for similar and greater ($^{230}Th/^{238}U$) ratios. There is also a weak correlation between $^{226}Ra/^{230}Th$ and $^{231}Pa/^{235}U$.
These data do not indicate a simple mixing trend between an N-MORB and an enriched component in the $^{231}Pa/^{235}U$ versus $^{230}Th/^{238}U$ diagram since the MORBs which do not have the most radiogenic isotope signatures compared with the Azores island basalts have some of the largest ($^{230}Th/^{238}U$) and $^{231}Pa/^{235}U$. Clearly, the dynamics of melting must have played a role in generating larger ^{230}Th and ^{231}Pa excesses beneath the Mid-Atlantic ridge. We infer that this must be due to the absence of a lithospheric lid as larger excesses of ^{230}Th and ^{231}Pa can be generated for longer melting columns. Thus, ridge-hotspot interaction cannot imply a simple transfer of melt from the hotspot to the ridge.
The $^{230}Th/^{238}U$ and $^{226}Ra/^{230}Th$ data across the Azores plateau shows a maximum for the island of Terceira and mimics the depth anomaly which is thought to result from the hotspot. This trend is also consistent with observations of rare gases (M. Moreira pers. comm.) and suggests that it must be related to the presence of deep material. The U-series trend is the reverse of the trend found in Hawaii by Sims et al. (2000) which was attributed to variations in upwelling rates across the rising plume. This observation can be rationalized in the context of an equilibrium melt transport model (Spiegelman and Elliott, 1993) where U-series disequilibria are sensitive to upwelling rates. For slow upwelling rates such as below the Azores, larger ^{230}Th excesses are predicted in the center of the plume. This suggests that the upwelling rate beneath the center of the plume must be of the order of a few cm per year which is an order of magnitude lower than values estimated for Hawaii.

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T32C-08 1545h

The Foundation Hotspot-Pacific-Antarctic Ridge System: What Happens When a Ridge Approaches a Hotspot?

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The Foundation chain formed during the last 21 Ma by the action of a hotspot, presently located roughly 35 km west of the axis of the Pacific-Antarctic Ridge (PAR). The Foundation-PAR system is the best documented case of a fast spreading ridge approaching a hotspot and interacting with it. The eastern part of the chain, near the Pacific-Antarctic ridge, is formed by volcanoes younger than 5 m.y., built on a plate less than 5 Ma old. They are distributed along two subparallel lines. The distance between these two lines diminishes towards the PAR. The north line, corresponding to the larger volcanoes, is the main locus of the volcanism. The south line was probably formed along fissures on top of the flexural arch resulting from the emplacement of the north line. The approach of the PAR to the hotspot resulted in the reduction of the effective elastic thickness (Te) of the plate towards the spreading ridge from 5 to 0 km. This spatial variation of Te correlates with a change in the morphology and in the volume of the volcanoes and with the reduction in the distance between the north and south lines, suggesting an important control of the lithosphere on the volcanic processes. Off axis, the chemical and isotopic composition of the basalts reveal a growing influence of the ridge on the plume volcanism. The pattern is coherent with a mixing between two sources, occurring when the two melting zones merge and overlap. The morphology, crustal structure and the chemical composition of the lavas of the axial area of the PAR show evidence of the influence of the hotspot. The crust is 1.5 km thicker where the hotspot is nearer to the PAR. Anomalous ridge elevation is 650 m and the along-axis width of the chemical anomaly is at least 200 km. A comparison of these axial parameters with those derived for other ridge-hotspot systems, suggests that the amount of plume material reaching the ridge axis is smaller for the Foundation-PAR system. This implies a weaker connection between plume and ridge. Cumulative effects of a fast spreading rate and of a fast ridge-hotspot relative motion can be responsible for this weak plume-ridge flow. The flow from the hotspot may be less efficiently channeled towards the ridge axis when a fast ridge is rapidly moving towards a hotspot.

T32C-09 1600h

Geodynamic models of motion of the Easter Hotspot Plume, and implications on its location relative to the East Pacific Rise during the past 40 Ma.

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Models of deformation of a plume conduit in large-scale mantle flow are used to compute the motion of the Easter hotspot in a mantle reference frame. A large number of different models of mantle flow, and with different values for plume buoyancy, age and location were computed to test the robustness of the results. Consistently all models showed an initial eastward motion of the plume, followed by a westward motion. The former corresponds to eastward flow in the upper part of the mantle, from the upwelling in the central Pacific to the subduction zone under South America, the latter to the flow in opposite direction in the lower part of the mantle: The upper part of the plume conduit gets dragged towards the subduction zone, but then the conduit straightens up due to its buoyancy. Hence the transition from eastward to westward motion happens earlier, if an older plume age, or a larger buoyancy is assumed.

Predicted hotspot track, age progression and relative location of hotspot and ridge additionally depend on plate motions in the same mantle reference frame and evolution of the Pacific-Nazca plate boundary, hence models and uncertainties of those will be discussed.

