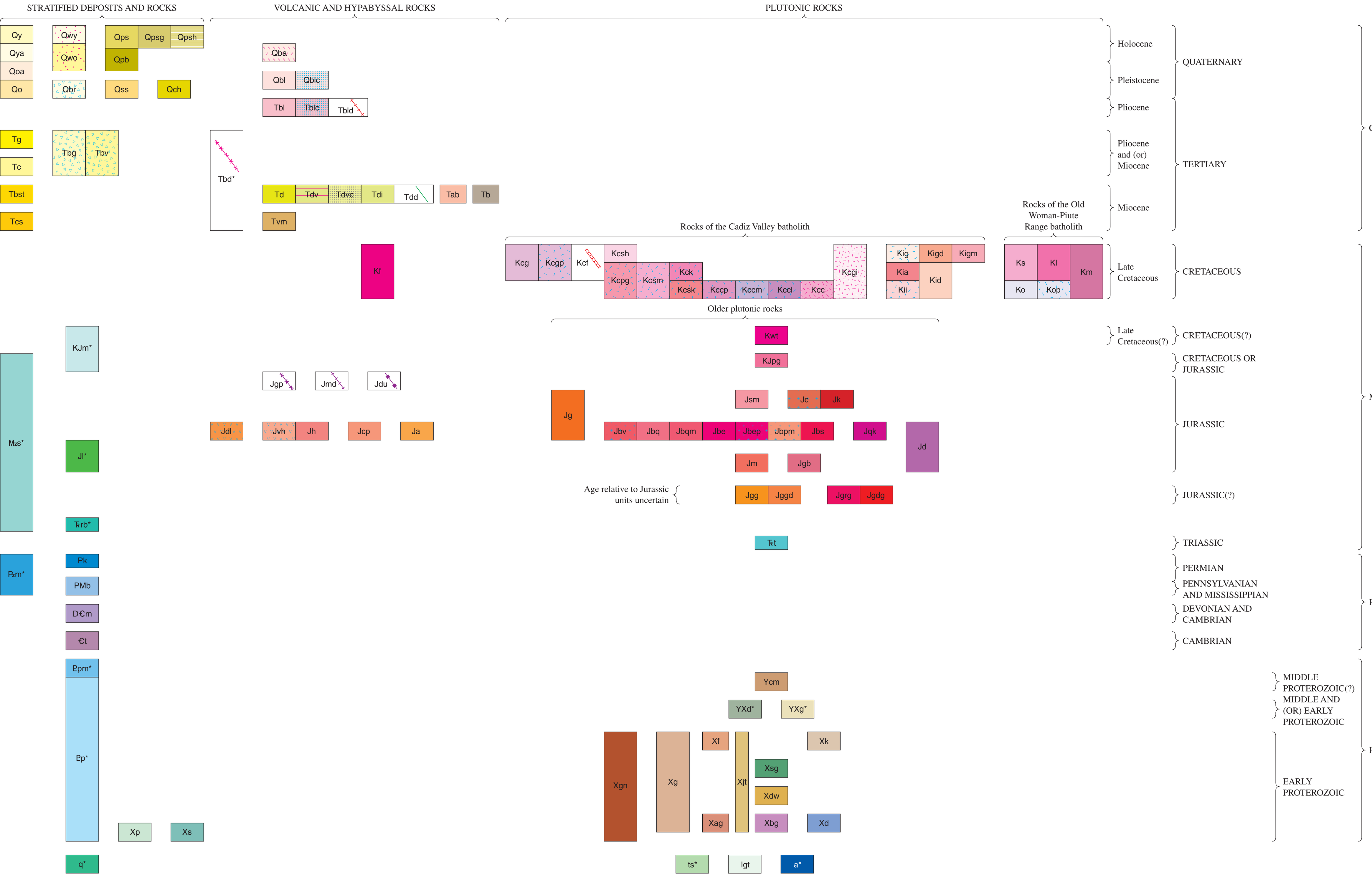
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

CORRELATION OF MAP UNITS



*See Description of Map Units for specific age assignment.

DESCRIPTION OF MAP UNITS

STRATIFIED DEPOSITS AND ROCKS

Alluvium—Divided into:

Qy **Youngest alluvium (Holocene)**—Poorly sorted sand and sandy gravel of locally derived angular and subangular clasts. Floors active washes. Downstream reaches blend with the younger alluvium (Qya) unit

Qya **Younger alluvium (Holocene and Pleistocene?)**—Sand and poorly sorted sandy gravel of angular and subangular clasts derived from adjacent mountains. Forms alluvial fans. Surface commonly characterized by bars and swales; older parts slightly dissected and may exhibit lightly varnished desert pavement. Locally includes a component of windblown sand

Qoa **Older alluvium (Pleistocene)**—Sandy gravel of angular and subangular clasts derived from adjacent mountains. Forms partly dissected fans, benches, and terraces, commonly surfaced by dark pavement of varnished stones. Reddish soil developed under surface. Age is late Pleistocene

Qo **Oldest alluvium (Pleistocene)**—Poorly sorted sandy gravel of angular and subangular clasts. Surfaced by dark desert pavement in places, but more commonly tilted, faulted, and dissected. Clast assemblage commonly mismatched from adjacent bedrock mountains due to fault displacement, for example, near the Pinto Mountain, Cleghorn Pass, Cleghorn Lakes, and Sheep Hole faults (Bacheller, 1978; Jagiello and others, 1992; Howard and Miller, 1992; and Howard and others, in press a,b)

Windblown sand deposits—Loose, fine to medium sand deposited as dunes and sheets. Dune crests identified on aerial photographs indicated by short dashes. Sand deposits and their age have been discussed by Tchakerian (1989, 1992). Divided into:

Qwy **Younger windblown sand (Holocene)**—Active dunes and sand sheets

Qwo **Older windblown sand (Holocene and Pleistocene)**—Stabilized (fossil) dunes. Supports growth of shrubs. Age is late Pleistocene and Holocene

Playa deposits—Mixed with alluvial sand and gravel and windblown sand at some playa margins. Surface and subsurface stratigraphy of the Bristol, Cadiz, Danby, and Dale Lake playas have been discussed by Bassett and others (1959), Smith (1960, 1970), Bassett and Kupfer (1964), Calzia and Moore (1980), Rosen (1989, 1991), Rosen and Warren (1990), Calzia (1991a,b,c, 1992), and Brown and Rosen (1992). The cross sections include older (Pleistocene) similar deposits in these units. Divided into:

Qps **Silt and clay (Holocene)**

Qpsg **Silt, clay, gypsum, and celestite (Holocene)**—At Cadiz and Danby dry lakes, gypsum caps wind-eroded pedestals (Bassett and Kupfer, 1964)

Qpsh **Silt, clay, and halite salt (Holocene)**—These deposits are commonly associated with brine

Qpb **Playa-bar deposits (Holocene and Pleistocene)**—Forms low hills near playa shorelines. Includes windblown sand. Age is late Pleistocene and Holocene

Qbr **Sedimentary breccia (Pleistocene)**—Present in the Bullion Mountains and near the Pinto Mountains. Interfingers with the oldest alluvium (Qo) unit. Breccia and megabreccia deposited as landslides

Qss **Sandstone (Pleistocene)**—Present adjacent to the Pinto and Bullion Mountains and east of the Sheep Hole Mountains north of Dry Lakes. Friable, massive, arkosic sandstone and locally mudstone. Mostly brownish or reddish, but includes greenish sandstone in the southwestern corner of the quadrangle. Interfingers with the oldest alluvium (Qo) unit. Contains well-rounded pebbles in exposure east of Sheep Hole Mountains. Exposures near the Pinto Mountains in the southwestern corner of the quadrangle contain a bed of volcanic ash up to 4 m thick that Bacheller (1978) correlated (using trace-element content) with the 0.7-Ma Bishop Tuff

