

V12C MC: Hall D Monday 1330h**Mantle Petrology****Presiding: R Rudnik**, University of Maryland**V12C-0985 1330h POSTER****Geodynamics of Yarlung Zangbo Suture Zone (YZSZ): Implications for Origin of Related Tibetan Ophiolites**Rejean Hebert¹ (418-656-3137;hebert@ggl.ulaval.ca); Francois Huot² (02-98-49-87-10; huot@univ-brest.fr); Veronika Varfalvy² (02-98-49-87-10; varfalvy@univ-brest.fr); Mathieu Benoit² (02-98-49-87-10; mbenoit@univ-brest.fr); Viviane Dubois-Cote¹ (418-656-2193; vidubois@ggl.ulaval.ca); Celine Dupuis¹ (418-656-2193; celine.dupuis@ggl.ulaval.ca); Chengshan Wang³ (86-28-4078892; wcs@cdit.edu.cn); Yalin Li³ (86-28-4078892; ly@cdit.edu.cn); Jarda Dostal⁴ (902-420-5747; jarda.dostal@stmarys.ca)¹Departement de Geologie et de Genie Geologique, Universite Laval, Ste-Foy, Qbc, Can, G1K 7P4²Institut universitaire europeen de la Mer, UMR Domaines oceaniques, Plouzan, France, 29280³Institute of Sedimentary Geology, Chengdu University of Technology, Chengdu, China, 610059⁴Geology Department, St Marys University, Halifax, Nova Scotia, Can, B3H 3C3

YZSZ is a major tectonic feature which runs roughly E-W marking the limit between Tibet Block and Himalayan Domain. It is believed to represent the surface expression of the collision between Eurasia and India plates. Summer 2001 field work on flysch, turbidite deposits and polymictic conglomerates derived from Indian side of the suture zone allowed us to study blocks of intrusive rocks and their metamorphic counterparts and blocks of unknown origin which are currently under investigation. Collision mode and timing are matters of debate because of the irregularity of Indian indenter and Eurasian continental margin causes a diachronous interaction. Lack of extensive absolute datation prevents establishing a complete picture of the collisional event which allowed obduction of Jurassic-Cretaceous Tethyan ophiolites characterizing the suture zone. Since 1998 a reassessment of ophiolitic sequences revealed unprecedented complexity of their genesis. Ophiolite complexes are in thrust contact with ophiolitic mélange made of sedimentary and igneous and metamorphic rocks set in a serpentinite matrix. Mineral and geochemical results obtained to date suggest the mélange is derived from tectonic dismemberment of nearby ophiolitic complexes. Undated foliated amphibolitic blocks derived from a now destroyed dynamothermal aureole indicate the dismemberment may start at high temperature in an intraoceanic setting and continue at low temperature until final emplacement onto Indian continental margin. We do not know the interval of time involved from intraoceanic detachment to obduction. The study of the main ophiolitic sequences also reveals complex history related to both primary and superimposed secondary features. Degree of preservation largely varies. Mantle composition ranges from depleted harzburgite to fertile lherzolite. Olivine-spinel equilibrium suggests the mantle was extracted from depth varying from 15 to more than 50 km. NiO content of olivine (0.15-0.70), Cr# of spinel (0.10-0.90), Al₂O₃ content of clinopyroxene and orthopyroxene (1.0-5.5 and 0.3-7.0 wt % respectively) attest for complex partial melting, melt percolation and subsolidus reequilibrations events. Several gabbroic facies show tschermakitic amphibole as an igneous phases indicating that significant amount of water was dissolved in the magma. Accordingly calculated Fe³⁺ of spinel (corresponding to up to 15 wt.% Fe₂O₃) shows relatively high values similar to arc spinels. By using spinel as a petrogenetic indicator the ophiolites are likely to be generated in a suprasubduction zone environment. Trace element and REE geochemistry suggests (e.g. TiO₂ varies from 0.5-2 wt.%) that several igneous sequences are imbricated to build the ophiolitic sequences and imply interaction of various sources.

V12C-0986 1330h POSTER**Inclusions of Sulphide Immiscible Melts in Primitive Olivine Phenocrysts from Mantle-Derived Magmas; Preliminary Results**Leonid Danyushevsky¹ (61-3-62262469; L.Dan@utas.edu.au)Chris Ryan² (c.ryan@syd.dem.csiro.au)Vadim Kamenetsky¹ (Dima.Kamenetsky@utas.edu.au)Anthony Crawford¹ (Tony.Crawford@utas.edu.au)¹School of Earth Sciences and CODES SRC University of Tasmania, GPO Box 252-79, Hobart, TAS 7001, Australia²CSIRO Exploration and Mining, Po Box 136, North Ryde, NSW 2113, Australia

Sulphide inclusions have been identified in olivine phenocrysts (and in one case in a spinel phenocryst) in primitive volcanic rocks from mid-ocean ridges, subduction-related island arcs and backarc basins. These inclusions represent droplets of an immiscible sulphide melt and are trapped by olivine crystals growing from silicate melts. Sulphide melt is usually trapped as separate inclusions, however combined inclusions of sulphide and silicate melts have also been observed.

Sulphide inclusions have rounded shapes and vary in size from several up to 100 microns in diameter. At room temperature sulphide inclusions consist of several phases. These phases are formed as a result of crystallisation of the sulphide melt after it was trapped. Crystallisation occurs due to decreasing temperature in the magma chamber after trapping and/or when magma ascends from the magma chamber during eruptions.

In all studied sulphides three different phases can be identified: a high-Fe, low-Ni, low-Cu phase; a high-Fe, high-Ni, low-Cu phase; and high-Fe, low-Ni, high-Cu phase. Low-Cu phases appear to be monomineralic, whereas the high-Cu phase is usually composed of a fine intergrowth of high- and low-Cu phases, resembling the quench 'spinel' structure. Fe, Ni and Cu are the major elements in all sulphides studied. The amount of Ni decreases with decreasing forsterite content of the host olivine phenocryst, which is an index of the degree of silicate magma fractionation. Since Ni content of the silicate magma is decreasing during fractionation, this indicates either that the immiscible sulfide melt remains in equilibrium with the silicate melt continuously changing its composition during fractionation, or that the sulfide melt is continuously separated from the silicate melt during fractionation, with later formed droplets having lower Ni content due to the lower Ni content of the evolved, stronger fractionated silicate melt.

Trace element contents of the sulfide inclusions have been analysed on the proton microprobe at CSIRO in Sydney. The main trace elements in the sulfide inclusions are Zn, Pb, Ag, and Se. Other trace elements are below detection limits, which are normally at a level of several ppm. Zn concentrations (120 +/- 40 ppm) in sulphides are similar to those in silicate melts. This indicates that separation of the sulfide melt does not affect Zn contents of silicate melts. On the contrary, Ag (30 +/- 10 ppm) and Pb (40 +/- 10 ppm) contents in sulphides are at least in order of magnitude higher than in the silicate melt, and thus separation of the immiscible sulfide melt can significantly decrease Pb and Ag contents of the silicate magma.

The widespread occurrence of sulfide inclusions, which were also described in olivine phenocrysts from ocean island basalts, indicates common saturation at low pressure of mantle-derived magmas with reduced sulfur.

V12C-0987 1330h POSTER**Water in clinopyroxene from the deeply subducted crust: An evidence for water transportation into the mantle**Ikko Katayama¹ (katayama@geo.titech.ac.jp)Satoru Nakashima¹ (satoru@geo.titech.ac.jp)¹Department of Earth and Planetary Science, Tokyo Institute of Technology, O-okayama, Meguro, Tokyo 152-8551, Japan

Input of water into the earth's interior is restricted to subduction zones. However, the subducted oceanic crusts are dehydrated in shallow depth, and then transformed to dry eclogite containing no hydrous minerals at over temperature of 700 C and pressure of 30 kbar. It is therefore believed that subducted crusts cannot carry significant water into deeper mantle. Recently, several researchers reported clinopyroxenes contain trace water, up to 1,840 ppm OH from kimberlite xenoliths. This hydroxyl is reported to be associated with cation vacancy in the pyroxene (Smyth et al, 1991). In this study, we found clinopyroxenes containing cation vacancy from eclogites of the Kokchetav ultrahigh-pressure (UHP) metamorphic terrane, which had been subducted to more than 150 km depth (the world deepest). Infrared spectra of the clinopyroxenes show three hydroxyl absorptions in the regions of 3440-3460 cm⁻¹, 3500-3530 cm⁻¹ and 3600-3625 cm⁻¹. The hydroxyl absorbance increases with recrystallized pressure of the eclogites and vacancy in the pyroxene structure (CaEskola component). Since the clinopyroxenes represent about 40-50 volume % of the eclogites, the bulk eclogites can contain approximately 1300 ppm hydroxyl at depth greater than 150 km. Thus, the subducted oceanic crusts can carry water into the upper

mantle, even in the absence of nominally hydrous minerals.

