Geologic Map of the Morena Reservoir 7.5-Minute Quadrangle, San Diego County, California

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Introduction

Mapping in the Morena Reservoir 7.5-minute quadrangle began in 1980, when the Hauser Wilderness Area, which straddles the Morena Reservoir and Barrett Lake quadrangles, was mapped for the U.S. Forest Service. Mapping was completed in 1993–1994. The Morena Reservoir quadrangle contains part of a regional-scale Late Jurassic(?) to Early Cretaceous tectonic suture that coincides with the western limit of Jurassic metagranites in this part of the Peninsular Ranges batholith (PRB) (fig. 1). This suture, and a nearly coincident map unit consisting of metamorphosed Cretaceous and Jurassic back-arc basinal volcanic and sedimentary rocks (unit KJvs), mark the boundary between western, predominantly metavolcanic rocks, and eastern, mainly metasedimentary, rocks. The suture is intruded and truncated by the western margin of middle to Late Cretaceous Granite Mountain and La Posta plutons of the eastern zone of the batholith (fig. 1). Figure 1 also shows geologic quadrangles and geographic locations mentioned in the text.

Rock Units

Julian Schist

The southern end of the Morena Reservoir roof pendant of Berggreen and Walawender (1977) (referred to here as a "screen" because of its tabular shape and steep contacts with surrounding plutons) extends into the northeast part of the Morena Reservoir quadrangle. The rocks of this screen and two smaller exposures of prebatholithic rocks in the northeast corner of the quadrangle are assigned by most workers to the Jurassic-Triassic Julian Schist of Hudson (1922) (unit JŦm; Weber, 1963; Berggreen and Walawender, 1977; Hoggatt and Todd, 1977). Berggreen and Walawender (1977) characterized metamorphic rocks of the screen as a sequence of amphibolite-grade quartzo-feldspathic schist and gneiss with rare metaconglomerate. Semi-pelitic cordierite-biotite schist of the sequence contains andalusite and sillimanite, and gneiss and conglomerate commonly contain quartz plus mafic and calcsilicate minerals (diorite, actinolite, clinozoisite, plagioclase, calcite, wollastonite) (Berggreen and Walawender, 1977).

The part of the Morena Reservoir screen that crops out in the Morena Reservoir quadrangle consists mainly of quartzo-feldspathic schist and gneiss interlayered with amphibolite and meta-andesite(?). The rocks are folded into such tight isoclinal folds that bedding has been largely obliterated. The overall composition of the metamorphic rocks suggests an origin as a sequence of metasedimentary rocks intercalated with silicic, intermediate, and mafic volcanic/volcaniclastic rocks. Whereas the Julian Schist contains ~5% metavolcanic components, mainly amphibolite and mafic schist (Todd and Shaw, 1979; Grove, 1987), the proportion of probable metavolcanic rocks in the Morena Reservoir screen may be significantly larger than that in Julian Schist screens in the Cuyamaca and Laguna Mountains to the east.

