UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE ALPINE QUADRANGLE

SAN DIEGO COUNTY, CALIFORNIA

by

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Open-file report

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Geologic map of the Alpine quadrangle, San Diego County, California

Purpose of project:

Published maps indicate that rocks of the Peninsular Ranges batholith in southern San Diego County comprise a relatively unfaulted block, but topographic maps and imagery at all scales reveal numerous prominent lineaments that cross the block in many directions. The purpose of this 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 direction of displacement of faults within the block and along its eastern margin (Elsinore fault zone) are being evaluated. The primary product of the project will be 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 Alpine quadrangle is the eighth map of a series of maps that show the structure of the batholith and the distribution of the crystalline rocks. Previous maps in the series include the Cuyamaca Peak, Descanso, Agua Caliente Springs, Viejas Mountain, Monument Peak, Mount Laguna, and Sweeney Pass quadrangles.

Introduction:

The Alpine 7-1/2' quadrangle lies within the Cretaceous Peninsular Ranges batholith of southern California and Baja California (Fig. 1). 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 roof pendants and screens in the batholith. These include a migmatitic schist and gneiss unit derived in part from prebatholithic rocks and in part from plutonic rocks.

Previous usage has been followed in referring to the twelve rock units as plutonic, even though most of the rocks in this part of the batholith have undergone significant synkinematic recrystallization. Foliation in the plutonic rocks was attributed to magmatic flow by earlier workers (Everhart, 1951). However, foliation appears to consist chiefly of the orientation of recrystallized mineral grains and aggregates (Fig. 2). Gneissic plutonic textures grade into augen gneiss and mylonite gneiss. Petrographic study confirms that igneous textures were modified by strain at temperatures high enough for recrystallization to occur, indicating that foliation formed by solid-state flow at elevated temperatures.

The metamorphism of the wall rocks was thought to pre-date emplacement of the batholith in this area (Everhart, 1951). However, foliations and plutonic contacts commonly parallel or are co-planar with those of the metasedimentary wall rocks and together they form a penetrative tectonite fabric in the area studied thus far. Although commonly concordant with plutonic contacts, foliation locally crosses contacts and, therefore, appears in part younger than the intrusion of the igneous rocks. These findings indicate that in this part of the batholith plutons were emplaced during regional metamorphism and deformation and that deformation and recrystallization continued long after emplacement.

Nature of plutonic contacts:

Although an overall sequence of intrusion of major plutonic units has been worked out, these age relationships locally appear reversed, so that the older of two plutons has a chilled margin against the younger pluton, sends dikes into the younger pluton, and carries inclusions of it (Fig. 3). These contacts were deformed during the regional deformation, with the result that both normal dikes (younger pluton of an intrusive pair into older) and anomalous (synplutonic) 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 places, but when many outcrops are examined, plutonic age relationships show overall consistency. The prevalence of these anomalous contacts indicates that the entire batholith remained mobile throughout emplacement. The presence of mutual chilled margins and 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.

Rock units:

The bedrock units are described below and their overall intrusive sequence is depicted in Figure 4. Preliminary modal and normative data for the plutonic units is given in Figure 5. The following descriptions are based in part upon observations of rock units and contact relations in the adjacent quadrangles, which are shown in Figure 1, but are fully applicable to the Alpine quadrangle. The bedrock units are overlain locally by unconsolidated upper Cretaceous(?) and Quaternary deposits.

Metamorphosed prebatholithic rocks.--Screens of prebatholithic rocks in southern San Diego County consist of interlayered metasedimentary and metavolcanic rocks (Jm). Metamorphic grade increases eastward to upper amphibolite facies as preservation of sedimentary and volcanic structures decreases. Rocks of volcanic and calcareous origin predominate in the western part of the area, while rocks of clastic origin are more abundant in the east. However, all of the above rock types are found throughout the area. The source of the clastic rocks may have been largely volcaniclastic, because pyroclastic layers grade into clastic layers in many places.

Metasedimentary rock types are, in order of abundance, fine-grained quartzo-feldspathic semischistose rock; micaceous, feldspathic quartzite; andalusite-bearing pelitic schist; fine-grained calc-silicate rock variably composed of epidote, garnet, plagioclase, pyroxene, quartz and hornblende; and metamorphosed calcareous grit, pebble and small cobble conglomerate. The rocks are medium to dark gray, weather dark reddish-brown and typically underlie ridges and hills. The quartzo-feldspathic semischistose rocks and feldspathic quartzites are thin-layered, typically laminated and probably originated as fine-grained, argillaceous sandstones and siltstones with calcareous cement, now represented by calc-silicate minerals. Cross-bedding and graded beds are present locally but deformation generally has obliterated sedimentary structures. Metavolcanic rocks consist of fine-grained black amphibolite and laminated grayish-white quartzite (meta-tuff?); pinkish-white to gray felsic tuff breccia; and felsic and mafic flows. Commonly, mafic and felsic rocks are interlayered.

In the Alpine and Viejas Mountain quadrangles prebatholithic screens are less than 1 km thick and consist chiefly of migmatite. An exception is a large screen of predominantly metavolcanic rock in the northwest corner of the Alpine quadrangle. Contacts between plutons of tonalite of Japatul Valley (Kjv) and screens are marked by migmatite zones as much as 0.5 km wide. The migmatite grades from granitic rock containing variably assimilated but recognizable prebatholithic inclusions, through various hybrid rocks displaying igneous or metamorphic character, to prebatholithic rock with ganitic layers (probably concordant dikes). Migmatite with layering greater than several cms thick is injection migmatite, but locally, thinner veins of granitic material have been mobilized as a low-temperature melt or segregate. These zones probably originated as intrusion breccia between tonalite plutons and wallrock all of which remained at metamorphic temperatures during regional deformation. Most of the metasedimentary component in the migmatite consists of calcsilicate minerals--epidote and garnet in sharply defined inclusions, hornblende and plagioclase in banded, partially assimilated inclusions. Calc-silicate rock appears to be more abundant in the Viejas Mountain and Alpine quadrangles than in the eastern part of the range. Amphibolite also increases westward and in the Alpine quadrangle grades into foliated metabasalt. Pelitic schist decreases westward forming only a minor part of the prebatholithic screens in the Alpine quadrangle.

In the Alpine quadrangle, small bodies of gabbro occur within the prebatholithic rocks and parts of these gabbro bodies contain abundant inclusions of prebatholithic rock. Contacts between the two rock types interfinger complexly. At one place, gabbro appears to grade, with decrease in grain size, into fine-grained amphibolite intercalated with metasedimentary rock. This gradational relation is difficult to separate from subsequent metamorphic effects, but field relations at several localities in the eastern part of the range also suggest primary gradation rather than homogenization.

Where prebatholithic screens contain abundant granitic gneiss layers, a schematic pattern of lensoid bodies has been added to the geologic map. In some cases the granitic gneiss consists of recognizable (Kjv) dikes which can be traced into nearby plutons. Where the granitic material is intimately intercalated with Jm its origin is not clear and therefore it has been called simply "granitic gneiss."

Cuyamaca Gabbro:--The name Cuyamaca Gabbro was applied by Everhart (1951) to the mafic body in the Cuyamaca Mountains. He assumed that all of the large mafic bodies (Guatay Mountain, Viejas Mountain, Poser Mountain) in south-central San Diego County are coeval, and the present study supports 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 be the oldest plutonic rock. Because the granitic intrusive bodies form sheets in gabbro, it is difficult to determine which rock is older from map relations in any one local area. However, relations over a large area show that many of the gabbroic bodies are lensoid screens surrounded by sheeted complexes of younger granitic rocks which form dikes in gabbro and have chilled margins against it. For example, discontinuous gabbroic screens locally as thin as one meter or less occur between granodiorite and tonalite plutons in the Mount Laguna quadrangle. Thus, the present outlines of gabbroic bodies and their distribution do not necessarily reflect either the original extent of gabbro or the original shapes of gabbroic plutons.

Virtually all of the gabbro observed is strongly foliated, and in most cases primary compositional layering is parallel or near-parallel to the foliation of recrystallized mineral aggregates. This recrystallization fabric either was not recognized by past workers, or was considered a local, protoclastic fabric. A second, cross-cutting metamorphic foliation has been superposed on this fabric locally. In marginal parts of the gabbro and in many small bodies, foliation is concordant with regional foliation. Foliation is less well-oriented in the interior parts of large bodies where it may be concordant or discordant to regional foliation, possibly because of the presence of more than one foliation. Foliation within the gabbro appears to have formed at least in part by synkinematic recrystallization (solid-state flowage).

One reason for ambiguity over the relative age of the Cuyamaca Gabbro is that locally the unit has broad, fine-grained and porphyritic margins next to younger granitic plutons. 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 in these zones locally. In other places, contacts between gabbro and granitic plutons are sharp and the granitic plutons send dikes into gabbro. Both types of contact may occur together in a given area. The intrusion breccia zones are strongly deformed parallel to the regional foliation and they grade into highly contaminated margins of granitic plutons which contain abundant, large, fine-grained gabbro inclusions. Inclusions of metasedimentary rock occur in some intrusion breccia zones between gabbro and granitic plutons, but there are many places where no metasedimentary rocks appear to be involved and where grain size of gabbro decreases systematically as contacts with granitic plutons are approached.

Some contacts between the tonalite of Japatul Valley (Kjv) and the Cuyamaca Gabbro (Kc) are so complexly interfingering and diffuse that they cannot be mapped accurately at this scale. Two map patterns have been used on the Alpine quadrangle in order to portray this kind of gabbro-tonalite contact: 1) a pattern of irregular blocks in gabbro indicates that bedrock consists of intrusion breccia whose chief component is fine-grained gabbro and/or heterogeneous gabbro containing large, chilled tonalite dikes; and 2) a pattern of inclined dashed lines in the tonalite where as much as 50 percent of the tonalite outcrop consists of gabbroic inclusions. Scattered, small gabbroic inclusions are indicated by solid ellipses. These zones actually grade into one another.

Fine-grained gabbro dikes emanating from gabbroic plutons cut the intrusion breccia zones surrounding most of the large gabbroic bodies. Such dikes also cut the youngest granitic units. This relation suggests that parts of the gabbroic plutons remained liquid after younger, granitic plutons had solidified. In many places, fine-grained gabbro bodies appear continuous with, or cannot be distinguished in the field from, the fine-grained and porphyritic mafic and intermediate dikes (Kmd) which cut all units. Some or all of these dikes may in fact be late differentiates of the parent magma of the Cuyamaca Gabbro.

Tonalite of Las Bancas:--The extensive group of rocks called Green Valley tonalite by previous workers after F. S. Miller, 1937, has systematic compositional, textural and structural variations. The unit includes rocks which were formerly called Bonsall tonalite because of the presence of mafic inclusions, following Hurlbut' usage (1935), but the inclusion-bearing tonalite is fully gradational into so-called Green Valley tonalite. The informal name tonalite of Las Bancas was given to one of the compositional and textural varieties, the first encountered in this study, which underlies the Las Bancas plateau southeast of Descanso (Descanso 7-1/2' quadrangle, Hoggatt and Todd, 1977). This rock is dark gray on fresh surfaces, weathers to a reddish or buff-gray color, and typically forms extensive low bouldery outcrops. The rock is homogeneous and generally inclusion-free. Commonly it carries scattered 1 cm poikilitic biotite or hornblende grains. Within the project area, the unit has a fine-grained margin against Cuyamaca Gabbro in a number of places and it is intruded by the tonalite of Granite Mountain (Kgm), the granodiorite of Cuyamaca Reservoir (Kcr), the granite of Chiquito Peak (Kcp), the granite of Corte Madera (Kcm), and by fine-grained and porphyritic mafic and intermediate dikes (Kmd).

