

CHEMISTRY OF SOME ECLOGITE NODULES FROM KIMBERLITE; ECLOGITE FRACTIONATION
M.J. O'Hara and M.J. Saunders, Grant Institute of Geology, University of
Edinburgh, and E.L.P. Mercy, Department of Geology, Lakehead University,
Ontario.

Eclogite may be a crystal extract from primary magmas differentiating deep within the mantle perhaps on a trend which ultimately leads to kimberlite-like residual fluids (O'Hara and Yoder 1967). The chemistry of eclogites is therefore of fundamental importance. Two technical problems hamper assessment of the data - how far sampling problems affect the apparent results (eclogite hand specimens are generally small samples of coarse grained rocks), and how far contamination influences the chemistry (eclogites, like garnet-peridotites, are poor in many elements which are rich in the kimberlite matrix which encloses them).

Results. Table 1 contains analyses of eclogites (whole rock). Analyses of their pyroxenes (table 2) and garnets (table 3) enable the extent of possible contamination to be assessed. Whole rocks contain more TiO_2 than their constituent major minerals, but the difference could be made up by much less than 0.5% primary rutile which might be missed both during petrographic examination and mineral separation. Some TiO_2 in these eclogites has probably been introduced from the kimberlite. P_2O_5 is uniformly lower in the major minerals than in the bulk rocks; although the discrepancy lies within the range of possible primary apatite presence, some of this P_2O_5 probably represents contamination. The possible effect of contamination and alteration on major oxides can be evaluated from the data presented.

The ratios $\text{Mg}/\text{Mg}+\text{Fe}$ and $\text{Na}/\text{Na}+\text{Ca}$ show wide variations; which are in no way correlated with each other. Clearly, no simple geochemical trend connects all of these rocks. TiO_2 concentrations are moderately low relative to possible ultrabasic and basic magmas, as also are Cr_2O_3 and NiO . The rocks have generally olivine-basaltic major element composition, and their extracation from primary magmas of basaltic character would (obviously) not affect greatly the major ^{element} concentrations in the residual liquids. The eclogites are extremely variable in $\text{CaO}/\text{Al}_2\text{O}_3$ ratio which ranges from 0.4 to 1.0 (in weight per cent) and this is the ratio most affected by sampling error in the pyroxene/garnet ratio. However, the variation among the five Roberts Victor eclogites cannot be ascribed solely to sampling errors. The extracation of eclogite from possible primary partial melts of garnet peridotites will not necessarily produce non-basaltic $\text{CaO}/\text{Al}_2\text{O}_3$ ratios in the residual liquids.

Clinopyroxene, orthopyroxene and garnet from the garnet websterite and garnet lherzolite from Matsoku are also shown in tables 2 and 3. The lower $\text{Mg}/\text{Mg}+\text{Fe}$ and $\text{Cr}/\text{Cr}+\text{Al}$ ratios of the garnet-lherzolite relative to the garnet websterite, in whole rock (O'Hara et al. 1973) and minerals accords with the interpretation of the garnet lherzolite as a frozen liquid and the garnet websterite as a possible crystal cumulus.

Figures 1 and 2 (projection as in Ford et al. 1972, fig. 7) compare $\text{Mg}-\text{Fe}$ variations and silica saturation levels in eclogite, peridotite and basalt. Figure 2 shows that it is possible to choose source garnet lherzolite, residual harzburgite, 30 kb primary magmas and early eclogite accumulates such that substantial eclogite fractionation might be followed by substantial olivine fractionation yielding residual tholeiitic magmas without imposing excessively low $\text{Mg}/\text{Mg}+\text{Fe}$ on the residual liquids.

