UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE EL CAJON MOUNTAIN QUADRANGLE

SAN DIEGO COUNTY, CALIFORNIA

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

Geologic map of the El Cajon Mountain quadrangle, San Diego County, California

PURPOSE OF PROJECT

Published maps indicate that rocks of the Peninsular Ranges batholith in southern San Diego County (southern Santa Ana block) are relatively unfaulted, but topographic maps and imagery at all scales reveal numerous prominent lineaments that cross the region in many directions. The purpose of this mapping project is to evaluate the structural stability of the block, and in particular, to determine whether lineaments are related to faulting. Figure 1 shows the project area. The age, magnitude and sense of displacement of faults within the block and along its eastern margin (Elsinore fault zone) are being evaluated. The primary product of the project is a number of geologic maps at a scale of 1:24,000. Mapping of the bedrock geology of the batholith became an important part of the project because the geologic maps that were available when the study began were not detailed enough for determination of fault displacements. The El Cajon Mountain quadrangle is the tenth map of a series of maps that show the structure of the batholith, the distribution of the crystalline rocks, and post-batholithic faults. Previous maps in the series include the Cuyamaca Peak, Descanso, Agua Caliente Springs, Viejas Mountain, Monument Peak, Mount Laguna, Alpine, Tule Springs, and Sweeney Pass quadrangles (Hoggatt and Todd, 1977; Hoggatt, 1979; Todd, 1977-82).

INTRODUCTION

The El Cajon Mountain 7-1/2' quadrangle lies within the middle Cretaceous Peninsular Ranges batholith of southern California and Baja California (fig. 1). Roughly twelve plutonic units have been differentiated within the project area and informal names have been assigned to avoid confusion with earlier nomenclature. About half of the units were not recognized previously and published names for rocks in the study area included one or more of these unrecognized units. The name Cuyamaca Gabbro (Everhart, 1951) has been retained. Other bedrock units consist of metasedimentary and metavolcanic rocks of uncertain age which occur as screens in the batholith.

Most of the plutonic rocks in this part of the batholith have undergone significant synkinematic recrystallization. They are variably gneissic and their foliation consists chiefly of the planar orientation of recrystallized mineral grains and aggregates (fig. 2). Gneissic textures include augen gneiss and mylonite gneiss. Petrographic study reveals igneous textures modified by strain at temperatures high enough for recrystallization to occur, indicating that the plutonic rocks have undergone syn- and post-intrusive solid-state flowage at elevated temperatures.

Where noted by earlier workers, foliation was considered to be a primary igneous structure or protoclastic structure since, in general, foliaton (degree of strain and recrystallization) is strongest near the margins and in small plutons. The metamorphism of the wallrocks was thought to pre-date emplacement of the batholith in this area (Everhart, 1951). However, plutonic contacts and foliation commonly are parallel or co-planar with those of the metamorphosed wallrocks and together they form a complex penetrative regional fabric. Although commonly concordant with plutonic contacts, foliation locally crosses contacts and, therefore, appears to be in part younger than the intrusion of the igneous rocks. For example, in the case of dikes that have intruded plutons and wallrock screens discordantly, steeply dipping mineral foliation can be traced from the host rock into the dikes and back into host rock, crosscutting contacts at a high angle. These findings indicate that in this part of the batholith plutons were emplaced during regional metamorphism and deformation and that deformation and recrystallization continued after emplacement.

NATURE OF PLUTONIC CONTACTS

Although an overall mafic to felsic age sequence of intrusion of major plutonic units can be established, in detail this age sequence locally appears reversed, so that the older, more mafic pluton of a pair of plutons has a chilled margin against the younger pluton, sends dikes into the younger felsic pluton, and carries inclusions of it (fig. 3). These synplutonic contacts were deformed during the regional deformation, with the result that both normal dikes (younger pluton of an intrusive pair into older) and anomalous dikes (older pluton into younger) have been stretched, intricately folded, and pulled apart so that they resemble inclusions. Whether they originated as stoped inclusions or dismembered dikes, blocks of one pluton in the other are increasingly rounded and assimilated away from the contact between the two plutons. The resulting contact relations may be extremely ambiguous in any one place, but when many outcrops are examined, plutonic age relationships are in general consistent over the entire area. The prevalence of these anomalous contacts indicates that this region of the batholith remained mobile throughout emplacement of successive plutons. The presence of mutual fine-grained (chilled?) margins and quenched dikes suggests a continuing or recurring liquidity and flowage of magma, but rock textures and the relation between foliation and plutonic contacts imply solid-state flowage. Some combination of the two probably occurred. The field observation of overlapping intrusions fits well with chemical evidence of a number of coeval plutonic or magmatic suites (Todd and Shaw, unpublished data) and with the concept of a stationary western magmatic arc in this region from 120 to 105 m.y. ago (Silver and others, 1979). Preliminary K-Ar ages on recrystallized phenocrysts of biotite, hornblende and muscovite from plutonic rocks in the mapped area range from 70 to 110 m.y., suggesting that the Peninsular Ranges batholith in this region remained at metamorphic temperatures for a long period of time.

ROCK UNITS

The bedrock units are discussed below under the headings of four plutonic suites and a group of metamorphic rocks that occur as inclusions in, and between, plutons. The intrusive sequence is depicted in figure 4. Preliminary modal and normative data for the plutonic units is given in figure 5. The following discussion is based in part upon observations of rock units and contact relations in the adjacent quadrangles, which are shown in figure 1, but it is fully applicable to the El Cajon Mountain quadrangle. The bedrock units are overlain locally by unconsolidated Upper Cretaceous, Tertiary, and Quaternary deposits.

Metamorphic Rocks

Metasedimentary and metavolcanic rocks:--Metamorphic rocks in prebatholithic pendants and screens in southern San Diego County are dominated by two end-members, metasedimentary rocks in the eastern part of the study area, and metavolcanic in the western part. The western screens consist chiefly of amphibolite, which includes recognizable metagabbro and metabasalt in larger screens, interlayered with metamorphosed felsic tuffs, tuff breccias and flows; lesser intermediate volcanic rock, para-amphibolite and calc-silicate rock; and sparse metamorphosed clastic rocks. Locally in the El Cajon Mountain quadrangle, granitic pebble and cobble conglomerate; sillimanite-andalusite-muscovite-quartz-plagioclase-biotite semischist; and biotite-quartz schist occur in volcaniclastic wallrock inclusions. The eastern, predominantly metasedimentary assemblage includes fine-grained quartzofeldspathic semischistose rock; micaceous, feldspathic quartzite; andalusite-bearing pelitic schist; metamorphosed calcareous grit, pebble and small cobble conglomerate (in part tuff-breccia and/or reworked tuff-breccia); and interlayered with, and grading into, these rock types, significant amounts of western-type interlayered amphibolite and felsic metavolcanics. Thus, the screens appear to preserve remnants of a continental margin assemblage with a western predominantly volcanic component, grading eastward to fine-grained deep water turbidites with a predominantly continental source. The western rocks are similar to the Late Jurassic and Early Cretaceous(?) (Fife and others, 1967; Schoellhamer and others, 1982) Santiago Peak Volcanics of western San Diego County; all screens in the El Cajon Mountain quadrangle are tentatively assigned a Late Jurassic and Early Cretaceous(?) age for the purpose of this report.

The maximum metamorphic grade attained in screens in the region studied is upper amphibolite facies (high temperature-low pressure type) of regional metamorphism. Rocks in the western screens are commonly described as "low-grade" or greenschist facies rocks, but although grain size and degree of metamorphic differentiation generally increase eastward across the batholith, the high-grade mineral assemblages occur in western screens (e.g., sillimanite-muscovite in reworked felsic tuff, diopside-hornblende in amphibolites; plagioclase-epidote-quartz-diopside, and garnet-hornblende in calc-silicate rocks). Wherever they are located, larger screens tend to show better preservation and less deformation of primary structures as well as less metamorphic differentiation and/or incipient melting.

The boundary between predominantly metavolcanic and predominantly metasedimentary screen materials appears to lie about 5 to 10 km east of the El Cajon Mountain quadrangle. It coincides very closely with the first appearance of transitional I-S and S-type granitic plutons (Chappell and White, 1974); Todd and Shaw, 1979), as will be discussed below. The I- and S-type plutons and the included correspondingly igneous or sedimentary wallrocks, form distinctive hybrid associations along contacts between plutons and screens. Contacts between I-type tonalite and metamorphic screens in the El Cajon Mountain quadrangle are marked by compositionally and texturally heterogeneous 0.5 km-wide zones that consist of 1) granitic rock with variably assimilated but recognizable wallrock inclusions, 2) hybrid rocks of either igneous or metamorphic character, and 3) wallrock with granitic layers (probably concordant dikes). These three rock types are gradational. Most of the metamorphic component in these zones consists of calc-silicate minerals--epidote and garnet in discrete inclusions, hornblende and plagioclase in banded assimilated inclusions--reflecting the dominant metavolcanic character of the western screens. The thickness of layers within the migmatite, commonly greater than several cms, and the association of the migmatite with plutonic contacts indicate that they are injection migmatites. Local thin (several cm) leucosomes within the I-type migmatitic zones probably represent incipient melting of felsic volcanic rock. The migmatitic rock probably originated as intrusion breccia between tonalite plutons and wallrock which remained at metamorphic temperatures during regional deformation.

The typical eastern-type hybrid rock association formed where transitional I-S and S-type plutons intruded dominantly sedimentary wallrocks and it is distinctively different. In a central, transitional zone, east of the El Cajon Mountain quadrangle, I- and S-type plutons along with their characteristic hybrid rocks are complexly interlayered.

Where prebatholithic screens contain abundant granitic gneiss layers, a schematic pattern of lensoid bodies has been used on the geologic map. In most cases in the El Cajon Mountain quadrangle, the granitic gneiss consists of recognizable dikes of the granite of Corte Modera and the tonalite of Japatul Valley that can be traced into nearby plutons of these units. Where the granitic material is intimately intercalated with wallrock its origin is not clear and therefore it has been called simply "granitic gneiss."

