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K-FELDSPAR MEGACRYSTS FROM A PORPHYRITIC QUARTZ MONZONITE CENTRAL SIERRA NEVADA, CALIFORNIA

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ABSTRACT

Microcline megacrysts in samples of quartz monzonite from the Cathedral Peak pluton have higher Ba contents and lower obliquities than groundmass microclines. These observations suggest that the megacrysts crystallized earlier than the groundmass microclines.

INTRODUCTION

The Cathedral Peak porphyritic quartz monzonite is part of the Cretaceous Tuolumne intrusive series located in the east central Sierra Nevada, California, between Yosemite Valley and Mono Lake. It is believed (Bateman *et al.*, 1963) that the concentric arrangement of the plutons of this series was formed by a single mass of magma which crystallized in time from rim to core and that the contacts between the units originated by upward pulses of the core magma.

The Cathedral Peak pluton has recently been studied in detail by Broderson (1962). Most of the pluton contains megacrysts of microcline perthite having maximum dimensions of 1 to 3 inches, although rocks varying from slightly porphyritic quartz monzonite (maximum dimensions of microcline megacrysts = 1 inch) to aplite (dikes) occupy a small area. Dimensional orientation of the megacrysts is common near the margins of the pluton. Portions of the Half Dome quartz monzonite near the contact with the Cathedral Peak pluton contain microcline megacrysts.

Other plutons containing microcline megacrysts are widespread to the north and south of the area shown in Figure 1 (Broderson, 1962).

There has been considerable controversy as to the relative times of growth of K-feldspar megacrysts and groundmass minerals in the porphyritic granitic rocks of the Sierra Nevada. Some workers (Bateman *et al.*, 1963; Broderson, 1963) suggest that the megacrysts are magmatic, whereas others (Bradley and Lyons, 1953) contend that they are postmagmatic. The present study is an attempt to aid in the solution of this dilemma.

SAMPLES STUDIED

Three samples of porphyritic rock from the Cathedral Peak pluton were studied (Fig. 1). Samples 460 and 464 are typical Cathedral Peak

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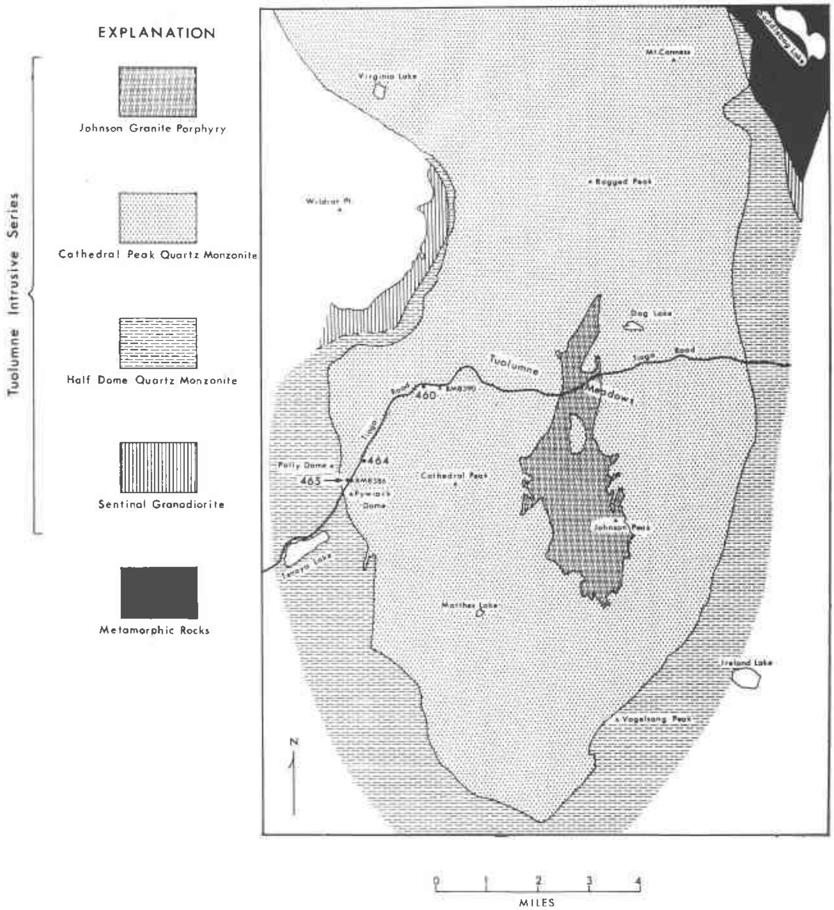

