DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Mafic plutonic rocks of the southern Sierra Nevada, California

by

Donald C. Ross

U.S. Geological Survey [1]

Open-File Report 87-275

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1] Menlo Park, California

1987

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ABSTRACT

Small bodies of gabbro, amphibolite, and ultramafic rocks are included as remnants in younger granitic rocks, and also appear to intrude the gneissic complex of the southernmost Sierra.

These mafic rocks are grossly assigned to three main age groups. On the west side of the Sierra Nevada the mafic rocks, on the basis of sparse radiometric data, are middle Cretaceous (from about 100-120 Ma). An olivine gabbro along the White Wolf-Breckenridge-Kern Canyon fault, and an isolated gabbroic mass north of the San Emigdio Mountains are most likely Jurassic. Gabbro patches in the eastern part of the Sierra Nevada are in part intruded by Triassic granitic rocks and are at least as old as Triassic. A gabbro-basalt serpentinite melange in the northwest part of the area is interpreted by Saleeby and Sharp (1980) as sea floor that was disrupted about 270-305 Ma. The gabbros in the eastern Sierra Nevada could be intrusives related to this event, but could be as young as Triassic and unrelated to the melange.

Abundant mafic lamprophyric dikes, probably representative of the Independence dike swarm of Moore and Hopson (1961), are present in the eastern Sierra Nevada between lat. 35°30' and 36°00' N.

INTRODUCTION

Small bodies of gabbro, amphibolite, and ultramafic rocks are scattered throughout the southern Sierra Nevada (Pl. 1). The largest is less than 20 km^2 in outcrop area, and from this size they grade downward to bodies no more than a few tens of meters in size. Some small fist-sized amphibolite inclusions may have originated as gabbro.

Most mafic rocks in the southern Sierra Nevada are now composed of some combination of dark green to black hornblende and intermediate to calcic plagioclase, exhibit primary igneous textures, and are best termed hornblende gabbro. Some have clinopyroxene and orthopyroxene enclosed in the hornblende suggesting that at least some of the hornblende has been derived from pyroxene either by hydrothermal alteration or retrograde metamorphism; thus at least some of the hornblende gabbro was originally pyroxene gabbro or norite. In some of the mafic rocks, dark colored hornblende is partially to completely replaced by pale green fibrous amphibole (actinolite or cummingtonite?) Many

of these rocks, with no obvious original igneous texture, are best termed amphibolite.

The gabbroic rocks are almost without exception included as remnants in younger granitic rocks and may be residuals of once larger bodies now engulfed by the granitic batholithic rocks. The one exception is the largest mass, the metagabbro of Tunis Creek, which is probably intrusive into the gneiss complex of the San Emigdio and Tehachapi Mountains. Other small plug-like gabbroic masses in this complex (Sams, 1986) are not delineated here. The gneissic complex is made up dominantly of orthogneisses of tonalitic composition, but range to dioritic and gabbroic compositions. Though some of these rocks could well be included in this report, they have a dominantly metamorphic fabric and are discussed in a companion report on metamorphic rocks of the southern Sierra Nevada (Ross, 1987). Distinguishing "igneous" rock from "metamorphic" is difficult in many parts of the gneissic complex.

The main purpose of this report is to record new petrographic data on the olivine gabbro of Bodfish (which has significance as a unit offset by the White Wolf-Breckenridge-Kern Canyon fault), and the gabbronorite of Quedow Mountain (which has temporal relation to the gneissic complex of the Sierra Nevada tail). In addition to discussing the gabbroic bodies, some discussion is given to various inclusion types, and the dark lamprophyric dikes.

OCCURRENCES SOUTH OF LAT 35° 30' N.

Most of these occurrences have been previously described in Ross (1983A, in press) and petrographic notes are recorded in Ross (1983B). Brief abstracted descriptions are included here for a more complete coverage and also for comparison with the more northerly occurrences that are covered in more detail in this report.

Metagabbro of Tunis Creek of Sams (1986)[1/]

A roughly circular mass of dark colored, fine- to coarse- grained rock has been delineated and named the Metagabbro of Tunis Creek (Sams, 1896). These rocks, presumably intrusive into other rock of the gneissic complex, are composed chiefly of plagioclase (zoned from $An_{30\ 50}$) and dark brown to green hornblende. Lesser amounts of clinopyroxene and hypersthene, as well as altered remnants of olivine are commonly preserved in the hornblende. Textures and remnant minerals suggest to Sams (1986) a cumulate pyroxenite as a protolith.

Small patches of hornblendite and other ultramafic rock are associated with the metagabbro, and similar ultramafic patches occur as plugs elsewhere in the gneissic complex. These rocks are noted as similar to the bodies in the Caliente area (Sams, 1986).

Serpentinite of Bean Canyon

In Bean Canyon south of the Garlock fault there is a scrap of much altered ultramafic rock that is thought by G.A. Davis (written commun., 1977) to be a fragment of disrupted ophiolite. These rocks, now largely serpentinized, are rich in colorless acicular amphibole that is studded with partially altered olivine crystals. Other fragments of altered gabbro, composed of hornblende, clinopyroxene, and plagioclase, are present in other outcrops of the Bean Canyon Formation west of Bean Canyon. The relation, if any, of these mafic and ultramafic rocks to those north of the Garlock fault is not known.

1/ The metagabbro of Tunis Creek is a borderline case between the realms of igneous and metamorphic rocks. It contains areas of fresh polygonal plagioclase and ortho- and clinopyroxene and even remnants of olivine that attest to preserved original igneous textures. However, much of the body is composed now dominantly of hornblende and plagioclase and contains a gneissic fabric in part and could well be termed an amphibolite or mafic gneiss. This is equally true of many of the smaller mafic bodies, such as Cameron, Caliente and Cummings.

Olivine gabbronorite of Breckenridge Road

Small remnants of strongly retrograded olivine gabbronorite are exposed along the Breckenridge Road. They are remnants in an intrusion breccia of tonalite and fine-grained felsic granitic rock.

Mafic remnants in the quartz diorite of Caliente

Within the quartz diorite of Caliente small remnants of mafic and ultramafic rock are present. Most are now gabbroic hornblendite composed of coarse-grained hornblende crystals (as long as 2 cm) that stand out as knobs on weathered surfaces and are set in a fine-grained groundmass: chiefly hornblende and clinopyroxene, with small amounts of labradorite. Less common are patches dominated by coarse-grained hornblende crystals that enclose many small crystals of highly altered olivine, and a few inclusions of hypersthene, and green spinel. These ultramafic remnants are locally intruded by the bimodal textured gabbroic rocks. Note has been made that these remnants resemble small plug-like bodies within the gneissic complex to the south (Sams, 1986).

Peridotite of Cameron

A small body of peridotite was noted (Ted Antonioli, written commun., 1980) but its relation to enclosing rocks that resemble the gneiss complex in the Tehachapi Mountains is not known.

Hornblende gabbro and amphibolite of Comanche Point Road

The Comanche body is only a few hundred meters across and is included in the tonalite of Bear Valley Springs. The grain size varies greatly and much is a coarsely crystalline aggregate of pale green hornblende and labradorite. Also present is a fine-grained granoblastic rock composed of a mat of labradorite, olive brown hornblende, hypersthene, and opaque grains. Nearby in the tonalite are numerous dark inclusions and amphibole-rich clots. One amphibolite, largely composed of labradorite and brown to pale-green hornblende, and lesser reddish brown biotite has strongly pleochic hypersthene cores in many hornblende grains.

Mafic rocks east of Cummings Valley

A thin disrupted arcuate belt of mafic rocks extends for some 10 km east and southeast of Cummings Valley. The smaller northern body is characterized by medium-grained granoblastic to gneissic rocks composed dominantly of labradorite and brown to olive brown hornblende. Strongly pleochroic hypersthene is common and some samples also contain clinopyroxene. These now metamorphosed rocks were probably originally gabbroic. The rest of the belt

is mostly magmatic hypersthene-bearing tonalite of unknown relation to the metamorphosed gabbroic rocks.

Mafic and ultramafic rocks of Eagle Rest Peak

A window in Tertiary rocks north of the west end of the basement rock of the San Emigdio Mountains exposes mafic and ultramafic rocks. The rocks in the window consist of gabbro, anorthositic gabbro, lesser pyroxenite (websterite), and presumed metavolcanic wall rocks of the gabbroic sequence. These mafic rocks are intruded by hornblende tonalite-quartz gabbro with minor biotite.

No counterparts of these rocks are known in the southern Sierra Nevada. Slivers and scraps of similar rocks have been found northward along the San Andreas fault (Ross, 1970). Possibly these rocks are related to the California Coast Ranges and are structurally separated from the southern Sierra Nevada.

Mafic rocks of Live Oak

The Live Oak body is dark colored, in part gabbroic and contains patches of strongly retrograded olivine norite. Also present is fine- to medium-grained amphibolite and hornblende-rich tonalite.

Mafic remnants in hypersthene-bearing tonalite near Pampa Peak

An elongate body of largely hypersthene-bearing hornblende-biotite tonalite contains possible remnants of gabbroic material and retrograded ultramafic rocks.

Hornblende Gabbro of Tweedy

A small body included in the tonalite of Bear Valley Springs is fine- to coarse-grained and rich in knobby hornblende as well as plagioclase and clinopyroxene.

Mafic rocks west of Walker Basin

A small body is present just west of Walker Basin that Dibblee and Chesterman (1953) mapped as "hornblendite and other ultrabasic rocks". These

rocks are strongly retrograded, but some samples rich in chlorite and blocky amphibolite with well-aligned bladed purplish inclusions (schiller-like?) may represent ultramafic rocks.

Gabbro of the San Joaquin Valley subsurface

These gabbro areas have been grossly delineated northwest of Bakersfield based on study of thin sections from well cores (hand specimens were unavailable). These thin sections show the rocks to be fine- to medium-grained and xenomorphic to ophitic. They consist mostly of andesine-labradorite and clinopyroxene that is partly replaced by fibrous pale amphibole. Chlorite and epidote are also common, and show the strongly retrograde conditions of these rocks.

OCCURRENCES NORTH OF LAT 35° 30' N

Most of these bodies have only been described briefly, or not at all, and therefore petrographic data on individual samples are included for some of them. Also some information is included for various mafic inclusions in the granitic rocks. The lamprophyric dikes are discussed with considerable petrographic detail for they were previously little known from the area along the eastern front of the Sierra Nevada.