Plutonic Rocks

Gabbroic rocks:

Cuyamaca Gabbro:--The name Cuyamaca Gabbro was applied by Everhart (1951) to the large mafic pluton in the Cuyamaca Mountains. He assumed that all of the large mafic plutons (Guatay Mountain, Viejas Mountain, Poser Mountain) in south-central San Diego County are coeval, and data of the present study support this interpretation. These bodies, consisting of peridotite, olivine gabbro, hornblende gabbro, and norite were considered by Everhart to post-date the granitic plutons in the northern part of the Cuyamaca Peak 15' quadrangle, but in this study gabbro has been found to overlap the granitic units in relative age. Because the granitic intrusive bodies typically form sheets in gabbro, it is difficult to determine which rock is older from map relations in any one area.

One reason for ambiguity over the relative age of the Cuyamaca Gabbro is that commonly the unit has broad, fine-grained and porphyritic margins next to granitic plutons which appear to have intruded it. Thin sections of gabbro from these margins show relict chilled igneous textures modified by recrystallization. These rocks are commonly associated with zones of intrusion breccia between gabbro and granitic plutons consisting of variably rounded blocks of fine-grained and porphyritic gabbro in a matrix of chilled, contaminated granitic rock. Orbicular gabbro occurs locally in these zones. The intrusion breccia zones are strongly deformed parallel to the regional foliation and grade into highly contaminated margins of granitic plutons which contain abundant, large, fine-grained gabbro inclusions. Inclusions of metamorphic wallrock occur in some intrusion breccia zones between gabbro and granitic plutons, but there are many places where no wallrock appears to be involved and where the grain size of gabbro decreases systematically as contacts with granitic plutons are approached.

Some contacts between granitic plutons and the Cuyamaca Gabbro are so complexly interfingering and diffuse that they cannot be mapped accurately at the scale of this series of maps. The Tule Springs quadrangle, which lies immediately to the east of the El Cajon Mountain quadrangle, contains an excellent example of a concentrically sheeted gabbro-granitic rock complex in which contacts between granitic and mafic rock are extremely complex and diffuse. The large-scale mapping that would be necessary to accurately portray this complex would result in literally hundreds of small plutonic lenses, sheets and inclusions.

Fine-grained gabbro dikes in some cases emanating from gabbroic plutons cut the intrusion breccia zones surrounding most of the large gabbroic bodies in the project area. Such dikes also cut the youngest granitic units. This suggests that parts of the gabbroic plutons remained liquid after younger, granitic plutons had solidified, or, as suggested above, that gabbroic and granitic magmas overlapped in age. In many places, fine-grained gabbro bodies appear continuous with, or cannot be distinguished in the field from, the fine-grained and porphyritic mafic to intermediate dikes which cut all units throughout the study area but are generally too small to be shown at the map scale. All of these dikes may in fact be late differentiates of the parent magma of the Cuyamaca Gabbro.

The Cuyamaca Gabbro appears to be deformed and recrystallized. Virtually all of the gabbro observed is strongly foliated and in most cases apparent primary compositional layering is parallel or nearly parallel to the foliation of recrystallized mineral aggregates. Locally, a second, crosscutting metamorphic foliation has been superposed on this fabric. In marginal parts of the gabbro and in many small bodies, foliation is concordant with regional foliation. It is more complex in the interior parts of large bodies where it may parallel regional foliation, but generally shows discordant patterns, possibly because of the presence of more than one foliation. Foliation within the gabbro appears to have formed in part by solid-state flowage.

In the El Cajon Mountain quadrangle, the Cuyamaca Gabbro crops out in small (0.5 to 3 km-long), lenticular plutons of hornblende gabbro which typically grade into amphibolite of the closely associated prebatholithic screens. These plutons and sheets are on strike with, and can be traced discontinuously eastward into, larger plutons of Cuyamaca Gabbro. The small western plutons are chemically similar to small satellitic plutons and marginal hornblende gabbro of the large eastern plutons and complexes. The gradation into metabasalt suggests that the gabbroic magma chambers vented to the surface, i.e., that at least some prebatholithic volcanoes were part of the magmatic arc that produced the older, western plutons of the batholith.

Granitic rocks:

Quartz norite, quartz diorite and tonalite suite

Quartz norite and tonalite of Las Bancas:--The dark, inclusion-free rock called Green Valley Tonalite by F. S. Miller (1937) is equivalent to the quartz norite and tonalite of Las Bancas (Todd and Shaw, 1979). The Las Bancas unit consists of K-feldspar-bearing biotite-pyroxene tonalite and quartz norite with 57 to 63 percent SiO_2 and plagioclase of $An_{>50}$.

The quartz norite and tonalite of Las Bancas is a fine- to medium-grained, weakly gneissic rock, approximately equigranular, with lenticular, recrystallized mafic aggregates. The rock is dark gray on fresh surfaces, weathers to a bluish or buff-gray color, and typically forms prominent blocky outcrops. The rock is homogeneous and virtually inclusion-free. Typically it carries 1 cm poikilitic biotite and/or biotitized hornblende grains. The rock of the Las Bancas unit has 15 to 20 percent quartz, up to 10 percent K-feldspar, relict zoned phenocrysts of andesine to labradorite, and a color index ranging from 25 to 30 percent. Next to gabbro plutons, the rock is more mafic and contains less than 10 percent quartz and plagioclase as calcic as bytownite. Thus, some of the Las Bancas-type rock is quartz gabbro according to the classification of Streckeisen (1973), or quartz norite because the ratio of opx : cpx is approximately 3:1, but these rocks are petrographically similar to the tonalite and there is a complete gradation between quartz norite and tonalite. Most samples contain hypersthene, biotite, and lesser hornblende, the latter occurring as sparse, narrow rims on corroded orthopyroxene cores with partial jackets of clinopyroxene. Both pyroxene and hornblende are poikilitically enclosed by biotite. The igneous reaction sequence of the mafic assemblage was thus opx → cpx → olive green hornblende → yellowish-brown biotite. These igneous reaction textures have been modified by solid-state recrystallization.

Large plutons of Las Bancas-type rock are commonly surrounded by a marginal phase of coarser-grained, less mafic, more foliated tonalite. The marginal facies has large lenticular mafic grains and aggregates, and contains abundent hornblende and biotite; locally, scattered larger grains of biotite or hornblende give it a near-porphyritic texture. Rusty-weathering spots are common. Large (~30 cm) rounded blocks of Las Bancas-type rock occur as sparse inclusions in the marginal facies. This marginal phase appears to be a zone where quartz norite has reacted with screens of prebatholithic rock. The tonalite of the marginal phase is chemically indistinguishable from the tonalite of Japatul Valley.

In the El Cajon Mountain quadrangle, an elongate, north-trending pluton of quartz norite lies east of El Cajon Mountain. This pluton has a marginal zone of hornblende-biotite tonalite against a septum of prebatholithic rocks that separates the quartz norite pluton from the large leucogranite pluton that underlies the high peaks of El Cajon Mountain (granite of Corte Madera). The Las Bancas unit and the granite of Corte Madera are not in contact in the El Cajon Mountain quadrangle, but elsewhere in the project area, plutons of the Corte Madera unit appear to dike adjacent plutons of quartz norite.

The eastern margin of the north-trending quartz norite pluton has a gradational contact with the tonalite of Alpine over a zone of less than 1 km in which the two rock types are interlayered. Near this contact, the quartz norite contains isolated narrow zones of rock with abundant mafic inclusions. Locally, swarms of inclusions of prebatholithic rock lie along, or near, the contact. Hypabyssal dikes of pyroxene granodiorite and tonalite that are very similar petrographically to the rocks of the Las Bancas unit cut the tonalite of Alpine. Distinctively different chemical trends for these two units suggest that this gradational relation represents a zone of mixing between two coeval magmas that had different source materials.

The small lensoid pluton of quartz norite of Las Bancas in the southwest corner of the El Cajon Mountain quadrangle has a fine-grained (chilled?) margin against gabbro. The Las Bancas unit is not in contact with the granite of Chiquito Peak (or its probable equivalent, the granite of Barona Valley), but in the eastern part of the county, the granite of Chiquito Peak intrudes quartz norite and is backveined by it.

Tonalite and granodiorite suite

Tonalite of Alpine:--Tonalite that typically carries abundant mafic inclusions (Bonsall Tonalite of C. S. Hurlbut, Jr., 1935) has compositional and textural variations that have enabled us to map two gradational units--the tonalite of Alpine, a mafic variety, and the tonalite of Japatul Valley, a more leucocratic variety. The tonalite named for the town of Alpine has abundant mafic inclusions and is itself quite mafic, although color index and inclusion content are variable. The tonalite is medium- to coarse-grained, with recrystallized aggregates of hornblende and biotite, and it bears elongate, flattened, black-weathering, fine-grained mafic inclusions alined parallel to foliation. Locally the rock carries 1-2 cm poikilitic hornblende or biotite grains. In addition to discrete mafic inclusions, 2-3 cm ragged clots of mafic grains are common; apparently they are relicts of assimilated inclusions. Subhedral plagioclase (An_{+50}) is common, and locally hornblende is subhedral too. Corroded grains of both ortho- and clinopyroxene are present. In general, mineral grains and aggregates appear recrystallized, and the rock has a strong gneissic texture. It grades into, and is chemically and isotopically similar to, the tonalite of Japatul Valley.

Tonalite of Japatul Valley:--The tonalite of Japatul Valley grades into the tonalite of Alpine but is locally separated from it by screens of gabbro and wallrock. The tonalite of Japatul Valley is lighter in color and less mafic than the tonalite of Alpine, and its abundant mafic inclusions are typically weathered out in relief. They may be large and irregular in shape, or streamlined parallel to foliation. Many inclusions are fine-grained and some of these are peppered with subhedral plagioclase grains; a few coarser-grained inclusions are gabbroic. Large inclusions of Las Bancas-type tonalite occur locally. Characteristic of the rock are discrete subhedral plagioclase (An_{42-48}) and hornblende grains, although recrystallized mafic aggregates also occur. The unit contains no pyroxene. The tonalite is medium- to coarse-grained, distinctly equigranular, and the subhedral grains give it a more igneous-appearing texture than that of the Las Bancas or Alpine varieties. However, the rock is locally strongly foliated and the subhedral grains are generally alined parallel to the regional foliation.

