Tertiary picrites from Greenland: modelling sources and petrogenesis from melt inclusion compositions

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Picrites rocks from Greenland are suggested to be related to the mantle plume responsible for the opening of Atlantic Ocean (Brooks, 1973; Nielsen, 1975). We attempt to estimate compositions of primary magmas, mantle temperature and source compositions through thermodynamic modelling of melt inclusion composition.

Melt inclusions compositions

Compositions of homogenised inclusions in phenocrysts from picrites from West and East Greenland have been studied in detail (Table 1).The majority of inclusion compositions from West Greenland picrites scatter along the common olivine control line.

Inclusions in the most magnesian olivines (Fo_{89} and Fo_{92}) and in xenocrysts (Fo_{90}) fall off the line. They are characterized by significantly lower FeO contents for a given concentration of MgO (Table 1, #2). This may result from magma mixing. Inclusions in East Greenland picrite show so far a narrow compositional range.

Modelling of generation of highly magnesian melts

Host olivines in equilibrium with their trapped melts are much less magnesian than olivines from mantle peridotites. The trapped melts, therefore, do not represent parental magmas, but evolved melts. They

TABLE 1. Compositions of homogenised melt inclusions (EMP)

	1	2	3	4	5	6	7	8	9	10
Host	Ol	Ol	Ol	Ol	Ol	Ol	Ol	Cpx	Cpx	Sp
SiO_2	46.79	51.61	47.24	52.85	45.37	46.00	51.22	52.44	49.30	50.50
TiO_2	1.24	0.93	1.31	1.34	1.34	1.21	3.11	2.85	3.58	1.70
Al_2O_3	12.96	13.64	14.26	15.36	13.30	12.38	9.71	7.90	8.46	13.00
FeO*	10.95	6.52	10.51	8.66	11.60	14.03	10.50	10.94	14.70	10.10
MgO	14.85	10.11	12.46	9.20	11.64	10.44	9.01	10.43	8.48	9.38
MnO	0.09	0.09	0.16	0.13	0	0	0	0	0	0
CaO	11.46	11.85	12.16	10.28	11.34	11.18	12.83	12.84	12.25	11.19
Na_2O	1.64	2.40	1.81	2.10	1.60	1.64	1.40	1.97	1.90	2.01
K_2O	0.10	0.08	0.09	0.56	0.13	0.13	1.24	0.81	0.47	0.70

1,2 GGU332771 (WG); 3 GGU400450(WG); 4 GGU176669(WG); 5,6 GGU362148(WG);7–9 GM75-755(EG); 10 GM40644(EG)

TABLE 2. Modelling of the generation of picritic melts

	1	2	3	4	5	6	7	8	9
SiO_2	45	44.78	46.12	46.61	46.79	43.74	49.15	52.01	52.44
TiO_2	0.201	0.19	1.12	1.22	1.24	0.13	2.19	2.93	2.85
Al_2O_3	4.45	4.31	11.72	12.79	12.96	0.42	5.82	7.78	7.9
FeO^*	8.05	8.08	11.17	11.28	10.95	8.2	11.16	11.24	10.94
MgO	37.8	38.22	17.81	14.95	14.85	46.88	19.98	10.43	10.43
CaO	3.55	3.52	10.41	11.36	11.46	0.55	9.65	12.88	12.84
Na_2O	0.36	0.32	1.62	1.78	1.64	0.06	1.42	1.9	1.97
K_2O	0.029	0.005	0.029	0.032	0.1	0.03	0.62	0.82	0.81

1. bulk silicate Earth (McDonough and Sun, 1995); 2. 40% of (1) minus continental crust after Wedepohl (1995); 3. composite melt produced from (2) by critical melting on adiabatic decompression from 37 kbar (1682°C) to 20 kbar (F^{cr} = 1%; n_D = 2). Calculated using PARMEL computer code (Ryabchikov, 1994); 4. melt produced by 9% fractional crystallisation of (3).; 5. homogenised glass inclusion in olivine phenocryst from GGU332771 (#1 in Table 1); 6. harzburgite xenolith (PAT 2-29) from La Palma, Canaries; TiO_2 content is increased compared to original analysis; 7. partial melt generated from (6) at 15 kbar, 1510°C and 4.30% fraction of melt; calculated by PARMEL computer code; 8. melt produced by 25% fractional crystallisation of olivine from (7); 9 composition of homogenised glass inclusion in olivine from GM 75-755 (Table 1, #8).

were derived from more primitive magmas that were subjected to crystallisation in magma chamber(s) en route to the surface. We have modelled the observed compositions of melt inclusions with the computer program PARMEL (Ryabchikov, 1994),which simulates partial melting of peridotite at high pressure and temperature, in combination with a simple algorithm that models fractional crystallisation of olivine at constant K_d(Mg/Fe).

The combined calculations model the production of a derivative magma with a given MgO content. By varying the key parameters governing this complex process (pressure range of adiabatic decompression melting, magmatic porosity of source rock etc) and minimizing deviations between calculated and observed oxide concentrations we refine the solution of the inverse problem: the estimation of the potential temperature of the peridotite and its composition. The method was applied to more magnesian melt inclusions in olivine phenocrysts from West Greenland picrites (Table 2). Here the composition of the natural melt is consistent with lherzolitic source that underwent the adiabatic decompressional melting between *c*. 37 and 20 kbar with 1% retained melt in intergranular space in the source. The parent melt, produced by mixing of instantaneous melts from the pressure interval in the melting column, contains approximately 18% MgO and potential temperature is about 1550°C, which is approximately 150° higher than for the generation of NMORB from a similar source (Ryabchikov, 1997).

Olivine from West Greenland sample GGU362148 (Table 1, #6) contains inclusions of melt with significantly higher FeO contents compared to other samples from the region. An attempt to model its generation gave initial pressure of decompression melting > 50 kbar.

The conclusion reached above on the basis of the modelling of melt inclusion data is in accord with earlier results by Holm *et al.* (1993), suggesting that liquids with MgO contents of at least 19% were erupted in the West Greenland Tertiary Volcanic province. Homogenised glass inclusions in olivines from picritic rocks of East Greenland typically yield compositions with significantly lower alumina and CaO contents by comparison with melts produced by dynamic decompression melting of lherzolite. A successful modelling of such magmas may only be attained with a harzburgitic source. (Table 2, #6-#9).

Two interpretations are offered: (1) Harzburgite is assumed to constitute a significant part of the lithospheric mantle, and as the model for the West Greenland picrites points to a lherzolite source, the harzburgite source for the East Greenland picrites may imply a significant lithospheric input in East Greenland, whereas West Greenland picrites were mainly generated from plume lherzolite. This would be in accord with the widely accepted views, e.g. Holm *et al.* (1993). (2) Alternatively, the harzburgite signature in East Greenland may represent recycled lithospheric mantle and – in the manner suggested by MacKenzie and O'Nions (1983) – suggest that East Greenland picrites are derived from the core of a plume.