Non-hydrostatic stress field orientation inferred from orthopyroxene (Pbca) to low-clinoenstatite (P21/c) inversion in partially dehydrated serpentinites

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**ABSTRACT**

The direction of the main compressional stress, at the origin of the orthoenstatite (Oen) inversion to low-clinoenstatite (LCen) lamellae observed in partially dehydrated antigorite-serpentinites, has been inferred based on the crystallographic orientation relationship between Oen host crystals and the LCen lamellae by means of electron backscattered diffraction (EBSD) combined with optical microscopy. This technique was applied to two samples: a transitional lithology (Atg-Chl-Ol-Opx) and a metaperidotite (Chl-Ol-Opx), both collected within 3 m from the serpentinite dehydration front exposed in Cerro del Almirez (Betic cordillera, South Spain). The metaperidotite displays a clear crystal-preferred orientation (CPO) of both Oen and LCen. The transitional lithology shows weaker CPOs. The metaperidotite contains LCen crystals representative of two possible variants of the Oen to LCen martensitic transformation with distinct orientations, which are consistent with a unique compression direction at ca. 45° to the normal to the foliation and to the lineation of the precursor serpentinite. In contrast, in the transitional sample, calculated compressional stresses display an almost random orientation. The observation of such a variation in the stress field recorded by two samples separated by <3 m rules out the tectonic origin for the stresses producing the LCen in these metaperidotites. We interpret therefore these stresses as resulting from compaction during dehydration. The present analysis implies that compaction-related stresses, though variable at the meter scale, may be organized at the centimeter scale during dehydration reactions of serpentinites.

**Keywords:** Clinoenstatite, stress field, martensitic transformation, serpentinite, dehydration reactions, non-hydrostatic stress

**INTRODUCTION**

Experimental work (Sclar et al. 1964; Boyd and England 1965; Grover 1972; Yamamoto and Akimoto 1977; Khodyrev and Agoshkov 1986; Angel et al. 1992; Wunder and Schreyer 1992, 1997; Luth 1995; Ulmer and Stalder 2001; Jahn and Martohák 2009) provides evidence for the existence of several polymorphs of enstatite MgSiO3 (Fig. 1): orthoenstatite with a space group Pbca, orthoenstatite (Oen, Pbca), a high-pressure clinoenstatite (HCen, C2/c), a low-pressure high-temperature clinoenstatite (C2/c), and a low-pressure and low-temperature clinoenstatite with a space group P21/c (LCen). More recently, Zhang et al. (2012) discovered a second high-pressure clinoenstatite with the space group P21/c. Enstatite occurs in mantle and crustal rocks almost exclusively in the Oen form. LCen is known to occur in stony meteorites for some time, but its occurrence on Earth was not reported until the work of Dallwitz et al. (1966). Most terrestrial descriptions are related to volcanic rocks, which contain multiply twinned LCen (Dallwitz et al. 1966; Dietrich et al. 1978; Komatsu 1980; Shiraki et al. 1980; Yasuda et al. 1983). A minor proportion of described LCen crystals has a metamorphic or a deformational origin; these crystals are typically untwinned (Trommsdorff et al. 1968; Frost et al. 1978; Bozhilov et al. 1999; Ruiz Cruz et al. 1999; Padrón-Navarta et al. 2015; Zhang et al. 2017). Twinned LCen in meteorites and in terrestrial rocks is interpreted to form by cooling from protoenstatite (Brown and Smith 1963; Boyd and England 1965; Yasuda et al. 1983), whereas untwinned LCen is interpreted to form by martensitic transformation from Oen due to shear on (100) planes in the [001] direction (Turner et al. 1960; Cole 1970; Raleigh et al. 1971; Cole and Muller 1973; Cole and Kirby 1975; Frost et al. 1978).

Clinoenstatite with a space group P21/c has also been described in peridotites from presumed ultrahigh-pressure origin such as Alpe Arami (Bozhilov et al. 1999), Dabie-Sulu garnet pyroxenites (Zhang et al. 2002), Indus ophiolite (Das et al. 2015), and in the Luobusa ophiolite (Zhang et al. 2017). In these cases, the occurrence of LCen was interpreted as the result of decompression from the stability field of Hcen with a space group C2/c (Fig. 1), implying exposure of these rocks to ultrahigh pressures >10 GPa corresponding to more than 300 km depth, although a martensitic transformation from Oen cannot be discarded. Cole and Muller (1973) established experimentally the relation between the Oen/LCen crystallographic orientations and the sense of shear during the transformation (Fig. 2), providing a potential technique to infer the orientation of the principal stresses in a similar way to the analysis of calcite, diopside, and plagioclase mechanical twins (e.g. Turner 1953; Raleigh and Talbot 1967; Egydio-Silva and Mainprice 1999). The study of Frost...