structure, order/disorder phenomena, bonding characteristics of Si and Al atoms, and possible surface defects like screw dislocations and point defects are discussed. Our model allows detailed investigation of the endmembers of the plagioclase series, albite and anorthite. We analyzed the movement of steps, congruency of dissolution, inhibition, anisotropy effects, and surface composition as a function of both saturation state of the solution and crystallographic orientation of the crystal surface. Additionally, we compared the dissolution rates of albite and anorthite in the context of their ratio of Si-O-Si to Al-O-Si bonds. These results will be extended to the whole feldspar series so as to predict the fundamental behavior of feldspar dissolution and evaluate the general role of Si-O-Si and Al-O-Si bond behavior.

V11E MCC: Level 1 Monday 0830h

Crustal and Mantle Processes in Ophiolites and Ocean Crust Generation I Posters *(joint with GP, OS, T)*

Presiding: **W G Minarik,** University of Maryland

V11E-0532 0830h POSTER

Using Breccia-Hosted Spinels of Abyssal Peridotites to Obtain a Representative Local Mantle Composition

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Surprisingly little is known about the extent, scale, and causes of local (outcrop/dredge) heterogeneity in the oceanic mantle. Our primary sources of information are abyssal peridotites, which are fragments of the residual MORB mantle tectonically exposed on the ocean floor at mid-ocean ridges. On a ridge scale it is impossible to objectively pick representative samples for detailed petrological and geochemical analyses, due to analytical limitations and financial restrictions, as well as operator-biased sample selection. This is particularly important for the ultraslow spreading Gakkel Ridge (Arctic Ocean), where thousands of individual peridotite specimens from nearly forty sampling locations are available. Preliminary conventional (i.e. major and trace element mineral analyses in-situ) petrological investigations at Gakkel Ridge have revealed variable dredge-scale heterogeneities, which are related to regional changes in the extent and relative proportion of melting/melt-migration. In order to better assess the extent and distribution of dredge-scale chemical variations, we have separated spinel grains out of carbonate-cemented peridotite breccias that were collected along with normal serpentinized peridotites (and which are common on the ocean floor). The rationale for this is that the spinel clasts may provide a more representative composition of the local outcrop, or slope from which the serpentinite fragments were sedimented by mass wasting. In a pilot study, we selected 29 breccia samples from 7 dredge hauls. For each of these dredge hauls major and trace element mineral data of more than 8 normal residual abyssal peridotite (RAP) samples are available. The major element spinel compositions of the RAP hand specimens (n=95) were then compared with those obtained on breccia-hosted (BH) spinels (n=1300) from the same dredge haul. The agreement between BH spinels and those from the RAP is very good. As expected, BH-spinels cover a larger range than RAP-spinels, although each individual breccia only covers a part of the entire spectrum within a single dredge. This may mean that the spinels are derived quite locally and not mixed much. The Cr#-Ti systematics of the spinels can be used to infer degrees of melting, extent of reaction with percolating melts, and spatial distribution and abundance of dunites channels. Besides spinels from residual peridotites, the breccias host spinels from peridotites affected by high-level melt percolation, such as plagioclase-bearing peridotites or ones affected by crosscutting dykelets. In most cases, it possible to distinguish the non-residual from the residual ones (e.g. dredge D34: 40% residual, 50% dunitic, 10% vein-influenced; n=162). Despite some limitations (higher spinel mode in dunite, possible preferential weathering of dunite), this may prove a useful tool to estimate the local proportions of residual mantle, melt transport channels, and the volume of mantle affected by late-stage crosscutting dykelets.

V11E-0533 0830h POSTER

Petrological insights of the first recovered chromitites from Site 1271, ODP Leg 209, MAR 15°N

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ODP Leg 209 recovered several podiform chromitites at Site 1271, Mid-Atlantic Ridge close to the 15° 20'N fracture zone. These chromitites are the first sampled from the Mid-Atlantic Ridge. Furthermore, Site 1271 is only the second chromitite locality that has been found along any Mid-Ocean Ridges. The first chromitite found, which from near the East Pacific Rise at Hess Deep at ODP Site 895 (Arai and Matsukage, 1996), is a single, elongate, discontinuous train of chromite grains <1 cm wide. In contrast, the Site 1271 chromitites are rounded rather than elongate, have sharp contacts with surrounding peridotite, and are clearly massive. It has been proposed that the formation of chromitite occurs during subduction-related arc magmatism only, because the formation requires hydrous magmas (Matveev and Ballhause, 2002). Therefore high Cr#s have been cited as evidence that most ophiolites with high Cr# in mantle spinels do not form at normal Mid-Ocean ridges. Based on our results, confirming the Hess Deep observation, it is clear that chromitites are not restricted to arc magmatism. However, there is abundant high-temperature amphibole in core from Site 1271, some of which could be igneous. Based on the of unusually high-Cr# (>0.6) in spinels from harzburgite and dunite dredged from the Mid-Atlantic Ridge in the 14° to 16°N region (Bonatti et al., 1992; Dick and Kelemen, 1992; Sobolev et al., 1992) andthe general observation that spinels in chromitites have higher Cr# than spinels in residual mantle peridotites (e.g.,Dick and Bullen, 1984), we anticipate that the Cr#'s Site 1271 chromitites are the highest yet found in spinel from Mid-Ocean ridge setting. High Cr#s can provide insight into the processes of chromitite formation and may give rise tonew interpretation of ophiolite provenance.

