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Preliminary Bedrock Geologic Map of the Blythe 30' x 60' Quadrangle, California and Arizona

Compiled by Paul Stone, Jon E. Spencer, and L. Sue Beard

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Cover. Photograph of west side of McCoy Mountains, California, showing south-dipping strata of McCoy Mountains Formation near McCoy Spring. Photograph by Paul Stone, U.S. Geological Survey.

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)

Datum

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929.

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

AZGS Arizona Geological Survey

K-Ar potassium-argon

Ma mega-annum

U-Pb uranium-lead

Preliminary Bedrock Geologic Map of the Blythe 30' x 60' Quadrangle, California and Arizona

Compiled by Paul Stone[1], Jon E. Spencer[2], and L. Sue Beard[1]

Introduction

The Blythe 30' x 60' quadrangle in southeastern California and southwestern Arizona (fig. 1) displays complex geology that includes Mesozoic contractional deformation, metamorphism, and magmatism in addition to Cenozoic extensional deformation and magmatism. Existing geologic map compilations (Stone, 1990, 2006a, b) predate recent geologic mapping efforts that contribute new insights into the stratigraphy and structure of this quadrangle. The map accompanying this pamphlet was compiled in collaboration with the Arizona Geological Survey (AZGS) to incorporate this recent mapping and thus provide an updated depiction of the quadrangle's geologic framework. The scope of the present map is limited to bedrock units of Miocene and older age because the younger deposits have not been mapped in enough detail across the quadrangle to support a systematic compilation.

The geology of the Blythe 30' x 60' quadrangle was originally compiled by Stone (1990). That map was later digitized, and the west half of the quadrangle was upgraded by Stone (2006b). At about the same time, digital data for the east half of the quadrangle were released by Stone (2006a). In the updated bedrock compilation depicted in the accompanying map sheet, the east half of the quadrangle incorporates detailed geologic mapping published since 1990 (Richard and others, 1993; Tosdal and Stone, 1994; Spencer and others, 2015, 2016; Gootee and others, 2017; Johnson and others, 2017; Strickland and others, 2017); the west half of the quadrangle is largely unchanged from the map of Stone (2006b).

An index map showing the primary sources of geologic mapping for this compilation is provided on the map sheet. Sources of mapping for the previous compilations of Stone (1990, 2006b) are provided in those publications. The digital data for this map compilation are presented separately (Stone and others, 2022).

For this compilation, we created a uniform set of map units to which we assigned the various units distinguished in the source maps. In some areas, particularly the southern Plomosa Mountains, this process was interpretive. For example, the map of Richard and others (1993) contains many Cretaceous or Jurassic sedimentary rock units that we assigned to the relatively small number of units we considered appropriate for the compilation. Some of our unit assignments there are questionable (denoted by queries) and alternative unit assignments might be possible. With respect to the geologic line work, we remained as true to the source mapping as possible, except for deletion of contacts separating units that we combined and faults of minor significance. An unpublished 1:100,000-scale geologic map of the Plomosa Mountains prepared by J.E. Spencer and S.M. Richard for the AZGS in 2014 was a useful guide for our compilation in that complex area.

Regionally significant geologic features exposed in the Blythe 30' x 60' quadrangle include (1) variably metamorphosed and deformed Paleozoic to early Mesozoic sedimentary rocks stratigraphically correlative with cratonal platform strata of the Colorado Plateau region (Hamilton, 1964, 1982, 1984; Miller, 1970; Stone and others, 1983; Yeats, 1985; Stoneman, 1985a, b); (2) Jurassic plutonic and volcanic rocks (Tosdal and others, 1989); (3) thick sequences of moderately to weakly metamorphosed sedimentary rocks of the Jurassic to Cretaceous McCoy Mountains Formation (Pelka, 1973; Harding, 1982; Harding and Coney, 1985; Tosdal and Stone, 1994; Barth and others, 2004; Spencer and others, 2011); (4) ductile folds and faults of the Late Cretaceous Maria fold and thrust belt (Reynolds and others, 1986; Richard and others, 1994; Salem, 2009); and (5) Miocene detachment faults in the Big Maria Mountains, Copper Peak area, and Plomosa Mountains (Hamilton, 1982; Spencer, 1984; Spencer and Reynolds, 1991; Spencer and others, 2018). The open-pit Copperstone Mine, 3 kilometers (km) northeast of Copper Peak (fig. 1), yielded about 14,000 kilograms of gold from specular hematite and amethystine quartz along a north-dipping, lower Miocene low-angle normal fault cutting Jurassic volcanic rocks (Spencer and others, 1988, 2018; Arizona Gold Corp., 2020).

