

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

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PETROGRAPHIC (THIN SECTION) NOTES ON SELECTED  
SAMPLES FROM HORNBLENDE-RICH METAMORPHIC  
TERRANES IN THE SOUTHERNMOST SIERRA NEVADA,  
CALIFORNIA

by  
Donald C. Ross

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## ABSTRACT

Medium- to high-grade metamorphic rocks that are commonly hornblende-rich, and probably largely of "oceanic" affinity, are widespread in the southernmost Sierra Nevada, California. These metamorphic rocks are largely amphibolite, mafic and felsic gneiss, granofels, and hypersthene granulite. The mineral assemblages suggest that these rocks are at least in part of granulite grade, represent relatively deep crustal levels, and may be exposed parts of the root zone of the Sierra Nevada batholith. Access to the largest area of these rocks is relatively limited and for this reason petrographic data (textures and mineral content based on thin section study) are summarized here. Directions to readily accessible localities are presented, however, where the major metamorphic rock types can be examined and sampled.

## INTRODUCTION

Medium- to high-grade metamorphic rocks that are commonly hornblende-rich and probably largely of "oceanic" affinity, are widespread in the southernmost Sierra Nevada, California (fig. 1). These metamorphic rocks dominate the "tail" of the Sierra Nevada (fig. 2) and are also present as large inclusions in the granitic terrane to the northeast (fig. 3).

Because mafic rocks of the main body of in the Sierran tail are largely on private land where access is restricted, it seems worthwhile to summarize the thin section petrographic notes for these rocks that cannot easily be visited and sampled. The petrographic data will also counter the frustration that is all too common when reading reports on basement rocks that deluge one with analytical data, but provide little or no information on specific mineral assemblages. These rocks are important to the regional framework because they are widespread and distinctive. In addition, they are at least in part of granulite grade indicative of a crustal depth and setting that suggest that they are part of the Sierra Nevada batholith root zone (Ross, 1983).

Most of the smaller mafic bodies to the northeast (fig. 3) are accessible, at least in part, from public roads. Directions for locating these bodies and brief descriptions are found in Ross (1983). Petrographic data are also presented here for four of the smaller mafic bodies that have special significance. In and near the Live Oak body are gneissic, amphibolitic, and granulitic(?) rocks that are far removed from the San Emigdio-Tehachapi mafic terrane. The Caliente body is a good example of a mixture of plutonic and metamorphic rocks. The Hoffman body is particularly enigmatic because of its location and character. In addition, some data are presented for the Cummings belt of hypersthene granulite and related rocks, which is also not generally accessible to the public.

## ACCESS TO THE MAJOR ROCK TYPES OF THE MAFIC TERRANES

The following localities are perhaps the easiest places to see and sample the main rock types of the mafic terranes. Garnetiferous amphibolite and mafic gneiss are well exposed in Waterfall Canyon (fig. 2), just north of California State Highway 58 (hike northeast to the canyon on the northwest side of the diversion dike that reaches the Highway at BM 3770 about 2.5 km (1.5 mi.) east of the Cameron overpass; Monolith 7-1/2' quadrangle). Both mafic and felsic gneiss, lithologies that dominate the San Emigdio-Tehachapi terrane, are exposed in large roadcuts west of the Cameron off-ramp of Highway 58. Mafic and felsic gneiss in the San Emigdio-Tehachapi mafic terrane itself are most easily seen in roadcuts in Grapevine Canyon about 5 to 7 km (3 to 4 mi.) north of the Grapevine Interchange of Interstate Highway 5 (fig. 2, 4A) (Grapevine 7-1/2' quadrangle). Hypersthene granulite can be seen in the Loop inclusion swarm in roadcuts east of the Tehachapi Loop Viewpoint on the Woodford-Tehachapi road (Keene 7-1/2' quadrangle; the Loop is in sec. 27, T. 31 S., R. 32 E.). Hypersthene granulite is also present in mafic outcrops just north of Horsethief Flat (fig. 2) (Bear Mountain 7-1/2' quadrangle) and in roadcuts just west of Horsethief Flat (Tejon Ranch 7-1/2' quadrangle) on the Comanche Point Road. This public road is accessible from the east from the Stallion Springs Development (west of Tehachapi) and from the west from Arvin. The Comanche Point Road is a graded gravel road, but may be inaccessible in wet weather.

### SAN EMIGDIO-TEHACHAPI MAFIC TERRANE

The San Emigdio-Tehachapi mafic terrane is a suite of dominantly hornblende-rich metamorphic rocks. Most common are massive to gneissic hornblende-plagioclase rocks that range from obviously metamorphic amphibolite to obviously plutonic tonalite. Hypersthene granulite is locally important, but more widespread is granofels with various proportions of hornblende, plagioclase, quartz, biotite, and in some rocks, conspicuous red garnet crystals and coarse shiny graphite flakes. Quartzofeldspathic gneiss is widespread and, along with minor impure quartzite and rare calc-hornfels, testifies to metasedimentary admixtures in this dominantly meta-igneous suite of "oceanic" rocks.

The following thin section descriptions are grouped according to the major rock types. Sample locations are shown on Figures 4A and 4B. Letters in parenthesis, after the thin section number, key the location of the thin section to the various 7-1/2' quadrangles of the area (code shown on figure 4A).

#### Amphibolite

This dark massive to weakly foliated rock type is composed almost exclusively of intermediate plagioclase and green to brown hornblende. Garnet, clinopyroxene, biotite, and quartz are present in subordinate amounts in some specimens. Strongly foliated specimens are described under "Gneiss."

Some of the amphibolite samples (particularly those that are quartz-bearing) could be referred to as diorite, quartz diorite, or tonalite. Commonly it is difficult to determine if the texture is xenoblastic and granoblastic (metamorphic) or xenomorphic granular (plutonic). Wiese (1950) leaned toward calling the mafic rocks diorite and gabbro, and I was similarly inclined early in my study. I began to realize, after much confusion, however, that homogeneous, plutonic-looking rocks rarely occur in discrete

masses of any size in the mafic terrane. Plutonic-looking material is almost invariably closely associated with unquestionably metamorphic rocks. Thus, the term amphibolite more correctly characterizes these rocks.

DR-715A —/ (SM)--Fine-grained granoblastic mat of well-twinned, weakly zoned labradorite and green hornblende. Minor epidote, sphene, apatite, and opaque grains. Interlayered with "tonalitic" material.

DR-3014B (ERP)--Foliated rock dominated by selectively-oriented light green hornblende and lesser, somewhat twinned, plagioclase (about An<sub>50</sub>). Minor quartz, epidote (primary?), and apatite. Scattered rounded, small sphene crystals.

DR-3020C (ERP)--Essentially a granoblastic fabric, but some foliation shown by elongated mineral grains. Composed of about equal parts of well-twinned, somewhat zoned plagioclase as calcic as An<sub>60</sub> and moderate green hornblende. Liberal sprinkling of opaque grains (some is pyrite) and traces of apatite, zircon, and epidote.

DR-3028B (PH)--Foliation shown by elongate patches and lenses of pale green hornblende, which with fresh, well-twinned plagioclase (as calcic as An<sub>50</sub>), makes up most of the rock. Minor rounded quartz grains (mostly in hornblende) and rare brown biotite. Also opaque grains, sphene, apatite, zircon, and some prehnite lozenges in chloritized biotite.

DR-3091B (G)--Granoblastic mat of well-twinned, in part zoned, andesine and light brown hornblende. Metallic opaque grains are common and some are rimmed by sphene. Quartz and light-brown biotite are also present. The rock is studded with rounded, poikilitic red garnets as large as 1 cm.

DR-3095 (G)--Granoblastic or xenomorphic granular texture. Plagioclase has unusual splotchy zoning and is not well-twinned. Hornblende grains tend to occur in clusters; individual grains have brown cores and grade to green margins. Abundant reddish-brown biotite and opaque grains; also apatite and sphene. Traces of quartz. Anhedral garnet present in thin section and abundant in outcrop.

DR-3097, 3098 (G)--Same as 3095; range from massive to well-foliated, and contain garnet.

DR-3101 (FM)--Granoblastic grains of well-twinned, in part concentrically zoned plagioclase (about An<sub>50</sub>) and pale-green hornblende. Also metallic opaque grains, sphene, epidote, and apatite. Rock studded with red garnet (much like 3091B).

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—/ Letter following field number (for example: DR-715A) identifies a specific sample in my collection. On the maps (Figures 4, 5, 6, 7, and 8) the letters are omitted as all lettered samples with the same field number (for example: DR-3391A and DR-3391B) are from the same outcrop. At a few localities, more than one rock type was sampled at the same outcrop. (For example: DR-3020). The rock type symbol on the map (fig. 4) is the dominant lithology of the outcrop.

DR-3235 (G)--A weakly gneissic fabric but dominantly composed of granoblastic grains of andesine and pale-green to brownish hornblende. Rounded quartz grains widely scattered. Minor chloritized brown biotite and some opaque grains.

DR-3246 (FM)--Granoblastic texture with ragged mafic minerals and much granulation. Well-twinned andesine and olive-brown hornblende most abundant. Lesser strained and granulated quartz and minor chloritized biotite. Scattered opaque grains, apatite, and zircon.

DR-3250 (PC)--Weakly gneissic, but mostly a polygonal net of equant labradorite crystals and pale-brown hornblende.

(Rocks similar to DR-3235 and 3250 have previously been referred to as "diorite" in this region).

DR-3254A (PC)--Much like 3246, but less alteration and cataclasis.

DR-3268 (PC)--Much like 3246 and 3254A.

DR-3276 (PC)--Granoblastic texture composed of well-twinned labradorite and pale green hornblende. Abundant epidote in granular masses and as elongate euhedral bladed crystals and aggregates. Minor, partially granulated, interstitial quartz.

DR-3285 (PC)--Could be a xenomorphic granular texture as well as granoblastic. Well-twinned plagioclase (as calcic as An<sub>50</sub>) and olive-brown hornblende are most abundant. Interstitial quartz (in part granulated) and minor red-brown biotite. Scattered sphene and opaque grains. Ranges from massive to foliated in outcrop.

DR-3349 (WR)--Original texture, probably granoblastic, is now much affected by cataclasis and development of retrograde minerals. (Note this sample is from near the Garlock fault). Some original grains of plagioclase (about An<sub>50</sub>) and pale brown hornblende. Much hornblende now retrograded to pale acicular amphibole, and plagioclase much altered to sericitic and epidote masses. Also much chlorite.

DR-3351 (WR)--Weakly gneissic but dominantly a granoblastic combination of well-twinned plagioclase (about An<sub>50</sub>) and pale-green hornblende. Weathered surface of hand specimen looks relatively fresh, but thin section shows much alteration by epidote and sericite.

DR-3359 (WR)--Pronounced granulated fabric. Olive-brown hornblende and cleanly-twinned andesine remnants. Much acicular amphibole. Scattered opaque grains. Cataclasis and some retrograde minerals may also reflect close proximity to Garlock fault.

DR-3368 (WR)--Fine-grained granoblastic aggregate of stubby olive-green hornblende crystals to 1 mm and rounded crystals of twinned plagioclase (about An<sub>70</sub>). Scattered opaque grains and sphene.

DR-3381 (WR)--Fine-grained, sugary rock composed of well-aligned fresh well-twinned labradorite and pale-olive to brown hornblende. Liberal sprinkling of opaque grains.

DR-3400 (WR)--Original texture could be xenomorphic granular or granoblastic. Olive-brown hornblende veined and altered by epidote and chlorite. Plagioclase much replaced by sericite and epidote. Rather abundant, well-strained quartz. Minor chloritized brown biotite. Scattered opaque grains, commonly rimmed by sphene.

