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NOTES FOR FIELD FROLIC

SEPTEMBER 1-3, 1989

TO

THE ISABELLA PLUTON

LORENCE G. COLLINS

The Isabella Pluton

The evidence for a replacement origin of enclaves and their host granitoids is provided by the relationships observed in and around the Isabella pluton. The oldest rocks bordering the pluton are Paleozoic (?) Kernville metasediments (Fig. 21) consisting of weakly metamorphosed phyllites, mica schists, marbles, and quartzites (W.J. Miller, 1931; W. J. Miller and Webb, 1940; Elan, 1985). Intruded into these metasediments are gabbro and diorite, which have been dated by Rb-Sr methods as 120.1 millon years old (Kistler, written communication, 1983). Locally, the diorite and gabbro intrusions have created higher grade metamorphic zones in a thermal aureole 1.5 km wide which contains orthopyroxene, sillimanite, garnet, cordierite, and andalusite. Temperatures of 730° to 850°C at the contact and declining to 430° to 475°C at the margin of the aureole are estimated (Elan, 1985). The gabbro northwest of Isabella, California, contains olivine, but pyroxene- and hornblende-bearing gabbro are more common in other parts of the complex. Ferromagnesian silicates in the diorite are generally hornblende and biotite. Adjacent to the contact between diorite and metasedimentary rocks, xenoliths of the metasedimentary rocks persist for only a few meters and then disappear, and the diorite is enriched in biotite (up to 15 percent). This suggests that the diorite composition resulted where gabbro magma intruded the metasediments and assimilated additional K, Na, and Si to modify its composition to diorite. This hypothesis is supported by an apparent loss of K from the metasedimentary rocks in the contact aureole (Elan, 1985). Wollastonite xenolithic pods are found in a few places in the gabbro near the contact with the sedimentary rocks, and this wollastonite suggests that partial absorption of calcareous metasediments in these areas has helped to preserve the gabbroic composition.

Apparently intrusive into the gabbro-diorite masses is the Isabella 'granodiorite' pluton which varies from a quartz diorite rim to a granite core (Fig. 21). By Rb-Sr dating methods, the 'granodiorite' is 112.6 million years old (Kistler, written communication, 1983). Modal compositions for the Isabella pluton and the diorite-gabbro wall rocks are summarized in Figure 22. This figure shows that all plutonic rocks grade compositionally into each other although sharp contacts locally occur between the more granitic rocks and the diorite-gabbro body.

The evidence for an initial replacement origin of the Isabella pluton is observed in (1) the contact relationships of the diorite-gabbro mass with the Isabella pluton, (2) the changes in mineralogy, and (3) the changes in chemical composition. Each of these topics is described in more detail below.

Contact Relationships

W.J. Miller and Webb (1940) outlined the diorite-gabbro mass 7 km northeast of Isabella, California, as in irregular L-shaped body with a broad base at the south against Kernville metasedimentary rocks and tapering to a point at the northern edge against the Isabella pluton (Fig. 21). When mapped on a larger scale, however, the diorite-gabbro mass appears as an elongate, faulted body (Fig. 23). At the northern edge of the diorite-gabbro body many thousands of north-south to N15°W-trending aplite-pegmatite 'dikes' extend from the Isabella pluton into the diorite-gabbro (not shown in Fig. 23 because of their relatively narrow dimensions). (The term 'dikes' is used although these are probably nonmagmatic in origin). Southward, the 'dikes' disappear progressively until only fifteen to twenty granitic 'dikes' cut the diorite-gabbro mass on the north side of Cyrus Canyon. Here, the 'dikes' trend north-south to N15°E. South of Cyrus Canyon only two or three 'dikes' remain, and these disappear before the southern contact with the Paleozoic metasediments is reached.

The obvious assumption is that the granitic 'dikes' represent extensions of the Isabella pluton, intruding as magma into cracks and fractures in the older diorite-gabbro mass. Crosscutting relationships in a few places, sharp contacts, and contrasting mineral and chemical compositions between the two rock types seem to imply this magma origin. But if the Isabella pluton were magmatic and intrusive into cracks in the northern margin of the diorite-gabbro mass, then the many hundreds of granitic 'dikes' in this area should have spread apart the apex of the diorite-gabbro body because of the added volume of rock in the cracks. If that occurred, the diorite-gabbro mass would have opened up like a spreading fan, just as pushing matter between one's fingers will spread the fingers apart. The absence of any dilation from west to east across the northern part of the diorite-gabbro mass suggests that intrusion of magma did not occur, but instead, the granitic 'dikes' formed by volume-for-volume replacement. The thin section evidence cited below supports this.

Changes in Mineralogy

Examples of the changes in mineralogy that occur in the conversion of diorite-gabbro to granitic rocks can be observed in the diorite-gabbro wall rocks on the north side of Cyrus Canyon where the canyon cuts across the diorite-gabbro mass (Fig. 23). Here, the fifteen to twenty granitic 'dikes' range from less than 10 cm to 5 m wide and extend vertically through the mountain face and northward to join the many thousands of 'dikes' at the northern border. Progressively from 30 meters away in the diorite-gabbro wall rocks and then into the granitic 'dikes' , the thin sections show that the interlocking textures of the relatively unsheared diorite-gabbro are subjected to increasing degrees of cataclasis: broken grains, bent twin lamellae, mortar textures, and development of a foliation because of shearing. Across this same zone, progressive replacement occurs to heal the cataclastic textures and change the mineralogy. Depending upon the degree of shearing and replacement and upon the compositions of the original diorite-gabbro wall rocks, the granitic end products look like feldspathic quartzites, aplite-pegmatite 'dikes', migmatites, or well-foliated, interlayered, quartzose and mafic 'metasediments'. Each zone of replacement contains myrmekite and shows diminished amounts of pyroxene, hornblende, and biotite relative to the amounts present in the adjacent relatively unsheared, myrmekite-free diorite-gabbro. Where plagioclase exhibits bent twin lamellae, poorly developed quartz sieve textures occur in hornblende and biotite, but where the plagioclase is undisturbed, the hornblende and biotite are unreplaced by quartz. In more strongly sheared and replaced rocks, the hornblende disappears as quartz increases in abundance. Across this transition zone biotite also shows a progressive replacement by quartz, but biotite does not disappear as rapidly as hornblende, and some biotite generally remains in the granitic residue. In the early stages of replacement the plagioclase grains may retain their oscillatory zoning with calcic cores, but in the granitic aplite 'dikes', they recrystallize as unzoned crystals. The An content is reduced from higher values (An_{40-70}) in the gabbro and diorite to lower values (An_{20-35}) in the 'dikes'. In the pyroxene gabbro the sheared rocks are replaced to form 'dikes' rich in quartz (40 to 60 percent) and plagioclase (30 to 50 percent) and relatively poor in microcline (0 to 20 percent). Locally, the 'dikes' contain trace amounts of garnet and tourmaline (schorl) (J.G. Moore and others, 1983), but none occurs in the adjacent gabbro. In the biotite-hornblende diorite the sheared rocks are recrystallized as 'dikes' containing less quartz (10 to 30 percent) and more microcline (20 to 35 percent). See Appendix A for descriptions of rock samples.

