Collier

OV 3

FROLICING PLACES

Friday

Vasquez Volcanics
Tropico volcanics & Mine tour
Red Rock Canyon - El Paso basin
Coso volcanic field
No Name Canyon
Camp at Lake Diaz

Saturday

Whitney Portal
Kern Knob & Long John Pluton
Mammoth Mtn. & Devils Postpile
Camp at Horseshoe Lake

Sunday

Earthquake Fault
Inyo Craters
Lookout Mtn.
Panem Crater
Casa Mtn.
Kaolinite Mine
Hot Spring
Mammoth Rock
Camp at Horseshoe Lake

Monday

Convict Lake
Big Pumice Cut
Owens Gorge

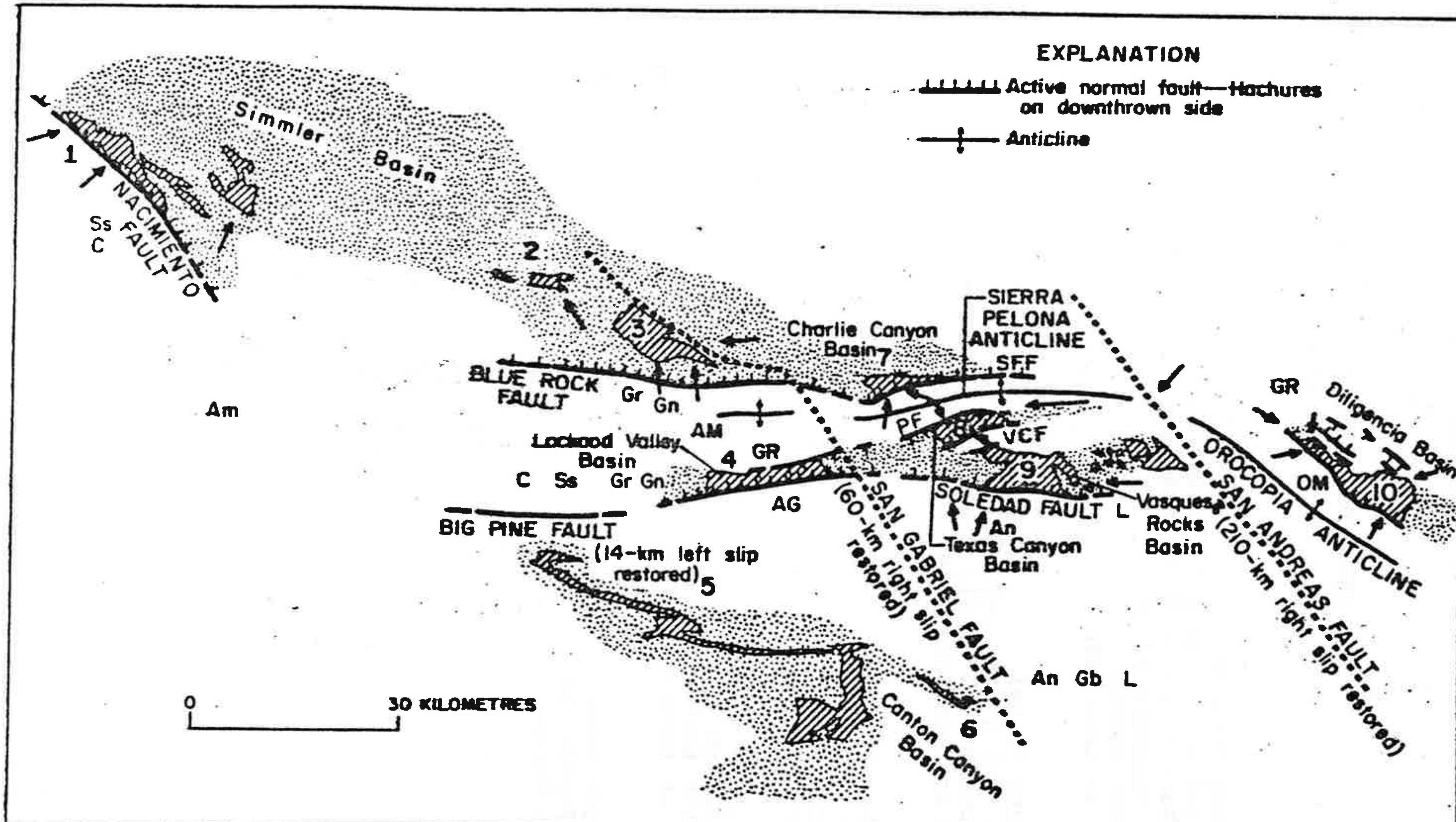
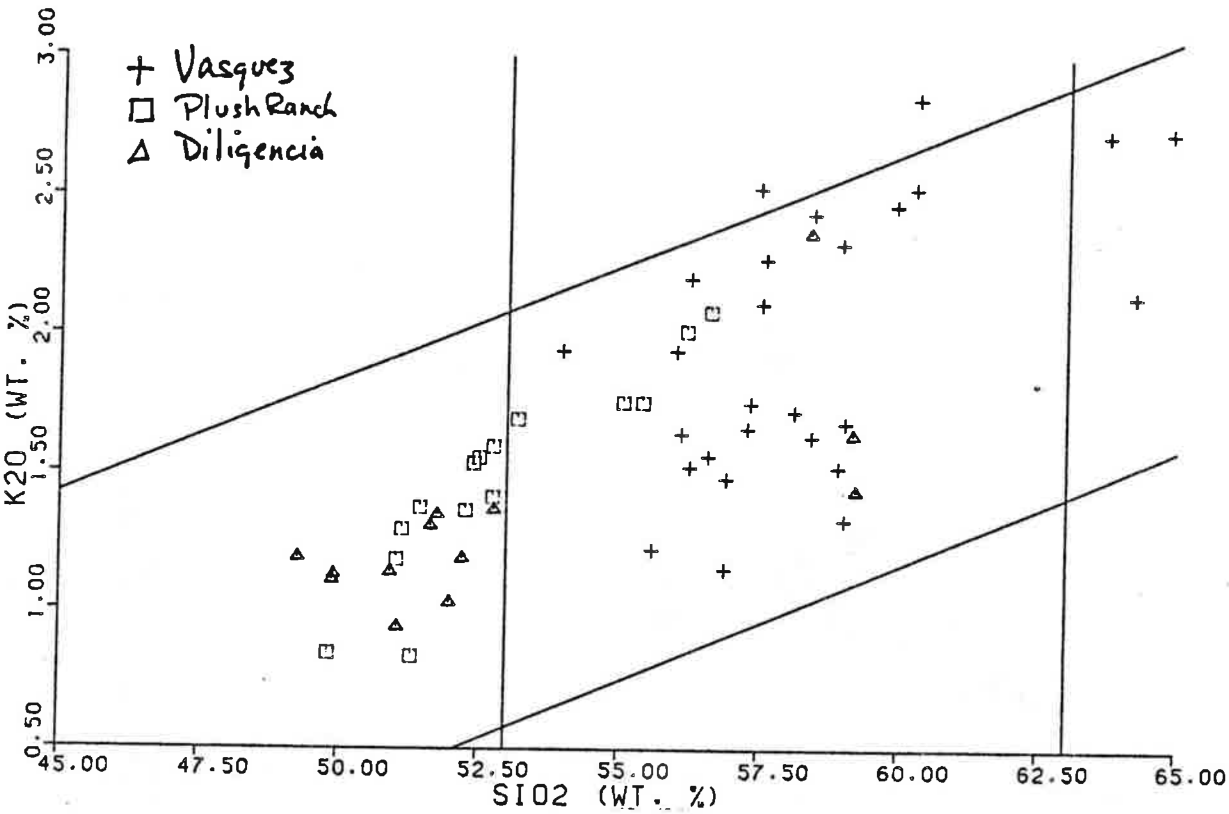
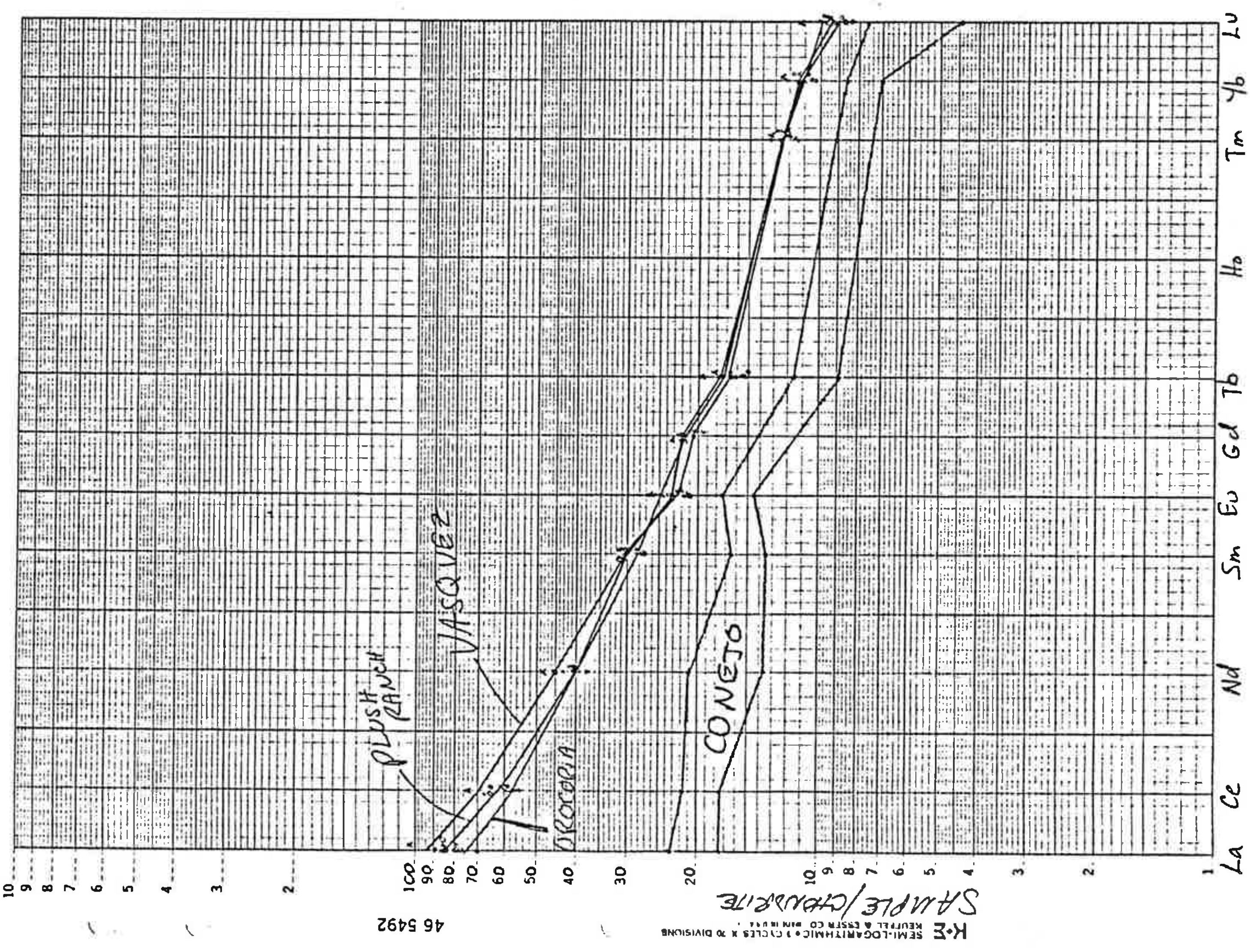