V12C-0988 1330h POSTER**Nanometer-sized OH-bearing inclusions in olivine from mantle derived xenoliths from different locations.**Richard Wirth¹ (49 331 288 1319; wirth@gfz-potsdam.de)Natasha Khisina² (urusov@geol.msu.ru)¹Richard Wirth, GeoForschungsZentrum Potsdam Telegrafenberg Dev. 4.1, Potsdam D-14473, Germany²Natasha Khisina, Institute of Geochemistry and Analytical Chemistry of Russian Academy of Sciences Kosygin st.19, Moscow 117975, Russian Federation

Nanometer-sized inclusions have been observed in olivine of mantle-derived xenoliths from different locations such as kimberlites from Yakutia (Siberia) and Bultfontein (South Africa), and in a peridotite from Finero (Alps). The inclusions from Yakutia consist of three types of inclusions: (1) "large" inclusions up to several hundred nm in size composed of serpentine + talc +10-phase; (2) lamellar defects and (3) very small inclusions (10 nm in size), which consist of "hydrous olivine. All three types of inclusions contain OH- or water. Olivine from xenoliths in kimberlites from Bultfontein and from the Finero peridotite only shows serpentine+talc+10-phase as mineral assemblages. "Hydrous olivine is characterised by a superperiodicity in the olivine structure, which is visible in electron diffraction pattern in TEM. The superperiodicity is suggested to have formed by ordering of M1 vacancies located in the (100) and (001) octahedral layers of the olivine lattice thus forming ordered arrays of planar defects. The ordered array of planar defects causes the band-like contrasts in HRTEM patterns as well as the superperiodicity in the electron diffraction pattern. Hydrous olivine (Mg_{1-y}Fe_{2+y})₂xv_xSi₄O₁₂x₂ has a modular structure and a discrete composition with x-values 0.33 or 0.25. It is proposed that the "hydrous olivine has formed by exsolution from water saturated olivine at high pressure and temperature conditions. The observed OH-bearing inclusions in mantle derived olivine indicate the presence of water in the earth mantle.

V12C-0989 1330h POSTER**Water concentrations in enriched mantle components in the South Atlantic: Evidence for efficient dehydration of recycled crust and sediments**Loretta Leist¹ (305-361-4812; lleist@rsmas.miami.edu)Jacqueline Dixon¹ (305-361-4150; jdxion@rsmas.miami.edu)Jean-Guy Schilling² (401-874-6628; jgs@gso.uri.edu)¹RSMAS/Univ. of Miami, 4600 Rickenbacker Cswy., Miami, FL 33149, United States²GSO/Univ. of Rhode Island, Narragansett Bay Campus, Narragansett, RI 02882-1197, United States

A major uncertainty in the earth's water cycle is the amount of water that enters the deep mantle through subduction and recycling of hydrated oceanic lithosphere. We measured dissolved H₂O and CO₂ concentrations in basaltic glasses from the Mid-Atlantic Ridge (40°S to 54°S) to examine volatiles in two distinct mantle plumes containing recycled crustal components. Sr-Nd-Pb isotopic compositions (Douglass and Schilling, 1999, JGR, 104: 2941-2962) show evidence for mixing of 3 mantle components: (1) ambient depleted MORB mantle (DMM), (2) a common plume source, mildly HIMU-influenced, similar to the Easter-Salas y Gomez plume in the south Pacific (C) and (3) enriched mantle (EM) thought to represent recycled crustal materials. Based on Hf-Nd-Pb-Sr isotope systematics, the EM component shows a strong continental origin, but distinct from recycled Pb-rich pelagic sediments (Andres, 2001, MS Thesis, URI). Shona anomaly (~51.5°S) glasses form 2 groups, with group 1 showing mixing DMM and C, and group 2 showing additional influence of the EM component. The isotopic composition of the Discovery anomaly (~47.5°S) glasses are consistent with pseudo-binary mixing of C, DMM and EM components. Water correlates positively with similarly incompatible elements (e.g., K₂O or Ce) for the south Atlantic and Pacific samples, but with different slopes for the different regions. Shona group 1 glasses are similar to Easter Microplate and Seamount Chain and south Atlantic (31-46°S) glasses, which form a linear correlation between enriched (H₂O/K₂O=~1.4; H₂O/Ce=~210) and depleted (H₂O/K₂O=~3; H₂O/Ce=~150) endmembers, consistent with binary mixing between depleted MORB and C-like sources (Simons et al., G-cubed, in press). Water enrichment in the C endmember is intermediate between La and Ce, consistent with their relative order of incompatibility, therefore either the

plume source taps a more juvenile, less depleted source or the recycled oceanic crustal component (HIMU) has not suffered any preferential enrichment or depletion in water different from that expected during mantle/melt fractionations.

Samples having EM isotopic signatures (Shona group 2 and Discovery) have significantly lower H₂O concentrations at a given K₂O content and have lower H₂O/Ce (as low as 114) than the EMP, ESC and depleted south Atlantic samples. These low water concentrations are not caused by degassing. EM components in the south Atlantic mantle are associated with lower water concentrations than the C plume component. The results of this study are consistent with results from the North Atlantic (Dixon et al., this volume) and previous work on Hawaii, where the Koolau (EM1) component was found to be depleted in water (Dixon and Clague, 2001, JPet, 42: 627-654; Hauri, 2001, Chem. Geol., in press). We suggest that relatively dry EM components are common and not unique to Hawaii, thus, water is efficiently extracted during subduction.

V12C-0990 1330h POSTER

Geochemistry of the Othris Ophiolite, Greece: Evidence for Refertilization?

Matthias G Barth¹ (+31 30 253-5063; barth@geo.uu.nl)

Paul R D Mason¹

Gareth R Davies²

Martyn R Drury¹

¹Universiteit Utrecht, Faculteit Aardwetenschappen, Budapestlaan 4, Utrecht 3584 CD, Netherlands

²Vrije Universiteit Amsterdam, Faculteit der Aardwetenschappen, De Boelelaan 1085, Amsterdam 1081 HV, Netherlands

Mantle peridotites exposed at the Earths surface provide direct information about processes controlling the geochemical evolution of the upper mantle. Detailed studies are required to deconvolve the superimposed effects that have affected mantle rocks. Studies of peridotite massifs, such as orogenic herzolites, are especially useful because geochemical variations can be determined on scales from micrometers to kilometers and constraints from geological observations can be combined with those based on petrological and geochemical data.

Our study of the Othris peridotite massif is focused on a 3 km continuous section in the Fournos Kaitza area, which consists of layers of harzburgite, plagioclase harzburgite, and plagioclase herzolite with accurately known stratigraphic level. Representative samples were selected based on detailed structural and petrographic studies. We measured mineral major and trace element concentrations to examine the evolution of the Othris Ophiolite and to determine whether the plagioclase herzolites represent unmelted fertile peridotite, incomplete melt extraction, or a region of melt impregnation and accumulation. Refractory, Cr-rich spinel compositions and depleted clinopyroxene rare earth element (REE) patterns in the harzburgites are consistent with 10-15% partial melting in the spinel stability field. Compositional zoning of pyroxenes most likely reflects the sub-solidus transition from spinel- to plagioclase-facies mineralogy, indicative of a relatively cool mantle structure. The plagioclase peridotites have higher Ti and REE contents in the pyroxenes than the harzburgites but similar refractory spinel compositions, suggesting that these plagioclase peridotites may be products of impregnation of harzburgites with a fractionating melt, which crystallized plagioclase and clinopyroxene (and possibly orthopyroxene). These observations are in good agreement with previous structural studies (Dijkstra et al., J. Petrol., 2001) and do not support the origin of the Othris Ophiolite in an arc environment.

