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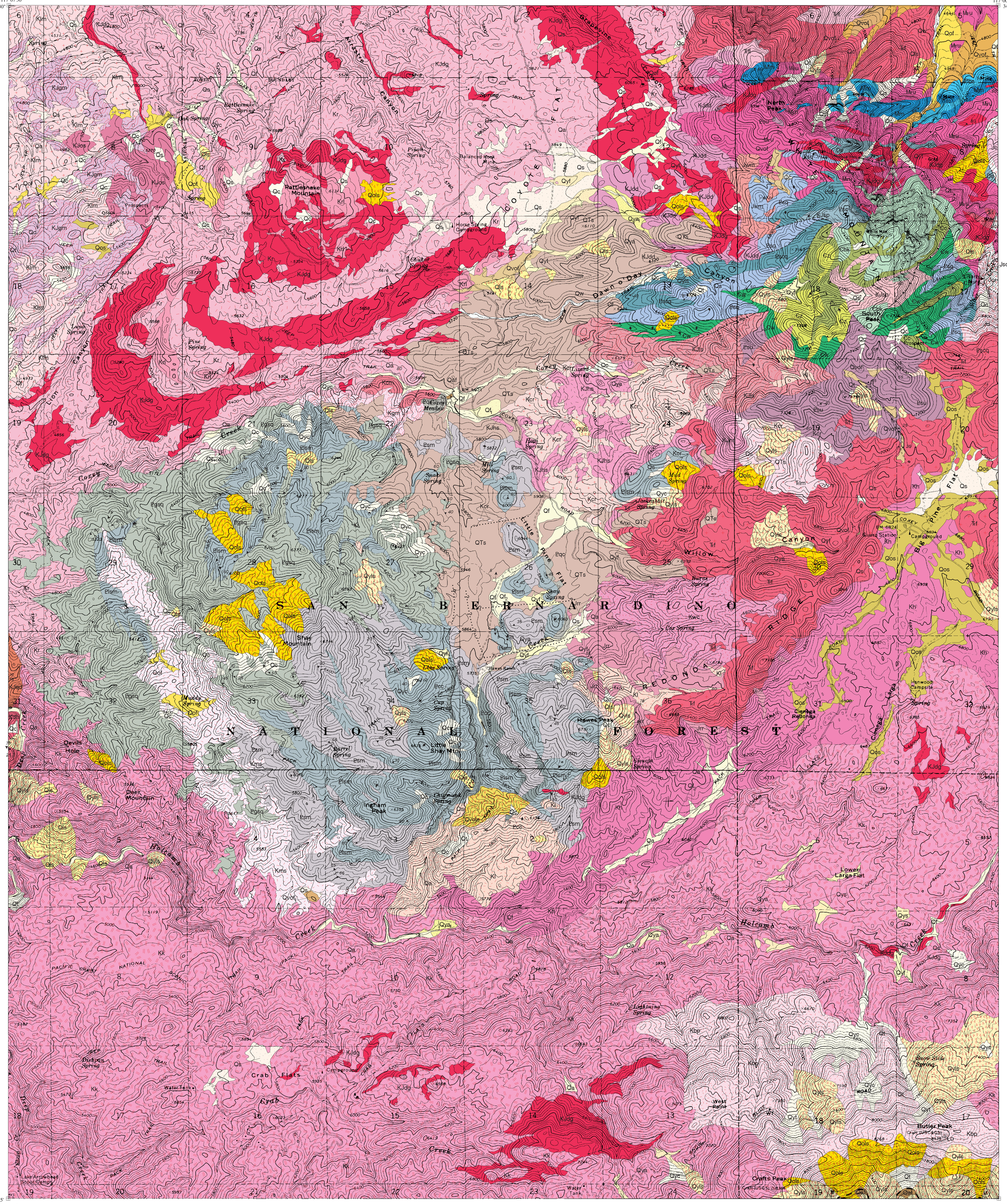
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
U.S. FOREST SERVICE (San Bernardino National Forest) and the
CALIFORNIA DIVISION OF MINES AND GEOLOGY

OPEN-FILE REPORT 00-145



Base from U.S. Geological Survey
7.5' Butler Peak quadrangle, 1971

Lambert conformal conic projection

GN MN 13.5°

SCALE 1:24,000

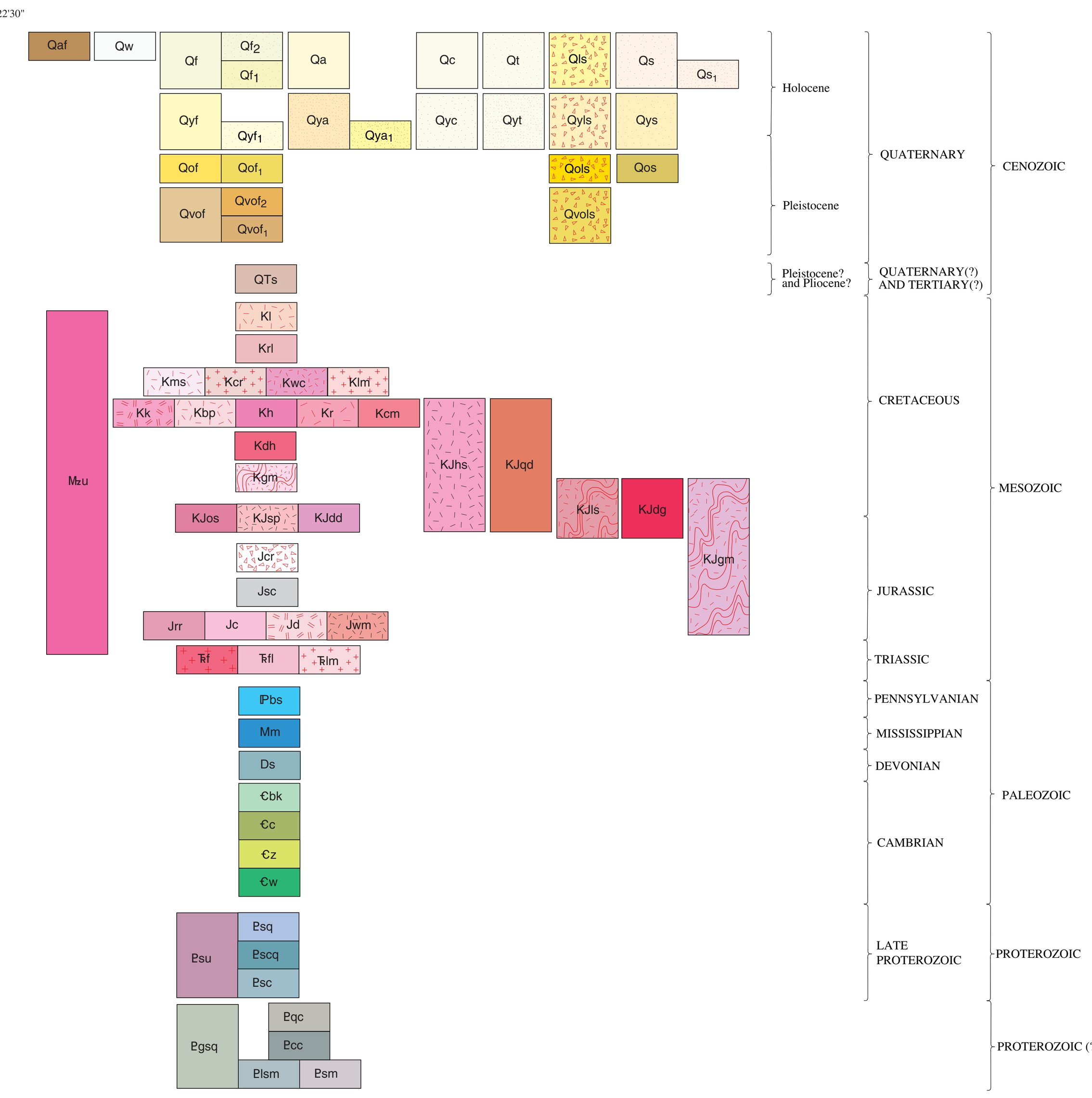
1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET

Geology mapped by F.K. Miller, 1975-1976, 1997-1998; J.C. Matti, 1991-1996; H.J. Brown, 1978-1982

CORRELATION OF MAP UNITS



Contact—Solid where located within ±15 meters; dashed where located within ±30 meters; queried where uncertain

Fault—High angle. Solid where located within ±15 meters; dashed where located within ±30 meters; dotted where concealed; queried where uncertain

Fault—Intruded. Pre-intrusive, existence inferred on basis of anomalous stratigraphic units separated by granitic bodies, and projection of mapped faults

Linement—Aligned notches, swales, gulches, and saddles. Most are eroded joints, but some appear to be faults having localized, discontinuous movement along them

Strike and dip of metamorphic foliation

70 **Inclined**

Vertical

Strike and dip of primary igneous foliation

70 **Inclined**

Vertical

Strike and dip of primary igneous layering

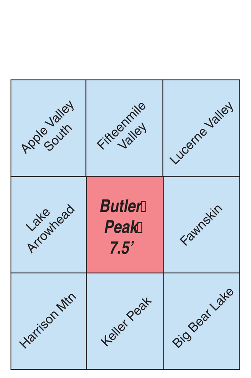
70 **Inclined**

Bearing and plunge of linear features

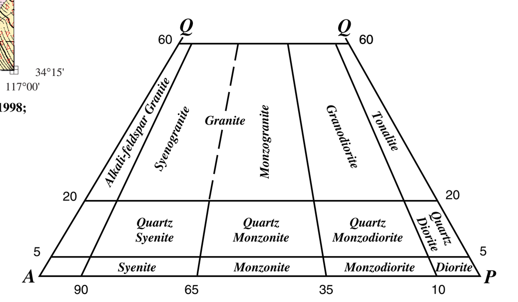
70 **Aligned minerals**

70 **Crushed and streaked mineral grains**

70 **Minor fold axes in metamorphic rocks**



SURROUNDING 7.5' QUADRANGLES



Classification of plutonic rock types (from IUGS, 1976, and Streckeisen, 1976). A, alkali feldspar; P, plagioclase feldspar; Q, quartz.

DIGITAL GEOLOGIC MAP OF THE BUTLER PEAK 7.5' QUADRANGLE, SAN BERNARDINO COUNTY, CALIFORNIA

Version 1.0

By

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DESCRIPTION OF MAP UNITS

MODERN SURFICIAL DEPOSITS—Sediment recently transported and deposited in channels and washes, on surfaces of alluvial fans and alluvial plains, and on hillslopes. Soil-profile development is non-existant to minimal. Includes:

Qaf — **Artificial fill (late Holocene)**—Sand, gravel, and bedrock from pits and quarries; mapped primarily where used for construction of highways and water catchment basins

Qw — **Active wash deposits (late Holocene)**—Chiefly sand and gravel in modern washes; pebble to boulder clasts are sparse to abundant

Qf — **Modern alluvial fan deposits (late Holocene)**—Undissected, unconsolidated to loosely compacted deposits of active parts of alluvial fans. Mainly small alluvial cones at mouths of canyons. Includes:

Qf$_2$ — **Modern alluvial fan deposits, Unit 2**—Undissected, unconsolidated to loosely compacted deposits of alluvial fans. Distinguished as high-level terrace cut into Qf sediments

Qf$_1$ — **Modern alluvial fan deposits, Unit 1**—Undissected, unconsolidated to loosely compacted deposits of gravel and sand. Distinguished as lower-level terrace cut into Qf sediments

Qa — **Modern axial valley floor deposits (late Holocene)**—Unconsolidated to locally cemented deposits of sand and fine gravel; lesser silt

Qc — **Modern colluvial deposits (late Holocene)**—Unconsolidated to slightly consolidated sandy and pebbly deposits of hillslopes and base of slopes; much is angular, derived from grus. No soil development

Qt — **Modern talus deposits (late Holocene)**—Unconsolidated, only partially stabilized deposits of angular and sub-angular pebble-, cobble-, and boulder-sized clasts that form scree and rubble on hillslopes and at bases of slopes

Qls — **Landslide deposits (late Holocene)**—Slope-failure deposits that consist of displaced bedrock blocks and (or) chaotically mixed rubble. Most deposits may be active or recently active

Qs — **Surficial deposits undifferentiated (late Holocene)**—Sand and pebble to small cobble gravel not assigned to any specific surficial materials unit. Unconsolidated to slightly consolidated. Includes wash, alluvial fan, colluvial, and valley-filling deposits. In Coyote Flats area, includes grus and possibly older Quaternary deposits. Locally subdivided into:

Qs$_1$ — **Surficial deposits undifferentiated, Unit 1**—Sand and pebble to small- cobble gravel not assigned to any specific surficial materials unit. Similar to Qs, but distinguished on basis of terrace development

YOUNG SURFICIAL DEPOSITS—Sedimentary units that are slightly consolidated to cemented and slightly to moderately dissected. Alluvial fan deposits (Qyf series) typically have high coarse:fine clast ratios. These young surficial units have upper surfaces that are capped by slightly to moderately developed pedogenic-soil profiles (A/C to A/AC/$B_{cambric}C_{ox}$ profiles). Includes:

Qyf — **Young deposits of alluvial fans (Holocene and late Pleistocene)**—Slightly consolidated to cemented, undissected to slightly dissected deposits of poorly sorted boulders, cobbles, gravel, and sand that form inactive parts of alluvial fans. Subunits of Qyf commonly form nested terraces; includes

Qyf$_1$ — **Young deposits of alluvial fans, Unit 1 (early Holocene and late Pleistocene)**—Slightly consolidated to cemented, undissected to slightly dissected deposits of poorly sorted boulders, cobbles, gravel, and sand. Distinguished as terrace cut into Qyf sediments

