TABLE 4

Results of experimental runs on the gabbroic anorthosite composition at 900–1200 °C (note: additional results depicted in fig. 2 are taken from GREEN, 1967)

Pressure (kb)	Temperature (°C)	Time (hrs)	Type of sample capsule	Phases present†						Comments
11.3 then 4.3	900 900	13 24	Ag–Pd	px	plag	—	—	—	—	Fine grained; plag ≫ px
11.3 then 6.2	900 900	11½ 24	Ag–Pd	px	plag	—	—	—	—	Fine grained; plag ≫ px
11.3 then 7.7	900 900	12 24	Ag–Pd	px	plag	ga	qtz?	—	—	Medium grainsize; plag > px > ga, qtz? uncertain X-ray evidence for quartz
9	900	4	Ag–Pd	px	plag	—	—	—	—	Fine grained; plag ≫ px; no garnet observed
11.3 then 9.6	900 900	12½ 25	Ag–Pd	px	plag	ga	qtz?	—	—	Fine grained; plag ≫ px > ga, qtz?; uncertain X-ray evidence for quartz
10.1	900	4	Ag–Pd	px	plag	ga	—	—	—	Fine grained; plag ≫ px ≫ trace garnet
10.1	900	12	Ag–Pd	px	plag	ga	qtz?	—	—	Fine grained; plag ≫ px > ga, qtz? uncertain X-ray evidence for quartz
18	900	48	Au	px	plag	ga	qtz	—	—	Medium grainsize; plag > px > ga > qtz; $a_{ga} = 11.66 \pm 0.01$ Å
22.5	900	48	Au	px	plag	ga	qtz	—	—	Medium grainsize; px, plag ≫ ga > qtz; $a_{ga} = 11.76 \pm 0.02$ Å
22.5 then 22.5	1000 900	48 64	Au	px	plag	ga	qtz	—	—	Medium grainsize; px > plag ≫ ga > qtz (c.w. 22.5 kb 1000 °C run, plag content lower; ga, qtz higher)
36 then 22.5	1000 900	48 72	Au	px	plag	ga	qtz	—	—	Well crystallized; px > plag > ga > qtz; plag definitely grown compared with 36 kb 1000 °C run
25	900	48	Au	px	felds	ga	qtz	ky?	(amph)	Medium grainsize; px ≫ ga > qtz > felds > ky? minor amphibole also present; $a_{ga} \approx 11.72 \pm 0.02$ Å
27	900	30½	Ag–Pd	px	felds	ga	qtz	ky?	—	Fine grained; px ≫ ga > qtz > felds > ky?; evidence for kyanite not definitive, felds (trace only) probably K-felds, no plag
27	900	48	Au	px	felds	ga	qtz	ky?	—	Medium grainsize; px ≫ ga > qtz > felds > ky?; felds trace amount only; $a_{ga} \approx 11.76 \pm 0.02$ Å
36	900	48	Au	px	felds	ga	coes	ky?	—	Medium grainsize; px ≫ ga > coes > felds > ky?; felds trace amount only; $a_{ga} \approx 11.76 \pm 0.02$ Å
9	1000	11½	Ag–Pd	px	plag	—	—	—	glass	Fine grained; minor glass; plag ≫ px
22.5	1000	48	Au	px	plag	ga	qtz	ky?	—	Medium grainsize; px > plag, ga > qtz > ky?; $a_{ga} = 11.71 \pm 0.01$ Å
25	1000	24	Au	px	plag	ga	qtz	ky?	—	Medium grainsize; px ≫ plag, ga > qtz > ky?
27	1000	48	Au	px	felds	ga	qtz	ky?	—	Medium grainsize; px ≫ ga > qtz > felds, ky?; felds trace amount only; $a_{ga} = 11.74 \pm 0.01$ Å
36	1000	48	Au	px	felds	ga	coes	ky?	—	Medium grainsize; px ≫ ga > coes > felds, ky?; felds trace amount only; $a_{ga} = 11.76 \pm 0.02$ Å
13.5	1060	3	Au	px	plag	ga	—	—	—	Fine grained; plag ≫ px > ga
11.3	1100	4	Ag–Pd	px	plag	—	—	—	—	Fine grained; plag ≫ px
12.4	1100	4	Ag–Pd	px	plag	ga	—	—	—	Medium grainsize; plag ≫ px > ga
13.5	1100	2	Ag–Pd	px	plag	ga	qtz?	—	—	Medium grainsize; plag ≫ px > ga > qtz?; uncertain X-ray evidence for quartz
28.8	1100	23	Ag–Pd	px	plag	ga	qtz	ky?	—	Medium grainsize; px ≫ ga > qtz ≫ plag > ky?
16.0	1200	2½	Pt	px	plag	ga	—	—	glass	Medium grainsize; minor glass, plag ≫ px > ga

† Underlines denote phases identified by optical means only.

px = pyroxene; plag = plagioclase; qtz = quartz; ga = garnet; felds = feldspar (K-rich); coes = coesite; ky = kyanite; amph = amphibole.