V11E-0534 0830h POSTER

Mont Albert to Buck Mountain: Provenance of Appalachian Ophiolite Chromites Using Osmium Isotopes

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Osmium $^{187}Os/^{188}Os$ isotopic ratios have been determined for chrome-rich spinels from a suite of Appalachian ophiolites thought to represent Iapetus margin mantle formed and emplaced during the Ordovician. Because Re is incompatible during mantle melting while Os is compatible, non-radiogenic initial $^{187}Os/^{188}Os$ can constrain the average source and the timing of melt extraction, especially as Os is concentrated in chromite. Radiogenic ratios indicate contamination from aged sources with high Re/Os, such as mafic or continental crust. In rocks where spinel is the only remaining primary mineral, these properties can constrain the tectonic environment of formation as well as active-margin Os transport. There is little correction for ^{187}Os in-growth since the Ordovician due to very low sample Re. Each ultramafic unit (from Mont Albert on the Gaspé Peninsula of Québec down to the Blue Ridge of North Carolina) forms a unique cluster of $^{187}Os/^{188}Os$ ratios, spanning 1 to 3%, but the whole range is about 10%. This corresponds to a range of initial γOs of -1 to +9, where γOs is the percent deviation from a chondritic source at the age of formation (roughly 500 Ma). Within ophiolites where detailed mapping and other geochemical information are available, there is a correlation between mantle-like Os and tholeiitic basalts; radiogenic Os and boninites (Thetford Mines). Continental arc-related mantle chromites (Baltimore Mafic Complex; γOs +4 to +7) are the most radiogenic. The least radiogenic are chromites from the Staten Island serpentinite and Mont Albert (γOs -1 and 0, respectively), either indicating formation from a previously depleted source or that they predate the other Taconic ophiolites. The restricted range of each ophiolite, compared to the whole of the data set, allow provenance links to be made between isolated bodies. For example, the Buck Creek, NC ultramafic complex, which has undergone granulite facies metamorphism, (Tenthorey et al., 1996) has a similar $^{187}Os/^{188}Os$ to other Ordovician NC Blue Ridge dunites ($\gamma Os = +6.5$ to +8.5), but distinctly different from a NC Piedmont chromitite ($\gamma Os = +2$, Falls Lake mélange, Stoddard et al, 1989) that is inferred to be Neoproterozoic in age.

V11E-0535 0830h POSTER

Asymmetric Zoning in Peridotitic Spinels - Disequilibrium Melt/Rock Reaction in the Oceanic Mantle

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Models of melt migration and melt/rock reactions in the mantle are based on the assumption of an instantaneous local equilibrium (Kelemen et al., 1992). These local equilibrium models have been thought to provide the most realistic outline for future investigations so far. Plagioclase lherzolites from Gakkel Ridge are characterised by strong compositional variations in all phases with an overall range of spinel Cr# from 10-55 of the sample suite often in a single thin section. The spinels show distinct asymmetric zonation that is not in accordance with orientation, shape of the grains or other textural indicators. The zoning is best developed where the spinel grains are rimmed by plagioclase. Plagioclase trace element composition show that they originate by an intruding depleted melt. Symmetrical zoning with consistent orientation of Al-rich and Al-poor regions with respect to lineation and grain shape like in mylonitic peridotites from the Miyamori ophiolitic complex (Ozawa, 1988) was not observed. The Gakkel Ridge samples show only weak deformation; therefore a different explanation is required. Residual spinel peridotites from the same dredge are generally unzoned and have homogeneous compositions. The absence of crosscutting veins and the extreme chemical disequilibrium suggest melt injection conditions very close to the lherzolite solidus. The asymmetric zoning shows that diffuse reactive melt migration can take place at low melt/rock ratios in local disequilibrium conditions. If this is a general process then the assumption of local equilibrium cannot be made, at least in a major part of the melting system. Kelemen, P. et al. (1992) Nature, 358, p. 635-641; Ozawa, K. (1988) Nature, 338, p. 141-144.

V11E-0536 0830h POSTER

Melt Percolation and Melt Rock Interaction in the Ophiolitic Peridotites of the Alpine Apennine System (Italy): a Main Step in the Rift Evolution of the Jurassic Ligurian Tethys

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Ophiolites exposed along the Alpine - Apennine chain represent the oceanic lithosphere of the Jurassic Ligurian Tethys basin which separated the Europe and Adria plates. Pre-oceanic rifting of the Europe-Adria lithosphere caused: i) the tectonic exhumation of the sub-continental lithospheric mantle, and ii) the adiabatic upwelling and decompressional partial melting of the asthenosphere. Mantle peridotites of the Alpine-Apennine ophiolites (Lanzo (Western Alps) Erro-Tobbio (Liguria), Ligurides (Northern Apennines), Monte Maggiore (Corsica)) are variably depleted spinel lherzolites. They show a complete equilibrium recrystallisation under spinel-facies conditions at T = 900-1100°C, attained during their accretion to the