The tonalite of Las Bancas is a medium-grained weakly gneissic rock, approximately equigranular, with lenticular recrystallized mafic aggregates. The rock has 15-20 percent quartz, traces of K-feldspar up to 5 percent, relict zoned phenocrysts of andesine to labradorite, and a color index ranging from 25-30. Locally (in some cases next to gabbro), the tonalite is more mafic, carrying less than 10 percent quartz with An content of plagioclase as high as bytownite. Thus some of the Las Bancas-type rock is quartz norite and quartz gabbronorite according to the classification of Streckeisen, 1973, but these rocks are petrographically very similar to the tonalite and there is a complete gradation between quartz gabbro and tonalite. Most samples contain chiefly pyroxene and biotite, with the hornblende occurring as sparse, narrow rims on corroded pyroxene cores and both pyroxene and hornblende poikilitically enclosed by biotite. The reaction sequence of the mafic assemblage is opx → cpx → olive green hornblende → yellowish-brown biotite. These igneous reaction textures have been modified by 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 both hornblende and biotite, locally with scattered larger biotite or hornblende grains giving it a near-porphyritic texture. Rusty-weathering spots 2 cm across are common. Sparse inclusions in the marginal facies are commonly large ($\sim$ 30 cm) rounded blocks of Las Bancas-type tonalite.

Tonalite of Alpine.--The tonalite in and around the town of Alpine (Ka) is quite mafic and has abundant mafic inclusions, 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 relicts of assimilated inclusions. Subhedral plagioclase is common, and locally hornblende is subhedral too. An content of plagioclase is An 50 or less. In general, mineral grains and aggregates appear recrystallized, and the rock has a strong gneissic texture. It grades into both the tonalite of Las Bancas and the tonalite of and Japatul Valley (Kjv).

Tonalite of Japatul Valley.--A third variety of tonalite, the tonalite of Japatul Valley (Kjv) (named after exposures in Japatul Valley in the Viejas Mountain quadrangle, fig. 1 and Todd 1978a), is an extensive rock in the project area which grades into Las Bancas-type tonalite but is partly separated from it by gabbro (Kc) and prebatholithic screens. The tonalite of Japatul Valley is distinctly different from the Las Bancas rock. It is lighter in color, less mafic, and its abundant mafic inclusions are typically weathered out in relief. They may be large and irregular in shape, or streamlined parallel to foliation, both occurring within the same outcrop. Many are fine-grained, but some inclusions are peppered with subhedral plagioclase grains and a few are gabbroic. Large inclusions of Las Bancas-type tonalite are commonly seen. Characteristic of the rock are single subhedral plagioclase (An 42-48) and hornblende grains, although recrystallized mafic aggregates also occur. The tonalite is medium- to coarse-grained, distinctly equigranular, and the subhedral grains give it a more igneous-appearing texture than those of the Las Bancas or marginal varieties. However, the rock is strongly foliated and the subhedral grains are alined parallel to the regional foliation. Although the origin of the marginal facies of Klb and the Japatul-type tonalite may not be the same, they both show the same age relation to the Las Bancas facies and preliminary chemical data indicates that they are identical in major element chemistry.

The Japatul tonalite grades into, and appears to be intruded by a more leucocratic rock texturally identical to the tonalite but ranging to granodiorite and granite in composition. The leucocratic variety is always found in association with Japatul-type tonalite and Jm calc-silicate injection migmatite zones. It is shown on the geologic map by a stipple pattern in Kjv and where calc-silicate rock is an appreciable constituent, a pattern of flattened ellipses has been superimposed on Kjv. The distribution of these rocks by necessity is shown in a generalized manner on the map for they are interlayered complexly on both large and small scales. The following lihologies are always present:

1) Japatul-type tonalite.
2) Leucocratic Japatul rock, including medium- to coarse-grained gneissic granodiorite layers and large, concordant, chilled granitic dikes.
3) Jm, typically calc-silicate, as partly assimilated inclusions, and as migmatite with leucocratic matrix; local intrusion breccia with matrix of modified Japatul-type tonalite (fine-grained, leucocratic).

4) pegmatitic Japatul-type tonalite; grading to layered rock with coarse-grained leucocratic and mafic layers; to coarse, porphyritic tonalite having abundant 1-2 cm subhedral plagioclase grains.

5) heterogeneous (grain size, mafic content) schlierically layered rock, apparently modified Japatul-type tonalite.

6) minor gabbro and/or fine-grained mafic rock.

Locally, Japatul-type tonalite is markedly leucocratic over about 10 cm or less next to relict metasedimentary inclusions, suggesting that the origin of the leucocratic, fine-grained matrix of the calc-silicate intrusion breccia and migmatite is modified tonalite. The following contact relations between tonalite and the calc-silicate zones were observed:

1) sharp, Japatul-type tonalite coarse-grained up to and next to contact with leucocratic matrix

2) interlayered

3) gradational

4) inclusions of Japatul-type tonalite in leucocratic matrix

5) porphyritic, pegmatitic and layered tonalite locally form matrix of calc-silicate intrusion breccia fragments

Dikes of Kcm granite, alaskite and aplite commonly have intruded along and near these zones. Typically they are crosscutting, but they may also be schlierically mixed with Japatual and Jm rocks.

This rock association suggests a genetic relationship between tonalite and granite magmas (Kjv and the granite of Chiquito Peak, Kcp). The leucocratic Japatul rock is identical to contaminated Kcp (shown by dashed pattern in Kcp on Cuyamaca Peak and Descanso geologic maps). In these two quadrangles, this inclusion-rich granodiorite grades into and locally is intruded by, uncontaminated Kcp granite. Thus Kjv and Kcp seem to be in part coeval and in part, granite is younger than tonalite. Kcp consistently intrudes the Las Bancas-type tonalite. If the contaminated Kcp is interpreted as being part of the Japatul tonalite, then the granite plutons consist of relatively small, discrete bodies (Chiquito Peak) and large, schlieric, partly gradational dikes. These shapes and age relations suggest a differentiated sequence. The Jm zones may be remnants of screens that once separated closely-related pockets of differentiating magma.

The Japatul-type tonalite also shows an important field relationship to the tonalite of Granite Mountain (Kgm), which is discussed below. The latter appears to form a connecting link between Kt_1, La Posta-type tonalite, and Japatul-type tonalite. Idiomorphic Kgm grades into Japatul tonalite by increase in deformation and recrystallization texture. In other places, Japatul tonalite is in contact with La Posta-type tonalite and here it has a subporphyritic texture caused by abundant 0.5 to 1 cm, euhedral, almost equant, waxy plagioclase phenocrysts to which mafic minerals appear interstitial.

Tonalite of Granite Mountain:--Outcrops of the tonalite of Granite Mountain (Kgm) are light in color because of white-weathering, euhedral to subhedral plagioclase. Abundant hornblende prisms in a range of sizes up to 2 cm long are diagnostic, the grains tending to be stubby or blocky (1 x 2 cm) rather than acicular. Biotite content is variable, but in general biotite is sparse and grains are small and appear recrystallized. Small subhedral grains are seen locally. The texture of the rock is typically idiomorphic, although in some areas it has been deformed and recrystallized to a considerable degree and the texture is similar to that of older plutonic gneisses. Even rock which has retained igneous texture, however, is well foliated, due to alignment of subhedral hornblende grains and biotite aggregates. Quartz is medium grained, but 1 cm recrystallized lenticular grains or aggregates are seen locally. Flattened and aligned mafic inclusions, some obviously gabbroic, are locally abundant. Sphene is present but rarely are grains large enough to be obvious in outcrop.

In thin section, the tonalite shows relict igneous texture with a widely varying degree of modification by strain and recrystallization. The rock consists of plagioclase (An 41 to 49), stubby pale brown and greenish-tan hornblende, dark reddish-brown biotite, and fine-grained, recrystallized sphene after biotite and hornblende. No K-feldspar has been seen. Occasional sphene relict phenocrysts measure more than 1 mm across. In some samples, hornblende contains large hypersthene cores with relict euhedral shapes, and the hornblende is jacketed by biotite. Biotite after pyroxene reaction pairs are also seen.

The areal extent of the tonalite of Granite Mountain has not yet been determined, and because of this and the textural differences resulting from varying degrees of deformation and recrystallization, assignment of all occurrences of this rock to a single unit is still considered tentative. Where its texture is idiomorphic Kgm has many features in common with rocks of the younger La Posta lithology (see section on Kt_1) which themselves vary considerably in ratio of biotite books to hornblende prisms and in degree of deformation. Indeed, parts of plutons called Kgm in the project area were considered part of the La Posta pluton by some workers.

It was noticed early in the present study that Kgm bears a field and petrographic similarity to the tonalite of Japatul Valley (Kjv). Mapping thus far tends to confirm the close relationship between Kgm and La Posta tonalite on the one hand, and between Kgm and Kjv on the other. In the Alpine quadrangle, Kgm occurs as an envelope of variable thickness around a La Posta-type (Kt_1) pluton, lying between Kt_1 and Japatul-type tonalite. The contact between La Posta tonalite and the more mafic, hornblende-rich Kgm may be gradational or abrupt, the latter consisting of La Posta and Kgm interlayered over a distance of a few meters. Contacts between these layers are sharp to indistinct, and layering is schlieric. A few dikes of La Posta in Kgm are seen in these zones. Kgm contains inclusions of a type seen elsewhere only in La Posta plutons--rhythmically layered, pseudograded schlieren composed of coarse-grained, idiomorphic leucocratic and mafic rock whose overall mineralogy is the same as that of Kgm. In the Alpine quadrangle, La Posta and Kgm plutons are deeply weathered and covered by low brush, and the contact is not well exposed. However, it can be mapped approximately as an overall change from broad, flat white outcrops (La Posta) to pale grayish-white, upright, oblong boulders of disintegration with rounded corners (Kgm).

The contact between idiomorphic Kgm and the tonalite of Japatul Valley (Kjv) is gradational. The chief difference is in the degree of recrystallization and strain modifying the igneous texture. The Japatul-type tonalite is the least deformed of the granitic plutonic units, excluding Kgm and La Posta tonalite, and in outcrop, there are many textural similarities between Kgm and Japatul-type tonalite. Thus there seems to be a spatial progression inward from deformed hornblende tonalite (Kjv), to less deformed, idiomorphic hornblende tonalite (Kgm), to moderately foliated La Posta tonalite (Kt_1), and finally to weakly deformed or undeformed La Posta leucotonalite in the cores of plutons. Kgm and Kt_1 plutons appear to be younger than Kjv, apparently emplaced as deformation waned.

In the eastern part of the project area, Kgm intrudes the marginal facies of a large Klb pluton. Pegmatitic dikes with euhedral mafic grains appear to emanate from the Kgm pluton and intrude marginal Klb. Locally Kgm appears to grade into marginal Klb by increase in degree of recrystallization and increase in biotite content. Kgm also carries large round inclusions of mafic, Las Bancas-type rock.

