U. S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

# PRELIMINARY GEOLOGIC MAP OF THE WHITNEY POCKET 7.5-MINUTE QUADRANGLE, CLARK COUNTY, NEVADA

by

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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 carbonate rocks in south and east part of quadrangle, and dominantly Proterozoic rock clasts in north and west part. 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 found on west side of mesa capped by Tertiary calcrete (Tc) in southwest part of quadrangle and overlying Navajo Sandstone in extreme southern part. Sand on west side of mesa probably derived from nearby Muddy Creek deposits and from Virgin River to west of quadrangle. 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 discontinous undercoatings of carbonate. Thickness about 0 to 30 m

Qoct **Older colluvial, talus and rockfall deposits (Holocene and Pleistocene)**--Isolated deposits of partly cemented, 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

$Qa_2$ **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; clasts are surrounded by calcium carbonate to the extent that the soil horizon is mostly plugged. Deposits on large fan complex in central part of quadrangle are faulted, with offset as much as 2-5 m (Menges and Pearthree, 1983). 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, where preserved, is as much as 1 m thick. Profile of calcrete deposit

shows well-developed horizontal laminated structure and clasts completely embedded in carbonate. Thickness 0 to 10 m or more

**Qls** **Landslide deposits (Early Middle Pleistocene?)**--Three separate deposits exposed in quadrangle: 1) slump blocks of Tertiary Rainbow Gardens Member of the Horse Spring Formation, exposed in extreme south part of quadrangle. Blocks are underlain by shales of Cretaceous Willow Tank Formation, and one landslide block is overlain by $Qa_1$ alluvial deposits. Slump blocks are up to .4 km long, parallel to cliff to the east from which slide blocks derived. 2) Rubbly landslide deposit in east-central part of quadrange, comprised of unsorted blocks of Callville Limestone (Pc). 3) Slump blocks of Cambrian Muav Limestone (Cm) overlying and floating in matrix of Cambrian Bright Angel Shale (Cba); these blocks rest on Proterozoic basement rocks.

**QTf** **Fine-grained alluvial fan deposit (Plio-Pleistocene)**--dissected deposits of pale brown, yellowish brown and pale red sand and cobble capping northeast corner of mesa in southwest part of quadrangle. Includes reworked cobble and sand material from underlying Muddy Creek conglomerate deposits (Tmcc) and fine-grained red sand deposits probably derived from Navajo Sandstone and Horse Spring Formation deposits to the east. Deposit younger than and inset 2-4 m below calcrete deposit (Tc) that caps most of mesa. Thickness 0 to 5 m or more

**Tc** **Calcrete (Pliocene)**-Well-developed, highly resistant white calcrete soil developed on high mesa of conglomerate of the Muddy Creek Formation (Tmcc) in southwest part of quadrangle. The calrete soil, from 2-3 m thick, is brecciated and has multiple laminar layers; clasts are completely isolated in a matrix of carbonate. Probably correlative to Mormon Mesa surface widely exposed in Mesquite basin area north and west of quadrangle (D. L. Schmidt, pers. commun., 1991)

BEDROCK UNITS

**Muddy Creek Formation (Miocene and early Pliocene))**

**Tmcc** **Conglomerate--** Exposed in far northwest corner and southern part of quadrangle. Northwestern exposure is light to medium gray, coarse alluvial fan deposits derived from nearby bedrock. Composed of angular clasts of Proterozoic rock, ranging from pebble to boulder in size. Outcrop in southern part of quadrangle is mostly light gray to tan, clast-supported, well-imbricated conglomerate, commonly containing subrounded clasts of predominantly Paleozoic rock, but including Proterozoic, Mesozoic and Tertiary rock. Clasts average 10-20 cm in size but range up to 60 cm. Imbrication suggests source of conglomerates is from the east. Interlayered with well-sorted pebbly sandstone with minor amounts of coarse sandstone with floating granules. Rounding of clasts and imbrication suggest deposited in integrated main stream of a fluvial system, rather than locally derived alluvial fans.

Tmc **Sandstone, siltstone and claystone**--pale red-brown to tan, fine to medium grained, poorly to moderately consolidated sandstone, siltstone and mudstone. Bulk of exposed section is continous, parallel-bedded siltstone and mudstone with minor amounts of thin, discontinuous, normally graded sandstone beds. Upper 10-20 m locally contains large-scale, cross-stratified eolian sands and trough stratified, channelized fluvial deposits.