Qch **Sedimentary deposits of Campbell Hill (Pleistocene)**—Present in southwestern part of quadrangle. Varicolored fluvial and lacustrine beds containing clasts of basalt, granite, marble, and quartzite derived from the San Bernardino Mountains west of the quadrangle. Moderately to poorly indurated sand, bedded clast-supported gravel, silt, marl, clay, and minor fanglomerate. At least 370 m thick. Contains a Rancholabrean vertebrate fauna (Bassett and Kupfer, 1964; Bacheller, 1978; Jefferson, 1992)

Tg **Gravel (Pliocene and (or) Miocene)**—Present in the Pinto and southern Bullion Mountains. Caps bedrock ridges at levels high above present stream grade. Contains clasts (quartzite in Pinto Mountains, rhyolite in Bullion Mountains) derived from distant, now-isolated sources. Age is late Miocene and (or) Pliocene

Sedimentary breccia (Pliocene and (or) Miocene)—Landslide megabreccia. Age is late Miocene and (or) Pliocene. Divided into:

Tbg **Granitic-clast breccia**—Present in northern Coxcomb Mountains, southern and eastern Iron Mountains, and western Granite Mountains. Clasts derived from Cretaceous granites and granite gneisses

Tbv **Volcanic-clast breccia**—Present in eastern Bullion and in southwestern Calumet Mountains. Clasts derived from Miocene dacitic volcanic rocks

Tc **Alluvial conglomerate (Pliocene and (or) Miocene)**—Present on the flanks of Lead Mountain. At least 500 m thick on east side of Lead Mountain, where clast assemblage (including muscovite granite and wollastonite marble) matches now-isolated sources in the eastern Bullion Mountains south of the America Mine. Age is late Miocene and (or) Pliocene

Tbst **Breccia, sandstone, and tuff (Miocene)**—Present in northern Calumet Mountains. Age is inferred to be early Miocene

Tcs **Conglomerate and sandstone (Miocene)**—Present in northern Calumet Mountains. Steeply dipping conglomerate and tuffaceous sandstone. Granite clasts are as large as 25 cm across. Age is inferred to be early Miocene

KJm **McCoy Mountains Formation of Miller (1944) (Cretaceous and Jurassic?)**—Present in Coxcomb Mountains. Phyllitic metamorphosed siltstone and calcareous siltstone

Mzs **Metasedimentary gneiss of Sheep Hole Mountains (Mesozoic)**—Present also in Bullion and Calumet Mountains. Layered garnet-hornblende-epidote-quartz gneiss and associated schist and calc-silicate rock. Widely intruded by granitoids; no internal stratigraphy is apparent. Includes quartzite in Calumet Mountains. Associated with marble (Pzm) unit. Protolithic age inferred to be early Mesozoic

Jl **Limestone (Jurassic?)**—Present in southern Bullion and in eastern Pinto Mountains

Trb **Buckskin Formation of Reynolds and Spencer (1989) (Triassic)**—Present in Kilbeck Hills. Calc-schist, pelitic schist, and gneiss. These rocks are considered to be correlative with the Moenkopi Formation

Pzm **Marble (Paleozoic)**—Present in northern and southern Calumet and eastern Bullion Mountains. Calcitic white marble and wollastonite marble. Includes rocks of the metamorphosed Bird Spring Formation and Redwall Limestone. Age is late Paleozoic; as mapped, may also include some Mesozoic strata

Pk **Metamorphosed Kaibab Limestone, Coconino Sandstone, and Hermit Shale, undivided (Permian)**—Present in Kilbeck Hills. Dolomitic calcitic marble (Kaibab Limestone), fine-grained metaquartzite (Coconino Sandstone), and calc-schist (Hermit Shale)

PMb **Metamorphosed Bird Spring Formation (Permian and Pennsylvanian) and Redwall Limestone (Mississippian), undivided**—Present in Kilbeck Hills and Old Woman Mountains. Layered calcitic marble, quartzitic and wollastonite marble, and quartzite (Bird Spring Formation) and calcitic white marble with siliceous metachert layers (Redwall Limestone)

D€m **Marble and dolomite marble (Devonian and Cambrian)**—Present in Kilbeck Hills, Old Woman Mountains, and southern Calumet Mountains. Brownish dolomitic marble and underlying laminated gray calcitic marble. Includes the metamorphosed Bonanza King Formation and overlying strata. Cambrian and Devonian protolithic age

€t **Metamorphosed Bright Angel Shale and Tapeats Sandstone, undivided (Cambrian)**—Present in Kilbeck Hills, Old Woman Mountains, and southern Calumet Mountains. Pelitic schist (Bright Angel Shale) and fine-grained to conglomeratic, cross-bedded quartzite (Tapeats Sandstone). Nonconformable on the Fenner Gneiss (Xf)

Pp **Quartzite of Pinto Mountain (Proterozoic)**—Nonconformable on the granite of Joshua Tree (Xjt). Metamorphosed. Partly conglomeratic. Protolithic age may be Early or Middle Proterozoic or Late Proterozoic and Early Cambrian. Locally, includes:

Ppm **Marble**—Marble and calc-silicate rock comprising the uppermost part of the Pinto Mountain unit

Xp **Pinto Gneiss of Miller (1938) (part) (Early Proterozoic)**—Present in Pinto Mountains. Quartzitic granofels and gneiss

Xs **Schist, gneiss, and quartzite (Early Proterozoic)**—Present in small areas of Granite and Old Woman Mountains

q **Quartzite (age unknown)**—Present in small areas in eastern Sheep Hole Mountains and north of Sheep Hole Pass. Pre-Late Cretaceous

VOLCANIC AND HYPABYSSAL ROCKS

Qba **Basalt of Amboy (Holocene or Pleistocene)**—Olivine basalt. Pahoehoe flow, described by Parker (1963), Greeley and Iverson (1978), and Hazlett (1992). Composition and petrology discussed by Glazner and others (1991). Age is late Pleistocene (Glazner and others, 1991) or early Holocene (Parker, 1963; Miller, 1989)

Qbl **Basalt of Lead Mountain (Pleistocene)**—Olivine basalt. Aa flow. Age is late Pleistocene as indicated by K-Ar dating of whole rock (0.36±0.04 Ma; Howard, 1993). Locally, includes:

Qblc **Basalt cinders**—Present at source vent south of Lead Mountain

Tbl **Basalt of Deadman Lake volcanic field (Pliocene)**—Present in northwest part of quadrangle. Contains ultramafic xenoliths. Age is inferred to be late Pliocene. Locally, includes:

Tblc **Basalt cinders**—Present at source vents

Tbld **Basalt dike**

Tbd **Basalt dikes (Pliocene? and Miocene)**—Present in Bullion and Iron Mountains and at Valley Mountain

Td **Dacitic rocks (Miocene)**—Age is early Miocene. Ages determined by K-Ar dating of biotite and hornblende are oldest in the east and youngest in the west, as follows: 22.4±1.6 Ma for intrusive dacite (Tdi) in the Iron Mountains (Miller and Howard, 1985), 21.4±0.6 and 21.3±1.3 Ma for dacitic volcanic rocks (Tdv) in the Calumet Mountains (Howard and John, 1984), and 20.1±1.0 Ma and 20.8±0.5 Ma for dacitic volcanic rocks (Tdv) at Lead Mountain (Howard, 1993). Locally, divided into:

Tdv **Dacitic volcanic rocks**—Present at Lead Mountain, northeastern Bullion Mountains, and Calumet Mountains. Flows and tuff, ranging in composition from andesite to rhyolite

Tdvc **Volcaniclastic rocks**—Present at Lead Mountain. Tuff, agglomerate, sandstone, and flows