In the Alpine quadrangle, Kgm interfingers with gabbro along their contact. The gabbro tends to be fine- to medium-grained near its contact with tonalite. In the eastern part of the project area, Kgm carries gabbro inclusions, fine-grained mafic dikes (Kmd) and forms intrusion breccia at contacts with small gabbro bodies. Thus this tonalite shares the same ambiguity in age relations with gabbro as do older tonalites.

In the Alpine quadrangles the tonalite of Granite Mountain contains dikes of the granite and granodiorite of Corte Madera (Kcm), which, from other evidence throughout the project area, is the youngest granitic unit. These dikes are restricted to marginal parts of Kgm. The age relations between Kgm and other plutonic units, based upon field evidence, are shown schematically in Figure 4.

Granite of Chiquito Peak:--The granite of Chiquito Peak (Kcp) is a medium-grained, strongly foliated, light-weathering rock with color index ranging from 5-12 percent. The unit includes some granodiorite. Typically the unit was emplaced in a series of steeply-dipping, interconnected sheets and lenses. The granite of Chiquito Peak intruded older plutons intimately, chilled against them, and locally shows a high degree of contamination through assimilation of stoped inclusions. This is particularly true where granite is in contact with metasedimentary or mafic rock. The contamination and post-intrusive deformation have given rise to complex hybrid zones between these plutons. These rocks are intimate mixtures of granite, granodiorite, and tonalite representing both contaminated granite and mafic inclusions which have been variably assimilated.

The plagioclase feldspar is oligoclase (An 29 in one sample by electronmicroprobe) with relict euhedral zoning and the mafic minerals are chiefly dark greenish-brown biotite which appears to be derived from reaction of dark green to brown hornblende. Both biotite and hornblende have recrystallized but igneous relicts are present. Prominent accessory minerals are sphene and allanite. Granite with color index ranging from 2 to 7 percent locally contains no hornblende and slightly more quartz than the average Kcp. It grades into and intrudes the more mafic granite and granodiorite. For example, the rock which underlies Stonewall Peak is leucogranite with abundant 1 to 2 cm relict euhedral K-feldspar grains. Some of the rock mapped as leucocratic Kcp is alaskite and aplite. Locally, Kcp is fine- to medium-grained, sub-porphyritic (1 cm relict euhedral white K-feldspar phenocrysts) and contains abundant mafic inclusions. This rock appears to be a chilled facies of average Kcp.

In a number of places within the project area and in the northwestern part of the Alpine quadrangle, the tonalite of Japatul Valley grades into, and also is intruded by, leucocratic rock which is textually identical to the tonalite but ranges to granodiorite and granite in composition. This rock may or may not have abundant flattened mafic inclusions. This leucocratic rock is only found in association with the Japatul facies and in particular, with metasedimentary injection migmatite zones as mentioned above. The leucocratic Japatul rock is indistinguishable from contaminated Kcp.

The thin-sheeted style of intrusion, extensive stoping and chemical reactions with mafic rocks, finer grain size and mafic mineral suite of Kcp help to distinguish it from the younger granites, Kpv and Kcm.

Felsic tonalite:--The southeastern part of San Diego County is underlain by a distinctive tonalite pluton (Kt_1) (Todd, 1977a), part of the La Posta pluton (Miller, 1935) which underlies much of the southeastern Peninsular Ranges in San Diego County and northern Baja California.

Average Kt_1 is homogeneous, coarse-grained light-colored tonalite with color index (due chiefly to biotite) ranging from 8.5 to 14 percent. It has few inclusions or dikes except near its margins. Where inclusions are present in the interior, they appear assimilated, with faint borders that grade into biotitic schlieren with pseudo-graded and rhythmically layered structures. In the Alpine quadrangle, the rock carries scattered, irregularly shaped mafic inclusions, local gabbroic inclusions 5 to 10 cm long, and sparse larger inclusions of deformed mafic tonalite with its own mafic inclusions (Kjv?).

Quartz ranges from 29 to 35 percent and occurs in distinctive 0.5 to 1 cm grains with polyhedral (some blocky to subrectangular to rhomboid) shapes in less foliated rock, and as ovoid grains in more foliated rock. Thin sections show either highly stained single quartz grains or polygonized aggregates apparently derived from large single grains. Quartz is interstitial to, and replaces plagioclase, and contains small, early euhedral plagioclase and biotite grains. K-feldspar ranges from 2 to 5.5 percent, in some samples comprising enough to make the rock granodiorite, and occurs as 5 cm poikilitic grains that show large, reflective cleavage surfaces on rock faces. Plagioclase, sodic to intermediate andesine, has retained hypidiomorphic texture--delicate euhedral oscillatory zoning and synneusis aggregates--with minor recrystallization. Biotite occurs as euhedral, approximately barrel-shaped 0.5-1 cm books in less foliated rock, and as more abundant-appearing, finer, scaly, recrystallized aggregates in more foliated rocks. The average tonalite has sparse euhedral biotite books scattered in rock with abundant, finer-grained biotite aggregates. Most tonalite contains sparse acicular to subhedral hornblende grains 0.5 to 1 cm long. Accessory minerals are sphene, allanite, epidote, apatite, zircon and black opaque minerals.

Some tonalite has approximately equal amounts of hornblende and biotite, and the more hornblende-rich samples tend to have medium-grained quartz grains rather than large phenocrysts as in the more biotitic rocks. The hornblendic La Posta may indeed grade into Kgm locally. Initially it appeared that it would be possible to subdivide the La Posta rocks into biotitic and hornblendic facies, but subsequent mapping indicates a gradation between the two. For the purposes of this report, the name Kt_1 will be used to connote leucotonalite with euhedral biotite, large quartz phenocrysts and minor hornblende, as well as rock which has low color index, abundant medium-grained quartz and subequal euhedral biotite and hornblende. Both lithologies have large poikilitic K-feldspars.

Kt_1 ranges from strongly to slightly foliated, and leucotonalite appears unfoliated. Foliation is produced by alignment of elongate quartz aggregates and grains and scaly biotite aggregates. In thin section the rocks show textures indicating moderate strain and recrystallization of quartz, feldspar and biotite. Strongly foliated tonalite occurs near the margins of the body and less foliated rock is found in more central parts. The marginal rock tends to have higher apparent color index because of the breakdown and dissemination of biotite, and to be finer-grained than the rocks of the interior. Near the pluton's walls, foliation trends become more consistently oriented parallel to the walls, and to foliation in the surrounding plutonic rocks and wallrock screens. Within the pluton, trends show some consistency over small areas (several square km). The foliation in Kt_1 arises from both deformation and attendant minor recrystallization and is similar to, but much less intense than, strain and recrystallization effects in older plutonic rocks of the Laguna Mountains. Hence it is tentatively considered a late-tectonic structural feature.

In the Alpine quadrangle and adjacent Viejas Mountain quadrangle, the La Posta pluton consists of a northwest-elongate body which may be either an apophysis of the main La Posta pluton or a satellitic body. It is elongate parallel to the dominant northwest structural grain and is surrounded by a more deformed shell of Kgm and tonalite of Japatul Valley. The rock forms white-weathering, large flat outcrops underlying a plateau of decomposed Kt_1 with a cover of less than a meter (on the average) sand and gruss which supports low brush. This gruss cover is presently being eroded and the rocky exposures of Kt_1 occur in canyons and on steep slopes.

Within the Peninsular Ranges block, the contact relations observed between Kt_1 and other plutonic rocks are 1) gradational and intrusive contact between Kt_1 and Kgm (Kt_1 dikes Kgm), 2) Kmd dikes in Kt_1, and 3) in the Alpine quadrangle, dikes of Kcm leucogranite in marginal parts of Kt_1. Kcm dikes are localized in metasedimentary screens along contacts between older tonalite plutons but a few dikes penetrate into Kt_1 where contacts are either sharp, or vague and schlieric. The Kt_1 pluton is cut by numerous pegmatite and aplite dikes which have a different appearance from those associated with Kcm and, at least in the Alpine quadrangle, do not seem to extend into other units.

Two occurrences in the Alpine quadrangle suggest a definite age relation between Kt_1 and the tonalite of Japatul Valley. One is fine-grained, chilled euhedral Kt_1 against Japatul-type tonalite, with a discontinuous metasedimentary screen between them. The second is the occurrence of large pegmatite dikes containing bodies of coarse-grained, idiomorphic leucocratic and mafic "La Posta-type" schlieren cutting across the fabric of deformed mafic inclusions and foliation in tonalite of Japatul Valley.

The weak deformation of the unit supports its placement as one of the youngest plutonic rocks (see map explanation) but its exact age relative to Kcp and Kcm is not yet known.

Granite of Corte Madera:--The granite of Corte Madera (Kcm) appears to be a leucocratic variant of the granite of Pine Valley (Kpv) (Todd, 1977b); Kcm crops out in the Descanso, Viejas Mountain and Alpine quadrangles. Both Kcm and Kpv are coarse-grained and have elongate 2 to 3 cm gray quartz lenticles, probably relicts of large phenocrysts. Kcm has the same age relationship to other units as Kpv, occurring typically as steeply-dipping sheet-like dikes in older plutons. Both rocks are white-weathering and underlie highlands. In the field the chief difference between Kpv and Kcm is that the latter has a lower color index, less than 5 percent as compared to 5 to 10 percent for Kpv. Kcm plutons consist of strongly foliated leucogranite and leucogranodiorite (Fig. 5). 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 electronmicroprobe) 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.

In the Alpine quadrangle the granite of Corte Madera (Kcm) occurs as large, steeply-dipping dikes and dike swarms along or near contacts between tonalite of Japatul Valley (Kjv) and Kt_1, in which cases it has chilled textures and contains swarms of partly assimilated inclusions of metasedimentary rock and lesser amounts of gabbro. Locally, Kcm is chilled against gabbro.

Kcm and Kpv are probably closely related to one another because of local gradational relationship, textural and petrographic similarities and similar age relationship to other plutonic units. Kcm grades into pegmatite, alaskite and aplite which locally occur as dikes in the unit.

Pegmatite, alaskite and aplite:--Leucocratic dikes (Kl) of pegmatite, alaskite and aplite occur in all crystalline units except Kmd. In some areas they can be traced into a parent pluton, in the Alpine quadrangle, Kcm. 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.

Mafic dikes:--The youngest plutonic unit is an ubiquitous system of mafic dikes (Kmd) which cut all other plutonic rocks. Few are large enough to be shown at 1:24,000 scale. The dikes are dark gray to black, mostly fine-grained to very fine-grained. Some however, have fine- to medium-grained centers with chilled margins, while others are variably porphyritic. The dikes consist of plagioclase, hornblende, local pyroxene, biotite, sphene and traces of quartz, and range from tonalite to gabbro in composition, although most samples are quartz diorite. Their textures are synkinematic, i.e., the rock recrystallized as it was strained, and only the plagioclase phenocrysts in porphyritic dikes show relict euhedral outlines and oscillatory zoning. A few dikes seen in the Descanso quadrangle appeared undeformed. The dikes are abundant in the vicinity of bodies of the tonalite of East Mesa (Kem), a unit which occurs in the Cuyamaca Mountains (Todd, 1977b), and locally grade into these bodies. They also cut Kem, and locally crosscut one another. The dikes are abundant near the margins of all of the large Kc bodies, consisting in part of gabbro, and in several places apparently emanating from the Kc bodies. For this reason, they may in part be late synplutonic Kc dikes.

