It can readily be seen that this geothermometer is relatively insensitive for Fe/Fe + Mg ratios greater than about 0.7, because the garnet produced is very close to pure almandine (Fig. 2). For ratios lower than this it can be computed than an error in ln K of 0.2, is equivalent to a temperature error of 50°. For a typical K of 6, such an error would correspond to an error of roughly 1.1 in determination of K. If this error in turn is assigned entirely to analytical error, it would correspond roughly to an error of 10% in the Fe/Mg + Fe ratio of both garnet and cordierite. Determination of this accuracy does not appear to present any problems in the present state of the art, either by electron probe methods, or by concentration of minerals. It follows that for favourable compositions the method should give results accurate within 50°, and probably considerably better.

Eq. 12(a) has been applied to the data in Table 1. These data indicate that the temperature reached about 600° in the southeastern part of the area, and almost 700° in the northwestern part of the area, at pressures of 5.1 and 5.8 kilobars respectively.

We have also applied the geothermometer to the data of Reinhardt (1968), and Wynne-Edwards and Hay (1963) (Table 1). For the simplest mineral assemblage garnet-cordierite-sillimanite quartz (Reinhardt's specimen D-102) the computed conditions are 675°C and 6.2 kilobars. For his other specimens containing biotite, excepting specimen D-56, the garnet-cordierite pair, indicates a temperature of $675 \pm 10°$, and pressure of 6.1 ± 0.3 kbars, in aggreement with the conditions indicated by specimen D-102. This agreement strongly suggests that the geothermometer is applicable to nearly all cordierite-garnet-sillimanite-quartz gneiss. It is possible that D-56 illustrates the partial breakdown of one of the assumptions, but it is also possible that an analytical error is involved. The other specimens which show significant variations in Fe/Mg ratios in biotite, demonstrate the independence of the thermometer from other Fe and Mg bearing phases.

Throughout this analysis the pressure of H_2O has been ignored. In Fig. 3 we have combined data for the garnet-cordierite equilibrium with data for the aluminosilicate triple-point (Gilbert *et al.*, 1968), the biotite breakdown curve (Eugster and Wones, 1964), and the muscovite breakdown curve (Evans, 1965). The following conclusions, although based on the Gilbert et al triple point, are also applicable to most of the other suggested triple points discussed by Zen (1969). The occurrence of andalusite in equilibrium with sillimanite, as observed in the southeastern part of the region, and the total absence of muscovite cannot be explained if $P_{H_2O} = P_{total}$. However if P_{H_2O} is much less than total pressure, the field data may be reconciled with experimental data. The data of Reinhardt (1968) require very low water pressures, approaching 0.2 total pressure. According to Gilbert *et al.* (1968), for the deduced P-T conditions these rocks would contain sillimanite as the stable polymorph. Under these conditions, garnet and cordierite can coexist with biotite, in the absence of muscovite, and in the presence of either andalusite and sillimanite. These latter polymorphs can both be present in equilibrium with compositions having Fe/Fe + Mg greater than 0.8. In order for the observed coexistence of cordierite with Fe/Fe + Mg less than 0.3 with garnet (Fe/Fe + Mg < 0.7) to take place, as it does north of Loughborough Lake, both temperature and total pressure must increase to roughly 700° and 6.5 kilobars

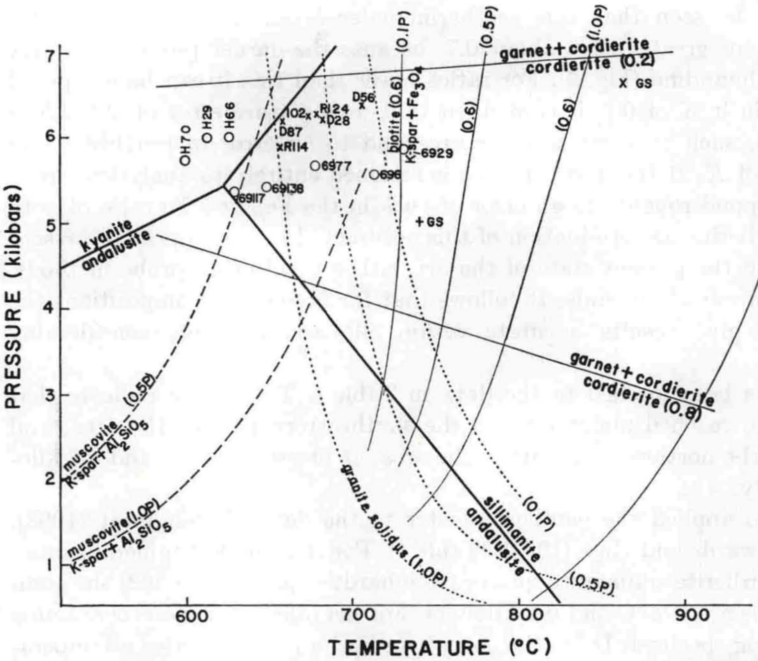

Fig. 3. *PT* projection of garnet cordierite equilibrium and other relevant experimental data. The figures in brackets on the experimental univariant curves give the Fe/Fe+ Mg ratio of the starting materials, while the figures at the end of the curves (e.g. 0.5 P) give the water pressure as a fraction of total pressure. The biotite breakdown curve is calculated for the quartz-fayalite magnetite buffer. Numbered and lettered points are those shown in Tables 1 and 4. The two points labelled GS represent the migmatitic and nonmigmatitic garnet-cordierite gneisses analyzed by Gable and Sim (1969). Specimen 69117 contains andalusite plus sillimanite, while all others contain sillimanite, although specimens H 70, H 29, and H 66 appear to fall in the Kyanite field

in a distance of roughly 10 miles. This increase coincides with an abrupt transition to proxene granulite faciesmetamorphism observed by Wynne-Edwards (1967).

Wynne-Edwards and Hay (1963) have shown that garnet-cordierite assemblages are a persistent accompanient of hornblende granulite facies metamorphism. It seems reasonable to suppose that the conditions deduced for the Opinicon Lake region, temperatures of 600–700°, total pressures of 5–6.5 kilobars, and water pressure less than half total pressure, are typical for this facies of metamorphism. The data on the transition from hornblende to pyroxene granulite facies suggests that both temperature and total pressure are even higher in the latter facies.

The internal consistency of the data, the generally good agreement with other experimental data, and the reasonable agreement between the experimentally temperatures, pressures and water pressures and the field data strongly suggest that garnet-cordierite equilibrium forms a good geothermometer and geobarometer. Saxena and Hollander (1969) however claim that the value of K, in this equilibrium measured in natural rocks, decreases with increasing temperature, in direct contradiction with the experimental results. This conclusion is reached