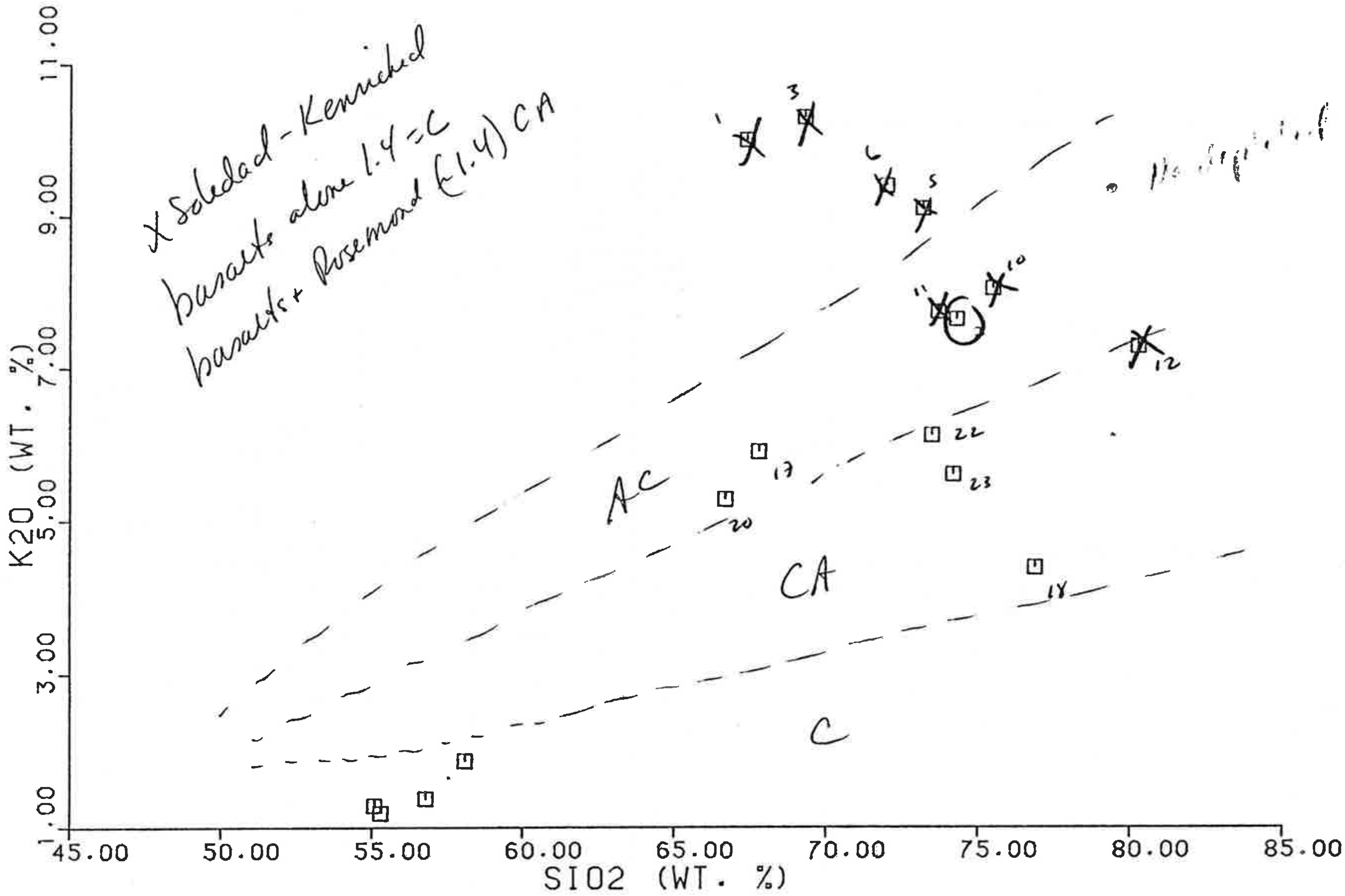
Figure 3.--Map showing proposed distribution of mid-Tertiary basins after palinspastic restoration of slip on the San Andreas, San Gabriel, and Big Pine faults. Arrows indicate transport directions; stipple indicates inferred depositional areas of basins. Ss, sandstone; C, conglomerate; Gr, granitic; GR, granite; Gn, gneiss; AG, augen gneiss; An, anorthosite; Gb, gabbro; L, Lowe Granodiorite; SFF, San Francisquito fault; VCF, Vasquez Canyon fault; PF, Pelona fault; AM, Abel Mountain; OM, Orocopia Mtns. of Miller (1946). Numbered areas refer to fig. 1. Lined pattern indicates present outcrop areas.



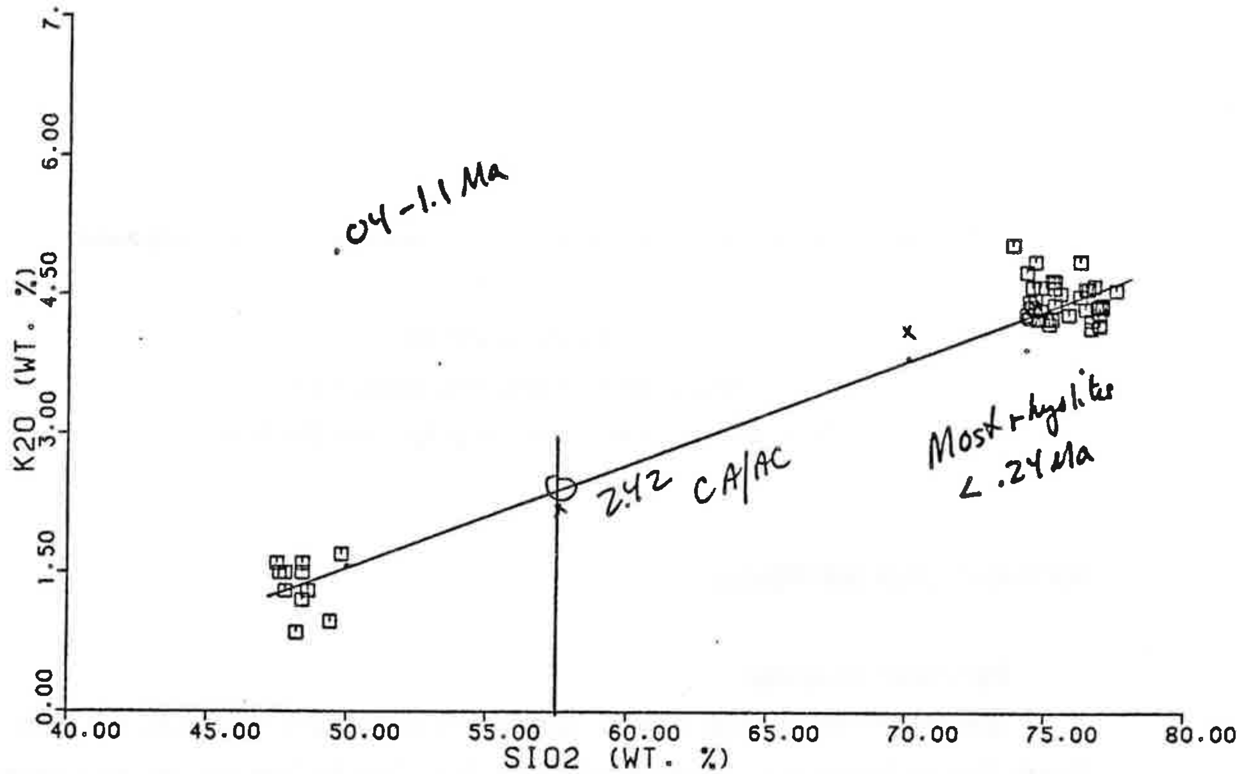
+ Vasquez
□ Plush Ranch
△ Diligencia
K2O (WT. %)
SIO2 (WT. %)
0.50
1.00
1.50
2.00
2.50
3.00
45.00
47.50
50.00
52.50
55.00
57.50
60.00
62.50
65.00



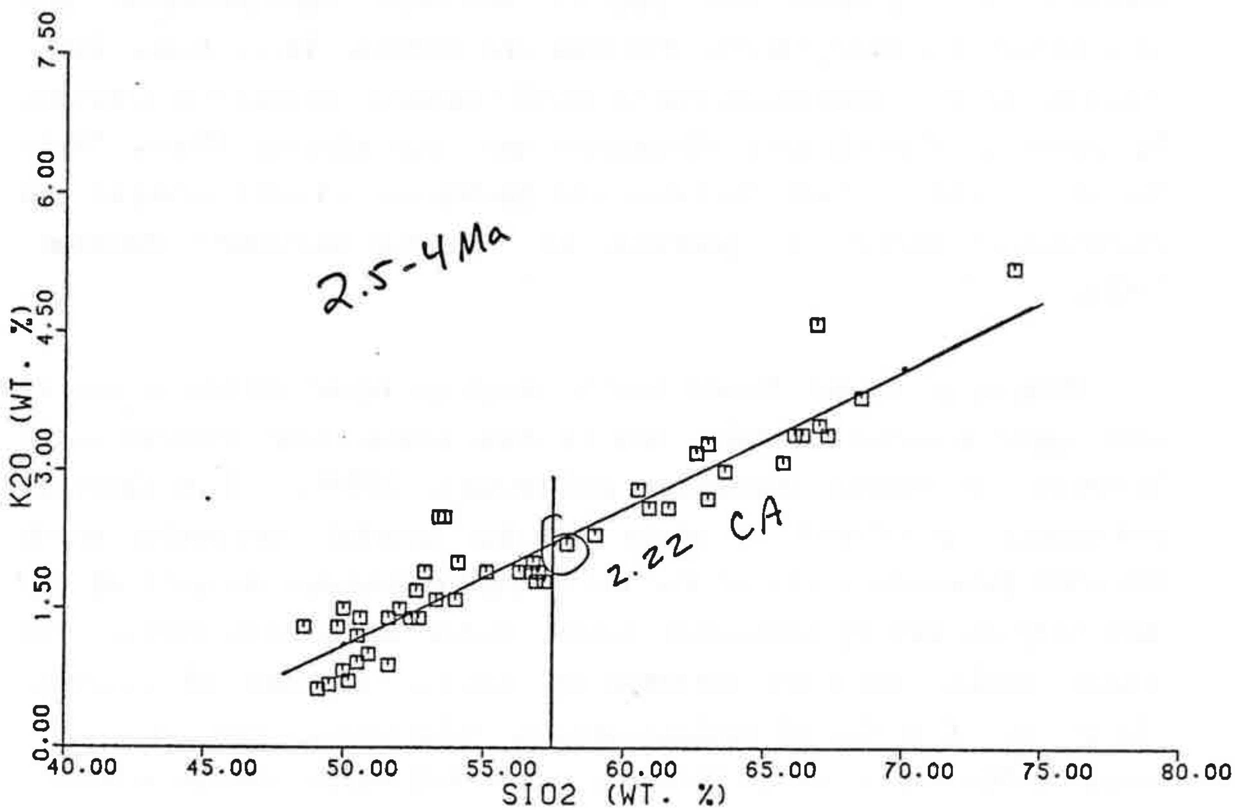
La
Ce
Nd
Sm
Eu
Gd
Tb
Ho
Tm
Yb
Lu
PLUSH RANCH
VASQUEZ
CONEJO
SAMPLE/CHONDRITE
46 5492