Although in some places the mafic dikes crosscut regional foliation, for the most part the largest dikes were emplaced concordant to foliation or have become alined during deformation. With few exceptions, foliation of the dikes' mineral grains is parallel to the surrounding regional foliation, regardless of the dikes' orientation.

The mafic dikes have typically been reintruded by their host rocks. Most of the dikes are highly deformed; many are pulled apart and resemble inclusions. They typically contain folded bodies of chilled granitic rock that in some cases are continuous with the granitic host rock but in others are not.

Old fanglomerate:--Dissected remnants of indistinctly bedded, poorly sorted bouldery alluvium (KTf) occur on a broad, uplifted erosion surface developed on tonalite, on flat-topped bedrock ridges, and in perched valleys. These deposits appear to be parts of an old basal conglomerate consisting chiefly of Kcm and Kc clasts. For some of these isolated deposits the closest possible sources for the distinctive clasts are many kilometers distant, and are separated from the KTf deposit by major contemporary drainages (e.g., the Sweetwater River) whose recent alluvium lies at much lower elevations. These old deposits are the only ones found to date which do not have a direct spatial relation to source. They are not at all similar to the early Tertiary conglomerates of the coastal area but may correlate with the upper Cretaceous Lusardi Formation which occurs 12 km to the west.

Colluvium:--Colluvial deposits (Qc) consist of poorly sorted sand, silt and gravel mixtures formed by slopewash. They have been mapped only where they are thick enough to completely obscure bedrock outcroppings over a large area. As much as 5 m colluvium is present on the lower slopes of the Sweetwater River valley in the southwestern quarter of the Alpine quadrangle. This material is being undermined and is slumping into the creek.

Gabbro hills have a characteristic shape with steep upper slopes and gentle lower slopes separated by an abrupt break. The lower slopes are graded to the broad valleys and resemble alluvial deposits. However, where cut by young streams they can be seen to consist of weathered gabbro with a thin veneer of colluvium.

Alluvium:--Alluvium (Qal) consists of gravel, sand, silt and clay in stream valleys. The alluvium in stream valleys consists of two kinds of deposits: older deposits which cover the valley floors and thin modern deposits in the beds of narrow channels that cut the older alluvium to depths of up to 15 meters. A preliminary C^{14} age of 920 ± 60 years B.P. has been obtained on charcoal from one of the lowest exposed beds in older alluvium in Pine Valley in the Descanso quadrangle (Stephen W. Robinson, U.S. Geological Survey, Menlo Park). This data indicates only that the older alluvium is no older than 920 ± 60 years B.P., because the charcoal may have been reworked from midden deposits of Indians living in Pine Valley.

Considerable erosion of older alluvium has occurred in historic times, as suggested by the headward cutting of gullies 1 to 2 meters deep along wagon ruts in a few 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. Since bedrock is exposed in most of the modern streambeds, the total thickness of older alluvium is probably about 15 m or less. Fine-grained sediments in broad mountain valleys probably formed in situ by chemical weathering with minor stream deposition.

While the maximum thickness of alluvium seen in the Cuyamaca and Laguna Mountains was about 6 m, in the Loveland Reservoir area of the Viejas Mountain and Alpine quadrangles it is more than 13 m. There, tan silty alluvium in stream valleys eroded in tonalite has a well-developed soil profile with a light-colored, calichified B-horizon and a dark red A-horizon. In the upland hills west of Chocolate Canyon (south wall of the canyon of the San Diego River), underlain by tonalite, prisms of thick (5 to 6 m) dark red-brown, stratified alluvium occur near the heads of small stream valleys tributary to Los Coches Creek. These deposits merge headward and laterally into meadows with at least several meters residuum and into lower hill slopes covered by aprons of colluvium. If it were not for deep incision by narrow, headward-cutting young channels, it would be impossible to differentiate these various materials or to gauge their thickness. Nowhere have patches of alluvium been found on steep hillsides suggesting that there has not been a blanketing of the present terrane by sediment in Quaternary time.

Soils:--In general, bedrock at the elevations of the Alpine quadrangle (<1 km) is much more deeply weathered than that at higher elevations in the eastern part of the project area. A soil profile in excess of 3 m thick has formed on deeply weathered tonalite (Klb, Ka, and Kjv). It consists of a 2 to 3 m friable red-brown A-horizon above a hard pale greenish-gray B-horizon. Locally, a less well-developed, younger(?) soil may be present; a yellowish soil with no B-horizon was seen in gruss over intact Klb tonalite. A 1 to 2 m soil profile was seen on gabbro, consisting of a dark brown, friable A-horizon above a light grayish-green, caliche-cracked B-horizon, over highly weathered and fractured gabbro.

The La Posta-type tonalite (Kt_1) weathers and erodes to a distinctive broad mesa surface with 1 meter or less (more in swales and gullies) soil and gruss cover, supporting a healthy chapparal. Fresher bedrock is exposed chiefly on steep slopes and in streambeds. That this material is residuum and not alluvium is verified by distinctive, resistant leucocratic dikes which thread the mesa surface.

As is true at higher elevations, soil, colluvium and alluvium are being gullied and eroded at an apparently rapid rate. Yet, some gullies have mature oak trees growing in their floors and walls, suggesting that some of the gully formation in the Alpine quadrangle had taken place prior to several hundred years ago.

Summary of rock units:--The data of this report suggest that rock units which are distinctly different in the field and which differ petrographically may be closely related, in part coeval. Thus, in some areas relatively sharp contacts among Kjv, Kgm and Kcp plutons can be mapped with no ambiguity. Elsewhere, these units seem to grade into one another and clearcut contacts cannot be mapped at 1:24,000 scale. In addition, complex contacts record repeated mutual intrusion between plutons, implying that the classical methods of determining sequence of intrusion, such as chilled margins, presence of dikes and inclusions, yield misleading results where applied here. Yet there is order in the data and the same contact and age relations are seen consistently throughout a large area.

Preliminary K-Ar ages on recrystallized 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. Recrystallization was accompanied by deformation, which continued after emplacement of plutons, as indicated, for example, by the presence of isoclinally folded leucocratic dikes (Kl). The prevalence of synputonic contacts indicates that early plutons interacted magmatically with later ones. One would expect complex interplutonic contacts and ambiguous age relations to occur in a setting where temperatures remained high while the rocks were being strained. Detailed studies of specific plutonic problems and other kinds of data such as geochemistry and zircon geochronology are necessay to substantiate or amend this picture.

Structure of batholithic rocks:

Within the project area, the plutonic units occur in steeply dipping sheets and lenticular plutons which are separated locally by screens of metasedimentary rock. All of these features 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 plutons, of prebatholithic screens, and of foliation within plutonic and metamorphic rocks, imparts a structural grain only a small part of which can be seen 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 (Fig. 6). In the Cuyamaca Peak, Monument Peak, and Mount Laguna quadrangles, it is predominantly north-northwestward, and the regional dip is eastward. In the Descanso quadrangle, the structural grain is north-northwest in the eastern half of the quadrangle and northwest to east in the western half; the regional dip is strongly to the northeast (Hoggatt and Todd, 1977). In the Viejas Mountain quadrangle, the structural grain is dominantly east in the southern and central parts of the quadrangle, swinging to northerly trends in the northern part. The steep, northward and northeastward regional dip of contacts, which is seen in the Cuyamaca Peak and Descanso quadrangles, is also observed in the Viejas Mountain quadrangle: in the extreme northeast corner, contacts dip steeply northeast and in the central and southern parts, west-northwest to east-striking contacts dip northward (irrespective of local attitudes). The east-striking structural grain of the Viejas Mountain quadrangle continues into the Alpine quadrangle as west-northwest to northwest trends, with most contacts dipping northward. The swing to northerly trends seen in the northern part of the Viejas Mountain quadrangle is repeated in the northwestern corner of the Alpine quadrangle and in the eastern part of the El Cajon quadrangle, suggesting the existence of a large-scale flexure or flexures in batholithic contacts and foliation, having a steep northeast plunge (Fig. 6). This is also the direction and plunge of mineral lineation and concordant crenulation observed on foliation planes in both metasedimentary and plutonic rocks.

Locally, plutonic contacts and foliation describe smaller fold forms (outcrop area 10-15 km^2) about steeply plunging axes (Fig. 6). Several of these fold forms include metasedimentary screens which are folded concordantly with plutonic contacts and foliation. One such structure, involving Kc and Kcp, occurs just west of the center of the Cuyamaca Peak quadrangle. In the Descanso quadrangle, one involving prebatholithic rock and Kcr occurs in the center of the map; a second, involving Kc, Kcp and Jm lies south of it. Several of these large fold forms occur in the Viejas Mountain quadrangle, e.g., an S-shaped one in the south-central part and another flexure in the east-central part. An open fold with a near-vertical axis involving Jm, a tonalite unit equivalent to Kgm, and Kc, with Kt_1 in the core occurs in the northeast corner of the Monument Peak quadrangle (Todd, 1978b). A similar structure occurs in the northeastern corner of the Mount Laguna quadrangle, involving Klb, Jm and hybrid units. The structure of the northern part of the Alpine quadrangle consists of several of these folds in the hinge area of the larger flexure pictured in Figure 6. Foliations in the Klb pluton (northeast part of map), and the Klb-Kcm contact and foliations within the large Kcm pluton (northwest part of map) appear to swing northeast, then west, then north. Contacts between thin Kcm dikes and tonalite of Japatul Valley which cross Harbison Canyon just south of the large Kcm pluton swing southwest and then north (in the El Cajon quadrangle).

The fact that foliation in the metasedimentary screens is folded along with plutonic contacts and foliation indicates that these structures are tectonic in origin. Yet, the distribution of Jm and Kc in the east-central part of the Viejas Mountain map suggests a pushing-apart of these screens and remnants by intruding magma and the growth of cells or pods of granitic rock. These cells or pods of granitic rock occur in the hinge areas of the folded Jm screens which may have been relatively low strain sites initially for emplacement of magma. Magma also pried apart Jm screens parallel to layering. Prebatholithic screens and zones of prebatholithic inclusions in tonalite plutons, traced throughout the Viejas Mountain quadrangle, appear to be parts of a once-continuous body. This fragmentation of screens suggests that intrusion has been an important agent of deformation The impingement of these folds upon one another suggests a condition of unsteady shearing rather than systematic tectonic folding.

An alternative possibility is multiple folding--an early phase of isoclinal folding with axial planes parallel to overall foliation and contacts, followed by folding about steeply plunging northeast axes (or the two phases may have taken place in separate, side-by-side domains). Figure 6 suggests a third folding on north-northwest axes. The abrupt dying-out of phase two folds might be expected if the rocks were hot, ductile, and partly magmatic, conditions expected during syntectonic intrusion.

Locally, the dips of plutonic contacts within the project area appear to be gentle to moderate, such as along the western contact of the Rattlesnake Mountain pluton in the northeastern part of the Cuyamaca Peak quadrangle, and the Kc-Kcp contacts in the Buckman Mountain area, southeastern corner of the Descanso quadrangle. In the Viejas Mountain quadrangle, a few Kcm dikes in the southeastern corner of the map are rather flat-lying and here, foliation in both dikes and host rock dips more steeply than plutonic contacts. In the

Monument Peak quadrangle, some late leucocratic dikes are gently-dipping. In all cases, steeply-dipping foliation can be traced from the host rock into the dikes and back into host rock, crosscutting contacts at a high angle. Thus, it appears that deformation continued after intrusion.

