American Mineralogist, Volume 64, pages 329–336, 1979

Chessboard-twinned albite from Franciscan metaconglomerates of the Diablo Range, California

DIANE E. MOORE[1] AND JUHN G. LIOU

Department of Geology, Stanford University
Stanford, California 94305

Abstract

Chessboard-twinned albite is abundant in some Franciscan metaconglomerates and associated metagraywackes in the Diablo Range of California. The chessboard albite occurs in pebbles of sedimentary rocks, felsic volcanic and plutonic pebbles, and in the graywacke matrix of the metaconglomerates, where it has probably formed during blueschist-facies metamorphism. The mode of occurrence of chessboard albite in felsic igneous pebbles suggests that this albite formed by replacement of potash feldspar (albitization); potassium released from the feldspar reacted with aluminous silicates to form white mica. Similarly, chessboard-twinned albite in Franciscan metagraywackes may also result from albitization of detrital potash feldspars. Thin-section examination of many Franciscan metagraywackes has revealed that chessboard albite is selectively distributed among pumpellyite- and lawsonite-bearing rocks which now lack potash feldspars. Variation of chessboard albite content in such rocks may be related to differences in the original potash feldspar content.

Introduction

Chessboard-twinning is an unusual twin form characterized by albite twin lamellae which, when viewed under crossed polarizers, have a pattern of alternating black and white rectangles resembling a chessboard. The lamellae wedge out or are truncated by planes parallel to (001), and are best seen in sections perpendicular to (010). Such twinning is restricted to albite with low An contents. Chessboard-twinned albite was first described by Becke in 1906 and has since been recorded in keratophyres (Battey, 1955; Carstens, 1966), granites (Anderson, 1928; Gilluly, 1933), and some low-grade metamorphic rocks (Starkey, 1959; Voll, 1969). In most of these occurrences, the albite was considered to have replaced potash feldspar during metamorphism or metasomatism. The origin of the checkered pattern in such albite is not known; the most common hypotheses include some combination of stress and inherited characteristics of the potash feldspar lattice in the replacing albite (Starkey, 1959; Voll, 1969). Callegari and de Pieri (1967) proposed that internal stresses which developed on account of the marked volume difference between replacing albite and the original potash feldspar could cause the chessboard twin pattern (see also Smith, 1974, p. 290).

During our investigations of Franciscan metaconglomerates from the Diablo Range of central California (Platt *et al.*, 1976; Moore, 1977), various amounts of chessboard-twinned albite were found. The selective distribution and textures of the checkered albite in the igneous pebbles from the metaconglomerates led us to conclude that the chessboard-twinned albite indeed results from the albitization of potash feldspar during blueschist-facies metamorphism. This note describes the occurrence and origin of checkered albite in Franciscan conglomerates of the Diablo Range and its significance for interpreting the primary composition of Franciscan graywacke. Our findings may in part explain the rare occurrence of potash feldspar in some Franciscan metamorphic rocks (Bailey and Irwin, 1959; Bailey *et al.*, 1964), and the modal abundance of chessboard albite in Franciscan metagraywackes may potentially be used as a rough estimate of their original potash feldspar content.

Petrological survey of some Franciscan conglomerates

Pebbles and graywacke matrix of 40 Franciscan metaconglomerate bodies and associated metagray-

[1] Present address: U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025.

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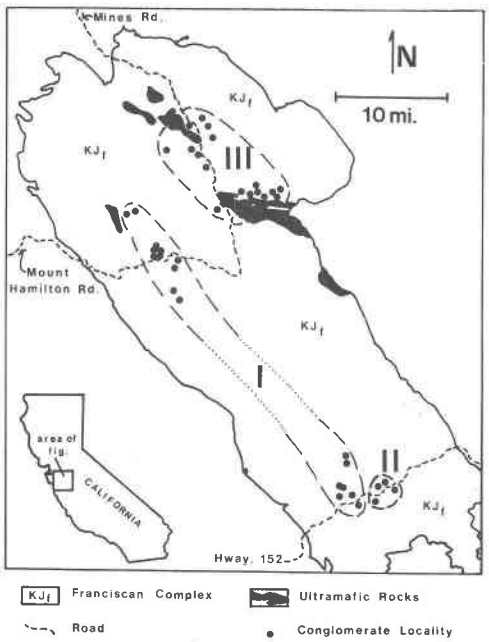

