Subsolidus phase relations and textural constrains to the spinel-plagioclase transition in mantle rocks: an experimental approach

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Introduction

Mantle dynamic at extensional settings is governed by two fundamental processes, i) lithosphere extension and thinning, leading to subsolidus tectonic exhumation of the lithospheric mantle, ii) asthenosphere upwelling and melting, causing production and migration of melts through the overlying lithospheric mantle. In these geodynamic environments (passive continental margins vs. mid-ocean ridges) plagioclase-bearing peridotites are thus formed, and their origin can be related to both melt impregnation and metamorphic recrystallization from spinel to plagioclase facies conditions by decompression. The distinction between the two processes represents an actually debated topic, because the two processes can be concomitant and petrologic criteria are not yet available to properly define the metamorphic origin. Indeed few studies have documented the spinel-plagioclase transition in mantle peridotites from both on-land (Kornprobst and Tabit, 1988; Rampone et al., 1993, 2005) and oceanic settings (Cannat et al., 1995), and available experimental data have been performed only on simplified chemical systems and compositions ($CaOMgOAl_2O_3SiO_2$ - CMAS, CMAS + Na, CMAS + Fe; pyrolite), and at high temperatures (T = 1000-1300°C; Presnall et al., 1979; Presnall et al., 2002). High pressure (HP) and high temperature (HT) synthesis by solid media piston cylinder have been carried out at Dipartimento di Scienze della Terra, Milan (Fumagalli and Poli, 2005), on synthetic peridotite compositions (fertile lherzolite, depleted lherzolite, harzburgite), approaching natural lithospheric mantle compositions and modelled in complex chemical system (CMAS + Na + Fe + Cr + Ti). These experimental investigations aim to reproduce products recorded in natural plagioclase peridotites of metamorphic origin (900-1100 °C; Rampone et al. 1993, 2005), thus providing compositional and thermo barometric constraints to the spinel to plagioclase transition.
Furthermore, three series of experiments with different run durations from 10^3 to 10^6 seconds have been performed in order to follow also the kinetics of the reaction spinel to plagioclase.
An accurate characterization of run charges in term of modal distribution of phases (identification and quantification of crystalline phases present) and crystallite size is crucial to provide a better definition of the origin of plagioclase peridotites by subsolidus recrystallization. Especially, it is fundamental in the case of experimental products with very fine grain size which prevent phases identification by EDS and WDS investigations.

Experimental

The low amount (3-5 mg or even less) of sample obtained by HP/HT synthesis are not enough to be properly examined with conventional laboratory X-Ray powder diffraction. Synchrotron radiation experiments were carried out at BM08 Gilda beamline in order to obtain X-ray powder patterns with proper resolution and excellent counting statistic essential for accuracy in phase quantification especially for phase present in low percentage like spinel and plagioclase.
The samples investigated consist of fragments of 20 HP/HT synthesis. Each sample was contained in a 0.3 or 0.5 mm glass capillary depending on fragments size. The diffraction pattern was collected using a monochromatic X-Ray beam having a size of 100 µm and the data was recorded with an image plate detector. The collected diffraction patterns provide a good resolution to separate the diffraction peaks and an excellent counting statistic to obtain a reliable phases quantification.

Results

Prelyminarly Rietveld analysis performed on collected diffraction patterns has revealed different phase associations at variable pressure and temperature conditions investigated (fig.1), and has provided preliminar modal phases proportions consistent with those of natural mantle peridotites. The accurate phases identification and quantification obtained by Rietveld analysis, coupled to combined EDS and WDS investigation, will allow us to properly locate the spinel to plagiocalse transition in function of pressure, temperature and composition.
Diffraction peack profile analysis performed on time resolved experiments has given us data about the crystallinity of phases and the grain corsening rate of major phases (orthopyroxene and clinopyroxene) (fig.2, fig.3). This provide a very useful information to better understand the kinetics of the solid state reaction investigated.

