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# Amphibole chemistry from the Penteli metamorphic core complex: implication for the metamorphic evolution of eastern Attica

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The amphiboles represent one of the predominant minerals of HP/LT metabasites. Their composition depends on the effective bulk composition, the solid solution‘s gaps and the P-T conditions during the various metamorphic stages. The distribution of the cations Si, Al and Na, at the crystal sites of the amphibole crystals is mainly controlled by the physicochemical conditions during their crystallization. The $Al_2O_3$ content is tightly connected with pressure and temperature increase. The $Al^{IV}$ and $Na_A$ increase are related with temperature increase whereas that of $Al^{VI}$ and $Na_B$ with pressure one. In particular, the Na-rich amphibole zonation is expressed in terms of $Al^{IV}$, $Al^{VI}$, $Fe^{+2}$, $Fe^{+3}$, $Na_B$ and $(Na+K)_A$. Increase of $Si^{+4}$ and decrease of $Al^{VI}$ and $(Na_A+Na_B)$ is concurrent with pressure decrease. The $Na_A$ and Ti increase is associated with temperature increase, whereas the $Al^{VI}$ and $Na_B$ are increased with pressure increase at constant temperature. From the above is obviously the sensitivity of amphibole chemistry with degree of metamorphism.

The aim of the present work is to provide, for first time, the detailed description of the amphibole‘s chemistry from the broad area of Penteli. We focus on Ca-and Na-rich amphiboles in order to delight the relation of zonation with (1) the physicochemical conditions during amphibole‘s formation and (2) the different P-T stages during prograde and retrograde evolution of the Penteli metamorphic complex.

The lower tectonic unit (LTU) metamorphic features of the Penteli metamorphic complex, such as the glaucophane, pumpellyite and epidote inclusions in garnet from the metabasites, formation of hornblende around glaucophane and actinolite and the high Si content of Phengite from the orthogneisses, support the high pressure/low temperature character of the studied rocks. The maximum pressures are range from 1.2-1.3 GPa for the area of Penteli. The garnet and hornblende formation occur after maximum of pressure and is followed up by increasing temperature.

We focus on the amphibole relations and their zonation profiles. The discrimination in the core-rim compositional profiles suggests distinct P-T conditions of formation. The prograde path is depicted by the $Al^{VI}$ increase with coeval $Na_B$ increase and $Al^{IV}$ decrease which suggest the gradual glaucophane formation rimming actinolite during ongoing subduction. The glaucophane replacement by actinolitic hornblende suggests temperature increase during decompression. Furthermore, many of the amphibole zonations suggest retrograde metamorphic evolution; though pressure decrease associated with contemporaneous increase of temperature. In particular, the core-rim $Al^{VI}$ decrease suggests the replacement of glaucophane by actinolite or hornblende associated with temperature increase.

One of the predominant amphibole‘s complex profile is depicted by Na-rich amphiboles rimmed Fe-rich hornblende or actinolitic hornblende core whereas they mantled by actinolite or actinolitic hornblende rim. This complex amphibole zonation is associated with pressure-temperature decrease. On such complex amphibole profile, scarce glaucophane growth at the outer rim, suggests increase of pressure during ongoing subduction. The latter, in an ordinary subduction zone is difficult to occur; however, a possible stair-stepping evolution during exhumation of the LTU from Penteli area cannot be excluded.