At the northern boundary of the diorite-gabbro mass the same kinds of mineral changes occur in the rocks adjacent to the granitic 'dikes' as in Cyrus Canyon, but these changes occur also northward progressively into the granitic pluton. Here, the foliation of dark bands of biotite and hornblende in the diorite-gabbro mass project undisturbed into the granitic rocks of the pluton. Across a distance of 10 to 100 meters the ferromagnesian silicates gradually 'fade out'. Because of nearly complete replacement of the diorite-gabbro in this area to form a leucocratic rock, few enclaves of the diorite-gabbro are presented in the replaced rock. Here, the diorite-gabbro has been converted to granodiorite and locally to granite. In the transition zone the hornblende and biotite are replaced by quartz to form quartz sieve textures before they disappear to form larger residual quartz grains in the granitic pluton. Thus, the changes in mineralogy along the northern contact show that a granitic magma has not been physically injected into the diorite-gabbro mass to assimilate the basic components, but that some kind of 'passive process' has caused the basic components to be markedly diminished. The disappearance of ferromagnesian silicates and the residual enrichment in quartz and feldspar imply a loss of Ca, Al, Fe, Mg, Mn, and Ti (changes in chemical composition are described below).

Along the western border of the diorite-gabbro mass a narrow granodiorite unit (100 to 300 m wide) extends southward from the Isabella pluton between Kernville metasediments on the west and the diorite-gabbro body on the east. This unit is strongly sheared and foliated (Fig. 21) (J.G. Moore and others, 1983). Where the rock is rich in quartz (30 to 50 percent), locally the plagioclase may contain coarse quartz vermicules in myrmekite, which I suggest is evidence that the rock was once gabbro (see earlier discussion in Chapter 3). This assumption is reasonable because the adjacent wall rock to the east is gabbro (see samples 12 and 13, Table VI and Fig. 23). In a broad zone (300 m wide) in the gabbro adjacent to the granodiorite all stages of replacement to form granodiorite can be found, including many quartz-rich zones and pegmatites containing traces of tourmaline. At the southern end of the unit south of Cyrus Canyon, the vermicules in the myrmekite are less coarse, and the adjacent rock is diorite.

South of Cyrus Canyon this same narrow granodiorite unit is offset to the east along a fault trending east-west. Farther south the diorite-gabbro mass is offset again along a second fault trending N45°E (Fig. 23). South of this second fault, however, the rock in the same 'stratigraphic' position as the granodiorite unit north of the fault is diorite containing abundant biotite schist xenoliths. This suggests that the rock unit north of the fault at one time also contained abundant schist xenoliths, but that the additional biotite so weakened the rock structurally that it was more easily sheared and replaced by myrmekite-bearing granodiorite. In this same diorite unit south of the second fault, localized zones occur in which microcline and myrmekite replace the diorite to form more felsic rocks (sample 22, Fig. 23).

On the eastern side of the diorite-gabbro mass the contact zone is against a quartz diorite. In Cyrus Canyon (Fig. 23) the quartz diorite has a well-developed foliation parallel to the contact, and many elongated enclaves of diorite are aligned parallel to this foliation. Because of the irregularity of the contact, parts of the diorite-gabbro mass project parallel to its foliation into the quartz diorite of the pluton, and remnants of the diorite-gabbro extend from these projections as elongate enclaves. These enclaves may be ellipsoidal, subangular, or angular, and it is obvious that they have formed in place and have not been brought in from an outside source. The compositions, textures, and color are the same as the wall rock. Where the quartz diorite of the pluton grades into rocks that have a strong foliation near the contact, the mineral composition of the quartz diorite gradationally changes to granite; hornblende disappears from the quartz diorite as quartz, microcline, and myrmekite increase. In the adjacent, less sheared, poorly foliated diorite of the wall rock, hornblende and biotite exhibit quartz sieve textures, but farther into the diorite, hornblende and biotite lack replacement by quartz. Where the diorite wall rock shows less cataclasis and is only partly replaced, hornblende is still present but in lesser quantities (3 to 15 percent) than in the unreplaced diorite (15 to 25 percent). Biotite also occurs in lesser quantities in the strongly foliated diorite (5 to 10 percent) than in the unreplaced diorite (10 to 15 percent). The decrease in biotite and hornblende corresponds to a sympathetic increase in microcline and quartz. Thus, the eastern contact is also a zone of replacement, but here the replacement is incomplete because broken fragments remain as enclaves.

Farther east (100 to 500 m) from the eastern contact and into the quartz diorite of the Isabella pluton, the enclaves are more ovoid than elongate. On the east slope of a mountain ridge 0.5 km north of sample 4 (Fig. 23), large, isolated masses of 'blocky' diorite enclaves (1 to 3 m wide and 30 m long) are enclosed by quartz diorite of the Isabella pluton. The composition and texture of these masses and of hundreds of smaller, lenticular or irregular-shaped enclaves that occur in the adjacent quartz diorite are identical to the composition, texture, and physical appearance of isolated 'blocky' diorite units (10 to 30 m wide and several 100 m long) that occur in the diorite-gabbro mass in Cyrus Canyon 7 km to the northwest (Fig. 23) (Collins and Brown, study in progress). Surrounding these coarse crystalline units in the diorite-gabbro body are the more cataclastically disturbed units that may exhibit a strong schistosity and which locally are replaced by granitic 'dikes'. Because the blocky diorite in the diorite-gabbro body and the blocky enclaves in the quartz diorite of the pluton are the same rock type, it follows that the schistose diorite adjacent to the blocky diorite in the wall rock and the quartz diorite adjacent to the large blocky enclaves could be related. Chemical data support this hypothesis (given below). Because scattered enclaves and localized swarms of enclaves occur throughout the Isabella pluton, and because the same kinds of myrmekite-bearing granitic rocks (Sacatar quartz diorite) occur in diorite-gabbro masses adjacent to the Isabella pluton on its eastern border (W.J. Miller and Webb, 1940), the implication is that the whole granodiorite pluton was derived by similar replacement processes.

Changes in Chemical Composition

Chemical analyses of major and trace elements for nine Isabella plutonic rocks (samples 3 through 9, 11 and 25), ten diorite-gabbro wall rocks (samples 12 through 15, 17, 18, 20, 21, and 24), three partly replaced transition rocks (samples 16, 22, and 23), one granitic 'dike' rock (sample 9), and three Kernville biotite schists (samples 1, 2, and 10) are listed in Tables VI and VII. The modal compositions and sample locations are shown in Figures 22 and 23. The analyses for the igneous rocks have been plotted against % SiO_2 in Figures 24 and 25 to show the relative trends of the chemical data in the various rock types, but the data for the three biotite schist samples show no apparent correlation with the data for the plutonic igneous rocks and have been omitted from the figures.

Figures 24 and 25 show that as K_2O and SiO_2 increase, there is a progressive decrease of Fe_2O_3 (total Fe), MgO, Al_2O_3, TiO_2, CaO, and Mn in the rocks from both the diorite-gabbro body and the Isabella pluton; Na_2O and P_2O_5 remain nearly constant.

Pb, Ba, and Rb tend to follow the same distribution patterns as K_2O, whereas Cu, Zn, Mo, Co, and Ni show the same relative distribution patterns as Fe_2O_3 and MgO. The enrichment of Ba, Pb, and Rb in the granitic rocks probably occurs because the Ba^{+2} (1.35 Å), Pb^{+2} (1.20 Å), and Rb^{+1} (1.48 Å) ions are similar in size to the K^{+1} (1.33 Å) ion, and this allowed them to substitute for K^{+1} in microcline and biotite.