Tdi **Intrusive dacite**—Present as stock at Lead Mountain, as laccolithic bodies in the Iron Mountains, and includes dikes in the Calumet and eastern Bullion Mountains

Tdd **Dacitic dikes**—Makes up the eastern Bullion dike swarm in Bullion Mountains and present in Calumet Mountains

Tab **Amygdaloidal basalt (Miocene)**—Present at Lead Mountain. Largely intrusive. Intrudes the volcaniclastic rocks (Tdvc) unit and is intruded by the intrusive dacite (stock) (Tdi) unit. Age is early Miocene

Tb **Basalt in Iron Mountains (Miocene)**—Pyroxene-phyric basalt. Ages determined by J.K. Nakata (written commun., 1993) by K-Ar (whole rock) are 18.6±0.5 and 20.5±0.5 Ma (early Miocene)

Tvm **Basalt of Valley Mountain (Miocene)**—Olivine basanitoid flow and intrusion. Early Miocene age indicated by K-Ar age dating of whole rock (22.7±0.7 Ma) (Howard, 1993)

Kf **Felsic dikes (Late Cretaceous)**—Microgranite in Pinto Mountains near Marbolite Mine. K-Ar age (secondary muscovite) 71.9±1.8 Ma (Howard and others, in press a)

Jgp **Granite porphyry dikes (Jurassic)**—Present in Pinto and Bullion Mountains. Includes dike in Old Woman Mountains that resembles the Chubbuck Porphyry (Jc)

Jmd **Mafic dikes (Jurassic)**—Present in Pinto, Bullion, and Sheep Hole Mountains and at Valley Mountain. Hornblende microdiorite. Age is Late(?) Jurassic

Jdu **Dikes, undivided (Jurassic and Jurassic?)**

Jdl **Dale Lake Volcanics (Jurassic)**—Named here for Dale Lake, in the southwest part of the quadrangle. North-trending ridge in the Pinto Mountains 7 km southeast of Dale Lake and 1.5–2 km northeast of the Iron Age Mine (SW 1/4 sec. 17 unsurveyed, T. 1 S., R. 13 E., New Dale 7.5' quadrangle, San Bernardino County) is designated as type locality. Present in the western part of the Pinto Mountains. Consists of porphyritic, aphanitic, and epiclastic rocks, including flows, polymict breccias, and tuffaceous sedimentary rocks. Locally vuggy or laminated. Phenocrysts include plagioclase, chloritized biotite, chloritized hornblende, pyroxene pseudomorphs, quartz, and alkali feldspar; the alkali feldspar phenocrysts are generally lavender and subspherical and resemble phenocrysts in the Virginia Dale Quartz Monzonite and other units of the Bullion Mountains Intrusive Suite. In the type locality of the Dale Lake Volcanics, upright, graded-bedded tuffaceous sandstone contains clastic lavender alkali-feldspar crystals and underlies a sill or thick flow of porphyritic granitoid, indistinguishable from the Virginia Dale Quartz Monzonite, that contains identical alkali-feldspar crystals as phenocrysts. These relations are taken to indicate that crystal-bearing eruptive rocks of the Dale Lake Volcanics locally predated the Virginia Dale Quartz Monzonite, but the magmas were so closely similar that the Dale Lake Volcanics probably overlap in age with the Virginia Dale Quartz Monzonite. Analyzed volcanic rocks contain 64 to 66 percent SiO_2 (5 samples) and exhibit potassium enrichment indicative of potassium metasomatism in the groundmass (Howard and Allen, 1988; Jagiello, 1991). Age is Jurassic based on apparently coeval relations described above with the Virginia Dale Quartz Monzonite

Jvh **Volcanic and hypabyssal rocks, undivided (Jurassic)**—Present in Pinto and Bullion Mountains. Includes welded tuffs in the Bullion Mountains. Two analyzed volcanic rocks in the Bullion Mountains contain 56 and 60 percent SiO_2 (Jagiello, 1991). Volcanic rocks in the unit are probably correlative with the Dale Lake Volcanics

Jh **Hypabyssal rocks (Jurassic)**—Present in Pinto and Bullion Mountains. Rocks of intermediate composition

Jcp **Hypabyssal quartz monzonite of Cleghorn Pass (Jurassic)**—Present in Bullion Mountains as the Cleghorn Pass pluton; also, tentatively includes similar rocks in the southeastern Bullion Mountains and Pinto Mountains (after Jagiello, 1991). Porphyritic. Locally clinopyroxene-bearing (Jagiello, 1991). Rocks are bleached white and albitized.

Ja **Altered intrusive rocks (Jurassic)**—Present in the Bullion Mountains. Identified at Valley Mountain from Landsat imagery based on spectral similarity to unit Jcp

PLUTONIC ROCKS

Rocks of the Cadiz Valley batholith

Coxcomb Intrusive Suite—The Coxcomb Granodiorite of Miller (1944) is adopted and here revised as the Coxcomb Intrusive Suite in order to clarify its areal distribution and to subdivide it into numerous mappable units of granite and granodiorite. Named for the Coxcomb Mountains in the south-central part of the quadrangle and south of the quadrangle. Type locality is designated as area alongside highway 62 in sec. 9, T. 1 S., R. 15 E., Cadiz Valley SW 7.5' quadrangle, San Bernardino County. Consists of light-colored granite, granodiorite, and minor quartz monzodiorite. Occupies much of the Coxcomb, Calumet, and southern Calumet Mountains and Kilbeck Hills and major parts of the Sheep Hole and eastern Bullion Mountains. Comprises the largest part of the Cadiz Valley batholith. Age is Late Cretaceous based on U-Pb dating of zircon from the Clarks Pass Granodiorite and from a granodiorite body south of the quadrangle (approximately 70 Ma; Calzia and others, 1986; Wright and others, 1987). On this map, most nonporphyritic rocks (except for the Sheep Hole Pass Granite, foliated granite dikes, and a unit of granite, granodiorite, and metaigneous inclusions) are grouped as unit Kcg. Porphyritic rocks are divided into several units distinguished only by their areas of exposure and by their subtle textural or compositional variations. Divided into:

Kcg **Granite (Late Cretaceous)**—Occupies much of the Sheep Hole, Coxcomb, and Calumet Mountains. Equigranular, biotite and muscovite-biotite monzogranite, leucomonzogranite, and granodiorite. Forms several plutons. Foliated, lineated, and recrystallized in southern Cadiz Valley. Locally, includes:

Kcgp **Porphyritic granite and granodiorite facies**—Rocks contain alkali-feldspar phenocrysts 1–2 cm across. Gradational with and intrudes unit Kcg

Kcf **Foliated granite dikes**—Present in northwestern Coxcomb Mountains. Mylonitic, equigranular, fine-grained biotite monzogranite gneiss

Kcsh **Sheep Hole Pass Granite (Late Cretaceous)**—Named here for Sheep Hole Pass located between the Sheep Hole and Bullion Mountains in the west-central part of the quadrangle. Type locality designated as the west side of Sheep Hole Pass (unsurveyed sec. 28, T. 2 N., R. 12 E., Dale Lake 7.5' quadrangle, San Bernardino County). Exposed widely in the eastern Bullion Mountains as the Sheep Hole Pass pluton. Medium-grained, equigranular biotite-muscovite monzogranite, leucomonzogranite, and granodiorite. Similar rocks in other plutons are mapped as parts of unit Kcg. Intrudes the Sheep Hole Mountains Granodiorite (Kcsm)

Kcgi **Granite, granodiorite, and metaigneous inclusions (Late Cretaceous)**—Granite, granodiorite, and abundant screens and inclusions of older metamorphic rocks in intrusive contact zones

Kcpg **Porphyritic granodiorite (Late Cretaceous)**—Medium- to coarse-grained, porphyritic sphene-biotite granodiorite. Quartz grains as large as 1 cm. Appears gradational into unit Kcg

