

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

J.P. PADGETT, M.E. McCALLUM and H.O.A. MEYER

Department of Earth Resources, Colorado State University, Fort Collins, Colorado 80523;

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

H. PALME, E. JAGOUTZ, C. GÖPEL, B. SPETTEL AND H. WÄNKE

Max-Planck-Institut, Abt. Kosmochemie, D-6500 Mainz, W-Germany

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

STEPHEN E. HAGGERTY and LINDA A. TOMPKINS

Dept. of Geology, University of Massachusetts, Amherst, MA 01003, USA

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)

show that: (1) all are characterized by large concentrations of ilmenite ( $\text{Ilm} \gg \text{Gt} \gg \text{Px}$ ) with Mali > Liberia > Guinea > Sierra Leone; (2) Antoschka (Guinea) exhibits the largest variety of opaque minerals ( $\text{Ilm} + \text{Rut} + \text{Sp}$ ); (3) Mali is characterized by low T anatase+Hem replacement of Ilm, and Sierra Leone has abundant sulfides ( $\text{Cpy} + \text{Po} + \text{Pn}$ ) within Ilm; (4) extremely large (10–15 cms) Ilm are derived from Liberia; (5) Sierra Leone and isolated sites in Liberia have high MnO (16wt% max) contents in Ilm associated with calcite; (6) large variations and considerable overlap exist within and between kimberlite clusters in Ilm-Geik-Hem contents; (7) subsolidus reduction of Ilm to 2  $\text{Ilm}_{\text{SS}} + \text{Sp}_{\text{SS}}$  is unique to Sierra Leone whereas exsolution of  $\text{Ilm}_{\text{SS}}$  from Ilm-Geik-Hem $_{\text{SS}}$  are restricted to Liberia and Antoschka; (8)  $\text{Cr}_2\text{O}_3$ -MgO variations are either tightly clustered along a parabolic curve delineated by  $\text{Mg}_{\text{Ilm}}/\text{Mg}_{\text{Sp}}$  or dispersed within a broad hyperbolic envelope; (9) a coherent pattern of compositional variations is established between Ilm-Ilm $_{\text{SS}}$  pairs which define a decompositional loop in the ternary Ilm-Geik-Hem that is consistent with experimental data at variable T- $\text{fO}_2$ ; and (10) by using the data from (9) and combined with Ilm compositions from southern Africa it is concluded that the dominant control on Ilm compositions is the T- $\text{fO}_2$  dependency of immiscibility within the system Ilm-Geik-Hem, such that Ilm-Hem $_{\text{SS}}$  and Ilm-Geik $_{\text{SS}}$  are permissible, Geik-Hem $_{\text{SS}}$  are absent, and intermediate (Ilm-Hem)- (Geik-Hem) $_{\text{SS}}$  are restrictive because  $\text{Sp}_{\text{SS}} + (\text{Pb} + \text{Kar} + \text{FPb})_{\text{SS}}$  is stable at low P.

## D27

### COMPLEX TITANATE COMPOUNDS ( $\text{MO}_2$ , $\text{M}_2\text{O}_3$ , $\text{M}_3\text{O}_5$ , $\text{M}_4\text{O}_7$ , $\text{M}_{22}\text{O}_{38}$ ) IN KIMBERLITES: MINERAL REPOSITORIES FOR AND THE PARTITIONING OF LIL ELEMENTS.

STEPHEN E. HAGGERTY

Dept. of Geology, University of Massachusetts, Amherst, MA 01003, USA

The mineralogy and genesis of components hosting large concentrations of (R) refractory (e.g., Cr, Nb, Ta, Zr) and LIL (e.g., K, Ba, Sr, REE) elements in kimberlites and kimberlite nodules provide insights to the nature of mantle reservoirs, may be used to impose constraints on degrees of partial melting, and may yield independent estimates of originating depths and sites of equilibration. R and LIL are abundant in rutile ( $\text{MO}_2$ ), perovskite ( $\text{M}_2\text{O}_3$ ), armalcolite-related ( $\text{M}_3\text{O}_5$ ), zirconolite ( $\text{M}_4\text{O}_7$ ), and crichtonite-related ( $\text{M}_{22}\text{O}_{38}$ ) minerals. However, with the exception of  $\text{MO}_2$  ( $\text{TiO}_2$  II) none of these compounds have established high P stabilities. It is proposed that substitution of Cr, Zr, and Nb into  $\text{TiO}_2$  may be accomplished in compounds related to the high P parent structure  $\alpha\text{PbO}_2$  by

