the basis for further study to gain a molecular-level understanding of actinide-bacterial cell association using soft x-rays.

V51A-1239 0830h POSTER

EXAFS Analyses of Innersphere Surface Complexations of Arsenate and Silicate on Natural Hydrous Ferric Oxides

Caterina Elisabetta Tommaseo[1] (+49 6131 3924780; tommc000@students.uni-mainz.de)

Michael Kersten[1] (+49 6131 3924366; Michael.kersten@uni-mainz.de)

[1]Johannes Gutenberg-University, Becherweg 21, 55099 Mainz, Germany 55099, Germany

X-ray absorption spectroscopy (EXAFS) was used to determine the near range order of three elements (Fe, As, Si) on the surface of hydrous ferric oxide (HFO) from thermal water scales. Fe K-edge EXAFS analyses of the 2nd shell show a better fit including Si as backscattering neighbor. Validation of the Si-Fe bond was obtained by Si K-edge EXAFS spectra, where the light absorber element is surrounded favourably by much heavier second-shell elements. Least-squares fitting of the second-shell Fourier-filtered EXAFS spectrum in the k-range of 5-11 $Å^{-1}$ yields in a Si-Fe distance of 3.10-3.13Å, and a Si-Si distance of 3.00Å. Both these interatomic distances and the coordination number N = 2 obtained for the Si-Fe shell are consistent with the formation of a corner-bridging bidentate binuclear (^{2}C) surface complex on the HFO surface. The Si-Si bonds and existance of a vibrational band at 964 cm^{-1} in the infrared spectrum indicate polymerisation of the silicate on the HFO surface (Tommaseo & Kersten). As K-edge XANES analyses showed the As present in form of arsenate scavenged by the HFO phase. As and Si K-edge EXAFS analyses revealed both elements to compete for ^{2}C surface complexation sites. A mean As-Fe distance of 3.03Åindicate an approx. equal distribution of arsenate between ^{2}C (3.24Å) and another ^{1}E (bidentate mononuclear surface complexation) sites (2.84Å). The average Fe-(O,OH) bond length of 2.09Åis compatible with a high proportion of distorted surficial $Fe^{III}(O,OH)_6$ octahedra in the colloidal HFO precipitates of the scale deposits. The slight distortion of the $Fe^{III}(O,OH)_6$ octahedra is consistent with the apparent strong binding of the ^{1}E arsenate surface complexes (Manceau, 1995). The adverse effect of silicate would therefore be overpredicted without surface complexation models constructed to account for both surface functional groups. The Si K-edge EXAFS data provide also a basis for explaining at the molecular level the poisoning of HFO particle growth and the slowing down of the transformation of HFO to crystalline goethite. The inhibition of crystal growth by both oxoanions form a kind of passivation layer which protects HFO from recrystallization and concomitant release of part of the arsenic upon otherwise rapid ageing in the thermal waters.

LITERATURE

Manceau, A., The mechanism of anion adsorption on iron oxides: Evidence for the bonding of arsenate tetrahedral on free Fe(O,OH)6 edges. Geochim. Cosmochim Acta, Vol. 59, No 17, 3647-3653 (1995).

Tommaseo, C.E. and Kersten, M., EXAFS analysis of competitive adsorption of arsenate and silicate on natural hydrous ferric oxides in thermal water scales. Environ. Sci. Technol. (submitted).

V51B MCC: Hall C Friday 0830h

Metamorphism, Ultrahigh Pressure Metamorphism, and Diamonds Posters

Presiding: **S Sorensen,** Smithsonian Institution**; L A Taylor,** University of Tennessee

V51B-1240 0830h POSTER

Deformation, Fluid-Rock Interaction, and REE Equilibration in Eclogite and Garnet Amphibolite

S. S. Sorensen[1] (202 357 4010; sorena@volcano.si.edu)

F. M. Brouwer[2] (brouwer@geo.unibe.ch)

[1]Smithsonian Institution, Dept. Mineral Sci., NMNH, Washington, DC 20560-0119, United States

[2]Universitaet Bern, Inst. fuer Geologie, Bern 3012, Switzerland

The intensity of fluid-rock interaction and deformation within an accretionary wedge vary over time. Both could affect trace element equilibration between slab protoliths and exotic components. We studied REE in garnet, epidote, apatite and titanite. These minerals, and 7 host samples of relatively dry, coronitic and mylonitized eclogite from the Monviso (M) and Voltri (GdV) massifs in the Alps, and of fluid-rich, less- and more-mylonitized eclogite from the Franciscan Complex (FC), California, were analyzed by LA-ICP-MS. INAA mineral and rock data for clinopyroxene-bearing and migmatitic garnet amphibolites from the Catalina Schist (CS), southern California, compare an extremely fluid-rich setting.

Whole-rock-normalized plots and budgets show that these 4 minerals contain most of the REE in the rocks. Chondrite-and whole-rock-normalized REE patterns show garnets depletion of LREE relative to HREE. The REE patterns of other minerals vary more. Most complement garnet, with LREE-richer, HREE-poorer patterns, but LREE abundances and fractionations also reflect the assemblage. For example, retrograde epidote from one dry Alpine eclogite shows the LREE of former apatite; epidote in another sample shows garnet-like LREE. Deformed samples yield similar results to coronitic ones. These features suggest closed system partitioning of REE among garnet, epidote, and apatite on the thin section scale, and preservation of protolith REE contents. Fluid-rich FC samples yield similar conclusions. In contrast, migmatitic CS garnet amphibolites, which manifest intense fluid-rock interaction, show trace element disequilibrium among garnet, titanite, and apatite. This probably reflects lack of equilibration with very REE-rich hydrothermal epidote.

During high P/T metamorphism, in both fluid-poor and fluid-rich terranes (M, GdV, F), deformation neither creates nor enhances disequilibrium REE distributions amongst garnet, epidote, apatite, and titanite in eclogite. However, extremely fluid-rich migmatitic garnet amphibolites (CS) testify to both disequilibrium and bulk REE addition. Only extreme fluid-rock interaction greatly disturbed REE systematics of slab rocks from these paleosubduction zones.

V51B-1241 0830h POSTER

The effects of deformation mechanisms on thermobarometry of plagioclase-bearing metamorphic rocks.

Kurt J Steffen[1] (ksteffen@unm.edu)

Jane Selverstone[1] (selver@unm.edu)

[1]EPS Dept., Univ. of New Mexico, Albuquerque, NM 87131, United States

The development of Garbenschiefer texture (large, radiating hornblende porphyroblasts) in the Greiner zone of the Eastern Alps resulted from complex interactions between deformational and metamorphic processes (Steffen et al. 2000, GSL spec pub 186). These interactions produced a wide variety of matrix plagioclase zoning types, even within individual samples. An understanding of the nature and timing of the processes responsible for the formation of plag zoning relative to equilibration with other phases is critical to the accurate interpretation of thermobarometric calculations.

Four plag types are preserved in the Greiner Zone: (1) Coarse (50-200 micron), concentrically zoned plag (cores: An5-20; rims: An25-35) with high dislocation densities that accommodated strain via Regime 2 dislocation creep. (2) Fine-grained plag (20-75 microns) with low dislocation densities that experienced moderate amounts of grain-boundary diffusion creep (GBDC, a grain-size sensitive, fluid-mediated strain accommodation process); plag 2 shows chaotic zoning with rim compositions of An15-40. (3) Chemically homogeneous (An30-35) and dislocation-free plag that experienced pervasive GBDC. (4) Homogeneous (An30-35), 30-200 micron plag that formed during late hbl breakdown. Model pressures calculated from An+Ab+Act = Gro+Pyr+Parg+Qtz equilibria at 575C using rim compositions of each plag type are (1) 6-7 kbar, (2) 3-7.5 kbar, (3) 3-4.5 kbar and (4) 3-4.5 kbar. Only the plag 1 pressures agree well with other estimates for these rocks. Despite the high diffusion rates associated with GBDC, ?new? and ?relic? plag 2 compositions are randomly distributed and it is not possible to determine a priori which compositions represent equilibrium with other mineral phases. Regime-3 dislocation creep is also likely to produce scattered P-T results. Plag 3 values likely reflect ongoing plag GBDC after growth of other minerals ceased, and are hence spurious. Plag 4 values may represent conditions of the hbl-out reaction. P-T and PTt-path calculations are thus sensitive to changes in deformation mechanism during metamorphism. Understanding the deformational processes that prevailed during metamorphism (determined from grain size and shape, chemical zoning patterns, and dislocation density) is an essential precursor to selection of appropriate mineral compositions for P-T calculations.

V51B-1242 0830h POSTER

Evolution of Himalayan Metamorphism and the Genesis of Inverted Metamorphic Gradients: Evidence From the Sutlej Valley, NW India

Mark Caddick[1] (+44-1223-333474; mark00@esc.cam.ac.uk)

Mike Bickle[1]

Tim Holland[1]

Nigel Harris[2]

[1]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, United Kingdom

[2]Department of Earth Sciences, Open University, Walton Hall, Milton Keynes MK7 6AA, United Kingdom

An inverted metamorphic gradient is commonly preserved where the high-grade Greater Himalayan Crystalline Sequence (GHCS) overthrusts the Lesser Himalayan foreland. This structural break (the Main Central Thrust, or MCT) is a key feature of Himalayan tectonics, generally considered to have taken up at least 200-300 km of shortening since the Early Miocene. The timing of displacement along the MCT and its relationship with inverted metamorphism is debated, with existing temperature inversion models requiring either (a) post-metamorphic faulting along young shear zones; (b) continual or episodic syn-metamorphic thrust development; or (c) single phase pre- to syn-metamorphic thrusting and subsequent thermal relaxation. Here, we use the P-T-t evolution of individual rock samples to study the contrasting histories of the GHCS and LHS units and deduce the relationship between metamorphism and thrusting.

The Sutlej River Valley exposes an inverted metamorphic succession consisting of a 9-km thick amphibolite-facies core (the GHCS), structurally underlain by greenschist and amphibolite-facies Lesser Himalayan Sequence (LHS) metapelites which preserve garnet-in, staurolite-in and kyanite/sillimanite-in isograds. The GHCS displays kyanite-in and sillimanite-in isograds, with migmatisation at the top of the sequence. A major thrust-zone (interpreted as the MCT) separates the LHS from the GHCS.

The application of rim-thermobarometry to Sutlej samples identifies both the inverted metamorphic gradient in the LHS and GHCS units, and the inherent frailty of cation-exchange thermobarometers when studying high-grade rocks that have been subjected to subsequent retrograde diffusion. The construction of pseudosections and contouring of mineral composition isopleths, however, identifies the PT-paths that both units have taken, allowing a detailed reconstruction of the burial and uplift histories of the units that constitute the MCT-zone. Pseudosections in the systems KFMASH and MnKFMASH suggest that upper regions of the GHCS reached an early (pre initiation of MCT slip?) kyanite-grade peak, before undergoing decompression to ≈ 0.7GPa and further heating to ≈ 750°C. Staurolite-grade LHS samples, however, reached a synkinematic peak of ≈ 650°C, before subsequent decompression and cooling. This suggests that (a) whilst GHCS metamorphism was early, LHS metamorphism is intrinsically linked with the MCT; and (b) MCT-zone activity was either prolonged, or the thrust was reactivated after a period of quiescence, as suggested for the central Nepalese Himalayas by Catlos *et al*, 2001.