It was first noticed in the Mount Laguna and Monument Peak quadrangles that outcrops of Klb commonly display two foliations at large angles to one another, both appearing to be recrystallized mineral foliations. Locally in these quadrangles, east-trending foliation is reoriented by north-trending foliation, and the latter is associated with black cataclastic rock (grading to gneissic tonalite) and parallel slabby jointing. The north-trending foliation may be in part a later, lower-temperature structure. This double foliation is widely developed, particularly in the Alpine quadrangle within Klb, Ka, Kjv, Kc, Jm and Kt_1. In outcrops of gabbro (Kc), one mineral foliation is typically parallel to compositional layering but has a steeper dip than layering. On the north side of McGinty Mountain (R.1 E., T. 16 S., at the boundary of sections 26 and 27), two mineral foliations were measured, a weaker and a stronger. Here, the weaker foliation (N39W NE76) disrupts and reorients large mafic aggregates (layering) which lie parallel to the stronger foliation (N23E 90). Near a gabbro tonalite contact, one foliation (north-striking, 80 west) is parallel to the alined mafic inclusion fabric in tonalite and near-parallel to compositional layering in Kc. A second foliation (northeast-striking, 90) occurs in the tonalite. Two crossing foliations are present in a layered mixture of partly assimilated Jm inclusions in a contaminated leucocratic matrix derived from Japatul-type tonalite. The first, a N50W NE86 foliation involving alined Jm inclusions and mineral grains in both matrix and inclusions, was concordant with regional foliation, contacts and intrusive layering of the matrix. This foliation is crossed by a second mineral foliation at right angles; the second foliation has re-oriented a few mafic and Jm inclusions. The doubly foliated rock has been indicated on the map by intersecting strike and dip symbols. The double foliation may account for some of the local apparent fluctuations in foliation elsewhere in the project area, since only one foliation may show up well in a given outcrop. The origin of double foliation may be related to polyphase folding.

Faults of the Alpine quadrangle:

Faults mapped in the Alpine quadrangle fall into roughly four groups (Fig. 7). To date, no unequivocal displacement of Quaternary alluvium or colluvium has been documented within the quadrangle, although locally, bedrock faults appear to continue into alluvium as prominent lineaments. These may be faults, or features caused by draping of sediment over bedrock scarps). As noted in earlier reports on south-central San Diego County, the faults consist of many short, sub-parallel breaks which lie in zones with northerly and easterly strikes, forming a more or less orthogonal pattern, and commonly are parallel to older structural trends and to large-scale fracture patterns. A fault zone lying near, or along, a prominent lineament recognized on high-altitude aerial photographs (Merifield and Lamar, 1976), will be discussed under the heading of the appropriate lineament.

Peutz Valley faults:--A swarm of short (1 km or less), sub-parallel east- to east-northeast-trending lineaments in and near Peutz Valley in the northeasten part of the quadrangle (Fig. 7) show up well on 1:16,000 aerial photographs; at least some of these features are faults. The lineaments occur in tonalite and cross the strike of northwest regional foliation. The zone extends eastward up Peutz Valley into the western edge of the Viejas Mountain quadrangle. Lineaments of this trend extend westward across the northernmost part of the quadrangle, and may have determined the east-northeast course of the valley of Los Coches Creek (Fig. 7) which old highway 80 and I-8 now follow. These lineaments consist chiefly of strong vegetation lines and/or straight reaches of secondary streams. Features indicating faulting associated with lineaments are as follows:*

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N60E 69NW average for family of small faults	punky to well-indurated gouge, cataclasite; 0.3m and typically 3-5 cm; epidote and iron oxide mineralization	Klb; Kl (?)	dip-slip, 1 m, NW side down
2) N80W 80NE	earthy gouge, 0.5 m; iron oxide	Klb	?
3) N10W 72SW	0.3-0.5 m dense black cataclasite and waxy gouge; epidote	Klb	?
4) N33W 58NE	0.3-0.5 m dense black cataclasite	Klb	?
5) N50E steep, average for multiple thin faults	5-7.5 cm breaks composing zone up to 25 cm wide; punky white gouge; pink (K-feldspar) alteration	Klb	?

*The exact locations of fault features have not been cited in this report. A detailed report for south-central San Digeo County in preparation will list all such localities.

Commonly, leucocratic dikes (Kl) have served as loci of faulting, and locally gouge in or next to a leucocratic dike appears to be cut and offset by another dike suggesting that at least some faults formed at a late stage of batholithic emplacement when tonalite was solid enough to fracture and late-stage leucocratic magma filled fractures. The mineralization of crushed material may then represent the action of hydrothermal fluids evolved from late-stage leucocratic magma.

Harbison Canyon-Galloway Valley faults:--From north to south, Chocolate Canyon, Galloway Valley and the relatively straight northern reach of Harbison Canyon aline to form a gently-curving north- northeast-trending lineament which is approximately on strike with the northeast, 30 km-long San Diego River Valley lineament (Fig. 7). Merifield and Lamar (1976) proposed as much as 630 m right-lateral fault separation along this lineament. Then northeast-striking canyons were probably eroded along a shear zone. The southern reach of Harbison Canyon trends northward. Short, sub-parallel northeast-trending faults are exposed in the hills on both sides of Harbison Canyon and similar lineaments extend to the southwestern margin of the quadrangle. Roadcuts in the narrow southern end of Galloway Valley (R.2 E., T.15 S., northwest corner of section 31) expose highly fractured, brown-weathering Kcm.

Some measured faults in this zone have the following characteristics:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N67E 89NW, average for group of small faults	gouge typically 15 cm but 1 thicker breccia and gouge zone seen	Kc	?
2) N21E steep SE, average for a dozen faults	gouge <15 cm	Kjv	?
3) N46E 90 , several faults	3 m fault zone; individual faults no more than 0.3 m; white calichified gouge, hard but breaks with finger pressure; pink, K-feldspar mineralization in broader envelope of fractured, altered tonalite	Kjv	?
4) N23E steep NW, average for group of faults	0.3m, white gouge; pink K-feldspar	Kc	?
5) N61E 90 to steep NW, average of several faults	7.5 cm punky, altered gouge	Kc	?

Streams tributary to Peutz Valley follow northerly to northwest-trending lineaments in the northeastern part of the Alpine quadrangle, east of Chocolate Canyon. These lineaments strike northward into the El Cajon Mountain quadrangle, geneally parallel to the San Diego River Valley. No evidence of north-striking faults has been found in this area although locally, float of cataclastic leucocratic dike rock and epidotized cataclastic tonalite suggest some shearing. However, roadcuts along Arnold Way, between old highway 80 and Harbison Canyon Road (I-8, Dunbar Lane exit) expose numerous small faults just west of a north-northwest-trending lineament:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N11E 81 SE, average of several faults	whole zone 15-20 cm; whitish gouge with hydrothermal alteration	Ka	?
2) abundant slickensided surfaces approximately parallel to road (north-northwest) with gently-plunging to near-horizontal ridges and grooves	discrete small faults with hydrothermal alteration	Ka, Kl	10-12 cm apparent dip-slip offset of 1 fault by a second; many faults show no offset
3) N40W 89 SW; 4 faults	whole zone 0.6 m	Kl	flat-lying leucocratic dike repeatedly dropped down to southwest 20 cm

A series of concordant northwest-striking contacts, plutonic foliation, metasedimentary screens and steeply-dipping dikes cross the northeast-trending Harbison Canyon-Galloway Valley fault zone at right angles, providing a means for measuring lateral separation on these faults. Two groups of distinctive contacts cross this zone with no significant lateral offset: a northern group consists of Kjv tonalite with up to 50 percent gabbro inclusions (dashed line pattern) grading westward into a series of aligned gabbro bodies. In the southwest corner of the map, gabbro with thin Kcm dikes crosses the zone with apparent lateral displacements of about 0.1 km.

Loveland Reservoir lineament:--The Loveland Reservoir lineament is a west-northwest feature named for Loveland Reservoir on the south fork of the Sweetwater River, in the southeastern part of the Alpine quadrangle (Fig. 7). Merifield and Lamar (1976) describe the lineament as "expresed by gently curving valleys continuing for about 10 km (6 mi) in a west-northwest direction." In the Viejas Mountain quadrangle (Todd, 1978a), minor faults were found in two parallel east-trending valleys. The faults and valleys follow Cretaceous structural trends.

In the Alpine quadrangle, this more or less well-defined lineament splays westward into a broad zone of fractures and faults (Fig. 7). The major array extends west-northwest from the eastern margin of the quadrangle to Harbison Canyon, in part coinciding with Japatul-Dehesa Road and the north fork of the Sweetwater River. Minor east-northeast-trending faults appear to have blocked out the western arm of Loveland Reservoir. These two groups of lineaments cross in the area north of Loveland Reservoir. These faults have produced no obvious displacement of contacts.

The west-northwest-trending faults compose an en echelon array faithfully following west-northwest contacts and foliation. They are expressed in the topography by alined linear valleys, ridges and benches. Many of the faults occur at or near Kcp-Kjv contacts. Good exposures of this shear zone can be seen in roadcuts in Kcp along Japatul-Dehesa Road before it turns southwest into the broad valley of the north fork of the Sweetwater River. The Kcp granite is highly fractured with pink K-feldspar alteration. One group of thin faults, with crush zones individually less than 8 cm wide, has an average trend of N77W 59NE. Indistinctly bedded colluvial deposits lie on truncated faults striking N80E 54NW.

Other faults in the west-northwest part of the fault zone measured:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) numerous nearly flat-lying faults	10 cm black cataclasite, white punky gouge	Kjv; Kl	thin leucocratic dikes offset 0.5 m; locally, dikes cross faults with no offset or crushing in dike; one pegmatite dike contains epidote, pink K-feldspar; suggests some faulting was pre-dikes.
2) N51E 88NW, average for many small faults	individual faults average 8 cm, up to 0.5 m; whitish cataclasite with K-feldspar and epidote alteration in brown, sheared granite	Kcm	?
3) N44E NW57, family of parallel faults locally marginal to leucocratic dikes; steeply plunging slickensides	largest 15-20 cm; greenish-white gouge with epidote, caliche(?)	Kjv; Kl; Kmd	18 cm leucocratic dike offset 25 cm, apparent reverse dip-slip separation; west side up
4) N50W 74SW	< 0.3 m	Kl	oblique-slip
5) N83E 77SE, average for many small faults	complex shear zone 20-25 m; individual faults no > several mm; hydrothermal alteration	Kcm	?

Many short, parallel northwest-striking lineaments occur in the Alpine Heights area, north of the well-marked west-northwest fault zone. If these are also associated with faulting, then Galloway Valley and the valley of Alpine Creek may have been eroded along the intersection of two fracture zones--east-northeast and northwest-trending. Otherwise, this valley is anomalous because the entire northeastern part of the Alpine quadrangle is underlain by Klb and Ka tonalites which typically have been eroded to a flat, or gently rolling surface which stands above Galloway Valley.

The east-northeast faults in the Loveland Reservoir area form a less well-defined zone. Faults observed in the area north of the reservoir are minor:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N21E SE60, average for group of small faults	individual faults 5-8 cm	Kt_1; Kl	?
2) N48E 87SE, average for 6 faults	coalescing faults form zone 0.5 m; altered gouge	Kt_1	?
3) N43W 88SW; N2W 67SW; N72E 81SE	gouge in zone of sheared, altered rock	Kt_1	?