Because these distribution patterns are normally expected in differentiated rocks, these changes in major oxide and trace element contents by themselves are not proof that the Isabella pluton has been derived by replacement of portions of a diorite-gabbro body that once occupied the same volume. Nevertheless, the distribution patterns of K_2O, Na_2O, Rb, and Sr shown in Figures 24 and 25 and their direct correlation to the changes in mineralogy of the transition rocks suggest that a relationship exists, and that the Isabella pluton is derived from diorite-gabbro by replacement (prior to melting). For example, the K_2O and Na_2O contents of the original diorite-gabbro are changed in the transition rocks as the ferromagnesian silicates are replaced by quartz and as plagioclase either (1) remains or (2) becomes replaced by microcline and myrmekite. In either case Fe_2O_3 (total Fe), Al_2O_3, CaO, MgO, TiO_2, and Mn decrease during the early stages of replacement.

In the first case where the plagioclase is unreplaced by microcline and myrmekite and where biotite and K-bearing ferromagnesian silicates are replaced by quartz, K_2O also decreases (the 'granodioritization process' of Marmo, 1971). As the K-bearing ferromagnesian silicates disappear, the residue is proportionately enriched in plagioclase, which in turn enriches the whole rock in Na_2O (see arrows in Figs. 24 and 88 for the depletion of K_2O that corresponds to the enrichment in Na_2O). As K_2O decreases, Rb, whose chemical properties are similar to K, also decreases. The enrichment in plagioclase and Na_2O simultaneously enriches the rock in Sr because most common strontium is in plagioclase and not in the disappearing ferromagnesian silicates. But some radiogenic strontium, ^{87}Sr, is lost with the Rb that goes out with the K_2O (see later discussion in Chapter 7). Therefore, the simultaneous increase in Sr and SiO_2 in sheared and replaced transition rocks and the subtraction of other trace elements and major oxides cause a change in chemical composition: mafic gabbro or diorite in the wall rock converts to felsic quartz monzodiorite, quartz diorite, or granodiorite. Although the residual chemical compositions resemble compositions of felsic rocks, their present modal compositions cause them to be classified as quartz diorite, tonalite, or mafic granodiorite. Note the abrupt shift of the transition rocks shown in Figure 25 (ppm Sr versus % SiO_2) from the diorite-gabbro trend to the trend of the more felsic Isabella plutonic rocks. This compositional shift is unexpected when the rocks are examined at the outcrops because the converted diorite-gabbro rocks with a faint foliation are just as black as the adjacent unaltered, relatively unsheared, massive diorite-gabbro, but now the black, converted diorite-gabbro rocks have the same chemical composition as the more leucocratic Isabella 'granodiorite' rocks.

In the second case in which the plagioclase in the transition rocks is partly replaced by microcline and myrmekite, there is an increase in K_2O, Rb, and SiO_2 and a decrease in common Sr (see Figs. 24 and 25). In early stages of this replacement the rocks are still relatively dark black, but their chemical compositions are converted from mafic gabbro or diorite to that of felsic granodiorite or granite. These rocks also shift from the diorite-gabbro trend to the trend of the Isabella plutonic rocks (Figs. 24 and 88; see ppm Sr versus % SiO_2). Therefore, if continued replacement of the ferromagnesian silicates occurs and if melting takes place where the rocks have been converted to more granitic compositions, the transition rocks can crystallize from a magma as quartz monzodiorite, granodiorite, or granite. All are found in different parts of the Isabella pluton. In the midst of these plutonic igneous rocks, island remnants of unsheared and unreplaced blocks of the diorite-gabbro occur as scattered microgranitoid enclaves, and some of these remnant masses carry microcline and myrmekite preserved from early stages of replacement of these rocks. The oscillatory zoning in the plagioclase provides evidence for melting in the plutonic rocks that surround the enclaves. There is a possibility that these zoned plagioclase crystals are inherited as xenocrysts from the diorite-gabbro, but their lower An content suggests that they were replaced and recrystallized in an earlier cycle and then were melted in place.

These arguments support my hypothesis that the Isabella pluton was once a diorite-gabbro mass, whose composition varied from place to place. Some places were richer in biotite, others in hornblende or pyroxene. Where shearing occurred, hydrous fluids introduced SiO_2 plus K_2O; and these fluids removed basic elements, resulting in a cataclastic residue of more granitic composition than before the shearing. Where the temperatures became hot enough to melt this residue, the end products were the various relatively felsic facies of the Isabella pluton. Finally, any isolated or massive areas subjected to minimal shearing and replacement became wall rocks or island remnants (microgranitoid enclaves) scattered throughout the pluton. These changes resulted from a single cycle of cataclasis.

More than one cycle of cataclasis produced several different results. After the solidification of the felsic quartz diorite, granodiorite, and quartz monzodiorite of the Isabella pluton, a later episode of shearing and replacement of these plutonic rocks in a second cycle resulted in the formation of rim myrmekite on the primary oscillatory zoned plagioclase and locally deformed the earlier-formed enclaves into elongate or lenticular shapes. In moderately or intensely sheared and replaced zones, introduced K_2O replaced the plagioclase to form microcline megacrysts with wartlike myrmekite and changed the rock composition to quartz monzonite or granite. Any remnant enclaves in these more granitized rocks were destroyed as the rock became more leucocratic.

On the one hand, melting temperatures created felsic granitic rocks of the Isabella pluton without myrmekite in some parts of the terrane (one cycle). But later these rocks were replaced by quartz monzonite and leucogranite with rim myrmekite and wartlike myrmekite (a second cycle). On the other hand, in these same two cycles low temperatures below the melting interval for granite created granitic replacement 'dikes' and 'transition rocks' in other parts of the terrane (the wall rocks). That parts of the diorite-gabbro body did not become hot enough to cause melting is evident by the preserved cataclastic textures in these rocks. The continued replacement of the ferromagnesian silicates in these rocks created the various kinds of granitic 'dikes' and migmatites. Where K_2O and Rb were introduced, the plagioclase was replaced by microcline and myrmekite; where SiO_2 entered, the ferromagnesian silicates were replaced by quartz. This decreased the total Sr content as well as the amounts of CaO, Al_2O_3, TiO_2, Fe_2O_3 (total Fe), MgO, and Mn, as the SiO_2 content increased. Note that the granitic 'dikes' plot in Figure 24 in the same place as the granitic rocks of the Isabella pluton. This coincidence of data points occurs because both granitic rock types have similar chemical compositions and are derived from the same parent rocks. The timing of their transformation to granite, however, as indicated by Rb-Sr dating methods, is different (see discussion in Chapter 7).