Fig. 1. Map showing location of Franciscan metaconglomerates used in this study, separated into three groups according to types of igneous pebbles. Group I contains abundant felsic as well as mafic volcanic and plutonic detritus; Group II contains mafic volcanic and plutonic rocks; and Group III contains predominantly mafic volcanic rocks.

wackes from the central and northern Diablo Range were examined (Fig. 1). Most of the metaconglomerates occur sporadically as allochthonous blocks in Franciscan mélange, in association with other tectonic blocks of metagraywacke, greenstone, red chert, and glaucophane schist; a few metaconglomerates occur as thin lenses or channel fills in larger metagraywacke blocks in the mélange terrains. The metaconglomerates contain abundant clasts of various sizes (1–30 cm) and lithologies. Although mineral assemblages and textures of these clasts have been modified by blueschist-facies metamorphism, the original sedimentary and igneous features of the clasts are well-preserved. Pebbles of sedimentary origin include mildly deformed quartz-rich sandstone, quartzite, gray and black chert, graywacke, and orthoconglomerate, which occur in varying amounts in all metaconglomerates. The igneous pebbles consist of plutonic and volcanic rocks ranging in composition from granodiorite and dacite to gabbro and basalt; representative chemical analyses of the igneous pebbles are listed in Table 1. No true granites or rhyolites were found. In contrast to the sedimentary detritus, igneous pebbles of certain compositions are selectively distributed among the metaconglomerates. Igneous detritus in one group of metaconglomerates consists almost exclusively of mafic volcanics, a second group of metaconglomerates contains mafic volcanics and plutonics, and a third contains numerous felsic as well as mafic igneous rocks, both volcanic and plutonic. Metaconglomerates belonging to each group are geographically associated, as shown in Figure 1.

All conglomerates are metamorphosed to lawsonite+albite-bearing assemblages, and several contain sparse to abundant jadeitic pyroxene. Albite is the only feldspar in the metaconglomerates. It is abundant in the matrix, and occurs in nearly every pebble. Albite is also a vein-forming mineral. Microprobe analyses of albite from various sources, including jadeite-bearing metaconglomerates, are listed in Table 2. The albite has a very narrow range of composition with An $\leq$ 2 and Or $\leq$ 1. Iron, probably substituting for aluminum, occurs in amounts up to 0.25 weight percent Fe_2O_3. In various pebbles and in the graywacke matrix, albite is commonly associated with idioblasts of lawsonite or grainy aggregates of pumpellyite. In some metaconglomerates, albite is partly replaced by sprays of jadeitic pyroxene. Law-

Table 1. Selected chemical analyses of igneous pebbles from Franciscan metaconglomerates of the Diablo Range, California, by rock-powder electron-microprobe techniques

Oxide	9S-8[1]	65-13[2]	65-14[3]	93-4[4]	50-4[5]	90-8a[6]	92-4[7]
SiO_2	48.2	49.2	59.9	65.3	57.8	64.2	75.9
TiO_2	0.6	1.1	0.6	0.1	0.5	0.4	0.1
Al_2O_3	18.5	16.2	10.3	15.2	17.6	15.6	13.3
FeO*	7.3	9.1	8.8	1.7	8.8	5.5	1.0
MgO	4.6	10.0	7.4	1.1	4.1	3.4	0.8
CaO	8.0	7.1	5.4	6.0	1.8	1.6	0.2
Na_2O	3.2	4.4	4.6	1.9	3.0	3.6	4.4
K_2O	0.8	0.3	0.4	0.7	2.7	2.2	1.6
Anhydrous total	91.2	97.4	97.4	92.0	96.3	96.5	97.3

1. Gabbro** containing the assemblage: lawsonite + glaucophane + quartz + chlorite + phengite + sphene + opaques.
2. Basalt**: albite + chlorite + relict clinopyroxene + pumpellyite + sphene + quartz + aragonite.
3. Andesite**: crossite + albite + quartz + relict clinopyroxene + phengite + chlorite + aragonite + relict hornblende + opaques.
4. Tonalite**: quartz + lawsonite + albite + chlorite + phengite + sphene + opaques.
5. Granodiorite**: albite + chlorite + quartz + phengite + aragonite + sphene + opaques; some albite is chessboard-twinned.
6. Granodiorite**: quartz + albite + phengite + chlorite + lawsonite + sphene + opaques + glaucophane + aragonite; some albite is chessboard-twinned.
7. Granodiorite**: albite + quartz + phengite + lawsonite + sphene + opaques; some albite is chessboard-twinned.

