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PRELIMINARY GEOLOGIC MAP OF THE NORTH-CENTRAL SAN BERNARDINO MOUNTAINS, CALIFORNIA

SUMMARY PAMPHLET TO ACCOMPANY GEOLOGIC MAP

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INTRODUCTION

This pamphlet briefly describes the lithology and stratigraphy of rock units shown on the accompanying geologic map of the north-central San Bernardino Mountains.

DESCRIPTION OF MAP UNITS

QUATERNARY SURFICIAL MATERIALS

Qw **Active-wash deposits** (Holocene)--Unconsolidated to locally cemented sand and gravel in active washes of streams and on active surfaces of alluvial fans.

Ql **Lacustrine deposits** (Holocene and Pleistocene)--Unconsolidated to moderately consolidated sand, silt, and clay of Baldwin Lake.

Qc **Colluvial deposits** (Holocene and Pleistocene)--Deposits of unbedded to crudely bedded angular gravel. Includes active talus deposits and dissected older talus deposits.

Qs **Undivided surficial deposits** (Holocene and Pleistocene)--Composite map unit consisting mainly of inactive deposits of alluvial fans, alluvial plains, and talus fields, but locally includes active deposits that cannot be differentiated at the map scale. Where possible, divided into younger surficial deposits and older surficial deposits:

Qys **Younger surficial deposits** (Holocene and latest Pleistocene)--Slightly consolidated to cemented, undissected to slightly dissected deposits of gravel and sand that form inactive parts of alluvial fans and alluvial plains.

Qos **Older surficial deposits** (Pleistocene)--Moderately consolidated to cemented deposits of gravel and sand that form abandoned, well dissected alluvial fans and alluvial plains. Locally includes gravel assigned by Shreve (1968) to his Cushenberry Formation.

Qols **Older landslide deposits** (Pleistocene)--Occurs on the north face of Blackhawk Mountain where unit consists of intact and shattered blocks of Bird Spring Formation (middle and upper members) that have ridden over various in-place units, including Bird Spring Formation, Old Woman Sandstone, and Cretaceous monzogranite. On Blackhawk Mountain, Sadler (1981, 1982d) included these deposits within his unit of marble cataclasite (Sadler, 1982m, unit fc).

QUATERNARY AND TERTIARY SEDIMENTARY AND VOLCANIC ROCKS

QTo **Old Woman Sandstone** (Pleistocene and Pliocene)--Includes two informal units: an *upper unit* consists of pebble-cobble conglomerate and subordinate pinkish sandstone and pebbly sandstone interlayered with and overtopped by landslide breccia and catastrophic debris sheets composed mainly of carbonate rock but locally composed of granitoid debris. Debris sheets include (a) large blocks of bedrock that retain original stratigraphic or petrologic features even though the blocks may be shattered, and (b) chaotically organized debris. Shreve (1968) grouped the catastrophic debris sheets and associated fanglomerate into his Cushenberry Formation. A *lower unit* consists of pinkish to very pale-brown, fine to coarse sandstone, pebbly sandstone, and minor pebble-cobble conglomerate. Northwest of the Blackhawk Mtn area this lithology grades laterally into greenish-brown claystone and mudstone. We include in the Old Woman Sandstone some conglomeratic deposits that Sadler (1981, 1982c,d,f) assigned to his unit of relict fanglomerate (rf2m and rf2m' of Sadler, 1982m).

Tb **Basalt** (Miocene?)--Flows of olivine-bearing basalt containing ultramafic inclusions (basanite basalts of Antelope Creek described by Neville, 1983, p. 45-46; also see Neville and Chambers, 1982)

Ts **Undifferentiated sedimentary rocks** (Miocene? to Pliocene?)--Nonmarine deposits of sandstone and gravel that have little or no paleogeographic relation to current landscape setting. ***West part of map area***: Unit probably is correlative with the Miocene Crowder Formation (of Meisling and Weldon, 1989) in the Cajon Pass area. ***Central part of map area***: Unit consists of pinkish, white, and greenish sandstone and pebbly sandstone and angular-gravel deposits mapped as talus breccia by Richmond (his unit Qb) and as relict fanglomerate by Sadler (1981, 1982d,f,m his unit rf2m and rf2m'). These workers believe the deposits to be entirely Pleistocene in age. An early Pleistocene age cannot be ruled out for younger parts of the unit. However, based on their dissected geomorphology, lithology, thickness, and degree of faulting, we believe these deposits mainly are equivalent with the Santa Ana Sandstone (of Vaughan, 1922, as used by Sadler, 1981 and Sadler and Demirer, 1986) and thus are late Miocene and Pliocene in age. ***East part of map area***: Unit includes arkosic sediment locally containing clasts of marble, metaquartzite, and porphyritic volcanic rocks; included by Sadler (1982b,h) in his units ?a [arkose] and acq [quartzite-clast-bearing conglomerate]. The unit probably is correlative with the Santa Ana Sandstone as proposed by Sadler (1981, 1982m). Locally includes sedimentary rocks that may be correlative with the Old Woman Sandstone

