UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE TULE SPRINGS QUADRANGLE

SAN DIEGO COUNTY, CALIFORNIA

by

Victoria R. Todd

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 Tule Springs quadrangle, San Diego County, California

Purpose of project:

Published maps indicate that rocks of the Peninsular Ranges batholith in southern San Diego County (southern Santa Ana block) are relatively unfaulted, but topographic maps and imagery at all scales reveal numerous prominent lineaments that cross the region in many directions. The purpose of this project is to evaluate the structural stability of the block, and in particular, to determine whether lineaments are related to faulting. Figure 1 shows the project area. The age, magnitude and type 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 Tule Springs quadrangle is the ninth map of a series of maps that show the structure of the batholith, the distribution of the crystalline rocks, and post-batholithic faults. Previous maps in the series include the Cuyamaca Peak, Descanso, Agua Caliente Springs, Viejas Mountain, Monument Peak, Mount Laguna, Alpine, and Sweeney Pass quadrangles.

Introduction:

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

Previous usage has been followed in referring to the twelve rock units as plutonic, even though most of the rocks in this part of the batholith have undergone significant synkinematic recrystallization. The plutonic rocks are variably gneissic and their foliation consists chiefly of the planar orientation of recrystallized mineral grains and aggregates (fig. 2). Gneissic textures include augen gneiss and mylonite gneiss. Petrographic study reveals igneous textures modified by strain at temperatures high enough for recrystallization to occur, indicating that the plutonic rocks have undergone solid-state flowage at elevated temperatures.

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

Nature of plutonic contacts:

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

Rock units:

The bedrock units are discussed below and their overall intrusive sequence is depicted in figure 4. Preliminary modal and normative data for the plutonic units is given in figure 5. The following 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 Tule Springs quadrangle. The bedrock units are overlain locally by unconsolidated Tertiary(?) and Quaternary deposits.

Metamorphic rocks of prebatholithic screens:--Metamorphic rocks (Jm) in prebatholithic pendants and screens in southern San Diego County are dominated by two end-members, metasedimentary rocks in the eastern part of the study area, and metavolcanic in the western part. The western screens consist chiefly of amphibolite, which includes recognizable metagabbro and metabasalt in larger screens, interlayered with metamorphosed felsic tuffs, tuff breccias and flows; lesser intermediate volcanic rock, para-amphibolite and calc-silicate rock; and local clastic rocks. The eastern, predominantly metasedimentary assemblage includes fine-grained quartzo-feldspathic semischistose rock; micaceous, feldspathic quartzite; andalusite-bearing pelitic schist; metamorphosed calcareous grit, pebble and small cobble conglomerate (in part tuff-breccia and/or reworked tuff-breccia); and interlayered with, and grading into, these rock types are significant amounts of western-type amphibolite and felsic metavolcanics. The metavolcanic admixtures persist into the western Colorado Desert where metacarbonate becomes abundant. Thus, the screens appear to preserve remnants of a continental margin assemblage with a predominantly volcanic western content, grading eastward to deep water turbidites (graded beds) and finally to a shelf(?) assemblage. The western rocks are similar to the Late Jurassic and Early Cretaceous(?) (Schoellhamer and others, in press) Santiago Peak Volcanics of western San Diego County; all screens are tentatively assigned a Late Jurassic and Early Cretaceous(?) age for the purpose of this report.

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

The boundary between predominantly metavolcanic and predominantly metasedimentary screen materials appears to lie in about the eastern one-third of the Tule Springs quadrangle. It coincides very closely with the first appearance of "I-S"(?) or "S-type"(?) granitic plutons (Todd and Shaw, 1979; Chappell and White, 1974), as will be discussed below. The two type, "I" and "S"(?) plutons and their correspondingly igneous or sedimentary wallrocks form distinctive hybrid associations along contacts between plutons and screens. Contacts between "I-type" tonalite and metamorphic screens are marked by compositionally and texturally heterogeneous 0.5 km zones consisting of granitic rock with variably assimilated but recognizable wallrock inclusions, that grades to various hybrid rocks of igneous or metamorphic character, to wallrock with granitic layers (probably concordant dikes). Most of the metamorphic component in these zones consists of calc-silicate minerals--epidote and garnet in discrete inclusions, hornblende and plagioclase in banded assimilated inclusions--reflecting the dominant metavolcanic character of the western screens. The thickness of layers within the migmatite, commonly greater than several cms, and their association with plutonic contacts indicate that they are injection migmatites. The migmatitic rock probably originated as intrusion breccia between tonalite plutons and wallrock which remained at metamorphic temperatures during regional deformation. The typical eastern-type hybrid rock association formed where "I-S"(?) or "S-type"(?) plutons intruded dominantly sedimentary wallrocks and are distinctively different. Hybrid zones are broader, up to 5 km, and have characteristics that may bear upon the origin of the suspected "S-type" magma; they are discussed more fully in a later section. In the central, transitional zone, "I"- and "S-type" plutons along with their characteristic hybrid rocks are complexly interlayered.

Where prebatholithic screens contain abundant granitic gneiss layers, a schematic pattern of lensoid bodies has been superposed on the geologic map.

In some cases the granitic gneiss consists of recognizable dikes which can be traced into nearby granitic plutons. Where the granitic material is intimately intercalated with wallrock its origin is not clear and therefore it has been called simply "granitic gneiss."

Cuyamaca Gabbro:--The name Cuyamaca Gabbro was applied by Everhart (1951) to the mafic pluton in the Cuyamaca Mountains. He assumed that all of the large mafic plutons (Guatay Mountain, Viejas Mountain, Poser Mountain) in south-central San Diego County are coeval, and data of the present study support this interpretation. These bodies, consisting of peridotite, olivine gabbro, hornblende gabbro, and norite were considered by Everhart to post-date the granitic plutons in the northern part of the Cuyamaca Peak 15' quadrangle, but in this study gabbro has been found to be the oldest plutonic rock. Because the granitic intrusive bodies typically form sheets in gabbro, it is difficult to determine which rock is older from map relations in any one area. However, relations over a large area show that many of the gabbroic bodies are lensoid screens surrounded by sheeted complexes of younger granitic rocks. In the extreme case, discontinuous gabbroic screens locally as thin as one meter or less occur between granitic plutons in several places. 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. Virtually all of the 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 and in many small bodies, foliation is concordant with regional foliation. It is more complex in the interior parts of large bodies where it may parallel regional foliation, but generally shows discordant patterns, possibly because of the presence of more than one foliation. Foliation within the gabbro appears to have formed at least 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 locally in these zones. In other places, contacts between gabbro and granitic plutons are sharp and the granitic plutons send dikes into gabbro. Both types of contact may occur together in a given area. The intrusion breccia zones are strongly deformed parallel to the regional foliation and they grade into highly contaminated margins of granitic plutons which contain abundant, large, fine-grained gabbro inclusions. Inclusions of metamorphic wallcock occur in some intrusion breccia zones between gabbro and granitic plutons, but there are many places where no wallrock appears to be involved and where grain size of gabbro decreases systematically as contacts with granitic plutons are approached.

Some contacts between granitic plutons and the Cuyamaca Gabbro (Kc) are so complexly interfingering and diffuse that they cannot be mapped accurately at this scale. The Tule Springs quadrangle contains an excellent example of a concentrically sheeted gabbro-granitic rock complex (south-central part of geologic map) in which contacts between granitic and mafic rock are extremely complex and diffuse. The large-scale mapping that would be necessary to accurately portray this complex would result in literally hundreds of small plutonic lenses, sheets and inclusions. The problem of which rock intruded which here is truly a variation on the "chicken or egg" problem! Two map patterns have been used on the Tule Springs quadrangle in order to portray this kind of contact. A pattern of irregular blocks in gabbro indicates that bedrock consists of intrusion breccia whose chief component is fine-grained gabbro, whereas a pattern of dash lines in granitic rock means that as much as 50 percent of the granitic outcrop consists of fine-grained gabbroic inclusions. These zones actually grade into one another.

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

Tonalite of Alpine:--The widespread inclusion-bearing tonalite called by previous workers Bonsall tonalite, after C. S. Hurlbut, Jr. (1935), is gradational into dark, inclusion free rock called Green Valley tonalite (F. S. Miller, 1937). The latter is equivalent to our quartz norite of Las Bancas (Todd and Shaw, 1979) which does not crop out in the Tule Springs quadrangle. The inclusion-rich tonalite has compositional and textural variations which have enabled us to map two gradational units--the tonalite of Alpine (Ka), a mafic variety, and the tonalite of Japatul Valley (Kjv), a more leucocratic variety. The Las Bancas unit, consisting of K-feldspar-bearing biotite-orthopyroxene quartz norite ($An_{>50}$), is at 57 to 63 percent SiO_2 the mafic end-member of the tonalite series, in contrast to tonalite of Japatul Valley with 61 to 66 percent. Tonalite of Alpine falls between with average SiO_2 content 60 to 63 percent. The more leucocratic tonalite of Japatul Valley contains sparse inclusions of quartz norite. Contacts between the tonalite of Alpine and the Las Bancas unit are in part gradational and in part, the two rocks are interlayered.

