar whole rock). Outcrops in southeast corner of quadrangle comprised of multiple flows that are part of Pakoon Springs sequence of basalts of the Grand Wash Trough. The uppermost flow at Pakoon Springs is dated at 4.7 +/- 0.07 Ma (Cole, 1989)

BEDROCK UNITS

Tv **Altered mafic volcanic rock (Miocene)**--Dark green to black, highly vesicular basalt or andesite. Coarse-grained equigranular matrix with plagioclase, clinopyroxene, and olivine crystals. Presence of large bombs suggests rocks are proximal vent deposits deposited on Rainbow Gardens. Outcrop, about 200 m wide, is enclosed by highly faulted and brecciated rocks of the Rainbow Gardens member of the Horse Spring Formation and field relations suggest volcanism was concurrent with or postdated faulting of Rainbow Gardens. Occurs as clasts in immediately overlying sediments of the Thumb member of the Horse Spring Formation

Horse Spring Formation (Tertiary)--Includes, in descending order, the Thumb and the Rainbow Gardens members (Bohannon, 1984)

Thumb Member (Miocene)--Stratigraphy of unit complicated due to rapid facies changes and structural disruptions, but in general includes lacustrine and alluvial facies (Bohannon, 1984). Consists of, in descending order, conglomerate and sandstone (Thc, Thcw, and Thcs), and sandstone, siltstone, gypsum and tuff (Tht and Thts). Megabreccia deposits (Thmb) occur locally at or near base of both units. Conglomerate unit unconformably overlies lower unit (Tht) in proximal settings close to mountain fronts or faults, but intertongues with lower unit distally. To south, in Azure Ridge and Gold Butte quadrangles, entire exposed thickness of Thumb member is conglomerate

Thc **Conglomerate and sandstone unit (Miocene)**--Red-tan to pale-brown conglomerate, sandy conglomerate and conglomeratic sandstone, poorly exposed. Base of unit placed at lowest persistent conglomerate. Maximum thickness unknown, but probably at least 350 m. Clast types and sizes vary stratigraphically upward and laterally. Clast types include Precambrian gneisses, foliated granites, and schists; Paleozoic carbonate and subordinate clastic rocks; and minor well rounded quartzite cobbles and chert pebbles recycled from Mesozoic conglomerates.

Clasts mostly pebble- to cobble-size, although boulders as much as 1 m diameter are present. On west side of Whitney Ridge, base of conglomerate commonly contains abundant Proterozoic basement rocks. On south side of Whitney Ridge, Paleozoic clasts are predominant throughout conglomerate unit. Clasts of Rainbow Gardens member of Horse Spring Formation and of distinctive, red silicified Jurassic Navajo Sandstone occur near base of unit on south side of Whitney Ridge. The Navajo clasts are derived from silicified fault zones between the Navajo and Rainbow Gardens in the Mud Hills and at the south end of Whitney Ridge. On southwest side of Pakoon Ridge, along Pakoon fault, base of unit marked by distinctive conglomerate dominately composed of boulders and cobbles of Permian Kaibab and Toroweap Formations. Largest clasts occur where deposit is faulted against west side of Pakoon Ridge

Thcw **White conglomerate unit**--Conspicuous light gray conglomerate composed mostly of clasts of Cambrian Undivided Dolomites and exposed in elongate north-south outcrop on west side of Whitney Ridge. At western edge of outcrop, unit overlies red sandstone and conglomerate unit (Thts), at northeast edge of outcrop deposit is faulted against Proterozoic rocks, and at the southeast edge white conglomerate depositionally overlies Cambrian Muav Limestone and Undivided Dolomites. Thickness as much as 180 m

Thcs **Sandstone and conglomerate unit**--Red, well-bedded sandstone and siltstone and channel-filling conglomerate exposed on the southwest side of Pakoon Ridge and beneath basalts in southeast part of quadrangle. Grades downward into and probably intertongues laterally with conglomerate and sandstone unit (Thc). Thickness unknown; 1200 m exposed beneath basalt