MESOZOIC PLUTONIC ROCKS

A variety of plutonic rocks crop out in the north-central San Bernardino Mountains. The youngest and geographically most widespread of these is a suite of granitoid rocks that mainly are biotite bearing and monzogranitic in composition (units Km, Kmm, Kgp, Kgm, Khqm, Kqd). These rocks probably are Cretaceous in age based on potassium-argon and argon-argon age determinations from the San Bernardino Mountains and from similar rocks in the Mojave Desert region (Armstrong and Suppe, 1973; Miller and Morton, 1980; Cameron, 1981). The Cretaceous granitoids intruded an older suite of granitoid rocks and associated hypabyssal rocks that probably are Jurassic in age (units Jdb, Jdg, and Jh). The Jurassic rocks in turn intruded a distinctive alkalic hornblende monzonite and associated rocks (units ŦRhm and ŦRd) that are Triassic in age.

mi **Mixed igneous rocks** (Cretaceous and older)--Heterogeneous migmatitic mixed-rock unit recognized by Smith (1982a,b). In vicinity of White Mountain, unit consists of intermingled biotite monzogranite (Km), hornblende monzonite (Ŧhm), and diorite (Ŧd). East of White Mountain, biotite monzogranite (Km) is intermingled mainly with volcanic rocks of the hypabyssal dike complex (Jh) but locally includes hornblende monzonite (Ŧhm). In the vicinity of Greenlead Mine the unit includes mylonitic plutonic rocks.

Km **Monzogranite** (Cretaceous)--Medium to coarse grained, texturally massive to lineated, leucocratic, equigranular to porphyritic biotite monzogranite. Includes more than one plutonic body, but individual plutons like the porphyritic monzogranite of Rattlesnake Mountain (MacColl, 1964) are not differentiated. Locally contains muscovite and garnet.

Kmm **Muscovite-bearing monzogranite** (Cretaceous)--Medium grained, texturally massive to lineated, leucocratic biotite monzogranite that is muscovite- and garnet-bearing. Probably is a phase of unit Km.

Kgp **Granite porphyry** (Cretaceous)--Fine grained leucocratic monzogranite containing phenocrysts of biotite, quartz, microcline-perthite, and plagioclase. Richmond (1960) and Sadler (1981) interpreted this rock as a border phase of the widespread biotite monzogranite pluton (unit Km), an interpretation we share; however, Dibblee (1964, p. 3) indicates that the granite porphyry grades into the hypabyssal dike complex (Jh) and has affinities with these older rocks.

Kgm **Mylonitic granitoid rock** (Cretaceous)--Fine to medium grained granodiorite to monzogranite that is mylonitized and displays strong streaking lineation. Appears to be mylonitized hybrid rock localized along intrusive contact between unit Km and prebatholithic metasedimentary rocks.

Khqm **Hornblende quartz monzonite** (Cretaceous)--Medium to coarse grained, texturally massive to slightly foliated, porphyritic to equigranular hornblende-biotite quartz monzonite to monzogranite. Probably an early border phase of the large body of biotite monzogranite (unit Km) that occurs west of Big Bear Lake.

Kqd **Quartz diorite** (Cretaceous)--Medium grained, texturally massive to foliated to locally gneissose hornblende-biotite quartz diorite and tonalite. Contains numerous inclusions where intrusive into quartzofeldspathic and biotitic metasedimentary rocks. Intruded by unit Km.

Jdb **Diorite of Bertha Peak** (Jurassic)--Medium grained, equigranular to porphyritic, hornblende-biotite quartz diorite and diorite (tonalite porphyry of Richmond, 1960; Bertha Diorite of Cameron, 1981). The unit has a minimum age of 126.7±3.6 Ma and a model argon-retention age of 158 Ma (determined by Cameron, 1981, p. 334 using the $^{40}Ar/^{39}Ar$ method). Cameron (1981, p. 179) observed textural and compositional similarities between the Diorite of Bertha Peak and the hypabyssal dike complex (unit Jh), and he proposed that the two units may be comagmatic. Intruded by unit Km.

Jdg **Diorite and gabbro** (Jurassic)--Texturally massive to lineated, fine to coarse grained diorite, gabbro, and amphibolite. May be equivalent to Jurassic Diorite of Bertha Peak in the Fawnskin area (unit Jdb). Intruded by units Km and Kqd.