Kcsm **Sheep Hole Mountains Granodiorite (Late Cretaceous)**—Named here for the Sheep Hole Mountains. Type locality designated as the northern Sheep Hole Mountains 2–3 km NNE of Sheep Hole Pass (secs. 15 and 22, T. 2 N, R. 12 E., Dale Lake 7.5' quadrangle, San Bernardino County). Exposed in the northern Sheep Hole Mountains and small parts of the eastern Bullion Mountains as the Sheep Hole Mountains pluton. These rocks were previously called the granodiorite of Green Scorpion Mine by Howard and John (1984). Porphyritic, medium- to coarse-grained sphene- and muscovite-bearing biotite granodiorite. Blocky potassium-feldspar phenocrusts 2–10 cm long. Discrete, anhedral quartz 3–15 mm in diameter. Cut by dikes of the Sheep Hole Pass Granite. Locally gradational with unit Kcg. Tentatively includes similar but areally separate rocks in the southern Calumet Mountains

Kck **Granodiorite of Kilbeck Hills (Late Cretaceous)**—Medium-grained, porphyritic biotite granodiorite. Alkali-feldspar phenocrysts 1 cm across. Foliated and recrystallized in southernmost exposures. Intrudes and possibly grades into the Old Woman Mountains Granodiorite (Ko)

Kcsk **Quartz monzodiorite of southern Kilbeck Hills (Late Cretaceous)**—Gneissic, porphyritic biotite granodiorite and quartz monzodiorite. Alkali-feldspar phenocrysts 1–2 cm long

Kccp **Clarks Pass Granodiorite (Late Cretaceous)**—Named here for Clarks Pass at the south end of the Sheep Hole Mountains in the south-central part of the quadrangle. Type locality is designated as the eastern side of the Sheep Hole Mountains, 2–3 km north of Clarks Pass (sec. 7, T. 1 S., R. 14 E., Clarks Pass 7.5' quadrangle, San Bernardino County). Exposed in southern part of the Sheep Hole Mountains and 2 km southeast of Clarks Pass. Medium-grained, mostly porphyritic, hornblende-bearing, sphene-biotite granodiorite. Potassium-feldspar phenocrysts typically subequant, 1–1.5 cm across. Mafic content 5–15 percent. Commonly foliated. Cut by rocks of the porphyritic granite and granodiorite facies (Kcpg) unit. Age is Late Cretaceous based on U-Pb dating of zircon (approximately 70 Ma; Wright and others, 1987). Tentatively includes similar rocks in a separate intrusive body in the northern Calumet Mountains

Kccm **Granodiorite of southern Calumet Mountains (Late Cretaceous)**—Medium-grained porphyritic biotite granodiorite. Alkali-feldspar phenocrysts as large as 2.5 cm. Intruded by unit Kcg

Kccl **Granodiorite of Cadiz Lake (Late Cretaceous)**—Medium- to coarse-grained, porphyritic granodiorite to monzogranite containing biotite, sphene, and sparse muscovite. Alkali-feldspar phenocrysts as large as 2.5 cm. Rocks in southeasternmost exposures are intruded by unit Kcg and exhibit a mylonitic foliation like the Iron Granodiorite Gneiss (Kii)

Kcc **Porphyritic granodiorite of Coxcomb Mountains (Late Cretaceous)**—Medium- to coarse-grained biotite granodiorite. Alkali-feldspar phenocrysts 1–5 cm long. Unit is equivalent to part of the Coxcomb Granodiorite of Miller (1944)

Iron Mountains Intrusive Suite—Named here for the Iron Mountains in the southeastern part of the quadrangle. Type locality is designated as the southern Iron Mountains at Granite Pass (sec. 21, T. 1 S., R. 17 E., Granite Pass 7.5' quadrangle, San Bernardino County). Widely exposed in the Iron and Granite Mountains. Age is Late Cretaceous based on K-Ar dating of muscovite and U-Pb dating of zircon (approximately 70 Ma; Miller and Howard, 1985; Wright and others, 1987). Closely similar in age, composition, and texture to the Coxcomb Intrusive Suite and rocks of the Old Woman-Piute Range batholith. Divided into:

Kig **Granite Pass Granite (Late Cretaceous)**—Named here for Granite Pass between the Iron and Granite Mountains in the southeastern part of the quadrangle. Type locality designated as the south side of Granite Pass adjacent to the intersection between Twentynine Palms Highway (State highway 62) and highway to Desert Center (State highway 177) (sec. 32 unsurveyed, T. 1 S., R. 17 E., Granite Pass 7.5' quadrangle, San Bernardino County). Widely exposed in the southern Iron Mountains and northern Granite Mountains as the Granite Pass pluton. Coarse-grained, porphyritic muscovite-biotite monzogranite to granodiorite. Alkali-feldspar phenocrysts 1–4 cm long. Intrudes the Danby Lake Granite Gneiss (Kid). Locally, includes:

Kigd **Equigranular facies**—Medium-grained muscovite-biotite granodiorite. Grades into unit Kig

Kigm **Muscovite-garnet granite facies**—Muscovite-rich, medium-grained monzogranite to granodiorite. Garnet-bearing locally. Grades into units Kig and Kigd

Kia **Garnet aplite (Late Cretaceous)**—Mylonitized dikes present in northern Iron Mountains. Intrudes the Iron Granodiorite Gneiss (Kii)

Kid **Danby Lake Granite Gneiss (Late Cretaceous)**—Named here for Danby Lake in the southeast part of the quadrangle. Type locality is designated as area along both sides of transmission-line road 1 km north of Iron Mountain Pumping Plant (secs. 19 and 20 unsurveyed, T. 1 N, R. 18 E., Danby Lake 7.5' quadrangle, San Bernardino County). Crops out extensively in the Iron Mountains. These rocks were previously called the granite gneiss of Iron Mountains by Miller and Howard (1985) and Howard and others (1989a). Medium-grained, leucocratic muscovite-biotite monzogranite gneiss. Accessory zircon and sphene. Alignment of deformed and recrystallized micas, quartz, and feldspar produces distinct mylonitic foliation and lineation; S-C fabric indicates shear sense top to east-northeast. As mapped, tentatively includes similar gneissic granite in the eastern Granite Mountains. Intrudes and grades into the Iron Granodiorite Gneiss (Kii). Protolithic and metamorphic ages are Late Cretaceous

Kii **Iron Granodiorite Gneiss (Late Cretaceous)**—Named here for the Iron Mountains in the southeast part of the quadrangle. Type locality is designated as area 2 km west of the Iron Mountain Pumping Plant, (secs. 24 and 25, T. 1 N., R. 17 E., Iron Mountains 7.5' quadrangle, San Bernardino County). Crops out extensively in the Iron Mountains. These rocks were formerly called the porphyritic granodiorite gneiss of Iron Mountains by Miller and Howard (1985) and Howard and others (1989a). Porphyritic, medium-grained biotite granodiorite gneiss. Accessory muscovite, garnet, zircon, and sphene. Alkali-feldspar relict phenocrysts occur as augen porphyroclasts 0.5–1.5 cm long. Alignment of deformed and recrystallized micas, quartz, and feldspar produces distinct mylonitic foliation and lineation. Contains rare zones, 1 to 10 cm thick, of black mylonite aligned approximately parallel to foliation of gneiss. Protolithic and metamorphic ages are Late Cretaceous

Rocks of the Old Woman-Piute Range batholith

Ks **Granite of Sweetwater Wash (Late Cretaceous)**—Present in Old Woman Mountains as the Painted Rock pluton and other bodies, and in northern Kilbeck Hills. Medium-grained, muscovite-biotite leucomonzogranite, commonly containing garnet. Intrudes the Old Woman Mountains Granodiorite (Ko). Age (determined north of the quadrangle) is approximately 71 Ma by U-Pb dating of zircon (Foster and others, 1989; Miller and others, 1990)

