UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC MAP OF MONUMENT PEAK QUADRANGLE, SAN DIEGO COUNTY, CALIFORNIA

By

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Open-file report

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

Geologic map of the Monument Peak 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, 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 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 Monument Peak quadrangle is the fifth 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 and Viejas Mountain quadrangles.

Introduction:

The Monument Peak 7 1/2' quadrangle lies within the mid-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. Roughly 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 recognizable metasedimentary rocks of uncertain age which occur as roof pendants and screens in the batholith and a migmatitic schist and gneiss unit derived in part from metasedimentary rocks.

Previous usage has been followed in referring to the twelve 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.

Where noted by earlier workers, foliation was considered to be a primary igneous structure or protoclastic structure. 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 regional tectonite fabric. Although commonly concordant with plutonic contacts, foliation locally crosses contacts and, therefore, is 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 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 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 discussed below and their overall intrusive sequence is depicted in Figure 4. Modal data for the plutonic units is given in Figure 5. The following discussion is based in part upon observations of rock units and contact relations in the adjacent quadrangles, which are shown in Figure 1 but it is fully applicable to the Monument Peak quadrangle. The bedrock units are overlain locally by unconsolidated Quaternary deposits.

Metasedimentary rocks:--The predominant metasedimentary lithologies are quartzo-feldspathic, micaceous semischistose rock and schist, and pink and buff-weathering calcareous quartzite. The semischistose rock and schist contain thin (0.2 to 0.5 cm) quartzo-feldspathic metamorphic segregations, commonly in isoclinal folds. Pelitic schist is crowded with 1 cm grains of andalusite. The semischistose rock and quartzite typically are finely laminated and although sedimentary structures have been transposed, lamination is parallel to larger-scale compositional layering that probably reflects original bedding (perhaps preserved in the limbs of undetected isoclinal folds). Where compositional layers have been preserved in the Laguna Mountains, they are on the order of 15 cm or less in thickness. Interlayered with these rocks is fine-grained, black amphibolite (locally with greenish-gray diopsidic layers), graphitic phyllite, minor amounts of green tremolite-epidote schist, and grit and pebble conglomerate.

The metasedimentary rocks are very similar in appearance and composition to those in the Cuyamaca Mountains to the west (Fig. 1), but lack preservation of sedimentary structures, are coarser grained (medium-grained), and have undergone more metamorphic differentiation. They appear to have originated as thin-bedded, impure calcareous siltstones and sandstones, which were interbedded with mafic flows and/or tuffs. Metasedimentary rocks in the northern, northeastern and eastern parts of the quadrangle (western Colorado Desert) may be of higher metamorphic grade than TRm exposed in the southern, southwestern and western parts (Peninsular Ranges block).

In the western Colorado desert, metasedimentary rocks are intimately mixed with plutonic rocks to form a complex which was mapped previously as a hybrid gneiss-granodiorite-quartz diorite unit (Weber, 1963). This complex consists of metasedimentary rocks which were intruded sequentially by associated gabbro and diorite, mafic tonalite (Kt_2) and its distinctive pegmatite dikes, fine- to medium-grained tonalite dikes, and a younger tonalite (Kt_1) and its associated pegmatite dikes. The abundance of pegmatite dikes of two generations lends this complex a distinctly chaotic aspect. Apparently, younger plutons intruded along or close to older contacts. The complex has been shown on this map as Kt_2 when it predominates and as TRm or Kt_1 when these rocks are most abundant, but it could be differentiated on a larger scale map. It forms a distinctive outcrop band in the desert (Fig. 6).

Cuyamaca Gabbro:--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 support this interpretation. These bodies, consisting of peridotite, olivine gabbro, hornblende gabbro, and norite were considered by Everhart to post-date the granitic plutons in the northern part of the Cuyamaca Peak 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 screens surrounded by sheeted complexes of younger granitic rocks. 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.

The Cuyamaca Gabbro appears to be deformed and recrystallized. All gabbro observed 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 to the southwest

(Fig. 1) suggests the presence of flexures having near-vertical axes which might explain the perturbations in the strike of gabbro foliation. Foliation within the gabbro appears to have formed in part by solid-state flowage.

One reason for ambiguity over the relative age of 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. The intrusion breccia grades into highly contaminated margins of granitic plutons which contain abundant, large, fine-grained gabbro inclusions.

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 gabbro is in contact with younger granitic rocks. Inclusions of metasedimentary rock do occur in many intrusion breccia zones between gabbro and granitic plutons, but there are places where no metasedimentary rocks appear to be involved and where grain size of gabbro decreases sytematically as contacts with granitic plutons are approached.

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

Mafic tonalite:--Medium- to coarse-grained, mafic tonalite (Kt_2) intrudes both TRm and diorite and gabbro in the desert part of the Monument Peak quadrangle and in the Agua Caliente Springs quadrangle (Todd, 1977b). The tonalite is strongly foliated (dynamothermal metamorphic fabric) with textures ranging from gneissic to porphyroclastic and locally, mylonitic. Hornblende and biotite constitute about 25 percent of most rock--in some rocks, hornblende is replaced by epidote-actinolite intergrowths. Mafic inclusions are abundant and characteristic of the unit. The inclusions are in large part gabbroic. The heterogeneity, higher color index, and abundant inclusions distinguish the mafic tonalite (Kt_2) from the younger, felsic tonalite (Kt_1). In the Campbell Grade area (Fig. 7) the mafic tonalite grades into coarse-grained, leucocratic tonalite and garnetiferous pegmatite consisting of quartz, plagioclase and biotite. In addition to gradational contacts, the pegmatite intrudes the tonalite as sharp-walled dikes. Foliation in both average and pegmatitic tonalite, except where the latter is exceptionally coarse-grained, is parallel to that in the metasedimentary rocks.

In the Monument Peak quadrangle, the mafic tonalite was found to consist of 2 or more closely related tonalites, including the tonalite of Las Bancas (Klb) and the granodiorite and tonalite of Cuyamaca Reservoir (Kcr). In the eastern part of the quadrangle the mafic tonalite is continuous with Klb. The relationships among these three tonalites are discussed below.

Tonalites of Las Bancas:--The tonalite of Las Bancas (Klb) is a widespread unit in the project area. 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 to the southwest (Fig. 1) where it was first described. There it is homogeneous and underlies a broad plateau at about 1200 m elevation named Las Bancas. The tonalite has complex contacts with metasedimentary rocks, gabbro and granitic units marked by intrusion breccia and hybrid rocks formed by contamination-assimilation reactions. Locally, injection migmatite occurs between the tonalite of Las Bancas (Klb) and metasedimentary rocks. Within the project area, the tonalite has a fine-grained margin against Cuyamaca Gabbro in a few places and it is intruded by the granodiorite and tonalite of Cuyamaca Reservoir (Kcr), the granite and granodiorite of Corte Madera (Kcm) (probably a leucocratic facies of the granite and granodiorite of Pine Valley), and by fine-grained and porphyritic mafic dikes (Kmd).

The tonalite of Las Bancas is a medium-grained gneissic rock, approximately equigranular, with lenticular recrystallized mafic aggregates. The rock has 15-20 percent quartz, traces of K-feldspar, relict zoned phenocrysts of andesine to labradorite, and a color index ranging from 25-50 percent. Locally it contains 1 cm poikilitic biotite or hornblende grains. 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.

The extensive Klb plutons have compositional and textural varieties which appear to grade into one another (Todd, 1977a). Two varieties occur in the Monument Peak quadrangle, the Las Bancas-type, described above, and a coarser grained, less mafic marginal tonalite which is probably the equivalent of the Japatul type (Todd, 1977a), although it lacks the subhedral texture of the Japatul-type tonalite. The foliation in the marginal facies with its large lenticular mafic grains and aggregates is more obvious than in the darker, fine- to medium-grained Las Bancas-type tonalite. The marginal facies contains both hornblende and biotite, locally with scattered larger biotite or hornblende grains giving it a near-porphyritic texture. Rusty-weathering spots are common. Sparse inclusions in the marginal facies are commonly large (~30 cm) rounded blocks of Las Bancas-type tonalite. There are virtually no inclusions in the darker, central part of the Klb pluton. Where lighter colored rock occurs within the pluton, it is associated with TRm and Kc inclusions. The distributon of the marginal facies of Klb is indicated by a stippled pattern on the geologic map.

In the desert part of the quadrangle (and in the Mount Laguna quadrangle to the south), the marginal facies interfingers with Kcr, which it greatly resembles at the contact. Away from the contact, the two rocks can be distinguished readily. This relationship is discussed further below.

