Wave velocities of (Mg, Fe)SiO_3 *orthopyroxene*

Three polycrystalline samples of (Mg, Fe)SiO_3 orthopyroxene were prepared by means of high-pressure sintering technique at 40 kbar and at 1,200°C using the tetrahedral anvil press. Compositions of these samples are $MgSiO_3$(ortho-enstatite), $FeSiO_3$(ortho-ferrosilite) and $(Mg_{0.7}Fe_{0.3})SiO_3$. Ultrasonic wave velocities of these samples were measured by the pulse transmission method (Mizutani, 1971). Results are summarized in Table I. The dependence of the compressional- and shear-wave velocities of orthopyroxene upon density is shown in Fig.6 and 7. A systematic decrease of the compressional- and shear-wave velocities with the increase of the mole percent of $FeSiO_3$ component was found. Recently Kumazawa (1969) measured the elastic constants of a natural single crystal of bronzite of which the chemical composition was near $(Mg_{0.85}Fe_{0.15})SiO_3$. The velocities averaged by the Voigt-Reuss-Hill scheme (Hill, 1952) are also shown in the figures. This averaged value is in good accordance with our data. It is noted that the $MgSiO_3$–$FeSiO_3$ orthopyroxene isomorphic line is approximately parallel to the Mg_2SiO_4–Fe_2SiO_4 olivine isomorphic line. Although the shear-wave velocity changes quite linearly with the FeO/(FeO + MgO) ratio, the compressional-wave velocity increases rapidly at the $MgSiO_3$ rich side. This non-linear behaviour may be related to the non-ideality of the $MgSiO_3$–$FeSiO_3$ system (Matsui et al., 1968).

HIGH PRESSURE TRANSFORMATIONS IN SiO_2

Phase equilibria

Since the first synthesis of coesite (Coes, 1953) and stishovite (Stishov and Popova, 1961) there has been great interest in determining their temperature-pressure stability fields, because of silica's role as one of the principal rock-forming oxides. Once the quartz–coesite transformation curve was definitely established, it may eventually offer a convenient basis for pressure calibration at high temperatures. The interest in determining the physical properties and stability of stishovite is in part motivated by the acceptance that this mineral probably is a major constituent of the earth's lower mantle.

A number of equilibrium investigations have been reported in the quartz–coesite transformation during the past ten years. Fig.9 contains the pressure-temperature curves given in three different equilibrium studies of this system (Boyd, 1964; Kitahara and Kennedy, 1964; Takahashi, 1963), as well as a single equilibrium point reported by Boyd et al. (1967) and Green et al. (1966). The agreement is reasonably satisfactory, and this guarantees that the quartz–coesite transformation curve is of practical use for the pressure calibration point in the pressure range 30– 40 kbar at high temperatures.

Following the report by Stishov and Popova (1961), Wentorf (1962), Sclar et al. (1962), Ringwood and Seabrook (1962), Bendelyany and Verestshagin (1964) and Minomura et al. (1964) have described the synthesis of stishovite using different types of high-pressure

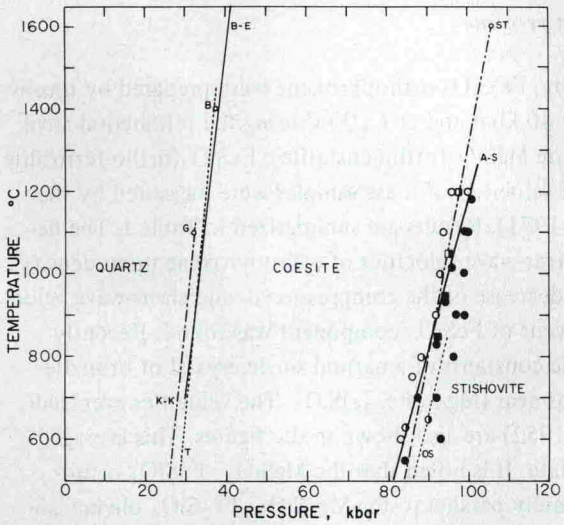

Fig. 9. Phase diagram for quartz–coesite–stishovite transition of SiO_2. For quartz–coesite transition, B-E = Boyd (1964); K-K = Kitahara and Kennedy (1964); T = Takahashi (1963); B = Boyd et al. (1967); G = Green et al. (1966). For coesite–stishovite transition, ST = Stishov (1963); OS = Ostrovsky (1965, 1967); A-S = Akimoto and Syono (1969).

apparatus, but they provide no detailed data on its stability range. The first attempt to determine the coesite–stishovite transformation curve was made by Stishov (1963). He derived the standard entropy of stishovite from the linear relationship between entropy and density empirically found in the rutile-type oxides, and calculated the transformation curve passing through the equilibrium point 106 ± 5 kbar, 1,600 ± 100°C experimentally determined. Further data on the direct experimental determination of the transformation curve in the temperature range 410–830°C were provided by Ostrovsky (1965, 1967). Thereafter, an extension of these investigations of the coesite–stishovite curve to a wider range of temperatures has been attempted at the author's laboratory. Akimoto and Syono (1969) determined the coesite–stishovite transformation curve over the temperature range 550–1,200°C in the pressure range 83–101 kbar by means of the tetrahedral anvil press. In order to determine the transformation curve accurately and to examine the reversibility of the reactions, runs with different kinds of starting materials were practised. Amorphous anhydrous silica, α quartz, coesite and stishovite were used as the starting materials. Results of experimental runs are shown in Fig.9. Successful reverse reactions from stishovite to coesite were demonstrated at two different temperatures using single-phase stishovite as the starting material. Summarizing all the experimental data, the boundary curve for the coesite–stishovite transformation was fitted by the linear relation $P(\text{kbar}) = 67 + 0.028\,T\,(°\text{C})$.★

In Fig.9 the coesite–stishovite transformation curve reported by Stishov (1963) and Ostrovsky (1965) is also reproduced for comparison. Since the pressure values used by these investigators are based on Bridgman's "volume scale", in which Bi III-V transition was fixed

★ A change in the transformation pressure for Sn I-II from 92 kbar in the previous paper (Akimoto and Syono, 1969) to 94 kbar causes a slight alteration in the numerical values of the equation.