Olivine Gabbro of Bodfish and Related Bodies

Olivine Gabbro of Bodfish

A small body of mafic and ultramafic rocks underlies an area of about 10 km^2 south of Bodfish. On the south, these dark rocks are intruded by the granodiorite of Mount Adelaide and pegmatite. On the west, the Kern Canyon fault truncates the mafic and ultramafic rocks, and rocks near the fault are intensely sheared. The relation of the mafic rocks to the bounding metamorphic rocks on the north and east is unclear. Miller and Webb (1940) included this body in their Summit gabbro unit and noted that "in the western part of the (Kernville) quadrangle was found one small area of olivine gabbro." They make no specific reference to the Bodfish body, but presumably it is the olivine gabbro they were referring to. My study and sampling have been limited to road cuts at the north end of the body near Bodfish and along

the Saddle Spring Road (fig. 1).

In some olivine gabbro in the Bodfish body the olivine forms distinctive small rounded reddish to black spots visible in hand specimen which in thin section study are shown to be enclosed by thin reaction mantles (kelyphitic rims). In part these rocks weather to conspicuous spheroidal piles ("cannonballs").

The gabbro is dominated by a decussate mat of fresh well-twinned plagioclase crystals (as calcic as An_{70}), which is liberally studded with rounded to equant crystals of olivine and clinopyroxene as large as 4 mm across. The olivine crystals are mantled by kelyphitic rims of acicular pale amphibole crystals with associated green spinel, which is in part in vermicular intergrowth with the amphibole. The clinopyroxene crystals are generally in sharp contact with the matrix plagioclase. Some of the pyroxene is strikingly pleochroic (pale to reddish), suggesting orthopyroxene, but the reddish crystals have markedly inclined extinction and are biaxial (+) with a moderate 2V, so it is more likely that they are anomalously pleochroic clinopyroxene. Light brown hornblende is locally present, and in part intergrown with the clinopyroxene. These gabbroic rocks grade by increase in plagioclase to anorthositic gabbro and less commonly to anorthosite. Most outcrops show some layering. Most mineral percentages given throughout the report are estimates based on thin section study; a few are thin section modes based on 1000 points.

Less common, but locally important in the Bodfish body, are ultramafic rocks (dunite or wehrlite) rich in olivine and clinopyroxene. Extensive alteration to serpentine in some of these rocks is concentrated along thinly spaced fractures that appear to record a strong tectonic fabric.

Following are brief petrographic notes based on thin section study of selected samples of the gabbro of Bodfish. Sample locations are shown on figure 1B.

4801-- Polygonal mat of fractured olivine crystals (90%) to 4 mm (incipiently to extensively serpentinized). Interstital colorless acicular amphibole aggregates (10%) with scattered green spinel (<1%). Some discrete pale brown amphibole crystals with no reaction at olivine contacts. Altered dunite

5043A- Polygonal mat of well-twinned fresh labradorite (48%) liberally sprinkled with anhedral, generally rounded crystals of olivine (35%) and clinopyroxene (16%) to 4 mm. Olivine has thin reaction rims against labradorite; clinopyroxene in sharp contact with labradorite. Rare pale brown hornblende (<1%) and scattered opaque grains (1%). Sample contains a 1 cm. anorthositic layer and other layering noted in the field. Troctolitic olivine gabbro.

5043B- Polygonal mat of sub-rounded olivine crystals (>90%) to 3 mm with minor interstitial clinopyroxene (<5%) and plagioclase (<5%) altering to prehnite. Strongly aligned pattern of serpentine (?)-filled fractures or shears. Some reddish brown amphibole (<1%) and scattered green spinel (<1%). Probably a tectonized cumulate. Dunite

5044B-- Polygonal mat of well-twinned fresh labradorite (61.5%) and ophitic crystals of clinopyroxene (distinctly pleochroic in shades of pink or light brown (20%)) as large as 5 mm. Some clinopyroxene is patchily replaced by pale green hornblende (17.5%). Rounded sphene crystals (1%) are scattered in the replacement hornblende. Anorthositic layers present in the gabbro here. Gabbro

5469-- Strongly retrograded--now a mat of acicular amphibole (60%) and lesser chlorite (20%). Abundant opaque material (15%), rarely in discrete grains. Some probable talc patches (5%) and possible relics of mantled olivine crystals (<1%). Amphibolite (altered ultramafic)

5045-- Strongly foliated with anastomosing fabric like 5043B. Described in field as a "10 m basalt sill intruding gabbro" like 5044. Abundant opaque material, rarely in discrete grains. Some probable talc patches and possible relics of mantled olivine crystals.

5470-- Polygonal, well-twinned mat of labradorite (60%) inset with rounded to equant olivine (15%) and clinopyroxene (20%) crystals to 2 mm. Olivine commonly rimmed by cross-fiber colorless acicular amphibole. Clinopyroxene patchily replaced by colorless to brownish amphibole (5%). Resembles 5465, 5466 of Wofford Heights Marina. Olivine gabbro

5471-- Polygonal mat of labradorite (60%) inset with rounded crystals and aggregates of clinopyroxene (25%) that are being replaced by pale to brown amphibole (15%). Brown pleochroic hornblende crystals with abundant bladed opaque inclusions in some clusters. Resembles 5463 of Wofford Heights Marina. Gabbro

5473-- Polygonal mat of somewhat rounded (cumulate?) olivine crystals to 3 mm (>90%). Interstitial masses of epidote, acicular amphibole, and distinctly reddish pleochroic amphibole. Some clinopyroxene and also green spinel in acicular hornblende aggregates. Alignment of serpentinized fractures in olivine suggests tectonite? Dunite

5474-- Polygonal mat of labradorite (40%) inset with rounded to equant olivine (30%) and clinopyroxene (20%) crystals to 4 mm. Local brown interstitial hornblende (5%). Generally fresh but some patches of acicular pale amphibole and green spinel (<1%) and local orange olivine alteration.

5475-- Tabular to polygonal mat of labradorite (85%) crystals that are relatively well-aligned and as large as 4 mm (mostly much smaller). Sprinkled with clots of anhedral to subhedral clinopyroxene (6%) to 3 mm that is altered to acicular pale amphibole (9%). Notable layering in the field (relative abundance of mafic minerals). Anorthositic gabbro

5476-- Tabular to polygonal mat of labradorite (67%) inset with anhedral (6%) olivine crystals to 3 mm that are much altered to orange iddingsite (?) and mantled by acicular pale-green to colorless amphibole. Also clinopyroxene (14%) crystals to 2 mm and some interstitial, "lacy" brown hornblende (13%). [Mantled olivine rocks that weather to "cannonballs"]. Olivine gabbro

5478-- Much like 5476 but with a higher proportion of dark minerals. Characterized by anhedral olivine (5-10%) crystals mantled by acicular pale-green amphibole (in part vermicular in surrounding plagioclase (50%). Olivine much altered to opaque material. Also abundant clinopyroxene (20%) and brown hornblende (20%) looks primary). Olivine gabbro

5481-- Decussate mat of elongate labradorite (50%) to 2 mm (most of these gabbros have decussate rather than polygonal plagioclase). Inset with anhedral to subhedral clinopyroxene (30%) crystals to 2 mm that are splotched with brown hornblende (10%). Some probable lamellar twinned orthopyroxene (10%). Gabbronorite

5482-- Coarse well-twinned labradorite (37%) inset with subhedral clinopyroxene (23%) and pale-brown hornblende (40%) much altered (?) to pale green amphibole. Gabbro

5485-- Chrysocolla veins and replacement patches in brown weathering, strongly altered gabbro and ultramafic rock in the Kern Canyon fault zone.

Mafic Rocks near the Marina south of Wofford Heights

Mafic rocks are exposed along the west side of Isabella Lake on a broad headland that extends about 1 km south from the marina south of Wofford Heights. The mafic rocks presumably intrude the metasedimentary rocks adjacent on the west, but the contact is poorly exposed. The best exposures of the mafic rocks are along the graded road that skirts the headland.

The most distinctive rocks in the body are exposed about halfway down the headland and are marked by spheroidal weathering piles of "cannonballs". These rocks have a polygonal mat of well-twinned plagioclase (about An_{75}) in which are set subrounded olivine crystals to 2 mm with thin mantles of cross-fiber acicular amphibole. Some of the olivine grains are partly altered to serpentine minerals. In addition, the plagioclase mat is studded with subhedral to anhedral crystals of clinopyroxene as large as 1 mm. Some of the clinopyroxene crystals are partly altered to brown hornblende, but most are relatively fresh. The olivine gabbro exposed on the headland south of the Marina is abundant and virtually identical to the most common rock type in the Bodfish body, suggesting that these two mafic bodies were once part of the same mass that is now disrupted by movement on the Kern Canyon fault.

The marina headland also exposes olivine-free gabbro consisting of sodic labradorite, moderate brown hornblende, and clinopyroxene. One ultramafic sample was collected that has very minor interstital plagioclase. The rock is now dominantly hornblende. Remnant original pale-brown hornblende and crystals of olivine and pleochroic hypersthene are now immersed in pale green secondary amphibole. Following are brief petrographic descriptions of samples from the body near the marina south of Wofford Heights (Fig. 1C).

4746-- Polygonal to "diabasic" mat of labradorite (50%) to 3 mm long. Inset with rounded to elongate olivine (25%) crystals to 2.5 mm that are mantled by acicular colorless to pale green amphibole. Also common are smaller, rounded clinopyroxene (20%) crystals that are commonly in sharp contact against plagioclase, but locally altered to amphibole (5%) (some brownish). Olivine gabbro

4747-- Bladed, coarse well-twinned labradorite (50%) (to An_{70}) and pale green to brownish amphibole (40%) dominant. Some amphibole crowded with opaque and "schiller-oriented" inclusions and some clinopyroxene (<10%) remnants. Local olivine (<5%) remnants mantled by acicular pale green amphibole. Hornblende gabbro

5463-- Bladed to polygonal labradorite (50%), moderate brown hornblende (20%), and clinopyroxene (15%). Much pale green secondary amphibole (15%). Local orangish serpentinitic-looking masses that suggest iddingsite pseudomorphs after olivine. Gabbro

5464D- Scattered, granular largely untwinned plagioclase (<10%) in a rock that is now dominantly pale green to pale brown amphibole (<90%) with scattered remnants of olivine (<5%) and hypersthene (<5%). Looks strongly retrograded and in part has sugary hornfels texture in contrast to relatively fresh plagioclase-rich gabbros. Retrograde ultramafic

5465A- Polygonal mat of bytownite (toAn_{75}) (70%) inset with sub-rounded olivine (20%) crystals to 2 mm with thin mantles of acicular amphibole (cross-fibered and vermicular with enclosing plagioclase). Lesser and smaller anhedral clinopyroxene (10%) crystals generally in sharp contact against plagioclase, but most are partly altered to brownish hornblende.