Granodiorite and tonalite of Cuyamaca Reservoir:-- The granodiorite and tonalite of Cuyamaca Reservoir (Kcr) weathers to reddish and yellowish-brown and is light to dark gray on fresh surfaces depending upon its mafic content, which ranges from 14-29 percent. Where the unit is in contact with Kc, it consists of mafic tonalite and contains abundant fine-grained mafic inclusions that are flattened parallel to foliation. Although grading from tonalite to granodiorite, the unit is texturally homogeneous--fine to medium-grained, very gneissic and, on the average, more deformed than the other plutonic units. In thin section, the granodiorite and tonalite of Cuyamaca Reservoir shows some of the most strained and recrystallized igneous textures of all units.

All samples of the unit 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 the granodiorite and tonalite of Cuyamaca Reservoir and other granitic units may be related to intimate mixing of the former with metasedimentary rocks. The unit is especially gneissic, locally porphyroclastic and mylonitic, next to large bodies of metasedimentary rock. Here it contains abundant partly assimilated inclusions of metasedimentary rock and is rich in mica. Fine-grained granodiorite and tonalite may grade into hybrid gneiss (Khc) which locally occurs as sheets between the granodiorite and tonalite unit and metasedimentary rocks.

The granodiorite and tonalite of Cuyamaca Reservoir locally has chilled margins against and sends dikes into Cuyamaca Gabbro. Contact relations between the granodiorite and tonalite unit (Kcr) and the tonalite of Las

(Klb) have now been observed over a wide area,
Bancas/ and are summarized below. They suggest that Kcr is partly coeval with, and partly later than, Klb.

1. Contact schlieric, interfingering; both rocks are texturally similar and possibly compositionally similar, but Kcr is brown to orange-weathering and Klb is pinkish gray-weathering. Locally, they appear gradational.
2. Contact schlieric, interfingering, Kcr tends to be finer grained (fine to medium) next to Klb, and/or more leucocratic, sheared (porphyroclastic); Klb texturally unchanged to contact.
3. Neither rock shows textural change; they are separated by thin (locally <1 m) screens of Cuyamaca Gabbro, gabbro intrusion breccia, or metasedimentary rock (TRm). (Kcr has inclusions of TRm; Klb does not).
4. Kcr occurs as large dikes in Klb and as schlieric inclusions.
5. Contact relatively sharp; Klb texturally unchanged up to contact; Kcr also unchanged but occurs as blocky inclusions in Klb margins. This relation suggests that Kcr may locally be in part older than Klb, or the inclusions may be synplutonic or tectonic in origin.

In the part of the Monument Peak quadrangle which lies within the western Colorado Desert, the tonalite mapped as Kt_2 in the Agua Càliente Springs quadrangle (Todd, 1977b) was found to consist of both Klb and Kcr, with the rocks either so intimately interlayered that they could not be mapped separately, or with Kcr concentrated along the contacts of the tonalite of Las Bancas with metasedimentary rocks. This is probably also the explanation of the compositional variations in Kcr in the Cuyamaca Mountains (granodiorite to tonalite; 14-29% mafic minerals). Kcr may be entirely a comagmatic marginal facies of the Klb tonalite and the greater degree of deformation and deuteric alteration of the former may be the result of shearing against water-rich metasedimentary wallrocks.

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. 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 centimeters long, the latter locally grading into ghostly metasedimentary inclusions.

Study of thin sections indicates that the rock has undergone virtually complete recrystallization while being strained (synkinematic metamorphic texture). A few plagioclase grains retain delicate oscillatory zoning and locally, K-feldspar grains enclose small, early, subhedral plagioclase phenocrysts but typically, relict textures are lacking and the hybrid gneiss is too rich in quartz and mica to be a straightforward meta-igneous rock. K-feldspar has been converted to muscovite in many samples.

The hybrid gneiss is not migmatite, although migmatite does occur locally at contacts with metasedimentary rocks (TRm) and with the granodiorite and tonalite of Cuyamaca Reservoir (Kcr). Contacts between hybrid gneiss and metasedimentary rocks 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 may be 1) fine-grained, containing abundant partly assimilated inclusions of TRm, or 2) coarse-grained, sub-pegmatitic, leucocratic and full of TRm inclusions and biotitic lenses. These rocks are interpreted as margins and/or dikes of Kcr plutons which were originally in contact with metasedimentary rock. Elsewhere, Kcr is interlayered with Khc near the contact. In a few places, Khc has intruded other plutons which indicates that the rock was locally as mobile as the plutonic units.

The abundant metasedimentary inclusions, plus the high proportion of quartz and mica attest to the rock'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 probably both before and after emplacement of Kcr. 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.

Contaminated granitic dikes are numerous where Klb, Kcr and Khc are in contact but are not large enough to show at the map scale. Where the dikes are abundant, the symbol ◇ has been used on the geologic map. They consist of brown- and orange-weathering, leucocratic granitic rock with ℞m inclusions and/or micaceous lenses up to 4 cm long. They are light gray on fresh surfaces, fine- to medium-grained, with chilled margins. Although locally containing pegmatite, the dikes are distinct from the crosscutting Kpv and Kt_1 leucocratic dikes and are cut by them. Contaminated granitic dikes as much as 8-10 meters thick occur between Klb and Khc and have an interfingering contact with Klb. Contacts are blurred over 1-2 cm; Klb is unchanged texturally up to the contact but the dike rock is especially gneissic, finer-grained and more leucocratic next to Klb and carries Klb inclusions. These large dikes are locally directly on strike with Khc outcrops and may be part of Khc. Elsewhere, similar but smaller dikes with chilled margins cut Klb. The dikes also occur in Khc and in migmatitic schist and gneiss (Km) where the dikes either intrude these units or appear gradational to them. They have not been seen in Kcr, and may represent a late-stage, leucocratic magma derived from Kcr, which has become contaminated by ℞m. The dikes also resemble leucocratic parts of the hybrid gneiss unit. In one place where Khc and Klb are in contact, Klb inclusions occur in Khc margins, and Khc becomes finer grained and more granitic appearing toward the contact. Whether more closely related to Kcr or Khc, the dikes support the interpretation that both Kcr and Khc are in part younger than Klb.

Migmatitic schist and gneiss:--In the Laguna Mountains and western part of the Colorado desert, a separate category, migmatitic schist and gneiss (Km), had to be devised to designate rocks which fall between TRm and Khc. These rocks contain migmatitic metasedimentary schist, and Khc-type gneiss in a variety of contact relationships, as well as TRm quartzite and amphibolite as discrete layers, lenses and boudins. Limited outcrops of these rocks were seen in the Cuyamaca Mountains to the west where they were mapped with TRm or Khc. However, in the Monument Peak quadrangle, they underlie relatively large areas of outcrops between homogeneous Khc and typical TRm. Although to some extent a "wastebasket" unit (especially where the terrane is very brushy and/or steep), Km forms a fairly discrete outcrop band which may help in delineating the overall structure.

Going from TRm toward Khc, over a distance that varies from 0.1 km to 1 km, the schist in TRm becomes more segregated, migmatitic and abundant with the more refractory quartzite and amphibolite occurring as screens, lenses or boudins in the migmatitic rocks. Next comes a zone in which large migmatitic schist inclusions are embedded or suspended in Khc, then Khc with small schist inclusions, and finally, Khc with micaceous spots. Locally, the segregation layering in the migmatitic schist widens and coarsens in grain size until the texture is that of a gneiss. Elsewhere, recognizable TRm and Khc alternate over distances of only a few meters, and since these areas strike into the gradational type, they have also been mapped as Km.

Granite and granodiorite of Pine Valley:--The granite and granodiorite of Pine Valley (Kpv) forms large (several km across), discrete plutons which are relatively inclusion-free and uncontaminated within the project area as a whole. The unit typically has been emplaced in steeply dipping sheet-like bodies. The Rattlesnake Mountain pluton, part of which lies within the western part of the quadrangle, is an exception, being a large, almost flat-lying sheet.

The rock is white-weathering and underlies highlands except where faulted. It is chiefly coarse-grained granite 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 with which it is in contact except the tonalite, quartz diorite and gabbro of East Mesa (Kem) in the Cuyamaca Peak and Descanso quadrangles, which it locally intrudes syn-plutonically. The unit is strongly foliated.

Pegmatite, alaskite and aplite:--Leucocratic dikes (Kld) of pegmatite, alaskite and aplite occur in all units. In some areas they can be traced into a parent pluton, locally Kpv. 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.

