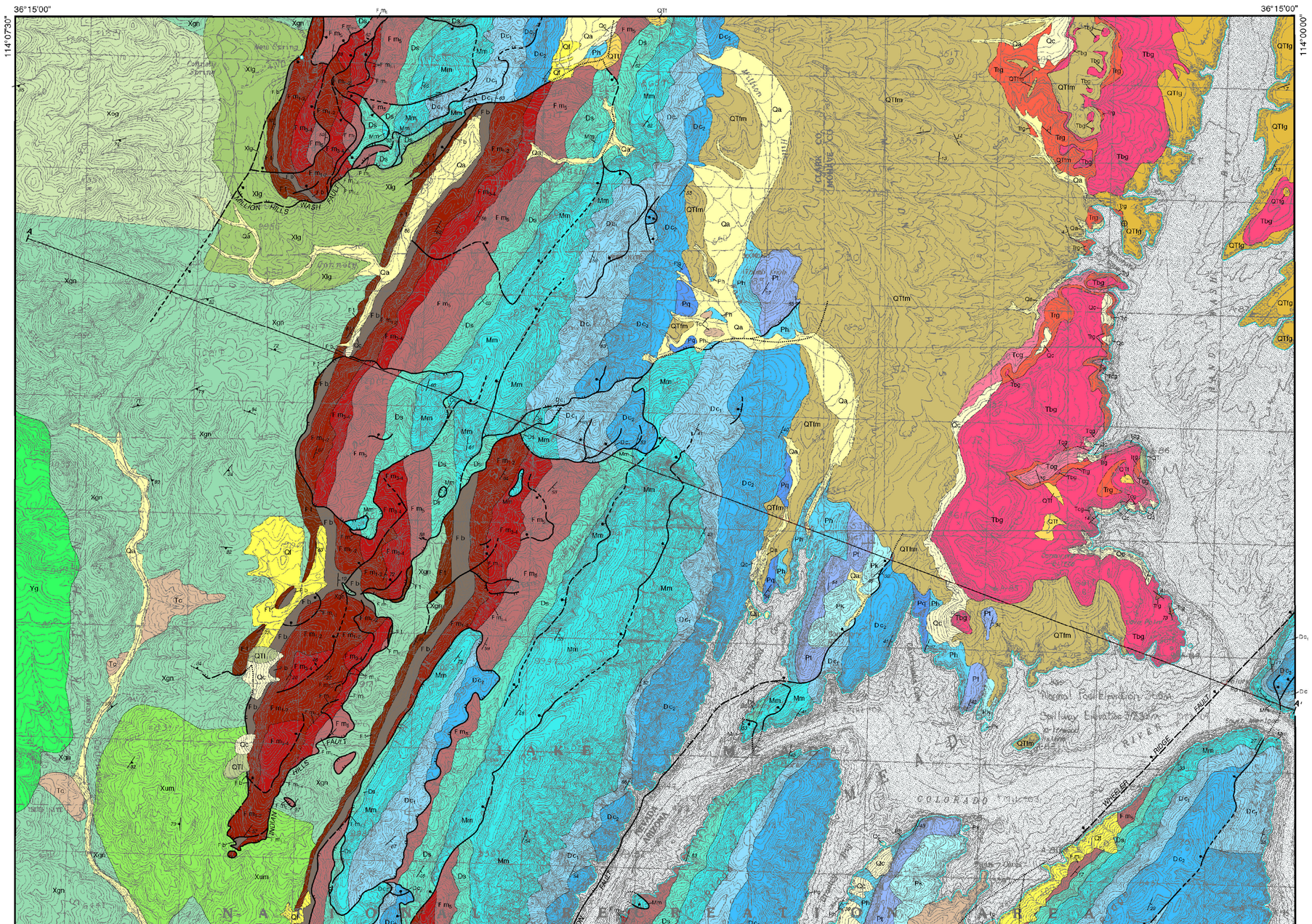
NEVADA BUREAU OF MINES AND GEOLOGY

Prepared as part of the STATEMAP component of the National Cooperative Geologic Mapping Program in cooperation with the U.S. Geological Survey

OPEN-FILE REPORT 03-18

PRELIMINARY GEOLOGIC MAP OF THE ICEBERG CANYON QUADRANGLE, CLARK COUNTY, NEVADA AND MOHAVE COUNTY, ARIZONA



Robert J. Brady, Joan E. Fryxell, and Brian P. Wernicke

2002

Qa **Alluvial deposits (Holocene)** Gray to light-brown or light-reddish-brown, unconsolidated, poorly sorted and typically subangular to angular gravel, pebbles, sand, and silt. Thin (~3 cm) to medium bedded. Incised into all older rock units; variable thickness up to ~10 m.