Strickland and others (2017, 2018a) recently discovered that the Late Cretaceous to Paleogene Orocopia Schist crops out structurally below undated gneiss in the northern Plomosa Mountains. This discovery marks the northernmost exposure of Orocopia Schist found in western Arizona to date and suggests that the entire Blythe quadrangle is underlain by this extensive, tectonically underplated subduction complex (Haxel and others, 2015, and references therein). Other recent contributions include documentation of post-middle Miocene transtensional

[1] U.S. Geological Survey

[2] Arizona Geological Survey

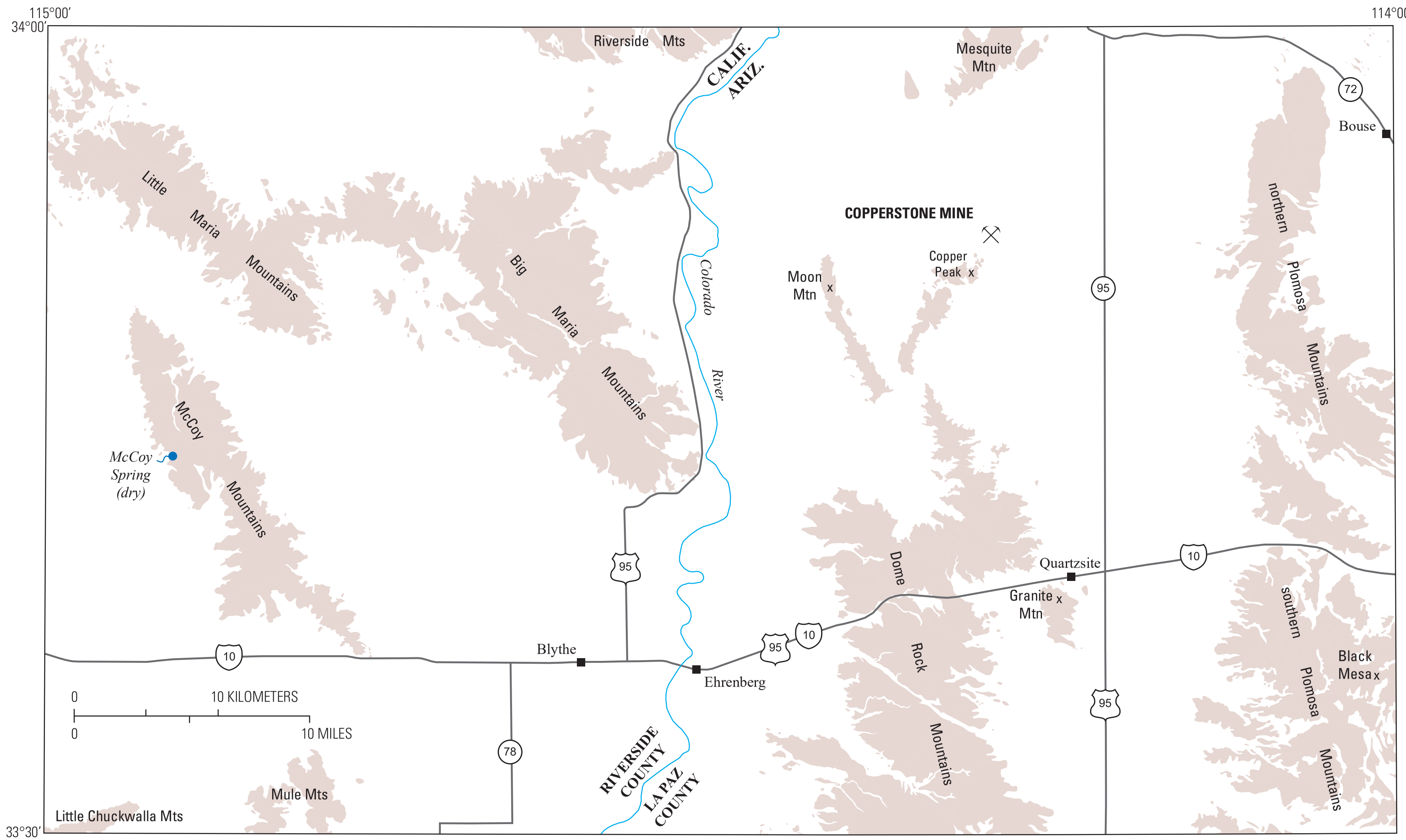

Figure 1. Map of Blythe 30' x 60' quadrangle showing bedrock outcrop areas (shaded) and geographic locations noted in text.

deformation in the northern Plomosa Mountains and at Mesquite Mountain (Strickland and others, 2018b) and determination of new age constraints on Late Cretaceous ductile deformation in the Big Maria Mountains (Flansburg and others, 2019).

Finally, in the west half of the quadrangle, we added a concealed, northwest-striking fault to account for about 50 km of apparent right-lateral offset of the base of the McCoy Mountains Formation between the northern McCoy Mountains and the southern Dome Rock Mountains. Inferred movement on this fault, which was not shown by Stone (2006b), could have taken place at any time since the Late Cretaceous. The concealed fault trace partially coincides with that of the Cibola Fault of Richard (1993), who interpreted that fault to have undergone 7 km of right-lateral slip since 10 mega-annum (Ma, million years ago).

