syenite body yielded a U-Pb age of 1673 +/- 23 Ma, which is most likely the time of pluton emplacement. Concordant ages were also discovered from microprobe analysis of monazite grains. Hornblende separates produced 40Ar/39Ar plateau cooling ages of 1623 +/- 2 Ma for the syenite and 1657 +/- 5 Ma for the host amphibolite. K-feldspar from the syenite and field relations indicate the SC cooled to <100*C at around 750 Ma, which is near the age of the great unconformity between the SC and the overlying Big Cottonwood Formation. Reheating to 325 +/- 30*C occurred from around 400-250 Ma. This event was most likely caused by burial of up to 12 km of sedimentary successions during passive margin and Oquirrh Basin development. The feldspar cooled to its closure temperature (200*C) at around 100-200 Ma, which was a time of wide spread basin inversion associated with Cordilleran contractional events. Apatite fission track analysis indicates rapid exhumation around 5-7 Ma, which is associated with activity along a segment boundary of the Wasatch Fault. Field mapping and structural analysis show the SC is internally layered parallel to the most penetrative foliation, which was produced by mostly pure shear and is sub-parallel to the overlying great unconformity.

T31F MC: 310 Wednesday 0830h

Processes Within the Subduction Factory: The Mantle Wedge *(joint with OS, S, V, DI, MR)*

Presiding: **R J Stern,** University of Texas at Dallas**; S Schwartz,** UC Santa Cruz

T31F-01 0830h

The Geoid-Topography Paradox in Multiscale Dynamic Models of Subduction Zones

Magali I. Billen[1] ((626) 395-3382; magali@gps.caltech.edu)

Michael Gurnis[1] ((626) 395-6979; gurnis@gps.caltech.edu)

[1]California Institute of Technology, Seismological Laboratory, MC 252-21, Pasadena, CA 91125, United States

Regional 3-D dynamic models of the Tonga-Kermadec and Aleutian subduction zones are used to constrain lateral variations in viscosity in the upper mantle. The overriding plate of the Tonga-Kermadec subduction zone is characterized by active island-arc volcanism and back-arc spreading, shallow bathymetry, and large positive geoid anomalies (ΔN) on lengthscales of 100–2000 km (regional variations of ΔN=10–50 m). The overriding plate of the central portion (170–200° longitude) of the Aleutians has an active island-arc system but no back-arc spreading, deep bathymetry and only moderate geoid anomalies (regional variations of ΔN=10–25 m). Dynamic models include age variations of the lithosphere, crustal thickness variations associated with active and remnant arcs and slab density due to thermal anomalies based on a kinematic model of subduction. Modeling the dynamic topography of the overriding plate for the Tonga-Kermadec subduction zone requires a low viscosity wedge above the slab to decouple the flow of the slab from the surface and a region of low density material ($\delta\rho$=20 kg/m^3) coincident with the low viscosity region. While these efforts lead to a good fit of the observed bathymetry for a slab with a density anomaly of ∼0.08 g/cm^3, consistent with the density anomaly for old lithosphere due to temperature, the geoid above the subduction zone is too large by 20–40 m at lengthscales of 100–1000 km. A reduction of the slab density by a factor of 2 is needed to match both the geoid and topography, suggesting the density anomaly of the slab due to temperature is compensated within the upper mantle (∼100–300 km). Similar modeling for the Aleutians, including a low viscosity wedge but no low density region in the wedge, is able to fit the geoid and topography without reducing the slab density. The differing results for these two regions may reflect differences in the history of subduction including subduction rates, age of the lithosphere, influences of back-arc spreading, dewatering of the slab and melting in the wedge.

T31F-02 0845h

High Field Strength Element Indicators of Temperature at the Subducted Slab - Mantle Wedge Interface

Julian A. Pearce[1] (PearceJA@cardiff.ac.uk)

J. Huw Davies[1] (daviesjh2@cardiff.ac.uk)

Pamela D. Kempton[2] (p.kempton@nigl.nerc.ac.uk)

[1]Dept. Earth Sciences, Cardiff University, P.O.Box 914, Park Place, Cardiff CF1 3YE, United Kingdom

[2]Isotope Geosciences Laboratory, British Geological Survey, Keyworth, Nottingham NG12 5GG, United Kingdom