Qf **Alluvial fan and pediment deposits (late Pleistocene? to Holocene)** Gray to brown poorly consolidated, poorly sorted subangular to angular pebble to cobble, clast-supported conglomerate with subordinate lenses and thin beds of matrix-supported pebble and cobble conglomerate and coarse-grained sandstone. Clasts are locally derived, often from dissected older conglomerate (QTf, QTcg, QTg, QTfg, QTfm, and Tcg). Bedding ranges up to 1.5 m thick. On steeper slopes, uppermost beds are overlain by minor colluvium. Probably post-extensional because the deposits cover exposures of the Grand Wash (not on this quad) and Wheeler Ridge faults. Up to 15 (?) m thick.

Qc **Colluvium (Pleistocene? to Holocene)** Gray to light-brown, usually unconsolidated, rarely calcite cemented, poorly sorted, subangular to angular, boulder to sand. Although occurring on many slopes, this unit was only mapped where it was thick enough to conceal the underlying unit.

QTfg **Alluvial fan and pediment deposits of Grand Wash Bay (Pleistocene? to Holocene)** Gray to brown, poorly sorted, poorly to moderately consolidated, subangular to angular pebble to cobble clast-supported conglomerate with medium- to coarse-grained sand matrix and subordinate lenses and beds of coarse-grained sandstone; clast composition suggests derivation from QTfm, Tbg, Trg, Tcg, and Tc. Occurs as slightly to strongly dissected erosional remnants adjacent to Grand Wash Bay, as much as 3 m higher than nearby Qa.

QTl **Landslide and talus deposits (Pliocene? to Holocene)** Slump blocks and unconsolidated rubbly debris composed of angular cobbles and boulders of local bedrock; blocks range up to ~50 m in length and are up to ~10 m thick.

QTf **Older alluvial fan and pediment deposits (Pliocene? to Pleistocene)** Gray to brown, poorly sorted, poorly to moderately consolidated, subangular to angular pebble to cobble clast-supported conglomerate with medium- to coarse-grained sand matrix and subordinate lenses and beds of coarse-grained sandstone; beds generally up to 2 m thick; lithologically similar to Qf with clasts locally derived, often from dissected older conglomerate (QTcg, QTg, QTfm, and Tcg). Occurs as slightly to strongly dissected erosional remnants as much as 3 m higher than nearby Qf and Qa. Some upper surfaces contain clasts with rock varnish and thin caliche crusts suggesting relatively long exposure. Up to 15(?) m thick.

QTg **Pediment, stream, and alluvial fan deposits of Grapevine Wash (Pliocene? to Pleistocene)** Unconsolidated to poorly consolidated, moderately to subrounded, poorly sorted pebble to cobble clast-supported conglomerate and subordinate sandstone lenses and beds. Clasts are apparently derived from Tc and exposed Paleozoic units in Wheeler Ridge, they range in diameter from a few mm to 0.75 m and consist of various lithologies including varnished basalt, granite, Paleozoic and Mesozoic limestone, chert, and sandstone. Medium- to coarse-grained sand matrix. Exposed as a thin veneer in the southeast corner of the quadrangle.

QTfm **Fanglomerate of Million Hills (Pliocene? to Pleistocene)** Weakly to moderately indurated, medium to thick beds of poorly sorted, moderately rounded to subangular clast-supported conglomerate containing a coarse-grained sand matrix cemented by calcite; clast lithologies include abundant Proterozoic gneiss and granite, as well as Paleozoic and Mesozoic limestone, chert, and sandstone. Crops out as a deeply incised alluvial fan surface throughout the Million Hills, between Grand Wash Bay and Azure Ridge; taps onto Tbg, indicating a Pliocene or younger age.

QTcg **Colorado River gravels (Pliocene to Pleistocene)** Unconsolidated to weakly consolidated, moderately to well-sorted, clast-supported conglomerate. Clasts are composed of well rounded to rounded pebbles and cobbles (1.5-20 cm in length) of resistant Paleozoic limestone, chert, fine-grained sandstone/quartzite (each ~30%), and ~10% Proterozoic granite, gneiss and pegmatitic quartz with a fine to coarse sand matrix. Clasts are commonly coated with rock varnish. Crops out only as erosional remnants (usually < 2 m thick) exposed on tops of small hills near Lake Mead.