FIG. 1. Map of the southern part of the Cathedral Peak pluton and related plutons, showing location of samples studied (geology from Broderson, 1962).

rocks and contain 25 to 35 percent (by volume) of microcline perthite megacrysts in a groundmass of plagioclase, quartz, perthite, biotite, hornblende and accessories. Sample 465 is from a cluster of megacrysts containing perhaps 50 percent megacrysts. Such megacryst clusters are common near the external contacts of the Cathedral Peak pluton (Fig. 2).

The megacrysts are perthitic, containing patches and stringers of well-twinned, exsolved plagioclase, and enclose all mineral species which also occur in the groundmass. The grain size of plagioclase and quartz included within the megacrysts is appreciably smaller than that in the groundmass. Mafic minerals are concentrated in zones parallel to the margins of

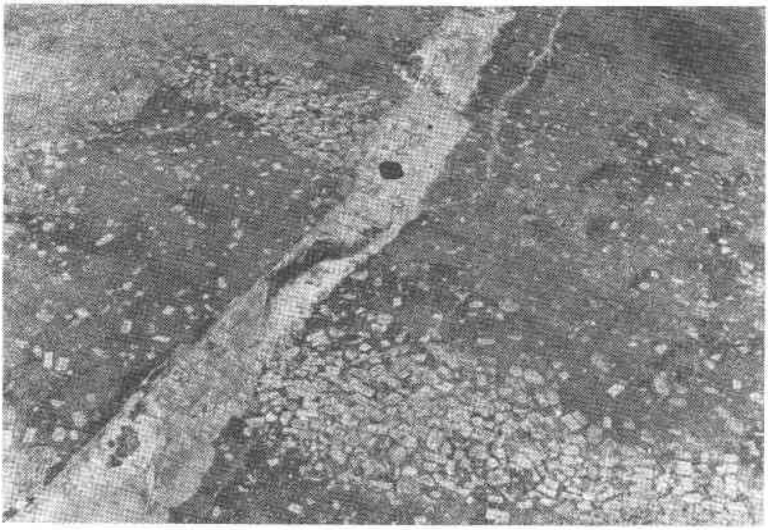

FIG. 2. Cluster of K-feldspar megacrysts and coarse-grained quartz-K-feldspar dike. Dike apparently filled fault which caused right-lateral displacement of megacryst cluster. Locality: near contact with metamorphic rocks west of Saddlebag Lake.

the crystals (Fig. 3). In sample 464 the included plagioclase[1] shows a strong preferred orientation of the broad (010) faces parallel to the margins of the host megacrysts.

Electron Microprobe Analyses

Electron probe microanalyses were made on megacrysts, included minerals within the megacrysts and on groundmass minerals. The resultant data are given in Tables 1, 2 and 3. For feldspars, only analyses which total more than 98 mole percent Or+Ab+An+Cn are given. Probe traverses were made from rim to center of the megacrysts; the distance between successive analyzed points was about 400 microns. Centers of the crystals were determined by the concentric arrangement of mafic minerals (Fig. 3).

Microclines. The only apparent difference observed between analyses of the megacrysts and the groundmass microclines is the generally higher Ba contents of the former compared to the latter (Fig. 5). Megacrysts of samples 460 and 464 are relatively high in Ba throughout, while the cen-

[1] The writer uses the term "included plagioclase" for large, euhedral to subhedral crystals incorporated during growth of the megacrysts (Fig. 4), while "exsolved plagioclase" is used for the albitic aggregates forming the perthitic texture.

tral part of the megacryst of sample 465 has a core high in Ba and a rim with Ba values similar to the groundmass microclines. In hand specimen, the central high-Ba parts of the megacrysts of sample 465 are light gray, visibly contrasting with the low-Ba rims which are pinkish and resemble groundmass microclines. The maximum celsian content found is nearly 5 mole percent (sample 464). Beam scanning for Ba shows that the areas of high Ba are in the form of irregular patches.