Tht **Sandstone, siltstone, gypsum and tuff unit**--Dominant rock types are sandstone, siltstone, and mudstone with local thick deposits of gypsum. Airfall tuff beds a few cm to as much as 3 m in thickness are common throughout the section. Includes sandstone and conglomerate unit, probably representing proximal lake and distal alluvial-fan facies, that is mapped separately as Thts. Mega-breccia deposits or monolithologic boulder conglomerates (Thmb) crop out locally near or at top of sandstone and conglomerate unit (Thts). Stipple pattern in map unit just south of Mud Hills and along St. Thomas Gap road denotes unusual facies containing granule- to cobble-size bombs of altered mafic volcanic rock, compostionally different from Tv described above but probably from similar source. At south end of Whitney Ridge, and in exposures on southwest side of Pakoon Ridge, base of unit truncates faults cutting the underlying Rainbow Gardens member of the Horse Spring Formation. Basal 10-30 m commonly marked by rubble zones or conglomerate layers, composed mostly of underlying Rainbow Gardens carbonate but locally containing boulders to house-size blocks of Mesozoic rocks. Total thickness ranges from 50 to as much as 500 m because of erosional relief on underlying and overlying surfaces. Overlain by conglomerate and sandstone unit (Thc)

Sandstone, siltstone, and mudstone--brown, fine-grained, well-sorted sandstone and yellowish tan siltstone in thin, parallel continuous beds. Commonly calcareous, sometimes ripple-laminated, sometimes with thin granule or pebbly layers. Minor pale brown mudstones in thin structureless, continuous beds

Gypsum--White to gray gypsum in even- to wavy-bedded layers that are finely laminated or massive and recrystallized. Layers a few centimeters to as much as 0.5m thick can be traced laterally a few hundred meters. Gypsum layers typically pure, but locally can contain sandstone and siltstone

Tuff--pale-green to white or gray, fine-grained, airfall tuff with rare to common phenocrysts of biotite, hornblende, sanidine and plagioclase; tuff commonly is

reworked and locally contains lithic fragments. Tuff beds are massive or cross bedded where filling channels and occur throughout the section. Beds range in thickness from a few cm to 5 m

Thts **Sandstone and conglomerate unit**--brown to red, fine- to coarse-grained sandstone, conglomerate and siltstone. Sandstone and siltstone well-bedded, commonly cross-stratified, with parallel to lenticular bedding. Locally contains abundant thin beds of channel- filling conglomeratic sandstone and conglomerate as well as medium to thick beds of structureless to crudely-stratified, poorly-sorted sandstone with floating pebbles and granules

Thmb **Megabreccia deposit**--well-cemented sedimentary breccia, composed of very angular, crackle-brecciated blocks, from a few centimeters to a few tens of meters in size, in a matrix of granulated Paleozoic carbonate. Largest deposit, composed of middle- Paleozoic carbonate rocks, is within sandstone and conglomerate of lower Thumb unit (Thts), about 30 m below contact with white conglomerate unit (Thcw) in the northwest corner of the quadrangle. Interpreted as large rock-avalanche deposit, using criteria outlined in Yarnold and Lombard, (1989). Exposed areal extent is about one square kilometer, thickness as much as 30 m. Several small outcrops, in eastern part of the quadrangle (sec. 20,29, T. 35 N., R. 16 W.), are composed of rubble of Tertiary Rainbow Gardens Member of Horse Spring Formation. Rubble is poorly bedded, unstratified and unsorted and ranges in clast size from cobbles to boulders; northernmost deposit in sec. 20 consists of a brecciated block about 30 m long. Unit name in parentheses following symbol Thmb indicates dominant clast type

Thr **Rainbow Garden Member (Miocene to Oligocene?)**--consists of three units, in descending order: cliff-forming, nonmarine limestone unit, underlain by slope-forming, lithologically variable unit of sandstone, siltstone, limestone and tuff, and basal resistant conglomerate. Member locally eroded beneath Thumb Member; maximum total thickness about 300 m

Upper limestone unit--White to pink-white, marly to coarsely crystalline limestone; poorly bedded, locally cherty. Contact with overlying Thumb sandstone, siltstone, gypsum and tuff unit is disconformable to unconformable