Tbg **Basalt of Grand Wash Bay (early Pliocene)** Porphyritic olivine basalt; columnar jointed with spacing ranging from ~20 cm at the top to ~50 cm at the base; layering suggests at least 3 flows in the vicinity of Cormorant Cove; overlain by QTf, QTfg, and QTfm; intercalated with Trg. The basalt has yielded a 3.8±0.11 Ma K-Ar age (Damon and others, 1978) and has been correlated to the Sandy Point basalt (Lucchitta, 1966), which yielded an $^{40}Ar/^{39}Ar$ age of 4.4 ±0.03 Ma (whole rock) (M. Kunk, as discussed by Wallace and others, in press), which overlies QTcg, indicating that a through-going Colorado River had developed by ~4.41 Ma.

Trg **Red sandstone and siltstone of Grand Wash Bay (middle Miocene? to early Pliocene)** Red, poorly to moderately consolidated sandstone and siltstone. Alternating beds of fine- to medium-grained sandstone, siltstone, and mudstone with subordinate lenses and minor interbeds of pebble conglomerate with coarse sand matrix; clasts mostly composed of granite or individual angular to subrounded grains of quartz, feldspar, and mafic minerals, clasts of Tbg locally abundant; lenses of primary and/or secondary(?) gypsum locally common with individual laths 1-2 cm in length oriented perpendicular to bedding. This unit was previously included in the sandstone and siltstone facies of the Muddy Creek Formation (Longwell, 1936) and Muddy Creek Complex (Lucchitta, 1966), and the red sandstone unit of the rocks of the Grand Wash trough (Bohannon, 1984). Trg is intercalated with Tbg, suggesting an early Pliocene age for its top, the age of the base of the unit is unknown; this unit is possibly correlative in part with Tsgw.

Tcg **Conglomerate of Grand Wash Bay (middle Miocene? to early Pliocene)** Medium grayish-red, poorly to moderately consolidated conglomerate and sandstone. Alternating beds of medium to coarse-grained sandstone and pebble to cobble conglomerate with coarse sand matrix; clasts mostly composed of granite or individual angular to subrounded grains of quartz, feldspar, and mafic minerals, with lesser amounts of Paleozoic carbonate and sandstone. Crops out underneath Trg on the west side of Grand Wash Bay; it is unclear whether this represents the base of Trg, or a coarse-grained bed intercalated with Trg; this unit is possibly correlative with Tsgw and/or Tc.

Tsgw **Sandstone and siltstone of the Grand Wash trough (middle Miocene to early Pliocene?)** Red to gray and brown poorly to moderately consolidated sandstone and siltstone. Alternating beds of fine- to medium-grained sandstone, siltstone, and mudstone with subordinate lenses and minor interbeds of pebble conglomerate with coarse sand matrix; clasts mostly composed of granite or individual angular to subrounded grains of quartz, feldspar, and mafic minerals; root/stem traces and burrowing are common; lenses of primary and/or secondary(?) gypsum locally common with individual laths 1-2 cm in length oriented perpendicular to bedding. This unit was previously named the sandstone and siltstone facies of the Muddy Creek Formation (Longwell, 1936) and Muddy Creek Complex (Lucchitta, 1966), as well as being included in the red sandstone unit of the rocks of the Grand Wash trough (Bohannon, 1984). Non-welded air-fall tuffs in the Pearce Ferry area (Tpf) intercalated within Tsgw yielded fission track ages of 10.8±0.8 Ma to 11.6±1.2 Ma (Bohannon, 1984). Another nonwelded air-fall tuff was found intercalated within Tsgw, near lake level, ~2 km north of Pearce Ferry and just east of the edge of the quadrangle, and was dated at 13.94±0.12 Ma (plateau age, $^{40}Ar/^{39}Ar$; step heating experiment; isochron age: 13.69±0.11 Ma). Tsgw crops out in the southeast corner of the quadrangle, east of Wheeler Ridge, where it interfingers westward with Tc. Tsgw could be sourced from the South Virgin Mountains to the west, the Internal Mountains or Garnet Mountain to the south, or a paleo-Colorado or Virgin River flowing from the north and/or east. Exposed thickness is as much as 120 m; probably was much more extensive before erosion by the modern-day Colorado River.