Table 1. Eclogites

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O
1	42.01	.35	20.30	.058	1.18	11.54	.27	.064	14.14	7.84	0.67	.19
2	44.60	.33	16.93	.078	0.69	11.35	.31	.062	14.10	8.20	1.53	.26
3	46.31	.34	16.67	.082	1.09	9.58	.33	.030	13.75	8.60	2.08	.35
4	46.49	.42	11.94	.39	3.40	8.90	.30	.059	14.52	9.94	1.55	.84
5	48.34	.44	11.90	.12	1.32	9.14	.23	.064	13.51	10.30	2.41	.35
6	43.98	.44	18.33	.118	2.34	10.12	.36	.014	12.32	8.33	1.73	.20
7	45.18	.46	17.06	.15	0.92	11.43	.17	.024	11.92	8.96	2.10	.38
8	45.62	.72	13.45	.036	2.99	9.34	.12	.015	10.23	15.52	1.14	.09
9	45.97	.52	13.26	.043	3.91	9.06	.26	.042	10.51	12.28	0.76	.20
10	44.15	.86	13.54	.022	2.81	8.13	.10	.046	12.37	12.89	0.33	.02

(Eclogite analyses also contain ~ 0.01 – 0.41 P₂O₅ and 0.6 – 4.5% H₂O)

Table 2. Pyroxenes

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
from (1)	56.62	.37	8.29	0.081	0.00	4.52	.08	.068	11.46	14.06	4.44	-	-
from (2)	54.09	.33	7.22	0.09	1.18	4.16	.13	.050	12.32	14.75	3.90	.17	-
from (3)	55.49	.35	9.04	0.10	1.33	3.00	.083	.040	10.98	13.96	5.19	.18	.052
from (4)	54.05	.24	4.36	0.48	1.73	5.70	.14	.031	14.59	16.32	1.98	.18	.032
from (5)	54.71	.39	6.03	0.15	1.92	4.61	.12	.039	12.54	14.99	4.06	.15	.60
from (6)	52.84	.44	9.79	0.15	1.03	3.81	.093	.023	11.21	13.71	4.46	.16	.011
from (7)	54.03	.42	9.28	0.18	0.71	4.04	.090	.033	10.44	13.67	5.23	.18	.000
from (8)	51.58	.49	7.24	0.029	2.71	3.95	.035	.024	11.68	19.87	1.98	.04	.009
from (10)	52.31	.53	6.23	0.033	2.24	3.56	.046	.012	12.19	19.78	2.49	.03	.085
from 1031	54.66	.14	2.42	0.80	1.13	2.78	.11	.063	16.66	19.50	1.34	.03	.013
from 1032	54.12	.23	2.63	1.43	1.63	3.60	.11	.069	16.26	18.09	1.65	.04	-
from 1031	56.85	.087	0.72	0.15	0.72	6.71	.15	.13	33.28	0.85	0.18	.03	.019
from 1032	56.12	.11	0.95	0.26	1.10	8.40	.086	.13	31.42	1.30	0.22	-	-

Table 3. Garnets

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	MnO	NiO	MgO	CaO	P ₂ O ₅
from 1	41.24	.29	22.25	.054	.10	14.32	.36	.016	15.17	5.91	.038
from 2	41.06	.28	22.17	.076	.61	15.00	.40	.009	14.67	5.61	.028
from 3	41.03	.27	22.55	.080	.50	14.38	.47	.008	15.32	5.18	.042
from 4	40.74	.33	21.73	.34	.73	16.86	.46	.007	14.44	4.39	.032
from 5	40.58	.35	22.45	.11	.37	16.60	.44	.008	14.58	4.39	.032
from 6	40.61	.39	22.09	.12	.41	15.61	.49	.005	13.14	6.96	.027
from 7	40.64	.34	22.15	.15	.46	16.36	.48	.006	12.89	6.45	.032
from 8	39.58	.24	21.24	.034	1.04	17.84	.46	.004	8.38	11.07	-
from 10	39.93	.06	21.65	.024	.69	19.16	.42	.003	10.96	5.90	.036
from 1031	41.89	.19	22.15	2.00	1.21	9.18	.22	.005	18.51	4.94	.008
from 1032	40.67	.40	19.56	3.97	.06	12.75	.38	.011	17.07	5.18	.014