DR-3402A(PC)--Granoblastic to polygonal mat of well-twinned labradorite and pale-green to pale-brown hornblende. Some aligned purplish bladed inclusions (schiller?) in brown hornblende. Abundant opaque grains.

(3402A is the kind of rock Wiese (1950) called gabbro. The intimate association of this rock with gneiss and other definitely metamorphic rocks suggests it is also metamorphic, rather than an intrusive gabbro).

DR-3403 (PC)--Weak layering and foliation from elongation and varied proportions of well-twinned labradorite and olive green to pale green hornblende. Hornblende crystals are liberally sprinkled with opaque grains.

(3403 is fine-grained, weakly gneissic, but definitely metamorphic rock that is invariably found near the more "gabbro-like rocks).

DR-3442 (CM)--Granoblastic or xenomorphic granular texture with some granulation. Rock composed mostly of fresh, well-twinned andesine with weak concentric zoning, and olive-brown hornblende. Lesser amounts of quartz and reddish brown biotite. Minor pale-green clinopyroxene. Hornblende in part altered to pale acicular patches of actinolitic(?) amphibole.

(3442 is good example of a rock that is hard to classify. It has the mineral content of a tonalite, yet the hornblende and biotite colors are those of the amphibolitic metamorphic rocks. Texture is equivocal).

DR-3566 (TR)--Sample of a large body of fine-grained sugary mafic rock. Granoblastic matrix of labradorite and grayish-green hornblende. Some quartz and minor brown biotite. Scattered opaque grains and apatite.

(3566 is another rock type commonly found as ovoid inclusions in the granitic plutons. Its physical appearance is similar to 3549A (granofels), but the mineral content is quite different).

DR-3886B (ERP)--Fine-grained with a strongly aligned fabric of grayish-green hornblende crystals set in a granoblastic mat of andesine and lesser quartz. Scattered opaque grains and epidote.

DR-3894 (PH)--Somewhat gneissic with well-aligned pale-green hornblende lenses and layers but overall the thin section shows a granoblastic mix of andesine, lesser quartz, and poikilitic red garnet crystals. Opaque grains and apatite abundant. A float sample of the mafic gneiss and amphibolite to the south. Haloed garnets to 2 cm are present in the float rocks here.

DR-3901 (G)--Coarse granoblastic mat of twinned andesine and pale-brown hornblende. Lesser strained quartz. Traces of sphene, but surprisingly, almost no opaque grains.

DR-3905 (G)--Granoblastic mat of well-twinned labradorite with weak concentric zoning, and light-olive hornblende. Abundant opaque grains and apatite. Rounded poikilitic red garnet to 1 cm with bleached haloes are common in hand specimen.

DR-3930 (PC)--Fine-grained granoblastic mat of pale-olive-green hornblende and twinned plagioclase (about  $AN_{50}$ ). Scattered opaque grains and some pink garnet.

DR-3938 (WR)--Considerable local variation in grain size and dark mineral content but all the rocks near here are dominated by well-twinned, concentrically to splotchy zoned sodic labradorite and grayish-green to olive hornblende. Opaque grains are abundant, and minor quartz is present. Coarse, poikilitic, red garnet crystals to several cm are conspicuous with haloes devoid of dark minerals.

(3938 is the most probable source area for the garnetiferous boulder locality described by Murdoch (1939).

DR-3941 (WR)--A finer-grained and darker version of the rocks at 3938 and without quartz.

DR-3949 (WR)--Granoblastic fabric. About one-half of rock is polygonal, well-twinned labradorite and other half is olive-green hornblende. Poikilitic to euhedral red garnet present. Scattered opaque grains.

DR-3962B (TR)--Fine-grained mafic rock with granoblastic fabric. Sugary mat of well-twinned plagioclase (about  $AN_{50}$ ), olive-green hornblende, and lesser brown to reddish brown biotite and quartz.

DR-3985B (G)--Granoblastic mat of about half fine-grained olive hornblende and about half a mixture of andesine and quartz. Scattered poikilitic garnet crystals to 3 mm and opaque grains.

### Gneiss —

Comprises all the strongly foliated gradations from granofels (felsic quartzofeldspathic gneiss) and amphibolite (amphibolitic to tonalitic gneiss).

DR-3015B (ERP)--Epidote-rich tonalitic gneiss--Strongly foliated (relative concentrations of elongate mafic minerals and selective orientation of plagioclase. Most abundant is well-twinned andesine. Also common are green hornblende, brown biotite and equigranular quartz. From 15 to 20 percent of rock is discrete, in part euhedral, epidote crystals to 2.5 mm long. Scattered opaque grains.

— High-grade gneissic metamorphic rocks commonly consist of layers rich in amphibole and mica with preferred orientation associated with (and commonly dominated by) nondirectional quartz and feldspar. Harker (1939) long ago noted that as metamorphic grade increases the segregation into light and dark layers increases, mineral alignment (schistosity) decreases, and a granoblastic mat of essentially equidimensional crystals with sutured boundaries results. Gneissic metamorphic rocks in the southernmost Sierra Nevada with both directional and nondirectional elements pose a texture name problem. Commonly the texture in thin section is dominantly granoblastic, but the outcrop shows marked foliation. In noting both foliation and granoblastic textures in some rocks in the "Gneiss" category, I have chagrined some of my colleagues. The crux of the problem is that as one approaches and enters melt conditions (ultrametamorphism), metamorphic nomenclature designed for slate, schist, and even gneiss, breaks down in the transition conditions between metamorphic and magmatic environments.



DR-3016 (ERP)--Plagioclase amphibolitic gneiss--Granoblastic fabric, but foliation shown by concentration and alignment of hornblende grains and preferred orientation of andesine. Well-twinned calcic andesine, rounded quartz, and anhedral elongate green hornblende make up most of this rock. Scattered "primary" epidote. Chloritic alteration of biotite accompanied by prehnite lozenges.

DR-3025 (PH)--Gray gneiss--Granoblastic mat of poikilitic epidote and much altered pale green hornblende. Abundant rounded pink garnet crystals and scattered quartz. Abundant ovoid grains of sphene and apatite. Unusual gneissic layer in rocks like 3017B (see Granofels).

DR-3027A (PH)--Biotite quartzofeldspathic gneiss--Foliation and alternating light and dark bands mainly the result of varying amounts of brown to reddish-brown biotite. Equigranular dusty andesine and quartz are both abundant throughout the rock. Minor pale-green hornblende in some biotite-rich layers. Trains of garnet, crystals that are orange in hand specimen, rather common small opaque grains, and apatite; tiny zircon crystals.

DR-3043C (PH)--Hornblende schist (amphibolite)--Composed dominantly of pale-brown hornblende (in part rimmed with pale-green amphibole) and well-twinned labradorite. Abundant rounded sphene crystals.

DR-3044B (PH)--Plagioclase amphibolite (gneissic)--Gneissic fabric shown by relative concentration of aligned pale-brown hornblende crystals in dark layers relative to abundance of equigranular, well-twinned, weakly concentric to undulatory zoned labradorite in light layers. Scattered sphene and apatite; almost no opaque grains.

DR-3057B (G)--Amphibolitic gneiss--Darker layers made up mostly of selectively oriented pale brown hornblende (some-pale green margins) and lesser reddish-brown biotite. Lighter layers rich in andesine and quartz. Sprinkles of opaque grains, apatite, sphene, and zircon. Pink garnet locally abundant.

DR-3058B (G)--Quartzofeldspathic gneiss--Anastomosing trains and lenses of well-aligned reddish-brown biotite, muscovite, and lesser coarse graphite alternate with thicker layers dominated by equigranular, well-twinned andesine and quartz. Scattered small garnet crystals that are pink to pale-purple in hand specimen; local concentrations of apatite.

DR-3093 (G)--Biotite quartzofeldspathic gneiss--Relative concentrations of red-brown biotite show foliation and accentuate compositional layering. Rock is dominated by equigranular, well-twinned andesine and quartz (local granulation). Commonly the biotite has abundant pleochroic haloes about highly birefringent included grains. Fine-grained graphite also common in biotite. Red garnet (colorless in thin section) abundant in some layers.

DR-3094 (G)--Quartzofeldspathic gneiss--Much like 3093, but lighter colored, less mafic minerals and minor pale green hornblende. Some discrete epidote crystals do not look like obvious alteration products.

DR-3100 (G)--Gneissic plagioclase amphibolite--Pale-olive-brown hornblende crystals show foliation by selective orientation. Twinned and somewhat concentrically zoned andesine crystals are anhedral and some are rounded. Rather abundant quartz that tends to be interstitial and granulated. Traces of chlorite (former biotite?). Abundant opaque grains (mostly in hornblende) and some apatite.

DR-3232 (G)--Hornblende-quartzofeldspathic gneiss--Bimodal grain size distribution suggests cataclasis. Plagioclase grains to 3 mm set in matrix of much finer grained equigranular quartz and plagioclase. Weak foliation shown by small, selectively oriented acicular pale-green hornblende crystals. Scattered pink garnet and opaque grains. Elongate tiny zircon crystals are fairly common.

DR-3237 (G)--Quartzofeldspathic gneiss--Alternating layers as much as a few cm-thick of felsic layers dominated by andesine and quartz and mafic layers with, in addition to andesine and quartz, various amounts of red-brown biotite, muscovite, and graphite.

DR-3274 (PC)--Sheared tonalitic gneiss--Fresh rock with a subtle gneissic foliation. Mostly subequant grains of sutured, well twinned andesine and weakly oriented olive-brown hornblende. Lesser light-brown to reddish-brown biotite. Quartz is abundant in mosaicked and sutured interstitial aggregates, which give rock a bimodal grain size distribution and suggest cataclasis.

DR-3284 (PC)--Garnetiferous biotite quartzofeldspathic gneiss--Gneissic foliation from relative concentrations of olive brown biotite, but most of rock a sutured, subequant mat of poorly twinned plagioclase and quartz. Some opaque grains and red garnet. Discrete epidote crystals do not look like alteration products. Some cataclasis.

DR-3391A (PC)--Biotite quartzofeldspathic gneiss--Abundant well aligned brown biotite in varied amounts gives foliation, but nonaligned granoblastic mat of well-twinned andesine and quartz dominates in the rock.

DR-3391B (PC)--Hornblende quartzofeldspathic gneiss--Variable amounts of anhedral olive hornblende crystals in trains and lenses impart a weakly foliated fabric to an otherwise granoblastic mat of andesine and quartz. Minor opaque grains and rounded (detrital?) zircon and apatite. Rare epidote rimmed allanite looks "primary."

(Note mineral contrast between DR-3391A and B; two layers from the same outcrop).

DR-3395 (PC)--Biotite quartzofeldspathic gneiss--Lenses and layers rich in brown biotite define a foliation, but sutured and nonaligned (granoblastic) andesine and quartz are dominant. Minor untwinned K-feldspar is present. Patches of epidote and associated allanite do not look like obvious alteration products.

DR-3396 (PC)--Hornblende clinopyroxene quartzofeldspathic gneiss--Compositional layers shown by differences in mineral amounts, but thin section fabric is dominantly granoblastic. Varying amounts of well-twinned andesine, somewhat sutured and undulose quartz, pale-green clinopyroxene, and olive-green hornblende. Opaque grains, apatite, and rounded sphene and zircon. Scattered grains of reddish-brown strongly pleochroic tourmaline.

DR-3399 (PC)--Garnetiferous tonalitic gneiss--Weak anastomosing gneissic foliation imparted by aligned red-brown biotite crystals, but overall the fabric of the rock is granoblastic with a mat of fresh, well-twinned andesine, quartz, and lesser olive-green hornblende. Abundant pink garnet in poikilitic crystals to several mm. Scattered, discrete epidote crystals look primary. Bimodal grain size distribution (much quartz as small rounded interstitial grains) and broken and bent plagioclase crystals suggest cataclasis.