DESCRIPTION OF MAP UNITS

QTu **Sedimentary deposits, undivided (Holocene to Miocene)**—Consists of alluvial deposits derived from local bedrock uplands, alluvial deposits of the Colorado River, and the Bouse Formation (Stone, 2006a, b). Alluvial deposits range from fine-grained sand to boulder conglomerate and typically are nonconsolidated to weakly consolidated. Includes disturbed ground at Copperstone Mine

Tbm **Basalt of Black Mesa (Miocene)**—Olivine basalt flows that cap Black Mesa and other mesas in southern Plomosa Mountains. Whole-rock potassium-argon (K-Ar) age of 17.24±0.43 Ma (Shafiqullah and others, 1980)

Ts **Sedimentary rocks (Miocene and Oligocene)**—Conglomerate, sandstone, and minor limestone. In Dome Rock and southern Plomosa Mountains, consists of massive to indistinctly bedded, dissected fanglomerate containing angular to subrounded clasts of local derivation. In northern Plomosa Mountains and Moon Mountain area, consists of an upper unit of poorly sorted conglomerate having diverse clast compositions and a lower unit of arkosic sandstone, conglomerate, and limestone. Age based on regional correlations and geochronologic data from associated volcanic rocks

Tx **Sedimentary breccia (Miocene and Oligocene)**—Unbedded, unsorted deposits of angular gravel, boulders, and slide blocks, commonly monolithologic, interpreted to have been deposited by landslides. Slide blocks are large, angular, generally brecciated blocks and slabs of Paleozoic sedimentary rocks, Jurassic volcanic or granitic rocks, and crystalline rocks of Proterozoic or Mesozoic age

Tsx **Sedimentary rocks and sedimentary breccia, undivided (Miocene and Oligocene)**—Mapped in Riverside Mountains

Ti **Felsic intrusive rocks (Miocene and Oligocene)**—Fine-grained, hypabyssal intrusive rhyolite to dacite. Includes dacite in Big Maria Mountains that has a hornblende K-Ar age of about 22 Ma (Martin and others, 1982)

Tv **Volcanic rocks, undivided (Miocene and Oligocene)**—Rhyolitic to basaltic volcanic rocks of diverse lithologic character. The most extensive outcrops, in central Plomosa Mountains, consist largely of dacite lava flows and flow breccia along with less common, bedded pyroclastic rocks including tuff. In northern Plomosa Mountains, consists largely of mafic volcanic rocks that are interstratified with sedimentary rocks (unit Ts). In southern Plomosa Mountains, includes welded tuff, rhyolite lava, andesite flows and domes, and minor sedimentary rocks. Outcrops near Copper Peak are basalt. In Riverside Mountains, includes andesite that has a whole-rock K-Ar age of 23.5±1.0 Ma (Martin and others, 1982). In Plomosa Mountains, includes rhyodacite that has a hornblende K-Ar age of 19.6±0.6 Ma and a biotite K-Ar age of 20.7±0.6 Ma (Miller and McKee, 1971; ages recalculated by the method of Dalrymple, 1979)

Tg **Granite (Miocene)**—Southwest of Copper Peak, consists of unfoliated to weakly foliated, medium- to coarse-grained biotite granite and hornblende-biotite granite; the biotite granite has a uranium-lead (U-Pb) zircon age of 20.8±3.2 Ma (Knapp, 1989). In northern Plomosa Mountains, consists of medium-grained, biotite granite (Mudersbach granite of Scarborough and Meader, 1983, 1989) that has a U-Pb zircon age of 20.4+1.8/-2.1 Ma (Spencer and others, 2015)

Tic **Mylonitic intrusive complex of northern Plomosa Mountains (Miocene)**—Bimodal complex of leucocratic and intermediate-composition dikes, sills, and intrusive bodies (Strickland and others, 2017). Leucocratic rocks are mostly mylonitic and consist of tonalite, granodiorite, and rare granite. Intermediate-composition rocks are mostly nonmylonitic to protomylonitic and consist of diorite, less abundant quartz diorite and quartz monzodiorite, and rare quartz monzonite. Unit largely consists of layered tabular bodies subparallel to mylonitic foliation, although nonmylonitic dikes locally cut across well-foliated layers. U-Pb zircon ages of three mylonitic granodiorite sill and dike samples range from 22.58±0.55 to 22.81±0.49 Ma; U-Pb zircon age of one nonmylonitic diorite dike sample is 20.46±0.15 Ma (Strickland and others, 2017)

TKg **Granite (Miocene to Cretaceous)**—At Mesquite Mountain, consists of fine- to coarse-grained biotite granite that intrudes migmatitic gneiss (Knapp, 1989). At Copper Peak, consists of weakly to strongly foliated biotite granite (Copper Peak granite of Knapp, 1989). Undated; age based on lithologic comparison to nearby dated plutons

TXg **Granitoid rocks (Miocene to Paleoproterozoic)**—Small outcrops of dark granitoid rocks of unknown age in northern Plomosa Mountains (Spencer and others, 2015)

Orocopia Schist (Paleogene to Cretaceous)—Identified, mapped, and dated in northern Plomosa Mountains by Strickland and others (2017)