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 ($An_{\pm 50}$) is common, and locally hornblende is subhedral too. Corroded grains of both ortho- and clinopyroxene are present. In general, mineral grains and aggregates appear recrystallized, and the rock has a strong gneissic texture. It grades into both the Las Bancas and Japatul-type tonalites. In the Tule Springs quadrangle, the tonalite adjacent to the concentrically sheeted gabbro-granitic rock complex mentioned above is particularly contaminated by mafic inclusions and schlieren. In some cases inclusions are so flattened and elongated that outcrops appear thinly banded by light and dark layers in about equal proportions. Large (1 cm) relict euhedral plagioclase phenocrysts are especially abundant.

<u>Tonalite of Japatul Valley</u>:--The tonalite of Japatul Valley (Kjv) is an extensive unit which grades into the tonalite of Alpine but is partly separated from it by screens of gabbro and wallrock. The tonalite of Japatul Valley is distinctly different from the Las Bancas type. It is lighter in color, less mafic, and its abundant mafic inclusions are typically weathered out in relief. They may be large and irregular in shape, or streamlined parallel to foliation. Many inclusions are fine-grained but some are peppered with subhedral plagioclase grains and a few are gabbroic. Large inclusions of Las Bancas-type quartz norite are seen locally. Characteristic of the rock are single subhedral plagioclase (An_{42-48}) and hornblende grains, although recrystallized mafic aggregates also occur. The unit contains no pyroxene. The tonalite is medium- to coarse-grained, distinctly equigranular, and the subhedral grains give it a more igneous-appearing texture than that of the Las Bancas or Alpine varieties. However, the rock is 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 texturally identical to the tonalite but ranging to granodiorite in composition. The leucocratic variety is always found in association with wallrock screens and injection migmatite zones. The distribution of these rocks is shown only grossly on the map for they are interlayered complexly on both large and small scales. The following lithologies are always present:

1) Japatul-type tonalite.
2) medium- to coarse-grained gneissic granodiorite and large, concordant, chilled granitic dikes.
3) partly assimilated inclusions of wallrock; injection 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 and 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 gabbro and/or fine-grained mafic rock.

Locally, tonalite of Japatul Valley is markedly leucocratic over about 10 cm or less next to wallrock inclusions, suggesting that the origin of the leucocratic, fine-grained matrix of the intrusion breccia and migmatite is modified tonalite. Dikes of younger granite, alaskite and aplite commonly have intruded along and near these zones. Typically the dikes are crosscutting, but they may also be complexly interlayed with tonalite and wallrocks.

This rock association suggests a genetic relationship between tonalite and more leucocratic magmas (i. e., granite of Chiquito Peak). The leucocratic Japatul rock is identical to contaminated granite of Chiquito

Peak, shown by dashed pattern on Cuyamaca Peak (Todd, 1977) and Descanso (Hoggatt and Todd, 1977) geologic maps. In these two quadrangles, this inclusion-rich granodiorite grades into, and locally is intruded by, "clean" granite (adamellite by classification of Williams and others, 1954). Thus, tonalite, granodiorite and granite seem to form a differentiated series. The granite plutons consist of relatively small, discrete bodies, e.g., Chiquito Peak in Viejas Mountain quadrangle (Todd, 1978a), and large, schlieric, partly gradational dikes in tonalite. These shapes and age relations suggest a differentiated sequence. The migmatite zones associated with granodiorite and granite may be remnants of screens that once separated differentiated pockets of magma.

Tonalite and quartz diorite of East Mesa:--The tonalite and quartz diorite of East Mesa (Kem) is the most heterogeneous and, in terms of age, most problematical plutonic unit in the project area. Typical plutons consist of narrow, steeply-dipping sheets, i.e., large dikes, which are complexly intersheeted with surrounding granitic plutons. Plutons of East Mesa type are strongly foliated, especially near their margins. The pluton in the Tule Springs quadrangle, for example, consists almost wholly of mylonitic gneiss.

Tonalite and quartz diorite form the major part of the unit. Quartz diorite whose hornblende encloses pyroxene cores (opx $\rightarrow$ cpx) may contain plagioclase of $An_{>50}$ and according to the classification of Streckeisen (1973) should therefore be called quartz norite. Where coarse-grained this rock is identical to the quartz norite of the Las Bancas unit. The typical rock is dark gray, fine- to medium-grained, locally sub-porphyritic quartz diorite with relict subhedral phenocrysts of plagioclase and hornblende. A common textural variety has a spotted or streaked appearance due to poikilocrysts of biotite in a fine-grained groundmass. The typical rock grades to mixtures of the dark, fine-grained quartz diorite and coarser-grained, more leucocratic-appearing tonalite containing inclusions of fine-grained mafic rock. Age relations between tonalite and quartz diorite are seldom clearly discernible, except that locally, tonalite with mafic inclusions appears as partly assimilated inclusions in quartz diorite.

Pale tan to green hornblende is either the dominant mafic mineral in quartz diorite 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. Plagioclase in one dark, fine-grained sample is An_{39} by electron microprobe, and in a coarser-grained tonalite, An_{47}. Medium-grained rock carries abundant, fine-grained mafic inclusions, less than 0.3 m 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.

Small and large bodies of gabbro occur within the quartz diorite as discrete inclusions, in intimate mixtures of the two rocks, and in apparent gradation. The gabbro is generally fine- to medium-grained and cannot be distinguished in the field from small bodies of fine- to medium-grained Cuyamaca Gabbro. 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, a variety of internal contacts were seen locally and undoubtedly the history of the unit is complex.

The East Mesa unit sends dikes into and has chilled margins against all plutonic units except the Las Bancas, Alpine and Japatul Valley units. The unit is locally continuous with, and also cut by, the mafic to intermediate dikes mentioned earlier in the section on the Cuyamaca Gabbro. Locally, these age relations are reversed, as where granitic host rocks have re-intruded quartz diorite (fig. 3). This is especially true where the latter intrudes granodiorite (Kcr) and granite (Kcp). In the southeastern part of the Descanso quadrangle, for example, quartz diorite and these more leucocratic units have been contaminated by one another. In the Tule Springs quadrangle, contacts among these three units are generally more distinct, although locally, narrow zones of extreme mixing are seen, as in the northeastern corner of the map. These "mixed" zones consist of mylonite consisting of quartz diorite, tonalite, granite, granodiorite and wallrock in which original contacts are rarely preserved, except that granite (Kcp) occurs as chilled dikes in quartz diorite locally.

In the Tule Springs quadrangle, quartz diorite and the "I-S-Type"(?) granodiorite of Cuyamaca Reservoir have a complex interfingering contact and it is extremely difficult to distinguish between deformed lenses of one rock in the other. The distinction is more easily made away from the contact where the following criteria are helpful:

Quartz diorite of East Mesa	Granodiorite of Cuyamaca Reservoir
crops out poorly forming low blocky outcrops with thick dark soil; weathers pinkish-gray, locally tan; underlies smooth, rounded brushy hills and meadows.	crops out resistantly to prominent slabs due to higher quartz content and strong foliation; weathers characteristic orange-tan color; underlies high hills and ridges with numerous areas of bare rock.
small (<1 ft) wallrock inclusions	small (<1 ft) wallrock inclusions
fine-grained and porphyritic quartz diorite has igneous (felty) texture (recrystallized); near contacts and inclusion trains, rock is mylonitic, more micaceous and igneous texture disappears.	medium-grained on average, micaceous and strongly gneissic throughout; no igneous texture; some rock contains relict horn-blende but grains are totally recrystallized.
quartz not obvious in outcrop	quartz appears abundant in outcrop

Age relations observed in the Tule Springs quadrangle between the large northern pluton of granodiorite of Cuyamaca Reservoir and the adjacent quartz diorite pluton are summarized below:

1) quartz diorite has fine -grained (chilled?) margins against granodiorite; quartz diorite dikes in granodiorite; granodiorite re-intrudes marginal quartz diorite leading to production of rounded inclusions of fine-grained quartz diorite in granodiorite near contact; locally both rocks show decrease in grain size at contact.

2) "inclusions" of each rock type in the other in zone of contact; interfingering contact; gradation (may be side effect of deformation of interfingering contact); two rocks not distinguishable locally.

3) swarms or trains of small (<1 ft) wallrock inclusions along contact.

4) leucocratic granodiorite dikes (Kcr) in quartz diorite near contact.