V51B-1243 0830h POSTER

Geology of the Acasta Gneiss Complex in Slave Province, northern Canada: Appreciating new geological evidence of the oldest rocks in the world

Tsuyoshi Komiya[1] (tkomiya@geo.titech.ac.jp)

Tsuyoshi Iizuka[1] (tiiduka@geo.titech.ac.jp)

Ikuo Katayam[1] (katayama@geo.titech.ac.jp)

Yuichiro Ueno[1] (ichirp@geo.titech.ac.jp)

Yusuke Uehara[1]

[1]Tokyo Institute of Technology, Ookayama 2-12-1, Meguroku, Tokyo 152-8551, Japan

We made three types of geological and sketch maps in the Acasta Gneiss Complex in western Slave Province in 2000 and 2002. One is 1:5,000 geological map of 8x8 km^2 whole region, second is 1:1,000 geological map of 2x2 km^2 main area, and others are 1:100 to 1:10 sketch maps of many geological critical areas. In addition, we collected about 1,000 rock samples all over the Acasta Gneiss Complex. The Acasta Gneiss Complex comprises mainly of Gray Gneiss, White Gneiss, and Foliated Granite, with many aplite and basaltic intrusions. Gray Gneiss occurs as enclaves within White Gneiss and Foliated Granite, in the range from 3x1 km^2 to 10x10 cm^2 in scale. They form block, boudin

and layer. Some of blocks have asymmetrical structure, showing direction of deformation at the formation of gneissic structure after tonalitic and granitic intrusion (White Gneiss). White Gneisses are widely distributed all over the Acasta Gneiss Complex. Moreover, they also occur as intrusions within Grey Gneiss or blocks within Foliated Granite. Foliated granite is 3.6 Ga, relatively younger than other granitoid gneisses. It is foliated and folded in some places, but has no gneissic structure. Foliated Granite predominantly occurs as some thick intrusions up to 100 m wide in the western part, whereas thin intrusions of foliated granite are present all over Acasta Gneiss Complex. There are two types of basaltic intrusions based on difference of the metamorphic grade; namely the age. Some of them were metamorphosed under amphibolite facies condition, where others are apparently not metamorphosed. There are massive hornblendite within Gray and White Gneisses. Protoliths of most of them are basaltic blocks, and are sporadically present as layers or blocks in Gray and White Gneisses. They rarely occur together with pods felsic magma with many thin hornblenditic residual layers along boundary between Gray and White Gneisses, and were formed as residue of in-situ melting by tonalitic magmas (White Gneiss).

Massive and banded White Gneisses occur only in eastern part of the Acasta Gneiss Complex, whereas layered White Gneiss and foliated granite are present only in eastern part. The boundary is defined by a northeast-trending fault. The strikes of foliations and gneissic structures within White Gneisses and Foliated Granite are quite various, and bent along Gray Gneiss enclaves, but the distribution of the lithologies changes from northwest-trending in the western part to north-trending in the eastern part at the fault. Gneissic structure of Gray Gneiss is completely inconsistent, and is oblique to structure of White Gneiss and Foliated Granite. Paragenesis and chemical composition of metamorphic minerals in basaltic intrusions show progressive metamorphism from epidote-amphibolite in the eastern area to amphibolite facies in the western area. Geological evidence shows (1) intrusion of granodiorite (Gray Gneiss), (2) metamorphism (gneissic structure of Gray Gneiss), (3) intrusion of tonalite and granite (White Gneiss), (4) intrusion of basaltic dikes (5) progressive metamorphism2 (gneissic structure of White Gneiss and metamorphism of basaltic intrusions), (6) intrusion of granite (Foliated Granite) and week contact metamorphism and deformation, (7) fault at the boundary between eastern and western parts (8) intrusion of basaltic dikes.

V51B-1244 0830h POSTER

Complex Oxygen Isotope Systematics in the Buckskin-Rawhide Metamorphic Core Complex, Arizona: Paleo-fluid Conduits Within a Detachment Fault System?

Keegan L. Schmidt[1] (208 792-2283; klschmidt@lcsc.edu)

Jean Morrison[2] (213 740-3551; morrison@usc.edu)

[1]Natural Sciences Div. Lewis-Clark State College, 500 8th Ave., Lewiston, ID 83501, United States

[2]Dept. of Earth Sciences Univ. of Southern Calif., 3651 Trousedale Pkwy, Los Angeles, CA 90089-0740, United States

Lithologies formed in the mid-crust were juxtaposed against upper-crustal lithologies in metamorphic core complexes of the Cordillera during pronounced Cenozoic crustal extension. Detachment fault systems within these complexes record the evolution from early and deep mylonitic deformation to late and shallow chloritic breccia formation as mid-crustal assemblages were exhumed. Previous oxygen isotope studies in the Whipple Mountains metamorphic core complex are interpreted to indicate thermal gradients within the lower plates of these fault systems that are too large to result from conductive cooling alone, suggesting that circulating meteoric fluids may have been involved in heat extraction during the evolution of the complex. New epidote and quartz oxygen isotope compositions from the Planet Peak and Rawhide Mine areas of the Buckskin-Rawhide metamorphic core complex in Arizona yield complex systematics. Values of $\delta^{18}O$ are broadly similar to the Whipple Mountains data. Quartz $\delta^{18}O$ varies from +4.6 to +6.6 $^{o}/_{oo}$, and epidote varies from +1.8 to -2.9 $^{o}/_{oo}$. Values of Δ_{qtz-ep} for coexisting quartz-epidote pairs vary from 3.7 to 8.2, which, if they reflect equilibrium, yield temperatures of 250 to 500 ^{o}C and result in an overall thermal gradient on the order of 6 ^{o}C/m. However, detailed sampling of the detachment fault system in the Buckskin-Rawhide complex indicates even sharper thermal gradients at the meter scale. For example, in the Rawhide Mine area, mean temperatures calculated from coexisting mineral pairs vary from 350 ^{o}C at 5 m below the detachment surface to 250 ^{o}C at 7 m, and 410 ^{o}C at 15 m, indicating thermal gradients at the scale of 2 to 8 m that are an order of magnitude greater than the gradient through the entire fault system. These data are interpreted to indicate that footwall refrigeration by surface-derived fluids may be a widespread phenomenon in metamorphic core complexes and fluids may have been channelized within 5-10 m wide zones in detachment fault systems.

V51B-1245 0830h POSTER

New 40Ar/39Ar Data From Opholite and Metamorphic Complexes of the South Anyui Suture Zone, Northeast Russia.

Sergei D. Sokolov[1] (7-095-2308006; sdsokolov@mtu-net.ru); Paul W. Layer[2] (player@gi.alaska.edu); Jeremy Hourigan[3] (hourigan@pangea.stanford.edu); Grigoriy Ye. Bondarenko[1] (grisha@geo.tv-sign.ru); Igor I. Podgorniy[1] (podgorniy@geo.tv-sign.ru); Alexander V. Ganelin[1] (ganelin@geo.tv-sign.ru)

[1]Geological Institute, Russian Academy of Sciences Pyzhevsky 7, Moscow 109017, Russian Federation

[2]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775, United States

[3]Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305, United States

The South Anyui Suture Zone (SAZ), northeastern Russia, formed as a result of the closure of the Anyui ocean basin and collision of the continental masses of the Siberia and the Chukotka-Arctic Alaska Microcontinent. Many of the aspects of the evolution of the SAZ remain poorly understood. The scarcity of geochronologic data from ophiolitic and metamorphic rocks involved in this collision has hampered. The following represents a summary multiple new 40Ar/39Ar data from the SAZ collected as part of an ongoing international collaborative project aimed at a detailed understanding of the tectonic evolution of the suture zone.

Ophiolites: (1) A hornblende fraction from gabbro in the Vurguveem massif yields a 312.2 $\pm$ 11.1 Ma (Weighted Mean Plateau Age (WMPA), and a 320.3 $\pm$ 11.1 Ma (Inverse Isochron Age (IIA)); (2) Horblende from a diabase dike complex of the Alyuchin ophiolite gives 226.6 $\pm$ 10.5 Ma (WMPA), 198.8 $\pm$ 34.7 Ma (IIA); (3) A hornblende fraction from a gabbro-diabase complex of the Alyuchin ophiolite yields a 220.0 $\pm$ 3.9 Ma plateau age. Metamorphic rocks: (1) Hornblende from amphibolites in the metamorphic sole of an ophiolite complex in the Uyamkanda region yields ages of 239.1 $\pm$ 3.8 Ma (WMPA), and 243.7 $\pm$ 4.6 Ma (IIA); (2) Amphibole from greenschists at the base of a tectonic sheet composed of Carboniferious volcanics and limestones give ages of 156.5 $\pm$ 3.9 Ma (WMPA), and 151.7 $\pm$ 6.7 Ma (IIA); (3) A whole rock samples from greenstones and greenschists in the Bystryanka region yields ages of 112.7 $\pm$ 2.0, 104.1 $\pm$ 2.8, 108.4 $\pm$ 1.2, and 120.6 $\pm$ 3.5 Ma (IIA).

The new data support the Paleozoic age assigned to Vurguveem ophiolite in the literature and on geologic maps. The Aluchin ophiolite, previously supposed to be Paleozoic in age, now may be viewed as a fragment of Triassic oceanic crust. 40Ar/36Ar data from metamorphic rocks of the SAZ may indicate a three stage metamorphic evolution: Triassic, Late Jurassic, and mid-Cretaceous (Aptian-Albian). Triassic ages are derived from heterogeneous, chaotically deformed units which suggests metamorphism occurred in a subduction zone setting. (5) Late Jurassic ages coincide with the beginning of regional shortening and the formation of thrust fault systems. (6) The mid-Cretaceous ages may reflect late orogenic cooling or cooling during extension accompanied by normal faulting and orogenic magmatism. Improved resolution of the tectonic evolution of the South Anyui Suture Zone will require further detailed geologic and geochronologic investigations.

Supported by RFBR (grant 02-05-64217, 01-05-64535), Russian FCP "Integracia" (grant 0382).

V51B-1246 0830h POSTER

Pressure-Temperature Constraints on the ~2800 Ma Metamorphic Event Affecting southwestern Akilia Island, Southwest Greenland

Jessica L. Block[1] (jess_block@yahoo.com)

Craig Manning[1] (manning@ess.ucla.edu)

Stephen J. Mojzsis[2] (Stephen.Mojzsis@Colorado.EDU)

[1]University of California, Los Angeles, Department of Earth and Space Sciences, 595 Charles Young Drive East, Box 951567, Los Angeles, CA 90095-1567, United States

[2]University of Colorado, Boulder, Geological Sciences, 399 UCB, Boulder, CO 80309-0399, United States

Banded gneisses of the Itsaq Gneiss Complex, and mafic and ultramafic gneisses of the Akilia Supracrustal Association, are well exposed on the southwestern portion of Akilia Island, off the southwest coast of Greenland. Both groups of gneisses have experienced two major metamorphic events, the first at ~3600 Ma and the second at ~2800 Ma. Cross-cutting the gneisses are the Ameralik Dykes, which have experienced metamporphism only at ~2800 Ma. The Fe-Ti oxide assemblages from the dykes and the gneisses were used to constrain the oxygen fugacity, and in turn the pressure-temperature conditions, during the younger metamorphic event. Combining the constraints from oxygen fugacity for each lithology gives a pressure range of 3.7-5.8 kbars and a temperature range of 786 - 824 degrees C, well within that expected for amphibolite to upper amphibolite facies metamorphism, as indicated by petologic observation. This new information adds to our understanding of the complex geologic history of an area that has been much discussed in recent literature.