Leucocratic dikes in the area east and southeast of the Rattlesnake Mountain pluton are most abundant in the vicinity of the pluton and are probably related to it. Several intersecting sets are present, including gently west-dipping dikes, and steep dikes both parallel to foliation and cross-cutting it. Regardless of their orientation, the metamorphic fabric passes through these dikes parallel to that of the host rock. Swarms of these leucocratic dikes are indicated by the symbol ◆ on the geologic map.

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 adjacent Cuyamaca Peak and Descanso quadrangles, the sizes and shapes of Kem bodies vary in the plan view 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. A small part of the Deer Park Kem body forms the only mappable exposure of the unit in the Monument Peak quadrangle (southwestern corner).

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 oikocrysts 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 strong oscillatory zoning with calcic cores. Medium-grained Kem carries abundant, fine-grained mafic inclusions, less than 5 cm 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 containing scattered plagioclase relict phenocrysts and others containing abundant relict euhedral plagioclase grains.

Kem whose hornblendes enclose pyroxene cores (opx$\rightarrow$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 with which it is in contact except Klb and mafic and porphyritic dikes (Kmd). Kem is locally continuous with, and also cut by, dikes of Kmd. Locally, age relations are reversed where host rocks have intruded Kem (Fig. 3). This is especially true where Kem intrudes granite and granodiorite units.

The Kem bodies are strongly foliated, expecially near their margins. The Deer Park body in the eastern part of the Cuyamaca Peak quadrangle, for example, consists almost wholly of mylonite gneiss (Todd, 1977c).

It can be seen from Figure 5 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 of Klb (Todd, 1977a). Well-exposed outcrops in the south-eastern part of the Viejas Mountain quadrangle suggest a gradational relationship between Klb and Kem. 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 granite units, whereas Klb plutons are intruded by the granites. 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.

Some dark-appearing Kem rocks are modally identical to the lighter tonalites and their darker tone is due solely to their finer grain size. Other dark rocks are quartz diorites. Field evidence suggests that the dark fine-grained Kem rocks are a hybrid formed from Klb and Kc. The Kem bodies commonly occur where Cuyamaca Gabbro is in contact with Klb, particularly in places where small gabbro lenses and screens are surrounded by tonalite. These zones appear to have undergone considerable physical and chemical mixing. Since the dark, fine-grained Kem bodies appear to be younger than Klb, they may be synplutonic hybrid rocks. In the Monument Peak quadrangle, the small Kc bodies in the southeastern quarter give way along strike to the north to systems of large dikes consisting of variable, dark, fine- to medium-grained, porphyritic quartz diorite or tonalite which is identical to the dark fine-grained facies of Kem. Until more data are available, bodies which crosscut granite plutons will be designated Kem and those which are intruded by granite will be called Klb. However, parts of Kem bodies are probably composed of Klb.

Felsic tonalite:--The eastern part of the Monument Peak quadrangle is underlain by a distinctive tonalite (Kt_1) which intrudes ℞m, Klb, Kt_2, Kcr and Km. It is part of a northern lobe of the vast La Posta body (Miller, 1935) which underlies much of the southeastern Peninsular Ranges in San Diego County and Baja California.

Average Kt_1 is homogeneous, 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. Dikes of fine-grained, dark gray rock texturally resembling Kt_1 (large quartz grains and large biotite books) were seen in the unit locally in upper Canebrake wash.

Quartz ranges from 29-35 percent and occurs in distinctive 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-section views show either highly strained 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 two to 5 and one-half percent and occurs as 5 cm poikilitic grains that show large, reflective cleavage surfaces on rock faces. Plagioclase 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 very sparse acicular hornblende grains 0.5-1cm long. Accessory minerals are sphene, allanite, epidote, apatite, zircon and black opaque.

A leucocratic variety of Kt_1, grading from leucotonalite to micro-pegmatite and pegmatite dikes, occurs near its contacts. The large pegmatite dikes contain tourmaline and, like average Kt_1, contain large, euhedral biotite books which distinguish them from the Kt_2 pegmatite. A porphyritic variety of Kt_1 with subhedral white plagioclase phenocrysts and feldspar-quartz aggregates 2 cm across also occurs near the margins of the pluton. Dikes of Kt_1 in Kt_2 may also have this texture. Crosscutting pegmatite dikes with pale pink or white K-feldspar, scaly biotite aggregates, minor quartz and tiny red garnets; white quartz veins; and layered pegmatite-alaskite dikes are also abundant in marginal parts of Kt_1. Abundant schlieren and inclusions are associated with Kt_1 margins. Schlieren, consisting of biotitic clots and streaks, or layers of more and less mafic tonalite less than 15 cm thick may be concordant or discordant to rock foliation. The layers have both sharp and gradational contacts. Elliptical to spherical inclusions up to 25 cm across appear to be partly assimilated Kt_2. Commonly, leucocratic phases of Kt_1 increase in abundance toward the contact with ℞m and Kt_2 and highly injected and contorted inclusions occur in Kt_1 near these contacts. The adjacent metasedimentary rock is thoroughly diked by leucocratic Kt_1 and the contact between the two units is arbitrarily placed where their ratio is about one to one.

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 Kt_2 and ℞m. 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 plutonic rocks of the Laguna Mountains. Hence it is tentatively considered a late-tectonic structural feature.

A network of fine- to medium-grained generally sharp-walled tonalite dikes crosscuts Kt_2 and ℞m adjacent to the Kt_1 pluton. The dikes are too small to be shown on the geologic map at 1:24,000 scale, but they undoubtedly represent a significant plutonic event for they are widespread. The dikes are foliated parallel to foliation in the host rocks rather than to dike walls. The rock contains lenticular aggregates of quartz, local quartz-feldspar aggregates, relict subhedral plagioclase grains with locally preserved euhedral oscillatory zones and markedly calcic cores, and reddish-brown biotite (about 25 percent). Accessory minerals include sphene and allanite. Locally, these dikes are schlierically interlayered with Kt_2 implying that the two rocks became intimately mixed during deformation. The tonalite dikes are most likely a chilled phase of Kt_1. Deformation may have waned between the time of emplacement of the dikes and the main body of Kt_1, because Kt_1 has a late-tectonic fabric. Alternatively, the dikes and main body of Kt_1 may have been emplaced simultaneously but the dikes may have cooled and solidified more rapidly than the large parent pluton, at a time when deformation was still going on. The evidence for this relationsip is 1) local gradation of the fine- to medium-grained dikes into Kt_1 alaskite, 2) localization of the dikes in wallrocks of the Kt_1 pluton, and 3) virtual absence of these dikes in Kt_1.

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. Their presence is indicated on the geologic map by a symbol X . 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 typically been re-intruded by 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 in others are not.

Palm Spring and Canebrake Formations--Plio-Pleistocene sedimentary deposits (Qp) form a narrow outcrop band in the northeastern part of the quadrangle. These rocks have been studied comprehensively by Woodard (1963) in the Arroyo Tapiado 7 1/2' quadrangle (Fig. 1) and identified as the Palm Spring and Canebrake Formations. The Palm Spring Formation is of early middle Pleistocene age in this area according to Woodard and represents alluvial floodplain deposits laid down adjacent to the Peninsular Ranges. Minor, intercalated marine beds represent periodic fluctuations of the last northern transgression of the Gulf of California into the Colorado Desert. Woodard considered the Palm Spring beds to be marginal deposits whose accumulation accompanied the gradual retreat of the Gulf. In the Agua Caliente Springs quadrangle, the Palm Spring Formation grades laterally and downward into the Canebrake Formation described by Woodard as coarse, marginal pediment boulder to cobble fanglomerate and lesser pebbly arenite. The Canebrake Formation is the marginal equivalent of both the Palm Spring Formation and of the older marine Imperial Formation of middle(?) Pliocene to early Pleistocene age (Woodard, 1963).

The Qp deposits consist chiefly of poorly indurated, pale gray-weathering sands with abundant pebble and cobble interbeds with fluvial cross-bedding, cut and fill structure and gravel lenses. The rocks were deposited upon a surface with relief similar to the arroyos and hills of the present mountain front. In most places in the quadrangle, the depositional contact has been obscured by normal faulting. Well-rounded cobbles and boulders (lag gravel) derived from conglomerate cover much of the sedimentary exposure, but out-cropping conglomerate is rare and washes cutting the bouldery material expose chiefly pebbly and cobbly sands. Where conglomerate crops out, it contains cobbles of Kt_1 and Kt_2 ($Kt_1 \gg Kt_2$), as well as porphyritic Kt_1, pegmatite, and the distinctive, foliated muscovite-garnet alaskite seen in the area as dikes in Kt_1. Metasedimentary clasts are abundant, range from cobble to small boulder size and are commonly rounded to well-rounded. They consist of all of the lithologies found in the nearby TRm and Kt_2 exposures in approximately the same relative proportions. The same granitic and metamorphic lithologies occur in coarse clastic interbeds in the sands. The source of granitic and metamorphic clasts thus appears to be very local.