5466-- Similar to 5465A, but most of olivine converted to acicular amphibole (30%)--only small remnant olivine crystals in center of some acicular amphibole "balls". Also minor remnant clinopyroxene (<5%) (most converted to amphibole). Surprisingly fresh polygonal to bladed labradorite (65%). Mantles have vermicular texture with cover of acicular colorless amphibole. Hornblende gabbro (altered olivine gabbro?)

5467-- Strongly trachytoid rock dominated by clusters and intergrowths of clinopyroxene (40%) and pale brown hornblende (30%) to 4 mm long. Elongate labradorite (30%) crystals to 1.5 cm. Gabbro

Olivine-bearing mafic inclusion west of Wofford Heights

A mass of gabbroic rocks, no more than a few hundred meters across, is poorly exposed along a road to an abandoned tungsten prospect that is north of Highway 155 in the NE 1/4 of sec. 27, T. 25 S., R. 32 E. (Alta Sierra 7-1/2'

quadrangle). The gabbroic rocks are composed of well-twinned labradorite, rounded olivine crystals with reaction mantles of pale green acicular amphibole, weakly pleochroic hypersthene with abundant bladed inclusions ("schiller"), and brown to olive hornblende with similar bladed inclusions. Rounded cores of clinopyroxene are found in some hornblende crystals. The amount of labradorite and clinopyroxene varies considerably in this mafic inclusion mass. In general, however, the inclusion has a higher percentage of mafic minerals than do the gabbroic rocks of the Bodfish body, but the overall appearance, mineralogy, and the mantled olivine crystals, suggest a correlation. Float near the olivine gabbro inclusion is hornblende gabbro composed of twinned labradorite, olive hornblende choked with bladed dark inclusions, and much acicular amphibole, chlorite, and sericite. Some clinopyroxene is present in the hornblende. This rock is compatible with, and most probably correlative with, the altered gabbroic rocks of the Bodfish Body. Following are brief petrographic descriptions of some samples from the small inclusion west of Wofford Heights (fig. 1D).

5516A- Mat of well-twinned labradorite (30%) inset with abundant rounded to irregular olivine crystals (20%) to 2.5 mm. Some mantled with secondary pale green amphibole. Abundant, in part lamellar-twinned orthopyroxene (15%) and lesser clinopyroxene (10%). Pale to moderate brown interstitial lacy hornblende (10%) with aligned (schiller?) inclusion. Local reddish brown biotite (<5%), which like pale green amphibole (15%) is surely secondary. Local green spinel in pale green amphibole. Olivine gabbronorite

5516B- Much like 5516B, but with more clinopyroxene and labradorite. These two samples contain more mafic minerals than gabbros of Bodfish and Marina, and also notably more orthopyroxene, but they are still compatible and probably related. Olivine gabbronorite

5515-- Float of hornblende gabbro that looks like a more retrograded version of 5516.

Gabbronorite of Quedow Mountain and related bodies

The gabbronorite of Quedow Mountain (also variously spelled Credow and Cuidado on some maps) is one of a group of presumably related gabbroic bodies that crop out in the White River 15' quadrangle (the northwest part of the map

area). A number of smaller bodies of mafic rock surround the larger Quedow Mountain mass, and are similar enough to the larger body to suggest correlation (Fig. 2).

The freshest samples from these rocks contain labradorite, orthopyroxene, clinopyroxene, and opaque minerals--probably largely magnetite. Small amounts of altered olivine in some samples show that it was also an original constituent. Various amounts of hornblende, ranging from thin skins around pyroxene grains to large oikocrysts that contain remnant crystals of pyroxene, show that hornblende developed at the expense of the pyroxene. Some samples also contain significant amounts of fibrous to acicular pale green to colorless amphibole that suggests in turn a retrograde reaction with the hornblende. The hornblende gabbros probably were derived from an original gabbronorite parent.

Some descriptive petrographic notes follow for individual samples from several of the bodies.

6021-- Very fresh rock with coarse, bladed, well-twinned plagioclase crystals (to An_{60}) to 3 mm long and anhedral olive brown hornblende that encloses remnants of clino- and orthopyroxene. Also minor reddish brown biotite and abundant opaque grains. Traces of interstitial quartz. Mode: plagioclase, 58; hornblende, 21; pyroxene, 18; magnetite, 2, biotite, 1. Two pyroxene-hornblende gabbronorite.

6022-- Virtually same texture and mineralogy as 6021. Perhaps less hornblende and pyroxene tends to be in isolated grains. Two pyroxene-hornblende gabbronorite.

6023-- Much the same texture as 6021 and 6022. Ferromagnesian minerals altered to pale green, fibrous amphibole. Reddish spots in amphibole are only evidence of original pyroxene. Retrograde gabbronorite (?)

6034-- Float from Galley Mountain to west. Fine-grained diabasic matrix of bladed plagioclase (55%) (well-twinned and zoned to An_{55}) and small-rounded orthopyroxene grains (25%). Inset with coarser plagioclase (5%) (to 5 mm) and orthopyroxene (5%) (to 2.5 mm). Minor clinopyroxene (<5%) and olive brown hornblende (<5%) (some rimming orthopyroxene). Scattered opaque grains (<5%). Diabasic norite.

6035-- Float from Galley Mountain to west. Layered rock with coarser layers

of labradorite inset with small grains of orthopyroxene and clinopyroxene that is in part replaced by pale green to olive hornblende. Fine-grained layers are rich in olive hornblende and clinopyroxene. Some coarse labradorite crystals in finer grained layers. Opaque mineral grains common throughout the sample. Layered hornblende gabbro

6038-- Subequant plagioclase grains (50%) (well-twinned and to An_{60}) as large as 2 mm, and both clinopyroxene (15%?) and orthopyroxene (20%?) in a somewhat polygonal mat. Abundant rather coarse opaque grains (5%) which in part have a distinctive myrmekitic texture. In part pale olive hornblende (10%) coats some pyroxene. Gabbronorite.

6040— Hypautomorphic (almost decussate) mat of bladed coarse, well-twinned plagioclase grains to 3.5 mm with scattered irregular anhedral grains of clinopyroxene and orthopyroxene. Brown biotite, green hornblende, and interstitial quartz also present as are coarse opaque grains. Mode: plagioclase, 72; pyroxene, 6; biotite, 7; hornblende, 6, quartz, 6, opaque grains 3.
Biotite-hornblende-quartz gabbronorite.

6042-- Much the same texture and mineral content as 6040. Very fresh rock. Hornblende-biotite-quartz gabbronorite.

6043-- Somewhat finer grained decussate mat of plagioclase crystals (65%) (well-twinned, subhedral, to 2.5 mm long) and smaller anhedral to subhedral clinopyroxene (10-15%)? and orthopyroxene grains (15-20%)?. Only rare green hornblende present. Abundant opaque grains (2-3%). Gabbronorite.

6045-- Dark gray, medium-grained rock with following mode: plagioclase, 66%; quartz, 7%; biotite, 12.5%; hornblende, 4.5%; orthopyroxene, 10%. Orthopyroxene-quartz diorite.

6055-- Float from Galley Mountain. Very much like 6043 with mat of fresh, well-twinned labradorite crystals (75%) to 2 mm long liberally sprinkled with smaller clinopyroxene and orthopyroxene grains (together about 25%) and common opaque grains (<5%). Green hornblende (<5%) coats some pyroxene and less commonly brown biotite partially coats pyroxene. Some orthopyroxene is coated by clinopyroxene. Gabbronorite.

6058-- Labradorite mat (55%) with pale green hornblende crystals (40%)

intergrown with or rimming clinopyroxene (5-10%). Also abundant opaque grains (2-3%) and scattered coarse apatite crystals (1%). Fibrous actinolitic amphibole is also locally common with the pale green hornblende. Labradorite is locally strongly sericitized (but most is quite fresh). Hornblende gabbro (retrograde gabbronorite?).

6090-- Float from Bald Mountain. Subhedral mat of well-twinned fresh labradorite crystals (50%), coarse orthopyroxene grains (20%), and large oikocysts of pale brown hornblende (15%). Small iddingsite-altered olivine (5%) crystal remnants are scattered about the sample. Also pale green, in part fibrous amphibole (10%) masses suggest retrograde conditions (clear to pale mica patches are also associated with the amphibole). Scattered opaque grains are in part myrmekitic. Olivine gabbronorite (retrograde).

6099-- Small mass satellitic to the Quedow Mountain mass. Decussate to polygonal mat of well-twinned labradorite crystals (50%) to 3 mm in length and pale olive hornblende (20%) oikocrysts and clusters. Inclusion of both clinopyroxene (<5%) and orthopyroxene (<5%) in hornblende. Much pale green to colorless, fibrous to acicular amphibole (20%) also. Traces of reddish brown biotite and abundant metallic opaque (5%) grains. Hornblende gabbro (retrograde from gabbronorite?).

6100-- Quedow Mountain Mass near where zircon collected (Saleeby and Sharp, 1980) for Pb-U age determination. Much like 6099 except more orthopyroxene and clinopyroxene and much less retrograde amphibole. Also contains some interstitial quartz. Hornblende gabbronorite.

6124-- Good hypautomorphic mat of clean-well-twinned, labradorite (65%) and pale green hornblende (30%), epidote (<5%) and lesser pale green chlorite (2-3%). No residual pyroxene. Scattered coarse anhedral sphene with opaques in cores. Minor interstitial quartz. Hornblende gabbro (retrograde from gabbronorite?).

Summit gabbro of Miller and Webb (1940)

The term Summit gabbro was first used by Miller and Webb (1940) to describe all the mafic rocks in the Kernville 30-minute quadrangle. Presumably the type area was near the summit of Walker Pass where a body of mafic rocks underlies a few square kilometers and is intruded by the quartz

diorite of Walker Pass. Also included in the original Summit gabbro were a number of mafic bodies that appear to be inclusions in or are closely associated with the granodiorite of Sacatar to the north of Walker Pass. Miller and Webb (1940) first noted this "intimate association" of gabbro with the Sacatar unit which made mapping separation difficult. Bergquist and Nitkiewicz (1982) commented that the Summit gabbro may be an early border phase of the Sacatar rocks. Taylor (1984) noted some small bodies of pyroxenite and suggests that these bodies may represent small-scale magmatic differentiation within the gabbro.

I have examined only the two larger masses of gabbro, and in a cursory way. These rocks are generally medium-to-coarse grained and consist chiefly of relatively fresh, well-twinned labradorite and amphibole. The amphibole ranges from colorless or pale green acicular masses to dark olive hornblende, commonly choked with opaque dust. Some hornblende contains skeletal clinopyroxene cores. Minor interstitial quartz is present, locally. Some labradorite in samples near Walker Pass has crinkly sutured margins and contains fine-grained granular zones in otherwise fresh crystals. This texture suggests some recrystallization.