In conclusion, the Othris Ophiolite has a moderately depleted mantle section with signs of melt impregnation, which probably originated at a slow-spreading mid-ocean ridge.

V12C-0991 1330h POSTER

A Li Isotope Profile in a Dunite to Lherzolite Transect Within the Trinity Ophiolite: Evidence for Isotope Fractionation by Diffusion

Craig C. Lundstrom¹ (217 244-6293; lundstro@uiuc.edu)

Marc Chaussidon² (33-3-83-59-42-25; chocho@crpg.cnrs-nancy.fr)

Peter B Kelemen³ (508 289 2956; peterk@whoi.edu)

¹Dept of Geology, University of Illinois, 1301 W Green St, Urbana, IL 61801, United States

²CRPG-CNRS, BP 20 15, rue Notre Dame des Pauvres, Vandoeuvre-les-Nancy 54 501, France

³Dept of Geology and Geophysics, Woods Hole Oceanographic Inst., Woods Hole, MA 02543, United States

Recent experimental work suggests that alkali elements will diffuse from ascending magmas into surrounding peridotite wallrock due to gradients in alkali activities (Lundstrom, Nature, 2000). However, no observational evidence for this process occurring yet exists. In order to seek evidence for alkali diffusion as well as to test whether Li isotopes might be fractionated by diffusion, we have measured Li isotopes by ion microprobe (CRPG-Nancy) in ophiolite samples and piston cylinder experiments.

Because geochemical signatures argue that dunites are former pathways of melt ascent (Kelemen et al., Nature, 1995), Li isotope ratios were measured in clinopyroxenes as a function of distance from dunite in a transect of dunite to plagioclase herzolite in the Trinity Ophiolite (northern CA; transect TP90-9, with a gradient in REE in CPX, Kelemen et al., Nature, 1992). 3-10 analyses were made on CPX from the same thin section at a given location producing external precision of ~2‰. δ⁷Li is similar to MORB in the dunite (+4), decreases to lower values (0 to -5) for 1 m into the adjacent harzburgite, then increases back to positive values far from the dunite (5 to 12). Seawater has δ⁷Li = +30 so that alteration cannot account for the trough observed. The observed profile is consistent with a simple model of Li isotope fractionation by diffusion in which the ⁶Li melt diffusion coefficient is slightly greater than that of ⁷Li, reflecting the 16% mass difference in Li isotopes. Further profiles will be measured to determine if the trough observation is robust. A caveat is that the length scale of the δ⁷Li gradient is similar to the length scale of the REE gradient. If the δ⁷Li gradient is due to diffusion, then diffusivities of Li and REE are similar, or REE concentrations result from advective porous flow of melt.

A piston cylinder experiment at 1250 C and 0.9 GPa simulated a melt conduit-harzburgite boundary by juxtaposing basanite enriched in ⁶Li with a harzburgite containing 20% melt for 7 minutes. The resulting Li isotopic profile is smooth and fit by D_{Li} of 10⁻⁶ cm²/s. However, the steep portion of the curve is not centered at the original interface but significantly shifted into harzburgite portion of the experiment, consistent with ⁶Li diffusing faster than ⁷Li.

V12C-0992 1330h POSTER

Origin Of Pyroxenites From San Jorge And Santa Isabel (Solomon Islands).

Thomas Berly¹ (02 6125 5131; thomas@geology.anu.edu.au)

Richard J Arculus (02 6125 3778; richard.arculus@anu.edu.au)

Joerg Hermann (02 6125 8842; joerg.hermann@anu.edu.au)

Stephen M Eggins (02 6125 9965; Stephen.Eggins@anu.edu.au)

Henriette Lapierre (33 4 76 63 59 06; lapierre@ujf-grenoble.fr)

¹Thomas Berly, Australian National University (ANU), Acton, ACT 0200, Australia

The Solomon Islands are a NW to SE-trending double chain of islands, the older basement of which was formed by SW-directed subduction of the Pacific Plate beneath the Indo-Australian Plate, between the Eocene and Early Miocene. At 10 Ma, the Ontong Java Plateau (OJP) collided with the Solomon arc, and in response to this collision, a polarity reversal of subduction occurred; NE-directed subduction beneath the Solomon arc began. Consequent to this collision, thin fault slices of peridotites, pyroxenites, gabbros, and basalts, some of which are demonstrably obducted OJP, are now exposed in SE Santa Isabel and neighbouring San Jorge. The pyroxenites are associated with harzburgites, dunites and sometimes incorporated into serpentine massifs (NW San Jorge). These fresh, coarse-grained rocks contain variable proportions of orthopyroxene (70 < En < 85) and clinopyroxene (Wo=47.5; En=49.5), and minor Cr-spinel (60 < Cr# < 73), rare olivine (85 < Fo < 93) and small amounts of magnesiohornblende. Two-pyroxene thermometry (Wells et al.) gives a large range of equilibration temperatures between 700 and 1000°C. The assemblage cpx-opx-sp-ol requires 7 < equilibration pressures < 17 kbar. The pyroxenites are characterised by high and relatively constant mg-numbers (87-92) comparable with the peridotites (90). However CaO content is variable (2-20%) reflecting varied mineralogy, and the Al₂O₃ content is very low (<5%). Trace element abundances (determined by LA-ICP-MS) of both whole rock and cpx shows that: cpx dominates the whole-rock budget for rare earth (RE) and other lithophile elements (E); there is variable depletion in light relative to medium REE (0.1 < (La/Nd)_N < 0.5) and flat to convex medium to heavy REE (0.5 < (Sm/Yb)_N < 1.5); overall REE abundances ranging from 0.4 to 1.3 times chondritic. Primitive mantle-normalized multi-element diagrams of cpx are marked by positive anomalies in Cs, Ba, Pb and Sr. Similar selective enrichments in pyroxenites from Ronda have been attributed by Garrido et al (1998)

to chromatographic effects of melt percolation through peridotite. But according to Downes (2001), enrichments in these elements in ultramafic rocks requires metasomatism by hydrous fluids from subducting slabs. The high abundances of Ba, Rb, Cs, Pb together with Li and B (relative to the REE) are clearly associated with fluid inclusion-rich zones of individual cpx. The presence of fluid inclusions indicates that (hydrous) fluid-mobile elements may play an important role in the crystallisation of coarse-grained pyroxenites within a subduction zone environment. In arc settings, current opinion is that melting of some sediment as well as dehydration of other deeper crustal components (at depths ~150-200km) is required to account simultaneously for the enrichment in arc magmas of (hydrous) fluid-mobile elements (e.g., Cs, Rb, Ba, Sr, Pb, U) (Johnson & Plank, 1999), even those arcs associated with old, cold slabs. But Schmidt et al (1998), suggest that the dehydration of the descending slab is continuous involving hydrous phases as chlorite, lawsonite, phengite, epidote, and amphibole. At low pressures (~15kbar), aqueous fluids start to be released, and are enriched in Si, Na, Ca (Gao et al, 2001). The ascending fluids can interact with the mantle wedge crystallising pyroxenites with features identified in the Solomon Islands. These px-rich rocks may have been exhumed by backthrusting of arc portions during the collision of the OJP (Petterson et al, 1998) or/and carried by buoyant serpentinites (Hermann et al, 2000).

V12C-0993 1330h POSTER

Geochemistry and 40Ar-39Ar ages of the Mashhad Ophiolite, NE Iran: A Rare Occurrence of a 300 Ma (Paleo-Tethys) Oceanic Crust

A. Mohamad Ghazi¹ (404-651-2272; mghazi@gsu.edu)

Ali A. Hassanipak¹ (404-651-2272; mghazi@gsu.edu)

Patrick J. Tucker¹ (404-651-2272; pjtzn@hotmail.com)

Katayoun Mobasher¹ (404-651-2272; mobasher_katy@yahoo.com)

Robert A. Duncan² (541-737-5206; rduncan@oce.orst.edu)

¹Georgia State University, Department of Geology, Atlanta, GA 30303, United States

²Oregon State University, COAS, Corvallis, OR 97331, United States

The Alborz mountains of northern Iran marks a zone of collision in the Alpine-Himalayan orogenic belt, and it forms a bridge between the of Hindu-Kush and Himalayan in the Middle and Far East and the Lesser Caucasus and Alpine in the Mediterranean and Europe. The tectonic evolution of the Alborz orogenic belt is considered to be related to northward subduction of the Paleo-Tethys under Eurasia which led to the collision between the Iranian microcontinent and Eurasia. The remnant of the Paleo-Tethys oceanic crust are very scarce along Alborz, and except the 300 Ma Mashhad ophiolite, the rest are in the form of small patches of serpentinized ultramafic rocks.