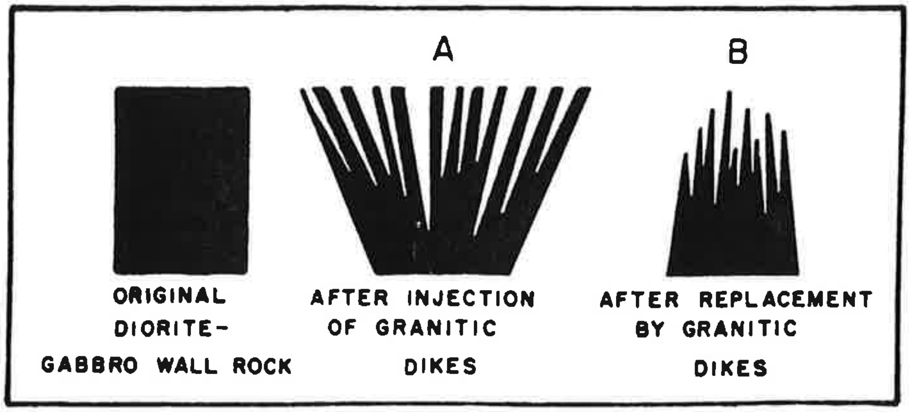
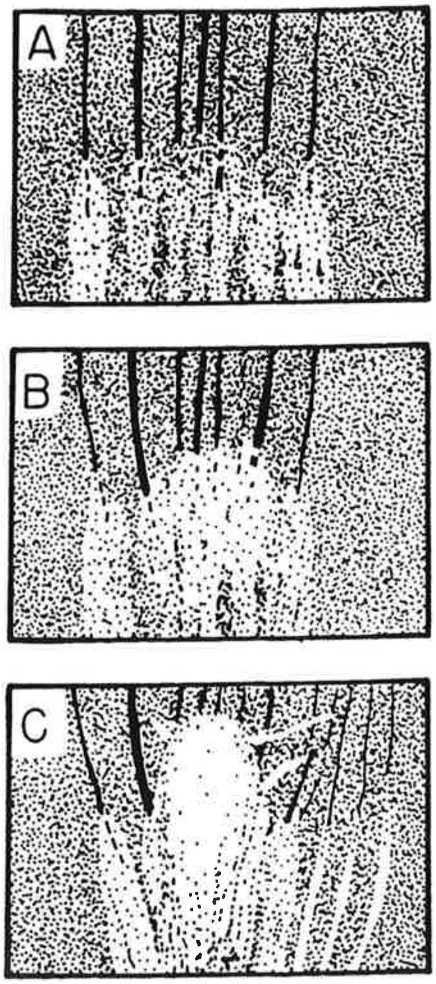


Figure 5. Diagram to show (A) the effects of physical injection of magma to form granitic dikes versus (B) the effects of replacement to form granitic dikes.



◀ Figure 4. Diagram to show stages in the origin of the Isabella pluton and its enclaves. A. Original, massive diorite-gabbro with localized vertical shear zones where hydrous fluids have introduced silica causing replacement of mafic silicates by quartz to form a leucocratic residue. Elements that were displaced from the mafic silicates were carried upward and deposited in over-lying lamprophyres, skarns, appinites, and mafic volcanic rocks (shown only in part as black feeder-dikes). B. Continued localized replacement of sheared rocks by silica- and potassium-bearing fluids formed myrmekite-bearing granitic rocks. Island remnants of unreplaced blocks form enclaves. C. Local melting and upward plastic flow of magma formed a granodiorite pluton that transported remnant enclaves of former diorite-gabbro. Replacement aplite and pegmatite dikes formed in marginal wall rocks.

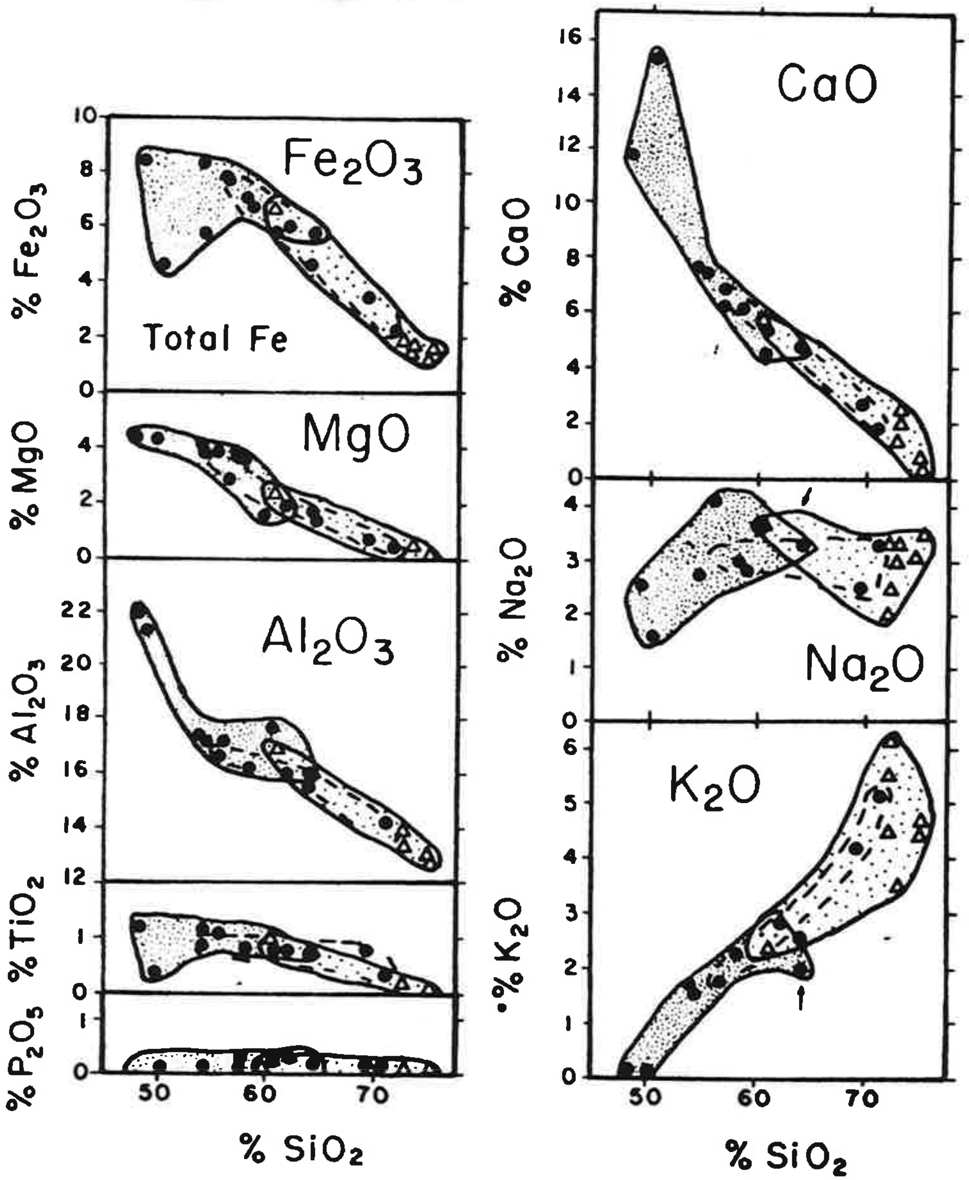


Fig. 24. Percent compositions of major element oxides plotted against weight percent SiO_2 for rocks in and near the Isabella pluton; data from Tables VI and VII. Solid circles in dark-dotted field = diorite-gabbro; and open triangles in light-dotted field = granitic rocks of the Isabella pluton. Field outlined by dashed lines enclose samples 16, 22, and 23, which are transition rocks between diorite-gabbro and the granitic rocks of the Isabella pluton. Data for biotite schist samples (1, 2 and 10, Table VII) have been omitted. Arrows show decrease in K_2O and increase in Na_2O; see also Figure 88.