thermal lithosphere.Prior to their exposure at the seafloor in mid-Jurassic time, the peridotites were affected two main mantle processes which are related to the rifting stage of the basin: 1) a subsolidus decompressional evolution, as evidenced by the development of km-scale extensional shear zones and by incipient recrystallisation under decompression to plagioclase-facies conditions; 2) the porous flow percolation and impregnation, as indicated by textural, chemical and thermal modifications of the pristine spinel peridotites, and the subsequent focused melt migration in replacive dunite channels. Recent field, petrologic and geochemical investigations indicate that, during the pre-oceanic rifting stage of the basin, pyroxene-undersaturated melts migrated through the extending mantle lithosphere via diffuse and reactive porous flow, and became progressively pyroxene-(silica)-saturated. Reactive melt percolation produced depletion of the lower lithospheric mantle levels (i.e. pyroxenes dissolution) and impregnation and chemical refertilization of the shallower mantle levels (i.e. addition of basaltic components, in form of interstitial gabbroic microgranular aggregates, and significant trace element enrichment of the mantle minerals, when they attained the geochemical equilibrium with the impregnating melts). Thermometric estimates reveal that magmatic aggregates and mantle porphyroclasts in the impregnated peridotites record the same equilibrium temperatures ($T>1250^{\circ}C$) indicating a significant heating of the lithospheric mantle during melt percolation. Accordingly, the lithospheric mantle represented by the Alpine-Apennine ophiolitic peridotites was subjected to significant thermochemical erosion (chemical refertilization plus heating) during the asthenosphere/lithosphere interaction which accompanied the rifting stage of the basin. The widespread occurrence of impregnated plagioclase peridotites within the Alpine - Apennine ophiolites indicates that the asthenosphere/lithosphere interaction via melt percolation played a fundamental role in the opening of the Jurassic Ligurian Tethys.

V11E-0537 0830h POSTER

Bulk Rock and Mineral Chemistry of Peridotites From Mariana Forearc Seamounts (ODP Leg 195, Site 1200A, and ODP Leg 125, Sites 779A and 784A) and the Petrogenesis of Mantle Wedge Peridotites

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Ocean Drilling Program Leg 195 recovered serpentinised peridotites from the South Chamorro Seamount, a serpentinite mud volcano located in the Mariana forearc (Shipboard Scientific Party, 2002). At Site 1200A the mud encloses clasts of mostly harzburgite, with minor dunite and lherzolite, strongly serpentinised and tectonised. The primary mineralogy includes olivine, orthopyroxene, clinopyroxene and chromium-spinel. Bulk-rock chemistry shows Mg# = 91-93, and high Ni and Cr contents. Low CaO and $Al_{(2)}O_{(3)}$ contents, and very low REE contents with U-shaped, strongly LREE-enriched and HREE-depleted, patterns confirm that most peridotites are highly depleted and suffered extensive partial melting, and contain an enriched component. The only lherzolite sample shows a significantly lower degree of depletion. A new set of peridotite clasts from Sites 779A and 784A, located in two Mariana forearc mud volcanoes drilled during ODP Leg 125, have been investigated. Some of the peridotite clasts have experienced more extensive melt extraction than those from South Chamorro Seamount. Modeling of the REE composition of the clinopyroxenes provide evidence that the onset of partial melting of most of Leg 125 and Leg 195 peridotites occurred under garnet-facies condition and followed during the upwelling of the asthenosphere at shallow, spinel-facies, level. The effect of melt migration or entrapping have also been recognised. The late stages of the evolution comprise sub-solidus re-equilibration, with clinopyroxene exsolution from primary high-Ca orthopyroxene. Reference: Shipboard Scientific Party, In Salisbury, M.H., Shinohara, M., Richter, C., et al., Proc. ODP, Init. Repts., 195, College Station, TX (Ocean Drilling Program), 1-233, [CD-ROM] (2002).

V11E-0538 0830h POSTER

A Geochemical Investigation of the Woodlark Spreading Center-Solomon Islands Arc Triple Junction

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The triple junction formed by the subduction of the Woodlark spreading ridge beneath the Solomon Islands arc (New Britain and San Cristobal trenches) is an area of tectonic, volcanic, and geochemical complexity. Anomalous volcanism along the Simbo and Ghizo ridges and the presence of numerous arcuate faults near the triple junction suggest the area is under extreme tectonic stress, and the absence of a deep trench or strong Benioff zone beneath the New Georgia Group (NGG) of the Solomon Islands suggests that subduction is being stifled by the impingement of the high-standing ridge on the trench. The tectonic effects of the ridge collision may have also led to NGG volcanic activity, including the currently active Kavachi volcano, which is anomalously close to the trench (30 - 90 km) in what would normally be considered the forearc region. A previous episode of Pacific Plate subduction, prior to the current subduction of the Australian Plate, may have geochemically enriched the mantle beneath the triple junction. To identify the source(s) of enrichment for the arc-like lavas in the study area, major and trace element concentrations and radiogenic isotopic ratios for rocks from the NGG and Woodlark Ridge have been analyzed. NGG lavas are generally more enriched in LILE and LREE relative to Woodlark lavas for a given silica content, and Woodlark Basin lavas become progressively less enriched with distance from the triple junction. Different trends in correlations between Sr and Nd isotopic ratios with trace element concentrations suggest that NGG and Woodlark Basin magmas were enriched by different sources. NGG enrichments may have been supplemented by partial melts from the subducting Australian Plate, as they exhibit enrichments in HFSE and depletions in HREE and Y. The subducting Australian Plate is young (<6 my) and hot, which may allow it to partially melt at relatively shallow depths.