* Total Fe as FeO.

** Rock names obtained by comparison of CIPW normative mineral proportions to the igneous classifications of Streckeisen (1967, 1974).

Table 2. Microprobe analyses of selected albites from Franciscan metaconglomerates of the Diablo Range, California

Sample No.	90-3[1]	92-4[2]	64-4[3]	64-129[4]	95-16[5]
SiO_2	68.72	68.80	67.90	67.84	68.42
TiO_2	0.05	-----	-----	-----	-----
Al_2O_3*	19.64	19.78	19.84	19.98	19.75
Fe_2O_3	0.08	-----	0.25	0.12	0.06
MgO	-----	-----	0.04	0.01	-----
CaO	0.03	0.01	0.07	0.23	0.02
K_2O	0.08	0.05	0.07	0.07	0.06
Na_2O	11.60	11.51	11.68	11.59	11.71
Anhydrous total	100.20	100.15	99.85	99.84	100.02
	Atomic Proportions, 0 = 8				
Si	2.99	3.00	2.97	2.97	2.99
Al	1.01	1.01	1.02	1.03	1.02
Fe^{3+}	----	----	0.01	----	----
Ca	----	----	----	0.01	----
Na	0.98	0.97	0.98	0.98	0.99
K	----	----	----	----	----

*Total Fe as Fe_2O_3

[1]Albite replacing plagioclase grains in metagraywacke matrix.

[2]Chessboard-twinned albite in volcanic pebble; average of 2 crystals.

[3]Albite associated with sodic amphiboles in plutonic pebble; average of 3 crystals.

[4]Albite partly replaced by jadeitic pyroxene in porphyritic volcanic pebble.

[5]Vein albite.

sonite occurs in shale clasts and is intergrown with phengitic white mica in the graywacke matrix. Pumpellyite commonly occurs with chlorite in volcanic detritus and with phyllosilicates in the graywacke matrix. Aggregates of chlorite and phengite replace biotite in the metaconglomerates and chlorite and/or sodic amphibole replace hornblende. Aragonite is the stable polymorph of calcium carbonate in the metaconglomerates; it occurs in veins and as a patchy replacement of feldspars. None of the metaconglomerates contains potash feldspar.

Strata of Franciscan metagraywacke elsewhere in the Diablo Range also contain albite as the only feldspar (McKee, 1962; Ernst *et al.*, 1970; Cowan, 1972; Crawford, 1975). The alteration of calcic plagioclase to albite and a calcium-bearing mineral during low-grade metamorphism has been well documented, and is used to explain the absence of calcic plagioclase from the Franciscan metamorphic rocks (*e.g.*, Ernst *et al.*, 1970). However, the absence of potash feldspar from the metagraywacke is not well understood. It has been suggested that the sources of Franciscan detritus may have been deficient in potash feldspar (*e.g.*, Bailey *et al.*, 1964). The contents of potash feldspar in Franciscan metagraywackes have also been correlated to both degree and time of metamorphism (*e.g.*, Cowan, 1972; Crawford, 1975). The granodioritic and dacitic pebbles which are abundant in several metaconglomerates of the Diablo Range commonly contain more than 2 weight percent K_2O (Table 1). Some of the potassium in such pebbles may have been contained in potash feldspar which has since been replaced, most probably during blueschist-facies metamorphism.

Chessboard-twinned albite

Mode of occurrence

Chessboard-twinned albite commonly occurs in the felsic volcanic and plutonic pebbles and in the graywacke matrix of the metaconglomerates which contain many such pebbles. It is *not* found in the mafic igneous pebbles and is rare in the graywacke matrix of metaconglomerates in which such pebbles predominate. Igneous pebbles similar in composition to pebbles #1–4 of Table 1 never contain chessboard albite; on the other hand, igneous pebbles similar to #5–7 characteristically contain up to 20 modal percent chessboard albite. Pebbles of sedimentary rocks commonly contain scattered grains of checkered albite. Chessboard twinning is not a common twin form; therefore, the ubiquitous occurrence of checkered albite in pebbles of volcanic, plutonic, and sedimentary rocks and in the graywacke matrix is better explained by its formation during blueschist-facies metamorphism of the conglomerates rather than in each separate source terrain.