Qya — **Young deposits of axial valley floors (Holocene and late Pleistocene)**—Slightly to moderately consolidated sand and pebble-cobble gravel. Includes:

Qya$_1$ — **Young deposits of axial valley floors, Unit 1**—Slightly to moderately consolidated sand and pebble-cobble gravel. Distinguished as terrace cut into Qya sediments

Qyc — **Young colluvial deposits (Holocene and late Pleistocene)**—Undissected to slightly dissected, slightly consolidated, relatively stabilized deposits of grus that has moved. Includes deposits of sand- and pebble-sized clasts on hillslopes and at bases of slopes

Qyt — **Young talus deposits (Holocene and late Pleistocene)**—Slightly consolidated, relatively stabilized deposits of angular and sub-angular pebbles, cobbles, and boulders that form scree and rubble on hillslopes and at bases of slopes

Qyls — **Young landslide deposits (Holocene and late Pleistocene)**—Relatively stabilized slope-failure deposits that consist of displaced bedrock blocks and (or) chaotically mixed rubble. Slightly dissected. Deposits are probably inactive under current climatic conditions

Qys — **Young surficial deposits undifferentiated (Holocene and late Pleistocene)**—Sand- to boulder-sized deposits not assigned to any specific surficial materials unit of this age. Includes wash, alluvial fan, colluvial, and valley-filling deposits. Slightly dissected, slightly consolidated

OLD SURFICIAL DEPOSITS—Sedimentary units that are moderately consolidated and slightly to moderately dissected. Old surficial deposits have upper surfaces that are capped by moderately to well-developed pedogenic soils (A/AB/B/C_{ox} profiles and Bt horizons as much as 1 to 2 m thick and maximum hues in the range of 10YR 5/4 and 6/4 through 7.5YR 6/4 to 4/4 and mature Bt horizons reaching 5YR 5/6). Includes:

Qof — **Old deposits of alluvial fans (late to middle Pleistocene)—**Reddish-brown alluvial fan deposits of primarily sand- to boulder-sized clasts that are moderately consolidated and slightly to moderately dissected. Includes:

Qof$_1$ — **Old deposits of alluvial fans, Unit 1**—Reddish-brown alluvial fan deposits of primarily sand- to boulder-sized clasts that are moderately consolidated and slightly to moderately dissected. Distinguished as terrace cut into Qof sediments

Qols — **Old landslide deposits (late to middle Pleistocene)**—Relatively stabilized, consolidated, moderately dissected slope-failure deposits that consist of displaced bedrock blocks and (or) chaotically mixed rubble

Qos — **Old surficial deposits undifferentiated (late to middle Pleistocene)**—Sand- to boulder-sized deposits not assigned to any specific surficial materials unit of this age. Includes wash, alluvial fan, colluvial, and valley-filling deposits. Moderately dissected, moderately consolidated

VERY OLD SURFICIAL DEPOSITS—Sediments that are slightly to well consolidated to indurated, and moderately to well dissected. Upper surfaces are capped by moderate to well developed pedogenic soils (A/AB/B/C_{ox} profiles having Bt horizons as much as 2 to 3 m thick and maximum hues in the range 7.5YR 6/4 and 4/4 to 2.5YR 5/6)

Qvof — **Very old deposits of alluvial fans (middle to early Pleistocene)**—Reddish-brown, strongly pigmented alluvial fan deposits of primarily sand- to boulder-sized clasts that are well-consolidated and well-dissected. Includes:

Qvof$_2$ — **Very old deposits of alluvial fans, Unit 2 (middle to early Pleistocene)**—Reddish-brown, strongly pigmented alluvial fan deposits of primarily sand- to boulder-sized clasts that are well-consolidated and well-dissected. Similar to Qvof$_1$, but distinguished by lower terrace level

Qvof$_1$ — **Very old deposits of alluvial fans, Unit 1 (early Pleistocene)**—Reddish-brown, strongly pigmented alluvial fan deposits of primarily sand- to boulder-sized clasts that are well-consolidated and well-dissected. Similar to Qvof$_2$, but distinguished by higher terrace level

Qvols — **Very old landslide deposits (middle to early Pleistocene)**—Slope-failure deposits that consist of displaced bedrock blocks and (or) chaotically mixed rubble. Deposits are well-dissected, and inferred to have accumulated during Pleistocene uplift of San Bernardino Mountains

QTs — **Conglomerate, conglomeratic arkose, and clayey arkose (Pleistocene? and Pliocene?)**—Consolidated to poorly indurated conglomerate and conglomeratic arkose. Upper and lower parts are highly pigmented (5YR 4/6 to 7.5YR 4/6), main body of unit much less so. Clasts range from small pebbles to 40 cm-wide boulders; moderately rounded to subangular. Matrix ranges from fine silt to coarse sand; poorly sorted. Clasts are marble, quartzite, and granitic rocks all of which appear to be locally derived from identifiable San Bernardino Mountains sources; no volcanic rocks or metavolcanic rocks found

Kl — **Leucocratic granitic rocks (Cretaceous)**—Fine- to coarse-grained leucocratic granitic rocks, chiefly monzogranite composition; color index typically less than 3. Forms dikes, sills, pods, and small bodies in many parts of quadrangle, most too small to map. Includes alaskite, pegmatite, aplite, and heterogeneous monzogranite. Large mass south of Little Shay Mountain is composite body of sheet-like masses of pegmatite, micropegmatite, and monzogranite. Rocks are generally nonfoliate, nonlineate, and spatially associated with Cretaceous plutons

Mzu — **Mesozoic granitic rocks, undivided (Mesozoic)**—Monzogranite to diorite, including small areas of monzonite. Underlies highly irregular area in northeastern part of quadrangle. Includes heterogeneous, nondistinctive granitic rocks that cannot be assigned to larger granitic units in quadrangle. Fine- to coarse-grained; massive to foliate and lineate. Eastern part of unit is mixed monzogranite and granodiorite that resembles nearby Cretaceous rocks; color index generally less than 12. Most of unit is heterogeneous mix of monzogranite, monzodiorite, diorite, and monzonite that resembles nearby Cretaceous, Jurassic, and Triassic rocks, and has color indicies ranging from 10 to 50

Krl — **Leucocratic rocks of Rattlesnake Mountain pluton of MacColl, 1964 (Cretaceous)**—Fine- to coarse-grained leucocratic granitic rocks, chiefly monzogranite. Spatially restricted to Rattlesnake Mountain pluton of MacColl (1964); forms several noncontiguous bodies that mimic form of large mafic bodies in pluton. Appears to be much more uniform with respect to texture and composition than leucocratic granitic rocks unit (Kl). Distinguished by low color index and fine-grained margins in outer 2 m of bodies. Color index rarely more than 2; unevenly distributed biotite is only mafic mineral in rock. Nonfoliate, but locally shows intergranular, cataclastic grain-size reduction