TROPICO GROUP



COSO LATE



COSO EARLY

Mesozoic Intrusions in the Inyo Mountains : an overview

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SOUTHERN INYO MOUNTAINS

Geologic Setting

The Inyo Mountains are a normal-fault bounded horst, within the Great Basin Province, separated from the Sierra Nevada on the west by the down-dropped graben of the Owens Valley, and bounded on the east by Saline Valley (Figure 1). Exposed bedrock consists of thick accumulations of Paleozoic continental-shelf deposited sedimentary rocks, primarily limestone, dolomite, quartzite and shale, which are overlain by Triassic and younger Mesozoic shallow-marine and terrestrial volcanic strata (Stevens and others, 1979; Ross, 1967; Merriam, 1963). This Paleozoic to early Mesozoic section was intruded by Jurassic through late Cretaceous granitic plutons (Ross, 1965; Merriam, 1963). Late Tertiary and Quaternary basalts overlie the pre-Cenozoic section in portions of the Inyo Mountains (Merriam, 1963).

Several prominent thrust faults displace Lower Paleozoic strata over Upper Paleozoic strata, and in some cases, also involve early Triassic (?) strata (Burchfiel and others, 1970). This faulting presumably is related to early Mesozoic crustal shortening which affected Paleozoic rocks of the White-Inyo Mountains, as well as the Talc City-Saline-Argus-Panamint Ranges (Dunne and others, 1978). The entire region has been affected by several episodes of folding, tilting and faulting of various styles, orientations and ages. The range fronts are sites of Cenozoic and recent Basin and Range normal faulting.

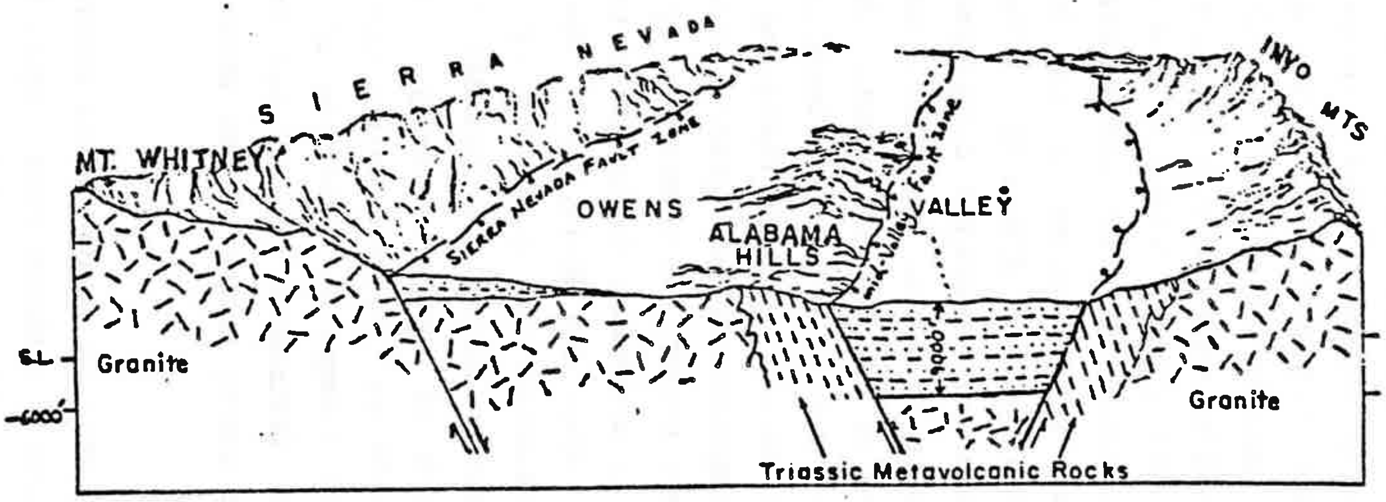


Figure 1. Diagrammatic cross section near Lone Pine. The Alabama Hills are the exposed portion of a block that has dropped midway between the crest of the Sierra and the bedrock low of Owens Valley. A subsurface fault zone on the east flank of the Alabama Hills has an escarpment that is higher than the visible Sierran escarpment to the west (after Von Huene and others, 1963).

Geologic History

Pre-batholithic strata reflect a change from a quiet to an active tectonic environment. Carbonates deposited on a broad continental shelf during the early Paleozoic contain increasingly more clastic material during Permo-Pennsylvannian time. The appearance of Early to Middle Triassic (?) terrestrial volcanic and volcaniclastic deposits associated with shallow marine strata evidence the beginnings of uplift and arc-related igneous activity (Oborne and Dunne, 1982; Oborne and others, 1983; Burchfiel and others, 1980), which is expressed throughout the remainder of the Mesozoic section by emplacement of granitic plutons (Figure 2). Walker and others (1984) further constrain this paleogeographic change from passive margin to Andean-type arc to Early Triassic. Arc-related activity resulted also in thermal weakening of the Mesozoic crust. Repeated episodes of compression of this crust caused much deformation along the eastern margin of the Sierra Nevada batholith (Dunne and others, 1978). Two major periods of compressional and igneous activity, consisting of multiple compressional pulses, were separated by a short interval of Late Jurassic crustal extension, during which the Independence dike swarm was emplaced (Chen and Moore, 1979; Chen, 1977; Moore and Hopson, 1961). Calc-alkaline granitoids of the Sierra Nevada batholith were emplaced during the Jurassic to late Cretaceous, spanning both periods of igneous activity. The Jurassic Hunter Mountain alkalic suite was emplaced during the first period as a coeval, however not comagmatic, satellite of the Sierra Nevada batholith. Late Cretaceous peraluminous leucogranitoids were emplaced during the waning stages of the second period of igneous activity.

The field trip stop is located where several Mesozoic plutons intrude the upper plate of a thrust sheet (Figure 3). The upper plate consists of Lower Paleozoic strata which are folded by the northward extension of the Front Ridge anticline (Wright, 1970), which is a major, doubly- plunging, northwest-trending anticline. The lower plate consists of Upper Paleozoic strata as well as Early Triassic (?) marine rocks, which are seemingly unintruded. Distribution of

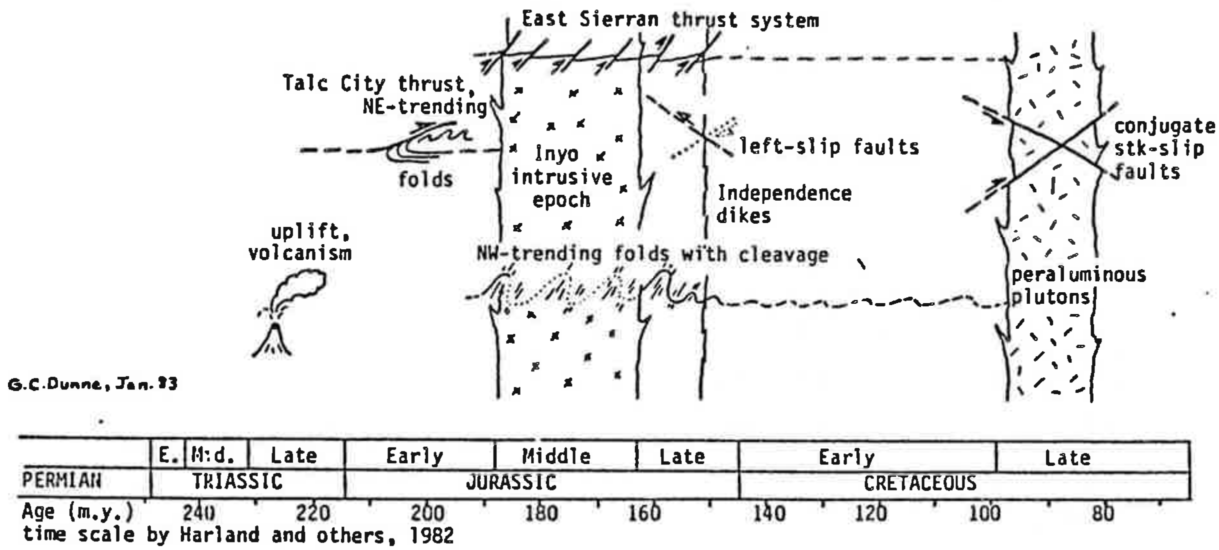


Figure 2 Schematic time-event diagram depicting major igneous and deformational events in eastern California during the Mesozoic.