Large, irregular variations exist in the K and Na contents of both the megacrysts and groundmass microclines (Table 1). No apparent correlation exists between the Ba content and the Or/Ab ratio of successive analyzed points within the microclines. It is probable that some ex-

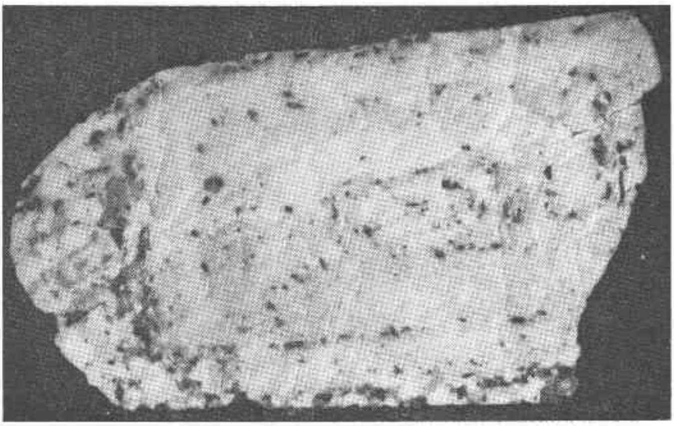

Fig. 3. Microcline megacryst showing concentric zones of mafic minerals (mostly hornblende). Length of specimen, 2.5 inches. Sample 464.

tremely sodic points (*e.g.* groundmass microclines of sample 465) represent contamination by exsolved plagioclase. In thin section, the exsolved plagioclase occurs as moderately coarse aggregates and the surrounding microcline appears to contain no exsolved plagioclase (Fig. 4). Because of the coarseness of the perthite, most exsolved plagioclase exposed to the beam was readily detected by fluorescence. It is believed that the Na/K variations observed in most cases are the chemical variations of the optically homogeneous host microclines. Piwinskii (1968, p. 216) also notes large, random variations in the Or and Ab contents of K-feldspars in Sierra Nevada granitic rocks.

Plagioclase. Probe analyses were made on included and groundmass plagioclase in samples 464 and 465. Both included and groundmass plagioclase are irregularly zoned from calcic cores to sodic rims. In both sam-

TABLE 1. OR, AB AND AN CONTENTS OF K-FELDSPARS FROM SAMPLES OF CATHEDRAL PEAK PORPHYRITIC QUARTZ MONZONITE[a]

	Orthoclase (mole %)	Albite (mole %)	Anorthite (mole %)
460 megacryst			
max.	95.5	11.8	—
min.	84.8	2.4	—
av	87.8 (33)	11.3 (33)	—
460 groundmass			
max.	92.8	39.3	3.0
min.	59.7	5.1	—
av	88.1 (24)	10.2 (24)	.4 (10)
464 megacryst			
max.	97.0	17.2	.4
min.	81.0	3.9	—
av	89.1 (60)	9.8 (60)	.2 (52)
464 groundmass			
max.	93.7	15.9	.5
min.	82.8	5.5	—
av	88.7 (56)	10.0 (56)	.2 (31)
465 megacryst			
max.	98.1	21.4	.4
min.	76.3	2.3	—
av	91.3 (103)	8.8 (103)	.2 (82)
465 groundmass			
max.	92.8	55.8	.8
min.	42.0	7.7	—
av	85.4 (65)	13.4 (65)	.2 (38)

[a] Numbers in parentheses indicate total number of analyses for averages.

ples, the maximum An content of cores of plagioclase included in the megacrysts (An_{32-35}) is slightly less than that of the groundmass (An_{36-37}); however, because these values may not represent true core compositions, they are of little value for comparative purposes. Compositions of rims of the included plagioclase in the megacrysts of both samples (An_{9-13}) are more sodic than the groundmass plagioclase (An_{19}). The thin, sodic rims of the included plagioclase are optically distinct. In some cases, myrmekite is developed at the junctions between these rims and the host microcline. The birefringence of the sodic rims is identical to that of the surrounding perthitic plagioclase. It is probable that the rims