DR-3406 (WR)--Tonalitic gneiss or granofels--Weakly gneissic (compositional banding) but dominantly a granoblastic fabric. Clean, well-twinned andesine, and olive green to olive brown hornblende are most abundant. Abundant quartz and minor brown biotite. Opaque grains and zircon are present.

DR-3408-1 (WR)--Hornblende-rich tonalitic gneiss--Foliation (mineral alignment) and compositional layering well-developed. Rock composed of calcic andesine, quartz, grayish green to olive-brown hornblende, and brown biotite. Scattered opaque grains, acicular apatite, and rounded zircon.

DR-3415A (WR)--Graphitic biotite quartzofeldspathic gneiss--Bright red brown biotite and shiny gray flakes of graphite as large as 1.5 mm define a good foliation. Much more abundant, however, are equigranular, well-twinned andesine and commonly rounded quartz in a sutured mat. Zircon marked by pleochroic haloes is common in biotite.

DR-3434A (TR)--Tonalitic gneiss--Texture could be either xenoblastic (metamorphic) or xenomorphic granular (magmatic); weak foliation shown by alignment of biotite). Adjacent to strongly foliated layers in outcrop. Well-twinned andesine, strongly mosaicked and sutured quartz, brown biotite, and deep-olive-green hornblende are a typical tonalite mineralogy. From the "transition zone" where both metamorphic and plutonic traits are present and commonly difficult to separate.

DR-3435A (LT)--Gneissic plagioclase amphibolite--Retrograded foliated rock originally comprised chiefly of plagioclase and brown hornblende; lesser biotite. Now much plagioclase strongly saussuritized, biotite converted to chlorite, and some hornblende altered to fibrous amphibole.

DR-3439A (LT)--Gneissic plagioclase amphibolite--Much like 3435A, with notably brown hornblende and minor quartz.

DR-3547 (A)--Biotite quartzofeldspathic gneiss--Thin layers rich in well-aligned reddish-brown biotite with included haloed zircons. Coarser layers of mostly nonaligned, sutured quartz and well-twinned andesine. Scattered sphene and apatite.

DR-3562 (TR)--Quartzofeldspathic gneiss--A largely granoblastic rock with weak anastomosing foliation imparted by scattered aligned biotite flakes. Twinned plagioclase (about An<sub>30</sub>), grid-twinned K-feldspar, and rounded grains of quartz. Scattered brown biotite flakes. Some K-feldspar augen, but cataclastic look of hand specimen not as evident in thin section.

DR-3884B (ERP)--Fine-grained amphibolite gneiss--Strong aligned fabric from hornblende crystals. More or less interlocking network of light-green hornblende, epidote, plagioclase, highly chloritized, olive-brown biotite and lesser quartz.

DR-3893 (PH)--Garnetiferous quartzofeldspathic gneiss--Weak foliation and compositional layering shown by colorless amphibole. Mat of sutured, subequant andesine and quartz dominates the rock; lesser epidote, and traces of brown biotite. Opaque grains are widespread and abundant as are rounded subhedral poikilitic pink garnets to 3 mm.

DR-3908 (G)--Gneissic plagioclase amphibolite--Mafic minerals give hand specimen an overall anastomosing foliation, but thin section fabric dominantly granoblastic. Well-twinned andesine and grayish-green hornblende are most abundant. Also significant amounts of quartz and chloritized biotite. Scattered opaque grains.

DR-3912A (PC)--Tonalitic gneiss--Thin dark layers rich in well-aligned brown to reddish-brown biotite and olive ("plutonic") hornblende alternate with somewhat thicker layers rich in sutured, subequant well-twinned andesine and quartz.

DR-3933 (TR)--Felsic tonalitic gneiss--Abundant well-aligned brown biotite flakes and lesser olive-green ("plutonic") hornblende concentrations define a prominent foliation, but rock dominated by sutured mat of andesine and quartz. Some allanite rimmed with epidote.

(3933 is another example of a good granitic mineralogy and a metamorphic fabric. Common, particularly here in the "transition zone").

DR-3951 (WR)--Biotite quartzofeldspathic gneiss--Foliation and compositional layering reflected by varied amounts of brown biotite, but overall the rock is dominated by an equigranular (granoblastic) mat of quartz and andesine. K-feldspar is locally abundant, and less common is olive-green hornblende. Discrete epidote crystals, some with allanite cores. Although red garnet is present nearby, it is absent from this specimen.

DR-3952 (WR)--Biotite quartzofeldspathic gneiss--Strong foliation imparted by lenses and irregular layers of aligned reddish-brown biotite flakes and lesser graphite flakes and pleochroic-haloed zircon. Light layers are dominated by granoblastic mat of quartz and well-twinned andesine, and minor untwinned K-feldspar.

DR-3962 (TR)--Tonalitic gneiss--Anastomosing foliation imparted by aligned trains and lenses of brown to reddish-brown biotite. Rock nevertheless dominated by sutured, equigranular (granoblastic) mat of quartz and well-twinned, weakly zoned andesine. Pale-olive-green hornblende also present.

(3962 has the mineralogy of many of the ovoid mafic inclusions that are widespread in granitic rocks of the Sierra Nevada batholith).

DR-3965B (TR)--Biotite quartzofeldspathic gneiss--Fine-grained mat of mosaicked quartz and lesser andesine. Abundant well-aligned brown to reddish-brown biotite flakes. Traces of clear to pale-green amphibole. Scattered rounded (detrital?) zircon.

DR-3966 (TR)--Quartzofeldspathic gneiss--Weak to strong layering dependent on relative concentration of brown biotite, but most of the rock is a granoblastic mat of quartz and andesine and lesser clinopyroxene. Minor olive hornblende and traces of opaque grains and sphene.

DR-3985A (G)--Garnetiferous biotite schist--Coarse flakes of reddish-brown biotite with numerous zircon(?)--cored haloes is dominant in well-aligned layers and lenses. Well-twinned andesine is abundant. Pink garnet in rounded to subhedral grains to 3 mm is common. Only minor quartz.

## Granofels

Massive, medium-grained, granoblastic rocks composed of varying amounts of plagioclase, hornblende, quartz, biotite, and clinopyroxene. Pink to red garnet and coarse, gray shiny flakes of graphite are characteristic of many rocks that bear resemblance to metamorphic rocks in the western Santa Lucia Range (some 300 km to the northwest). Some finer-grained varieties could as well be called hornfels. The distinction between granofels and tonalite is a problem in places in the southernmost Sierra Nevada.

DR-3017B, 3018C, 3019B, 3020B (ERP)--Felsic garnetiferous granofels--Mat of well-twinned, weakly zoned, anhedral plagioclase (about An<sub>50</sub>). Lesser quartz in large anhedral grains and small granulated interstitial grains. Widely scattered, small, pale-green hornblende crystals. Sparse, rounded pink garnet. Minor biotite (in part chloritized), muscovite, epidote, apatite, and opaque grains.

DR-3028A (PH)--Tonalite or granofels(?)--Texture could be either granoblastic or incipient development of the bimodal (granulated) texture common in many rocks in the Antimony Peak mass. Equant to somewhat rounded fresh, well-twinned labradorite. Abundant quartz is somewhat interstitial and much mosaicked and sutured and in part granulated. Liberal scattering of pale green hornblende and lesser brown biotite shreds. Opaque grains, zircon, and apatite.

DR-3042 (PH)--Quartzofeldspathic granofels--Granoblastic mat of well-twinned plagioclase (about An<sub>50</sub>) and lesser, rounded quartz. Some foliation shown by alignment of reddish brown biotite and very pale green hornblende. Minor K-feldspar and traces of allanite and apatite.

DR-3295 (PC)--Garnetiferous quartzofeldspathic granofels--Granoblastic mixture of well-twinned andesine, brown biotite and red garnet (rounded to euhedral, in part poikilitic crystals as large as 1 cm). Minor quartz and trace of muscovite and epidote (looks "primary"). Common opaque grains (not graphite).

DR-3303 (PC)--Clinopyroxene quartzofeldspathic granofels--Some compositional layering but dominantly a granoblastic fabric. Fresh, well-twinned andesine and quartz are most abundant. Small anhedral pale-green clinopyroxene crystals are widespread and common. Lesser amounts of olive-green hornblende and untwinned K-feldspar. Sprinkles of opaque grains, apatite, sphene, and zircon. Some rounded accessory grains look detrital.

DR-3369 (WR) Graphitic quartzofeldspathic granofels--Some compositional layering but overall texture is granoblastic. Most abundant is well-twinned plagioclase (about An<sub>50</sub>) and coarsely mosaicked quartz. Darker, finer-grained layers are liberally sprinkled with clinopyroxene, red-brown biotite, and graphite, and minor pale-green hornblende and sphene, but still have a matrix of quartz and plagioclase.

(3369 is another example of a rock that is similar to the granofels of the western Santa Lucia Range).

DR-3380 (WR)--Quartzofeldspathic granofels--Somewhat aligned fabric but mostly a granoblastic mosaic of quartz and clean, well-twinned calcic andesine. Abundant scattered shreds of red-brown biotite and graphite. Locally abundant pale pink garnet.

(This lithology (3380) is common and characteristic of some metamorphic rocks of the western Santa Lucia Range).

DR-3387 (WR)--Garnetiferous quartzofeldspathic granofels--Xenoblastic (metamorphic) or xenomorphic or granular (magmatic) texture. Well-twinned andesine and abundant quartz. Red-brown biotite common and widespread. Rounded to subhedral pink garnet crystals to 3 mm. Minor opaque grains and primary(?) muscovite.

(3387 is another rock that has both plutonic and metamorphic traits. The thin section texture could easily be called "granitic," but the mineralogy is atypical of plutonic rocks of the area).

DR-3392 (PC)--Garnetiferous tonalitic granofels--Granoblastic andesine, quartz, olive-green hornblende, and opaque grains. Rock includes coarse, poikilitic red garnet with bleached haloes.

DR-3425 (TR)--K-feldspar-clinopyroxene granofels (hornfels)--Thin compositional layers, but dominantly a granoblastic mat of grid-twinned K-feldspar and lesser quartz. Abundant rounded to stubby pale-green clinopyroxene crystals and lesser gray-green to light-olive hornblende. Traces of brown biotite. Abundant strongly pleochroic sphene.

DR-3428 (TR)--Garnetiferous biotite quartzofeldspathic granofels--Fine-grained "sugary," granoblastic rock. Most abundant is well-twinned labradorite and rounded, weakly strained quartz. Brown to red-brown biotite defines a weak foliation. Poikilitic red garnet masses to several mm include drop-like quartz, opaque grains, and biotite. Scattered grains of olive, highly pleochroic tourmaline.

DR-3549A (A)--Dark gray sugary tonalitic hornfels--Granoblastic fabric but some alignment of dark minerals. Fine-grained mat of well-twinned andesine (50%), rounded quartz (15%), brown biotite (14%), light-olive hornblende (20%) and opaque grains (1%).

(3549A is from a large mass associated with gneiss and calc-hornfels. Such masses in various sizes are common in the mafic metamorphic terranes and are similar to some of the ovoid mafic inclusion material in the granitic rocks).

DR-3929 (PC)--Garnetiferous tonalitic granofels--Weak foliation in a sugary, granoblastic rock composed of andesine, quartz, dark-brown biotite, and minor olive-green hornblende. Some pink garnet in poikilitic crystals.

### Hypersthene granulite

Hypersthene-bearing varieties of amphibolite and granofels that are considered diagnostic of the granulite metamorphic facies.