Gabbro of Freeman Canyon

A narrow elongate mafic pendant about 2 km long is present in the quartz diorite of Walker Pass north of Freeman Canyon and northeast of Walker Pass. These rocks, which I have only examined along the Pacific Crest Trail, are variable in grain size and texture. Some parts look like typical Sierran mafic inclusion material and some parts suggest metavolcanic parentage. Some coarser hornblende gabbro consists of bladed pale olive hornblende crystals that are color-zoned and as long as 5 mm. Stubby to interstitial plagioclase grains are as calcic as An_{75}. Also present are scattered brown biotite, spene, and opaque grains. From the present sparse data I would suggest that this mafic mass is an inclusion mass related to the bodies of the Summit gabbro.

Amphibolite and gabbro of Sage Canyon

Amphibolites that, at least in part, show derivation from gabbroic parent rocks are found in small inclusion patches in the younger granitic rocks along

Sage Canyon and at an abandoned quarry west of Armistead. Float of dark gabbroic rocks was also noted on the south side of Freeman Canyon east of Walker Pass and near the mouth of Gap Canyon on the northwest side of the Scodie Mountains, suggesting other gabbro outcrops are present in the Scodie Mountains. Harner and others (1983) delineated several small areas of hornblende-rich rocks in their mineral appraisal of the Scodie Mountain Roadless Area. J.F. Seitz (oral commun., 1981) noted that hornblende-rich dioritic and gabbroic rocks were widespread in the Roadless Area, but were mixed with younger, more felsic granitic rocks and were rarely present in mappable units of any great extent. In my examination of a limited number of mafic rocks collected during the Scodie Mountains Roadless area study, some of the samples were tonalitic rocks typical of the normal dark Sierran inclusions. Others were amphibolites that could well be metagabbro. It thus appears that the small gabbro remnants near Sage Canyon may be only a sample of a much larger area sprinkled with such rocks.

In the small abandoned quarry west of Armistead (about 4 km southwest of Robbers Roost) the mafic rocks (loc. 6186) consist of schistose amphibolite, tremolite schist (with talc?) and a rock composed solely of pale green amphibole and clinopyroxene in a coarse almost decussate fabric. These metamorphosed rocks may have been derived from gabbro and ultramafic rocks.

Mafic amphibolite is present as an inclusion patch (loc. 6191) in the granite of Onyx about 6 km west of loc. 6186. The amphibolite consists chiefly of a granoblastic and nematoblastic mat of pale green hornblende and labradorite with abundant anhedral magnetite grains to 1 mm that are commonly coated with sphene.

A much larger inclusion patch in the granite of Onyx is present just south of loc. 6191. Here at loc. 6197 pale green hornblende and labradorite also dominate. Anhedral magnetite is also abundant, but lacks sphene coatings. Also in contrast to loc. 6191, the plagioclase retains more original plutonic form and is well-twinned. The hornblende crystals also contain bladed schiller-like inclusions as well as small orange grains with a micaceous appearance that may be iddingsite. Thus there are hints of former presence of olivine and pyroxene. The rocks of loc. 6197 are amphibolites also, but preserve more hints of their former gabbroic heritage than do the rocks of loc. 6191, which have been metamorphosed to hornfels.

An inclusion from loc. 78 has a texture and mineral content that is similar to the samples from loc. 6191. Other samples collected from loc. 78 were rocks similar to standard Sierran inclusions--samples from this locality, collected by J.L. Harner and J.F. Seitz, were discarded, but fortunately the thin sections were saved--the above statement is based on my study of those sections.

Dark amphibolite (metagabbro?) having an unusual flamboyant texture and composed of moderate green hornblende and calcic andesine (well-twinned, but somewhat granulated) crops out at loc. 6393 about 8 km northwest of Freeman Junction. Field notes describe interlayered dark gneiss and massive diorite but the relation of these rocks to the quartz diorite of Walker Pass is at present uncertain. I suspect the "massive diorite" is amphibolitic material included in the Walker Pass mass and that the "dark gneiss" is sheared Walker Pass rock. The overall appearance of sample 6393 is similar to the metagabbro of the Sage Canyon area.

The mafic rock float near the mouth of Cap Canyon (loc. 6144) looks like normal hornblende gabbro in hand specimen. In thin section, however, the rock is dominated by granoblastic largely untwinned plagioclase to 0.4 mm and pale green, somewhat acicular hornblende. Some hornblende aggregates form large (to 5 mm) crystals. Clinopyroxene is present both as large crystals and as part of the hornfelsic mat. Abundant epidote forms a lacy mat locally. Sphene and opaque minerals are sparsely represented. One sample has flamboyant-textured hornblende similar to that at loc. 6393. These amphibolite (metagabbro) float samples indicate that rocks similar to the amphibolite and gabbro of Sage Canyon also crop out in the Scodie Mountains. The metamorphosed gabbroic and ultramafic (?) rocks of the Sage Canyon area may be related to the Summit gabbro.

Just north of Manter Meadow a small dark pod (loc. 5392) is included in the granodiorite of Castle Rock. Although tens of kilometers removed from the small metagabbro remnants near Sage Canyon, it is "on-strike" considering the regional grain of nearby metamorphic bodies. The dark pod is not typical Sierran inclusion material but is best described as retrograde hornblende gabbro in which the hornblende is pale green and in part acicular or granoblastic. The labradorite is generally fresh and well-twinned, but is strongly sericitized locally. Minor epidote, sphene, and metallic opaque

grains are also present.

Gabbro of Bull Run Basin

A small body of hornblende gabbro is exposed along Bull Run Creek. It is essentially a large inclusion, covering no more than 1 km^2, in the granite of the Kern River.

These dark-colored, medium-to-fine-grained rocks are now composed largely of well-twinned labradorite and amphibole. Some olive green hornblende is probably primary, but much of the amphibole is secondary and mimics an original ophitic texture. The lacy, interstitial amphibole has abundant clinopyroxene remnants. Opaque grains are common and brown biotite (secondary?) is uncommon. Petrographic notes on some samples show the following.

5271A- Elongate, thinly twinned calcic andesine crystals to 4 mm long in a good preferred orientation. Abundant amphibole ranging from olive-green (primary?) hornblende to pale green to colorless (secondary) aggregates (in part pseudomorphing original grains). Some clinopyroxene remnants. Scattered brown biotite and also irregular opaque grains to 1.5 mm. Hornblende diorite/gabbro

5271B- Polygonal mat of fresh, well-twinned labradorite to 3 mm long. Original ophitic texture shown by lacy interstitial amphibole choked with powdery opaque inclusion matter and clinopyroxene remnants. Abundant opaques (some rimmed by sphene) and rare biotite. Hornblende gabbro

5271C- Much like 5271B with good ophitic texture and less remnant clinopyroxene. Hornblende gabbro

Gabbro-basalt serpentinite melange of Saleeby and Sharp (1980)

In the northwest corner of the map area largely tectonic blocks of various gabbro and basalt units are enclosed in a serpentinite matrix. This melange is disrupted and internally mixed oceanic lithosphere of latest Paleozoic to possibly early Mesozoic age according to Saleeby (1979). This melange is considered to be intruded by voluminous plutons ranging from olivine-hornblende gabbro to biotite granodiorite and ranging in age from 125

to 102 m.y. These are presumably the rocks of Quedow Mountain and the related masses. I have not examined these melange rocks.

Leucogabbro - gabbronorite of Cyrus Flat of Fox (1981)

Within the quartz diorite of Cyrus Flat is a small body that ranges in composition from leucogabbro to pyroxene-hornblende gabbronorite (Fox, 1981). Fox (1981) also found a xenolith of olivine-hornblende melagabbro within the small body. The relation of these gabbroic rocks to the quartz diorite of Cyrus Flat is still uncertain.

The leucogabbro to gabbronorite is composed principally of plagioclase (intermediate to calcic) and hornblende; present in variable amounts are both ortho- and clinopyroxene, biotite, and metallic opaques. The melagabbro xenolith is composed of sub-equal parts of calcic plagioclase, hornblende, and olivine, with some orthopyroxene and biotite (Fox, 1981).

Fox (1981) suggests that the gabbroic rocks intruded the quartz diorite of Cyrus Flat. However, it seems more likely that the gabbroic rocks are a slightly older border facies of the quartz diorite or are an included mass in the quartz diorite.

Mafic Lamprophyric dikes

Mafic dikes a few centimeters to tens of centimeters thick are fairly common along the east front of the Sierra Nevada, primarily intruding the granodiorite of Sacatar, but they also intrude the quartz diorites of Walker Pass and Long Valley. Similar dark dikes, possibly related, also cut the body of gabbroic rocks south of the Wofford Heights Marina. Much more opaque metallic material is present in these latter dikes.

These mafic dikes are generally fine-grained, weakly porphyritic, and somewhat diabasic. Phenocrysts of andesine and green hornblende are as large as 2 mm across. These dikes contain chiefly andesine and hornblende, with small amounts of brown biotite. Sparse amounts of quartz and K-feldspar are present in some dikes. Most of these dikes are hornblende microdiorite and correspond to spessartite lamprophyre. They range from exceptionally fresh to highly altered mats of chlorite, epidote, sericite, and calcite. The abundance of lamphrophyric dikes along the east front of the Sierra suggests

they are part of the west margin of the Independence dike swarm of Moore and Hopson (1961), which is impressively represented in the low mountains east of Ridgecrest about 30 km east of the map area.

Plate 1 locates where thin sections of the mafic dikes were examined and, in light of their possible regional significance, petrographic notes on these samples follow.

Dark gray, fine-grained dikes into quartz diorite of Walker Pass

6174-- Largely an anhedral mat of untwinned green hornblende (60%), untwinned plagioclase (30%), and minor brown biotite (5-10%) and quartz to 0.2 mm. Some clusters of hornblende and biotite to 1 mm appear to mimic original hornblende phenocrysts as do rare clusters of plagioclase crystals. Scattered subhedral to euhedral epidote crystals (<5%), particularly in the femag clusters.

6176-- Mat of anhedral green hornblende (60%) and weakly twinned plagioclase (40%) and minor brown biotite to 0.2 mm. Small hornblende phenocrysts and aggregates of hornblende and biotite mimic phenocrysts. Also rare plagioclase aggregates mimic small phenocrysts. Scattered epidote, sphene, and metallic opaque grains.

Dark gray, fine-grained dikes into granodiorite of Sacatar

6426-- Porphyritic with weakly twinned, blocky to elongate plagioclase crystals as long as 3 mm in part strongly saussuritized. Groundmass of elongate brown biotite (30%) (almost diabasic), elongate to blocky green hornblende (30%), and twinned blocky anhedral plagioclase (30%) to 0.5 mm. Much less quartz (5%) and K-feldspar (5%). Scattered opaque grains, sphene, and epidote (some in saussuritzed plagioclase, but also associated with biotite and hornblende.