Examination of the mode of occurrence of chessboard-twinned albite in the felsic igneous clasts sheds some light on its origin. In all the volcanic and plutonic pebbles which contain chessboard-twinned albite, two distinct types of albite were recognized: the first type never has a checkered pattern, whereas the second type commonly, though not always, is chessboard-twinned. The non-chessboard-twinned albite usually occurs as coarse-grained (up to 5 mm long) subhedral to euhedral crystals which commonly enclose some lawsonite or pumpellyite (Fig. 2A). Mild sericitic alteration gives this feldspar a pale greenish color in plane polarized light and a grainy extinction under crossed polars (Fig. 2B). This type of albite usually predominates in both felsic and mafic pebbles. In contrast, the chessboard-twinned albite is commonly finer-grained and rarely contains euhedra of lawsonite or pumpellyite (Fig. 2A). In some plu-

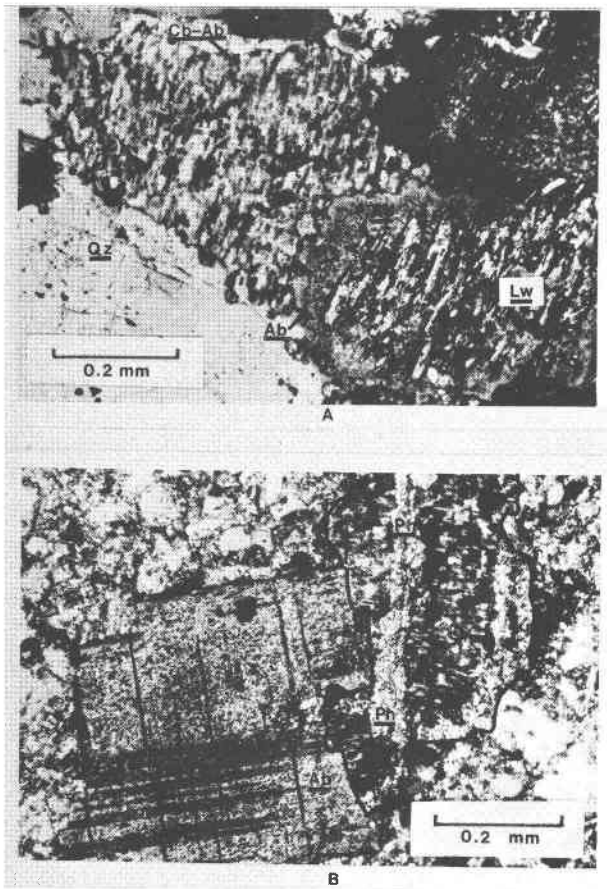

Fig. 2. Albite occurrences in igneous pebbles of Franciscan metaconglomerates of the Diablo Range, California. (A) 51-2, granodiorite; chessboard-twinned albite crystal at upper left of photomicrograph; at lower right a plagioclase crystal has been replaced by lawsonite and untwinned albite; (B) 92-4; albite phenocrysts in fine-grained granodiorite pebble. The subhedral crystal at lower left is albite-twinned and has a grainy appearance; to the right of this crystal an irregularly-shaped chessboard-twinned albite is rimmed and veined by fine-grained phengite. Symbols: Ab = albite; Cb–Ab = chessboard albite; Lw = lawsonite; Ph = phengite.

tonic pebbles chessboard-twinned albite rims subhedral plagioclase, whereas in others it is intergrown with quartz. In a few pebbles, chessboard albite replaces feldspar phenocrysts which were originally Carlsbad-twinned. In plane-polarized light, the chessboard-twinned albite frequently shows a dusty appearance, due to the presence of minute dark inclusions which may be iron oxides (Poldervaart and Gilkey, 1954). Fine-grained phengite is found at the edges of or along fractures through many chessboard-twinned albite crystals (Fig. 2B). The consistent occurrence of these two distinct types of albite in the granodiorite and dacite pebbles is believed to indicate that albite in the Franciscan metaconglomerates has originated from two different feldspars—the subhedral albite intergrown with lawsonite or pumpellyite was originally a calcic plagioclase, whereas chessboard-twinned albite was potash feldspar.