DR-3385 (WR)--Fine-grained granoblastic mat (in part polygonal) of well-twinned labradorite, anhedral discrete crystals of hypersthene (in clean contact with adjoining minerals), and lesser olive-brown (in part lacy) hornblende. Abundant opaque grains and scattered quartz.

DR-3402C (PC)--Polygonal mat of well-twinned calcic plagioclase (An<sub>85</sub>) and irregular, large brown hornblende crystals (with aligned purplish inclusions). Associated clear to pale-green amphibole has hypersthene cores.

(3402C is an example of a Wiese (1950) "gabbro" that by its mineralogy and association is more likely a high-grade metamorphic rock).

DR-3405A (PC)--Xenoblastic (metamorphic) or xenomorphic granular (magmatic) texture. Clean, well-twinned andesine, brown to reddish brown biotite, olive-green to olive-brown hornblende, and abundant quartz. Scattered reddish serpentinitic(?) patches in hornblende suggest former presence of orthopyroxene. Probably a granulite-grade metamorphic rock, but could be tonalite.

DR-3420 (WR)--Compositional layering from variable amounts of biotite. Mostly a granoblastic fabric, however. Fresh well-twinned plagioclase (about An<sub>50</sub>), abundant weakly strained quartz and reddish-brown biotite. Scattered anhedral hypersthene in sharp contact with adjoining grains. Also scattered graphite and rounded zircon and apatite grains.

DR-3432D (CM)--Dark streaky patch in foliated tonalite. Granoblastic mat of well-twinned labradorite, weakly strained quartz, brown biotite, and olive hornblende. Also abundant anhedral grains of hypersthene in sharp clean contact with other minerals. (A rock of tonalite composition with hypersthene).

DR-3440 (LT)--Xenomorphic granular or granoblastic texture. Well-twinned plagioclase (to An<sub>50</sub>) and olive green ("plutonic") hornblende are most abundant. Also common are strongly pleochroic (pink to green) hypersthene crystals (commonly included in hornblende, but contacts unaltered). Quartz is abundant and in part granulated. minor reddish-brown biotite. May be either granulite-grade metamorphic rock or a tonalite.

DR-3341 (LT)--Much like 3440, but more biotite and some altered patches of blue-green acicular amphibole and fine granular quartz.

DR-3943 (WR)--Dark, medium-grained rock made up dominantly of granoblastic to polygonal labradorite and olive-green hornblende. Pleochroic (pink to green) hypersthene is present both as isolated grains and as inclusions in hornblende. Contacts of hypersthene with plagioclase and hornblende are sharp and clean. Hornblende is commonly somewhat "bleached" adjacent to included hypersthene. Opaque grains are common and minor quartz is present.

### Impure Quartzite

Rocks that are dominantly composed of quartz and are of unquestionable sedimentary origin.

DR-3092C (G)--Mostly quartz (showing only minor strain, lesser well-aligned muscovite (both in coarse grains and dense aggregates). Minor light brown biotite and pale-green chlorite. Scattered pink garnet crystals and minor twinned plagioclase.

DR-3362C (WR)--Weak directional fabric, but dominantly a granoblastic mat of quartz with liberal sprinkles of plagioclase, olive-green hornblende, lesser reddish brown biotite, and small amounts of K-feldspar and sphene.

DR-3381B (WR)--Coarse incipiently mosaicked mat of quartz that is in part granulated. Sprinkles of red-brown biotite, muscovite, and pink garnet. Rock is about 95 percent quartz.

DR-3416C (WR)--Fine-grained granoblastic fabric of anhedral sutured, somewhat undulose quartz grains. Lamination shown by various admixtures of plagioclase, K-feldspar, bright-red-brown biotite, muscovite, and graphite. Haloed zircon common in biotite.

(3416 is essentially a quartz-rich variation of 3415 (see "Gneiss") and the other quartzofeldspathic granofels and gneiss).

DR-3417B (WR)--Similar to 3416, but more mafic admixture including scattered pale-brown hornblende. Local concentrations of apatite suggest phosphatic material in sedimentary protolith. Shiny gray flakes of graphite are particularly noticeable.

DR-3353 (A)--Granoblastic mosaic of sutured quartz with varied amounts of reddish-brown biotite and poorly twinned plagioclase. Zircons as haloed inclusions in biotite, and scattered opaque grains.

DR-3556B (A)--Dominantly a coarsely mosaicked and sutured mat of quartz. Thin layering shown by various admixtures of plagioclase, reddish brown biotite, and abundant muscovite.

DR-3915A (PC)--Mosaic of sutured quartz (shape oriented) sprinkled with epidote, plagioclase, sphene (droplets), graphite flakes, and minor pale-green hornblende and brown biotite.

DR-3918A (PC)--Foliation from preferred orientation of quartz and red-brown biotite. Also plagioclase, lesser K-feldspar, and minor muscovite.

### Calc-hornfels

Rare layers of fine-grained gray-green rock that contain significant amounts of colorless to pale-green clinopyroxene or epidote and are suggestive of a calcareous sedimentary protolith.

DR-3548 (A)--Quartz-plagioclase-clinopyroxene calc-hornfels--Fine-grained granoblastic mixture of quartz, weakly twinned plagioclase, and clinopyroxene. Small scattered poikilitic patches of clinozoisite-epidote with anomalous deep blue interference colors. Scattered sphene.

DR-3918B (PC)--Plagioclase-clinopyroxene calc-hornfels--Granoblastic, fine-grained mat of andesine and clinopyroxene. Lesser pale-green hornblende and minor quartz.



DR-3955B (WR)--Siliceous calc-hornfels--Sutured mat of quartz inset with abundant euhedral crystals of epidote. Scattered anhedral sphene and minor fibrous pale green amphibole.

### Tonalite of Antimony Peak

A dark, somewhat gneissic, plutonic(?) rock that appears to intrude the mafic San Emigdio-Tehachapi terrane at its western end.

DR-3000A (West of ERP)--Hornblende biotite tonalite-granodiorite-- Hypautomorphic granular, but much retrograded and some cataclasis. Twinned and somewhat concentrically zoned, but strongly dusted andesine. Abundant weakly twinned K-feldspar. Abundant quartz, but generally interstitial and much granulated and slivered. Green hornblende and brown biotite with much alteration to epidote and chlorite. Large sphene crystals, also apatite and zircon.

DR-3000B (West of ERP)--Biotite tonalite-- Much like 3000A, but less hornblende and no K-feldspar.

DR-3000D (West of ERP)--Biotite tonalite-- Much like 3000B, but less cataclasis.

DR-3007 (ERP)--Hornblende biotite tonalite-- Much like DR-3000 specimens, but many prehnite lozenges in reddish-brown biotite, and some veinlets and discrete crystals of prehnite.

DR-3023 (ERP)--Hornblende tonalite (foliated)-- Foliation defined by aligned dark minerals, but a relatively good granitic texture. Most abundant are well-twinned andesine and pale-green hornblende. Quartz is interstitial and tends to be in rounded grains. Originally brown biotite is much leached or altered to chlorite. Minor epidote and apatite. Prehnite is locally abundant as lozenges and rosettes in leached biotite, and also occurs in veinlets and as "primary" crystals. Close physical resemblance to sample 3007.

DR-3029A (PH)--Hornblende tonalite-- Bimodal grain size distribution of coarser equant to rounded twinned and concentrically zoned andesine crystals set in a somewhat cataclastic(?) finer-grained matrix dominated by rounded quartz and shred-like mafic minerals. Grayish-green hornblende much more abundant than bleached brown biotite that includes prehnite lozenges.

Bimodal grain distribution representing cataclasis(?) or quenching(?) is characteristic of this body. DR-3028A may also be a similar tonalite, rather than a granofels(?).

DR-3111 (ERP)--Retrograded hornblende biotite tonalite-- Hypautomorphic granular texture with an abundance of subhedral twinned and weakly zoned, strongly dusted andesine crystals. Abundant quartz is strongly mosaicked, slivered, or granulated. Brown biotite more common than olive-green hornblende and both highly altered to epidote and chlorite. Rare prehnite lozenges.

DR-3133 (SM)--Foliated hornblende biotite tonalite-- Hypautomorphic granular texture with subhedral, somewhat dusty andesine with weak concentric zoning. Quartz is common, but tends to be interstitial and much mosaicked. Scattered untwinned K-feldspar. Reddish-brown biotite is abundant and much

looks somewhat bleached, but little chlorite. Olive-green hornblende much less abundant. Very pale green clinopyroxene in abundant discrete crystals (anhedral) and only some included in hornblende. Prehnite lozenges are scattered in biotite.

DR-3152B (PH)--Hornblende tonalite--Bimodal (cataclastic?) texture that has coarser well-twinned, concentrically and in part oscillatory zoned andesine (to An<sub>50</sub>) crystals in a finer-grained matrix of mosaicked quartz, andesine, and shreds of pale-green hornblende and lesser brown biotite. Traces of zircon, sphene, apatite, and opaque grains.

DR-3153 (PH)--Hornblende tonalite--Similar to 3152B with well-developed bimodal cataclastic fabric.

DR-3158 (CV)--Retrograded hornblende biotite tonalite--Xenomorphic granular texture with dusty plagioclase (some crystal boundaries against quartz) and lesser grid twinned K-feldspar. Quartz much mosaicked and sutured. Rare remnants of olive-green hornblende and reddish-brown biotite, but most mafic minerals are altered to chlorite (with sphene droplets), epidote, and calcite.

#### Other Plutonic(?) Rocks

DR-3407 (WR)--Hornblende diorite--Xenomorphic granular texture with polygonal plagioclase (An<sub>40-45</sub>) and abundant light-olive hornblende. Minor interstitial quartz and brown biotite. Traces of opaque grains.

(This rock clearly has a granitic appearance, but in the regional context of gneissic-amphibolitic-granulitic rocks it may well be a metamorphic rock!).

DR-3927 (PC)--Gneissic tonalite--Foliated (concentrations of dark minerals) but a good xenomorphic to hypautomorphic granular texture. Twinned and concentrically zoned andesine, abundant quartz, and "plutonic" olive-green hornblende and brown biotite. A good plutonic texture and mineralogy within the mafic metamorphic belt.

#### Live Oak Body and Related(?) Rocks

The Live Oak body (fig. 5) contains unquestionable mafic and ultramafic intrusive rocks that contain hypersthene and olivine. Also present are amphibolitic rocks that suggest resemblance to rocks of the San Emigdio-Tehachapi mafic terrane. Figure 5 also locates closely associated gneissic and granulitic(?) rocks.

DR-4192A Hornblende tonalite--Xenomorphic granular texture with much cataclasis. Fresh well-twinned, weakly concentrically and locally oscillatorially zoned plagioclase (to An<sub>50</sub>) is most common. Also abundant are acicular aggregates of pale-green hornblende with remnant olive-brown hornblende. Undulatory to granulated quartz is also common. Red-brown biotite minor. Abundant opaque grains in hornblende.

(Much resemblance to the mafic "messy" amphibolite-tonalite of the San Emigdio-Tehachapi belt. Virtual absence of biotite is atypical of "plutonic" tonalite).

DR-4192B Plagioclase amphibolite--Fine-grained dark-gray rock made up of a selectively-oriented mat of intermediate labradorite and pale-olive-green hornblende. Abundant opaque grains and minor brown biotite.

DR-4193B Hornblende gabbro or plagioclase amphibolite--Decussate mat of elongate labradorite crystals and large pale-green hornblende aggregates that contain skeletal colorless to pale-green clinopyroxene cores. Local coarse muscovite flakes in hornblende aggregates.

(A medium-grained rock that looks like amphibolite in hand specimen, but fresh decussate mat of plagioclase suggests this may be a gabbro).