Jh **Hypabyssal dike rocks** (Jurassic?)--Aphanitic to fine grained porphyritic rocks ranging in composition from andesite to quartz latite porphyry. Intrudes unit Ŧhm; intruded by unit Km.

Ŧhm **Hornblende monzonite** (Triassic)--Medium to coarse grained foliated to massive hornblende monzonite to quartz monzonite. The unit has a minimum age of 214.1±2.1 Ma determined by the $^{40}Ar/^{39}Ar$ method (Cameron, 1981, p. 334). Intruded by units Khqm and Km.

Ŧd **Diorite** (Triassic)--Medium to coarse grained foliated to massive diorite and gabbro. We adopt Smith's (1982a,b) interpretation that the dioritic rocks are comagmatic with the unit of hornblende monzonite (Ŧhm)

mpm **Mixed plutonic and metasedimentary rock** (Mesozoic and (or) Paleozoic and (or) Proterozoic)--Complexly intermingled Mesozoic granitoid rocks and pre-Mesozoic metasedimentary rocks. Plutonic rocks contain abundant xenoliths and inclusions, are texturally massive to gneissose, and have heterogeneous compositions that include monzogranite, granodiorite, and amphibolite. Prebatholithic rocks include screens, pendants, and small bodies of quartzofeldspathic gneiss, schist, and marble that we interpret as deformed and highly assimilated equivalents of less deformed Paleozoic and late Proterozoic metasedimentary rocks differentiated elsewhere on the map. Locally, this unit consists of gneissose crystalline rock that is indistinguishable from unit qfgn and that resembles leucocratic phases of the Baldwin Gneiss

PREBATHOLITHIC METASEDIMENTARY ROCKS

Metasedimentary rocks in the north-central San Bernardino Mountains originally formed as assemblages of quartz sand, shale, and calcareous sediment deposited in marine continental-shelf environments of the late Proterozoic and Paleozoic North American continental margin. Subsequent to their deposition, the quartzite, shale, limestone, and dolomite rock units formed in this setting were complexly deformed by multiple generations and styles of folds and faults and were intruded by various Mesozoic granitoid plutons. This protracted geologic history is recorded by the screens, pendants, and large bodies of metaquartzite, phyllite, schist, and calcitic and dolomitic marble now occurring in the north-central San Bernardino Mountains.

All the prebatholithic sedimentary rocks in the north-central San Bernardino Mountains are metamorphosed. Original depositional fabrics are preserved only in the lower-grade metamorphic rocks that have not been pervasively recrystallized. In the metacarbonate rocks, depositional fabrics locally include algal and sedimentary lamination, rip-up breccias, graded bedding, and depositional textures that include both grain-supported and mud-supported frameworks. In the metaquartzites, depositional fabrics include various kinds of dune and ripple cross laminations and bed forms, planar laminations, mud cracks, pebble conglomerate, and organic burrows and traces. Metamorphic mineral growth is pervasive in most of the metacarbonate sequences, leading to fine to coarse hornfelsic calcite and dolomite textures containing tremolite, forsterite, brucite, epidote, and other mineral phases that Richmond (1960, p. 20-24) tentatively assigned to the lower amphibolite facies. Metamorphic effects also are pervasive in the metaquartzite sequences, where quartzose and quartzofeldspathic fabrics are recrystallized and where pelitic schist intervals contain muscovite, biotite, and andalusite. Cameron (1981, p. 290-299) indicates that metamorphism occurred in the upper greenschist to lower amphibolite facies under regional dynamothermal conditions that preceded and accompanyed polyphase deformation, with more localized contact metamorphism adjacent to plutons. Richmond (1960, p. 13-14) earlier had proposed that the sedimentary rocks had undergone only contact metamorphism by static thermal processes related to intruding granitoid plutons.

Attempts to describe and classify the metasedimentary rocks began with the investigation by Vaughan (1922), who divided the sequence into the Arrastre Quartzite, Saragossa Quartzite, and Furnace Limestone (fig. 1). Gillou (1953) revised the Saragossa Quartzite and referred to part of that unit as the Chicopee Formation. Stewart and Poole (1975) and Tyler (1975, 1979) recognized that the Saragossa Quartzite and lowest Furnace Limestone are lithologically similar to rock units in the southern Great Basin and Mojave Desert, and Tyler (1975, 1979) extended the Great Basin nomenclature into the San Bernardino Mountains. Cameron (1981, 1982) acknowledged lithologic similarities between some of the quartzite units in the San Bernardino Mountains and southern Great Basin, but he pointed out lithologic differences that led him to propose his Big Bear Group and its several included formations that span all of Vaughan's (1922) Arrastre and Saragossa Quartzites (fig. 1). Cameron (1981) anticipated the later work of Brown (1984, 1987, 1991) by suggesting that the Furnace Limestone also has lithologic intervals that are similar to rock units widely recognized in the southern Great Basin. Brown's subsequent detailed geologic mapping in the north-central San Bernardino Mountains led to the formal recognition of Great Basin carbonate formations and members that preempt use of Vaughan's Furnace Limestone (fig. 1).