In other areas, similar dual origins for coexisting checkered albite and polysynthetically-twinned or untwinned albite in igneous rocks have also been proposed. In New Zealand, both chessboard albite and albite phenocrysts with uninterrupted albite twin lamellae have been found in keratophyre; the albite-twinned phenocrysts generally contain inclusions of sericite and chlorite in contrast to clear chessboard albite (Battey, 1955). The chessboard-twinned albite may have replaced potash feldspar, and the mottled albite phenocrysts may be a "primary phase, or a plagioclase metasomatized to albite" (Smith, 1974, p. 288). From the Italian Dolomites, Callegari and de Pieri (1966, 1967) described the simultaneous development of checkered and untwinned albite in Triassic green tuff. They proposed that the checkered albite originated from replacement of a sanidine–cryptoperthite, whereas the untwinned albite crystallized at the expense of andesine plagioclase. In an albitite, Ogniben (1956) described a chessboard-twinned albite which formed at the expense of pre-existing microcline and a normally-twinned albite which formed from calcic plagioclase.

Albitization reactions

Potash feldspar in both pebbles and matrix of the Diablo Range metaconglomerates was unstable with respect to phengitic white mica at the presumed conditions of metamorphism. However, textures in the felsic igneous pebbles indicate that potash feldspar crystals are not directly replaced by phengite; instead the alteration takes place in two steps. In the first step, potassium is replaced by sodium in the feldspar, according to the reaction

$$KAlSi_3O_8 + Na^+ = NaAlSi_3O_8 + K^+ \qquad (1)$$

The albite formed by such an exchange reaction characteristically displays chessboard twinning. In the second step, K^+ produced in (1) reacts with other silicates in the pebble to form phengite.

A number of experimental studies have demonstrated the readiness with which reaction (1) proceeds at moderate temperatures in the presence of appropriate alkalic salt solutions (Orville, 1962, 1963). The solutions which promote the completion of reaction (1) may be near neutral (Gruner, 1944; O'Neil, 1948), with $Na^+/(Na^+ + K^+)$ ratios high enough to ex-

change Na^+ for K^+ in feldspars. Orville (1962, 1963) determined the composition of the fluid phase coexisting with two alkali feldspars in the temperature range 400°–670°C and concluded that the products of exchange reaction are controlled by the ratio of m_{KCl}/m_{NaCl} of the solution but are nearly independent of total concentration at fixed temperature and pressure. Extrapolation of his experimental curve to lower temperatures shows that albitization of potash feldspar at 250°C requires m_{KCl}/m_{NaCl} ratios less than 0.04 and at 300°C less than 0.12. These values are closely consistent with other experimental data (Hemley, 1959; Hemley *et al.*, 1961; Iiyama, 1965) and calculated activity ratios (Helgesen, 1969, 1974).

The concentration of white mica along fractures and veinlets through chessboard albite in the igneous pebbles suggests that fluids similar to those described above may have been important in the albitization of potash feldspar. In addition, the abundance of hydrous metamorphic minerals in the igneous pebbles and the low anhydrous totals of the pebble compositions (Table 1) indicate that 2 to 8 weight percent H_2O may have been added to different igneous pebbles during blueschist-facies metamorphism. Seawater trapped in pore spaces of the graywacke matrix is a likely source of the water introduced into the igneous pebbles during the metamorphism. Fresh seawater analyzed by Seyfried (1977) contains 383 ppm K and 10305 ppm Na, which is a ratio m_K/m_{Na} of 0.022. Such concentrations of Na and K in intergranular fluids would promote completion of reaction (1) and the production of chessboard albite.

In the second step of the alteration, K^+ ion in the solution reacts with other silicates in the igneous pebbles to form phengite. Reactions were written to model this second step in the pebbles. The granodiorite and dacite pebbles which contain chessboard-twinned albite have very similar metamorphic mineral assemblages, usually consisting of quartz + albite + phengite + chlorite + lawsonite (and/or pumpellyite) + sphene + aragonite ± opaques. Chlorite replaces igneous biotite or hornblende in different pebbles; small amounts of hematite typically occur as a replacement of magnetite. Aragonite commonly occurs as a patchy replacement of feldspar. For the reactions, compositions of metamorphic chlorite and phengite in the pebbles were obtained from electron microprobe analyses; representative analyses are presented in Table 3. Compositions of primary hornblende and biotite are taken from Deer *et al.* (1963). For simplification, end-member anorthite is used in reactions involving an original calcic plagioclase. The observed phengite–chlorite–sphene assemblage in the igneous pebbles may have formed through reaction of the K^+ in solution with some of the primary igneous minerals as follows:

$$\begin{aligned}
&1\ \underset{\text{biotite}}{K_2Mg_{2.2}Fe^{2+}_{2.1}Fe^{3+}_{0.5}Ti_{0.5}Al_3Si_{5.6}O_{21.5}(OH)_{2.5}} \\
&+ 8.69\ \underset{\text{anorthite}}{CaAl_2Si_2O_8} + 5.84\ K^+ + 4.37\ \underset{\text{quartz}}{SiO_2} \\
&+ 11.46\ H_2O + 8.19\ CO_2 \\
&\rightarrow 3.95\ \underset{\text{phengite}}{K_2Mg_{0.3}Fe^{2+}_{0.2}Fe^{3+}_{0.1}Al_{4.9}Si_{6.5}O_{20}(OH)_4} \\
&+ 0.24\ \underset{\text{chlorite}}{Fe^{2+}_{5.4}Mg_{4.2}Al_{4.8}Si_{5.6}O_{20}(OH)_{16}} + 0.5\ \underset{\text{sphene}}{CaTiSiO_5} \\
&+ 0.05\ \underset{\text{hematite}}{Fe_2O_3} + 8.19\ \underset{\text{aragonite}}{CaCO_3} + 5.84\ H^+
\end{aligned} \tag{2}$$

$$\begin{aligned}
&1\ \underset{\text{hornblende}}{Ca_{1.8}Na_{0.3}Fe^{2+}_{1.4}Fe^{3+}_{0.3}Mg_3Ti_{0.1}Al_{1.6}Si_{6.8}O_{22}(OH)_2} \\
&+ 7.9\ \underset{\text{anorthite}}{CaAl_2Si_2O_8} + 6\ K^+ + 1.9\ \underset{\text{magnetite}}{Fe_3O_4} \\
&+ 0.7\ \underset{\text{quartz}}{SiO_2} + 12\ H_2O + 9.6\ CO_2 \\
&\rightarrow 3\ \underset{\text{phengite}}{K_2Mg_{0.3}Fe^{2+}_{0.2}Fe^{3+}_{0.1}Al_{4.9}Si_{6.5}O_{20}(OH)_4} \\
&+ 0.5\ \underset{\text{chlorite}}{Fe^{2+}_{5.4}Mg_{4.2}Al_{4.8}Si_{5.6}O_{20}(OH)_{16}} + 0.3\ \underset{\text{albite}}{NaAlSi_3O_8} \\
&+ 0.1\ \underset{\text{sphene}}{CaTiSiO_5} + 9.6\ \underset{\text{aragonite}}{CaCO_3} + 1.9\ \underset{\text{hematite}}{Fe_2O_3} + H^+
\end{aligned} \tag{3}$$

Reactions (2) and (3) produce assemblages consistent with those observed in the igneous pebbles; with the exception of H_2O and CO_2, all materials necessary for the crystallization of phengite are available within the pebbles. The common occurrence of aragonite in the pebbles indicates that some CO_2 has indeed been introduced. Thus, reactions (1)–(3) are consistent with both the textures and mineralogy of the igneous pebbles.

Application to Franciscan metagraywackes

In addition to its occurrences in the felsic igneous pebbles, chessboard-twinned albite has been observed in pebbles of sedimentary origin and in the graywacke matrix of Franciscan metaconglomerates of the Diablo Range. Chessboard albite in such metasedimentary rocks probably has also resulted from the albitization of detrital potash feldspars. The abundance of chessboard-twinned albite in Francis-

Table 3. Chemical compositions of phengite and chlorite in igneous pebbles from Franciscan metaconglomerates of the Diablo Range, California