Key to analyses of eclogites and their minerals

1. Eclogite, Roberts Victor mine 11063; garnet $n=1.759$; clinopyroxene $\alpha=1.670$, $\beta=1.679$, $\gamma=1.696$.
2. Eclogite, Roberts Victor mine, 11062; garnet $n=1.757$; clinopyroxene $\alpha=1.671$, $\beta=1.681$, $\gamma=1.697$. Garnet partly as blebs in pyroxene. Some interstitial phlogopite and spinel.
3. Eclogite, Roberts Victor mine 11060; garnet $n=1.758$; clinopyroxene $\alpha=1.668$, $\beta=1.678$, $\gamma=1.891$; some phlogopite, trace apatite, epidote.
4. Eclogite, Roberts Victor mine 11061.
5. Eclogite, Roberts Victor mine 11064.
6. Eclogite, Jagersfontein 352; garnet $n=1.761$.
7. Eclogite, Wesselton.
8. Eclogite, Vissers Pipe (No. 8), Tanganyika cf. sample 37079 (O'Hara and Yoder 1967), garnet $n=1.767$; clinopyroxene $\alpha=1.681$, $\beta=1.693$, $\gamma=1.710$.
9. Eclogite 509; Shinyanga.
10. Eclogite, Matsoku pipe Basutoland.
1031 garnet websterite, Matsoku pipe
1032 garnet lherzolite, Matsoku pipe (rock analyses in O'Hara et al this vol.)

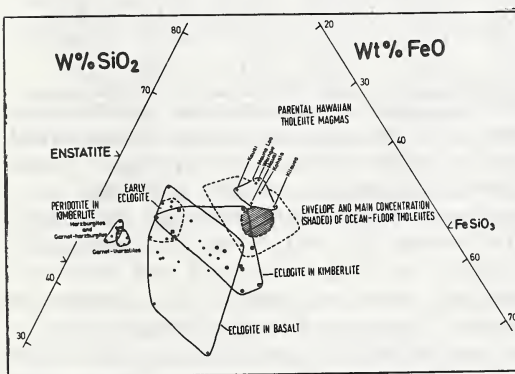


Fig 1

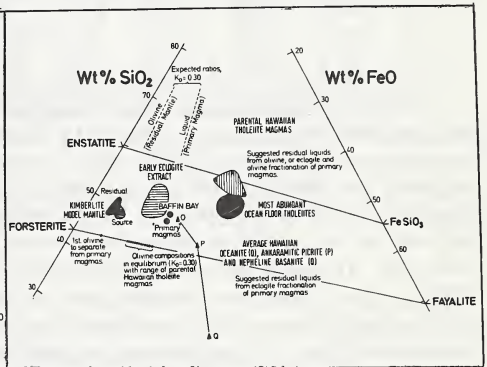


Fig 2

The field indicated 'early eclogites' (fig 1) encloses the compositions of the diopside 42.5%+pyrope 57.5% mixture from A3-10596 which lies close to the possible early eclogite precipitate at 30 kb (O'Hara and Yoder 1967) shown by a cross; and eight eclogites (small filled circles) which have the merits of preserving high temperature, high pressure mineralogy and actually occurring among basalt, from diatremes in Hawaii, Kenya and Australia. Their compositions are listed in table 4. O'Hara (1969) has argued from data projections that rocks such as these probably retain garnet as a separate phase under all subsolidus conditions where the garnet-clinopyroxene assemblage is stable itself and are therefore correctly described as eclogites rather than exsolved clinopyroxenites. The point has been proved experimentally for the specific case of R.392 by Irving and Green (1970) who quote 20% as the minimum amount of garnet seen in their run products.

Table 4. Analyses representing possible early eclogite extracts in fractionation of primary magmas within the upper mantle