The number of acceptable models can however be severely constrained by comparision of predicted and observed geometry and age progression of the hotspot track, as well as by the different gravity signature of Nazca versus Sala y Gomez ridge, which may indicate that the former was formed by a plume beneath the ridge, while the latter was formed by an off-ridge plume. Some more speculative thoughts on how details of the hotspot track may relate to ridge reorganizations and related changes in mantle flow pattern will also also be presented.

T32C-10 1615h INVITED

Plume Capture by Divergent Plate Motions: Implications for the Distribution of Hotspots, Geochemistry of Mid-Ocean Ridge Basalts, and Heat Flux from the Core-Mantle Boundary

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The coexistence of mantle plumes with plate-scale flow is problematic in geodynamics. Significant problems include the fixity of hotspots with respect to plate motions, the spatial distribution and duration of hotspots, the geophysical and geochemical signatures of plume-ridge interactions, and the relation between mantle plumes and heat flux across the core-mantle boundary. We present results from laboratory experiments aimed at understanding the effects of an imposed large-scale circulation on thermal convection at high Rayleigh number (up to 10^9) in a fluid with a strongly temperature-dependent viscosity. In a large tank, a layer of corn syrup is heated from below while being stirred by large-scale flow due to the opposing motions of a pair of conveyor belts immersed in the syrup at the top of the tank. Three regimes are observed, depending on the velocity ratio V of the imposed horizontal flow velocity to the rise velocity of plumes ascending from the hot boundary. When V<<1, large scale circulation has a negligible effect and convective upwelling occurs as randomly-spaced axisymmetric plumes that interact with one another. When V>10, plume instabilities are suppressed entirely and the heat flux from the hot lower boundary is carried by a central sheet-like upwelling. At intermediate V, ascending plumes are advected along the bottom boundary layer, and the heat flux from the boundary is found to scale (according to a simple boundary layer theory) with V and the ratio of the viscosity of cold fluid above the thermal boundary layer to the viscosity of the hottest fluid in contact with the bottom boundary. For large viscosity ratios (10-100), only about 1/5th or less of the total heat flux from the hot boundary layer is carried by plume instabilities, even for modest imposed horizontal flow velocities (V of order 1).

When applied to Earth, our results suggest that plate-scale flow focuses ascending mantle plumes toward mid-ocean ridges, and that plumes may be entirely captured by sufficiently rapid upwelling flow beneath ridges. This behavior may explain why hotspots are more abundant near slow-spreading ridges than near fast ridges. Such a model also predictes, in apparent accord with geochemical observations, that while slow ridges exhibit more variable isotopic and trace element signatures than fast ridges, their average signatures should be about the same. The laboratory experiments further suggest that plumes originating at the core-mantle boundary (CMB) may carry only a small fraction of the total CMB heat flux, the remainder being swept away by large-scale mantle flow associated with plate-scale convection.

T32C-11 1635h

Geophysical Evidence for a Possible Late Jurassic Mantle Plume in the Gulf of Mexico

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Gravity, magnetic and seismic refraction data reveal a prominent basement structure beneath the Keathley Canyon area of the western Gulf of Mexico. Several seismic refraction profiles acquired near and over the structure indicate depths to its crest range from 10.5 to 12 km, rising from basement depths of 14 to 16 km below sea level. Because of the presence of extensive salt features, seismic reflection data are unable to accurately image the structure but several reflection profiles indicate the existence of a basement high in the area. A positive free-air gravity anomaly associated with this basement structure extends 200 km from 93.9° W, 26.4° N along a roughly WNW-ESE directed path to 91.7° W, 25.9° N where it turns northeastward. Bathymetric and seismic reflection data indicate the gravity anomaly is not produced by seafloor topography or shallow sedimentary sources, but can be attributed to the basement relief documented. Its amplitude and wavelength decrease to the ESE, from 70 mGal and 100 km wavelength to 35 mGal and 40 km wavelength. A positive magnetic anomaly with a 130 nT amplitude and 30 km wavelength coincides with the WNW end of the free air gravity anomaly. It extends to the ESE in a similar manner to the gravity anomaly, but its amplitude decays more rapidly.

Most models for the formation of the Gulf of Mexico basin culminate in a late Jurassic-early Cretaceous phase of seafloor spreading as the Yucatan Block rotates counterclockwise away from North America. The shape of the free air gravity anomaly over the deep basement structure defines a geometry that is similar to those produced by other hotspot tracks, such as the New England Seamounts, Rio Grande Rise or Vitoria-Trindade seamount chain. The WNW-ESE direction is broadly consistent with motion of North America in the hotspot reference frame at the time of basin formation. Such an interpretation suggests that a minor mantle plume may have been active during spreading and played a significant role in the development of the basin. We consider the westerly end of the gravity anomaly to roughly delineate the ocean-continent boundary beneath >15 km of sediments off the Texas coast. At its eastern end, the gravity anomaly turns northeastward and may correspond to the location of a fossil sea floor spreading center.

