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GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE VIEJAS 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.

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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, begun in 1974, 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 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 Viejas Mountain quadrangle is the fourth of this series.

Introduction:

The Viejas Mountain 7 1/2′ quadrangle lies within the mid-Cretaceous Peninsular Ranges batholith of southern California and Baja California (Fig. 1). Ten plutonic units have been differentiated within the project area and informal names have been assigned to avoid confusion with earlier nomenclature. Five of the units were not recognized previously and published names for rocks in the study area included one or more of these five units. The name Cuyamaca Gabbro (Everhart, 1951) has been retained. An eleventh bedrock unit consists of metasedimentary rocks of uncertain age which occur as roof pendants and septa in the batholith.

Previous usage has been followed in referring to the ten rock units as plutonic, even though all of the rocks in this part of the batholith have undergone dynamothermal metamorphism. The plutonic rocks are 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 solid-state flowage at elevated temperatures. Foliation is locally concordant with plutonic contacts, but commonly crosses contacts and, therefore, is in part younger than the intrusion of the igneous rocks. Where noted by earlier workers, foliation was considered to be a primary igneous structure or protoclastic structure. The foliations form a regional tectonite fabric which is concordant with that of the metasedimentary wall rocks. The metamorphism of the wall rocks was thought to pre-date emplacement of the batholith in this area (Everhart, 1951). Preliminary results of the present study 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 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, so that many outcrops had to be examined before consistent plutonic age relationships were worked out. The prevalence of these anomalous contacts indicates that the entire batholith remained mobile throughout emplacement. The presence of mutual chilled margins and quenched dikes suggests a continuing magmatic component of mobility, 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 discussed below and their overall intrusive sequence is depicted in the map legend. Modal data for the plutonic units is given in Figure 4. The following discussion is based in part upon observations of rock units and contact relations in the surrounding quadrangles, which are shown in Figure 5. The bedrock units are overlain locally by unconsolidated Quaternary deposits.

Metasedimentary rocks.--Metasedimentary rocks (TRm) in southern San Diego County consist, in order of abundance, of 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. Fine-grained black amphibolite intercalated with the metasedimentary rocks may be meta-basalt or meta-basaltic tuff. 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. Cross-bedding and graded beds were observed locally but deformation generally has obliterated sedimentary structures.

In the Viejas Mountain quadrangle, contacts between the widespread Klb plutons and TRm bodies are marked by migmatite zones as much as 0.5 km wide consisting of rock which is compositionally and texturally heterogeneous. The migmatite grades from granitic rock containing variably assimilated but recognizable metasedimentary inclusions, through various hybrid rocks locally displaying chiefly igneous or metasedimentary character, to metasedimentary rock with granitic layers (probably concordant dikes). The thickness of layers within the migmatite, commonly greater than several cms, and their association with plutonic contacts indicate that they are injection migmatites. They probably originated as intrusion breccia, between Klb plutons and TRm wallrock, which remained at metamorphic temperatures during regional deformation.

Most of the metasedimentary component in the migmatite consists of calc-silicate minerals--epidote and garnet in intact inclusions, hornblende and plagioclase in banded assimilated inclusions. Calc-silicate rock appears to be more abundant in the Viejas Mountain quadrangle than in the Cuyamaca Peak and Descanso quadrangles.

Although complex in detail, the migmatitic rocks include a number of distinctive lithologic and textural varieties which can be recognized even when contacts between Klb and TRm are covered by vegetation, as in the quadrangles to the north where float of 5 or 6 of these rocks may occur in one place.

Where TRm contains abundant granitic gneiss layers, a schematic pattern of lensoid bodies has been superposed on TRm on the geologic map. In some cases the granitic gneiss consists of recognizable Klb dikes which can be traced into nearby Klb plutons. Locally, the granitic gneiss resembles Kcr. Where the granitic material is intimately intercalated with TRm its origin is not clear and therefore it has been called simply granitic gneiss.

<u>Cuyamaca Gabbro</u>:--The name Cuyamaca Gabbro was applied by Everhart (1951) to the large 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 data of the present study agrees with 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 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 Kc bodies are screens surrounded by sheeted complexes of younger granitic rocks. Thus, the present outlines of gabbro bodies and their distribution do not necessarily reflect either the original extent of gabbro or the original shapes of gabbro plutons.

The Cuyamaca Gabbro appears to be deformed and recrystallized. All gabbro observed in the Viejas Mountain and surrounding quadrangles is strongly foliated and in most cases apparent primary compositional layering is parallel or near 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, foliation is concordant with regional foliation. It is more complex in the interior parts of the bodies where it may parallel regional foliation, but also shows swirling patterns. Mapping in the well-exposed rocks of the Viejas Mountain quadrangle suggests the presence of flexures having near-vertical axes which might explain the perturbations in the strike of gabbro foliation. Foliation within the gabbro, and by inference, the apparent primary layering, appear to have formed by solid-state flowage.

One reason for ambiguity over the age of Cuyamaca Gabbro is that locally the unit has broad, fine-grained and porphyritic margins against younger granitic plutons. Thin sections of gabbro from these areas 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. 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. The intrusion breccia grades into highly contaminated margins of granitic plutons which contain abundant, large, fine-grained gabbro inclusions. Although the intrusion breccia is younger than Kc, it is shown on the map by a block pattern superimposed on Kc because 1) fine-grained gabbro makes up most of the rock, 2) the zones of intrusion breccia grade into gabbro complexly and commonly cannot be mapped as separate zones, and 3) the granitic matrix may have as its source Kcp, Kpv, Kcm or Klb.

Locally, gabbro intruded metasedimentary rocks to form a zone of intrusion breccia consisting of a matrix of fine-grained gabbro surrounding variably assimilated metasedimentary inclusions. It was thought that granitic plutons might have utilized these zones during intrusion with the result that fine-grained Kc is in contact with younger granitic rocks. Inclusions of metasedimentary rock do occur in many intrusion breccia zones between Kc and granitic plutons, but there are places where no metasedimentary rocks appear to be involved and where gabbro grain size decreases systematically as contacts with granitic plutons are approached. Fine-grained gabbro dikes emanating from Kc plutons cut the intrusion breccia zones surrounding most of the large gabbro bodies in the project area. Such dikes also cut units as young as Kpv. This suggests that parts of Kc plutons remained slightly above the solidus while younger granitic plutons were below the solidus. In many places, fine-grained gabbro bodies cannot be distinguished in the field from the fine-grained mafic dikes (Kmd) which cut all units. All of the Kmd dikes may be late Kc dikes.

Tonalite of Las Bancas:--The tonalite of Las Bancas (Klb) is a widespread unit in the project area. The unit was formerly called Green Valley tonalite (Everhart, 1951). It is dark gray on fresh surfaces and weathers to a reddish or buff-gray color. Typically, the tonalite forms extensive, low bouldery outcrops. The unit has few mafic inclusions in the Descanso quadrangle where it was first described. There it is homogeneous and underlies a broad plateau at about 1200 m named Las Bancas. Klb has complex contacts with ℞m, Kc and granitic units marked by intrusion breccia and contamination-assimilation reactions. Locally, injection migmatite occurs between Klb and ℞m. Klb has a fine-grained margin against Cuyamaca Gabbro in a few places and it is intruded by Kcp, Kcr, Kcm and Kmd.

The tonalite of Las Bancas is a medium-grained gneissic rock, approximately equigranular, with lenticular recrystallized mafic aggregates. Locally it carries 1 cm poikilitic biotite or hornblende grains. The rock has 15-20 percent quartz, traces of K-feldspar, relict zoned phenocrysts of andesine to labradorite, and a color index ranging from 25-30 percent. The reaction sequence of the mafic assemblage is opx -> cpx -> olive-green hornblende -> yellowish-brown biotite. 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. These igneous reaction tectures have been modified by recrystallization.

The extensive Klb plutons have compositional and textural varieties which appear to grade into one another. In any one area these varieties may be very difficult to distinguish with certainty, but over a large area the rocks are sufficiently different-looking so that in the past different names have been applied to different parts of a single pluton. The variables are proportions of minerals, grain size and shape, and amount of mafic inclusions. Figure 6 portrays the major variations within the unit in a very general way. Locally, some of the variation may be apparent, relating to local differences in weathering characteristics. Also, outcrops in areas that have been completely burned over during forest fires present a very different appearance from adjacent unscorched rock.

In addition to the Las Bancas tonalite, four types have been distinguished in the field: the Alpine type, the Japatul type, a leucocratic Japatul type, and a very mafic tonalite seen only in the area north of Loveland Reservoir. All are shown as Klb on the geologic map. The contacts between different varieties of tonalite, although gradational, commonly are marked by septa of TRm and large dikes of Kcm. Locally, a sharp contact occurs.

The tonalite in and around the town of Alpine has abundant mafic inclusions and is 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 relicts of assimilated inclusions. Subhedral plagioclase is common, and locally hornblende is subhedral too. In general, mineral grains and aggregates appear recrystallized, and the rock has a strong gneissic texture. It grades into the Las Bancas tonalite to the east, and into Japatul-type tonalite to the north and southeast. In the area north of the Sweetwater Canyon, the tonalite carries fine-grained pink- to tan-weathering inclusions (TRm?) as well as black mafic inclusions.