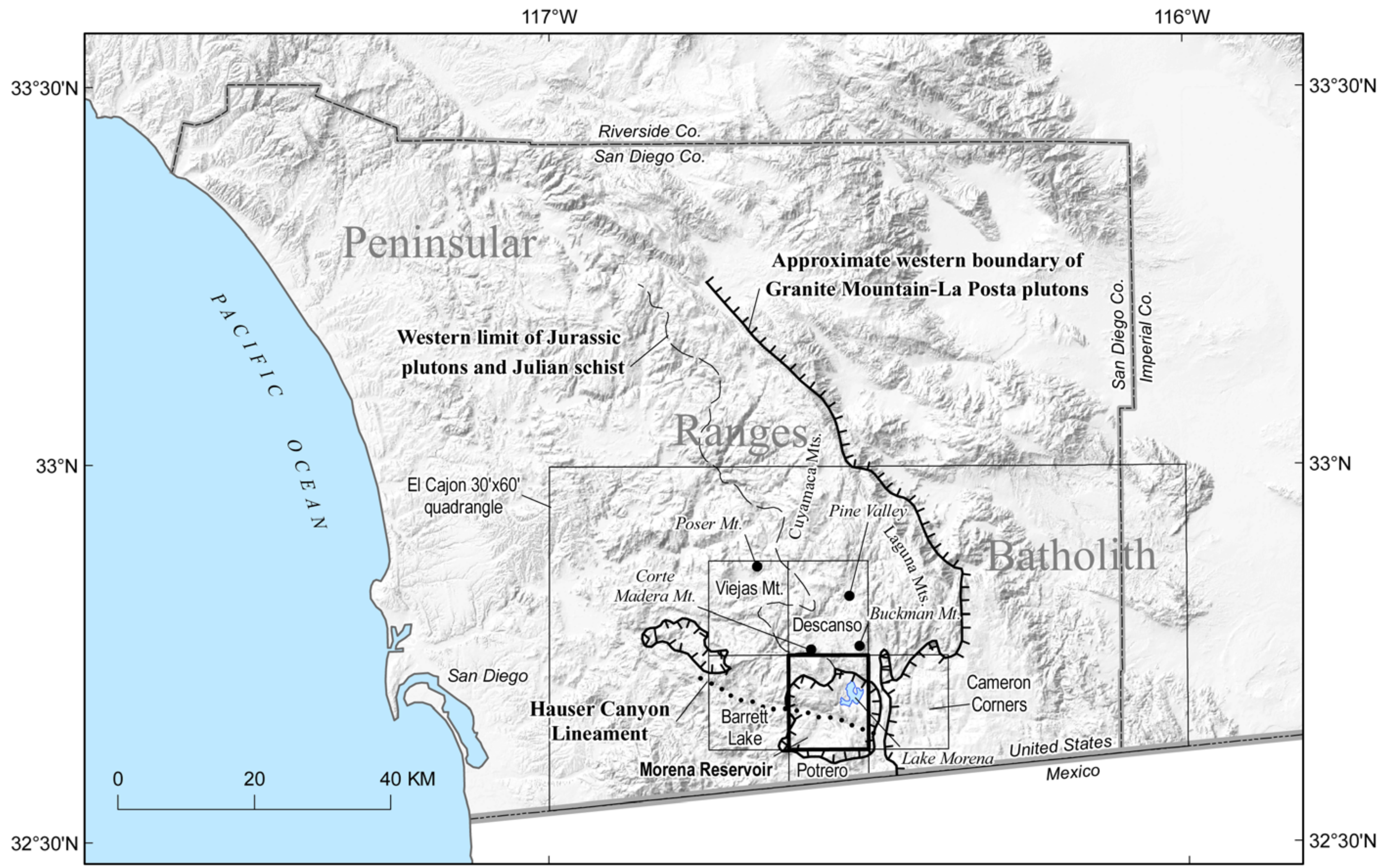

Figure 1. Index map of part of San Diego County showing location of the Morena Reservoir quadrangle and surrounding 7.5-minute quadrangles, geographic locations named in the text, and major structural features. Geographic locations shown by solid circles. Dashed line, western limit of Jurassic metagranite plutons and Julian Schist wallrocks; hachured boundaries, approximate western boundary of large Granite Mountain- and La Posta-type plutons, and two smaller satellitic plutons/plutonic complexes. Dotted line, Hauser Canyon lineament.

Gneiss of Harper Creek

The gneiss of Harper Creek (unit Jhc; Todd, 1977) comprises metamorphosed granitic plutons as much as 20 km long and 6 km wide in the central part of the map area. The unit has a small exposure in the northeast corner of the Morena Reservoir quadrangle, where it is intruded on the east and south by the monzogranite of Chiquito Peak and is bordered on the west by a narrow pluton of the granodiorite of Cuyamaca Reservoir. These two Jurassic plutons together with a narrow band of Julian Schist comprise a screen within the Chiquito Peak unit.

The Harper Creek unit consists of fine- to medium-grained, gneissic and mylonitic biotite granodiorite and tonalite with lesser monzogranite; the rocks are composed of plagioclase, quartz, biotite, and K-feldspar grains set in a fine-grained matrix of recrystallized quartz, feldspar, and mica (average color index, C.I., 24). The Harper Creek also contains variable amounts of cordierite, muscovite, sillimanite, and rare garnet. The rocks are medium to dark gray on fresh surfaces, weather to distinctive reddish- and yellowish-brown colors, and are markedly rich in quartz and mica. They are characterized by abundant, uniformly distributed, raft-like inclusions of metasedimentary rocks and amphibolite in a range of sizes from 10 cm to several meters long. These inclusions, together with lenticular biotite aggregates ranging from 0.5–3 mm in thickness and 1–5 cm in length, are oriented parallel to mineral foliation defined by recrystallized grains and aggregates. Locally, mineral foliation and gneissic layering are observed to be parallel to the axial planes of outcrop-scale isoclinal folds.

Contacts between the Harper Creek unit and the granodiorite of Cuyamaca Reservoir are gradational, interfingering, or sharp. Locally, textural and compositional changes in the Cuyamaca Reservoir against the Harper Creek suggest that the Cuyamaca Reservoir magma intruded the Harper Creek. Although early-determined U-Pb zircon ages for the Harper Creek ranged from 193±16 Ma to 149±12 Ma (Thomson and Girty, 1994), more recent U-Pb zircon dating yielded ages that cluster in the Middle Jurassic (Shaw and others, 2003).

Granodiorite of Cuyamaca Reservoir

The granodiorite of Cuyamaca Reservoir (unit Jcr; Todd, 1977) forms elongate, steep-walled plutons as much as 20 km long and 5 km wide in the central part of the map area. The plutons underlie low hills, ridges, and broad meadows whose outcrops have a distinctive orange-tan weathered color. The Cuyamaca Reservoir unit consists of fine- to medium-grained, light- to dark-gray biotite and hypersthene-biotite granodiorite and tonalite. The rocks are composed of plagioclase, sub-equal quartz and biotite, K-feldspar, and hypersthene±actinolitic amphibole±hornblende. They are strongly foliated and, along metasedimentary screens, consist of mylonitic gneiss that carries swarms of small refractory metasedimentary inclusions.