crystallographic shear (CS) comparable to those in the series  $\text{M}_n\text{O}_{2n-1}$  -  $\text{M}_n\text{O}_{3n-2}$  ( $n=1,2,3$ ) and to  $\text{Cr}_2\text{Ti}_{n-2}\text{O}_{2n-1}$  ( $n=3,4,5$ ). Such compounds, on ascent-equilibration, yield a viable explanation for the occurrence of  $\text{M}_3\text{O}_5$  (armalcolite type) in association with rutile and ilmenite, and for the ubiquitous presence of rutile and ilmenite intergrowths. Ba-K (Sr, Pb, Ca, REE) members of  $\text{M}_{22}\text{O}_{38}$  compounds decompose to rutile+spinel+X...n phases suggestive of site occupation of LIL at high P into phases other than CS based structures. Using the model precursors of CS and non-CS structured compounds (i.e.,  $\alpha\text{PbO}_2$  and  $\text{M}_{22}\text{O}_{38}$ ) and constraints in paragenesis, two distinct R + LIL evolutionary trends emerge: (a) in which Nb+Zr+Cr+K are complexed as high P incompatible liquid residua into  $\text{MO}_2$ ,  $\text{M}_4\text{O}_7$  ( $\text{Cr}_2\text{Ti}_2\text{O}_7$ ) or  $\text{M}_{22}\text{O}_{38}$  type compounds in nodules; and (b) low P melt residua in which Ti fractionates to form R-depleted ilmenite and a Ti+REE sink in perovskite at the terminal stages of kimberlite crystallization.

## D28

### A LAYERED DUNITE - WEHLRITE - WEBSTERITE FROM NEWLANDS, SOUTH AFRICA; EVIDENCE FOR SMALL SCALE FRACTIONAL CRYSTALLIZATION IN THE MANTLE.

L.R.M. DANIELS;

Falconbridge Explorations (Botswana) (Pty) Limited, P.O. Box 1463, Gaborone.

A layered mantle xenolith, LDN-10, has been found in the Newlands kimberlite. The bulk composition, calculated from modal mineral proportions, approximates a peridotitic Komatiite. The following layers are recognised: a) Dunite b) Wehrlite c) Gt-Wehrlite d) Gt-Websterite. Olivine and orthopyroxenes show minor chemical variations across the xenolith. The garnets and clinopyroxenes are strongly zoned, particularly with respect to  $\text{Cr}_2\text{O}_3$ , which also decreases systematically from the wehrlitic layers to the websteritic layer.

The layering in LDN-10 can be interpreted in terms of a fractional crystallisation model that is consistent with phase relations established for the CMAS tetrahedron (O'Hara, 1968). In this model, with a liquid corresponding to the bulk composition for LDN-10, the first mineral phase to crystallise will be olivine, followed by clinopyroxene, garnet and orthopyroxene respectively. This crystallisation sequence is reflected by the observed mineral assemblages in LDN-10 and is consistent with the observed  $\text{Cr}_2\text{O}_3$  variation of both clinopyroxene and garnet.

Gurney et al (1975) proposed a fractional crystallisation model for the Matsoku xenolith suite. It is suggested that LDN-10 represents a similar type of mantle process, but on much smaller scale.

#### References:

- Gurney J.J., Harte B., and Cox K.G. 1975: *Phys. Chem. Earth* 9, 507-523.  
O'Hara M.J., 1968: *Earth Sci. Rev.* 4, 69-133.

## (Late abstract)

### MANTLE MINERAL ASSEMBLAGES AND PALAEOGEOTHERMS

A. B. THOMPSON and S.L. HARLEY

(ETH Zurich, CH-8092 Zurich, Switzerland)

Many recent studies of the quenched mineral assemblages in magmas considered to have a deep mantle origin (alkali basalts and kimberlites) and their enclosed nodules, have sought to determine the depth at which the mineral geothermome-

ters closed to further reequilibration. If the deduced P-T-points lie on a curve, then they are frequently interpreted to define the P-T-location of a palaeogeotherm. If the deduced P-T-points form an array, then uncertainties in P-T-calibra-