THE DETAILED CHEMISTRY OF THE REACTION SP + PX = GT + OL IN PYROXENITE
INCLUSIONS FROM SALT LAKE CRATER, HAWAII

J.B. Reid, Jr. (School of Natural Science, Hampshire College, Amherst,
    MA, 01002 and G-6, LASL, Los Alamos, NM, 87545)
Margaret Eggleton (School of Natural Sciences, Hampshire College,
    Amherst, MA, 01002).

In most of the garnet pyroxenite inclusions at Salt Lake Crater,
Hawaii, garnet is not a primary mineral but rather has formed during
the cooling of an assemblage of aluminous pyroxene(s) and spinel
(Green, 1966). The garnet occurs mainly as reaction rims between spinel
and clinopyroxene; it may also occur as directly exsolved blebs in
certain occasional grains of clinopyroxene. The goal of this study has
been to reconstruct the modal proportions and chemical compositions of
the pre-garnet mineralogy in these rocks, and thereby identify the com-
ponents of the initial pyroxenes and spinels which have contributed to
the formation of the garnet and olivine in the rock. For each major
element determined by microprobe analysis in the phases of a given rock,
a mass-balance equation can be written:

$$a \left[e_i\right]_{SPI} + b \left[e_i\right]_{CPXI} + c \left[e_i\right]_{OPXI} = d \left[e_i\right]_{GTII} + e \left[e_i\right]_{OLVII} + f \left[e_i\right]_{OPXII} + g \left[e_i\right]_{CPXII} + h \left[e_i\right]_{SPII}$$

(where I refers to the initial, pre-garnet rock and II refers to the pre-
sent analysed rock. a through h are modal proportions (wt.%) and e_i refers
to one of the eight analysed elements. All of the terms on the right side
of the equation are known, leaving a system of eight equations and at the
outset, 27 unknowns.)

A number of additional compositional and textural constraints exist.
Even in a single rock, spinels are surrounded by garnet coronas of dif-
fering relative size, and show a systematic linear variation in compo-
sition as a function of the degree to which the garnet-forming reaction
has proceeded. (As the reaction progresses the remnant spinel becomes
richer in Cr, Fe, Ti, and Mn and poorer in Al and Mg.) Although the
reasons for this variation are unclear, one can extrapolate these trends
to GT/SP = 0, and closely fix the composition of the pre-garnet spinel
(SPI). The modal proportion of SPI is determined by knowing the com-
positions of SPI and SPII, the modal proportion of SPII, and by the obser-
vation that to a first order approximation the initial spinel's Cr budget
simply becomes concentrated in the eventual, smaller, garnet-rimmed
spinel. (In such rock studied in detail, SLC8, Cr_2O_3SP/Cr_2O_3GT ranges
from 10 for low Cr spinels (2.3%Cr_2O_3) to 22 for spinels with about 9%
Cr_2O_3; Cr_2O_3SP/Cr_2O_3CPX ranges from 18 to 47 over the same range).

The combined composition and modal proportion of CPXI plus OPXI are thus determined, allowing a balanced relation, for SLC8, to be written:
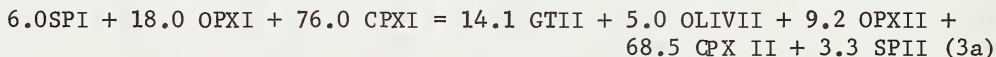
$$6.0SPI + 94.0\ PXI = 14.1\ GTII + 5.0\ OLIVII + 9.2\ OPXII + 68.5\ CPXII + 3.3\ SPII \quad (2a)$$

or equivalently

$$2.7\ SPR + 16.3\ PXR = 14.1\ GTII + 5.0\ OLIVII \quad (2b)$$

where SPR and PXR refer to the components contributed to the reaction by the initial spinel and combined pyroxene. If just prior to garnet formation, the rock had simply consisted of SPI + a single subcalcic pyroxene (combination of OPXI + CPXI), PXR would be the actual contribution from that pyroxene. Textures indicate however that such a single pyroxene, if it ever existed, had exsolved to discrete grains of opx and cpx prior to garnet formation.

