T51B-0881 0830h POSTER

Evaluation of the Long-Term Segmentation of the Wasatch Fault Footwall Using (U-Th)/He Thermochronometry

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The Wasatch fault zone (WFZ) is a 350-km-long normal fault system that is separated into ten segments based on its surface fault trace and topographic salients in the footwall Wasatch Mountains. The presence of the topographic salients, E-W striking fault zones that cut across the Wasatch, and apparent changes in depth of exposure of footwall rocks at the segment boundaries suggest these boundaries partition long-term footwall uplift and exhumation between the segments. To determine low-temperature (∼65° C) cooling ages and infer exhumation rates within and between footwall segments, we measured multiple, single-grain laser (U-Th)/He ages on 11 footwall samples collected from the five central segments at a common elevation (∼1500 m) along the range front. Pooled ages from this study average 5.3 ±1.2 Ma for most of the Wasatch Front. Age ranges within segments, arranged north to south, are as follows. Two samples from the Brigham City segment yield average sample ages of 4.5±1.3 to 5.7±1.2 Ma. Four samples from the Weber segment have ages of 3.8±0.3 to 6.4±1.7 Ma, with the youngest ages in the center of the segment. Two samples from the northern Salt Lake segment yield ages of 3.4±1.1 to 5.2±1.2 Ma. Two closely spaced samples from the Provo segment and one from the Nephi segment yield ages of 6.4±1.2 Ma. Typical age variations within and between segments are relatively small with overlapping uncertainties, except on the Salt Lake segment, where several multiple-grain furnace (U-Th)/He ages from the Cottonwood Intrusive Belt (CIB) in the southern Salt Lake segment (Armstrong et. al. AGU, 1999) are about half those of the rest of the segment and the Wasatch Front average. The relatively consistent late Miocene to early Pliocene ages along nearly 200 km of the WFZ suggest similar exhumation rates along most of the Wasatch front for the last ∼6 Ma. With the exception of the CIB, simple calculations assuming monotonic cooling and typical geothermal gradients suggest average exhumation rates of 0.2 to 0.5 mm/yr for the WFZ segments. These relations also suggest the structural features that form some of the segment boundaries were established prior to the cooling event recorded by the (U-Th)/He data. The exception is the segment boundary between the Salt Lake and Provo segments where range front ages suggest exhumation rates in the CIB have been greater by a factor of two or more than in the Provo segment to the south. This difference was probably accommodated by slip on the E-W-striking Deer Creek fault system.

T51B-0882 0830h POSTER

Constraints on Transport Direction Along a Shallow Detachment in the Upper Precambrian of the Eastern Midcontinent

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Dipping reflections observed on seismic reflection profiles imaging the eastern midcontinent display no evidence of west dipping reflections that can be associated with the Coshocton Zone, but support northwest directed transport along a shallow late-Precambrian detachment. Multi-channel seismic reflection profiles were reprocessed and/or analyzed along 60 km east-west and north-south transects that cross at the midpoint. These profiles display south dipping reflectors on the north-south transect and east dipping reflectors on the east-west transect. These dipping reflectors appear to penetrate to 5 km depth and are buried beneath undisturbed, subhorizontal Paleozoic sediments of the Appalachian Basin in southern Ohio and northern Kentucky. These features dip approximately 30 degrees south on the north-south line and 40 degrees east on the east-west line. No reflections with conflicting dips were observed on either transect. Other industry profiles reported in this region display similar reflections with predominately east dipping orientations in the shallow Precambrian section. In no case do these profiles have cross lines that provide limited three-dimensional control. Farther north, west-dipping reflections of the Coshocton Zone are imaged on COCORP Ohio line 2. These reflections dip approximately 40 degrees west beginning directly beneath Paleozoic cover. The shallowest of these reflectors appear to be crosscut by east dipping reflections that merge into a much deeper detachment. However, reflections observed on the westernmost portion of Ohio line 2 do not appear to be consistent with reflections observed 20 km to the north on a shorter industry profile. This southwest-northeast transect displays northeast dipping reflections in the shallow Precambrian that extend to at least 5 km depth.

The constraints imposed by these data are interpreted as evidence for northwest oriented transport direction along an approximately 5 km deep detachment. A late Grenville age of this detachment in the south is presumed to be consistent with that inferred from other regional profiles. The Coshocton zone is either not imaged in these profiles, has a markedly different reflective character than that displayed to the north or does not extend as far west as previously hypothesized. The northeast dipping reflections to the north of Ohio Line 2 are inferred to image a previously unidentified Grenvillian lateral ramp. Such an interpretation is consistent with other fold and thrust belts found throughout the world.

T51C MC: Hall D Friday 0830h

Ophiolites and Continental Margins of the Pacific Rim and the Caribbean Region I *(joint with GP, OS, V)*

Presiding: **Y Dilek,** Miami University; **M F Flower,** University of Illinois at Chicago

T51C-0883 0830h POSTER

Quaternary Tectonics Inferred From Seismic Survey Results Conducted in and Around the Osaka Bay, Southwestern Japan.

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We conducted seismic surveys in and around the Osaka Bay. The Pliocene-Pleistocene Osaka group in this region has many characteristic reflectors of which ages are easily determined by deep boring data and outcrops, or by simple assumptions. Using the dated reflectors, we estimated ages of geological events seen in seismic sections. Main results are as follows: (1) Slip rates (vertical component) of the Osaka-wan Faults and Uemachi Fault have been nearly constant since 1Ma and are about 0.5-0.7m/ky and 0.4-0.5m/ky, respectively. Slip rate (vertical component) of the Osaka-wan Faults before 1Ma is not well determined. But it is nearly equal to that after 1Ma in some sites and is relatively smaller than that after 1Ma in other sites. (2) New sedimentation of the Osaka group in the Harima-nada and the new faulting activities in the northwest coast of Awaji Island to Harima-nada have been closely related, and have both started around 0.9Ma-1Ma. (3) Slip rates (vertical component) of the Median Tectonic Line (MTL) and of the Sumoto-oki Faults changed at around 1Ma: about 0.1-0.2m/ky before 1Ma and averagely about 1-2m/ky after 1Ma in the MTL, and about 0.1-0.2m/ky before 1Ma and about 0.5m/ky after 1Ma in the Sumoto-oki Faults. (4) The unconformity beneath the Kii Channel formed around 0.7-0.8Ma.

Our results suggest a drastic tectonic change may exist around 1Ma in this region. In some period of Quaternary, the stress field was changed from N-S trending compression to E-W trending compression at the inner zone of southwestern Japan. Whatever the cause of the change was, it is thought to have occurred around 1Ma. This is suggested by the facts that (1) new activity of the MTL active fault system has begun since 1-1.2Ma at the Kinokawa Valley area (Mizuno, 1992) and (2) the Ise Bay and the Nobi Plain have started to form around 1.1Ma (Makinouchi, 1999). The drastic change around 1Ma stated above may be related to the change of stress direction around 1Ma.