6427-- Tan, brany dike with blocky phenocrysts of quartz and twinned andesine as long as 2 mm. (mostly smaller). Groundmass of dominantly anhedral andesine (60%) and minor quartz (5-10%) and K-feldspar (5-10%) with scattered elongate reddish brown biotite (20%) and minor blocky green hornblende (10%) to 0.3 mm. Scattered epidote, sphene, and metallic opaque grains.

6440-- From small roadcut on Highway 178. Fine grained, but somewhat coarser than most mafic dikes. Seriate texture with stubby to elongate intermediate andesine and green hornblende crystals to 2 mm long. Crystals range downward to 0.5 to 1 mm in size and consist of dominantly andesine (50%) and hornblende (50%) in a subophitic intergrowth; minor quartz (<5%) and altered brown biotite (<5%). Scattered metallic opaque grains and minor epidote and apatite.

6444-- A 10-cm thick dike which consists of a somewhat decussate mat of blocky to tabular moderate green hornblende (40%) and rounded to tabular, much altered, plagioclase (50%) crystals to 1 mm long. Scattered K-feldspar (5%) and quartz (5%), and minor altered brown biotite (<5%) and sphene.

6452-- Dark gray dike swarm with individual dense dikes as thick as 20 cm and chilled against granodiorite of Sacatar host rock. Subdiabasic intergrowth of green hornblende (70%) and lesser plagioclase (30%) to 0.2 mm. Some "micro-phenocrysts" of plagioclase to 0.5 mm and clusters of hornblende also mimic phenocrysts and appear as dark spots in hand specimen. Minor K-feldspar and brown biotite.

6463-- Dark gray, 20-cm dike in granodiorite of Sacatar. Texture of hand specimen appears sugary, but in thin section shows a notable diabasic mat of green hornblende (40%) and plagioclase (50%) with lesser chloritized brown biotite (5%) in tabular crystals to 1 mm, but generally only 0.5 to 0.8 mm long. Rare plagioclase phenocrysts to 2 mm long. Tiny blocky metallic opaque grains (5%) are common. Minor sericitic dust in some plagioclase grains and minor epidote, but overall this is a fresh rock.

6465-- Fine grained, dark gray, sugary textured dike, associated with uncommon but persistent felsic dikes that are coarser and not obviously from the aplite-alaskite-pegmatite assemblage. Dark sample is xenomorphic, almost aplitic and consists chiefly of blocky to rounded to tabular crystals of well-twinned intermediate andesine (60%) and dark green hornblende (30%). Much less common is brown biotite (10%). Scattered about are grains of metallic opaque minerals, sphene, zircon, epidote, and sericite. In most exposures the rock is fresh.

6470-- Dense dark gray dike, 1-m thick. Pronounced porphyritic texture with euhedral blocky plagioclase crystals (some zoned) to 1.5 mm long. Also elongate green hornblende crystals that are as long; one exceptional

hornblende phenocryst is 1 cm long. The groundmass is a diabasic intergrowth of andesine (70%), hornblende (20%), and minor olive brown biotite (5%); some quartz (5%) is present in the finer grained interstitial material. Also present are minor amounts of dark opaques, epidote, allanite, and sphene. This dike, with chilled margins, is exceptionally fresh.

6473-- Dark gray-green dense dike. Porphyritic with subhedral crystals of plagioclase (20%) that are stubby and as long as 2 mm. Rare green hornblende phenocrysts are much smaller. Olive green biotite (15%) exceeds hornblende (10%) in a groundmass dominated by plagioclase (50%). Possibly about 5 percent of interstitial quartz is also present, as are scattered opaque grains and sphene. Sericite, calcite, and some epidote in plagioclase shows minor alteration, but overall the rock is fresh, although somewhat more recrystallized and less "diabasic" than 6470. Some of the epidote is discrete and subhedral and appears to be primary, although see sample 6484.

6484-- Gray dense rock that is a suspected dike in a much broken up outcrop of the granodiorite of Sacatar. Dense mat of epidote, chlorite, calcite, and white mica. Some original brown biotite and quartz. Very little primary plagioclase, and no hornblende. Extensive alteration, not obvious in hand specimen, is reminiscent of altered mafic dikes in the Inyo Mountains (Ross, 1965, p. 046). Presence of subhedral epidote crystals to 1 mm long in this much altered rock suggests the crystals are reconstituted alteration products, not primary crystals and cast suspicion on "discrete, primary" epidote crystals in other samples (for example, 6473).

6486-- Olive gray, dense dike rock with evident microphenocrysts in hand specimen. Porphyritic with scattered plagioclase and green hornblende phenocrysts as long as 1 mm (one exceptional hornblende crystal to 2 mm long). Groundmass contains only traces of diabasic texture, but abundant preserved plagioclase (30%), hornblende (40%), and bleached brown biotite (5-10%). Abundant epidote (5-10%), chlorite (5-10%), and sericite (5-10%) alteration materials in groundmass suggests this sample is intermediate between much altered sample 6484 and fresh sample 6470.

6487-- Dense gray dikes relatively coherent in a much shattered outcrop of granodiorite of Sacatar. Porphyritic texture with scattered to 1 mm long crystals of originally feldspar but replaced by pseudomorops of white mica. Tabular crystals that were probably originally hornblende, now completely altered to mats of green chlorite and opaque grains. Also clusters of quartz grains may have been phenocrysts (or vesicle fillings?). Original felty groundmass mimicked by alteration products (chlorite, white mica, epidote, and calcite.) This dike is anomalously rich in opaque material and generally is more felsic than most lamprophyric dikes of the region. Many felsic dikes in this region present in this area of abundant mafic dikes. They are tentatively considered to be Cretaceous aplite, alaskite and pegmatite. However, some or all, may be part of the Jurassic dike swarm.

6500-- Gray, fine grained 30 cm-thick porphyritic dike with chilled margins. Phenocrysts of plagioclase and chiefly hornblende to 2 mm. Scattered plagioclase phenocrysts completely altered to white mica and epidote but zoning still visible in pseudomorphs. Abundant hornblende phenocrysts now completely altered to pale green acicular amphibole that retains characteristic hornblende form. Altered groundmass retains some diabasic character with dark green hornblende and plagioclase, but much epidote, white mica, and chlorite alteration. Hornblende much in excess of chloritized biotite. Only scattered opaque grains. K-feldspar present, but mostly in cross cutting veinlets. Coarser phenocrysts are much more altered than finer grained groundmass.

6522-- Several dark gray dikes to 1/2 m-thick. Some suggestion that these dikes <u>cut</u> associated pegmatite dikes. Diabasic porphyritic texture with phenocrysts of elongate green hornblende and lesser plagioclase to 2 mm in length. Fine-grained groundmass of hornblende (40%), plagioclase (40%), brown biotite (10-15%) and minor quartz (<5%) and K-feldspar (<5%). These dikes characteristically only contain sparse metallic opaque grains: Some sericite and epidote alteration.

6523B- A gray, fine-grained dike, 1/2 m thick, also appears to <u>cut</u> the pegmatite. Well aligned fabric shown by olive green biotite (50%) in part in elongate clots and lenses. Also discrete epidote crystals (20%) to 0.2 mm across. Untwinned plagioclase (30%) and minor K-

feldspar (<5%) and quartz (<5%). A fresh rock with no hornblende. Euhedral red opaque minerals to 0.8 mm. Contact with pegmatite enriched in aligned biotite, but no noticeable chilling. Very atypical mineral content (no hornblende).

Dark dikes into the quartz diorite of Long Valley

6509-- Gray, fine grained 20 cm-thick dike. Xenomorphic mat of subequant grains to 0.2 mm. Dark green hornblende (65%) dominant over intermediate andesine (40%). Traces of sphene and red opaque material; some secondary epidote and sericite.

6510-- Sample from one of a number of dikes as thick as 1 m. Xenomorphic mat of largely dark green hornblende (40%) and andesine (55%). Subordinate dark brown biotite (5-10%) and quartz (<5%). Generally equigranular crystals to 0.3 mm. Tiny scattered sphene crystals and rare metallic opaque grains.

[Samples 6509 and 6510 do not have porphyritic and diabasic textures like many of the samples from the Sacatar mass. The samples from the Long Valley mass are also generally fresh. They are microdiorites with a xenomorphic rather than typical lamprophyric texture.]

Dark gray dense dike intrusive into the olivine gabbro of Bodfish

5465-- Sparsely porphyritic with euhedral plagioclase crystals to 1.5 mm long. Pronounced diabasic groundmass with bladed, well-twinned plagioclase (45%) crystals as long as 0.5 mm and more equant space filling masses of pale green hornblende (55%). Abundant tiny metallic opaque (<5%) grains. Fresh rock with some calcite veinlets. Abundant opaque grains and felty dense matrix is somewhat different from most other lamprophyric dikes. This dike may be related to the Bodfish gabbroic body and not be part of the Independence dike swarm.

Dark gray, fine-grained dike intrusive into the Summit gabbro

6219-- Somewhat trachytic with bladed labradorite (45-50%) crystals to 0.8 mm long (a few somewhat larger micro-phenocrysts). Pale green hornblende

matrix (40%), much of which is drenched with opaque dust. Also abundant discrete magnetite grains (10-15%). Traces of brown biotite. Almost complete absence of alteration products. Very similar in mineral content and texture to 5465, but coarser grained. This dike may also be related to the gabbroic rocks it intrudes rather than part of the Independence dike swarm.

Miscellaneous mafic bodies [1]

About 4 km west of Poso Flat at Round Mountain my field notes describe a small pod of dark rocks as "hornblende gabbro". My only sample of these rocks (6323) is medium-grained tonalite with abundant quartz (19 percent) and is much like the surrounding tonalite. Possibly Round Mountain is a somewhat gabbro-contaminated patch in the tonalite.

A possibly similar dark pod of rocks (6333) is located on the Pine Mountain Road about 3.5 km northwest of Pine Mountain. Here a medium-grained quartz diorite (11 percent quartz) is exposed amidst the tonalite. Some of the rock of this pod looks like dark inclusion material and it is porphyritic.

Fresh gray hornblende gabbro is exposed in a road cut along the Old Hot Spring Road about 1 km north of King George Ridge (loc. 6047). This rock, composed chiefly of plagioclase (65 percent) and amphibole (33 percent), is within the outcrop area of the tonalite of Carver-Bowen Ranch. It may well represent some contamination of that unit by the nearby gabbroic rocks to the northwest, or be an inclusion in the tonalite.