Tc **Conglomerate of the Grand Wash trough and Gregg Basin (middle Miocene to early Pliocene)** Brown, pinkish, and light gray poorly sorted, moderately to poorly consolidated fanglomerate facies of the Grand Wash trough and Gregg Basin. Previously named Gregg's breccia by Lee (1908), the conglomerate and breccia units of the Muddy Creek Formation (Longwell, 1936), and conglomerate-breccia facies of the Muddy Creek Complex (Lucchitta, 1966). Angular to subangular clasts of the conglomerate range in size from pebbles to large boulders (>5 m). Bedding thickness ranges up to ~2 m; weakly to moderately cemented by calcite. Grades laterally into and interfingers with overlying sandstone/siltstone facies (Tsgw). Clasts of Gold Butte granite and pebble imbrication indicate a predominant westerly provenance from the Gold Butte block in the South Virgin Mountains 6-15 km away. The clasts have been described by Volborth (1962) as a rapakivi-type granite and by Lucchitta (1966) as coarsely porphyritic, euhedral to subhedral perthite-biotite granite with a medium- to coarse-grained groundmass consisting of potash feldspar, quartz, plagioclase, and biotite. The perthite is mantled by oligoclase and albite and clumps of biotite aggregates; local sericitization and saussuritization have also been documented. The Gold Butte granite has yielded $^{40}Ar/^{39}Ar$ (Brady, 1998; Reiners and others, 2000) and K-Ar (Wasserburg and Lanphere, 1965) ages of 1.4 Ga on muscovite and a U-Pb zircon age of 1.45±0.25 Ga (Silver and others, 1977). Within the quadrangle, Tc crops out along the west flank of Gregg Basin, in the valley west of Wheeler Ridge, and in the southeastern corner of the quadrangle as a deeply incised alluvial fan, which was apparently sourced from the South Virgin Mountains to the west, and built eastward through a paleo-canyon that cuts through Wheeler Ridge. Total thickness is unknown but exposed thickness is ~250 m.

Tbp **Crackle breccia (middle to late Miocene)** Reddish brown and gray, moderately to well indurated clast-supported crackle breccia; lithologies are entirely composed of Paleozoic strata. Tbp is deposited disconformably on Paleozoic strata. Tbp probably originated as large rock-avalanche deposits derived from the steep slopes of the South Virgin Mountains. Total thickness is unknown due to burial under younger conglomerates, total exposed thickness is approximately 20 m.

Tfpf **Tuff of Pearce Ferry (middle Miocene)** White fine- to medium-grained nonwelded biotite tuff with laminations consisting of 1 to 10 mm of brown mud. Contains ~5% phenocrysts of which ~40% are quartz, ~30% plagioclase, ~20% sanidine, and ~10% greenish-brown biotite. Groundmass consists of volcanic glass shards (~100-250 µm in length) preferentially oriented parallel to bedding. Nonwelded air-fall tuffs a few meters stratigraphically above Tfpl in the Pearce Ferry area have yielded zircon fission track ages of 10.8±0.8 Ma and 11.6±1.2 Ma (Bohannon, 1984); this tuff is intercalated with Tsgw near or at the shore of Lake Mead in the Pearce Ferry area. Thickness is ~0.5 to 2 m.

Th **Horse Spring Formation (middle Miocene)** Brown to red cobble conglomerate and medium to coarse-sandstone; beds 10 to 50 cm thick; well indurated. Clasts include Paleozoic carbonates and sandstones, and Proterozoic gneiss and granite. This unit crops out for ~100 m along the wash that cuts through the ridge east of Iceberg Canyon. It's base is disconformable with the underlying Dc_2; bedding dips fan upsection, decreasing from ~58° to ~17° through the ~100m of exposed section. The rapid fanning of dips suggests that this outcrop is correlative with the syntectonic Thumb member of the Horse Spring Formation (Bohannon, 1984; Beard, 1996).

Pk **Kaibab Formation (Permian)** Thick to medium bedded, cliff-forming, medium light gray, aphanitic limestone with abundant dark brown chert stringers and nodules (fossiliferous). Basal bed is a thin (~1-2 m), red, cobble conglomerate, composed of clasts of Dc_1 and Dc_2 in a matrix of medium to coarse red sand; this bed is very recessive and rarely exposed. Total thickness ~150 m.

Pt **Toroweap Formation (Permian)** Thick to medium bedded, cliff-forming, light gray to pinkish gray, aphanitic limestone, includes dark brown chert stringers and nodules (fossiliferous); distinguishable from Pk primarily by difference in color and less abundant chert. Total thickness ~85 m.