Tmcs **Spring deposit**--chalky white, silty carbonate and gysum marl, and altered, bleached sandstone and claystone of the Muddy Creek Formation (Tmc). Deposits in southwest part of quadrangle lie along discontinuous north-south line marking trace of Tertiary fault; deposits are in turn cut by younger fault that disrupts deposits as young as Pleistocene

**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). Occurs in two separate exposures in quadrangle: 1) deposits in southeastern-most part of quadrangle are limestone (Thtl), overlain by sandstone, siltstone, gypsum and tuff (Tht) that grades laterally eastward into sandstone and conglomerate (Thts); both units are overlain by coarse conglomerate (Thc). 2) deposits in southwestern part consist of, in ascending order, sandstone, siltstone, gypsum and tuff (Tht) and conglomerate and sandstone (Thcc). One megabreccia deposit (Thmb) occurs in the sandstone/gypsum deposit (Tht) at or near contact with overlying conglomerate (Thc). In this and other quadrangles to south and east (Beard and Campagna, 1990, Beard, 1991) the conglomerate unit (Thc) unconformably overlies lower unit (Tht) in proximal settings close to mountain fronts or faults, but intertongues with lower unit distally.

Thtc **Conglomerate and sandstone unit (Miocene)**--Red-tan, pale-orange brown, and 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. In southeast exposure, unit overlies gypsiferous Thumb deposits (Tht) at western edge of exposure and sandstone and conglomerate unit (Thts) at eastern edge. Basal 10-20 m of unit is composed of Proterozoic gneisses, foliated granites, and schists that match rock types exposed in Whitney Ridge a few miles east of the quadrangle, overlain by predominantly Paleozoic clast conglomerate. In southwest exposure, conglomerate unconformably overlies contorted gypsum beds of Tht. Base of unit marked by distinctive

conglomerate dominately composed of boulders and cobbles of Permian Kaibab and Toroweap Formations and of vuggy, pink carbonate clasts of Rainbow Gardens Member of the Horse Spring Formation. Upward, clast types are dominated by lower and middle Paleozoic clasts. Includes clasts of Proterozoic amphibolite, gneiss, biotite schist and mega-crystic granite at fault contact with Muddy Creek conglomerate in northwest corner of sec 31, T N R W.

**Thtmb** **Megabreccia deposit**--well-cemented sedimentary breccia, composed of very angular, crackle-brecciated blocks of carbonate of the Rainbow Gardens Member of the Horse Spring Formation. Blocks range from a few centimeters to a few tens of meters in size, and are embedded in a matrix of granulated carbonate. Deposit, about 100 m in long dimension, rests on and deforms underlying gypsiferous deposits of Thumb (Tht). Exposed in southernmost part of quadrangle

**Thts** **Sandstone, siltstone, gypsum and tuff unit**--Dominant rock types in region are sandstone, siltstone, and mudstone with local thick deposits of gypsum. Green to white airfall tuff beds a few cm to as much as 3 m in thickness are common throughout the section.

**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. Gypsum beds dominate Tht section exposed in southwest part of quadrangle and are highly contorted

**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 locally throughout the section. Beds range in thickness from a few cm to 5 m

**Thtsc** **Sandstone and conglomerate unit--**brown to red, fine- to coarse-grained sandstone, conglomerate and siltstone, exposed only in southeastern corner of quadrangle. Sandstone and siltstone well-bedded, commonly cross-stratified, with parallel to lenticular bedding. Commonly contains 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. Conglomerate clasts are mid-Paleozoic carbonate and sandstone

**Thtl** **Limestone unit--**medium to dark gray, parallel to wavy laminated, well bedded limestone; locally gypsiferous. Continuous, even beds range from 20-40 cm thick; thinner beds locally exhibit low-angle cross-stratification. Upper surfaces of beds can be mudcracked. Contact with overlying

siltstone/gypsum unit (Tht) not exposed, but in quadrangle to south (Beard and Campagna, 1990) limestone unit grades laterally and vertically with Tht. Rests unconformably on upper limestone unit of Rainbow Gardens Member. Exposed thickness about 30 m