A small sliver of dark rock is exposed on the east side of Lynch Canyon about 2 km south of Squirrel Mountain Valley (loc. 5175). Similar(?) mafic rocks are exposed along the contact between metavolcanic rock of the French Gulch pendant and bounding metasedimentary rocks further south on the ridge about 1 km south. The rock at 5175 is fine- to medium-grained and quite dark colored. It is composed largely of ophitic plates of brown hornblende many millimeters across that are liberally studded with small subhedral plates of labradorite as much as 1 mm across. Much of the hornblende has been replaced by pale green to colorless fibrous amphibole, but the plagioclase remains

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[1] Some of the following described rocks appear dark colored in outcrop, but have considerable amounts of felsic minerals and are not actually mafic rocks.

fresh and unaltered. In outcrop, these rocks resemble the dark Rabbit Island rocks to the east, but their mineralogy and texture makes a close relationship unlikely.

A number of small "diorite-gabbro" bodies were mapped on the west side of the Kelso Valley Road north and south of the site of Sageland. The only locality that was sampled is the small dark body west of the St. John mine (loc. 4383). Here the rocks are medium-to-coarse grained and composed principally of a hypautomorphic granular mixture of plagioclase (to An_{50}) and olive green hornblende. Some interstitial quartz and opaque grains are present. Small chlorite patches may have originally been biotite.

Mafic, "typical" Sierra Nevada inclusions

Mafic, "typical" Sierra Nevada inclusions are common in this region but they have been very sparsely sampled. Some examples of these rocks are listed as follows:

4660-- Porphyritic rock with well-twinned subhedral andesine crystals (45-50%) and green hornblende subhedral crystals and aggregates (15-20%) to 1.5 mm. This sample also includes lesser brown biotite (10%) and weakly grid-twinned K-feldspar (5-10%) and rather abundant quartz (10-15%). Biotite-hornblende tonalite porphyry.

4744— A mixed outcrop of metasedimentary rocks, aplite, and "diorite" contains diabasic rocks with subhedral, well-twinned, well-zoned andesine (50%) as well as green hornblende (50%) in anhedral to subhedral crystals as large as 4 mm. Minor reddish-brown biotite (<5%) is altered to sphene, chlorite, and muscovite, but generally this rock is fresh. This hornblende diorite may be either an inclusion mass or a dike related to the microdiorites (spessartite lamprophyre). The relations in outcrop are not obvious.

5887-4 Andesine phenocrysts (10%) and also biotite and hornblende glomerophenocrysts as large as 5 mm long. Much finer-grained matrix in an almost diabasic mat of andesine (55-60%), biotite (brown) (10%), hornblende (20-25%) (green), and scattered opaque grains. Only minor interstitial quartz. Porphyritic diabasic(?) biotite-hornblende quartz diorite.

5943-- Diabasic mat of well-twinned, weakly zoned andesine (about An_{35}) (50%), dark brown biotite (25-30%), and dark green to opaque hornblende (5-10%). Large areas of oikocrystic K-feldspar (15-20%) and quartz (5%). Very abundant euhedral apatite needles (about 5 to 1 elongation). Sort of a mass in outcrop--can't tell for sure if it is a dike or inclusion material (texture suggests intrusive, but form much like nearby inclusion material). Fine-grained diabasic granodiorite (may be stretching it to call this sample a "mafic Sierran inclusion").

6019-- Dark colored, fine grained inclusion mass, tens of meters in extent in the tonalite of Carver-Bowen Ranch. Visibly porphyritic with phenocrysts of well-twinned plagioclase (10%) to 5 mm long. Groundmass generally from 0.3 to 0.5 mm and composed of a xenographic mat of andesine (45-50%), green hornblende (15-20%), and brown biotite (15-20%). Minor interstitial quartz (5-10%). Opaque grains as large as 0.2 in diameter, commonly rimmed with andesine. Biotite-hornblende diorite

6501-- Dark colored fine-grained inclusion in the granodiorite of Sacatar. Texture of hand specimen looks sugary but proves somewhat diabasic in thin section. Weakly porphyritic with elongate plagioclase crystals (5-10%) as long as 3 mm. Also some subequant clots of porphyritic green hornblende, and brown biotite to the same size. Groundmass, most of rock, composed chiefly of andesine (40-50%), green hornblende (25-30%), and olive brown biotite (10-15%). Minor quartz (5%) and epidote (3-5%) (which is in discrete crystals that look primary). Very minor opaque minerals (but some equant grains as large as 0.6 mm across) and sphene. Traces of apatite and allanite. Biotite-hornblende quartz diorite

Unusual mafic inclusions in granitic rocks

Most of the inclusions in the granitic rocks are various kinds of biotite-hornblende diorite or tonalite and are usually characterized by the term "typical Sierra Nevada inclusions". In addition, there are some inclusions that are unusual and warrant some individual description.

Following are some of these:

Included in the granodiorite of Hatchet Peak are fine-grained gray rocks that have some resemblance to rocks associated with the southern Sierra Nevada mafic complex. They do not appear to be closely related to the gabbronorites, as they are both fine-grained and show no obvious retrograde reaction between the common orthopyroxene and hornblende and biotite. These rocks are much like the dark inclusion rocks of the "Loop" inclusion swarm (Ross, 1983A). Characteristically, one sample (loc. 5910) is medium- to fine-grained and consists mostly of a xenomorphic mat of well-twinned plagioclase (to An_{50}) (57%). Abundant also are extremely fresh crystals of brown biotite (21%), olive hornblende (13%), and orthopyroxene (9%). There is also minor interstitial quartz. Another sample contains fresh orthopyroxene (20%) with sharp, well defined contacts against reddish brown biotite and contains no hornblende.

A large inclusion mass, possibly a dike and 15-20 meters long in its largest exposed dimension, is also present in the Hatchet Peak rocks at locality 5864. It is a dark rock that is a diabasic mat of fresh well-twinned andesine (50%) and equant to elongate dark green hornblende (50%) with abundant powdery opaque inclusions. Some of the hornblende crystals are as long as 1.5 mm. Quartz and opaque grains are very scattered.

Included in the Walt Klein mass are dark rocks that are a fine-grained xenomorphic mat of andesine (?) (50%) and pale green hornblende (50%), with much less orangish brown biotite (loc. 6088-1). This rock is amphibolite and much different from typical Sierra Nevada inclusions.

At loc. 6089 there are common large inclusion masses in the Walt Klein rocks that are a diabasic mat of andesine (50-55%), green hornblende (20%), and lesser brown biotite (10-15%). Commonly phenocrysts (15-20%) occur of plagioclase and hornblende (commonly aggregates that mimic euhedra) to 3 mm--minor interstitial quartz is present, as is abundant opaque grains and dust. These porphyritic, diabasic inclusion masses (?) closely resemble the dark dike rocks in the granodiorite of Sacatar along the east front of the Sierra Nevada, rocks which are thought to belong to the Independence dike swarm of Moore and Hopson (1961).

The Claraville mass (loc. 5598) contains large masses of dark rock, which I identified as "diorite" in the field. These rocks are a xenomorphic granular mat of anhedral well-twinned and zoned sodic labradorite and olive green hornblende (about 60 percent hornblende and 40 percent plagioclase). Sphene, opaque grains and apatite are scattered about. Locally, plagioclase cores are intensely altered, hornblende contains some chlorite and epidote, but most of the rock is unaltered. This hornblende gabbro is also unlike most of the Sierran inclusions. It may be related to the metavolcanic rocks of the French Gulch pendant or the dark Rabbit Island rocks, or may be a scrap of the gneiss complex (Ross, 1985).

AGE OF MAFIC ROCKS

Radiometric dating of the mafic rocks has been extremely limited. Only three bodies, a metagabbro within the mafic complex, the Eagle Rest Peak gabbro, and the Quedow Mountain gabbronorite have been dated. Age data are summarized on Table 1.

Pb-U determinations on zircon from two samples of the metagabbro of Tunis Creek give an age of 102 ±2 Ma (Sams, 1986). This metagabbro is intrusive into the mafic complex of the San Emigdio and Tehachapi Mountains that is dated by a number of samples of tonalitic and granitic gneiss at 110-120 Ma (Sams, 1986).

One date has been determined by the Pb-U method on zircon of about 115 Ma from the gabbronorite of Quedow Mountain (Saleeby and Sharp, 1980).

An additional dated locality is Eagle Rest Peak. Here a Pb-U determination on zircon gave an age of 161 Ma (James and others, 1986) on a tonalite-quartz gabbro that is intrusive into gabbroic and ultramafic rocks. These Eagle Rest Peak outcrops are physically separated from the basement rocks of the Sierra Nevada (Plate 1) and their relation to those rocks is not known. The Eagle Rest Peak rocks may be structurally separate and unrelated to the southern Sierra Nevada.

The mafic lamprophyric dikes probably intruded about 148 Ma based on the following data. These dikes are physically and chemically similar to those in the extensive Independence dike swarm east and north of the southern Sierra Nevada (Moore and Hopson, 1961). Granite porphyry and diorite porphyry dikes

associated with that swarm in the southern Argus Range (about 45 kilometers east of the southern Sierra Nevada) have yielded zircon that gives concordant ages of 148 Ma. by the U-Pb method (Chen and Moore, 1979).

A few mafic dikes in the olivine gabbro of Bodfish resemble the abundant lamprophyric dikes cutting the granodiorite of Sacatar. This suggests the gabbro of Bodfish and its related bodies is at least as old as Late Jurassic.

Less direct evidence based on possible intrusive relations suggests the Summit gabbro is at least as old as Triassic. The quartz diorite of Walker Pass presumably sends dikes into the body of Summit gabbro north of Walker Pass. Several Rb/Sr determinations on whole rock of the quartz diorite of Walker Pass give an isochron of 240.4 ± 14 Ma (R.W. Kistler, written commun., 1986). This age, considering the possible range, is from Upper Triassic to late Early Permian. The data suggest the Summit gabbro age is somewhere in the range from early Mesozoic to late Paleozoic.

The gabbro-basalt serpentinite melange of Saleeby and Sharp (1980) in the northwest part of the map area is considered by them to have been derived from an ocean floor assemblage. Zircon from a small block of metaplagiogranite associated with gabbro, and amphibolite blocks in altered melange matrix has yielded discordant ages ranging from 165 to 191 Ma. Saleeby and Sharp (1980) have interpreted these age data as suggesting a "safe age assignment" of 270 to 305 m.y. representing the age of the ocean-floor assemblage they were originally a part of.

The leucogabbro-gabbronorite of Cyrus Flat, which is mostly surrounded by quartz diorite, probably is a little older than the quartz diorite as both bodies have somewhat similar mineralogy, although Fox (1981) considers them chemically distinct. The surrounding quartz diorite has been dated by the U-Pb method on zircon at 100 ± 3 Ma (Saleeby and Busby-Spera, 1986). I suggest that the leucogabbro-gabbronorite was of about the same age as the gabbronorite of Quedow Mountain (dated by only one sample at 115 Ma).

