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THE INDEPENDENCE DIKE SWARM IN EASTERN CALIFORNIA*

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ABSTRACT. A dike swarm up to 15 miles wide and at least 85 miles long cuts northwestward across the Sierra Nevada, Inyo Range, and Argus Range in eastern California. The dike rocks range from lamprophyre to granodiorite porphyry, the more mafic types predominating. The dikes are probably of Cretaceous age, for they intrude some granitic plutons of the Cretaceous Sierra Nevada batholith but are truncated by others. The dikes in the Sierra Nevada were metamorphosed by the younger granitic intrusives. In the Inyo and Argus Ranges the dikes are hydrothermally altered, but otherwise unmetamorphosed.

Two sequences of granitic intrusion in the Sierra Nevada batholith (Mount Pinchot quadrangle) can be separated by the dike swarm. Each sequence apparently began with the emplacement of mafic granodiorite and concluded with alaskite; succeeding intrusions in each sequence were progressively more felsic. Two cycles of differentiation seem indicated. Chilled dike margins where the swarm cuts earlier plutons indicates that a significant time interval separated emplacement of pre-dike and post-dike plutons.

The dike swarm shows no apparent offset where it crosses Owens Valley. This argues against suggested major strike-slip faulting along the line of Owens Valley since Cretaceous time.

INTRODUCTION

A group of predominantly mafic dikes in the Sierra Nevada, Inyo Range, and Argus Range in eastern California forms a large northwest-trending swarm traceable for 85 miles. The dikes have already been described in isolated localities, but a dike swarm of regional extent has not previously been recognized. The name "Independence dike swarm" is proposed, from the town of that name in Owens Valley on line with the swarm (fig. 1).

The dike swarm is of interest not only as a major petrologic and structural feature but also as a means of separating two sequences of granitic intrusions in the Sierra Nevada batholith.

We have investigated the dikes in detail in the Mount Pinchot quadrangle in the Sierra Nevada during three and a half summers of mapping (Moore, 1954; and a report in preparation). The dikes of the Inyo Range and Alabama Hills were studied by us only in reconnaissance. E. M. MacKevett, C. W. Merriam, C. A. Nelson, W. C. Smith, D. C. Ross, and W. E. Hall have generously supplied additional data on the dikes in the Inyo and Argus Ranges, and P. C. Bateman on the dikes in the Sierra Nevada north of the Mount Pinchot quadrangle.

EXTENT OF THE DIKE SWARM

The dikes are most abundant and best exposed along the high crest of the Sierra Nevada. The main group, centering in the Mount Pinchot quadrangle, consists of hundreds of steeply dipping dikes striking northwestward across

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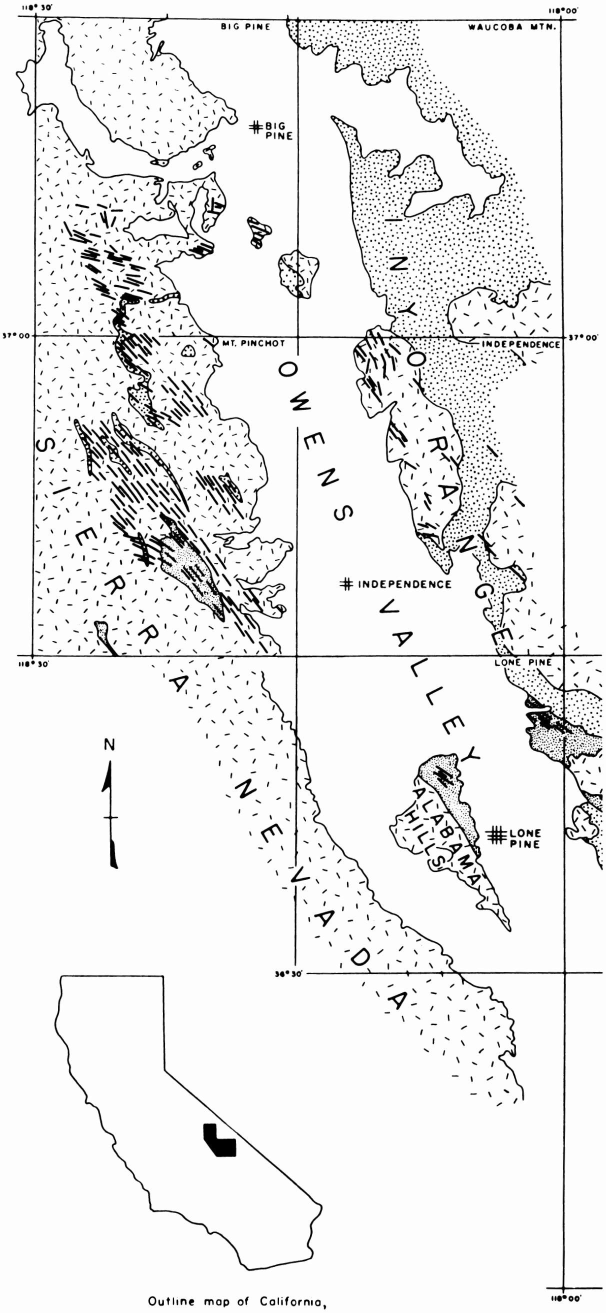
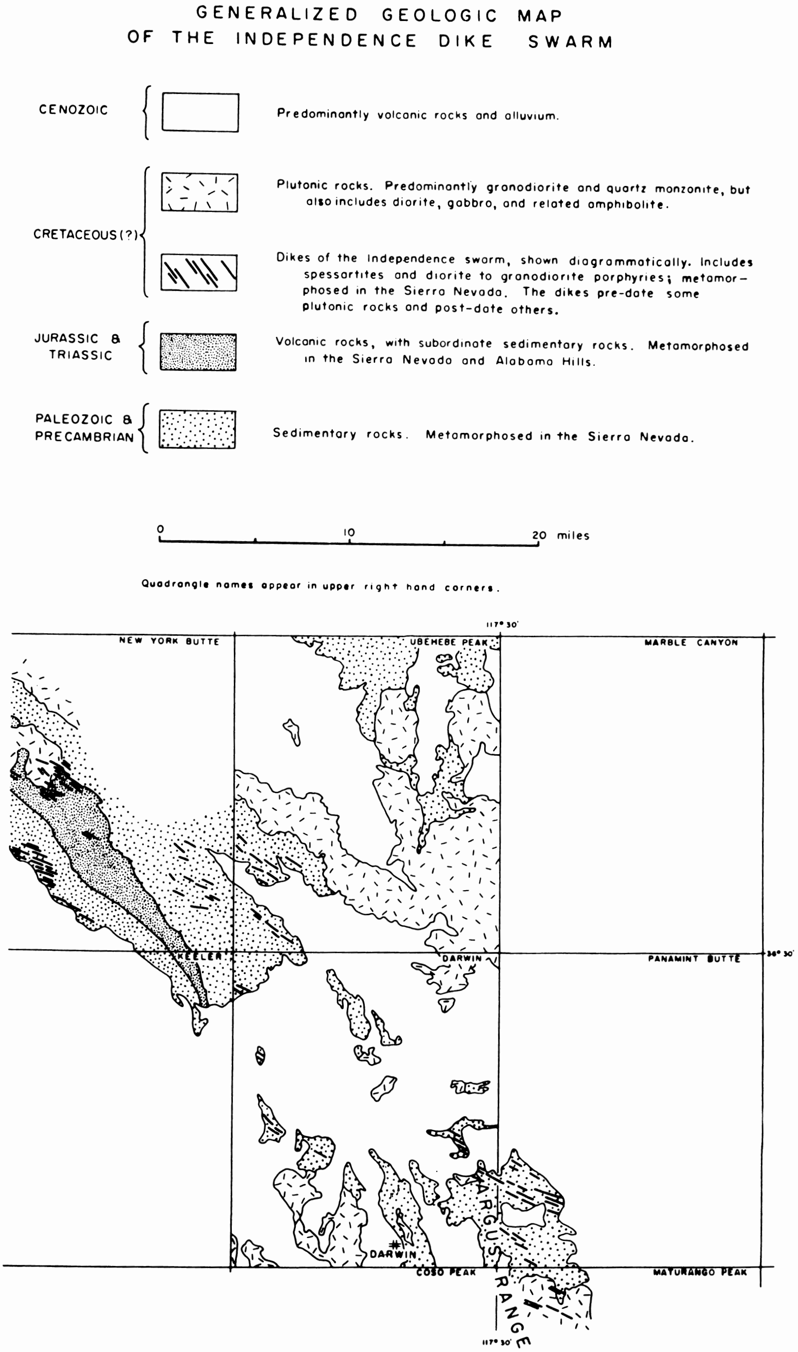