In the northeast corner of the Morena Reservoir quadrangle, the granodiorite of Cuyamaca Reservoir forms a narrow pluton within a screen of Jurassic plutonic rocks. The age of the unit is considered to be Middle Jurassic on the basis of recently determined Middle Jurassic U-Pb zircon ages of Cuyamaca Reservoir plutons to the north (Shaw and others, 2003).

Metavolcanic and Metasedimentary Rocks

The metamorphic screen in the northwestern part of the Morena Reservoir quadrangle and a smaller screen bordering the eastern side of Morena Butte are tentatively assigned to map unit KJvs, which consists of metavolcanic and metasedimentary rocks that are interpreted as deposits of a back-arc basin (Todd, 2004). At the type locality in the Ramona 7.5-minute quadrangle, unit KJvs is composed of quartzite, pelitic schist, meta-tuff(?), calcsilicate rocks, and mega-breccia interlayered with as much as 50 percent amphibolite (basalt of MORB affinity) and fine-grained gabbro. The rocks of these two screens are lithologically similar to those of map unit KJvs and are interpreted to be partly, if not wholly, of volcanic origin. The KJvs unit has been dated at a single locality to the north as Middle Jurassic and Early Cretaceous (D.L. Kimbrough, written commun., 2009).

Quartz Diorite of East Mesa

The quartz diorite of East Mesa (unit KJem; Todd, 1977) crops out in a 10- to 12-km-wide zone in the central part of the map area. This north-northwest-striking zone contains plutons that have undergone strong ductile deformation (Cuyamaca-Laguna Mountains shear zone, CLMSZ, Todd and others, 1988; Thomson and Girty, 1994). Plutons of the East Mesa unit are elongate and have strongly foliated to gneissic or mylonitic textures. Smaller plutons are dike-like and tail off into swarms of fine-grained dark-colored dikes. The East Mesa rocks weather dark gray to reddish gray and crop out spottily in low brushy hills and valleys. Fine-grained mafic inclusions are present chiefly in a medium-grained textural facies of the unit; in porphyroclastic gneiss, they are greatly flattened and elongated parallel to foliation, whereas in less-strained rocks, shapes of inclusions are more variable. Some East Mesa rocks also contain swarms of metasedimentary inclusions.

Plutons of the East Mesa unit are texturally and compositionally heterogeneous, consisting of fine- to medium-grained, dark-gray quartz diorite and tonalite with lesser quartz monzodiorite, diorite, and gabbro (C.I., 23–52). Small bodies of fine-grained gabbro intrude and (or) appear to grade to quartz diorite. Quartz diorite and tonalite are composed of plagioclase, hornblende, sub-equal quartz and biotite, and minor pyroxene and K-feldspar. Pyroxene, chiefly hypersthene, makes up as much as 14 percent of some samples; augite, partially jacketing hypersthene, is present as large, partly resorbed relict grains in hornblende. Although minor in most rocks, chlorite locally makes up as much as 7 percent of the unit, as does K-feldspar. A textural variant of the East Mesa unit is a very fine grained to porphyritic rock with scattered plagioclase phenocrysts and biotite oikocrysts as much as 1 cm across, the latter imparting a spotted appearance to the rock. In these rocks, hornblende (altered to actinolite) is present in recrystallized aggregates containing opaque oxide (ilmenite only) and relics of hornblende and pyroxene.

The East Mesa body that crops out in the northeast part of the Morena Reservoir quadrangle is the southern end of a dike-like pluton that is exposed in the Descanso quadrangle to the north, a pluton that intruded the Morena Reservoir screen along its eastern margin. This East Mesa body consists of fine-grained quartz diorite and diorite that grade locally to fine- to medium-grained porphyritic gabbro. Near its contact with the Morena Reservoir screen, the East Mesa unit contains amphibolite inclusions that appear to grade(?) to the adjacent screen. If this zone of fine-grained quartz diorite and amphibolite represents a volcanic-to-plutonic transition, then the age of the East Mesa unit in the Morena Reservoir quadrangle is pre-Cretaceous. However, it is also possible that metavolcanic inclusions were stoped from wallrocks of the screen and partly assimilated by East Mesa magma, thus producing a pseudo-gradational contact. Recent U-Pb zircon dating of two East Mesa plutons yielded both Early Cretaceous and Middle Jurassic ages (Shaw and others, 2003).