>20 mol%) from the Adirondacks. Dioritic gneisses of similar chemical composition to andesite also occur, but contain little or no garnet. The garnet tends to be lowest or absent in rocks with the highest quartz content, the rocks most closely approaching the diorite of this paper in composition. Both the gabbroic anorthosite and diorite assemblages are dominated by plagioclase with subordinate clinopyroxene and minor garnet. Comparison with the experimental results indicates probable *P–T* conditions of about 750 °C and 5 kb. DE WAARD (1966) suggests pressures as high as 10 kb and temperatures up to 800 °C for the metamorphism in the Adirondacks, in which case garnet would be expected in rocks of intermediate composition under anhydrous conditions.

DAVIDSON (1943) refers to a garnet-bearing anorthositic gneiss (plagioclase dominant, with subordinate garnet and minor clinopyroxene and hornblende) on South Harris. In the same area DEARNLEY (1963) describes tonalites (approximately equivalent to andesite in composition) with the assemblage orthopyroxene–clinopyroxene–plagioclase. Also in basic rocks there is a reaction relation between olivine and plagioclase (producing garnet and quartz). Conditions satisfying these 3 features would be 3–5 kb at 700–800 °C as indicated by the present work and work of GREEN and RINGWOOD (1967).

DEN TEX and VOGEL (1962) and ESKOLA (1952) record intermediate rocks with assemblages orthopyroxene–clinopyroxene–plagioclase–quartz indicating *P–T* conditions in the field below the incoming of garnet in fig. 1. QUENSEL (1951) and GROVES (1935) refer to intermediate composition rocks with the assemblage: –2 pyroxenes–plagioclase–garnet–quartz–hornblende, indicating metamorphism under *P–T* conditions within the garnet field of fig. 1. GROVES (1935) also notes reaction rims involving hypersthene–plagioclase reacting to form diopside and garnet and indicates that the pyroxene becomes increasingly omphacitic in composition. Similarly KOZLOWSKI (1958) reports an intermediate rock with the assemblage garnet (grossular 22%), omphacitic pyroxene, plagioclase (oligoclase), quartz and minor microcline, biotite, amphibole and rutile. Kozlowski's conclusion that this assemblage was formed under conditions which would have produced eclogites from basalts is consistent with the present experimental results.

4.3. *Lower crustal mineralogy*

Assuming a linear extrapolation of the incoming of garnet and the final disappearance of plagioclase to probable temperatures in the stable lower crust (300–700 °C; BIRCH, 1955; CLARK, 1961, 1962) an indication of the mineralogy of an anhydrous lower crust of overall andesite and/or gabbroic anorthosite composition may be obtained. As mentioned in section 2, RINGWOOD and GREEN (1966) have argued that large areas of stable continental crust are essentially dry, and it is emphasized that the present results are only applicable to a consideration of the mineralogy of a dry crust.

For an andesitic composition the highest pressure assemblage obtainable below the quartz to coesite transition (coesite is only known to have formed naturally in association with meteorite impact) consists of clinopyroxene, quartz, garnet and K-feldspar, but for likely *P–T* conditions in the lower crust, the final breakdown of plagioclase in this composition is not attained, so that some sodic plagioclase will occur as well. This is similar to the assemblage proposed by R NGWOOD and GREEN (1966) except for the absence of kyanite. This phase was not identified in any of the experimental runs on andesite, but it may have occurred in amounts up to about 5% (see section 3.2), but not 15% as calculated by Ringwood and Green. This suggests that the high pressure assemblage obtained experimentally is probably richer in aluminous pyroxenes, quartz and garnet than the assemblage calculated.

Similarly, in the case of the gabbroic anorthosite, the mineralogy expected under stable lower crustal *P–T* conditions would consist of plagioclase, pyroxene, minor garnet, minor quartz and possibly minor kyanite. The grossular content of the garnet would be significant, and for any given bulk composition, increase with increasing pressure of formation.

4.4. *Experimental results and geophysical models for the lower crust*

Seismologists generally recognize compressional wave velocities of 5.8–6.3 km/s as characteristic of the upper crust, increasing to 6.6–7.4 km/s in the lower crust (GUTENBERG, 1955, 1959; RICHARDS and WALKER, 1959; STEINHART and MEYER, 1961; JAMES and STEINHART, 1966). The nature of the downward increase in velocity is controversial (for a summary see JAMES and