Outline map of California,
showing location of the Independence area.

Fig. 1. Generalized geologic map



showing the Independence dike swarm.

the quadrangle in a swarm at least 9 miles wide (fig. 2). Northward the dike swarm extends into the Big Pine quadrangle (P. C. Bateman, 1958, written communication), but there it is truncated on the northwest by younger granitic intrusions. The possible northwestward continuation of the dikes into the Mount Goddard quadrangle (west of the Big Pine quadrangle) has not been investigated.[3]

In the Inyo Range the dikes have been mapped only in isolated localities: in the Burgess Mine area, west-central New York Butte quadrangle (E. M. MacKevett, 1958, written communication), in the Cerro Gordo mine area, southwestern New York Butte quadrangle (C. W. Merriam, 1958, written communication; Page, 1951, p. 24), in the Santa Rosa mine area, northwest Darwin quadrangle (MacKevett, 1953), and in the Independence quadrangle (D. C. Ross, 1959, written communication). C. A. Nelson (written communication, 1959) reports northwesterly-trending dark-colored dikes in the extreme southwestern corner of the Waucoba Mountain quadrangle. We have mapped the dikes in reconnaissance along the west flank of the Inyo Range in the New York Butte and Lone Pine quadrangles, and in the Alabama Hills, Lone Pine quadrangle.

Nearly 15 miles of alluviated valley separates the dike swarms in the Sierra Nevada and Inyo Range. Fortunately an upfaulted block of crystalline bedrock, the Alabama Hills, is in the valley directly on strike with both dike swarms. Here similar northwest-trending dikes link the Sierra Nevada and Inyo swarms.

Similar dark-colored dikes, striking northwestward on line with the Sierra Nevada-Inyo Range swarm, occur in the Argus and other desert ranges to the southeast: in the southwest corner of the Panamint Butte quadrangle and in the northwest corner of the Maturango Peak quadrangle (W. E. Hall, 1958, written communication), in the Darwin quadrangle (Hall and MacKevett, 1958), and in the southwest corner of the Ubehebe Peak quadrangle (McAllister, 1956). The dikes near Darwin, called andesite porphyry by Hall, are similar to those in the Inyo Range which we call diorite porphyry. The possible southeastward continuation of the dikes beyond those shown in the Maturango Peak quadrangle has not been investigated.[4]

The map of the dike swarm (fig. 1) has been compiled from the above sources, with the geologic map of the Owens Valley region (Bateman and Merriam, 1954) serving as a base.

THE DIKE ROCKS

The Independence dike swarm, on both sides of Owens Valley, consists predominantly of dark-colored dike rock but includes leucocratic types as well. The swarm is, in fact, a dike series, with a wide range of intermediate rock

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[3] In the summer of 1960 Moore and F. C. Dodge mapped predominately northwest-trending dikes through the Mount Goddard quadrangle (bordering the Big Pine quadrangle on the west) and into the Blackcap Mountain quadrangle (bordering the Mount Goddard quadrangle on the west.).

[4] After this paper went to press G. I. Smith (Geol. Soc. America Program, 1960 Annual Meetings, Denver, p. 211) reported a similar dike swarm cut by the Garlock fault, which is probably the southeastern continuation of the Independence swarm. Total length of the Independence swarm plus that mapped by Smith is greater than 160 miles.