Tonalite of Japatul Valley

The tonalite of Japatul Valley (unit KJv; Todd, 1978a) forms a small exposure in the northwest quarter of the Morena Reservoir quadrangle. The unit is extensive in the western part of the batholith where it consists of medium- to coarse-grained, equigranular hornblende-biotite tonalite and granodiorite, both compositions bearing scattered to abundant mafic inclusions. Modal minerals of the unit are plagioclase, quartz, biotite, hornblende, and K-feldspar (all minerals±minor pyroxene). Weathered color of the rocks varies from light gray to grayish white, and the mafic inclusions commonly weather out in relief on outcrop surfaces. The tonalite of Japatul Valley is moderately to strongly foliated, and its mafic inclusions are variably flattened and elongated parallel to regional foliation. Subhedral plagioclase, hornblende, biotite, and quartz have undergone variable solid-state strain and recrystallization. Both magmatic and recrystallized grains are aligned parallel to PRB regional foliation.

In the Morena Reservoir quadrangle, the tonalite of Japatul Valley is intruded by the tonalite of Granite Mountain. This intrusive contact can be traced almost continuously from the Morena Reservoir quadrangle westward into the Barrett Lake quadrangle, southward through the Potrero quadrangle, and eastward into the Cameron Corners quadrangle. Intrusion of the concentrically zoned plutonic complex composed of the tonalites of Granite Mountain and La Posta, which is centered at Long Potrero, apparently reoriented foliation of semi-solid Japatul Valley rocks into parallelism with the margin of the Long Potrero complex. In places, the contact between the Granite Mountain and Japatul Valley units can be difficult to discern, because marginal rocks of the Granite Mountain may also be recrystallized and strongly foliated. However, in general, the texture of the Japatul Valley is visibly more recrystallized. The age of the Japatul Valley in the Potrero quadrangle is ~102 Ma (Early Cretaceous) (S.E. Shaw, written commun., 2009).

Monzogranite of Chiquito Peak

The monzogranite of Chiquito Peak (unit Kcp; Todd, 1977) forms diapir-like plutons and steeply inclined dikes, both typically underlying peaks and ridges in the west-central part of the map area. The unit consists of medium-grained, grayish-white-weathering hornblende-biotite monzogranite and granodiorite (C.I., 2–16) with lesser trondhjemite, leucogranite, alaskite, and pegmatite. Modal minerals are plagioclase, quartz, and biotite±hornblende. Two common variants of the Chiquito Peak unit are (1) medium- to coarse-grained leucomonzogranite with subhedral white K-feldspar grains as long as 2 cm that carry scarce, small mafic inclusions and (2) fine- to medium-grained granodiorite and tonalite that carry abundant mafic inclusions as well as inclusions of stoped, partly assimilated wallrocks. Although contacts between the two variants may be gradational, the leucocratic phase commonly intrudes the more mafic phase as large concordant dikes with diffuse margins.

In the Morena Reservoir quadrangle, the Chiquito Peak unit is present as the southern part of an elliptical gabbro-granite complex centered at Buckman Mountain in the Descanso quadrangle to the north. There, Chiquito Peak leucogranite dikes intrude the Buckman Mountain gabbro pluton concentrically, whereas in the Morena Reservoir quadrangle, granodiorite and tonalite containing, and contaminated by, abundant fine-grained gabbroic inclusions are the predominant Chiquito Peak compositions. Textures of the more mafic, contaminated Chiquito Peak in the Morena Reservoir quadrangle range from strongly foliated to protomylonitic. These rocks were intruded by strongly foliated, leucocratic monzogranite-granodiorite dikes that have vague, schlieren-like margins against the surrounding more mafic phase.

In the Morena Reservoir quadrangle, the monzogranite of Chiquito Peak intrudes gabbro of the Buckman Mountain pluton and is intruded by the tonalite of Granite Mountain. A Chiquito Peak pluton in the Cuyamaca Mountains yielded an U-Pb zircon age of ~114 Ma (S.E. Shaw, written commun., 2009). L.T. Silver (oral commun., 1979) reported an age of ~117 Ma for a second pluton in the Cuyamaca Mountains. The age of the Chiquito Peak unit is considered to be Early Cretaceous.

Monzogranite of Corte Madera

The monzogranite of Corte Madera (unit Kcm; Hoggatt and Todd, 1977) forms diapir-like and lenticular plutons, as well as steeply oriented dikes. Corte Madera bodies are more resistant to weathering than any other granitic unit and, together with the Cuyamaca Gabbro, underlie peaks with the greatest relief in the map area. The Corte Madera unit consists of medium- to coarse-grained, leucocratic biotite monzogranite, granodiorite, and syenogranite (C.I., 1–11); dike facies of the unit include leucogranite, alaskite, and pegmatite-aplite. Monzogranite and granodiorite contain sub-equal quartz and plagioclase with lesser K-feldspar and biotite; roughly half of all samples contain scarce hornblende relics. Major minerals of syenogranite are K-feldspar, quartz, plagioclase, and biotite. Corte Madera outcrops weather white with a pinkish-orange (peach) hue. The plutons are weakly to strongly foliated due to alignment of 2- to 3-cm lenticular grains and aggregates of light-gray quartz and white-weathering feldspar and of 1- to 2-cm scaly mafic aggregates. The wide (>2 cm), even spacing of mafic aggregates imparts an “ermine-spotted” appearance to rock surfaces oriented perpendicular to foliation.