The temperatures of the subducted slab - mantle wedge interfaces of the various subduction systems at depths relevant to magma genesis are still open to debate. One difficulty is that geochemical (observation and experiment) and thermal modelling indicators often give divergent results. There is consensus that, during ridge subduction, temperatures are high enough for both subducted sediments and oceanic crust to melt. It is also, therefore implicit that, for "cooler" subduction systems, there must be a range of conditions over which sediments melt while crust dehydrates. Many geochemical indicators suggest that this must always be the case and hence that temperatures of over 650C must always be reached: for example, experiments suggest that Th is immobile in aqueous fluids but mobile in melts, while Th is enriched in every known volcanic arc. Thermal models for the "coolest" subduction systems, on the other hand, give slab geotherms that fail to cross even the water-saturated melting curves of pelagic sediments without incorporating large, and probably unattainable, degrees of shear heating. Our own contribution to this debate is the use of Hf and Zr elemental concentrations, and Hf isotope ratios, as indicators of slab temperature. Experiment shows that the Zr, and hence Hf, content of the subduction component is dependent on zircon solubility, which increases mainly as a quantifiable function of temperature and produces detectable levels in arc magmas only above the solidus. In "hot" subduction systems, Zr and Hf are both clearly enriched in arc magmas, consistent with their transfer from the slab in a high temperature melt. In "cool" systems, however, there may be no perceptible enrichment in these elements and this is further emphasised by no or little shift in Hf isotope ratio toward subducted sediment compositions. Our latest results from the "cool" Tonga-Kermadec system (characterised by ultra-rapid to rapid subduction of volcanogenic-pelagic sediments of 110-140m.y. age beneath a hot wedge) further support this conclusion. Within each major component of the system (Northern arc, main Tofua arc, Kermadec arc, East-to-Central Lau spreading centre), Zr and Hf abundances are typically low relative to known mobile elements while Hf isotope ratios, unlike Sr, Pb and Nd isotope ratios, show no significant dispersion toward Pacific volcanogenic or pelagic sediment. Our high-field strength element data from the Tonga system therefore indicate that, if there is any sediment melting at all, it must take place at temperatures low enough that Zr and Hf transport is undetectable. This result places limitations both on geochemical models for slab-to-wedge fluxes and on the contribution of shear heating at the slab-wedge interface.

T31F-03 0900h

Temporal Evolution of the Mantle Wedge in the SW Pacific: Hf-Nd-Pb Isotopes

J. B. Gill[1] (831-459-3842; jgill@es.ucsc.edu)

P. D. Kempton[2]

J. A. Pearce[3]

[1]Dept. Earth Sciences, UCSC, Santa Cruz, CA 95064, United States

[2]NERC, Isotope Geosciences Laboratory, Keyworth NG12 5GG, United Kingdom

[3]Dept. Earth Sciences, Cardiff University, Cardiff CF10 3YE, United Kingdom

The primary source of melt in the subduction factory is variably depleted MORB-source mantle to which some elements are added from the subducting slab. Hf-Nd and Pb isotopes can be used to distinguish Pacific from Indian MORB sources, and this distinction can be used to trace the evolution of the mantle wedge if correction is made for slab additions. This has been done for Late Eocene to Quaternary volcanic rocks from Fiji which accompanied subduction of the Pacific beneath the Indian Plate at the Vitiaz Arc Pb, Nd, and Hf all were mobile during subduction. After correction, both Hf-Nd and 208Pb/204Pb isotopes lay on the discriminant boundary between Indian and Pacific MORB sources from arc inception until dismemberment in the late Miocene when the Ontong Java Plateau collided with the arc, causing reversal of subduction polarity. Notably, the mantle wedge did not change during opening of the South Fiji (backarc) Basin. Tonga and Lau are slightly more Pacific-like than western Fiji. After arc reversal, enriched mantle with high-HFSE contents and "Indian"-like Hf-Nd-Pb isotopes entered the mantle wedge from the north. Therefore, the mantle wedge beneath the easternmost edge of the Indian Plate remained "Pacific"-like in isotopic character until the spatial continuity of suduction was interupted.

T31F-04 0915h

The HFSE budget of arc magmas: new models from Hf isotopes and isotope dilution measurements of Nb/Ta, Zr/Hf and Lu/Hf in Kamchatka arc rocks

Carsten Münker[1] (++49-251-8333401; muenker@nwz.uni-muenster.de)

Gerhard Wörner[2]

Tanya Churikova[3]

Klaus Mezger[1]

[1]Institut für Mineralogie, Correnssstr. 24, Münster 48149, Germany

[2]Geowissenschaftliches Zentrum der Universitt Göttingen GZG), Abt. Geochemie, Goldschmidtstr. 1, Göttingen 37077, Germany

[3]Institute of Volcanology and Geochemistry, Piip Avenue 9, Petropavlowsk, Russian Federation

There is still no consensus as to whether the HFSE depletion in subduction rocks is caused by the immobile behaviour of these elements during slab dehydration or by the presence of residual accessory phases in the magma sources. To assess this problem, we analysed Nb/Ta, Zr/Hf and Lu/Hf by isotope dilution, together with Hf isotopes, in arc rocks from Kamchatka. Using a mixed ^{180}Ta-^{94}Zr-^{180}Hf-^{176}Lu tracer and the MC-ICPMS in Mnster, we are able to achieve external precisions and accuracies of ±0.5 to ±1% for Lu/Hf and Zr/Hf and of ±5% for Nb/Ta (2σ uncertainties). In contrast to older techniques (e.g. quadropole ICPMS), this analytical protocol results in a nearly 10-fold improvement in analytical resolution.

