TRACE-ELEMENT CHEMISTRY OF ECLOGITIC INCLUSIONS IN DIAMOND AND COMPARISONS WITH HOST ECLOGITE, MIR KIMBERLITE, RUSSIA

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We report the first ion-probe trace-element analyses of coexisting eclogitic inclusions (both garnet and clinopyroxene) in a diamond and compare these to the trace-element chemistry of garnet and clinopyroxene in the host eclogite. The sample studied, M-46, is from the Mir kimberlite pipe, Siberia, Russia. In contrast to the trace-element analyses for separate garnet and clinopyroxene inclusions from two separate diamonds from the Udachnaya pipe, Siberia (Ireland et al., 1994), our garnet-clinopyroxene pairs show evidence that the host eclogite is more large-ion lithophile element (LILE)-depleted and HREE-enriched than the corresponding inclusions in diamond. We attribute this LILE-depletion in the host to subsequent melting of the host after diamond formation. It would appear that the alarm sounded for a re-evaluation of geochemical models for Siberian eclogites (e.g., Ireland et al., 1994) is unwarranted at this time.

Introduction -- Debate continues on the relationship of diamonds to their hosts, whether they be from kimberlite or from mantle xenoliths. Some say that the diamonds are cogenetic with the host eclogite, others indicate that they must pre-date major eclogite formation, and still others argue that the diamonds were formed after eclogite production. Furthermore, the hosts for the diamonds could have been affected by later kimberlitic addition or metasomatic alteration. However, inclusions in diamond are considered to be coeval with diamond formation. These diamond inclusions are isolated from later mantle differentiation and/or kimberlitic addition and metasomatism and provide the first evidence of primary eclogite composition during diamond formation. Therefore, diamond inclusions contain invaluable data for modelling geochemical processes during the earliest periods of evolution of the Earth.

In 1971, A.I. Botkunov and N.V. Sobolev found the first large inclusions of both garnet and clinopyroxene in a diamond crystal, weighing 0.3 carats, from a diamond-bearing eclogite from the Mir kimberlite, Siberia (M-46). These inclusions of garnet and clinopyroxene do not exceed 0.1 to 0.3 mm in longest dimension (Sobolev, 1977). Sobolev et al. (1972) reported electron microprobe analyses of the minerals both from the diamond and the host eclogite. With the recent advent and perfection of ion microprobe techniques, we are able to analyze trace-elements in such tiny inclusions. Ireland et al. (1994) reported ion probe-trace-element analyses of a single garnet inclusion in one diamond in an eclogite and a single clinopyroxene inclusion in a diamond from another eclogite, both from the Udachnaya kimberlite pipe, Siberia. However, trace-element data for eclogitic garnet-clinopyroxene pairs from a single diamond hosted by an eclogite have never

Table 1: Major-Element Composition of Host Rock and Diamond Inclusions of M46 eclogite

	Garnet (12) Host	Garnet (7) Inclusion	Cpx (12) Host	Cpx (10) Inclusion
SiO_2	39.4 (2)	39.0 (2)	55.7 (2)	55.8 (2)
TiO_2	0.47 (2)	0.34 (1)	0.52 (6)	0.46 (3)
Al_2O_3	21.6 (1)	21.8 (1)	10.0 (1)	10.0 (1)
Cr_2O_3	0.05 (2)	0.05 (1)	0.05 (2)	0.05 (2)
FeO	19.5 (2)	20.9 (1)	4.62 (8)	5.10 (7)
MnO	0.41 (2)	0.44 (3)	0.06 (2)	0.03 (1)
MgO	9.61 (7)	8.67 (8)	8.97 (9)	8.67 (7)
CaO	8.34 (5)	8.18 (6)	13.1 (1)	13.2 (1)
Na_2O	0.17 (1)	0.12 (1)	6.41 (8)	6.06 (5)
K_2O	n/a	n/a	0.09 (2)	0.31 (2)
Total	99.6	99.5	99.5	99.7
Mg#	46.9	42.5	77.7	75.0

been reported. Now, more than twenty years after their discovery, we report the first trace-element analyses of these garnet-clinopyroxene pairs from a Mir diamond and compare them to the chemistry of the host eclogite.

