Chemical microstructure of Franciscan jadeite from Pacheco Pass, California

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ABSTRACT

The chemical microstructure of five jadeitic pyroxenes from three Franciscan quartzose metagraywacke samples was investigated by backscattered electron imagery, element mapping, and electron microprobe microanalysis. These clinopyroxenes are neoblastic, subhedral grains or subradial aggregates replacing albite. For each compositionally zoned Cpx grain, a series of up to five parallel, polished sections were cut essentially normal or parallel to the crystallographic c axis. Five investigated grains, single and subradial aggregates, were examined quantitatively and three-dimensional chemical sections of the grains were constructed. Chemical zoning progresses from the Na-Cpx core to rim in four distinct regions (Q, L, Acm, and T). Region Q consists of microcrystalline blebs of quartz and jadeite ($x_{jd}$ = 0.95) and has a bulk composition of nearly pure albite. Very rarely it contains albite. L is jadeite ($x_{jd}$ = 0.80) that contains lawsonite inclusions. Acm is acmite-rich Cpx ($x_{jd}$ = 0.65), and T consists of TiO$_2$-bearing jadeite (1–2 wt% TiO$_2$, $x_{jd}$ = 0.95). Isolated Cpx grains and prismatic aggregates display the same chemical architecture regardless of crystallographic orientation. The earliest growth stage, Q, represents a volume-for-volume replacement of pre-existing albite by nearly stoichiometric jadeite plus quartz. As prisms grew, diffusion from the lithic matrix progressively enriched outer Na-Cpx zones in Fe$^{3+}$, Ca, and Mg. Terminal stages of high-pressure growth are represented by TiO$_2$-bearing jadeitic pyroxenes, possibly reflecting a temperature increase or relatively long-term annealing under the same conditions in the presence of titanite and rutile. The core Q and rim T regions represent a jadeite plus quartz assemblage and confirm our earlier notion that the jadeite zone of Franciscan metamorphic rocks was subducted to depths where the assemblage jadeite and quartz was stable, at pressures of more than 10 kbar.

INTRODUCTION

Since recognition of the widespread occurrence of jadeitic pyroxene in Franciscan metagraywackes of the central Diablo Range, California Coast Ranges (McKee 1962), the Franciscan Complex has been regarded as a classic high-pressure (blueschist facies) metamorphic terrane. Ernst (1971) showed that in the Pacheco Pass area, where albite and jadeite occur together, neoblastic jadeite needles nucleated within precursor metastable albite, then grew as subhedral aggregates, and finally thoroughly replaced the pre-existing albite as coarse prisms. Maruyama et al. (1985) and Terabayashi et al. (1996) documented zoning in jadeitic pyroxene at Pacheco Pass and argued that jadeitic pyroxene crystallized under near-equilibrium conditions, coexisting stably with excess albite and quartz. These contrasting interpretations of the growth history of jadeitic pyroxene have led to different inferred P-T paths for the metamorphic complex and thus different tectonic interpretations of the subduction-zone metamorphic process.

Subradial fibrous-to-prismatic aggregates of jadeite that show wavy extinction are an important metamorphic phase in Franciscan graywackes (Bloxam 1956). The chemical structure of this mineral is most clearly revealed by backscattered electron images (BEI) combined with quantitative electron microprobe analysis. This technique was used by Brothers and Grapes (1989) to support their much-contested hypothesis for the detrital origin of the jadeite grains. On the basis of a more recent BEI study, Ernst and Banno (1991) proposed that, at Pacheco Pass, jadeite-bearing metagraywackes overstepped the univariant P-T equilibrium curve defined by the assemblage of pure jadeite + quartz + albite and entered the P-T stability field of jadeite + quartz, where nearly pure jadeitic pyroxene crystallized irreversibly. This inferred crystallization history is consistent with the earlier interpretation of Ernst (1971). All recent studies have documented the heterogeneity of Na-clinopyroxene (Na-Cpx) in the Pacheco Pass metamorphic graywackes, where jadeite contents in zoned grains range between $x_{jd}$ = 0.65 and 0.95.

The present study quantifies the detailed chemical microstructure of Franciscan jadeitic pyroxene to further constrain the growth mechanism of this high-pressure