Ph **Hermit Formation and Coconino Sandstone (Permian)** The Hermit Formation is a red, fine grained sandstone and mudstone; bedding generally indistinct, with occasional thick (~2 m) beds of red and white cross-bedded, medium grained sandstone. Includes at its top the Coconino sandstone, which is a grayish yellow to orange, medium grained, cross-bedded sandstone (~10 m thick). Total thickness ~475 m.

Pq **Queantoweap Sandstone (Permian)** Medium to thick bedded, moderate red and white, medium grained, cross-bedded sandstone. Total thickness ~110 m.

Dc_2 **Upper Member of the Callville Formation (Pennsylvanian)** Thick to medium bedded, slope forming, light gray limestone and pinkish gray sandy limestone, with occasional beds of yellowish gray sandy limestone. Basal bed is cross-bedded sandy limestone ~2 m thick that usually weathers to form a conspicuous dark brown horizon. Upper ~30 m is equivalent to the Pakoon Limestone (c.f. Billingsley, 1997). Total thickness ~100 m.

Dc_1 **Lower Member of the Callville Formation (Pennsylvanian)** Thick bedded, slope forming, very light gray limestone. Abundant orange to reddish brown chert stringers occur near the top of the unit. Total thickness ~150 m.

Mm **Monte Cristo Formation (Mississippian)** Thickly bedded yellowish-gray limestone and dolostone overlain by a conspicuous horizon of interbedded gray dolostone and dark brown chert, generally fossiliferous, in turn overlain by medium bedded light gray to yellowish gray sucrosic dolostone. This formation is a very prominent cliff-former, commonly holding up ridge crests in the area. Total thickness is ~150 m.

Ds **Sultan Formation (Middle Devonian)** Prominent cliff-forming olive-gray dolostone, frequently including abundant silicified stromatolites or vugs, overlain by less resistant, well-bedded olive gray to light gray dolostone. Well-sorted, well rounded pale pink to white quartzarenite beds or pinkish-gray sandy dolostone beds are occasionally found below the olive gray dolostone. These may belong to the Mountain Spring Formation. Total thickness is ~140 m.

Fm_{5} **Muav Limestone Formation, Unit 5 (Late Cambrian)** Equivalent to the upper part of the Banded Mountain Member of the Bonanza King Formation, although the beds equivalent to the uppermost Banded Mountain Member have been erosionally removed by the sub-Devonian unconformity. Prominent bench of light gray, burrow mottled dolomite overlain by medium gray burrow mottled dolomite and interbeds of light gray to white cryptalgal dolomite. Total thickness is ~300 m.

Fm_{3-4} **Muav Limestone Formation, Units 3 and 4 (Middle to Late Cambrian)** Equivalent to the lower part of the Banded Mountain Member of the Bonanza King Formation. Unit 3 is a dark gray, cliff forming, burrow mottled dolostone with some orange overprint on silt-rich portions. Unit 4 is slightly less resistant, dark to medium-gray dolostone with interbeds of light gray to white cryptalgal dolomite. A prominent horizon of brown chert lenses occurs ~10 m above the base of Unit 4. Total thickness is ~80 m.

Fm_{1-2} **Muav Limestone Formation, Units 1 and 2 (Middle Cambrian)** Equivalent to the Papoose Lake Member of the Bonanza King Formation. Prominent cliff-forming light gray limestone overlain by medium gray, bedded, burrow mottled limestone and dolostone with an orange overprint, particularly on silt-rich burrows and along some bedding planes. The top of Unit 2 is marked by a recessive orange buff, cross-bedded carbonate grainstone. Total thickness is ~200 m.

Fb **Bright Angel Formation (Middle Cambrian)** Shale and subordinate limestone. The basal parts consist of green and reddish brown shale containing worm burrows, oscillation ripples, and local cross-beds. The upper part consists of a light brown and dark gray oncolitic silty limestone, which is overlain by green shale with worm burrows. Approximate thickness ranges from 20 to 40 m.

Ft **Tapeats Sandstone (Early Cambrian)** Highly indurated pale brown to pale reddish-brown thin to thick bedded, locally cross-bedded fine- to coarse-grained sandstone; includes both silica and calcite cement. Unconformably overlies Early Proterozoic metamorphic rocks. Thickness ranges from 20 to 40 m.

Bcu **Undifferentiated Proterozoic crystalline rocks (Proterozoic)** Includes a variety of foliated and unfoliated crystalline rocks including, but possibly not limited to: Yg, Xlg, Xmfg, Xum, and Xgn, and Xog. Bcu exposed only in cross section.

