LETTER

The acoustic emissions signature of a pressure-induced polytypic transformation in chlorite

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ABSTRACT

We present results of an acoustic emissions (AE) study of single crystals of chromian-clinochlore during compression to 10 GPa at room temperature. Distinct AE are detected associated with the type Ia → Ib transition at 6 GPa. Analysis of AE source locations and first motions at transducers are consistent with a rapid collapse of the c-axis of the sample and AE originating within the sample and not the surrounding pressure medium. This is the first time that AE have been detected directly from a phase transformation in the multi-anvil press and opens new possibilities for kinetic studies and studies of deep-seismogenesis.

Keywords: High-pressure studies, mechanical properties, new technique, chlorite

INTRODUCTION

Oceanic crust becomes highly hydrated during its passage from spreading ridge to subduction zone. Within the greenschist facies, chlorite commonly develops as a hydrous mineral of the MORB component of the crust (e.g., Banerjee and Gillis 2001). During subduction this chlorite undergoes structural rearrangements in response to the increased confining pressure and, at high temperatures, transforms to amphibole-bearing assemblages. However, in subduction zones with low thermal gradients, a recent experimental study (Fumagalli and Poli 2005) indicates that chlorite transforms to assemblages containing the “10-Å phase,” a mono-hydrated sheet silicate with interlayer H2O. There is also evidence for a nearly polymorphic high-pressure transformation between lizardite and chlorite (Dódony and Buseck 2004). Chlorite also undergoes a pressure-induced reversible polytypic transformation at 6 GPa and 298 K (Welch and Crichton 2005), and the Ib polytype undergoes anomalous transformational behavior at 9 GPa and 298 K that involves exceptionally large positive increases in the vibrational frequencies of hydrogen-bonded OH groups (Kleppe et al. 2003; Welch et al. 2004). Thus, a rich variety of transformations between sheet silicates could occur in cooler subduction zones. These transformations can involve small, but potentially significant, volume changes. If the transformational behavior is sufficiently rapid (negligible hysteresis), it might contribute to the mechanisms of subduction-related seismicity.

Here we report results of a multi-anvil acoustic-emission study of the 6 GPa polytypic transformation Ia → Ib in Type-I chlorite (Welch and Crichton 2005). This transformation is rapid and reversible.

METHODS

Crystals of chromian-clinochlore from Erzincan, Turkey were taken from the same hand specimen as that of Welch and Crichton (2005), who reported a chemical composition (anhydrous) of Mg4.93(4)Cr0.77(5)Fe3+1.1(3)Al1.20(2)Si2.96(5)O14. Two inclusion-free, unfractured, tabular crystals of good optical quality were chosen, having dimensions approximately 1.5 × 5 × 5 mm with the c-axis being parallel to the short dimension. Each crystal was packed in a semi-sintered MgO octahedral cell of 14 mm edge-length. Crystals were placed in the cell such that the normal to (001) was coincident with a threefold axis of the cell and off-centered along this axis by approximately 1 mm. An internal pressure calibrant consisting of Bi -foil was placed in the MgO cell in a symmetrically equivalent position with the sample. A schematic section of the cell arrangement is presented in Figure 1. The Bi I-II (2.25 GPa) and Bi III-V (7.7 GPa) transformations were detected by changes in the electrical conductivity of the foil and used to calibrate the cell pressure against press load. We estimate that the precision of pressures interpolated from these fixed-points is better than 0.1 GPa. The MgO cell was compressed by 8 tungsten carbide anvils with 8 mm truncations in a standard 6–8 double-stage multi-anvil geometry (Kawai et al. 1973) using the 1000 tonne press at University College London.

Acoustic emissions (AE) were monitored using an 8-transducer system developed from the technique described by Dobson et al. (2004). Lead-zirconia titanate transducers were used with a 5 MHz resonant frequency and 1/4-wavelength back-plates. These transducers, which had a flat response to P-waves across the 1–5 MHz frequency range, were bonded onto truncations on the back corners of all 8 anvils and connected to a Vallen high-speed AE recorder via programmable-gain pre-amplifiers. For all experiments reported here the gain was set to 35 dB. The Vallen system sampled waveforms at a rate of 10 MHz for each transducer; this

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FIGURE 1. Schematic diagram of the high-pressure cell.