**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 brecciated, locally vuggy with white, coarsely crystalline laminated infillings. Beds massive, from 30 cm to 1 m thick. Base of unit marked by 4 m thick pink to red micrite with abundant floating sand grains and pebbles with thick carbonate rinds; upper part of bed contains abundant calcite filled tubelets (see Bohannon, 1984) that are probably root casts. This bed is interpreted as calcrete soil developed on underlying unit. Contact with overlying Thumb is erosional unconformity, marked by upper surface of Rainbow Gardens as manganese coated white sparry limestone breccia with local pockets and infillings of reddish siltstone from overlying Thumb. Thickness about 60 m

**Middle unit**--sandstone, claystone and limestone. 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. An age of 24.3 +/- 1.0 Ma (K-Ar, biotite) was obtained by Carpenter and Carpenter (1990) from interbedded tuffs in similar rocks located about 15 km northeast of 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. In exposure below and west of hill with elevation of 952 m (sec 33, TN RW), Paleozoic clast conglomerate clast is interbedded with dark red, cross-bedded, channelized sandstone with abundant small (1-3 cm) pebbles of well-rounded chert, quartzite and argillite. Well-rounded pebbles recycled from underlying Cretaceous rocks and nearby Jurassic through Triassic rocks. The basal 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

**Kb** **Baseline Sandstone (Cretaceous)**--Red, purple-red and yellow-tan, fine-grained quartz sandstone; medium-bedded, commonly cross-bedded. Lithologically similar to and probably derived from Navajo Sandstone. Rests conformably on Willow Tank Formation. Occurs only in southernmost

part of quadrangle where overlain with gentle (1-2°) angular unconformity by Rainbow Gardens Member of Horse Spring Formation (Thr). Considered equivalent to Baseline Sandstone (Bohannon, 1979) exposed in the Muddy Mountains to the west of the quadrangle because of similar lithology to and stratigraphic setting as Baseline. Thickness 0 to 60 m

**Kwt** **Willow Tank Formation (Cretaceous)**--Variegated light- to dark- gray, tan, and red claystone, with interbedded, lenticular bodies of brown and yellow-brown sandstone. Sandstone in lower part of formation is in part conglomeratic, with sparse to abundant, small (2-4 cm) clasts of black and gray chert, red-brown quartzite, and orange-brown pebbly lithic sandstone. Pale-brown, moderately rounded, cobble conglomerate occurs very locally at base. Includes clasts (5-20 cm diameter) of quartzite, carbonate, and chert in a sandy matrix. Unconformable contact with underlying Navajo Sandstone. Thickness ranges from about 0 to 100 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

**Jmk** **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. Only uppermost part of Kayenta Formation is exposed in quadrangle. Erosional unconformity on underlying Triassic Chinle Formation (not exposed in map area) 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. 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. Where sandstone or conglomerate of the Springdale member is missing, lower part of Kayenta 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

**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). Shnabkaib and Virgin mapped as one informal unit (Trmsv). Only the lower red, Virgin, and Shnaibkaib members are exposed in the quadrangle. Thickness of Moenkopi ranges from about 600 to 650 m

**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 occurs 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

Trmi **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

**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

**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

Pt **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

Pt **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. Also locally contains channelized buff-colored, well-sorted sandstone with 1 m crossbedded sets that forms cliff. Quartz is coarse- to medium-grained, well-rounded and frosted. This sandstone bed was previously mapped in the region as Permian Coconino Sandstone, but is now considered part of the Toroweap Formation (G.H. Billingsley, pers. commun.). Contact with underlying Hermit Shale is sharp unconformity. Unit from 0 to15 m thick throughout the study area

**Ph** **Hermit Shale (Lower Permian)**--Mostly brick-red to red-brown, medium-bedded, fine-grained, in part cross-stratified sandstone and siltstone, interbedded with deep-red, structureless to ripple-laminated, shaly siltstone. Forms steep slopes with stairstep topography commonly covered by talus and colluvium. Conformable 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 dolomite, locally cherty . Unit weathers into ledge-slope with slightly gentler topographic profile than underlying Callville Limestone. Disconformable contact with Callville is difficult to see in outcrop and is only 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, locally erosional contact with underlying Redwall Limestone. Basal 40 m of

formation is distinctive reddish slope, composed of thin bedded samy limestone and limy sandstone that forms excellent marker bed. 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. Extensively dolomitized in this quadrangle. Distinctive banded chert unit, the Thunder Springs Member, is about 45 m above base of formation and contains 5-10 cm thick bands of white to gray chert that weather yellow and black and form a distinctive marker bed. Has disconformable contact with underlying Temple Butte Limestone. Because dolomitization and faulting have obscured contact with underlying Temple Butte Formation, I have mapped the base of the Redwall at the bottom of the Thunder Springs Member. Thickness about 140 m