Various outcrops in the project area suggest a true gradational relationship between East Mesa-type quartz diorite and the much more voluminous tonalite and quartz norite series described above. Figure 5 shows that these units overlap in modal and chemical composition. Where the East Mesa unit is medium- to coarse-grained with color index 25 to 35 percent, it is very similar to the Japatul-type tonalite. Where quartz diorite is fine-grained and mafic, its chemical composition overlaps with that of the Las Bancas-type unit. Everhart (1951) noted this similarity between these rocks, which he called Green Valley tonalite and Cretaceous diorite, and he suggested that they were the same. The chief reason for mapping two units in the present study was that the rocks named for the East Mesa pluton in the Cuyamaca Peak quadrangle consistently <u>intrude</u> granite units, whereas tonalite plutons <u>are intruded by</u> granite (fig. 4). Also, quartz diorite and the major tonalite units tend to be mutually exclusive in their areas of outcrop. In the few places where they are in contact, they grade into one another. This gradation is similar to contacts between the medium- to coarse-grained, more leucocratic-appearing East Mesa tonalite and the fine- to medium-grained darker quartz diorite. The tonalite in the East Mesa unit is probably Alpine or Japatul tonalite.

Field evidence further suggests that the dark fine-grained quartz diorite may be a hybrid, formed at greater depths, from tonalite and gabbro magmas. The quartz diorite plutons commonly occur where the Cuyamaca Gabbro is in contact wtih tonalite, 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 East Mesa-type bodies intrude units that are coeval with, or intrude tonalite, the former may be synplutonic, hybrid small plutons and dikes. In the Monument Peak quadrangle (Todd, 1978b), small gabbro plutons in the southeastern quarter give way to the north along strike to a system of large dikes that consist of variable, dark, fine- to medium-grained, porphyritic quartz diorite and tonalite identical to the East Mesa rock. Until more data are available, bodies which crosscut granite plutons will be designated East Mesa, even though parts of these bodies are probably composed of tonalite of Japatul Valley or Alpine.

Granodiorite of Cuyamaca Reservoir:--The granodiorite of Cuyamaca Reservoir (Kcr) occurs chiefly in the eastern part of the study area. It weathers to distinctive reddish and orange-brown colors and is light to dark gray on fresh surfaces depending upon the mafic content, which ranges from 14 to 29 percent. Where the unit is in contact with gabbro, it consists of more mafic tonalite and contains abundant fine-grained mafic inclusions that are flattened parallel to foliation. Although locally grading from granodiorite to tonalite, 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 of Cuyamaca Reservoir shows some of the most strained and recrystallized igneous textures in the region.

The granodiorite of Cuyamaca Reservoir contains andesine (one sample has An_{37} as determined by electron microprobe), greatly modified by recrystallization, and pale straw to foxy red-brown biotite. Most samples contain no hornblende, but tonalite of the unit contains hornblende and pyroxene relicts within biotite aggregates; intergrowths of actinolite and epidote have replaced hornblende. The chief accessory minerals are ilmenite, allanite and sphene. The mineralogical and textural differences between the granodiorite of Cuyamaca Reservoir and "I-type" granitic units may be related to derivation of the former from primarily metasedimentary rocks. The unit is especially gneissic and is locally porphyroclastic and mylonitic next to large screens of metamorphic rock and is rich in mica. Fine-grained granodiorite grades into and intrudes the gneiss of Harper Creek (Khc), two mica granodiorite gneiss which has many of the characteristics of "S-type" granitic rocks and is abundant only in the eastern quadrangles, as sheeted plutons between the granodiorite unit and wallrock screens. Local hornblende and gradation into "I-type" tonalite suggest that the Cuyamaca Reservoir unit is a transitional "I-S" granitic rock. Determination of initial Sr isotopic ratios is underway on an east-west suite of samples of these suspected "I-S" and "S-type" rocks.

The granodiorite of Cuyamaca Reservoir locally has chilled margins against and sends dikes into Cuyamaca Gabbro. Contact relations between the unit and the quartz norite-tonalite series--Las Bancas (Klb), Alpine (Ka) and Japatul Valley (Kjv)--have been observed over a wide area, and are summarized below. They suggest that the granodiorite is essentially coeval with the "I-type" units.

1. Contact schlieric and interfingering; both rocks are texturally and compositionally similar, but granodiorite is brown- to orange-weathering and "I-type" tonalite is pinkish-gray-weathering. Locally, they appear gradational.

2. Contact schlieric, interfingering, granodiorite tends to be finer-grained (fine to medium) next to tonalite, and more leucocratic and sheared (porphyroclastic); tonalite texturally unchanged right up to contact.

3. Neither rock shows textural change; they are separated by thin (locally 1 m) screens of Cuyamaca Gabbro, gabbro intrusion breccia, or wallrock (Jm).

4. Granodiorite occurs as large fine-grained dikes in tonalite <u>and</u> as schlieric inclusions.

5. Contact relatively sharp; "I-type" tonalite texturally unchanged up to contact; granodiorite also unchanged but occurs as blocky inclusions in tonalite margins.

6. Dark gray-weathering, fine-grained dikes (quartz norite?) observed in granodiorite locally along the contact between a large quartz norite pluton and granodiorite of Cuyamaca Reservoir (Mount Laguna quadrangle, Todd, 1979).

These area-wide indications of co-existing magmas are supported by relations in the Tule Springs quadrangle. Much of the contact between granodiorite of Cuyamaca Reservoir and tonalite of Japatul Valley and/or tonalite of Alpine is complex, interdigitating and it is difficult to say which rock intrudes the other. Discontinuous wallrock screens of western type occur along part of the contact as do large leucocratic dikes. Locally, tonalite appears coarse-grained and texturally unchanged up to the contact whereas granodiorite becomes more leucocratic and somewhat finer-grained toward it. In some places, both units appear to be more leucocratic near the contact--this may be due to assimilation by both of felsic tuff-breccia. Tonalite of Japatul Valley is locally chilled against the intervening screen. In the stretch of the contact on the western side of the San Diego River, granodiorite contains rotated, rounded inclusions of tonalite which appears coarser-grained, on the average, than the surrounding granodiorite. Although the two rocks are schlierically mixed here, the granodiorite locally appears chilled; both contain small (< 1 ft) wallrock inclusions.

Hybrid gneiss of Harper Creek:--The hybrid gneiss of Harper Creek (Khc) is a gray and yellow-weathering, cordierite(?)-sillimanite-bearing, quartz-biotite-plagioclase-K-feldspar/muscovite gneiss. The only outcrops of hybrid gneiss in the Tule Springs quadrangle occur in the extreme south-central part. The unit, which is remarkably homogeneous over large areas, includes rocks that closely resemble granodiorite of Cuyamaca Reservoir (Kcr) as well as rocks that are clearly metasedimentary in origin. The unit 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 gneiss is too rich in quartz and mica to be a straightforward metaigneous rock. K-feldspar has been converted to muscovite in many samples.

The gneiss is not migmatite, although migmatite does occur locally at contacts with metasedimentary rocks (Jm) and with the granodiorite of Cuyamaca Reservoir (Kcr). Contacts between gneiss and metasedimentary rocks may be sharp, or may be marked by alternating layers of gneiss and wallrock that are too small to be depicted at the map scale. Contacts between gneiss and granodiorite may be gradational or sharp, Where they are gradational, granodiorite may be 1) fine-grained, containing abundant partly assimilated inclusions of wallrock, or 2) coarse-grained, sub-pegmatitic, leucocratic and full of inclusions and biotitic lenses. These rocks are interpreted as margins and/or dikes of granodiorite plutons which were originally in contact with metasedimentary rock. Elsewhere, granodiorite is interlayered with gneiss near the contact. In a few places, gneiss of Harper Creek has intruded other plutons which indicates that the rock was as mobile as the other plutonic units.

The abundant metasedimentary inclusions, presence of aluminosilicates, and the high proporton of quartz and mica attest to the rock's partial sedimentary origin. Local relict igneous textures and gradation into granodiorite of Cuyamaca Reservoir indicate that the unit originated either by mixing of granodiorite and wallrock enhanced by deformation and metamorphic temperatures that existed over a considerable period of time, probably both before and after emplacement of granodiorite, or by ultrametamorphism of sedimentary rocks. Whatever the origin of this unit may be, it is always spatially associated with granodiorite of Cuyamaca Reservoir and screens, and for this reason, is probably essentially coeval with the granodiorite.

Granite of Chiquito Peak:--The granite of Chiquito Peak (Kcp) is a medium-grained, strongly foliated, light-weathering rock with color index ranging from 5-12 percent. The plagioclase feldspar is oligoclase (An 29 in one sample) 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. The unit was emplaced as a series of steeply-dipping, interconnected sheets and lenses.