The investigated suite of Kamchatka arc rocks comprises a cross-arc transect at 56° (element budget largely controlled by variable fluid flux into the subarc mantle, Dohrendorf et al. 2000) and a suite from volcanoes in the Northern Central Kamchatka depression (NCKD, largely controlled by slab melts, Yogodzinski et al. 2001). Coupled Hf-Nd isotope variations (ϵHf = 12-18, ϵNd = 6-10) in all samples from the central Kamchatka depression (CKD) and from the back-arc suggest mixing between an OIB source and a MORB source in the wedge. However, samples from the arc front are slightly displaced from the Hf-Nd array towards less radiogenic Nd, indicating selective addition of minor sediment derived Nd to the mantle wedge by fluids high in Nd/Hf. The Zr/Hf (30-42) in all arc rocks are anti-correlated with Lu/Hf (^{176}Lu/^{177}Hf= 0.01-0.03), suggesting that the budget of Zr and Hf is controlled by the degree of mantle depletion rather than by the slab component. NCKD samples are slightly offset from the southern array towards lower Lu/Hf-Zr/Hf, suggesting that Zr-Hf is controlled by slab melts. The back-arc samples show superchondritic Zr/Hf (>35), consistent with the presence of an OIB source component (typical Zr/Hf>35) in their source.

Nb/Ta in the Kamchatka rocks range from 11-18 and are decoupled from Zr/Hf and Lu/Hf. The samples from the arc front show an increase in Nb/Ta with Sr/Nd and Ba/Th, indicating that the Nb-Ta budget in these samples is controlled by fluids derived from the subducted slab. Samples from the NCKD (slab melt controlled) overlap in their Nb/Ta and Zr/Hf with samples from the CKD further south (fluid controlled). Such overlapping HFSE patterns, similar in range to MORB, suggest that accessory phases in the slab, if present, can only cause minor Zr/Hf and Nb/Ta fractionation in the subarc fluids or melts.

References Dorendorf, F., Wiechert, U. and Worner, G. (2000): Earth and Planetary Science Letters 175: 69-86. Yogodzinski, G.M., Lees, J.M., Churikova, T., Dorenforf, F., Worner, G., and Volynets, O.N., (2000): Nature 409, 500-504.

T31F-05 0930h

Vapor-Saturated Melting of Fertile Peridotite Revisited: A new Experimental Approach and Re-evaluation of the Hydrous Peridotite Solidus

Timothy L Grove ((617)253-2878; tlgrove@mit.edu)

Timothy L. Grove, Massachusetts Institute of Technology 54-1220, Cambridge, MA 02139, United States

The vapor-saturated melting relations of peridotite have been determined for a fertile mantle composition of Hart and Zindler (1986, Chem Geol 57: 247) over the pressure range of 1.2 to 2.4 GPa. For example, at 1.2 GPa melt is present at a temperature of 980° C and at 2.4 GPa melt is present at 920° C. These temperatures should be viewed as maximum values for the vapor-saturated solidus (although see below) because the initial melting temperature of multiphase, multicomponent systems can often be difficult to detect. At 2.4 GPa the melt composition is highly silica-undersaturated and very aluminous (∼ 21 wt. %

T

Al_2O_3). Wet mantle melts are thought to be high in silica, but this is not the case for these hydrous melts. At 1.2 GPa, melt fractions are too small to allow reliable analysis.

The experiments have been carried out in a piston cylinder apparatus using Au capsules. The starting material is an oxide mixture containing 14.5 wt. % H_2O added as brucite. Free water present in the experiment after quenching indicates subsolidus conditions. The absence of fluid in experiments above the vapor-saturated solidus shows that all of the free H_2O is dissolved in the melt. The high H_2O content of the starting material moves the bulk composition close to the vapor-saturated melt composition, therefore increasing the amount of melt produced close to the solidus and making detection of low melt fraction possible. Studies of the hydrous peridotite solidus carried out between 1970 and 1975 by Mysen and Boettcher, Kushiro and others, Green and Millhollen and others at 2.0 GPa ranged from < 800 to $\sim 1000^{\circ}$ C, a variation of over 200 degrees.