V51B-1247 0830h POSTER

The Metamorphic Evolution of the Ogcheon Metamorphic Belt, South Korea

Kim Sungwon[1] (82-63-270-3397; okseihara@hanmail.net)

Oh Changwhan (82-63-270-3397; ocwhan@moak.chonbuk.ac.kr)

Hyodo Hironobu (81-86-256-8480; hhyodo@rions.ous.ac.jp)

Itaya Tetsumaru (81-86-256-9722; itaya@rins.ous.ac.jp)

[1]Chonbuk National University, Basic Science Research Institute, Chonju 561-756, Korea, Republic of

The Hwasan area, southwestern part of the Ogcheon metamorphic belt, consists mainly of metasediments and the metamorphic sequence is divided into three Zones I, II and III in the ascending order of metamorphic grade. In Zone I, the main mineral assemblage is chlorite+ biotite+muscovite+plagioclase and minor one is K-feldspar+biotite+muscovite+plagioclase. Zones II and III are characterized by the first appearance of garnet and staurolite, respectively. The typical assemblage of the pelitic rocks are garnet+biotite+muscovite+chlorite+plagioclase+quartz in Zone II and staurolite+garnet+muscovite $\pm$ chlorite+plagioclase+quartz in Zone III. The P-T conditions for the core and rim formations of garnet in Zone III are 2.0 ~ 5.0 kb and 410 ~ 540 ^{o}C, and 6.5 ~ 9.0 kb and 570 ~ 620 ^{o}C, respectively. This including the condition (4.2 kb at 400 ^{o}C) of Zone I shows that the metamorphic sequence has undergone an intermediate P/T type of regional metamorphism. The garnet has also recorded the prograde P-T path in rocks as its core and rim have Pl+Ilm+Bt+Qtz and Pl+Ilm+Bt+Ms+Rt+Qtz assemblages, respectively. The Jurassic granites have affected thermal metamorphism on the rocks near the granites under the conditions of 530 ~ 600 ^{o}C and 1.7 ~ 3.5 kb. However, the thermal structure formed by the intermediate P/T type of regional metamorphism has never disturbed by the igneous activity. Consequently, whole the metamorphic sequence in this area has experienced a clockwise P-T evolution. We dated muscovite and biotite from metasediments and granites, and amphiboles from amphibole schists by the conventional K-Ar method as well as the laser prove Ar/Ar method using single crystal. Muscovite and biotite ages from metasediments and granites are concentrated in the middle Jurassic (ca. 160 Ma). The age data suggest that the exhumation and cooling of metamorphic rocks and the cooling of granitic rocks occurred simultaneously in the middle Jurassic. Amphiboles have very large variation in age. In particular, spot dating on amphiboles revealed the heterogeneous age (162 ~ 1209 Ma). This suggests that heterogeneous excess argon was incorporated into hornblendes during metamorphism, probably as inherited argon in the pre-Ogcheon mafic rocks.

V51B-1248 0830h POSTER

Fluorine-bearing grossular-rich garnet - an indicator for UHP - LT metamorphism of metagranitoids.

Michael Burchard (+49 234 3224141; michael.burchard@Ruhr-uni-bochum.de)

Institute of Geologie, Mineralogy and Geophysics, Ruhr-University-Bochum Universtaetsstr. 150, Bochum, NRW 44795, Germany

Melting experiments on biotite-phengite-gneiss at pressures of 1.5 to 4.5 GPa and temperatures of 675^{o}C to 1000^{o}C were performed to clarify the phase assemblages of S-type metagranitoids at high pressures. The starting material used was S-type granitic biotite-phengite-gneiss, which represents the country rock for the pyrope-quarztites from the Dora-Maira-Massif, Western Italy. These pyrope-quarztites contain the silicate ellenbergerite, which, together with the growth of pyrope, indicates P and T of more than 3 GPa and

700°C. Experimental evidence confirms that the presence of ellenbergerite indicates high water activities. For this reason all experiments were performed with a water fraction of 1.9 to 9.9 wt.%. The most important phases in the run products are melt, K-feldspar / K-felspar-hydrate, coesite / quartz, phengite, jadeite-rich clinopyroxene, almandine-grossular garnet, epidote, rutile and sphene. At pressures between 3.5 and 4.5 GPa and T of less than 675°C or 775°C, respectively, small, rare crystals of grossular garnets were observed. These grs-rich garnets form corona structures around the alm-grs garnets of the starting material. EMP-analysis shows that these garnets contain up to 1.2 wt.% F at 700°C, decreasing with temperature to 0.4 wt.% at 750°C. A garnet analysis from a run at 4 GPa and 700°C yields 69% grossular, 8% hydrogrossular, 6% fluorgrossular, 6% almandine, 2% spessartine and 3% andradite. The coexistence of such garnets with sphene and epidote in HP experiments shows that the high-pressure reaction sph + zoi -> grs + coe + H_2O suggested by Chopin et al (1991) is not relevant at these conditions.

From Chopin et al (1991) and Schertl at al (1991) it is known that there are extremely rare inclusions of grs-rich garnet in plagioclase and alm-grs garnet in the original rock, but these authors unfortunately did not analyze the F content. During a reinvestigation of the biotite-phengite gneiss grs inclusions in sph were found that consist of 66% grs, 10% H-grs, 8% F-grs, 6% alm, 3% spess and 5% andr.

It can be concluded from these observations that grs-rich garnets are indicators of UHP-metamorphism of S-type metagranitoids at T below 750°C. A high F content of such garnets could be evidence for LT duringmetamorphism. Nevertheless, further experimental work is needed to determine the influence of P, T and system composition on the composition of such garnets.

Chopin et al., Eur. J. Mineral. 3, 1991 Schertl et. al., Contrib. Min. Petrol. 108, 1991

V51B-1249 0830h POSTER

Origin and metamorphism of ultramafic rocks associated with Paleozoic eclogite in the Hida Mountains, SW Japan

Tatsuki Tsujimori[1,2] (tatsukix@pangea.Stanford.EDU)

Juhn G Liou[2] (liou@pangea.Stanford.EDU)

[1]Okayama Univ of Sci, Res Inst Nat Sci, Okayama, JPN 700-0005

[2]Stanford Univ, Dept Geol Env Sci, Stanford, CA , Stanford, United States

Ultramafic rocks associated with UHP-HP metamorphic rocks are commonly serpentinized and metamorphosed. These hydration processes sometimes erase every trace of primary mineralogic features. However, detailed examination of minor relict minerals provides a key to decipher the origin and metamorphism of severely hydrated ultramafics. Ultramafic rocks from the Omi area of the Hida Mountains are closely associated with HP rocks, and extensively serpentinized. However, some meta-dunites with chromitite layers exhibit critical features that suggest a supra-subduction origin. Meta-dunite is composed mainly of antigolite pseudomorphs after olivine and minor euhedral Cr-Spinel (CrSp) (0.2-1.0 mm). Few intercalated meta-chromitite layers consist of subhedral CrSp (0.5-5.0 mm) and minor antigolite and chlorite. CrSp shows distinct chemical zoning: the cores have high Cr# (0.70-0.75) and low Fe3+# (<0.15); both Cr and Fe3+ increase remarkably towards the rim through a transition zone between core and ferritchromite rim. Moreover, the cores also contain abundant tiny inclusions of mainly pargasitic amphibole and rare diopside. These inclusions were completely replaced by dolomite and chlorite at the rim. Although the Mg# of the core (0.20-0.43) is significantly lower than that of those CrSp in both Alpine and abyssal peridotites, the observed mineral inclusions and the analysed Cr# at the core are interpreted to be relics of igneous stage prior to the HP metamorphism. The hydrous mineral inclusions provide a critical evidence for crystallization of CrSp from hydrous melt, and the high Cr# is a unique feature of mantle peridotite beneath island-arc or subcontinental arc. The CrSp with low Mg# (around 0.2) has been documented in some ultramafics in the UHP-HP terranes (e.g. Ladakh; Sambagawa). The low Mg# may be related to cation redistribution between CrSp and its coexisting mafic minerals at low-T conditions during HP metamorphism. Compositional characteristics and the occurrence of hydrous mineral inclusions of the zoned CrSp in investigated rocks suggest that these ultramafics may have derived from the mantle wedge above a subduction zone and subsequently metamorphosed at blueschist facies condition.

V51B-1250 0830h POSTER

Excess Argon-free Phengite in Ultrahigh-Pressure Metamorphic Rocks From the Lago di Cignana Area, Western Alps

Chitaro GOUZU[1] (gouzu@rins.ous.ac.jp)

Tetsumaru ITAYA[2]

Hironobu HYODO[2]

[1]Grd School of Sci Tec, Kobe Univ, Nada-ku, Kobe 657-8501, Japan

[2]Res Ins Nat Sci, Okayama Univ of Sci, Ridai-cho, Okayama 700-0005, Japan

In $^{40}Ar/^{39}Ar$ phengite analyses, UHP rocks have provided discordant ages. However, we have had a working hypothesis that a rock with a simple metamorphic history should have an insignificant amount of excess Ar. We have carried out Ar/Ar phengite analyses on six samples collected from three sites in an area (20m x 200m) by the Lake Cignana in the Zermatt-Saas zone consisting of Tethyan oceanic lithosphere which have suffered UHP metamorphism. Samples can be classified into three groups; garnet-phengite schist (01B, 02A), zoisite-clinozoisite schist (01A, 02B, 03B) and piemontite schist (03A). Sample 02A has coesite included in garnet. They have different mineral assemblage, but should have experienced the same P-T-t history during the UHP metamorphism and the subsequent exhumation. EPMA data indicate that phengites have more or less chemical variations in each sample and among samples. The former characteristics have formed during the retrograde chemical reaction and deformations, and the latter were due to difference of bulk chemistry of rocks. Ar/Ar analyses were carried out with a laser probe step-heating method using a single crystal and a spot dating method using thin sections. In age spectra by step heating, the zoisite-clinozoisite schists gave plateau ages of 38 and 42Ma, the garnet-phengite schist, 37-39Ma and the piemontite schist ,37Ma, indicating that phengites have similar ages despite their chemical variations. This suggests that the closure temperature of phengite has insignificant dependence on its chemistry. Some phengites show disturbed age spectra with significantly young age fractions (ca. 30Ma) which are due to overcorrection of non-radiogenic Ar by an apparently large amount of ^{36}Ar. Spot dating was carried out on both matrix phengite and inclusion phengite in garnet. The result shows that the matrix phengite gave 39Ma, and the inclusion phengites yield 43-44Ma which are slightly older than the plateau ages by step heating method. Ages obtained in this study are consistent with SHRIMP age (44Ma: Rubatto et al., 1998), and Sm-Nd and Rb-Sr ages (40 and 38Ma, respectively: Amato et al., 1999). This indicates our working hypothesis was correct in a case of UHP rocks from this area.