**Temple Butte Formation (Upper and Middle? Devonian)**--Divided into upper and lower informal members. Total thickness about 180 m

Dtu **Upper member**- light-gray, fine-grained or micritic limestone that weathers very light-gray and forms cliff. Extensively altered to vuggy, massive dolomite in which all traces of bedding can be erased. Dolomitization commonly extends into lower Redwall Limestone below Anchor Member, thereby obliterating the contact between the Redwall and Temple Butte. For mapping purposes, top of upper member placed at base of Anchor.

Dtl **Lower member**- dark brown to black-gray, 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 both at contact with upper member and in lower part. Dolomite forms cliffs and sandstone forms slopes creating stair-step topography. Basal contact is erosional unconformity.

Cwd **White dolomite (Upper Cambrian?)**- white to light-gray, medium to coarse-grained, medium bedded dolomite that forms a cliff. Beds are commonly burrowed, and locally contain oncolites. Originally mapped as part of Pogonip Group rocks of Ordovician age (Seager, 1966, 1970). Mapped separately here because not known if part of Cambrian Nopah Formation or possible Middle Devonian. Thickness varies from 10 to 30 m beneath Temple Butte unconformity

Cn **Nopah Formation (Upper Cambrian)**- yellow-brown, locally 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 southeast of quadrangle). Basal 5 or so meters is a slope-forming shaley unit with thin (10-20 cm), wispy-laminated grey limestone beds that correlates lithologically to the Dunderberg Member of the Nopah Formation (A. R. Palmer, pers. commun.). At latitude 36°35'45", longitude 114°10'25", Palmer collected a limestone bed at the very base of the Dunderberg interval that contained *Dicanthopyge sp.* trilobite fragments, and about 2 m higher, possible *Aphelaspis sp.* trilobite fragments. Remainder of unit is series of

medium-bedded light gray dolomites with abundant oncolites, interbedded with thin bedded, nodular sandy dolomites. Approximately 30 meters thick

**Cu** **Unclassified Dolomite (Cambrian?)**--Consists of two units, a lower, less resistant white and gray striped unit, overlain by massive light-gray medium-grained to coarsely crystalline dolomite that becomes glauconitic near the top. 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. 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. Base of unit mapped at base of lowest thick limestone bed (equivalent to Lyndon Limestone), above which are several meters of green micaceous shale. Distinctive orange-weathering layer, about 15 m thick, occurs about 20 m below top of formation. Forms series of prominant cliffs. 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 gradational with Muav Limestone. Gradational with underlying Tapeats Sandstone. Forms slope. Thickness about 90 m

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

## CRYSTALLINE BASEMENT ROCKS

[ Descriptions modified and simplified from Beal (1965). See Beal for more detailed descriptions of basement rocks]

**Xp** **Pegmatite (Early Proterozoic)**--pink to cream, very-coarse-grained pegmatite dikes and pods, composed of quartz and feldspar, commonly containing minor muscovite and\or biotite. Locally intermingled with aplite. Very common in exposures of Proterozoic rock but mapped separately only in northeast part of quadrangle where a swarm of dikes (1-10 m wide) parallels regional foliation in garnet-silliminite gneiss (Xgsn). Also occurs as thin (2-5 cm) lit-par-lit veins in garnet gneiss (Xggn) and garnet-silliminite gneiss (Xgsn)

**Xg** **Biotite granite (Early Proterozoic)**--small body of gray-brown, weakly-foliated medium-grained equigranular biotite granite that crops out in northwest part of quadrangle, sec 26, T. Weathers into dark red-brown slabby boulders. Southeast border of body is sheared and chloritically altered

**Xgrn** **Granite Gneiss (Early Proterozoic)**--pale pink to tan, microcline-rich granitic gneiss, locally mylonitic with microcline augen and quartz ribbons on foliation surfaces. Weathers to distinctive red or dark pink-brown hue. Composed of medium-grained microcline and quartz with minor (1-5%) biotite, muscovite, and oligoclase; locally flooded with veins and patches of coarse-grained microcline and granular epidote. Occurs in western part of quadrangle as large bodies within the biotite-hornblende gneiss (Xbhn), sometimes closely associated with granodiorite gneiss (Xgdn), and as two narrow sills in northwest part of quadrangle. Also crops out in northeast corner of quadrangle, at or near contact with Xgdn