The granite of Chiquito Peak typically intruded older plutons in complexes of dikes, chilled against them, and locally shows a high degree of contamination through assimilation of stoped inclusions. This is particularly true where granite is in contact with wallrock, gabbro and quartz diorite of East Mesa. The contamination and post-intrusive deformation have given rise to complex hybrid zones between these plutons. A contaminated granite category (dashed pattern) has been used elsewhere [Hoggatt and Todd (1977), Todd (1977)] to designate parts of granite plutons which are particularly inclusion-rich and contaminated. Included in this pattern are intimate mixtures of granite, granodiorite, and tonalite representing places where tonalite of Japatul Valley graded to, and was intruded by, granodiorite and granite.

A textural variant of granite of Chiquito Peak (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 granite and occurs near wallrock screens.

A granite with color index ranging from 2 to 7 percent that is locally devoid of hornblende and contains slightly more quartz than the average rock grades into and intrudes the average granite. The leucogranite with abundant 1 to 2 cm relict euhedral K-feldspar grains which underlies the Stonewall Peak area is an example. The thin-sheeted style of intrusion, extensive stoping and reactions with mafic rocks, finer grain size and mafic mineral suite help to distinguish this unit from younger granites which do not crop out in the Tule Springs quadrangle.

Pegmatite, alaskite and aplite:--Leucocratic dikes (K1) of pegmatite, alaskite and aplite cut across all units. In some areas they can be traced into a parent pluton. Where no associaton with larger bodies was established, the dikes have been mapped separately. These dikes share the metamorphic fabric of the other plutonic rocks.

Surficial deposits:--Surficial deposits in the Tule Springs quadrangle consist of Quaternary alluvium in stream valleys and older alluvium that occurs as patchy remnants at high elevations or is crosscut by the modern drainage system. The latter may be as old as late Cretaceous or early Tertiary in some areas.

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

Patchy deposits consisting of thick (10 m+) lenses of well-bedded conglomeratic sands and well-rounded, poorly indurated fanglomerate of local derivation (gabbro, leucogranite and prebatholithic rock) occur in a variety of settings at elevations between 1400 and 4000 ft (TQo). These older deposits lie partly on ridges and spill into adjacent valleys, or form a broad fill, now deeply dissected and eroded, in the larger valleys. The older deposits may grade into Quaternary alluvium because of reworking and redeposition of material on steep slopes by Quaternary streams. Sparse rounded cobbles of the same resistant lithologies and small scattered lenses of sand suggest that similar materials once blanketed the broad Cretaceous-Tertiary(?) erosion surface in the west-central part of the Tule Springs map. These older deposits probably represent more than one cycle of erosion and deposition, but both types may be as old as late Cretaceous or early Tertiary if they correlate with the Lusardi Formation of San Diego County, which is the post-batholithic basal continental conglomerate (Kennedy and Peterson, 1975). The crystalline rocks, chiefly tonalite, beneath these deposits are deeply weathered and have a well-developed soil profile. The gabbro-dominated bouldery deposits which occur on the west side of Cuyamaca Peak are of this nature and probably older than the Quaternary age assignment given them in the Cuyamaca Peak quadrangle, which was the first map of the series. These deposits are designated Tertiary-Quaternary (TQo) on the geologic map due to the age uncertainty.

Also present on the erosion surface in the Tule Springs quadrangle is a dark red-weathering lag gravel consisting of mafic inclusions that have weathered out of the underlying mafic tonalite. This cobble-sized material generally does not appear water-rounded and is probably not related to the older alluvial deposits described above.

Structure of batholithic rocks:

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

The structural grain varies over the project area. In the Cuyamaca Peak, Descanso, Monument Peak and Mount Laguna quadrangles it is predominantly north-northwestward, and the regional dip is eastward (fig. 6). It swings to northwest to west strikes in the western part of the study area; the regional dip is strongly to the north and northeast (Viejas Mountain, Tule Springs and Alpine (Todd, 1980) quadrangles). The swing to northerly trends seen in the northern part of the Viejas Mountain quadrangle is repeated in the northwestern corner of the Alpine quadrangle, suggesting the existence of a large-scale flexure or flexures in batholithic contacts and foliation having a steep northeast plunge (fig. 6).

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

It was first noticed in the Mount Laguna quadrangle that ourcrops of quartz norite of Las Bancas commonly display two foliations at large angles to one another, both of which appear to be recrystallized mineral foliations. Locally in this quadrangle an east-trending foliation is reoriented by 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. Once observed, this double foliation was seen more widely in tonalite, gabbro and metamorphic screens. In outcrops of gabbro, one mineral foliation is typically parallel to compositional layering but has a steeper dip, near vertical, than does this layering. Double foliation may account for some of the apparent fluctuations in foliation in the project area, since only one foliation may show up well in a given outcrop.

Faults of the Tule Springs quadrangle:

Faults in the quadrangle have been grouped under four geographic headings: the first three groups are parts of more extensive fracture systems while the last is local and of small extent (fig. 7). As was found throughout the project area, the faults are short, sub-parallel and occur in zones rather than as large through-going single faults.

Conejos Valley faults:--The north- to north-northwest-trending faults in and near Conejos Valley (fig. 7) are on strike with faults to the south that bound the east side of Viejas Mountain and appear to cut alluvium which may be as old as late Cretaceous-early Tertiary(?) (Viejas Mountain quadrangle). Two faults in the Tule Springs quadrangle may offset granite dikes (Kcp) very slightly. The northern group of faults are expressed by lineaments in gabbro, tonalite and the overlying older alluvium (TQo). All of these faults parallel Cretaceous structure; a glance at Figure 6 indicates that faulting may have been localized by a zone of deformed granitic rocks between two resistant plutons. Over a dozen small faults are exposed in the v-shaped bend of Conejos Valley road in the NW 1/4 of sec. 5, T. 15 S., R. 3 E. Their average strike is north and they dip 72° to the west.

Included with the Conejos Valley faults are northwest- to north-northwest-trending faults on the west flank of Viejas Mountain (fig. 7). The latter in part parallel, and in part crosscut Cretaceous structural trends. There is about 0.8 km apparent left-lateral offset of contacts across the fault zone in the hinge area of a sharp flexure.

In summary, the Conejos Valley faults crosscut Cretaceous plutons and structures, and are not intruded or crosscut by plutonic rocks. They follow Cretaceous structure in large part. They may cut alluvium of Tertiary(?) age but are not known to cut Quaternary deposits.

Cuyamaca Mountains faults:--The north- to north-northwest-trending Cuyamaca Mountains fault zone (Todd, 1977) extends into the eastern part of the Tule Springs quadrangle where a narrow graben or notch separates tonalite (Ka), granodiorite (Kcr), and quartz diorite (Kem) on the west from Cuyamaca Gabbro on the east. The contacts and faults are obscured by bouldery debris flows consisting of gabbro and lesser metamorphic rocks (TQo) which spill down the western flank of Cuyamaca Peak into the valley of Boulder Creek. Similar debris flows appear to be cut by faults of this zone in the western part of the Cuyamaca Peak quadrangle (Sherilton Valley). In the Tule Springs quadrangle bouldery alluvium is cut by two breccia-gouge zones in a roadcut of Boulder Creek road. Elsewhere along the road, the base of TQo deposits truncates bedrock faults.

The large steeply-inclined flexure of contacts in the eastern part of the quadrangle (fig. 6) does not appear to be offset laterally by the fault zone but considerable vertical displacement may have taken place if erosion surfaces on the two sides of the zone were once continuous. Broad meadows in the Cuyamaca Peak quadrangle lie at an elevation of 4800 ft, whereas west of the Cuyamaca Mountains in the Tule Springs quadrangle accordant summits that are underlain by the same rock types and structures lie at 3200-3600 ft. It is also possible that the ultramafic rocks of Cuyamaca and Middle Peaks acted as a resistant barrier to peneplanation and that the two surfaces formed simultaneously.

Some faults of this zone are marked by dense cataclasite which probably resulted from late shearing in the batholith. Other faults are marked by gouge and breccia formed at or near the ground surface.

Thus, faulting in the Cuyamaca Mountains zone may have begun at depth during the late stages of batholithic emplacement and before deposition of possible Tertiary deposits (TQo), and continued after deposition of these deposits. More recent movements have not been documented.