Kms — **Monzogranite of Muddy Spring (Cretaceous)**—Medium- to coarse-grained muscovite-biotite monzogranite. Forms very elongate, highy irregular body that intrudes Cretaceous monzogranite of Keller Peak and Proterozoic quartzite and gneiss units west of Shay Mountain. Distinguished by uniform grain size, abundant potassium feldspar (microcline), low color index, and potassium feldspar much more abundant than plagioclase (calcic oligoclase). Color index averages about 5; biotite is only mafic mineral. Muscovite is sparse and fine grained. Nonporphyritic; has no directional or penetrative fabric. Resembles and may be related to monzogranite of Coxey Road

Kcr — **Monzogranite of Coxey Road (Cretaceous)**—Biotite monzogranite. Forms highly irregular body that intrudes Cretaceous and Jurassic mixed rocks of Hopi Springs north of Little Pine Flat. Distinguished by very abundant quartz, abundant potassium feldspar (microcline), low color index, and potassium feldspar more abundant than plagioclase (calcic oligoclase). Has sparse, irregularly distributed, 1.5-cm-long, highly perthitic microcline phenocrysts. Color index ranges fron 3 to 5. Biotite is only mafic mineral. Looks heterogeneous near contacts with mixed granitic rocks of Hopi Springs (KJhs), due to incomplete ingestion of that rock. Texture is hypidiomorphic-granular; rock has no directional fabric. Resembles and may be related to monzogranite of Mud Spring, but contains no muscovite

Kwc — **Monzogranite of Willow Canyon (Cretaceous)**—Biotite monzogranite. Coarse- to very coarse-grained; slightly porphyritic. Phenocrysts are 1-cm-long, poorly formed, pale-pink microcline. Plagioclase is calcic andesine. Biotite is only mafic mineral; color index averages 12. Sphene moderately abundant. Except for sparse, poorly formed phenocrysts, texture is hypidiomorphic-granular. Unit is fairly uniform with respect to composition and texture. Considered Cretaceous on basis of textural and compositional similarity to nearby Cretaceous plutons

Klm — **Monzogranite of Luna Mountain (Cretaceous)**—Biotite monzogranite. Medium- to coarse-grained. Informally named for Luna Mountain, 0.5 km west of quadrangle. With respect to composition and texture, part of unit is highly heterogeneous and part is relatively uniform. Heterogeneity due largely to contamination by incomplete mixing of digested host rocks. Potassium feldspar is microcline; plagioclase is sodic andesine. Color index ranges from 8 to 15, biotite is only mafic mineral. Sphene is ubiquitous, but sparse. Most rock is even-grained, but seriate texture is common. Contains very abundant pods and screens of metamorphic and granitic rocks. Considered Cretaceous on basis of textural and compositional similarity to nearby Cretaceous plutons

Kk — **Monzogranite of Keller Peak (Cretaceous)**—Coarse-grained biotite monzogranite; grain size ranges from very coarse to medium. Very large body, extending 10 km or more south and southwest and 5 km east of quadrangle. Irregularly porphyritic; has sparse, 2-cm-long, well-formed microcline phenocrysts, which, in places are pink. Plagioclase is calcic oligoclase to sodic andesine. Contains sparse sphene. Average color index 9; biotite is only mafic mineral. In western part, rock has trace amounts of muscovite. Texture is hypidiomorphic-granular; rock has no directional fabric. Conventional K-Ar age on biotite is 71.1 Ma; considered cooling age (Miller and Morton, 1980)

Kbp — **Monzogranite of Butler Peak (Cretaceous)**—Fine- to medium-grained muscovite-biotite monzogranite. Found only in southeast corner of quadrangle, and continues 1 km southeastward. Distinguished by even-grained texture and presence of muscovite. Color index averages 6; biotite is only mafic mineral. Biotite:muscovite ratio averages 3:1 but varies widely. Texture is hypidiomorphic-granular; rock has no directional fabric. Highly broken and cut by numerous subhorizontal fractures and gouge zones probably related to landsliding. Completely surrounded by, grades into, and probably related to monzogranite of Keller Peak

Kh — **Granodiorite of Hanna Flat (Cretaceous)**—Coarse-grained hornblende-biotite granodiorite. Irregularly porphyritic; has 2-cm-long, poorly formed, scattered phenocrysts of orthoclase containing patches of microcline. Plagioclase composition averages intermediate andesine. Average color index 15 in northern part, grading to 10 in southern part; concentration of hornblende and sphene decreases from north to south also. Body probably represents outer part of monzogranite of Keller Peak that was contaminated where it intruded Triassic Fawnskin monzonite (Ŧf). Conventional K-Ar ages on hornblende and biotite, respectively, are 70.5 Ma and 71.5 Ma (Miller and Morton, 1980); $^{40}Ar/^{39}Ar$ incremental age on same hornblende sample is 76.5 Ma (R.J. Fleck, written commun., 1996)

Kr — **Rattlesnake Mountain pluton of MacColl, 1964 (Cretaceous)**—Biotite monzogranite and hornblende-biotite monzogranite. Pluton contains large bodies of leucocratic and highly mafic rocks. Coarse-grained, locally ranging to very coarse-grained and medium-grained. Typically porphyritic, microcline phenocrysts forming up to 20 percent of rock, but in places, sparsely and irregularly scattered. Average plagioclase composition is between intermediate and calcic oligoclase. Average color index is 10, but ranges up to 18; less than half of pluton contains hornblende. Very abundant sphene, and trace amounts of allanite and muscovite, the latter probably secondary. Most rocks have hypidiomorphic-granular texture, but in places phenocrysts show crude alignment. Primary flow structure is poorly to moderately well defined in much of pluton by wispy streaks of concentrated mafic minerals and by aligned flat inclusions. Considered Cretaceous on basis of textural and compositional similarity to nearby Cretaceous plutons

Kcm — **Granodiorite of Coxey Meadow (Cretaceous)**—Hornblende-biotite granodiorite and biotite granodiorite. Forms small, elongate body northwest of Coxey Meadow. Medium- to coarse-grained, seriate to even-grained. Color index about 15. Contains abundant sphene. Rock may be a varient of Rattlesnake pluton monzogranite, but is more mafic, non-porphyritic, and appears to to be texturally more homogeneous internally compared to Rattlesnake body

KJhs — **Mixed granitic rocks of Hopi Spring (Cretaceous and Jurassic)**—Biotite quartz monzonite or quartz monzodiorite intruded by small to moderate amounts of monzogranite of Coxey Road (Kcr). Contacts between rock types highly gradational. Rocks are medium to coarse grained, except constituent biotite is medium to fine grained. Quartz averages 10 to 15 percent. Plagioclase is sodic andesine; potassium feldspar is orthoclase. Color index ranges from 15 to 20; biotite is only mafic mineral, but opaque mineral(s) much more abundant than in other units of similar composition. Sphene is abundant, allanite and epidote present but sparse. Texture is seriate; no obvious directional fabric. Cretaceous and Jurassic age based on textural similarities of KJhs with nearby Cretaceous granitic rocks, and of quartz monzonite or quartz monzodiorite composition with nearby Jurassic granitic rocks