V11E-0539 0830h POSTER

Insights Into Melt Extraction Beneath Mid-Ocean Ridges From the Geochemistry of the Peridotite Section of the Oman Ophiolite

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A suite of peridotites from a single Wadi section in the Oman ophiolite has been studied with the aim of: (1) investigating the role of subsolidus processes in controlling mineral compositions and (2) investigating the extent to which peridotite whole-rock trace element compositions can be used to determine the porosity during melting. Firstly, detailed major element zoning profiles through crystals indicate extensive subsolidus exchange. For example, orthopyroxene adjacent to spinel is zoned to lower Cr and Al at the margin and spinels have an outer zone of lower Cr-number suggesting subsolidus growth of spinel. Also, a small clinopyroxene in a dunite is surrounded by olivine depleted in calcium. Mass balance indicates that the clinopyroxene could have formed in the sub-solidus utilising calcium released from olivine. Notably, the REE composition of the clinopyroxene is approximately in equilibrium with MORB. The Ca content of olivine in dunites globally are lower than would be in equilibrium with MORB suggesting that subsolidus clinopyroxene growth may be a generally important process in dunites (and harzburgite). Secondly, whole-rock trace element compositions have been determined by both bulk solution ICP-MS analysis and reconstruction based on modes and clinopyroxene ion probe trace element analysis. Both methods give similar HREE abundances but the LREE are much higher in the bulk analyses. The reconstructed compositions have been modelled using Monte Carlo simulations to determine the best fitting residual melt porosity during melting. A porosity of about 2 percent fits the data best and a similar value is obtained by repeating this approach for published abyssal peridotite data.

V11E-0540 0830h POSTER

Helium Isotope Signatures of Peridotites and Basalts from Atlantis Bank, Indian Ocean

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Helium isotopic compositions have been measured in clinopyroxene separates from a suite of abyssal peridotites including a harzburgite, a websterite and 5 lherzolites, collected from Atlantis Bank during R/V Kairei KR00-06 cruise in 2000. The Atlantis Bank is an oceanic core complex, flanking the Atlantis II Fracture Zone at 57°E on the Southwest Indian Ridge (SWIR), Indian Ocean. Along the AII-Fracture Zone, a massive mantle section is exposed at 32°50'S, between 5000 and 3000 m water depth. The samples were selected from two ROV-Kaiko dive traverses: the uppermost section of Dive 173 and the entire length of Dive174 with intervals of several hundreds meters. Throughout the sample suite, the range of $^3He/^4He$ ratios overlap with that of MORB, falling between 7.9 and 8.5 R_A. In a plagioclase-free lherzolite 10K173R20, $^3He/^4He$ ratio was not determined due to a very low helium concentration ($5x10^{-10}cm^3STP/g$). With the exception of this helium depleted sample, ^4He concentrations vary from $3.0x10^{-8}$ to $6.5x10^{-7}cm^3STP/g$. Duplicate measurements of clinopyroxenes of lherzolite 10K173R23 show significant variation of ^4He content, exceeding a factor 4. Comparison of He released by crushing in vacuo with furnace melting of crushed powders (hereafter powder melting), shows that most of the helium was released by powder melting in the sample. This suggests that helium may not be contained in fluid inclusions, and that helium is heterogeneously distributed, e.g. dissolved in melt inclusions distributed throughout the clinopyroxenes. For comparison, two basalts were selected from neighboring localities. One came from the present-day spreading center; the other came from a ring volcano located on 1Ma seafloor to the south in the transform. Both areas were investigated by a manned submersible. Both glass samples have helium isotope signatures close to MORB: 8.69R_A. The glass from the south contains $3x10^{-5}cm^3STP/g$ of ^4He, a very high concentration that is almost equivalent to gas-rich 'popping rocks'. The helium isotopic differences between the basalts and the related peridotite/clinopyroxene separates are very small. We have found no evidence of the extreme low $^3He/^4He$ values (down to 6.2R_A) that were recently reported from the western region of SWIR (Georgen et al., 2003). These results indicate that an area of 'normal' helium isotope signature found around the Rodriguez T.J. and the SE Indian Ridge, with values > 8R_A, may extend at least as far as the AII Fracture Zone, in contrast to the low helium isotopic signature from 9°E to 25°E on the western SWIR.