The remnants of the Paleo-Tethys oceanic crust in the proximity of the Mashhad include three distinct rock assemblages, which are the ophiolite complexes (Mashhad and Virani), deep-sea turbidites and a sequence of layered pyroclastic. The ophiolite-coloured melange complexes consists of a mixture of ophiolite and sedimentary rocks. Although the ophiolite stratigraphy in this area is largely dismembered, with the exception of sheeted dike complex it contains all the rock units that are representative of an ophiolite suite. The rocks from these complexes include 1) ultramafic rocks (herzolites and wherlites and pyroxinite) which are highly serpentinized and sheared, 2) gabbros, some of which are pegmatitic, 3) pillow basalts, and 4) uniformly bedded pelagic fossiliferous limestone and chert.

In using different tectonomagmatic classification diagrams (e.g., Zr-Nb-Y and Zr/Y-Zr) we have found that there are at least two different types of basalts (i.e., A and B for the purpose of this preliminary work) in Mashhad ophiolite. Type-A basalts show volcanic arc-like chemical characteristics, whereas the type-B basalts have E-MORB-like chemical affinity. These geochemical differences among the two types of basalts are also clearly evidenced in terms of the REE chondrite-normalized diagrams. The type-A basalts have LREE enriched patterns [(La/Yb)_{ave} = 6.7 and (La/Sm)_{ave} = 3.4] in comparison to the type-B (E-MORB-like) basalts with [(La/Yb)_{ave} = 2.3 and (La/Sm)_{ave} = 1.05]. Furthermore type-A basalts have a distinctive negative Eu anomalies. A similar type of comparison using primitive mantle-normalize patterns also show clear differences between the two types of basalts.

Two 40Ar-39Ar plateau ages of 281.4 Ma and 277.4 Ma for hornblende gabbros corresponding to isochrone ages of 287.6 and 281.7 Ma. In a separate K/Ar analysis, the same two samples gave values of 273 and 265 Ma, suggesting late Pennsylvanian-early Permian ages (i.e., Paleo-Tethys age for the oceanic crust).

V12C-0994 1330h POSTER

Petrological Characteristics of Upper Mantle Peridotites from the Izu-Ogasawara-Mariana-Palau-Yap and Tonga Forearcs; Relation to Troodos and Semail Ophiolites.

Teruaki ISHII¹ (81-3-5351-6447; ishii@ori.u-tokyo.ac.jp)

Hiroshi SATO¹

Kantaro FUJIOKA²

¹Ocean Res. Inst., Univ. of Tokyo, 1-15-1, Minamidai, Nakano-ku, Tokyo 164-8639, Japan

²Japan Marine Science and Technology Center, Nat-sushima, Yokohama, Kanagawa, Japan

Many ophiolitic igneous complexes in the ocean floor have been reported along trench inner wall of the Izu-Ogasawara-Mariana-Palau-Yap and Tonga trenches. These igneous bodies from the ocean floor are called as proto-ophiolite in this paper.

Serpentinite diapiric seamonts have been only reported from the forearc area of the Izu-Ogasawara-Mariana (excluding Southern Mariana) arc-trench system in the world. Petrological characteristics of mantle peridotites constituting those seamonts were summarized in comparison with other trench region peridotites. Mantle peridotites drilled from the Conical seamonts during ODP Leg 125 (Site 779) have distinctive compositions both in bulk rock chemistry and mineral chemistry. Their compositions suggest that they underwent a higher degree of partial melting (more than 30 %) that is related to island arc volcanism in the mantle wedge. Most of compositions of mantle peridotites collected by submersible dives from other serpentinite seamonts (the Pacman seamont by Alvin, the Hahajima seamont by Shinkai 2000 and the Chamorro seamont by Shinkai 6500) in the Izu-Ogasawara-Mariana forearc have also similar compositions to those from the Conical seamont. It indicates that most mantle peridotites from the seamonts are refractory residues (harzburgite and dunite) derived from partial melting in the high degree during the island-arc volcanism, including boninite and island-arc tholeiite.

On the other hand, mantle peridotites recovered from the Tonga forearc exhibit wider chemistry including more fertile and intermediate peridotites as well as deplete peridotites, suggesting that the former are residues of relatively lower degrees of partial melting. It is probable that they are related to the volcanism during the formation of the back arc basin. Furthermore, although mantle peridotites of the Tonga forearc are considered to be derived from a layered sequence from the upper crust through the lower crust to the upper mantle rather than serpentinite seamont. They are suggesting wider degrees of partial melting range, that is, they can include refractory residual peridotites (harzburgite, lherzolite and dunite) induced by the magmatic activities of high-magnesian andesite (including boninite) and island-arc tholeiitic basalt as well as back-arc basin basalt.

The "remnant mantle diapir (RMD)" hypothesis was previously proposed for origin of the mantle peridotites constituting serpentinite diapiric seamonts. It is plausible that part of RMDs constitutes the serpentinite seamonts. The Troodos and Semail ophiolites can be assumed as a modern analog of the above mentioned proto-ophiolites in the Izu-Ogasawara-Marian (excluding Southern Mariana) and Tonga (and also Yap) forearcs, respectively.

V12C-0995 1330h POSTER

Li Isotopic Composition of the Mantle

Roberta L. Rudnick¹ (301 405 1311; rudnick@geol.umd.edu)

Claude Dalpe¹

William F. McDonough¹

Paul Tomascak¹

Thomas Zack¹

¹Geochemistry Laboratory, Dept. of Geology University of Maryland, College Park, MD 20742, United States

$\delta^7\text{Li}$ values of mantle-derived magmas are relatively constant (+3 to +5 per mil for MORB and OIB, Chan et al., 1992, EPSL, Tomascak et al., 1999, GCA) and Li isotopes are not fractionated by high temperature processes such as crystal fractionation (within the precision of measurement: ± 1 per mil; Tomascak et al., 1999, GCA). It is therefore expected that the upper mantle should have average $\delta^7\text{Li}$ values similar to oceanic basalts. What is not clear is whether these values represent a single, primitive mantle composition, or are averages of a heterogeneous source region, influenced to variable degrees by addition of recycled components. To date, there are few reliable Li isotopic measurements on peridotites, in part due to problems

associated with purifying Li for TIMS analyses in high Mg, low Li samples such as peridotites (e.g., James and Palmer, Chem. Geol., 2000). We are investigating the Li isotopic composition of the upper mantle by MC-ICPMS measurement of $\delta^7\text{Li}$ in well-characterized peridotite xenoliths from different tectonic settings and their minerals. Our initial investigation focuses on peridotite xenoliths from the Newer basalt field, SE Australia. The peridotites were selected for having bulk compositions typical of fertile and refractory mantle lithosphere, with ϵ_{Nd} ranging from 0 (refractory) to +10 (fertile) (McDonough and McCulloch, 1987, EPSL), indicating typical cryptic metasomatism. In addition, the peridotites contain homogeneous minerals (including Nd isotopes), they contain no significant hydrous phases, and the minerals exhibit equilibrium partitioning of lithophile trace elements (Eggins et al., 1998, EPSL and references therein). We will report $\delta^7\text{Li}$ for each of the silicate minerals (olivine, orthopyroxene and clinopyroxene) as well as whole rocks. Comparison of mineral and whole rock data will demonstrate the extent to which whole rock data can be used to infer the intrinsic Li isotopic compositions of mantle xenoliths and the overall $\delta^7\text{Li}$ values will provide some of the first lithium isotopic results for continental lithospheric mantle that has experienced a protracted history of magmatism.