The Japatul tonalite grades into, and locally appears to be intruded by, a more leucocratic rock texturally identical to the tonalite but ranging to granodiorite and granite in composition. This leucocratic rock is very similar to the granite of Chiquito Peak, and may represent places where Chiquito Peak magma graded into, and intruded, Japatul Valley magma. The leucocratic variety is commonly found in association with wallrock screens and injection migmatite zones. The distribution of these rocks is shown only grossly on the map for they are interlayered complexly on both large and small scales. Dikes of the granite of Corte Madera commonly have intruded along and near these zones. Typically the Corte Madera dikes are crosscutting, but they may also be complexly interlayered with tonalite, granodiorite, and wallrocks.

This field association suggested a genetic relationship between tonalite of Japatul Valley and more leucocratic magmas (i. e., granite of Chiquito Peak and granite of Corte Madera) and it was thought that tonalite, granodiorite and granite formed a differentiated sequence. However, chemical data indicate that the leucocratic granodiorite and granite of the Chiquito Peak, Barona Valley, and Corte Madera plutonic units form a distinct group that is separate from the tonalites of Alpine and Japatul Valley and that probably formed by partial melting of different source materials.

Leucocratic granite and granodiorite suite

Granite of Chiquito Peak:--The granite of Chiquito Peak is a medium-grained, strongly foliated, light-weathering rock that locally grades into granodiorite and has color index ranging from 5 to 12. The plagioclase feldspar is oligoclase with relict euhedral zoning and the mafic minerals are chiefly dark greenish-brown biotite that appears to be derived from reaction of dark green to brown hornblende with magma. Both biotite and hornblende have recrystallized but igneous relicts of both are present. Prominent accessory minerals are sphene and allanite.

The granite of Chiquito Peak typically intruded intermediate plutons in complexes of dikes, chilled against them, and locally shows a high degree of contamination through assimilation of stoped wallrock inclusions. The contamination and post-intrusive deformation have given rise to complex hybrid zones between the granite and neighboring rocks. These zones include intimate mixtures of granite, granodiorite, and tonalite.

A textural variant of the granite of Chiquito Peak is a fine- to medium-grained, sub-porphyritic (1 cm relict euhedral white K-feldspar phenocrysts) rock locally contaminated by abundant mafic inclusions. This rock appears to be a chilled facies of average granite and occurs near wallrock screens.

A granite with color index ranging from 2 to 7 percent that is locally devoid of hornblende and contains slightly more quartz than the average rock grades into and intrudes the average granite. The leucogranite with abundant 1 to 2 cm relict euhedral K-feldspar grains which underlies the Stonewall Peak area in the Cuyamaca Peak quadrangle is an example. The thin-sheeted style of intrusion, extensive stoping and reactions with wallrocks, finer grain size and mafic mineral suite help to distinguish this unit from other granites. The granite of Chiquito Peak grades into the granite of Corte Madera in several places in the project area.

Granite of Barona Valley:--The granite of Barona Valley is a weakly foliated biotite granite (adamellite according to the pre-I.U.G.S. classification of Williams, Turner, and Gilbert, 1954) with abundant lenticular grey quartz grains ranging from 1 to 1.5 cm in length. Although weakly foliated, in thin section the granite shows grain textures that indicate solid-state strain and recystallization. Relations on the northern side of Barona Valley indicate that the granite interfingers with (grades into and/or intrudes) a leucocratic phase of the tonalite of Japatul Valley (granodiorite).

The granite of Barona Valley resembles the granite of Chiquito Peak, a unit that includes granodiorite and granite and is exposed in the eastern part of the quadrangle. In the eastern part of the study area, the Chiquito Peak unit grades into, and intrudes, granodiorite of the Japatul Valley tonalite unit. Much of the tonalite of Japatul Valley that is exposed in the northwestern part of the El Cajon Mountain quadrangle is granodiorite, and some could be mapped as granite of Chiquito Peak, except that the complex gradational and interfingering relations between tonalite and granodiorite cannot be mapped accurately at this scale. Thus, the pluton that underlies Barona Valley has contact relations with the tonalite of Japatul Valley that are identical to those that exist between the tonalite unit and the granite of Chiquito Peak elsewhere in the project area.

The chief difference between the granites of Barona Valley and Chiquito Peak is that in the former, plagioclase tends to occur in large (modified) subhedral grains and K-feldspar in interstitial grains, while in eastern plutons of the latter, plagioclase is more commonly interstitial and K-feldspar phenocrystic. The two rocks appear to be similar except that chemically the eastern plutons of granite of Chiquito Peak are slightly more potassic than samples of the Barona Valley pluton.

Granite of Corte Madera:--The granite of Corte Madera is coarse-grained and has elongate, 2 to 3 cm, gray quartz lenticles, which probably are relicts of large phenocrysts. The unit occurs typically as steeply-dipping, sheet-like dikes in older plutons and as large, pod-shaped plutons. The rock is white-weathering and underlies highlands. The granite has a color index less than 5 percent; plutons consist of strongly foliated leucogranite and leucogranodiorite. Mafic minerals are dark yellowish-brown biotite and small skeletal relicts of dark bluish-green hornblende. Many samples contain no hornblende. The plagioclase feldspar is oligoclase (An 11 and 12 by electron microprobe) occurring as relict, euhedrally zoned grains. Prominent accessory minerals are sphene, allanite, and epidote. The unit locally has chilled margins against, and occurs as dikes in, all units.

An important relation between granite of Corte Madera and felsic volcanic rocks of prebatholithic screens is exposed in the El Cajon Mountain quadrangle. Felsic volcanics (not differentiated on the geologic map from the associated intermediate and mafic volcanic rocks) occur as a partial shell around, and as concordant sheeted inclusions in, the complex El Cajon Mountain pluton, whose fringing dikes interdigitate with bodies of metavolcanic rocks. Commonly, it is very difficult to distinguish between the indistinctly, thinly layered, locally porphyritic, border facies of the pluton (shown by stipple pattern) and the metamorphosed, partly melted felsic volcanic rocks. Locally, the two appear to be gradational. This relation was first noticed in the pluton composed of granite of Corte Madera in the northwest part of the Alpine quadrangle (fig. 1). This gradation may indicate that the felsic plutons of the western part of the batholith vented to the surface. It is similar to the local gradational relation between small bodies of fine-grained porphyritic gabbro and screens of mafic volcanic rocks, now amphibolite. The marginal and interior (infolded?) inclusions of metamorphosed felsic volcanic rock in the El Cajon Mountain pluton locally contain intermediate and mafic volcanic rock, which suggests that at least some of these inclusions are not coeval volcanic rocks, but are foundered or infolded volcanic strata, or subvolcanic tuffisites. The apparent gradational relation between marginal granite of Corte Madera and felsic tuffs and tuff-breccias may represent places where magma intruded, included, and partly melted felsic wallrock. However, the extremely intimate and complex relations between the two, and the peculiar layered aspect of the marginal granite, point to the possibility of a coeval relation between the granitic and volcanic magmas. Preliminary petrographic studies suggest that the felsic volcanic inclusions are richer in K-feldspar (microcline) than is the pluton. The pluton, its fringing dikes, and the metavolcanic screens resemble a deformed ring complex.

The El Cajon Mountain pluton appears to have intruded and pushed apart large, tight isoclinal folds in prebatholithic rocks, as in the west-central part of the map, and also to have diapirically intruded and expanded a steeply layered, generally north-trending sequence of plutons ranging in composition from quartz norite to granite. Although mapping of the granite of Corta Madera pluton and its included wallrock sheets is not sufficiently detailed to prove this, internal structural relations locally suggest that some folding of the granite and wallrock inclusions took place during (?) and after intrusion. The overall shape of the pluton suggests that it underwent syn- or post-intrusive ductile deformation.

Like the granite of Chiquito Peak, plutons of the granite of Corte Madera differ slightly across the batholith in their K-feldspar to plagioclase feldspar ratio. In the western plutons, K-feldspar is interstitial to plagioclase phenocrysts, whereas in the eastern ones, the opposite tends to be true. Overall feldspar ratios are similar from west to east, but K_2O is slightly higher in eastern plutons.

Pegmatite, alaskite and aplite:--Leucocratic dikes of pegmatite, alaskite and aplite occur in all crystalline units. In some areas they can be traced into a parent pluton, in the El Cajon Mountain quadrangle, chiefly the granite of Corte Madera. Where no association with larger bodies was established, and the dikes are large enough to show at 1:24,000 scale, they have been mapped separately. These dikes share the metamorphic fabric of the other plutonic rocks.

Sedimentary Deposits

Lusardi Formation:--Remnants of indistinctly bedded, poorly sorted, moderately rounded, poorly to non-indurated bouldery debris flows occur beneath conglomerate of the Eocene Poway Group on a broad, uplifted, dissected erosion surface developed on tonalite. These deposits represent a basal conglomerate consisting chiefly of resistant clasts of granite of Corte Madera and gabbro. They are strikingly different from the overlying Eocene conglomerate and are correlated with the Upper Cretaceous Lusardi Formation (Kennedy and Peterson, 1975) in the eastern San Diego metropolitan area. Most gabbro clasts are cobbles or small boulders, but the granite clasts include boulders as much as several meters across, giving the deposits a rubbly white-spotted appearance from afar. The deposits are no more than a few meters thick, suggesting erosion of the conglomerate prior to deposition of the Poway gravels.