**Xgdn** **Granodiorite gneiss (Early Proterozoic)**--light to medium gray, weathering gray to reddish brown, medium- to coarse-grained, biotite-hornblende granodiorite gneiss. Contains alternating light-gray/dark-gray compositional bands from a few cm to tens of cm in width; dark bands are commonly amphibolitic. Larger pods, several to tens of meters in length, of amphibolite are locally abundant. Contact with biotite-hornblende gneiss (Xbhn) is typically high strain zone that is strongly foliated. High strain zone contains large feldspar augen embedded in dark matrix and highly contorted migmatitic feldspar-quartz-garnet bands. Forms broad north-northeast striking band in northeast part of quadrangle, offset in left lateral sense by north-northeast faults. Also occurs as two small bodies in western part of quadrangle

**Xa** **Amphibolite (Early Proterozoic)**- dark gray to black, medium-grained amphibolite grading to white-black "salt and pepper" hornblende-plagioclase gneiss, and minor black hornblende-pyroxene gneiss. Locally altered to massive biotite. Occurs as many small bodies throughout basement terrane that are not mapped, and as two large outcrops in western part of quadrangle. Small outcrop in Key West Mine area in northeast part of quadrangle is sliver caught in left-lateral fault system, and is offset from extensive body exposed in Riverside quadrangle to north (Williams and others, in prep)

**Xggn** **Garnet Gneiss (Early Proterozoic)**-dark gray, weathering reddish-brown, migmatitic garnet-biotite gneiss and schist that contains abundant mineral segregation bands of pink microcline-quartz-garnet veins and stringers. Distinctive dark red garnets are typically .5 cm diameter but can range up to 2 cm. Commonly strongly foliated and lineated; strike of foliation varies widely. Intensely folded in most outcrops. Widely exposed in basement terrane west of left--lateral fault system that cuts through the Key West Mine area

**Xbhn** **Biotite-hornblende gneiss (Early Proterozoic)**-medium gray, weathering to dark gray to black, medium-grained biotite-hornblende-plagioclase-quartz gneiss. Bands, patches, and augen of pink microcline are common.

Moderately foliated, poorly to nonlineated. Contact with garnet gneiss (Xggn) is gradational and contact with granodiorite gneiss (Xgdn) is high strain zone. Widely exposed west of left-lateral fault system that cuts through Key West Mine area

**Xgsn** **Garnet-silliminite schist and banded gneiss (Early Proterozoic)**-dark gray, migmatitic garnet-silliminite-biotite schist, grading to banded gneiss composed of leucocratic plagioclase-quartz layers and dark brown biotite-muscovite-plagioclase layers. Strongly foliated, locally lineated and tightly folded. Crops out in east-northeast striking band in northeast corner of quadrangle, east of Key West Mine left-lateral fault system. Contact with granodiorite gneiss to north is high-strain, retrograde deformation zone, reactivated by Tertiary left-lateral faulting ( called the Cabin Canyon fault zone by Beal, 1965)

**Xm** **Marble (Early Proterozoic)**-pale gray to white, coarse-grained marble containing thin highly folded quartz-rich layers. Weathers to brown pitted surface with less resistant thin quartz layers in bold relief. Unit strikes east-northeast in narrow discontinous zone; individual pods are from 1-6 m wide and up to 500 m long. Found within garnet-silliminite gneiss (Xgsn) unit on southeast side of pegmatite swarm, and closely associated with small amphibolite bodies (not shown on map)