North of Loveland Reservoir, the tonalite is dark gray to black, unusually mafic and superficially resembles gabbro. It has very little quartz and may be in part diorite in composition. Hypersthene is a prominent constituent. The dark tonalite is full of fine-grained, pink- to tan-weathering inclusions which are dark gray on fresh surfaces. These inclusions are partly hornblendized, particularly around their margins. This rock is very similar to Klb near the large Kc body north of Corte Madera Mountain in the Descanso quadrangle, where the marginal part of the Klb pluton contains abundant gabbro and TRm inclusions and is contaminated locally to gabbro composition. The northern contact of the dark tonalite in the Viejas Mountain quadrangle with the Alpine tonalite coincides approximately with a septum of TRm. To the east, it grades into Alpine tonalite.

The Japatul tonalite is best seen in the southeastern part of the Viejas Mountain quadrangle, where it was named for Japatul Valley. Identical tonalite occurs in the Tule Springs quadrangle to the north, and the Japatul tonalite can be traced continuously eastward into the Descanso quadrangle where it apparently grades into Las Bancas tonalite but is largely separated from it by Kc and TRm bodies. The tonalite of Japatul Valley is distinctly different from the Las Bancas rock. The Japatul tonalite is lighter in color, This rock association is important because it suggests a genetic relationship between tonalite and quartz monzonite magmas (Klb and Kcp). The leucocratic Japatul rock is indistinguishable in the field, and probably 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, clean Kcp quartz monzonite. Thus, Klb and Kcp seem to be in part coeval and in part, quartz monzonite is younger than tonalite. Kcp consistently intrudes the Las Bancas-type tonalite. If the contaminated Kcp is re-interpreted as being part of Klb, and keeping in mind that the stippled Klb areas on the Viejas Mountain quadrangle are in part Kcp, then the quartz monzonite 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 TRm zones may be remnants of screens that once separated closely-related pockets of differentiating magma.

Hybrid gneiss of Harper Creek:--The hybrid gneiss of Harper Creek (Khc) is a gray and yellow-weathering, cordierite- and sillimanite-bearing, quartz-biotite-plagioclase-K-feldspar/muscovite gneiss with a well-developed dynamothermal metamorphic texture. The unit, which is remarkably homogeneous over large areas, includes rocks that closely resemble Kcr in the field as well as rocks that are clearly metasedimentary in origin. Khc contains abundant metasedimentary inclusions, up to several meters in length, as well as evenly and closely spaced micaceous lenses, several cm long, which grade into partly assimilated metasedimentary inclusions. These inclusions, plus the high proportion of quartz and mica attest to the rocks's partial sedimentary origin. Local relict igneous textures and gradation into Kcr indicate that the Khc unit originated by mixing of Kcr and TRm enhanced by deformation and metamorphic temperatures that existed both before and after emplacement of Kcr. In some samples of hybrid gneiss muscovite has replaced K-feldspar. In a few places, Khc has intruded plutons which indicates that the rock was locally as mobile as the plutonic units.

The hybrid gneiss is not migmatite, although migmatite does occur locally at contacts with TRm. These contacts may be sharp, or may be marked by alternating layers of Khc and TRm that are too small to be depicted at the map scale. Contacts between Khc and Kcr may be gradational or sharp. Where they are gradational, Kcr is fine-grained and contains abundant partly assimilated inclusions of TRm. This rock is interpreted as chilled margins and/or dikes of Kcr plutons which were originally in contact with metasedimentary rock. Elsewhere, Kcr is interlayered with Khc near the contact. Whatever the origin of this unit may be, it is always spatially associated with Kcr and TRm and for this reason, is probably essentially coeval with Kcr.

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. Many are fine-grained, but some inclusions are peppered with subhedral plagioclase grains and a few are gabbroic. Locally, inclusions of Las Bancas-type tonalite were seen. Characteristic of the rock are single subhedral plagioclase 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 Alpine varieties. However, the rock is strongly foliated and the subhedral grains are alined parallel to the regional foliation.

The Japatul tonalite grades into, and appears to be intruded by, a more leucocratic rock, typically inclusion-free, texturally identical to the tonalite but ranging to quartz monzonite in composition. The leucocratic variety is always found in association with Japatul-type and TRm injection migmatite zones. It is shown on the geologic map by a stipple pattern in Klb and where calc-silicate rock is an appreciable constituent, a pattern of flattened ellipses has been superimposed on Klb. The distribution of these rocks is shown only grossly on the map for they are interlayered complexly on both large and small scales. The following lithologies are always present:

1) Japatul-type tonalite.
2) leucocratic Japatul rock, locally granodiorite (or quartz monzonite); south of Poser Mountain leucocratic rock occurs both as medium- to coarse-grained gneissic granodiorite layers and as widespread large, concordant, chilled granitic dikes.
3) TRm, typically calc-silicate, as partly assimilated inclusions, and as migmatite with an aplitic 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.
5) heterogeneous (grain size, mafic content), schlierically layered rock, apparently modified Japatul-type tonalite.
6) minor Kc

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 aplitic matrix.
2) interlayered
3) gradational
4) inclusions of Japatul-type tonalite in aplitic 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 shclierically mixed with Japatul and TRm rocks.

Granodiorite and tonalite of Cuyamaca Reservoir:--The area of outcrop of the granodiorite and tonalite of Cuyamaca Reservoir (Kcr) is small in the Viejas Mountain quadrangle, but the unit underlies larger areas in the northern and eastern parts of the project area. Because of this and the fact that Kcr is intruded by younger plutons, it is difficult to determine the original shapes of Kcr plutons solely from exposures in this quadrangle. Kcr is interlayered with younger units in sheeted fashion around older plutons. The rock weathers to reddish and yellowish-tan and is light to dark gray on fresh surfaces depending upon its mafic content, which ranges from 14-29 percent. Locally, Kcr contains abundant fine-grained mafic inclusions that are flattened parallel to foliation. These occur where Kcr is in contact with Kc and the tonalite is unusually mafic here. Although changing compositionally from tonalite to granodiorite, the unit is texturally homogeneous and the two compositional varieties seem to grade into one another. The rock's texture is fine to medium-grained, very gneissic and, on the average more deformed than the other plutonic units. In thin section, Kcr shows some of the most strained and recrystallized igneous textures of all units.

All samples of Kcr contain some K-feldspar, the plagioclase is andesine, greatly modified by recrystallization, and pale reddish-brown biotite is the chief mafic mineral. Some samples contain no hornblende, others show a few hornblende relicts within biotite aggregates, but in most rocks intergrowths of actinolite and epidote have replaced hornblende. The chief accessory minerals are allanite and sphene. The mineralogical and textural differences between Kcr and other granitic units may be related to intimate mixing of the Kcr unit with metasedimentary rocks. The granodiorite and tonalite are especially gneissic, locally porphyroclastic and mylonitic, next to large bodies of metasedimentary rock. Here the unit contains abundant partly assimilated inclusions of TRm and is rich in mica. Fine-grained granodiorite and tonalite may grade into Khc which locally occurs as sheets between Kcr and TRm.

A noticeable decrease in Kcr grain size occurs 1 to 2 meters from contacts with gabbro (Kc) and tonalite of Las Bancas (Klb) suggesting that Kcr is younger. Many of these contacts are poorly exposed so these age relations must still be considered tentative and subject to re-interpretation with further mapping.

Quartz monzonite and granodiorite of Chiquito Peak:--The quartz monzonite and granodiorite of Chiquito Peak (Kcp) is a medium-grained, strongly foliated, white-weathering rock with color index ranging from 5-12 percent. The plagioclase feldspar is oligoclase 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. Although the unit forms at least two fairly large plutons (north of the town of Descanso), it typically was emplaced in a series of steeply-dipping, interconnected sheets and lenses.

The quartz monzonite and granodiorite 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 quartz monzonite is in contact with metasedimentary rock, Kc, and Kem. The contamination and post-intrusive deformation have given rise to complex hybrid zones between these plutons. A contaminated quartz monzonite category has been used (dashed pattern) to designate parts of Kcp plutons which are particularly inclusion-rich and contaminated. These rocks are intimate mixtures of quartz monzonite, granodiorite, and tonalite representing both contaminated quartz monzonite and mafic inclusions which have been almost completely assimilated. These zones are closely associated with mafic plutons and stoping of mafic plutons (both older and younger than Kcp) has probably been a factor in the origin of the heterogeneous zones. As discussed in the section on Klb, the inclusion-rich Kcp closely resembles the leucocratic facies of Japatul tonalite.

A textural variety of Kcp 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 Kcp.

A quartz monzonite with color index ranging from 2 to 7 percent, locally no hornblende and slightly more quartz than the average Kcp grades into and intrudes the more mafic quartz monzonite and granodiorite. For example, the rock which underlies Stonewall Peak is leucoadamellite with abundant 1 to 2 cm relict euhedral K-feldspar grains. Some of the leucocratic Kcp is alaskite and aplite that locally resembles the leucocratic facies of the younger quartz monzonite and granodiorite of Pine Valley (Kpv).

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 Kpv.

Quartz monzonite and granodiorite of Pine Valley:--In plan view the quartz monzonite and granodiorite of Pine Valley (Kpv) forms large (several km across), discrete plutons which are relatively inclusion-free and uncontaminated compared to Kcp. The unit has been emplaced in steeply-dipping sheet-like bodies.

The rock is white-weathering and underlies highlands. It is chiefly coarse-grained quartz monzonite with color index ranging from 5 to 10 percent. 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 that occurs as relict, euhedrally zoned grains. Prominent accessory minerals are sphene, allanite, and epidote. In the Arroyo Seco area (Cuyamaca Peak quadrangle) and in the town of Pine Valley (Descanso quadrangle) the rock contains white, relict euhedral K-feldspar grains 2 cm long and has sub-porphyritic texture. Everywhere, elongate, gray, 2 to 3 cm recrystallized quartz lenticles, probably relicts of large igneous grains, are characteristic of Kpv. The unit locally has chilled margins against, and sends dikes into, all units except Kem, which it locally intrudes synplutonically. The unit is strongly foliated.

