

ments. Samples at the extreme ends of the geotherm differ by 220°C and reflect depth differences of the order of 60km. These results together with those of Koffiefontein and Frank Smith suggest that many megacrysts may have come from widely differing depths and environments in the mantle.

## D20

### SINGLE-CRYSTAL STRUCTURE REFINEMENTS OF SUPER-SILICIC CLINOPYROXENES FROM THE ZAGADOCHNAYA KIMBERLITE PIPE, YAKUTIA, USSR.

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It has often been suggested that supersilicic (cation-deficient) clinopyroxenes contain vacant sites, probably in the form of solid-solution of the CaEs end-member ( $\text{Ca}_{0.5}\text{Al}_1\text{Si}_2\text{O}_6$ ), but full structure refinements by X-ray diffraction have not previously been made. Refinements are now presented for optically-clear supersilicic clinopyroxenes from two grosspyrite nodules from the Zagadochnaya kimberlite pipe.

In sample Zaga/O, both refinements and electron microprobe analysis indicate intergrain inhomogeneity but intragrain homogeneity. The refinements are compatible with vacancies in M2 and with the microprobe analysis (Jd<sub>45</sub>Di<sub>38</sub>CaTs<sub>07</sub>CaEs<sub>10</sub>), but they do not prove the existence of vacancies in M2. The space group is C2/c such that this is the only confirmed disordered omphacite with around 50 % Jd. This primary clinopyroxene co-existed with garnet, kyanite and corundum, but has been partially replaced by secondary clinopyroxene (Jd<sub>17</sub>Di<sub>66</sub>CaTs<sub>17</sub>), clinoamphibole, plagioclase, quartz and zoisite. This rock thus displays the simultaneous expulsion of excess SiO<sub>2</sub> and breakdown to an amphibolite-facies paragenesis.

Sample Zaga/8 differs in containing secondary clinopyroxene in an exsolution texture. Both samples share some features in common with certain supersilicic clinopyroxenes from the Roberts Victor kimberlite pipe, S. Africa, though direct exsolution of SiO<sub>2</sub> has not been observed in these Zagadochnaya samples.

## D21

### ON THE CHARACTERISATION AND CREDIBILITY OF SUPERSILICIC, STOICHIOMETRIC, AND SUBSILICIC PYROXENES

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$X_{n-s} = 100 (S - (N+D)) / (S + (N+D))\%$  in the natural chemical system SAND (where S = Si + Ti, A = Al + Fe<sup>3+</sup> + Cr - Na - K, N = 2Na + 2K, and D (divalents) = Ca + Mg + Ni + Fe<sup>2+</sup> + Mn, all in cation proportions) is proposed as a useful indicator of pyroxene non-stoichiometry. The S : A : (N+D) diagram conveniently demonstrates : 1. supersilicic, stoichiometric, or subsilicic pyroxenes for which  $X_{n-s}$  is positive, zero or negative, respectively ; 2. the irrelevance of trivalent cations to pyroxene stoichiometry (since their oxides also have 4 cations (C) per 6 oxygens (O), such that  $X_{n-s}$  isopleths radiate from the A apex ; 3. that supersilicic pyroxene is most simply considered as a solid solution of stoichiometric pyroxene with SiO<sub>2</sub> rather than with any A-bearing end-member ; 4. the im-

probable existence of subsilicic pyroxene which requires C>4 per O=6 ; 5. the "bimineralic eclogite line" between A and (N+D)<sub>2</sub>S<sub>2</sub> upon which lie all stoichiometric pyroxenes and garnets.

All theoretical supersilicic pyroxene end-members (e.g. D<sub>1.5</sub>AS<sub>2</sub>O<sub>6</sub>, DA<sub>1.67</sub>S<sub>2</sub>O<sub>6</sub>) have no N, since in alkali pyroxene all other cation sites already have the highest-valent cation possible. However, Jd solution aids the stability of M-site vacancies, more so than Di solution, by providing more similarly-charged M-sites and a smaller volume. Exsolution of the excess Si as quartz (e.g. in Norway, Greenland and S. Africa) can create Al(IV) at lower T than if the CaTs proportion was in equilibrium with garnet.

The recent suggestion of O<sup>-</sup> stability allows the not too remote possibility of new high-density supersilicic "pyroxene" end-members (e.g. AS<sub>2</sub>O<sub>5</sub><sup>-</sup>, D<sub>1.5</sub>S<sub>2</sub>O<sub>5</sub><sup>-</sup>) at high P.

