of the severe energy requirements and the need to accommodate a beam condenser [273]. However, it is possible that new instrumentation involving tunable diode lasers in the IR may overcome these difficulties.

Many of the original studies to attempt to create Mbar pressures were done with shock waves [274]. As previously stated, this is a rather difficult and destructive way to study the problem. Modern techniques using the diamond anvil cell to Mbar pressures and 3000°C are now available, and this should provide impetus to this field.

Table 27 shows some examples of early general results or effects of t and p (50 kbar or less) on minerals. Transformation of minerals with t and p indicate that few minerals found on the surface would be stable in the deep interior of the earth, an observation made by Bridgman in 1945.

The effects of t and p on interatomic distances in oxygen-based minerals have been reported [298,299]. Mechanisms of Si(IV) to Si(VI) in silicate minerals have also been determined [300]. Other mineral studies have also appeared recently in the literature [301,302].

Some more recent studies of minerals at higher pressure are outlined in Table 28. Ming and Bassett [296] have found from their t and p studies that at 250 kbar and 1000°C ferromagnesium silicate breaks down to the simple oxides of iron, magnesium and silicon. In the interior of the earth, below 650 km, it is believed that these oxides constitute the main mineral constituents in the mantle. The presence of iron oxides is of considerable interest since they play a major role in determining the optical, electrical and thermal properties of the mantle as well as in the evolution of the earth.

An interesting result of studies at high pressure and temperature were those of Bell et al. [297]. Studying iron-rich basaltic glass at 100—150 kbar and ca. 2000°C they showed that the ferrous-bearing compounds would disproportionate into a ferric iron phase plus a metallic iron phase. Thus, both a highly oxidized crust and a metallic core can coexist and can be simultaneously formed, obviating some early evolutionary history of earth. The results lend support to the fact that the core and mantle may exist in a chemical equilibrium.

TABLE 27

Some mineral transformations at relatively low pressures

	Temp. (°C)	Pressure (kbar)	Ref.
β-Quartz ⇌ α-quartz	573— 800	24	275
α-Quartz ⇌ coesite	400— 600	10	276, 277
	700—1700	20	278
Sillimanite ⇌ kyanite	1000—1500	5	279, 280
Albite ⇌ jadeite + quartz	600—1000	50	281
Fayalite ⇌ spinel		25	282, 283

TABLE 28

Transformation of several minerals at high temperatures and pressures [296]

Mineral	Pressure (kbar)	Temp. (°C)	Products	Ref.
$FeSiO_3$, ferrosilite	95	1000	Fe_2SO_4 + SiO_2, stishovite	284
(Fe, Mg)SiO_3, clinopyroxene	80—180	1000	$(Fe, Mg)_2SiO_4$, spinel + SiO_2, stishovite	285, 286
$MgSiO_3$, clinoenstatite	200—280	1000	Mg_2SiO_4, β-phase + SiO_2 stishovite	287
β-Mg_2SiO_4	>280	1000	γ-Mg_2SiO_4, spinel	287
Fe_2SiO_4, spinel	250	1000	FeO + SiO_2, stishovite	288, 289
$(Mg, Fe)_2SiO_4$, olivines	50—150	1000	Spinel, γ-phase	290—294
Mg_2SiO_4, fosterite	330	1000	MgO + SiO_2, stishovite	295
Complex basalt	100—150	2000	Fe_2O_3 + Fe	297

Minerals containing iron, such as olivine and spinel, under pressure, appear to indicate that a marked increase in conductivity occurs with pressure in excess of 100 kbar [303]. Similar results have been indicated with other solid phases approaching metallic behavior with pressure. In addition, charge transfer properties change in these minerals due to pressure effects on electronic orbitals [286]. These effects bear heavily on the earth's internal temperature and electrical conductivity, as well as on models of earth formulated to date. The question of whether the thermal conductivity in earth is radiative or conductive may, in part, have been answered in the Bell et al. [297] experiment. Both iron and ferric oxides are opaque to thermal radiation, but have high thermal conductivities.

We have only attempted to briefly indicate some geological applications of T and P. Further discussions are available in several reviews [274,303,304], and other reports [305—307].

G. SUMMARY

A summary of the solid state pressure effects discussed in the previous sections follows.

(i) Structural transformations

We have discussed a number of structural transformations that occur in the solid state under pressure. These are summarized below. (1) Phase changes in alkali metal halides, rare earth monochalcogenides from NaCl to CsCl structure where C.N. 6 → 8. (2) Transitions occurring in minerals where C.N. 4 → 6. (3) Transitions to metallic state, e.g., rare earth monochalcogenides, iodine,