Poway Group:--Hill-capping, red-brown weathering remnants of a once extensive blanket of river gravels occur in the northwestern part of the quadrangle where they overlie the Lusardi Formation. They are correlated with the Stadium Conglomerate of the Eocene Poway Group (Kennedy and Peterson, 1975). The conglomerate of the Poway Group is well-sorted, distinctly bedded, moderately indurated, and its clasts are very well-rounded. Clast size ranges from large cobbles to small boulders, most less than one meter across, and on the average smaller than those of the Lusardi Formation. The clast population is dominated by a lithology which has not been found anywhere within the Peninsular Ranges batholith: light-weathering pink and purplish-red, porphyritic, felsic volcanic rock. The lower part locally consists of buff-gray sand and silt which is covered by a lag gravel of cobbles.

Older alluvium: Gravel, sand, and silt deposits occur as patchy remnants along the sides of valleys. A preliminary C^{14} age of 920 ± 60 years B.P. has been obtained on charcoal from one of the lowest exposed beds in the older alluvium in Pine Valley in the Descanso quadrangle (Stephen W. Robinson, U. S. Geological Survey, Menlo Park). Considerable erosion of older Quaternary alluvium has occurred throughout the mapped area in historic times, as suggested by the headward cutting of gullies 1 to 2 meters deep along jeep trails in several places. Roads (even one paved road) which show up on aerial photographs taken within the past 25 years have been entrenched to this depth by gullies. During the winter rainy season of 1979-80, asphalt and dirt secondary roads were completely washed out by 3 to 4 m gullies. Since bedrock is exposed in most of the modern streambeds, the total thickness of this alluvium is probably less than the depth of the stream channels, about 15 m. Finer-grained sediments in broad upland meadows probably formed in situ by chemical weathering.

Younger alluvium:--Younger alluvium consists of gravel, sand, silt, and clay in modern stream valleys, the latter incised into older alluvium that once covered broad valley floors.

Quaternary colluvium:--Colluvium consists of unsorted to poorly sorted deposits of gravel, sand and silt that occur at or near the base of steep slopes. Locally, these materials grade into older and younger alluvium.

STRUCTURE OF BATHOLITHIC ROCKS

The plutonic units occur as steeply dipping sheets and lenticular bodies that are separated locally by screens of metamorphic rock. The sheets, lenticular bodies, and screens range from a few meters to several kilometers in thickness and the larger ones continue for tens of kilometers along strike. Small plutons tend to be sheet-like, whereas larger ones are lenticular. In plan view, the preferred orientation of the long dimensions of plutonic sheets and lenticular plutons, of wallrock screens, and of foliation within plutonic and metamorphic rocks, imparts a structural grain to this part of the batholith. Only a small part of this structural grain can be see in any one 7-1/2' quadrangle. Successive intrusions parallel to this structural grain have resulted in stratiform complexes of three to four units.

The structural grain varies over the project area. In the Cuyamaca Peak, Descanso, Monument Peak and Mount Laguna quadrangles, it is predominantly north-northwestward, and the regional dip is eastward (fig. 6). It swings to northwest and west strikes in the western part of the study area with the regional dip strongly to the north and northeast (Viejas Mountain, Tule Springs, and Alpine quadrangles). The swing to northerly trends seen in the northern part of the Alpine quadrangle continues into the El Cajon Mountain quadrangle. The structural pattern suggests the existence of a large-scale flexure or flexures in batholithic contacts and foliation having a steep northeast plunge (fig. 6).

Locally, plutonic contacts and foliation delineate smaller (10-15 km^2) fold-like forms about steeply plunging axes. Many of these folds include metamorphic screens which are folded concordantly with plutonic contacts and foliation. The fact that the screens are folded along with plutonic contacts and foliation suggests that these fold-like structures are tectonic in origin. Yet, the structural patterns in the western part of the batholith suggest a pushing-apart of screens and plutons by intruding magma and/or metamorphically-flowing solid rock, and the growth of cells or pods of granite, e.g., in the east-central part of the Viejas Mountain quadrangle. These cells or pods may occur in the hinge areas of the folded screens which probably were preferred, low-pressure sites for emplacement of magma (see especially El Cajon Mountain quadrangle). Magma also pried apart screens parallel to layering. If wallrock screens and zones of inclusions are traced throughout the area, they appear to be parts of once-continuous bodies, which suggests that intrusion has been an important agent of deformation. The local impingement of these folds upon one another indicates a condition of unsteady flow rather than systematic tectonic folding. The above relations seem to be compatible with syntectonic intrusion.

It was first noticed in the Mount Laguna quadrangle that outcrops of quartz norite of Las Bancas commonly display two foliations at large angles to one another, both of which appear to be recrystallized mineral foliations. Locally in this quadrangle an east-trending foliation is reoriented by a north-trending foliation, and the latter is associated with black mylonitic rock (grading to gneissic tonalite) and parallel slabby jointing. Thus, the north-trending foliation appears to be a later deformation structure. This double foliation has since been seen more widely in tonalite, gabbro and metamorphic screens. In outcrops of gabbro, one mineral foliation typically strikes parallel to compositional layering but has a steeper dip, nearly vertical, than does this layering. The second typically crosses the first at a high angle, nearly ninety degrees, and has a steep dip.

In the El Cajon Mountain quadrangle and the area immediately to the south, scattered double foliations in quartz norite and tonalite of Las Bancas and tonalite of Alpine may mark the overprinting of a ductile recrystallization fabric related to the intrusion and growth of the diapiric El Cajon Mountain pluton (granite of Corte Madera) on an early north-trending fabric.

FAULTS OF THE EL CAJON MOUNTAIN QUADRANGLE

San Diego River fault zone

The most significant fault zone in the El Cajon Mountain quadrangle crops out in, and along, the San Diego River Valley (fig. 7). Because most of the valley floor is either under water (El Capitan Reservoir) or covered by alluvium, faults that underlie the valley are poorly exposed. The northeast-trending San Diego River Valley is part of a striking 30-km long lineament in southern San Diego County which Merifield and Lamar (1976) consider to be a fault zone with right-lateral separation. The southern extension of the lineament in Chocolate Canyon, Galloway Valley, and northern Harbison Canyon (Alpine quadrangle, Todd, 1980) is the site of short, parallel, northeast-striking faults which do not offset batholithic contacts. The central reach of the San Diego River canyon crosses the northwest corner of the Tule Springs quadrangle. Here, and in the Santa Ysabel quadrangle immediately to the north, west-northwest-striking contacts appear to be offset right-laterally by 300 m in one place and 450 m in a second. There are a series of short, parallel northeast-trending lineaments in the vicinity of the canyon in this area; most lie on the northwest side of the river (Ramona and El Cajon Mountain quadrangles), and at least some of these are faults. A major fault is exposed in the valley floor in the Tule Springs quadrangle which adjoins the El Cajon Mountain quadrangle on the east. Contacts in the east-central part of the El Cajon Mountain quadrangle strike across the canyon in a northwest direction. A small offset (600 to 1,050 m) is possible, but not proven, given the sinuosity of most of the plutonic contacts in the area. Many swarms of small faults (crush zone 5 to 10 cm) and some larger faults (crush zone up to 1 m) are exposed in the roadcut of an abandoned waterway which follows the eastern shore of the reservoir, and locally along the western shore (1 crush zone 5 to 6 m) (Table 1). The abundance of these small faults suggests the presence of larger ones in the axis of the canyon. Lineaments that trend parallel to the canyon occur in both walls.

Although some reaches of the canyon are remarkably linear and coincident with the northeast lineament, the river makes many bends away from this trend. Thus, the canyon is not determined by a single master fault over its entire length. However, it is likely that faults of magnitude similar to those described above underlie parts of the canyon and that one or more such faults is responsible for the apparent right-lateral offset. Small-scale sharp flexures in batholithic contacts occur elsewhere in the project area where there is no evidence of faulting. Final interpretation of the San Diego River Valley lineament awaits detailed mapping over its full length. The number of faults and joints and closeness of fracturing increase markedly as the canyon is approached by the few truck trails in the area which provide roadcuts into the deeply weathered bedrock. This indicates that the main canyon is fault-controlled.

Faults in the western part of Conejos Creek and El Capitan Dam area

The San Diego River makes an abrupt bend to the west in the southeastern corner of the El Cajon Mountain quadrangle. The presence of numerous small, steep northeast-trending faults and brittle shear zones (Table 1) in the walls of El Capitan Reservoir in this east-west stretch, and the apparent right-lateral offset of contacts in Conejos Creek suggest that a larger fault (or faults) underlies this east-west section of the San Diego River. Two contacts between quartz norite of Las Bancas and tonalite of Alpine that cross the river in the vicinity of the dam do not appear to have been deflected. However, these are gradational contacts and the accuracy of their location is comparable to the magnitude of the apparent offset of the contacts in Conejos Creek, i.e., 250 m. The San Diego River lineament, defined in this area by the river's linear north-trending canyon, may itself be offset in a right-lateral sense. The case is complicated by the fact that the contacts in the extreme southeast corner of the quadrangle appear to have undergone ductile bending, probably at a time when plutons had crystallized but were still near intrusion temperatures, which may account for the right-lateral displacement. Subsequent development of two sets of brittle faults oriented at about 90 degrees to one another, perhaps related to uplift and unloading of the batholith, may simply have been controlled by older zones of weakness (flexures and lithologic contacts). In any event, the exposed faults appear to have formed at relatively shallow depths (1-3 km?) since they are commonly marked by products of low temperature hydrothermal alteration (chlorite, epidote, sericite, K-feldspar, clays) and were subsequently exposed by erosion. Some faults are marked by loose earthy gouge, suggesting surficial reactivation. There is, however, no definitive evidence for displacement of Quaternary sedimentary deposits in this area.

Faults lying north of El Monte Road

Contacts in the southwest corner of the El Cajon Mountain quadrangle swing from north-northeast to east-west trends as they cross the mountain slope north of El Monte Road, which follows the San Diego River west of El Capitan Dam (fig. 7). A number of prominent east-west lineaments cross this brushy slope and several small faults were observed (Table 1).