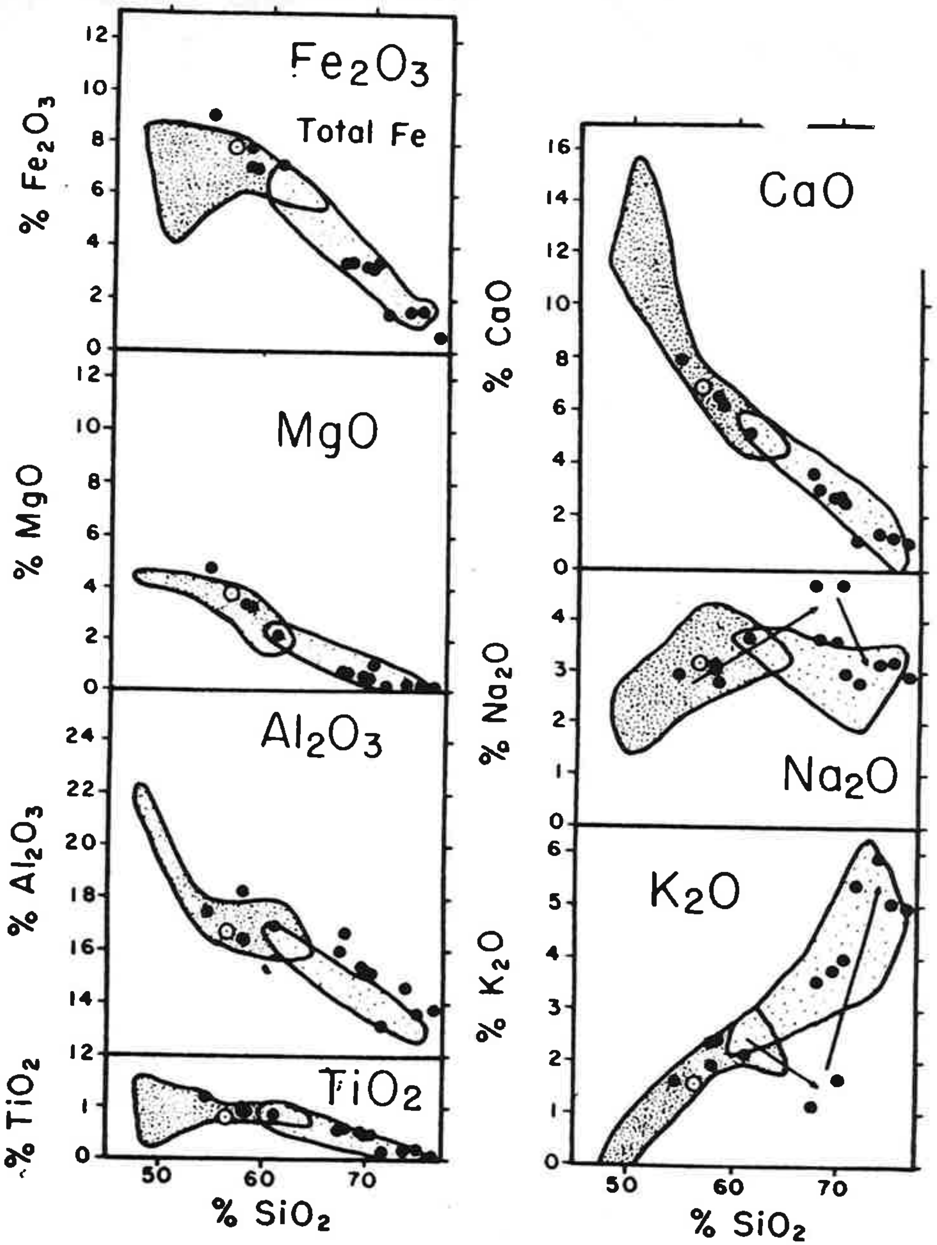


Fig. 88. Weight percentages of major oxides plotted against % SiO_2 for sample nos. 13-16 and 33-44 (black dots), including diorite, transition rocks, and aplite 'dikes' in diorite-gabbro wall rocks adjacent to the Isabella pluton. Open circle = sample no. 16. Outlined fields trace positions of diorite-gabbro wall rocks (dark shaded field) and granitic rocks of the Isabella pluton (light shaded field) shown in Figure 24. Arrows indicate relative loss of K_2O and proportional enrichment in Na_2O; see also Figure 24.

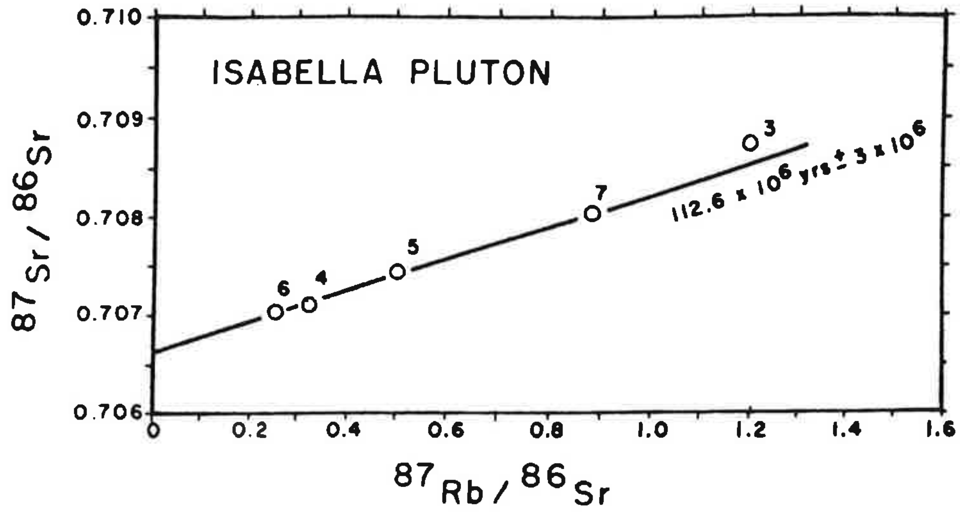


Fig. 91. Isochron plot of rocks in the Isabella pluton. Data are taken from Table XV.

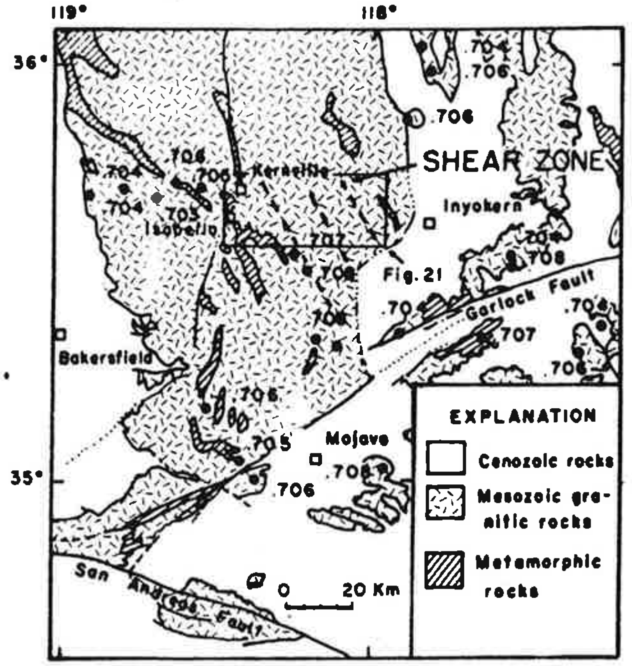


Fig. 92. Generalized geologic map of vicinity of Garlock Fault zone, California, showing $^{87}Sr/^{86}Sr$ initial ratios of granitic rocks (after Kistler and Peterman, 1978, but adding shear directions near the Isabella pluton and changing the style of presentation). Small, elongate rectangle enclosing the cities of Kernville and Isabella shows position of Figure 21. Dashed lines indicate trend of shear zones that have created cataclastic textures in the diorite-gabbro wall rocks and the trend of schlieren and myrmekite-bearing granitic bands in the pluton.