Some measured faults of the Cuyamaca Mountain zone:*

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
N21E 90°		Cuyamaca Gabbro	
1) many thin (6 in) faults averaging N60W 82NE	friable gouge; pink (K-feldspar) and green (epidote) alteration	Ka	?
2) 1.5 ft fault N45W 85NE		"	?
3) sinuous shear zone, average trend N17E NW70 (1 zone 2 ft thick)	punky whitish alteration (caliche?)	Ka	leucocratic dike offset, normal dip-slip, 1.5-2 ft, NW side down
1) 1 ft zone with multiple faults, N8W 88NE		Ka	?
2) many small (2 in) faults averaging N20W 58SW	dense cataclasite	"	?
small fault in fractured zone 1 m wide, N17W 90°	gouge	Ka	?
small fault N40E SE 75	gouge	Ka	?
two faults each several ft wide; average strike N83E, dips 80-85 and 60°NW; total crush zone several m wide in envelope of closely broken rock	breccia and gouge	Kc	?
several small faults in zone 1 m wide; N72E SE79	gouge	Kc	?
small fault N14E NW74	gouge	Ka	?
small fault N14E SW78	gouge	Ka	?

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

San Diego River Valley faults:--The northeast-trending San Diego River Valley is part of a striking 30-km long lineament in southern San Diego County which Merifield and Lamar (1976) consider to be a fault zone with right-latral separation. The southern extension of the lineament, Chocolate Canyon-Galloway Valley-northern Harbison Canyon (Alpine quadrangle, Todd, 1980) is the site of short, parallel northeast faults which do not offset batholithic contacts. The canyon of the central reach of the San Diego River crosses the northwest corner of the Tule Springs quadrangle. Here, and in the Santa Ysabel quadrangle immediately to the north, west-northwest-striking contacts appear to be offset right-laterally by 300 m in one place and 450 m in a second. Although some reaches of the canyon are remarkably linear and coincident with the northeast lineament, the river makes many bends away from this trend. Thus, the canyon is not determined by a single master fault over its entire length. There are a series of short, parallel northeast-trending lineaments in the vicinity of the canyon in this area; most lie on the northwest side of the river (Ramona and El Cajon Mountain quadrangles), and at least some of these are faults. Therefore, it is likely that faults of similar magnitude underlie parts of the canyon and that one or more such faults is responsible for the apparent right-lateral offset. However, small-scale sharp flexures in batholithic contacts occur elsewhere in the project area where there is no evidence of faulting. Final interpretation of the San Diego River Valley lineament awaits detailed mapping over its full length. The number of faults and joints and closeness of fracturing increase markedly as the canyon is approached by the few truck trails in the area which provide cuts into the deeply weathered bedrock. This indicates that the main canyon is fault-controlled.

Faults of San Diego River Valley:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) several small faults, largest trends N50W 72NE 2) multiple small faults striking WNW with flat to moderate northward dips	gouge	Kcr	?
multiple small faults of variable trends including flat faults; appears to be shear zone; N45-50W 75NE	gouge	Kcr	?
extensive flat (northward dip) 1 ft gouge zone with brecciated granodiorite above; other thin faults trending N45W, steep dips	black gouge	Kcr	?
N18W 90°, one of two faults, larger 10 in wide; localized by small leucocratic dike	punky greenish-white gouge; pink K-feldspar alteration	Ka	?
4-5 m breccia zone localized in large leucocratic dike, dipping gently to moderately to north		Ka	?
N45E 87SE average for number of small faults (hairline to several in width) which increase in number toward floor of canyon		Ka	1 fault offsets thin leucocratic dike several inches, normal dip slip, SE side down; (2 faults appear offset by dikes)
large fault in zone several tens of feet wide, NNE, steep	poorly indurated breccia and gouge; reddish alteration	Jm	?
small fault N87W NE 89		Ka	?

Poverty Gulch faults:--The stretch of Goudie Truck Trail (sec. 10, T. 15 S., R. 3 E.) which leads into Poverty Gulch (King Creek) exposes a large number of small faults; north-trending gabbro-tonalite-metamorphic screen contacts in this area *may* be slightly offset in an (apparent) t-lateral sense. The canyon of King Creek trends approximately east, but the stream has a zigzag course, of which the straightest reaches are northwest, parallel to indistinct northwest vegetation lineaments. The following faults were measured in the road:

Strike and dip of fault plane	Type, width and alteration of crushed rock	Unit(s) cut by fault	Type and amount of separation
1) N65W NE80 and N52E 87NW, small faults associated with leucocratic dikes	whitish gouge	Kc	?
2) 8 in fault trending N73W NE78 plus other small faults striking in various directions	whitish gouge	Kc	?
numerous sub-parallel minor faults; N20E 90°	whitish gouge	Ka	?
small fault N28E 83NW	whitish gouge	Ka	?

Minor faults:--Small faults such as the ones above were seen in roadcuts in many parts of the quadrangle, but most were not associated with a major lineament and were impossible to trace further because of thick soil and vegetation. A number of short, northwest-trending lineaments in the NE 1/4 of the map are parallel to contacts and foliation and may reflect jointing along these ancient trends. Some of these lineaments are probably related to faulting, e.g., the rather prominent lineaments and aligned saddle and canyon in the Devil's Punchbowl area (sec. 9, T. 14 S., R. 3 E.). Here, local seams of dense cataclasite (old?) follow strong foliation in granodiorite of Cuyamaca Reservoir (Kcr).

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traverses made in this eastern part of the Capitan Grande Reservation were not sufficient to fully map the complex geology of this part of the Tule Springs quadrangle, due to the size of the area, lack of roads and trails and heavy brush. Color aerial photographs were used to supplement my observations on the ground.

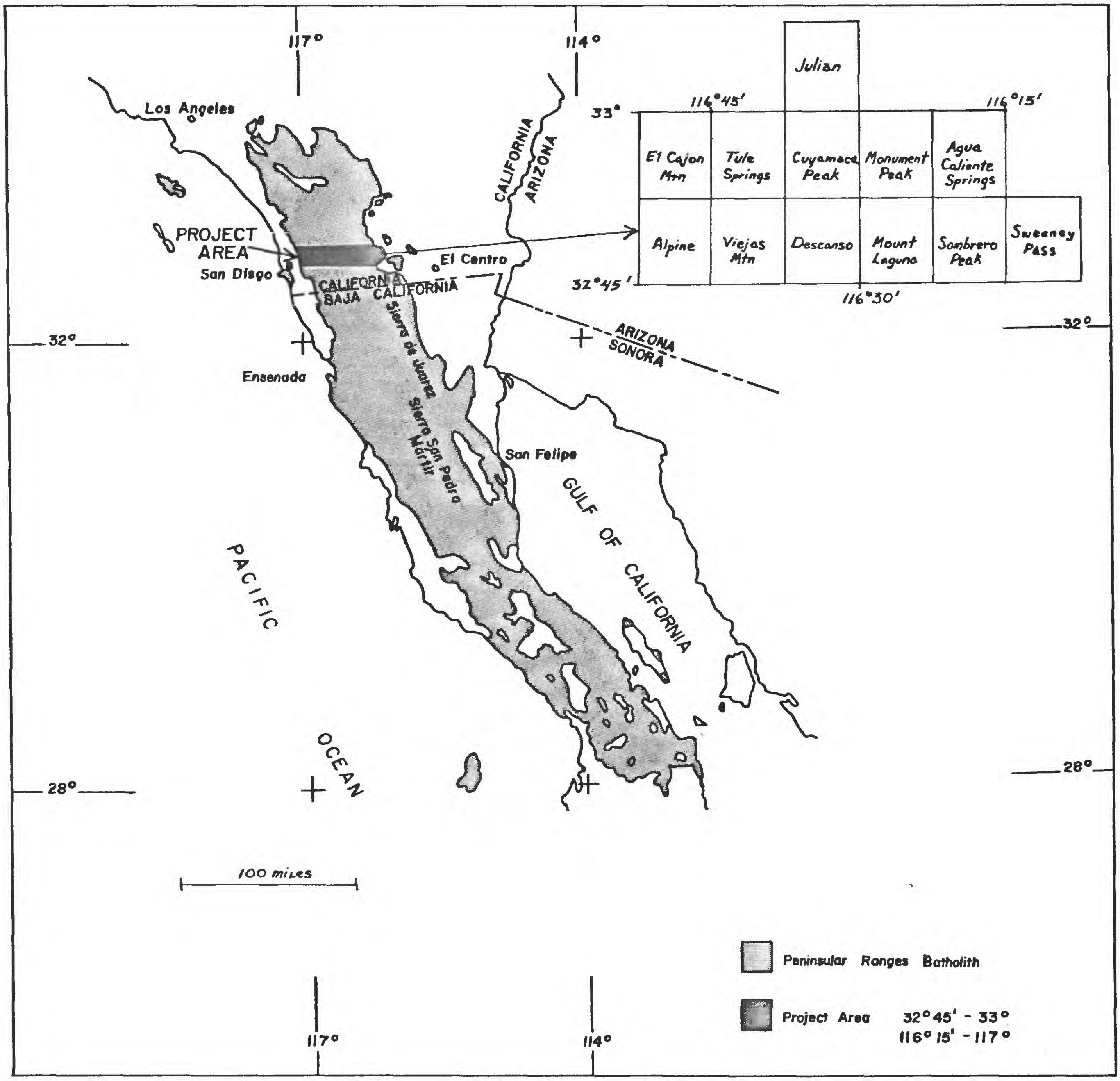

Figure 1. Peninsular Ranges batholith in southern California and Baja California and project area.