South of the reservoir, two sizeable crush zones trending N65E 72NW cross West Boundary Truck Trail between Sloan Ranch and Loveland Reservoir. The faults consist of bluish-black cataclasite and punky, white altered gouge in highly fractured Kt_1. A larger fault or faults may lie beneath the reservoir, since the density of small faults appears to increase toward the reservoir.

Northwest and west-northwest-striking faults in the southwestern corner of the Alpine quadrangle:--The high valleys called Beaver Hollow and The Mesa are probably eroded in part along northwest-trending Cretaceous contacts and foliation and in part along en echelon faults parallel to them. Measured faults are as follows:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N84W 80SW; also, several moderately to gently-dipping faults	individual faults 0.3m; gouge in highly fractured tonalite	Ka	?
2) N49W 87NE, average for several sub-parallel faults	gouge	Ka	?
3) northwest-trending shear zone at foot of north side of McGinty Mountain, near and along contact between Ka and Kcm	faults 0.5 m; white punky altered gouge; breccia	Ka	?
4) N36W 84NE	0.3 m soft gouge	Ka	?
5) N16E steep; N31E 83SE	dark greenish-gray hard cataclasite and greenish-white gouge as much as 2-3 m; faults associatd with large quartz-aplite dike and zone of intense hydrothermal alteration; dike has been mined.	Kc	?

REFERENCES CITED

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

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 Range province, southern California and Baja California, in Geology of Southern California, California Division of Mines Bulletin 170, Sept. 1954, p. 29-52.

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.

Miller, W. J., 1935, A geologic section across the southern Peninsular Range of California: California Journal of Mines and Geology, v. 31, p. 115-142.

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., 1977a, Geologic map of the Agua Caliente Springs quadrangle, San Diego County, California: U.S. Geological Survey Open-file Report 77-742.

_____1977b, Geologic map of the Cuyamaca Peak quadrangle, San Diego County, California: U.S Geological Survey Open-file Report 77-405.

Todd, V. R., 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.

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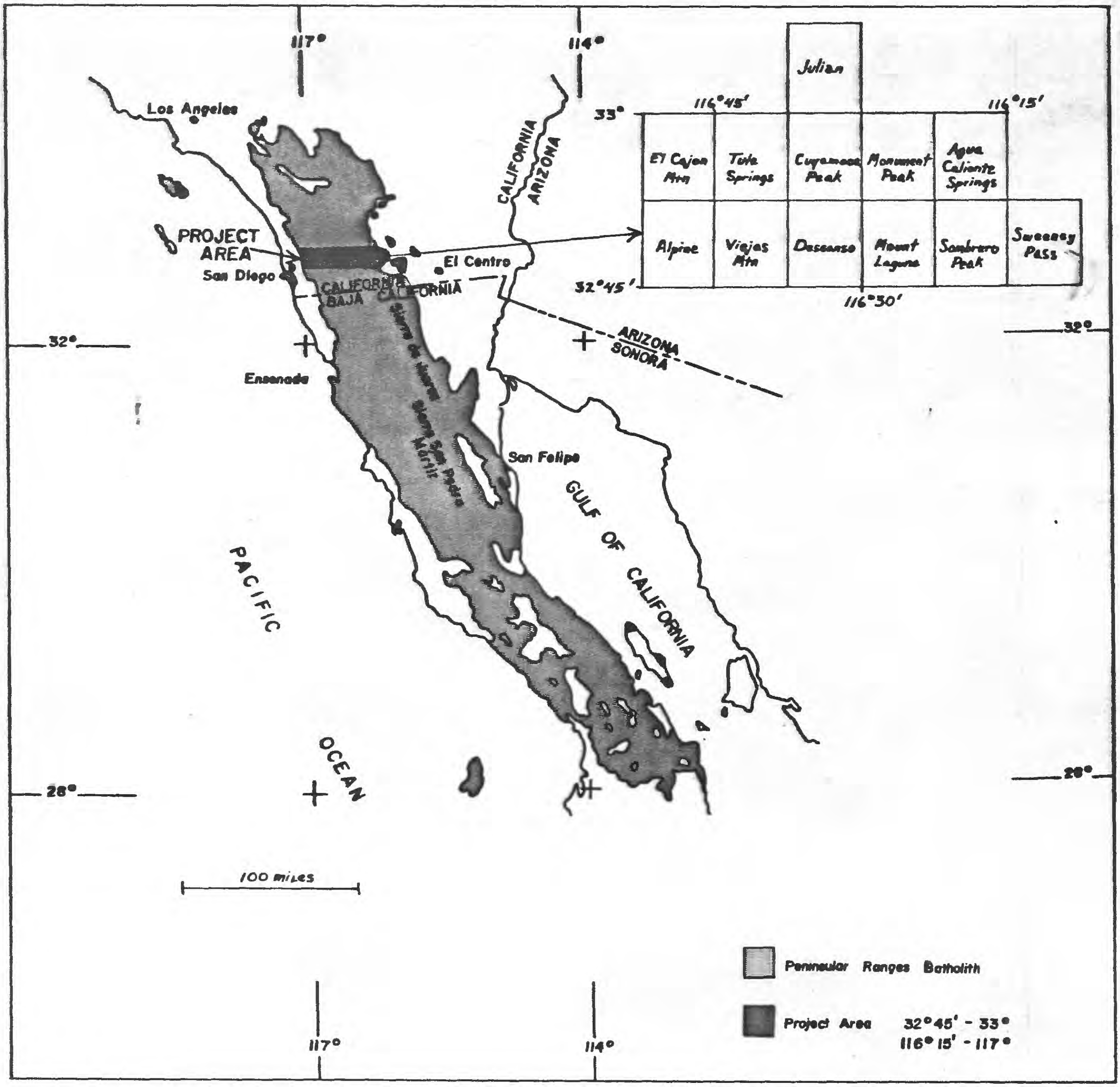


Figure 1. Peninsular Ranges batholith in southern California and Baja California and project area.

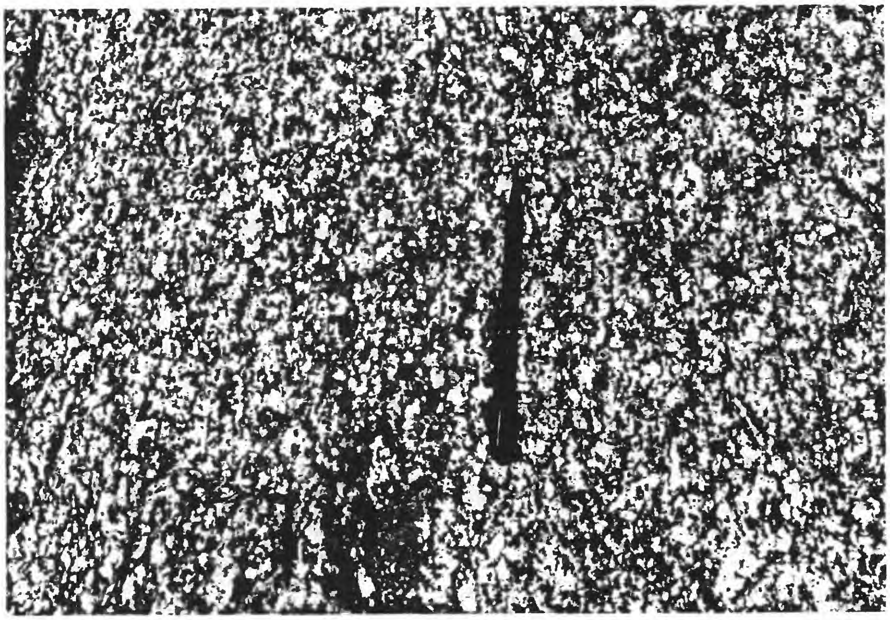


Figure 2a.--Kpv outcrop, trace of foliation parallel to pencil, color index appears higher than 5-10 percent because mafic minerals have broken down and recrystallized into fine-grained aggregates.

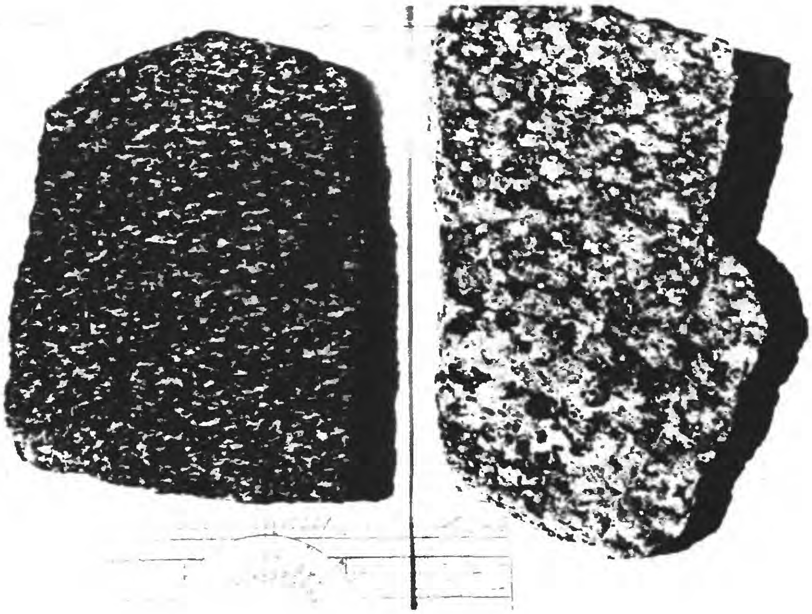


Figure 2b.--Slabs cut at right angles to foliation. Left, Kcp granodiorite; right, Kpv quartz monzonite. Stained for K-feldspar and plagioclase; 6-inch scale.

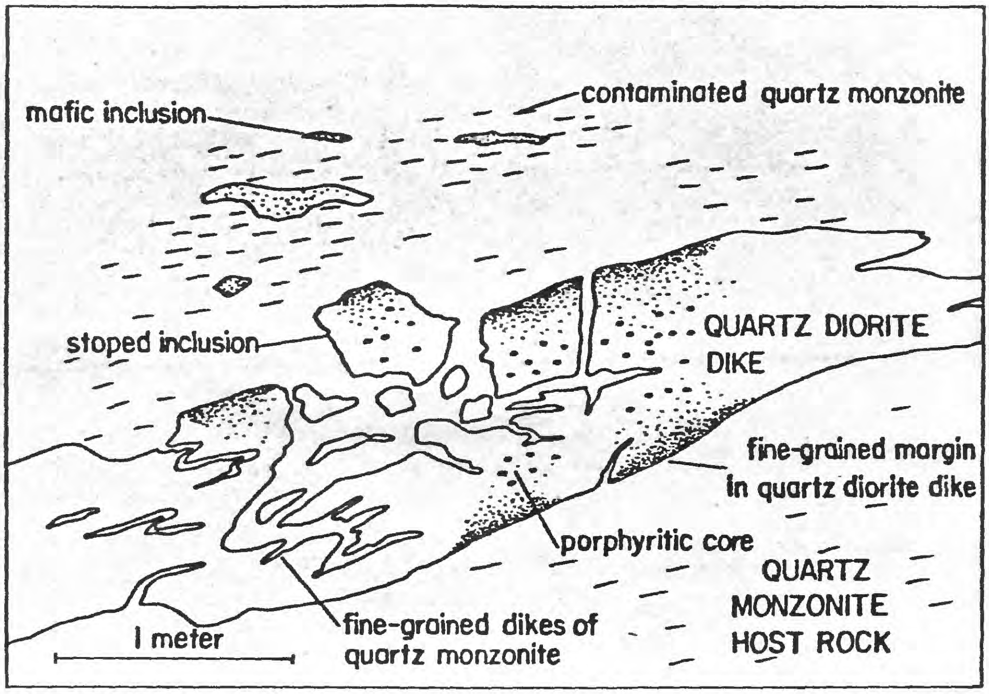


Figure 3. Sketch diagram of common relation between Kem dike and Kcp host rock. From field relations, sequence of intrusion was: 1) emplacememt of quartz monzonite

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.