Quartz monzonite and granodiorite of Corte Madera:--The quartz monzonite and granodiorite of Corte Madera (Kcm) appears to be a leucocratic variant of Kpv which crops out in the Descanso and Viejas Mountain quadrangles. Although Kpv and Kcm are not shown in contact on these two maps, small amounts of Kpv occur locally in Kcm plutons in a gradational relationship to Kcm. Both Kcm and Kpv are coarse-grained and have elongate gray quartz lenticles up to several cm long. Kcm has the same age relationship to other units as Kpv and typically occurs as sheets in older plutons. The chief difference between Kcm and Kpv is that Kcm has a lower average color index than Kpv. Most parts of the Kcm bodies are leucoadamellite, leucogranodiorite or leucogranite. Kcm and Kpv are probably closely related to one another because of the 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 (Kld) of pegmatite, alaskite and aplite occur in all units. In some areas they can be traced into plutons of Kpv, Kcm or Kcp. Where no association with larger bodies was established, the dikes have been mapped separately. These dikes share the metamorphic fabric of the other plutonic rocks.

Tonalite, quartz diorite and gabbro of East Mesa:--The tonalite, quartz diorite and gabbro of East Mesa (Kem) is the most heterogeneous plutonic unit. In the plan view the sizes and shapes of Kem bodies vary because the unit has intruded older plutons in multiple sheets which have moderate to steep dips. The sheets are interconnected and commonly are localized along older contacts.

Tonalite and quartz diorite form the major part of the unit. The rocks are typically dark gray, fine- to medium-grained, and locally sub-porphyritic with relict subhedral phenocrysts of plagioclase and hornblende. A common textural variety has a spotted appearance due to poikilocrysts of biotite in a fine-grained groundmass. Pale tan to green hornblende is either the dominant mafic mineral or is about equal in abundance to pale reddish-brown biotite. Color index decreases in a regular manner as modal quartz increases. Color indices of quartz diorite samples range from 35 to 50 percent, while those of tonalites range from 25 to 35 percent. In some samples, hornblende has been altered to actinolite and biotite to chlorite. Relict phenocrysts of plagioclase show stong oscillatory zoning with calcic cores. Medium-grained Kem carries abundant, fine-grained mafic inclusions, less than one foot long, some of which are elongate parallel to foliation but many of which are angular or irregularly shaped blocks. Typically, these are only slightly darker than the host rock and therefore have a "faded" appearance.

Dark gray quartz diorite locally grades into fine-grained black dikes, some with scattered plagioclase relict phenocrysts and others choked with relict euhedral plagioclase grains.

A more leucocratic, sub-porphyritic variety of the Kem unit in the southern part of the Descanso 7 1/2′ quadrangle intrudes dark gray to black Kem. Distinctive pale greenish-white aplite dikes cut this leucocratic variant. This leucocratic rock occurs as dikes in Klb in the Viejas Mountain quadrangle.

Kem whose hornblendes enclose pyroxene cores (opx => cpx) grades into the less abundant gabbro of the unit. The gabbro is generally fine- to medium-grained and cannot be distinguished in the field from small bodies of fine- to medium-grained Kc. The distribution of tonalite, quartz diorite and gabbroic rocks within the Kem plutons shows no regular pattern. Although these plutons were not studied in detail, internal contacts were seen locally and undoubtedly the history of the unit is complex.

The Kem unit sends dikes into and has chilled margins against all plutonic units except Klb and Kmd. Kem is locally continuous with, and also cut by, dikes of Kmd. Locally, age relations are reversed where host rocks have intuded Kem (Fig. 3). This is especially true where Kem intrudes Kcr and Kcp. In the southeastern part of the Descanso quadrangle, these three units are intimately interlayered, their contacts have been deformed, and granitic rocks and Kem have been contaminated by one another. A stippled map pattern for Kem indicates that it contains up to about 50 percent of granitic inclusions, chiefly quartz monzonite.

The Kem bodies are strongly foliated, especially near their margins. The Deer Park body in the eastern part of the Cuyamaca Peak quadrangle, for example, consists almost wholly of mylonite gneiss.

Well-exposed outcrops in the southeastern part of the Viejas Mountain quadrangle suggest a gradational relationship between Klb and Kem. Dark, fine- to medium-grained rocks in Horsethief Canyon were first identified as Kem but then were observed to grade westward into Japatul-type tonalite and eastward into Las Bancas tonalite. In Horsethief Canyon, this dark tonalite intrudes large bodies of black mafic rock ranging from medium-grained gabbro in the central parts of larger bodies to fine-grained mafic rock near margins and in smaller bodies. Elsewhere, such bodies have been called Kmd, but their close spatial relation with the frayed western margin of the large gabbro body north of Corte Madera Mountain suggests that they may be late Kc dikes. The tonalite apparently has stoped inclusions from these mafic bodies and is noticeably darker in these areas. It also forms networks of chilled, isoclinally folded dikelets in the mafic bodies. The dark tonalite is cut by large Kcm dikes but also intrudes Kcm locally as dikes with chilled margins and it carries inclusions of Kcm.

It can be seen from Figure 4 that Klb and tonalitic rocks of Kem overlap in modal composition. The few chemical analyses available at this time indicate that they are indistinguishable chemically. Where Kem tonalite is medium- to coarse-grained with color index 25 to 35 percent, it is very similar to the Japatul-type tonalite. Everhart (1951) noted this similarity between these rocks, which he called Green Valley tonalite and Cretaceous diorite, and suggested that they were the same. The chief reason for mapping two units in the present study was that the rocks called Kem consistently intrude the quartz monzonite units, Kcp and Kpv, whereas Klb plutons are intruded by the quartz monzonites. Also, Kem and Klb tend to be mutually exclusive in their areas of outcrop. In the few places where they are in contact, the two units appear to grade into one another. This gradation is similar to contacts between the medium- to coarse-grained, more leucocratic-appearing Kem tonalite and the fine- to medium-grained darker Kem rocks.

The Kem bodies may be large, late-stage, marginal dikes of Klb plutons. Some dark-appearing Kem rocks are modally identical to the lighter tonalites and their higher color index is due solely to their finer grain size. Other dark rocks are quartz diorites, suggesting that the later, marginal phase of Klb was somewhat more mafic. Another possibility is that the dark fine-grained Kem rocks are a hybrid formed from Klb and Kc. Until chemical analyses are available, bodies which crosscut quartz monzonite plutons will be designated Kem and those which are intruded by quartz monzonite will be called Klb. However, parts of Kem bodies may actually be composed of Klb.

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 map scale. The dikes are dark gray to black, mostly fine-grained to very fine-grained, but some have fine- to medium-grained centers with chilled margins, while others are variably porphyritic. The dikes consist of plagioclase, hornblende, biotite, sphene and traces of quartz, and overlap Kem in modal composition. Their textures are dynamothermal metamorphic, 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 were undeformed. The dikes are abundant in the vicinity of bodies of Kem, and locally grade into these bodies. They also cut Kem, and locally crosscut one another. They are also abundant near the margins of all of the large Kc bodies mapped to date. Here the dikes consist in part of gabbro and in several places appear to emanate from the Kc bodies. For this reason, they may all be late Kc dikes. Although in some places the mafic dikes crosscut regional foliation, for the most part the largest dikes were emplaced concordant to foliation. 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 a synplutonic relationship with their host rocks. Most of the dikes are highly deformed; many are pulled apart and resemble inclusions. They typically contain folded bodies of aplite that in some cases are continuous with the granitic host rock but mostly are not.

Surficial deposits:--Surficial deposits have been divided into alluvium, colluvium and landslide materials. Although most of the deposits have not been dated, they are probably Quaternary in age. Alluvium (Qal) consists of gravel, sand, silt and clay in stream valleys and meadows. The alluvium in stream valleys consists of 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 6 meters. A preliminary C^{14} age of 920 $\pm$ 60 years B.P. has been obtained on charcoal from one of the lowest exposed beds in older alluvium in Pine Valley (Stephen W. Robinson, U.S. Geological Survey, Menlo Park). This data indicates only that the older alluvium is no older than 920 $\pm$ 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. This was found to be generally true throughout the mapped area. 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 6 m or less. Fine-grained sediments in the high meadows probably formed in situ by chemical weathering in addition to minor stream deposition. These sediments are being stripped from the meadows by headward-cutting gullies and most meadows contain bedrock exposure.

Colluvial deposits, Qc, consist of poorly sorted sand, silt and gravel mixtures and formed by slopewash; they grade into bouldery deposits that fill small, steep valleys. The latter are probably debris flow deposits and locally, they form topographic ridges which are being eroded by modern gullies. Colluvial deposits have been mapped only where they are thick enough to completely obscure bedrock outcroppings over a large area. Thick colluvium deposits commonly are associated with fault-steepened topography. In general, their thickness is no more than a few meters, indeed, most slopes are bedrock which is essentially bare of colluvium or soil.

In the Viejas Mountain quadrangle, a soil profile has developed on weathered tonalite (Klb) of valleys and in swales in higher ground. It consists of less than one meter of unindurated, red-brown, poorly sorted sand (colluvium) lying over a light gray to green (calichified?) layer also less than one meter thick. The entire soil is somewhat thicker than one meter and is underlain by weathered Klb. Locally, the soil has been gullied to expose bedrock.