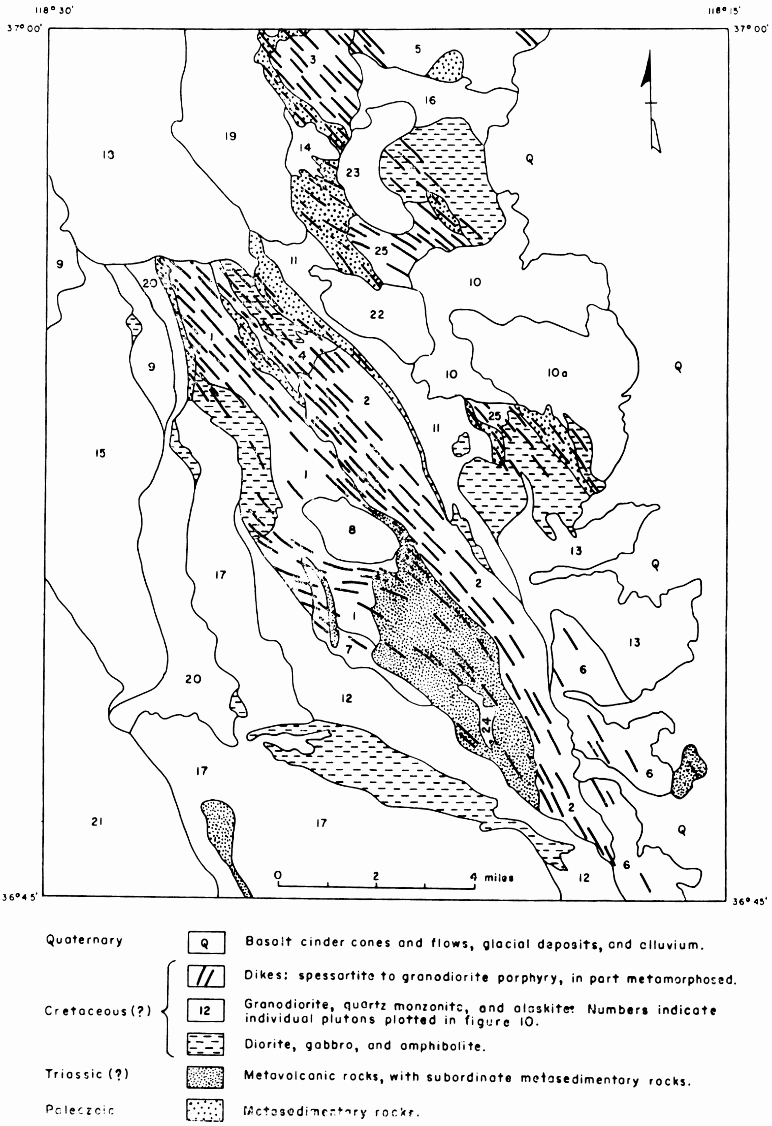

Fig. 2. Generalized geologic map of the Mount Pinchot quadrangle, California.

types. Lamprophyre, most commonly spessartite,[5] is the mafic end member of the series, and granodiorite prophyry is the usual felsic end member. The nearly complete range of intermediate types (chiefly diorite and quartz diorite

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[5] Following Rosenbusch (1887, p. 308-309), lamprophyre is used here to mean a dark-colored, fine-grained or porphyritic rock, which, if porphyritic, is characterized by two generations of ferromagnesian minerals but not of feldspar. The texture is typically panidiomorphic. Spessartite is the variety carrying sodic plagioclase and hornblende and/or augite as the principal primary minerals.

porphyries) suggests that all members of the dike swarm share a close genetic relationship. Similar dike series are known from Washington (Waters, 1927), Scotland (Flett, 1905; Bailey and Maufe, 1916; King, 1937), and Ireland (Reynolds, 1931).

The dike rocks of the Inyo Range and Alabama Hills are similar petrographically and will be described together. Those in the Sierra Nevada have been deformed and recrystallized; they are described separately.

Inyo Range and Alabama Hills.—The dikes in the Inyo Range cut Paleozoic and Triassic sedimentary and volcanic rocks. Locally they also intrude Cretaceous (?) granitic rocks (MacKevett, 1953, p. 5), and are nonconformably overlain by Pliocene (?) pyroclastic rocks. Hall and MacKevett (1958, p. 13) consider the dikes in the Darwin quadrangle to be Cretaceous (?).

Large local swarms of dikes are found along the foot of the range 6 miles north-northeast and 8 miles southeast of Lone Pine. Spessartite, diorite porphyry, and quartz diorite to granodiorite porphyry are the principal dike rocks, the darker-colored types being most abundant. These dikes average 2 feet in width, sharply transect the country rock, and display chilled margins.

The dark-colored dike rocks are generally porphyritic, with hornblende or augite phenocrysts. These mafic minerals, now almost completely altered, were originally present in the groundmass as well, giving the two-generation texture typical of lamprophyres. Plagioclase is also common as phenocrysts,

TABLE 1

Modal analyses of dike rocks, Inyo Range and Alabama Hills

Minerals	D-1	D-2	D-11
Plagioclase (altered)	42.3	42.6	35.5
Quartz	2.4	2.8	
Hornblende	7.2		30.4
Montmorillonoid			15.6
Epidote	19.4	24.0	15.1
Chlorite	18.0	22.3	
Sphene	5.5	1.3	
Leucoxene			3.4
Apatite	0.8	0.8	
Carbonate minerals	tr.	6.1	
Opaque accessories	4.4	0.1	
Total vol. %	100.0	100.0	100.0
Points counted	1098	1066	1048

D-1 Spessartite. West flank of the Inyo Range, north of Dolomite Station on the Southern Pacific Railroad.

D-2 Spessartite. Crest of the Inyo Range, two miles southeast of New York Butte. (Abundant primary hornblende and biotite in D-1 and D-2 is almost entirely altered to chlorite and epidote).

D-11 Spessartite. North end of the Alabama Hills.

Note: The above three modal analyses have low accuracy due to the extremely fine-grained and altered condition of the rocks. X-ray data suggest that the quartz content of D-1 and D-2 is higher than shown, also that considerable muscovite is present (mainly as a fine, "sericitic" alteration of the plagioclase). Staining and X-ray data also suggest the presence of potassium feldspar in all three rocks.

especially in the more felsic dike rocks. Most of the dike rocks are so intensely altered that primary minerals are scarcely recognizable. The plagioclase (originally sodic andesine) is strongly saussuritized, and the ferromagnesian minerals are decomposed to chlorite, epidote, and magnetite or hematite. Sphene and ilmenite are altered to leucoxene. Carbonate minerals have extensively replaced primary minerals in many dikes. Modal analyses of two typical spessartites from the Inyo Range are given in table 1. The more felsic dike rocks are as intensely altered as the mafic dikes. They consist of sericitized and saussuritized feldspar (chiefly sodic plagioclase), quartz, and chloritized biotite or hornblende.

Northwest-trending dikes in the Alabama Hills are as much as 30 feet wide but average 3 feet. These dikes have chilled margins and they cut Triassic (?) metavolcanic rocks in the northern part of the hills. None, however, were observed to cut the Cretaceous granitic rocks, though a detailed search was not made. The age of the dikes in the Alabama Hills, therefore, can be placed no closer than probably post-Triassic.

Petrographically the dike rocks of the Alabama Hills closely resemble those of the Inyo Range. They range from spessartite to granodiorite porphyry, the darker-colored types predominating. The mode of a typical spessartite appears in table 1. The spessartites have the panidiomorphic texture typical of lamprophyres, with two generations of euhedral hornblende (fig. 8). Plagioclase (oligioclase to sodic andesine), green hornblende, and probably biotite were the primary dike minerals, but alteration has profoundly modified the rock. The plagioclase is intensely saussuritized, and hornblende is partly changed to pale grayish green actinolitic amphibole with patches of greenish montmorillonoid. Granules of secondary epidote, patchy aggregates of fine green montmorillonoid, chlorite, leucoxene, and tiny needles of apatite are disseminated throughout the groundmass.

The intermediate and felsic dike rocks are mineralogically similar to the spessartites, but they have smaller amounts of dark minerals, and plagioclase phenocrysts are more abundant. Spherulitic granodiorite porphyry is the most felsic end member of the dike series in the Alabama Hills. The more felsic dike rocks, too, are strongly altered, so that even the most felsic appear dark colored because of the finely disseminated epidote, chlorite, and sericite.