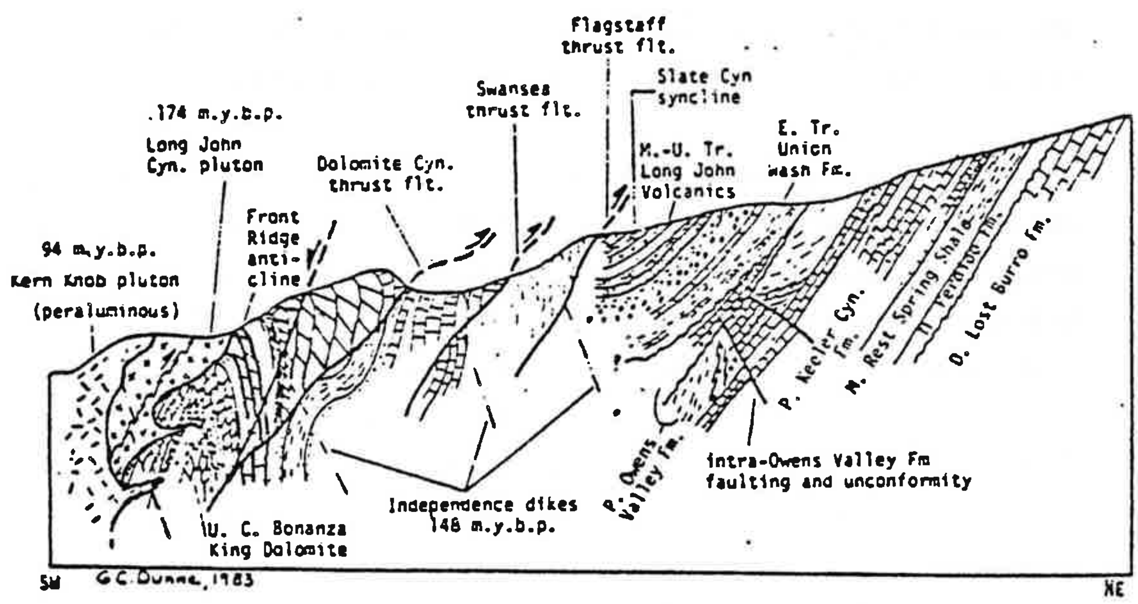


Figure 3. Schematic cross section through Kern Knob pluton showing portions of the Mesozoic fold thrust belt in the southern Inyo Mountains (after Dunne, 1983).

granitic rocks approximately parallels the trend of major structures in the area. The entire area is intruded by lamprophyre dikes which are considered correlative to the Independence dike swarm.

MESOZOIC LAMPROPHYRE DIKES

Introduction

Dark-colored lamprophyre dikes crop out in Paleozoic sedimentary and Mesozoic plutonic rocks throughout this area (Figure 4). Both foliated and non-foliated varieties are present. These dikes are typically oriented in a northeasterly direction, although rare northwest-trending dikes occur. Petrographic and chemical data indicate both orientations of dikes are related and have affinities with the regional Independence dike swarm intruded throughout this portion of eastern California in Late Jurassic time.

This regional swarm of dikes extends for greater than 250 km (Smith, 1962), from the eastern Sierra Nevada southward to the Garlock fault and continues, with offset, into the Mojave Desert (Chen and Moore, 1979; Figure 5). These dikes were first described and named as the Independence dike swarm by Moore and Hopson (1961) and later discussed by Smith (1962) and Chen and Moore (1979).

These predominantly dark-colored dikes comprise a calc-alkalic magmatic series ranging from microcrystalline diorite or diorite porphyry (lamprophyre) to microcrystalline granite or granodiorite porphyry (Moore and Hopson, 1961; Chen and Moore, 1979). Concordant U Pb isochrons on zircon from the more felsic dikes yield a Late Jurassic age (148 Ma) for emplacement of the dike swarm (Chen, 1977; Chen and Moore, 1979). Emplacement typically occurred in extension-related, steeply-dipping, predominantly northwest-trending en echelon fractures, with associated minor northeasterly conjugate fractures, during a hiatus in subduction-related magmatism (Smith, 1962; Chen and Moore, 1979). The general trend of the dike swarm is N25oW indicating maximum extension was oriented N65oE (Chen and Moore, 1979). Regional

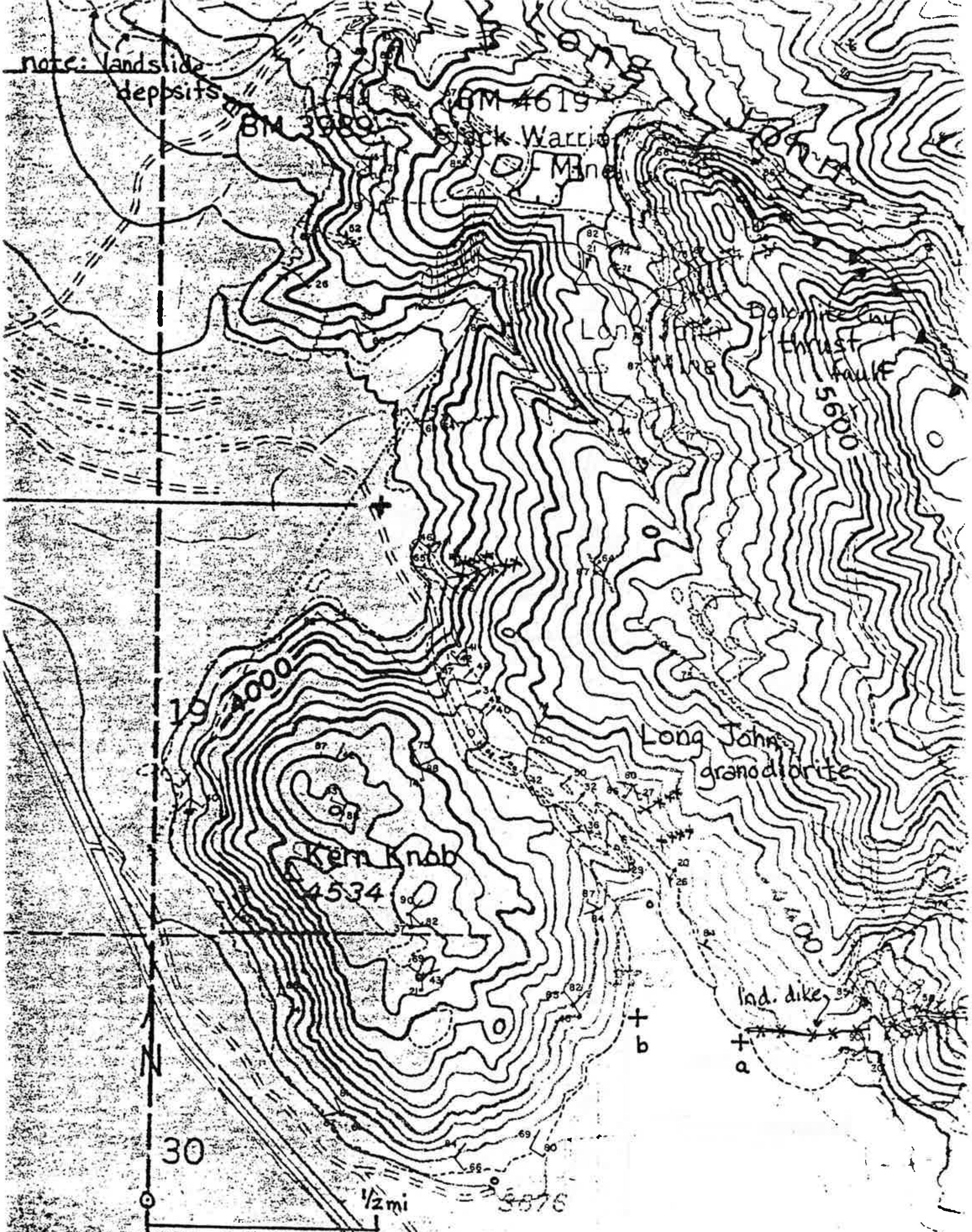


Figure 4. Locations of mafic Independence dikes near Kern Knob pluton.

o - amazonite (in alluvium)
+ - field trip stop
✱✱ - Independence dikes

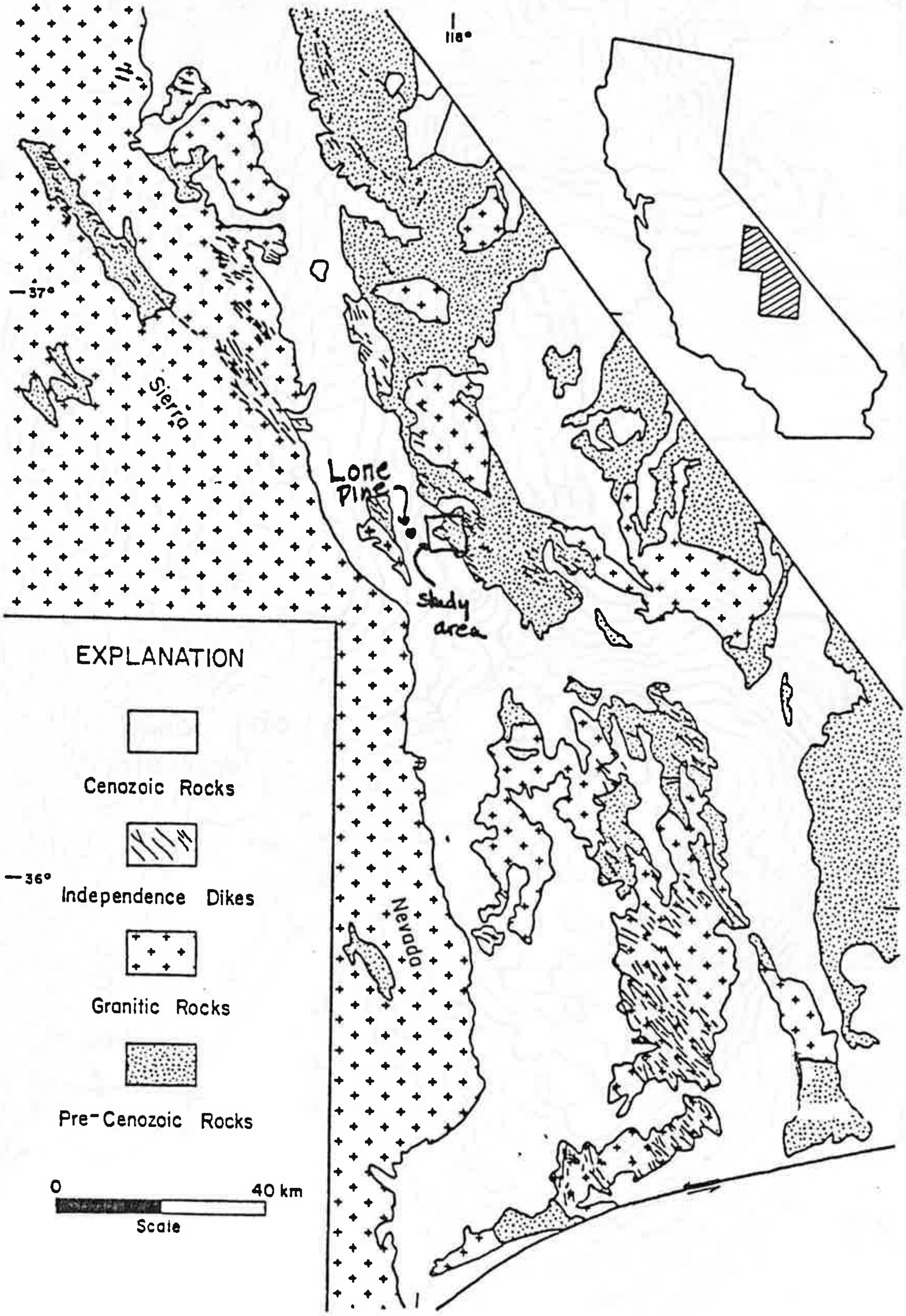


Figure 5. Generalized geologic map showing distribution of Independence dike swarm (148 Ma) north of the Garlock fault (from Fowler, 1982 after Chen and Moore, 1979).

crustal extension occurred during a reorganization of subduction geometry which produced back-arc extension and led to subsequent injection of the dikes into the resultant fracture system (Chen and Moore, 1979).