Pennsylvanian, Mississippian, and Devonian metacarbonate rocks

The upper part of Vaughan's (1922) Furnace Limestone in the north-central San Bernardino Mountains is dominated by metamorphosed limestone and subordinate dolomite. Although Cameron did not map these rocks, he (Cameron 1981, p. 142-147) identified lithologies correlative with the Bird Spring Formation, Monte Cristo Limestone, and Sultan Limestone--rock units all named by Hewett (1931) in the Goodsprings district of southern Nevada. Brown (1984, 1987, 1991) later mapped the distribution of these units, subdivided them into members, and established their stratigraphic and tectonic contacts (fig. 1).

Pb **Bird Spring Formation (Pennsylvanian)**--Upper part of Furnace Limestone of Vaughan (1922) as mapped by Guillou (1953), Richmond (1960), Dibblee (1964), Hollenbaugh (1968), and Sadler (1981); correlated with Bird Spring Formation of southern Great Basin by Cameron (1981) and Brown (1984, 1987, 1991). We recognize four members:

Pbu **Upper member**--Generally light-colored, medium- to thick-bedded, medium to coarsely crystalline calcite marble that locally is pelmatozoan bearing. Typical lithologies include white, gray, or mottled marble and cherty silicified marble that are interstratified in packages as much as 40 ft thick. Yellowish to brownish gray phyllite is a subordinate rock type.

Pbm **Middle member**--Medium- to thick-bedded, generally medium- to dark-gray, chert-bearing calcite marble containing lenses and thin layers of quartz silt and fine sand. Locally pelmatozoan bearing.

Pbl **Lower member**--Medium- to thick-bedded, light-gray to white, medium to coarsely crystalline calcite marble containing intermittent layers up to 10 ft thick of minor brown-weathering dolomite marble and (or) siliceous marble horizons and thick- to very thick-bedded, medium- to dark-gray calcite marble.

Pbb **Basal member**--Very thick bedded white quartzite, thin- to medium-bedded olive-green metasiltstone, and orange-brown to gray interbedded chert and metalimestone overlain by heterogeneous light and dark colored metalimestone and metadolomite that is burrow mottled (?) and locally cherty.

Mm **Monte Cristo Limestone** (Mississippian)--Upper part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960), Dibblee (1964), and Sadler (1981). Correlated with the Monte Cristo Limestone of the southern Great Basin by Cameron (1981), and mapped by Brown (1984, 1987, 1991) who recognized several formal stratigraphic members named originally by Hewitt (1931). In this report we recognize three members:

Mmy **Yellowpine member**--Heterogeneous medium- to thick-bedded interlayered light- and dark-gray calcite and dolomite marble.

Mmb **Bullion member**--Thick- to very thick-bedded, light-gray to white, texturally massive, very pure bioclastic calcite marble. Grain size varies from fine to coarsely crystalline depending on metamorphic grade.

Mml **Lower member**--Interlayered dark-gray and light-gray calcite marble that is thin to thick bedded, pelmatozoan-bearing, texturally massive to mottled, and chert-bearing. Includes the Dawn and Anchor members of the southern Great Basin that could not be differentiated at the map scale.

Ds **Sultan Limestone** (Devonian)--Middle part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960), Dibblee (1964), and Sadler (1981). Cameron (1981) and Brown (1984, 1987, 1991) correlated rocks in this interval with members of the Sultan Limestone (of Hewitt, 1931) in the southern Great Basin. We recognize three members of the Sultan Formation:

Dsc **Crystal Pass Member**--Thin- to thick-bedded white calcite marble with intermittent thin intervals of dark-gray calcite and dolomite marble. Lower part of unit commonly is irregularly dolomitized and contains greater number of gray metalimestone layers. White marble layers locally are pyrite-bearing, and commonly are stained with iron oxide on fracture surfaces and layering surfaces.

Dsv **Valentine Member**--Thin- to very thick-bedded, light-gray, pale-yellowish-brown, and white finely crystalline metadolomite that is laminated to texturally massive; some intervals contain lenticular to irregular nodules of white to very pale-brown chert. Lithologically resembles Sevy Dolomite of Basin and Range Province. Is more dolomitic than the type Valentine Limestone Member described by Hewett (1931, p. 14-15).

Dsi **Ironside Member**--Medium- to very thick-bedded, dark-gray dolomite marble that is texturally massive; locally has thin white calcite stringers resembling worm tubes.