In a subduction zone environment a fluid-rich component released from the slab ascends into hotter overlying mantle and melting initiates at the vapor-saturated solidus. Melting would begin at a depth of ~ 75 km in the mantle wedge, for a realistic thermal structure. Melting would continue as these initial H_2O-rich buoyant melts ascend into hotter, shallower mantle and re-equilibrate with their surroundings. The initiation of melting deep in the mantle wedge has implications for both chemical and mechanical processes in the subduction zone environment.

T31F-06 1005h

Numerical Models of Decompression Melting at Volcanic Arcs

James A Conder[1] (314-935-7965; conder@seismo.wustl.edu)

Douglas A Wiens[1] (314-935-6517; doug@kermadec.wustl.edu)

[1]Washington University, Dept of Earth and Planetary Sciences Campus Box 1169, St. Louis, MO 63130, United States

Petrological studies suggest that some decompression melting occurs in volcanic arcs. Although decompression melting clearly occurs in a mid-ocean ridge environment, it seems contradictory to observe decompression melting in the cold, downwelling environment of a subducting slab. We use a 2-D numerical viscous flow model, patterned after the Tonga Subduction Zone, to explain the production of decompression melting beneath volcanic arcs. Key to the creation of decompression melting in volcanic arcs is coupling of the subducting slab to the viscous mantle beneath the seismogenic zone and decoupling of the slab from the overriding plate within the seismogenic zone. Because the slab is coupled to the viscous mantle beneath the seismogenic zone, the down going slab entrains the high-viscosity base of the overlying lithosphere, thinning the plate. As the overlying plate is thinned, hot, low-viscosity asthenosphere is drawn upwards to fill in the gap beneath the overlying plate, triggering decompression melting in the mantle wedge. A cold upper corner develops in the forearc because the slab is decoupled from the brittle overlying plate, and remains cold because of its proximity to both the surface and the coldest portion of the subducting slab. The cold corner inhibits melting from occurring where the slab is shallow, possibly governing the spacing between the trench and the volcanic front. The cold corner is also consistent with observed seismic attenuation and heat flow at arcs. Because this decompression melting may be shallower than much of the melting from hydration of the wedge, decompression melting may govern the pathways of melt extraction from the mantle.

T31F-07 1020h

Hot Fingers in the Mantle Wedge: New Insights Into Magma Genesis in Subduction Zone

Yoshihiko Tamura[1] (81-468-67-3969; tamuray@jamstec.go.jp)

Yoshiyuki Tatsumi[1] (tatsumi@jamstec.go.jp)

Dapeng Zhao[2] (zhao@sci.ehime-u.ac.jp)

Yukari Kido[1] (kidoy@jamstec.go.jp)

Hiroshi Shukuno[1] (shukuno@jamstec.go.jp)

[1]IFREE, JAMSTEC, Yokosuka 237-0061, Japan

[2]Geodynamics Research Center, Ehime University, Matsuyama 790-8577, Japan

The mechanism of mantle melting at convergent plate boundaries is generally thought to be twofold. On one hand, fluxing of fluids released from the subducted slab into the mantle wedge lowers the mantle solidus, facilitating magma generation and volcanism at the surface. In addition, the descent of the plate stirs up the mantle, bringing upward a current of warmer mantle material from the depth, again resulting in magma generation where temperature for attainment of melting are achieved. These processes are often discussed by using two-dimensional model cross section of a convergent margin. Apparently, however, the third dimension, along-strike length, is necessary to understand the actual production of magmas. The specific distribution of arc volcanoes along convergent plate boundaries may provide insights into such three-dimensional dynamic processes occurring in the mantle wedge below the arc.

Quaternary volcanoes in the Northeast Japan arc can be grouped into 10 volcanic clusters striking transverse to the arc; these have an average width of 50 km, which are separated by parallel gaps > 30 km wide. This clustering of volcanic centers, topographic profiles, low-velocity regions in the mantle wedge and local negative Bouguer gravity anomalies along the rear of the volcanic arc are closely correlated. All these observations may be related to locally developed hot regions within the mantle wedge that have the form of inclined, 50 km-wide fingers. Each of the 10 fingers recognized extends from deep mantle (> 150 km) below the back-arc region towards the shallower mantle ($\sim$50 km) beneath the volcanic front. Quaternary volcanoes are built immediately above the hot mantle fingers. Volcanic basements are uplifted by repeated injection of magmas into the crust, accompanied by Quaternary volcanic activity on the surface. Although volcanic activity is rare along the Japan Sea coast, the hot mantle fingers exist within the mantle wedge as evidenced by tomographic results. The negative Bouguer anomalies at the rear of the volcanic arc could be caused by magmas supplied from the hot mantle fingers, which have not yet been erupted, but have accumulated at the Moho discontinuity.