Petrology of non-foliated dikes

Non-foliated dikes are fine to medium grained and only mildly saussuritized. Euhedral to subhedral hornblende, plagioclase (An_{45} - An_{50}), and K-feldspar crystals are the most common constituents; minor biotite and sericite are present as alteration products of the primary minerals. Modal data for three non-foliated samples are presented in Table 1. Chilled margins are common within dikes and minor baking occurs in intruded carbonate wallrocks.

TABLE 1. SUMMARY OF MODAL ANALYSES FROM NON-FOLIATED MAFIC DIKES EXPOSED IN THE SOUTHERN INYO MOUNTAINS.

Sample No.	LJ-97	LJ-86	LJ-26
No. Points	(500)	(500)	(500)
Trend	N59°E	N85°W	N50°E
% Plagioclase	3.8	5.0	55.0
% K-feldspar	25.6	14.0	trace
% Quartz	--	0.2	--
% Hornblende	58.8	72.8	35.0
% Biotite	--	1.8	10.0
% Opaques	0.2	4.8	trace
% Sericite or epidote	11.6	1.4	trace

Geochemistry

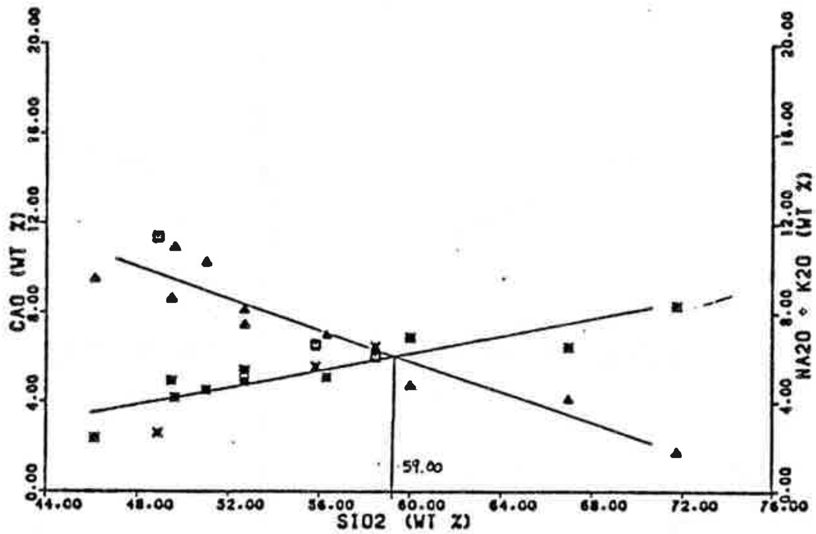
Geochemical data collected from dikes cropping out in diverse areas of the swarm form smooth curves or clusters on covariance or triangular diagrams which substantiates a consanguinous origin for these dikes (Chen and Moore, 1979). The suite is calc-alkalic, in the sense of Peacock (1931; Figure 6a), and is marginally subalkaline, in the sense of Irvine and Berringer (1971; Figure 6b). Harker diagrams presented in Figure 7 show variation of major oxides with respect to silica. Some oxides show straight-line variation (e.g. FeO_{total}, K_2O, CaO, and MnO); the remainder have chevron-shaped curves which change slope between 50 - 55 % SiO_2. These chevron-shaped curves are probably due to the fractionation, or removal, of a phenocrystic phase during the early stages of magmatic evolution. A likely explanation is large amounts of hornblende were removed from the melt (up to 40 % of the original magma) during the early stages of differentiation. However, as differentiation continued hornblende removal became a less important process which resulted in the change in trend on the variation diagrams. Those elements which show straight line variation were in equilibrium between the melt and hornblende, and were thus unaffected by hornblende fractionation.

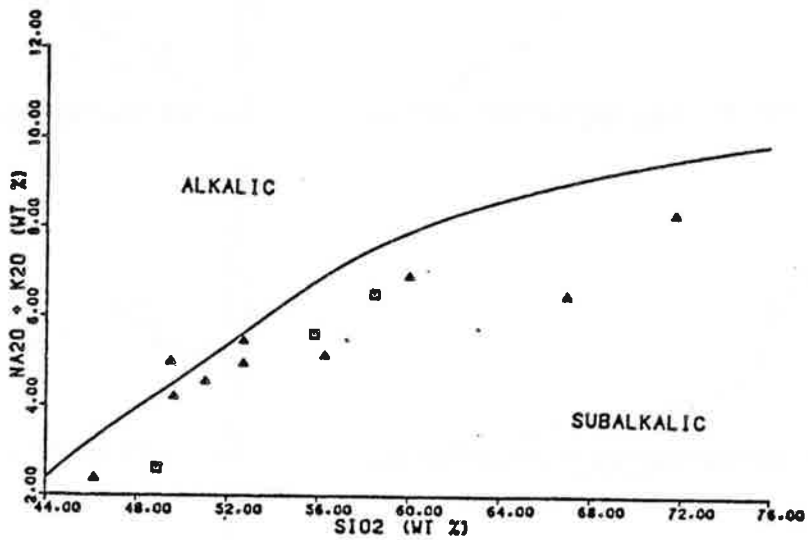
PERALUMINOUS SUITE AND RELATED HIGHLY-EVOLVED ROCKS - a background

Introduction

Peraluminous granitoids sensu stricto are a chemical class of alumina-saturated felsic igneous rocks whose whole-rock molar ratio of Al_2O_3 (CaO + Na_2O + K_2O), hereafter referred to as A CNK, is greater than 1.0 (Shand, 1943). These rocks are commonly referred to as: (1) "two-mica" granites due to the occurrence of muscovite with biotite, and (2) "S-type" granitoids, in reference to a genetic classification proposed for igneous rocks in the Lachlan Fold Belt, Australia (Chappell and White, 1974). These terms are not necessarily synonomous with peraluminous and are avoided here for clarity.

Emplacement of peraluminous granitoids seemingly is limited to syn- to post-tectonic settings (Dunne, 1983; Clemens and Wall, 1981; Anderson and Rowley, 1981) with magma genesis inferred in areas of amphibolite-grade regional metamorphism (Farmer and DePaulo, 1983; Anderson and Rowley, 1981; Goad and Cerny, 1981; Longstaffe and others, 1981; Strong and Hamner, 1981). Petrologic evidence indicates





Explanation of symbols :

□ INDEPENDENCE DIKES - INYOS

▲ INDEPENDENCE DIKE SWARM - REFS

Figure 6. Diagrams used for classification of members of Independence dike swarm.

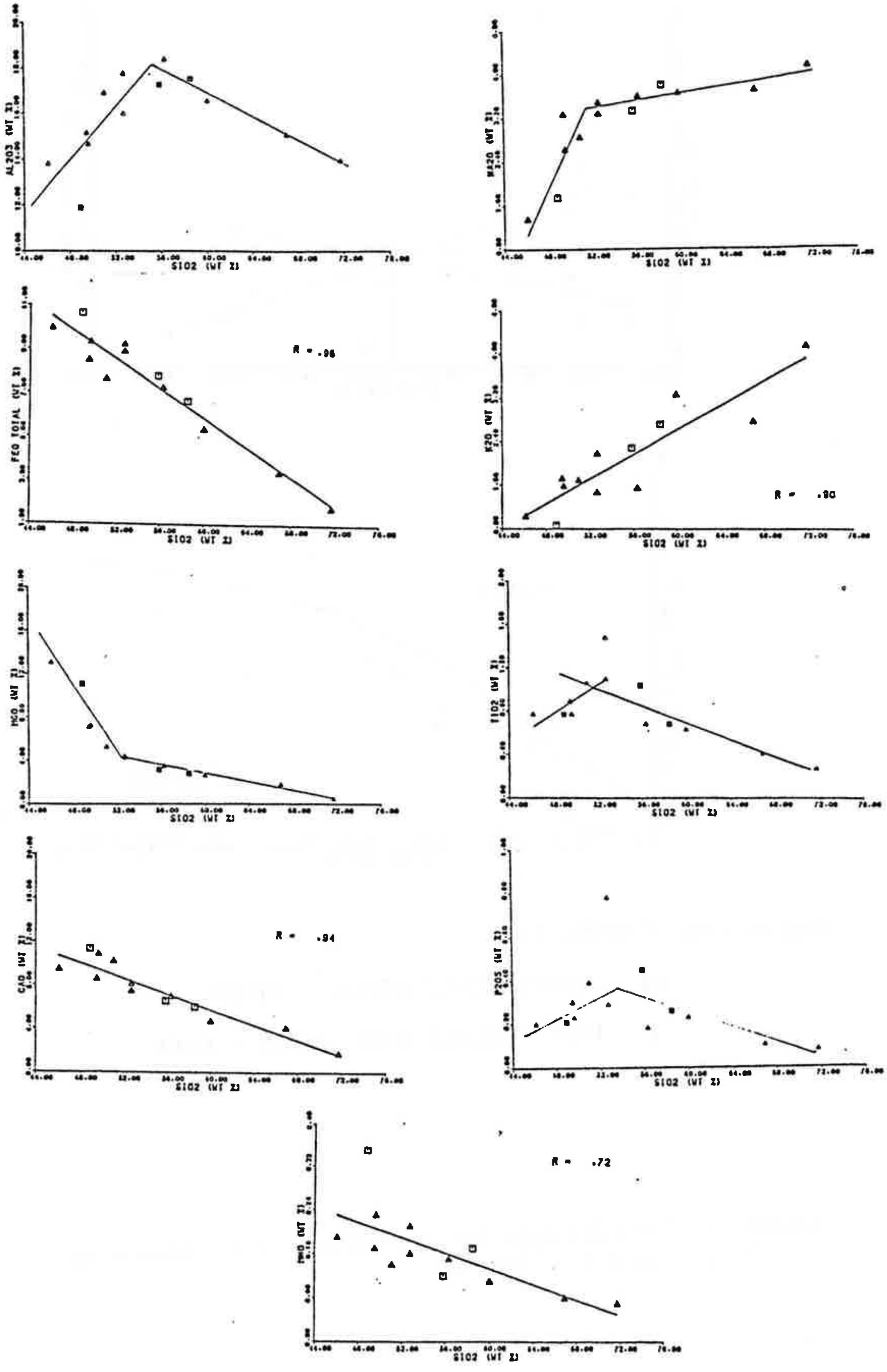


Figure 7. Barker variation diagrams for Independence dike swarm.

that many were emplaced at depths as shallow as 9 km (2 kb; Anderson and Rowley, 1981; Wright and Haxel, 1982; Miller and others, 1981). In the Cordilleran of western North America they form a discontinuous, late Cretaceous-early Tertiary belt inland of the coastal batholiths and the initial ^{87}Sr ^{86}Sr 0.706 isopleth (Miller and Bradfish, 1980; Miller, 1982; Kistler and Peterman, 1973). Many of these peraluminous intrusions in the Cordillera are related to the formation and emplacement of metamorphic core complexes (Rehrig, 1982; Hamilton, 1982; Farmer and DePaulo, 1983).