Alteration of the dike rocks in the Inyo Range and the Alabama Hills was probably caused by residual fluids during the final stage of dike crystallization. The alteration is not localized along later fractures but is dispersed throughout the interior of each dike, decreasing in intensity toward the chilled margins. The abundance of carbonate minerals in many of these altered dike rocks indicates that CO_2-rich fluids played an important role in the alteration.

Sierra Nevada (*Mount Pinchot quadrangle*).—West of Owens Valley the dike swarm continues northwestward from the Alabama Hills with no apparent offset, cutting granitic rocks of the Sierra Nevada batholith and associated septa of metamorphic rocks. The main swarm trends diagonally through the center of the Mount Pinchot quadrangle, crossing the Sierra crest in the vicinity of Mount Baxter. It is magnificently exposed in the bare, glacially scoured basins at Twin Lakes, Woods Lake (figs. 3 and 4), and along the up-

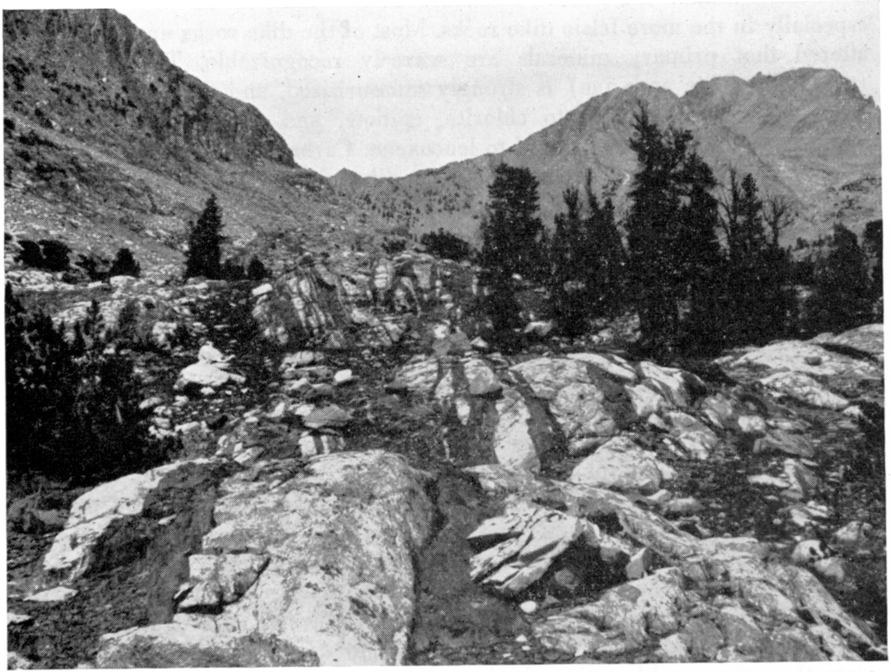

Fig. 3. Mafic dikes east of Woods Lake in the west-central Mount Pinchot quadrangle. Dikes in foreground are about 2 feet thick and dip steeply northeast.

per South Fork of Woods Creek. Farther north a second large concentration of dikes (fig. 5) crosses the Sierra crest at Taboose Pass (Knopf and Kirk, 1918, p. 71). All dikes are sharply intrusive, dilating transected planar structures (fig. 6), and displaying chilled margins.

In the Mount Pinchot quadrangle the following relations are important: granitic rocks of the Sierra Nevada batholith are intrusive into metasedimentary rocks of probable Paleozoic age, metavolcanic rocks of probable early Mesozoic age, and gabbroic and dioritic rocks of mixed origin, also of probable Mesozoic age. The granitic rocks form a mosaic of 26 elongate north- to northwest-trending plutons, commonly separated by thin concordant septa of metamorphic and dioritic rock (fig. 2). The dikes cut the metamorphic rocks and some of the granitic plutons, but are truncated by other plutons. Thus the dikes are younger than some plutons but older than others.

Radiometric dating of plutonic rocks in the eastern Sierra[6] indicates the main bulk of Sierran granitic rocks to be of Late Cretaceous age. Granitic rocks along the western foothills of the Sierra, however, are Late Jurassic (Curtis, Evernden, and Lipson, 1958, p. 10). Granitic rocks in the Mount Pinchot quadrangle have not been dated radiometrically, but their close rela-

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[6] Granitic rocks along the Sierra Nevada crest near Bishop (30 miles north of the Mount Pinchot quadrangle), dated by the zircon lead-alpha method, range in age from 90 to 111 m.y. (Faul and others, 1954, p. 265). Granitic rocks in the Yosemite region (70 miles northwest of the Mount Pinchot quadrangle), dated by the K^{40}/A^{40} age of their biotites, range from 77 to 95 m.y. (Curtis, Evernden, and Lipson, 1958, p. 12).

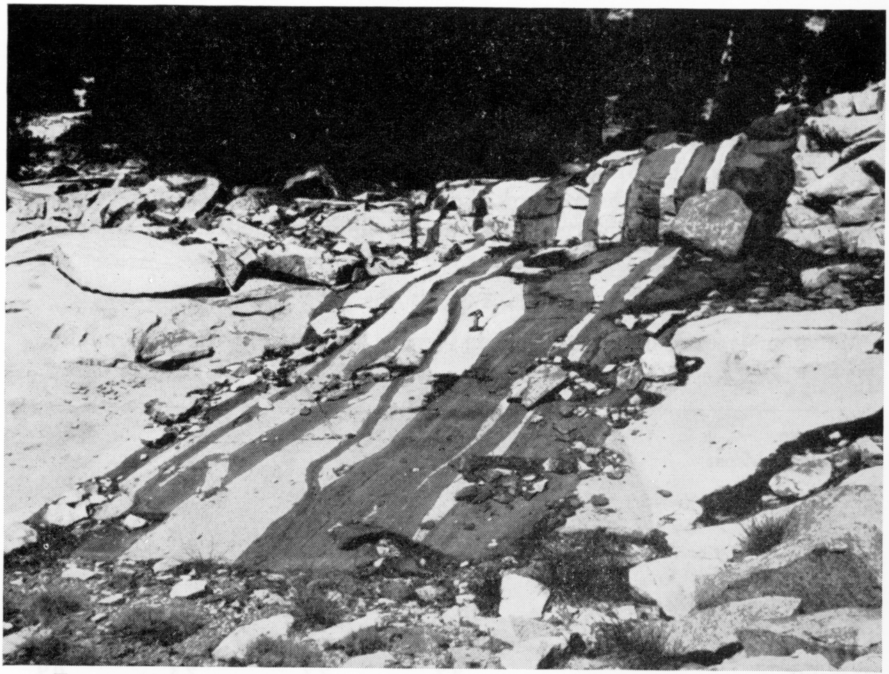


Fig. 4. Mafic dikes cutting quartz monzonite near Twin Lakes, Mount Pinchot quadrangle. Note branching and rejoining of dikes. Hammer (center) gives scale.

tionship to eastern Sierra rocks of known age indicates that they, too, are Cretaceous. The dikes, therefore, bracketed by these granitic rocks, are probably also Cretaceous.