The present distribution of Qp outcrops suggests a narrow wedge thinning west-northwest. Although it is not known how far northeast and southwest Qp deposits may have extended originally, the distribution of coarse- and fine-grained facies and preservation of on-lap relations on both sides of Carrizo

Valley (Todd, 1977b) suggest that the original Qp basin of deposition occupied approximately its present position and has not been measurably broken by strike-slip faults.

Older alluvium:--Dissected alluvium (Qoa) locally merging into modern fan material (Qal) underlies most of the valley areas in the Monument Peak quadrangle. Unconsolidated to poorly indurated, flat-bedded, bouldery deposits consisting of detritus of ₨m, Kt_2, Khc, Kc and leucocratic dike rock occur in the upper reaches of the large canyons that drain northeastward into the desert from the Laguna Mountains rim (Fig. 7). Most of this material probably correlates with the late Pleistocene to Recent Mesa Conglomerate (Woodard, 1963) which lies in angular unconformity on Qp in the Agua Caliente Springs quadrangle to the east.

Younger alluvium:--Only small amounts of modern alluvium (Qal) occur in the desert part of Monument Peak quadrangle, consisting of 1) reworked Qoa and Qp clasts forming a thin veneer on dissected Qoa and Qp and 2) sand and gravel in modern washes. These two deposits are probably coeval. Qal deposits are generally finer-grained than Qoa fan detritus except at the mountain fronts. No detailed study was made of the alluvial fans, but in general, materials of different ages (Qoa and Qal) show up well on 1:24,000 aerial photographs.

Mappable alluvium and colluvium is virtually absent from the mountainous part of the quadrangle. Bedrock is exposed in all of the modern streambeds, and the total thickness of alluvial lenses is about 6m or less. Fine-grained sediments in the high meadows are chiefly residuum formed in situ by chemical weathering (Mayo and Lower, 1976) and even in the largest meadow, Laguna Meadow, this material is so thin that bedrock knobs form most of the surface. All of these sediments are being stripped from the meadows by headward-cutting gullies and streams, as is true throughout the project area.

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, Kcr 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.

Preliminary K-Ar ages on recrystallized biotite, hornblende and muscovite from plutonic rocks 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 fold leucocratic dikes (Kld). The prevalence of synplutonic contacts indicates that early plutons remained capable locally of interacting magmatically with later ones. One would expect complex inter-plutonic 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 are necessary to substantiate or amend this picture.

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 kilometers in thickness and the larger ones continue for tens of kilometers along strike. Small plutons tend to be sheet-like, whereas larger ones are lenticular. In plan view, the preferred orientation of the long dimensions of plutonic sheets and lenticular plutons, of TRm 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 three to four units.

The structural grain varies over the project area. In the Cuyamaca Peak quadrangle, it is predominantly north-northwestward, and the regional dip is eastward, with the exception of the eastern margin of the Cuyamaca Mountains gabbro body whose walls dip steeply 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 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 part, east-striking contacts dip northward (irrespective of local attitudes). East-striking contacts in the southern part of the quadrangle are essentially vertical. The Monument Peak quadrangle, the structural grain is dominantly north-northwest, with a strong eastward regional dip of both contacts and foliation. There is a tendency for a decrease in dip toward the east. Foliations and contacts swing around to an easterly trend in the northeast part of the quadrangle.

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 TRm and Kcr occurs in the center of the map; a second, involving Kc, Kcp and TRm 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. 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 Viejas Mountain 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 Viejas Mountain 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.

There are two types of large folds in the Monument Peak quadrangle, an open fold with a near-vertical axis involving TRm, Kt_2, and Kc, with Kt_1 in the core in the northeast corner; and possibly several tight folds with steep axes in Klb and TRm in the southeast part of the quadrangle. Here contacts and foliation appear to be folded but the structure was probably intruded by the Kt_1 pluton and later was broken by normal faults.

Locally, the dips of plutonic contacts within the project area 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 in both dikes and host rock dips more steeply than plutonic contacts. In the Monument Peak quadrangle, some late leucocratic dikes are gently-dipping. 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 deformation continued after intrusion.

Outcrops of Klb in the Mount Laguna quadrangle and locally in the Monument Peak quadrangle commonly display two foliations at large angles to one another, both of which appear to be recrystallized mineral foliations. Locally, the east-trending foliation is re-oriented by the 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 a later, lower-temperature deformation structure. Locally, the east-trending foliation in Klb appears to swing to an approximately northward trend near north-striking contacts. 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 apparent fluctuations in foliation elsewhere in the project area, since only one foliation may show up well in a given outcrop. Two crossing foliations were also seen locally in Kc and Kt_1.

Geomorphology:

The highest part of the Laguna Mountains, including the Monument Peak quadrangle, is characterized by a topography rather different from that of the batholith at lower elevations. Whereas the large, homogeneous Klb plutons at lower elevations are eroded to an essentially flat or gently rolling surface, in the Monument Peak and Mount Laguna quadrangles they underlie an uneven surface broken by north-northwest-trending linear ridges and valleys, controlled by the structural grain of contacts and foliation. That at least some of these striking linear features are also fault-controlled is suggested by the fact that adjacent ridge-tops lie at different elevations; blocks are variably tilted so that drainage reversals are common; and meadows underlain by a single rock unit have been eroded into a series of steps (nick points), and are associated with hanging valleys. Mapping indicates that predominantly vertical faults extending from the desert floor into the mountain block may be responsible for these features.

Faults of the Monument Peak quadrangle:

For the purpose of discussion, faults have been divided arbitrarily into four fault zones: Oriflamme Canyon-Chariot Canyon; Laguna Meadow; base of the Laguna Mountains escarpment; and foot of the Vallecito Mountains (Fig. 7). The first two zones strike north- to north-northwest; the third strikes northwest and the zone at the foot of the Vallecito Mountains strikes generally east. Actually, the desert floor, escarpment and mountain block are all broken by faults of more than one trend, and one fault "zone" probably merges into another. The Oriflamme Canyon faults extend northward into Chariot Canyon to join the Elsinore fault where Banner and Chariot Canyons branch (Julian quadrangle). The southern part of the Elsinore fault traditionally has been dotted through Mason and Vallecito Valleys. However, the data of this study indicate that faulting in the southern part of the Elsinore fault zone is complex, and that faults extend up into the Peninsular Ranges block to the southwest. The two major fault zones are those bounding the Laguna escarpment and the Vallecito Mountains. Since faults in the desert cut sediments as young as late Pleistocene to Recent, similar faults in the mountain block may also be as young.

Oriflamme Canyon-Chariot Canyon faults:—The faults of Oriflamme Canyon are major, the largest having a crushed zone 50-100 m thick (Todd, 1977c). No throughgoing faults were located immediately south of Oriflamme Canyon, but cataclasite and gouge are present at several places in the brushy Pine Mountain area (R. 5E., T.14S., Section 29) and these are aligned with faults to the south. Faults in the eastern wall of the north-trending reach of Noble Canyon (Fig. 7) are north-trending, parallel to foliation in TRm, although in detail fault planes curve along strike and vertically. Where well-exposed, these fault planes are closely spaced and coalescing, the largest with gouge and breccia zones up to one meter thick. Commonly, these faults are mineralized and there are numerous prospects and mines in the area. One fault plane trends N2W 83SW with slickensides plunging obliquely -> N27W. Crushed zones of these faults are not as large as those of the Oriflamme Canyon faults, but are similar to faults in the Pine Valley-Cottonwood Valley areas to the west and south (Hoggatt and Todd, 1977).

Laguna Meadow faults:--These faults strike north-northwest toward Oriflamme Canyon. Laguna Meadow(R. 5E., T. 15S., sections 3, 4, 10, 15) appears to be a long, narrow down-faulted block or graben flanked on the east by en echelon, subdued west-facing scarplets. Material on the scarp faces is well-sorted small boulders with finer material winnowed to the feet of the scarps. Epidotized cataclastic tonalite, flinty black cataclasite, anomalously thick reddened soil and slickensides are associated with these scarplets. They line up with vegetation stripes, springs and linear valleys. In the Mount Laguna quadrangle to the south, the probable extension of these faults is marked by almost 2 m gouge. Since there is virtually no alluvium in Laguna Meadow, the recency of faulting is unknown. Material on the scarplets has undergone considerable erosion and sorting, but the Lagunas receive enough moisture to be heavily forested, so that the scarplets would have eroded rapidly and are probably at least Quaternary in age.