TKos **Mylonitic schist**—Quartzofeldspathic schist composed primarily of quartz, plagioclase, biotite, and muscovite, commonly containing graphitic plagioclase porphyroblasts 1 to 5 mm long. Commonly cut by mylonitic to protomylonitic dikes and sills, especially near intrusive contact with unit Tic. Paleogene to Late Cretaceous age of protolith deposition inferred from U-Pb analyses of detrital zircons (Strickland and others, 2017)

TKoa **Amphibolite**—Medium-grained hornblende amphibolite locally interlayered with mylonitic schist and leucocratic mylonitic sills. Includes abundant thin layers of quartzite (metachert) that locally are isoclinally folded

Kgb **Gabbro and diorite (Cretaceous)**—Weakly foliated gabbro and diorite in Big Maria Mountains. Late Cretaceous U-Pb zircon ages of 74.72±0.47 and 71.70±0.36 Ma reported by M.E. Flansburg (University of Texas, written commun., 2020). Previously considered Jurassic (Hamilton, 1984; Stone, 2006b)

Kg **Granite (Cretaceous)**—Variably foliated and lineated, medium- to coarse-grained biotite granite to granodiorite containing phenocrysts of potassium feldspar 1 to 5 cm long; present at northwest end of Little Maria Mountains (Ballard, 1990) and in northern Dome Rock Mountains–Moon Mountain area (Tyson Wash granite of Boettcher and others, 2002). A biotite K-Ar age of 55.2±7.8 Ma, indicating the minimum age of crystallization, has been reported from the Little Maria Mountains (Martin and others, 1982). Tyson Wash granite is Late Cretaceous based on a poorly constrained U-Pb zircon age of 83±25 Ma and a more precise U-Pb age of 86±1 Ma on sphene (Boettcher and others, 2002)

KJqm **Quartz monzonite (Cretaceous or Jurassic)**—Medium-grained, locally porphyritic quartz monzonite interpreted to intrude Paleozoic rocks and unit KXgn in northern Plomosa Mountains (Southern Cross pluton of Stoneman, 1985a, b). Locally contains orthoclase phenocrysts as long as 3 cm

KJg **Granite (Cretaceous or Jurassic)**—Weakly foliated, fine-grained leucocratic granite interpreted to intrude Paleozoic rocks in northern Plomosa Mountains (Spencer and others, 2015)

KJd **Diorite and andesite (Cretaceous and Jurassic)**—Fine-grained mafic rocks intruded as irregular sills in the McCoy Mountains Formation and the sedimentary rocks of Apache Wash

KXgn **Gneissic rocks, undivided (Cretaceous to Paleoproterozoic)**—Strongly foliated and lineated mylonitic gneiss, augen gneiss, amphibolite, and migmatite interpreted to be derived primarily from Mesozoic plutonic rocks and Proterozoic metamorphic and plutonic rocks. Migmatitic gneiss of Mesquite Mountain is interlayered with synmetamorphic sills of medium- to coarse-grained biotite granite of Late Cretaceous age (67.2±1.4 Ma; Knapp, 1989)

McCoy Mountains Formation (Cretaceous and Jurassic?)—Primarily sandstone and conglomerate; minor shale, mudstone, and siltstone (Pelka, 1973; Harding, 1982; Stone and Pelka, 1989; Tosdal and Stone, 1994). Largely or entirely of fluvial origin (Harding and Coney, 1985). Weakly to moderately metamorphosed; beds commonly exhibit crosscutting foliation or cleavage. Age bracketed by underlying Late Jurassic (~160 Ma) volcanic rocks (Jv) and by Late Cretaceous (~73 Ma) plutonic rocks that intrude the formation in Coxcomb Mountains 30 km west of map area (Barth and others, 2004). Detrital-zircon U-Pb age determinations in map area indicate that members C through L were deposited after ~110–120 Ma (Barth and others, 2004); members A and B could be as old as Late Jurassic (Fackler-Adams and others, 1997). In Dome Rock Mountains, member F contains tuff having a U-Pb zircon age of about 79 Ma (Tosdal and Stone, 1994) and numerous detrital zircon grains with dates between 80 and 108 Ma (Spencer and others, 2011). Maximum thickness of formation about 8 km. Members A–L are mapped individually in McCoy Mountains (Stone and Pelka, 1989); members A–B and C–E are combined as units KJmba and Kce in Dome Rock Mountains and southern Plomosa Mountains, where correlations with individual members are uncertain (Tosdal and Stone, 1994)

Kml **Member L (Cretaceous)**—Light-gray arkosic sandstone, conglomerate, and minor shale, all micaceous and phyllitic. Conglomerate clasts are quartzite, volcanic rocks, and granitic rocks. Contains detrital zircons as young as ~84 Ma (Barth and others, 2004). Base and top are faulted. Exposed thickness approximately 300 m