TABLE 2. ANALYSES OF PLAGIOCLASE IN SAMPLES OF CATHEDRAL PEAK PORPHYRITIC QUARTZ MONZONITE

	Anorthite (mole %)	Albite (mole %)
Sample 464		
Included in megacrysts		
most calcic core	32.5	66.4
most sodic rim	9.3	91.0
Groundmass		
most calcic core	36.5	60.5
most sodic rim	18.8	30.8
Sample 465		
Included in megacrysts		
most calcic core	34.7	65.2
most sodic rim	13.1	85.0
Groundmass		
most calcic core	36.9	62.6
most sodic rim	18.7	79.1

represent sodic plagioclase exsolved from the originally homogeneous alkali feldspar megacrysts.

Biotite. As shown in Table 3, there are no consistent differences between the compositions of included and groundmass biotites in samples 464 and 465.

OBLIQUITY

Obliquity measurements were made on megacrysts and groundmass microclines in samples 460 and 464 by measuring the angular separation of the 131 and $1\bar{3}1$ X-ray peaks (Deitrich, 1962). The Δ-values given in

TABLE 3. AVERAGED ANALYSES OF BIOTITES IN MEGACRYSTS AND IN GROUNDMASS OF SAMPLES OF CATHEDRAL PEAK PORPHYRITIC QUARTZ MONZONITE[a]

	K_2O	FeO	MgO	MnO	Al_2O_3
465 megacryst	9.8	15.7	14.5	.9	13.9
465 groundmass	9.8	16.7	14.2	.2	13.5
464 megacryst	9.1	16.5	12.4	.7	13.8
464 groundmass	9.1	16.7	12.5	.6	13.3

[a] Values in wt. percent.

Table 4 are a direct measurement of the obliquity; maximum microcline has a Δ-value of 1.0, while Δ=0.0 in monoclinic potash feldspars. It is seen that the obliquities of the groundmass microclines are 2 or 3 times larger than the megacrysts.

Discussion and Conclusions

The tendency for Ba to enrich in early formed K-feldspars has been suggested by several workers (Heier, 1962). Oftedahl (1959, 1961) has clearly demonstrated this in pegmatitic K-feldspars where there is cogent

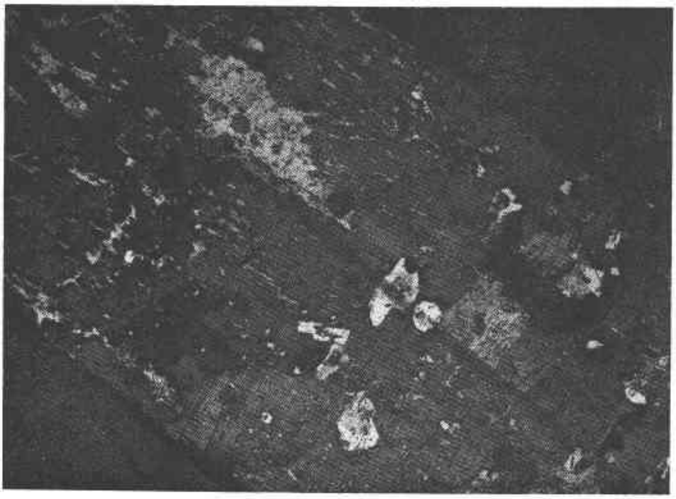

Fig. 4. Thin section of K-feldspar megacryst. Small, irregular, light-colored stringers are exsolved albite. Large patch of exsolved albite above center of photo. Several grains of included plagioclase shown in lower right half of photo. Sample 465. X20 Polarizers not crossed.

evidence for the relative periods of growth of the feldspars. Boettcher *et al.* (1967) have recently shown Ba zonation from high-Ba cores to low-Ba rims in K-feldspar phenocrysts of samples from trachyte dikes. In the present study, the high Ba content of the megacrysts in relation to the groundmass microclines would thus suggest that the former crystallized before the latter. Growth of groundmass microclines in sample 465 was probably accompanied by the formation of low-Ba rims on the megacrysts. Providing that subsolvus changes have not *completely* altered the structural state of the feldspars and that the Or/Ab ratio of the megacrysts and groundmass microclines are equal, obliquity should be a measure of relative temperature of formation (MacKenzie and Smith, 1961). Although appreciable variations exist in the Or/Ab ratios of the mega-