Middle unit--sandstone, claystone, limestone and tuff. Sandstone green-white or red, thin bedded, lithic; some beds contain abundant, small (2-4 cm) black chert pebbles. Claystone green-gray, thick-bedded, with floating chert pebbles, occurs locally with lithic sandstones. Calcareous siltstone and silty limestone red-orange to orange-tan, thin-bedded, commonly found just above the basal conglomerate. Locally, crystalline limestone pink to red, vuggy, crystalline limestone with vertical calcite-filled tubelets (see Bohannon, 1984) at gradational contact with the overlying limestone unit. Tuff common in most exposures and most abundant in outcrops on southwest side of Pakoon Ridge. Contains sanidine and biotite phenocrysts, and locally glassy pumice as much as 1 cm in length. Tuff beds massive to cross-bedded, 0 to 2 m in thickness. An age of 24.3 +/- 1.0 Ma (K-Ar, biotite) was obtained by Carpenter and Carpenter (1990) from similar rocks located about 15 mi north of the quadrangle

Basal unit-- Dark-brown to red-brown, pebble to cobble conglomerate, composed mostly of subangular to subrounded, poorly- to non-imbricated, Paleozoic carbonate and chert clasts, in calcareous, sandy matrix. The conglomerate lies on erosional surface with local relief of as much as 5 m cut into lower part of Jurassic Navajo Sandstone (Bohannon, 1984). Unit has gradational contact with overlying beds. Thickness about 2 to 10 m

Jn **Navajo Sandstone (Lower Jurassic)**--Red, less commonly white or pale-yellow, medium- to fine-grained, well-sorted eolian quartz sandstone. Bedding discontinuous, nonparallel, with distinctive large-scale (as much as 15 m thick) planar cross-stratification except near base of unit where thinner (0.5 -2 m), low-angle tangential cross-stratification bedding is common. Variable thickness due to pre-Rainbow Gardens erosion. Thickness ranges from 0 to about 300 m

Jk **Kayenta and Moenave Formation, undivided (Lower Jurassic)**--Mostly Kayenta Formation, except basal conglomerate and locally, buff-colored sandstone that is tenatively correlated with Springdale Sandstone Member of the Moenave Formation. Lower half of Kayenta is dark red, lenticular trough-crossbedded sandstone and brick red, parallel bedded, commonly cross-stratified siltstone, with minor persistent thin limestone beds and local gypsiferous claystone. Erosional unconformity on underlying Chinle formation is commonly marked by dark red-brown to green-brown pebble conglomerate or locally by buff colored, channelized sandstone. Conglomerate is trough-cross-stratified and clasts are mostly well-rounded, highly polished quartzite and chert, but include limestone and sandstone. Sandstone, medium-grained, cross-stratified, is deposited in lenticular channels. Where conglomerate is missing, lower part of unit is dominated by lenticular deposits of the gypsiferous claystone. Upper half of formation is slope-forming red and orange gypsiferous sandstone and siltstone, parallel bedded, cross-stratified. Uppermost 20m of section is red, thin to medium bedded, channelized cross-stratified sandstone, interbedded with thin, massive to parallel laminated silty fine-grained sandstones. Thickness about 300 m

Trc **Chinle Formation (Upper Triassic)**--Includes, in descending order, the Petrified Forest and Shinarump Members. Thickness of Chinle Formation about 250 m

Petrified Forest Member--Chocolate-brown, gray, and pale-red to pale-purple, interbedded sandstone, siltstone, and claystone. Bentonitic clay derived from volcanic ash present locally in mudstones

Shinarump Member--Yellow- or green-brown to dark red-brown conglomerate, conglomeratic sandstone and sandstone. Includes well-rounded to rounded chert, quartzite, and minor carbonate clasts. Forms unconformable contact with underlying Moenkopi Formation

Moenkopi Formation (Middle? and Lower Triassic)--Includes, in descending order: the upper red, Shnabkaib, middle red, Virgin, and lower red members, as defined by Stewart and others (1972). The middle red not present in this quadrangle. Lower red (Trml) and upper red (Trmu) mapped separately. Shnabkaib and Virgin mapped as one informal unit (Trmsv). Thickness of Moenkopi ranges from about 600 to 650 m