KJqd — **Quartz-bearing diorite (Cretaceous or Jurassic)**—Hornblende-biotite diorite; typically contains 2 to 4 percent quartz; up to 15 percent quartz near contact with monzogranite of Devils Hole (Kdh). Restricted to small area near Devils Hole along west edge of quadrangle. Medium- to fine-grained; slight foliation, but too indistinct to measure. Plagioclase is calcic oligoclase to sodic andesine; potassium feldspar is orthoclase. Color index averages 20, but varies widely; hornblende and biotite occur in subequal amounts. Age based on overlapping compositional and textural similarities to Cretaceous and Jurassic granitic rocks

Kdh — **Monzogranite of Devils Hole (Cretaceous)**—Biotite monzogranite. Coarse-grained; very porphyritic. Pale pink, slightly perthitic orthoclase phenocrysts make up as much as 25 percent of some rocks. Phenocrysts average 2.5 cm, are as long as 4 cm, and contain 20 to 50 percent included plagioclase (intermediate oligoclase). Some appear to be tectonically shaped. Color index averages 13; biotite is only mafic mineral. Texture is porphyritic, but groundmass grain size is distinctly bimodal. Groundmass contains irregular shaped masses of fine-grained felsic minerals between coarse grains of same minerals. Rock is cut by thin shear zones containing broken and rehealed minerals. Some quartz is highly strained and tectonically shaped, and some biotite is disaggregated and strung out along thin shear zones. Deformation is apparent in thin section only, not in exposed rocks. Rock is considered Cretaceous based on similarity of composition and primary igneous texture to that of nearby Cretaceous granitic rocks. However, deformation seen in monzogranite of Devils Hole is not common in Cretaceous rocks

Kgm — **Mixed granitic rocks and metamorphic rocks (Cretaceous)**—Heterogeneous mixture of granitic rocks ranging from leucocratic monzogranite to mafic diorite that contains inclusions, pods, and screens of quartztite, schist, and calcsilicate rock. Underlies about 0.5 km^2 west of Coxey Meadow. Grades northward into granitic rocks and southward and eastward into metamorphic rocks

KJls — **Mixed granitic rocks, quartzite, and schist of Lizard Spring (Cretaceous or Jurassic)**—Heterogeneous mixture of leucocratic biotite monzogranite, biotite quartz monzonite and quartz monzodiorite, fine- to medium-grained quartzite,and fine-grained feldspar-quartz-biotite schist. Locally, schist contains andalusite and (or) sillimanite, and very locally schist contains pods and small screens of calcsilicate rock. Leucocratic monzogranite resembles monzogranite of Coxey Road (Kcr), but is compositionally and texturally more heterogeneous. More quartz-deficient granitic rocks resemble Jurassic quartz monzonite of Crystal Creek (Jc), mixed rocks of South Peak (KJsp), and Jurassic quartz monzodiorite of Dry Canyon (Jd). Quartzite in unit probably from Cambrian Zabriskie Quartzite (Ꞓz), Cambrian Wood Canyon Formation (Ꞓw), and Proterozoic Stirling Quartzite (Ᵽsu). Schist in unit probably derived from Wood Canyon Formation, and calcsilicate from carbonate-bearing parts of Stirling Quartzite. Internal and boundary contacts highly gradational

KJdg — **Mixed diorite and gabbro (Cretaceous and Jurassic)**—Biotite-hornblende diorite and quartz diorite, hornblende-biotite diorite and quartz diorite, pyroxene-hornblende gabbro, and hornblende gabbro. Fine- to coarse-grained. Dioritic rocks appear to have possible spatial relation to Paleozoic carbonate rocks and intermediate composition Mesozoic plutons. Rocks of this unit have wide compositional and textural range, but are distinguished from rocks of other units by their very high color index, which averages 45. Compositions of large mafic bodies within Rattlesnake pluton of MacColl, 1964 (Kr), are particularly variable, partly due to contamination by monzogranite of Rattlesnake pluton. Unit may include rocks of more than one period of intrusion

KJgm — **Mixed granitic rocks, quartzite, and fine-grained leucocratic rocks (Cretaceous and Jurassic)**—Heterogeneous mixture of biotite monzogranite, biotite quartz monzodiorite, fine- to medium-grained quartzite, and fine-grained quartz-feldspar hornfels, with or without biotite and trace muscovite. Monzogranite is chiefly monzogranite of Luna Mountain (Klm), but some is more leucocratic than found in that unit. Quartz monzodiorite resembles quartz monzodiorite found in mixed granitic rocks of Oak Spring (KJos), and probably is related to that unit. Fine-grained leucocratic rocks include rocks indistinguishable from Jurassic fine-grained rocks of Silver Canyon (Jsc), but also include some that have characteristics more like porphyritic, fine-grained, leucocratic, hypabyssal rocks. Origin of quartzite unknown. Internal and external contacts highly gradational

KJos — **Mixed granitic rocks of Oak Spring (Cretaceous and Jurassic)**—Predominently biotite quartz monzodiorite, but includes abundant dikes, pods, and irregular masses of monzogranite of Luna Mountain (Klm). Quartz monzodiorite is medium grained, containing about 15 percent quartz. Plagioclase is intermediate to calcic oligoclase; potassium feldspar is microcline. Color index averages 18; biotite is only mafic mineral. Contains abundant sphene and opaque mineral(s), and trace epidote and allanite. Texture is even grained. Contacts are gradational over several tens of meters. Age based on compositional and textural similarities to nearby rocks of Cretaceous and Jurassic age

KJsp — **Mixed granitic rocks of South Peak (Cretaceous and Jurassic)**—Biotite quartz monzonite, ranging to quartz syenite, and containing abundant inclusions, and small screens of Cambrian and Late Proterozoic metasedimentary units. Also includes minor leucocratic monzogranite probably of Cretaceous age. Main mass of granitic rock is shown on map, but dikes, sills, and irregular masses are found over much of White Mountain area and westward. Biotite quartz monzonite is medium to coarse grained and equigranular to seriate. Plagioclase is calcic oligoclase. Potassium feldspar is highly perthitic microcline, and very abundant. Rock has highest average potassium feldspar to plagioclase ratio in quadrangle. Color index varies widely from about 3 to about 15; biotite is only mafic mineral. Texture ranges from eqigranular to seriate. Has compositional and textural characteristics of both Cretaceous and Jurassic plutons in region

KJdd — **Quartz monzonite of Dawn o'Day Canyon (Cretaceous or Jurassic)**—Biotite quartz monzonite; averages about 15 percent quartz. Fairly heterogeneous, containing variable amounts of metasedimentary schist, and inclusions and dikes of other granitic rocks. Color index ranges from 5 to 18, commonly within a single large outcrop. Biotite is only mafic mineral; rock typically has trace amounts of very fine grained muscovite, probably not primary. Potassium feldspar is microcline, plagioclase is calcic andesine. Has compositional and textural characteristics of both Cretaceous and Jurassic plutons in region