The monzogranite of Corte Madera underlies Spur Peak in the northwest corner of the Morena Reservoir quadrangle, Morena Butte in the east-central part of the quadrangle, and the western wall of Round Potrero in the southwestern part of the quadrangle. South of Spur Peak, a screen of metavolcanic rocks separates the Corte Madera from the tonalites of Japatul Valley and Granite Mountain. The Corte Madera unit age relative to the Los Pinos gabbro pluton is unclear. In the Descanso and Viejas Mountain quadrangles to the northwest, Corte Madera rocks next to a gabbro pluton (Corte Madera Mountain gabbro pluton) display textures that indicate magma mingling between monzogranite and gabbro, but the Los Pinos gabbro pluton may be significantly younger (~99 Ma, Matthew Taylor, oral commun., 1993) than the gabbro pluton at Corte Madera Mountain. In McAlmond Canyon in the Barrett Lake quadrangle, west of Round Potrero, the monzogranite of Corte Madera is intruded by the tonalite of Granite Mountain. Morena Butte, together with a metavolcanic screen and a small gabbro body, apparently forms a screen within the Granite Mountain unit. Uranium-Pb zircon ages of ~113 to 114 Ma are reported for Corte Madera plutons in the western part of the map area (D.L. Kimbrough, oral commun., 2009). The age of the unit in the Morena Reservoir quadrangle is considered to be Early Cretaceous.

Leucocratic Dikes

Dikes (unit Kl) composed of leucogranite, granophyre, alaskite, pegmatite, and aplite cut most of the plutonic units in the map area. Dikes that are spatially associated with Chiquito Peak or Corte Madera plutons are assumed to represent late silicic differentiates of those magmas, whereas dikes that cut the middle to Late Cretaceous Granite Mountain and La Posta units are most probably derived from Granite Mountain and La Posta parental magmas. When no spatial or genetic association is clear, leucocratic dikes are mapped as a separate unit. Their age is considered to be Cretaceous.

Cuyamaca Gabbro

Mafic and ultramafic plutons (unit Kc) in the map area, which are assigned to the Cuyamaca Gabbro of Everhart (1951), display an east-west asymmetry in outcrop distribution. Plutons in the western part of the map area are mainly large (as much as 50 km^2 in outcrop area), elliptical in plan, steep-walled, and intersheeted with granitic units in the outer parts. These large gabbro plutons are surrounded by smaller, satellitic gabbro bodies and swarms of gabbroic dikes. In the eastern part of the map area, scarce gabbro is present mainly in small plutons and dikes. All gabbro displays the same rock types, textures, and chemical compositions (Everhart, 1951; Nishimori, 1976; Walawender, 1979). Interior parts of larger gabbro plutons consist of gradational hornblende-bearing gabbronorite, olivine gabbro, anorthositic gabbro, and peridotite, whereas the marginal parts (and the smaller plutons and dikes) consist mainly of hornblende gabbro and diorite. Virtually all of the large gabbro plutons have ambiguous contacts with surrounding granitic plutons, for example, granitic dikes are present in gabbro and gabbroic dikes in granitic plutons. Contacts between gabbroic and granitic plutons are concordant, intricate, and in many cases indicate mingling of coeval magmas.

Cuyamaca Gabbro plutons have a moderate to strong, steeply inclined foliation imparted by variably recrystallized igneous grains and aggregates. The strike of primary compositional layering, considered by most workers to be of cumulate origin, is commonly parallel to this foliation, but the dip of primary layering is typically less steep (~15° less) than that of mineral foliation. In marginal parts of large plutons, and in satellitic plutons, foliation is concordant with regional foliation in the batholith, but it is more variable in the interior parts where two foliations oriented at high angles to one another may be present.

Uranium-Pb zircon ages of several gabbro plutons in the northern PRB indicate that emplacement ages of mafic magmas were similar to those of neighboring granitic magmas (D.L. Kimbrough, oral commun., 1992). The gabbro pluton at Poser Mountain in the Viejas Mountain quadrangle yielded a U-Pb zircon age of 107±2 Ma (D.L. Kimbrough, oral commun., 1993). Within the Morena Reservoir quadrangle, the Los Pinos gabbro pluton intrudes the tonalite of Granite Mountain (unit Kgm; Morena Reservoir pluton of Rector, 1994) along the eastern margin of the Los Pinos, and basaltic dikes cut the Granite Mountain. Outcrops at the contact show ductile mixtures of fine-grained gabbro and contaminated tonalite whose textures suggest that the Morena Reservoir tonalite pluton was not completely solidified at the time of gabbro intrusion. These relations are consistent with a preliminary U-Pb zircon age for the Los Pinos gabbro of ~99 Ma (Matthew Taylor, oral commun., 1993) and an age of 101±2 Ma for the Morena Reservoir pluton (Granite Mountain unit) (D.L. Kimbrough, oral commun., 1993). The age of the Buckman Mountain gabbro pluton, fragments of which are engulfed by the monzogranite of Chiquito Peak in the northeast corner of the map, is unknown, but it is probably older than the Los Pinos gabbro pluton. The age of the gabbroic rocks in the Morena Reservoir quadrangle is considered to be Cretaceous.