V11E-0541 0830h POSTER

Igneous Petrology, Geochemistry and Geochronology of the Dongcaohe Ophiolite From the Qilian Fold Belt, NW China

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Abstract The Dongcaohe ophiolite, a nappe-type ophiolite, occurs as a fault-bounded block within a volcanic belt in the Tuo-Lai Mountains, southern margin of the north Qilian fold belt. Field works show that the Dongcaohe ophiolite is composed of an intrusive sequence and an extrusive sequence. The intrusive sequence in turn consists of a layered cumulate dunite-troctolite-anorthosite-gabbro series and an isotropic gabbro-norite-hornblende gabbro series. The extrusive sequence consists of hornblende diabase and hornblende basalt. The lithological and structural features show that the Dongacohe ophiolite is analogous to the lherzolitic ophiolite type (LOT) and to the present-day slow-spreading oceanic ridge. Petrographic textures show that the sequence of mineral crystallization of the plutonic mafic-ultramafic sequence of the Dongcaohe ophiolite is olivine-Cr-spinel-plagioclase-clinopyroxene-orthopyroxene-Fe-Ti oxide minerals, similar to that of tholeiitic magma crystallizing in an anhydrous and low-pressure chamber. The Cr-spinels which occur commonly in the layered dunite-troctolite-anorthosite-gabbro cumulate series frequently carry solid inclusions of anhydrous silicate minerals such as clinopyroxene and orthopyroxene, hydrous high-temperature silicate minerals such as Na-phlogopite and pargasite, hydrous low-temperature silicate minerals such as chlorite, serpentine, hydrogarnet, and analcite, Fe-Ti oxide minerals, and base-metal sulfides. The compositions of the hydroxyl-sodic phases (pargasite and Na-phlogopite), similar to those of the Oman ophiolite, suggest a subduction-related origin. The REE patterns of basaltic lavas show slightly depleted LREEs, identical to that of typical normal-type mid-ocean ridge basalt (N-MORB). Also the tectonomagmatic discriminating diagrams of Ti/V, Zr/Y-Y, Zr-Ti-Y, Nb-Zr-Y, and Hf-Th-Nb suggest that they have both N-MORB and IAT (island arc tholeiite) geochemical characteristics simultaneously, similar to the BABB (backarc basin basalt). Separated zircons from the isotropic gabbro were studied with SHRIMP, and a 15-points concordant age of 497.3±5.5 Ma was obtained. The Dongcaohe ophiolite is associated with the island arc tholeiite, boninite, and ocean island basalts which crop out nearby, implying that the volcanic belt of the Tuo-Lai Mountain is part of an oceanic lithosphere in a supra-subduction zone. The geological significance of the Dongcaohe ophiolite is that the southward subduction of the paleo-Qilian oceanic lithosphere did occur in lower Ordovician period and gave rise to a backarc oceanic lithosphere.

V11E-0542 0830h POSTER

Oceanic Basalts of the Paleo-Asian Ocean: Geochemistry and Structural Setting in Folded Zones of Altai and East Kazakhstan (Central Asia)

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Four periods of basaltic volcanism of the Paleo-Asian Ocean have been studied: 1) Vendian-Early Cambrian (Kurai zone); 2) Early-Middle Cambrian (Katun zone); 3) Late Cambrian-Early Ordovician (Zasurin Formation) and 4) Late Devonian-Early Carboniferous (Chara belt) ages. The studied entities are oceanic basalts incorporated in four Caledonian accretion-collision zones.The Early Cambrian collision of the Siberian continent and Gondwana-derived terranes formed the Kurai and Katun accretionary zones in Gorny Altai. The Late Cambrian-Early Ordovician collision of the Siberian continent and Gondwana-derived terranes formed shear zones comprising oceanic sediments and basalts (Zasurin Formation). The Late Devonian-Early Carboniferous collision of the Siberian and Kazakhstan continents formed the Chara shear belt including basaltic terranes (Buslov et al., 2001). Geochemical features of tholeiites, subalkaline and alkaline basalts incorporated in accretionary terranes illustrate the history of oceanic volcanism with OIB, OPB and MORB affinities. According to REE there are LREE-enriched, transitional and MORB/OPB-like samples. LREE vary and are considerably enriched (LaN (ppm) 25-65 for Kurai, 35-55 for Katun, 100-160 for Zasurin, and 35-105 for Chara OIB) relative to chondrites. HREE have much smaller ranges: 6 to 13 times that of chondrites for Kurai and Katun and 10 to 20 times for Zasurin and Chara. There is also a positive correlation between La/Yb and SiO2. In the multi-element diagrams Kurai samples display Sr enrichment relative to K, whereas Zasurin and Chara samples show negative Sr peaks. Except for the Katun wedge, most display moderate to strong Nb-Ta depletion suggesting fractionation of ilmenite and magnetite at the base of the crust or a previous melting episode in the source. For all groups of basalts, transitions between end members of basalts: from N-MORB, through E-MORB and T-MORB (OPB?) to OIB were found. Zr/Y and Sm/Nb ratios show two distinct linear trends suggesting two independent magma sources regardless of ages: near-constant Zr/Y=2-3 and Sm/Nb=1-1.5 probably represent MORB or OPB while Zr/Y=6 and Sm/Nb=5-6 represent OIB-type rocks. The oceanic metabasalts from those four areas display many common geochemical features. On one hand, they could have been melted at different degrees of partial melting and at different depths. On the other hand they could have melted from one mantle source, but then differently influenced and/or contaminated by the upper mantle, for example, a weakly depleted oceanic mantle could interact with upwelling plume melts. Thus, the fragments of oceanic crust from Gorny Altai, North-West Altai and East Kazakhstan comprise not only ophiolitic rock units, but also oceanic plateau and oceanic island units as important markers in reconstruction of the structure of foldbelts. It is concluded that intraplate volcanism was active in the Vendian to Early Carboniferous period of the evolution of the Paleo-Asian Ocean. The fragments of weakly to strongly differentiated oceanic basalts have been preserved in accretion-collision zones and their geochemical data indicate that the Altai and East Kazakhstan metabasalts could have been formed at mid-oceanic ridges, oceanic islands or oceanic plateaux of the Paleo-Asian Ocean in Vendian to Early Carboniferous times. This study was supported by RFBR grants no. 01-05-65228, 02-05-64627 and 03-05-64668.