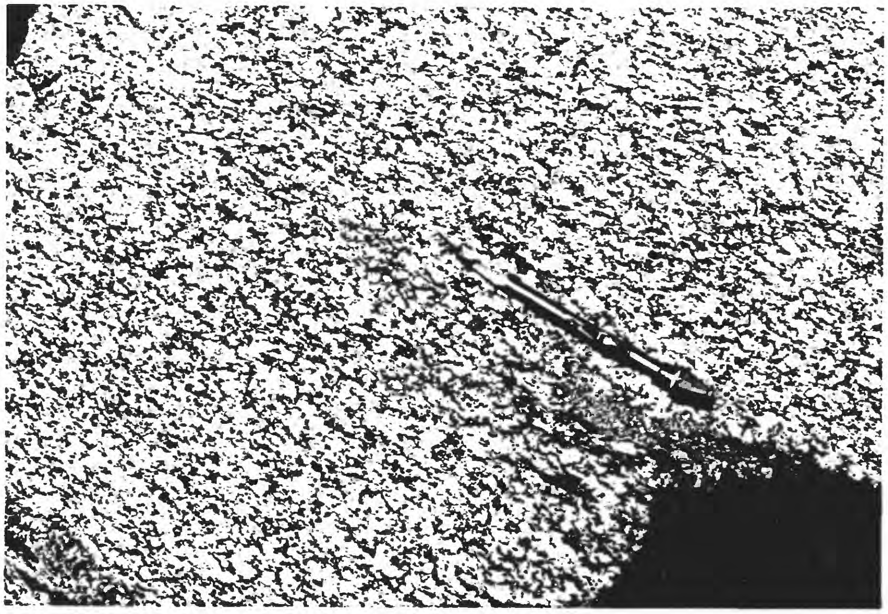

Figure 2a.--Kpv outcrop, trace of foliation parallel to pencil, color index appears higher than 5-10 percent because mafic minerals have broken down and recrystallized into fine-grained aggregates.

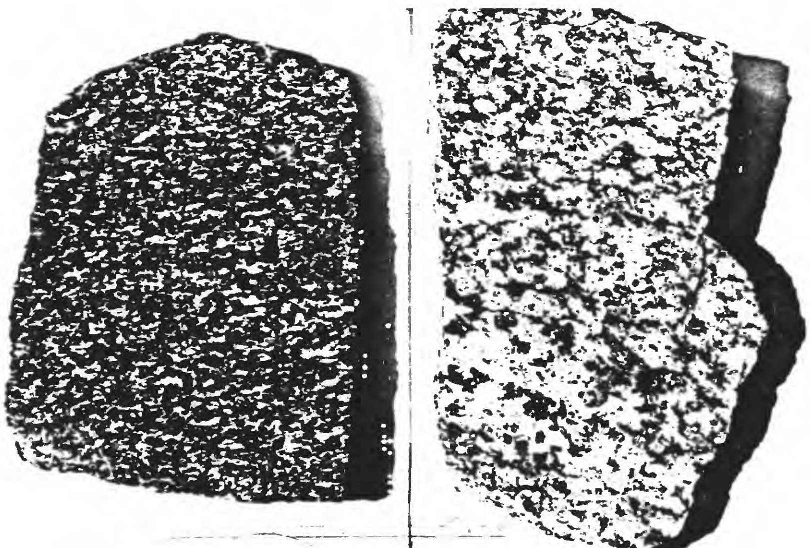

Figure 2b.--Slabs cut at right angles to foliation. Left, Kcp granodiorite; right, Kpv quartz monzonite. Stained for K-feldspar and plagioclase; 6-inch scale.

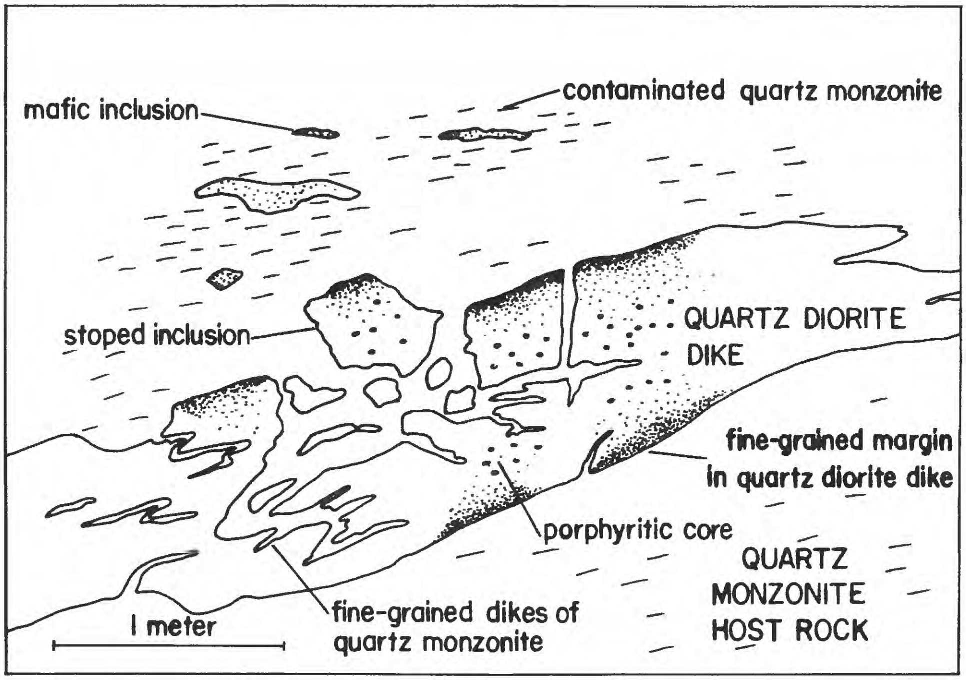

Figure 3. Sketch diagram of common relation between Kem dike and Kcp host rock. From field relations, sequence of intrusion was: 1) emplacememt of quartz monzonite