V51B-1251 0830h POSTER

Fe-Al-Rich Tridymite-Hercynite Rock Xenoliths With Positive Cerium Anomalies: Preserved Paleosols and Paleoclimate Implication

Haibo Zou[1] ((310) 206-1938; hzou@ess.ucla.edu)

Kevin D McKeegan[1] (kdm@ess.ucla.edu)

Xisheng Xu[2] (xxu@public1.ptt.js.cn)

Alan Zindler[3] (zindler@magnet.fsu.edu)

[1]University of California at Los Angeles, Department of Earth and Space Sciences, Los Angeles, CA 90095, United States

[2]Nanjing University, Department of Earth Sciences, Nanjing 210093, China

[3]Florida State University, National High Magnetic Field Laboratory and Department of Geological Sciences, Tallahassee, FL 32306, United States

Unusual tridymite-hercynite rock xenoliths in the Tertiary (14-16 Ma) Niutoushan tholeiites in southeast coast of China have extremely high Al_2O_3 (31.90-34.37%) and total iron (19.97-22.33%), positive cerium (Ce) anomalies, positive $\epsilon(Nd)(+3.2to\ +\ 4.2), andhigh^{87}Sr/^{86}Sr$ (0.7050-0.7058) and $^{206}Pb/^{204}Pb$ (18.8-19.1). Their chemical and isotopic compositions suggest that these xenoliths represent preserved paleosols that are not genetically related to host tholeiites. The paleosols are probably ferruginous bauxites or aluminous laterites, and could have consisted mainly of halloysite and iron oxyhydroxides with minor amounts of $CaCO_3$ and $BaSO_4$. Because such sedimentary materials with strongly desilicated clay minerals form by weathering under tropical conditions, there may be a paleoclimate implication that tropical weathering conditions existed in SE China 14 Ma ago. Strong Ce anomalies have not been reported in present sedimentary soils in SE China, which indicates that the uppermost part of the Tertiary weathering profile with Ce anomalies has generally been eroded now, but unexpectedly, is preserved in the Tertiary Niutoushan basalts.

V51B-1252 0830h POSTER

New Calibrations of Garnet - Clinopyroxene Thermobarometers

Melroy R Borges[2] (melroy.borges@fiu.edu)

Youxue Zhang[1] (youxue@umich.edu)

Eric J Essene[1] (essene@umich.edu)

[1]Geological Sciences, University of Michigan, Ann Arbor, MI 48109, United States

[2]Earth Sciences, Florida International University, Miami, FL 33199, United States

Present calibrations of geothermometers based on garnet (grt) - clinopyroxene (cpx) equilibria are inconsistent with each other and limited in their application. Geobarometers based on the same mineral pair are not as well studied. A new calibration has been undertaken for the grt - cpx Fe-Mg exchange thermometer,

$1/3Mg_3Al_2Si_3O_{12}(grt) + CaFeSi_2O_6(cpx) \Leftrightarrow 1/3Fe_3Al_2Si_3O_{12}(grt) + CaMgSi_2O_6(cpx)$ ...(1)

and the grt - cpx barometer,

$CaMgSi_2O_6(cpx) + CaAlAlSiO_6(cpx) \Leftrightarrow 2/3Ca_3Al_2Si_3O_{12}(grt) + 1/3Mg_3Al_2Si_3O_{12}(grt)$ ...(2)

using thermodynamic and experimental data from the literature. The GEOTAB program was used to calculate thermodynamic data for the reactions at different temperatures and pressures. Linear regression was done on the data to obtain expressions relating T, P, $\ln K_{D(calc)}$ and $\ln K_{(calc)}$, (K_D and K are equilibrium constants from thermodynamic calculations for reactions 1 and 2 respectively). Literature experimental data used cover 1 - 7 GPa and 650 - 1800 °C and are mostly melting experiments using mafic to ultramafic starting material, and grt - cpx equilibration experiments.

In this study, thermodynamic formulation is used as much as possible, including component activities of garnet using a recent mixing model. From experimental data, 'equilibrium' constants are calculated assuming an ideal mixing model for cpx with specific assumption of cation distribution and ordering. The differences between thermodynamically calculated equilibrium constants and experimentally obtained 'equilibrium' constants i.e. $\Delta\ln K_D$ and $\Delta\ln K$ are attributed to nonideality. Multiple linear regression was done on $\Delta\ln K_D$ and $\Delta\ln K$, and compositional parameters. The final thermometer equation reproduces the temperatures of most experimental data with a 2σ error of $\pm$ 120 °C. This represents an improvement over previous thermometers for the same data set. The thermometer should be applied to low-K or K-free systems. The equation for the geobarometer reproduces the pressure of most experimental data with a 2σ error of $\pm$ 0.6 GPa. The error in calculated pressure is greater at lower pressures (1 - 3 GPa) probably due to disequilibrium in the low P-T experiments.

V51B-1253 0830h POSTER

A Detailed P-T Path for Eclogites in the Tromso Nappe, N Norwegian Caledonides - a Complex History of Subduction, Exhumation, Reheating and Recrystallization

Erling J,K Ravna[1] (47-776-44413; erlingr@ibg.uit.no)

Michel R,M Roux[1]

[1]Erling J K Ravna, University of Tromso Department of Geology Tromso N 9037, Norway, Tromso N 9037, Norway

The Tromso Nappe is the uppermost tectonic unit within the northern Scandinavian Caledonides. It contains eclogites, garnet peridotites and related HP rocks, variously retrograded and recrystallized to lower grade assemblages. Post eclogite partial melting of the mafic rocks yielding trondhjemitic/tonalitic leucosomes is a common feature. The Troms Nappe is separated from the underlying Skattora migmatite complex (formed at ca 950 °C, 1.0 GPa) by a mylonitic thrust fault.

Micro-textures of metabasites within this unit give detailed information about the P-T evolution. Inclusions of hbl + pl (An12) + qtz in eclogite grt apparently coexisted with the enclosing grt at 600-650 °C/1.45 GPa. Rare inclusions of omph (Jd53) + ab in outer rim of grt gives slightly higher conditions (660 °C/1.6 GPa). Max P conditions based on coexisting grt + omph + phe + ky + qtz + $CaCO_3$ (arag?) are calculated to 2.8 $\pm$ 0.3 GPa at 725 $\pm$ 60 °C. Post eclogite decomposition of high-P phases includes formation of symplectites after omph to Na-aug + olig, and phe to bt + pl, while grt + qtz react to di + plag. Three successive stages of symplectite formation - S1, S2 and S3 - after omph have been found. They are distinctly different in both size and composition

of cpx and pl lamellae. The width of the symplectite lamellae varies in the order S1>S3>S2, suggesting that $T_{S1}>T_{S3}>T_{S2}$. There is also a systematic decrease in $XJd_{S1}>XJd_{S2}>XJd_{S3}$. Composition of the corresponding pl lamellae is fairly constant (An15). Estimated conditions for the symplectite stages are T/P_{S1} = 840 °C/1.68GPa, T/P_{S2} = 700 °C/1.34GPa, and T/P_{S1} = 740 °C/1.19GPa, respectively.

The post-symplectite stages included local hydration to hbl + pl ep qtz assemblages, succeeded by neo-growth of garnet between hbl and pl and finally recrystallization to a mosaic textured assemblage of grt + hbl + di + pl ± ep + qtz at ca. 650 °C, 1.0 GPa.

The inferred P-T path indicates an early subduction of continental crust to depths of ca. 90 - 95 km, succeeded by initial uplift to about 55 km with a moderate temperature increase of ca. 100 °C. Partial melting of the eclogites was most probably associated this stage. Subsequent cooling towards a more normal geothermal gradient to ca. 700 °C at 45 km was succeeded by a new thermal pulse at a depth of about 40 km. The heat source most probably was the still very hot Skattora migmatite complex, upon which the Tromso nappe has been thrust. Later cooling and uplift accompanied with hydration to amphibolite facies assemblages preceded a new event of pressure increase and deformation resulting in total recrystallization at high amphibolite/HP granulite facies conditions. This event may, speculatively, be attributed to a now totally removed tectonic unit being emplaced on top of the Tromso nappe.

V51B-1254 0830h POSTER

Partial Melting During Exhumation of Eclogite, Evidence From Experiments and the Tromsdalstind Sequence, North Norway

Kjell P Skjerlie (47 77644408; kjell@ibg.uit.no)

Institute of Geology, University of Tromso, Dramsveien 201, Tromso 9020, Norway

Major crustal thickening during orogeny is generally followed by catastrophic collaps of the orogen and exhumation of high and ultra-high pressure rocks. During exhumation, the high-P rocks may follow P-T paths that overstep the solidus in the presence of hydrous fluids. Evidence for this is given by geothermometry and the presence of syn-exhumation felsic leucosomes and pegmatite dykes in some exhumed terrains. The formation of partial melts during exhumation is potentially important because it may significantly lower the strength of the crust and thus help to explain the very fast exhumation rate of many high-P terrains.

The Tromsdalstind sequence of north Norway consists of variably retrogressed (amphibolitized) eclogite with numerous minor pods, veins and lenses of trondhjemitic/tonalitic composition. Field evidences show that these pods formed during retrogression of eclogite which took place during exhumation of the high P rocks at 454Ma.

In order to better understand partial melting of eclogite during exhumation, piston cylinder experiments with variable amounts of added water (1, 2, 4, 6, 8, 10 wt%) have been performed on a mafic eclogite at 27, 21, 15 and 10 kbar. Partial melting occurs at temperatures that can be reached during exhumation if small amounts of water is present (<4 wt%). The composition of the partial melts (tonalite-trondhjemite-granodiorite) and the solid residues vary significantly with pressure (27 and 21 kbar: cpx-zoi-gt, 15 kbar: cpx-hbl-zoi±gt, 10 kbar: cpx-hbl-zoi-pl). Thus, melts formed by melting of mafic eclogite during exhumation should be expected to show a range of major and trace element compositions.

The experiments show that zoisite is an important residual phase at all the investigated pressures at relevant temperatures, and its thermal stability increases with decreasing amount of added water. The highest thermal stability is 950°C at 21 kbar, 2% added water. The incongruent formation of zoisite suggests that melts formed during exhumation of eclogite should generally be Sr-poor, despite the absence of residual plagioclase. In the present bulk composition, zoisite is stable to higher pressures than amphibole, confirming that the formation of zoisite is an important way of transporting water to deep crustal levels and in subduction zones.

V51B-1255 0830h POSTER

Ca. 400 Ma Recrystallization of Norwegian Ultrahigh-pressure Eclogites: an ion Microprobe and Chemical Abrasion Study

David B Root[1] (1-805-893-7999; dbr@geol.ucsb.edu)

James M Mattinson[1] (jmm@geol.ucsb.edu)

Bradley R Hacker[1] (hacker@geol.ucsb.edu)

Joseph L Wooden[2] (jwooden@usgs.gov)

[1]Dept. of Geological Sciences, University of California, Santa Barbara, CA 93106-9630, United States

[2]USGS-SUMAC, Stanford University, Stanford, CA 94305-2200, United States

Understanding the formation and exhumation of the ultrahigh-pressure (UHP) rocks of western Norway hinges on precise determination of the time of eclogite recrystallization. Our study consists of SHRIMP analysis, in conjunction with CL imagery, of zircon from four UHP and high-pressure (HP) eclogites; and detailed TIMS analysis of zircon from two samples subjected to combined thermal annealing and multi-step chemical abrasion (CA).

SHRIMP analyses of the Otnheim and Langenes eclogites yield Caledonian spot ages of ca. 400 Ma from zircon rims. CL imagery and Th/U ratios from the Langenes eclogite indicate formation of rims by recrystallization of inherited zircon.