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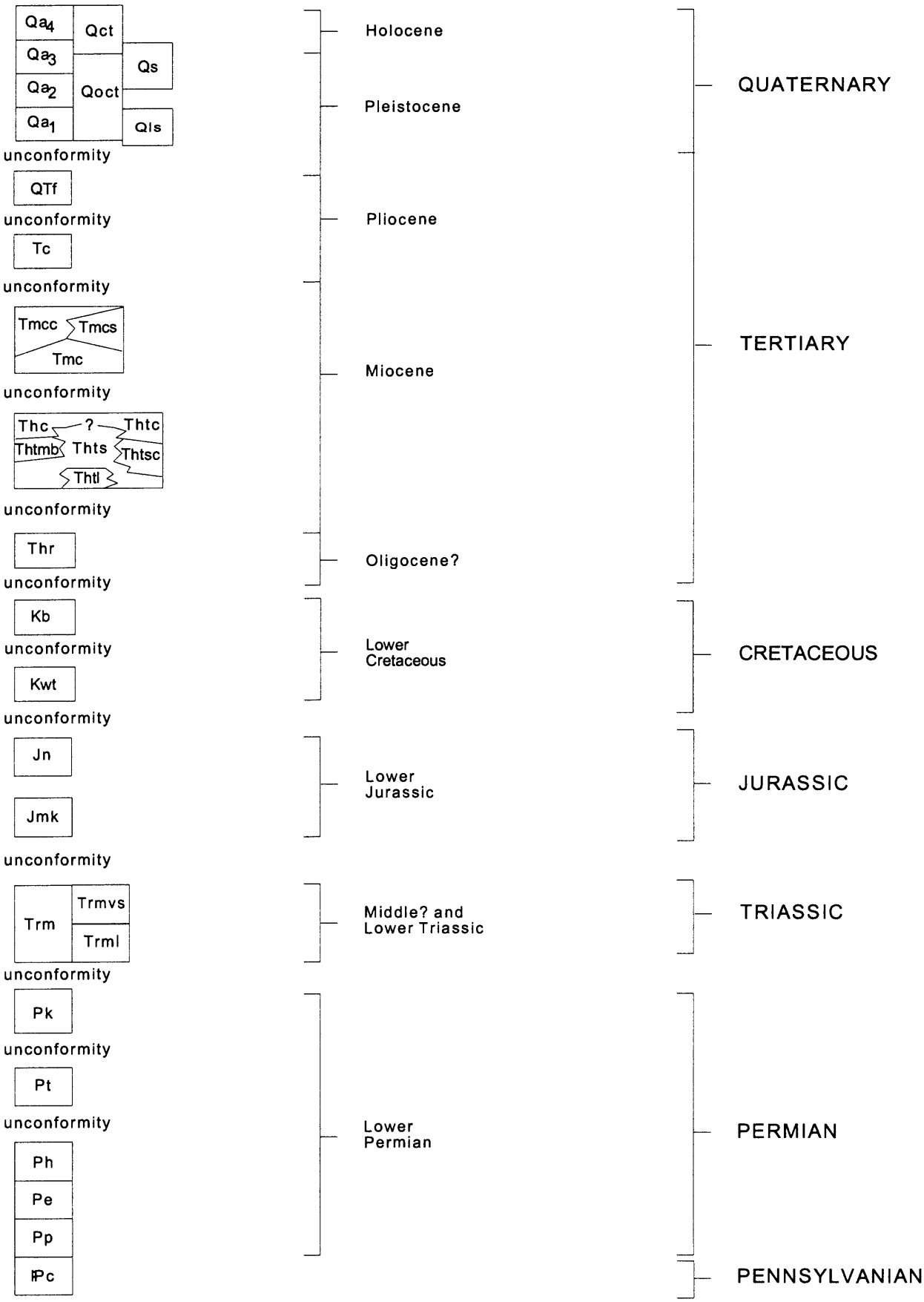
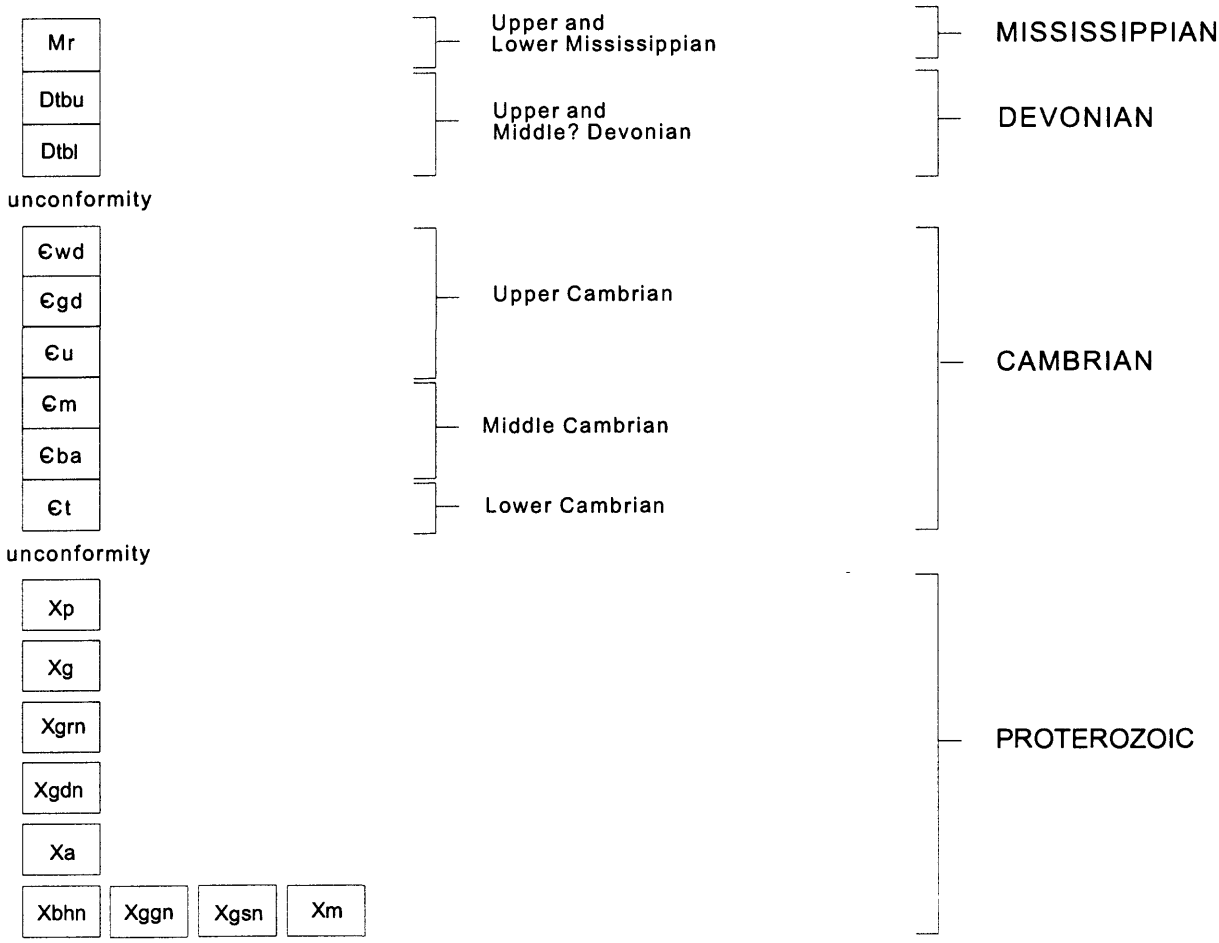
# CORRELATION OF MAP UNITS