Faults crossing the foot of the Laguna Mountains escarpment:--A major fault zone crosses the Monument Peak quadrangle in a northwest direction from the upper Potrero through the upper reaches of Storm and Cottonwood Canyons to Mason Valley. Faults cross each of the northeast-trending spurs that finger into Vallecito and Mason Valleys. The major topographic expression of the zone are two prominent low saddles located in the southwest corner of the Agua Caliente Springs quadrangle (Todd, 1977b) and at the intersection of sections 25 and 36, R. 5 E., T.14S. and 30 and 31, R. 6E., T.14S. Here the fracture zone is located at or close to a major lithologic contact. Elsewhere in the zone, faults are marked by aligned saddles, northwest-striking tributary canyons, scarps, benches, vegetation lines and springs. To the southeast, beyond the Monument Peak quadrangle, the fault zone continues across the upper reaches of Canebrake, Indian and Bow Willow Canyons, just below the edge of the Inkopah Mountains plateau. The northern part of the zone, in Mason Valley, bounds Oriflamme Mountain, which appears to be a fault-bounded "step" intermediate between the Laguna crest and desert floor.

These faults are commonly parallel or sub-parallel to unit contacts and foliation. Exceptions are east-trending faults such as the ones crossing Storm Canyon; northeast-striking faults either were observed or suspected from aerial photographs, and may in part have determined the northeast grain of the spurs and linear canyons in the desert portion of the quadrangle. Where scarps are present, they face northeastward, and the mountain blocks are higher than the valley blocks. Although the rocks underlying the spurs (TRm, Km, Khc and Klb) are in general equally resistant to erosion, fault-bounded segments are of successively lower elevation to the northeast, suggesting that these short, sub-parallel faults are normal faults with the valley sides down. Certainly the faults bounding Mason and Vallecito Valleys on the northeast, and the frontal faults of the Tierra Blanca Mountains to the east, are normal faults along which the valleys have been down-dropped relative to the Vallecito and Laguna Mountains (Fig. 7).

Where scarps and/or benches are present, there are at least two, and higher ones are successively less distinct. Where scarps are in crystalline rock, the material on the scarp face is well-sorted angular cobbles. The scarps and benches may be accompanied by cataclasite, breccia (locally mineralized), gouge, porphyroclastic granitic rock, very weathered brown granitic rock, anomalously large amounts of sand; springs, trees and grass; and clayey, pale gray, white or greenish-white soil (weathered gouge).

The faults are short and discontinuous at the surface, and undoubtedly many more small breaks are present than the map shows, continuing up into higher, less accessible parts of the escarpment where many saddles and lineaments can be seen.

The thickness of crushed rock associated with these faults ranges from less than one meter to (commonly) 1-2 m and less commonly, 6-7 m. Where well-exposed, gouge and cataclasite zones undulate along strike. The thickest zones occur in the segment between Storm Canyon and the Potrero, where as much as 15 m of black cataclastic rock and gouge occurs in TRm. The host rock probably in part determines the nature and thickness of crushed material; in general, faults in TRm schist are marked by thinner crushed zones (dense black cataclasite) than those in granitic rock (green and brown cataclasite), whereas in TRm quartzite, faults are marked by coarse breccia.

Measured faults in this zone trend as follows:

Strike	Dip	Thickness of crushed rock (m), other
N33W	steep	6
N9E	59 NW	1
N22W	steep	0.04
N21E	89 NW	0.15
N58W	NE 84	0.15 (1 meter left-lateral offset)
N37W	NE 84	-
N23W	steep SW	0.04
N4E	90°	-
N16W	90°	coalescing faults, each 0.03
N41E	steep SE	(horizontal slickensides)
N7W	NE 59	polished fault plane, striations -> N64E downdip
N11W	NE 42	polished fault plane, striations -> 94 downdip
N23W	steep	-
N23W	steep	1 - 2
N36W	NE 55	1 - 2

Both north- northwest-striking and east-striking faults locally cut Qoa and Qal.

Faults bounding Vallecito Mountains:--Short normal faults bound Vallecito Mountains in Vallecito and Mason Valleys. The range-bounding faults strike northwest, west-northwest and east-northeast. They are crossed locally by northeast-trending faults. Two faults in the vicinity of Campbell Grade appear to curve completely around, parallel to a large fold with a steep axis (R. 5E., T. 14S, section 1). The faults cut crystalline rocks, Qp, Qoa and Qal and have their north, or mountain, sides up relative to the valleys.

In Vallecito Valley, the range-bounding faults are expressed by multiple benches in crystalline rock capped by patches of Qp sediment; up to 2 m of gouge, cataclasite and breccia were seen locally. Multiple scarps with boulders on the faces and pebbles and cobbles (fines) at the feet occur in Qp conglomerate and sandstone. All of the clasts are desert-varnished. As much as 5 m hard, gray earthy gouge was seen locally in faults cutting Qp. Scarplets are present in Qoa sands. The sand is hard, red-brown, indistinctly bedded and stirred-looking and contains dispersed angular granules and small pebbles of granitic rock. It is crossed by caliche-filled cracks. The Qoa scarplets are on strike with narrow linear zones of hummocky, hard sand from which lag gravel is missing, although it is present on both sides of the zone, and with vegetation stripes.

On the northeast side of Mason Valley, normal faults with the valley block down cut crystalline rock, Qp and Qoa. Caliche-cemented breccia in TRm occurs in zones as much as 10 m wide, one of which is on strike with a linear zone of sand in lag gravel, a notch, and a swale with ponded sand on Qoa. Multiple, sub-parallel caliche-filled cracks in Qoa, the thickest about 0.3 m, trend N48W 82SW. They strike into vegetation lineaments, aligned arroyos, and eroded scarplets with fine material winnowed to their feet. These faults are well-exposed just northeast of highway S-2 in the southernmost part of the Earthquake Valley quadrangle.

East-northeast- and northeast-striking, near vertical faults have vertically offset an east-dipping thrust of TRm over Qp sandstone in the northeast wall of Mason Valley. One of these faults strikes N52E, dips 90° and has brought Qp against brecciated TRm along a crushed zone 5-10 m wide. The thrust is also cut by faults trending approximately parallel to the valley and as a result is discontinuously exposed. The Qp under the thrust lies in depositional contact on TRm.

The faults north and northeast of Campbell Grade undoubtedly merge with those to the south and southwest, for there are major and minor cataclastic zones throughout the area. A major zone crosses this bedrock spur just southwest of Campbell Ranch; it consists of gouge and breccia containing several faults, and its trace is also marked by vegetation, a spring, and punky white colluvium derived from the gouge. One fault in this zone strikes N62W and dips steeply. The springs at Campbell Ranch are probably located at the intersection of two (or more) faults. The same is probably true for the densely vegetated area immediately west of Campbell Grade but nothing indicative of faulting can be seen on the ground except deeply incised, gray alluvium (gouge-derived?). The aerial photographs suggest several vegetation lineaments. Campbell Grade is the area through which the Elsinore fault has been dashed traditionally (Fig. 7). Even if there were a single master fault, the continuity of the large fold in the crystalline rocks makes significant lateral displacement impossible in this area.

