polymorphs are not simply pressure-dependent so that further mineralogical information is necessary to label say, the sillimanite-subfacies as being formed at a *higher pressure* (and not just a higher temperature) than the andalusite-subfacies. In this respect, Miyashiro's (1961) recognition that staurolite characterizes certain Barrovian rocks whereas cordierite is found at Abukuma, is particularly useful.

It is possible to put tentative values on pressures of formation of the amphibolite facies rocks from the Scottish Highlands and the Abukuma plateau, by taking the mineralogical assemblages from these two areas (Fig. 2) and superimposing them on Hess's (1969) grid. Hess himself concluded that the Abukuma rocks must have formed at total pressures below 3 kilobars to place them outside the field of stability of staurolite. Similarly the assemblages of the Barrovian amphibolite facies can be placed on Hess's grid at total pressures above 6.5 kilobars.This leads to the schematic arrangement shown in Fig. 2, a framework that will prove useful in discussing the metamorphism of the Haliburton area.

Mineral facies in Glamorgan township

The mineral assemblages found in this part of the Haliburton Highlands are shown in Table 2. Those assemblages that can be plotted on the usual ACF and AKF diagrams are shown in Fig. 3. A comparison of Fig. 3 with Fig. 2 indicates the obvious similarities that exist between the Glamorgan rocks and both Barrovian and Abukuma assemblages. For example, staurolite *and* cordierite are found in Glamorgan township. In fact these two minerals are observed in other parts of the Grenville province in Ontario (e.g. Lal & Moorhouse 1969, Shaw 1962).

A reasonable inference from the similarity of Glamorgan rocks with what Miyashiro (1961) calls andalusite-sillimanite, and kyanite-sillimanite types of metamorphism, is that the Canadian occurrence forms part of a low pressure intermediate facies series. Added support for this conclusion is provided by the fact that andalusite (Lumbers 1967) as well as sillimanite and kyanite (Best 1966) occur in adjacent parts of the Grenville province, and Miyashiro (1961) has suggested that the occurrence of all three Al_2SiO_5 polymorphs is diagnostic of low pressure intermediate type metamorphism.

Physical conditions of metamorphism

In order to place limits on conditions of formation of the Glamorgan rocks, the following field observations prove useful.

(a) Sillimanite occurs in the scarce pelitic rocks of the region, and also in some of the non-granitic bands in migmatite.
(b) Staurolite occurs in some of the pelitic rocks.
(c) Cordierite is found in some of the paragneisses.

Conditions of formation that could give rise to the appearance of these three important index minerals can be estimated by reference to an internally consistent body of experimental work due to Richardson and coworkers (Fig. 4). Within the stippled area of the diagram, sillimanite, staurolite and cordierite may all form. In other words, the stippled area represents limiting metamorphic conditions for the Glamorgan rocks. By inspection, the limits prove to be 4.5 to 7 kilobars total pressure, and (in round figures) 600 to 700 °C.

Discussion

In any exercise such as the foregoing, choice of experimental curves is obviously critical. In the case of staurolite and cordierite, no problem of choice arises, since Richardson's (1968) study is the only one to delimit clearly the field of mutual stability of the two minerals. However, with sillimanite almost an embarassment of choice exists. The work of Richardson et al. (1969) was used here because of its compatibility with Richardson's other work. Furthermore, it is consistent with Newton's reversals of the kyanite-sillimanite (1966b) and the kyanite-andalusite (1966a) reactions. The biggest problem arises with the sillimanite-andalusite boundary, which is an approximation at best. By comparison with other work (notably Weill 1966, Althaus 1967) it appears possible that the boundary may have been placed at too high a temperature. However, if we take the estimated uncertainty in the location of the triple point (Richardson et al. 1969), we can drawn an extreme, lower temperature sillimanite-andalusite curve consistent with Weill and Althaus. This curve would be approximately as shown by the lower dotted line in Fig. 4.

The temperature limits for the Glamorgan rocks now became 700 °C represented by the staurolite-quartz breakdown as before, and by the extreme triple point at about 580 °C. The upper pressure limit remains the same (7 kb.)—the intersection of the staurolite-quartz curve with the kyanite-sillimanite boundary. The lower pressure limit moves to 3.5 kb., the lowest pressure at which the Glamorgan assemblage staurolite-almandine-quartz is stable.

An important factor not yet explicitly considered is the equilibrium partial pressure of water (PE_{H_2O}). The reactions of Fig. 4 were determined under conditions where PE_{H_2O} was equal to P_{load}. Lowering PE_{H_2O} relative to P_{load} would have no effect on the solid-solid boundaries, but the staurolite-quartz reaction under such conditions could be expected to occur at lower temperatures than shown on Fig. 4. Thus 700 °C remains as an upper temperature limit for the metamorphism. In similar fashion the staurolite-almandine-quartz reaction will move down temperature in systems where PE_{H_2O} is less than P_{load}. This cannot result in a broadening of the pressure and temperature limits.