Trmu **Upper red member**--Red shale, gypsiferous, interlayered with thin, resistant, red-brown, ripple-laminated, fine-grained sandstone and siltstone. White to yellow-brown, fine-grained sandstone lenses with rare, small floating chert pebbles are present in lower half of member, and purple and white mottled conglomeratic sandstone locally about 5-10 m below the top. Above upper sandstone are dark red-brown, thin mudstone to siltstone beds, separated by thin recessive green shale with vertical silt-filled mudcracks. Gradational contact with underlying Shnabkaib member

Trmvs **Shnabkaib and Virgin Limestone Members, undifferentiated**--Aggregate thickness about 200 m

Shnabkaib member--Thin interlayered beds of white gypsum, gray limestone, and pale-green or -red siltstone and shale

Virgin Limestone member--Composed of light-gray to yellow-gray, fine-grained to micritic, thin-bedded dolomite and limestone, interbedded with gray or green-gray siltstone. Commonly crops out as two resistant ridges, separated by a slope

Trml **Lower red member**--Pale-red to red-brown gypsiferous shale interbedded with dark-red or red-brown, ripple-laminated siltstone and fine-grained sandstone; generally very poorly exposed

Pk **Kaibab Formation (Lower Permian)**--Includes, in descending order, Harrisburg and Fossil Mountain Members, as defined by Sorauf and Billingsley (1991). Thickness variable owing to sub-Triassic unconformity, ranging from 120 to 170 m

Pkh **Harrisburg Member**--White-gray to gray and light-red, interbedded limestone, dolomite, gypsum, and siltstone. Gypsum and siltstone form slopes; limestone and dolomite form staircase topography. Present locally beneath unconformity at base of Moenkopi Formation

Pkf **Fossil Mountain Member**--Pale yellow-brown to gray, medium- to thick-bedded limestone; fossiliferous with brachiopods, bryozoans, gastropods, bivalves, corals, and crinoids. Chert very common, occurs as nodules, ribbons, or fine disseminated networks. Typically forms cliff

Ptc **Toroweap Formation and Coconino Sandstone, undifferentiated (Lower Permian)**--Includes, in descending order, the Woods Ranch, Brady Canyon, and Seligman Members of the Toroweap Formation and the Coconino Sandstone

Toroweap Formation--Total thickness about 110 m

Woods Ranch member--White to yellow-gray or medium-gray, interbedded gypsum, calcareous siltstone and sandstone, and minor limestone and dolomite. Forms slope

Brady Canyon member--Medium gray, thick-bedded limestone and dolostone; cliff-former. Fossil fragments, especially crinoids and brachiopods, are common as are rounded nodules and ribbons of chert. Gradational contact with overlying Woods Ranch and underlying Seligman members

Seligman member--Tan to red- and yellow-tan or gray-orange, slope-forming unit that contains siltstone, sandstone, and limestone; locally, thick gypsum deposits dominate unit. Forms disconformable contact with underlying Coconino Sandstone

Coconino Sandstone--White to buff-colored, coarse- to medium-grained, well-sorted eolian sandstone with 1 m crossbedded sets; forms cliff. Quartz grains well-rounded and frosted. Contact with underlying Hermit Shale is sharp unconformity. Unit thin to nonexistent (15-0 m) throughout the study area

Ph **Hermit Shale (Lower Permian)**--Brick-red to red-brown, thin- to medium-bedded, fine-grained, in part cross-stratified sandstone and siltstone, interbedded with deep-red, structureless to ripple-laminated, shaly siltstone. Forms steep slopes commonly covered by talus and colluvium. Unconformable contact with underlying Esplanade Sandstone. Thickness about 270 to 300 m

Pe **Esplanade Sandstone (Lower Permian)**--White to pink or pale-red, fine- to medium-grained, well-sorted, medium- to thick-bedded sandstone. Has both large-scale planar cross-stratification and low-angle, tangential cross-stratification in thin sets. Basal 20 ft of formation is red shale interbedded with red sandstone and pale-red gypsum; thin-bedded. Conformable contact with underlying Pakoon Limestone. Thickness about 60 to 80 m

