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Ancient accretionary complexes exposed on land might have suffered from seismic process in the subduction zone and presents an analogue to geology of the Nankai Seismogenic zone. We investigated the Shimanto Accretionary Complex in SW Japan and found several seismogenic fault candidates during the underthrusting of the complex.
The most clear geologic evidence of seismicity is the recognition of psuedotacylyte originated from frictional melting and was firstly reported from the Shimanto accretionary complex in SW Japan (Ikesawa et al., 2000, Sakaguchi et al., 2000). The pseudotachylite is located along a fault between different lithological units; underplated melange and offscraped coherent units. Such geologic setting of the fault is analogous to seismogenic decollement in modern subduction zone. Detailed P-T analysis of host rocks (about 250°C, 200MPa) and the pseudotachylite (about 700°C) by using mineral assemblange and fluid inclusion within mineral veins suggests the setting.
Second candidate for the seismogenic fault rock; ultracataclasite is commonly observed within melange. The fault shows a straight brittle fault with a few milimeters thick cataclastic vein. The faults systematically displace the melange for a few meters. Fabric relationship of the fault with melange is systematic and suggests a brittle breakage in the last stage of ductile shear of melange. Pressure solution creep of melange and the cataclastic breakage appear to be inter- and co-seismic deformation in the subduction zone, respectively.
Third seismogenic rock is cataclastic basalt block encircled by melange. The cataclastic basalt suggests a brittle breakage of oceanic crust and involvement into the tectonic melange of accretionary complex. Extremely sharp and thin fault veins of untracataclasites surrounded by less deformed cataclastic basalts are commonly observed within basalt blocks. Such occurrence suggests seismic event associated with asperity breakage of the oceanic basement.

T51G-12 1135h

In-situ pressure - temperature condition of tectonic melange : constraints from fluid inclusion analysis of syn-melange veins-

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One of the most reliable settings for the tectonic melange with composite planar fabric is along the decollement in the subduction zone (e.g. Cowan, 1985; Moore and Byrne, 1987; Kimura and Mukai, 1991). The decollement is developed from aseismic shallow part to seismogenic zone of several to tens of kilometer in depth. The decollement-related-melange, now exposed on land, might therefore record the deformation process along the aseismic to seismogenic decollement.
Trapped pressure and temperature of fluid inclusion is estimated from "syn-melange" veins developed around the necks of boudin of sandstone blocks in the melange of the Shimanto Belt, SW Japan. The melange was decollement-related tectonic melange. Fluid inclusion analysis from "syn-melange" veins might be only tool to reveal the P-T condition during melange formation. The result of P-T estimation ranges from about 150(25)°Cto 220(31)°C for temperature and from 81 (+15) MPa to 235 (18) MPa for pressure. Geothermal gradient estimated from the result is between about $10.0(+0.2/-1.5)$°C/km (lithostatic) and $4.2(+0.1/-0.9)$°C/km (hydrostatic) if the fluid pressure ratio to lithostatic pressure is constant in each datum.
The estimated lithostatic thermal gradient is much closer to that calculated from the oldness of the subducting oceanic plate. P-T range suggests that melange was formed enough within the seismogenic zone hypothesized by thermal model although the deformation mechanisms of melange, dominant diffusive mass transfer with minor brittle breakage, do not show the seismic deformation. One possible explanation for this discrepancy is that the melange was formed during the interseismic period. Alternative explanation is that melange formation was accomplished before subducting into the seismogenic zone but around the seismic front. Lithification front hypothesis for the seismic front suggests such frontal setting for the melange.

T52A MC: Hall D Friday 1330h

The Initiation and Early Evolution of Young Ocean Basins II *(joint with OS, S)*

Presiding: **F Martinez,** University of Hawaii**; P Huchon,** Observatoire ocanologique de Villefranche