Kagami et al.(1983) found turbidites began to deposit around 0.7Ma at the bottom of the Nankai trough. To explain the age, Kagami(1989) suggested the rapid uplift of the Shikoku Mountains due to change of subduction direction of the Philippine Sea plate. The unconformity stated above may be related to this uplift.

T51C-0884 0830h POSTER

The mode and nature of faulting and deformation and the emplacement history of the Mineoka ophiolite, NW Pacific Rim: From mid-ocean ridge spreading to tectonic accretion on land

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The Boso Peninsula (Japan), currently located north of the oblique subduction boundary between the Philippine Sea and North American Plates, occurs in a unique area where the Pacific Plate is subducting westwards under the Philippine Sea Plate near the Boso TTT-triple junction. In the southern part of the peninsula, Tertiary chert and limestone and mafic-ultramafic rocks are distributed together with island arc volcaniclastics and continentally-derived detrital rocks, forming an ophiolitic melange (Mineoka belt). The Mineoka ophiolitic melange has developed at the boundary between three different realms of oceanic, continental and island arc settings. Although its stratigraphy and lithologic units are well studied, the structural relations of each rock body in the Mineoka belt and their tectonic implications are not well constrained. Our detailed structural studies show that the fault systems within the basaltic rocks record two episodes of deformation during the evolutionary history of the melange belt. The normal fault system characterized by calcite and zeolite (laumontite, analcime, natrolite, etc.) veining and cataclasis along extensional faults and shear zones of various types and directions marks the first-stage of deformation. These veins were developed either as hybrid extension/shear fractures or cataclastic shear fractures, suggesting high pore-fluid pressures associated with hydrothermal event(s). The second stage of deformation is characterized by thrust-fault related shear zones with a significant strike-slip component. These shear zones are parallel to the general structural trend of the Mineoka belt and are spatially associated with igneous rocks showing MORB, IAT, and/or BABB affinities. We infer that the first stage of deformation, as displayed by the mafic rocks in the melange, is related to extensional tectonics and associated normal faulting at a mid-ocean ridge, and the second stage of deformation related to the final emplacement of the fossil oceanic crust on land by oblique subduction-obduction processes. The mid-ocean ridge component (MORB rocks) of the Mineoka belt formed during the Eocene as part of an oceanic plate, which we interpret as the counterpart of the North New Guinea plate in the south. This oceanic plate (Mineoka Plate) subsequently moved northwards towards the NW Pacific Rim, and part of it was tectonically accreted into the corner of the TTT-type triple junction setting during the Miocene to form the Mineoka ophiolitic melange belt.

T51C-0885 0830h POSTER

The Tectonic Set-up of the Junction Zone Between the Verkhoyansk Chukotka and Koryak Kamchatka Folded Belts

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The two principal tectonic features of NE Asia?the Verkhoyansk Chukchi and Koryak Kamchatka folded belts?exhibit dissimilar structural plans and tectonic histories. The former is characterized by collisional structures and microcontinents, and the latter by accretionary structures and ophiolitic terranes. Structures of the West Koryak orogenic system are developed along the boundary between, and discordantly relative to, these belts. The junction zone displays

island-arc rock assemblages of a broad, Late Paleozoic to Cretaceous age interval, and ophiolitic, oceanic, and island-arc accreted terranes. Based on new data, the Taigonos, Penzhina, and Pekulnei segments of the Asian continental margin are described and paleotectonic reconstructions proposed. For the Late Jurassic to Early Cretaceous, the extensive Uda?Murgal island-arc system, which marked the Asian continent/NW Pacific convergent boundary, is restored. This arc?s southern portion represented an Andean-type margin, which passed northward into an ensialic arc, giving way further north still to an ensimatic arc. The convergent boundary is shown to have existed over a lenghty period, beginning at least in the Carboniferous. On the outboard side of the boundary, various allochthonous terranes of Pacific provenance were docked. In its rear, northern Asian continental features, Kolyma Loop terranes, Anyui oceanic basin, etc., occurred. These made up a system of plates and microplates unrelated to the Pacific plates. This long-lived convergent boundary is responsible for the dramatic contrast in structural plans between the Verkhoyansk Chukchi and Koryak Kamchatka folded areas. Supported by RFBR (grant 99-0565649)

T51C-0886 0830h POSTER

Continental Margin of Kamchatka Peninsula, Russia: the Mode and Nature of Crustal Growth in the Accretionary Orogen

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Tectonic accretion of island arc terranes is the process widely developed in Pacific Rim in the present and in the past. The mode and nature of crustal growth of continental margins during arc accretion are various and essentially determined by deformation of the margin. The Cenozoic Kamchatka orogen formed by the accretion of two island arc terranes: Achaivayam-Valaginskaya arc (A-V, Eocene) (2) and Kronotskaya arc (terminal Miocene) to the continental margin of Asia. During the Early Eocene, the southern segment of the A-V arc collided with the Sredinny metamorphic massif, which was the frontal part of the Asian continental margin (3). New results from SHRIMP dating of zircons (1) from metamorphic rocks of Sredinny massif (Kolpakovskaya series) show that the massif contains an abundance of Archean, Proterozoic and Phanerozoic detrital zircon cores, and ubiquitous 77 Ma rims. The youngest ages are from four 47-53 Ma unzoned zircon cores, with dull cathodoluminescence, and irregular morphology. We regard the 47-53 Ma episode of zircon growth in the Sredinny massif as evidence for superimposed metamorphism induced by continental margin subduction at the beginning of its collision with the A-V arc in the early Eocene. Physical modeling experiments of arc-continent collision suggest that deformation at continental margin is controlled by strength of the subducting crust. Failure, accretion and erosion-activated extrusion/exhumation of the subducted crust occur in the continental margin in the case when the margin is weakened by pre-existing faulting, extension, or heating. At the beginning of the continental margin subduction, crust of the margin fails along the continent-vergent thrust. The subducted crustal slice is, then, completely scraped from the mantle base and accreted to the fore-arc block. Subsequent thrusting and thickening of the subducting crust within the continental margin lead to formation of the accretionary orogen composed of crustal slices in front of the collided arc. Erosional unloading causes the previously subducted crustal slice of the continental margin to slide with a strong horizontal compressional squeezing, and buoyant force. After some subduction of the continental margin, the overriding plate fails in the arc area along the continent-vergent fault, which results in subduction of the fore-arc block. In Kamchatka, the Sredinny massif is considered to represent the crustal slice detached from the mantle base of the leading edge of the Asian continental margin, accreted and exhumed in front of the collided A-V arc. This work is supported by Russian Foundation of Basic Research, project no 316, Geosphaera Research Center, and DOE.