Landslide deposits (Qls) are of the slump and rockslide type and occur in terrain which has been oversteepened by faulting or erosion subsequent to

Structure of batholithic rocks:

The plutonic units occur as steeply dipping sheets and lenticular bodies which are separated locally by screens of metasedimentary rock. The sheets, lenticular bodies and screens range from a few meters to several kms in thickness and the larger ones continue for tens of kms 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 bodies, of ₮m 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 seen in any one 7 1/2′ quadrangle. Successive intrusions parallel to this structural grain have resulted in stratiform complexes of 3 to 4 units. The structural grain varies over the project area. In the Cuyamaca Peak quadrangle, it is predominantly eastward, with the exception of the eastern margin of the Cuyamaca Mountains gabbro body whose walls dip inward. 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 stongly to the northeast. 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 dips 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 part, east-striking contacts dip northward (irrespective of local attitudes). East-striking contacts in the southern part of the quadrangle are essentially vertical. The swing to northerly trends is probably part of a structure larger than this quadrangle. The foliation pattern is complex in the area of the two Kc bodies, Viejas and Poser Mountains, where at first sight it seems that foliation in the younger Klb pluton resulted from flowage around the gabbro bodies. But, as suggested in Viejas Mountain and more obvious in Poser Mountain, the gabbro foliation is approximately concordant with that of the surrounding granitic rocks and therefore both are probably the result of some regional factor. The shapes of the two gabbro bodies also conform to the northerly structural trend. The distribution of metasedimentary screens and zones of abundant ₮m inclusions in Klb in the vicinity of the gabbro bodies indicates that their present margins are close to the original ones. The interpretation of foliation trends within the Kc bodies is complicated by locally dense vegetation which covers them and the fact that two foliations are present locally. One is sub-parallel to compositional and textural layering and the second, rarely seen, is discordant and near vertical. Both appear to have involved mineral recrystallization.

Locally, plutonic contacts and foliation describe large fold forms about steeply plunging axes. Several of these large 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 ₮m and Kcr occurs in the center of the map; a second, involving Kc, Kcp and ₮m lies south of it. It is not clear at this time whether these structures are tectonic, i.e., systematic folds, or relicts of local deformation due to plutonic intrusion. Probably, they are the result of a combination of the two processes. Several of these large fold forms occur in the Viejas Mountain quadrangle, e.g., an S-shaped one in the south-central faulting. The landslides are small (50-250 m wide) and are characterized by steep scarps, which are freee of colluvium and vegetation, above the landslide deposits.

Summary:--The data of this report suggest that rock units which are distinctly different in the field and which differ petrographically may be very closely related, in part coeval. Thus, in some areas relatively sharp contacts among Klb, Kcp and Kem plutons can be mapped with no ambiguity. Elsewhere, these units seem to grade one into another and clearcut contacts cannot be mapped at this 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, cannot be applied here. Yet there is order in the data and the same contact and age relations are seen consistently throughout a large area.

If the Peninsular Ranges batholith in this region consisted of a differentiating magma held at metamorphic temperatures for a long period of time during regional deformation, it might have resembled a gigantic "stewpot", in which early ingredients remained capable locally of interacting magmatically with later ingredients. One might expect the above kinds of complex interplutonic contacts and ambiguous age relations to occur. Detailed studies of specific plutonic problems and other kinds of data such as geochemistry are necessary to substantiate or amend this picture.

part and another apparent flexure in the east-central part. The fact that foliation in the metasedimentary screens is folded along with plutonic contacts and foliation suggests that these structures are tectonic in origin. Yet, the distribution of TRm and Kc in the east-central part of the map suggest a pushing-apart of these screens and remnants by intruding magma and/or metamorphically-flowing solid rock, and the growth of cells or pods of granitic rock. These cells or pods occur in the hinge areas of the folded TRm screens which may have been preferred sites initially for emplacement of magma. Magma also pried apart TRm screens parallel to layering. If TRm screens and zones of TRm inclusions in Klb plutons are traced throughout the quadrangle, they appear to be parts of an once-continuous body which suggests that intrusion has been an important agent of deformation. The impingement of these folds upon one another suggests a condition of unsteady flow rather than systematic tectonic folding. The above would seem to be exactly the conditions expected to result from syntectonic intrusion.

Locally, the dips of plutonic contacts appear to be gentle to moderate, e.g., the contacts 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 dips more steeply than plutonic contacts. Steeply-dipping foliation can be traced from the host rock, Khc, into Kcm dikes and back into Khc, crosscutting contacts at a high angle. Thus deformation continued after intrusion. The presence of both steeply- and moderately-dipping leucocratic dikes makes for a very complex outcrop pattern with many small, irregularly-shaped screens and remnants of TRm and Kc. This area is even more confusing because of the meeting of east and north-south structural trends.

The dips of plutonic contacts may appear less steep than they truly are because of a combination of the sheeted style of intrusion and poor exposure (dense vegetation). Apparently, magma moved upward utilizing steep planes of weakness such as bedding in ℔m, and interplutonic contacts, and older plutonic rocks tend to occur as screens which are underlain by and separated by younger plutonic rock. Where the present level of erosion is close to the highest level to which a younger magma intruded (and therefore to the keel-shaped bottoms of screens of ℔m and older plutonic rocks), valleys expose chiefly the underlying, younger plutonic rocks. If exposure is limited, an approximate contact drawn between the younger plutonic rock and the host rocks may cut across many thin screens and thus appear flatter than it truly is.

If, as seems likely, the Cuyamaca gabbro is the oldest plutonic unit, then the present Kc bodies are not individual plutons but are remnants of original plutons. The distibution of ℔m remnants (probable wallrocks) in relation to Kc over the project area suggests that while some present Kc bodies coincide approximately with original plutons, others may not. The Cuyamaca Mountains body may be one of the former in which case it had a north-northwest-elongate shape originally. Younger granitic plutons apparently have divided the original gabbro plutons into a number of lobes--in the case of the Cuyamaca Mountains body, a northern lobe consisting of Middle Peak and North Peak, and a southern Cuyamaca Peak lobe. The gabbro body north of Corte Madera Mountain in the Descanso quadrangle also shows partial division into lobes by granitic plutons. This is particularly obvious in the southeastern part of the Viejas Mountain quadrangle where a ragged array of small gabbro bodies appears to be the western edge of the large body north of Corte Madera Mountain. Some of these small gabbro bodies appear to be synplutonic dikes in Kcm (T.16 S., R. 3 E., sections 3, 4 and 10) (structure section B-B^1). They are fine- to medium-grained, locally porphyritic, and have been re-intruded synplutonically on a small scale by surrounding Kcm. The rock is not different in the field from other small Kc bodies. Thus we seem to have two rock units involved in three stages of mutual intrusion!

Faults of the Viejas Mountain quadrangle:

<u>Viejas Valley faults</u>: Figure 5 shows fault zones and geographic features to be discussed. Viejas Valley may be a graben narrowing to the north. The eastern flank of Viejas Mountain is probably bounded by a north-northeast-trending zone of en echelon faults, the largest about 1.5 km long. This zone coincides approximately with the contact between Klb and Kc. Near the southern end of Viejas Mountain, the faults are expressed by a break in slope--steep slopes above aligned benches, the latter covered by thick colluvium consisting of large gabbro blocks and reddish soil. Colluvium has flowed downslope in a number of large lobes to cover the Klb-Kc contact. A good trail extends part-way up the east side of the mountain to an old prospect; above the Klb-Kc contact, but below the prospect, a rather wide zone of small, variably oriented faults, each marked by a few mm of gouge, crosses the trail (T.15S., R.3 E., sec. 19, north-central part). Measured fault trends are:

N-S east 79^{o}
N46E 90^{o}

The gabbro in the zone is hydrothermally altered and epidotized, principally along joints. This zone lines up with a lineament to the northeast marked by a sliver of Klb which separates low Kc hills on the east from Viejas Mountain. The fault zone passes northward through a linear valley into the Tule Springs quadrangle where it is marked by vegetation stripes and benches for many kilometers. It is not clear how far faults extend to the southwest, but the Klb-ꞀRm structure which partially wraps around the southern tip of Viejas Mountain appears to be grossly intact.

A number of parallel, linear vegetation stripes and scarplets cross the eastern foot of the mountain immediately above Viejas Valley. Some of these appear to offset colluvium. These lineaments have been queried on the geologic map.

If the present topography reflects the direction of displacement, then Viejas Mountain may have been uplifted relative to the valley. Other lineaments, trending north-northeast and east, can be seen on aerial photographs of Viejas Mountain proper, but no direct evidence of faulting was observed where these were crossed.

On the east side of Viejas Valley (west side of Chiquito Peak), many north-northwest-trending lineaments show up clearly on aerial photographs but only poorly on the ground, except from certain angles under certain light conditions. These are also parallel to geologic contacts and foliation and are associated with extensive colluvial deposits, here mainly Kcp blocks. The lineaments consist of west-facing breaks-in-slope, notches, poorly developed benches and vegetation stripes and some appear to have displaced colluvium. Two of the lineaments expose cataclastic and fractured tonalite, locally replaced by epidote and pink K-feldspar. One such zone is at least a meter thick. In its vicinity, thin leucocratic dikes have gougey margins.

The westernmost of these two faults appears to continue southward across the canyon of the Sweetwater River where it may offset a leucocratic dike right-laterally. No gouge was seen but the fault's possible extension is indicated by parallel, west-dipping breaks-in-slope almost bare of vegetation with thick red soil covering the tonalite below them, and an alined, straight reach of the river. The contacts immediately to the south are not offset. The side-canyons entering the river from the south are preferentially aligned in this north-northwest direction, which may represent a fundamental joint system in the Klb tonalite.