Though little change is evident from the map pattern, many of the dikes are strongly deformed and recrystallized. They have: (1) developed internal schistosity; (2) been broken and boudinaged; (3) been mobilized and reinjected into their granitic wall rock; and (4) been partly granitized.

Internal shearing has formed a schistosity within the dikes, commonly subparallel to their contacts. The schistosity does not extend out into the wall rock. The dikes, incompetent relative to the granitic wall rock, were evidently zones of weakness along which considerable differential movement in the area was localized. In the Woods Lake region the schistosity pattern is shaped like a reversed integral sign, being oblique in the interior but curving around parallel to the contacts in the marginal portions of the dikes. The orientation of oblique schistosity in nearly every dike indicates left-lateral movement. It is not clear whether the schistosity was formed during the closing stage of dike solidification or at some later time. Cataclastic texture is lacking, showing that recrystallization outlasted or postdated the movement.

Other movements are clearly later than dike intrusion. Plastic flow of the granitic host rock has locally disrupted the dikes, leaving trains of dismembered dike fragments similar to boudins. More rarely, these disrupted dikes have themselves been remobilized, injecting the plastically deformed granitic rock. This is shown by delicate dikelets, which extend from the boudins but which are themselves not deformed by the flow which disrupted the main dike. Evidently after the plastic granitic rock had acquired sufficient rigidity to fracture, the recrystallizing mafic rock was squeezed into small dislocations.

Disruption of the dikes was locally accompanied by granitization. Parts of some dikes are replaced by light-colored, coarser, more granitic-appearing rock. Whole segments of other dikes are replaced, leaving only a nebulous outline and isolated skialiths to mark the original structure. Elsewhere replacement followed the dike margins, leaving the interior uneffected. Perhaps the dike contacts formed a channelway for the granitizing solutions.

TABLE 2

Modal analyses of dike rocks, Sierra Nevada (Mount Pinchot quadrangle)

Minerals	MP-52b	B-533	B-820b	B-428	B-727a
Plagioclase	38.7	44.7	45.6	59.6	53.5
Potassium feldspar					7.7
Quartz	0.9	1.8	3.2	1.1	10.4
Hornblende	50.5	34.9	29.5	30.1	14.8
Biotite	8.8	13.1	15.5	3.6	10.0
Epidote			1.2		0.3
Sphene	1.0	1.2	1.5	2.7	1.7
Apatite	0.1	0.9	1.3	0.6	0.7
Zircon		0.2		tr.	tr.
Magnetite		3.2	2.2	2.3	0.9
Total vol. %	100.0	100.0	100.0	100.0	100.0
Points counted	1058	1045	1054	1123	1083

MP-52b	Meta-spessartite (relict texture). Woods Lake Basin.
B-533	Meta-spessartite. One-half mile ENE of Pyramid Pk.
B-820b	Meta-spessartite. Cardinal Mountain (east ridge).
B-428	Meta-spessartite (?). Charlotte Lake.
B-727a	Mafic meta-granodiorite porphyry. Taboose Pass.

The mafic dikes, which greatly predominate over the felsic types, are green hornblende-plagioclase rocks, with biotite and subordinate quartz as common accessories. The plagioclase is calcic oligoclase to sodic andesine, unzoned in some dikes and with weak progressive zoning in others. Modes of typical mafic dike rocks from this area are given in table 2.

With few exceptions these like rocks have been partially to completely recrystallized. Relict lamprophyric texture survives in a few mildly recrystallized dikes (fig. 7), but most dikes have been transformed into granoblastic mosaics, either hornfelsic or foliated. Large "clots" of small hornblende granules are the recrystallized relics of original mafic phenocrysts.

In general the primary textures have survived better in the felsic dike rocks. In the granodiorite porphyries the groundmass is recrystallized to a fine granoblastic mosaic of feldspar and quartz, but the original plagioclase phenocrysts are well preserved. All the recrystallized dike rocks are clean and fresh, in contrast to the strongly altered dike rocks of the Inyo Range and Alabama Hills.

Fig. 5. Taboose Pass (foreground) and Goodale Mountain along the High Sierra crest, Mount Pinchot quadrangle. Abundant mafic dikes, trending northwest, are visible at the upper and lower right and at the center of the photograph (arrows). These dikes are truncated by a younger quartz monzonite pluton at Goodale Mountain (dashed line).

The mafic dike rocks were originally spessartite, rather than diabase. This is shown, in the least-recrystallized dikes, by the relict panidiomorphic, rather than ophitic texture, and by the sodic, rather than calcic plagioclase. Moreover, only the most mafic dike rocks are chemically similar to diabase.

DIKE CORRELATION

The following data suggest that the dikes on both sides of Owens Valley are of approximately the same age and belong to a single great swarm:

(1) The northwest-trending dikes in the Sierra Nevada, the Alabama Hills, and the Inyo Range are aligned, and are separated only by the alluvium in Owens Valley.

(2) The dikes on both sides of the valley are of the same rock types. They range from spessartite to granodiorite porphyry (or the metamorphosed equivalents), evidently as a continuous dike series. Relict textures and mineralogy indicate that before they were altered and metamorphosed they were very similar.

(3) The dikes from the three areas all fall in the same general composition range. In lieu of chemical analyses of the dike rocks, their compositions are compared by their specific gravities and by the refractive index of their fused beads (fig. 9). The latter, an approximate measure of SiO_2 content

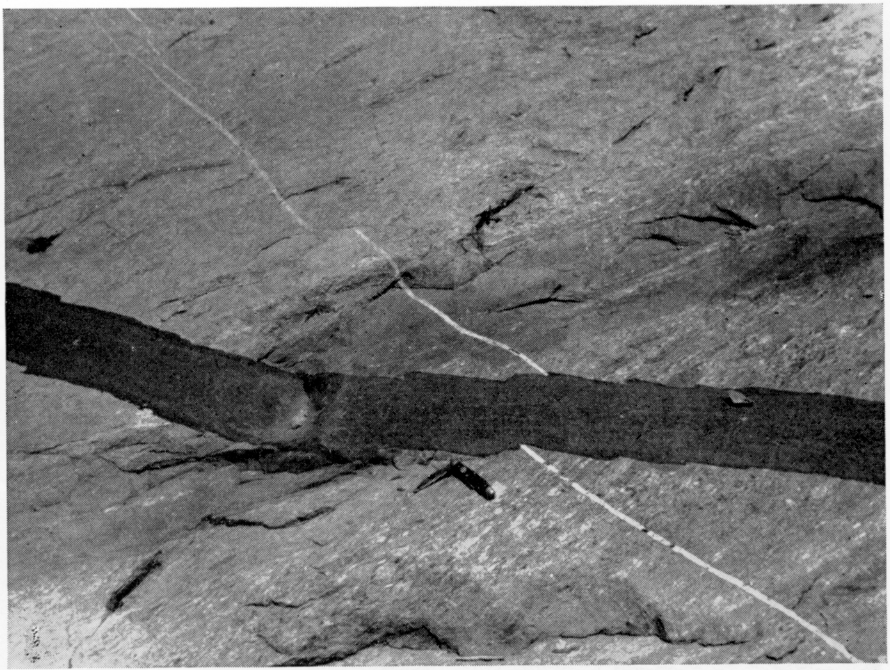


Fig. 6. Mafic dike in west-central Mount Pinchot quadrangle cutting metamorphosed volcanic breccia. The dike offsets a thin aplite dike and dark bands in the host rock perpendicular to its walls. Note matching walls, flow structure, and finer-grained, chilled margins.