Tonalite of Las Bancas

The tonalite of Las Bancas (unit Klb; Hoggatt and Todd, 1977) forms large, homogeneous, inclusion-free plutons in the west-central batholith. The rocks weather to dark-reddish gray and tan colors and can usually be distinguished from the adjacent mafic inclusion-bearing tonalites of Alpine and Japatul Valley by the more resistant, evenly jointed character of the Las Bancas. The most abundant Las Bancas rock is dark gray to black, medium-grained hypersthene biotite tonalite; the unit also includes lesser quartz gabbro, quartz diorite, and granodiorite. Modal minerals are plagioclase, sub-equal quartz and biotite, hypersthene, hornblende, augite, and K-feldspar. Large (0.5 to 2.5 cm) poikilitic biotite grains that enclose earlier crystallized mafic minerals are evenly distributed in tonalite, appearing as reflective grains on weathered rock faces. The tonalite of Las Bancas has a moderate magmatic foliation due to the preferred alignment of most minerals. Rarely, discontinuous, 2-cm-thick planar concentrations of felsic and mafic minerals produce cumulate layering oriented parallel to mineral foliation.

The Las Bancas unit forms a small arcuate body surrounded by tonalite of Granite Mountain in the northwestern part of the Morena Reservoir quadrangle. In the Potrero quadrangle to the south, a similar Las Bancas body lies between the tonalite of Japatul Valley on the south and the tonalite of Granite Mountain on the north. These two bodies may be fragments of a larger Las Bancas body that was intruded by the tonalite of Granite Mountain, stretched and pulled apart as the Granite Mountain-La Posta and Long Potrero plutonic complexes expanded. D.L. Kimbrough (written commun., 2009) reported U-Pb zircon ages of ~109 to 107 Ma and 101 to 102 Ma for Las Bancas plutons in the map area. The age of the unit is considered to be Early Cretaceous.

Tonalite of Granite Mountain

In the western part of the map area, the tonalite of Granite Mountain (unit Kgm) is present as a discontinuous shell of narrow but variable width around the Late Cretaceous tonalite of La Posta (Todd, 1980). In the central-eastern part, the Granite Mountain forms large zoned plutons (Grove, 1987; Todd and others, 1987; Lampe, 1988). The tonalite of Granite Mountain is composed of medium- to coarse-grained, grayish-white-weathering biotite-hornblende tonalite, and hornblende-biotite tonalite and granodiorite. The rocks consist of plagioclase, quartz, and sub-equal hornblende and biotite±pyroxene±K-feldspar. Some rocks contain pale-tannish-green actinolite intergrown with hornblende, biotite, and chlorite.

Medium-sized quartz and abundant euhedral and subhedral hornblende grains, the latter as long as 2 cm, are characteristic of the unit. Most rocks contain flattened mafic inclusions, aligned with mineral foliation. Magmatic foliation, marked by alignment of subhedral hornblende and plagioclase grains and mafic aggregates, is present in the interior parts of Granite Mountain plutons, grading outward to more marked, protoclastic foliation near pluton margins. In the northeast part of the map area, Granite Mountain plutons have undergone strong syn-intrusive, locally mylonitic, deformation (Grove, 1987).

In the Morena Reservoir quadrangle, the tonalite of Granite Mountain forms a sizeable shell around the La Posta pluton at Long Potrero. Rector (1994) referred to the Granite Mountain unit in this quadrangle as the Morena Reservoir pluton. In this report, the Granite Mountain tonalite is mapped as four phases, from the margin inward: (1) marginal biotite-hornblende tonalite (Kgm_1) that is finer grained and more strongly foliated (solid-state foliation overprinting magmatic foliation) and has a higher C.I. than the average rock of the interior; (2) biotite-hornblende tonalite (Kgm_2) with idiomorphic texture, moderate to weak magmatic foliation, and lower C.I. than the marginal phase; (3) relatively leucocratic hornblende-biotite tonalite and granodiorite (Kgm_3) with a moderate to weak magmatic foliation and large, oval biotite grains±small acicular hornblendes; and (4) mafic biotite-hornblende tonalite (Kgm_4) with subidiomorphic texture, scattered poikilitic biotites, strong to moderate foliation, and relatively high C.I.. All four phases bear mafic inclusions, and Kgm_1 contains small diorite-gabbro bodies next to which the tonalite is contaminated. Phases 1–3 are intruded by locally abundant pegmatite-aplite dikes.