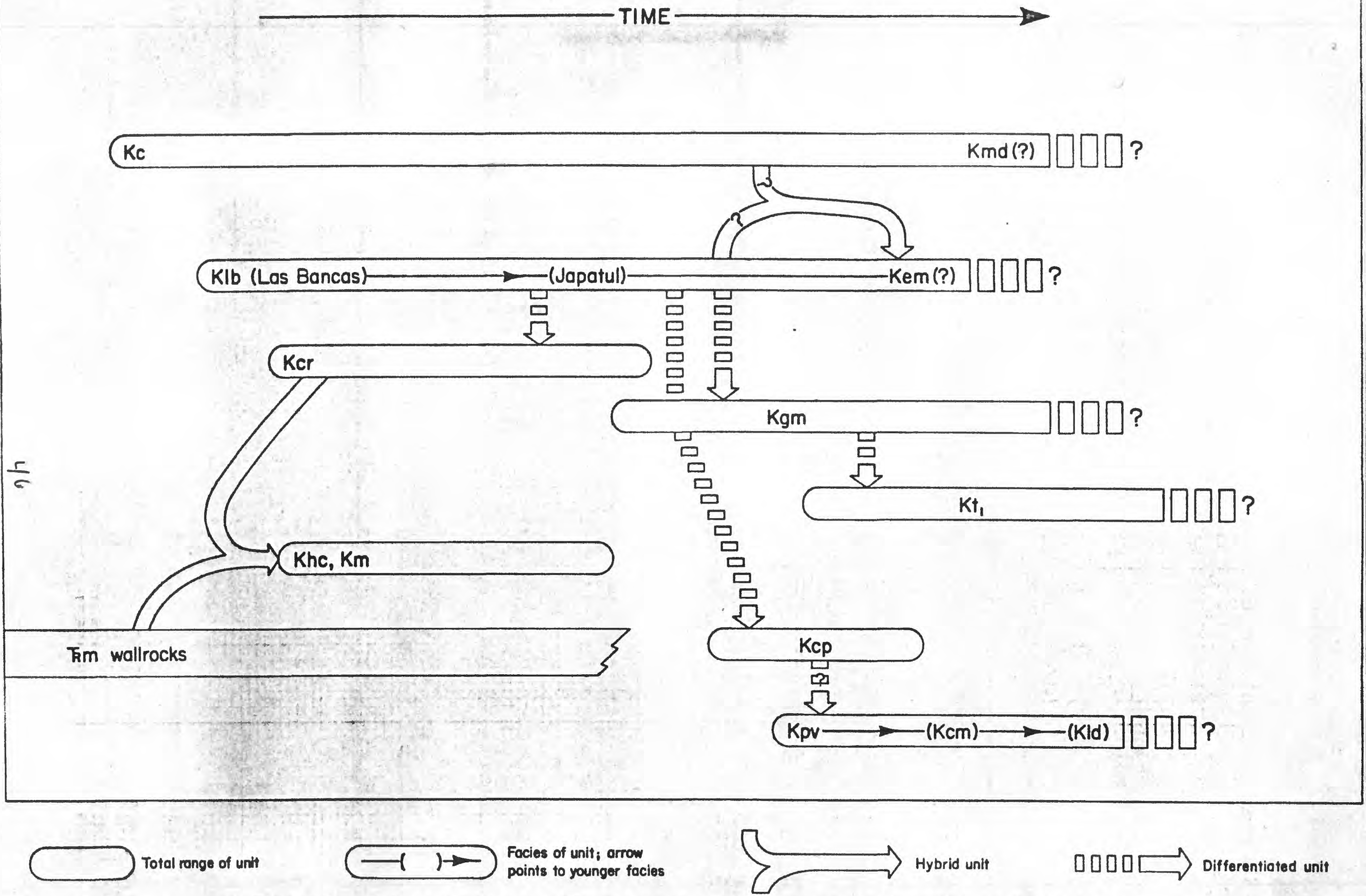
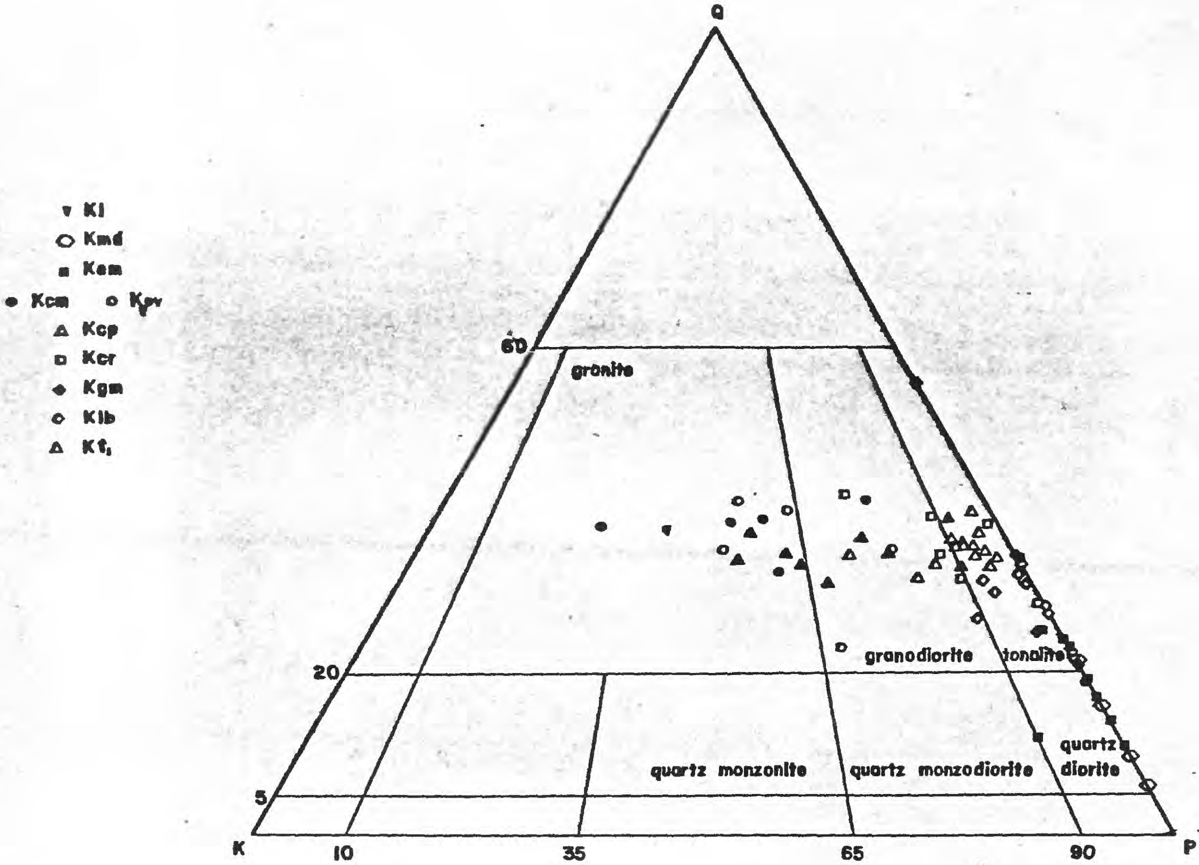


Figure 4.--Schematic diagram of intrusive sequence and relationships as indicated by field evidence. Units shown on same bar are probable phases of single magma. Overlap of bars means units are coeval. Probable hybrids , facies and differentiates are indicated.



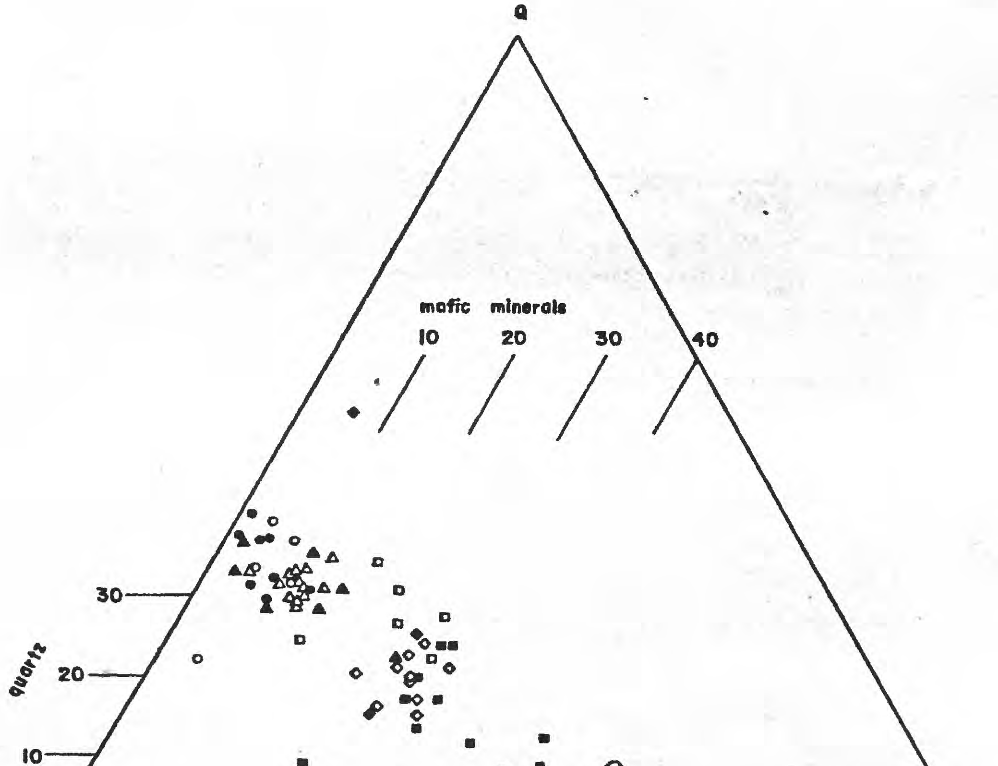


Figure 5a.--Q-K-P and Q-F-M plots of modal minerals of granitic rocks from Cuyamaca Peak and Mt. Laguna 15' quadrangles. Classification from Streckeisen, 1973.