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T51C-0887 0830h POSTER

Tectonic model of the Bering shelf in Mesozoic and Cenozoic

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To understand the tectonic evolution of the Bering Sea Area (BSA), onland geologic data from Alaska and Russia must be integrated with offshore geological and geophysical data. New data from this region, a result of collaborative work between U.S. and Russian researchers, can be used to create a better working model for the formation of this vast, mostly submerged continental region. The BSA includes the continental Bering shelf, and the adjoining Aleutian deep-water basin to the south. Cretaceous oceanic crust, a trapped piece of the Pacific Kula plate, underlies the Aleutian basin. Oceanic crust of this age is also found as tectonic fragments in accretionary complexes in both the Koryak Highlands and southern Alaska. Subduction processes shaped Koryak and Southern Alaska beginning in the Mesozoic, with the development of the many island arcs and accretionaries complexes. Plate tectonic and paleomagnetic data indicate that all terrains accreted in western Koryak traveled on the Izanagi plate. At the same time, accretion of terrains in Central and East Koryak, and also Alaska traveled with the Farallon plate. Subduction/accretion along these plate boundaries was coeval with significant crustal shortening in the Brooks Range culminating in Berriasan-Valanginian time. Medium to high P/T metamorphism and deformation during shortening is dated at 113 Ma (min. age) in Brooks Range, 125 Ma (min. age) on Seward Peninsula, 124 Ma (min. age) in Chegutin Valley, Chukotka and 132 Ma near Providenya Bay. Deformation was linked to the southward motion of the Arctic-Alaska-Chukotka microplate, which became the northern part of the Bering Shelf. Subduction/accretion and crustal shortening set the stage for the main phase of creation of the Bering Shelf at the 110-115 Ma. Accretionary processes in the Koryak Highlands led to accretion of the Yanranay oceanic terrain, during development of the Kankaran island arc. This phase was over by the end of Albian and resulted in cessation of Kankaran Island Arc magmatism, which stepped seaward with time, in conjunction with roll-back of the subducted slab. Extension of previously deformed and accreted crust occurred in the Brooks Range, Central Alaska, and offshore Bering Shelf as well during the interval 115-90 Ma. At this time, continued of subduction along the continental margin of Asia resulted in the formation of the Okhotsk-Chukchi volcanic belt, which developed in a weakly extensional tectonic regime. The formation of several island arcs all occurred in Late Cretaceous in Koryak as a broad belt of plutons were emplaced in Alaska. The Eocene was an important time, when plate motions changed again and subsequent formation of the Aleutian Arc. Sinking of the subducted slab at this time resulted in continued extension within the Bering Shelf and the beginning of formation of deep sedimentary basins. The combination of extension with right-lateral strike-slip faulting in Alaska resulted in the formation of a right-slip boundary along the edge of the Bering Shelf, with transpressional pull-apart basins developed along the shelf edge as final consequence of these motions. In conclusion, the geodynamic history of the BSA was dictated by a series of events and complex processes related to subduction of oceanic lithosphere along the Pacific plate boundary. In particular, under the active North American continental margin, two similar events involved the southern migration of subduction zones, together with variable extension of crust

T51C-0888 0830h POSTER

Constraints on the crustal structure of the Aleutian island arc from wide-angle seismic data: Inference and assessment using an SVD approach

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An important problem in earth sciences has been the suggestion that the continental crust has grown in the Phanerozoic by means of accretion of island arcs. Using the seismic velocity of the crust as a yardstick for bulk composition, we can compare the seismic velocity structure of island arcs with compilations of seismic velocity of the continents. Seismic data from a 1994 study of the Aleutian island arc indicate that the seismic velocity in this island arc is too high to match the structure of typical continental crust, which suggests that island arcs must differentiate upon accretion if they are the building blocks of newly formed continental crust. To test these notions we do not need to image small-scale (smaller than 10 km) variations in seismic velocity of island arcs, but we must measure the average seismic velocity and crustal thickness with high accuracy. We apply a singular value decomposition (SVD) to the inversion matrix of a tomographic data set to obtain resolution and covariance matrices for seismic velocity and layer thickness. These matrices can subsequently be collapsed to provide error bounds on the average seismic structure. Using the Aleutians data set as an example, we show that spatially averaged seismic velocities and crustal thickness can be estimated accurately, even when our knowledge of the detailed velocity structure is ambiguous.

T51C-0889 0830h INVITED POSTER

Thickened Ocean Crust or Basal Island Arc Origin for the Pitka Mafic-Ultramafic Complex, Northern Alaska

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Scattered occurrences of Mesozoic mafic-ultramafic rocks that extend over 1000 km across northern Alaska occupy a tectonic position similar to many suprasubduction zone ophiolites. The mafic-ultramafic (mum) complexes occur as klippe; the structural layers range downward from ocean protoliths, immediately below the mum complexes, to distal continentally-derived metasediments, to more proximal metasediments. The mum complexes lack the classic full or even partial ophiolite section and consist only of ultramafic and mafic plutonic rocks which are not genetically related to structurally underlying cherts, metagabbros and metabasites. Most of the mum complexes do have metamorphic soles and/or retrograde shear zones, which have strikingly similar ages (∼166 Ma) throughout northern Alaska. The protoliths and metamorphic histories of the mum complexes and the rocks immediately beneath them vary, which may provide the key to understanding the origin and emplacement of these "ophiolites".

The Pitka complex, one of the easternmost of the northern Alaska mum complexes, has a similar protolith to other complexes, containing predominantly layered gabbros, harzburgite, and lherzolite. It is anomalous compared to those in northern Alaska in that the mafic-ultramafic rocks are high-P granulite facies. Metamorphosed mafic rocks contain plagioclase (pl)-clinopyroxene (cpx)-garnet (grt)-orthopyroxene (opx)-hornblende (hb). Scapolite is present locally but quartz (qtz) is absent. Metamorphosed ultramafic rocks contain olivine-cpx-opx-spinel. Grt-cpx Fe-Mg exchange temperatures (T) range from 770 to 860 C at 10 kbar. Opx-cpx geothermometry yields T's from 715 to 810 C at 10 kbar. Maximum pressure based upon grt-pl-cpx equilibria without qtz is near 10 kbar at 800 C. Ar/Ar dates from hornblende range from 169.5± 0.3 Ma in the granulite facies rocks to 166 ± 0.6 and 164.8 ± 1.1 Ma in epidote-amphibolite shear zones. Many rocks show little evidence of retrogression (symplectites are rare) and apparently underwent rapid, relatively dry cooling. The Pitka complex appears to correlate with the Kanuti complex to the west, which also preserves evidence for high-P and high-T metamorphism. We prefer an interpretation that the metamorphism reflects conditions present when the Kanuti and Pitka complexes crystallized, rather than subsequent tectonic burial. The pressures require a model for origin of either basal island arc or anomalously thick ocean crust. Final assembly of the mum klippe over oceanic and passive margin sequences occurred during Late Jurassic-Early Cretaceous collision of the Arctic margin with an island arc.