Another lineament on the west side of Chiquito Peak is marked on the ground only by an over-steepened bedrock slope covered with sand-sized soil undergoing vigorous erosion; cobble-sized and larger float blocks have accumulated below on a poorly developed bench. Other, similar lineaments expose nothing unusual.

Poorly-defined lineaments cross the south side of Poser Mountain (north-eastern margin of Viejas Valley). They swing from west-northwest on the south side through northwest to north-northwest on the west side of Poser Mountain and may represent a crossing of two structural trends--north and east. Gouge(?) was seen in only one place, but locally, Qc deposits appear to end against lineaments. Northwest lineaments in the valley itself appear to lie in Qal!

Most of these lineaments are not shown in the geologic map because of the complexity of the map pattern. They are shown, with Qc deposits, in Figure 7. Their origin is still under investigation.

Faults north of and parallel to the Sweetwater River:--There are many short, east-northeast-trending lineaments, approximately parallel to regional foliation, in the area between Interstate 8 and the Sweetwater River. They extend westward in a zone about 1.5 km wide from the southern base of Chiquito Peak and eventually merge with the river's course. Below Chiquito Peak, the lineaments are marked by vegetation stripes and brown-weathering, cataclastic granitic rock and slickensided surfaces. Colluvium deposits appear to end against the lineaments. South of Viejas Valley, the lineaments are chiefly vegetation bands, aligned notches, benches and gullies. Some are faults, but equally half of those checked expose no crushed rock. For those that do, many thin gouge zones occur typically along and in the vicinity of lineaments. A few measured features are

N48E	steep (80-85^{o}?)	- about 1 ft gouge
N59W	85-90^{o}	- 3-5 mm cataclastic, epidotized tonalite
N20E	88 SE	- 6-7cm gouge

slickensides plunge near-vertically down a polished plane trending N85W 80 SW

Some gouge is caliche-cemented. Lineaments which do not expose gouge consist of distinctive vegetation bands in red-weathering, hydrothermally altered tonalite which is highly gullied. In the town of Alpine, similar-trending lineaments cross Bell Bluff truck trail but no crushed rock was observed. However, two lineaments immediately west of the truck trail are faults, one a zone perhaps 6-7 m wide of brown, weathered, friable Klb containing at least two zones, 1-2 m each, of well-indurated, greenish-gray earthy breccia. One such zone trends N3E 89 SE. The second fault exposes more than 1 m of breccia and gouge in tonalite. Nearby a prominent lineament follows a porphyritic Kmd dike in tonalite that has been preferentially eroded.

Horsethief and Secret Canyons faults:--About a meter of breccia in the streambed in Secret Canyon in the southeastern corner of the Viejas Mountain quadrangle indicates that the Secret Canyon faults extend a short distance into the map area from the Descanso quadrangle. Several parallel lineaments on the hillside to the southeast may also be faults. The lowest of these exposes brown, friable Kc intrusive breccia with an anonymously thick soil cover. Two of these lineaments appear to offset thin Kcm dikes slightly in a left-lateral sense.

The east-striking fault which extends westward into the Viejas Mountain quadrangle from Espinosa Canyon in the Descanso quadrangle has a substantial gouge and breccia zone. This fault, or related breaks, may extend westward through Pine Creek to join 2 faults which cross the Horsethief Canyon truck trail (not shown on map). One of these continues up a linear gully to Japatul Rd. They are marked by light tan, earthy, well-indurated gouge with anastomosing seams of caliche. Colluvium lying over these faults is not displaced.

Several gouge zones within very disturbed tonalite are exposed in a roadcut along Horsethief Canyon truck trail comprising a sizeable fault in and approximately parallel to Horsethief Canyon (T.16S., R.3E.,sections 22 and 23). The fault does not appear to break the ground surface or its colluvial cover. The following gouge zones were measured (approximate strike):

N23W	78 SW	-about 0.5 m gouge
N60E	steep NW	-about 0.5 m gouge, slickensides and grooves on polished plane oriented N27E 83 SE plunge steeply down-dip
N30E	62 NW	-about 3 m gouge; slickensides plunge steeply down-dip and WNW

Breccia and a spring immediately to the north in the streambed mark the continuation of this fault.

Further north in Horsethief Canyon, an almost north-trending series of lineaments on the lower west wall of the canyon are defined by a distinct break in slope, fractured and locally brown-weathering Kcm, sparse float of cataclastic Kcm, with thick soil and gullying below the break in slope. No gouge was seen. Further north, black cataclastic Khc is exposed at several places along the streambed in thin zones parallel to the canyon.

The sinuous course of Pine Canyon is crossed by lineaments in three directions: north-northeast, northeast, and west-northwest. Almost all of these appear to be joints or erosion along foliation planes in Khc. Minor hydrothermal alteration is associated with some north-northeast-trending joints but there is no offset of leucocratic dikes. Most tributaries of Pine Canyon are sub-parallel to northwest foliation.

East-striking faults in the southern part of Viejas Mountain quadrangle:--The north wall of Taylor Canyon exposes a break in slope--steep, relatively fresh tonalite outcropping above a bench consisting of gullied, thick soil over weathered tonalite. The feature resembles a small scarp. No gouge was seen along the lineament, but the tonalite is brown-weathering and very friable where exposed. Several sub-parallel vegetation stripes are aligned with the lineament.

Similar lineaments were observed in the north wall of Peterson Canyon but here minor cataclastic tonalite was seen in float below the lineament. To the east, a lineament or lineaments forms a bench in Qc and continues eastward into tonalite. A patch of Qc about 2 m thick lying on tonalite may have been uplifted on the north side of this lineament. Vegetation stipes cross the opposite wall of the canyon.

The south wall of the canyon which strikes northwestward into Loveland Reservoir immediately south of Japatul-Dehesa Road exposes an en echelon series of northwest-trending benches that coincide in part with a geologic contact and are parallel to foliation. Anomalously thick colluvium covers bedrock on the benches. No crushed rock was seen at the break in slope above the benches. Cataclastic, epidotized tonalite is exposed locally in the valley below. A striking array of northwest-trending vegetation lineaments can be seen in the valley below. This entire zone strikes into the eastern arm of Loveland Reservoir.

Summary: Many of the lineaments discussed above cannot be tied unequivocably to faults and many of those which can be seen insignificant features when compared to some faults within the project area that expose thick zones of crushed rock. However, some of the lineaments appear to cross and offset Qc deposits which suggests that they are young features. This may explain why their crush zones are minor. In almost all cases, the faults are parallel or sub-parallel to foliation and geologic contacts, are individually short in length, and commonly are associated with hydrothermal alteration. They do not disrupt major geologic structures, e.g., the large fold forms in the southeastern part of the quadrangle are not offset where they are crossed by east-trending canyons. Possible exceptions are the faults in Horsethief Canyon which are discussed below. This suggests that the Peninsular Ranges block in this region has undergone many small adjustments to stress within the block following old planes of weakness. These commonly coincide with major geologic contacts, such as those between gabbro and granitic rocks. The relationship of some faults to colluvium and the fact that thick colluvium is practically restricted to faulted terrain suggest that some of these adjustments are geologically recent, possibly continuing to the present.

Relation of faults to large-scale linear features observed on high-altitude imagery:--Two large-scale lineaments occur within the quadrangle (Fig. 5). The Sweetwater River-Horsethief Canyon lineament has been described by Merifield and Lamar (1976) as the second most prominent linear feature on spacecraft photography of the Peninsular Ranges. The lineament extends northeastward from the international border approximately to the Elsinore fault zone, a distance of about 50 km. It consists of closely spaced, en echelon, approximately linear stream valleys. Although no single through-going fault has been found to coincide with this lineament in the Cuyamaca Peak and Descanso quadrangles, about 600 m of right-lateral flexure of geologic contacts in the Cuyamaca peak quadrangle is possible. Similarly, in the Horsethief Canyon segment in the Viejas Mountain quadrangle, no single through-going fault was found in the canyon or surrounding area, but there is a definite indication of right-lateral flexure of some contacts by a similar amount. This may be an old structural feature which has been reactivated by young faults.

The second prominent linear feature is named the Loveland Reservoir linear by Merifield and Lamar (1976) and described as "expressed by gently curving valleys continuing for about 10 km (6 miles) in a west-northwest direction." This feature coincides approximately with Taylor and Peterson canyons. En echelon to the Loveland Reservoir linear but beginning a few kilometers to the southeast is the Pine Creek Linear (Merifield and Lamar, 1976) which coincides with Espinosa and Pine Creeks. Faults have been found along the Pine Creek linear and they probably also occur in the vicinity of the Loveland Reservoir linear. As already stated, there is no one through-going fault and complex batholithic structure is not obviously offset.