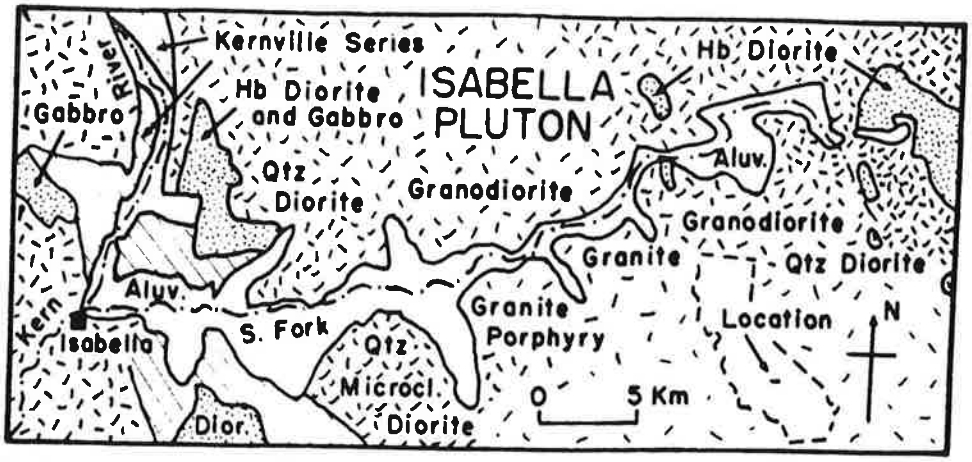


Fig. 21. Geologic map of the Isabella pluton, showing location of hornblende (Hb) diorite and gabbro wall rock and the Kernville metasedimentary series; see text. (Modified after W.J. Miller, 1931, and W.J. Miller and Webb, 1940, keeping their generalized map pattern but emphasizing locations of different rock facies).

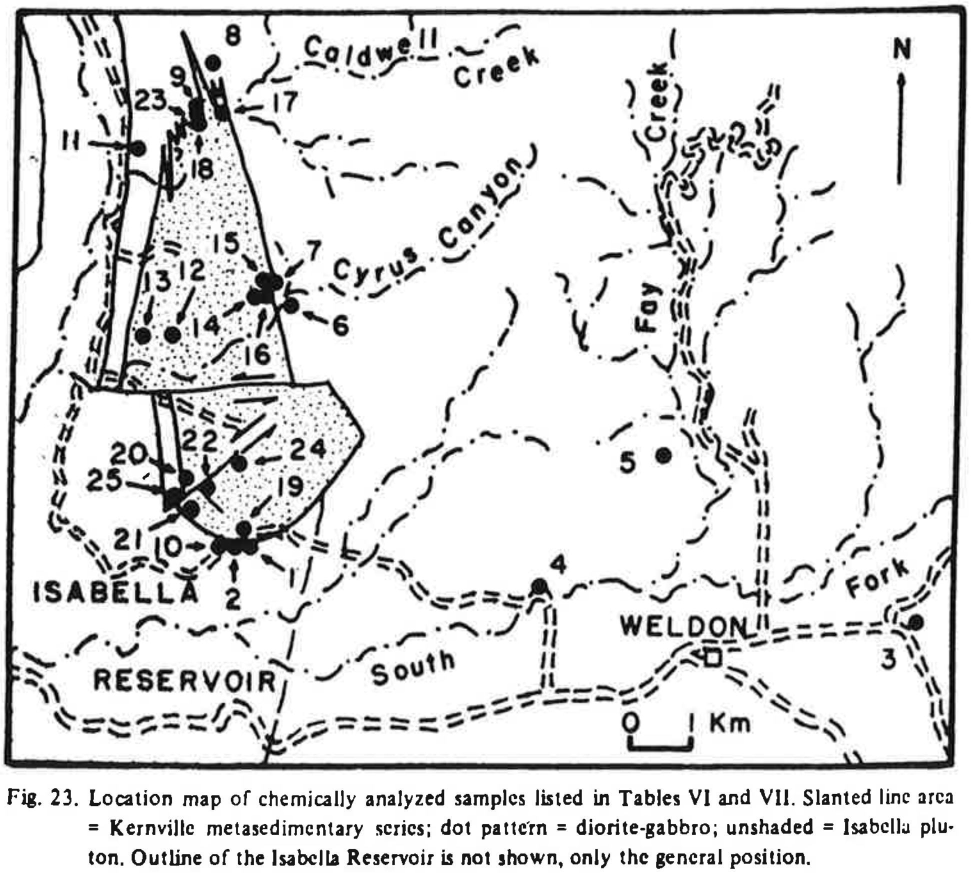


Fig. 23. Location map of chemically analyzed samples listed in Tables VI and VII. Slanted line area = Kernville metasedimentary series; dot pattern = diorite-gabbro; unshaded = Isabella pluton. Outline of the Isabella Reservoir is not shown, only the general position.

