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Strength of Solid Pressure Media and Implications for High Pressure Apparatus

J. M. Edmond* and M. S. Paterson

Department of Geophysics and Geochemistry, Australian National University, Canberra, Australia

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Abstract. The stress-strain properties of talc, pyrophyllite, silver chloride, sodium chloride, boron nitride and graphite have been measured under confining pressures up to 8 or 10 kb at room temperature, and, in the case of talc, also at temperatures up to 900° C. The extrapolation and application of these results to solid medium high pressure apparatus of piston-cylinder type is discussed and a calculation made of the correction to nominal pressure ("friction correction"), taking into account the stress gradients in the medium and the shearing between the medium and the cylinder wall. Correction to the nominal differential stress measured in solid medium stress-strain apparatus is also discussed.

Introduction

Solid media such as talc and pyrophyllite are widely used in experiments at high pressure, especially above 10 kb. These media are chosen, in part, because of relatively low or negligible strength. However, there is little published information on their stress-strain properties, although measurements on shearing discs give some indications (Bridgman, 1935, 1937; Vereshchagin and Zubova, 1961; Bundy, 1962; Towle and Riecker, 1969). Graf and Hulse (1964) and Hulse and Graf (1965) tested pyrophyllite and talc in compression at atmospheric pressure and elevated temperatures but their results are of doubtful relevance to high pressure conditions since they do not take into account either the effect of pressure itself or, at high temperatures, the effect of any water of decomposition on the strength.

The need for further information on the strength of solid pressure media is evident from discussions in the phase equilibrium field of the magnitude of the "friction corrections" to the nominal pressure in piston-cylinder apparatus, which probably involve in large part the strength of the medium. The corrections, obtained empirically from hysteresis measurements or from calibration against a known phase transition, vary widely between laboratories. For example, Boyd and England (1960a and 1960b) initially used a correction of -13 percent at room temperature and -8 percent at high temperature, while Green, Ringwood and Major (1966) arrived at a correction of -10 percent for use over a wide pressure and temperature range. Klement, Jayaraman and Kennedy (1963) found a correction that increased more slowly with pressure and Pistorius (1967) uses a correction that is independent of pressure. Different effects of temperature on the correction have also been found. Thus Boyd and England (1963) concluded that correction could be neglected in high temperature work whereas some workers

* Present address: P.O. Box 456, Luanshya, Zambia.

find relatively little decrease with increase in temperature (a number of the observations have been reviewed recently by Boettcher and Wyllie, 1968). Whether the final pressure is approached from below or from above also affects the correction.

We have therefore measured the stress-strain properties over a range of confining pressure up to 10 kb at room temperature of a number of materials used in solid media apparatus. We have also extended the measurements on talc at 4 kb up to 900° C. Whilst these do not represent normal operating conditions, extrapolation of the measurements permits more realistic estimates than hitherto of the properties of interest at high pressures.

Apparatus and Experimental Methods

The room temperature experiments were done in an apparatus previously described by Paterson (1964) in which the pressure medium was kerosene. The high temperature experiments were done in another apparatus (Paterson, 1970) which has an internal furnace and in which the pressure medium was argon. The temperature gradient along the specimens at high temperature is unlikely to have exceeded 10° C.

In both cases a small correction is applied for apparatus distortion and in the room temperature experiments there is a correction for piston friction; in the high temperature apparatus no friction corrections were necessary since an internal load cell was used. Correction has also been made for the small load borne by the copper jacket on the specimen. These various corrections and the procedures for deriving the stress-strain curves are discussed in more detail in the above references. Experimental errors are believed to be small compared to the scatter in results between individual specimens, except at strains less than about 1 percent. The results given are the means from two or three experiments in all cases except where individual measurements are indicated (as in Fig. 4).

The stress quoted is the "differential stress", that is, the difference between the total axial stress and the confining pressure. It has been calculated on "actual" cross-sectional area, obtained by assuming that the specimen has undergone uniform strain with no volume change.

The specimens were 10 mm in diameter and 20 mm long with ends ground true and flat within 0.02 mm. They had been air dried for at least several days before testing. They were then sealed in annealed copper jackets of 0.25 mm wall thickness. The strain rate was approximately 4×10^{-4} sec^{-1}. In the high temperature experiments on talc, after applying the pressure, the specimens were held at the test temperature for about 30 min before testing.

Materials Tested

1. Talc

(a) *Three Springs Talc (West Australia).* This consisted of fine-grained talc, threaded by veins and irregular patches of coarser-grained talc. X-ray texture goniometer measurements revealed no obvious preferred orientation and stress-strain measurements on orthogonally drilled specimens showed no anisotropy in strength. The density (2.71 gm cm^{-3}) was approximately 97 percent theoretical.