Cambrian metacarbonate units

The lower part of Vaughan's (1922) Furnace Limestone in the north-central San Bernardino Mountains consists of metamorphosed dolomite and limestone lithologies that are difficult to subdivide because metamorphism and secondary dolomitization have blurred and obscured lithologic differences that elsewhere allow easier subdivision. This difficulty is compounded by polyphase folds and thrust faults that can repeat units or delete them: these structures can go undetected and the sequence of carbonate lithologies can be misleadingly different from that of more intact carbonate sequences of the Mojave Desert and southern Great Basin. In particular, we had difficulty subdividing dolomitic marble sequences within the stratigraphic interval occupied in the Mojave Desert and southern Great Basin by the Nopah and Bonanza King formations. Subdivision was facilitated where distinctive marker units like the Dunderberg Shale Member of the Nopah Formation and silty impure marble and argillite marker intervals of the Bonanza King Formation are present. However, these markers commonly are discontinuous because of tectonic factors, and in their absence it commonly is not easy to discriminate the larger stratigraphic units they separate. Rocks in the lowest part of Vaughan's Furnace Limestone provide an exception to this generality: this interval includes distinctive calc-silicate rock, phyllite, metaquartzite, and calcitic marble that Stewart and Poole (1975) and Tyler (1975, 1979) showed to be correlative with the Carrara Formation of the southern Great Basin.

Ꞓn **Nopah Formation** (Cambrian)--White to light-gray, thin-bedded to very thick-bedded, fine to medium crystalline dolomite that mainly is texturally massive but locally is laminated. Middle part of Furnace Limestone of Vaughan (1922) as mapped by Richmond (1960), Dibblee (1964), and Sadler (1981). Much of the unit lithologically resembles the Smoky Member of the upper Nopah Formation as recognized in the southern Great Basin by Christiansen and Barnes (1966); their Halfpint Member of the Nopah is more calcareous than typical rocks in the north-central San Bernardino Mountains, but thin bedded and laminated dolomite units in the map area may be lithologic counterparts of the flaggy splitting and very thin-bedded calcareous Halfpint.

Ꞓnd **Dunderberg Shale Member, Nopah Formation** (Cambrian)--Brownish to greenish hornfels, metaquartzite, phyllite, and silty impure calcitic and dolomitic marble. Lower part of Furnace Limestone of Vaughan (1922) as mapped by Dibblee (1964), Richmond (1960), and Sadler (1981). Correlative with the Dunderberg Shale Member of the Nopah Formation as used by Christiansen and Barnes (1966) in the southern Great Basin.

Ꞓb **Bonanza King Formation** (Cambrian)--Lower part of Furnace Limestone of Vaughan (1922) as mapped by Guillou (1953), Richmond (1960), Dibblee (1964), and Sadler (1981). Named by Hazzard and Mason (1936) from exposures in the Providence Mountains, the unit has been recognized widely throughout the Mojave Desert and southern Great Basin (see discussions by Gans, 1974, Stone and others, 1983, and Brown, 1991). In the type area, Hazzard and Mason (1936) recognized five informal subdivisions of the Bonanza King. Many informal units have been recognized regionally within the formation (Gans, 1974), but in the southern Great Basin these have been grouped within two formal members (Papoose Lake and Banded Mountain) that comprise lower and upper parts of the formation (Barnes and Palmer, 1961; Barnes and others, 1962). In the highly metamorphosed and deformed carbonate sections of the Mojave Desert, Stone and others (1983) were not able to subdivide the Bonanza King into constituent units. However, the carbonate sequence in the north-central San Bernardino Mountains is not as severely metamorphosed, and here we locally have subdivided the Bonanza King interval into subunits. Where this was not possible, we group Bonanza King rocks into an undivided unit (Ꞓb) of thin- to thick-bedded, white to medium-gray, fine to coarsely crystalline dolomitic and calcitic marble.

Ꞓbu **Upper member**--Mainly consists of medium- to thick-bedded, medium-gray, texturally massive to mottled, fine- to medium- crystalline dolomite marble and calcareous metadolomite interlayered with subordinate light-gray to white dolomite marble and calcareous metadolomite.

Ꞓbdw **White dolomite member**--Thin- to very thick-bedded, uniformly white to light gray, texturally massive to laminated, finely crystalline dolomite marble that is similar to the Nopah Dolomite.

Ꞓbdg **Gray dolomite member**--Thin- to thick-bedded, medium-light gray to medium-gray, texturally massive, finely crystalline dolomite marble.