DR-4194B Plagioclase amphibolite--Xenomorphic granular (magmatic) or xenoblastic (metamorphic) fabric composed of medium-grained fresh labradorite and pale-green hornblende aggregates. Some pale-olive-brown remnant "original" hornblende. Some chlorite, epidote, and muscovite in pale-green hornblende aggregates. Rare metallic opaques.

DR-4245--Plagioclase amphibolite--Small fine-grained ovoid dark-gray inclusion in tonalite about 1 km NW of the Live Oak mafic body. Granoblastic mat of well-twinned, weakly concentrically zoned labradorite and much larger poikilitic pale-brown hornblende masses. Hornblende includes reddish-brown biotite, chlorite, and muscovite. Scattered opaque grains.

(Not physically part of the Live Oak body, but mineralogy and close proximity suggests a possible relation).

About 500 m east of the Live Oak body, hypersthene-bearing rocks (4208 of figure 5) are present along Highway 178 whose relation to the enclosing(?) tonalite of Bear Valley Springs is not known. These hypersthene-bearing rocks, close to the Live Oak body, and to gneissic patches in the tonalite to the northeast, physically resemble samples 3593 to 3596 of the Cummings belt.

DR-4208A--Hypersthene hornblende tonalite (or granulite)--Texture is certainly acceptably granitic with some subhedral plagioclase and hornblende. Dark minerals in clotty aggregates, but this is common in some tonalites of this region. Plagioclase is well-twinned and concentrically and in part oscillatorially zoned calcic andesine. Anhedral, largely interstitial quartz shows only minor strain. Light-olive to light-olive-brown hornblende is much more abundant than reddish-brown biotite. Pleochroic hypersthene is abundant and generally is insulated from adjoining grains by pale, acicular amphibole. Anhedral opaque grains to 0.5 mm are common in the mafic minerals. Apatite and zircon also present. This rock has the following mode (in volume percent):

Plagioclase	62
Quartz	14
Biotite	4
Hornblende	12
Hypersthene	8
	<u>100</u>

## Caliente Body

The Caliente body (fig. 6) has many hints of possible relation to the San Emigdio-Tehachapi terrane (gneiss, amphibolite, and hornblende-rich "plutonic" rocks). Following are petrographic notes on three Caliente samples, examples of the kinds of rocks (along with mafic and ultramafic plutonic rocks) that can be seen here along public roads.

### DR-3636--Plagioclase amphibolite

Location: Low roadcuts and outcrops along Bena Road just south of the overpass of State Highway 58. About 1.6 mi. (2.6 km) west of the Junction of State Highways 58 and 223.

Sheets and leaves of fine-grained gray rock in the tonalite matrix rock. Granoblastic mixture of twinned andesine and grayish-green hornblende. About 5 to 10 percent quartz and less than 5 percent red-brown biotite. Abundant opaque grains.

(General resemblance to DR-4192B of the Live Oak body).

### DR-3630--Quartz diorite or amphibolite(?)

Location: Roadcut on Highway 58 about 0.8 mi. (1.3 km) west of DR-3636. Xenomorphic granular texture--a fresh granitic-looking rock, but with splotchy aggregates of dark minerals. Plagioclase is fresh and well-twinned (calcic andesine). Next most abundant is pale-green to light-olive-brown hornblende. Reddish-brown biotite is much less abundant and is commonly in aggregates with the hornblende. Quartz is scattered in smaller interstitial grains. Opaque minerals are abundant--many are bladed, but do not appear to be graphite. Apatite, sphene, and zircon are present.

(This is a good example of the relatively mafic rocks of the Caliente body. They are grossly granitic in appearance, but have splotchy messy dark minerals, hornblende much in excess of biotite, and associated amphibolitic and gneissic rocks. In short, they are similar to many rocks in the San Amigdio-Tehachapi terrane--granitic or metamorphic is a constant question! A slab sample very close to the thin section sample has the following mode (in volume percent): plagioclase, 51; hornblende, 35; biotite, 10; quartz, 4; and a specific gravity of 2.82).

### DR-3633-1A--Impure quartzite

Location: Roadcut on State Highway 58 about 2.3 mi. (3.7 km) west of State Highway 223 junction.

Fine-grained gray rock that has a granoblastic mat of quartz (about 65 percent) liberally sprinkled with colorless to pale-green clinopyroxene, pale-green hornblende, twinned andesine, and minor epidote. Small sphene crystals common and metallic opaque grains are sparse.

(Not in itself a particularly diagnostic lithology, but it is associated in a large roadcut with streaky gneissic, and hornblende-rich rocks, whose overall appearance suggests similarity to the San Emigdio-Tehachapi mafic terrane).

## Jawbone Body

The amphibolitic and gneissic rocks of the Jawbone body are in some ways similar to the mafic rocks of the San Emigdio-Tehachapi terrane, but in other ways they may be somewhat different and of lower metamorphic grade. The following descriptions are of samples that are from easily accessible exposures along Jawbone Canyon (fig. 7). Much tonalite and more felsic granitic rock intrudes these mafic rocks in Jawbone Canyon. Another locality to see the relations of these mixed lithologies is also marked on figure 7 at the mouth of Hoffman Canyon.

DR-4497B--Plagioclase amphibolite--Medium-grained, dark-gray rock--has the appearance of many of the ovoid mafic inclusions in granitic rocks of the area. Granoblastic mat of well-twinned, concentric zoned plagioclase (about An<sub>50</sub>) and moderate green hornblende. Much of the hornblende has bladed, aligned opaque inclusions (schiller-like). Abundant anhedral opaque grains to 1 mm. Scattered brown biotite (with prehnite lozenges) and minor quartz.

DR-4499--Plagioclase amphibolite--Much like 4497B, but biotite is somewhat more abundant, in part reddish, and looks altered (bleached).

DR-4498A--Biotite quartzofeldspathic gneiss (or schist)--Dark-gray gneiss with anastomosing fabric. Layering and foliation shown by relative concentrations of aligned biotite but rock dominated by a sutured granoblastic mat of well-twinned andesine and quartz. Abundant light-olive to light-olive-brown biotite contains common haloed zircon(?) grains. Minor coarse muscovite flakes and anhedral epidote. Traces of red opaque grains. This rock is a borderline case between gneiss and schist.

DR-4498B--Quartz biotite plagioclase amphibolite--Dark-gray, fine-grained spotted rock. Polygonal to granoblastic fabric of pale-green hornblende, weakly twinned plagioclase, and lesser strained quartz and brown biotite. Dark spots of hand specimen are small clots of hornblende crystals. Minor apatite, aegirine, muscovite, and epidote.

## Cummings Belt

The Cummings belt contains undoubted hypersthene granulite associated with gneissic metamorphic rocks, but also rocks that could as well be called plutonic rocks (hypersthene-hornblende tonalite). The Cummings belt is also near the San Emigdio-Tehachapi terrane, but closely associated with marble-bearing metasedimentary rocks. Accessibility to these rocks is limited because, in part, they are "behind the wire" of the California Correctional Institution of Tehachapi and the rest of the belt is on a private development. Therefore, the following thin section descriptions will provide some data for comparison with the other mafic terranes. Location of samples shown on figure 8.

DR-3593--Hypersthene-hornblende tonalite (or granulite--Xenomorphic granular (magmatic) or xenoblastic (polygonal in part) (metamorphic) texture, medium-grained rock. Well-twinned calcic andesine (some concentric zoning). Abundant quartz with minor strain. Light-olive hornblende also abundant and includes (or is clustered with) pleochroic hypersthene. Hypersthene also in isolated grains in plagioclase matrix where it commonly is rimmed with pale fibrous amphibole. Similar and somewhat thicker rims of fibrous amphibole surround most hypersthene grains in hornblende, but there are some sharp, clean contacts. Minor brown biotite and scattered opaque grains.

DR-3594--Hypersthene hornblende tonalite (or granulite)--Similar to 3593, but somewhat darker. Note that outcrop contains dark ovoid inclusions. Moderate to dark-reddish-brown biotite is more abundant than in 3593. Most of the hypersthene is in clean sharp contact with adjoining plagioclase and hornblende. Fibrous amphibole is present but much less common than in 3593. Local very intensely saussuritized plagioclase crystals, but otherwise plagioclase and other minerals clean and unaltered.

DR-3595--Biotite hornblende tonalite (or granulite)--Another fresh rock like 3594. Only minor hypersthene in sharp contact with plagioclase and hornblende. Olive-green hornblende and moderate brown biotite have the "normal" granitic interference colors. If it were not for nearby granulite and other metamorphic rocks, this sample would unquestionably be referred to as a tonalite with accessory hypersthene.

DR-3596--Biotite hornblende tonalite (or granulite)--Much like 3595, but even less hypersthene in discrete small crystals in hornblende and less common in the plagioclase mat. Hypersthene commonly veined and locally rimmed with reddish alteration product, but fibrous amphibole virtually absent and most hypersthene-hornblende and hypersthene-plagioclase boundaries are sharp. From this locality the following K-Ar radiometric ages were determined by J. L. Morton (in Ross, in press): hornblende,  $88.1 \pm 2.6$  m.y.; biotite,  $85.9 \pm 2.6$  m.y.

Modes (in volume percent) of the above described tonalite (or granulite) samples are as follows:

	Plagioclase	Quartz	Biotite	Hornblende	Hypersthene	Specific Gravity
DR-3593	61	16	1	16.5	6.5	2.78
DR-3594	60	10	5	19	5	2.82
DR-3595	48	21	11	18	2	2.81
DR-3596	52	16	11	21	1	2.80

DR-3700A--Hypersthene granulite--Granoblastic texture, medium to coarse grained (hornblende crystals as large as 5 mm) rock. Well-twinned sodic labradorite and moderate olive brown hornblende are most common. Also abundant are anhedral crystals of pleochroic (pink to green) hypersthene in sharp clean contact with adjacent plagioclase and hornblende (rarely a thin colorless amphibole rim against brown hornblende). Opaque grains, rarely as large as 1 mm, are also widespread.

DR-3700B--Hypersthene granulite--A finer grained variant of 3700A, but with much pale, fibrous amphibole in contact with hypersthene. Minor bright-reddish-orange pleochroic micaceous material may be stilpnomelane(?).

DR-3986--Hypersthene granulite--Granoblastic texture featuring clots of anhedral dark minerals and somewhat polygonal plagioclase. In outcrop a dark gray, heterogeneous rock. Well-twinned, weakly concentrically zoned sodic labradorite and light-olive to pale-olive-brown hornblende are dominant. Hypersthene is common in cores of hornblende crystals where it is veined by reddish alteration material and cushioned from the hornblende by thick reaction rims of pale fibrous amphibole. Opaque grains are anhedral and in part lacy, and as large as 1 mm. Field note records "banding and associated felsic foliated rocks."

DR-3989A--Hypersthene granulite--Much like 3986; particularly distinctive is pale-olive-brown hornblende and almost no pale fibrous amphibole. Hypersthene in sharp clean contacts with hornblende and plagioclase. (In almost all hypersthene-bearing rocks, some crystals show thin lamellar twinning). Minor interstitial quartz in this specimen.

DR-3993A--Gneissic 2-pyroxene granulite--Medium-grained granoblastic fabric (foliation much less evident in thin section than in hand specimen and outcrop). Fresh rock composed mostly of well-twinned labradorite, light olive to olive-brown hornblende and clinopyroxene (biaxial (+) with a moderate 2V). Also present, but less abundant is hypersthene (biaxial (-) with a moderate 2V), which is not as distinctive as the pleochroism is very subtle to absent. Minor interstitial quartz and scattered opaque grains.

The heterogeneity (and metamorphic) character of the outcrop is shown by two thin sections that are markedly different in grain size, amount of foliation, proportion of clino- to orthopyroxene, and proportion of clean fresh hornblende to fibrous pale "secondary" amphibole.