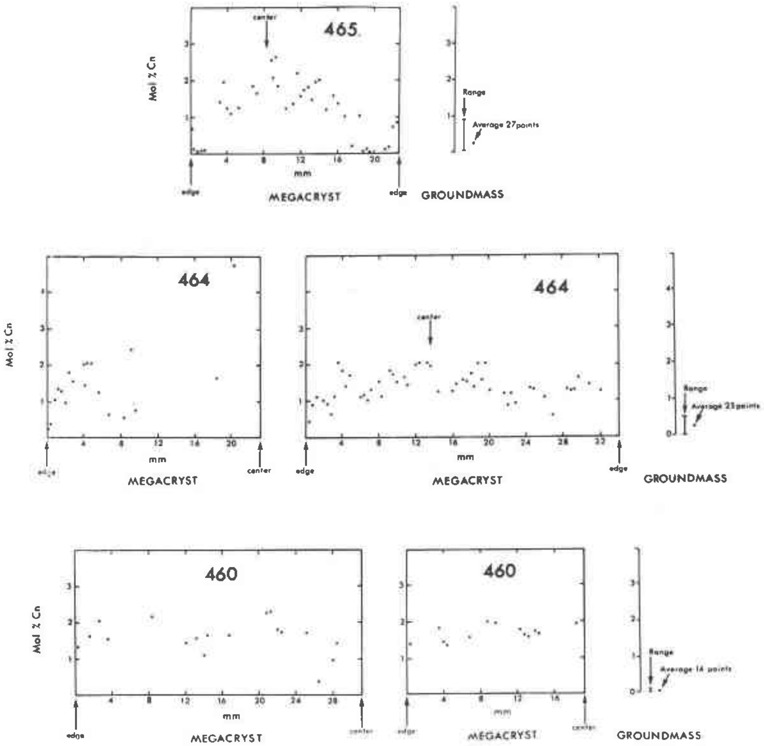

FIG. 5. Plots of analyzed celsian contents of megacrysts and corresponding groundmass K-feldspars. Megacryst analyses taken on straight-line traverses from edge to center of crystals. Range and average of groundmass K-feldspars shown to right of phenocryst plots with same vertical scale.

crysts and groundmass microclines, the average Or/Ab ratios of these phases in samples 464 and 460 are similar (Table 1), suggesting that the bulk compositions of the megacrysts and groundmass microclines are similar. It is thus believed valid to compare obliquity measurements as an indicator of the relative temperatures of formation of the megacrysts and

TABLE 4. OBLIQUITY DETERMINATIONS OF MEGACRYSTS AND GROUNDMASS MICROCLINES IN SAMPLES 460 AND 464[a]

	Sample 464	Sample 460
Megacryst	.02 ± .02	.07 ± .02
Groundmass	.04 ± .04	.26 ± .04

[a] $\Delta = 12.5\ [d_{131} - d_{1\bar{3}1}]$; values given are averages and ranges of ten determinations.

groundmass K-feldspars. The lower obliquity values in the megacrysts compared to the groundmass microclines suggest that the former crystallized at higher temperatures (*i. e.*, earlier) than the latter, which is consistent with the prediction from the Ba distribution.

The large variation in Na content in the megacrysts precludes the use of Barth's (1962) geological thermometer for prediction of temperatures of crystallization (see also Piwinskii, 1968, p. 217–218).

As the cores of the megacrysts contain all of the mineral species which also occur in the groundmass, it is probable that the magma was at least partially crystalline during growth of the megacrysts. The zonal concentration of mafic minerals in the megacrysts (Fig. 3) is consistent with the hypothesis of the existence of a partial melt during growth of the megacrysts, for it is difficult to imagine how this texture could arise by growth of the megacrysts in solid rock. In contrast, the interstitial nature of the groundmass microclines is consistent with late stage crystallization of this form.

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