Pp **Pakoon Limestone of McNair (1951) (Lower Permian)**--White to light-gray, fine- to coarse-grained, thin- to medium-bedded, cherty dolomite. Unit weathers into ledge-slope with slightly gentler topographic profile than underlying Callville Limestone. Disconformable, locally erosional contact with Callville, approximately located on map. Thickness about 120 to 140 m

Pc **Callville Limestone (Pennsylvanian)**--Medium-gray, medium-grained, cherty, fossiliferous limestone; interbedded with light-gray, fine-grained dolomite and red-orange-weathering, cross-stratified calcareous sandstone and shaly siltstone. Cliff-forming limestone and slope-forming sandstone and siltstone create stair step topography. Chert occurs as red nodules and stringers that are most abundant in the middle part. Dolomite increases in proportion to limestone toward top; cross-bedded, calcareous sandstone is more common in upper half of formation. Forms unconformable contact with underlying Redwall Limestone. Thickness about 140 to 200 m

Mr **Redwall Limestone (Upper and Lower Mississippian)**--Medium-gray, fine-grained to coarsely crystalline, fossiliferous limestone that forms massive cliff. Locally dolomitized. Distinctive banded chert unit, about 45 m above base of formation, contains 5-10 cm thick bands of white to gray chert that weather yellow and black and form a marker bed. Has disconformable contact with underlying Temple Butte Limestone. Thickness about 140 m

Dtb **Temple Butte Limestone (Upper and Middle? Devonian)**--Upper part light-gray, fine-grained or micritic limestone that weathers very light-gray and forms cliff. Commonly altered to coarse-grained dolomite. Lower part brown to black, medium bedded, fine-grained dolomite, with interbedded red-brown sandstone and sandy shale in lower 10 m. Dolomite characteristically has strong fetid odor when freshly broken. Cherty in lower part of lower unit. Dolomite forms cliffs and sandstone forms slopes creating stair-step topography. Basal contact is erosional unconformity. Thickness about 180 m

Cu **Unclassified Dolomite (Cambrian?)**--Light-gray to medium-gray or light-brown, medium-grained to coarsely crystalline dolomite and sandy dolomite; shale partings common in lower part of section. Thin- to medium-bedded, beds even and continuous. Fine laminae and mottling typical on weathered surfaces. Distinctive, white, thin-bedded, slope-forming dolomite at base. Upper 30 m is yellow-brown glauconitic dolomite previously mapped as Pogonip Group rocks of Ordovician age (Morgan, 1968, Seager, 1966, 1970) because McNair (1951) found small fragments of brachiopods and trilobites possibly younger than Cambrian at Whitney Ridge (about 6 km east of quadrangle). Included with Unclassified Dolomites in this map on basis of 1) Cambrian(?) fossils found by F.G Poole, (oral commun., 1988) in same interval on Whitney Ridge and 2) stratigraphic correlations by S.M. Rowland (written commun.,1990). Contact with underlying Muav is gradational. Thickness about 260 m

Cm **Muav Limestone (Upper Cambrian)**--Medium- to dark-gray, coarse- to medium-grained, medium- to thin-bedded dolomite, interbedded with thin-bedded light-gray or white sandy dolomite, and gray, fine-grained limestone. Medium- to dark-gray beds characteristically mottled yellow-gray or light-gray on weathered surfaces because of extensive burrowing. Distinctive orange-weathering layer, about 15 m thick, about 20 m below top of formation. Forms cliff. Thickness about 315 m

Cba **Bright Angel Shale (Middle Cambrian)**--Dominantly green micaceous shale, complexly burrowed. Lower 3-4 m consists of red-brown micaceous and glauconitic shale interlayered with thin red-brown sandstone beds. Upper contact placed at

base of first thick limestone bed. Gradational with underlying Tapeats Sandstone. Forms slope. Thickness about 120 m

Ct **Tapeats Sandstone (Lower Cambrian)**--Divided into two units. Lower unit is dark red, thin-bedded arkosic sandstone that rests unconformably on Proterozoic basement rocks and is locally absent. Thickness 0-10 m. Upper unit is light brown, medium-bedded orthoquartzite, cross-bedded, locally burrowed, commonly exhibiting complex liesegang bands on weathered surfaces. Thickness of upper unit about 65 m