T31F-08 1035h INVITED

Convection in the Wedge: Constraints From the Aleutian Arc

Peter B Kelemen[1] (peterk@whoi.edu)

Gene Yogodzinski[2] (gyogodzin@geol.sc.edu)

[1]WHOI, Woods Hole, MA 02543, United States

[2]Univ South Carolina, Columbia, SC 29208, United States

Lavas in the western Aleutian arc carry clear trace element signatures of a component derived via partial melting of subducted basalt in eclogite facies, but have Mg/Fe and Ni as high as primitive melts of mantle peridotite. These probably form via reaction between eclogite melt and overlying mantle (Kay, 1978; Yogodzinski & Kelemen, 1998). Lavas in the central and eastern Aleutian arc have high Th and radiogenic Pb isotopes. These probably include a component derived via partial melting of subducted sediment (Plank & Langmuir, 1993, 1998; Class et al., 2000). Thus, the entire Aleutian subduction zone is hot enough for partial melting of subducted material, despite variations in down dip subduction velocity from 75 to < 40 mm/yr, and a nearly constant age of 50 to 60 Ma for subducting oceanic crust. In contrast, thermal models for the Aleutians predict temperatures of 300 to 500 C for subducted sediment and basalt.

Four additional lines of evidence suggest that extant thermal models systematically underestimate temperatures, and overestimate mantle viscosities, beneath arcs.

(1) Estimated conditions of equilibration between primitive arc lavas and mantle peridotite are 1300 to 1350°C and 1 to 1.5 GPa in both the Cascades and NE Japan (Elkins et al., 2001; Gaetani & Grove, 2001; Sisson & Bronto, 1998; Tatsumi et al., 1983). In contrast, all arc thermal models predict temperatures less than 1300°C at depths less than 75 km.

(2) A sharp transition from high to low heat flow near the arc front (about 0.003 mW/m^3; Blackwell et al., 1982; Honda and Uyeda, 1983), requires a sharp transition from high temperatures in the uppermost mantle immediately beneath the arc to low temperature, static mantle beneath the forearc. Even the thermal models of Furukawa (1993), designed to fit the heat flow data, do not yield such steep heat flow gradients.

(3) Seismic tomography for NE Japan and Tonga reveals a 4 to 6% P-wave velocity anomaly in the uppermost mantle, immediately beneath the arc crust, which is continuous along the strike of the arc (Zhao and co-workers, 1992-97). 4 to 6% Vp anomalies beneath the East Pacific Rise relfect the presence of melt in mantle peridotite at temperatures greater than 1300VC (Forsyth et al., 1998). The regionally extensive nature of the Vp anomaly suggests melt is present at steady-state in the uppermost mantle beneath arcs.

(4) Viscous coupling between the mantle wedge and the subducting plate should produce a Bouger gravity low over arcs (Zhong and Gurnis, 1992), whereas no systematic variation is observed in the Bouger gravity signal over arcs. This discrepancy can be resolved if the mantle wedge has a lower viscosity, permitting mechanical decoupling between the wedge and the subducting plate (Billen and Gurnis, 2001).

Thermal convection in the wedge exceeding the rate of subduction can resolve the discrepancies between thermal models and observations. Convective velocities can be estimated using simple scaling from boundary layer theory (Turcotte and Schubert, 1982, equations 6-338 and 6-306) with a characteristic length scale of 200 km for the wedge and a temperature contrast of 1000 K. Convective velocities might exceed subduction velocities for wedge viscosity $< 10^{20}$ Pa s, and might be 10x $>$ than subduction velocities for viscosity $<$ 5 10^{18} Pa s. Such viscosities are within the range measured in olivine that includes substantial dissolved hydrogen, and in partially molten peridotite (Hirth and Kohlstedt, 1995, 1996; Kohlstedt et al., 1996; Mei and Kohlstedt, 2000). To date, no dynamic model of a subduction zone has incorporated such low viscosities.

T31F-09 1050h INVITED

Implications of Subduction Zone Anisotropy for Mantle Wedge Flow, Melt and Volatiles

Karen M. Fischer (401-863-1360; karen_fischer@brown.edu)

Department of Geological Sciences, Brown University, Providence, RI 02912, United States