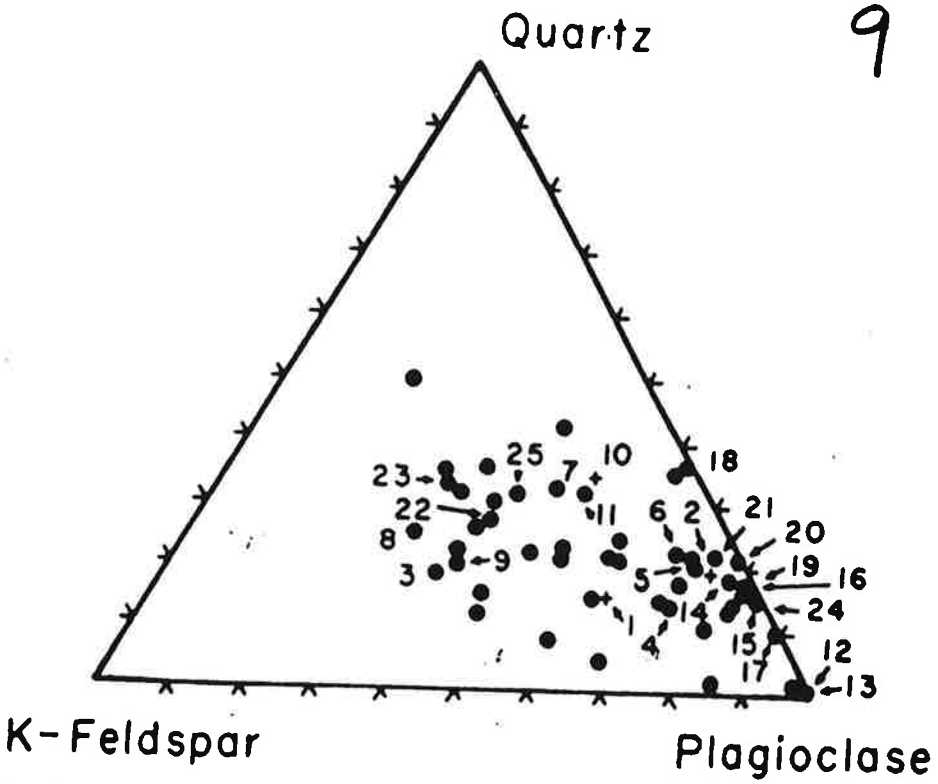
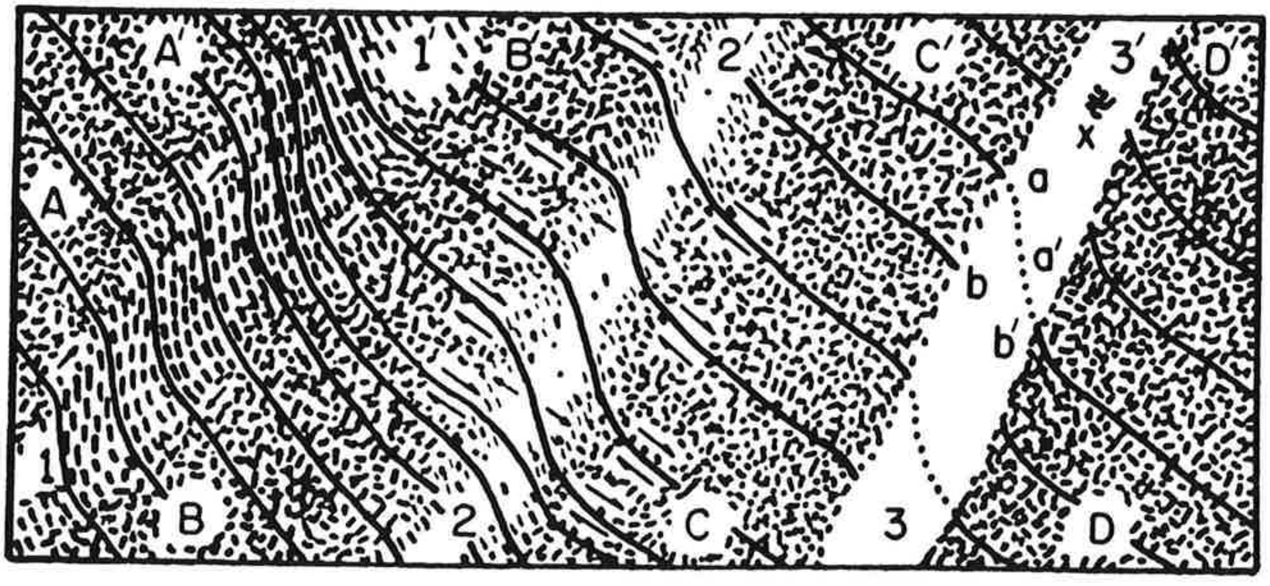


Fig. 22. Triangular diagram showing relative modal percentages of quartz, plagioclase, and K-feldspar of rocks in and near the Isabella pluton. Numbers 1 to 25 correspond to chemically analyzed samples (see Tables VI and VII). Solid dots represent igneous rocks; plus signs represent metasedimentary biotite schists (samples 1, 2, and 10).



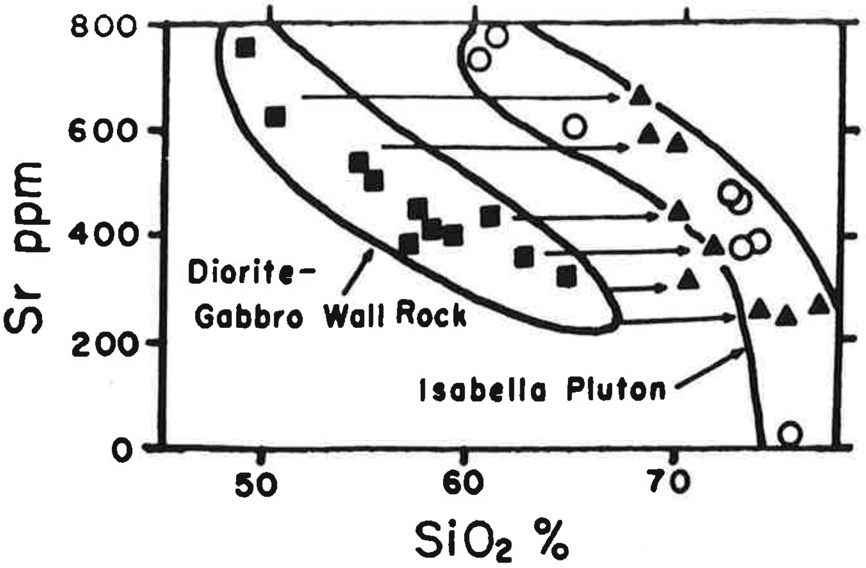


Figure 3. Plot of strontium in parts per million (Sr ppm) versus the percent by weight of silica SiO_2, showing data for diorite-gabbro wall rocks (field with solid squares); sheared and replaced, diorite-gabbro wall rocks (solid triangles); and various facies of the Isabella pluton (field with open circles). Arrows indicate hypothetical shift in chemical composition as quartz replaces biotite and hornblende in cataclastically disturbed diorite-gabbro (Collins, 1988).