Kmk **Member K (Cretaceous)**—Dark-gray, fine-grained arkosic to volcanic-lithic sandstone, light-gray phyllitic shale, and minor conglomerate. Conglomerate clasts are volcanic and granitic rocks. In fault contact with member L (member Kml). Exposed thickness approximately 300 m

Kmj **Member J (Cretaceous)**—Dark-gray, medium- to coarse-grained arkosic to volcanic-lithic sandstone and conglomerate, interbedded in lowermost part with minor light-gray arkosic sandstone. Conglomerate clasts are granitic and volcanic rocks. Thickness approximately 350 m

Kmi **Member I (Cretaceous)**—Light-gray, medium- to coarse-grained arkosic and micaceous sandstone, conglomeratic sandstone, and conglomerate. Conglomerate clasts are quartzite, carbonate rocks, and granitic rocks. Thickness approximately 300 m

Kmh **Member H (Cretaceous)**—Light-gray, fine-grained arkosic sandstone, conglomeratic sandstone, and shale, all micaceous and phyllitic. Contains detrital zircons as young as ~87 Ma (Barth and others, 2004). Thickness approximately 50 to 250 m

Kmg **Member G (Cretaceous)**—Upper part consists of dark-greenish-gray, fine-grained arkosic to volcanic-lithic sandstone. Lower part consists of light-gray to tan phyllitic and calcareous shale, tan calcareous sandstone, and conglomerate containing clasts of quartzite and carbonate rocks. Lower contact truncates beds in member F (unit Kmf) at a low angle and is interpreted as an intraformational unconformity (Stone and Pelka, 1989). Locally contains late Early Cretaceous or younger fossil wood fragments (Pelka, 1973; Stone and Pelka, 1989). Thickness approximately 200 to 600 m. Contains detrital zircons as young as ~93 Ma (Barth and others, 2004)

Kmf **Member F (Cretaceous)**—Light- to medium-gray, fine- to coarse-grained arkosic sandstone and conglomerate interbedded with less abundant light-gray phyllitic shale. Dark-gray to dark-greenish-gray, very fine grained to fine-grained volcanic-lithic sandstone and siltstone present in upper part. Conglomerate clasts are granitic rocks, quartzite, volcanic rocks, and minor carbonate rocks. Fines upward from conglomerate and sandstone in lower part to very fine grained sandstone and siltstone in upper part. In Dome Rock Mountains, includes a lenticular, 5-m-thick tuff bed that has a U-Pb zircon age of 79±2 Ma (Tosdal and Stone, 1994). Uppermost part of member in McCoy Mountains contains detrital zircons as young as ~91 Ma (Barth and others, 2004). Strata equivalent to member F in Palen Mountains 3 km west of map area contain fragments of late Early Cretaceous or younger fossil wood (Pelka, 1973; Stone and others, 1987). Unconformable on underlying rocks of McCoy Mountains Formation in Dome Rock and southern Plomosa Mountains (Richard and others, 1993; Tosdal and Stone, 1994). Thickness in McCoy Mountains approximately 2,600 m

Kmec **Members E, D, and C, undivided (Cretaceous)**—Lithofeldspathic sandstone, siltstone, and mudstone in Dome Rock Mountains (Tosdal and Stone,1994). Questionably mapped in southern Plomosa Mountains to include various units of sandstone, mudstone, and conglomerate mapped by Richard and others (1993) as depositionally above unit KJmba

Kme **Member E (Cretaceous)**—Light-gray phyllitic shale, light-gray, dark-gray, and greenish-gray arkosic and volcanic-lithic sandstone, and minor conglomerate and calcareous rocks. Conglomerate clasts are quartzite, volcanic rocks, and granitic rocks. Grayish-orange, calcareous shale present near top. Contains detrital zircons as young as ~165 Ma (Barth and others, 2004). Thickness about 1,500 m

Kmd **Member D (Cretaceous)**—Dark-maroon phyllitic shale and silty to sandy shale interbedded with minor volcanic-lithic sandstone and conglomerate containing clasts of quartzite and volcanic rocks. Locally intruded by foliated diorite (not mapped). Thickness about 300 m

Kmc **Member C (Cretaceous)**—Dark-gray to dark-greenish-gray, very fine grained to fine-grained volcanic-lithic sandstone and siltstone, dark-gray to dark-greenish-gray mudstone, and minor conglomerate. Mudstone commonly contains brown calcareous pods and lenses of unknown origin. Conglomerate clasts are quartzite and volcanic rocks. Thickness about 1,200 m. Contains detrital zircons as young as ~109 Ma (Barth and others, 2004)

Jmba **Members B and A, undivided (Jurassic?)**—Interbedded quartzite, maroon mudstone, and brown sandy limestone in Dome Rock and southern Plomosa Mountains. Unconformably overlies Jurassic volcanic rocks (Jv) in both ranges and laps onto Proterozoic crystalline rocks in southern Plomosa Mountains (Richard and others, 1993; Tosdal and Stone, 1994)

Jmb **Member B (Jurassic?)**—Maroon mudstone and siltstone, commonly containing brown calcareous pods and lenses of unknown origin. Interbedded with minor tan quartzite and brown, recrystallized limestone. Thickness about 100 m