Ꞓbd **Dolomite member**--Thin- to thick-bedded, light- to medium-gray, laminated to mottled dolomite marble and calcareous metadolomite. In its lower part this member contains thin intervals a few meters to a few tens of meters thick of greenish brown and grayish brown metasiltstone, argillite, hornfels, and impure limestone similar to the Dunderberg Shale Member of the Nopah Formation. These may correspond to silty impure carbonate intervals in the lower part of the Banded Mountain Member of the Bonanza King in the southern Great Basin (Barnes and others, 1962, p. D30-D31; Burchfiel and Davis, 1977, p. 1624). However, if our dolomite member coincides with the Banded Mountain Member, the conspicuous alternation of light-gray and dark-gray carbonate lithologies so characteristic of that unit regionally is not common in the north-central San Bernardino Mountains. The absence of this hallmark feature probably reflects metamorphic bleaching (see Burchfiel and Davis, 1977; Stone and others, 1983).

Ꞓbl **Lower member**--Thin- to thick-bedded, light- to dark-gray to white, texturally massive to mottled to laminated, fine- to coarsely crystalline calcite marble, dolomitic marble, and subordinate metadolomite. In areas where this member is faulted, fractured, or tightly folded the rock is secondarily dolomitized and difficult to distinguish from other members. Toward the top of the unit occurs a thin interval of greenish brown and grayish brown metasiltstone, argillite, hornfels, and impure limestone marble similar to intervals in the overlying dolomite member. Probably correlative with the Papoose Lake Member of the Bonanza King Formation.

Ꞓc **Carrara Formation** (Cambrian)--Heterogeneous calcite marble, phyllite, calc-silicate rock, and schist. Lower part of Furnace Limestone of Vaughan (1922) as mapped by Guillou (1953), Richmond (1960), Dibblee (1964), and Sadler (1981, 1982m, Furnace Limestone units F_1-F_3). 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, 1979) and Cameron (1981). The Latham Shale, Chambless Limestone, and Cadiz Formation of the Marble and Providence Mountains (Hazzard and Mason, 1936) occupy the same approximate startigraphic interval, but in the study area we assigned rocks of this interval to the Carrara Formation (Cornwall and Kleinhampl, 1961) because we had difficulty in mapping three distinct formations.

Cambrian and upper Proterozoic metaquartzites and associated rocks

Metasedimentary rocks in Vaughan's (1922) Saragossa Quartzite have been mapped in different ways by different workers (fig. 1). Gillou (1953) separated out the Chicopee Formation from part of the Saragossa, a protocol followed by Richmond (1960, his Chicopee Canyon Formation). Dibblee (1964, 1967, 1982) retained Vaughan's Saragossa Quartzite (with informal subunits) as a useful map unit at 1:62,500 scale. Modern stratigraphic interpretations began with the recognition by Stewart and Poole (1975) and Tyler (1975, 1979) that metaquartzite, phyllite, and schist units in the Saragossa Quartzite are lithologically similar to, and occupy approximately the same stratigraphic positions of, lower Cambrian and upper Proterozoic clastic units that are well known and geographically widespread throughout the southern Great Basin and Mojave Desert regions. This recognition has led to the use of new stratigraphic nomenclature for metasedimentary rocks formerly included within the Saragossa Quartzite (fig. 1).

Problems still remain regarding the classification, correlation, and mapping of some of these rocks. General agreement exists about how the upper part of the clastic sequence should be classified and mapped: all modern workers correlate the upper two units of the sequence with the Zabriskie Quartzite and Wood Canyon Formation (Stewart and Poole, 1975; Tyler, 1975, 1979; Cameron, 1981, 1982; Sadler, 1981, 1982a-m; Stewart, 1982, 1984), and Tyler (1979) and Cameron (1982) extended those names into the San Bernardino Mountains. Stratigraphic classification of the lower part of the sequence between the Wood Canyon Formation and the Baldwin Gneiss remains problematical, however--partly because of structural complexities in the north-central San Bernardino Mountains and partly because lithologic differences exist between rocks of the pre-Wood Canyon interval in the San Bernardino Mountains and their presumed counterparts in the Mojave Desert and southern Great Basin.

Classification of the pre-Wood Canyon interval in the San Bernardino Mountains requires that stratigraphic sequences in three areas be considered and compared--Jacoby Canyon and Delamar Mountain in the map area and Sugarloaf Mountain just south of the map area. At Jacoby Canyon, Stewart and Poole (1975) originally correlated pre-Wood Canyon quartzite and carbonate rocks with the Stirling Quartzite and Johnnie Formation of the southern Great Basin; they indicated that the metasedimentary section is attenuated and that carbonate rocks of the Johnnie Formation rest nonconformably on Baldwin Gneiss. Tyler (1975, 1979) applied the name Stirling Quartzite to all of these rocks. Like Stewart and Poole (1975), Tyler correlated the quartzite interval with Stirling Quartzite unit E as recognized by Stewart (1970) in the southern Great Basin, but unlike Stewart and Poole, Tyler correlated the carbonate rocks with Stirling unit D of Stewart (1970) and indicated that the carbonate unit is faulted against the Baldwin Gneiss. Moreover, Tyler (1979, p. 76) indicated that elsewhere in the Jacoby Canyon area, light-colored quartzites stratigraphically below the carbonate unit rest nonconformably on the Baldwin Gneiss, and this observation led him to conclude that all pre-Wood Canyon metasedimentary rocks in the Jacoby Canyon area belong to a Stirling Quartzite section that includes Stewart's (1970) unit A at its base.