KERN KNOB PLUTON

Introduction

Kern Knob pluton is a leucocratic granitoid located on the western flanks of the southern Inyo Mountains, approximately 5.6 km east of Lone Pine, California, where it occurs as an isolated hill, somewhat ovoid in shape, and occupies an area of 2.6 km2 (Figure 8). The eastern margin of the leuco-granitoid intrudes Early Jurassic granodiorite of the Long John pluton with a complex set of inter-layered sheetlike dikes within a saddle area between the two plutons; all other intrusive contacts are concealed by Cenozoic deposits. Kern Knob pluton stands out as a geomorphic, petrologic and geochemical anomoly in the southern Inyo Mountains. Petrographic study of Kern Knob pluton revealed a composition of subequal quartz, K-feldspar and plagioclase with accessory biotite and muscovite (Jorgensen, 1982), which: (1) hints at a highly-evolved, possible granite-minimum, peraluminous composition; and (2) suggests a correlation with plutons of the Cordilleran peraluminous belt described by Miller and Bradfish (1981). However, the chemical composition of Kern Knob pluton, while somewhat similar to other peraluminous granitoids in eastern California, has a distinct chemical signature which indicates differences in source material and or mode of genesis.

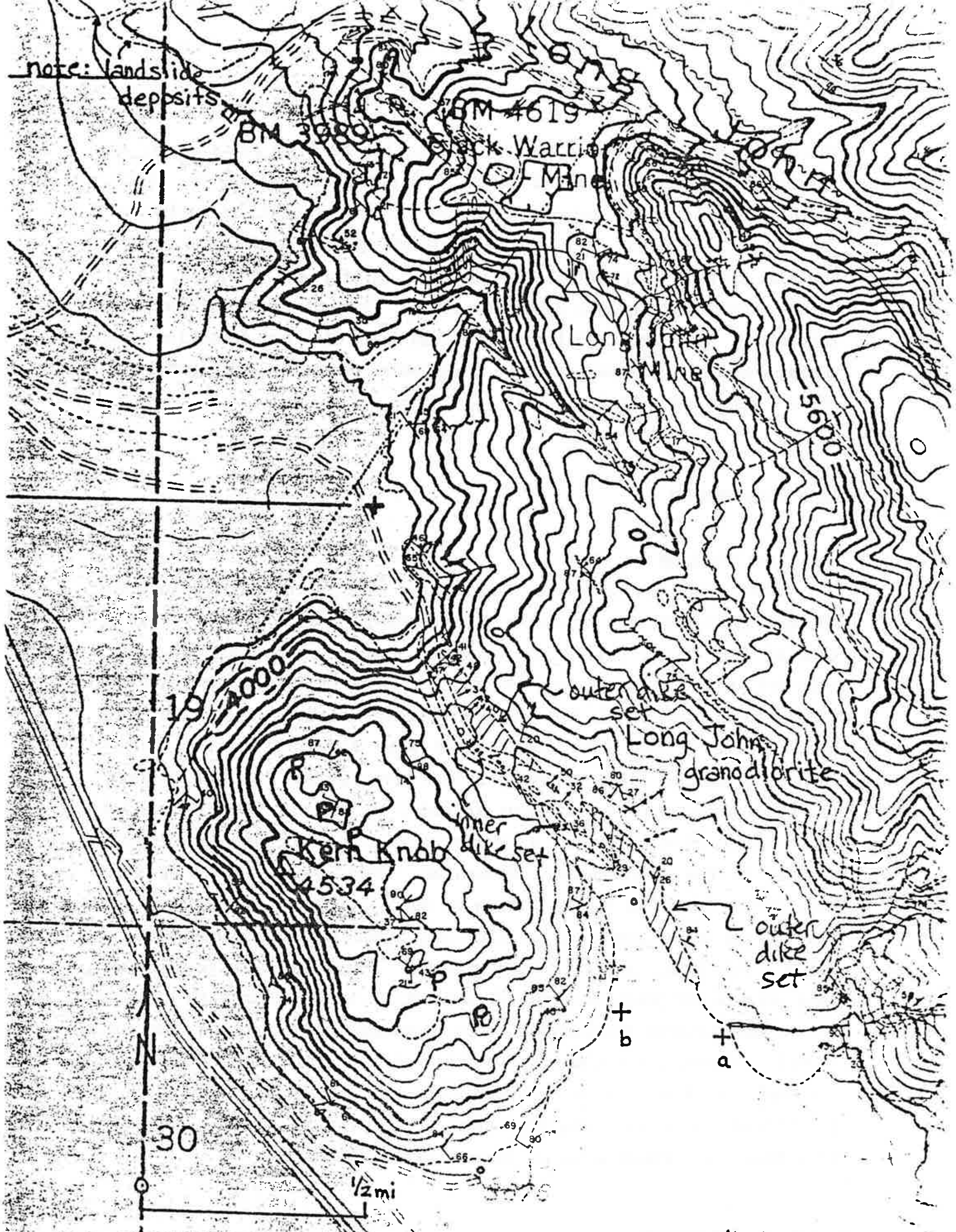


Figure 8. Location map for field trip stop area.

o - amazonite (in alluvium)
\+ - field trip stop
Independence dikes
P - pegmatite localities

Age

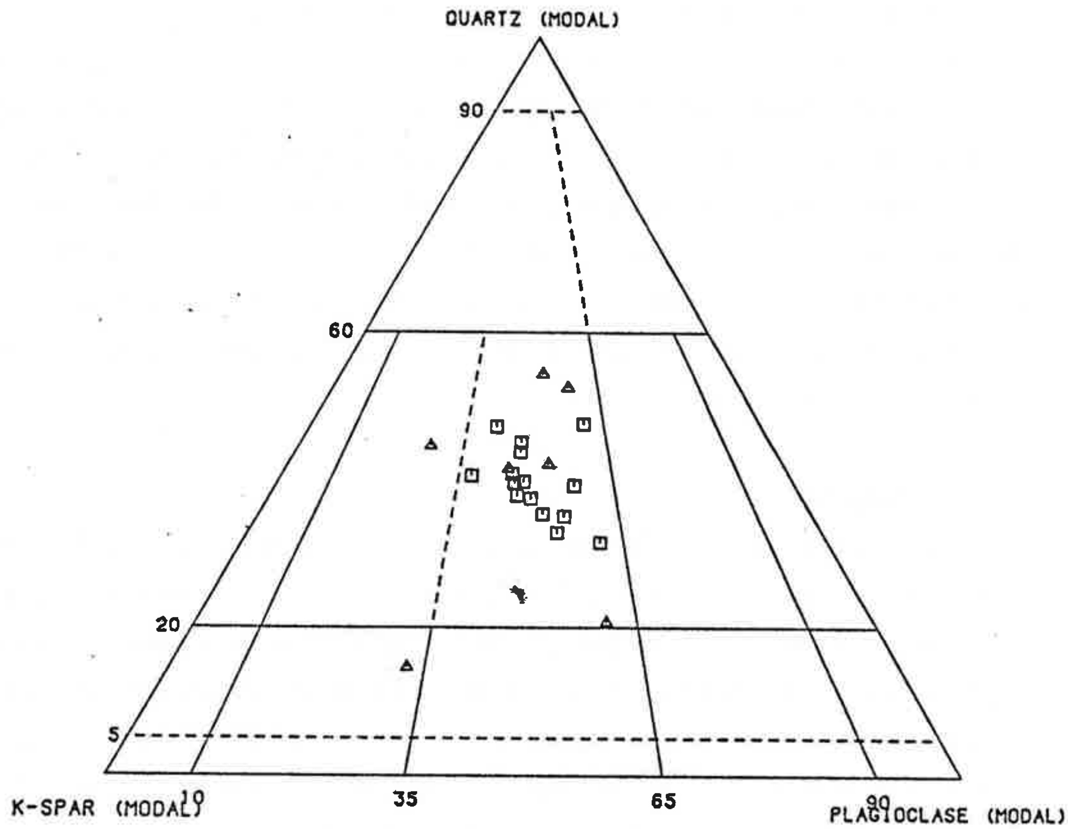
Kern Knob pluton is considered to be Late Cretaceous in age based on a single radiometic age determination and supported by cross-cutting relations with other dated igneous rocks. The leuco-granitoid intrudes granodiorite of the Long John pluton which has yielded a 174 Ma (Middle Jurrassic) U-Pb age from zircons (Chen, 1977; Chen and Moore, 1982). This Early Jurassic pluton is also intruded by NE-trending lamprophyre dikes, related to the 147 Ma Independence dike swarm, which are in turn truncated by the Kern Knob granitoid and its marginal dike sets. An ^{40}Ar ^{39}Ar radiometric determination on biotite yielded an age of 91.4$\pm$0.2 Ma, which is consistent with field relations noted above.

Petrography

Intrusive rocks related to Kern Knob pluton can, in general, be subdivided into two principal groups: the main intrusion and a set of marginal dikes. These groups are further subdivided into distinct facies which are spatially related. The main intrusion consists of a leucocratic facies, pegmatitic facies and aplitic dikes; the margin dikes are divided into an inner dike set, located nearest the main intrusion and parallel to its eastern margin, and an outer dike set, which is subparallel to the inner dike set. Additionally, fluorite- and beryl-bearing dikes occur sporadically as fracture fillings throughout portions of Long John pluton, adjacent to Kern Knob pluton.

Leucocratic facies

The main intrusion is composed primarily of quartz-rich, medium-grained, leucocratic monzogranite (Figure 9), hereafter referred to as the leucocratic facies. Modal composition is homogeneous, with the exception of the pegmatitic facies and marginal dike rocks. Outcrops consist of orthogonally-jointed, "desert varnish"-stained granite boulders which commonly are deeply weathered. Fresh surfaces of the granite are very light-gray to white and commonly have a distinctive, metallic-black, spotted appearance caused by cryptocrystalline manganese-iron-titanium "staining" which permeates the rock.