Jma **Member A (Jurassic?)**—Tan, fine- to medium-grained quartzite and minor chert- and quartzite-clast conglomerate; interbedded with less abundant maroon mudstone and siltstone that commonly contain brown calcareous pods and lenses of unknown origin. Thickness about 350 m. Unconformably overlies Jurassic volcanic rocks (unit Jv) in McCoy Mountains (Stone and Pelka, 1989); equivalent strata are interpreted to interfinger with underlying Late Jurassic volcanic rocks in Palen Mountains west of quadrangle (Fackler-Adams and others, 1997). Youngest known detrital zircons are 179 Ma (Barth and others, 2004). Queried outcrops at south end of McCoy Mountains consist of strongly foliated and folded phyllite and minor quartzite that overlie metamorphosed volcanic rocks (Jv?)

Sedimentary rocks of Apache Wash (Jurassic?)—Fining-upward sequence of sedimentary breccia, conglomerate, sandstone, and siltstone in southern Plomosa Mountains (Harding and Coney, 1985). Herein considered Late Jurassic(?) based on U-Pb analysis of detrital zircons (from unit Jaf) and on a U-Pb zircon age of ~154 Ma on a basaltic lava flow in a similar sequence just east of the map area (Spencer and others, 2011). Considered part of the McCoy Mountains Formation by Spencer and others (2011), but herein mapped as a lithologically distinct, possibly correlative unit in fault contact with the McCoy Mountains Formation as interpreted by Harding and Coney (1985). Total stratigraphic thickness approximately 1,900 m (Harding, 1980)

Jaf **Fine-grained clastic rocks**—Thin-bedded, locally laminated mudstone, siltstone, and very fine grained lithofeldspathic sandstone; thin beds of cobble conglomerate are also present. Unit generally weathers medium to dark gray, with phyllitic sheen; locally weathers greenish gray to brown. Analysis of detrital zircons from upper part of this unit yielded a youngest peak age of 160 to 170 Ma (Spencer and others, 2011)

Jas **Sandstone**—Medium-gray to greenish-gray, massive to medium-bedded, fine- to coarse-grained, lithofeldspathic sandstone and conglomeratic sandstone

Jau **Sandstone and conglomerate, undivided**—Conglomerate, conglomeratic sandstone, sandstone, and siltstone. Locally intruded by Late Jurassic mafic sills and interbedded with Late Jurassic mafic lava flows (Spencer and others, 2011). Stratigraphic relations unclear

Jac **Conglomerate**—Massive cobble to boulder conglomerate. Clasts include Jurassic volcanic rocks, lower Paleozoic sedimentary rocks, and Proterozoic granitoid rocks. Conglomerate clast assemblages vary across the outcrop area, reflecting local sediment sourcing (Richard and others, 1993)

Jax **Sedimentary breccia**—Massive, unsorted breccia, massive coarse conglomerate, and megablock breccia containing clasts of Paleozoic sedimentary rocks and Jurassic volcanic rocks as long as several hundred meters (Richard and others, 1993)

JŦu **Volcanic and sedimentary rocks, undivided (Jurassic and Triassic)**—Mapped locally in Riverside and Big Maria Mountains, where units Jv and JŦs are not distinguished owing to metamorphism and deformation

Jv **Volcanic rocks (Jurassic)**—Consists mainly of gray to greenish-gray, rhyodacitic volcanic and metavolcanic rocks composed of a microcrystalline, felsic groundmass and phenocrysts of plagioclase, quartz, potassium feldspar, and minor biotite averaging about 2 mm in diameter. Generally unbedded; commonly foliated and metamorphosed to greenschist and lower amphibolite facies. Interpreted in some areas to have originated as ash-flow tuff, flows, and hypabyssal porphyry (Tosdal, 1988; Tosdal and others, 1989; Fackler-Adams and others, 1997). Considered part of the Middle to Late Jurassic Dome Rock sequence of Tosdal and others (1989). North of Black Mesa in the southern Plomosa Mountains, includes (1) volcanic-lithic sandstone and conglomerate derived entirely from Jurassic ash-flow tuff, and (2) massive dark-gray lava with local fragmental texture. In Riverside Mountains, includes greenstone of Hamilton (1964). In southern Dome Rock Mountains, large part of unit contains no fragmental textures and may represent a massive hypabyssal intrusion (Spencer and others, 2015). Reported U-Pb zircon ages of unit are about 165 Ma in McCoy Mountains (Barth and others, 2004) and about 170 Ma in Dome Rock Mountains (Tosdal and Wooden, 2015). U-Pb zircon ages from equivalent unit in Palen Mountains west of quadrangle range from about 155 to 175 Ma (Fackler-Adams and others, 1997)

Jvbu **Upper bedded unit**—In Dome Rock Mountains, thin- to thick-bedded, fine-grained, felsic tuff and tuffaceous sedimentary rocks that form uppermost part of the Dome Rock sequence and concordantly underlie the McCoy Mountains Formation. Similar strata are present at the contact between units Jv and Jmba in southern Plomosa Mountains (Richard and others, 1993)