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T51C-0890 0830h POSTER

Metamorphism in the Tlikakila Complex, Lake Clark National Park, Alaska: Does it Record the Collision of the Peninsular Terrane With Alaska?

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The Tlikakila complex is a 80 km x 5 km belt of variably metamorphosed and deformed rocks thought to be part of the Peninsular terrane of southern Alaska. This project uses detailed mapping, structural analysis, and thermochronology to address the tectonic evolution of rocks thought to be part of the Peninsular terrane in southern Alaska. Both meta-igneous and metasedimentary rocks of Triassic (?) age are exposed. Meta-igneous protoliths include mafic (gabbro, basalt) and ultramafic rocks. Metasedimentary protoliths include limestone, chert, and other siliceous sediments. Metapelites are rare. Metamorphic rocks in the study area include two distinct occurrences. Smaller outcrops, appear to be roof pendants in Tertiary plutons. At Kasna Creek, near Kontrashibuna Lake, limestone beds were contact metamorphosed with copper sulfide mineralization within a mafic pluton. Larger outcrops in the Tlikakila complex are more continuous, more pervasively deformed, and more recrystallized.

A new 40Ar/39Ar analysis of white mica from a metasedimentary rock in the Tlikakila complex located just southwest of Saddle Lake yielded a monotonically increasing age spectrum, with the oldest high-temperature step giving a date of around 160 Ma, and the low-temperature step giving a date of 60.5 Ma. The oldest date could represent the timing of greenschist facies metamorphism of the Tlikakila complex. It is interesting that this 160 Ma date is similar to the youngest of the Middle to Late Jurassic plutons (174-158 Ma) in the Alaska-Aleutian Range batholith, considered to be part of the Peninsular terrane. Metamorphism in the Tlikakila complex could be related to the onset of the collision of the Peninsular terrane with Alaska, which also resulted in the cessation of arc magmatism. The youngest date from this sample overlaps with existing 59-63 Ma K-Ar dates from Tertiary volcanic and plutonic rocks in the area and records new mica growth associated with Tertiary magmatism.

T51C-0891 0830h POSTER

Orogeny and Orography of the Washington Cascades: Insights From Low-Temperature Thermochronometry and Thermo-Kinematic Modeling

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While the broad tectonic and magmatic history of the early (pre-Late Eocene) Washington Cascades is relatively well characterized, surprisingly little is known about the subsequent low-temperature thermal history and geomorphic evolution. Several lines of evidence, including deformation of Miocene through Pleistocene strata and paleobotanic constraints, suggest that much of the modern relief of the Washington Cascades may be younger than Late Miocene. We have investigated the exhumation and topographic development of the range using 52 new (a) apatite helium (AHe) (Tc $\sim 80^{\circ}$ C), (b) apatite fission track (AFT) (Tc $\sim 110^{\circ}$ C), and (c) zircon helium (ZHe) (Tc $\sim 200^{\circ}$ C) ages, combined with multidimensional thermo-kinematic models. These models include a spatially variable kinematic field and basal heat flow and are coupled with cooling-rate dependent kinetic models of thermochronometer sample ages.

In the north Cascades (near Mt. Baker), age ranges for samples collected over $\sim$1 km of relief are 6-11 Ma for AHe, 16-40 Ma for AFT. In the central Cascades (Stevens Pass/Mt. Stuart), age ranges for samples collected over $\sim$2.5 km of relief are 8-62 Ma for AHe, 40-83 for AFT, and 54-74 for ZHe. Samples from mid-Tertiary plutons in the southern part of the range (near Mt. Rainier), have AHe ages of 5-9 Ma. The 5-11 Ma AHe ages at all elevations in the north and south Cascades, and at low elevations in the Mt. Stuart area, could reflect relatively rapid exhumation of the upper 2-3 km of crust throughout the range in the Late Miocene, a time of significantly decreased magmatic output in the range. Alternatively, these data could represent steady, long-term, but spatially variable erosional exhumation rates in different parts of the range. In the context of the latter model, erosion rates in the north Cascades west of the drainage divide are locally as high as $\sim$2-3 mm/yr, and erosion rates in the south Cascades are around 0.2-0.5 mm/yr. Most notably, in the central part of the range, AHe ages increase (at a given elevation) towards the east, while AFT and ZHe ages do not. Preliminary thermo-kinematic modeling of AHe ages suggests that erosion and exhumation rates west of the present day drainage divide in the central Cascades are $\sim$0.1-0.2 mm/yr while those east of the drainage divide are $\sim$0.05 mm/yr.

Higher erosion rates on the west side of the central Cascades could be the result of the strong orographic effect across the range which may have enhanced fluvial and glacial erosion processes. This interpretation is consistent with: (a) present day mean annual precipitation rates of $\sim$120-280 cm/yr west of the drainage divide compared to $\sim$40-120 cm/yr east of the divide; (b) a strong west-to-east topographic and drainage divide asymmetry suggestive of a long-term orographic effect; and (c) the lack of significant post-Eocene faults capable of accommodating a west-side-up structural tilting of the range.

