d) Crystallization at 36 kb

Only two runs have been conducted on the high-alumina olivine tholeiite at 36 kb. Clinopyroxene and garnet are the only primary phases present in these runs. Garnet is more abundant than clinopyroxene in the near-liquidus run at 1535° C while at 1520° C clinopyroxene is the dominant phase. Similar crystallization occurs in the high-alumina quartz tholeiite composition where garnet and clinopyroxene are the near-liquidus phases at 1525° C and continue to be the only phases crystallizing at least down to 1420° C where minor quartz may be present. In the basaltic andesite composition at 36 kb garnet and clinopyroxene are the crystallizing phases in the partial melting field between 1440 and 1475° C. Garnet is the dominant primary phase at 1475° C but is subordinate to primary clinopyroxene at 1460 and 1440° C. These two phases are joined by quartz in the sub-solidus field (e.g. at 1380° C). The trend of increasing abundance of garnet as a near-liquidus phase from olivine tholeiite through quartz tholeiite to basaltic andesite continues to the andesite composition, where garnet is the liquidus phase at 1440° C. Garnet is the major crystallizing phase down to 1400° C; it is joined by clinopyroxene at 1420° C and by quartz at 1400° C; minor feldspar (probably potash-rich) is present in a near-solidus run at 1340° C. In the dacite composition quartz is the liquidus phase at 1450° C and is joined by clinopyroxene at 1420° C. These are the only phases identified down to a near-solidus run at 1320° C. The presence of garnet in 27 kb runs on this composition, and its absence at 36 kb suggests nucleation problems in crystallizing garnet at 36 kb.

olivine tholeiite, high-alumina quartz tholeiite and basaltic andesite compositions

quartz tholeiite					Basaltic andesite					
27 kb 1,385° C 35 mins	27 kb 1,400° C 30 mins	27 kb 1,420° C 20 mins	36 kb 1,490° C 15 mins	36 kb 1,510° C 10 mins	18 kb 1,250° C 60 mins	18 kb 1,280° C 60 mins	27 kb 1,360° C 40 mins	27 kb 1,390° C 35 mins	36 kb 1,460° C 20 mins	36 kb 1,475° C 15 mins
ga[b]	ga[b]	ga[b]	ga[b]	ga[b]	ga[b] plag[b]	—	ga[b]	ga[b]	ga[b]	ga[b]
50.5	50.5	49.5	50.5	50.5	50.4	50.5	50.6	49.9	50.0	50.5
1.2	1.2	1.0	0.9	0.8	1.3	1.0	0.9	0.7	0.9	0.6
14.4	13.0	13.0	14.3	13.2	14.2	11.7	13.8	13.1	17.3	15.3
6.7	6.2	5.8	5.6	5.1	10.5	9.7	6.7	7.6	7.0	6.8
9.8	11.0	12.2	10.3	11.4	10.2	12.2	9.9	11.2	7.3	10.0
14.8	15.3	15.4	14.4	14.6	13.9	14.8	15.1	14.8	11.8	13.1
2.4	2.3	2.1	2.8	2.6	1.2	1.2	2.2	2.1	2.9	3.1
99.8	99.5	99.0	98.8	98.2	101.7	101.1	99.2	99.4	97.2	99.4
72.3	75.9	78.9	76.6	79.9	63.4	69.2	72.5	72.5	65.0	72.4
1.8181	1.8253	1.7992	1.8273	1.8369	1.8009	1.8198	1.8329	1.8150	1.8278	1.8190
0.1819	0.1747	0.2008	0.1727	0.1631	0.1991	0.1802	0.1671	0.1850	0.1722	0.1810
0.4291	0.3792	0.3563	0.4370	0.4026	0.3988	0.3166	0.4220	0.3764	0.5731	0.4684
0.0325	0.0326	0.0273	0.0246	0.0219	0.0352	0.0541	0.0246	0.0192	0.0248	0.0162
0.2016	0.2172	0.1763	0.1694	0.1552	0.3137	0.2924	0.2029	0.2313	0.2140	0.2048
0.5262	0.5930	0.6613	0.5558	0.6184	0.5435	0.6555	0.5349	0.6075	0.3979	0.5371
0.5708	0.5924	0.5997	0.5582	0.5688	0.5322	0.5713	0.5861	0.5767	0.4621	0.5055
0.1675	0.1612	0.1481	0.1966	0.1832	0.0833	0.0840	0.1546	0.1482	0.2057	0.2165
2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1.93	1.98	1.97	1.94	1.95	1.91	1.97	1.93	1.96	1.88	1.95
40.5	43.2	46.0	43.3	46.0	39.1	43.2	40.4	42.9	37.0	43.1
15.5	13.7	12.3	13.2	11.6	22.6	19.2	15.3	16.3	19.9	16.4
44.0	43.1	41.7	43.5	42.4	38.3	37.6	44.3	40.8	43.1	40.5

dried pyrophyllite spacer was used.