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

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

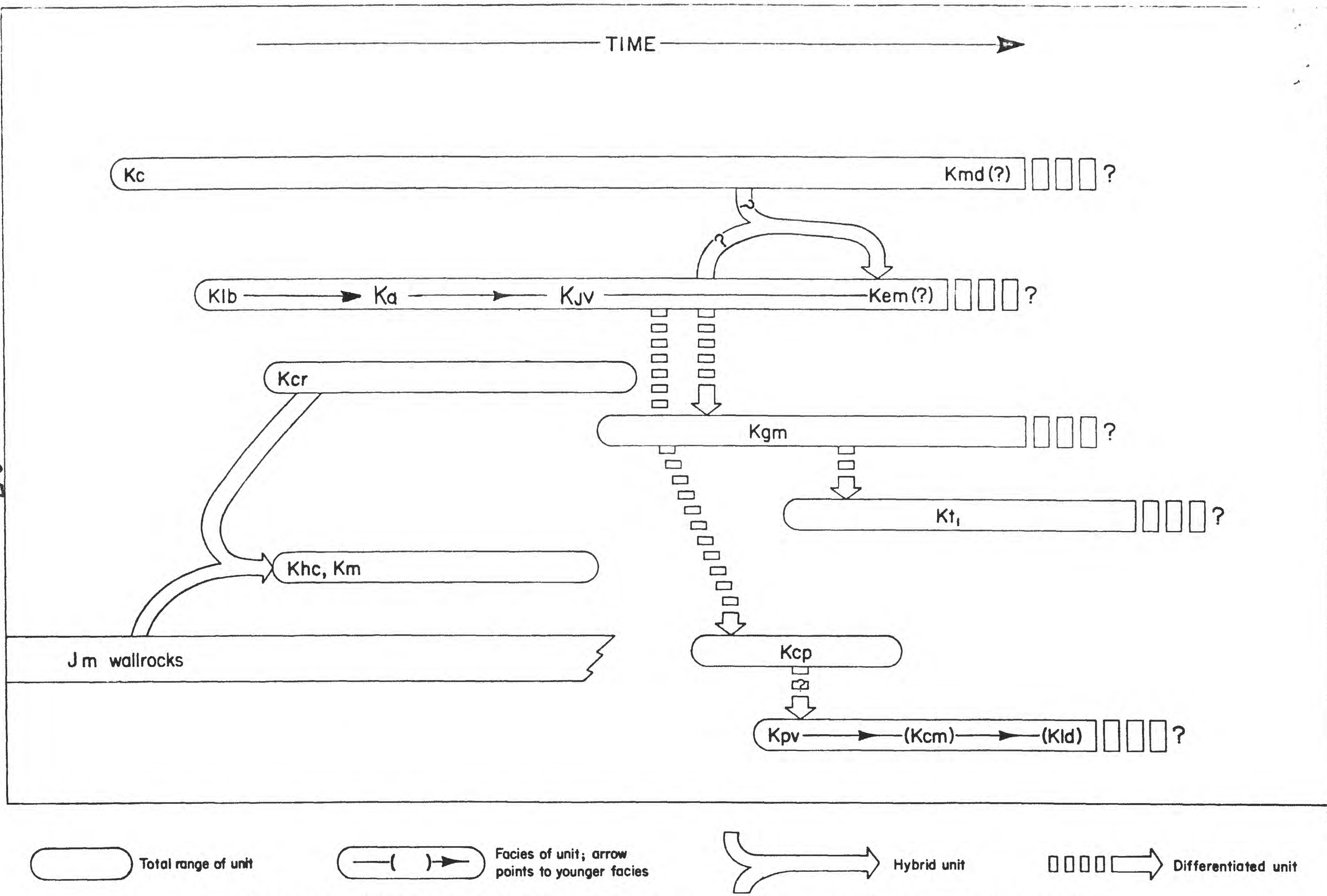

Figure 4.--Schematic diagram of intrusive sequence and relationships as indicated by field evidence. Units shown on same bar are probable phases of single magma. Overlap of bars means units are coeval. Probable hybrids , facies and differentiates are indicated.

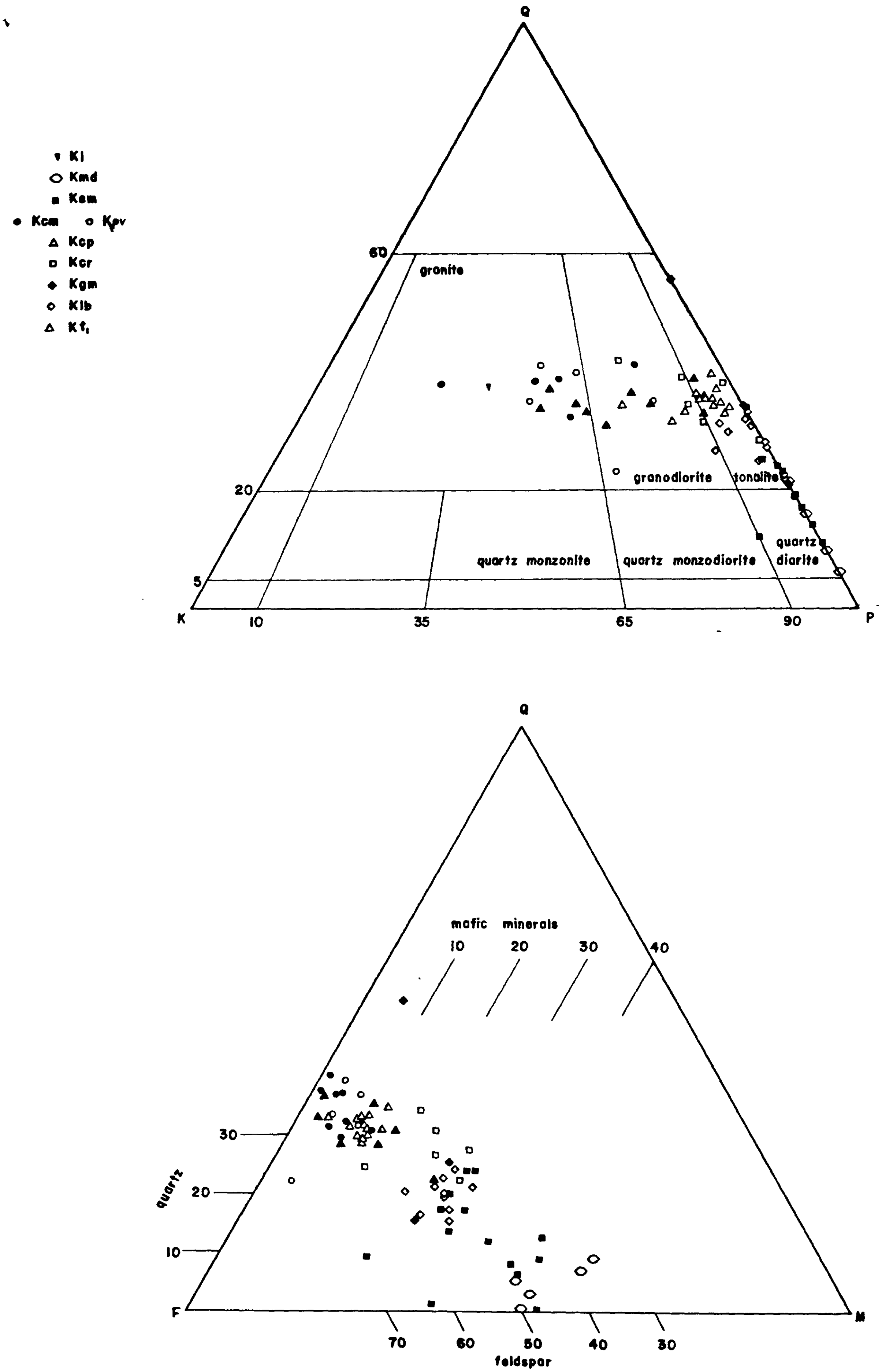

Figure 5a.--Q-K-P and Q-F-M plots of modal minerals of granitic rocks from Cuyamaca Peak and Mt. Laguna 15' quadrangles. Classification from Streckeisen, 1973.

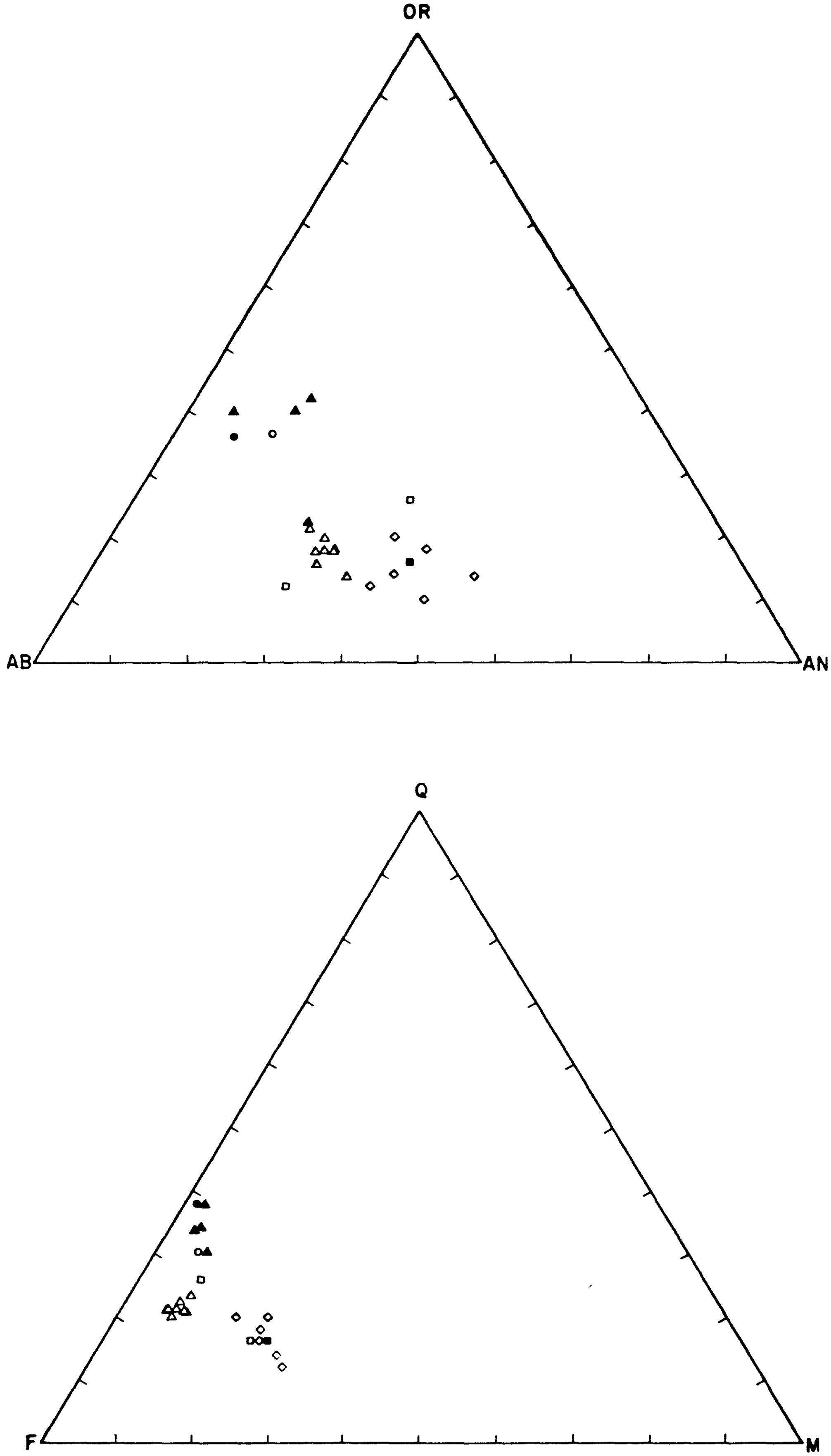

Figure 5b.--Normative OR-AB-AN and Q-F-M plots for some of the same rock samples as Figure 5a. Symbols same as Figure 5a.