SHRIMP analysis of the UHP Flatraket eclogite yielded a broad range of apparently concordant Caledonian ages. CA analyses of two fractions yielded moderate Pb loss from the first (lowest T) steps; possible minor Pb loss or minor growth at 400 Ma from the second steps; and a 407-404 Ma cluster of slightly discordant $^{206}Pb/^{238}U$ ages, most likely free from Pb loss, from the remaining steps. We interpret the latter to reflect recrystallization of inherited zircon, with possible new growth, at ca. 400-395 Ma. Alternatively, the high-temperature CA steps could represent growth at 407-404 Ma, with apparent discordance due to intermediate daughter product effects. HP/UHP zircon recrystallization in the Flatraket eclogite is inferred from three lines of evidence: i) zircon occurs as inclusions in garnet, omphacite, breunnerite, dolomite, and quartz, as well as in symplectites after phengite and omphacite; ii) association of zircon with rutile implies zircon formation during HP breakdown of Zr-ilmenite; and iii) chondrite-normalized ICP-MS analyses of the CA steps reveal small Eu anomalies and shallow HREE profiles, indicating zircon recrystallization in the presence of garnet.

CA analysis of the Verpeneset eclogite yielded distinctly discordant step ages from two steps comprising <90% of the sample, with $^{206}Pb/^{238}U$ ages of 408 and 414 Ma. CL imagery indicates incomplete recrystallization of inherited igneous zircon, in keeping with steep HREE profiles determined from chondrite-normalized ICP-MS analyses.

Our zircon age of ca. 400-395 Ma for the Flatraket eclogite is significantly younger than the 425 Ma age often cited for western Norway eclogite recrystallization, implying, in conjunction with 390-385 Ma $^{40}Ar/^{39}Ar$ white mica cooling ages, faster rates of exhumation (ca. 15 km/m.y.), and weakening the link between UHP metamorphism and ophiolite emplacement at 430-425 Ma.

V51B-1256 0830h POSTER

Exsolution of K-rich Phyllosilicate in Diopside from SuLu Garnet Perodotite

Krassimir N Bozhilov[1] (1-909-787-2998; krassimir.bozhilov@ucr.edu)

Harry W Green[1] (1-909-787-4505; hgreen@mail.ucr.edu)

Larissa F Dobrzhinetskaya[1] (1-909-787-2028; larissa@citrus.ucr.edu)

Zhiqin Xu[2] (xuzhiqin@ccsd.org.cn)

[1]Dept Earth Sci IGPP, Univ of California, Riverside, CA 92521, United States

[2]Inst of Geology, Chinese Acad Earth Sci, Beijing 1000000, China

A K-rich sheet silicate has been identified as topotactically oriented micron size exsolution lamellae in diopside from a garnet peridotite from the high-pressure metamorphic terrane in the SuLu area, eastern China. The orientation relationship between the phyllosilicate lamellae and the diopside host is such that the (001) plane of the sheet silicate is parallel to (100) of diopside. The average composition based on AEM of this sheet silicate phase is $K_{0.4}(Mg_{2.6}Fe_{0.1}Al_{0.2})(Si_{3.1}Al_{0.9})O_{11}$. The phase has a significant potassium content that is variable from 0.2 to 0.5 pfu based on 11 oxygens within individual grains but is always much less than that necessary to populate all interlayer sites. The unit cell parameters determined by SAED are a=5.3Å, b=9.2Å, c=10.1Å, β=99.5°. Electron diffraction and high-resolution imaging show domains of 0.2 to 2 μm in size along the c⋆ axis with variable stacking disorder, expressed by the typical streaking along c⋆ of hkl reflection rows for which k≠3n. Diffraction patterns from different orientations show that reflections with h≠3n are sharp, which suggests that the stacking disorder is due to layer rotations mostly of 120°. HRTEM imaging and electron diffraction show that polytypes with different stacking are present, along with the most abundant 1M polymorph. Domains with random stacking are observed as well as isolated occurrences of domains with periodicity corresponding to 12M and 15M polytypes.

The composition of this mica-type phase is intermediate between the dioctahedral phlogopite and the trioctahedral phengite, with significant interlayer vacancies or extra molecular H_2O occupying the interlayer sites, which is yet to be determined. The latter possibility would reflect a component of the so-called 10Åphase, known only from experiment.

The exsolution nature of the phyllosilicate lamella and the microstructural context of the host diopside suggest origin at high pressure and temperature, where K and H_2O have been incorporated originally in the diopside host.

V51B-1257 0830h POSTER

Ultrahigh-Pressure Corundum-Garnet Rock from the Sulu Terrane, Eastern China

Ruyuan Zhang[1] (650-723-5028; zhang@pangea.stanford.edu)

Juhn G Liou[1] (650-723-2716; liou@pangea.stanford.edu)

Bob Jones[1] (bobjones@pangea.stanford.edu)

Tatsuki Tsujimori[1] (650-723-5028; tatsukix@pangea.Stanford.EDU)

[1]Stanford University, Dept. of Geological and Environmental Sciences, Stanford, CA 94305, United States

Corundum (Crn)-pyropic garnet (Grt) rock occurs as an isolated block or thin dyke in mantle-derived, ultrahigh-P garnet lherzolite in Donghai of the Sulu terrane. This rock is pale pink color, massive and consists of 90-95 vol% garnet and 5-10 vol% corundum together with minor secondary high Al hydrous phases (zoisite/clinozoisite, pargasite) along microfractures. Garnet is coarse-grained and has high pyrope content ($Prp_{54-63}Grs_{26-36}Alm_{10-12}$). Red corundum with variable size (0.6-6 mm) contains considerable amount of Cr_2O_3 (1.1-1.4 wt. %), and shows three oriented sets of exsolved rutile needles. Fine-grained heazlewoodite (Ni_3S_2), pentlandite (0.15-0.20 mm), apatite, Mg-allanite (MgO > 4 wt%) and very rare stronianites (some contain Ba) occur as inclusions in garnet or corundum. Hydrous Ni-Si mineral vein (SiO_2, 22, FeO, 2, NiO, 54 wt%) crosscuts some euhedral heazlewoodite crystals. Mg-staurolite with Mg/(Fe+Mg) ratio of 0.79-0.82 and secondary sapphirine and chlorite occur along the boundaries between garnet and heazlewoodite. The Grt+Crn paregensis is stable at > 800°C and ∼30-42 kbar based on previous experiments of the system MgO-Al_2O_3-SiO_2-H_2O; secondary Mg- staurolite may have formed at slightly low pressures. This rock with 27-30 wt% Al_2O_3 may have formed by a metasomatic process at the mantle wedge above a subduction zone; this together with the host garnet lherzolite were experienced UHP metamorphism. Hydrous phases were formed during retrogression by fluid infiltration.

V51B-1258 0830h POSTER

Exsolution Features From the North Qaidam UHP Terrane, NW China

Chris G. Mattinson[1] (650-736-2215; cgm@pangea.stanford.edu)

Juhn G. Liou[1]

Robert E. Jones[1]

Cailai Wu[2]

Jingsui Yang[2]

[1]Dept. of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, United States

[2]Chinese Academy of Geological Sciences, Institute of Geology, Beijing 100037, China

Amphibolite-facies felsic gneisses of the North Qaidam Mountains enclose minor (<10 vol.%) peridotitie and pyroxenite (± garnet), and eclogite. Discovery of coesite in zircon from the felsic gneiss indicates Early Paleozoic UHP metamorphism (Yang et al. 2001, *Eos Trans. AGU, 82*(47), Fall Meet. Suppl., Abstract V32C-0979). Eclogite, garnetite, amphibolite, and pyroxenite preserve mineral exsolution textures probably formed during exhumation. Garnet in eclogite, garnetite, and garnet clinopyroxenite contains rutile rods aligned in multiple crystallographically controlled directions. Clinopyroxenites contain 4-6 mm diopside porphyroblasts in a 0.5-1 mm matrix of diopside and chlorite. These porphyroblasts contain rods and plates (30-50 μm long, 2-5 μm wide) of chromite and chromian hematite (18-22 wt.% Cr_2O_3) aligned in two directions, ilmenite rods (10-20 μm long, 1-2 μm wide) aligned in one direction, chlorite plates (100 μm long, 2-5 μm wide) aligned in one direction, and sparse prisms (∼5 μm wide) of a potassic phase, possibly phlogopite or K-feldspar. Omphacite grains in eclogite contain quartz rods (100-200 μm long, 1-2 μm wide) aligned in one direction. Apatite grains in felsic gneiss, eclogite, and amphibolitized eclogite contain opaque

V

rods (10-20 μm long, 1-2 μm wide) aligned in one direction (pyrite?). These exsolution features are similar to those reported from other UHP terranes and kimberlites, and are consistent with the increased solubility of Ti in garnet, and K, Ti, and Si ($\pm$ OH) in clinopyroxene indicated by UHP experiments.

V51B-1259 0830h POSTER

Petrogenesis of Ti-clinohumite-bearing Garnetiferous Ultramafic Rocks from Kokchetav@Massif

Atsumi Muko[1] (81-3-5286-1514; mukou@earth.edu.waseda.ac.jp)

Yoshihide Ogasawara[1] (81-3-5286-1514; ogasawara@earth.edu.waseda.ac.jp)

[1]Waseda University, 1-6-1 Nishiwaseda, Shinjyuku-ku, Tokyo 169-8050, Japan

Titanian clinohumite-bearing garnetiferous ultramafic rocks occur in close association with diamond-grade eclogite, and diamondiferous gneiss and marble in the Kumdy-Kol region, Kokchetav Massif; they are considered to be cofacial with the ultra high pressure metamorphic rocks. This rock has a peak metamorphic assemblage of Prp-garnet (Prp: -63%) + Ti-clinohumite (+ Mg-ilmenite: from Ti-humite?) + Mg-ilmenite (MgO: 8.1 wt. %) $\pm$ clinopyroxene $\pm$ phlogopite, with variably developed retrograde overprints comprising olivine + ilmenite symplectite, amphibole, zoisite, spinel, chlorite and serpentine minerals. Zircon and apatite occur as accessory phases in significant amounts. Garnets are generally compositionally homogeneous, but some display prograde zonation with increasing pyrope component from core (Prp: 52.2%) to rim (Prp: 59.5%). Textural and compositional evidence indicates that Ti-clinohumite + ilmenite may be breakdown products of Ti-humite. This texture is interpreted to have formed during metasomatism at or near peak P-T conditions. Symplectites of olivine + ilmenite are breakdown products of Ti-clinohumite. And this ilmenite has a lower Mg content (MgO: 2.6 wt. %) relative to earlier formed ilmenite (MgO: 8.1 wt. %) in garnet. These syemplectites are with amphibole and spinel during a later retrograde stage. Chlorite and serpentine minerals represent the latest formation. Peak conditions and retrograde history of this rock appear to be preserved in three or four stages of ilmenite growth. This Ti-clinohumite rock was high in HFSEs (Nb, Ti, Zr). Metasomatism may have resulted from the reaction between Ti-bearing (and other HFSE) fluids from the subducting slab and peridotite of the overlying wedge mantle.