V11E-0543 0830h POSTER

Evidence for transition from mid-oceanic ridge setting to supra-subduction zone setting in the lower crustal gabbroic sequence, Haylayn block, Oman ophiolite

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Origin of ophiolites has been a major focus of research over the past several decades, with most attention focusing on whether they form at mid-ocean ridges or above subduction zones. Oman ophiolite is well known as one of the greatest and the most complete ophiolites in the world, and occurrences of arc tholeiites, calc-alkaline rocks and boninites as well as MORB-type lavas have been reported. In the case of the lower crustal gabbroic sequence, however, clear identification of both arc- and mid-ocean ridge (MOR)- type gabbros has not been documented until now. In the Haylayn block of central part of the Oman ophiolite, we recognized two distinct magmatic suites from the lower gabbroic sequence. The earlier suite (GB1) consists of troctolites and olivine gabbros in the Layered Gabbro Sequence. The GB1 is characterized by MOR gabbro-type trend (Fo87: An93-Fo81: An83) in the plot of olivine (Fo) and plagioclase (An) compositions. On the other hand, the later suite (GB2) consists of olivine gabbros, olivine gabbronorites and gabbronorites from the Layered Gabbro Sequence and also from the upper Laminated Gabbronorite Sequence. The GB2 is characterized by more calcic plagioclase (Fo83: An91-Fo*72: An88, Fo* is calculated from Mg# of orthopyroxene in olivine-free gabbronorites) and clinopyroxene poorer in Ti and Na compared to those in the GB1. One of the most significant results of our new observations is that the GB2 completely continues in mineral composition to the ultramafic cumulate intrusives (dunites and wehrlites, DW; Fo92-83) within the lower portion of the Layered Gabbro Sequence. Calcic nature of the GB2 plagioclase and the crystallization sequence from the DW and the GB2 suggest that both the DW and the GB2 crystallized from a common hydrous magma. The isotopic compositions are consistent with those observations. The highest value of Fo from the DW is the same as the values from the harzburgites (Fo93-91) in the Mantle Sequence. These lines of evidence imply that the existence of the mantle-derived hydrous primary magma of the DW-GB2 suite rather than the injection of seawater from the roof of the magma chamber by hydrothermal circulation. On the contrary, the GB1 can be explained by crystallization from an essentially anhydrous magma. Since the GB2 constitutes the Layered Gabbro Sequence together with the GB1, very long time interval between the intrusions of the GB1 and the GB2 cannot be suggested.This transition probably resulted from the change from mid-ocean ridge setting to supra-subduction zone setting of the Oman ophiolite.

V11E-0544 0830h POSTER

Magnetization of upper mantle: Results from Oman Samail Ophiolite

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Based upon the new data on magnetization of upper lithosphere collected from sea floor and ophiolite, we present a new model for oceanic lithosphere magnetization. In our model, the thickness of each magnetic layer was assumed to be equal to that of a standard seismic model for oceanic crust: eg. 0.5km for layer 2A. However, the thickness of the upper mantle magnetic layer can not be obtained by the similar, simple assumption. To determine the thickness of magnetic layer of upper mantle, we studied magnetization of peridotites successively sampled from a series of outcrops exposed at the crust-mantle boundary section in Wadi al Hilti, Oman Ophiolite. The average NRM intensity calculated for 2km from crust-mantle boundary is 0.6 (+/-0.4) A/m, while that of the lower portion being 0.1 (+/-0.08) A/m, indicating that the effective thickness of the magnetic layer of the crust- mantle boundary/upper mantle section is about 2km: upper 2km portion from the crust-mantle boundary is much strongly magnetized than the lower portion. On the basis of this finding, together with the recent magnetization data from oceanic crust and upper mantle, we made a new magnetization model for upper oceanic lithosphere. The total oceanic lithosphere magnetization calculated from the new model is about 17,500 A, which can explain the MAGSAT magnetic anomalies over Pacific Cretaceous Quiet Zone. Our new model also explains the missing magnetization of upper oceanic lithosphere that has been a long standing problem in geophysics.