The marginal phase (Kgm_1) is interpreted as a chilled margin that underwent ductile shear against older wallrocks. Quenching and shearing of tonalite magma would account for the finer grain size and higher C.I. of this phase and, also, for the greater degree of flattening and elongation of its mafic inclusions relative to inner phases. In addition, the marginal phase is probably more mafic overall than the idiomorphic biotite-hornblende phase (Kgm_2) that it grades into. In turn, Kgm_2 grades to the hornblende-biotite phase (Kgm_3); this gradational zone is marked by a decrease in size and abundance of hornblende prisms together with an increase in size and abundance of biotite grains. Schlieren-like bodies of leucocratic biotite-rich tonalite in Kgm_2 may be dikes of Kgm_3. The biotite-rich rocks bear honey- or tan-colored euhedral sphene crystals.

The mafic tonalite phase, Kgm_4, is present only in the southern part of Round Potrero, where it grades to Kgm_2, which underlies the northern part of the valley and the lower slopes of its eastern and southern walls. The more easily weathered Kgm_4 may have originated by contamination of Kgm_2 by a small diorite-gabbro body, or bodies, in the northwestern and western parts of Round Potrero.

In the Morena Reservoir quadrangle, foliation in the Granite Mountain unit is generally parallel to its contacts with older wallrocks. Where the contact is irregular, for example, where tonalite intrudes the Morena Reservoir screen and the Los Pinos gabbro pluton, two foliations may be present; in such outcrops, the mafic inclusions are in places kinked or folded out of parallelism with the first foliation into parallelism with the second. This relation indicates that both foliations formed by magmatic or near-magmatic flow before final solidification of the tonalite's fabric.

The tonalite of Granite Mountain intrudes the monzogranites of Chiquito Peak and Corte Madera. In the northeastern part of the quadrangle, the Granite Mountain tonalite locally has a fine-grained margin against, and forms large, concordant, very fine-grained dikes in, the Chiquito Peak monzogranite. In McAlmond Canyon, just west of the Morena Reservoir quadrangle, a large, concordant fine- to medium-grained Granite Mountain dike is present in the Corte Madera unit. The contact between the tonalite of Granite Mountain and the Japatul Valley unit is relatively sharp, and, in one locality, the Granite Mountain carries inclusions of more mafic, recrystallized Japatul Valley tonalite.

The biotite-rich phase of the Granite Mountain unit (Kgm_3) is intruded by the tonalite of La Posta. The La Posta pluton centered at Long Potrero has a fine-grained, subporphyritic margin against Kgm_3, in accord with field observations and U-Pb zircon ages elsewhere in the map area that indicate an older age for the Granite Mountain unit (Walawender and others, 1990; Todd and others, 2003). North of Morena Reservoir, the Granite Mountain pluton was dated by U-Pb method as 101±2 Ma (D.L. Kimbrough, oral commun., 1993).

Tonalite of La Posta

The tonalite of La Posta (unit Klp; Todd, 1978b) comprises a vast pluton in the eastern part of the map area, as well as five smaller, satellitic plutons in the west-central part (fig. 1). The unit is generally equivalent to the La Posta Quartz Diorite of Miller (1935), but an informal name is used in the map area because rocks in and near the town of La Posta are not typical of the unit as a whole. Plutons of the La Posta unit are leucocratic, homogeneous, inclusion-free, and largely undeformed. The rocks consist of hornblende-biotite tonalite, trondhjemite, and granodiorite (C.I., 1–20). Modal minerals are plagioclase, quartz, biotite±hornblende, and K-feldspar; in some granodiorite samples, K-feldspar equals or exceeds biotite. Abundant white-weathering plagioclase grains impart a characteristic white color to La Posta outcrops. Light-gray bipyramidal quartz grains as much as 1 cm or more across, and euhedral biotite books 0.5–1 cm in diameter are also characteristic. Scattered 2- to 5-cm-long K-feldspar oikocrysts appear as glassy cleavages on outcrop surfaces, and pale-yellow euhedral sphene crystals are commonly visible in hand specimen.

Plutons of the La Posta unit are weakly foliated to massive, but locally, pluton margins and apophyses are ductilely deformed against, and along with, wallrocks. A moderate marginal magmatic foliation is present as far as 5 km from the walls of the large eastern La Posta pluton, but, inward away from the walls, the tonalite is only weakly foliated to massive. Rare inclusions are rafts of interlayered biotite-rich and quartzo-feldspathic rocks (cumulates) that grade to mafic and leucocratic schlieren, and variably flattened metapelitic inclusions.

In the Morena Reservoir quadrangle, the tonalite of La Posta forms the roughly equant core of a Late Cretaceous zoned plutonic complex that is centered at Long Potrero and has the tonalite of Granite Mountain as its outer shell. The interior La Posta rocks consist of medium- to coarse-grained biotite trondhjemite containing large idiomorphic quartz and biotite grains. Faint continuous ribbing on weathered outcrop surfaces may mark the presence of schlieren of slightly different composition. The rocks have a weak magmatic foliation that parallels the shape of the La Posta pluton. Aplite-pegmatite dikes are locally abundant in the interior.