Explanation of symbols :

KERN KNOB PLUTON

KERN KNOB SHEET DIKES

Figure 9. Modal data diagram with Streckeisen (1976) boundaries showing distribution of Kern Knob pluton samples.

Cataclastic and or protoclastic texture are common throughout the intrusion, and as previously mentioned, minor cataclasis grades into gneissic foliation at the eastern margin.

Leucocratic facies granite is fine to medium grained, and has hypidiomorphic, inequigranular texture. Major constituents, accounting for greater than 95 percent of mineralogy, are microcline, albite and quartz; minor or accessory minerals include biotite, muscovite, fluorite, hematite and psilomolene(?).

Pegmatitic facies

Pegmatites contained within Kern Knob pluton are mineralogically distinctive from the leucocratic facies; major constituents are blue-green microcline (amazonite), quartz and dark-green muscovite. Several small, isolated pod-like pockets occur within the marginal dike set, and thin veinlets, usually less than 1 cm thick, intrude into the adjacent granodiorite of Long John pluton; however, most pegmatites occur within the main intrusion where they form pod- or dike-shaped pockets. Spatial distribution of these pods and dikes implies existence of a N30W-trending pegmatite zone which may cross-cut much of the central portion of the pluton (Figure 8).

Pegmatitic pockets within this zone range from a few cm to nearly 2 m in thickness, and from 50 cm to 20 m in length (Jorgensen, 1982). Most pockets are fully enclosed within fine- to medium-grained granite of the leucocratic facies, and are completely crystal filled, although some larger pockets seem to contain a central void. Microcline commonly forms the largest crystals, up to 20 cm in size, and ranges in color from white to blue-green. Pegmatites contain abundant microcline and quartz, and compositions range from microcline-dominant pods to pure quartz veins (Jorgensen, 1982). Contacts between host rock and pegmatite pockets are sharp and are marked by coarse-grained, graphic intergrowths of quartz and feldspar grains which are elongated perpendicular to the pocket boundaries; the appearance is reminiscent of miarolitic cavities.

Marginal dikes

The eastern margin of Kern Knob pluton is separated from Long John pluton by two sets of discontinuous, sheet-like, foliated and lineated granitic dikes which intrude the granodiorite of Long John pluton within a north to south trending saddle area (Figure 8). Contacts between granite and granodiorite are sharp and parallel the eastern Kern Knob plutonic contact. Dikes vary in orientation from N45°W,50°NE in the northern portion of the saddle to N10°W,30°NE in the southern portion, and range in thickness from 2 cm to 60 m. Changes in dike orientation may reflect (1) variations in shape and size of the pluton at depth, or (2) deformation and warping due to shouldering aside of granodiorite host rock during emplacement of the main intrusion at Kern Knob. Dikes are informally divided into an inner dike set and an outer dike set on the basis of differing degree of cataclasis; the inner dikes occur in the western side of the saddle, nearest the main intrusion, and the outer dike set is present to the east. Cataclasis is pronounced within both dike sets, and varies from sheared and strongly-lineated textures within the inner dike set to highly-foliated and gneissic textures in the outer dike set. Deformation and recrystallization within these dikes has destroyed most original magmatic textures. Pegmatitic, lense-shaped pods, similar to non-cataclastic pegmatites within the main intrusion, occur within the marginal dikes, and are most abundant within the inner dike set.

Outer dike set

Rocks of the outer dike set are medium- to fine-grained, highly foliated, light-gray to yellowish-gray, quartz-rich monzogranite, with less abundant syenogranite. Gneissic foliation is well developed parallel to the dike contacts, and minerals are stretched and granulated within an average foliation plane of N37°W, 39°NE. A strong mineral lineation, oriented 40°, N46°E, occurs within the plane of foliation, and consists of elongate quartz, feldspar and mica grains; lineation is best displayed by elongated biotite grains which are aligned in the shear direction. Foliation and lineation are best developed towards the center of dikes and lessens in intensity near their margins. The most intensely sheared portions of these dikes are fine-grained mylonites. Several small faults, up to 30 m in length, occur along the contact between dikes and Long John granodiorite host rock, and commonly have slickensides with an average orientation of 34o, N44oE. These faults may be contemporaneous with emplacement of Kern Knob pluton.

Microcline, albite and quartz comprise greater than 90 % of modal mineralogy; accessory minerals are biotite, phengitic muscovite, hematite and fluorite. Fluorite occurrence and distribution are similar to those in the main intrusion. Biotite grains account for up to 2 % of the mode, and usually are small, subhedral, elongated and dark-colored. Muscovite is scattered throughout rocks of the outer dike set, and rarely comprises up to 12 % of the mineralogy. Muscovite, biotite and hematite often are associated, as in the main intrusion, with muscovite intergrown with and replacing biotite; faded or bleached patches in bioite grains are common. Hematite grains, ranging from 1 mm to 3 mm in diameter, give the outer dike set a reddish, spotted appearance. Red staining is best developed within the most highly sheared portions of the dikes.

Inner dike set

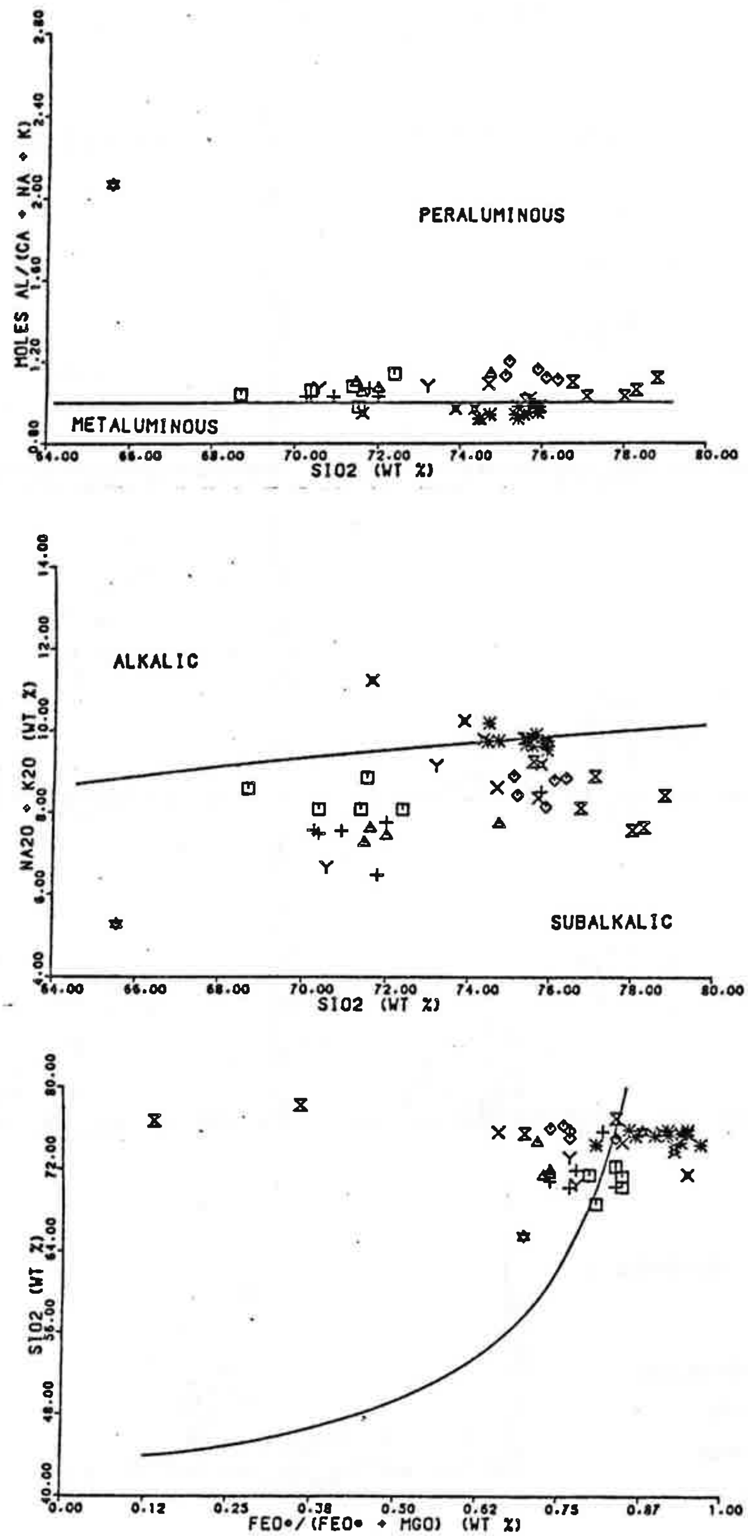
The dominant rock type in the inner dike set is fine- to medium-grained, white to light-gray, flow-banded monzogranite, with less abundant quartz syenite. Mineralogical content and associations are similar to monzogranite of the outer dike set. Flow banding is parallel to the margins of the dikes and forms tabular bands, 2 cm to 20 cm thick, which give these rocks a layered appearance. Alternating bands of fine- and medium-grained crystals, primarily quartz and feldspars, form the layering. Cataclasis is less intense than in the outer dike set, although shearing and lineations are common. Quartz and feldspar are weakly aligned wihin some portions of the dikes; however, strongly lineated granite with quartz porphyrocrysts is common. Euhedral quartz phenocrysts, up to 4 mm in diameter, are surrounded by a fine- to medium-grained matrix of albite, microcline, quartz and biotite. Crushed grain boundaries are common on all quartz phenocrysts, and grains are stretched parallel to the presumed shear direction. A recrystallization origin for quartz phenocrysts is indicated by albite inclusions within some grains.

Geochemistry

Seven additional late Cretaceous to early Tertiary plutons in eastern California, which along with Kern Knob pluton, occur along the westernmost margin of the Cordilleran peraluminous belt, were selected for geochemical study. A cursory examination of chemical data for these various leucocratic granitoid plutons indicates most samples are mildly peraluminous (A CNK < 1.1); however, Kern Knob pluton has an average metaluminous (A CNK $\geq$ 0.94) composition which was unexpected on the basis of mineralogy which is similar to the mildly peraluminous plutons (figure 10a). The metaluminous composition, therefore, probably reflects late-stage sodic alteration of Kern Knob pluton (Na_2O is as high as 8.00 wt. % in some samples), rather than initial magma chemistry.

Most late Cretaceous leucogranites sampled are subalkalic, whereas, Kern Knob is bordline alkalic-subalkalic to alkalic (Figure 10b). An iron saturation diagram (Figure 10c) also shows differences between Kern Knob and the other plutons; Kern Knob is iron-rich, whereas, the other plutons are generally iron-poor. Figure 11 shows Harker variation diagrams for each element, which in most cases are insufficient to distinguish Kern Knob from the other plutons. Kern Knob has a very restricted silica range (74 - 76 wt. %); contains low concentrations of CaO, MgO, TiO_2, and FeOtotal; is enriched in alkalis (e.g. Na_2O and K_2O); and has variable P_2O_5 and MnO (Figure 11).