Kl **Leucocratic granite (Late Cretaceous)**—Present on the west side of the Old Woman Mountains. These rocks were previously included as part of the leucogranite of Milligan by Howard and others (1989b). Equigranular, medium-grained biotite monzogranite. Bears a metamorphic foliation in which S-C fabric indicates shear sense top down to west (part of Western Old Woman Mountains shear zone of Carl and others, 1991). Intrudes the Old Woman Mountains Granodiorite (Ko)

Km **Leucogranite of Milligan (Late Cretaceous)**—Present in the Old Woman Mountains. Medium-grained, magnetite-biotite leucomonzogranite and leucosyenogranite. Intimately intermixed with the Kilbeck Gneiss (Xk). Local faint ghostlike relict(?) foliation suggests gradations into the Kilbeck Gneiss. Intrusive relations with Old Woman Mountains Granodiorite are uncertain, but probably older than and partly coeval with that unit

Ko **Old Woman Mountains Granodiorite (Late Cretaceous)**—Present in the Kilbeck Hills and widely in the Old Woman Mountains as the Old Woman pluton. Medium-grained, sphene-hornblende-biotite granodiorite. Age (determined north of the quadrangle) is 71±1 Ma by U-Pb dating of zircon (Foster and others, 1989; Miller and others, 1990). Locally, includes:

Kop **Porphyritic facies**—Present in the southern old Woman Mountains. Sphene-biotite granodiorite to monzogranite. Alkali-feldspar phenocrysts 0.5–1 cm across. Grades into unit Ko. Southeastern exposures exhibit mylonitic foliation and lineation and closely resemble the Iron Granodiorite Gneiss; asymmetric relict phenocryst porphyroclasts indicate shear sense top down to southeast

Older plutonic rocks

Kwt **White Tank(?) monzogranite of Trent (1984)(Late Cretaceous?)**—Informally named unit. Present in the western Pinto Mountains. Medium-grained biotite monzogranite. Quartz is discrete, subhedral. These rocks are regarded here as questionably equivalent to the White Tank monzogranite of Trent (1984) (equivalent to the White Tank Monzonite of Miller, 1938). Rocks are undated; other light-colored granitoids in the Pinto Mountains, 10–13 km west of the quadrangle, have yielded $^{40}Ar/^{39}Ar$ ages of 75 Ma (hornblende, informally named Queen Mountain monzogranite of Trent, 1984) and 90 Ma (muscovite, informally named Oasis monzogranite of Trent, 1984) (J.K. Nakata, unpub. data, 1991)

KJpg **Pink granite (Cretaceous or Jurassic)**—Present in southern Sheep Hole and northern Calumet Mountains. Medium-grained biotite monzogranite. Intrudes the quartz monzodiorite (Jbqm) unit and is intruded by the Clarks Pass Granodiorite (Kccp)

Jg **Granite (Jurassic)**—Undivided granitoid rocks present in Kilbeck Hills and Sheep Hole and Pinto Mountains

Jsm **Granite of Ship Mountains (Jurassic)**—Forms the Ship Mountains pluton. Leucocratic, medium- to fine-grained biotite quartz syenite, syenogranite, quartz monzonite, and fine-grained hypabyssal equivalents. Age by U-Pb dating of zircon is >150 Ma (L.T. Silver quoted by Bishop, 1964) or Middle or Late Jurassic (Gerber and others, 1995)

Jc **Chubbuck Porphyry (Jurassic)**—Named here for the abandoned site of Chubbuck railroad siding in the northern Kilbeck Hills in the northeastern quadrant of the quadrangle. Type locality is designated as area 1 km west of Chubbuck railroad-siding site as shown on the Chubbuck 7.5' quadrangle (1985 provisional edition; NW 1/4 of SE 1/4 sec. 10, T. 3 N., R. 16 E., San Bernardino County). These rocks were formerly mapped as porphyritic granite gneiss by Howard and others (1989a). Underlies small areas of the Kilbeck Hills. Biotite monzogranite and granodiorite gneiss. Phenocryst augen of alkali feldspar 1 cm long are in a dark, medium-grained to very fine grained foliated matrix. Contains mafic enclaves 2 cm across. Intrudes as sheets into Paleozoic strata. Intrudes the quartz diorite of Kilbeck Hills (Jqk) unit. Intrusive age from U-Pb dating of zircon is tentatively regarded as approximately 150 Ma (J.E. Wright, written commun., 1986)

Jk **Granite gneiss of Kilbeck Hills (Jurassic)**—Occupies a small area of the Kilbeck Hills. Medium-grained biotite monzogranite and monzogranite gneiss. Appears gradational into small unmapped exposures of the Chubbuck Porphyry. Intrudes the quartz diorite of Kilbeck Hills (Jqk) unit. Age from U-Pb dating of zircon is tenatively regarded as Late Jurassic (J.E. Wright, written commun., 1986)

Bullion Mountains Intrusive Suite—Named here for the Bullion Mountains on the west side of the quadrangle. Type locality is designated as southeast part of Valley Mountain, 10 km south of the Bullion Mountains (sec. 3, T. 2 N., R. 10 E., Valley Mountain 7.5' quadrangle, San Bernardino County). Widely exposed in the Bullion, Pinto, and Sheep Hole Mountains and small parts of the Calumet and Coxcomb Mountains. Consists of rocks ranging in composition from quartz monzodiorite to granite, most of which contain lavender alkali feldspar. Age is Jurassic based on dating of the Virginia Dale Quartz Monzonite (Jbv). Divided into:

Jbv **Virginia Dale Quartz Monzonite (Jurassic)**—Named here for the Virginia Dale Mine in the eastern Pinto Mountains, in the southwest part of the quadrangle. Type locality is designated as area along the west side of the Gold Crown Road east of Humbug Mountain, near the Virginia Dale Mine (sec. 19 unsurveyed, T. 1 S., R. 12 E., Humbug Mountain 7.5' quadrangle, San Bernardino County). Reference localities are designated as the Marbolite Mine area (west side of sec. 24 unsurveyed, T. 1 S., R. 10 E., Twentynine Palms Mountain 7.5' quadrangle, San Bernardino County) and the southeastern part of Valley Mountain (sec. 3, T. 2 N., R. 10 E., Valley Mountain 7.5' quadrangle, San Bernardino County). Widely exposed in the Pinto, Bullion, and Sheep Hole Mountains. Medium-grained, porphyritic sphene-hornblende-biotite and sphene-biotite quartz monzonite and monzogranite. Alkali-feldspar phenocrysts 1–2 cm across and typically lavender and round. Subspherical mafic enclaves 5–15 cm across common. Recrystallized and foliated (in places an augen gneiss) where near Cretaceous granitoids. Age is Jurassic based on dating of K-Ar hornblende (159±5 Ma) and biotite (155±5 Ma) at Valley Mountain (Calzia and Morton, 1980), K-Ar biotite (167±7) near Marbolite Mine in the Pinto Mountains (Bishop, 1964), and preliminary U-Pb dating of zircon from near Marbolite Mine (approximately 160–165 Ma: J.L. Wooden, oral commun., 1993). Provisionally includes rocks in the Pinto, northern Calumet, and northeastern Bullion Mountains that belong to separate plutons

Jbq **Quartz monzonite (Jurassic)**—Present in eastern Pinto and southeastern Bullion Mountains. Medium-grained, equigranular hornblende-biotite quartz monzonite, quartz monzodiorite, and monzogranite. Locally contains clinopyroxene. Recrystallized and foliated where present near the Sheep Hole Pass Granite. Grades into the hypabyssal rocks (Jh) unit. Locally grades into the Virgina Dale Quartz Monzonite; elsewhere either cuts or is cut by that unit