T32D MC: 310 Wednesday 1330h

Processes Within the Subduction Factory: Arc and Back-arc Basin Composition and Structure *(joint with OS, S, V, DI, MR)*

Presiding: **P Fryer,** University of Hawaii**; J Ryan,** University of South Florida

T32D-01 1330h

Volcanoes Track Mantle Flow Beneath Luzon Arc

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Volcanoes were grouped into a scheme according to whether they were associated with 1) microcontinent collisions (Luzon-Taiwan; Palawan-Mindoro), 2) subducting oceanic lithosphere with pelagic sediment cover (Philippine Sea Plate), 3) subducting transitional marginal basin with continent-derived sediment cover (South China Sea basin), and 4) incipient rifting with no underlying slab (Macolod corridor). Mgo-normalized major element and trace element compositions, along with limited isotope data suggest that 1) volcanoes associated with continental sediment/collision have more enriched signatures , 2) the volcano sources are variably fertile, with frontal arc volcanoes having more refractory sources, and 3) some Macolod volcanoes with no underlying slab have enriched signatures, suggesting that sediment-enriched mantle has migrated to their present source regions. Modeling Nd isotope and trace elements (e.g., Ba/Ce), the data cannot be explained by simple addition of sediment to a fertile mantle source. The data are best explained by fluid metasomatism (at shallow depths) of a variably refractory mantle, and probably later addition of sediment melt at deeper depths.

T32D-02 1345h

A Window Into Mantle Sources and Crustal Contamination in the Northern Cascade arc: Mafic Lavas From the Glacier Peak Area, Washington State

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Major element, trace element, and mineral compositions have been determined for four Quaternary mafic monogenetic cinder cones and flows located between 5 and 15 km south of Glacier Peak, a dacitic stratovolcano in the northern Cascade arc. The flows are the Whitechuck basalt, and the basaltic andesites of Indian Pass, Lighting Creek, and Dishpan Gap. Whitechuck has high concentrations of Al_2O_3 (> 18 wt.%) and low concentrations of K_2O (< 0.45 wt.%) and shares similar trace element characteristics with high alumina olivine tholeiites reported in the central and southern Cascades. The three basaltic andesites are calc-alkaline. Indian Pass and Lighting Creek have primitive compositions, with Mg# [100*Mg/(Mg+Fe*)] > 65, Cr > 200 ppm, and Ni > 100 ppm. Most samples have olivine in equilibrium with bulk rock compositions. Rb and Sr are relatively low in most flows, especially at Whitechuck and Dishpan Gap. Sr and La decrease with increasing SiO_2 in the Lightning Creek and Dishpan Gap cinder cones, indicating possible mixing with a Sr and La-poor felsic component represented by the most evolved Glacier Peak dacites. Petrographic observations of disequilibrium textures such as xenocrysts, xenoliths, quenched glass inclusions, and strongly-zoned phenocrysts in these two flows also indicate possible mixing. All flows are enriched in large ion lithophile elements and light rare earth elements relative to high field strength elements, showing that the mantle beneath Glacier Peak has been fluxed by a hydrous subduction component. Ba/Nb ratios (~40-110) are highest for the three basaltic andesites, indicating that they had the greatest amount of subduction component enrichment. Nb and Ta abundances are highest at Indian Pass (Nb =~7 ppm) and lowest at Whitechuck (Nb = ~2-3 ppm), indicating that Indian Pass and the other two basaltic andesites were produced by relatively low degree hydrous melts of depleted mantle. In comparison, the Whitechuck basalts were produced by relatively dry (<1% H_2O) slightly higher degree melting of a more depleted mantle (similar to NMORB) source. Of the three mantle-domains inferred beneath the Cascades, only a MORB-like mantle and a subduction-fluxed depleted mantle are represented beneath the Glacier Peak region. No OIB-like mantle domain is thus far represented in the Cascades north of the Mt. Rainier region.

T32D-03 1400h

The Juan de Fuca Slab-window and Coast Range Volcanics, California: Correlation between Subducted Slab Age and Mantle Wedge Geochemistry

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In the Coast Ranges of central and northern California, a suite of northward-younging volcanic centers erupts within the Juan de Fuca slab window. The slab window forms as the Mendocino triple junction migrates to the northwest, removing the subducting slab from beneath North America. This study looks at the most recent, post Mid-Miocene (< 12 Ma) set of volcanics that lie approx. 50 km onshore of and parallel to the California coastline. In an attempt to characterize the nature of their magma source and create a complete, consistent and representative geochemical dataset, we have analyzed 37 samples from 8 localities throughout this region. Major elements were determined via XRF (UMass lab) and trace and rare earth analyses were determined by ICP-MS at UC Davis. Using our data, supplemented by published datasets, we focus mainly on basalts with greater than 6-8% MgO. By studying these, the least differentiated and least contaminated samples, we can use the geochemistry of the basalts to investigate the characteristics of the source.