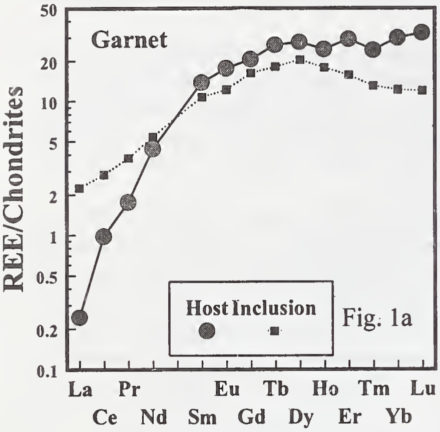

Fig. 1a

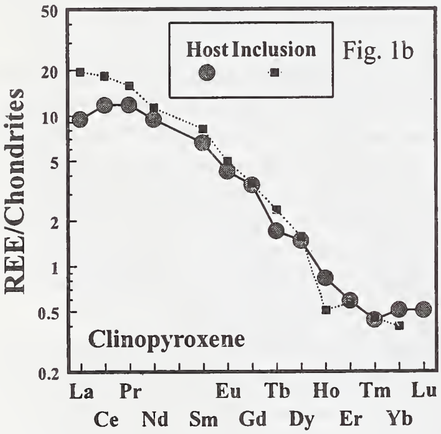

Fig. 1b

Petrography and Major-Element Chemistry -- The inclusions of garnet and clinopyroxene in diamond display octahedral habits, a reflection of the confining diamond morphology. The major-element chemical compositions of the inclusions in the diamond from M-46 (Table 1) are roughly similar to the corresponding minerals in the host eclogite, yielding evidence that the diamond was formed *in situ* approximately at the time of eclogite formation. However, there are subtle differences in the major-element chemistry which are consistent with later processing of the eclogite host. For both garnet and clinopyroxene, the diamond inclusions are more enriched in FeO and depleted in MgO relative to the host eclogite. For clinopyroxene, the diamond inclusion is enriched by a factor of 3 in K_2O. These results are essentially the same as reported by Sobolev et al. (1972).

Ion Probe Trace-Element Chemistry -- Ion microprobe analyses of the inclusions and host minerals were performed in the facilities at Washington University. Both garnet and clinopyroxene inclusions in diamond are more enriched in the LREE than the corresponding minerals in the host eclogite (Figure 1). The MREE and HREE for both host and inclusion clinopyroxene are, within analytical uncertainty, indistinguishable. However, the HREE for the garnet inclusion are depleted by a factor of 2-3 over that in the host.

We have calculated plausible eclogite whole-rock compositions for garnet-clinopyroxene assemblages in both the diamond inclusions and the host rock by using sub-equal modal abundances of garnet and clinopyroxene. Trace-element abundances, relative to primitive mantle (Sun and McDonough, 1989), of these reconstructed whole-rocks are shown in Figure 2. As can be seen, the elements to the right of Pr are progressively more depleted (with increasing compatibility, from left to right) in the eclogitic inclusions as compared to the eclogite host rock. The elements to the left of Pr are more enriched in the diamond inclusions than the those in the host (with the exception of Ta).

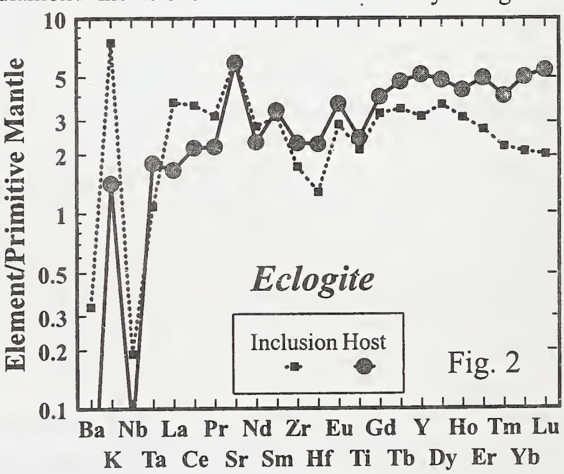

Fig. 2

Discussion -- As originally reported by Sobolev et al. (1972), we have further documented that the eclogitic inclusions in the M-46 diamond are depleted in Mg and enriched in Fe relative to the host eclogite. However, the pattern of enrichment and depletion of trace-elements in the diamond inclusions relative to the host eclogite are exactly the opposite of the patterns found by Ireland et al. (1994) for single garnet and clinopyroxene inclusions (not both minerals) from diamonds in Udachnaya eclogites. They found that the separate garnet and clinopyroxene inclusions in diamonds were in bothcases more depleted in the LILE than the host eclogite. They attributed this LILE enrichment in the host eclogite to "metasomatic enrichment of the eclogite [host] by passing melts." Based upon our data presented above, we cannot concur with this assessment. In fact, our data suggest that **the host Mir eclogite underwent a depletion event after diamond formation**. This depletion event could be due to partial melting, leaving behind a residue more depleted in incompatible LILE. Furthermore, such a model is consistent with that presented by Snyder et al. (1993) who postulate an early LILE enrichment of the eclogite, followed by a major LILE depletion event. This depletion event could have been caused by tonalite extraction as hypothesized by Ireland et al. (1994). However, unlike in their model, it is the eclogite host, and not the inclusions in diamond, which records evidence of this event.

That a comparison between inclusions in diamond and the host eclogite would yield such disparate results for samples from the Udachnaya and Mir kimberlites indicates either fundamental differences in the histories of eclogites from these pipes or extreme variability in the degree of metasomatism from sample to sample, even within the same pipe. We have already documented the unique nature of Udachnaya eclogites (Sobolev, 1994; Snyder et al., 1995; Snyder et al., 1995) as compared to other Siberian eclogites. However, we have also shown that most Udachnaya eclogites show little evidence of kimberlitic addition and/or metasomatism (Sobolev, 1994; Snyder et al., 1995). It is possible that the findings of Ireland et al. (1994) are somewhat atypical and may not be representative of most Siberian eclogites. In fact, their whole-rock reconstructions are hampered by the lack of coexisting mineral mates in the diamond inclusions, which necessitated the introduction of certain gross assumptions. Although we appreciate the need to continually re-evaluate models in light of new data, the warnings and call for re-evaluation of geochemical models for Siberian eclogites based on the presentation of Ireland et al. (1994) are premature at best.

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