Indian Head-San Vicente Mountain lineament

In the north-central part of the El Cajon Mountain quadrangle, a prominent north-trending lineament that consists of two parallel segments borders two peaks underlain by granite of Corta Madera on their eastern sides. The lineament is marked on the ground by aligned springs and by one suspect occurrence of breccia(?). Preliminary mapping indicates that granite-wallrock contacts are not offset by this lineament, suggesting that this feature is a prominent joint. However, because the marginal facies of the pluton composed of the granite of Corte Madera and the interlayered metamorphosed felsic volcanic rocks are very similar in appearance, more detailed mapping might reveal very small displacements of these contacts.

Age of Faulting

The age of the faults in the mountains east of San Diego is poorly constrained. In the San Diego River zone, middle Cretaceous contacts appear to have been offset in a right-lateral direction. Late Cretaceous and early Tertiary deposits (Lusardi Formation and Poway Group) occur only on the northwest side of this fault zone and therefore cannot be used as markers. The Late Cretaceous-Early Tertiary erosion surface lies at the same elevation on either side of the canyon of the San Diego River; if it has been affected by post-erosion movement, such movement is not discernible. The fact that the major zones of faulting are exposed in canyons eroded approximately 300 m below the erosion surface suggests that the faults were present prior to broad late Tertiary and Quaternary(?) uplift and down-cutting of the San Diego River. Furthermore, in the Alpine quadrangle just south of the El Cajon Mountain quadrangle, gouge zones associated with leucocratic dikes in tonalite are locally crosscut by younger leucocratic dikes (Todd, 1980). There is no evidence for offset of the Quaternary gravels which occur chiefly in the bottom of the canyon in the El Cajon Mountain and Tule Springs quadrangles. Thus, the age of the faulting is post-middle Cretaceous and pre-Quaternary.

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REFERENCES CITED

Chappell, B. W., and White, A. J. R., 1974, Two contrasting granite types: Pacific Geology, v. 8, p. 172-174.

Everhart, D. L., 1951, Geology of the Cuyamaca Peak quadrangle, San Diego County, California: California Division of Mines Bulletin 159, p. 51-115.

Fife, D. L., Minch, J. A., and Crampton, P. J., 1967, Late Jurassic age of the Santiago Peak Volcanics, California: Geol. Soc. America Bull., v. 78, p. 299-304.

Hoggatt, W. C., 1979, Geologic map of the Sweeney Pass quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 79-754.

Hoggatt, W. C., and Todd, V. R., 1977, Geologic map of the Descanso quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 77-406.

Hurlbut, C. S., Jr., 1935, Dark inclusions in a tonalite of southern California: American Mineralogist, v. 20, p. 609-630.

Jahns, R. H., 1954, Geology of the Peninsular Ranges province, southern California and Baja California, in Geology of Southern California: California Division of Mines Bulletin 170, Sept. 1954, p. 29-52.

Kennedy, M. P., and Peterson, G. L., 1975, Geology of the eastern San Diego metropolitan area, California: California Division of Mines and Geology Bulletin 200, p. 43-56.

Merifield, P. M., and Lamar, D. L., 1976, Fault tectonics and earthquake hazards in parts of southern California: Technical Report 76-1, NASA Lyndon B. Johnson Space Center, Houston, Texas.

Miller, F. S., 1937, Petrology of the San Marcos gabbro, southern California: Geological Society of America Bulletin, v. 48, p. 1397-1426.

Schoellhamer, J. E., Vedder, J. G., Yerkes, R. F., and Kinney, D. M., 1982, Geology of the northern Santa Ana Mountains: U. S. Geological Survey Professional Paper 420-D, 109 p.

Silver, L. T., Taylor, H. P., Jr., and Chappell, B., 1979, Some petrological, geochemical and geochronological observations of the Peninsular Ranges batholith near the International Border of the U.S.A. and Mexico, in Abbott, P. L., and Todd, V. R., eds., Mesozoic Crystalline Rocks: Department of Geological Sciences, San Diego State University, p. 83-110.

Streckeisen, A. L., 1973, Plutonic rocks, classification and nomenclature recommended by the I.U.G.S. Subcommission on the Systematics of Igneous Rocks: Geotimes, v. 18, no. 10, p. 26-30.

Todd, V. R., 1977, Geologic Map of the Cuyamaca Peak quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 77-405.

_____, 1978a, Geologic map of the Viejas Mountain quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 78-113.

_____, 1978b, Geologic map of the Monument Peak quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 78-697.

_____, 1979, Geologic map of the Mount Laguna quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 79-862.

_____, 1980, Geologic map of the Alpine quadrangle, San Diego County, California: U. S. Geological Survey Open-File Report 80-82.

-----, 1982, Geologic map of the Tule Springs quadrangle, San Diego County, California: U.S. Geological Survey Open-File Report 82-221.

Todd, V. R., and Shaw, S. E., 1979, Structural, metamorphic and intrusive framework of the Peninsular Ranges batholith in southern San Diego County, California, in Abbott, P. L., and Todd, V. R., eds., Mesozoic Crystalline Rocks: Department of Geological Sciences, San Diego State University, p. 177-231.

Williams, H., Turner, F. J., and Gilbert, C. M., 1954, Petrography: an introduction to the study of rocks in thin sections: W. H. Freeman and Company, San Francisco, California, 406 p.

Table 1. Some measured faults of the El Cajon Mountain quadrangle*:

San Diego River fault zone

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
____________	0.5 m calichified gouge	Ka	unknown
N27E 90; average for group of small faults		K1b	"
N1W SW69; zone of small faults several m across within wider envelope of sheared rock		K1b	"
N4W 90; zone of small faults, several m wide		Ka	"
N30E 65SE; 6 small faults, largest 0.25 m across	gouge with hematite and clays	Ka	"
hairline fractures in grussy tonalite		Ka	caliche layers in gruss offset vertically?
Group of ENE-striking small faults		Ka	unknown
N41E, strike of fault zone 0.6 to 0.9 m wide, one of 6 to 8 complex faults; largest zone dips SE81.		Ka	"
Broad zone of brittle shear and hydrothermal alteration; one undulatory steep fault is one m wide, strikes N10E; surrounding tonalite is		Ka	"

colored pink, gray-green and white, contains abundant discrete shear planes.			
Family of shear planes N8E 90		"	"
Five to 6-m brittle shear zone; locally, shears follow mafic or pegmatite-quartz dikes.		"	"
N2E SE 77 broad (6m) zone of closely spaced small faults; one fault is 0.3 to 1 m across	Punky white gouge, green (chlorite) and pink (hematite) alteration rind.	Ka	"
N-S; small steep fault.			
N30E 90; faulted thin (< 0.3 m) leucocratic dike; 0.7 m fault plus thinner adjacent faults	Punky cream-colored grunge, reddened (hydrothermal alteration).	Ka	"

<u>Conejos Creek and El Capitan Dam area</u>

N40-65E ~90; small fault		Ka	unknown
N43E 87NW, N15E 75NW; two of 4+ small faults, sited along combined mafic-leucocratic dike.		Ka	"
N42E 35SE, 0.3-0.6 m fault; plus additional, similar faults of variable orientations, spaced 4-5 m apart (or less).	Hard gouge; pink, green, brown, and white alteration colors.	Ka	"
N36E 88NW, 0.2-0.5 m fault; N50E 84SE, 0.3-0.7 m fault.	Punky to hard greenish-white and pink gouge	Ka	"
N47E 88SE, 0.3 m + fault plus several		Ka	"

others of similar size and orientation; one of these strikes N60E, dips 88 SE.			
N2E 87SE, small fault up to 0.3 m wide		Ka	"
N68E 59SE, small fault 0.3-0.7 m wide		Ka	"
N56E 75SE; N30E 88 SE (1 m wide); N67E 80NW; small faults		Ka	unknown
Small faults, 2 m apart; N33E and N45E, dip 85NW; larger 0.7- 1 m wide		Ka	"
N70E 82SE, several fractures and 1 small fault		Ka	"

Faults lying north of El Monte Road

N48-58E ~90, zone of small faults 8-10 m wide	pinkish and green alteration products	Kbv	unknown
Group of small faults, N72E ~90		Klb	"
Several small faults, 274 NE76	whitish gouge	"	"
Numerous thin (several cm) brittle shear planes (polished) sub-parallel to foliation; N 46E 86SE		Kjv	"
N24E 56SE, small fault; plus others of variable orientations, including moderately-to low-dipping		Kcp	"

* The exact locations of fault features have not been cited in this report. A detailed report for southern San Diego County in preparation will list all localities.