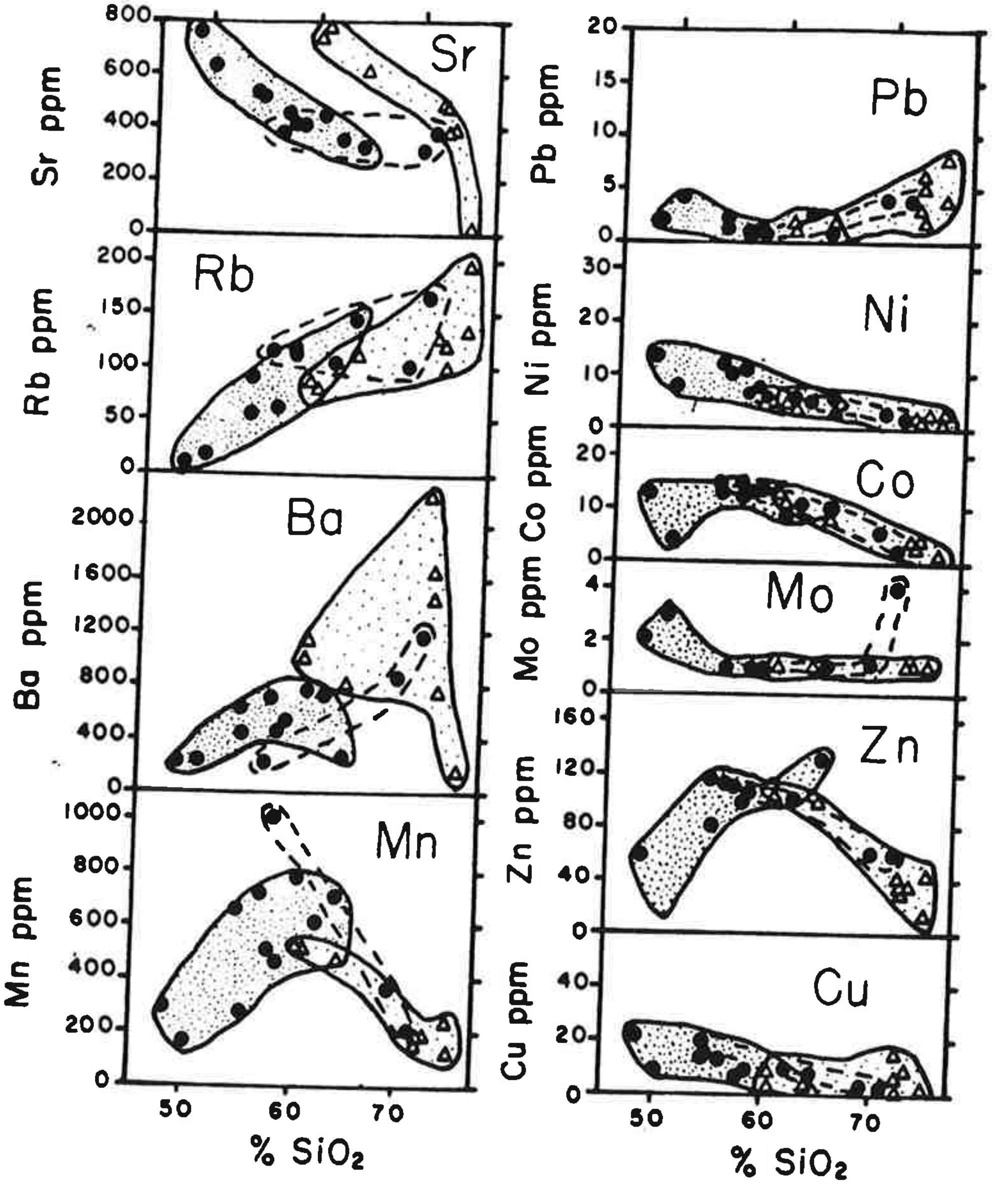


Fig. 25. Parts-per-million compositions of trace elements plotted against weight percent SiO_2 for rocks in and near the Isabella pluton; data from Tables VI and VII. Outlined fields are the same as those shown in Figure 24.

TABLE VI.
CHEMICAL ANALYSES OF MAJOR AND TRACE ELEMENTS IN THE ISABELLA PLUTON AREA.

Sample No.	Wall Rocks										Transition Rocks		
Wt. %	12	13	14	15	16	17	19	20	21	24	18	22	23
SiO_2	48.73	50.21	58.35	57.84	56.66	54.71	60.54	56.93	62.42	54.39	64.33	69.69	71.48
Al_2O_3	21.91	21.36	16.32	16.41	16.70	17.10	17.58	17.21	16.03	17.43	16.04	14.11	14.39
Fe_2O_3	8.38	4.50	6.87	7.06	7.75	8.45	6.55	8.12	6.10	8.51	5.72	3.37	2.23
TiO_2	1.49	0.41	0.92	0.93	0.80	1.14	0.79	1.08	0.80	1.14	0.73	0.40	0.28
MgO	4.44	4.39	3.28	3.31	3.76	3.85	1.47	2.97	1.95	4.05	1.62	0.90	0.26
CaO	11.77	15.37	6.18	6.45	6.85	7.36	4.54	6.20	4.57	7.53	3.78	2.61	1.57
Na_2O	2.39	1.59	2.76	3.05	3.13	2.79	4.01	4.21	3.14	2.95	3.23	2.55	3.25
K_2O	0.23	0.17	2.42	2.33	1.53	1.58	2.20	1.78	2.87	1.69	2.00	4.19	5.19
P_2O_5	0.15	0.08	0.13	0.11	0.27	0.24	0.24	0.26	0.34	0.23	0.17	0.13	0.06
LOI	0.82	0.74	1.11	1.23	1.70	0.42	0.65	1.05	0.79	1.04	0.92	0.67	0.58
Total	100.30	98.82	98.34	98.72	99.15	97.64	98.57	99.81	99.01	98.96	98.54	98.62	99.29
ppm													
Cu	22	9	8	6	16	13	6	11	10	19	5	6	3
Mo	2	3	1	1	1	1	1	1	1	1	1	1	4
Pb	2	4	1	1	2	1	1	1	3	2	1	4	4
Zn	58	21	100	95	112	82	117	110	100	110	130	60	60
Ni	14	8	7	8	12	10	4	6	5	12	5	3	1
Co	13	3	13	13	15	13	8	12	11	15	8	5	1
Mn	285	165	480	505	1,000	270	780	720	600	630	710	360	190
Ba	220	220	500	440	220	640	800	680	700	420	260	860	1,200
Rb*	10.0	13.5	117.0	110.0	113.0	57.7	71.6	57.7	103.0	91.2	148.0	99.5	171.0
Sr*	780.0	623.0	408.0	407.0	384.0	517.0	459.0	471.0	366.0	521.0	318.0	306.0	392.0

Analyses by Chemex Labs Ltd., except for Rb and Sr. LOI = loss on ignition

* Analyst R. Kistler

TABLE VII.
CHEMICAL ANALYSES OF MAJOR AND TRACE ELEMENTS IN THE ISABELLA PLUTON AREA.

Sample No.	Schist			Isabella Pluton								
Wt. %	1	2	10	3	4	5	6	7	8	9	11	25
SiO_2	54.34	59.88	48.74	72.58	60.23	64.35	60.61	73.05	72.26	72.58	74.96	75.22
Al_2O_3	19.36	17.29	25.59	13.66	16.92	15.51	16.81	13.52	13.64	14.07	13.04	12.84
Fe_2O_3	7.52	9.52	11.79	1.74	6.56	4.48	5.92	1.80	1.95	1.31	1.64	1.25
TiO_2	0.93	1.14	1.25	0.19	0.91	0.68	1.01	0.25	0.26	0.23	0.09	0.05
MgO	2.85	2.74	2.95	0.23	2.68	1.46	2.29	0.48	0.40	0.26	0.01	0.01
CaO	6.63	1.63	0.23	1.15	5.58	4.00	5.34	2.38	1.70	1.88	0.55	0.45
Na_2O	3.00	1.53	0.03	2.51	3.68	3.58	3.73	3.01	2.02	3.19	3.50	3.13
K_2O	1.31	2.56	4.10	6.24	2.28	2.62	2.30	3.45	5.55	4.50	4.40	4.73
P_2O_5	0.13	0.07	0.03	0.04	0.26	0.19	0.29	0.04	0.11	0.07	0.01	0.03
LOI	1.44	2.08	4.06	0.41	0.72	0.68	0.65	0.56	0.47	0.43	0.57	0.85
Total	97.51	98.44	98.77	98.75	99.82	97.55	98.95	98.54	98.36	98.52	98.77	98.56
ppm												
Cu	50	15	33	2	13	8	4	7	17	5	3	4
Mo	1	2	3	1	1	1	1	1	1	1	1	1
Pb	4	1	10	5	1	2	2	2	3	6	4	8
Zn	143	120	165	40	110	97	102	35	35	28	45	18
Ni	43	47	50	1	5	4	6	3	2	1	2	3
Co	15	17	22	2	12	8	10	3	3	3	1	1
Mn	605	670	480	180	520	445	510	185	135	155	240	115
Ba	1,780	320	540	1,440	980	820	1,180	760	2,250	1,660	160	160
Rb*	67.5	123.0	122.0	195.0	82.9	107.0	69.3	116.0	124.0	99.0	195.0	133.0
Sr*	445.0	165.0	35.6	470.0	732.0	615.0	776.0	378.0	480.0	366.0	29.6	28.9

Analyses by Chemex Labs Ltd., except for Rb and Sr. LOI = loss on ignition

* Analyst, R. Kistler