V51B-1260 0830h POSTER

Kulet Eclogite from the Kokchetav Massive, Kazakhstan: Transition from Low-grade Amphibolite to Eclogite

Juhn G Liou[1] (650-723-2716; liou@pangea.stanford.edu)

Ruyuan Zhang[1] (650-723-5028; zhang@pangea.stanford.edu)

Yoshi Ogasawara[2] (+81-3-5286-1514; yoshi777@waseda.jp)

[1]Stanford University, Dept. of Geological and Environmental Sciences, Stanford, CA 94305, United States

[2]Waseda University, Dept. of Eartn Sciences, Tokyo 169-8050, Japan

Massive pale-color Kulet eclogites of the Kokchetav Massif contain coarse-grained zoisite and amphibole that have been previously considered to be eclogite-facies minerals. Detailed examination of parageneses, microstructures and mineral compositions indicate that these rocks show three distinct stages of recrystallization: (1) pre-eclogite, (2) eclogite, and (3) retrograde stages characterized by Amp $\pm$ Pl $\pm$ Bt + Ttn. The eclogite bodies are associated with coesite-bearing mica schist and whiteschist, and consist of eclogite and transitional coronitic eclogite without shape boundaries. The Kulet eclogite consists of fine-grained euhedral Grt, Omp, Qtz, Rt $\pm$ Phn. Coronitic eclogites show pre-eclogite stage relict and eclogitic domains; the relict domain consists of coarse-grained (0.5->10 mm) euhedral Zo, Amp, and minor Qtz $\pm$ Phn and fine-grained garnets developed along boundaries of zoisite and amphibole as a discontinued corona. Fine-grained, star-like clouded garnets and omphacite laths occur as prograde products in euhedral zoisite, and increase in size from core (2-3 μm) to rim (100 μm) of zoisite. Garnets of the eclogite contain high Alm component ($Alm_{56-63}Spe_1Grs_{19-31}Prp_{12-18}$). Garnets of the coronitic eclogite contain lower Alm and exhibit large compositional variation ($Alm_{42-56}Spe_1Grs_{22-31}Prp_{17-32}$). Two patterns of Grt zoning were identified: Alm and Prp (or Grs and Prp) increase with decreasing Grs (or Alm) components from core to rim. Omphacite in both domains has relatively homogeneous composition ($Jd_{30-36}Aug_{63-66}Age_{1-5}$ in eclogite and $Jd_{30-37}Aug_{70-63}$ in coronitic eclogite). Pre-eclogite stage amphiboles are pale or light color and vary from calcic to sodic-calcic including magnesiohornblende, and barroisite, whereas retrograde amphiboles are dark-green magnesiokatophorite. Zoisite contains very low Fe_2O_3 (0.78-2.40wt%). Fe-Mg partitioning between coexisting Grt and Omp of eclogites yields 640-710 $\pm$ 50°C at assuming 30 kbar and that in the coronitic eclogite gives 720-840 $\pm$ 50°C. These data and previous age dating indicate amphibolite-facies metamorphic protoliths of the Kulet eclogites together with country rocks were subjected to Cambrian-age UHP metamorphism at 530 $\pm$ 7 Ma. The transformation from low amphibolite to eclogite exhibits dehydration reaction; preserve of early stage parageneses is due to fast exhumation and localization of fluid flow.

V51B-1261 0830h POSTER

Morphology and Distribution of Microdiamonds in Dolomite Marble From Kokchetav UHP Massif

Kyoko Imamura[1] (imamura@toki.waseda.jp)

Nobuhiro Yoshioka[1] (yoshioka@earth.edu.waseda.ac.jp)

Yoshihide Ogasawara[1] (ogasawara@earth.edu.waseda.ac.jp)

[1]Department of Earth Sciences, Waseda University, 1-6-1,Nishiwaseda, Shinjuku-ku, Tokyo 169-8050, Japan

The detailed morphology of microdiamonds combined with its distribution was examined for dolomite marble from the Kokchetav massif, northern Kazakhstan. In the dolomite marble, abundant microdiamonds are included mainly in garnet and somewhat in diopside. The concentration of microdiamonds is heterogeneous and the morphologies of microdiamonds are varied. In the highest concentration domain of dolomite marble (sample no. ZW46), a single garnet grain includes several thousands of microdiamonds. We chose a sample, no. C43 as a typical one that has an average diamond concentration to investigate the relations between the distribution and the morphologies of microdiamonds. In this sample, each garnet grain includes several tens of microdiamonds.

The microdiamonds in the Kokchetav UHP marble are classified into 4 major types by the morphology and other characters; S, R, RS, T-types (Ishida et al., 2003, in press; this study). S-type diamond, which is most abundant one, consists of the translucent single crystal core and the transparent polycrystalline overgrown rim. R-type diamond is the translucent crystal with rugged surface and has very thin rims on the core. RS-type diamond is a transitional type between R-type and S-type. T-type diamond is the transparent crystal with smooth surfaces and its size is smaller than the other types.

In the sample no. C43, the distribution of microdiamonds is heterogeneous in garnet and diopside. The distribution maps of microdiamonds including morphological information were made by marking the location and the morphologies of microdiamonds for each host mineral. Four grains of garnets and one grain of diopside was examined by this method. These maps for garnet hosts show that microdiamonds concentrate in the mantle and/or the rim of the host whereas the core of host garnet lacks microdiamond and graphite. In the host diopside, most of microdiamonds occur in the mantle and rim and rare in the core. The deviations by domains from the average populations of each type microdiamond were not detected although the microdiamond distribution is heterogeneous. No particular relationship was observed between the morphology and the distribution of microdiamonds.

The lack of microdiamonds in the core in most of the garnets and diopsides hosts may new some information for the growth mechanism of microdiamond.

Reference: Ishida H. & Ogasawara Y. 2003. Journal of Metamorphic Geology

V51B-1262 0830h POSTER

Microdiamonds Identified from the Maksyutov Metamorphic Complex, South Urals, Russia

Benjamin C. Bostick[1] (650-723-4152; bbostick@pangea.stanford.edu); R. E. Jones[1] (650-725-1677; bobjones@pangea.stanford.edu); Cynthia Chen[1] (650-723-4152; cynchen@pangea.stanford.edu); W. G. Ernst[1] (650-723-0185; ernst@geo.stanford.edu); Mary L Leech[1] (mary@geo.stanford.edu); Rachel J Beane[2] (rbeane@bowdoin.edu)

[1]Stanford University, Department of Geological and Environmental Sciences, Stanford, CA 94305-2115, United States

[2]Bowdoin College, Department of Geology, Brunswick, ME 04011-8468, United States

Unit #1 of the Maksyutov Complex consists of dominant garnet mica schist and gneiss enclosing volumetrically minor mafic eclogite boudins. Here, we constrain the pressure of formation for this formation through the identification of ultrahigh pressure indicator mineral inclusions in garnet and zircon. Multiple cuboidal microdiamond aggregate inclusions (2-5 mm in diameter) in garnets from eclogite lenses in the Shubino area have been identified employing Raman spectroscopy. Broad absorption spectra of these microdiamonds suggest that the cuboids are exceedingly fine-grained aggregates characterized by limited long-range ordering. Their poor crystallinity is compatible with solid-state formation in the absence of a melt. The formation of microdiamonds requires ultrahigh-pressure (UHP) metamorphism at a minimum pressure of 3.2 GPa, assuming a maximum metamorphic temperature of 650°C. Blocky graphite grains up to 10+ mm across in the surrounding mica schist 35 km to the north at Karayanova probably represent pre-existing neoblastic diamond in the rock matrix. Thermobarometric calculations for analyzed coexisting garnet + omphacite + phengite from Maksyutov Unit #1 lithologies suggest physical conditions (T = 610-680°C, P = 1.7-2.6 GPa) close to, but lower pressure than, the coesite stability field, indicating backreaction. The complete conversion of diamond to graphite in the mica schists, and the recrystallization of coesite to quartz in both enclosing schist and eclogite pods reflect decompression (exhumation from at least 110 km depth to upper crustal levels over 60-80 m. y.) and sluggish polymorphic transformation in the carbon system compared to more rapid back-reaction rates for SiO2 polymorphs. Phengite inclusions in zircon and garnet hint at a modest activity of water during UHP metamorphism; the abundance of white mica in the schists probably reflects aqueous fluid-mediated, kinetically enhanced retrogression during post-UHP ascent of the subduction complex.

V51B-1263 0830h POSTER

New eclogitization and protolith ages for the Maksyutov Complex (south Ural Mountains) based on U-Pb zircon SHRIMP data

Mary L. Leech[1] (650-736-1821; mary@geo.stanford.edu); Ellen P. Metzger[2] (408-924-5048; metzger@geosun.sjsu.edu); Joseph L. Wooden[4] (650-725-9237; jwooden@usgs.gov); Robert E. Jones[3] (650-725-1677; bobjones@pangea.stanford.edu); Cynthia L. Schwartz[4] (650-723-2337; cschwartz@usgs.gov); Rachel J. Beane[5] (207-725-3160; rbeane@bowdoin.edu)

[1]Department of Geological Sciences, University of California at Santa Barbara, Santa Barbara, CA 93106-9630, United States

[2]Geology Department, San Jose State University, San Jose, CA 95192-0102, United States

[3]Geological Environmental Sciences, Stanford University, Stanford, CA 94305-2115, United States

[4]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025-3591, United States

[5]Geology Department, Bowdoin College 6800 College Station, Brunswick, ME 04011, United States

Precise new single zircon U-Pb ages for the eclogitic unit of the Maksyutov Complex indicate that peak eclogite-facies metamorphism occurred at 389 +/- 4 Ma (MSWD=0.81, n=10); these new data show that eclogitization was ca. 9-14 m.y. earlier than other workers have reported. Analyzed zircons from Maksyutov include three samples from quartzofeldspathic gneiss and mica schist in the eclogitic unit and one mica schist sample from the serpentinite melange unit. Zircons are rounded, slightly irregularly-shaped grains that display dark metamorphic rims under CL; some grains show zoned, sometimes euhedral, cores within thin metamorphic rims. Early Devonian ages are derived from dark, rounded grains and dark metamorphic rims under CL with very low Th/U ratios (less than 0.1). Groups of ages between 510 and 550 Ma in samples from both the eclogitic and serpentinite melange units yield weighted means of 206Pb/238U ages of 526 +/- 6 Ma (MSWD=2.8, n=7) and 541 +/- 7 Ma (MSWD=1.5, n=6), respectively and have much higher Th/U ratios (0.5-1.5); these ages probably record rift-related magmatism during the formation of the paleo-Uralian Ocean and correspond well with magmatism associated with ophiolites in the region. In addition, SHRIMP results in conjunction with CL imagery, indicate a minor inherited component with Late Archean and Early Proterozoic ages (1594 +/- 25 to 2578 +/- 36 Ma).

V51B-1264 0830h POSTER

High P and T Diamond Synthesis From Graphite in the Presence of H_2O in Natural Metamorphic Rock Systems

Larissa F Dobrzhinetskaya[1] (1-909-787-2824; larissa@citrus.ucr.edu)

Alex P Renfro[1]

Harry W Green[1] (1-909-787-4505; hgreen@mail.ucr.edu)

[1]Earth Sci Dept IGPP, Univ of California, Riverside, CA 92521, United States

We report here high P and T diamond synthesis from graphite in the presence of H_2O and in combination with different minerals so that bulk composition resembles natural diamond-bearing metasediments from ultra-high pressure terranes. Experiments were performed in a multianvil apparatus using a Pt graphite capsule with an enclosed graphite capsule at P=7-8.8 GPa and T=1200-1500°C for time periods ranging from 1 to 138 hours. We have explored the following systems: (1) graphite-brucite, (2) graphite-calcite-talc and graphite-dolomite-talc, (3) graphite-quartz-muscovite and (4) graphite-quartz-H_2O. Diamonds were found in all run products indicating that they crystallized from a supercritical COH fluid formed from the breakdown of water-bearing minerals and subsequent dissolution of graphite into liberated water or fluid-catalyzed graphite-diamond transformation.