T51C-0892 0830h POSTER

Ophiolites and Continental Margins of the Mesozoic Western U.S. Cordillera

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The Mesozoic tectonic history of the western U.S. Cordillera records evidence for multiple episodes of accretionary and collisional orogenic events and orogen-parallel strike-slip faulting. Paleozoic-Jurassic volcanic arc complexes and subduction zone assemblages extending from Mexico to Canada represent an East-Pacific magmatic arc system and an accretionary-type orogen evolved along the North American continental margin. Discontinuous exposures of Paleozoic upper mantle rocks and ophiolitic units structurally beneath this magmatic arc system are remnants of the Panthalassan oceanic lithosphere, which was consumed beneath the North American continent. Pieces of this subducted Panthalassan oceanic lithosphere that underwent high-P metamorphism are locally exposed in the Sierra Nevada foothills (e.g. Feather River Peridotite) indicating that they were subsequently (during the Jurassic) educted in an oblique convergent zone along the continental margin. This west-facing continental margin arc evolved in a broad graben system during much of the Jurassic as a result of extension in the upper plate, keeping pace with slab rollback of the east-dipping subduction zone. Lower to Middle Jurassic volcanoplutonic complexes underlain by an Upper Paleozoic-Lower Mesozoic polygenetic ophiolitic basement currently extend from Baja California-western Mexico through the Sierra-Klamath terranes to Stikinia-Intermontane Superterranes in Canada and represent an archipelago of an east-facing ensimatic arc terrane that developed west and outboard of the North American continental margin arc. The Smartville, Great Valley, and Coast Range ophiolites (S-GV-CR) in northern California are part of this ensimatic terrane and represent the island arc, arc basement, and back-arc tectonic settings, respectively. The oceanic Josephine-Rogue-Chetco-Rattlesnake-Hayfork tectonostratigraphic units in the Klamath Mountains constitute a west-facing island arc system in this ensimatic terrane as a counterpart of the east-facing S-GV-CR system to the south. The Guerrero intra-oceanic island arc system in Mexico was also part of the ensimatic arc terrane. Incorporation of this super arc terrane into the North American continent occurred diachronously along the irregular continental margin in the Middle Jurassic (in the north) through Early Cretaceous (in the south) during an arc-continent collision, marking a collisional orogenic episode in the North American Cordilleran history. Rifting of this accreted arc in the Late Jurassic (155-148 Ma) might have resulted from a sinistral transtensional deformation associated with the rapid NW motion of North America. Magmas generated during this rifting event probably migrated through the accreted arc crust and the continental margin units in the tectonic lower plate. The Franciscan subduction zone dipping eastwards beneath the continent was established in the latest Jurassic, following the collisional event and restoring the North American Cordillera back into an accretionary-type, Andean-style orogen. Different episodes of orogen-parallel intra-continental strike-slip faulting facilitated lateral dispersion of accreted terranes and continental margin units during the Early Cretaceous and transpressional deformation and batholithic magmatism in the Sierra Nevada magmatic arc in the Late Cretaceous. A Jurassic-Cretaceous island arc system (Wrangellia-Insular Superterrane) that had developed west of the Jurassic archipelago collapsed into the edge of North America during Late Cretaceous-Tertiary time and underwent northward lateral translation along the continental margin. These observations and interpretations have strong implications for the tectonic evolution of Central America and the Caribbean region.

T51C-0893 0830h POSTER

Ophiolite and Tectonic Development of the East Pacific Margin

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Well-preserved ophiolites represent oceanic crust and mantle formed at a spreading center and emplaced by collision of a mantle-rooted thrust fault (subduction zone) with a continental margin or island arc. Ophiolite nappes thus represent remnants of lithospheric plates; their basal thrusts (fossil subduction zones) intrinscally cannot be balanced; their displacements are unknown but very large. Many environments of formation are possible for ophiolites: mid-ocean ridge, back-arc, forearc, or intra-arc spreading vrnyrtd, but geochemistry alone is inadequate to differentiate between the possibilities; geologic field evidence is needed, as well.

Mesozoic ophiolites in western North America are associated either with the Stikine-Intermontane superterrane (e.g. Sierra Nevada, Klamath Mountains, California. Guerrero terrane, Mexico?), or lie west of it (e.g. Great Valley/Coast Range ophiolite and correlatives to north and south.). The "Great Arc" of the Caribbean (Burke, 1988), including ophiolitic rocks in Cuba, Hispaniola, Puerto Rico, Venezuela, and Colombia, may also correlate with the Great Valley/Coast Range ophiolite and/or with ophiolites in the Sierra Nevada. The Wrangellia/Insular superterrane may have extended to the south and at times may have included parts of the Chortis-Choco blocks of Central America, as well as the Cordillera Occidental of Colombia and Ecuador).

These relations suggest the hypothesis that in mid-late Mesozoic time, a separate intra-oceanic plate similar to the present Philippine plate, herein informally called "Americordilleria" was separated by active island arc complexes from the American andFarallon/Kula plates to the east and west, respectively. Basement rocks of the Colombian, Venezuelan, and Yucatan basins, as well as the Great Valley/Coast Range ophiolite, may represent remnants of "Americordilleria". Convergence and collision of "Americordilleria" and its island arc margins with the American continents were major factors in western American and Caribbean orogenic development. Direct contact between the Kula/Farallon plates and North America may not have occurred until late Cretaceous time.

T51C-0894 0830h POSTER

Implications of Volcanism in Coastal California for the Deformation History of Western North America

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The geologic record of coastal California includes evidence of numerous volcanic centers younger than 30 Ma that do not appear to have erupted in an arc setting. By correlating these volcanic centers with specific slab windows predicted from analysis of magnetic anomalies on the Pacific plate, we add new constraints to tectonic reconstructions since 30 Ma. Our correlations–such as erupting the Morro Rock-Islay Hill complex south of the Pioneer fracture zone and the Iversen Basalt south of the Mendocino fracture zone–require larger displacements within western North America than advocated by most previous authors. Specifically, we infer at least 325 km of motion in a direction of about N65W between the Sierra Nevada and rigid North America since 23 Ma, and at least 525 km of motion, also at about N65W, between Baja California and North America since about 15 Ma. A consequence

of inferring a large displacement of Baja California is that the Pacific-North American plate boundary must have developed most of its current form prior to 10 Ma.

We infer that the Monterey plate was captured by the Cocos plate at about 23 Ma, then transferred to the Pacific plate at about 19 Ma. A slab window developing from a Cocos-Monterey fracture about 100 km inboard from the continental margin reconstructs under nearly all of the southern California volcanic centers dated at 18-14 Ma. Most of the sedimentary basins associated with volcanic rocks show a brief period (<2 Myr) of rapid subsidence synchronous with volcanism, followed by slow subsidence of variable but often extended duration (∼10-20 Myr). This pattern is consistent with rapid extension of cold lithosphere over recently introduced hot asthenosphere.

T51C-0895 0830h POSTER

Complex Drainage Response to Migrating Tectonic Uplift: Example from the Northern California Coast Ranges.

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Triple junction migration produces rapid and dramatic changes in the processes and patterns of crustal deformation. In the case of the migration of the Mendocino triple junction (MTJ) in the northern Californian Coast Ranges, the Mendocino Crustal Conveyor geodynamic model (MCC) predicts a spatially and temporally varying pattern of crustal deformation and uplift. A combination of crustal thickening/thinning and dynamic topography creates a 'double-humped' pattern of uplift with a maximum of 3-4 km, rates of uplift/subsidence ranging from 1.5 to -1.5 mm yr1, and exhumation locally of up to 3 km. With such significant changes, the landscape will evolve in a manner that records the history of uplift and subsidence as the triple junction migrates. We can exploit this record to better constrain geodynamic processes and test models of landscape response to large scale tectonic forcing. Evidence that the tectonics are recorded by the geomorphology in the Coast Ranges include: topography that closely resembles the double-peaked shape of MCC-predicted topography; the pattern of drainage which is characterized by northwest trending streams (flowing either to the northwest or southeast) and east-west trending connecting rivers; two large drainage divides which are broadly coincident with predicted topographic peaks and separate northwest from southeast flowing streams and are topographically low suggesting they migrate in concert with MTJ migration; and slope-area statistics throughout the Coast Ranges - both stream concavity and steepness - show a pattern of variation that corresponds to the rate and amount of uplift predicted by the MCC.