DR-3993B--Biotite quartzofeldspathic gneiss--A nearby associate of 3993A. A strongly foliated rock comprised chiefly of sodic andesine, quartz, and brown biotite. Also small amounts of garnet and scattered flakes of muscovite. Bimodal grain size distribution suggests some cataclasis. Similar to quartzofeldspathic rocks in the San Emigdio-Tehachapi terrane.

DR-3999A--Two-pyroxene granulite--Xenomorphic granular (magmatic) or xenoblastic (metamorphic) texture. Dark minerals are in splotchy aggregates, but plagioclase in part has good planar grain boundaries. Plagioclase is well-twinned, weakly concentrically zoned and about An<sub>50</sub>. Hornblende is grayish-green to light-olive and biotite is brown to reddish-brown. Quartz is scattered in subrounded grains. Strongly pleochroic hypersthene is abundant, both in hornblende where it is in part skeletal, and less commonly with plagioclase. Hypersthene contacts are sharp--there is no fibrous pale amphibole. Lesser clinopyroxene (biaxial (+) with a moderate 2V and markedly inclined extinction) is present in some hornblende crystals. Opaque grains are extremely rare.

This sample could be called a tonalite, but the abundance of pyroxene, the paucity of quartz, and its close association with gneiss suggests it is more likely a granulite.

DR-3999C Hypersthene granulite (or tonalite)--Texture could be called either xenomorphic granular (magmatic) or xenoblastic (metamorphic). Dark minerals are very abundant in splotchy aggregates. Well-twinned plagioclase (about An<sub>50-55</sub>). Much grayish-green to light-olive-brown hornblende and reddish-brown biotite. Hypersthene is abundant as embayed and skeletal crystals in hornblende and as more discrete isolated grains. Lamellar twinning is well developed in some hypersthene crystals. Quartz is scattered. Opaque grains are extremely rare. The mode of this rock is (in volume percent):

Plagioclase	49
Quartz	10
Biotite	10
Hornblende	16.5
Hypersthene	<u>14.5</u>
	100.0



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Figure 1 . Index map

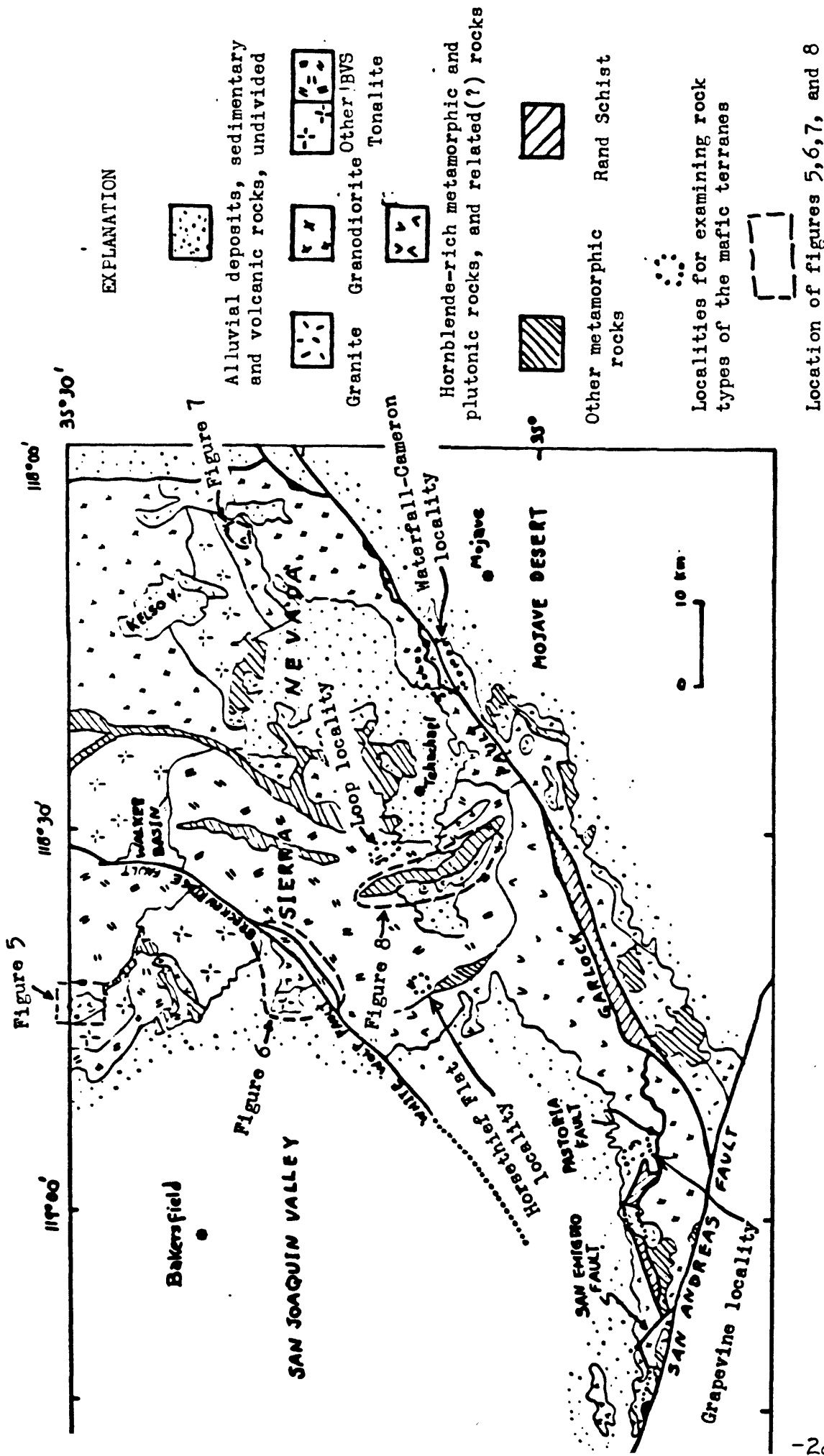
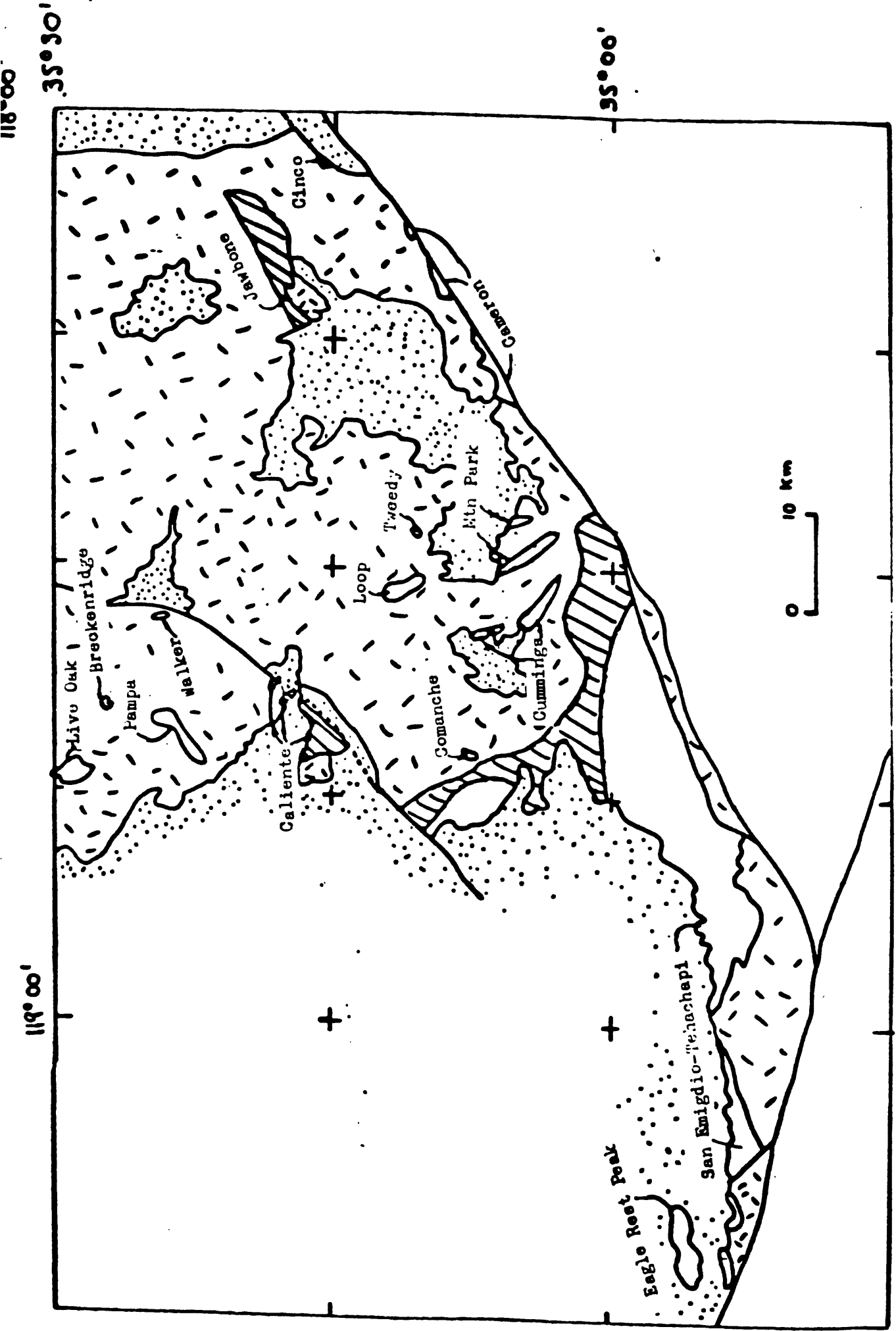


Figure 2. Generalized geologic map of the southernmost Sierra Nevada,

California, showing selected locations for examining rock types of the mafic terranes, and locations of figures 5, 6, 7, and 8.



**Figure 3** . Location of hornblende-rich metamorphic and magmatic terranes, southernmost Sierra Nevada, California. (Cross-hatched areas indicate hornblende-rich terranes that are extensively invaded by younger granitic rocks)