Jvbl **Lower bedded unit**—In Dome Rock Mountains, dark, thin-bedded, strongly metamorphosed sedimentary or volcaniclastic rocks that form the lowermost exposed part of the Dome Rock sequence. Rocks are composed largely of calc-silicate minerals, quartz, and biotite

Jvai **Altered hpabyssal intrusive(?) rocks**—In Dome Rock Mountains, sericitic schist containing small relict phenocrysts of quartz and feldspar

Jqp **Quartz monzonite porphyry (Jurassic)**—In Plomosa Mountains, massive, very light gray monzogranite intrusion containing abundant phenocrysts of potassium feldspar, plagioclase, and rounded quartz in a very fine grained groundmass. Similar to some rocks of unit Jv but coarser grained (Richard and others, 1993)

Jp **Plutonic rocks (Jurassic)**—Porphyritic granitoid rocks ranging from granodiorite and quartz monzonite to quartz syenite, and equigranular rocks of varied composition including leucocratic granite, granodiorite, and diorite. Commonly metamorphosed and foliated. Most abundant rock type is medium- to coarse-grained, strongly foliated to unfoliated, porphyritic granodiorite to monzogranite characterized by potassium feldspar phenocrysts 1 to 5 cm long and by clotted mafic minerals, primarily biotite. Leucocratic granite is fine to coarse grained and unfoliated to weakly foliated; it commonly intrudes the porphyritic granitoid rocks. Fine-grained, foliated granodiorite and diorite are present locally. Considered part of the Middle to Late Jurassic Kitt Peak-Trigo Peaks superunit by Tosdal and others (1989). Uranium-lead zircon ages from rocks in map area are about 160 Ma in Big Maria Mountains (L.T. Silver, oral commun. *in* Hamilton, 1982), 165 Ma in Mule Mountains (Tosdal, 1988), and 164–165 Ma in Dome Rock Mountains (Tosdal, 1988; Boettcher and others, 2002; Tosdal and Wooden, 2015). An unusually young uranium-lead zircon age of about 144 Ma was reported for leucogranite in the western Big Maria Mountains by Salem (2009)

Jpl **Leucocratic granite**—Light-colored, fine- to medium-grained, equigranular to slightly porphyritic granite containing 2 percent or less mafic minerals. U-Pb zircon age of about 160 Ma reported in Dome Rock Mountains (Boettcher and others, 2002)

Jpd **Foliated diorite to granodiorite**—Dark-colored, fine- to medium-grained plutonic rocks that typically exhibit foliation defined by biotite and saussurite marginal to feldspar grains

JXg **Granite (Jurassic or Paleoproterozoic)**—Diverse, undated granitic intrusions of unknown age northwest of Black Mesa in southern Plomosa Mountains (Richard and others, 1993), intruded by unit Jqp

JXt **Metamorphic tectonite (Jurassic or Paleoproterozoic)**—Strongly foliated, fine-grained metaigneous rocks that contain scattered small porphyroclasts of quartz and feldspar in Plomosa Mountains; interpreted to be derived from Jurassic volcanic rocks or Paleoproterozoic volcanic or plutonic rocks (units Jv, Xv, Xgd) (Richard and others, 1993). Northern outcrop area includes tectonized lenses of Paleozoic strata

JXu **Heterogeneous metamorphic rocks, undivided (Jurassic or Paleoproterozoic)**—Includes schist, gneiss, and fine-grained siliceous rocks in Dome Rock Mountains that could be quartzite, metavolcanic rocks, or both

JꞦs **Sedimentary rocks (Jurassic and Triassic)**—Variably metamorphosed sedimentary rocks of diverse lithology; interpreted as broadly correlative with Triassic to Jurassic formations of the Colorado Plateau and eastern Basin and Range (Hamilton, 1982, 1984; Yeats, 1985; Ballard, 1990; Richard and others, 1993) and with the Buckskin and Vampire Formations of west-central Arizona (Reynolds and others, 1989). Where best exposed in Little Maria Mountains, unit generally consists of, in descending order, (3) fine-grained, locally crossbedded quartzite possibly equivalent to Jurassic Aztec Sandstone; (2) conglomeratic rocks of uncertain regional correlation containing clasts of quartzite, carbonate rocks, and granite; and (1) greenschist, gypsiferous schist, and calcareous quartzite possibly equivalent to Triassic Moenkopi Formation (Hamilton, 1982; Ballard, 1990). In Dome Rock Mountains, consists of quartzofeldspathic schist and micaceous marble with layers of quartzite and quartz-pebble metaconglomerate. In southern Plomosa Mountains, consists of massive purple-gray, cobble to boulder conglomerate considered part of the the Vampire Formation by Reynolds and others (1989)