V12C-0996 1330h POSTER

Origin and Age of Modal Heterogeneities in Kaapvaal Cratonic Harzburgites

D. R. Bell^{1,2} (617-258-0201; drbell@mit.edu)

M. Gregoire² (27-21-6502931; mgregoire@geology.uct.ac.za)

T. L. Grove¹ (tlgrove@mit.edu)

S. A. Bowring¹ (sbowring@mit.edu)

¹Dept Earth, Atmospheric and Planetary Sciences, M.I.T., Cambridge, MA 02139, United States

²Dept. Geological Sciences, University of Cape Town, Rondebosch 7700, South Africa

Evidence for the nature and timing of processes responsible for the formation and consolidation of the ancient mantle roots to continents is commonly obscured by more recent mantle events. In this study we apply a number of analytical approaches to a suite of highly depleted garnet harzburgite xenoliths from the Bultfontein kimberlite, South Africa that were selected for their apparent lack of late-stage metasomatic features. Distinct textural varieties include harzburgites with large (up to 5 cm) garnet clots, enstatite poor garnet-chromite dunites, and samples with veins or irregular blobs rich in enstatite. Coarse, primary mica is commonly present. Mineral compositions are correlated with garnet texture and are highly refractory, including several samples with subcalcic garnets.

Sample BFT137 is a 30 cm-sized garnet harzburgite bounded by a 2 cm wide selvage of orthopyroxenite, containing abundant phlogopite and sulfide. Mineral compositions are the same in vein and host and are highly refractory (Fo94 olivine, subcalcic garnet). Sulfide is Ni- and PGE-rich, but many grains are affected by secondary serpentinization, recording kimberlite-like Pb-isotope compositions. Garnet trace element analyses by LA-ICP-MS indicate very low Ti and Zr contents, and bell-shaped to sinusoidal REE patterns rich in MREE. Phlogopite is similarly HFSE-poor but has high Ba and Cl contents, contrasting with a typical kimberlite-metasomatism signature. Petrographic and chemical evidence suggests that orthopyroxene was introduced into the highly depleted host rock by a mobile phase rich in Si, K, H, Cl and S, but extremely poor in Ca, Fe, HREE and HFSE. Garnet-dunites and other subcalcic garnet-bearing harzburgites without Si-enrichment show similar trace element compositions and abundance of primary phlogopite, suggesting pervasive infiltration of these rocks by a hydrous fluid poor in typical basaltic components. The large scale homogeneity of the BFT137 host-vein system indicates substantial equilibration, which at the relatively low temperatures (1000 C) indicated by geothermometry suggest long mantle residence times, currently under investigation by isotopic studies.

V12C-0997 1330h POSTER

Trace Element Compositions of Minerals in Mantle Xenoliths From the Canary Islands: Evidence for High Degrees of Partial Melting Followed by Carbonatite Metasomatism

Else-Ragnhild Neumann¹ (47 2285 6663; e.r.neumann@geologi.uio.no)

Norman J. Pearson² (npearson@laurel.ocs.mq.edu.au)

¹Else-Ragnhild Neumann, Dept. of Geology, University of Oslo, PO Box 1047 Blindern, Oslo N-0316, Norway

²Norman J. Pearson, GEMOC, Dept of Earth and Planetary Sciences, Macquarie University, Sydney, NSW NSW 2119, Australia

We report the results of laser ablation ICPMS trace element analyses of olivine and pyroxenes in spinel harzburgite and lherzolite xenoliths from the Canary Islands. The xenoliths form two main groups: HEXO: a large group of porphyroclastic harzburgites dominated by deformed exsolved orthopyroxene porphyroclasts, deformed porphyroclasts of olivine (Fo89.7-92.5), and minor amounts of Cr-diopside and chromite; HLCO: a small group of harzburgites and lherzolites where clear (no visible exsolution lamellae or strain features), poikilitic orthopyroxene grains coexist with strained olivine porphyroclasts (Fo89.9-90.3), plus minor amounts of poikilitic Cr-diopside and chromite. HLCO are only found in Tenerife. Trace amounts of phlogopite are common in xenoliths from Tenerife and La Palma. HEXO minerals are markedly depleted in incompatible trace elements relative to those in HLCO, although also HLCO samples may contain both highly depleted and mildly depleted orthopyroxene. Cr-diopside in xenoliths from Hierro and Lanzarote are more depleted in MREE and HREE than that in depleted MORB mantle, reflecting more extensive partial melting. Metasomatism, which is most strongly exhibited in HLCO xenoliths, involves melt/wall-rock reactions with formation of clinopyroxene at the expense of orthopyroxene, Ca-metasomatism [leading to (CaO/Al₂O₃)_{rock} >> 1], enrichment in incompatible trace elements (e.g. mild enrichment in LREE relative to MREE and HREE in Cr-diopside), and crystallization of phlogopite, dolomite and magnesite. Strong depletion in Zr-Hf and Ti relative to REE in Cr-diopside is accompanied by weak Zr-Hf depletion in coexisting poikilitic orthopyroxene. The mantle xenoliths of this study are interpreted as fragments of oceanic mantle lithosphere that has been subjected to extensive partial melting, later overprinted by metasomatism. The metasomatism is associated with the early part of the Canary Islands magmatic event. It is most likely caused by carbonatitic melts. The most extensive metasomatism has taken place in the upper mantle beneath Tenerife, the largest of the Canary Islands.

V12C-0998 1330h POSTER

Metasomatism of Abyssal Peridotite

Kent Ross¹ (808-956-6193; kross@soest.hawaii.edu)

Don Elthon² (713-743-8282; elthon@uh.edu)

¹Univ. of Hawaii, Geology and Geophysics, Honolulu, HI 96822, United States

²Univ. of Houston, Dept. of Chemistry, Houston, TX 77204, United States

On Leg 153 of the Ocean Drilling Program, cores of typical serpentinized abyssal peridotite were recovered from the western wall of the median valley of the Mid-Atlantic Ridge south of the Kane F.Z. In a sample from this suite, we have found evidence for extensive metasomatism, resulting in large changes in mineral compositions, with only minor changes in modal mineralogy. Large enrichments in Ti and Na in CPX, Ti, Cr and Fe in spinel and Fe in olivine are observed. A thin, CPX-ilmenite bearing vein cuts the sample. It appears that interaction between invading, or trapped melt and peridotite resulted in substantial shifts in mineral compositions in the host peridotite. CPX compositions in this sample range from Mg# 74-90.5, with TiO₂ contents varying from 1.1 to 0.1 wt. % and Na₂O from 0.6 to 0.2 wt. %. CPX in peridotite distal from the metasomatized zone has Mg# 90.5-93 and TiO₂ of 0.08 to 0.10 wt. %. Some chromian spinel in this sample is substantially enriched in Ti (up to 5 wt. %), exsolving crystallographically oriented ulvospinel, and is adjacent to ilmenite grains. Cr# in these Ti-enriched grains is 50 to 58. Typical spinels in this suite have Cr# of 30-33. Olivine in this sample is Fo 82-84, but in the host peridotite is Fo 90-91. Rare plagioclase grains are found in the peridotite matrix of the metasomatized sample, with An 50-58 composition. Away from the CPX-ilmenite vein cutting this sample, modal changes in the host peridotite are minor. Less than 1 % ilmenite and plagioclase are the only modal sign that the peridotite is unusual. The large shift in Fo in olivine and the low An in plagioclase are clear signs of quite extensive interaction with evolved, invading melt. Less extensive melt-peridotite interactions could produce the subtle Ti and Na enrichments observed in typical abyssal peridotites.

V12C-0999 1330h POSTER

Geochemical Evidence for a Late Miocene Shallow Subduction Zone in the Andean Southern Volcanic Zone near 37 S Latitude

Suzanne Mahlburg Kay (1-607-255-4701; smk16@cornell.edu)

Cornell University, Dept. Geological Sciences Snee Hall, Ithaca, NY 14853

Late Miocene high-K basaltic to dacitic flows (49 to 68 percent SiO₂) at the 7.3 to 5.4 Ma backarc Andean Chachahun volcanic center (near 37 S Lat.) which erupted approximately 500 km east of the Chile trench show trace element and isotopic evidence for a subduction-related component in their magmatic source. Features consistent with this component include elevated arc-like La/Ta (22 to 57) and Ba/La (22 to 40) ratios and low Ta/Hf ratios (0.17 to 0.27) and the presence of amphibole, titanite and magnetite phenocrysts signaling a hydrous, oxidizing magma. Evidence that these features are not derived from old continental lithospheric sources comes from their absence in 24 to 20 Ma and 5 to 1 Ma alkali basalts with non-arc La/Ta (10 to 15) and Ta/Hf (0.25 to 0.55) ratios that underlay and overlay the Chachahun flows. These alkaline lavas also have lower 87Sr/86Sr ratios at a given Epsilon Nd and less radiogenic Pb isotopic ratios consistent with a transient crustal-like component in the mantle source of the Late Miocene Chachahun mafic lavas. More radiogenic Sr and Pb isotopic ratios at the same Epsilon Nd allow this component to be related to a subducted slab. The best explanation for a transient Late Miocene subduction component in this part of the Southern Volcanic Zone backarc mantle is a Late Miocene episode of shallow subduction of the Nazca plate. Further evidence for shallow subduction comes from backarc compressional deformation that includes the Late Miocene uplift of the Sierra de Chachahun. Other support comes from the striking chemical and temporal similarities of the Late Miocene Chachahun lavas to backarc flows erupted more than 500 km east of the trench over the modern Chilean flatslab (28° to 33°S) and from similarities between block uplift styles of the Chilean flatslab Pampean Ranges and the Sierra de Chachahun.