We use landscape evolution modeling as a tool to test whether the geomorphic observations in the Coast Ranges can in fact be linked to the uplift/subsidence pattern of the MCC. Important in this analysis is developing an understanding of the conditions within a growing orogen that lead to flow reversal and migration of drainage divides. Many other landscape evolution modeling studies find that streams cut through or are diverted around a growing structure, incompatible with our observations in the northern Coast Ranges. Using CHILD we are testing the hypothesis that the effects of a migrating uplift function which produces a topographic gradient that switches between northwest and southeast trending is critical to driving flow reversal and divide migration. In many orogenic systems, pre-existing drainage patterns greatly influence river systems throughout its history, making the extraction of tectonic signals from landscape patterns difficult. In the case of the northern Coast Ranges, we are able to avoid this complication since the land surface for much of the present-day Coast Ranges was part of a submarine accretionary prism prior to MCC uplift. There should be only minor inherited drainage patterns in the land surface when it becomes subarial, and by using the present surface morphology in the southern Cascadia margin we can include those patterns. This allows us to test the landscape evolution we observe against our modeling.

T51C-0896 0830h POSTER

The Role of Mantle Flow in driving Pre-Collision Subduction-Accretion Cycles: Preliminary Caribbean Model

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Actualistic subduction-accretion models developed from studies of subduction initiation, volcanic arc splitting, and arc-trench rollback processes in the western and southwestern Pacific suggest that refractory magmas such as boninite, high-magnesium andesite, and adakite may be key petrologic signals of 'hot' subduction initiation. In the western Pacific, two types of model have recently been proposed: 1) asthenospheric mantle extrusion produced by diachronous continental collisions during Tethyan closure and 2) 'superplume' interaction with pre-existing subduction systems. The first of these is supported by the presence of boninitic rocks in virtually all Tethyan ophiolites and is consistent with the latter representing non-subducted, lithologic residues produced during pre- and post-collision subduction-accretion cycles. However, a model of the second type may be applied to equivalent stages of Caribbean plate evolution where Tethyan-type collisions were not in evidence. Here, lateral asthenospheric outflow from the Galapagos hotspot (marked by incipient thickening of the Farallon plate pre-Senonian) may have triggered subduction and the appearance of boninitic volcanism in the Late Jurassic along a NE-SE-trending transform fault. The consumption of Farallon plate lithosphere (formed in the Late Jurassic to Early Cretaceous) was terminated by the arrival of thickened plateau lithosphere at the hot, newly-formed, Greater Antilles subduction zone. This event triggered splitting of the boninitic arc and was followed by one or more cycles of basin opening and arc-trench rollback, eventually terminated by collision with the Bahamas Bank (North American Plate) at c. 45 Ma. According to this scenario, Cuba, Hispaniola, Puerto Rico, and other components of the Greater Antilles, represent a lithologic 'high-tide mark' (HTM) of products marking early stages of mantle extrusion, with ophiolites, in particular, yielding clues to the latters thermal, compositional, and dynamic state. The present-day Caribbean plate consists of two parts, the largely submerged remnant of thickened Farallon plate lithosphere, and the accreted fragments (Greater Antilles HTM lithologies and relict basins) comprising allochthonous Farallon plate fragments, relics of backarc, forearc, and arc lithologic successions, and their tectonized remnants. Asthenosphere flow driven by deep upwelling would have been compounded by eastward extrusion induced by the westward drift of North and South American plates, accelerated since the c. 30 Ma. Africa-Eurasia collision.

T51C-0897 0830h POSTER

Geotectonic Elements, Stuctural Constraints and Current Problems for a Kinematic Reconstruction of the Caribbean Plate Margins during the Cretaceous.

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In the Caribbean Plate deformed margins are found relics of the Mid to Late Cretaceous eo-Caribbean tectonic phases, indicating the occurrence of sub-continental subduction zones with melange formation, and HP/LT metamorphism of ophiolitic rocks, and two main stages of intraoceanic subductions involving the unthickened proto-Caribbean oceanic lithosphere and/or supra-subduction complexes. These two stages are marked by the occurrence of (a) HP/LT metamorphic ophiolites and volcano-plutonic sequences with island-arc tholeiitic (IAT) or calc-alkaline (CA) affinities; (b) unmetamorphosed tonalitic intrusions of CA affinity below the proto-Caribbean thickened oceanic plateau. Since the Late Cretaceous the kinematics of the Caribbean Plate is closely related to the eastward drifting of the proto-Caribbean oceanic plateau (Colombia and Venezuela Basins) that produced both a diachronous tonalitic magmatism from 85-82 Ma, associated with a westward dipping oblique subduction of the proto-Caribbean-Atlantic ocean floor below the plateau, and an opposite dismembering of subduction complexes, of different ages along an E-W trend (North and South Caribbean Margins). This seems to be the consequence of the eastward shifting of both the northern and southern triple junctions, while allowing further bending of the Aves- Lesser Antilles arc. Moreover, the Caribbean oceanic plateau was trapped by different rotation rates of the Chortis, Chorotega and Choco blocks, during the construction of the western plate margin (Central American Isthmus). The previous Mid-Late Cretaceous eo-Caribbean evolution, correspondent to the beginning of the compressional conditions in Central America area, is characterized by sub-continental and/or intraoceanic subduction systems with associated IAT and CA arc magmatism. This simplified kinematic approach falls short in explaining (1) the Early Cretaceous paleogeography and morphology of the margins of the North, South American continents and minor blocks; (2) the sinking direction of the previously subducted oceanic slabs; (3) the locations of and relationships between the intraoceanic and sub-continental subduction zones. Taking this points into account and on the basis of the new geological constraints, some alternative tectonic models can be elaborated, each of which needs kinematic releases (strike-slip faults) allowing either the simultaneous activation of intraoceanic and sub-continental collisions, or the progressive insertion by tectonic erosion of the rifted continental portions in the subduction complexes. In a whole transpressional regime the different subduction zones can be inferred to dip either eastward with a later flip westward below the oceanic plateau, or continuously westward; this last case is a better fit for the Northern margin than the Southern margin of the Caribbean plate, where a much more complicated kinematic mechanism should be envisaged.