(Mathews, 1951), suggests a range from about 48 percent silica (mafic dikes) to 75 percent silica (felsic dikes).

The dike ages are not in conflict with the correlation, but neither are they closely enough known to support it. The dikes in the Sierra are probably Cretaceous, those in the Inyo Range are probably post-Early Cretaceous but pre-Pliocene, and those in the Alabama Hills are probably post-Triassic.

Other mafic dikes, of decidedly different age and origin, occur near Mount Clarence King in the Mount Pinchot quadrangle. These are small, gently dipping apophyses from dioritic septa. Contact relations show these septa to be older than the granitic rocks they locally intrude. Evidently during granitic intrusion the dioritic wall rock was softened, perhaps partially melted, and squeezed into dislocations in the solidifying granite. These mobilized dioritic dikes are easily distinguished from dark-colored dikes of the northwest-trending swarm. They are not considered in the remaining discussion.

Probably all dikes of the main swarm in the Mount Pinchot quadrangle were nearly contemporaneous. In addition to forming a unified dike series no evidence for more than one period of dike emplacement has been found. For instance, there are no plutons which truncate dark-colored dikes but which are in turn cut by other dark-colored dikes. Because of the large number of plutons in the quadrangle (at least 26), and the great abundance of dikes, there would

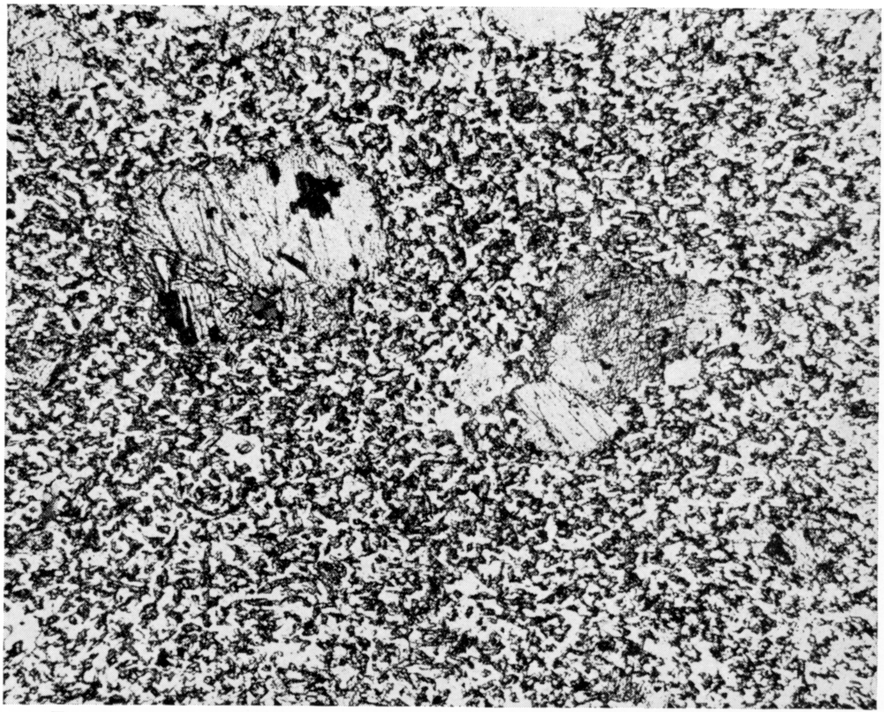


Fig. 7. Photomicrograph of a mafic dike rock from near Twin Lakes, Mount Pinchot quadrangle. Large relict phenocrysts of green hornblende, set in a recrystallized granoblastic matrix of green hornblende and andesine. Plain light, X 30.

be ample opportunity for relationships of this sort had there been more than one stage of dike intrusion.

METAMORPHISM OF THE DIKES

The deformation, recrystallization, and granitization of the dikes where they penetrate the Sierra Nevada batholith is attributed to the emplacement of the younger plutons. In the Mount Pinchot quadrangle 8 plutons, totaling about 40 square miles of present surface area, predate the dikes and serve as hosts for them. Eighteen other plutons, totaling about 120 square miles, probably postdate the dikes. Several of the plutons (numbers 10, 14, 16, and 18 of figure 2) clearly cut the mafic dikes. At the contact the dikes are sharply truncated, more coarsely recrystallized, included as broken fragments within the pluton, and cut by aplitic dikes satellitic to the pluton. However, the only criterion for other plutons' being younger than the dikes is the absence of dikes cutting these plutons.

The plutons were probably emplaced forcibly, pushing aside the wall rocks to make room for themselves. The northwest-trending, steeply isoclinally folded metamorphic rocks and elongate earlier plutons were split apart, like the pages of a book, by each succeeding pluton. Thus the earlier rocks were considerably squeezed and deformed during emplacement of the younger plutons. This

