

Talc dehydration to 50 kbar: Constraints on the volume of H₂O at high pressure

A.R. Pawley
B.J. Wood

CETSEI, Department of Geology, University of Bristol, Bristol
BS8 1RJ

Introduction

Recent experimental studies indicate that a variety of hydrous minerals may be stable in the earth to pressures of at least several tens of kilobars, that is well above the pressures at which reliable thermodynamic data for H₂O exist. Data for H₂O are needed to calculate the stabilities of the hydrous minerals, from which constraints can be placed on important mantle processes such as partial melting and the extent of H₂O recycling deep into the mantle at subduction zones. Existing equations of state of H₂O generally rely on extrapolation of the < 1 GPa data of Burnham *et al.* (1969), or on high-pressure shock-wave data. However, most of the currently-popular equations of state diverge from each other at high pressures, and shock-wave experiments suffer from a large temperature uncertainty. Therefore, additional high-pressure data are needed. Recent experimental measurements of the density of H₂O to 25 kbar (Brodholt and Wood, 1994) are in quite good agreement with the equation of state of Kerrick and Jacobs (1981) and the molecular dynamics simulations of Brodholt and Wood (1993). At higher pressures, Johnson and Walker

(1993) calculated the volume of H₂O along the brucite [Mg(OH)₂] dehydration curve to 150 kbar, by combining an experimental determination of the P-T location of the dehydration reaction with existing thermodynamic data for the solid phases. We have conducted a similar study of talc [Mg₃Si₄O₁₀(OH)₂] dehydration, to determine the volume of H₂O along the reaction talc = enstatite + quartz/coesite + H₂O.

Results

Experiments up to 40 kbar used an end-loaded piston-cylinder apparatus. Samples consisting of equal amounts of talc and enstatite + quartz were sealed in Pt capsules with 10 wt % H₂O. Reaction direction was determined from changes in peak proportions in X-ray diffractograms. The experiment at 50 kbar used a multi-anvil apparatus. The sample consisted of talc + H₂O, and dehydration was inferred by examining the sample close to the thermocouple for the presence of enstatite. The results are shown in Fig. 1, together with previous data on the reaction talc = enstatite + quartz + vapour. 50 kbar is the maximum pressure stability of talc under H₂O-saturated conditions; at higher pressures talc + H₂O reacts to form the 10 Å phase.

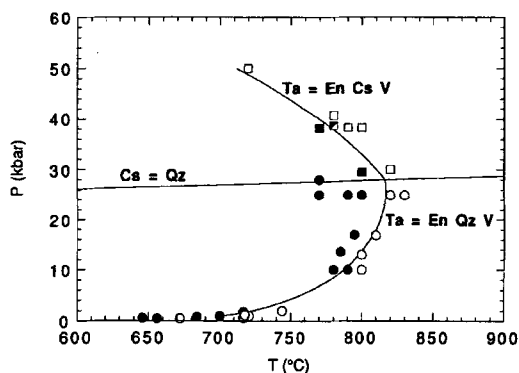


FIG. 1. Results of experiments on talc dehydration. Squares = this study: filled = talc grew, open = enstatite + coesite grew, half-filled = no reaction. Circles = previous studies: Chernosky *et al.* (1985) (< 25 kbar), Jenkins *et al.* (1991) (25 kbar). The curves were fitted through the experimental brackets.

A curve was fit through the experimental brackets, and $V_{\text{H}_2\text{O}}$ calculated using the method discussed by Johnson and Walker (1993). Fig. 2 shows $V_{\text{H}_2\text{O}}$ calculated using thermodynamic data for the solid phases, and for H₂O at one atmosphere pressure, taken from the Thermocalc database of Holland and Powell (1990). For simplification, this database includes constant values for compressibilities and thermal expansivities. Better fits to compressibility and expansion data for quartz, coesite and enstatite, taken from the literature, do not change the calculated $V_{\text{H}_2\text{O}}$ significantly. However, no thermal expansion data exist for talc, and its compressibility may be overestimated. Changes in these values do have a significant effect on the calculated $V_{\text{H}_2\text{O}}$. For example, an increase in the thermal expansion coefficient estimated by Holland and Powell (1990) of 50 % increases $V_{\text{H}_2\text{O}}$ by 10 %.

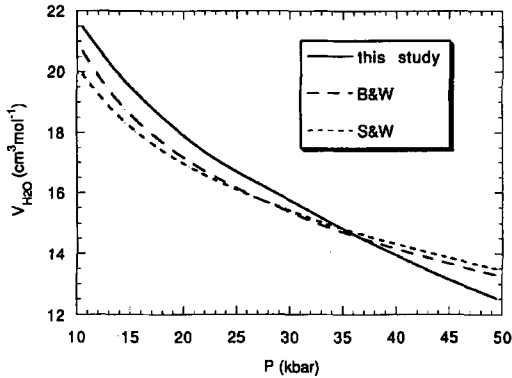


FIG. 2. Volume of H₂O along the talc dehydration curve calculated in this study, compared with values calculated using the equations of Brodholt and Wood (1993) (= B&W) and Saul and Wagner (1989) (= S&W).

Our data for H₂O, calculated using the simplified and estimated data for talc, are in good agreement with V_{H₂O} taken from the shock-wave-based equation of state of Saul and Wagner (1989), and even better agreement with V_{H₂O}

calculated using the molecular dynamics equation of state of Brodholt and Wood (1993). A better comparison between values will be possible when new data for the compressibility and expansivity of talc are available.

References

- Brodholt, J. P. and Wood, B. J. (1993) *J. Geophys. Res.*, **98**, 519–36.
- Brodholt, J. P. and Wood, B. J. (1994) (in press).
- Burnham, C. W., Holloway, J. R. and Davis, N. F. (1969) *Amer. J. Sci.*, **256-A**, 70–95.
- Chernosky, J. V. Jr., Day, H. W. and Caruso, L. J. (1985) *Amer. Mineral.*, **70**, 223–36.
- Holland, T. J. B. and Powell, R. (1990) *J. Metamorphic Geol.*, **8**, 89–124.
- Jenkins, D. M., Holland, T. J. B. and Clare, A. K. (1991) *Amer. Mineral.*, **76**, 458–69.
- Johnson, M. C. and Walker, D. (1993) *Amer. Mineral.*, **78**, 271–84.
- Kerrick, D. M. and Jacobs, G. K. (1981) *Amer. J. Sci.*, **281**, 735–67.
- Saul, A. and Wagner, W. (1989) *J. Phys. Chem. Ref. Data*, **18**, 1537–64.