Subsequent mapping by Cameron (1981, 1982) in the Delamar Mountain and Sugarloaf Mountain areas and by Sadler (1981, 1982a-m) there and at Jacoby Canyon provided stratigraphic classifications that differed from Tyler (1975, 1979) and in part from each other. Cameron (1981, 1982) argued that the pre-Wood Canyon metasedimentary sequence in the San Bernardino Mountains is so different lithologically from the pre-Wood Canyon interval in the southern Great Basin that completely different stratigraphic nomenclature is justified. Cameron (1982) organized the San Bernardino Mountains sequence into the Big Bear Group that he subdivided into the Wildhorse Meadows Quartzite, Lightning Gulch Formation, Moonridge Quartzite, Green Spot Formation, and Delamar Mountain Formation (fig. 1). Regional correlation of formations within the Big Bear Group is discussed by Stewart (1982) and by Stewart and others (1984).

Sadler (1981, 1982a-m) independently recognized the Wildhorse Meadows Quartzite, Lightning Gulch Formation, and Moonridge Quartzite (Sadler's Sugarloaf Quartzite), but he mapped a solution to complex structure on Sugarloaf Mountain without need for the marble sequence of Cameron's Green Spot Formation (Powell and others, 1983, also did not recognize the Green Spot Formation as a necessary stratigraphic solution to structural complexities on Sugarloaf Mountain). In addition, Sadler (1981, 1982a-m) mapped subdivisions C_1 through C_3 of his Chicopee Formation for rocks that Cameron referred to the Delamar Mountain Formation and subdivisions C_4 through C_6 of his Chicopee Formation for rocks that Cameron and other workers referred to the Wood Canyon Formation and Zabriskie Quartzite (fig. 1).

Our stratigraphic classification of pre-Wood Canyon metasedimentary rocks in the north-central San Bernardino Mountains borrows from the approaches of previous workers (fig. 1). We follow Stewart and Poole (1975) and Tyler (1975, 1979) who were impressed with lithologic similarities between rocks in the Jacoby Canyon area and those in the upper part of the Stirling Quartzite in the southern Great Basin, and we refer these rocks to the Stirling Quartzite. This violates Cameron's (1981, 1982) proposal that the Jacoby Canyon rocks and similar rocks at Delamar Mountain be referred to his Delamar Mountain Formation. However, we follow Cameron and Sadler in their recognition of distinctive metasedimentary formations (Wildhorse Meadows Quartzite, Lightning Gulch Formation, Moonridge Quartzite) depositionally overlying the Baldwin Gneiss; of these, we recognize the Wildhorse Meadows Quartzite in the map area. Our study does not address possible problems associated with Cameron's Green Spot Formation.

Ꞓz **Zabriskie Quartzite** (Cambrian)--Medium to very thick-bedded, white vitreous metaquartzite. Part of the Saragossa Quartzite of Vaughan (1922) as mapped by Dibblee (1964, 1982). Upper member of Chicopee Formation as mapped by Guillou (1953); upper member of the Chicopee Canyon Formation as mapped by Richmond (1960). Chicopee Formation unit C_6 as mapped by Sadler (1981, 1982d, f-h). Correlated with the Zabriskie Quartzite of the southern Great Basin by Stewart and Poole (1975).

Ꞓw **Wood Canyon Formation** (Cambrian)--Part of the Saragossa Quartzite of Vaughan (1922) as mapped by Dibblee (1964, 1982). Cross-laminated unit of Chicopee Formation as mapped by Guillou (1953); upper part of lower member of Chicopee Canyon Formation as mapped by Richmond (1960). Dibblee (1964) included some of these rocks in his phyllite unit of the Saragossa Quartzite. Correlated with the Wood Canyon Formation of the southern Great Basin by Stewart and Poole (1975). Mappable lithologic intervals not differentiated here include (from youngest to oldest): (1) an interval of interlayered black and white metaquartzite and subordinate phyllite (Chicopee unit C_5 of Sadler, 1981, 1982d, f-h; ; (2) an interval of white conglomeratic metaquartzite (Chicopee unit C_4 of Sadler, 1981, 1982d, f-h); and (3) an interval of dark gray metaquartzite and dark brownish gray to black hornfels, phyllite, metasiltstone, and biotite schist (Chicopee unit C_3 of Sadler, 1981, 1982d, f-h). Some of the metaquartzite lithologies are characterized by small to large-scale cross lamination. In the Greenlead area, rocks we show as Wood Canyon Formation locally include dolomite marble of the Bonanza King Formation.