Jbqm **Quartz monzodiorite (Jurassic)**—Present in eastern Pinto Mountains (largely quartz monzodiorite), southern Sheep Hole Mountains (largely quartz diorite), and western Coxcomb Mountains (largely monzogranite). Contains biotite and commonly hornblende. Locally contains alkali-feldspar phenocrysts. Darker than unit Jbq. Recrystallized and foliated where present close to Cretaceous granitic intrusions

Jbe **Granite east of Cleghorn Pass (Jurassic)**—Present in Bullion Mountains. Medium-grained, equigranular biotite monzogranite and leucomonzogranite. Locally, includes:

Jbep **Porphyritic facies**—Contains alkali-feldspar phenocrysts 2–3 cm across and plagioclase phenocrysts as wide as 1 cm. Closely resembles the Virginia Dale Quartz Monzonite

Jbpm **Mafic porphyritic quartz monzonite (Jurassic)**—Present in Bullion Mountains. Medium- to coarse-grained biotite-hornblende quartz monzonite, quartz monzodiorite, quartz diorite, and diorite. Abundant mafic enclaves 5 cm to 3 m across in places dominate this rock unit

Jbs **Syenogranite (Jurassic)**—Present in Bullion Mountains. Equigranular, medium-grained biotite-perthite leucosyenogranite. Near Cleghorn Lakes, syenogranite composition may be due to potassium metasomatism of monzogranite

Jqk **Quartz diorite of Kilbeck Hills (Jurassic)**—Medium-grained, equigranular, gneissic, metamorphosed hornblende-biotite quartz diorite, granodiorite, diorite, and quartz monzodiorite. Protolithic age of approximately 162 Ma (Jurassic) determined by U-Pb dating of zircons (J.E. Wright, written commun., 1986)

Jd **Diorite and quartz diorite (Jurassic)**—Present in Kilbeck Hills and Pinto, Sheep Hole, Bullion, and Calumet Mountains. Medium-grained, equigranular, hornblende-rich rocks. Includes hornblende-clinopyroxene diorite and gabbro in the Kilbeck Hills. Includes hornblende gabbro in the Pinto Mountains. In places metamorphosed to amphibolite and biotite amphibolite. Intruded by the Virginia Dale Quartz Monzonite (Jbv) and by the quartz monzonite (Jbq) unit. Age of quartz diorite in Pinto Mountains determined by U-Pb dating of zircon is tentatively determined as approximately 160–165 Ma (J.L. Wooden, oral commun., 1993)

Jm **Granodiorite of Music Valley (Jurassic)**—Present in Pinto Mountains as the Music Valley pluton. Medium-grained, equigranular sphene-hornblende-biotite granodiorite. Contains euhedral epidote. Mafic enclaves abundant. Commonly foliated. A preliminary $^{40}Ar/^{39}Ar$ date on hornblende is approximately 192 Ma (J.K. Nakata, written commun., 1992)

Jgb **Granitoid rocks of Goat Basin Mine (Jurassic)**—Present in Pinto Mountains in southwestern corner of quadrangle as the Goat Basin pluton. Consists of intergradational rock types: porphyritic biotite granite containing alkali-feldspar megacrysts as large as 6 cm, and medium-grained equigranular hornblende-biotite granodiorite (containing mafic enclaves), quartz diorite, and diorite. Contains euhedral epidote. Age tentatively 158–159 Ma based on U-Pb dating of zircon in granodiorite (J.L. Wooden, written commun., 1994)

Jgg **Granite gneiss (Jurassic?)**—Present in Sheep Hole Mountains. Medium-grained, equigranular biotite (+ hornblende) leucocratic granite gneiss; resembles the granite gneiss of Kilbeck Hills (Jk). Grades into the Virginia Dale Quartz Monzonite (Jbv). Locally, includes:

Jggd **Granodiorite gneiss**—Medium-grained, equigranular hornblende granodiorite and monzogranite gneiss. Mafic enclaves abundant

Jgrg **Dark granite gneiss (Jurassic?)**—Present in southern Calumet Mountains. Hornblende-biotite-bearing rocks. Ranges in composition from granodiorite to quartz monzonite. Sparse gray alkali-feldspar phenocrysts as large as 1 cm, or locally contains abundant relict lavender alkali-feldspar phenocrysts 1–2.5 cm long. Lavender phenocrysts suggest association with Jurassic units, but rocks are undated and may be Proterozoic in age

Jgdg **Granodiorite and tonalite gneiss (Jurassic?)**—Present in Granite Mountains and southern Calumet Mountains. Fine- to medium-grained granodiorite, tonalite, and quartz diorite gneiss. In places contains alkali-feldspar relict phenocrysts, or streamlined, highly flattened mafic enclaves. Rocks are undated and may be Proterozoic, instead of Jurassic, in age

Trt **Quartz monzonite of Twentynine Palms (Early Triassic)**—Present as four small bodies in the southwest corner of the quadrangle in Pinto Mountains; also occurs west of the quadrangle (Dibblee, 1967b, 1968; Trent, 1984). Equivalent to the informally named Twentynine Palms porphyritic quartz monzonite of Trent (1984). Porphyritic hornblende monzonite and quartz monzonite. Alkali-feldspar megacrysts 3 to 10 cm across. Commonly gneissic. An Early Triassic age inferred by Barth and others (1997) from U-Pb dating of zircon (242±30 Ma) and from similarity to other dated Triassic intrusions in southern California

Ycm **Augen gneiss of Calumet Mountains (Middle Proterozoic?)**—Present in northeastern Calumet and northeastern Bullion Mountains. Coarse-grained to very coarse grained granite gneiss, with augen of alkali feldspar. Tentatively correlated with porphyritic granite in the Marble Mountains to north, near Cadiz, dated as 1.4 Ga by U-Pb on zircon (Silver and McKinney, 1963), based on similar composition and grain size and on presence (in Calumet Mountains exposures) of medium-grained rounded allanite crystals similar to those in the rocks in the Marble Mountains

YXd **Gneiss of Dry Lakes valley (Middle or Early Proterozoic)**—Present in southern Calumet Mountains. Medium- to coarse-grained, muscovite-biotite syenogranite gneiss. Proterozoic protolithic age indicated by high measured ratio of $^{87}Sr/^{86}Sr$ (model age approximately 1250 Ma; M.A. Lanphere, written commun., 1984)

YXg **Granitoid gneiss (Middle and Early Proterozoic)**—Present in Old Woman Mountains. Includes coarse-grained porphyritic metagranodiorite and very coarse grained garnet-bearing metagranite. Late Early and Middle Proterozoic protolithic ages indicated by preliminary U-Pb dating of zircon (approximately 1.4 Ga and 1.62 Ga; J.L. Wooden, oral commun., 1993)

Xgn **Gneiss, undivided (Early Proterozoic)**—Present in Kilbeck Hills and in Calumet and Granite Mountains

Xg **Granodiorite gneiss (Early Proterozoic)**—Present in southern Calumet Mountains and northwest of Sheep Hole Pass. Striped gneiss; lithologically resembles parts of the Kilbeck Gneiss (Xk) that are least affected by Mesozoic metamorphism

Xf **Fenner Gneiss (Early Proterozoic)**—Present in Kilbeck Hills and Old Woman Mountains. Name was first used by Hazzard and Dosch (1937) (also called the Fenner Granite Gneiss). Very coarse-grained gneiss metamorphosed from porphyritic biotite granite, granodiorite, and quartz monzodiorite. Contains relict alkali-feldspar phenocrysts as large as 6 cm across, in places highly elongate owing to deformation. Protolithic age is Early Proterozoic as indicated by U-Pb dating of zircon north of the quadrangle (approximately 1.68 Ga; Wooden and Miller, 1990)