The source of the mantle material that fills the slab window has, in the past, seemed uncertain. Our preliminary analyses indicate that the relic mantle wedge to the east is a viable candidate. If the Coast Range volcanics source from the mantle wedge, they provide a probe of the wedge during the latter stages of subduction, just prior to Mendocino triple junction passage. This "tap" into the geochemistry of the mantle wedge over the time span of the Mendocino triple junction migration is made more interesting because the age of the subducting Gorda/Juan de Fuca plate has decreased from approx. 14 Ma to the present, young age of 5-6 Ma. Previous studies of the geochemical response within the mantle wedge to variations in the subducting slab age have, by necessity, compared arc volcanic products erupted from different plate boundaries. The Coast Range volcanic series provides an alternative means of sampling mantle wedge geochemistry, avoiding some of the potential problems inherent in sampling and comparing the geochemistry from different arcs. Our analyses of the primitive magmas erupted into the Coast Ranges allow us to test both the source location and whether mantle wedge chemistry has varied in response to changes in age (and hence thermal structure) of the subducted slab north of the triple junction. The unique geometry of the Coast Ranges therefore allows us to evaluate the slab-age component of the Subduction Factory in an alternative manner that avoids some of the limitations of other studies.

T32D-04 1415h

Are the Regional Variations in Central American Arc Lavas due to Differing Basaltic vs. Peridotitic Slab Fluxing Sources ?

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Arc magmas at subduction zones show systematic along-arc trends in melt chemistry that are well described, but poorly understood. For example, along the Central American arc between Nicaragua and Costa Rica, over the distance of a few hundred kilometers there is a progressive change in the Ba/La ratios of the arc lavas from high-end to near low-end global values. The mantle wedge melts to produce these lavas; melting is triggered by the upward flux of hydrous fluids from the subducting slab which are released from its crustal and mantle portions at different P-T conditions. Here, we investigate arc melting with a new, self-consistent, chemo-thermo-dynamical model for mantle flow, melting, and fluid release. Since the relevant water-releasing reactions consume latent heat, for internal consistency we include these cooling effects within the temperature solution. Tracer particles advect to track the changing slab chemistry.

What happens depends highly upon the initial slab petrology. Both the crustal thickness and the amount of chemically bound water in the downgoing slab are likely to vary significantly between different subduction zones, as do the processes that hydrate the slab. The basaltic oceanic crust hydrates at mid-ocean ridges as it forms. The underlying mantle, if hydrated (serpentinized), can potentially store even more chemically bound water than the crust. To hydrate mantle rocks, however, water must flow through the already hydrated, low permeability crust. When the lithosphere faults at the outer rise, these new cracks cross through the crust into the mantle, providing a path for seawater to penetrate into and serpentinize it. Since the depth-interval and intensity of fluid release from hydrated basalts and hydrated peridotites vary as a function of the initial slab petrology, the trigger mechanism for melting, fluid fluxing from the slab, will also vary. When the primary source of the released fluids changes from hydrated basalt to hydrated peridotite, the chemistry of the arc magmas may also change. We therefore propose that the changes in arc lava chemistry in Central America result from an along strike shift in the petrology of the incoming plate; from thin crust and thick hydrated mantle subducting beneath Nicaragua to thicker crust and a thin to non-existent serpentinite layer subducting beneath Costa Rica.

T32D-05 1430h

Quantifying SO2 (and other volatile component) Fluxes from Volcanic Arcs using Satellite Data Integrated with Geologic and Geochemical Data.

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Reliable measurement of arc volatile fluxes is an important focus of the subductory factory. Satellite methods for SO2 sensing using the TOMS instrument have been the most advantageous way of measuring eruptive SO2 releases from volcanoes for the past 20 years. Improvements in SO2 satellite remote sensing instrumentation as exemplified by OMI, SEVIRI, MODIS and ASTER detectors have now made the comprehensive measurements of arc degassing possible, including assessing low level fluxes. To maximize the utility of such measurements for the subduction factory studies we need to be able to extend the time scale of the data beyond the satellite era and back into history and prehistory. We also need to know how SO2 measurements relate to other gases such as CO2 and H2O. Besides satellite data, the systematic knowledge of volcanic history of volcanoes (reposes, eruption rates, volumes and frequencies) and petrologic information (geochemical and mineralogical characterization and magmatic oxygen fugacity) are needed. This requires a vast amount of data assembly coming from geology, geochemistry and remote sensing, but even with it we lack the ability to interpret it. The understanding of apparently random excess S releases in arcs is central to success in this pursuit. We need to try to test theories which can explain the excess, such as the idea of Giggenbach et al (1990, JVGR 42: 13-41) where the gas released in an eruption is thought to be derived not from the erupted magma alone but from crystallization of magma bodies for many years before eruption and trapped by a hydrothermal system until it is released early in explosive eruptions. Is it possible to geophysically detect gas pockets under volcanoes and above magma bodies? Can we use hydrothermal system evaluations to help test this idea? Are there other explanations which can be similarly tested and which might lead us to accurate arc volatile flux estimations?

T32D-06 1445h

Cl systematics in Lau Basin glasses: Constraints on the composition of subduction-related fluids in back-arc environments

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Cl is a potentially powerful tracer of saline slab-derived fluids in subduction zones. Salinity also controls the solubility of many other chemical species, and thus Cl contents are important for mass transfer considerations. Direct examination of the Cl contents of primitive arc magmas has been limited by a lack of suitable undegassed samples, however measurements in back-arc glasses provide a viable alternative. We report Cl concentrations in 18 primitive (6-9 wt.% MgO), well-characterised glasses from the Lau Basin and use these both to investigate Cl-systematics in back-arc magmas and to constrain Cl contents in slab-derived fluids from the associated Tonga arc. In addition 8 evolved glasses (1-5 wt.% MgO) were analysed to evaluate the effects of crustal-level processes. Glasses come from locations between 150 400 km from the Tonga trench, and thus also provide insight into the effects of transport through the mantle wedge on Cl and other elements.