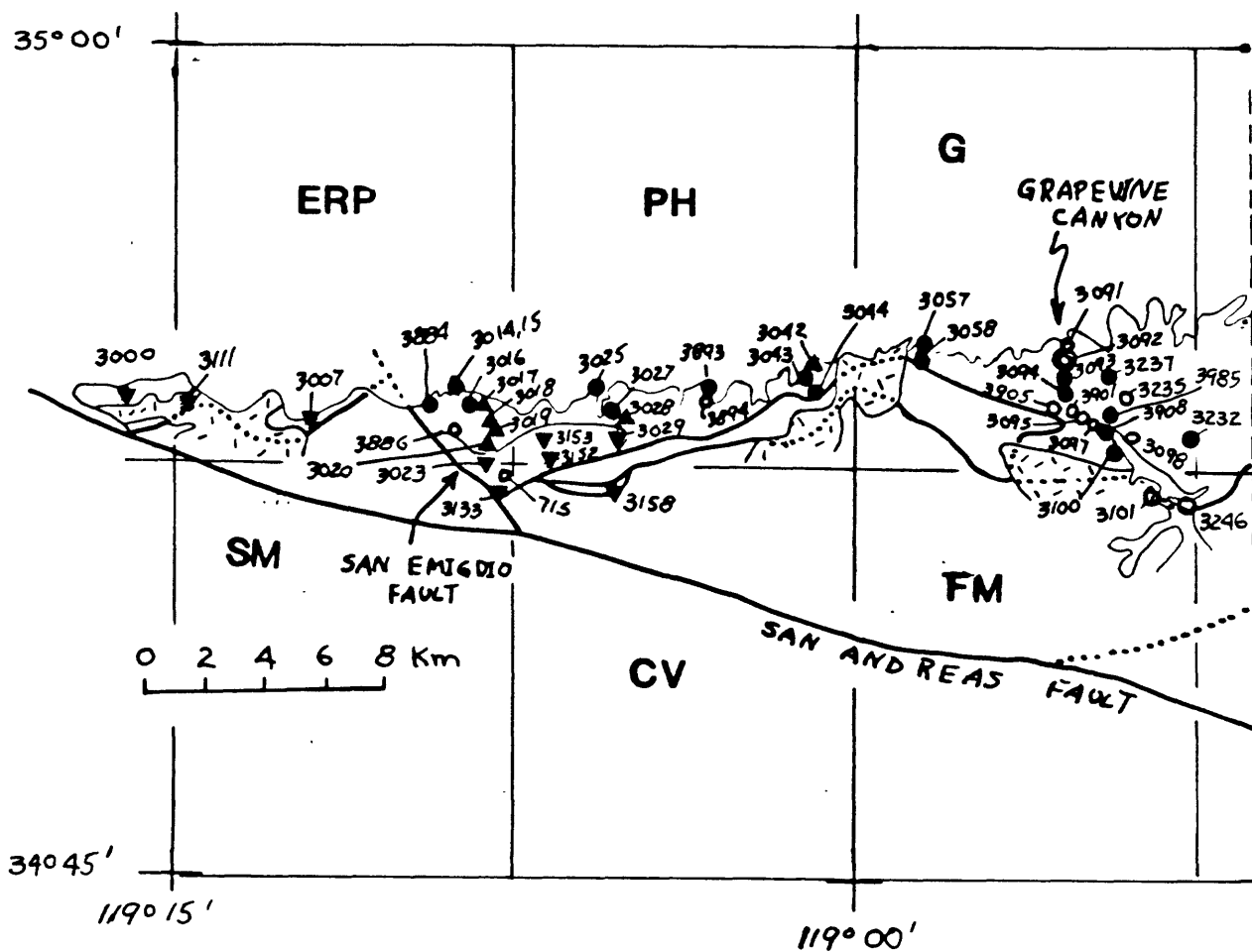


Figure 4A. Location of selected samples with petrographic notes from the western half of the San Emigdio-Tehachapi mafic terrane.

See key to rock type symbols and 7 1/2' quadrangles following Figure 4B.

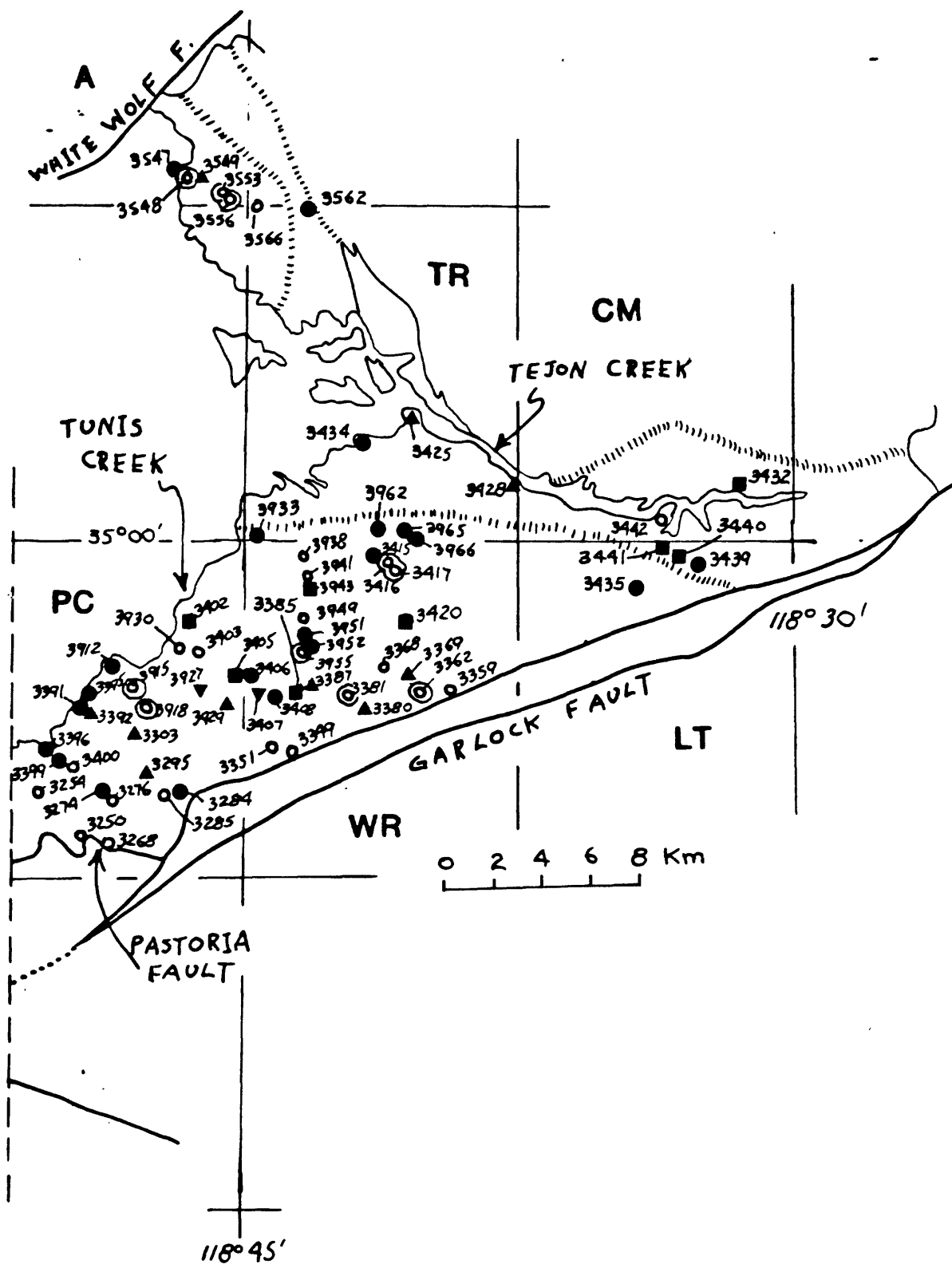
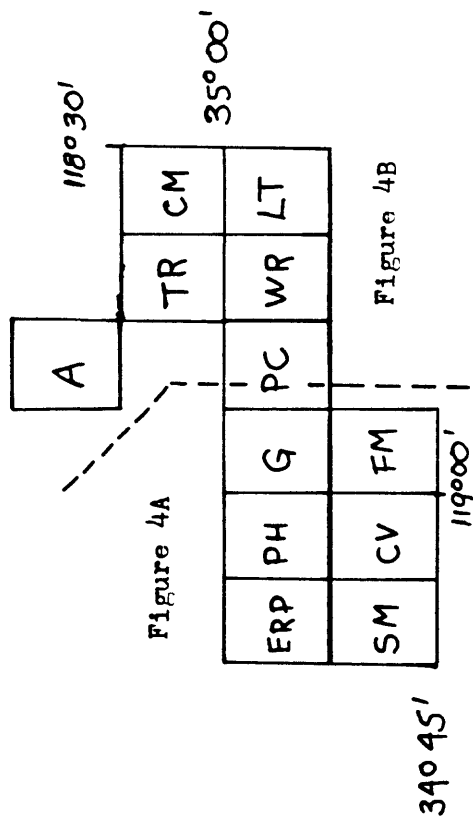


Figure 4B. Location of selected samples with petrographic notes from the eastern half of the San Emigdio-Tehachapi mafic terrane.



ERP Eagle Rest Peak  
SM Sawmill Mtn  
PH Pleito Hills  
CV Cuddy Valley  
G Grapevine  
FM Frazier Mtn

A Arvin  
PC Pastoria Creek  
TR Tejon Ranch  
WR Winters Ridge  
CM Cummings Mtn  
LT Leibre Twins

Figure 4B

Location key to 7 1/2' quadrangles of Figure 4.

- Amphibolite
- Gneiss
- ▲ Granofels
- Hypersthene granulite
- ◎ Quartzite and calc-hornfels
- ▼ Tonalite of Antimony Peak and other plutonic(?) rocks

Key to rock types of specimens located on Figure 4

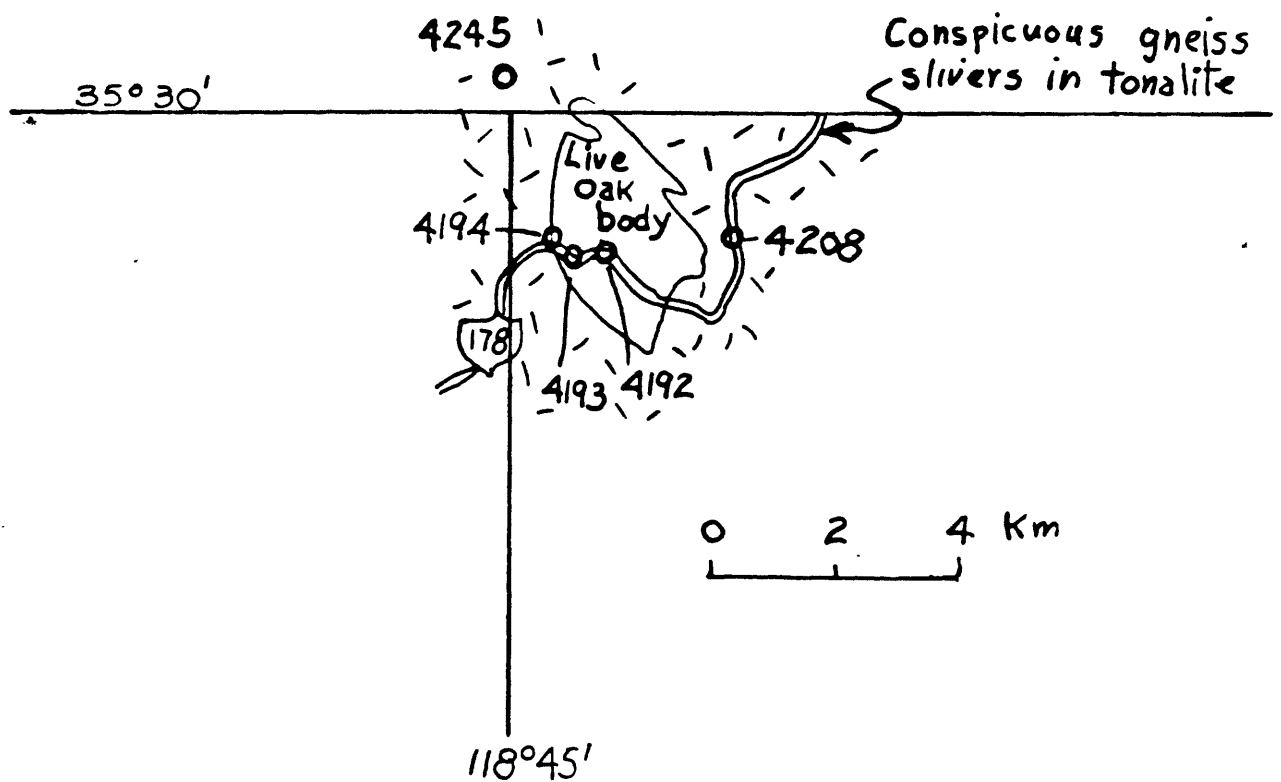


Figure 5 . Location of selected samples in and near the Live Oak body.