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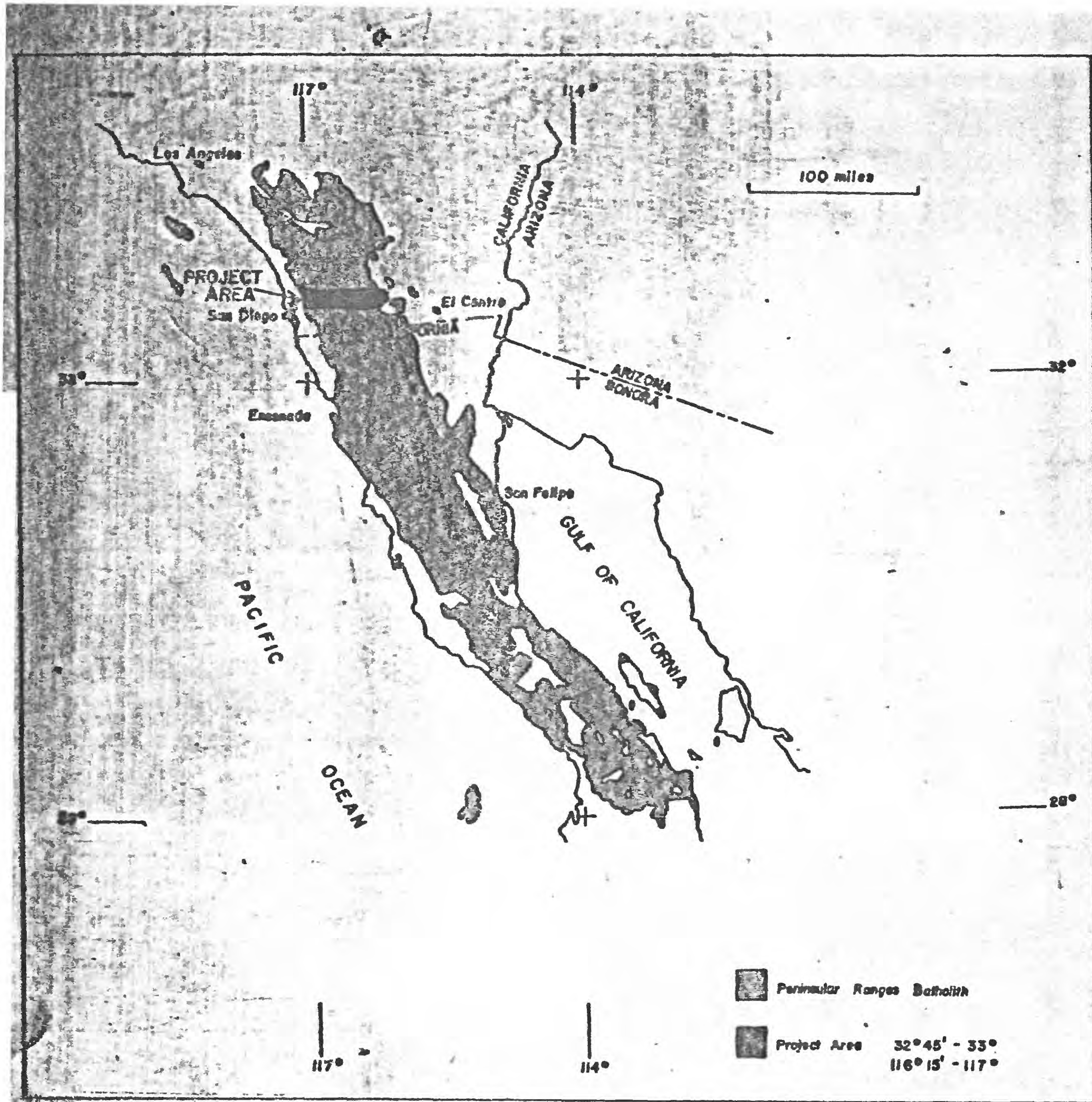

Figure 1. Peninsular Ranges batholith in southern California and Baja California and project area.

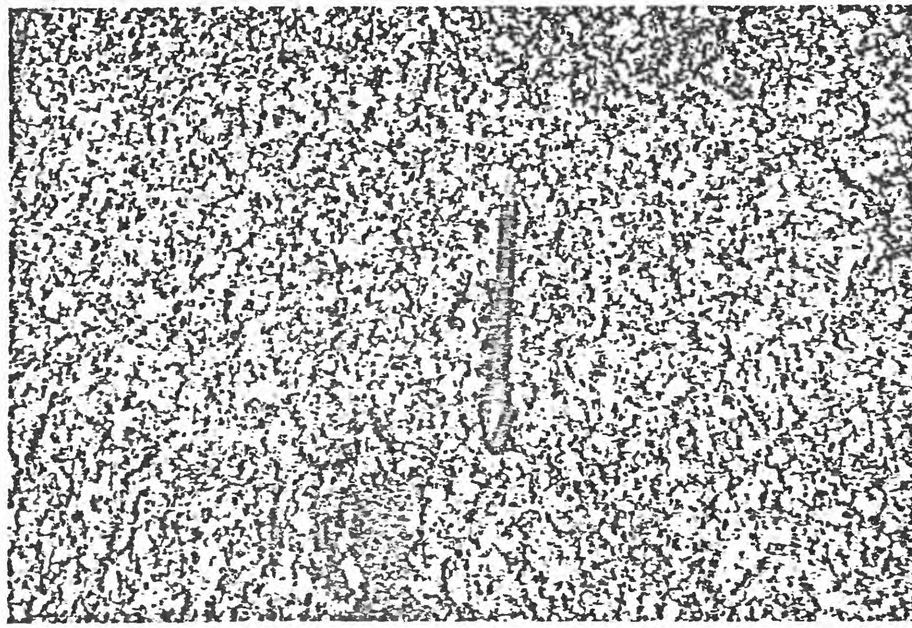

Figure 2a.--Kpv outcrop, trace of foliation parallel to pencil. Color index appears higher than 5-10 percent because mafic minerals have broken down and recrystallized into fine-grained aggregates.

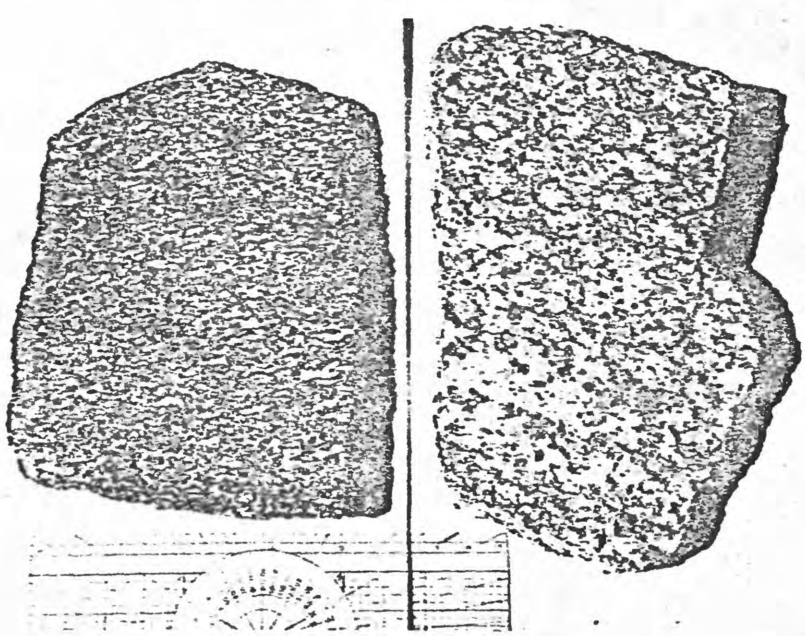

Figure 2b.--Slabs cut at right angles to foliation. Left, Kcp granodiorite; right, Kpv quartz monzonite. Stained for K-feldspar and plagioclase; 6-inch scale.

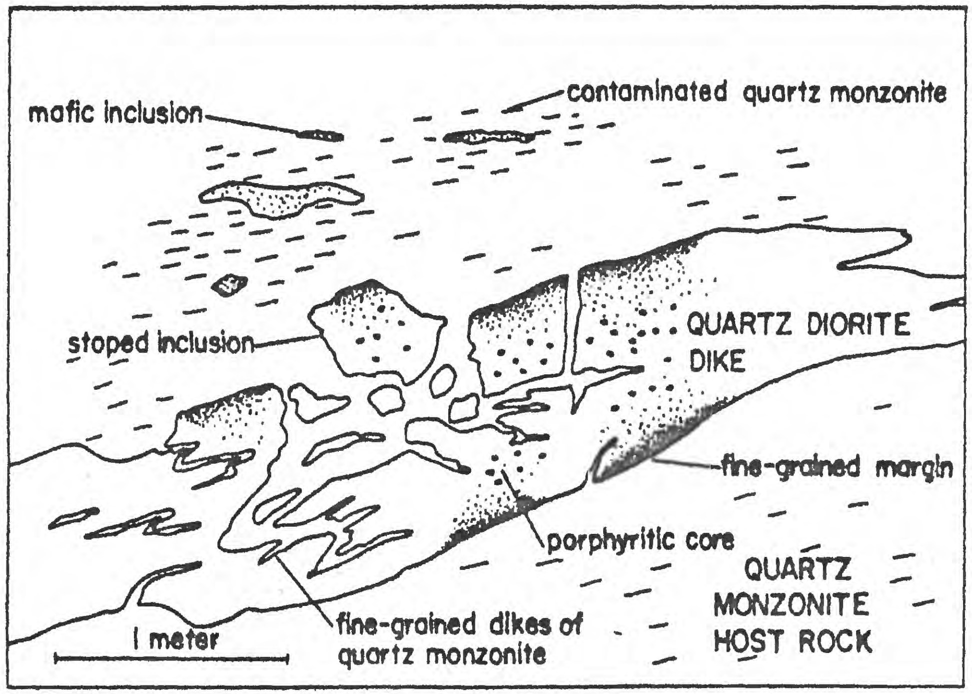

Figure 3. Sketch diagram of common relation between Kem dike and Kcp host rock.