Cl contents of Lau Basin glasses are variable (80-5500 ppm) and generally high with respect to uncontaminated MORB compositions (typically <200 ppm). In primitive glasses Cl/Nb ratios correlate strongly with tracers of slab-fluid input such as Ba/Nb and U/Th, consistent with the interpretation that Cl within Lau Basin magmas predominantly derives from the adjacent subducting slab. Glasses from the Central Lau Spreading Center have constant Ba/Nb, but show a marked positive correlation between Cl/Nb and $^{87}Sr/^{86}Sr$ and degree of differentiation which probably reflects assimilation of Cl-rich seawater-derived components. Cl/H_2O ratios in primitive glasses vary considerably, and may reflect variation in the salinity of the slab-derived fluids present within the back-arc. The observed range of Cl/H_2O is equivalent to fluid salinities of between 3.6-17 wt.% NaCl. Cl/H_2O also correlates with distance to the trench, suggesting that the salinity of slab-derived fluids are largely independent of the overlying mantle wedge composition and tectonic complexities within the back-arc. Relations between distance from the arc and ratios of Cl to other incompatible elements suggest that chromatographic effects during transport may influence the composition of slab-derived fluids present within the Lau back-arc.

T32D-07 1520h

Melt Inclusions in Mariana Arc Lavas: Volatiles, Trace Elements and Linkages to Subducted Components

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Melt inclusions (MIs) are particularly useful to study in volcanic arcs because they may provide samples of primitive liquids prior to extensive magma fractionation, assimilation, or crystal accumulation. Although volatile contents can also be inferred by a number of indirect petrological techniques, MIs also provide the only direct means of measuring volatile (H2O, CO2, etc.) concentrations in arc magmas, as most all other eruptive products are degassed. Volatiles are critical to the operation of the subduction factory since they are both the transport medium of material from the slab and the driver of melting in the mantle wedge. The presence of "fluid components" originating from subducted sediment or basaltic crust in arc magmas, however, is typically deduced from trace element compositions more than it is directly measured.

We studied MI populations within four basaltic scoria samples from Guguan, Pagan and Agrigan islands of the Mariana arc. All MIs selected for study are hosted by olivine (Fo 68-82), are 50-200 m in size, and are brown glass with no visible evidence of devitrification. We have analyzed these MIs for H2O and CO2 by FTIR, major elements by EMP and trace elements by laser ablation ICP-MS. H2O data reveal a range in water content of 1-4 wt%, and a tighter grouping of 2-4 wt% for basaltic inclusions (<52% SiO2, Fo 72-82), higher than the highest water content reported for the Mariana back-arc trough. The single inclusion with detectable dissolved CO2 (630 ppm) also had the highest H2O content, which may indicate that lower H2O contents in the other inclusions could be due to degassing. The MIs are broadly similar in both major and trace elements to lavas from the same islands, and appear to define liquid lines of descent consistent with plagioclase suppression increasing with water concentrations. These Mariana MIs do not include high-Ca compositions like those reported by Schiano, et al. (2000), rather they are normal tholeiitic arc basalts, and higher in Al than the compositions of Lee & Stern (1998).

These new data extend the range of trace element compositions observed in Mariana arc lavas. The MI from Agrigan with 4.2 wt% H2O has the largest Ce- and Nb-anomalies of any lava in the Mariana arc. Trace element systematics indicate that Agrigan receives the largest contribution from subducted sediment, suggesting a linkage between water content and the subducted sediment component in the Marianas.

T32D-08 1535h

Volcanic Supply Rate and Evolving of the Izu-Bonin Arc

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The Izu-Bonin Arc-Trench system is one of the oceanic arc-trench system which is crucial for understanding how to evolve island arc and continental crust during Archean. We estimated total volume of the volcanic materials accreted to IB arc since 48 Ma by the model crustal structure and bathymetric map available through IB arc which is divided into three segments by two tectonic lines. ODP Leg 125 and 126 have revealed the volcanic history of the IB arc. We took into account the spatial distribution and isotopic ages of the volcanic rocks and elucidated the arc evolution by the division of events occurred during 48-43, 43-34, 34-27, 27-15, 15-6, 6-2, and < 2Ma, respectively. Boninitic rocks pored out on the deep sea environment during 48-43 Ma. After the change of the Pacific plate motion strong boninitic and calc-alkalic volcanism took place along the paleo-IB arc during 43-34 Ma. The arc grew quickly to the shallow level and yielded explosive volcanic materials and debris flow deposits until 34 Ma. Paleo-IB arc split into to halves, present-day IB arc and Palau-Kyushu remnant arc to form Shikoku and Parece Vela backarc basins at 30-27 Ma. Volcanic activity during the 27-15 Ma was quiescent compared to the other stage because of the backarc spreading consumed a large amount of volcanic materials. Explosive and bimodal volcanism were dominated to form backarc depressions in the backarc area and strata-volcanoes on the volcanic front during 15-6 Ma. Finally, stratovolcanoes and catastrophic explosion of the caldera forming acidic volcanics were predominating on the volcanic front since 2 Ma. Through the volcanic history the IB arc was formed most part during initial 10 my to build a paleo-IB arc and volcanic supply rate during initial 10 my was very high, almost compatible to that of super plume.