Jcr — **Cataclastic rocks (Jurassic)**—Fine-grained to near-aphanitic cataclastic rocks. Medium- to dark greenish-gray. Derived primarily from extreme deformation of granitic units. In central part of unit rocks are very comminuted, nearly aphanitic; grades outward to borders of unit into progressively less deformed rock by appearance of progressively larger grains and grain aggregates

Jsc — **Fine-grained rocks of Silver Canyon (Jurassic)**—Pale-gray to medium-gray, very fine-grained porphyroblastic rock made up predominently of quartz, plagioclase, and potassium feldspar. Typically contains bands of very fine-grained quartz up to 2 mm thick, commonly separated by bands of concentrated feldspar. Contains variable amounts of biotite, up to 5 percent, and trace muscovite. Inferred to be metamorphosed mylonitic or cataclastic rocks of possible monzogranite to quartz monzodiorite composition, but could be very fine grained, slightly metamorphosed, leucocratic granitic rocks, or leucocratic metavolcanic rocks. Distinct and not derived from cataclastic rock unit (Jcr); differs in that recrystallization has erased nearly all traces of penetrative fabric. Protolith and age very uncertain. In adjacent Fawnskin quadrangle, Miller and others (1999) considered unit to be older than quartz monzodiorite of Dry Canyon; unit now thought to be younger, based on ubiquitous presence of 0.2- to 1-m-long, wispy, inclusion-like masses of Dry Canyon rock in Silver Canyon rock

Jrr — **Biotite quartz monzodiorite of Redonda Ridge (Jurassic)**—Medium- to coarse-grained biotite quartz monzodiorite, ranging to monzodiorite. Restricted to one large and several small bodies at west end of Redonda Ridge. Rocks average about 6 percent quartz, but some have less than 5 percent. Plagioclase is intermediate andesine, and potassium feldspar, averaging 12 percent, is orthoclase. Color index is about 18 and varies little; biotite is only mafic mineral. Contains abundant sphene. Even-grained to seriate, having no directional fabric, but locally containing abundant aligned, elongate inclusions. Strongly resembles Jurassic quartz monzodiorite of Dry Canyon (Jd), and may be noncontiguous part of same intrusion. Considered Jurassic based on compositional similarities to nearby Jurassic plutons

Jc — **Leucocratic quartz monzonite of Crystal Creek (Jurassic)**—Hornblende-biotite quartz monzonite and biotite quartz monzonite, ranging to monzonite. Leucocratic. Coarse-grained. Distinguished by low quartz content, low color index, and presence of hornblende and sphene in most samples. Plagioclase is calcic oligoclase; potassium feldspar is highly perthitic microcline and orthoclase. Average color index is 5, locally as high as 12. U-Pb age on sphene from quartz monzonite is 151 Ma (J.L. Wooden, written commun., 1997)

Jd — **Quartz monzodiorite of Dry Canyon (Jurassic)**—Biotite quartz monzodiorite, ranging to monzodiorite. Medium- to coarse-grained. Distinguished by relatively low quartz content and relatively high color index in a rock having biotite as its only mafic mineral. Quartz content ranges from 3 to 8 percent. Plagioclase is sodic andesine; potassium feldspar, very subordinate to plagioclase, is microcline. Color index averages 15. Contains sparse sphene, even where intruding sphene-rich Triassic monzonite of Fawnskin. Has wide gradational contact with fine grained rocks of Silver Canyon (**Jsc**). Considered Jurassic based on compositional similarities to nearby Jurassic plutons

Jwm — **Monzodiorite of White Mountain (Jurassic)**—Biotite monzodiorite, ranging to quartz monzodiorite and microcline-bearing quartz diorite. Medium- to coarse-grained. Quartz content ranges from 2 to 10 percent. Plagioclase is calcic oligoclase; potassium feldspar, very subordinate to plagioclase, is microcline. Color index is about 17; biotite is only mafic mineral. Contains sphene and abundant allanite. Strongly resembles quartz monzodiorite of Dry Canyon, and may be noncontiguous part of same intrusion. Considered Jurassic based on compositional similarities to nearby Jurassic plutons

Ŧf — **Monzonite of Fawnskin (Triassic)**—Hornblende monzonite, ranging to quartz monzonite and monzodiorite. Medium- to coarse-grained, locally porphyritic. Distinguished by very low quartz content and abundance of hornblende and sphene. Quartz generally less than 5 percent; where monzonite intrudes quartzite units, is as high as 12 percent, but most quartz is exotic. Hornblende commonly has altered pyroxene cores. Plagioclase is intermediate to calcic oligoclase; potassium feldspar is microcline. Ratio of microcline to plagioclase is highly variable, but generally greater than 3:2. Color index averages 18; hornblende, pyroxene, and less commonly biotite are mafic minerals. Texture is hypidiomorphic-granular to seriate, locally porphyritic. Flow aligned feldspar and hornblende impart foliate or lineate appearance to rock in places, but fabric is highly variable in orientation even on outcrop scale. Zircon U-Pb age is 231 Ma (J.L. Wooden, written commun., 1996)

Ŧfl — **Leucocratic monzonite of Fawnskin (Triassic)**—Identical to monzonite of Fawnskin, except color index is between 10 and 15, and microcline is generally much more abundant than plagioclase; unit ranges to syenite in places. Underlies two small areas in northeastern part of quadrangle, and a larger area in northwestern part of Fawnskin quadrangle (Miller and others,1999)

Ŧlm — **Fine-grained leucocratic monzonite (Triassic)**—Augite-hornblende monzonite, monzodiorite, and quartz monzodiorite. Fine-grained, equigranular to slightly and irregularly porphyritic. Quartz ranges from about 4 percent to 12 percent, but relatively high-quartz rocks of this unit have probably acquired some quartz from quartzite host rocks. Plagioclase is sodic andesine, and potassium feldspar is orthoclase. Ratio of orthoclase to plagioclase is less than 1:2 in all rocks, unlike typical monzonite of Fawnskin (Ŧf). Color index averages about 8, but is misleading in outcrop, because mafic minerals are fine grained, pale and do not look like mafic minerals. Considered Triassic on basis of mineralogical and compositional similarities to monzonite of Fawnskin (Ŧf), but high quartz content and relatively low potassium feldspar content are similar to some Jurassic granitic rocks in region