Weakly foliated, fine- to medium-grained muscovitic leucogranite intrudes the interior of the La Posta pluton in a broad band (not shown on map) across the northern part of Long Potrero. This rock contains evenly dispersed, 1-mm rectangular muscovite grains and ragged, oval biotitic inclusions ~2 cm in length. The muscovitic rocks appear to form a series of large dikes in the tonalite of La Posta, dikes that have both sharp and gradational contacts and carry inclusions of the tonalite. The muscovitic rocks and associated dikes are probably equivalent to garnetiferous muscovite-bearing La Posta cut by aplite dikes reported by Rector (1994) in the northern part of the Long Potrero pluton.

The La Posta pluton at Long Potrero has a fine-grained, subporphyritic margin against the surrounding biotite-rich phase of the Granite Mountain unit (Kgm_3). The chilled La Posta has a seriate texture due to scattered larger (0.75 cm) biotite grains set in a matrix of smaller biotites. The marginal La Posta is moderately foliated and contains scarce, small flattened mafic inclusions.

U-Pb zircon ages of 95±3 Ma were obtained from three samples of the large La Posta pluton in the eastern part of the map area (Clinkenbeard and others, 1986). A westernmost La Posta pluton (fig. 1) yielded a U-Pb zircon age of 104±2 Ma (D.L. Kimbrough, oral commun., 1993), which suggests that parental La Posta magmas younged to the east. The age of the La Posta pluton in the Morena Reservoir quadrangle is considered to be Late Cretaceous.

Fanglomerate

Fanglomerate deposits (unit QTf) consist of weakly indurated, poorly sorted conglomeratic sandstone and fanglomerate of local derivation (clasts of leucocratic monzogranite and granodiorite, gabbro, and prebatholithic rocks). As mapped, the deposits also include debris flows and small landslides. They overlie the tonalite of Granite Mountain and Cuyamaca Gabbro on the slope southwest of, and below, Morena Butte and also occur as patchy remnants on the broad erosion surface developed on the Granite Mountain tonalite on the north side of Hauser Canyon. The deposits may contain scarce, broken, originally rounded silicic volcanic clasts (Poway clasts), which suggests that they are mixtures of Neogene materials and reworked Eocene river gravels. Locally, fanglomerate grades to younger alluvium. The unit age is considered to be Pleistocene and older(?).

Colluvium

Colluvium (unit Qc) includes sand and gravel of slopewash, debris-flow, and talus deposits. Colluvium grades locally to younger alluvium. The unit age is Holocene and Pleistocene.

Younger Alluvium

Younger alluvium (unit Qya) consists of well-bedded to poorly bedded, unconsolidated deposits of sand, silt, and gravel that occur as moderately dissected terraces in stream valleys. Modern streams have cut the terrace deposits to depths as much as 15 m. A ^{14}C age of 920±60 yr B.P. was determined (S.W. Robinson, U.S. Geological Survey) for charcoal from younger alluvium in Pine Valley Creek in the Descanso quadrangle. The age of the unit is Holocene.

Alluvium of Active Washes

The alluvium of active washes (unit Qaw) includes sand, silt, and gravel in modern streambeds. Its age is Holocene.

Faults

Hauser Canyon Fault

The Hauser Canyon lineament (fig. 1) is a 25-km-long, west-northwest-striking linear feature that crosses the southwestern part of the map area. In the Morena Reservoir quadrangle, Hauser Canyon is eroded along a west-northwest-trending ductile fault (the Hauser Canyon Fault) that has cut the Granite Mountain-La Posta zoned plutonic complex centered at Long Potrero. In the Barrett Lake quadrangle to the west, a Granite Mountain-Japatul Valley contact is apparently offset in a left-lateral sense by the fault (Todd and others, 1983). In the southeastern part of the Morena Reservoir quadrangle, the fault appears to offset a contact between marginal Granite Mountain tonalite (Kgm_1) and the biotite-hornblende phase of the unit (Kgm_2) in a right-lateral sense. Between these two offsets, the fault truncated the northern end of the central La Posta pluton and the hornblende-biotite phase of the Granite Mountain unit (Kgm_3) of the Long Potrero complex. Although much of its trace is covered by alluvium or poorly exposed in deeply weathered tonalite, the fault appears to have originated as a ductile fault that healed during cooling and solidification of the Granite Mountain and La Posta plutons. Based upon structural study, Rector (1994) concluded that the Hauser Canyon Fault was active during, and soon after, intrusion of the Long Potrero plutonic complex, and he suggested that the dominant movement was dip-slip with the southern block uplifted relative to the northern block. His suggestion is supported by the exposure of inner (deeper) zones of the complex in the block south of Hauser Canyon, indicating that it is more deeply eroded than the northern block. This late batholithic fault was apparently reactivated during Cenozoic deformation; several short brecciated zones are exposed in or near the bottom of the canyon.

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