T32D-09 1550h

A Subduction Factory Laboratory: Tectonics of the Southern Mariana Convergent Margin

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Recent MR-1 side-scan sonar mapping, gravity and magnetics surveys, and sea floor sampling of the southernmost portion of the Mariana region reveal a convergent margin subject to complexly interacting stresses. The backarc spreading center and the crust it has produced is inflated as a consequence of proximity of the arc and backarc basin magma sources. The formation of backarc basin crust dates from only 3 m.y. ago based on interpretations of magnetics data. The westward extension of the more recent arc volcanic centers beyond Guam shows a general diminishing of arc volcanic centers and a coalescing with the spreading center in a zone of transition from magmatic to amagmatic extension. Magnetic and gravity data are consistent with this tectonic interpretation. It is possible, however, that newly imaged volcanoes on the West Mariana ridge may be active. They show high-backscatter characteristics on sonar imagery and coincide with the typical depths to slab for magma generation in subduction zones. The distance to trench axis and the level of seismic activity in the region is consistent with volcanic activity on this portion of the "remnant arc." If our hypothesis is correct, then the southern Mariana system preserves the transition from remnant arc through extension and formation of a backarc basin spreading center, to the reestablishment of a new active volcanic arc. It thus provides a natural laboratory for the simultaneous study of all of the fundamental processes of the Subduction Factory. In addition, the forearc is deeply dissected by profound faulting that exposes the structure of the arc massif along faults with throws of up to 4 km. There are several stair-stepping antithetic normal faults in the forearc south of Guam that expose intermediate depth (up to approximately 15 km) plutonics of arc origin, providing a potential record of the most complete crustal section through the arc substructure known to be exposed in an active arc. Finally, the deeply-excised forearc of the southeastern corner of the system is underlain by a subducting plate that has likely been torn, which dips more steeply to the west of the proposed tear, and which may thus provide an excellent location for the study of mantle flow in association with disruption of subducting slabs. Pacific mantle may be leaking westward past the slab, invading the backarc region. The backarc magmas of the Izu-Bonin-Mariana system have been characterized as of Indian Ocean mantle composition. The rapid rate of volcanism along the southern backarc spreading center may make it possible to trace the incursion rate of Pacific mantle across this boundary.

T32D-10 1605h

Structure, Composition and Evolution of the South Sandwich Island arc: Implications for Rates of arc Magmatic Growth and Subduction Erosion

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The South Sandwich island arc is a product of westward subduction of the South American plate beneath the small Sandwich plate. The Sandwich plate forms the eastern flank of the world's longest-lived, extant backarc basin, the East Scotia Sea. Magnetic anomalies on the western flank of the backarc indicate continuous spreading since at least 15 Ma. On the eastern flank, however, the present island arc appears to stand on backarc crust formed since 10 Ma. If earlier spreading was symmetric, crust formed at 15 Ma on the eastern flank now lies about 70 km east of the islands, and the arc at that time must have been even further east.

As part of the Sandwich Lithospheric and Crustal Experiment (SLICE), wide-angle seismic data were acquired using ocean bottom seismometers (OBS) deployed along two lines crossing the trench, arc and backarc basin. Both OBS data and multichannel seismic reflection (MCS) data were acquired simultaneously using a 5976 cu.in. (98 l) airgun source. The OBS data from the southern profile, which crosses the trench at $\sim 60^\circ$S, were modeled using 2-D travel-time inversion and synthetic seismogram methods to obtain a velocity model of the crust. The MCS data were used to constrain the shallow structure in the model. Coincident gravity data were also used to constrain the model. The maximum crustal thickness in the model is 15 km beneath the arc, decreasing to an average of about 10 km beneath the outer forearc. It also includes a 2-km-thick mid-crustal layer with velocity 6.0-6.5 km/s beneath the arc, similar to that observed beneath the Izu-Ogasawara arc, and interpreted as a composite granitic or dioritic intrusion.

The crustal basement beneath the arc and inner forearc on this line appears to have formed at the backarc spreading center since 12.5 Ma. The crustal thickness on this part of the model suggests an arc growth rate of ~ 60 km^3/km/Myr, assuming an initial oceanic crustal layer 6 km thick. If forearc slope retreat kept pace with arc migration relative to the Sandwich plate, the rate of subduction erosion may have been up to 47 km^3/km/Myr. Alternatively, assuming growth of the arc-trench gap in accordance with one published relation yields a lower subduction erosion rate of 31 km^3/km/Myr.