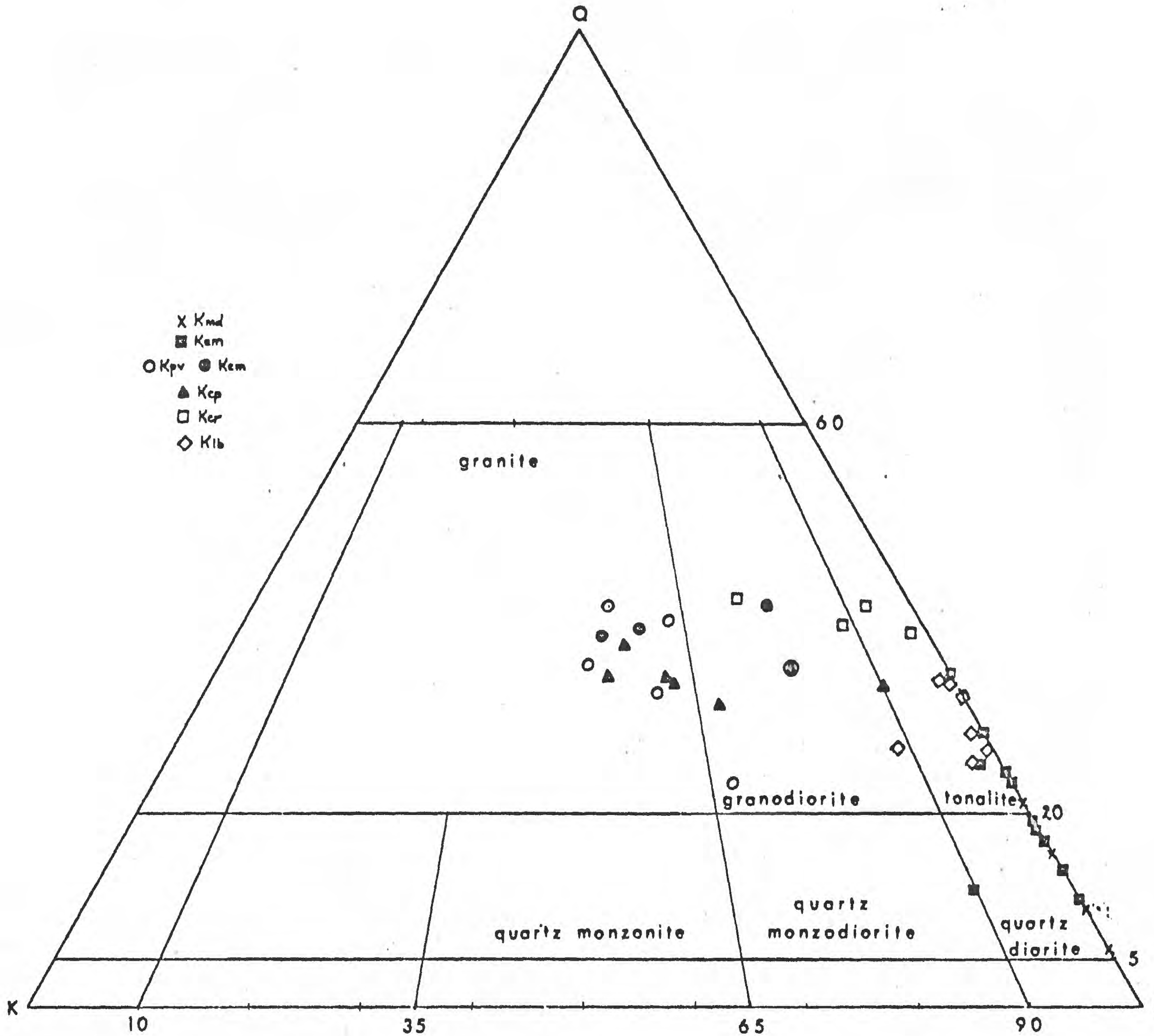

Figure 4a.--Modal data for granitic rocks from Cuyamaca Peak 15' quadrangle (classification according to Streckeisen, 1973).

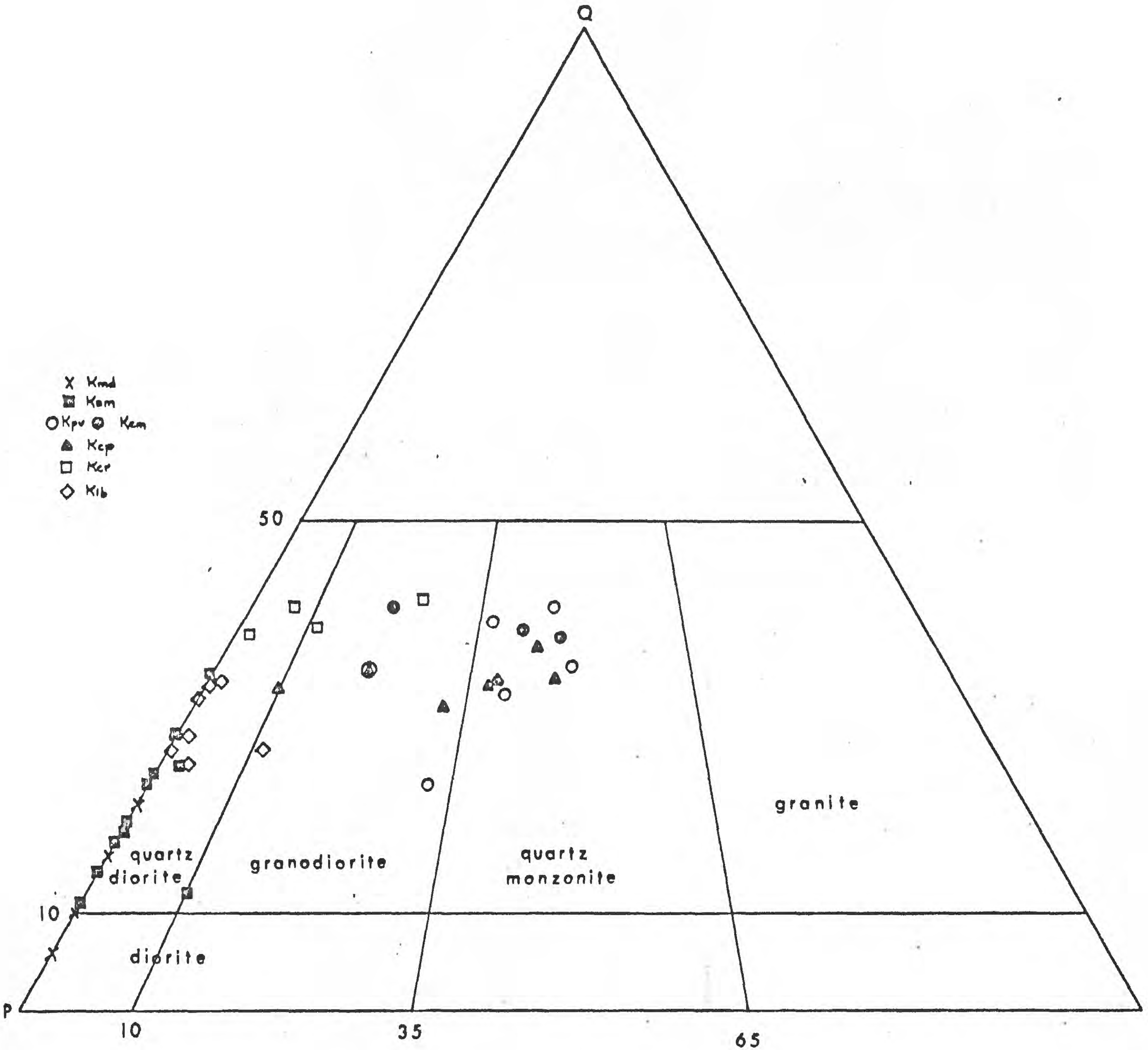

Figure 4b.--Modal data for granitic rocks from Cuyamaca Peak 15' quadrangle (classification according to Williams and others, 1954).