The ages of the other mafic bodies, mostly small, are not known from any direct evidence. Most probably the Live Oak, Breckenridge, Pampa, Walker Basin, Caliente, Comanche, Cummings, Tweedy, and Cameron bodies are Cretaceous and related to either the mafic complex or the gabbronorite of Quedow Mountain (or both). The gabbro of Freeman Canyon and the amphibolite and gabbro of

Sage Canyon are most probably related to the Triassic (?) Summit gabbro. This is mostly a guess based on proximity and suspicion. The gabbro of Bull Run Basin is a rather prosaic hornblende gabbro that gives no hint of its age. Again based on proximity, it is most likely Cretaceous and related to the Quedow Mountain rocks. The relation to any other mafic rocks in the region of the scrap of suspected disrupted ophiolite in Bean Canyon is unknown. Its relation to the enclosing Bean Canyon Formation of possible Jurassic age is also unknown. The age and relation to other mafic rocks is also unknown for the subsurface gabbro of the San Joaquin Valley.

SUMMARY

Mafic rocks are widespread but sparsely distributed, particularly along the west side of the southern Sierra Nevada. They may be scraps and remnants of a much more extensive mafic terrane that existed prior to being engulfed by the largely late Cretaceous granitic plutons and batholiths. These mafic remnants are only slightly older than the batholithic rocks, and probably most were intruded late in the Early Cretaceous. Much more extensive terranes of mafic remnants at least in part of the same age are present along the west side of the batholith to the north (Saleeby and Sharp, 1980).

The tail of the Sierra Nevada is made up largely of a terrane of diorite to tonalitic gneiss that is hornblende-rich and of about the same general age as the gabbroic scraps to the north in the area of Quedow Mountain. These gneissic rocks are considered to be subbatholithic and representatives of the substrate beneath the batholith (Ross, 1985). The gneissic rocks are intruded by several "gabbroic" bodies of nearly the same age as the batholithic rocks. The largest intruded mafic rock is the body of Tunis Creek, which is dated at 102±2 Ma. (Sams, 1986). The gabbroic rocks then nearly overlap the age of the batholithic rocks, at least here on the west side of the Sierra Nevada. It is possible that the gabbroic bodies near Quedow Mountain may nearly overlap the batholithic rocks in age for there is only one age determination for a considerable area of gabbroic rocks. Also there is K/Ar data suggesting Early Cretaceous here in the west (tonalite of Walt Klein Ranch, 111 ± 2.5 Ma, R.W. Kistler, written commun., 1986).

Thus there probably is no great age break between gabbroic rocks, once known as "basic forerunners" and the quartz-bearing batholithic rocks, at

least at this latitude for the west side of the Sierra Nevada. The much older (?) serpentinite melange body is presumably related to extensive older exposures farther north (Saleeby and Sharp, 1980) and is unlike other mafic rocks in the west part of the map area.

The olivine gabbro of Bodfish and its counterparts across the Kern Canyon fault possess different features than those in mafic bodies presumed to be of Cretaceous age. Distinctive features of the Bodfish gabbro include mantled olivine that gives outcrops a distinctly spotted appearance and weathering products that resemble piles of rounded cannonball-sized cobbles. In addition, scattered lamprophyric dikes in the olivine gabbro of Bodfish suggest it is Jurassic or older.

Further east the gabbroic rocks appear to be even older. One body of the Summit gabbro is cut by unusual quartz diorite dikes that are probably Triassic. The other bodies tentatively considered here part of the Summit gabbro have been examined only cursorily and nothing seems to set them apart. However most of these gabbroic bodies on the east side of the Sierra Nevada could be early Mesozoic and possibly even late Paleozoic.

From rather sparse scattered bits of evidence, there appear to be remnants of three different ages of gabbroic rocks in the southern Sierra Nevada. Probably these three intervals are grossly comparable to those described by Saleeby and Sharp (1980) from the area to the north in the southwest Sierra Nevada foothills that overlap somewhat with the northwest part of the map area.

The serpentinite melange was identified by Saleeby and Sharp as a representative of ophiolite genesis by sea-floor spreading. Perhaps the Summit gabbro scraps are also representative of that first interval. The second stage ophiolite genesis and sea-floor spreading extended from about 200 Ma through the remainder of the Jurassic. The olivine gabbro of Bodfish may be in that age interval. The third regime of Saleeby and Sharp (1980) involved first the emplacement of the mafic western portion of the batholith and "shortly" thereafter the emplacement of voluminous felsic granitic rocks. This would be represented by the numerous gabbronorite and gabbro remnants in the western part of the present batholith and the subsequent granitic intrusions that took place in early to late Cretaceous.

The Eagle Rest Peak gabbroic rocks may be part of the second period of emplacement in the Jurassic based on scattered ages. However it must be emphasized that these exposures are physically isolated from the basement of the Sierra Nevada by younger sedimentary rocks and they may well be isolated structurally as well. They are chemically and particularly physically dissimilar from any other mafic rock of the southern Sierra Nevada.

The gabbro of the San Joaquin Valley subsurface has nothing diagnostic that would enable relating it to any other gabbroic rocks of the region.

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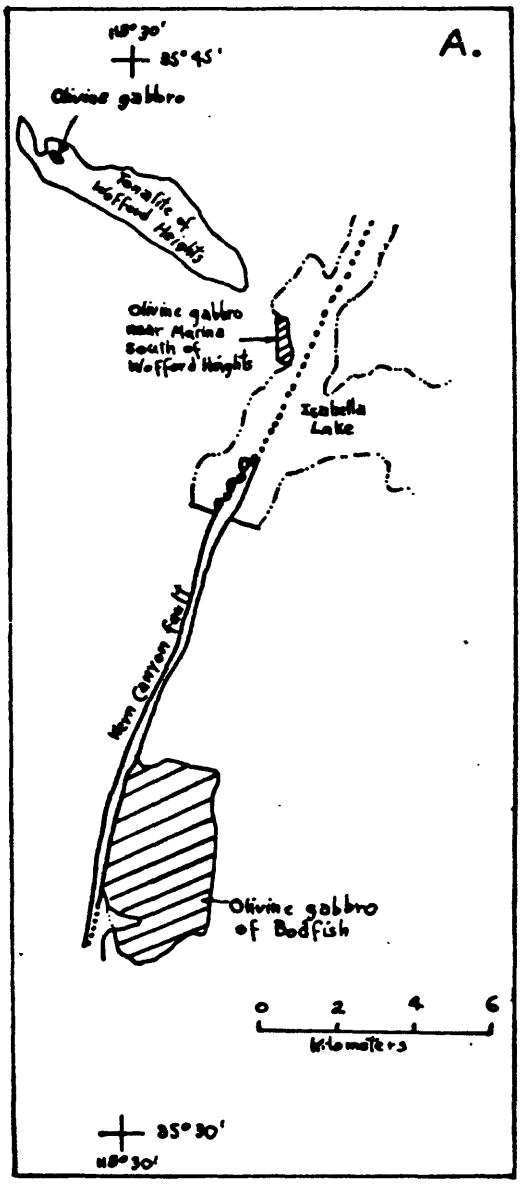
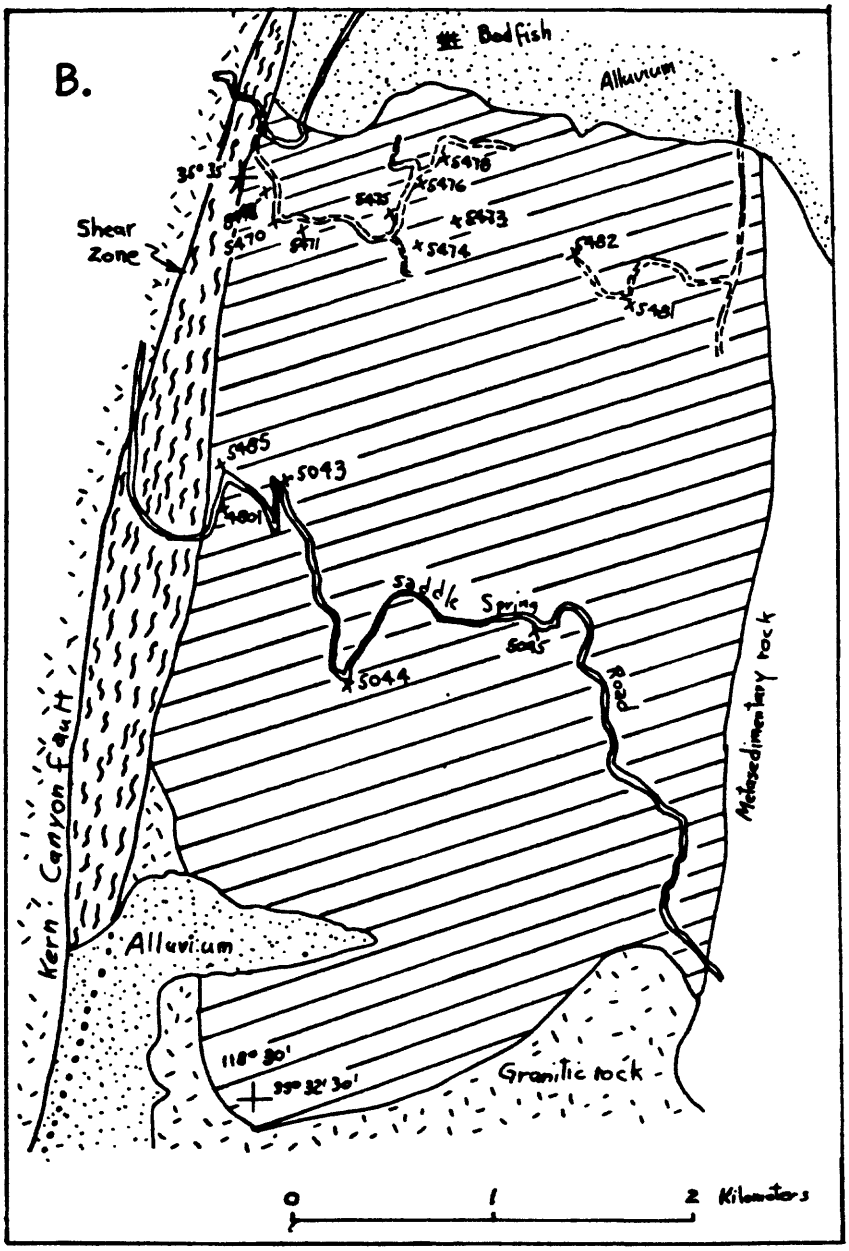
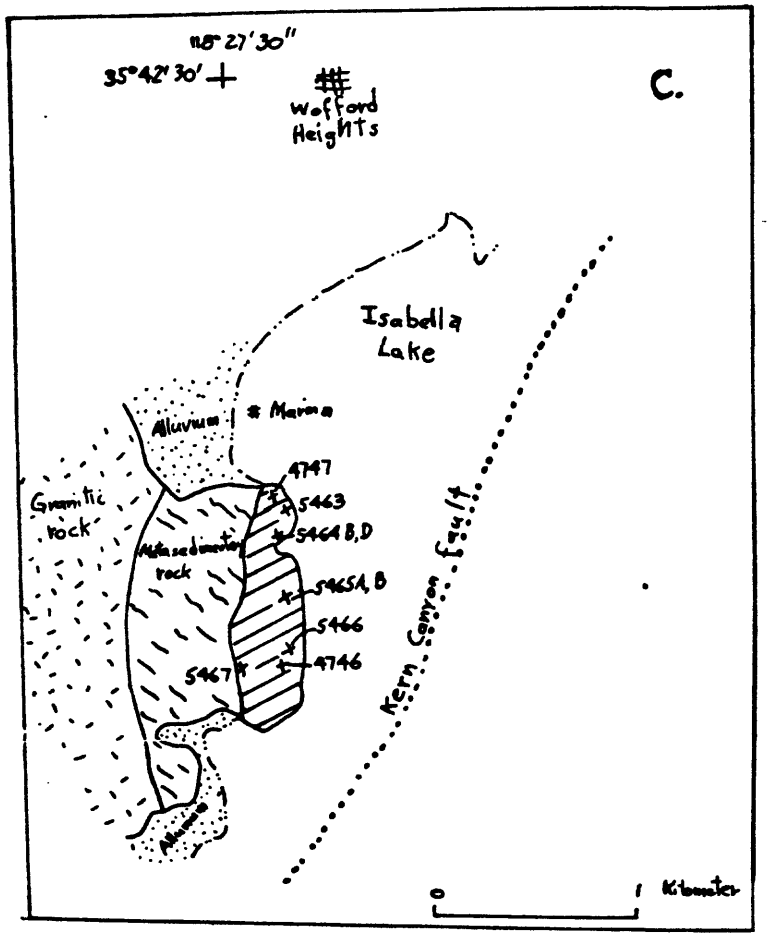
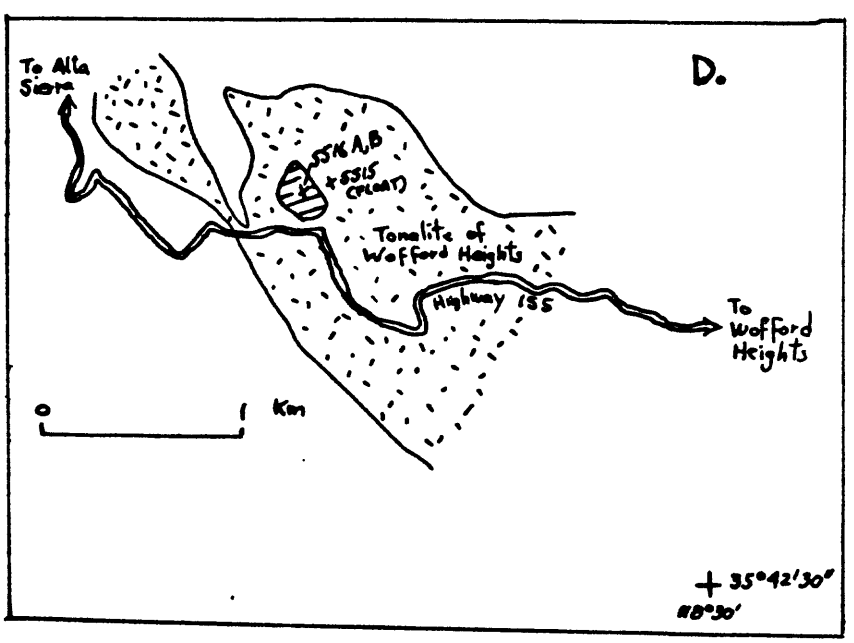