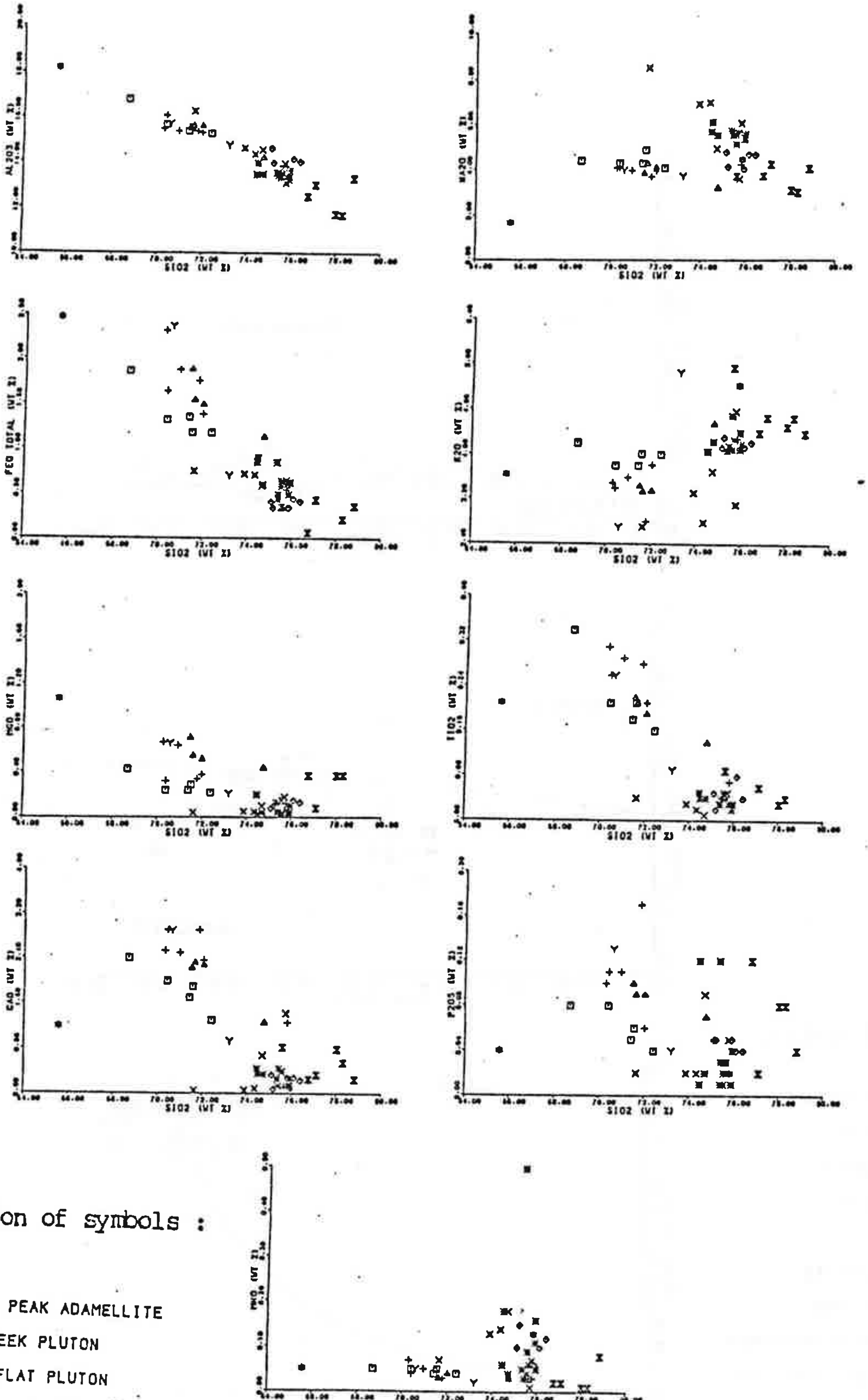
Trace element data are more useful in distinguishing between Kern Knob and the other Cretaceous leucogranites. Kern Knob is strongly depleted in Sr and Ba, and is enriched in Li, F, Zn, Rb, Cs, Hf, Ta, Pb, Th, and U. The latter two elements, Th and U, are concentrated by 50X and 25X, respectively, over the average concentration in the other plutons; these elements provide a good criteria for distinguishing Kern Knob from the other plutons.



Explanation of symbols :

- BOUNDARY PEAK ADAMELLITE
- BIRCH CREEK PLUTON
- PAPOOSE FLAT PLUTON
- HALL CANYON PLUTON
- SKIDOO PLUTON
- COPPER QUEEN ALASKITE
- NONAME CANYON PLUTON
- KERN KNOB PLUTON - MAIN PHASE
- KERN KNOB MARGINAL DIKE SETS
- KERN KNOB PLUTON - PEGMATITES

Figure 10. Diagrams used for classification of plutons from peraluminous suite.



Explanation of symbols :

- ⊡ BOUNDARY PEAK ADAMELLITE
- △ BIRCH CREEK PLUTON
- + PAPOOSE FLAT PLUTON
- X HALL CANYON PLUTON
- Y SKIDOO PLUTON
- ⧗ COPPER QUEEN ALASKITE
- ◇ NONAME CANYON PLUTON
- ✳ KERN KNOB PLUTON - MAIN PHASE
- × KERN KNOB MARGINAL DIKE SETS
- ⛝ KERN KNOB PLUTON - PEGMATITES

Figure 11. Harker variation diagrams for peraluminous suite.

Rare-earth element signatures (Figure 12) are also distinctive. Kern Knob pluton has flat REE slopes (at approx. 30X chondrite) and has a large negative Eu anomoly (Eu* Eu = 37), as compared to the less "evolved", negative REE slopes, with little or no Eu anomolies, associated with the other plutons.

In summary, the relative consistancy in major element chemistry is a function of the modal mineralogy which approaches granite minimum composition for these plutons. The trace element and rare-earth element data indicate that either different magma source regions or different mechanisms of differentiation are needed to explain the production of these plutons. The limited age range for emplacement (75 - 91 Ma) provides a constraint on large scale variation in tectonic setting. These plutons must have a common tectonic setting which allows for formation of different "kinds" of magma, and seems to preclude the model of a singular, shallow- to moderately-dipping subduction zone during late Cretaceous. One possible model to explain the production and emplacement of these different plutons during this limited time span is the subducted slab was essentially horizontal and was eroding the overriding crust allowing magma generation to be sourced at various crustal levels, ranging from the subducted slab itself up to middle or upper crustal levels. An alternative hypothesis is the chemical variations are due to melting of an inhomogeneous lower to middle crust above a typical Benioff-type subduction zone.

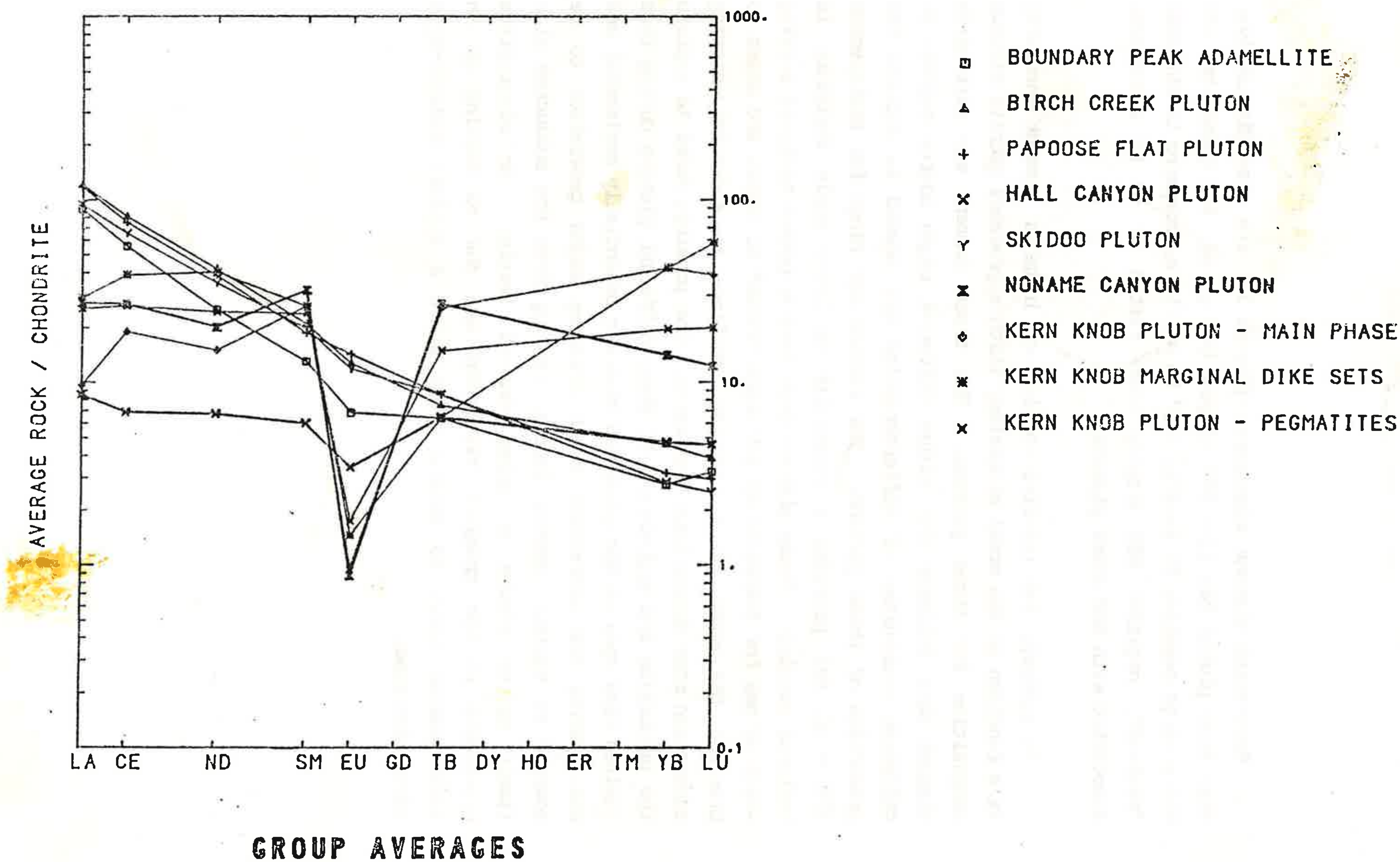


Figure 12. REE chondrite-normalized diagram showing average REE composition of peraluminous plutons.