Seismic anisotropy in subduction zones has the potential to constrain patterns of mantle flow and the distribution of melt and volatiles, both of which are key to understanding melting processes beneath arcs. In many subduction zones, the amount of shear-wave splitting in phases from local earthquakes increases with source depth, indicating that anisotropy exists within the mantle wedge and that the splitting cannot be explained solely by deformation in the upper plate. At back-arc stations, the fast directions of anisotropy inferred from shear-wave splitting show strong variations between subduction zones. For instance, in the Tonga back-arc, fast directions are roughly parallel to the azimuth of subducting plate motion, while in the southern Kurils, fast directions lie parallel to a back-arc strike-slip shear zone. In both cases, the observed anisotropy may be modeled by lattice preferred orientation of olivine in simple flow models driven by coupling to observed three-dimensional plate motions, assuming that olivine a-axes align with flow direction or maximum finite extension. At stations located within arcs, the implications of observed shear-wave splitting are more ambiguous. In most arcs, including Tonga, shear-wave splitting observations reveal anisotropy with a fast direction parallel to the arc. However, fast directions in the Izu and Mariana arcs are exceptions to this rule and lie roughly normal to the arc, closer to the directions of subducting and upper plate motions. Hypotheses for the origin of the arc-parallel fast directions include arc-parallel flow with arc-parallel olivine a-axes, arc-normal flow with arc-parallel a-axes due to high olivine volatile content (as proposed by Hung and Karato), or arc-parallel sheets of melt. However, the last two hypotheses would also predict arc-parallel fast directions in Izu and the Marianas, contrary to observed splitting. No obvious petrologic evidence demonstrates that the Tonga mantle is wetter on average than the Mariana or Izu mantles, and if melt sheets were present beneath the Izu and Mariana arcs, stresses caused by observed plate motions would tend to align them in an arc-parallel direction, although possible complications exist in Izu due to its proximity to a triple junction. Contamination of splitting observations at arc stations from slab anisotropy is being assessed. At present, variations in the direction of wedge flow beneath the arc (for instance, roughly arc-normal flow in Izu and the Marianas versus arc-parallel flow in Tonga) remain a viable explanation for observed shear-wave splitting.

T31F-10 1105h

Deformation Enhanced Fluid Focusing in Mantle Wedge

Saswata Majumder[1] (612-626-0572; saswata@olivine.geology.umn.edu)

David L kohlstedt[1] (612-626-1544; dlkohl@umn.edu)

[1]Univ of Minnesota, Dept Geolog Geophysics, 108 Pillsbury Hall, Minneapolis, MN 55455, United States

In this presentation, we describe the results of deformation at high temperature and pressure on the distribution of initially isolated pockets of pore fluid in rocks of mantle compositions. Deformation of the solid matrix in a low-porosity, solid-fluid aggregate alters the distribution of the pore fluid from that stable under a hydrostatic state of stress. In systems with a low fluid fraction, the pore fluid occupies grain corners, edges and/or boundaries depending on the wetting behavior of the solid-fluid system. Non-wetting fluids form isolated pockets at grain corners as well as along grain edges and boundaries, while wetting fluids form interconnected networks via fluid-filled tubules along grain

edges. Although the shape of an isolated non-wetting fluid-filled pore is not affected by deformation, the geometry of an initially random distribution of pores is substantially changed. To explore this phenomenon, deformation experiments were performed in a Paterson gas-medium apparatus on samples of olivine + aqueous fluid and diopside + aqueous fluid. In sheared samples, pore fluid is segregated into planar regions of high fluid fraction, which in 2D we refer to as 'bands of pore fluid. The bands form at an angle of 20° to the shear direction and in a sense antithetic to the shear. The degree of interconnection of pores within bands depends on the wetting behavior of the solid-fluid system and on the extent of deformation of the solid matrix. The permeability of the system to porous flow will be highly anisotropic under such conditions. Porous flow of fluid perpendicular to the length of the bands will be limited by flow in the relatively fluid-free regions between the bands. Porous flow parallel to the bands will be limited by grain size for non-wetting fluids and by channel dimensions for wetting fluids. In subduction zones, the subducting slab releases aqueous fluids upon devolatilization of hydrous minerals. Corner flow in the mantle wedge will focus the free aqueous fluid into linear bands. Thus, porous flow of the free aqueous fluid through the mantle wedge to the melting source region can take place along highly anisotropic, high-permeability paths.

T31F-11 1120h

The Role of Flux Melting on U-series Systematics of Young Lavas from Costa Rica and Nicaragua

Rebecca B. Thomas[1] (612-624-9598; thom0904@tc.umn.edu)

Marc M. Hirschmann[1] (hirsc022@tc.umn.edu)

Mark K. Reagan[2] (mark-reagan@uiowa.edu)

Hai Cheng[1] (cheng021@tc.umn.edu)

R. Lawrence Edwards[1] (edwar001@tc.umn.edu)

[1]Dept. of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455, United States

[2]Dept. of Geosciences, University of Iowa, Iowa City, IA 52242, United States

We have acquired U, Th and Pa isotope data for young lavas that derive from source regions affected by slab fluid addition that ranges in magnitude from minor beneath Costa Rica to substantial beneath Nicaragua. Four of the five Costa Rican samples have (^{231}Pa/^{235}U) and (^{230}Th/^{238}U)>1; five out of six Nicaraguan lavas have (^{230}Th/^{238}U)<1 and (^{231}Pa/^{235}U)>1, but (^{231}Pa/^{235}U) ranges to lower values in Nicaragua. On a (^{231}Pa/^{235}U) vs. (^{230}Th/^{238}U) diagram, the data, though limited in number, seem to define two trends with decreasing (^{230}Th/^{238}U), one with a slope of ~2.5 and the other with a slope of ~0.7. Trace element ratios indicate that the latter were affected more by addition of hemipelagic sediment, suggesting a link between subduction-fluid source and Pa-Th-U systematics.

