Table 5

Calculated compositions of liquid fractionates and crystalline residua derived from the high-alumina quartz tholeiite at 9–10 kb under wet conditions *.

Pressure		9 kb	10 kb	10 kb
Temperature		1040°C	960°C	920°C
Nature and estimated % of crystals extracted	Initial liquid	18% cpx 5% amph 2% opx 1% ilm	18% cpx 25% amph 2% opx 1% ilm	18% cpx 32% amph 3% plag 2% opx 1% ilm
Liquid fractionate				
SiO_2	52.9	55.9	59.7	64.5
TiO_2	1.5	0.8	0.4	0.1
Al_2O_3	16.9	19.4	20.2	19.9
Fe_2O_3	0.3	0.4	0.5	0.7
FeO	7.9	7.2	5.8	3.7
MnO	0.2	0.3	0.3	0.4
MgO	7.0	4.4	2.1	2.0
CaO	10.0	7.8	6.7	3.9
Na_2O	2.7	3.3	3.4	3.6
K_2O	0.6	0.8	0.9	1.0
	100.0	100.3	100.0	99.8
Mol. Prop. $\frac{100\ MgO}{MgO + FeO_{tot}}$	60.4	50.9	37.5	45.3
CIPW norm				
Qz		5.5	14.4	25.3
Or		4.8	5.4	5.9
Ab		27.9	28.8	30.5
An		35.7	33.2	19.3
Cor		–	1.4	5.8
Diop		2.4	–	–
Hyp		21.9	15.3	12.1
Mt		0.6	0.7	1.0
Ilm		1.5	0.8	0.2
Crystal residuum				
SiO_2		44.8	43.0	42.7
TiO_2		2.5	2.7	2.7
Al_2O_3		9.7	12.3	14.2
FeO		9.1	10.1	11.2
MgO		14.6	12.9	11.0
CaO		16.6	13.8	14.8
Na_2O		1.0	1.8	1.9
K_2O		0.04	0.2	0.2
		98.34	96.8	98.7
Mol. Prop. $\frac{100\ MgO}{MgO + FeO}$		74.2	69.5	63.7

* The orthopyroxene analysis obtained at 1040°C, 9 kb has been used in calculations for other experimental runs since it could not be analyzed in these runs. Since only 2% of orthopyroxene is extracted, any variations in its composition will not seriously affect the compositions of the liquid fractionates or crystalline residua. Also 1% of ilmenite is extracted as part of the crystalline residua. This is because an accessory iron-titanium rich opaque mineral phase occurred in the experimental runs in graphite capsules where no iron loss took place. This phase could not be analyzed quantitatively and as a first approximation for these calculations was taken as ilmenite.

alkaline series is derived from the mantle as the result of a two-stage process. In the first stage large piles of basalt of overall saturated composition develop in the earth's crust in such areas as island arcs and continental margins. Limited access of water to the basalt pile results in formation of amphibolite in the lower regions. The water content of the amphibolite may be of the order of 1%. Subsequent heating of this amphibolite, due to renewed or continued volcanic activity from the mantle may result in partial melting taking place. The pressures at which such partial melting takes place may be as high as 10 kb, corresponding to the base of the crust and water vapour pressure is likely to be less than the load pressure. The experimental work described in this paper indicates that the residual phases from such melting will consist mainly of amphibole with subordinate clinopyroxene and possibly calcic plagioclase and garnet, depending on the degree of partial melting. As in the first case the initial overall composition of the parent basic material and the temperature and depth at which partial melting occurs will be important factors in determining the composition of the derived calc-alkaline magmas. Similarly the residuum may transform to eclogite and sink into the mantle.

This second case is essentially a complementary two-stage model to that proposed in a previous paper (viz. the partial melting of a sinking quartz eclogite at 100–150 km depth [1]). Both models involve derivation of the calc-alkaline suite by a two-stage magmatic process, incorporating in the first stage large scale extrusion of saturated basaltic magma in the earth's crust. The subsequent history of this basalt pile, whether it remains dry and transforms to eclogite, or whether water has access changing it to amphibolite, determines whether the calc-alkaline suite is produced according to the eclogite melting model [1] or by melting of amphibolite as outlined in this paper. Both models explain the derivation of the calc-alkaline suite in areas where no sialic material occurs and so provide a mechanism for continental evolution from an undersaturated upper mantle.

Because of the sub-silicic nature of the residual phases (aluminous amphiboles, pyroxenes and possibly minor garnet and calcic plagioclase) hydrous fractional crystallization of a basaltic magma or partial melting of amphibolite at about 30–40 km depth provides a highly efficient way of deriving intermediate to acidic compositions from a basic parent. Thus in the derivation of andesite magma the mass ratio of residual phases to andesite magma produced is approximately unity. In contrast in models involving fractional crystallization of low pressure phases (e.g. from crystallization of dry basalt) the mass ratio of crystalline material to magma would be two or more, even under idealized conditions.

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