Xu **Undifferentiated crystalline rocks (Early Proterozoic)**--Tan to red, locally dark gray granite with minor quartz-feldspar pegmatite veins. Composed of quartz, feldspar, and minor amphibole. Dark gray granite contains as much as 5 percent magnetite

REFERENCES CITED

Bohannon, R.G., 1979, Strike-slip faults of the Lake Mead region of southern Nevada, in Armentrout, J.M., Cole, M.R., and TerBest, Harry, eds., Cenozoic paleogeography of the Western United States--Pacific Coast Paleogeography Symposium 3: Los Angeles, Pacific Section, Society of Economic Paleontologists and Mineralogists, p. 129-139.

_____, 1984, Nonmarine Sedimentary Rocks of Tertiary Age in the Lake Mead Region, southeastern Nevada and northwestern Arizona: U.S. Geological Survey Professional Paper 1259, 72 p.

Carpenter, Daniel G., and Carpenter, James G., 1990, New K-Ar age determinations from syntectonic deposits (Oligocene and Miocene), in southern Nevada and northwest Arizona: Isochron/West, No. 55, p. 10-12.

Cole, Erin D., 1989, Petrogenesis of Late Cenozoic alkalic basalt near the eastern boundary of the Basin-and-Range: Upper Grand Wash Trough, Arizona and Gold Butte, Nevada: Las Vegas, Nevada, University of Nevada, M.S. Thesis, 68 p.

McNair, A.H., 1951, Paleozoic stratigraphy of part of northwestern Arizona: American Association of Petroleum Geologists Bulletin, v. 35, p. 503-541.

Morgan, J.R., 1968, Structure and stratigraphy of the northern part of the South Virgin Mountains, Clark County, Nevada: Albuquerque, New Mexico, The University of New Mexico, M.S. thesis, 103 p.

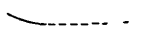
Seager, W.R., 1966, Geology of the Bunkerville section of the Virgin Mountains, Nevada and Arizona: Tucson, Arizona, University of Arizona, Ph.D. dissertation, 124 p.

_____,1970, Low-angle gravity glide structures in the northern Virgin Mountains, Nevada and Arizona: Geological Society of America Bulletin, v. 81, p. 1517-1538.

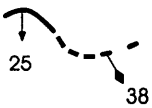
Sorauf, J.E. and Billingsley, G.H., 1991, Members of the Toroweap and Kaibab Formations, Lower Permian, northern Arizona and southwestern Utah: Mountain Geologist, v. 28, p. 9-24.

Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972, Stratigraphy of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region, with a section on sedimentary petrology: U.S. Geological Survey Professional Paper 691, 195 p.

Yarnold, John C., and Lombard, James P., 1989, A facies model for large rock-avalanche deposits formed in dry climates: in Colburn, Ivan P., Abbott, Patrick L., and Minch, John, eds., Conglomerates in basin analysis: A Symposium dedicated to A. O. Woodford: Pacific Section of the Society of Economic Paleontologists and Mineralogists, v. 62, p. 9-31.



Contact--dashed where approximately located

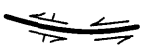


Fault--Dashed where approximately located, queried where uncertain, dotted where concealed. Arrow and number show direction and amount of dip; diamond-tipped arrow and number show trend and plunge of slickenlines

Normal, fault at moderate to high-angle to bedding--Bar and ball on downthrown side; ball open where normal-separation fault, solid where slip direction determined from slip indicators

Normal, fault at low-angle to bedding--Double tick marks indicate upper plate

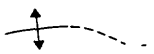
Reverse-Open sawteeth on hanging wall



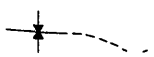
Lateral--Arrows indicate strike separation where sense of motion inferred, bar on arrow indicates slip direction determined from slip indicators and offset elements

Thrust--Solid sawteeth on upper plate; displaces older rocks over younger

Minor fold-symbol shows down-plunge asymmetry



Anticline--Showing trace of axial plane and direction of plunge, dashed where approximately located, dotted where concealed



Syncline--Showing trace of axial plane, dashed where approximately located, dotted where concealed

Strike and dip of beds

Horizontal

Inclined

Vertical

Approximate

Sinkhole

Brecciated rock