Yg **Gold Butte Granite (Middle Proterozoic)** Coarse porphyritic perthite-quartz-biotite granite or biotite rapakivi granite, light gray, weathering to light brownish gray. This rock is distinctive because of abundant perthite phenocrysts and ovoids commonly 1-3 cm long, and 0.5-2 cm wide, with some phenocrysts as long as 5 cm (Volborth, 1962); within the map area these large feldspar phenocrysts generally compose >50% of the rock by volume, but both abundance and size of crystals decreases westward (Fryxell et al., 1992). Occasionally the perthite phenocrysts are rimmed with oligoclase and albite (rapakivi texture). Average modal analysis (Volborth, 1962): 45.5% perthite, 27.2% quartz, 17.6% plagioclase, 6.2% biotite, 1.2% sphene, 0.75% chlorite (hornblende), 1.1% fluorite, oxides, apatite, and 0.45% allanite.

Xlg **Leucogranite gneiss (Early Proterozoic)** Weakly to moderately foliated fine- to medium-grained gneiss, equigranular to coarsely pegmatitic, light gray to pink, except where altered to red immediately under the sub-Cambrian unconformity (this alteration also affects other leucocratic rocks in the area); composed of quartz, potassium feldspar, plagioclase, and less than 5% biotite. Includes rare garnet phenocrysts (xenocrysts?). Equivalent to the microcline granite of Volborth (1962).

Xmgf **Granitic gneiss and amphibolite (Early Proterozoic)** Interleaved reddish-brown, fine-to medium-grained, weakly to moderately foliated granite and amphibolite; restricted to the southern part of the map area.

Xgf **Granitic gneiss (Early Proterozoic)** Medium-grained weakly to moderately foliated granite and granodiorite; consists mainly of potassium feldspar, plagioclase, quartz, hornblende, and biotite. Mafic mineral content 10-15% (Howard et al., in press).

Xum **Ultramafic rocks (Early Proterozoic)** Medium- to coarse-grained biotite, hydrobiotite, and vermiculite, intruded by migmatitic dikes from Xgn. The current mineral assemblage was probably metasomatized from an assemblage of hypersthene, diopside, hornblende, biotite, olivine, actinolite, and calcic plagioclase (Leighton, 1967).

Xog **Orthogneiss (Early Proterozoic, 1.7-1.8 Ga; Wasserburg and Lanphere, 1965; Bennett and DePaolo, 1987; work of L.T. Silver as discussed by Stewart, 1980)** Strongly foliated gneiss containing plagioclase, quartz, hypersthene, potassium feldspar, biotite, and clinopyroxene; equivalent to the charnockite gneiss of Volborth (1962). Includes leucocratic portions in which foliation is weakly developed or absent, possibly equivalent to the migmatitic portions of Xgn (Fryxell et al., 1992).

Xgn **Garnet gneiss (Early Proterozoic)** Strongly foliated gneiss and migmatite, contains garnet, biotite, cordierite, sillimanite, plagioclase, orthoclase, quartz, hercynite, and magnetite (Volborth, 1962; Thomas et al., 1988), migmatitic portions contain variably thick (1cm to > 10 m) layers of very coarse grained quartz, feldspar, and garnet, with no internal fabric. Garnet porphyroblasts are generally unaltered, and surrounded by halos of quartz and feldspar, forming striking white on red contacts; westward from the west edge of the quadrangle, the garnet porphyroblasts become increasingly retrogressively altered to chlorite and mafic minerals (Fryxell et al., 1992). Similar gneiss crops out in the North Virgin Mountains (Beal, 1965), at the west end of Frenchman Mountain, and to the south and west of this quadrangle (Blacet, 1975; Anderson et al., 1985; Thomas et al., 1988; Wooden and Miller, 1990; Wallace et al., in press). Protolith age is probably 1.69 Ga or older (e.g., Wasserberg and Lanphere, 1965; Karlstrom and Bowring, 1991).

PRELIMINARY GEOLOGIC MAP OF THE ICEBERG CANYON QUADRANGLE, CLARK COUNTY, NEVADA AND MOHAVE COUNTY, ARIZONA

Scale 1:24,000

0 0.5 1 kilometer

0 0.5 1 mile

0 1000 2000 3000 4000 5000 feet

CONTOUR INTERVAL 10 METERS

Base map: U.S. Geological Survey Iceberg Canyon 7.5' Quadrangle, 1983, Digital Raster Graphic (DRG)

Contact Dashed where approximately located, short dashes where inferred and dotted where concealed.