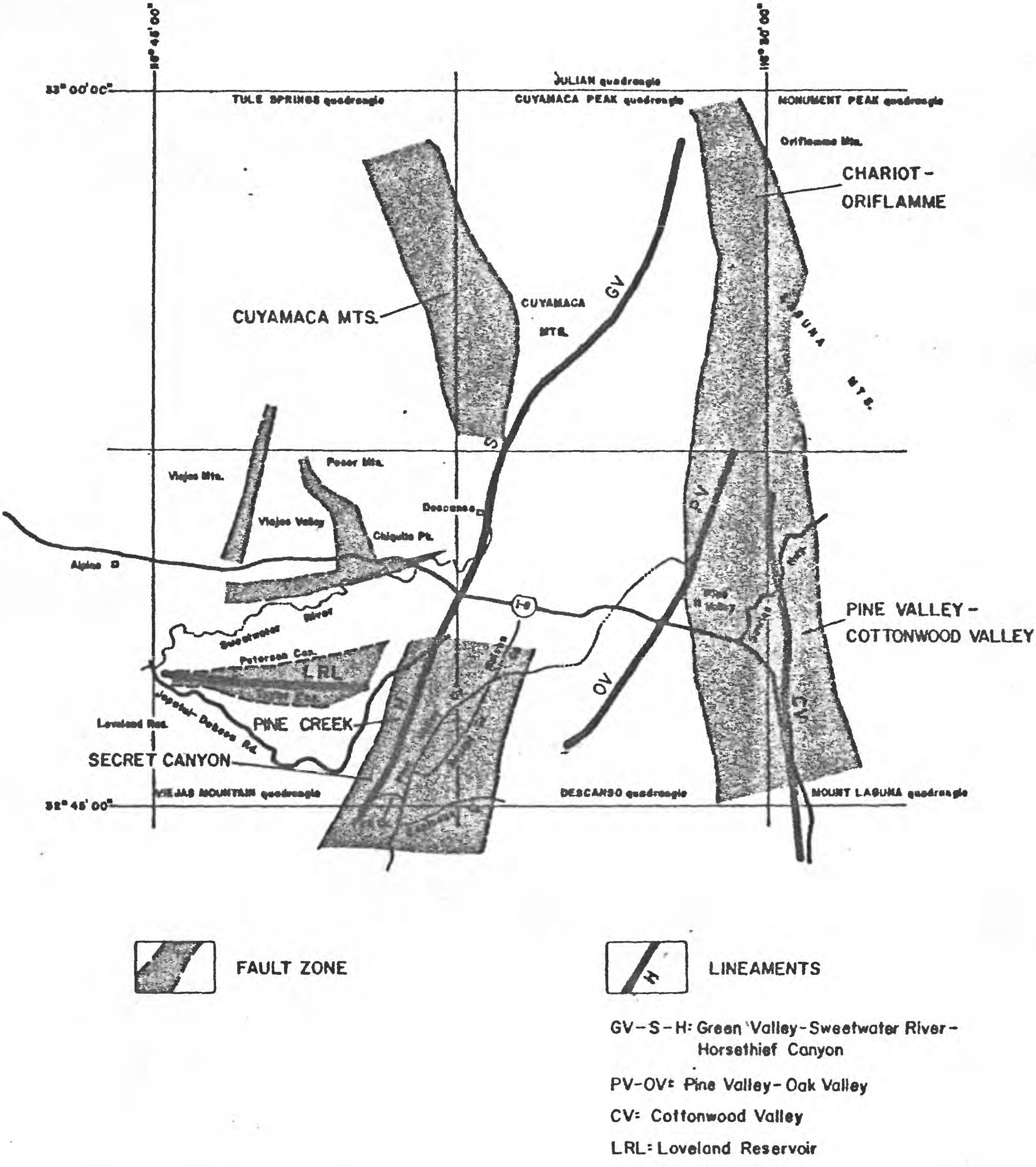

Figure 5. Index map showing lineaments, fault zones and geographic features.

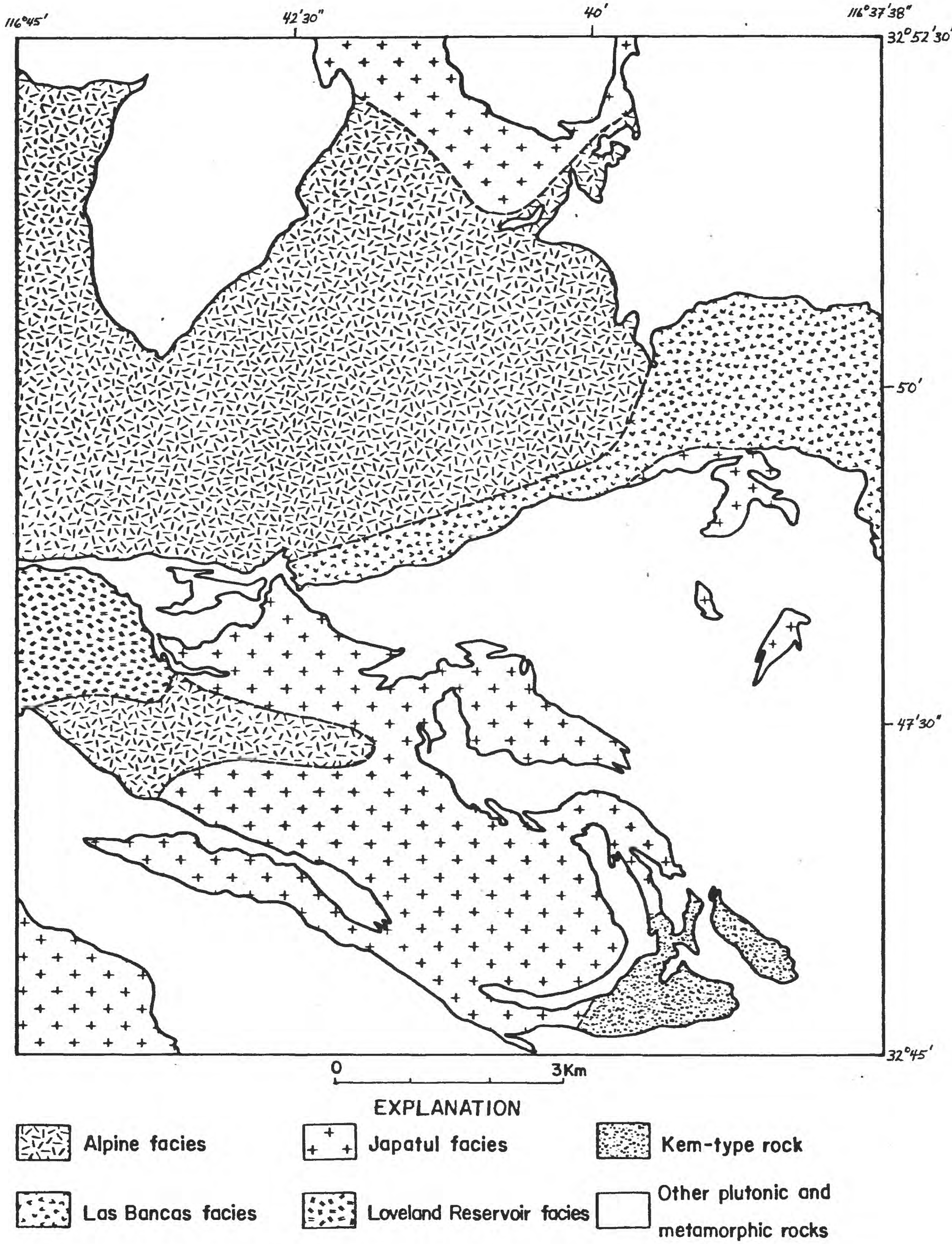

Figure 6.--Facies of Klb (distribution and contacts very approximate).

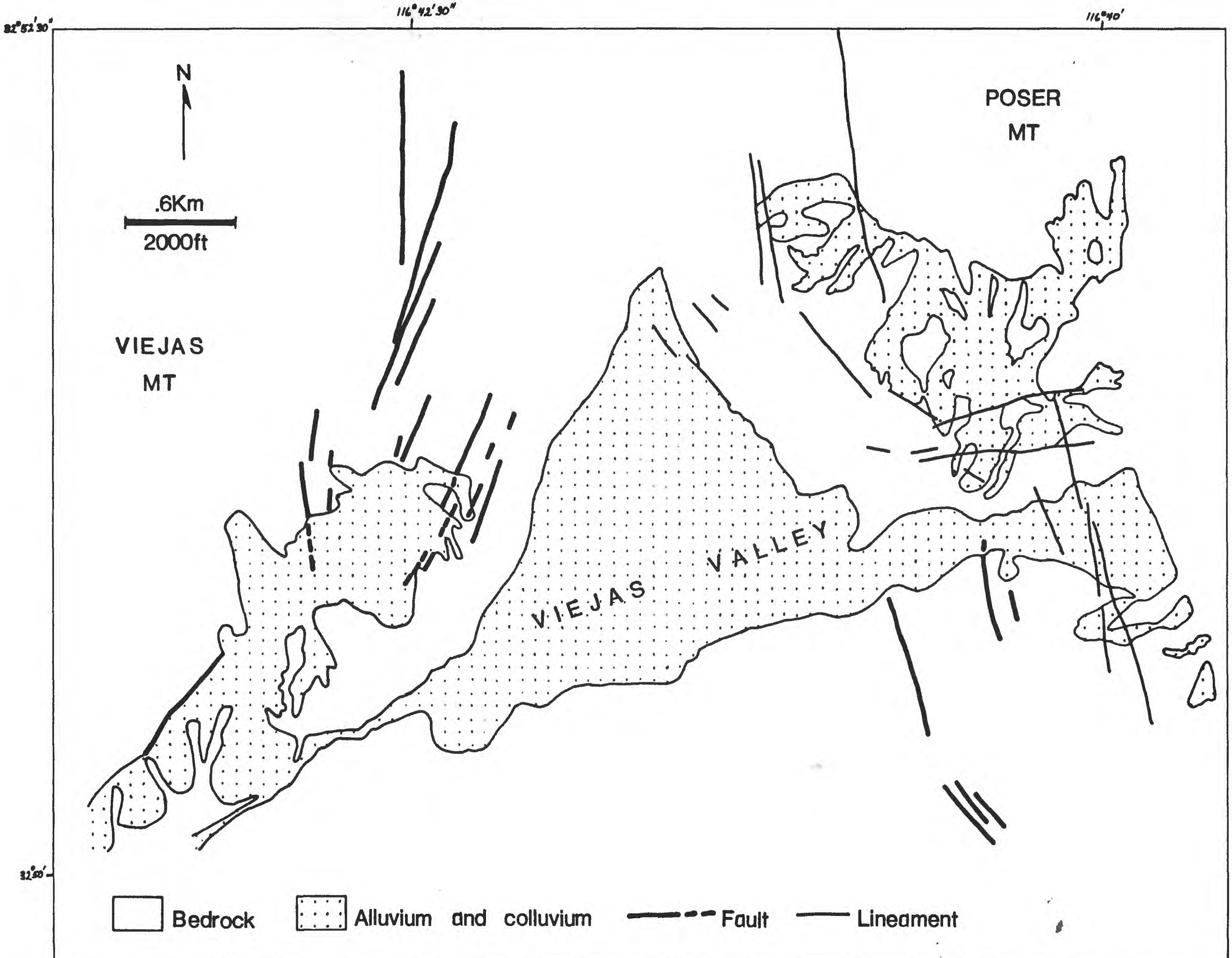

Figure 7. Faults and lineaments in and near Viejas Valley.