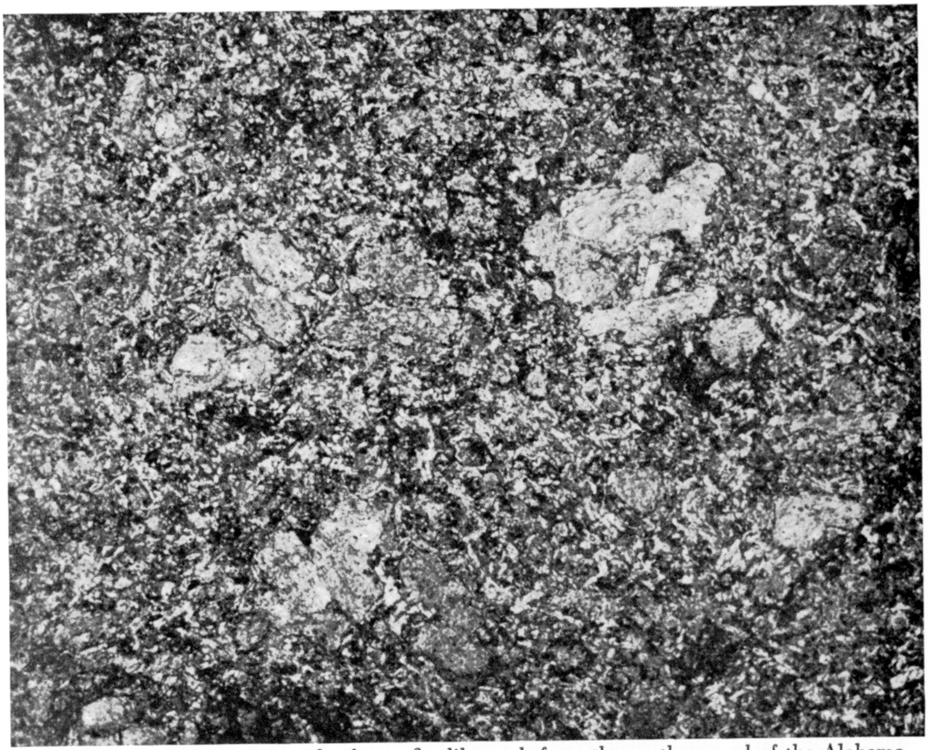


Fig. 8. Photomicrograph of a mafic dike rock from the northern end of the Alabama Hills. Green hornblende phenocrysts, set in a fine-grained matrix of hornblende, plagioclase, montmorillonoid, epidote, and leucoxene. The hornblendes are partially altered to pale grayish green actinolite amphibole, and the plagioclase is strongly saussuritized. Plain light, X 30.

deformation, together with the heat and fluids escaping from the younger intrusions, seems adequate to explain the metamorphism of the dikes.

The older granitic rocks show considerable evidence of strain, cataclasis, and recrystallization. In contrast, the primary hypidiomorphic texture of the youngest plutons remains nearly unchanged. There is no simple correlation between intensity of dike metamorphism and proximity to the contacts of younger plutons. All dike samples collected near younger plutons were indeed strongly recrystallized, and the least recrystallized specimens were quite distant from such contacts. Many intensely deformed and recrystallized dikes, however, also occur far from exposed younger plutons. This is not surprising, for the older plutons must have been squeezed, stretched, and deformed throughout to have accommodated such a vast bulk of younger intrusions.

A BREAK IN THE SIERRA NEVADA PLUTONIC SEQUENCE

In the Mount Pinchot quadrangle two groups of granitic plutons are separated by the dike swarm. The dikes have chilled margins against the earlier plutons. Furthermore, in both the pre-dike and post-dike groups of plutons the composition ranges progressively from mafic granodiorite to alask-

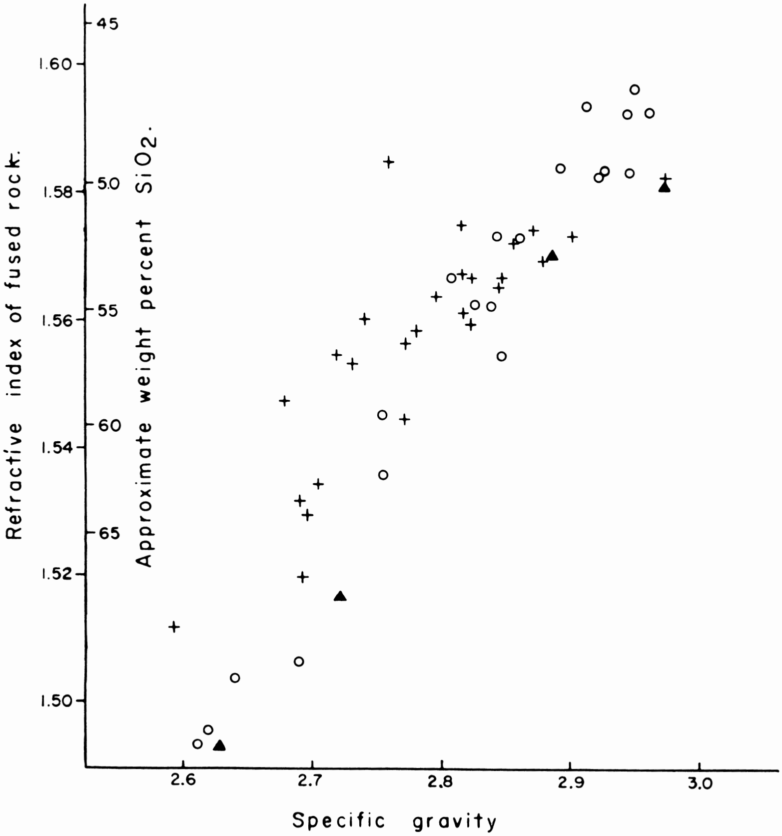
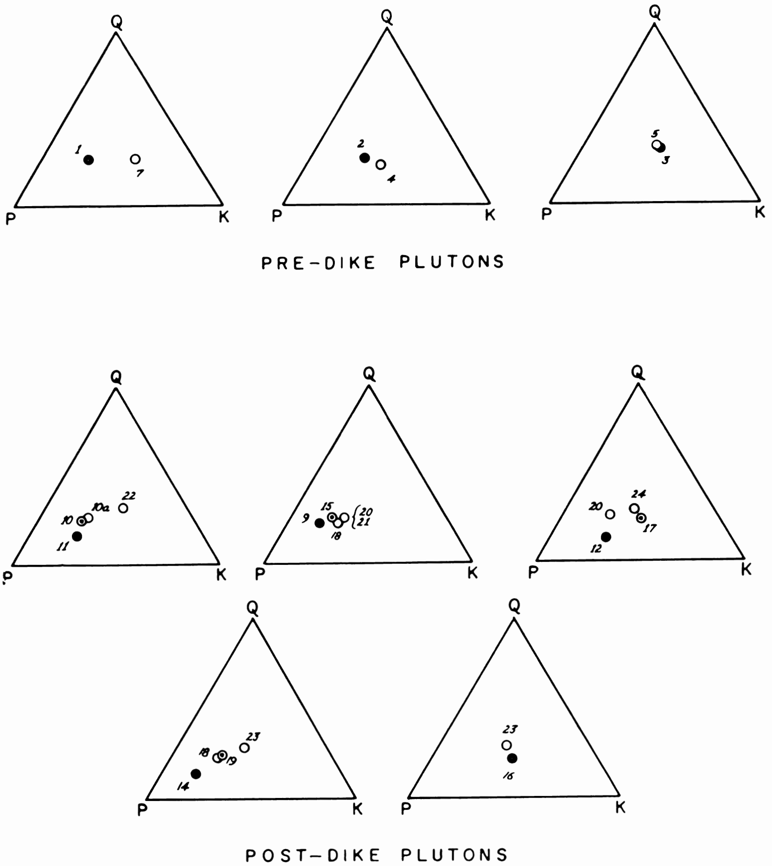


Fig. 9. Specific gravity of dike rocks plotted against the refractive index of the fused rock which is an approximate measure of percent silica (Mathews, 1951). Dikes from the Mount Pinchot quadrangle shown by circles, dikes from the Inyo Range by crosses, and dikes from the Alabama Hills by triangles.

ite, suggesting the possibility of two distinct sequences of magmatic differentiation in the area. These features indicate a larger break in time than is probably represented by intervals between successive plutons within each of the two series.