An approximate composition for CPXI is obtained by the recombination of CPXII and GTII, in those isolated clinopyroxenes showing exsolved garnet. This composition (particularly its Al_2O_3) is very sensitive to the proportions of CPXII and GTII used in the vicinity of the modally determined values. The best values for the compositions and modal abundances for both CPXI and hence for OPXI are obtained by choosing a CPXII/GTII ratio which allows the ratio Al_2O_3CPXI/Al_2O_3OPXI to be 1.5, a value consistently found in aluminous spinel lherzolites at Salt Lake Crater and Kilbourne Hole. (See table I for compositional data.) Equations (2a) and (2b) can now be rewritten:

$$6.0SPI + 18.0\ OPXI + 76.0\ CPXI = 14.1\ GTII + 5.0\ OLIVII + 9.2\ OPXII + 68.5\ CPX\ II + 3.3\ SPII \quad (3a)$$

and

$$2.7\ SPR + 8.8\ OPXR + 7.5\ CPXR = 14.1\ GTII + 5.0\ OLIVII \quad (3b)$$

Two interesting geophysical results follow from these data. (1) As predicted by MacGregor's experimental study of the effects of Cr content on the P-T position of the spinel-garnet boundary (MacGregor, 1970), the increasing Cr content of the garnet-rimmed spinels as the reaction proceeds indicates that spinel and garnet should coexist over a certain range of pressures for any given bulk composition, and that even if the upper mantle were regionally homogeneous with respect to Cr/(Cr + Al), one would not expect a sharp boundary or density contrast to exist at any depth. (2) It should be noted that the dominant contribution of CPXI to the garnet forming process is high in Mg (23.20%) and low in Ca (9.78%). This suggests that caution is needed when comparing apparent equilibration temperatures for garnet-bearing and garnet-free rocks using the simple En-Di solvus for clinopyroxene temperatures.

Table I

	SPI	SPII	SPR	CPXI	CPXII	CPXR
SiO_2	.00	.00	.00	50.71	51.97	42.86
TiO_2	.30	.23	.38	.74	.88	.00
Al_2O_3	64.00	62.90	65.31	7.36	6.80	13.04
Cr_2O_3	1.50	2.75	.00	.17	.16	.27
FeO	12.10	12.50	11.62	4.39	3.74	10.68
MnO	.10	.09	.11	.14	.10	.51
MgO	21.70	21.32	22.15	15.54	14.83	23.20
CaO	.00	.00	.00	18.60	19.71	9.78
Na_2O	.00	.00	.00	1.59	1.74	.34
	99.70	99.84	99.57	99.24	99.95	100.68

	OPXI	OPXII	OPXR	GTII	OLIVII
SiO_2	54.38	55.30	53.33	41.87	40.78
TiO_2	.34	.17	.51	.14	.00
Al_2O_3	5.42	4.30	6.59	23.70	.00
Cr_2O_3	.09	.10	.08	.16	.00
FeO	7.24	6.80	7.70	8.93	11.18
MnO	.12	.11	.14	.33	.14
MgO	31.52	31.99	30.99	19.81	47.72
CaO	.67	.66	.66	4.91	.08
Na_2O	.06	.11	.12	.00	.00
	99.84	99.55	100.12	99.91	99.97

References:
(1) Green, D.H. (1966) The Origin of the "eclogites" from Salt Lake
        Crater, Hawaii, EPSL, 1, 414-420.

(2) MacGregor, I. (1970) The effect of CaO, Cr_2O_3, Fe_2O_3 and Al_2O_3
        on the stability of spinel and garnet periodites, Phys. Earth
        Planet. Interiors, 3, 372-377.