ℙbs — **Bird Spring Formation (Pennsylvanian)**—Upper part of Furnace Limestone of Vaughan (1922) as mapped by Guillou (1953), Richmond (1960); correlated with Bird Spring Formation of southern Great Basin by Cameron (1981) and Brown (1991). Generally light-colored, medium- to thick-bedded, medium to coarsely crystalline calcite marble. Degree of recrystallization in quadrangle precludes confident subdivision of formation, but in Fawnskin quadrangle to east, typical lithologies include white, gray, or mottled marble and cherty, silicified marble. Some chert-bearing calcite marble contains lenses and thin layers of quartz silt and fine sand. Intermittent layers of minor brown-weathering dolomite marble, siliceous marble horizons, and dark-gray calcite marble. May or may not include yellowish- to brownish-gray phyllite (or schist), white quartzite, schistose metasiltstone, and interlayered chert and marble. In Butler Peak quadrangle, due to extreme recrystallization and deformation, layering in much of formation may or may not represent bedding

Mm — **Monte Cristo Limestone (Mississippian)**—Upper part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960). Correlated with the Monte Cristo Limestone of the southern Great Basin by Cameron (1981), and mapped by Brown (1984, 1987, and 1991) who recognized several formal stratigraphic members named originally by Hewitt (1931). Degree of recrystallization in quadrangle precludes recognition of detailed subdivisions, but includes heterogeneous, interlayered, light- and dark-gray, calcite and dolomite marble characteristic of Yellowpine Member, and thick-layered, light-gray to white, texturally massive, very pure calcite marble characteristic of Bullion Member

Ds — **Sultan Limestone (Devonian)**—Middle part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960); Brown (1991) correlated rocks in this interval with members of Sultan Limestone of Hewitt (1931) in southern Great Basin. Includes: (1) thin- to thick-layered, white calcite marble containing sparse thin layers of dark-gray calcite and dolomite marble characteristic of Crystal Pass Member; in part irregularly dolomitized. (2) Laminated to massive, light-gray, brown, and white, finely crystalline, locally chert-bearing metadolomite characteristic of Valentine Limestone Member

Ꞓbk — **Bonanza King Formation (Cambrian)**—Lower part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960). Originally named by Hazzard and Mason (1936) from exposures in Providence Mountains. In type area, Hazzard and Mason (1936) recognized five informal subdivisions of Bonanza King Formation. In Butler Peak quadrangle, Bonanza King is highly metamorphosed, and unlike in the adjacent Fawnskin quadrangle (Miller, and others, 1999) is not divisible into informal members. Consists mainly of dolomite and limestone (especially in lower part) marble. Thin- to thick-bedded, white to medium-gray, commonly striped, texturally massive to mottled, fine- to coarse-grained. Probably includes some or all of Cambrian Nopah Formation in some sequences. Contains intervals meters to tens of meters thick consisting of greenish-brown and grayish-brown metasiltstone, argillite, and hornfels.

Ꞓc — **Carrara Formation (Cambrian)**—Heterogeneous mixture of interbedded calcite marble, phyllite, calc-silicate rock, schist, and minor quartzite. In general, upper part contains large proportion of carbonate rock; lower part contains large proportion of phyllite and quartzite. Carrara is equivalent to lower part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960). Correlated with Carrara Formation of southern Great Basin by Stewart and Poole (1975, fig. 3), but name first used in map area by Tyler (1975). Latham Shale, Chambless Limestone, and Cadiz Formation of the Marble and Providence Mountains (Hazzard and Mason, 1936) occupy same approximate stratigraphic interval as Carrara, but it is not possible to map these three distinct formations in quadrangle

Ꞓz — **Zabriskie Quartzite (Cambrian)**—Dense, quartz-cemented, thoroughly recrystallized quartzite. Uniformly white, but some fracture surfaces are stained yellow, orange or hematite-red by iron oxides. Very pure; quartz is almost only mineral in rock. Medium- to fine-grained, but contains scattered grains up to 5 mm across which are not aligned to define bedding; within Butler Peak quadrangle, no original grain shapes survive recrystallization. Thick bedded to massive; bedding unrecognizable in most exposures. Locally, unit contains bedding plane partings of phyllitic argillaceous rock, which may or may not be restricted to a particular part of formation. Distinguished from quartzites of Cambrian Wood Canyon Formation (Ꞓw) and Late Proterozoic Stirling Quartzite (Ᵽsu) by purity, lack of feldspar grains, whiteness, and massive structure. Correlated with the Zabriskie Quartzite of the southern Great Basin by Stewart and Poole (1975). In Fawnskin quadrangle to east, average thickness as calculated from outcrop width is 400 m (Miller, and others, 1999). Variation in thickness in quadrangle is probably due to folding and faulting and does not represent changes in stratigraphic thickness

Ꞓw — **Wood Canyon Formation (Cambrian)**—Quartzite, quartzose phyllite, biotite schist, and minor calc-silicate rock. In Big Bear City quadrangle to east, formation consists of five subunits that are described here, but not subdivided in Butler Peak quadrangle due to degree of metamorphism; some subunits may not be present in Butler Peak quadrangle. (1) Lower 15-20 m is black, biotite-rich, quartz-bearing phyllite. Characterized by sparse but ubiquitous metamorphic tourmaline and locally abundant Scolithus and flaser-laminated zones. (2) Phyllite grades upward into 20-25 m of interbedded coarse-grained, cross-bedded, feldspathic quartzite, pebbly quartzite, and quartzose phyllite. (3) Relatively uniform lavender-gray, fine- to coarse-grained, trough-cross-bedded quartzite. (4) Black, quartzose phyllite of uncertain thickness. (5) About 20 m of medium-gray and brownish-gray, finely interbedded quartzite, phyllite and siltite. In Butler Peak quadrangle, color and nearly all sedimentary structures destroyed by metamorphism, and faulting and folding obscures internal stratigraphy. However, basic lithologies of all subunits are present

Ᵽsu — **Stirling Quartzite (Late Proterozoic)**—Part of Saragossa Quartzite of Vaughan (1922) as mapped by Dibblee (1964). Lower part of Chicopee Formation as mapped by Guillou (1953); lower member of Chicopee Canyon Formation as mapped by Richmond (1960). Correlated with Stirling Quartzite and Johnnie Formation of southern Great Basin by Stewart and Poole (1975). In Butler Peak quadrangle, unit is highly deformed, and very recrystallized; layering may or may not represent bedding. We recognize two informal members of Stirling Quartzite, upper member of metaquartzite and lower member of metacarbonate rock and metaquartzite. Very carbonate-rich part of lower member is locally subdivided. Includes:

Ᵽsq — **Quartzite member**—Light-gray, yellow-gray, and white feldspathic metaquartzite and conglomeratic metaquartzite. Approximately lower two-thirds of member is medium- to thick-bedded, poorly sorted, fine- to coarse-grained feldspathic quartzite containing sparse matrix-supported pebbles up to 1 cm across. Upper third is medium- to thin-bedded, poorly to moderately well sorted, fine- to medium-grained feldspathic quartzite. In relatively unmetamorphosed section in Fawnskin quadrangle, bedding in this part of member is parallel-planar, weathers slabby, and shows current and oscillation ripple-marked surfaces. Thickness there, as calculated from outcrop width, is approximately 230 m