Xjt **Granite of Joshua Tree (Early Proterozoic)**—Present in Pinto Mountains. Coarse-grained and very coarse grained monzogranite and syenogranite. Early Proterozoic age indicated by preliminary U-Pb dating of zircon (> 1.65 Ga; L. T. Silver as quoted by Powell, 1981)

Xk **Kilbeck Gneiss (Early Proterozoic)**—Present in Old Woman Mountains. Striped, medium-grained, biotite granite and granodiorite gneiss. Relict phenocrysts of alkali feldspar locally preserved. Field relations, in an area complicated by metamorphism and recumbent folding, suggest that these rocks underlie the undivided metamorphosed Bright Angel Shale and Tapeats Sandstone (€t). Protolithic age is Early Proterozoic as tentatively determined from preliminary U-Pb dating of zircon (J.L. Wooden, oral commun., 1993). Field relations suggest that the metamorphic to ultrametamorphic fabric is Late Cretaceous in age

Xsg **Spotted gneiss (Early Proterozoic)**—Present in Pinto Mountains. Gneiss spotted by dark chloritic pseudomorphs after garnet and possibly after pyroxene. As mapped, may include metamorphosed rocks of the Pinto Gneiss of Miller (1938) (part) (Xp) and the Dog Wash Gneiss. Metamorphic and protolithic ages are Early Proterozoic

Xdw **Dog Wash Gneiss (Early Proterozoic)**—Named here for Dog Wash, located in the southwestern part of the quadrangle. Type locality is designated in Pinto Mountains on the west side of Twentynine Palms Mountain along upper Dog Wash, section 19 unsurveyed, T. 1 S., R. 10 E., Valley Mountain 15' quadrangle and Twentynine Palms 7.5' quadrangle. Unit consists of light-buff-weathering, medium-grained leucogranite (leucomonzogranite to leucosyenogranite) gneiss, locally trondhjemitic. Color index 0.5 to 6. Contains allanite, clotted chlorite, muscovite, oxides, and biotite. Quartz streaks separate streaks of intergrown alkali feldspar and plagioclase; possibly the streaks originated from coarse grains of quartz and perthite in the protolith. SiO_2 content (one sample) 78 percent. Intrudes the Pinto Gneiss of Miller (1938) (part) (Xp) and the diorite and amphibolite unit (Xd). Minimum age 1.68 Ga (U-Pb on zircon)(Wooden and others, 1991). Rocks previously mapped as part of the Palms Granite by Evans (1964) and as part of undifferentiated Mesozoic plutonic rocks by Powell (1981)

Xag **Augen gneiss (Early Proterozoic)**—Present in Pinto Mountains. Biotite monzogranite and syenogranite gneiss containing alkali-feldspar augen 1 cm across. Metamorphism contrasts with nearby unmetamorphosed rocks of the Virginia Dale Quartz Monzonite

Xbg **Biotite granite gneiss (Early Proterozoic)**—Present in Pinto Mountains. Gray, fine- to medium-grained monzogranite gneiss

Xd **Diorite and amphibolite (Early Proterozoic)**—Present in Pinto Mountains. Lithologic and relative-age distinction from the diorite and quartz diorite (Jd) unit is not everywhere clear

ts **Tectonic schist (Proterozoic, protolithic age; Mesozoic, assembly and fabric age)**—Present in Old Woman, Iron, Calumet, and Granite Mountains and Kilbeck Hills. Highly foliated, schistose gneiss of heterogeneous composition, mostly quartzofeldspathic gneiss but some amphibolite and pelitic schist. Consists of Early Proterozoic gneisses highly strained and recrystallized during Mesozoic deformation—a tectonic schist (in the sense of Hutton, 1979) formed in zones of high strain. May locally include metaplutonic rocks of Middle Proterozoic and (or) Mesozoic protolithic age

lgt **Leucogranite gneiss south of Twentynine Palms Mountain (Mesozoic or Proterozoic)**—Present in Pinto Mountains. Leucomonzogranite and leucogranodiorite gneiss

a **Amphibolite (Mesozoic and (or) Proterozoic)**—Present in Granite and Old Woman Mountains

Contact

Fault—Showing dip. Dashed where inferred, dotted where concealed. Concealed faults inferred from geologic map or from aeromagnetic map.

Tectonic slide—Ductile thrust or lag (attenuation) fault. Teeth on upper plate

Normal fault—Bar and ball on downthrown side

Low-angle normal fault—Teeth on upper plate

Strike-slip fault—Arrows show separation or slip. Circles on cross section indicate movement toward (dot) or away (cross) from observer

Fault having Quaternary motion—Cuts Quaternary-age units

Lineament—Mapped from air photos. Most are fractures. Includes enigmatic radar lineament identified by Sugiura and Sabins (1980) on Bristol Lake playa, and subtle alinement of drainages in valley west of Dale Lake

Dike—Showing dip. Ornamentation and color designate geologic unit

Major quartz vein—Showing dip. In Bullion and Ship Mountains. K-Ar age of biotite in vein in Ship Mountains is 69.1±1.7 Ma (J.K. Nakata, written commun., 1985)

Bedding—Showing strike and dip
- **Inclined**
- **Vertical**
- **Horizontal**

Foliation—Showing strike and dip

Metamorphic foliation
- **Inclined**
- **Vertical**
- **Horizontal**

Magmatic foliation
- **Vertical**
- **Inclined**

Lineation—Showing trend and plunge. May be combined with foliation symbol
- **Mylonitic mineral lineation**
- **Nonmylonitic mineral lineation**
- **Fold Axis**

Mineralized joint—Showing strike and dip. Joints are mineralized by white mica and by hematite pseudomorphs after pyrite

Sand dune crest line

Strand line or marked vegetative change (from soil moisture?)—Identified from aerial photos around shores of dry lakes

Drill hole—Showing depth in meters. Shown for holes deeper than 100 m. Number of well refers to Table 1

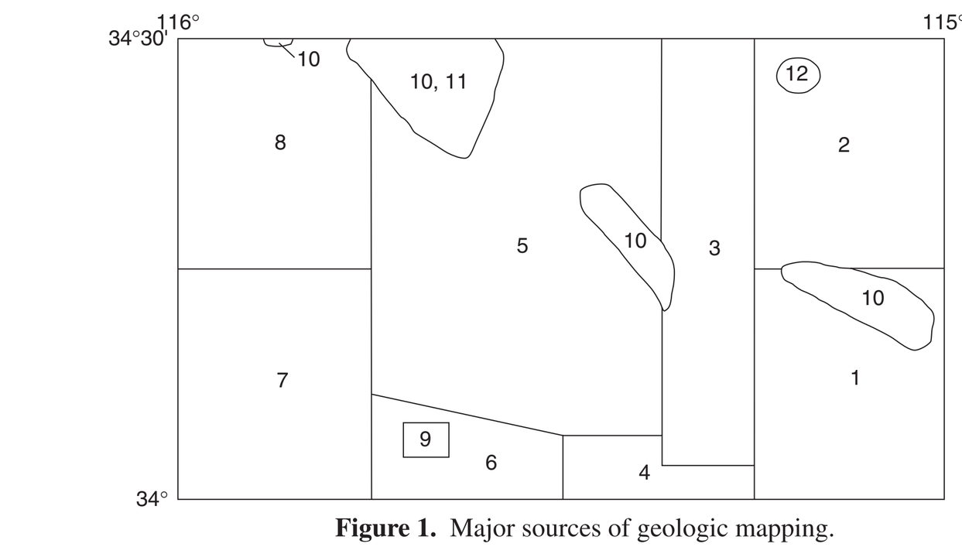


Figure 1. Major sources of geologic mapping.