Figure 1. Index map showing olivine gabbro of Bodfish and related bodies
A. Generalized map showing all bodies
B. Map of olivine gabbro of Bodfish, showing sampled localities
C. Map of related body near Marina south of Wofford Heights showing sampled localities
D. Map of small body west of Wofford Heights showing sampled localities


B.
Bodfish
Alluvium
35° 35'
5478
5476
5475
5473
5470
5471
5474
5482
5481
Shear Zone
5485
5043
5480
Saddle Spring
5045
5044
Road
Metasedimentary rock
Kern Canyon Fault
Alluvium
118° 30'
35° 32' 30'
Granitic rock
0
1
2 Kilometers


118° 27' 30"
35° 42' 30"
Wofford Heights
C.
Isabella Lake
Alluvium
Marina
Granitic rock
Metasedimentary rock
4747
5463
5464 B,D
5465A, B
5466
5467
4746
Kern Canyon Fault
0
1 Kilometer


To Alla Sierra
D.
5516 A,B
5515 (Float)
Tonalite of Wofford Heights
Highway 155
To Wofford Heights
0
1 Km
35° 42' 30"
118° 30'

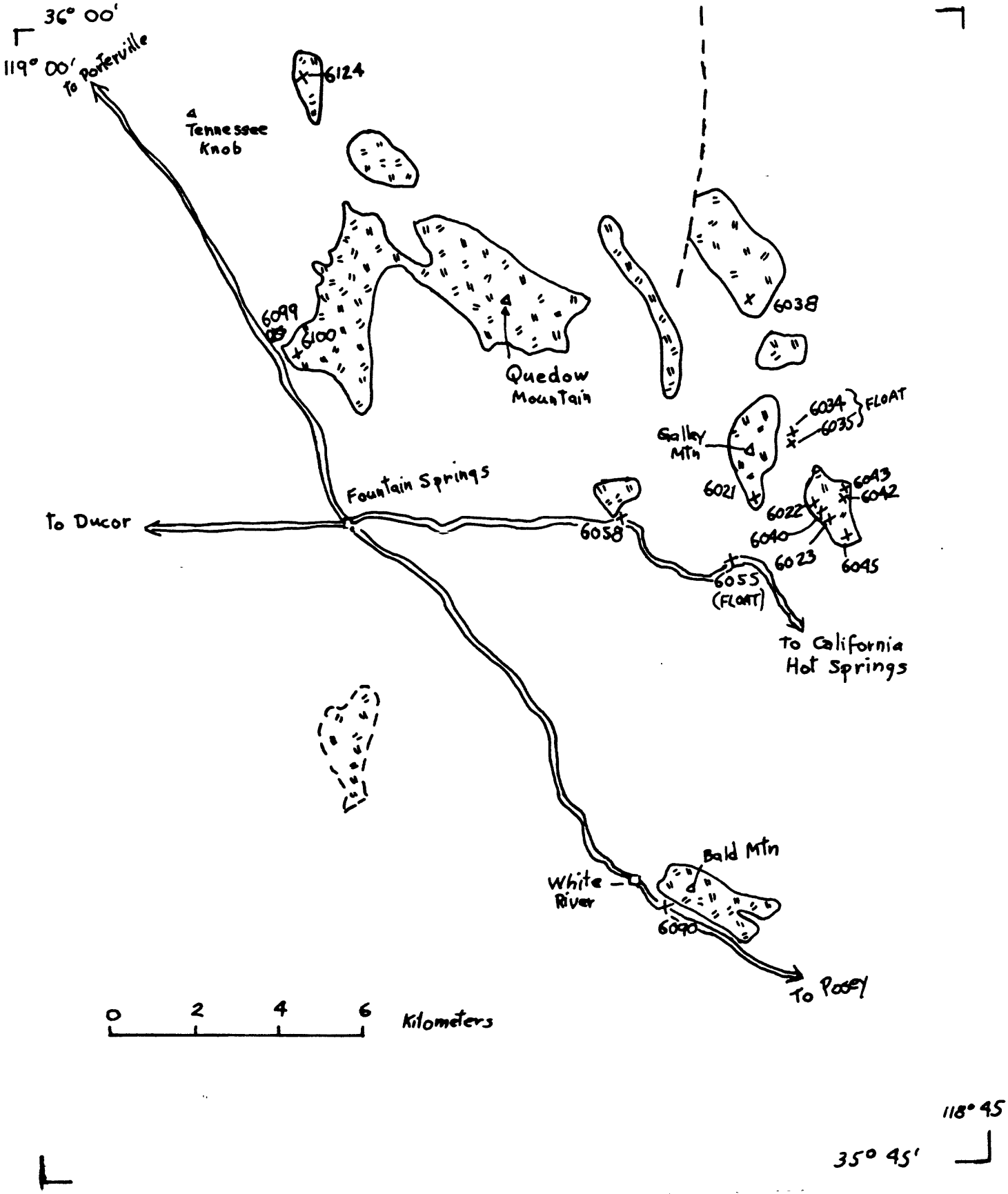


Figure 2. Index map showing gabbronorite of Quedow Mountain and related bodies. Sample localities also shown.

Table 1. Summary of age data for some mafic rocks

Unit	Age (in Ma)	Evidence of age
Metagabbro of Tunis Creek	102 ± 2	U-Pb on zircon (Sams, 1986)
Leucogabbro-gabbronorite of Cyrus Flat	≥100 ± 3 Ma	May be intruded by, or be a border facies of, the quartz diorite of Cyrus Flat, which has U-Pb date of 100 ± 3 Ma (Saleeby and Busby-Spera, 1986)
Gabbronorite of Quedow	115	U-Pb on zircon (Saleeby and Sharp, 1980
Mafic lamprophyric dikes	148?	U-Pb on zircon of related (?) dikes of the Independence dike swarm 45 Km to the east (Chen and Moore, 1979)
Gabbro of Eagle Rest Peak	Jurassic ?	Cut by tonalite-quartz gabbro dated by U-Pb on zircon as 161 Ma (James, and others, 1986)
Olivine gabbro of Bodfish	Jurassic ?	Cut by mafic dikes related (?) to the Independence dike swarm (Chen and Moore, 1979)
Summit gabbro	Triassic ?	Intruded (?) by quartz diorite of Walker Pass that has been dated by Rb/Sr method as 240.4 ± 14 Ma (R.W. Kistler, written commun., 1986)
Gabbro-basalt serpentinite melange of Saleeby and Sharp (1980)	270-305	Strongly discordant U-Pb dates on zircon from included plagiogranite block (interpreted by Saleeby and Sharp, 1980)