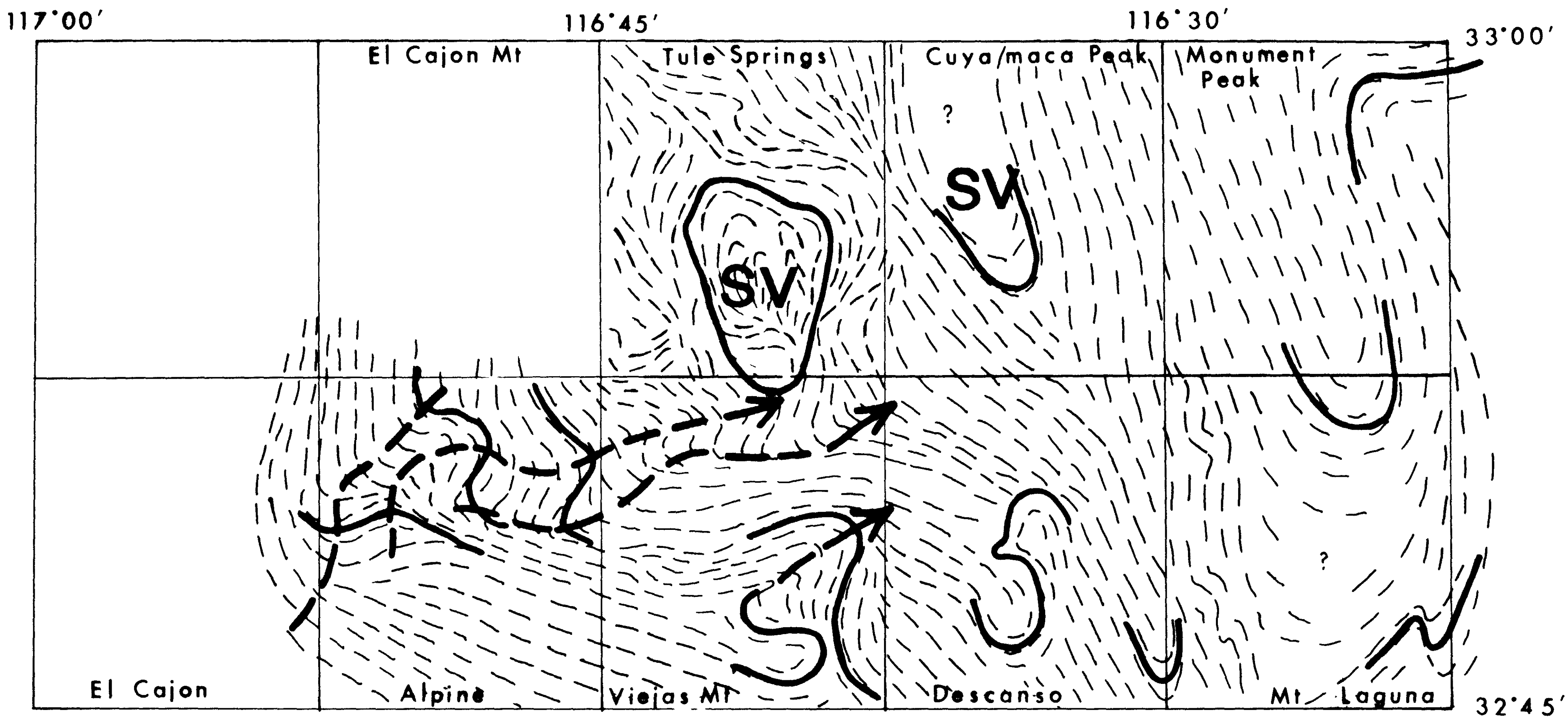

Figure 6. Sketch map of major Cretaceous structural trends in project area. Light dashed lines are generalized contact and foliation trends in plutonic and prebatholithic rocks. Heavy dashed lines are conjectural axes of NE-plunging folds. Heavy solid lines outline small fold forms (10-15 km^2) mentioned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

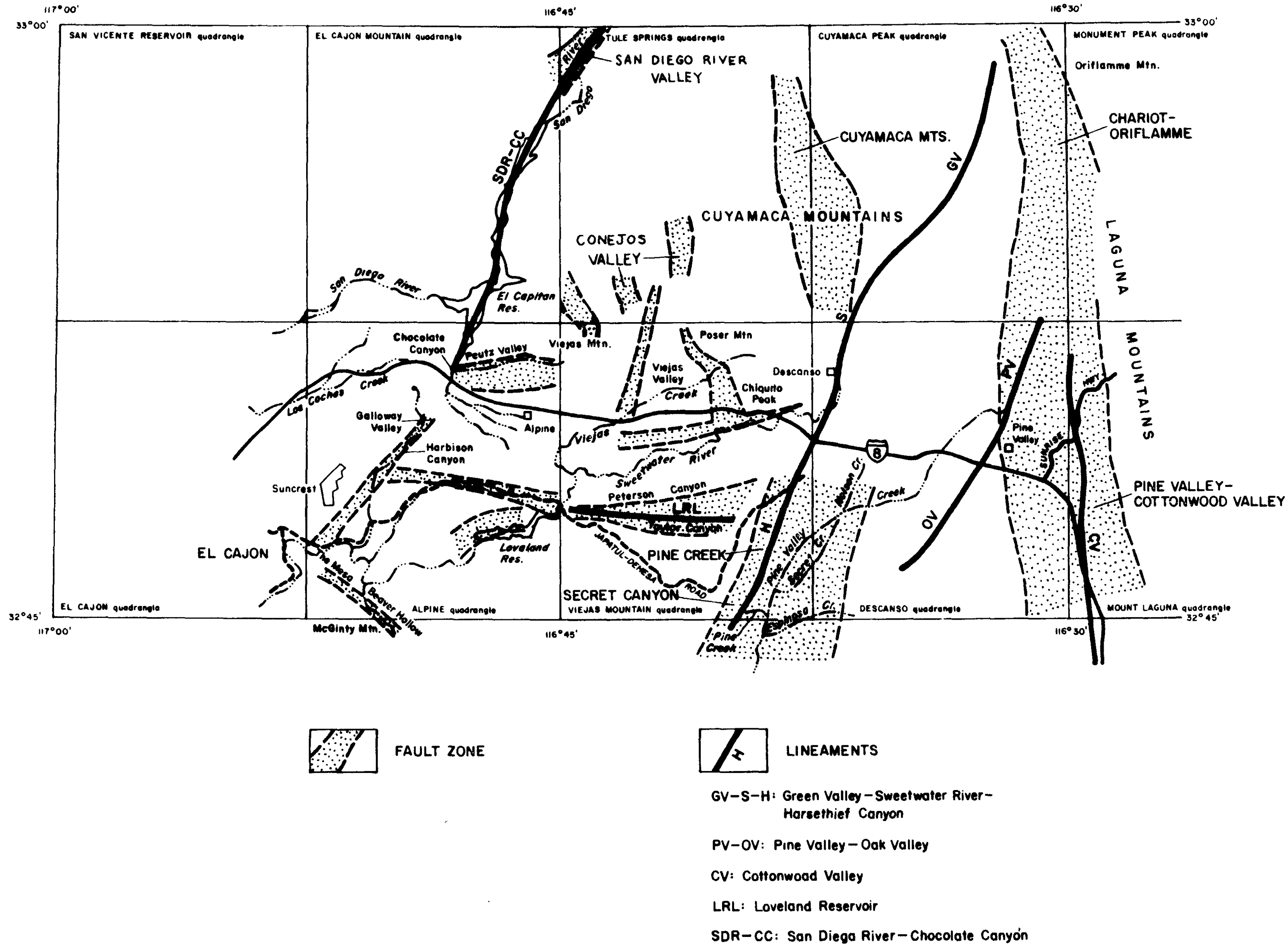

Figure 7. Index map showing lineaments, fault zones and geographic features.