Some measured faults in this zone include:

Strike	Dip	Thickness of crushed rock (m), other
N53W	89 SW	caliche-filled crack
N71E	49 SE	earthy calichified breccia in tonalite
N51E	71 SE	> 2 m gouge and breccia in Kt_1 with up-faulted QP
N66E	49 SE	polished surfaces in gouge;
N47E	55 SE	rumples on 1 surface 46° -> 153
N19E	87 NW	0.1
N74E	84 SE	2
(2)N70E	steep	0.3
(3)N40E	steep	1
N7W	steep	2
N11W	68 NE	polished fault plane,mineral smear lineation -> N84E down-dip

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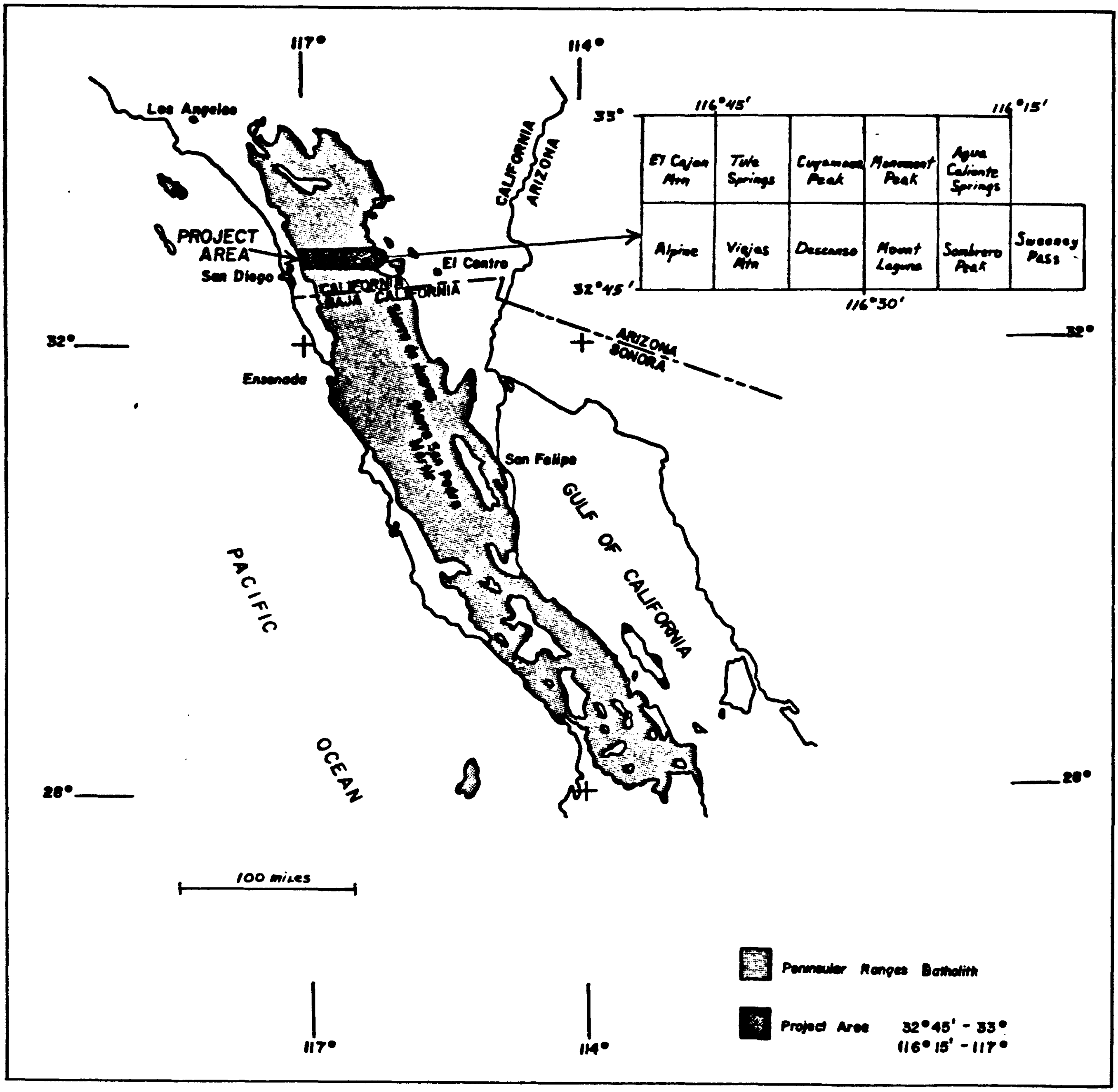

Figure I. Peninsular Ranges batholith in southern California and Baja California and project area.

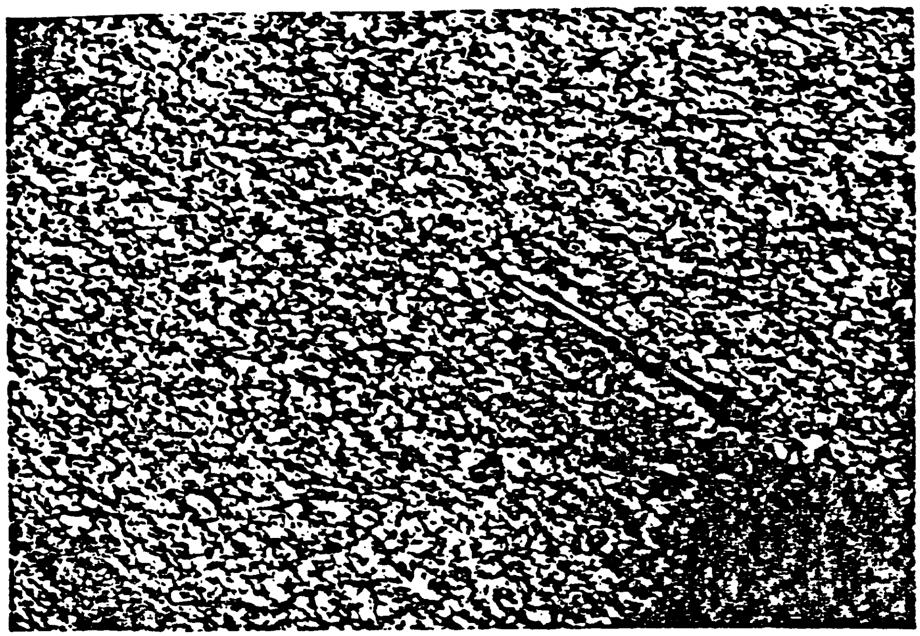

Figure 2a.--Kpv outcrop, trace of foliation parallel to pencil, color index appears higher than 5-10 percent because mafic minerals have broken down and recrystallized into fine-grained aggregates.

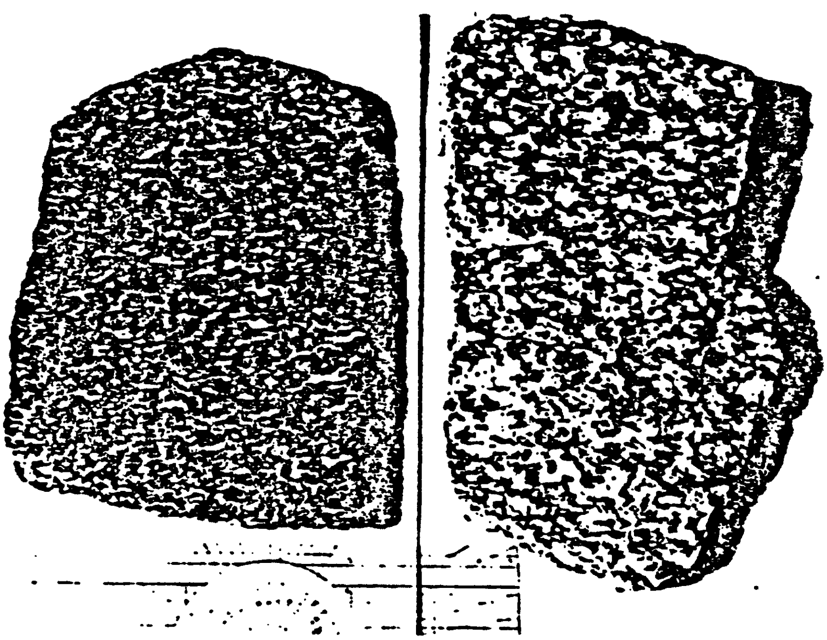

Figure 2b.--Slabs cut at right angles to foliation. Left, Kcp granodiorite; right, Kpv quartz monzonite. Stained for K-feldspar and plagioclase; 6-inch scale.