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T32D-11 1620h

Initial Observations From the Talkeetna Arc Continental Dynamics Project

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The Jurassic Talkeetna arc section in Alaska lies north of the Border Ranges Fault in the northern Chugach Mtns, extending NW into the southern Talkeetna Mtns. Previous studies have demonstrated that the section formed in an island arc prior to accretion on the North American margin; mass balance estimates for a "1D" cross-section showed that it has a basaltic bulk composition; and garnet gabbros juxtaposed with pyroxenite overlying residual mantle harzburgite were interpreted as indicating a crustal thickness of about 30 km. Primary goals of this study are to extend mass balance calculations to 2D via mapping and thermobarometry, constrain the change in the nature of primary magmas in the arc as a function of time during its (?) 20-30 Ma history, investigate the genesis of intermediate plutonic rocks, and evaluate the liklihood of lower crustal, convective instability ("delamination"). The project is designed to provide constraints on the evolution of continental crust via arc processes.

After reconnaissance in 2000, 2001 field work focused on additional sampling for thermobarometry and laboratory based seismic velocity studies near the base of the section, mapping and sampling in the Klanelneechina klippe (gabbros in a thrust sheet overlying a metamorphosed accretionary complex south of the Border Ranges Fault, with uncertain affinity to the Talkeetna arc), extensive sampling of mid-crustal gabbros for petrological and ion probe analysis, detailed stratigraphic studies in the volcanic section, and investigating the relationship of extensive, Jurassic quartz diorite and granodiorite in the southern Talkeetna Mtns (K/Ar ages 160-170 Ma) to dominantly gabbroic plutonic rocks in the arc further south and east (K/Ar and our new U/Pb and Ar/Ar ages 170-195 Ma).

Our preliminary thermobarometric estimates suggest that the crustal thickness may have been 20 to 25 km. This is important since an apparent discrepancy between the 30 km crustal thickness estimate and the 15 km structural thickness estimate in the eastern part of the arc section led earlier workers to suggest that roughly half of the section was missing.

We found that the Klanelneechina klippe includes garnet gabbros; the presence of garnet gabbros only 50 km apart, on both sides of the Border Ranges Fault, suggests that the Klanelneechina gabbros are part of the Talkeetna arc section, and that post-Jurassic strike slip displacement along the Border Ranges Fault has been small. We await additional geochronology data to corroborate this hypothesis.

Initial ion probe analyses of igneous clinopyroxene indicate a variety of different REE patterns for primitive magmas that formed pyroxenites near the base of the crust in the eastern part of the arc. However, new trace element data on gabbroic rocks and volcanics further west in the section have very uniform REE patterns. We sampled the easternmost volcanics and mid-crustal gabbros this summer in an attempt to resolve this apparent discrepancy.

New data on amphibolite lenses at mid-crustal depths, including garnet amphibolite, show that they were andesites with clear arc trace element signatures. Thus, they are not relicts of oceanic crust into which the arc was emplaced. They could be relicts of an older arc, or foundered Talkeetna volcanics that were buried early in the history of the arc, and then intruded by mid-crustal plutonic rocks.

T32D-12 1635h

Continental Crust Formation in Costa Rica and Nicaragua.

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Much work has been done in Costa Rica and Nicaragua on relating the variation in modern arc volcanism to variations in crustal type and thickness, sediment input and nature of the mantle wedge. However, little work has been done on the origin of the voluminous silicic ignimbrites in these sections of the arc. This is important because of the unusual abundance of silicic volcanism in a mature island arc environment where no continental crust occurs. The southern part of the Central American arc is the Chorotega block, which has developed on thickened oceanic crust. The boundary between the Chorotega block and the northern continental Chortis block is still a matter of debate. What is clear is that the Paleocene-Eocene island arc of the Chorotega block was built on a primitive basaltic crust (perhaps oceanic plateau?), which has evolved to the modern arcan evolutionary process that has led to the development of abundant silicic magmas.

In most island arc settings, abundant, high-silica volcanic deposits are not common, and this is generally attributed to the absence of continental crust. However, in Costa Rica and parts of Nicaragua, there are extensive silicic ignimbrite deposits. Because there is no recycling of continental crust in these sections of the arc, these silicic deposits represent the formation of new continental crust. This is in contrast to the northern part of the Central American Volcanic Arc where silicic magmatism is associated with older continental crust.

In Costa Rica the extensive ignimbrite sheets erupted from the Miocene to Pleistocene and occurred in three main areas: the Guanacaste province in the northwestern Costa Rica, Cordillera de Tillaran and Valle Central in central Costa Rica. In Nicaragua widespread ignimbrites developed from Eocene to as young as 6,000 yr bp (Ehrenborg, 1996). An important observation is that trace element ratios of these silicic volcanic deposits mimic the trace element ratios of basaltic to andesitic deposits from the modern arc. For example in southeastern Nicaragua and northwestern Costa Rica, samples from both the modern arc (basalt to andesite) and the ignimbrites have low Ce/Pb and high Ba/Nb ratios, indicating a large input from slab fluids. In Central Costa Rica samples from the modern arc (basalt to andesite) and the silicic ignimbrites have high Ce/Pb and low Ba/Nb ratios indicating a lower input from slab fluids. We interpret these data to indicate that the silicic melts were produced from partial melts of rocks chemically similar to the modern arc lavas, thus preserving the incompatible element ratio signatures (e.g. Ce/Pb and Ba/Nb ratios). There are no systematic variations of these trace element ratios in the different units with respect to age.