Mr
Dtbu
Dtbl
unconformity
Cwd
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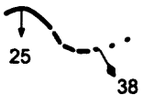
Cu
Cm
Cba
Ct
unconformity
Xp
Xg
Xgrn
Xgdn
Xa
Xbhn
Xggn
Xgsn
Xm
Upper and Lower Mississippian
Upper and Middle? Devonian
Upper Cambrian
Middle Cambrian
Lower Cambrian
MISSISSIPPIAN
DEVONIAN
CAMBRIAN
PROTEROZOIC

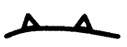
**Contact**--dashed where approximately located



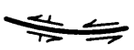

**Fault**--Dashed where approximately located, queried where uncertain, dotted where concealed. Arrow and number show direction and amount of dip; diamond-tipped arrow and number show trend and plunge of slickenlines

**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

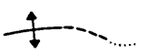


**Lateral**--Arrows indicate strike separation where sense of motion inferred, bar on arrow indicates slip direction determined from slip indicators and offset elements

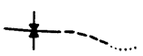
**Thrust**--Solid sawteeth on upper plate; displaces older rocks over younger



**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**

**Cleavage and schistosity**--may be combined with lineation; diamond tipped arrow and number show trend and plunge of striae on cleavage surface, c indicates striae on chloritic surface, h on hematitic surface


**Inclined**



**Vertical**


**Trend and plunge of lineation--**


**Combined with cleavage and schisosity**



**Sheared rock**

**Brecciated rock**




**Chloritic alteration**



**Tie line**--connects outcrops of same unit


**Mine Area**