to be similar in behavior and strength over the range of experimentation, and they remained brittle to 500°C. Quartz and quartzite proved to be the strongest of all materials tested. They remained brittle to at least 800°C.

*Riecker and Rooney* [1966*b*] tested the torsional shear strength of several minerals and rocks to 900°C to a confining pressure of 40 kbar. They found that shear strengths diminish with increasing temperature to at least 900°C at 40 kbar but in a relatively linear way and with considerable strength still remaining at 900°C. This behavior is illustrated in Figure 9 (top), where comparative data are given for granodiorite, dunite, pyrope garnet, and labradorite. Extrapolation to 1000°C indicates that at 40 kbar these rocks retain about 50% of their room temperature strength.

Also important is the fact that the room temperature transition to a reduced rate of shear strength increase (i.e., to predominantly slip deformations) at about 35 kbar persists to the highest test temperature with both granodiorite and dunite. Figure 9 (bottom) shows the change in shear strength of the respective rocks as a function of pressure at several specific temperatures.

Since the transition pressure of about 35 kbar corresponds to an earth depth of about 110 km and the calculated internal temperature of a downmoving slab at this depth is about 575°C, it can be assumed that this transition persists under real earth conditions.

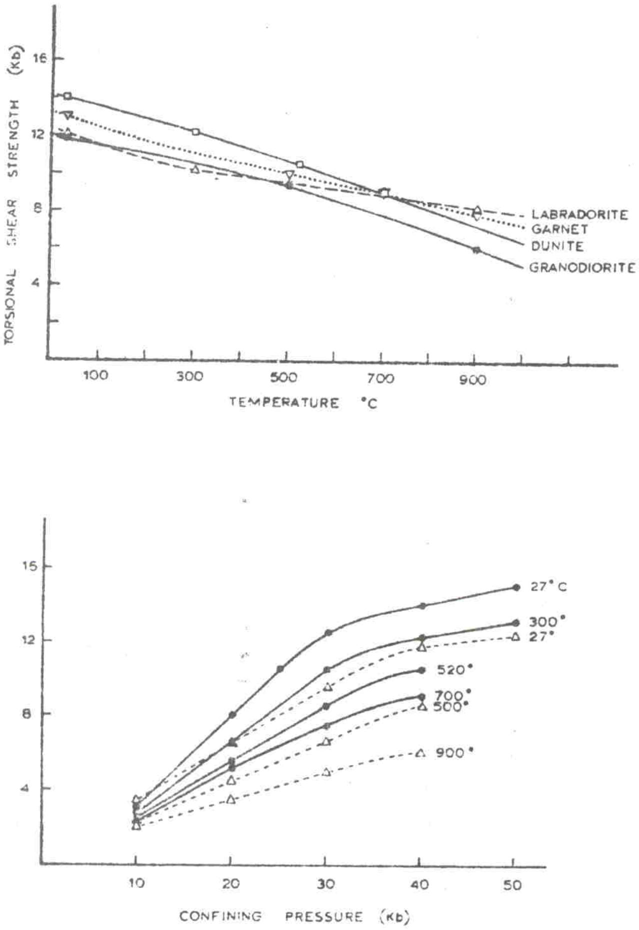

Fig. 9. (Top) The torsional shear strengths of labradorite, pyrope garnet, dunite, and granodiorite as a function of temperature at a confining pressure of 40 kbar given by *Riecker and Rooney* [1966*b*]. (Bottom) The torsional shear strength of dunite (solid line) as a function of pressure at temperatures of 27°, 300°, 520°, and 700°C and the torsional shear strength of granodiorite (dashed line) as a function of pressure at temperatures of 27°, 500°, and 900°C, both from *Riecker and Rooney* [1966*b*].

There are no direct experimental data by which the higher-pressure transition (75–100 kbar) to an increased shear strength can be appraised. There are, however, the following factors that can be considered. (1) *Bridgman* [1936] concluded that high-pressure mechanical phenomena at high temperature are at least qualitatively similar to those that occur at room temperature. (2) The 35-kbar transition has been shown to persist to a temperature approaching 1000°C. (3) The pressure range 75–100 kbar corresponds to a depth range 250–300 km, and the calculated temperature in a downmoving slab at this depth is 800°–1000°C. (4) The strength of rock remains appreciable to at least 900°C at 40 kbar of pressure, and the pressure derivative of strength is positive (about 0.12). (5) The microstructural observations from torsional experiments indicate that the high-pressure transition is related to a saturation of slip-type deformations, subsequent failure being caused by shear-induced fusion of the sample. Temperature would act to extend the degree of plastic deformation and probably also favor an earlier catastrophic failure by fusion. (6) The depth span 250–300 km has been shown to be one of concentrated seismic activity at the Fiji-Tonga trench.

The preceding observations are not conclusive. They do suggest, however, that the high-pressure transition to an increased shear strength and subsequent catastrophic failure can persist under real earth conditions. Some experimentally related support for this interpretation is possible by a rough calculation of the effect that the temperature gradient within a downmoving crustal slab would have on the room temperature shear strength.

The following experimental data are available. (1) The averaged torsional shear strength $S$ for the rocks dunite, garnet, labradorite, and granodiorite at 40 kbar (125 km) at an approximate crustal slab temperature of 600°C is about 9 kbar (Figure 9, top). (2) A rough approximation of the temperature derivative for the torsional shear strength at high pressures can be obtained from the data given by *Riecker and Rooney* [1966*b*] (Table 1).

A plot of averaged values for $(\Delta S/\Delta T)_P$ at 20, 30, and 40 kbar of confining pressure, with extensive extrapolation to 120 kbar, is given in Figure 10. When the data thus derived are used, it is possible to calculate a qualitative temperature modification for the room temperature failure diagram given in Figure 7. For example, values for the temperature derivative at 40, 70, and 120 kbar are −0.006, −0.008, and −0.009, respectively. The calculated strength $S$ at 40 kbar and 600°C is

$$S_{40\mathrm{kbar},600^\circ} = S_{20^\circ} + (\Delta S/\Delta T)_{40\mathrm{kbar}}$$

$$= 12.2 - 0.006(580^\circ) = 8.7\ \mathrm{kbar}$$

TABLE 1. Values for the Temperature Derivative of Torsional Shear Strengths Derived from the Experimental Data of *Riecker and Rooney* [1966*b*]

| $P$, kbar | $(\Delta S/\Delta T)_P$ Dunite | Garnet | Labradorite | Granodiorite | Average |
|---|---|---|---|---|---|
| 20 | -0.004 | -0.005 | -0.003 | -0.004 | -0.0035 |
| 30 | -0.007 | -0.004 | -0.004 | -0.005 | -0.005 |
| 40 | -0.007 | -0.006 | -0.004 | -0.007 | -0.006 |