Serpentine minerals discrimination by thermal analysis

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ABSTRACT

This paper reports a complete set of TG, DTG, and DTA data, coupled with emitted gas analysis, for well-constrained, almost pure serpentine samples. Serpentine dehydroxylation takes place between 550 and 800 °C, with DTG and DTA peak temperatures progressively decreasing from antigorite (720 and 715 °C, respectively) to lizardite (708 and 714 °C), polygonal serpentine (685 and 691 °C), and chrysotile (650 and 654 °C). Antigorite has an additional diagnostic signal at ~740–760 °C, always absent in the other serpentines, and dependent on antigorite superperiodicity (7 shift of ~20 °C from 36 to 49 Å modulation wavelength). A sharp exothermic peak occurs at extremely constant temperatures (~820 °C), independently from the starting serpentine structure. The high-T mineral assemblage is always represented by forsterite and enstatite.

Based on the observed relationships between serpentine structures and DTG/DTA dehydroxylation temperatures, thermal analysis may represent a useful tool for serpentine identification, particularly in the case of natural massive samples where different varieties are mutually intermixed. The accurate definition of serpentine mineralogy would have obvious implications in both geological-petrological and health-related issues.

Keywords: Serpentine, lizardite, antigorite, dehydroxylation, thermal analysis

INTRODUCTION

Serpentine minerals are an important component of the oceanic crust, and they play a chief role in lithosphere dynamics. Their structural and mineralogical modifications under increasing P-T or deformation conditions have primary implications in subduction zones, fault dynamics, and seismic behavior (e.g., Ulmer and Tronimosdorff 1995; Escartin et al. 2001; Peacock 2001; Boudier et al. 2010). The use of chrysotile in the asbestos industry represents an additional reason of interest, due to related lung diseases (e.g., Hodgson 1979; Kane 1993; Langer 2003; Dodson and Hammar 2006).

Mg-serpentines exhibit an extremely wide range of structural modifications, with almost constant composition close to Mg, Si, O, OH, and minor substitution for Al and Fe. Together with long-established varieties (lizardite, chrysotile, and antigorite, characterized by flat, rolled, and modulated 1:1 layers, respectively; e.g., Wicks and O’Hanley 1988), the serpentine group also includes polygonal serpentinite (in [100] fibers formed by 30 or 15 sectors of polygonalized flat 1:1 layers; e.g., Baronnet et al. 1994) and polyhedral serpentinite (Baronnet et al. 2007; Andreani et al. 2008). In natural occurrences, serpentine structural variants are reciprocally intermixed, giving rise to poorly crystalline, ultra-fine associations, and avoiding monomineralic samples and unbiased data to be collected (e.g., Cresse 1979; Viti and Mellini 1998).

The thermal behavior of serpentines has been the subject of many studies, with preferential attention to chrysotile due to obvious implications with respect to asbestos (Jolicoeur and Duchesne 1981; Khorami et al. 1984; Datta et al. 1986; Suquet 1989; MacKenzie and Meinhold 1994; Gualtieri and Tartaglia 2000; Dellisanti et al. 2002; Cattaneo et al. 2003; Candela et al. 2007; Gualtieri et al. 2008). Detailed models for chrysotile dehydration mechanisms and high-T crystallization are reported in Ball and Taylor (1963), Brindley and Hayami (1965), Martin (1977), and MacKenzie and Meinhold (1994). Few papers have dealt with the thermal behavior of antigorite (Drief and Nieto 1999; Perez-Rodriguez et al. 2005, 2008). Only McKelvy et al. (2004) report thermal analysis for lizardite, even though mineral identification was not clearly supported. Kohyama (2007, 2008) compared the DTG curves of chrysotile, lizardite, and antigorite samples, and suggested that thermal analysis could be successfully employed in serpentine distinction.

The present paper reports a complete set of thermal analyses for well-constrained, nearly monomineralic samples of antigorite, lizardite, polygonal serpentine, and chrysotile. The resulting unbiased thermal data allowed a constructive comparison among the different serpentines and found useful relationships between dehydroxylation temperatures and serpentine structural variants.

EXPERIMENTAL DETAILS AND SAMPLE DESCRIPTION

Thermal analyses (thermogravimetry, TG; differential thermogravimetry, DTG; and differential thermal analysis, DTA) have been carried out by a simultaneous differential thermal analysis (SDTA) Q600-TA Universal instrument. Data were