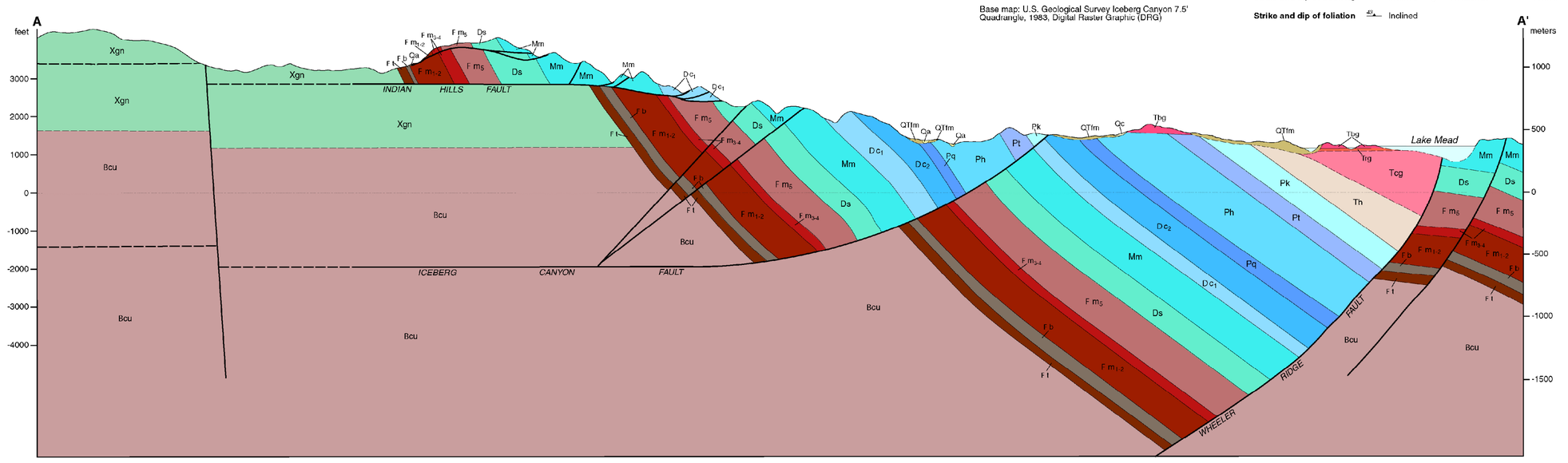
Normal fault Dashed where approximately located, short dashes where inferred; dotted where concealed, ball on downthrown side; showing strike and dip of fault plane and trend of fault striae.

Gently dipping normal fault Dashed where approximately located; short dashes where inferred; hachures on downthrown side.

Strike slip fault Dashed where approximately located, short dashes where inferred; arrows indicate relative motion.

Strike and dip of bedding Inclined ⊕ Horizontal ⊥ Vertical

Strike and dip of foliation Inclined



References Cited

Anderson, J.L., Young, E.D., Clarke, H.S., Orrell, S.E., Winn, M., Schmidt, C.S., Weber, M.E., and Smith, E.I., 1985, The geology of the McCullough Range wilderness area, Clark County, Nevada: Technical Report, University of Southern California, Los Angeles, 35 pp.

Beal, L.H., 1965, Geology and mineral deposits of the Bunkerville mining district, Clark County, Nevada: Bulletin of the Nevada Bureau of Mines and Geology, v. 63.

Beard, L.S., 1996, Paleogeography of the Horse Spring Formation in relation to the Lake Mead fault system, Virgin Mountains, Nevada and Arizona: Geological Society of America Special Paper 303, p. 27-60.

Bennett, V.C., and DePaolo, D.J., 1987, Proterozoic crustal history of the western United States as determined by neodymium isotopic mapping: Geological Society of America Bulletin, v. 99, p. 674-685.

Billingsley, G.H., 1997, The Permian clastic sedimentary rocks of northwestern Arizona, in Maldonado, F. and Nealey, L.D., eds., Geologic studies in the Basin and Range-Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, U.S. Geological Survey Bulletin 2153D, p. 106-124.

Blacet, P.M., 1975, Preliminary geologic map of the Garnet Mountain quadrangle, Mohave County, Arizona: U.S. Geological Survey Open-File Map 75-63, scale 1:24,000.

Bohannon, R.G., 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.