	---Phengite---		----------Chlorite----------			
Oxide	90-8a[1]	50-4[2]	90-8a[3]	90-13[4]	93-4[5]	50-4[6]
SiO_2	48.07	47.78	26.21	26.87	25.50	25.01
TiO_2	0.01	-----	0.14	0.19	0.04	-----
Al_2O_3	32.10	29.99	17.13	18.19	19.99	17.51
Fe_2O_3	2.09*	3.80*	-----	-----	-----	-----
FeO	-----	-----	28.08**	28.87**	24.04**	32.23**
MgO	1.09	1.25	12.80	13.41	14.83	10.27
CaO	0.01	0.08	0.06	0.17	0.02	0.03
Na_2O	0.12	0.07	0.01	0.01	0.02	0.05
K_2O	10.72	10.85	0.12	0.17	0.06	0.06
Anhydrous total	94.21	93.82	84.55	87.88	84.50	85.16
	Atomic Proportions					
	--- O = 22 ---		---------- O = 28 ----------			
Si	6.45	6.50	5.84	5.76	5.57	5.68
Al^{IV}	1.55	1.50	2.16	2.24	2.43	2.32
Al^{VI}	3.53	3.30	2.34	2.36	2.64	2.36
Ti	----	----	0.02	0.03	0.01	----
Fe^{3+}	0.22	0.39	----	----	----	----
Fe^{2+}	----	----	5.23	5.18	4.39	6.12
Mg	0.22	0.25	4.25	4.29	4.83	3.47
Ca	----	0.01	0.01	0.04	0.01	0.01
Na	0.03	0.02	----	----	0.01	0.02
K	1.84	1.89	0.03	0.05	0.02	0.02

[1]Phengite in albite crystal of granodiorite pebble.
[2]Phengite associated with chlorite in granodiorite pebble.
[3]Apple green chlorite in granodiorite pebble.
[4]Pale green chlorite in tuffaceous pebble.
[5]Medium green chlorite in tonalite pebble.
[6]Pale green chlorite after biotite in granodiorite pebble.

* Total Fe as Fe_2O_3 ** Total Fe as FeO

can metagraywackes without potash feldspar may therefore provide a means to distinguish between rocks which originally contained little or no potash feldspar and ones which contained some potash feldspar now replaced by albite. Such differences in detrital composition are apparent in metaconglomerates and metagraywackes of the Diablo Range. The graywacke matrices of metaconglomerates with abundant felsic igneous detritus (Group I in Fig. 1) contain considerable amounts of chessboard albite (60–200 grains of chessboard albite per thin section). In contrast, the graywacke matrix of metaconglomerates containing mafic, but little felsic, igneous detritus (Groups II and III in Fig. 1) contain only a few grains of chessboard-twinned albite (4–20 grains per thin section). In addition, metagraywackes geographically associated with metaconglomerates of each group contain chessboard albite in amounts similar to the metaconglomerates.

Thin sections of graywacke and metagraywacke from various parts of the Franciscan were also examined; localities are shown in Figure 3. Most unmetamorphosed or incipiently-metamorphosed rocks of the coastal belt contain little or no chessboard-twinned albite. Instead, many such rocks contain unaltered potash feldspar. Some laumontite-bearing graywackes contain potash feldspar, trace amounts of chessboard albite, and several partly altered potash feldspars with textures which may represent incipient development of chessboard twinning. Pumpellyite- and lawsonite-bearing metagraywackes characteristically lack potash feldspar and contain various amounts of chessboard albite, as shown in Figure 3. Examples of chessboard albite from pumpellyite-bearing Franciscan rocks of the northern Coast Ranges are shown in Figure 4.

In summary, potash feldspar is absent from Franciscan graywackes and conglomerates which have been metamorphosed to at least pumpellyite-bearing assemblages. Chessboard-twinned albite is selectively distributed among such metagraywackes, in that some contain many grains and others few or none. By analogy with the different groups of Franciscan metaconglomerates and metagraywackes examined in the