Ᵽscq — **Carbonate and quartzite member**—Wavy bedded, light-gray to light-tan-weathering dolomitic limestone interbedded with medium- and thick-bedded, medium-grained quartzite, laminated to texturally massive calcite marble, quartz-sand-bearing marble, and calc-silicate rock. Poorly and incompletely exposed, but dolomitic limestone and quartzite appear to predominate. Base not exposed in San Bernardino Mountains; unit is about 120 m thick in Jacoby Canyon in Big Bear City quadrangle to east. Locally includes:

Ᵽsc — **Carbonate-rich rocks**—Relatively pure carbonate rock similar to that making up most of carbonate and quartzite member (Ᵽscq); contains only minor thin beds of quartzite. Appears to be low in carbonate and quartzite member (Ᵽscq), but extreme deformation precludes accurate determination of stratigraphic relations

Shay Mountain metamorphic complex of MacColl, 1964 (Proterozoic?)—Name, Shay Mountain complex, used by MacColl (1964), is informally adopted here for highly recrystallized metamorphic rocks surrounded by younger granitic rocks in Shay Mountain-Coxey Creek area. Here subdivided into five units based on dominant lithology. Most metasedimentary rocks probably derived from Stirling Quartzite, Wood Canyon Formation, and possibly Zabriskie Quartzite and Carrara Formation. All contacts between units are highly gradational, ranging in width from 50 to 500 m; locally, placement of contacts are inherently subjective

Ᵽgsq — **Mixed gneiss, schist, and quartzite**—Heterogeneous mixture of (1) white and gray vitreous quartzite, (2) medium- to coarse-grained quartzofeldspathic biotite gneiss and locally andalusite-sillimanite-biotite schist, and (3) variable amounts of granitic rocks. Relative amounts of constituents are highly variable, both on local and unit-wide scale. Leucocratic granitic rocks ranging from biotite monzogranite to quartz diorite are very abundant in western and northern parts of unit; 1- to 100-m-long pods, dikes, and sills found irregularly throughout unit. Probably associated with nearby Cretaceous plutons, but some granitic rock appears to be result of localized partial melting of gneiss protolith during metamorphism

Ᵽqc — **Quartzite and calcsilicate rock of Little Pine Flat**—Interlayered white and gray vitreous quartzite, gray and white dolomitic marble, and calcite-epidote-tremolite-diopside hornfels. Highly recrystallized; all sedimentary structures destroyed by metamorphism. In contact with quartzite of Little Shay Mtn, but stratigraphic relations with that unit are unknown

Ᵽcc — **Biotite schist of Cox Creek**—Dark gray to nearly black, fine-grained plagioclase-muscovite-quartz-biotite schist. Locally contains andalusite or andalusite and sillimanite; andalusite is commonly retrograded to quartz and muscovite

Ᵽlsm — **Quartzite of Little Shay Mtn**—Massive to poorly layered, white and gray, highly recrystallized vitreous quartzite. Irregularly micaceous and foliate. Layering is probably transposed bedding, but some could be primary bedding. No primary sedimentary structures appear to have survived metamorphism

Ᵽsm — **Gneiss of Shay Mountain**—Well layered, medium- to coarse-grained quartzofeldspathic biotite gneiss containing thin, discontinuous zones of plagioclase-quartz-muscovite-biotite schist, and pods and layers of medium-grained leucocratic granitic rocks ranging from biotite monzogranite to quartz diorite. Contains some quartzite, particularly where gradational into quartzite of Little Shay Mtn (Ᵽlsm)

REFERENCES

Brown, H.J., 1984, Summary of the geology of the north range front of the San Bernardino Mountains, Lucerne Valley, California, *in* Kupferman, S., McIver, D., and Morton, P., eds., Major limestone producers of the western Mojave Desert, California: American Institute of Mining Engineers, 112th Annual Meeting, Los Angeles, Field Trip Guidebook, p. 12-19.

Brown, H.J., 1987, Geologic setting and operations overview, Lucerne Valley limestone mining district, Lucerne Valley, California, *in* Pierce, W., ed., 21st Annual Industrial Mineral Conference Proceedings: Arizona Bureau of Mines Special Report 4, p. 44-54.

Brown, H.J., 1991, Stratigraphy and paleogeographic setting of Paleozoic rocks in the San Bernardino Mountains, California, *in* Cooper, J.D., and Stevens, C.H., eds., Paleozoic Paleogeography of the western United States-II: Pacific Section, Society of Economic Paleontologists and Mineralogists, v. 67, p. 193-207.

Cameron, C.S., 1981, Geology of the Sugarloaf and Delamar Mountain areas, San Bernardino Mountains, California: Cambridge, Massachusetts Institute of Technology, Ph.D. Thesis, 399 p.

Dibblee, T.W., Jr., 1964, Geologic map of the Lucerne Valley quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-426, scale 1:62,500.

Guillou, R.B., 1953, Geology of the Johnston Grade area, San Bernardino County, California: California Division of Mines Special Report 31, 18 p.

Hazzard, J.C., and Mason, J.F., 1936, Middle Cambrian formations of the Providence and Marble Mountains, California: Geological Society of America Bulletin, v. 47, p. 229-240.

Hewitt, D.F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 171 p.

MacColl, R.S., 1964, Geochemical and structural studies in batholithic rocks of southern California: Part 1, Structural geology of Rattlesnake Mountain pluton: Geological Society of America Bulletin, v. 75, p. 805-822.

Miller, F.K., Matti, J.C., Brown, H.J., and Powell, R.E., 1996, Digital geologic map of the Fawnskin 7.5' quadrangle, San Bernardino County, California: U.S. Geological Survey Open-File Report 96-579, 18 p., scale, 1:24,000.

Miller, F.K., and Morton, D.M., 1980, Potassium-Argon geochronology of the eastern Transverse Ranges and southern Mojave Desert, southern California: U.S. Geological Survey Professional Paper 1152, 30 p.

Richmond, J.F., 1960, Geology of the San Bernardino Mountains north of Big Bear Lake, California, with a tabulated list of mines and mineral deposits by C.H. Gray, Jr.: California Division of Mines Special Report 65, 68 p.

Stewart, J.H., and Poole, F.G., 1975, Extension of the Cordilleran miogeosynclinal belt to the San Andreas fault, southern California: Geological Society of America Bulletin, v. 86, p. 205-212.

Streckeisen A., 1976, To each plutonic rock its proper name: Earth Science reviews, v. 12, p. 1-33.

Tyler, D.L., 1975, Stratigraphy and structure of the late Precambrian-early Cambrian clastic metasedimentary rocks of the Baldwin Lake area, San Bernardino Mountains, California: Houston, Texas, Rice University, M.S. thesis, 40 p.

Vaughan, F.E., 1922, Geology of the San Bernardino Mountains north of San Gorgonio Pass: California University Publications in Geological Sciences, v. 13, p. 319-411.