* Researches carried-out in the framework of the IGCP 433 Caribbean Plate Tectonics.

T51C-0898 0830h POSTER

The Tectonic Evolution of Caribbean Ophiolites

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Ophiolitic rocks (associated basalts, gabbros and ultramafic rocks) occur in many areas in the circum-Caribbean and Central America. These ophiolites are derived principally from two oceanic provinces: (1) the Atlantic realm, proto-Caribbean sea that formed when North America separated from South America during the opening of the North Atlantic during Jurassic and Early Cretaceous time. These ophiolites were emplaced during a series of late Cretaceous to early Tertiary arc-continent collisions as the east facing Antilles arc migrated into the Caribbean realm. These occurrences include Guatamala, northern Cuba, northern Hispaniola, and northern Venezuela. (2) the Pacific realm, late Cretaceous Caribbean-Colombian plateau that now occupies the central Caribbean, but outcrops on land in Costa Rica, SW Hispaniola, the Netherlands Antilles and western Colombia. Accretion, emplacement and uplift was aided by their buoyancy and took place at various times during the Caribbean plateaus insertion into the middle American continental gap. A third set of occurrences are more uncertain in origin. The central Hispaniola and SE Puerto Rico ophiolites seem to be Jurassic age oceanic plateau rocks that were emplaced in mid-Cretaceous time during an, subduction polarity reversal episode. The emplacement of the metamorphosed ophiolitic rocks of eastern Jamaica may also be associated with this event, but the adjacent, upper Cretaceous, Bath-Dunrobin complex seems to be more related to the Campanian Yucatan-Antillean arc collision. The ultramafic rocks of Tobago are not oceanic, but represent Alaksan-type, assemblages.

T51C-0899 0830h POSTER

Neogene Evolution of the Southern Costa Rica Arc: New Geological and Geochronological Data

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The Central American Volcanic arc is characterized by high topography (>3800m) and inactive volcanoes in southern Costa Rica (de Boer et al., 1995, Drummond et al., 1995, Abratis et al., 2001). New field mapping and $^{40}Ar/^{39}Ar$ geochronologic data place new

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constraints on the geology and tectonic history of this region. The Cordillera de Talamanca exposes tilted sections of interbedded basaltic lavas and shallow marine sedimentary rocks intruded by shallowly emplaced mafic to granodioritic plutons. These older volcanics range in age from 14.1 to 10.9 Ma. Younger calc alkaline volcanic rocks are locally preserved, mainly in the western flank of the Talamanca Massif and range in age from 6.4 to 3.5, indicating that this part of the arc did not shut off until at least 3.5 Ma. An apparent hiatus in volcanism from 10.6 to 6.4 Ma coincides with the time when most of the major plutonic complexes of southern Costa Rica were emplaced. The timing and history of surface uplift and tilting of the Cordillera de Talamanca is still not clear. Thermochronologic data from different intrusive complexes indicate that they all cooled very quickly (generally less than 0.5 million years) from ∼500 °C to ∼150 °C. But different plutons cooled at different times, reflecting their shallow levels of emplacement and not tectonic exhumation. In the Fila Costena, Eocene to Miocene sedimentary rocks are cut by east dipping thrust faults, which are in turn cut by gabbroic sills, dated at about 12 Ma. Mid to late Miocene shortening for southern Costa Rica is indicated by Oligocene to mid Miocene volcanic and sedimentary sequences overlain by flat-lying 6 Ma volcanics in the northwestern Talamancas Range.

The shutoff of volcanism, uplift of the Talamanca Range, and shortening in southern Costa Rica has commonly been ascribed to subduction of the buoyant Cocos Ridge. The late Miocene volcanic gap and the mid to Late Miocene shortening however are too early to be attributed the initiation of subduction of the Cocos Ridge, dated at $<\sim$2Ma based on reconstruction of ocean floor magnetic anomalies (Lonsdale et al., 1977). The cause for the change in magmatic output (from volcanic to plutonic) and the deformation of the arc during this interval is not clear, though it may have to do with the changing of the plate subducting beneath southern Costa Rica at this time (from Nazca to Cocos).

T51C-0900 0830h INVITED POSTER

Emplacement, Deformation, and Erosion of the Costa Rican Ophiolite Complexes

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Ophiolite complexes along the Pacific-Caribbean plate boundary cover an age range from Jurassic through Paleocene. We postulate that the spreading centre, which formed the oceanic crust that later became part of the Caribbean plate, was continuous to the spreading centre of the Central Atlantic ocean and eventually of the Penninic ocean of the Alps. Thus, a large, (E)NE-(W)SW trending spreading centre was formed. Based on geometric constraints from the present plate configuration and motion vectors within a global hotspot reference frame, and from global plate reconstructions we suggest that the later Caribbean crust formed further west relative to the Americas than it is presently located, but still in an inter-American position. In Middle Cretaceous to probably Campanian times the formation of the Caribbean Large Igneous Province, which was related to the mid-Cretaceous superplume event, thickened and stiffened the Caribbean plate. In the following the westward movement of the American plates started, which persists until present. Lateral displacement of more than 1000 km between the Caribbean plate and the North and South American plates is related to differences in plate motion velocities and reflects trench-parallel mantle flow along the western boundaries of the American plates as a response to their westward motion.

The convergence between Caribbean and Farallon plates led to deformation of the Central American ophiolites including nappe formation. The thickened oceanic crust of the Caribbean plate became unsubductable and the process of subduction erosion along the Central American convergent plate margin was initiated. This resulted in uplift and basal erosion of the ophiolite body. The onset of subduction erosion is not yet known but is suggested to have started shortly after the formation of the Caribbean plate, i.e. after Campanian. Unconformities of Lower Tertiary sediments overlying ophiolite rocks or older sediments indicate subsidence at least since the Paleogene.

Changing obliquity of the plate convergence throughout the Tertiary due to the breakup of the Farallon Plate into the Cocos and Nazca plates resulted in trench parallel displacement of fragmented ophiolite bodies. This process, however, is still not well understood and remains a major point of discussion.