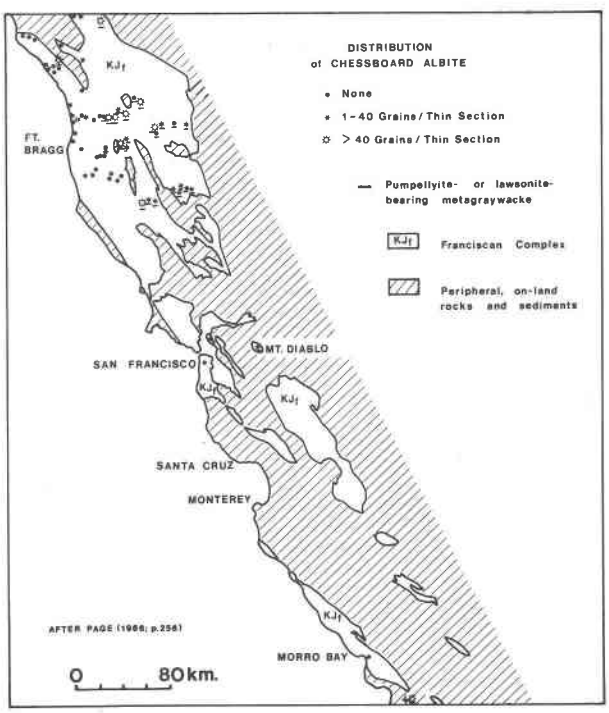

Fig. 3. Distributions of chessboard albite among some Franciscan metagraywackes. Thin sections were obtained from Professor W. R. Dickinson and from the Stanford University collection.

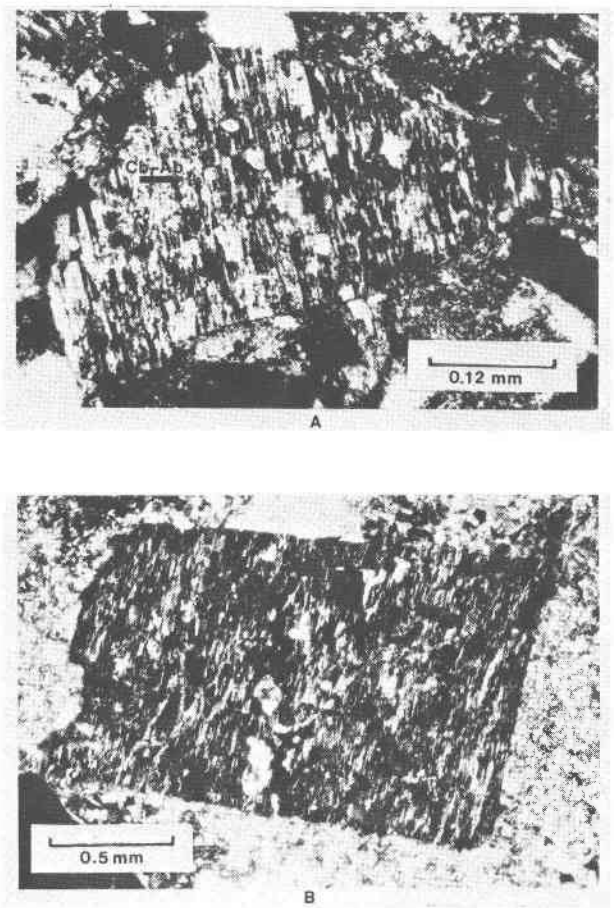

Fig. 4. (A) Chessboard albite replacing a feldspar clast in Franciscan metagraywacke from Oso Canyon, San Rafael Range (#S4-190, Stanford collection); (B) chessboard-albite replacing a phenocryst in a felsic volcanic pebble from a Franciscan pumpellyite-bearing metaconglomerate located near Hway. 261 between Dos Rios and Covela (#75-16E, Stanford collection).

Diablo Range, the differences in chessboard albite content may reflect initial differences in potash feldspar content and therefore differences in source materials.

To date, few reports have been made of chessboard-twinned albite in the Franciscan Complex (Fyfe and Zardini, 1967; Platt *et al.*, 1976). However, our cursory examination of Franciscan metagraywackes indicates that chessboard albite *is* present in many parts of the Complex. From consideration of this mode of formation, we expect that reexamination of other Franciscan metagraywackes will yield evidence of chessboard-twinned albite, and, in fact, the occurrence of such twinned albite after potash feldspar in Franciscan metasediments may well be ubiquitous. Although the chessboard-twinned albite appears in minor quantities in the Franciscan metaconglomerates and metagraywackes, its geologic significance may far outweigh its real abundance.

Acknowledgments

We are grateful for the financial support for this study provided by NSF grant EAR 76-22650 and by a Geological Society of America Penrose Grant #1970–75. We thank Professor B. M. Page of Stanford University for his contributions to the field study of the Franciscan metaconglomerates and Professor W. R. Dickinson for providing thin sections of Franciscan metagraywackes. Professor Page, Dr. E. H. Bailey of the U.S. Geological Survey, and Professor Wayne Dollase of U.C.L.A. are thanked for their critical comments on the manuscript.

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Manuscript received, April 3, 1978;
accepted for publication, September 2, 1978.