There are differences in the chemical and mineralogical composition among the ignimbrites and these differences most likely resulted from differences among source rocks and to crystallization processes. For example, although all of the samples are enriched in light rare earth elements, some units display positive Eu anomalies, whereas others do not. In addition, there are differences in the behavior of heavy REEs. These data most likely reflect the variability of hornblende and plagioclase in the sources for the melts, indicating to us that melting took place at the base of a thickened arc crust near the stability limit of plagioclase. Processes that formed the silicic volcanic rocks in this overthickened island arc or ocean plateau may be similar to processes that formed continental crust in the Archean.

T32E MC: Hall D Wednesday 1345h

Deformation, Fluid Flow, and Seismic Characteristics of Sedimentary Rocks *(joint with H, S, V, MR)*

Presiding: **N Brodsky,** Sandia National Laboratory**; J Wheeler,** University of Liverpool

T32E-0904 1345h POSTER

Strain Localization in Sandstone

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Based on petrographic and SEM observations of deformation mechanisms in sandstones of different compositional and petrophysical properties, we distinguish four types of deformation processes. All four deformation processes lead to the development of macroscopic deformation bands that appear similar in outcrop but differ significantly in microstructure. These four types of deformation bands are as follows: - In weakly consolidated to unconsolidated sand that has undergone limited mechanical compaction during burial we observed deformation bands that lack evidence of grain breakage but where porosity reduction is caused by grain sliding and rotation. Bands that are parallel to the tectonic shortening direction exhibit pure dilatation as revealed by an increase in porosity.

- In weakly- to well-cemented sandstone of high to intermediate porosity, deformation bands are composed of crushed grains that are compacted with or without shearing. As described by previous workers, porosity and permeability are strongly reduced within this kind of deformation bands.

- In a well-compacted sandstone of low porosity, fragmentation and formation of deformation bands are preceded by the formation of transgranular opening-mode fractures that occur in sets subparallel to the developing deformation bands. Unlike the first two types of deformation bands, these deformation bands have sharp boundaries to undeformed host rock. - In clay-rich sandstone, deformation bands are composed of elongated domains of finely crushed quartzo-feldspatic grains that are separated by clay-rich domains. In cathodoluminescence microscopy, these deformation bands resemble S-C fabrics with shear concentrated along the clay-rich domains.

The type of deformation is likely to depend on initial porosity, mineralogical composition, grain size, host rock cementation, and on stress boundary conditions. The specific mechanism of deformation band formation is likely to affect the permeability of these bands thus controlling the hydraulic properties of sandstone.

T32E-0905 1345h POSTER

Stress-Induced Acoustic Anisotropy in Sands: Preliminary Experiments and Models Comparison

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Stress anisotropy can affect the stability and induce mechanical failure in uncemented or poorly cemented sediment formations. Indirect and conventional methods such as seismic and sonic logs provide the potential to monitor stress changes and to reveal insights into the rock and sediment microstructure. Despite this fact, acoustic anisotropy in naturally occurring unconsolidated sediments has been neglected. The present work introduces an experimental study of stress-induced acoustic anisotropy in two different dry sand samples.

Induced acoustic anisotropy was detected using uniaxial stress tests. We acquired and processed acoustic wave signals in orthogonal directions. We measured the strains and stresses in the three Cartesians directions. Induced stresses in the planes orthogonal to the axial stress were higher in the unloading processes, and the strains showed a ductile behavior. We found considerable velocity anisotropy in both sands, i.e. velocities in the direction of the major stress were consistently faster than the velocities in the other two directions. The acoustic anisotropy was 71% to 99% for stress anisotropy of 12% to 33% in the coarse grain size sand, and the acoustic anisotropy was 66% to 89% for stress anisotropy of 12% to 27% in the fine grain size sand. The general trend of velocity anisotropy with stress was the same for both sands. The velocity hystereris was more notable in the directions of the induced stresses than in the applied stress. Also, we compared our results with four theoretical models based on the Effective Medium Theory and the Hertz-Mindlin contact model. There is an acceptable match of these models with our acoustic anisotropy data under certain conditions and adjustments except for an over-prediction of the induced stresses. We inferred that the main limitations of these models are the assumptions of identical spheres and non-slip between grains, which have to be substituted for better approximations. However, our results indicated that using acoustic velocities we can detect induced stress anisotropy in sands.

T32E-0906 1345h POSTER

New Insights Into the Elastic Moduli-Porosity Relationship in Sandstones

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The problem of inverting rock properties from seismic data is of paramount importance in a range of geophysical problems. In particular, attention has been focussed for many years, especially in petroleum industry, on the relationship between the seismic wave velocities (or elastic moduli) and the porosity of sedimentary rocks. The task of finding a simple universal relationship between those parameters has proved very difficult since the rock elastic moduli depend on many parameters other than porosity including mineralogy, grain shape and arrangement, degree of cementation, clay content, fluid composition, pore and confining pressure. Nevertheless, the most popular relationship between the elastic moduli and the porosity is