Ꞧqm **Quartz monzonite and monzodiorite (Triassic)**—Porphyritic biotite quartz monzonite and hornblende monzodiorite exposed in Mule Mountains near south edge of map. Age is about 213 Ma based on U-Pb analysis of zircon (Barth and others, 1990). Lithologically similar to Late Triassic Mount Lowe intrusion of the San Gabriel Mountains in southwestern California (Tosdal, 1988)

Ꞧd **Diorite and gabbro (Triassic?)**—Hornblende diorite and gabbro, locally metamorphosed to amphibolite, exposed in Mule and Little Chuckwalla Mountains near south edge of map (Tosdal, 1988; R.E. Powell, U.S. Geological Survey, written commun., 1989). Intruded by Triassic quartz monzonite and monzodiorite (unit Ꞧqm). Undated; age based on this intrusive relation and lack of lithologic similarity to older plutonic rocks known in region (Tosdal, 1988). Mixed with gneiss of probable Proterozoic age in Little Chuckwalla Mountains (R.M. Tosdal, U.S. Geological Survey, written commun., 1990)

Pzs **Sedimentary rocks, undivided (Paleozoic)**—Metamorphosed sedimentary rocks of presumed Paleozoic age consisting primarily of calcitic marble, dolomitic marble, calc-silicate rocks, quartzite, and schist. May include some rocks of Triassic and Jurassic age

P€s **Sedimentary rocks (Permian to Cambrian)**—Complete, or nearly complete, sequences of metamorphosed Permian to Cambrian strata equivalent to units PIPs and M€s combined, but too thin to subdivide at map scale

P̵Ps **Sedimentary rocks (Permian and Pennsylvanian)**—Variably metamorphosed sedimentary rocks interpreted to correlate with Permian and Pennsylvanian formations of the Colorado Plateau. In descending order, sequence consists of (4) cherty and non-cherty limestone, dolomite, and marble correlated with the Permian Kaibab Limestone; (3) fine-grained quartz sandstone and quartzite correlated with the Permian Coconino Sandstone; (2) quartzitic calc-silicate schist correlated with the Permian Hermit Formation; and (1) calcareous sandstone, quartzite, and calc-silicate rocks correlated with the Permian and Pennsylvanian Supai Formation (Miller, 1970; Hamilton, 1982; Stone and others, 1983; Ballard, 1990; Richard and others, 1993). Thickness of relatively undeformed, unmetamorphosed section in southern Plomosa Mountains is about 575 m (Miller, 1970); elsewhere, thickness is highly variable because of deformation and metamorphism

M€s **Sedimentary rocks (Mississippian to Cambrian)**—Metamorphosed sedimentary rocks interpreted to correlate with Mississippian to Cambrian formations of the Colorado Plateau. Where best exposed in Little Maria and southern Plomosa Mountains, sequence consists of, in descending order, (4) massive calcitic marble correlated with the Mississippian Redwall Limestone; (3) massive dolomitic marble of probable Devonian and Cambrian age; (2) schist and thin-bedded quartzite correlated with the Cambrian Bright Angel Shale; and (1) feldspathic quartzite and conglomeratic quartzite correlated with the Cambrian Tapeats Sandstone (Miller, 1970; Hamilton, 1982; Stone and others, 1983; Ballard, 1990; Richard and others, 1993). Thickness of relatively undeformed, unmetamorphosed section in southern Plomosa Mountains is about 290 m (Miller, 1970); elsewhere, thickness is highly variable because of deformation and metamorphism

YXg **Granite and granitic augen gneiss (Mesoproterozoic and Paleoproterozoic?)**—Coarse-grained granite and augen gneiss commonly characterized by phenocrysts or porphyroblasts of potassium feldspar 1 to 5 cm long. U-Pb zircon age in Big Maria Mountains is about 1.4 giga-annum (L.T. Silver, oral commun. *in* Hamilton, 1982); elsewhere, unit could include older rocks as well. Depositionally overlain by strata correlated with Tapeats Sandstone (basal part of unit M€s)

Xgn **Gneiss and amphibolite (Paleoproterozoic)**—Diverse gneissic and plutonic rocks in Riverside, Big Maria, and Little Maria Mountains including biotite gneiss, hornblende gneiss, schist, and amphibolite (Hamilton, 1964, 1982, 1984). Locally includes phyllonitic gneiss interpreted to stratigraphically underlie overturned Paleozoic rocks (Ballard, 1990)

Xgd **Granodiorite (Paleoproterozoic)**—Dark-colored, medium-grained, equigranular granodiorite in the southern Plomosa Mountains; moderately to highly fractured. U-Pb zircon age of 1,730 to 1,750 Ma (L.T. Silver, cited *in* Miller, 1970)

Xs **Schist (Paleoproterozoic)**—Fine-grained, micaceous schist and quartzite in Dome Rock Mountains

Xv **Metavolcanic rocks (Paleoproterozoic)**—Very fine grained, light- to dark-gray, felsic hornfels typically containing sparse quartz phenocrysts 1 to 2 mm in diameter. Rocks range from massive to compositionally banded on a decimeter to meter scale, with irregular lenticular lithosomes inferred to represent transposed primary lithologic units

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