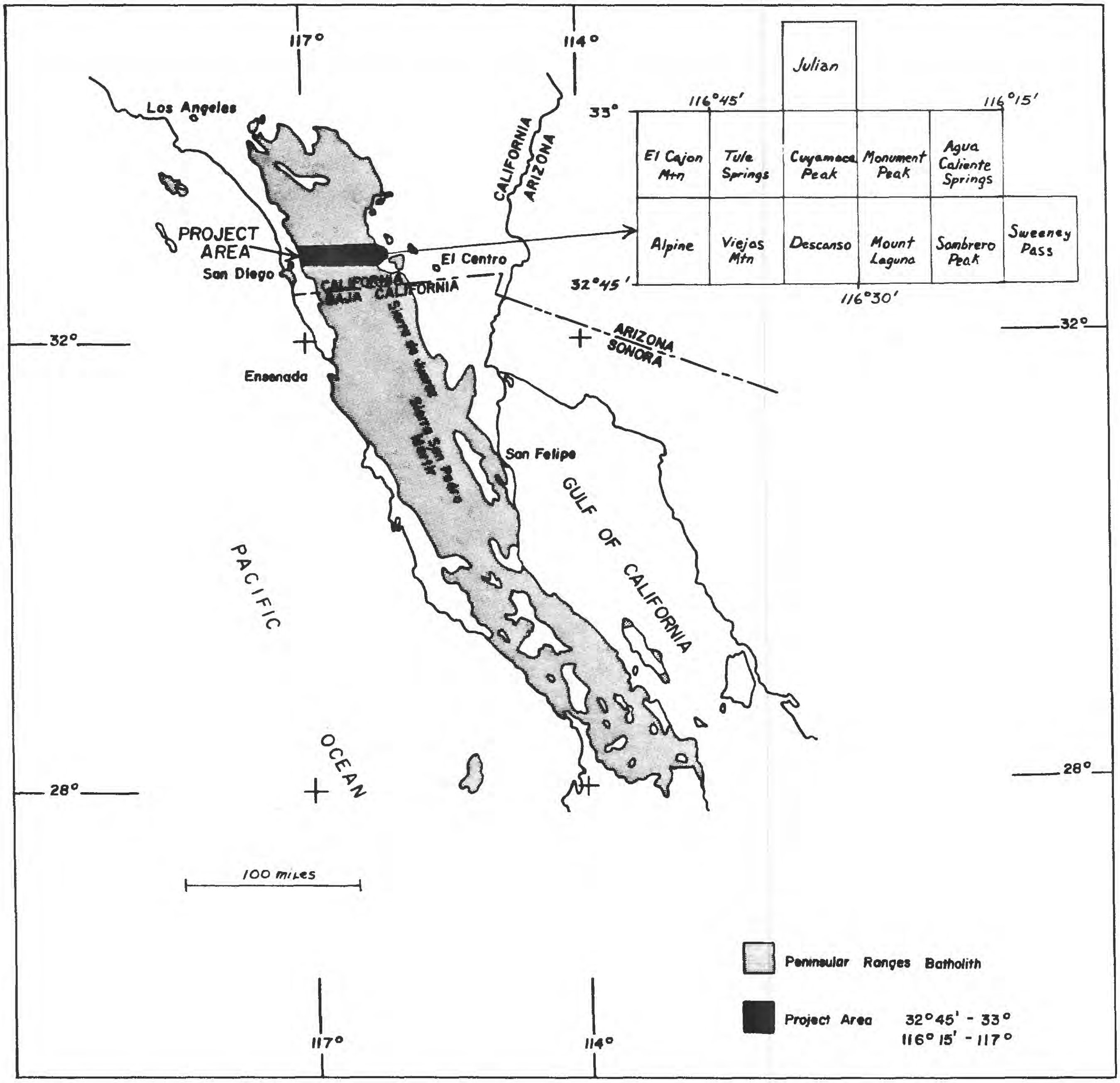


Figure I. Peninsular Ranges batholith in southern California and Baja California and project area.

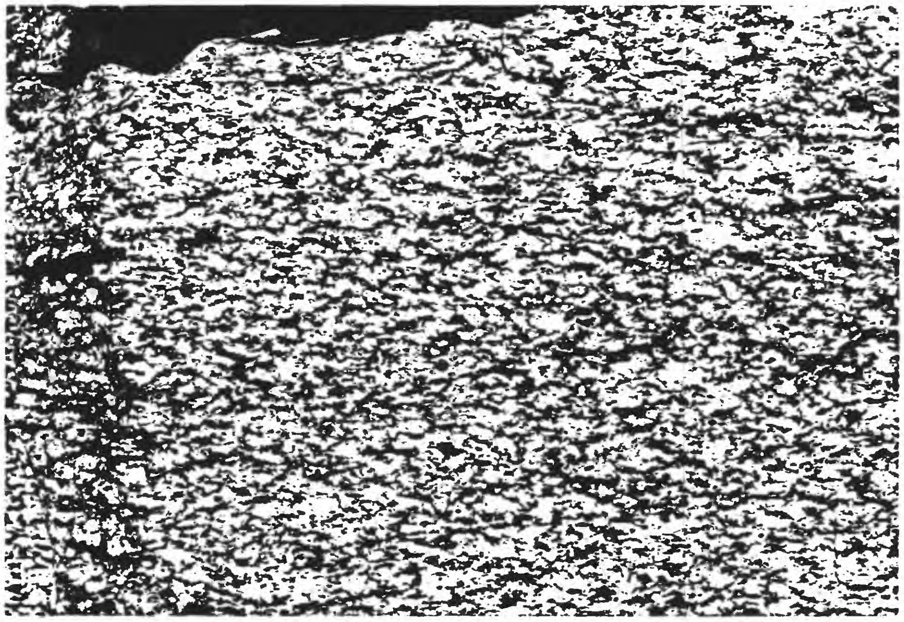


Figure 2a.--Kpv outcrop, trace of foliation parallel to pencil, color index appears higher than 5-10 percent because mafic minerals have broken down and recrystallized into fine-grained aggregates.

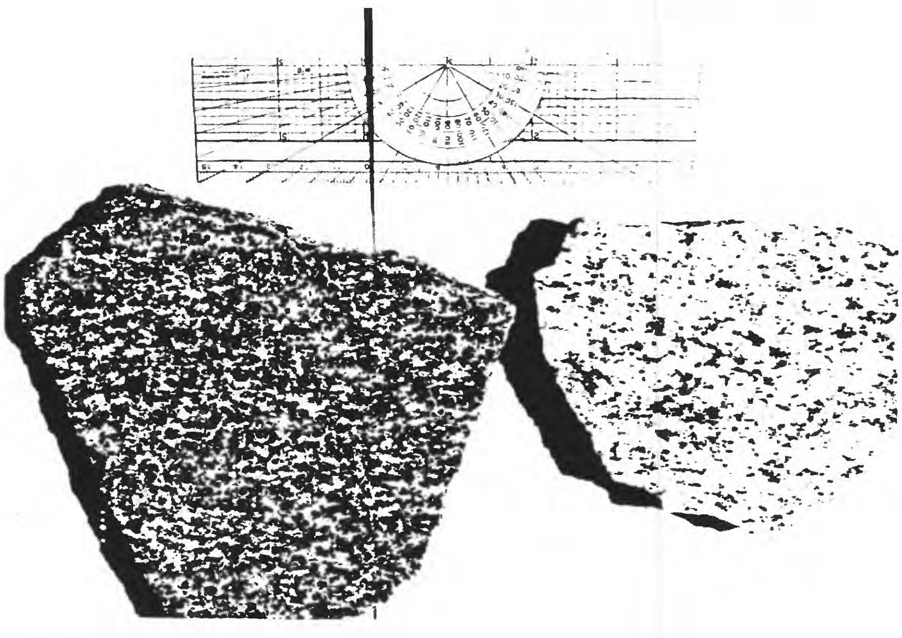


Figure 2b.--Slabs cut at right angles to foliation. Left, Kcp granodiorite; right, Kpv quartz monzonite. Stained for K-feldspar and plagioclase; 6-inch scale.

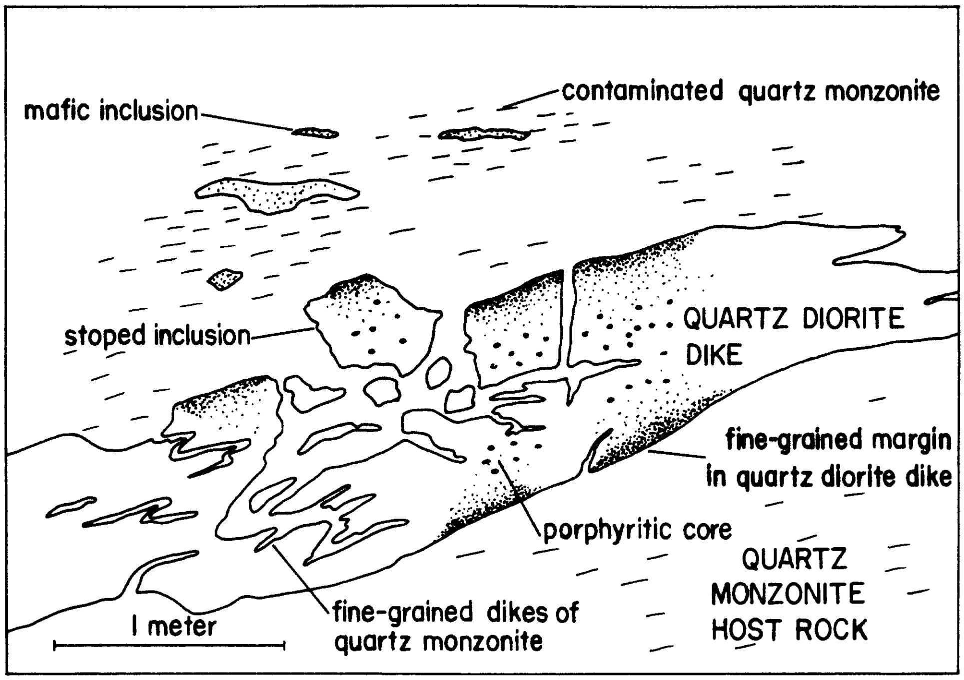


Figure 3. Sketch diagram of common relation between Kem dike and Kcp host rock. From field relations, sequence of intrusion was: 1) emplacememt of quartz monzonite

2) emplacement of quartz diorite dike with fine-grained (chilled) margin and coarser-grained, porphyritic core

3) fine-grained (aplitic) dikelets of quartz monzonite intrude quartz diorite dike; dikelets are continuous with surrounding coarse-grained quartz monzonite.