V11E-0545 0830h POSTER

Physical Properties of Gabbros and Serpentinized Peridotites at the MAR, 15°N. Shipboard Results from ODP Leg 209

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In May-July 2003, ODP Leg 209 recovered gabbroic rocks and serpentinized peridotites at several sites along the Mid-Atlantic Ridge, close to the 15°20' fracture zone. Gabbroic rocks are variously altered, generally evolved and oxide-rich. Peridotites and troctolites are strongly altered, and reveal various types and intensities of alteration. A series of physical properties were measured on board at ambient pressure and temperature, including bulk magnetic susceptibility, thermal conductivity, bulk and grain densities, porosity and compressional velocity. 235 values of thermal conductivity were measured on 92 samples, using the needle probe technique in the half-space mode. They are similar to values measured in gabbros and peridotites during previous ODP Legs. Gabbroic rocks and diabases range from 1.71 to 3.83 W/mK, with a mean of 2.16 W/mK. Serpentinized peridotites and troctolites range from 1.98 to 3.51 W/mK, with a mean of 2.64 W/mK, close to the serpentine and talc values. We measured an apparent anisotropy of the thermal conductivity by using different probe orientations on the split face of the half core. Estimated apparent anisotropies range from 0.06 to 12.60 %, with a mean of 3.92 %. In most samples, the thermal conductivity seems to be higher in the foliation plane. Bulk densities of gabbroic rocks and diabases range from 2.44 to 3.28 g/cm^3, with a mean of 3.00 g/cm^3. Such high densities reflect the abundance of oxides in many samples. In contrast, the densities of serpentinized peridotites and troctolites are very low, due to their strong alteration. They range from 2.26 to 2.90 g/cm^3, with a mean of 2.55 g/cm^3. Porosities

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are poorly constrained because of experimental limitations; they are high on average, in the order of 2 % for the gabbros, and 5 % for the peridotites. Except for one site, in which the late alteration is marked by abundant talc, the density of serpentinite samples is inversely correlated to their bulk magnetic susceptibility. The slope of the correlation is different at each site, and may be related to the type of hydrothermal alteration reactions. As expected in a highly altered environment, the P-wave velocities in serpentinized peridotites and troctolites are very low (2.82 to 5.14 km/s, with a mean of 3.88 km/s), and lower than in the gabbros and diabases (3.41 to 5.86 km/s, with a mean of 5.13 km/s). Most gabbros have slightly lower velocities than those sampled earlier at MARK (ODP Leg 153). Peridotites and troctolites are similar to those sampled earlier, or have lower densities and velocities. Our data are compared to seismic profiles (J.A. Collins
R.S. Detrick, pers. com.) in the same region, and to velocity-depth profiles calculated for gabbros and variously serpentinized peridotites. The in-situ velocities are lower than the velocities in completely serpentinized rocks, suggesting that the uppermost crust contains large-scale fractures. The seismic velocities near the seafloor are consistent with a composite crust, composed of serpentinized peridotites and altered gabbros.

V11E-0546 0830h POSTER

Shallow mantle and crustal structure beneath the Mid-Atlantic Ridge (35°N): melt supply and crustal construction

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P-waves recorded during wide-angle refraction experiments provide a measure of crustal thickness and the velocity structure of the crust and uppermost mantle along the Mid-Atlantic Ridge near 35N. We use 29,605 crustal refractions, 14,682 reflections from the base of the crust, and 9322 mantle refractions to generate a three-dimensional anisotropic P-wave image of sub-ridge structure that extends 60 km along the ridge, 50 km across the ridge, and to 10 km depth. These data were compiled from six separate two- and three-dimensional experiments which, taken together, include 49 ocean-bottom instruments and 5118 airgun shots. This section of the Mid-Atlantic Ridge is bounded to the north by the Oceanographer fracture zone and to the south by a non-transform offset and previous studies suggest that more melt is supplied to the center of the ridge segment than the ends. Shallow isotropic velocities are generally low in a band that parallels the ridge axis and this band is punctuated by a series of small, 10-km-long, low velocity anomalies of up to -1 km/s magnitude. The variability of shallow crustal structure suggests strong spatial and temporal variability of the melt supply to the shallow crust. In addition, in the shallow crust we detect a small amount of azimuthal anisotropy that indicates the presence of vertically aligned cracks that are oriented parallel to the strike of the ridge. Such cracks indicate that the shallow crust is experiencing tensional forces generated by plate spreading. At the center of the ridge segment, where a line of seamounts intersects the ridge, a 10x10 km^2 low-velocity region (-0.6-0.8 km/s magnitude) extends downward through the crust and into the mantle where it widens to 20x20 km^2 in width. The seismic image is consistent with a region of high temperatures and perhaps a small amount of melt and thus indicates the current magma supply system of the ridge. Although the aperture of our imaging does not extend completely to the segment ends, the crust is generally thinner towards the segment ends (5 km thick) and thicker at the center of the segment (8.5 km thick). Our results indicate that mantle-derived melts rising beneath this ridge segment are focused at mantle depths towards the center of the segment resulting in a thicker crust and a high-temperature, partial melt zone near the segment center. Within the median valley, a volcanic ridge runs northward from the segment center, but is not underlain by low velocities in the lower crust nor mantle. Thus, this ridge may be similar to an Hawaiian type rift zone, with magma fed to it laterally from the ridge segment's center instead of from directly below.