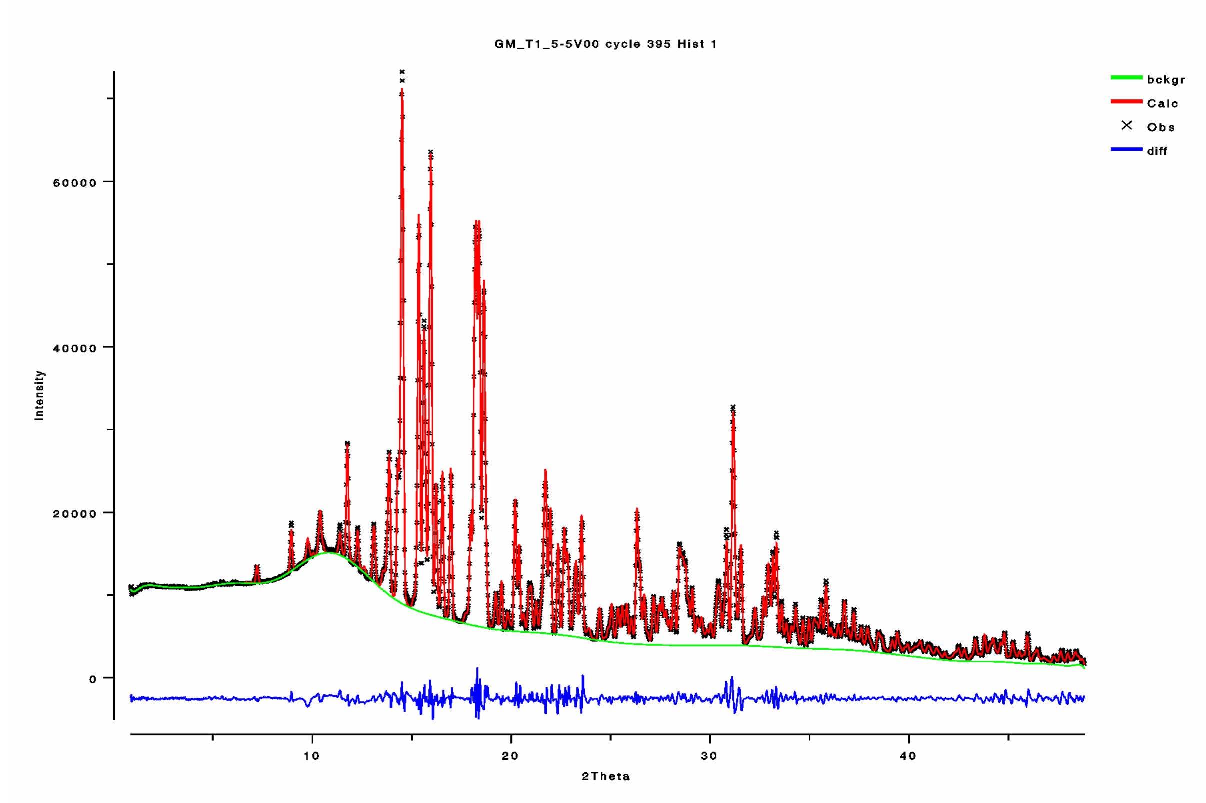

Fig. 1: Rietveld refinement of the run products at 1100°C and 1.0 GPa. Four phases can be identified and quantified: olivine (51.5%wt), orthopyroxene (33.8%wt), clinopyroxene (13.3%wt) and spinel (1.4%wt).

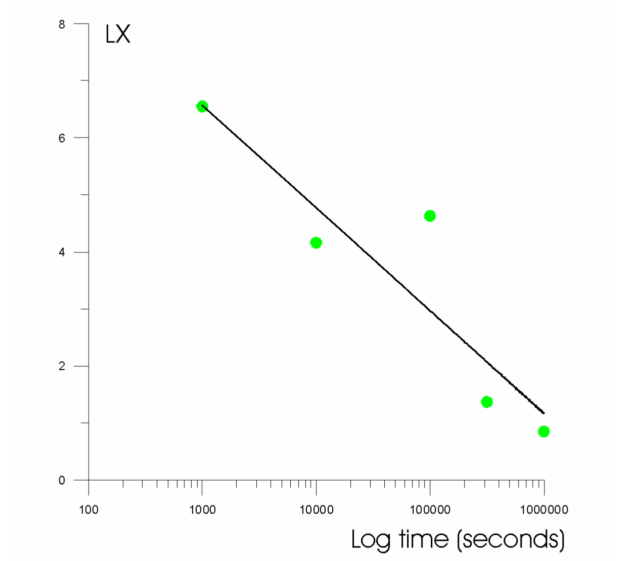

Fig. 2: Plot of Lorentian term (LX) of clinopyroxene versus time. LX was obtained with Rietveld analysis on time resolved experiments.

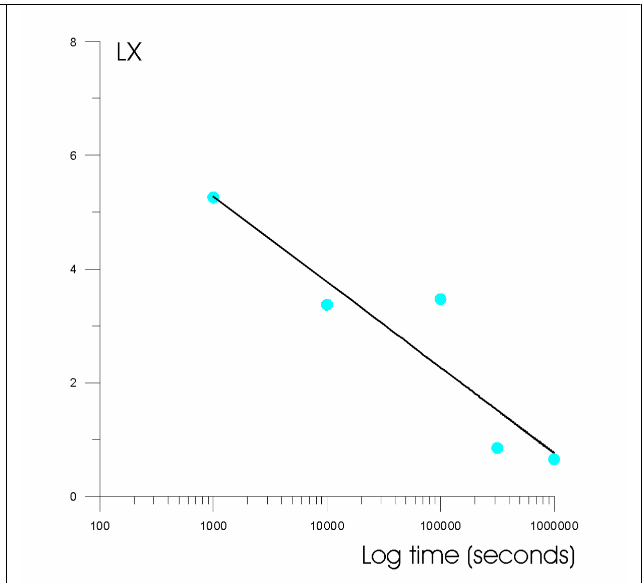

Fig. 3: Plot of Lorentian term (LX) of orthopyroxene versus time. The decreasing trend provide the grain coarsening rate of phase.

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Publications:

1) M. Segata, P. Fumagalli and E. Rampone (2006) – GRAIN GROWTH IN SPINEL AND PLAGIOCLASE PERIDOTITES: A TIME-RESOLVED EXPERIMENTAL STUDY ON TEXTURAL EVOLUTION, Ofioliti (in press)

2) G. Borghini, P. Fumagalli and E. Rampone (2006) - THE SUBSOLIDUS SPINEL TO PLAGIOCLASE TRANSITION IN MANTLE PERIDOTITES: NATURAL AND EXPERIMENTAL CONSTRAINTS, Ofioliti (in press)