Table 11. *Electron microprobe analyses of garnets from selected runs on the high-alumina*

Composition	High-alumina olivine tholeiite					High-alumina quartz tholeiite					
Conditions of run	18 kb 1,230° C 120 mins (Wet)	18 kb 1,260° C 120 mins (Wet)	27 kb 1,400° C 40 mins	27 kb 1,430° C 25 mins	36 kb 1,520° C 15 mins	18 kb 1,300° C 55 mins	27 kb 1,385° C 35 mins	27 kb 1,400° C 30 mins	27 kb 1,420° C 20 mins	36 kb 1,490° C 15 mins	36 kb 1,510° C 10 mins
Co-existing phase	cpx[b] plag[b]	cpx[b]	cpx	cpx[b]	cpx[b]	cpx[b], plag[b]	cpx[b]	cpx[b]	cpx[b]	cpx[b]	cpx[b]
SiO_2	41.0	41.3	39.0	38.5	40.0	39.0	39.0	39.0	39.5	39.0	39.5
TiO_2	1.8	0.8	1.1	0.7	1.2	1.5	1.5	1.8	1.4	1.3	1.3
Al_2O_3	22.0	22.8	20.4	21.6	22.8	22.9	22.6	23.0	23.0	22.7	23.1
FeO	17.7	9.1	14.3	10.2	13.8	15.2	14.8	14.4	12.9	13.8	12.1
MnO	0.4	0.4	0.4	0.3	0.4	0.5	0.4	0.5	0.4	0.4	0.4
MgO	12.6	17.9	13.4	16.9	13.3	11.6	10.9	11.7	12.8	11.4	12.4
CaO	7.8	6.7	7.9	7.6	8.9	7.2	7.9	7.9	7.7	8.3	8.1
	103.3	99.0	96.5	95.8	100.4	97.9	97.1	98.3	97.7	96.9	96.9
$\frac{100\,Mg}{Mg+Fe}$	55.9	77.8	62.6	74.7	63.2	57.6	56.8	59.2	63.9	59.6	64.6
Mol. Prop.											
Ti-andradite	4.7	2.1	3.1	1.8	3.3	4.7	4.8	5.2	4.2	4.0	4.0
Grossularite	15.1	15.0	17.1	17.5	19.8	15.5	17.8	16.9	17.3	19.5	19.1
Pyrope	44.4	63.9	49.0	59.8	48.1	45.3	43.4	45.4	49.6	45.0	49.1
Almandine	35.0	18.2	29.4	20.3	28.0	33.4	33.1	31.4	28.0	30.6	26.9
Spessartine	0.8	0.8	0.8	0.6	0.8	1.1	0.9	1.1	0.9	0.9	0.9

[a] Denotes calculated composition. [b] Denotes co-existing phase analyzed.

Analytical Data

Analyses of clinopyroxene, garnet and plagioclase crystallized in the high pressure runs are given in the accompanying tables (Tables 10—12).

a) Clinopyroxenes

Analyses of clinopyroxenes crystallizing from compositions ranging from high-alumina olivine tholeiite to dacite are given in Table 10, together with the chemical formula calculated on the basis of 6 oxygen atoms per formula unit. These analyses show an increase in soda content of the pyroxene with increasing pressure, and an increase in the alumina content and a decrease in the $\frac{Mg}{Mg + Fe}$ ratio with increasing degree of crystallization at a specific pressure. For comparable degrees of crystallization there is an increase in alumina in tetrahedral co-ordination in the pyroxene with increasing pressure (e.g. compare analyses of clinopyroxene at 9 kb with 8.8% Al_2O_3, GREEN, 1967a, with clinopyroxene at 18 kb with 9.4—12.0% Al_2O_3, Table 10; both pyroxenes are from high-alumina olivine tholeiite), until the pyroxene is joined by garnet (e.g. compare analyses of clinopyroxene from high-alumina quartz tholeiite co-existing with garnet near the liquidus at 27 and 36 kb with the analysis of a near-liquidus clinopyroxene at 18 kb). The overall alumina content of the clinopyroxene may continue to rise with increasing pressure, without obtaining more alumina in tetrahedral co-ordination, because the soda content is also increasing with increasing pressure.

b) Garnets (Table 11)

The garnets are all dominantly pyrope-almandine with a subordinate grossular-Ti-andradite component and a minor spessartine component. In general, for approximately equivalent pressures and degrees of crystallization the garnets become more almandine-rich as the parent composition becomes more acid (e.g. as it changes from high-alumina olivine tholeiite to rhyodacite near-liquidus garnet at 27 kb increases in almandine content from 33.5 mol. per cent to 67.1 mol per cent; analysis of rhyodacite garnet given in T. H. GREEN and RING-