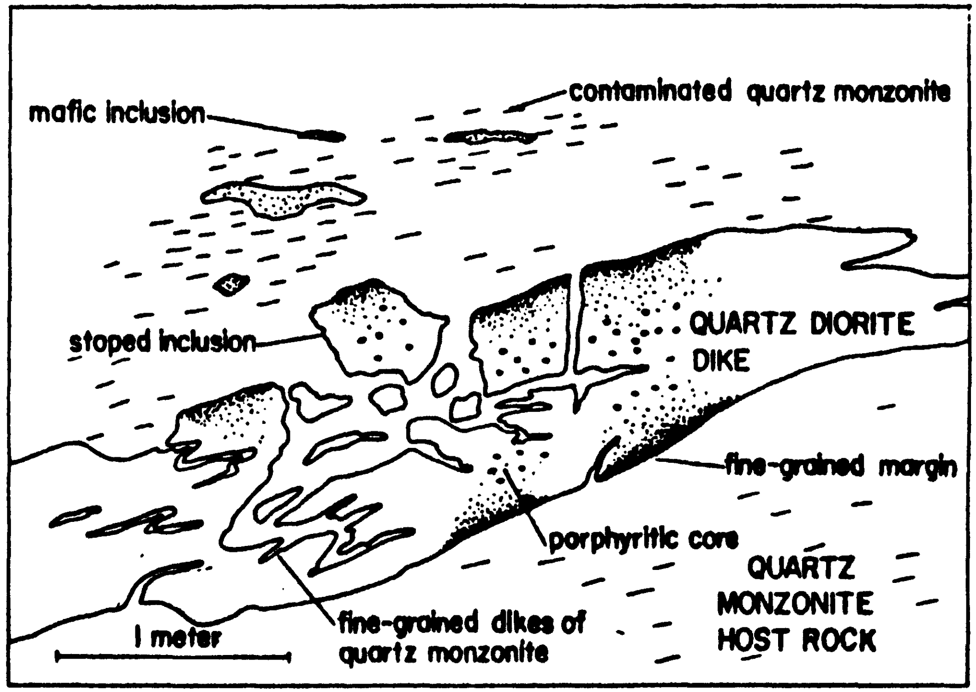

Figure 3. Sketch diagram of common relation between Kem dike and Kcp host rock.

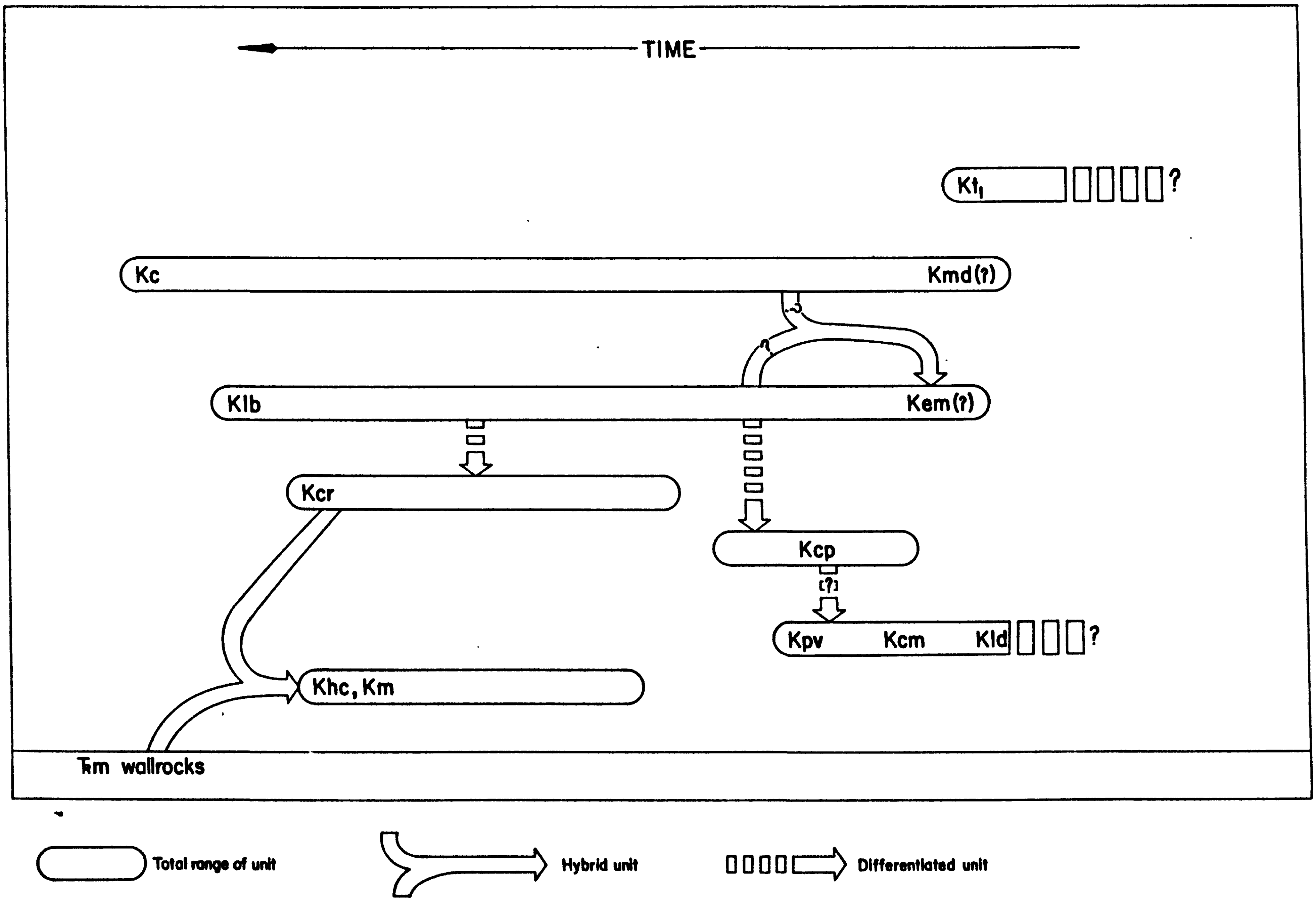

Figure 4.--Schematic diagram of intrusive sequence and relationships as indicated by field evidence. Units shown on same bar are probable phases of single magma. Overlap of bars means units are coeval. Probable hybrids and differentiates are indicated.

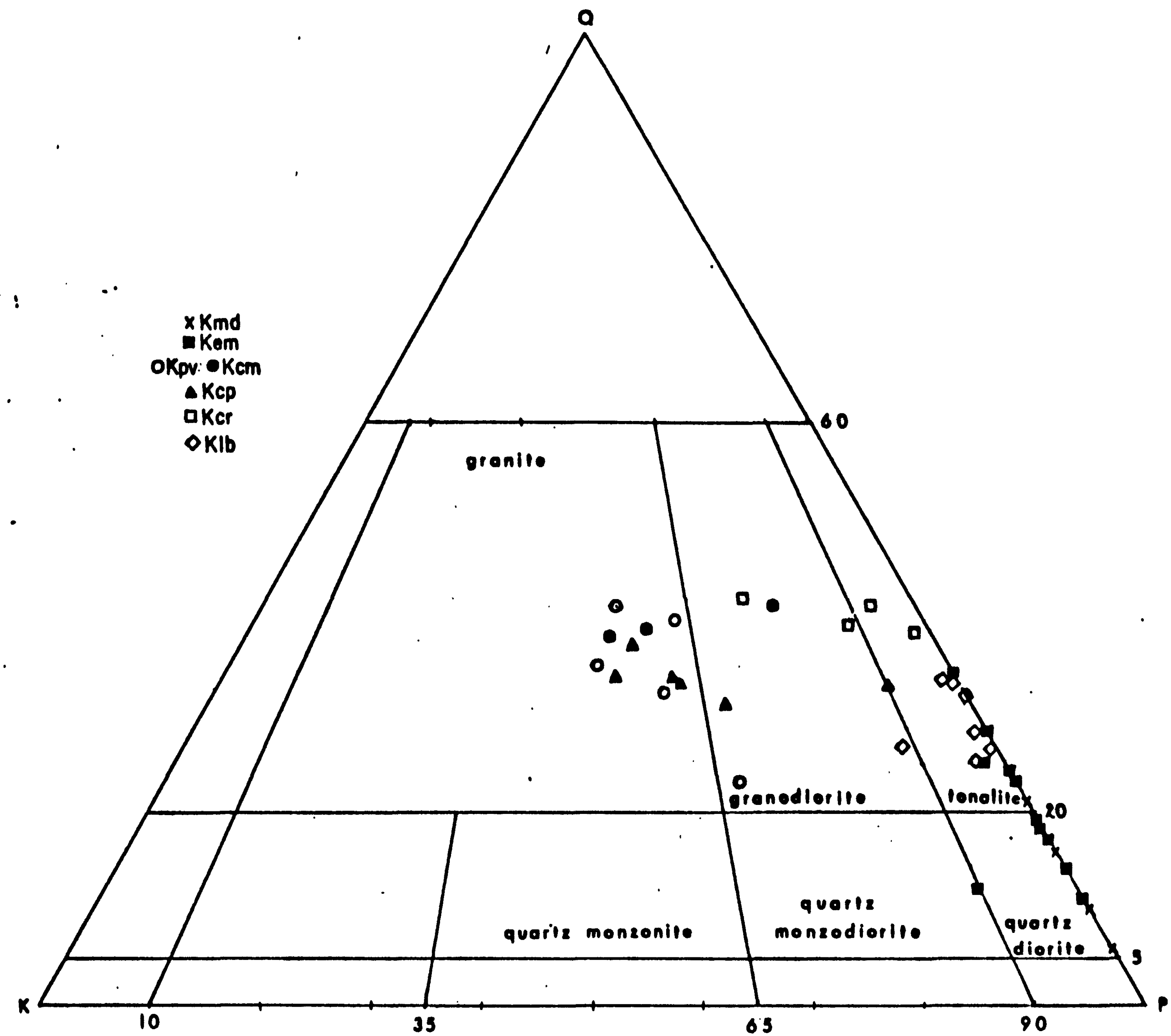

Figure 5.--Modal data for granitic rocks from Cuyamaca Peak 15' quadrangle (classification according to Streckeisen, 1973).