V12C-1000 1330h POSTER

Were Mantle Dynamics Responsible for the Closure of Atlantic-Mediterranean Marine Gateways and the Messinian Salinity Crisis?

Svend Duggen¹ (+49 431 600 2641; sduggen@geomar.de)

Kaj Hoernle¹ (+49 431 600 2642; khoernle@geomar.de)

Poul van den Bogaard¹ (+49 431 600 2129; pbogaard@geomar.de)

¹Svend Duggen, GEOMAR Research Center Wischhofstrasse 1-3, Kiel 24148, Germany

Laser-40Ar/39Ar ages of feldspar, biotite and amphibole phenocrysts as well as matrix and glass separates of ca. 70 volcanic rock samples from northern Morocco, the Alboran Sea and southern Spain, combined with the geochemical composition of the whole rocks and mineral separates, show a dramatic, large-scale change in major element, trace element and Sr-Nd-Pb isotopic composition from subduction-related volcanism to Na-rich, intraplate-type volcanism between 7 to 5.4 Ma (Messinian). During the Mid-Miocene tholeiitic series rocks erupted in the Alboran followed in the Middle to Late Miocene by calcalkaline volcanism, culminating with the eruption of K-rich rocks such as shoshonites and lamproites in the Late Miocene. The major and trace element and Sr-Nd-Pb isotope data of the Miocene igneous rocks is typical for those found in subduction zones. The geochemistry of the Na-rich post-Messinian alkali basalts point to an intraplate source, similar to other intraplate volcanic areas in Central and Western Europe, the Northeastern Atlantic and the Central Mediterranean. In the Late Miocene, the Mediterranean Sea almost completely dried up causing the "Messinian Salinity Crisis" (MSC) between 6.0-5.4 m.y. ago. Lowering of the global sea level and/or tectonics in the Alboran were commonly applied to explain the closure of the marine gateways in northern Morocco and southern Spain. The chemical shift from subduction-related to intraplate-type volcanism in the Messinian is likely to reflect large-scale movements in the mantle beneath the Alboran Region during the Late Miocene, which may have resulted in the uplift and closure of the Atlantic-Mediterranean marine gateways. We propose that basin closure and detachment of the subducting slab may have generated the uplift responsible for the Messinian Salinity Crisis.

V12C-1001 1330h POSTER

High-Resolution X-Ray Computed Tomography (HRXCT) of Diamondiferous Eclogites and the Origin of Diamonds

Lawrence A TAYLOR¹ (lataylor@utk.edu)

William D CARLSON² (wcarlson@mail.utexas.edu)

Mahesh ANAND¹ (anandm@utk.edu)

Kula C MISRA¹ (kmisra@utk.edu)

Nikolai V SOBOLEV³ (sobolev@uiggm.nsc.ru)

¹Planetary Geosciences Institute, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996, United States

²Dept. of Geol. Sci., Univ. of Texas, Austin, TX 78712, United States

³Inst. of Mineralogy & Petrography, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation

Three-dimensional, high-resolution X-ray computed tomography (HRXCT; Rowe et al., 1997, *Geotimes*) of numerous diamondiferous eclogite xenoliths from Siberia has successfully imaged diamonds and their textural relationships with co-existing minerals. Spatial relationships between diamonds and their surroundings provide clues to the processes that control diamond crystallization. These relationships are determined by rotating and viewing the model at different perspectives and orientations to look for any associations or alignments. Volume visualization software makes it possible to view any aspect of the 3-D model from any perspective. It is possible to render some of the model as transparent and display only one or two mineral phases at a time. Then by rotating the model, it is possible to look for spatial relationships between different crystals of the same mineral or different minerals. These visualizations are shown as an animation of the diamonds, garnets and Cpx.

As part of a comprehensive study of diamondiferous xenoliths, diamond growth, and diamond inclusions (DIs), we have conducted HRXCT studies of the 3-D textures of several eclogites from the diamond mines in Yakutia. This was followed by extensive chemical and isotopic investigations of the host eclogite, DIs, and the diamonds themselves (see abstracts by Anand et al. & Misra et al., this meeting).

The diamonds in these rich eclogites (74 macro-diamonds in one 65 g eclogite) are all associated with omphacite alteration along zones with a prominent sub-planar fabric of secondary mineralization - i.e., zones with increased permeability. However, diamond was never observed in direct contact with fresh garnet or clinopyroxene. Furthermore, sulfide minerals are not preferentially associated with diamond, although they do make up the largest number of DIs - i.e., there is insufficient sulfide mineralization to call upon diamond forming from an immiscible sulfide melt. The association of the diamonds with secondary minerals strongly suggests that the diamonds formed after the eclogite, perhaps in conjunction with metasomatic input(s) of C-O-H-N-S fluids. That is, the diamonds are not syngenetic with the garnet and clinopyroxene in the host eclogite.

V12C-1002 1330h POSTER

Paragenesis of Diamonds in Eclogite Xenoliths From Kimberlite Pipes, Yakutia: A View From the Host Eclogite

Kula C MISRA¹ (kmisra@utk.edu)

Mahesh ANAND¹ (anandm@utk.edu)

Lawrence A TAYLOR¹ (lataylor@utk.edu)

Nikolai V SOBOLEV² (sobolev@uiggm.nsc.ru)

¹Planetary Geosciences Institute, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996, United States

²Inst. of Mineralogy & Petrography, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation

The unusual diamondiferous eclogites from Yakutian kimberlites present a unique opportunity to study diamonds in their natural setting within their mantle hosts. The chemistry and textures of the minerals provide the setting for investigation of the origin of the diamonds and their own mineral inclusions. Detailed study of several such eclogite xenoliths in our collection provide constraints that must be explained by any scenario of diamond formation.

The eclogites are Group B and C types consisting of primary garnet that is typically almandine and grossular rich, omphacitic pyroxene with 3-10% Na₂O, and minor sulfides. A conspicuous feature is the presence of at least two fluid-inclusion events that have modified the host eclogite. The earlier of the two was a pervasive K-metasomatism, including partial melting, probably under mantle conditions, that converted the omphacite into a distinctive, spongy-textured assemblage consisting mainly of residual islands of Na-depleted clinopyroxene containing 2-3% less Na₂O, K-enriched glass (K₂O ~ 6%, Na₂O ~ 0.8%), and minor amounts of spinel. The colateral alteration of garnet is represented by amphibole-dominated kelyphyte that occurs as rims and thin veins. No diamond was observed to be in direct contact with the primary host minerals; instead, the altered-pyroxene assemblage is the typical site for the diamonds.

The products of this metasomatic event are superimposed by a later, dominantly chloritic alteration that

appears to be preferentially concentrated around sulfide grains and omphacite alteration patches. The sulfide grains are composed of pyrrhotite (Ni ~0.5%) close to troilite, exsolved pentlandite (Co ~1.5%, Cu ~0.2%), predominantly as oriented lamellar intergrowth, and minor chalcopyrite. The sulfide assemblages are rimmed by a thin rind of djerfisherite [(K,Na)₇(Fe,Ni,Cu)₂₄S₂₆Cl], an alteration product most likely related to the K-metasomatism, and cut by tentacles of chloritic alteration.