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	Fe ₂ O ₃	FeO	MnO	NiO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
(A)46.93	0.18	13.82	1.99	1.67	4.62	0.29	0.03	18.54	11.38	0.79	0.01	0.02	
(1)49.26	0.62	8.63	0.31	3.24	5.09	0.17	n.d.	19.40	12.44	0.88	0.06	0.02	
(2)48.46	0.43	7.96	0.54	3.55	4.92	0.17	n.d.	19.96	12.00	1.90	0.19	n.d.	
(3)48.41	0.62	10.41	0.43	2.58	5.61	0.18	n.d.	17.78	12.17	1.24	0.11	0.04	
(4)50.20	0.51	8.37	0.24	1.58	5.72	0.16	0.10	19.00	13.28	0.87	0.02	0.02	
(5)49.52	0.42	9.31	0.35	2.26	5.44	0.16	0.09	17.97	12.90	1.17	0.04	0.03	
(6)45.58	0.80	13.69	0.12	3.76	5.85	0.16	0.06	16.09	11.78	1.27	0.02	0.03	
(7)44.68	0.11	15.79	0.03	3.90	5.50	0.26	n.d.	15.74	10.32	1.22	0.13	0.09	
(8)46.12	0.44	15.05	0.16	1.49	4.87	0.11	-	15.09	14.61	0.82	0.22	0.04	

Notes (A) A3-10596 pyrope-diopside mixture (O'Hara and Yoder 1967); (1) - (6) Hawaii, (Macdonald and Katsura 1964, Kuno 1964, Yoder and Tilley 1962, and SAL 6, SAL 24 and SAL 7 from Jackson and Wright 1970); (7) Kenya (Saggerson 1968, no. 9); (8) Australia R392 (Lovering and White 1969).

Table 5

	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Cr ₂ O ₃	TiO ₂	Na ₂ O	K ₂ O	P ₂ O ₅
(1)	46.2	11.1	10.8	20.2	9.4	0.28	0.77	1.06	0.08	0.09
(2)	46.2	13.9	9.3	16.3	11.9	0.12	0.81	1.29	0.02	0.03
(3)	46.2	8.3	12.3	24.1	6.9	0.44	0.74	0.83	0.14	0.15
(4)	50.0	13.8	12.4	8.5	11.5	0.73	1.23	1.38	0.23	0.25
(5)	50.0	14.1	11.4	8.6	10.4	n.d.	2.53	2.16	0.39	0.26

Table 5 represents the results of a specific calculation in which a possible 30 kb primary magma (1; Clarke 1970 Baffin Bay group II picrite) has extracted from it 50% of an early eclogite in basalt (2; SAL 7 from Jackson and Wright 1970) to yield a putative high pressure residual liquid (3) from which 40% of olivine (mean composition Fog_{7.5}) has been extracted to yield a putative eruptive magma (4) which may be compared with the average Hawaiian parental tholeiite (5); Macdonald and Katsura 1964). All iron was converted to FeO for these calculations. Comparison of the putative eruptive liquid (4) with observed parental magma (5) indicates that if extensive eclogite and olivine fractionation are to be major factors in the evolution of liquids such as (5), either the primary magmas must contain more TiO₂ and Na₂O than (1) or the eclogite must contain less TiO₂ and Na₂O than (2). The calculation, nevertheless, indicates the essential feasibility of such an evolutionary scheme.

References

- Clarke, D.B. 1970. Contr. Mineral. Petrol. 25, 203-224.
 Ford et al 1972. Proc. 3rd Lunar Sci. Conf. Geochim. Cosmochim. Acta Suppl. 3, 1, 207-229
 Irving, A.J. and Green, D.H. 1970. Phys. Earth Planet. Int. 3, 385-389.
 Jackson, E.D. and Wright, T.L. 1970. J. Petrology 11, 405-430.
 Kuno, H. 1964. Advancing frontiers in Geology and Geophysics 205-220.
 Lovering, J.F. and White, A.J.R. 1969. Contrib. Mineral. Petrol. 21, 9-52.
 Macdonald, G.A. and Katsura, E. 1964. J. Petrology 5, 82-133.
 O'Hara, M.J. 1969. Geol. Mag. 106, 322-330.
 O'Hara, M.J. et al 1973 this volume.
 O'Hara, M.J. and Yoder, H.S.Jr. 1967. Scott. J. Geol. 3, 67-117.
 Saggerson, E.P. 1968. Geol. Rdsch. 57, 890-903.
 Yoder, H.S.Jr. and Tilley, C.E. 1962. J. Petrology 3, 342-532.