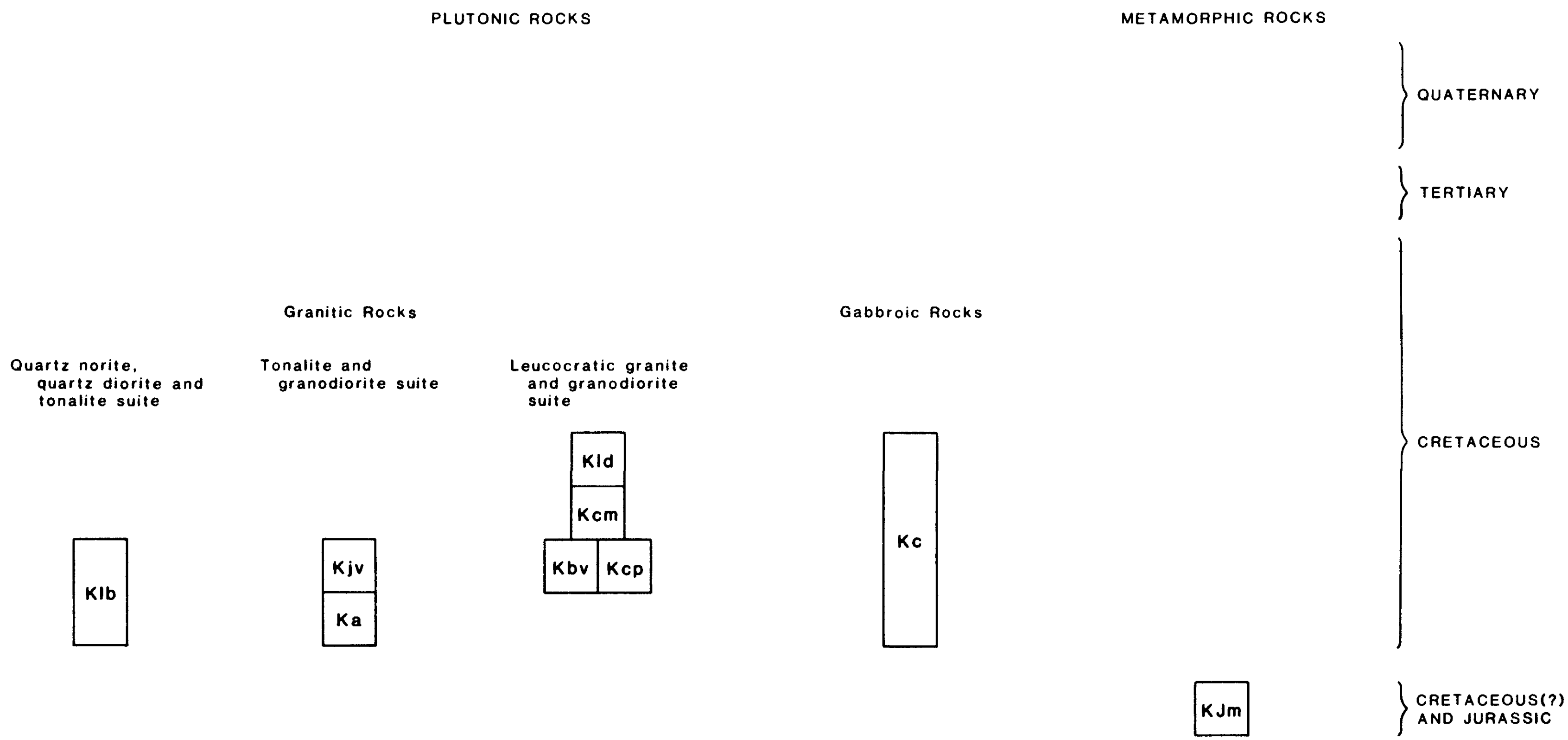


Figure 4. Intrusive sequence of plutonic units in southern San Diego County, California.

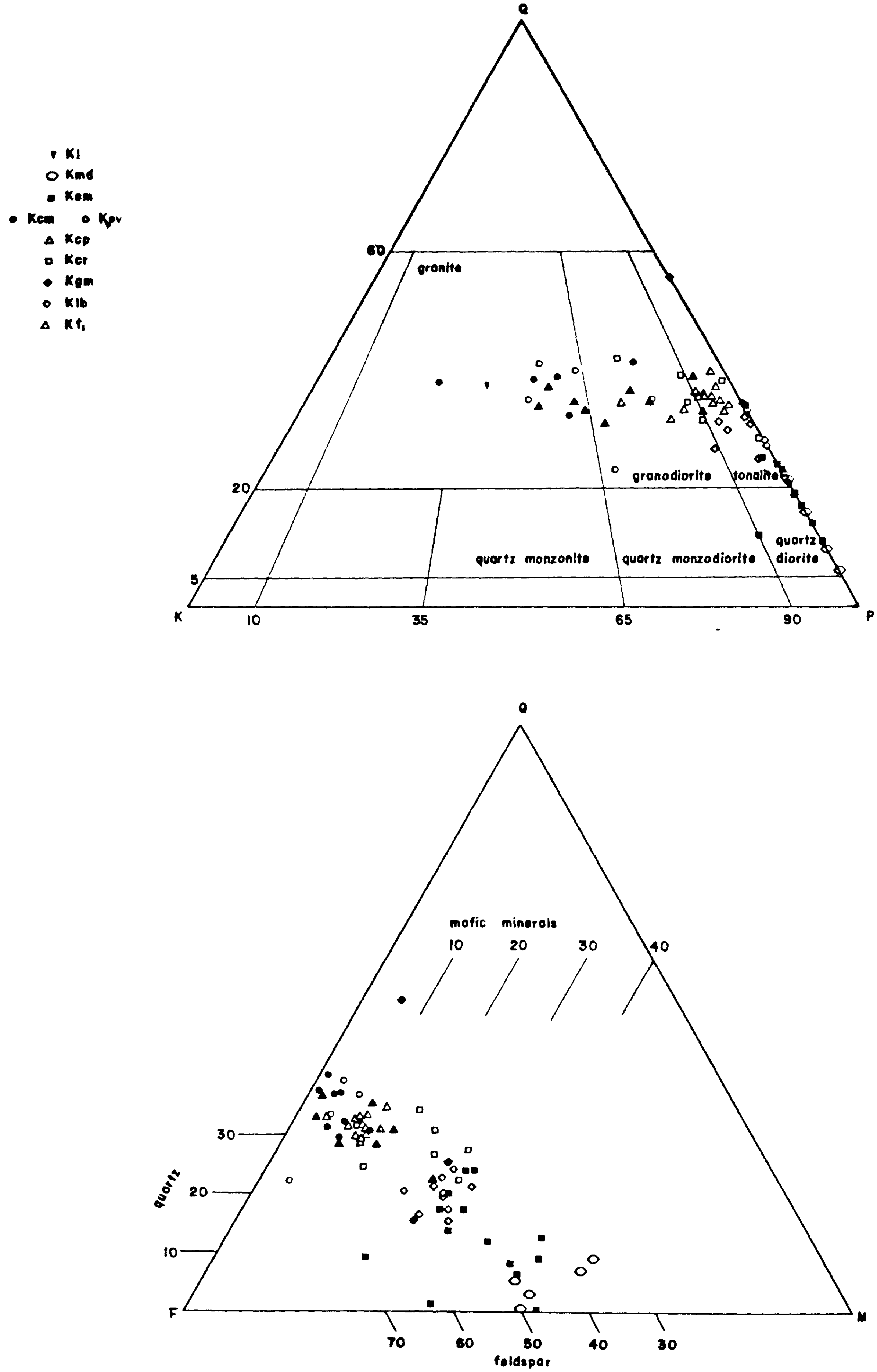
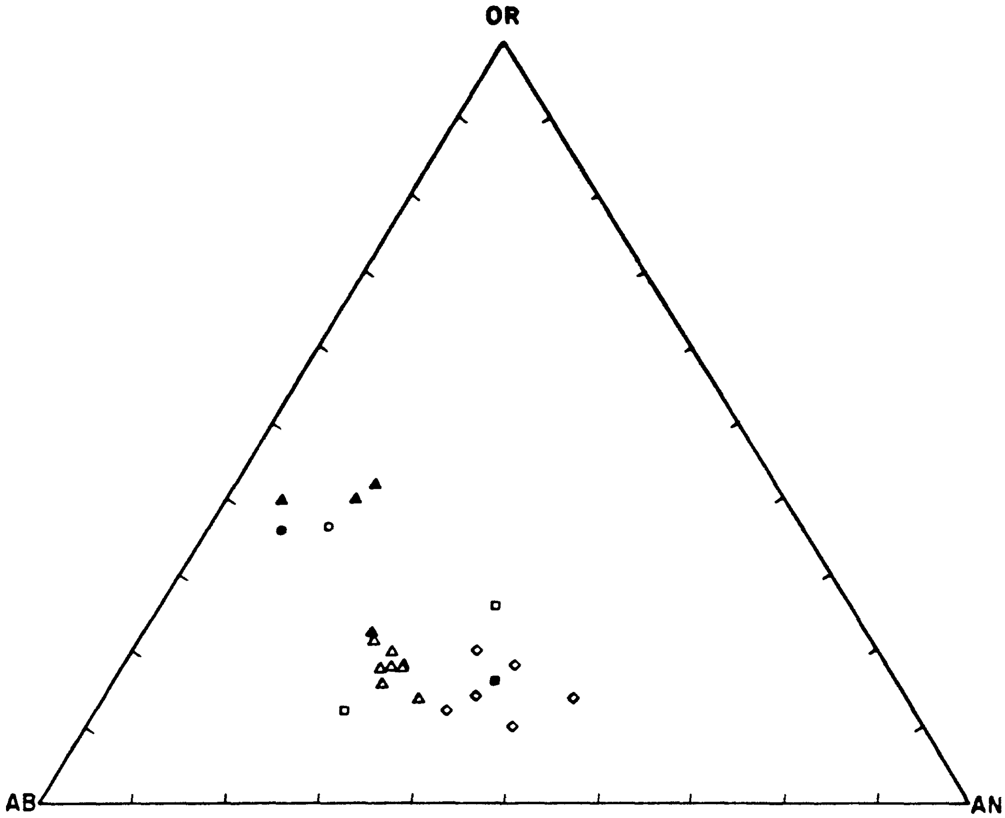


Figure 5a.--Q-K-P and Q-F-M plots of modal minerals of granitic rocks from Cuyamaca Peak and Mt. Laguna 15' quadrangles. Classification from Streckeisen, 1973.



