

Sound velocity of carbonate melts under high pressure and temperature conditions and the origin of mid-lithosphere discontinuity

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Introduction

CO₂-rich magmas, such as kimberlites and carbonatites, have been reported from all of the Earth's continents including Antarctica. Because both kimberlites and carbonatites are considered to be originated from upper mantle, it is, therefore, reasonable to assume that CO₂-rich magmas are ubiquitously distributed somewhere in the upper mantle beneath the continental crusts. In order to understand the origin and distribution of CO₂-rich magmas in the upper mantle beneath the continents, we have measured the compressional wave velocity (V_p) of carbonate melts under high pressure and temperature conditions.

Experimental method

High pressure and temperature experiments were carried out using a Paris-Edinburgh cell at Beamline 16 BM-B, HPCAT of the Advanced Photon Source, USA. A Si₃N₄ buffer rod was used for transmitting elastic waves between WC anvil and sample. A LiNbO₃ transducer, which generates and receives V_p , was attached to the top WC anvil. Because melt phase only 25 MHz electrical sine waves were used to determine V_p . The details on ultrasonic measurement setup are described in Kono et al. (2012). The starting materials were prepared by mixing reagent grade carbonate powders in appropriate ratios. The compositions of starting materials thus prepared are Na₂Mg(CO₃)₂, Na₂Ca(CO₃)₂, K₂Mg(CO₃)₂, and K₂Ca(CO₃)₂. The measurements were done up to about 2.2 GPa and 1200°C.

Experimental results

The compressible wave velocity in carbonate melts decrease with increasing temperature. The slopes, dV_p/dT , at high pressures obtained in the present study are almost the same as those obtained by the previous study at 1 atmosphere. The V_p in carbonate melts increases with increasing pressure (Fig. 1).

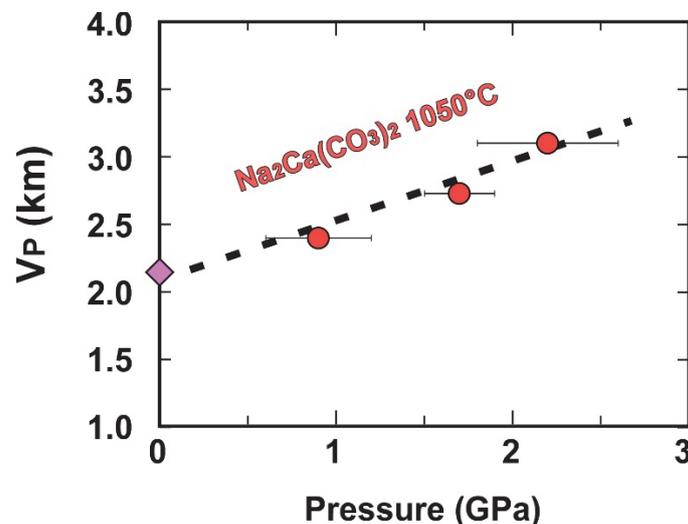


Figure 1: The compressible wave velocity (V_p) in carbonate melt as a function of pressure.

The V_p in carbonate melt, $\text{Na}_2\text{Ca}(\text{CO}_3)_2$, is faster than pure H_2O and slower than basaltic melt within the pressure and temperature conditions investigated. The V_p in carbonate melts decrease with increasing mean atomic weight.

Origin of the mid-lithosphere discontinuity in the continents

It has been reported that seismic body wave velocity drops by 2 to 6% at the mid-lithospheric depths of about 60 to 150 km in almost of all the continents (Karato et al., 2015). However, the origin of this reduction in seismic wave velocity has not been understood yet. According to our experimental results, those drops in seismic wave velocity can be explained by the presence of about 1 to 3 vol% of alkaline carbonate melts in peridotites. The presence of alkaline carbonate melts are often reported as the melt inclusions trapped in mineral grains in mantle xenoliths from sub-continental lithospheric mantle (Giuliani et al., 2012), which is considered to be the direct and natural evidence of the presence of alkaline carbonate melts at the mid-lithospheric depths in continental mantles.

References

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