The diamond crystals in the xenoliths formed before the chloritic alteration as their contacts are invariably marked by an abrupt termination of a rind of chloritic alteration. The absence of any alteration to the pristine diamond inclusions (see Anand et al., this meeting) would seem to indicate that the diamond growth preceded the initial K-metasomatic event.

V12C-1003 1330h POSTER

Inclusions of Hydrocarbons and Fullerenes in Diamond: Implications for Origin of Colors in Diamond

Irene Leung¹ (718-960-8572; leung@lehman.cuny.edu)

Ronald Winston² (leung@lehman.cuny.edu)

Constance Tsao³ (leung@lehman.cuny.edu)

¹CUNY, Lehman College, Dept of Geology and Geography, Bronx, NY 10468, United States

²Institute for Human Genetics Biochemistry, 718 Fifth Ave, New York, NY 10019, United States

³Linus Pauling Institute of Science and Medicine, 440 Page Mill Road, Palo Alto, CA 94306, United States

Diamonds from primary deposits of worldwide localities are mostly of industrial grade, i.e., they are flawed and non-transparent, not suitable for use as gems. Because of their overwhelming abundance and multi-faceted characteristics, they make superb samples for scientific research. Compared with perfect stones, they are more likely to yield useful information on how diamonds form in nature, and physicochemical states of Earth's interior.

Diamonds of Pipe 50 in Fuxian, Liaoning, China come in various colors: grey, colorless, black, brown, pink, buff, yellow, green, approximately in descending order of abundance. The rarest are red and magenta diamonds, but a few of the latter emerge regularly on a yearly basis. We report here results of our research on magenta diamonds. By infrared spectroscopy, we identified liquid and gas inclusions of a complex mixture of saturated and unsaturated hydrocarbons (alkanes and alkenes), saturated carbonyl hydrocarbons (alkyl ketones), as well as C-60 fullerene molecules. The origin of magenta color is possibly linked to the inclusions, because C-60 in an organic solvent gives a magenta solution. When C-60 in solution is exposed to light, ultraviolet radiation, or heat (200°C), it degrades in a matter of days, and precipitates reddish, brown, buff materials, and amorphous carbon. In natural diamonds, progressive degradation of fullerene inclusions might yield pink, brown, buff, grey, and black diamonds, dependent on annealing temperatures and residence time in Earth's mantle.

V12C-1004 1330h POSTER

Unusual mineral inclusions in some microdiamonds from Yakutian kimberlites: a comparison with inclusions in macrodiamonds

Nikolay Sobolev¹ (7-3832-33-26-05; sobolev@uiggm.nsc.ru)

Dmitri Zedgenizov¹

Alla Logvinova¹

¹Institute of Mineralogy and Petrography, Koptyug Av. 3, Novosibirsk 630090, Russian Federation

We present the first results of systematic study of mineral inclusions from microdiamonds (<1mm). About 250 microdiamonds from major Yakutian diamond mines were found to contain mineral inclusions related to ultramafic (U-type) and eclogitic (E-type) geochemical environments of the upper mantle. Abundance and compositions of these inclusions were compared with published and unpublished (by the authors) data on inclusions available from approximately 1500 macrodiamonds (>1mm) from the same sources. Along with general similarities, notable exceptions were detected in about 10% of examined microdiamonds, which contain inclusions with unusual mineral compositions. The most typical inclusion is olivine which was found in 65% of the samples, followed by spinel (18%), while the rest is represented by Cr-pyroxenes, E-type garnets and pyroxenes, and Fe-periclase. Spinel inclusions demonstrate the most unusual features (>20% of all spinels). They include chromites with high TiO₂ contents (up to 4.54 wt.%). (Mg,Fe)Al₂O₄ spinel inclusions with Mg#

65.3 and 63.7 respectively were found in two microdiamonds. One Cr-spinel possesses exceptionally high Mg# of 88.5, and another has anomalously high NiO content (0.26 wt.%) and low Mg# of 58.1. Olivines with anomalously high NiO (up to 0.64 wt.%) along with relatively low forsterite (Fo 86-89) were also detected. Wehrlitic pyrope-uvavovite garnet of unique composition (Cr₂O₃ 13.5 wt.%, CaO 12.1 wt.%) was found in one microdiamond. Two microdiamonds contain unusual E-type garnets, one with 17.1 wt.% CaO and another with exceptionally low Mg# of 30. Both these compositions plot outside of E-type garnet inclusions field (Meyer, 1987). We conclude that mineral inclusions in microdiamonds are more variable in their compositions compared with inclusions in macrodiamonds. This feature may be related to the specific composition of a part of microdiamonds source.

V12C-1005 1330h POSTER

Syngenetic Diamond Mineral Inclusions: Are They Really?

Prinya PROMPRATED¹ (prinya@utk.edu);
Lawrence A TAYLOR¹ (lataylor@utk.edu);
Christine FLOSS² (floss@wuphys.wustl.edu);
Mahesh ANAND¹ (anandm@utk.edu); Kula C
MISRA¹ (kmisra@utk.edu); Nikolai V SOBOLEV³
(sobolev@uiggm.nsc.ru)

¹Planetary Geosciences Institute, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996, United States

²McDonnell Center of Space Science, Washington Univ., St. Louis, MO 63130, United States

³Inst. of Mineralogy & Petrography, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation

Diamonds are time capsules containing mineral inclusions from long ago and far away. The major assumption made in almost all studies of diamond inclusions (DIs) is that they are formed at the same time and by the same process as the host diamond - i.e., syngenes. Evidence in support of such an assumption is usually omitted or weak at best. However, recent studies have documented extreme chemical variations of multiple DIs in individual diamonds (Sobolev et al., 1998, *Intl Geol Rev*; Taylor et al., 2000, *Intl Geol Rev*) that are contrary to derivation from a fractionating melt, and which are definitely not of a syngenetic origin. Indeed, the criteria for syngenes are weak and not unambiguous.

To further investigate this issue of syngenes, garnet mineral inclusions in unusually large diamonds (~20-108 carats) from Udachnaya, Mir, and Aikhal kimberlite pipes of Yakutia were analyzed for major and trace-element compositions. The most striking chemical feature is the sinusoidal REE patterns of harzburgitic garnet DIs, similar to those reported widely in the literature. Such sinusoidal REE patterns suggest a garnet petrogenesis that began with a partial-melting event, followed by metasomatic enrichment, particularly in REEs. Equilibration with the metasomatic fluids was established with respect to the LREEs in the garnets, whereas the M-HREEs were only partially re-equilibrated due to their slower diffusion rates. Negative anomalies of Ba and Sr in the garnets indicate that the fluids were not carbonatitic. The host diamonds must have grown after these events.

There is a large amount of evidence that effectively demonstrates that diamonds and their mineral inclusions in many, if not most, cases did not form at the same time, definitely not by the same processes. This casts serious doubts on the universal axiom in the literature that diamonds and their DIs are syngenetic. Interpretations based largely on 'assumed syngenetic relationships, therefore, require serious re-evaluation.

V12C-1006 1330h POSTER

In-Situ Chemical Analyses of Mineral Inclusions in Diamonds in Kimberlitic Eclogites From Yakutia

Mahesh ANAND¹ (anandm@utk.edu)

Kula C MISRA¹ (kmisra@utk.edu)

Lawrence A TAYLOR¹ (lataylor@utk.edu)

Nikolai V SOBOLEV² (sobolev@uiggm.nsc.ru)

¹Planetary Geosciences Institute, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996, United States

²Inst. of Mineralogy & Petrography, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation

Mineral inclusions in diamonds (DIs) are stated to provide P-T-X-t information regarding the formation of the diamonds and the nature of the upper mantle. In an endeavor to further understand the importance of diamonds and their DIs in relation to their host rocks,

we have investigated several diamondiferous eclogites from Yakutia, first by HRXC tomography (Taylor et al., 2001, this meeting) and then by dissection of the eclogites into their individual minerals. The mineralogy of the host eclogite is presented by Misra et al. (2001, this meeting).