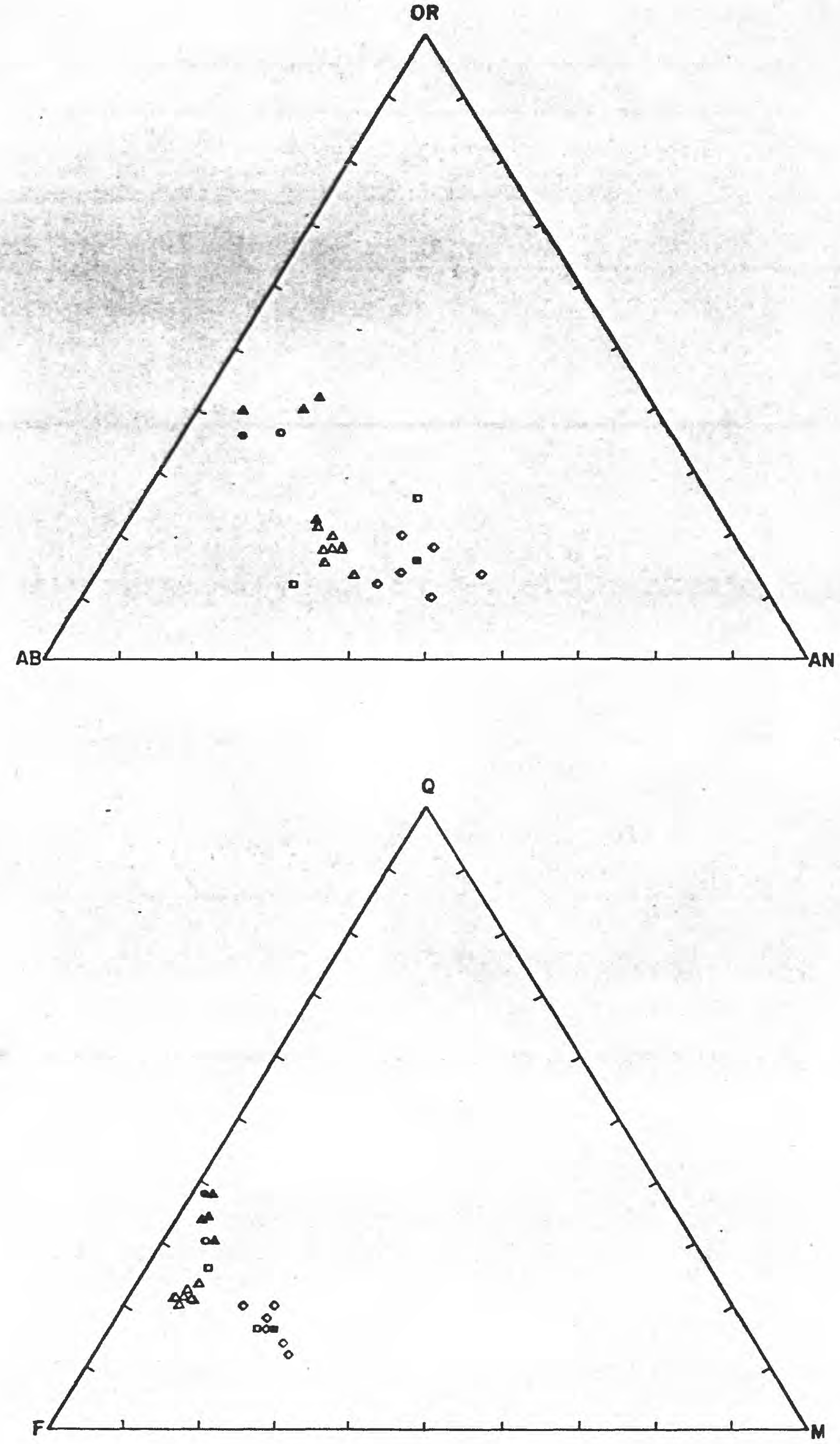


Figure 5b.--Normative OR-AB-AN and Q-F-M plots for some of the same rock samples as Figure 5a. Symbols same as Figure 5a.

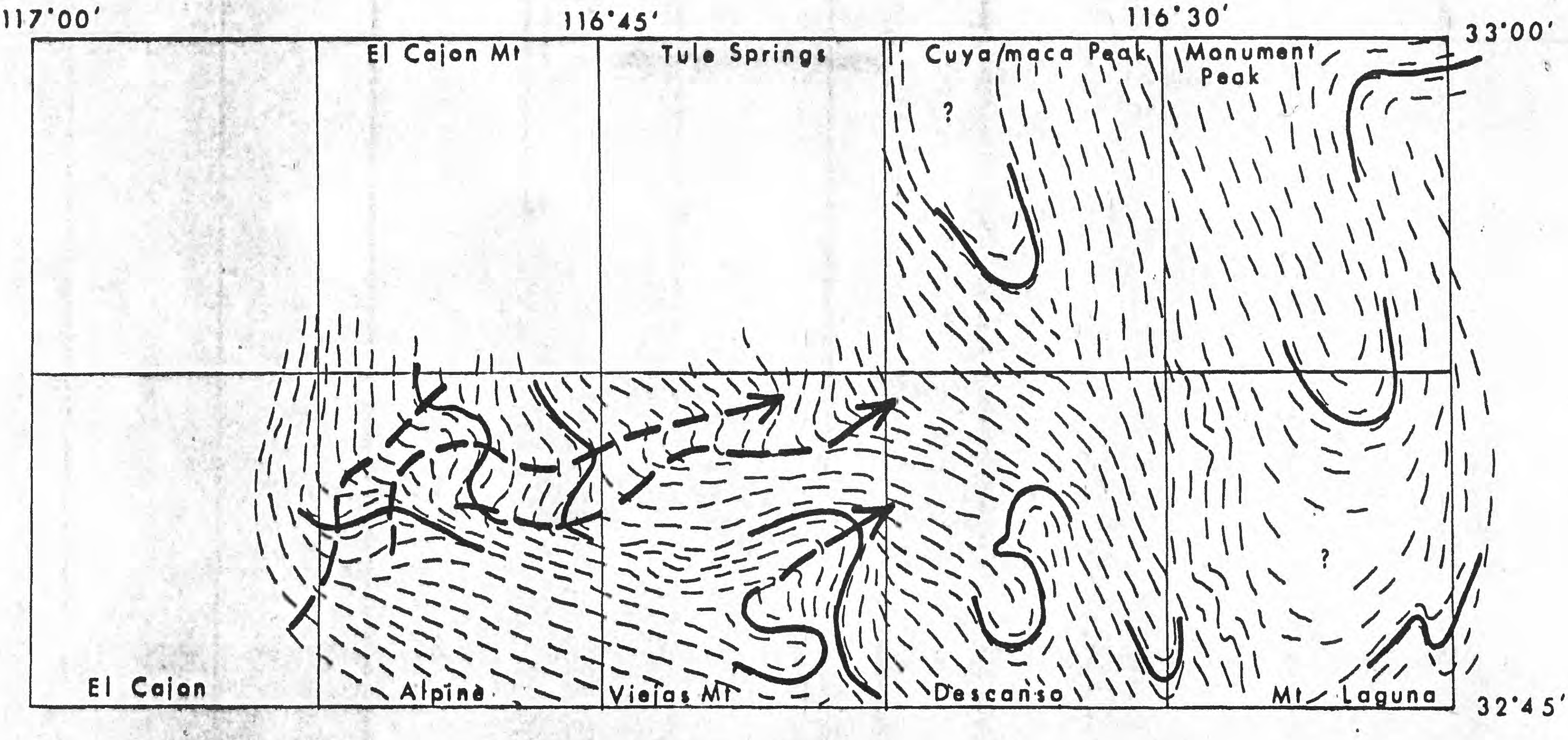


Figure 6. Sketch map of major Cretaceous structural trends in part of project area. Light dashed lines are generalized contact and foliation trends in plutonic and prebatholithic rocks. Heavy dashed lines are conjectural axes of NE-plunging folds. Heavy solid lines outline small fold forms (10-15 kms^2) mentioned in text. Regional dips (not indicated) are steep to north, northeast and east.

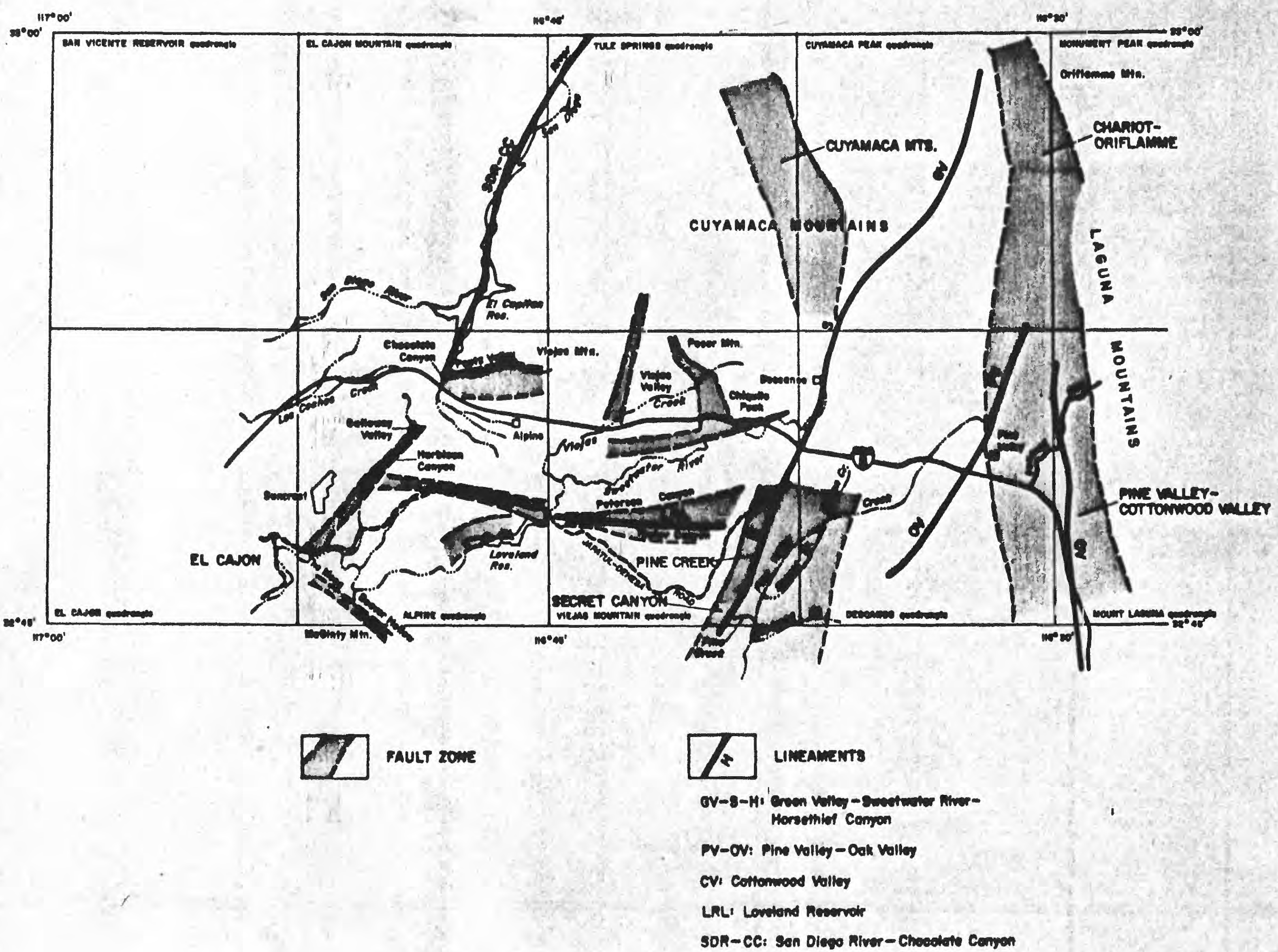


Figure 7. Index map showing lineaments, fault zones and geographic features.