V11E-0547 0830h POSTER

The Lower Crustal Melt Distribution Within the East Pacific Rise, 9°30′N, from a Combined Study of Compressional-Wave Velocities and Seafloor Compliance Data

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Most of the melt within the fast-spreading East Pacific Rise (EPR) crust at 9-10°N sits within a 4-6 km wide and 2-4 km tall lower crustal partial melt zone detected by seismic and seafloor compliance studies. However, we do not know how much melt there is or how it is stored and/or transported, because different combinations of temperature, melt fraction, melt geometry and rock composition can have the same compressional-wave velocity. Whole-crustal compressional-wave velocity and seafloor compliance data have been collected and separately interpreted at 9°30′N on the EPR. The compressional-wave velocity data was interpreted to indicate up to between 10% and 38% melt in the lower crust, depending on the melt geometry and the importance of anelasticity [Dunn *et al.*, 2000], but this interpretation only takes into account a subset of the possible melt geometries and does not account for the sensitivity of melt generation to rock composition. We investigate the range of possible melt amounts and geometries by modeling as broad a range of melt geometries as possible and testing the effect of compositional and melt geometry variations with depth. We first determine the large model space fitting the compressional-wave velocity model of Dunn *et al.* [2000]. We then reduce this model space by comparing the low-frequency (0.01 Hz) shear modulus calculated for each model with the measured seafloor compliance. Seafloor compliance measurements are sensitive to the crustal shear modulus at frequencies between 0.003 and 0.03 Hz, and the relationship between this shear modulus and the compressional-wave velocity at seismic frequencies (10-15 Hz) depends on the rock composition, melt geometry and the importance of anisotropy. We present the new model space and discuss its implications for crustal accretion at the East Pacific Rise.

V11F MCC: 3008 Monday 1020h

Modern Trends in Petrography: Textural and Microanalysis of Igneous Rocks II

Presiding: **D A Jerram,** University of Durham**; J P Davidson,** University of Durham

V11F-01 1020h INVITED

Geochemical microanalysis: The link between textural and geochemical characterization of igneous rocks

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In this presentation I will review recent advances in microanalytical techniques that allow us to directly couple textural and geochemical information to the study of igneous rocks, particularly with respect to the analysis of silicate melt inclusions. Textural examination has long been a mainstay of the classification and petrologic study of igneous materials. The advent of the electron microprobe over 50 years ago allowed textural and geochemical observations to be coupled at small spatial scales and directly related to the physical and chemical conditions of formation and subsequent melt evolution. This resulted in a revolution in the petrological investigation and understanding of igneous rocks that continues today. Recent advances in geochemical microanalysis techniques are providing exciting access to new geochemical information at smaller and smaller spatial scales. These are enabling measurement of the abundances, and in some cases isotopic compositions, of a range of elements in correspondingly smaller sample volumes. A case in point is the study of silicate melt inclusions. Although melt inclusions have been recognized and studied for over a century, there has been a recent surge in interest directly tied to development of techniques capable of performing in-situ analysis of trace element and volatile components at small spatial scales. Melt inclusions allow direct sampling of melts present during crystal formation, and are particularly useful for relating crystal textures and compositions to those of their source melts. Chemical compositions of melt inclusions reveal the diversity of igneous compositions present in igneous systems, and may be combined with textural observations to constrain a wide range of igneous processes, including degassing, assimilation, fractional crystallization and mixing.

V11F-02 1035h

A multidisciplinary approach to understanding the origin of peridotite cumulates

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The key to understanding the origin of igneous cumulates is to determine the relative importance of the competing processes of cumulate formation. Crystal sedimentation and/or in-situ growth, compaction, porous media convection and textural equilibration may all contribute to the final textural and chemical configuration of the rock. Using an integrated approach encompassing quantitative textural analysis, geochemistry and relatively new electron backscatter diffraction (EBSD) techniques has allowed the nature and extent of postcumulus textural and chemical modifications to be quantified, and illustrates that the final rock texture still carries essential information concerning magma-chamber processes and the early evolution of the cumulate rock. Quantitative textural analysis has highlighted several distinct olivine morphologies within individual peridotite layers from the Rum Intrusion, Scotland, and has demonstrated that in-situ growth alone cannot account for the textural variation within the peridotites because transport of at least one crystal phase is required from elsewhere in the magma chamber. The combined use of quantitative textural analysis to determine shape preferred orientations (SPOs) and EBSD to determine crystallographic preferred orientations (CPOs) has shown that the SPO and CPO for each peridotite layer are essentially in agreement. This, together with the presence of mixed olivine morphologies within a single rock, indicates that significant postcumulus recrystalization cannot have taken place and furthermore compaction by pressure solution is unlikely to have occurred to any significant extent. Whole-rock geochemical analysis of several of these peridotite layers has highlighted positive Sr- and Eu- anomalies but no textural evidence for cumulus plagioclase, suggesting that interstitial plagioclase grew when melt was able to move through the crystal framework. However, in-situ ion microprobe analyses have shown that interstitial clinopyroxene formed from the final trapped melt fraction. This final melt fraction was heterogeneously distributed throughout the rock in a manner ultimately governed by the packing arrangement of the crystals which is itself controlled by primary magma chamber processes such as crystal transport.

V11F-03 1050h

A History of one Olivine Crystal: Microsampling Melt Inclusions by Wire Saw

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Melt inclusions record magma composition, magma volatiles and magma depth (from volatile saturation pressures), but multiple melt inclusions are difficult to study within a single crystal. Often the sample geometry and preparation requirements (e.g. FTIR wafer) limit sampling density to one melt inclusion per crystal. Thus suites of crystals are studied but the relationship between multiple crystals and their melt inclusions