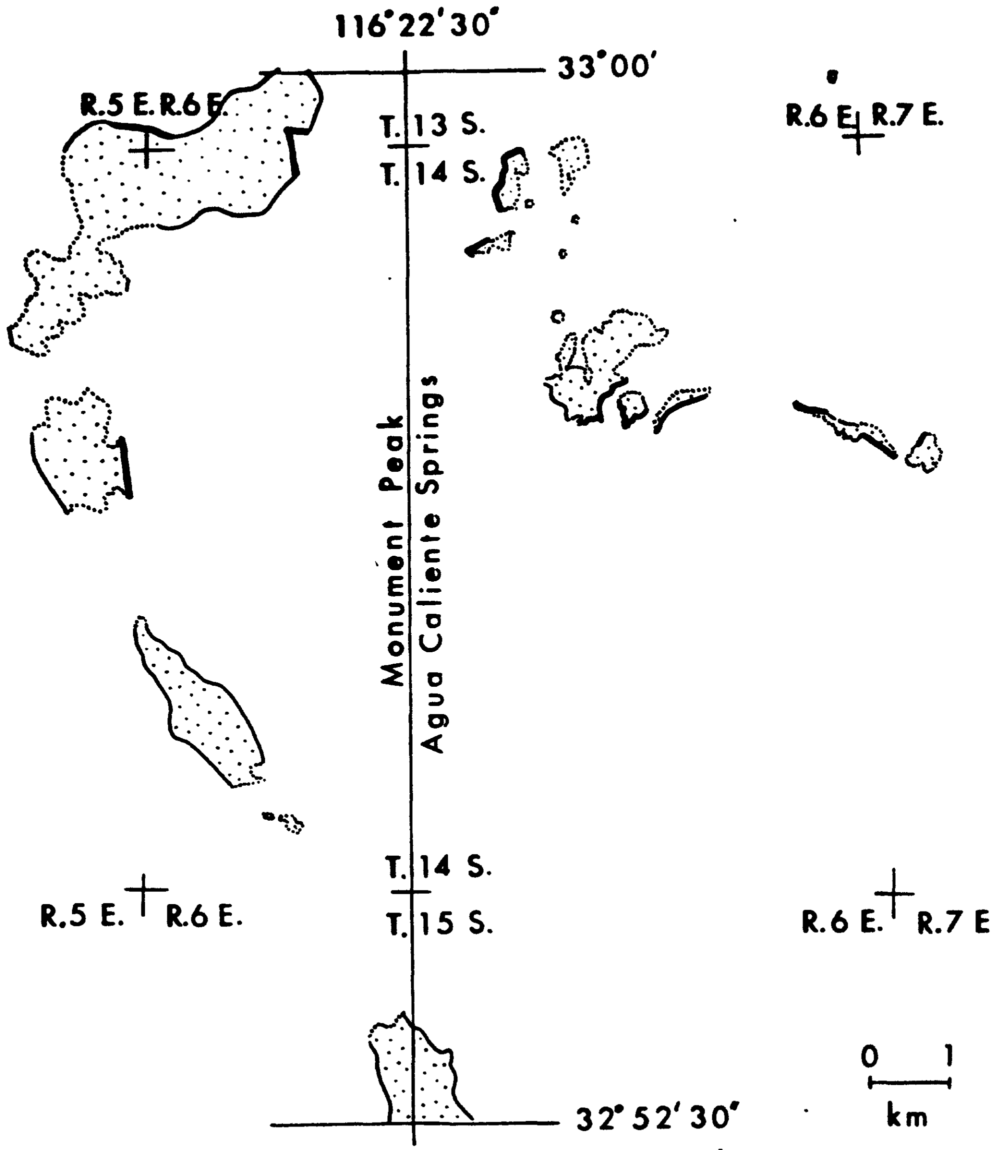

Figure 6. Distribution of TRm-Kc-Kt_2-leucocratic dike complex

fault
bedrock contact
alluvial contact

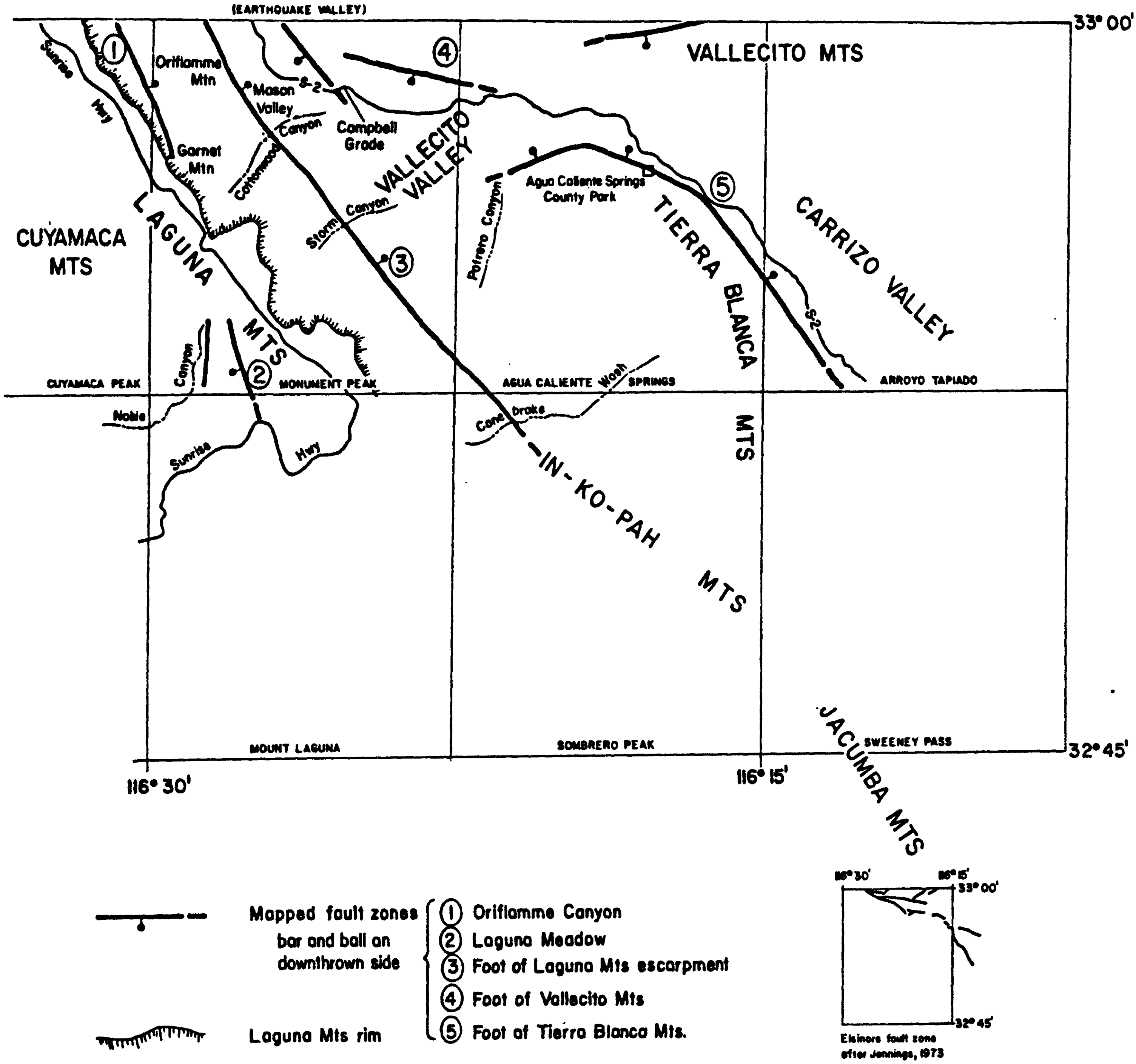

Figure 7.--Southern part of Elsinore fault zone, San Diego County, California.