Brady, R.J., 1998, The geology of the Gold Butte breakaway zone and the mechanical evolution of normal fault systems [Ph.D. dissertation]: California Institute of Technology, Pasadena, 188 p.

Damon, P.E., Shafiqullah, M., and Scarborough, R.B., 1978, Revised chronology for critical stages in the evolution of the lower Colorado River: Geological Society of America Abstracts with Programs, v. 10, no. 3, p. 101-102.

Fryxell, J.E., Salton, G.S., Schroetenboer, J.E., and Wernicke, B., 1992, Gold Butte crustal section, South Virgin Mountains, Nevada: Tectonics, v. 11, p. 1098-1120.

Howard, K.A., Hook, S.J., Phelps, G.A., and Block, D.A., Geologic Map of the Hiller Mountains Quadrangle, Arizona and Nevada: Nevada Bureau of Mines and Geology Map XXX, 1:24,000 scale, in press.

Karlstrom, K.E., and Bowring, S.A., 1991, Styles and timing of Early Proterozoic deformation in Arizona: Constraints on tectonic models: *in* Karlstrom, K.E., ed., Proterozoic and Ore Deposits of Arizona: Arizona Geological Society Digest, v. 19, p. 1-10.

Lee, W.T., 1908, Geologic reconnaissance of a part of western Arizona: U.S. Geological Survey Bulletin 352, 96 p.

Leighton, F.B., 1967, Gold Butte vermiculite deposits, Clark County, Nevada: Nevada Bureau of Mines and Geology Report 16, 18 p., 1:4,800.

Longwell, C.R., 1936, Geology of the Boulder Reservoir floor, Arizona-Nevada: Geological Society of America Bulletin, v. 47, p. 1393-1476.

Lucchitta, I., 1966, Cenozoic geology of the upper Lake Mead area adjacent to the Grand Wash Cliffs: Arizona [Ph.D. dissertation]: Pennsylvania State University, University Park, 218 p.

Reiners, P.W., Brady, R., Farley, K.A., Fryxell, J.E., Wernicke, B., and Lux, D., 2000, Helium and argon thermochronometry of the Gold Butte block, South Virgin Mountains, Nevada: Earth and Planetary Science Letters, v. 178, p.315-326.

Silver, L.T., Bickford, M.E., Van Schmus, W.R., Anderson, J.L., Anderson, T.H., and Medaris, L.G., Jr., 1977, The 1.4-1.5 b.y. transcontinental anorogenic plutonic perforation of North America: Geological Society of America Abstracts with Programs, v. 9, p. 1176-1177.

Stewart, J.H., 1980, Geology of Nevada: A discussion to accompany the geologic map of Nevada: Nevada Bureau of Mines and Geology Special Publication 4, 136 p.

Thomas, W.M., Clark, S.H., Young, E.D., Orrell, S.E., and Anderson, J.L., 1988, Proterozoic high-grade metamorphism in the Colorado River region, Nevada, Arizona, and California, in Ernst, W.G., ed., Metamorphism and crustal evolution of the western United States, Rubey Volume VII: Prentice-Hall, Englewood Cliffs, N.J., p. 526-537.

Wallace, M., Faulds, J., and Brady, R., Geologic Map of the Meadview North Quadrangle, Arizona and Nevada, Nevada Bureau of Mines and Geology, 1:24,000 scale, in press.

Wasserburg, G.J., and Lanphere, M.A., 1965, Age determinations in the Precambrian of Arizona and Nevada: Geological Society of America Bulletin, v. 76, p. 735-758.

Wooden, J.L., and Miller, D.M., 1990, Chronologic and isotopic framework for early Proterozoic crustal evolution in the eastern Mojave Desert region, SE California: Journal of Geophysical Research, v. 95, p. 20133-20146.

Volborth, A., 1962, Rapakivi-type granites in the Precambrian complex of Gold Butte, Clark County, Nevada: Geological Society of America Bulletin, v. 73, p. 813-832.

Field work done in 2002.

DRAFT

Preliminary geologic map. Has not undergone office or field review. May be revised before publication.

First Edition, first printing 2002
Printed by Nevada Bureau of Mines and Geology
Edited by
Cartography by Robert Chaney

Geologic mapping was supported by the U.S. Geological Survey STATEMAP Program (Agreement No. 01-HQ-PA-0003).

Nevada Bureau of Mines and Geology
University of Nevada, Mail Stop 178
Reno, Nevada 89557-0088
(775)784-6691, ext. 2; www.nbmg.unr.edu; nbmgsales@unr.edu