One of the notable features of diamond crystallization in most of the COH fluid environments investigated here is the considerable induction time that exists prior to diamond nucleation. This incubation period increases dramatically with decreasing temperature and also depends on the bulk composition of the starting material. No diamond was crystallized from graphite in SiO_2-rich system after 43-hour experiments at 8 GPa and 1500°C, while carbonate and brucite systems yielded diamonds after 10-20 hours at similar P and T conditions. Instead of diamonds in our SiO_2-rich experiment, we find fine-grained spherical graphite polycrystalline aggregates nucleated around newly crystallized coesite. This suggests that SiO_2 promotes nucleation of metastable graphite on its surface in the diamond stability field. It is also expected that SiO_2 has a high solubility in supercritical fluid at such P/T conditions. Therefore, the retardation of diamond nucleation from COH fluid saturated in SiO_2 allows us to conclude that free SiO_2 somehow hampers diamond nucleation. We are pursuing greater understanding of the kinetics of this process and the induction time required for diamond nucleation in SiO_2-bearing systems because this system is closest to the dominant rock type hosting natural UHP metamorphic diamonds.

V51B-1265 0830h POSTER

Cathode luminescence of microdiamond in UHP dolomite marble -New evidence for two stage growth of gstarh-shaped microdiamond-

Nobuhiro Yoshioka[1] (yoshioka@earth.edu.waseda.ac.jp)

Kyoko Imamura[1] (kyoko@toki.waseda.jp)

Yoshiihde Ogasawara[1] (ogasawara@earth.edu.waseda.ac.jp)

[1]Department of Earth Science Waseda University, 1-6-1 Nishiwaseda Japan, Shinzyuku-ku Tokyo 169-8050, Japan

Cathode luminescence (CL) studies for gstarh-shaped (S-type) microdiamond in UHP dolomite marble from the Kokchetav massif were conducted using ordinary polished thin sections. CL spectra from mm order size and CL images at the peak wavelength were obtained by a HITACHI S-4300SE SEM equipped with a CL spectrometer F-4500 with an accelerating voltage of 15kV. Prior to this analysis, the morphologies of 11grains of S-type microdiamonds in garnet were observed by an optical microscope in detail. S-type microdiamond is aggregates consisting of a single crystal core part and a small-grained polycrystalline rim part in which each grain have different crystal orientations with the core. This type is the most typical form and the most abundant one. All analyzed diamonds display a heterogeneous CL images; the rim was lighter than the core. In all samples, the spectrum of around 520 nm at peak was detected in both the core and the rim. The difference in intensity at 520 nm between the core and the rim was very clear; the intensity of rim was higher than the core. A different peak at about 380 nm of lower intensity was detected in two samples. These results in CL spectra are interpreted as new evidence for two-stage growth of S-type microdiamond.

V51B-1266 0830h POSTER

Diamond Inclusions From Snap Lake Kimberlite, Canada: An Insight From In-Situ Analysis

Prinya Promprated[1] (pinpromprated@hotmail.com); Lawrence A. Taylor[1]; Mahesh Anand[1]; Nikolai P. Pokhilenko[2]; Nikolai V. Sobolev[2]; Allan Patchen[1]

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

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

Mineral inclusions in diamonds have been the primary source of information for the origins, ages, and growth environments of the natural diamonds. Residing in the hardest substance known to man, the diamond inclusions (DIs) are often liberated from their hosts for study by either cracking or burning. Such techniques inevitably eliminate the opportunity to study the nature of diamond formation within textural and chemical context of both diamonds and their inclusions as they originally were in the mantle. In this investigation, we have utilized the more laborious *in-situ* technique, which involves polishing diamonds to expose their encapsulated DIs for EMP and Cathodoluminescence (CL) analysis. Of particular interest is the chemistry of multiple inclusions within a single diamond that occur in different growth zones. In addition, analyses of total N and $\delta^{13}C$ and $\delta^{15}N$ have been performed on selected diamonds.

The studied diamonds are from the Snap Lake kimberlite, the largest diamond discovery in the Northwest Territories *(Pokhilenko et al., 2001)*, which occurs in the SE portion of the Slave craton. These diamonds contain mostly olivine inclusions, with lesser amounts of enstatite, clinopyroxene, and sulfide, thus indicating peridotitic paragenesis for most of the diamonds. P-T estimates from the inclusion chemistry are approximately 1150°C and 60 kbar (∼200 km). As revealed by CL imaging, all diamonds display distinct growth zones, varying from simple to complex stratigraphy. These indicate changes in the conditions during the diamond formation that results in differences in nitrogen contents and nitrogen aggregation. These zones also reflect different stages of growth and changes in growth mode, as well as resorption, plastic deformation, incorporation of DIs, and continued growth.

As demonstrated in this study, the growth history of diamonds and their mineral inclusions is complex. Therefore, it is only through the *in-situ* study of DIs and their hosts that their true relationships can be addressed with respect to the complicated growth of diamonds within the mantle.

V51B-1267 0830h POSTER

Stratigraphy of Diamonds: Complex Growth Histories Highlighted by Cathodoluminescence

Mahesh Anand[1] (anandm@utk.edu)

Prinya Promprated[1]

Lawrence A. Taylor[1]

Nikolai V. Sobolev[2]

[1]Planetary Geosciences Institute, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37919, United States

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

Geochemical and isotopic investigations of mineral inclusions in diamonds (DIs) have significantly enhanced our understanding of the chemical conditions and timing of diamond formation in the upper mantle. However, the nature and significance of diamond growth zones, as evidenced by their complex growth patterns, are still not well understood. The methodology of using cathodoluminescence (CL) imaging on both P-and E-type diamonds, as well as examination of their DIs *in-situ*, can reveal the nature and significance of their complex growth history as this relates to processes in the upper-mantle.

We have investigated diamonds from Yakutia and Canada. Each diamond was cut and polished along relatively *soft* directions parallel to either (001) or (110) faces to obtain a cross-section, including the earliest-formed portion (core) and the latest-formed portion (rim) of the diamond. Examination by CL on an EMP demonstrates that the majority of the diamonds have CL zonations recording their severe, often torturous, and contorted, growth histories. These zones have different CL as a reflection of the different aggregation states and contents of nitrogen within the diamond structure. In addition, the majority of the diamonds show resorption features, due to hiatuses in growth, when the diamonds were partially dissolved back into the fluids from which they may have originally grown. Continued new growth of diamond over this resorbed zones was commonly accompanied by change in growth mode from cubic to octahedral. The outermost portions of many diamonds show weak to no CL, termed dead zones, and are likely due to metastable diamond growth during tenure in the host kimberlite melt.

These observations are consistent with previous suggestions that diamond growth is seldom simple and probably occurs over a significantly long geological time-period and under constantly changing fluid/melt compositions *(Taylor et al., 2000, Int. Geol. Rev.)*. This type of study, when supplemented by geochemical and isotopic data on multiple DIs, occurring in different growth zones, can improve our understanding of the nature and timing of diamond growth in the upper mantle.

V51B-1268 0830h POSTER

First Report of Majoritic-Garnet Diamond Inclusions From Yakutian Kimberlites

Nikolai V. Sobolev[1] (sobolev@uiggm.nsc.ru); L. A. Taylor[2]; A. M. Logvinova[1]; Y. V. Seryotkin[1]; V. I. Koptil[3]; E. S. Yefimova[1]

[1]Inst. of Mineralogy and Petrography, Russian Academy of Sciences, Siberian Branch, Novosibirsk 630090, Russian Federation

[2]Planetary Geosciences Inst., Univ. of Tennessee, Knoxville, TN 37996, United States

[3]Almazy-Rossii-Sakha Co Ltd, Mirny, Yakutia 678170, Russian Federation

The presence of a majoritic component in mantle garnets is significant in that it indicates a deeper-than-normal origin for their host diamonds. We have discovered the first majoritic garnets both of peridotitic (P-/U-type) and eclogitic (E-type) parageneses, included in microdiamonds (<1 mm) from three Yakutian kimberlite pipes: Yubileynaya, Komsomolskaya, and Krasnopresnenskaya, all located in the Alakit kimberlite field of Upper Devonian age. Up until now, a considerable number of majoritic garnets have been recovered from placers. The new finds of majoritic garnets reported here practically double the number of kimberlite pipes worldwide where such garnets have been detected.

Multiple inclusions of garnet and olivine occur in single P-type diamond from Yubileynaya. Here, a CrCa-rich majoritic garnet coexists with a CrCa-rich non-majoritic garnet and olivine, but the 3 grains are not in contact. Positive identification of the majoritic garnet was obtained by single-crystal X-ray diffraction: space group Ia3d; a = 11.775 (1) Å; V = 1632.6 (2) $Å^3$. All garnets were analyzed extensively by electron microprobe. The specific features of the compositions of coexisting majoritic and non-majoritic garnets, resp., are: Si (pfu) = 3.22 & 3.02: Cr_2O_3 (wt %) = 10.2 & 13.7; CaO (wt %) = 20.8 & 12.7; Mg# 77.6 & 69.9. Coexisting olivine is Fo 91.5, which is consistent with the relatively low Mg# of the majoritic garnet. This Yubileynaya majoritic garnet diamond inclusion (DI) represents the first find of a garnet, containing solid solution pyroxene, from a wehrlitic paragenesis. Furthermore, its CaCr-component (uvarovite) content is unusually high (∼50%). The chemical differences of the wehrlitic garnets in this one Yubileynaya diamond testifies directly to the complex history of this diamond, specifically to a large range of pressures.

Majoritic garnet DIs from the Komsomolskaya and Krasnopresnenskaya pipes are both of E-type and are characterized by the following compositional features respectively: Si (pfu) 3.13 & 3.05; TiO_2 (wt %) 1.9 & 0.4 ; CaO (wt %) 12.2 & 12.9; Na_2O (wt %) 0.93 & 0.43; Mg# 49.6 & 54.2. In both garnets Na (pfu) exceeds Ti (0.028 & 0.039, resp.).

It is of major significance that majoritic garnets have been found to occur as DIs from all known parageneses of P-/U-type garnets (harzburgitic, lherzolitic, and wehrlitic). These new results confirm the unusual character of DIs in 10-20% of the microdiamonds from Yakutian kimberlites *[e.g., Sobolev et al., 2001, EOS]*. A significantly deeper source and petrogenesis is indicated for these special microdiamonds.

V51B-1269 0830h POSTER

Crustal Signatures in Mantle Peridotites From Yakutian Kimberlites

Lawrence A. Taylor[1] (lataylor@utk.edu)

Z Spetsius[2]

R Wiesli[1,3]

Mahesh Anand[1]

John Valley[3]

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

[2]Alrosa Diamond Co., Alrosa Diamond Co., Mirny 678170, Russian Federation

V

[3]Dept. of Geology Geophysics, Univ. of Wisconsin, Madison, WI 53706, United States

Peridotites and eclogites are considered as the original hosts for diamonds in the mantle. However, it is now generally agreed that these mantle eclogites from kimberlites had their origin in the subduction of oceanic crust beneath the major cratons of the world. One of the first indications for such crustal protoliths was from studies of oxygen and carbon isotopes (e.g., Peter Deines and colleagues, Ian McGregor, as well as our group). Indeed, subsequent studies of such rocks have revealed several additional crustal signatures. A possible scenario involves the subduction of an ophiolite sequence, whereby the basaltic and lower mafic components were metamorphosed, devolatilized/partially melted, and otherwise transformed into eclogites. Being within the diamond-stability field, they later experience metasomatic diamond formation. Surprisingly, the closely associated diamondiferous peridotites are considered to be of original mantle origin. We pose the query: What became of the ultramafic portion at the bottom of the crustal sequence? Could this be the origin of at least some of the mantle peridotites?