Supersilicic pyroxenes are thus to be expected in Na-, Ca-, Al- & Si-rich systems at high P (blueschists, eclogites, experiments).

## D22

### GARNET AND CPX MEGACRYSTS FROM KASAI.

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Eastern Kasai xeno-tuff breccia kimberlite include a long set of megacrysts: garnet, cpx ilmenite, rutile, kyanite, corundum, zircon and baddeleyite. Neither olivine nor enstatite have been found. We are only concerned with garnet and cpx. About 200 specimen each have been sampled from Mbuji Mayi and Tshibua pipes, eastern Kasai.

All the garnets from Tshibua are Cr pyrope. They tend to have relatively low CaO contents (4.0 wt%) and Cr<sub>2</sub>O<sub>3</sub> values in the range 0.95-6.5 wt%. Two Cr pyrope show a particular zonation affecting only octahedral diadochic ions Al<sup>3+</sup> and Cr<sup>3+</sup>. All the cpx from Tshibua are diopsides. Except for one specimen the Cr<sub>2</sub>O<sub>3</sub> contents are below 0.9 wt% and Al<sub>2</sub>O<sub>3</sub> values below 1.90 wt%. Na<sub>2</sub>O ranges between 1.40 and 2.0 wt%. Garnets and cpx from Tshibua are all ranged in the lherzolitic suite.

Several garnet and cpx megacrysts from Mbuji Mayi resemble those from Tshibua and are ranged in the lherzolitic suite yet an important part of analysed minerals are quite different. Cpx have considerable contents of Na<sub>2</sub>O and Al<sub>2</sub>O<sub>3</sub> in the ranges 4.0-6.8 and 6.9-11.4 wt% respectively. Cr<sub>2</sub>O<sub>3</sub> contents do not exceed 0.2 wt%. These cpx are omphacitic. Some garnets belong to the pyrope-almandine-grossular series. Both these latter minerals have been ranged in an eclogitic suite.

Using enstatite-diopside thermometers, the lherzolitic cpx show a possible equilibration range from 950 to 1350°C. Isotopic ratios <sup>87</sup>Sr/<sup>86</sup>Sr of cpx are quite different of kimberlitic matrix. Garnet and cpx megacrysts show a reaction rim with the kimberlitic matrix. Thus a xenocrystal origin is proposed for garnet and cpx megacrysts.

## D23

### MG-ILMENITES IN ALKALI BASALTS FROM THE VOLCANIC HOGGAR AREA

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The Plio-Quaternary nephelinitic and basaltic volcanoes of the Tahalra area (Hoggar, south Algeria) contain numerous upper mantle xenoliths and xenocrysts (sp. lherzolite, pyroxenes and/or amphiboles rich inclusions, kaersutite and ferri-salite megacrysts). Mg-ilmenite have been observed with a distinct habit in two types of rocks:

\* Large polycrystalline xenoliths (3-20 cm) which contain only Mg-ilmenite grains (0.03 to 15 mm) with exsolution of titanomagnetite and Al-spinel. These xenoliths exhibit tectonic fabrics which can be ascribed to solid state flow followed by dynamic recrystallisation. Their rounded surfaces display cavities filled up with kaersutite, fassaite and olivine. These Mg-ilmenite xenoliths have the same chemistry (25 to 37 % mol. of geikielite) and the same texture as the Mg-ilmenites found in kimberlites (a lack of outward Mg enrichment is the only difference) (1).

\* Lherzite xenoliths in which interstitial undeformed Mg-ilmenite crystals (<2 mm) of identical composition are associated with kaersutite ( $\pm$  olivine and fassaite). From the study of a composite lherzite-sp. lherzolite xenolith, these nodules of Mg-ilmenite-lherzite are thought to be pieces of veins which may occur in the upper mantle lherzolites.

Textural relationships and chemical compositions suggest a similar origin for these two types of Mg-ilmenite. In both cases, they crystallised from a liquid of high-Ti nephelinitic composition in the upper mantle conditions. Ascending later magmas sampled both deformed and undeformed Mg-ilmenite xenoliths suggesting either several generations or different tectonic evolutions for the upper-mantle Mg-ilmenites. (1) Contrib. Mineral. and Petrol.