The combined ^{231}Pa-^{235}U and ^{232}Th-^{238}U-^{230}Th data provide constraints on the timing and mechanisms of fluid addition and partial melting beneath the Central American arc. Significant (^{231}Pa/^{235}U) excesses (>1.5) in both Costa Rica and Nicaragua require a melting process that allows for ingrowth, as simple batch or fractional melting cannot explain the excesses at melt fractions large enough to explain trace element abundances and ratios. We propose a flux-ingrowth melting model in which the mantle wedge flows downward with the subducting slab and partially melts as fluid is added to regions with suitably hot temperature. We assume critical melting at low porosity ($\sim 10^{-3}$) and that melt extraction and transport are rapid enough (< 8 kyr) to preserve observed ^{226}Ra excesses. Because solid mantle may traverse the melting region over 10^5-10^6 yrs., ^{231}Pa and ^{230}Th ingrow from U retained in the matrix. Magmas are aggregated instantaneously from all parts of the melting regime.

This flux-ingrowth model matches a wide range of U-series and trace element data from Costa Rican and Nicaraguan lavas, with required average extents of melting of ~1% and 8-10%, respectively. Integration of melts from regions that have experienced extensive fluid addition, partial melting and U-daughter ingrowth with those from incipiently fluxed and melted regions yields liquids with elevated (^{231}Pa/^{235}U) even after extensive fluid addition. The model produces linear arrays on Th isotope equiline plots which resemble isochrons, but which have no age significance. Upwelling and/or extensive melt-rock reaction is not required by U-series data from Central America or other arcs. Finally, the flux-ingrowth model is broadly consistent with substantial ^{226}Ra excesses in Nicaragua without requiring the action of a distinct late slab fluid.

T31F-12 1135h

New constraints on element transfer rates beneath the Tonga-Kermadec arc from combined U-Th-Ra, U-Pa and Be isotope data

Simon Turner[1] (+44 117 954 5440; simon.turner@bris.ac.uk)

Chris Hawkesworth[1] (+44 117 9545425; c.j.hawkesworth@bris.ac.uk)

Rhiannon George[1] (+44 117 954 5247; r.m.george@bris.ac.uk)

Julie Morris[2] (314 9356926; jmorris@levee.wustl.edu)

Bernard Bourdon[3] (331 44272461; bourdon@ipgp.jussieu.fr)

[1]Department of Earth Sciences, University of Bristol , Bristol Bs8 1RJ, United Kingdom

[2]Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130, United States

[3]Laboratoire de Gochimie et Cosmochimie, IPGP, 4, Place Jussieu, 75252, Paris Cedex 05, France

The intra-oceanic Tonga-Kermadec island arc has formed by westward subduction of Pacific oceanic lithosphere beneath the Australian plate. The arc volcanoes are located 110 km above the surface of the subducting plate and typically erupt basaltic-andesites and andesites with subordinate volumes of dacites and rhyolites. Active back arc spreading has formed the Lau Basin and Havre Trough behind the arc and resulted in the mantle wedge beneath the arc becoming highly depleted. This arc has been the focus of much interest because the depleted nature of the mantle wedge renders it highly sensitive to additions from the subducting plate. In common with many other island arcs, trace element and isotope data can be used to identify separate fluid and sediment contributions to the source of the erupted lavas and we have analysed U-Th-Ra, U-Pa and Be isotopes in order to place constraints on the time scales and physical processes involved in generating the Tonga-Kermadec lavas. Recognition of a Louisville volcaniclastic sediment contribution to the northern-most Tonga lavas has been used to estimate that addition of the sediment component may have occurred as long as 2-4 Myr ago. New Be isotope data show that Be isotope ratios range from 1-10 in the lavas but that the subducting sediments have quite low 10Be contents. Combined with the condensed sediment section this requires that almost the entire sediment section is subducted and that Be recycling into the arc lavas is 30% efficient. The largest Be isotope ratios are found in those lavas which also exhibit the largest U- and Ra-excesses which suggests that Be is stripped from the sediment pile and transported into the magma generation zone by fluids released from the underlying altered oceanic crust. This is consistent with recent fluid-mineral partitioning data and means that Be cannot be used to infer the sediment transfer time. Ra-Th activity ratios range from 1 up to 6.2, and the largest Ra-excesses occur in the most depleted rocks which also have the highest Ba/Th ratios indicating that the Ra-excesses also result from fluid addition. These disequilibria must have been formed within the last few 1000 years, however the U-Th and Pa-U data from Tonga both indicate U addition occurred 60 000 years ago. A simplified two-stage dehydration model has been developed to reconcile these data. Unlike U, Ra lost to the mantle wedge during initial dehydration is replenished in the subducting altered oceanic crust by in-growth from residual Th. Whereas the U budget was dominated by the first fluid flux, the Ra-excesses record the addition of fluid to the mantle wedge probably less than 1000 years ago. The large Ra-excesses in the primitive lavas place tight constraints on the time permitted for melt generation, segregation and ascent. However, Pa is enriched relative to U in the Kermadec lavas indicating that partial melting processes have over printed the fluid U addition in this section of the arc. This may require addition of small porous flow or dynamic melt fractions with large Pa-excesses to the rising magmas as they ascend through the hot centre of the mantle wedge. Finally, the Ra-excesses are negatively correlated with silica constraining the time scale for differentiation from basalt to dacite and rhyolite to be less than 6000 years.