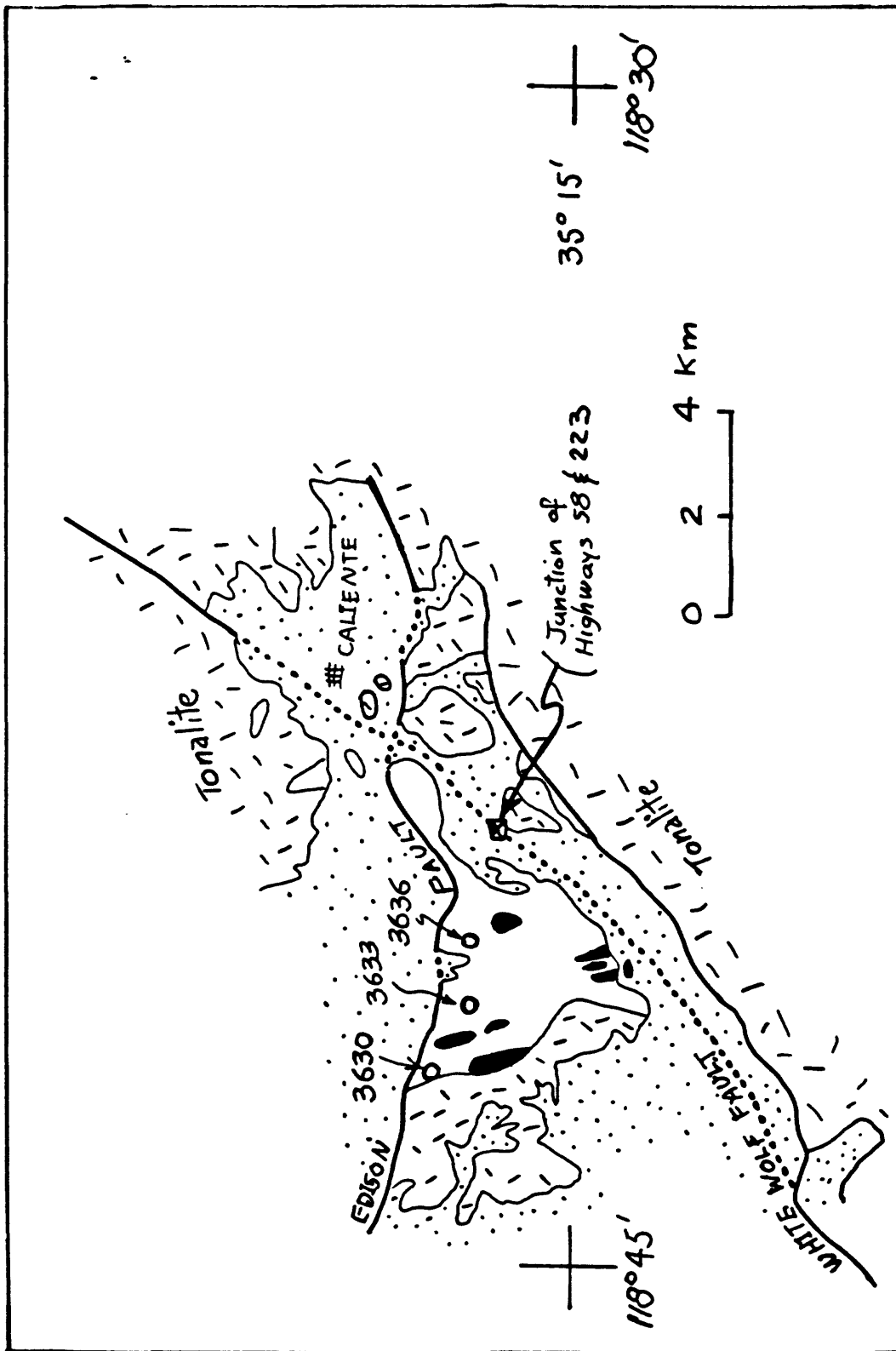


Figure 6 . Geologic setting of the Caliente body. Solid black areas consist of mafic and ultramafic rocks.

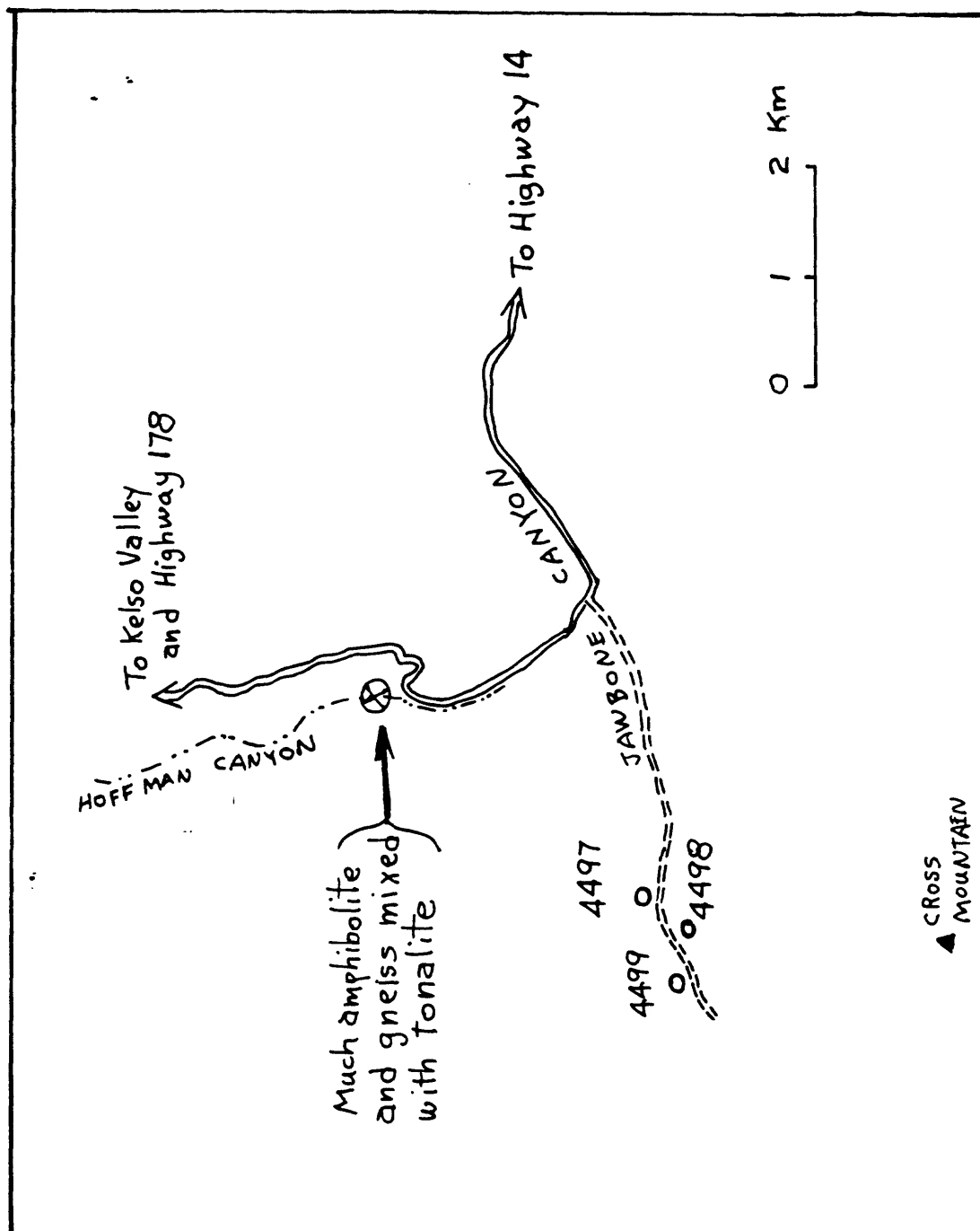
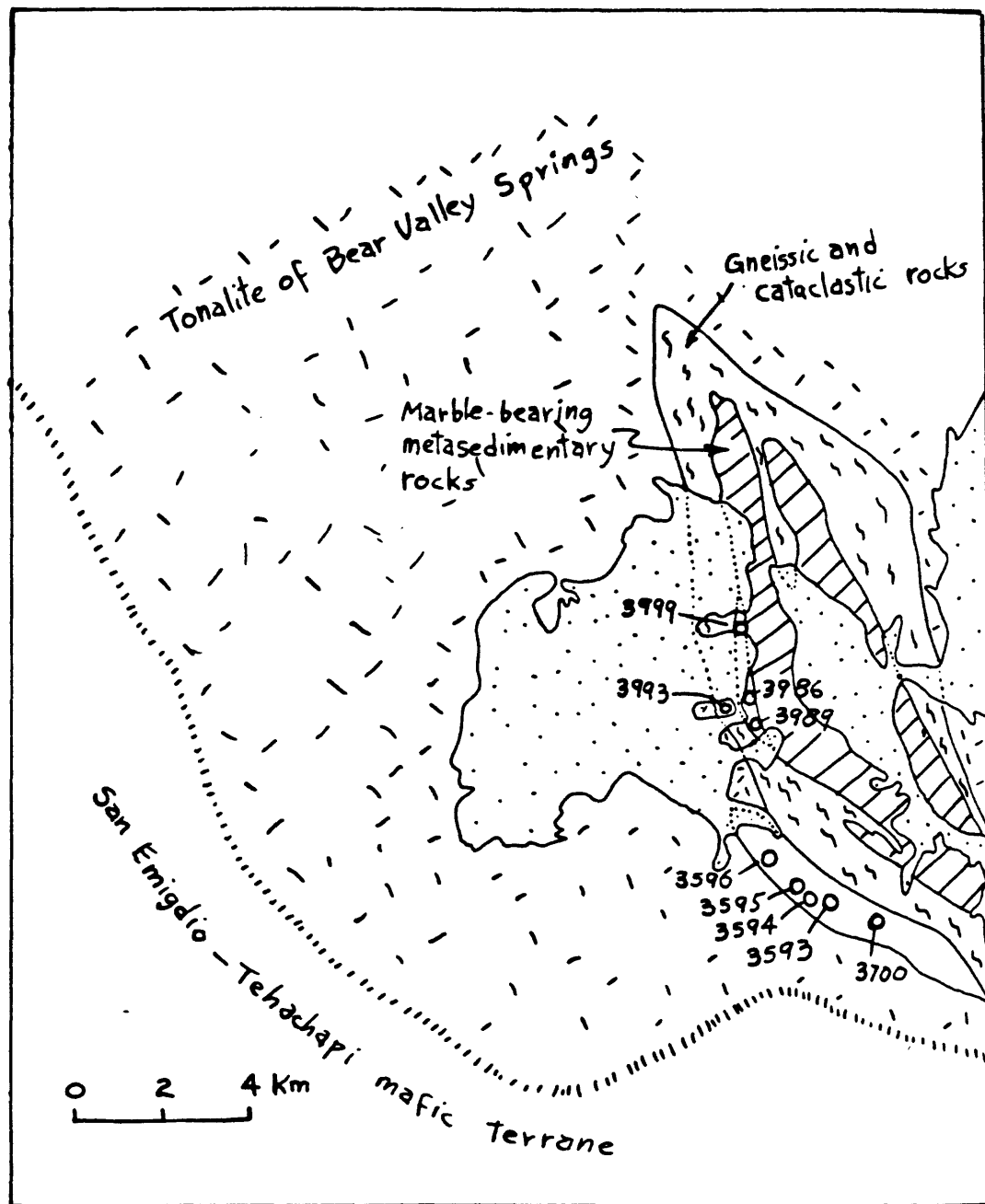


Figure 7 . Index to selected localities of amphibolitic and gneissic rocks of the Jawbone body.

35°15'

118°30'



35°00'

118°45'

Figure 8. Generalized geologic map showing the locations of selected samples from the Cummings belt.