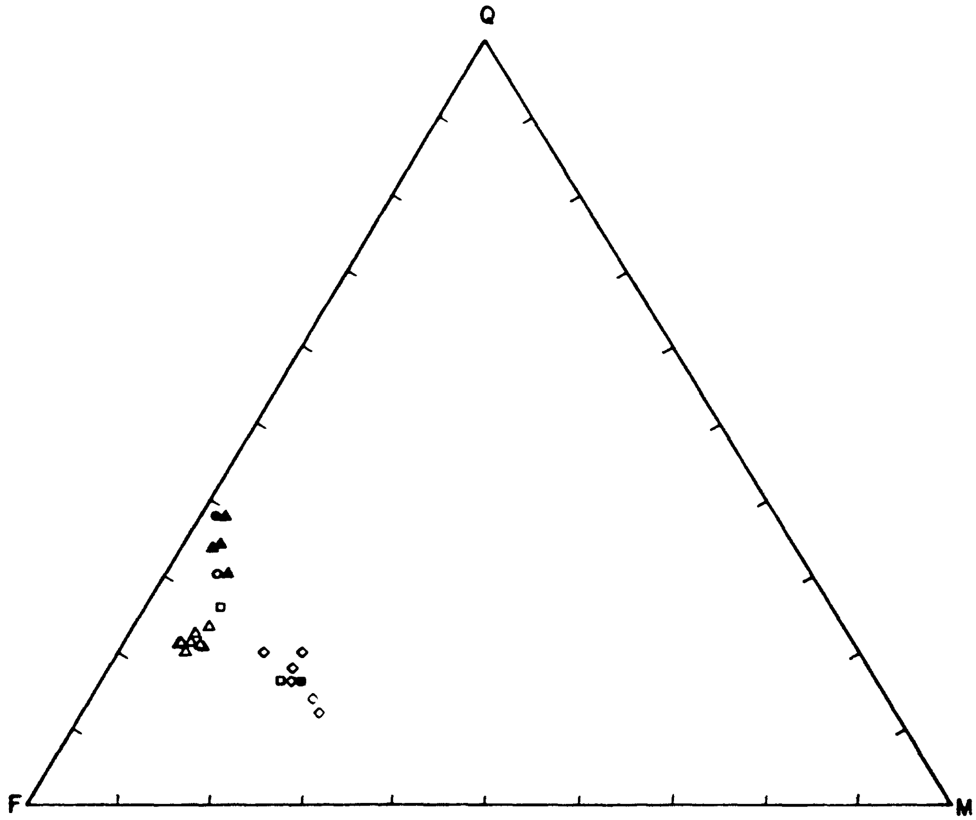


Figure 5b.--Normative OR-AB-AN and Q-F-M plots for some of the same rock samples as Figure 5a. Symbols same as Figure 5a.

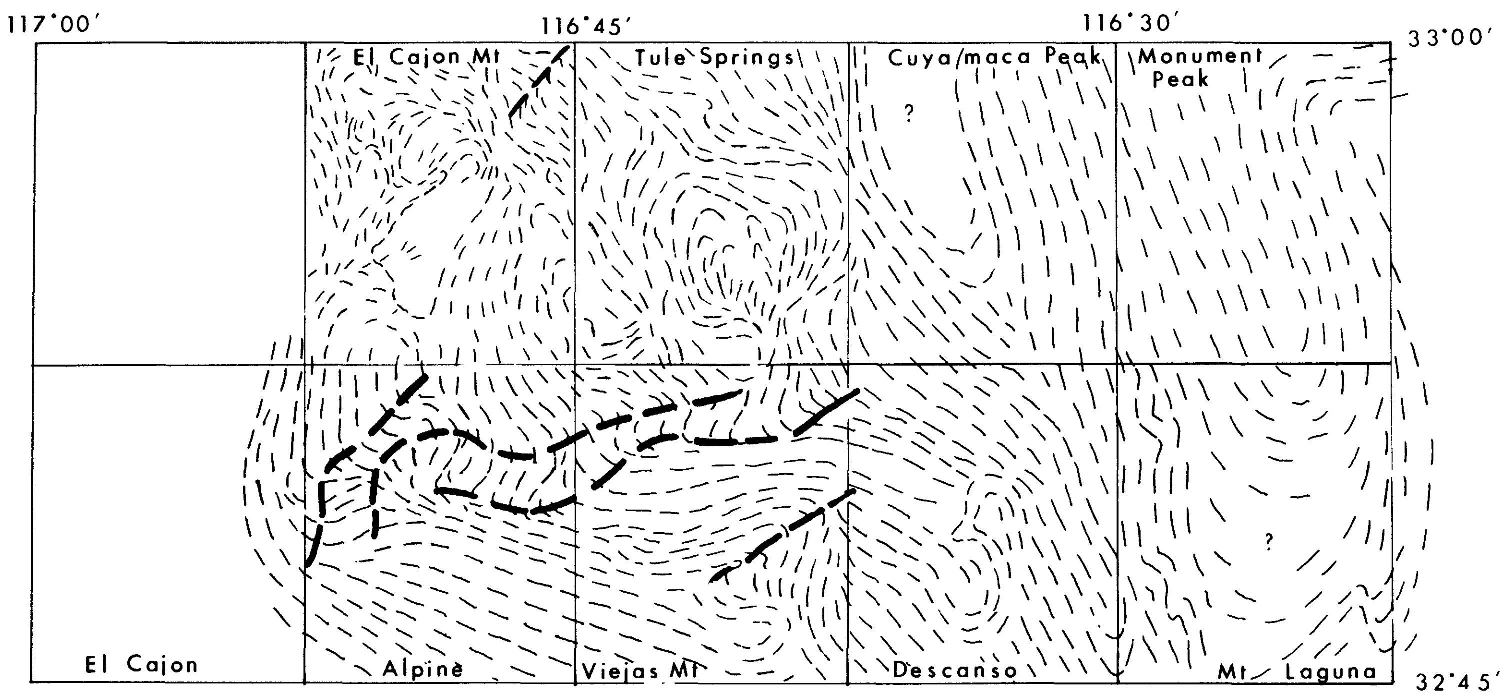


Figure 6. Sketch map of major Cretaceous structural trends in study area. Light dashed lines are generalized contact and foliation trends in plutonic and prebatholithic rocks. Heavy dashed lines are conjectural axial traces of NE-plunging folds. Regional dips (not shown) are steep to north, northeast, and east.

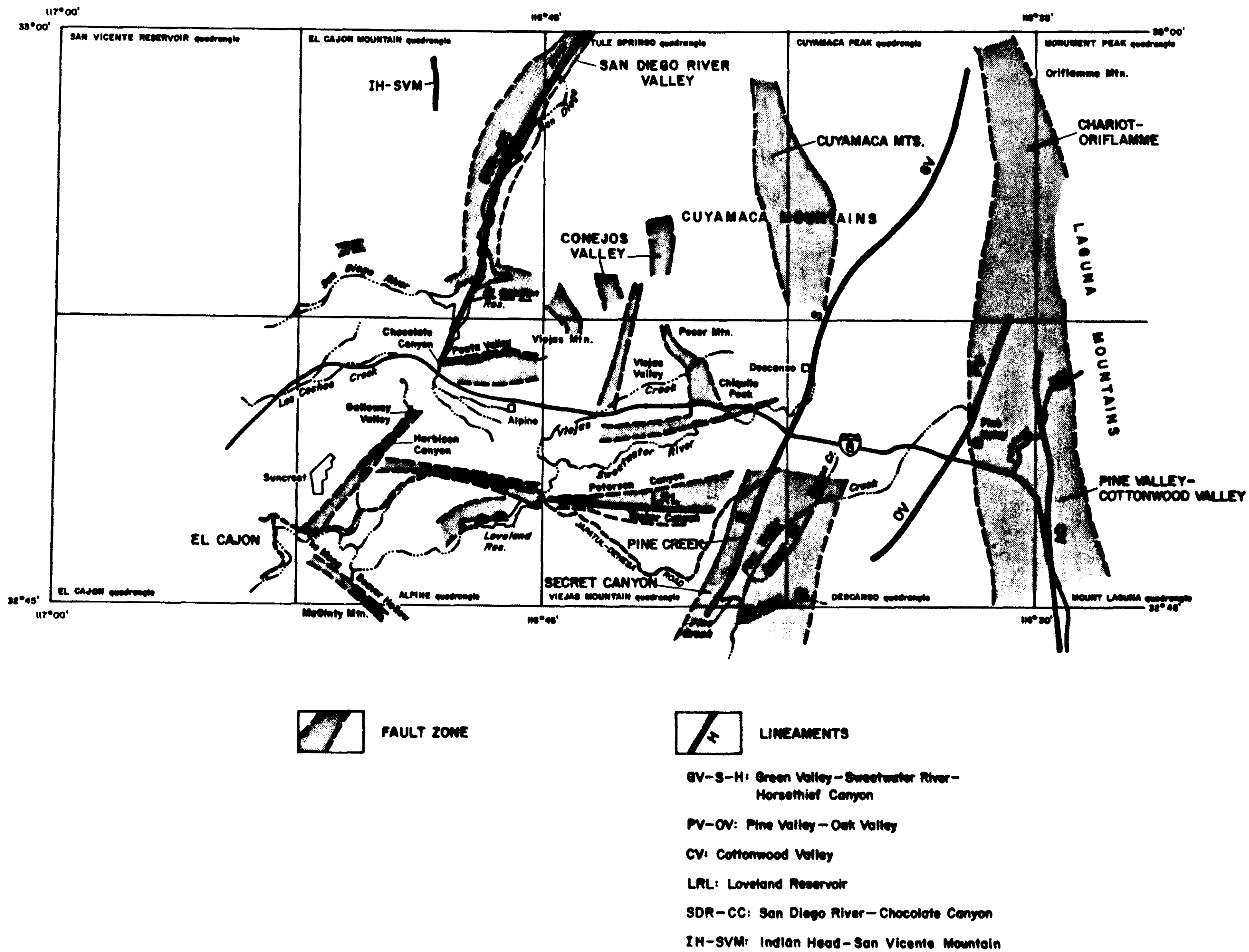


Figure 7. Index map showing lineaments, fault zones and geographic features.