Two of the diamondiferous eclogite xenoliths, although weighing but 66 g and 42 g, contain 74 and 47 macro-diamonds, resp. Based on HRXC imaging, appropriate sections were selected in the eclogite to extract diamonds with minimum loss of material. In the majority of cases, diamonds occur as perfect octahedron with well developed crystal faces. In some cases, however, diamonds occur as macles (twinned xls). The size range of the diamonds is 1-6 mm. Optical examination reveals the sulfides as the most common DIs in these diamonds, followed by clinopyroxenes and garnets. Each diamond was cut and polished along relatively soft directions parallel to either (001) or (110) faces so as to expose DIs for *in-situ* analyses. Examination by cathodoluminescence (CL) on an EMP demonstrated that the majority of the diamonds have minute, optically invisible, cracks from the DIs to the surfaces of the diamonds - i.e., the possibility of an open system. These diamonds show complicated growth histories and contain DIs that are in some cases, found to be associated with secondary alteration. In addition, the DIs in each diamond, examined *in-situ* are of different composition from the host and different from DIs in other diamonds, a relationship reported earlier (Taylor et al., 2000, *Intl Geol Rev*).

These observations raise serious doubts about the significance of DIs and the *pristinity* and *syngenes* of DIs removed by the typical *diamond crushing* procedure. Therefore, extreme caution must be taken when interpreting any of the P-T-X-t conditions of diamond growth, based on DIs.

V12D MC: Hall D Monday 1330h Hydrothermal Systems

Presiding: P Larson, Washington State University

V12D-1007 1330h POSTER

Oxygen isotope evolution of the lower ocean crust: an in-situ study by UV-laser-ablation oxygen isotope microprobe

Yongjun Gao^{1,2} (yjgao@mpch-mainz.mpg.de)

Jochen Hoefs¹ (jhoefs@gwdg.de)

Jonathan E. Snow² (jesnow@mpch-mainz.mpg.de)

¹Geochemisches Institut der Universitt Gttingen, Goldschmidt Strasse 1, Goettingen 37077, Germany

²Max-Planck-Institut fuer Chemie, PO Box 3060, Mainz 55020, Germany

Systematic analysis of mineral oxygen isotope compositions in gabbro has the potential to constrain the effects of cooling processes in the lower ocean crust. For this reason we measured three representative samples of gabbro from Hole 735B of Leg 176 by UV-laser microprobe for the oxygen isotopic compositions of their constituent minerals. Sample 28, from 514.79 mbsf, is located between two cataclastic faults, with both high and low temperature alteration; sample 1 (880.31 mbsf) is within a high-temperature deformation zone, and sample 16 (1402.16 mbsf) is in the lower part of the core, which is far away from both the crystal-plastic shear zone or from any fault. The measured results show that respective minerals in the three samples have very similar $\delta^{18}\text{O}$ values, although their geological settings and whole rock $\delta^{18}\text{O}$ values are quite different. Clinopyroxene and olivine have normal values for NMORB, $+5.5 \pm 0.4^\circ/\text{oo}$ and $+5.2 \pm 0.3^\circ/\text{oo}$ respectively, while plagioclases have heavier $\delta^{18}\text{O}$ values ($+6.6 \pm 0.3^\circ/\text{oo}$) than that of plagioclase in NMORB ($+6.0^\circ/\text{oo}$). This suggests that all three gabbros have encountered similar cooling histories from one source magma by a single intrusion. The large inter-crystal $\delta^{18}\text{O}$ difference in sample 28 between the unaltered plagioclase with $\delta^{18}\text{O}$ values about $+6.0^\circ/\text{oo}$ and the altered ones with $\delta^{18}\text{O}$ values about $+7.6^\circ/\text{oo}$ is most probably due to low temperature alteration by seawater. Considering the unaltered constant $\delta^{18}\text{O}$ values of olivine and clinopyroxene, the modification of the O-isotope composition of plagioclase must occur near the time of crystallization and the temperature should be higher or equal to the closure temperature for O-isotopes in plagioclase but lower than that for olivine and clinopyroxene.

V12D-1008 1330h POSTER

Petrology of a Calcic Skarn from Al-Madhiq, SW Saudi Arabia

Zulfiqar Ahmed ((+966-3)860-3879; zulfi@kfupm.edu.sa)

Department of Earth Sciences, King Fahd University of Petroleum and Minerals, Earth Sciences Dept., Box 5070, KFUPM., Dhahran 31261, Saudi Arabia

A new skarn occurrence, located in the SW Arabian shield in the country rocks of Neo-Proterozoic age, displays features typical of calcic skarns that host W-deposits. It is an exoskarn of the proximal type related to a granitoid contact with the regional rocks of mixed sedimentary and volcanic derivation. The skarn minerals include both the prograde (brownish red grossular, hedenbergite, aluminian sphene, albite), and retrograde (epidote, quartz and hornblende) assemblages. Grossular composition reflects a mildly reduced genetic environment. The garnet components range: grossular, 58.27 - 83.54 %; andradite, 6.5 - 21.6 %; uvarovite, 0 - 0.15 %; pyrope, 0 - 0.47 %; almandine, 4.33 - 18.75 %; spessartine, 0.4 - 8.58 %. A step-scan across a grossular crystal showed the sympathetic decrease of Mn and Fe in the core, concomitant with Ca decrease towards the rim. This variation trend deviates from the generally-known Fe-decreasing and Mn-increasing inwards trend of most metamorphic and igneous garnets. The aluminian sphene composition resembles that described only recently from the low-pressure calc-silicates.

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Decline of a Hydrothermal Vent Field Escanaba Trough 12 Years Later

Robert A. Zierenberg¹ (530-752-1863;

z@geology.ucdavis.edu); David A. Clague²; Alicé S. Davis²; Marv D. Lilley³; James S. McClain¹; Eric S. Olson³; Stephanie L. Ross⁴; Karen L. Von Damm⁵

¹University of California-Davis, Department of Geology, Davis, CA 95616-8605, United States

²Monterey Bay Aquarium Research Institute (MBARI), 7700 Sandholdt Road, P.O. Box 628, Moss Landing, CA 95039, United States

³University of Washington, School of Oceanography Box 357940, Seattle, WA 98195-7940, United States

⁴U.S. Geological Survey, Coastal and Marine Geology Team Mail Stop 999 345 Middlefield Road, Menlo Park, CA 94025, United States

⁵University of New Hampshire, Dept. of Earth Sciences, Durham, NH 03824-3525, United States

Hydrothermal venting was discovered in Escanaba Trough, the southern sediment-covered portion of the Gorda Ridge, in 1988. Large pyrrhotite-rich massive sulfide mounds are abundant at each of the volcanic/intrusive centers that have been investigated in Escanaba Trough, but the only area of known hydrothermal venting is the NESCA site along the ridge axis at 41°N. Hydrothermal fluids venting at 217°C and 108°C were sampled in 1988 on two sulfide mounds separated by about 275 m. The end-member fluid compositions were indistinguishable within analytical errors. Several sulfide mounds were observed in 1988 which had diffusely venting low temperature (< 20°C) fluids that supported extensive vent communities dominated by fields of *Ridgia*.

Nine holes were drilled in the NESCA area in 1996 on ODP Leg 169, including Hole 1036I that penetrated to basaltic basement at 405 m below sea floor (mbsf). Surveys of the area using the drill string camera located only one area of active venting at the same mound where 217°C vent fluids were sampled from two active vents in 1988. Drill hole 1036A was spudded between the two active vents on this sulfide mound (approximately 4 and 8 m away) and penetrated to 115 mbsf.

The NESCA site was revisited in 2000 using MBARI's *R/V Western Flyer* and *ROV Tiburon*. The hydrothermal vents appeared essentially identical to observations made from the drill string camera in 1996 despite the presence of a drill hole within meters of the two vents. The maximum vent temperature measured in 2000 was 212°C. Fluid samples have major element and isotopic compositions very similar to those collected in 1988. The vent fluids have higher methane (~19 mmol/kg) than those from the geologically similar Middle Valley vent field, but lower values than those at Guaymas Basin. Drill hole 1036A was weakly venting, but the diffuse hydrothermal fluids could not be sampled with the equipment available. The walls of the drill hole were colonized by palm worms, limpets, and snails. Four other drill holes showed no hydrothermal flow nor visible evidence of down hole recharge.

Mapping with *Tiburon* confirmed that the extent of hydrothermal venting at NESCA decreased dramatically since 1988. Formerly extensive colonies of *Ridgia* had vanished leaving no trace of their presence. Although hydrothermal venting has collapsed to a single mound, the temperature and composition of the fluids remained nearly unchanged. This is curious given that