1. Miller and Howard (1985)—Iron Mountains quadrangle.
2. Howard and others (1989b)—Milligan quadrangle.
3. Howard and others (1989a)—eastern parts of Cadiz Lake and Cadiz Valley quadrangles.
4. Calzia and others (1983)—Coxcomb Mountains Wilderness Study Area.
5. Howard and John (1984)—Sheep Hole-Cadiz Wilderness Study Area.
6. Howard and Allen (1988)—Southern part of Dale Lake quadrangle.
7. Howard and others (in press a)—Valley Mountain quadrangle.
8. Howard and others (in press b)—Lead Mountain quadrangle.
9. Jagiello (1991)—Twentynine Palms area.
10. Kupfer and Bassett (1962)—Bristol, Cadiz, and Danby Lakes.
11. Rosen (1991)—Bristol Lake.
12. K. McCaffrey, C. Miller, and J. Wooden (unpub. data)—in Old Woman Mountains.

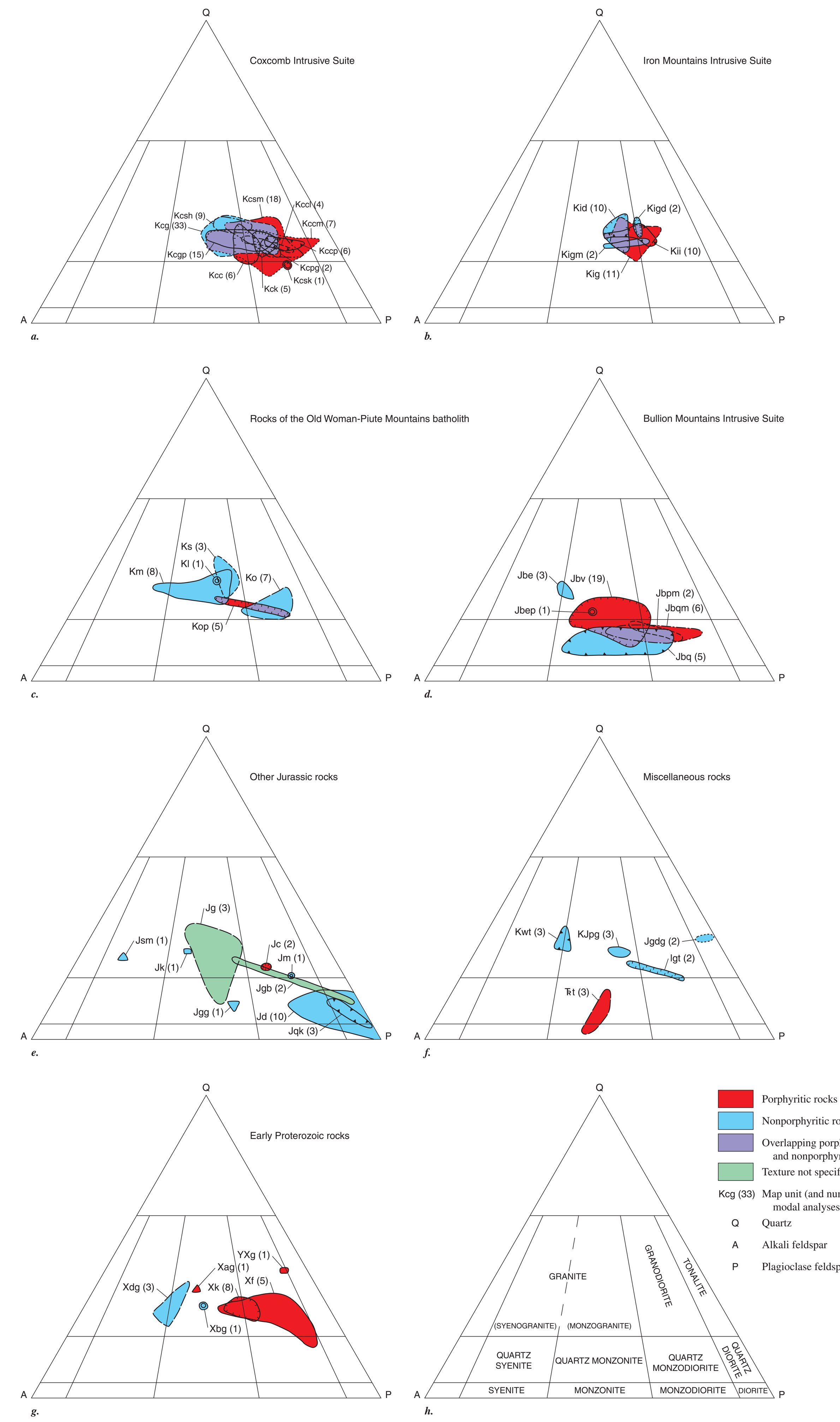


Figure 2. Modal proportions of minerals for some plutonic map units. Number of samples counted shown in parentheses. See Figure **2*h*** for explanation. (IUGS classification of plutonic rocks from Streckeisen 1973).

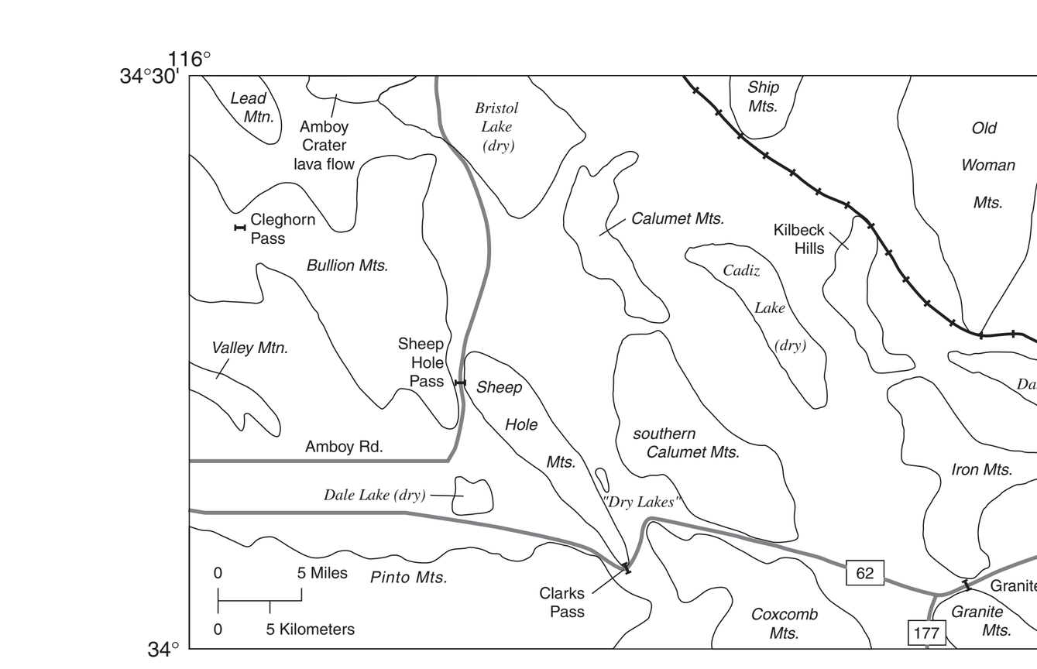


Figure 3. Index of geographic features.

GEOLOGIC MAP OF THE SHEEP HOLE MOUNTAINS 30' x 60' QUADRANGLE, SAN BERNARDINO AND RIVERSIDE COUNTIES, CALIFORNIA

By

Keith A. Howard

2002

This map was printed on an electronic plotter directly from digital files. Dimensional calibration may vary between electronic plotters and between X and Y directions on the same plotter, and paper may change size due to atmospheric conditions; therefore, scale and proportions may not be true on plots of this map.

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http://geopubs.wr.usgs.gov/map-mf/mf2344