The restricted $\delta^{13}C$ values for P-type (peridotitic) diamonds is commonly used as evidence for the mantle origin of peridotites. However, a compilation of $\delta^{13}C$ data, published by Peter Deines and our group, for P-type diamonds, mainly from numerous south African pipes, also shows a significant number of values that are well below the mantle field (to 20 $^o/_{oo}$).

Fresh, clean garnets were carefully selected from over a hundred peridotites collected from several Yakutian kimberlites. These were subjected to oxygen-isotope analyses by laser-fluorination at the University of Wisconsin. The majority of the $\delta^{18}O$ values plot within the accepted mantle value of 5.5±0.4 $^o/_{oo}$ *(Mattey et al., 1994)*. However, a significant number (~20%) lies outside this window, both above and below. These values are interpreted to represent the effects of both high- and low-temperature hydrothermal alterations that occurred in the crust.

Armed with these crustal signatures, we propose that some of the mantle peridotites that are hosts for diamonds have their ultimate origin in the crust, prior to subduction to depth, possibly along with eclogite crustal protoliths as well.

V51B-1270 0830h POSTER

Sr and Nd Isotope Decoupling in the Mantle Xenoliths Evidence for Carbonatitic Fluid/Melt Percolation Metasomatism

V. G. Malkovets[1,2] (vomal@uiggm.nsc.ru)

L. A. Taylor[1]

K. D. Litasov[3]

[1]Planetary Geosciences Institute, Dept. of Geological Sciences, Knoxville, TN 37996, United States

[2]Institute of Mineralogy and Petrography, Siberian Branch, Russian Academy of Sciences, Novosibirsk 630090, Russian Federation

[3]Center for Northeastern Asian Studies, Tohoku University, Aoba, Aoba-ku, Sendai 9808578, Japan

Garnet and spinel peridotite and pyroxenite xenoliths from three upper Cretaceous basanitic explosion pipes in the Minusa region, southern Siberia have been studied to characterize off-cratonic upper mantle near the southwestern boundary of the Siberian craton. A lithospheric mantle section was constructed based on EMP and LA-ICP-MS analyses of minerals in representative xenoliths *(Malkovets et al., 2000)*. Here we report results of a Sr-Nd isotope and trace-element study of metasomatized spinel-peridotite xenoliths from Kongarov and Krasnoozersk basanitic explosion pipes *(Malkovets et al., 2001)*. Some of those xenoliths plot off the Sr-Nd mantle array and show strong fractionation of elements with similar compatibility. We argue that those features can be explained by chromatographic effects of carbonatitic melt/fluid percolation in the peridotite mantle.

The contents of compatible to moderately incompatible elements in minerals of peridotites indicate that most of those rocks are residues after partial melting and melt extraction. The initially depleted xenoliths bear a record of later metasomatic events that produced enrichments in the incompatible-trace-element concentrations of pyroxenes. Trace-element compositions of clinopyroxene define two principal enrichment patterns. Type-I Cpx is characterized by very-high La/Ce and La/Nd ratios and lower concentrations of the middle REE and Sr, relative to Type-II Cpx. On primitive mantle-normalized, trace-element-distribution diagrams, Type-I Cpxs have nearly flat HREE-MREE patterns, with moderate depletions from Eu to Nd, and a steep La-Ce inflection. Type-II Cpx has lower HREE concentrations, with a continuous increase in normalized REE concentrations from Ho to Ce. Both types of Cpx have negative Ti, Zr, Hf, and strong negative Nb anomalies, in addition to small to moderate positive Sr anomalies.

Sr-Nd isotopic compositions of mineral separates from the xenoliths indicate an unusual type of enrichment, with Sr decoupled from Nd. This results in Type-I Cpx having high $^{87}Sr/^{86}Sr$ but low $^{143}Nd/^{144}Nd$ values, thereby resulting in displacement of the data points to the right of the mantle array on Sr-Nd isotopic plots. Formation of the two groups of Cpxs may be explained by the chromatographic effect during the percolation of carbonatitic melts/fluids through the peridotitic substratum. The chromatographic models imply the selective removal of elements with high Cpx/melt distribution coefficients, e.g., HREEs from a percolating melt. Those elements would interact with the Cpx from peridotite resulting in the progressive enrichment of the melt in incoherent elements at the percolation front. Since the cpx/melt K_D for Sr is lower than that for Nd, the front of Sr enrichment moves faster than the front of Nd enrichment. Thus, a zone can be formed in which the host peridotite has more radiogenic Sr. This would explain the position of the data points to the right of the mantle trend in the Sm-Nd isotopic plot. Type-I Cpx forms at the melt-percolation front. However, Type-II Cpx forms at later stages of the same metasomatic event and reflects larger degrees of the equilibrium with the percolating carbonatitic fluids/melts.

V51C MCC: 106 Friday 0830h

Evolution of the Igneous Rocks 2002 Edition I: The Rock Record, Models of Differentiation, and Assimilation

(joint with OS, P)

Presiding: **D Geist,** University of Idaho**; P B Kelemen,** Woods Hole Oceanographic Institution

V51C-01 0830h

Rocks Whose Composition is Determined by Crystal Sorting: the Volcanic Perspective

Dennis Geist[1] (208-885-6491; dgeist@uidaho.edu)

Mike Garcia[2] (garcia@soest.hawaii.edu)

[1]Geology, Univ. of Idaho - 3022, Moscow, ID 83844, United States

[2]Univ. of Hawaii, Geology and Geophysics, Honolulu, HI 96822, United States

Modern analytical and theoretical tools that were unavailable in Bowens time provide independent tests of the crystal fractionation hypothesis. This evidence indicates that most of the compositional variations among Galapagos and Hawaiian lavas are related to crystal sorting. In the Galapagos, Volcan Alcedo has erupted a sequence of tholeiitic basalt through rhyolite. Mass-balance, thermodynamic, and isotopic fractionation calculations are consistent with the generation of the rhyolites by about 85% crystallization of basalt. The geochemistry precludes significant assimilation or crustal anatexis. Phenocrysts in the basalts are mostly unrelated to their host liquid, indicating multistage hybridization. The prevalence of plagioclase-phyric lavas at high elevation and accumulative picrites in submarine lavas suggest segregation by density. During the basaltic phase, a steady-state chamber underlies the calderas, where plagioclase floats and mafic minerals sink. Rhyolite is created as the magma supply is reduced and the chamber and cumulate pile cool. Crystal sorting within Hawaiian volcanoes follows a different path because of the higher rate and near continuity of magma supply. These conditions limit the extent of fractionation and lead to the observation that virtually all Hawaiian lavas of the shield-building stage are basalts. Compositional diversity among the basalts is mainly related to the removal or accumulation of olivine. Olivine and rock compositions correlate well in weakly porphyritic lavas, indicating efficient crystal-liquid separation. In contrast, olivines in the porphyritic lavas span compositions from 78 to 91% Fo. Many of these crystals are deformed indicating they are xenocrysts. At Kilauea volcano, the summit magma body is thought to act as a filter to allow lower density, sparsely porphyritic lavas (2.6-2.7 g/cc) to be erupted in the caldera and to promote the injection of denser, olivine-rich magmas (2.75-2.9 g/cc) into the volcanos rift zones. The effects of crystal fractionation and accumulation are superimposed on a continually varying resident magma composition, which ungoes cyclic variation. The impact of assimilation on compositional diversity is minor, because it involves rocks of similar composition as the magma.

V51C-02 0845h

Rocks Whose Compositions are NOT Determined by Crystal Sorting: Lessons From the Skaergaard Intrusion

Alexander R. McBirney (541-344-2539; mcbirney@darkwing.uoregon.edu)

Dept. of Geological Sciences, University of Oregon, Eugene, OR 97403, United States

Wager and Deer's Skaergaard Memoir, published shortly after the appearance of Bowen's "Evolution of Igneous Rocks" was widely viewed as the ideal confirmation of the dominant role of crystal fractionation in magmatic differentiation. The mineralogical sequence followed a course predicted by phase equilibria, and the spectacular layering seemed to offer clear evidence of crystal settling. Although the liquid line of descent proposed by Wager was closer to the "Fenner trend" of iron enrichment than to the one Bowen favored, there was no evidence that the rocks represented liquid compositions; they must have been formed by crystal sorting. This interpretation was supported by the elegant "cumulate" concept proposed a few years later by Wager and Brown. An elaborate system based on petrographic textures seen in the Skaergaard rocks soon became a pervasive paradigm for interpreting coarse-grained igneous rocks. Because of its remote location, nearly half a century passed before the Skaergaard Intrusion was seen by geologists who were not members of Wager's team. When an independent group examined the body they reported two simple observations that conflicted with earlier interpretations. First, it was noted that the plagioclase in graded "sedimentary" layers was less dense than the liquid through which it was said to have settled, and, second, some of the rocks were found to have been severely altered, both in texture and in bulk composition. The most conspicuous evidence was found in swarms of angular anorthositic blocks that had fallen from the roof. The present composition of these blocks is much more felsic than that of the unit from which they fell. Rinds of ferromagnesian minerals appear to be the mafic component that was somehow expelled from the residual plagioclase. When examined under the microscope, the contact between the block and its host, which seems so sharp in outcrops, is seen to be indistinct and gradational. The changes seen in these blocks must have occurred after they, for otherwise they could not have sunk. Further studies have shown that most, if not all of the rocks owe their present compositions, not to gravitational sorting, but to late-stage "post-cumulate" processes. This is not to say that they were not products of crystal fractionation. The compositional evolution of the magma clearly required crystal fractionation, but these processes did not end at the liquidus or even the solidus. As temperatures slowly declined, the rocks continued to re-equilibrate just as metamorphic rocks do under similar conditions.

V51C-03 0900h

Nature and Timing of Magma Interaction Processes in Arc Volcanic Systems: Data from Rocks and from Phase Equilibria Experiments

Malcolm J Rutherford (401-863-1927; macr@brown.edu)

Geology department, Bown university, 324 Book St., Providence, RI 02912, United States

The ongoing andesite eruption on Montserrat is producing andesite with clear and abundant evidence for a mingled basalt component in the magma. In addition to enclaves of basaltic composition, the andesite has much textural and compositional evidence for heating by the basalt, including outer Ti-rich rims on Ti-magnetite phenocrysts and Cpx reaction rims on quartz. There are pargasitic hornblende microphenocrysts in the andesite that are identical to those in basalt enclaves, and this pargasite can not be crystallized from the andesite bulk composition under any set of conditions in the hornblende stability field. The large (1-1.5 cm) hornblende phenocrysts in the andesite are composed of up to seven growth cycles that are optically discernable in sections parallel to c. Each growth zone begins with a sharp increase in Si and Mg (and a drop in Al and Fe) and then the original composition is gradually regained. A few of the zones show evidence of small amounts of resorption prior to the new cycle growth. According to experiments the compositional cycles are produced by a temperature change from 830 to 860 at 130 MPa water pressure, but hornblende growth is aided by the mingling in of pargasite-bearing basalt. The slow breakdown of the unstable pargasite is critical to making the thick cycles of hornblende growth because the amount of hornblende that can be resorbed into the andesitic melt in going from 830 to 860 C is very small. Similar cyclic compositional zones are present in the hornblende crystals of the Fish canyon Tuff, although the zone are much thinner and variable in thickness in this large volume eruption. The compositions of hornblende phenocrysts in the F.C. Tuff indicate that injection of mafic magma and hornblende crystallization went on