Ᵽs **Stirling Quartzite** (Proterozoic)--Part of the Saragossa Quartzite of Vaughan (1922) as mapped by Dibblee (1964, 1982). Lower part of the Chicopee Formation as mapped by Guillou (1953; lower member of the Chicopee Canyon Formation as mapped by Richmond, 1960). Correlated with the Stirling Quartzite and Johnnie Formation of the southern Great Basin by Stewart and Poole (1975). We recognize three members of the Stirling Quartzite--two metaquartzite members separated by a metacarbonate member.

Ᵽsu **Upper member**--Light-gray, yellow-gray, and white feldspathic metaquartzite and conglomeratic metaquartzite (ripple-marked member of the Chicopee Formation of Guillou, 1953; unit C_2 of Sadler, 1981, 1982b,d,f-h,m). Stewart and Poole (1975) correlated this unit with the Stirling Quartzite; we follow Tyler (1979) and correlate the interval with Stirling Quartzite unit E of Stewart (1970). Cameron (1981, 1982) refers these rocks to member D2 of his Delamar Mountain Formation.

Ᵽsc **Carbonate member**--Light-gray to buff-weathering, laminated to texturally massive calcite marble, quartz-sand-bearing marble, metadolomite, and metaquartzite (lime silicate member of the Chicopee Formation of Guillou, 1953; unit C_1 of Sadler, 1981, 1982d, f-h). Stewart and Poole (1975) correlated the carbonate member with the Johnnie Formation of the southern Great Basin. We follow Tyler (1979) who correlated the unit with Stewart's (1970) Stirling Quartzite unit D.

Ᵽsl **Lower quartzite member**--White, light-gray, yellowish gray, and pink, medium- to very thick-bedded, texturally massive to cross-laminated metaquartzite. At the mouth of Arrastre Canyon, unit includes heterogeneous metaquartzite, phyllitic quartzite, and a body of mafic biotite-plagioclase phyllitic and hornfelsic greenstone that Vaughan (1922) included within his Arrastre Quartzite. These rocks in part may correlate with the Moonridge Quartzite and Lightning Gulch Formation on Sugarloaf Mountain.

Ᵽw **Wildhorse Meadows Quartzite** (Proterozoic)--White, light-gray, and pink, medium- to very thick-bedded, texturally massive to vitreous metaquartzite. In the Big Bear Lake area this member rests nonconformably on Baldwin Gneiss, but the depositional contact commonly has been modified and obscured by low-angle faulting that developed as the quartzite section detached and slid along the original depositional surface during folding events. In the west part of the map area, rocks we assign to the Wildhorse Meadows Quartzite are lithologically heterogeneous and may correlate with the Moonridge Quartzite and Lightning Gulch Formation at Sugarloaf Mountain.

qfgn **Quartzofeldspathic gneissose rock** (Mesozoic? and [or] Paleozoic? and [or] Proterozoic?)--Well foliated to compositionally layered crystalline rock. Overall composition mainly biotite granodiorite, but ranges from siliceous quartzose gneiss to biotite-rich quartzofeldspathic gneiss. Fabrics are strongly recrystallized, and much of the rock is mylonitic and has well-developed mineral-streaking lineation. Possible affinities and origins include: (1) deformed and assimilated equivalents of the upper Proterozoic and lower Cambrian quartzofeldspathic metaquartzite sequence (units Ᵽs, Ᵽw, Ꞓw) that have been injected with Mesozoic granitoid rock; (2) deformed and recrystallized Mesozoic plutonic rocks; (3) partly assimilated and deformed Baldwin Gneiss. We favor the first two interpretations; the last interpretation probably applies only to local mafic parts of the unit. Unit locally is indistinguishable from unit mpm.

Ᵽb **Baldwin Gneiss** (Proterozoic)--Heterogeneous lithologies including K-spar augen orthogneiss, compositionally layered muscovite-bearing quartzofeldspathic gneiss, and foliated porphyritic to equigranular orthogneiss. Locally mylonitic. Minimum age of 1,750±15 Ma for metaplutonic phase determined by the U-Pb method (Silver, 1971). Originally included by Vaughan (1922) as part of his Saragossa Quartzite, but differentiated as a separate unit by Gillou (1953).

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