T32A MC: Hall D Wednesday 1330h

Active Tectonics of Taiwan I *(joint with G, S)*

Presiding: **C M Rubin,** Central Washington University**; Y Chen,** National Taiwan Univ.**; J Suppe,** Princeton University

T32A-0861 1330h POSTER

Fault-Related Rocks From The Thrust Fault Zone in Miaoli Area, West Taiwan

Sheng-Rong Song[1] (886-2-23630231 Ext.2671; srsong@ccms.ntu.edu.tw)

Huei-Fen Chen[1]

Li-Jun Li[1]

Chia-Mei Liu[1]

Li-Wei Kuo[1]

[1]Department of Geosciences, National Taiwan University, 245 Choushan Road, Taipei, Tw 107, Taiwan

Taiwan is located in the orogenic belt, which the fault-related earthquakes were very common and severe in last few myrs. However, there are no any fault-related rocks have been reported until now. This research is the first article to report an unambiguous occurrence of pseudotachylyte and cataclasite in Taiwan. The fault-related rocks, including the pseudotachylyte and cataclasite have been found in the drilled core, about 600 meters in depth below the surface in the western foothill sedimentary sequences of Miaoli area, Taiwan. The pseudotachylytes are thin, submillimeter to centimeter in thickness and distribute intercalated in thick fault zone. They dominantly occur as injection veins, which contact sharply with host rocks, the sandstones and siltstones, and normal or cut with the major shearing zone. Petrogaphically, the pseudotachylytes consist of a black or dark brown, fine-grained to glassy aphanitic matrix with microlites, rounded or embayed clasts and numerous rock and mineral fragments. The presence of pseudotachylytes indicates that the fault zone has suffered the rapid seismic displacements. The cataclastic rocks include non-foliated clast-supported to matrix-supported cataclasites and foliated clastic-supported cataclasites. The former form either thin dark films underlining isolated shear plane or accumulating as thick lens or pods. The later have large varieties in structures, such as thin dark films displaying S-C fabrics silimar to those of mylonites, injected veins and well-polished slickensided surface. Under the microscope, the muscovite fragments show the structures of brittle-plastic shearing processes, such as fish, cleavage-steps, bending and folding. Those characteristics of cataclasites infer that the cataclasites may form under either the slow seismic movement or aseismic creep. From the occurrence, location and regional geology, this fault zone with abundant fault-related rocks may be correlated to the Shenchoshan thrust fault, which is a seismic fault moved in 1935. The coeval formation of pseudotachylyte and foliated cataclasite infers that the seismic displacement and aseismic creep occurred in the same shear zone.

T32A-0862 1330h POSTER

A High Vp/Vs Zone Along the Subducted Slab Edge of the Philippine Sea Plate Beneath Northeast Taiwan: Insights for Slab Dehydration and Thermal Activity

Shu-Kun Hsu[1] (886-3-4268316; hsu@oc.gep.ncu.edu.tw)

Jing-Yi Lin[1]

Yi-Ching Yeh[1]

[1]National Central University, Institute of Geophysics, Chung-Li 32054, Taiwan

The Philippine Sea Plate subducts northwards beneath the Ryukyu Arc and terminates in northeast Taiwan. The associated back-arc basin, the Okinawa Trough, is also propagating westward till the Ilan Plain of the northeast Taiwan. Because of the westward motion of the northwestward subduction of the Philippine Sea Plate, the northeast Taiwan is generally considered as a post-collisional and extensional region. To investigate the subduction-related magmatism, we have performed a seismic tomography in northern Taiwan area. The tomographic results show a high Vp/Vs ratio zone along the subducted slab near East Longitude 121.7.

T