Exsolution phenomena in pyroxenes from the Balmuccia Massif, NW-Italy

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Abstract: Pigeonite, orthopyroxene and clinoamphibole exsolution lamellae in slowly cooled augite are studied by conventional and high resolution transmission electron microscopy. The pigeonite lamellae lie close to the (100) and (001) planes of augite with about zero (generation I) and about 15° deviation (generation II). With increasing width of the lamellae, the interphase boundary becomes semicoherent. From a certain thickness, the pigeonite I lamellae are seen to contain (100) stacking faults and antiphase boundaries. The nucleation of pigeonite II occurs preferentially at dislocations. Semicoherent orthopyroxene lamellae lie parallel to the (100) plane of augite. They contain a high density of clinoenstatite lamellae on (100) planes. Clinoamphibole lamellae lie parallel to the (010) plane of augite. Their formation is via stacking faults, with a 1/2 [101] displacement vector, which are bounded by partial dislocations with Burgers vectors of the same type. The minimum width of the lamellae is 9Å, i.e. one double chain. Broadening of the lamellae is by the motion of partial dislocations along the interface. With increasing thickness, the clinoamphibole lamellae become semicoherent. Nucleation of clinoamphibole also occurs at augite/orthopyroxene interfaces.

The pigeonite/augite interface orientations and relative lattice rotations are used as geothermometers. Exsolution temperature estimates are about 900°C and ≈ 500°C for pigeonite generations I and II, respectively. These results, as well as the intergrowth relations between different phases, suggest the exsolution sequence: Orthopyroxene, pigeonite I, clinoamphibole, pigeonite II. The exsolution phenomena are related to the tectonic evolution of the Balmuccia Massif, as established previously from a microstructural study of the peridotites.

Key-words: Balmuccia Massif, websterite dyke, augite, exsolution lamellae, TEM.

Introduction

In the past, much work has been undertaken on pyroxenes showing that the phase distributions revealed by X-ray diffraction and TEM are the most diverse of any mineral group (for a review see Buseck et al., 1980). Several augites and pigeonites from lunar and terrestrial basalts were found to have microstructures consistent with exsolution by spinodal decomposition whereas those from plutonic environments show microstructures that are consistent with nucleation and growth. It is generally considered that within clinopyroxenes, where structural differences are only slight, exsolution occurs in rapidly cooled samples by spinodal decomposition while slowly cooled samples contain nucleated structures. The exsolution of clinopyroxene from orthopyroxene and vice versa does not permit the operation of the spinodal mechanism because of the difference in structure of the two phases. It has also been found that the nature of the phase boundaries depends on the respective structures of the parent and daughter phases and the conditions of formation of the pyroxene crystals. This cor-