T51C-0901 0830h POSTER

Relict Oceanic Lithosphere in Cuba: Types and Emplacement Ages

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According to their composition and tectonic position, three different types of relict oceanic lithosphere are present in Cuba: (1) the northern ophiolitic belt, a complex melange that extents more than 1000 km along the island, (2) the basement of the Cretaceous volcanic arc terrane: high temperature/low pressure amphibolites with some serpentinites and, (3) tectonic slices of serpentinite melanges (with eclogites and blueschists) and high pressure amphibolites, in the metamorphic Escambray massif (tectonostratigraphic terrane, microcontinent?) of southcentral Cuba. Available age constrains (paleontological and geochronological) indicate that relicts of oceanic lithosphere in Cuba are upper Mesozoic in age. Geochemical, petrological, and regional geology data suggest that such oceanic relicts probably originated in two different tectonic environments in the Proto-Caribbean basin; (1) a small oceanic basin of Upper Jurassic- Neocomian age, related to drift between North America and a southern continental mass and (2) a suprasubduction marginal basin, between the southeastern North American passive margin and an Aptian-Albian volcanic arc. Tectonic emplacement of the Cuban relict oceanic Proto-Caribbean lithosphere was likely related to several tectonic events and processes. Serpentinite melange slices and the high pressure amphibolites in the Jurassic and Cretaceous passive margin sequences of Escambray massif, characterized by low to moderate temperature and high pressure metamorphism, probably were emplaced from subduction and closure of the small oceanic depression located to the south (present geographic coordinates) of the volcanic arc in the Albian. The basement amphibolites of the volcanic arc terrane were derived from the Upper Jurassic-Neocomian oceanic crust, metamorphosed by the high temperatures and hot solutions related to the development on this crust of an Aptian-Albian volcanic arc with a north dipping subduction zone. These amphibolites were thrusted upon a southern continental mass (Escambray massif) due to the Albian collision with the volcanic arc. Ophiolites of the northern belt were probably derived from both, the small Late Jurassic- Early Cretaceous oceanic depression and the Aptian-Albian marginal basin. Several distinct episodes of tectonic emplacement of the ophiolites in the northern belt are recognized. a) Late Campanian: first clasts of serpentinites and other ophiolitic rocks in sediments derived from subaerial erosion in western Cuba (obduction?). Closing of the small oceanic basin located between the North American paleomargin and a second, Late Cretaceous, volcanic arc, with a south dipping (present coordinates) subduction zone. b) Late Maastrichtian: thrusting upon the volcanic arcs terrane in eastern Cuba (obduction?). Coeval movements probably were developed in western Cuba. c) Late Paleocene-Middle Eocene: thrusting upon the foreland basin, related to Cuban orogeny in western and central Cuba. d) Late Middle or Late Eocene: Recorded in a single locality along the Caribbean coast in easternmost Cuba and related to the first strike slip movements along the Oriente fault, with the development of a new Caribbean/North American plate boundary.

T51C-0902 0830h POSTER

Heat Flow Assessment From Bottom Simulating Reflectors at the Southern Colombia-Northern Ecuador Convergent Margin

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Bottom Simulating Reflectors (BSRs) identified on seismic reflection profiles across sedimentary margins generally coincide with the base of the gas hydrate stability field. BSRs are controlled by temperature and pressure conditions. Therefore BSRs can be used to assess heat flow and hence the thermal regime of the margin. Multichannel seismic reflection data acquired during the SISTEUR cruise along the Ecuador-Colombia convergent margin show a distinct BSR along both strike and dip seismic lines. The BSRs locally show a negative polarity and extend to depths of 0.15 s below the seafloor (bsf) on the upper margin (800 m of water depth) and to 0.78 s bsf at trench depths (3800 m). We assumed a purely conductive model to determine heat flow and its variation across the margin; seafloor temperature was obtained from local CTD measurements and the thermal conductivity of the sediments was extrapolated from ODP Leg112 offshore Peru.

Preliminary heat flow values range between 30-40 mW/m2 along the middle and upper margin slopes, whereas heat flow increases to 60-90 mW/m2 close to the trench. The highest near-trench values appear to coincide with the subduction of the young, hot lithosphere beneath the Colombia margin, whereas lower values fit with the subduction of the older and thicker Carnegie Ridge crust beneath Ecuador. From these data, a preliminary thermal model of the Colombia convergent margin, in the area of the great 1906 subduction earthquake, is presented. The late (?) Miocene (8-14 Ma) subducting Nazca plate is considered as the main thermal source because the interpreted ophiolitic nature of the margin is believed to have negligible radiogenic heat production. The model also integrates a 7 cm/year plate convergence rate, as well as the margin geometry and structures as obtained from the new SISTEUR multichannel seismic reflection and refraction data. Temperatures at the top of the subducting plate, as determined from the thermal model, provide important constraints on the width and nature of the seismically locked rupture zone associated with the great subduction earthquakes on the margin.

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Rocas Verdes Ophiolite Complexes in the Southernmost Andes: Remnants of the Mafic Igneous Floor of a Back-arc Basin that Rifted the South American Continental Crust in the Late Jurrassic and Early Cretaceous

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The Rocas Verdes are an en echelon group of late Jurassic and early Cretaceous igneous complexes in the southernmost Andes. They consist of mafic pillow lavas, dikes and gabbros interpreted as the upper portions of ophiolite complexes formed along mid-ocean-ridge-type spreading centers. When secondary metamorphic affects are accounted for, the geochemistry of mafic Rocas Verdes rocks are similar to ocean-ridge basalts (MORB). The spreading centers that generated the Rocas Verdes rifted the southwestern margin of the Gondwana continental crust, during the start of break-up in the southern Atlantic, to form the igneous floor of a back-arc basin behind a contemporaneous convergent plate boundary magmatic arc. Late Jurassic and early Cretaceous sediments from both the magmatic arc on the southwest and the continental platform on the northeast of the basin were deposited in the Rocas Verdes basin, and these sediments are interbedded with mafic pillow lavas along the margins of the Rocas Verdes mafic complexes. Also, mafic dikes and gabbros intrude older pre-Andean and Andean lithologies along both flanks of the Rocas Verdes, and leucocratic country rocks are engulfed in the Rocas Verdes mafic complexes. These relations indicate that the Rocas Verdes complexes formed in place and are autochthonous, having been uplifted but not obducted, which may explain the lack of exposure of the deeper ultramafic units. Zircon U/Pb ages of 150+/-1 Ma for the Larsen Harbour Formation, a southern extension of the Rocas Verdes belt on South Georgia Island, and 138+/-2 Ma for the Sarmiento complex, the northernmost in the Rocas Verdes belt, indicate that this basin may have formed by unzipping from the south to the north, with the southern portion beginning to form earlier and developing more extensively than the northern portion of the basin. Paleomagnetic data suggest that the Rocas Verdes basin developed in conjunction with the displacement of the Antarctic Peninsula and opening of the Weddell Sea during the break-up of southern Gondwana. Closure, uplift and deformation of the Rocas Verdes basin took place before the mid-Cretaceous as a result of flattening of subduction due to either ridge subduction or a global increase in plate convergence rates. Shoshonites, which erupted along shear zones on the eastern and northern margin of the Rocas Verdes basin, are the earliest documented post-extensional magmatic rocks and were generated by the processes that lead to the closure of the basin.