Of the 26 plutons mapped in the quadrangle 8 are older than the dikes and 18 are probably younger. The relative ages of contiguous plutons are generally shown by intrusive relations at their contacts. The known relative ages of pre-dike and post-dike plutons are shown graphically in figure 10. A complete sequence of intrusion cannot be established, because the relative ages of plutons not in contact are generally indeterminate.

Plutons of both the pre-dike and post-dike groups become more felsic with decreasing age. They are increasingly enriched in quartz and potassium feldspar (fig. 10), and show a progressively decreasing color index. This trend cannot be definitely established without knowledge of the complete sequence of intrusions (rather than of those just in mutual contact), but the fragmentary



PRE-DIKE PLUTONS

POST-DIKE PLUTONS

Fig. 10. Plots showing the change of average modal composition in successively younger plutons. Plotted in each triangle are only those plutons whose relative ages are known from observed contact relations. Solid circles represent the oldest pluton, circles with dot the intermediate pluton, and open circles the youngest pluton(s) of each group of plutons in contact. The relative age of two plutons in different triangles is generally unknown (e.g. a pluton plotted as a solid circle in one triangle may be younger than one plotted as an open circle in another triangle). Numbers correspond to plutons shown in figure 2. The plots show the general tendency for successively younger pre-dike and post-dike plutons to become progressively enriched in quartz and potassium feldspar. P, plagioclase; Q, quartz; K, potassium feldspar.

evidence available is strongly suggestive. Only one important reversal of this trend (fig. 10, plutons 17 and 20) is evident.

Only when the pre-dike and post-dike groups of plutons are considered separately does the trend for plutons to become increasingly more felsic with decreasing age become evident. If all plutons in the quadrangle were considered as a single group, numerous cases would occur in which the more felsic plutons were intruded by more mafic ones. Hence, two sequences of plutons are apparently present, each progressing from mafic granodiorite through increasingly more felsic rocks to alaskite. The dike swarm separates these two sequences.

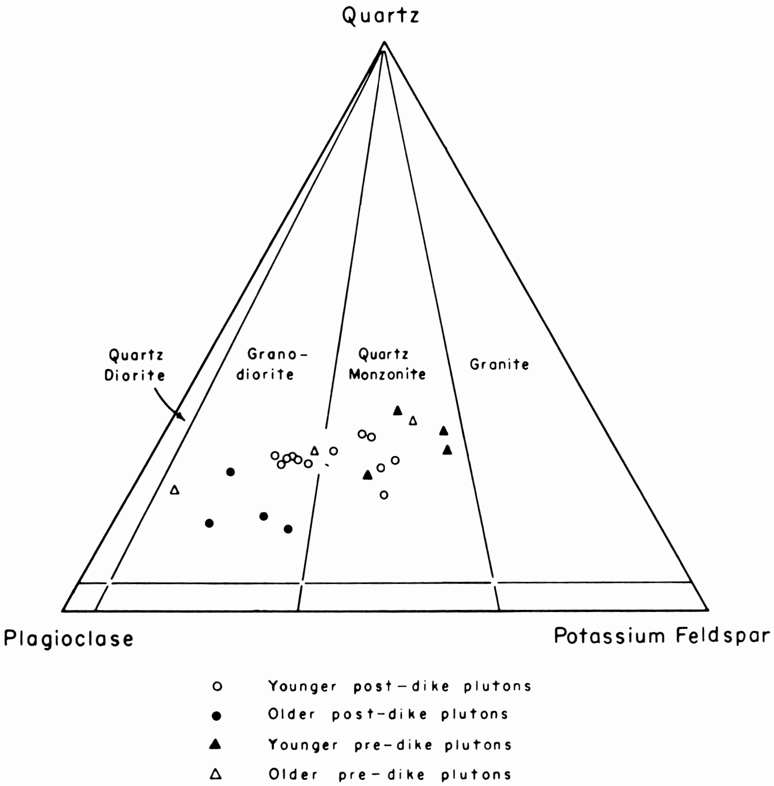


Fig. 11. Plot showing average modal composition of plutons in the Mount Pinchot quadrangle. Note the wide compositional difference between the younger pre-dike plutons and the next youngest intrusives, the older post-dike plutons. This difference emphasizes the break between the pre-dike and post-dike sequences of intrusion. Rock classification used here is modified from Johannsen (1931).

The possibility of two periods of granitic differentiation is thus indicated. It may also be significant that the break between the two sequences is marked by the greatest difference in composition of the plutons. The younger pre-dike plutons are in general the most silicic and potassic of all the granitic rocks, whereas the next succeeding group of intrusions, the older post-dike plutons, are in general the most mafic (fig. 11). This fact is difficult to reconcile if all the granitic rocks of the area represent but a single cycle of differentiation.

Metamorphosed mafic dikes have proved useful in other areas in establishing two periods of orogeny. In southwestern Finland, Sederholm used metabasaltic dikes to distinguish older and younger Archean granites (1926, p. 31-36). The dikes, intensely deformed and recrystallized during migmatization associated with formation and emplacement of younger granite, evidently mark a major break in the plutonic history of the Finnish Precambrian. Two periods of regional metamorphism and migmatization were similarly deciphered in the gneiss complex of West Greenland (Ramberg, 1948) and in the Lewisian gneisses in the North-West Highlands of Scotland (Sutton and

Watson, 1951). The dikes in each area were originally diabase, showing chilled margins against their crystalline wall rocks. Erosion to shallow depth, tension, and tapping of simatic material evidently separated periods of major plutonic activity, indicating a time interval of considerable duration between them.

In the Sierra Nevada, mafic dikes with chilled margins are similarly deformed and recrystallized. but two major orogenies are not involved. The time interval separating pre-dike and post-dike plutons was relatively short, probably only a part of a geologic period.

STRIKE-SLIP FAULTING ALONG OWENS VALLEY

Major strike-slip faulting along the line of Owens Valley has been suggested by Hill (1954, p. 10). The long, linear shape of the valley, the approximate parallelism of the valley with the San Andreas fault, and the observed strike-slip movement along small faults at the time of the 1872 earthquake (Hobbs, 1910, p. 379), suggest this possibility. But the continuation of the dike swarm along the same strike across Owens Valley without obvious offset seems to preclude strike-slip displacement of great magnitude since Cretaceous time, probably not exceeding a few miles at most.

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