## D24

### RELATIONSHIP BETWEEN GEOCHEMISTRY AND COLOR OF GARNET XENOCRYSTS FROM COLORADO-WYOMING KIMBERLITES

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Color of garnet grains obtained by alluvial and/or soil sampling programs may be a useful indication of the presence of kimberlite in a prospecting target area. Garnet xenocrysts from 12 kimberlites in northern Colorado and southern Wyoming were classified according to color and chemistry in order to ascertain their petrologic parentage and test the viability of using grain color as a means of rapid identification of kimberlite indicator garnets. Seventeen color groupings were established with the aid of a G.S.A. Rock Color Chart, and grouped into four major color categories: Group 5R (red garnets), Group 5RP (red purple garnets), Group 10R (reddish-orange to reddish-brown garnets), Group 5YR (brown garnets). Representative samples of each color grouping have been analysed by electron microprobe, and data for 91 garnets reveals distinct chemical trends between the major color categories. In general, CaO and Cr<sub>2</sub>O<sub>3</sub> increase whereas Al<sub>2</sub>O<sub>3</sub> decreases in order of Groups 5YR, 10R, 5R, and 5RP, FeO increases in order of groups 5R, 5RP, 10R, and 5YR, and TiO<sub>2</sub> increases in order of Groups 5YR, 5R, 5RP, and 10R. Groups 5R and 5RP have the highest Cr/Al and lowest TiO<sub>2</sub>, a "depleted" chemistry typical of rounded pyrope xenocrysts in kimberlite, Cr-rich garnet megacrysts, and

peridotite garnets. Groups 10R and 5YR have lower Cr/Al and higher TiO<sub>2</sub> and FeO, values that are characteristic of garnets from websterites, pyroxenites, eclogites, and granulites. Some Group 10R garnets have compositions similar to Cr-poor garnet megacrysts. (Study supported by Earth Sciences Section of NSF, Contract EAR-7810775)

## D25

### THE SIGNIFICANCE OF SULFIDES IN SPINEL AND GARNET LHERZOLITES AS CARRIERS OF PLATINUM METALS

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Ultramafic nodules from alkali basalts and kimberlites are a major source for estimating the chemical composition of the upper mantle. Concentrations of major elements and a large number of trace elements are surprisingly uniform in primitive nodules (1). Abundances of Ir and other noble metals also show little variations in spinel lherzolites. However the content of, for example Ir in these upper mantle samples is much higher than that expected from core mantle equilibrium. Since the relative abundances of Ir, Au etc. in these samples are the same as those of undifferentiated meteorites, it was suggested that these elements are derived from a late meteoritic component at a time when the core had already formed (1, 2, 3). This hypothesis has been recently questioned by Mitchell and Keays (4). These authors argued that the siderophile elements in mantle samples are the result of immiscible sulfide liquids, separated from basaltic liquids formed by partial melting of the mantle. Part of the evidence provided by Mitchell and Keays was the fact that only minor fractions of Ir, Au etc. are contained in the major minerals of upper mantle samples, and that therefore sulfides are the most likely host phases for these elements.

We have separated and analysed sulfides from spinel and garnet lherzolites. Preliminary results have been reported (1). Two main questions will be addressed in this investigation:

- Are sulfides the major host phase of noble metals in upper mantle samples?
  - What is the origin of these sulfides? Were the noble metals originally contained in other phases and did they partition into later formed sulfides? We are planning to analyse these sulfides for lead isotopes, in order shed light on their origin.
- Lit.: (1) Jagoutz, E. et al. Proc. 10th Lunar Planet. Sci. Conf. p. 2031 (1979); (2) Chou, C.L. Proc. 9th Lunar Planet. Sci. Conf. p. 219 (1978); (3) Morgan, J.W. et al. Tectonophysics 75, p. 47 (1981); (4) Mitchell, R.H. & Keays, R.R. Geochim. Cosmochim. Acta 45, p. 2425 (1981).

## D26

### OPAQUE MINERALOGY AND CHEMISTRY OF ILMENITE NODULES IN WEST AFRICA KIMBERLITES: SUBSOLIDUS EQUILIBRATION AND CONTROLS ON CRYSTALLIZATION TRENDS

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A regional survey of kimberlitic heavy mineral concentrates from Liberia (2 pipes and 13 probable dikes), Sierra Leone (3 pipes and 5 dikes), Guinea (3 pipes) and Mali (3 pipes and 1 dike)