T52A-0904 1330h POSTER

A MODEL OF THE KINEMATICS OF THE DANAKIL MICROPLATE

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We present a regional approach to the tectonics of the Afar depression, in which we attempt to relate reconnaissance-scale data to overall movement of a Danakil microplate. Topographic, satellite, airphoto, magnetic and gravity data from the flanks and interior of the Afar depression, NE Africa, are used to assess differing models of the dispersal of the Danakil microplate from its western to its eastern margin. The data are compared to small circles about published instantaneous poles to find evidence of strike-slip and transverse features. A good fit to such features is made using a statistically-significant modern pole to the NNE of the Afar depression. A possible reconstruction about this pole, which reunites branches of an inherited shear zone, is presented. This reconstruction is not consistent with a 'crank-arm' or 'saloon-doors' mode of opening for the Afar depression. Instead we suggest that only recently has the Danakil microplate come into existence, after the westwards propagation of the Gulf of Aden rift into the Afar depression. Prior to this time movement of Danakil occurred very slowly about the same pole, but as part of the Somalian plate; as shown by the continuity of ancient flowline features onto the Nubian margin of the Main Ethiopian Rift. At 7 Ma, possibly due to the onset of oceanic-type accretion in Afar where the lithosphere was hot and thin already from the presence of a hotspot, Danakil accelerated eastwards about this pole. In response the Gulf of Aden rift propagated westwards to form a new plate boundary between Danakil and Somalia. The newly-formed Danakil microplate is thus an intermediate stage in the transfer of all or part of the Danakil horst to the Arabian plate from the Somalian plate. Further south, at the Main Ethiopian Rift, continental lithosphere did not rupture but the presence of focussed accretion at Afar in a hitherto-diffuse plate boundary precipitated the southward migration of the SomaliaNubia pole to its present-day position. This event coincides with a change in volcanic style at the Main Ethiopian Rift.

T52A-0905 1330h POSTER

Mechanisms of Continental Extension and Africa-Arabia separation: Constraints from Laboratory Experiments

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We study the mechanisms of continental extension and rifting through the example of Africa-Arabia separation. The influence of the Zagros-Makran subduction and of the Afar hot-spot on the geometry and kinematics of rifting in the Aden-Red Sea region are investigated through laboratory experiments. Our goal was to unravel the effect of the dynamics of the subduction on the deformation of the subducted (Arabic) plate.
We used a three-layer analogue model where sand and silicone represent respectively the brittle and ductile lithosphere, and where honey represents the viscous upper mantle. The negative buoyancy of the sand/silicone unit is the main driving force for subduction, while the bending resisting force of the sand/silicone unit tends to slow down subduction. Preliminary models were realized to characterize the effect of the boundary conditions and the effect of an additional circular weakness corresponding to the Afar hot spot. In more complex models, we simulate the deformation of Northeast Africa during the Tethyan lithosphere subduction and Zagros collision simultaneously with the activity of the Afar hot spot.
These models contribute to explain the presence of distributed extensional deformation in northeast Africa before rifting and the final Africa-Arabia separation. They explain the timing of these extensional events. Subduction has been active since the Mesozoic and provides forces which lead to extension within the subducting plate. The Eurasia-Africa collision changes the boundary conditions and triggers the localization of rifting 30-35 Ma ago. These models also explain the location and the geometry of the rifting in the Gulf of Aden and in the Red Sea. The Afar hot spot localizes extension acting as a lithospheric weakness and constrains the rift geometry. The obliquity between the rift direction and the direction of extension explains the internal fault geometry.

T52A-0906 1330h POSTER

Along-axis steps in Ethiopian rift Bouguer gravity anomalies: Implications for crustal thinning and melt emplacement prior to breakup

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The southern Afar depression, Africa, is virtually the only area worldwide where the transition from continental rifting to seafloor spreading is exposed onshore. During mid-Miocene to Pleistocene time the rift valley was segmented along its length by long normal faults; since Pleistocene time, faulting and magmatism have jumped to a narrow ca. 60 km-long volcanic mound marked by small faults. These magmatic segments are structurally similar to slow-spreading mid-ocean ridges, yet the rift is floored by continental crust. As part of the Ethiopia Afar Geoscientific Lithospheric Experiment (EAGLE), we examine new and existing Bouguer gravity anomaly data from the rift to study the modification of the lithosphere by extensional and magmatic processes. New and existing Bouguer gravity anomaly data also show an along-axis segmentation of elongate relative positive anomalies that coincide with the magmatic segments. These anomalies are superposed on a regionally eastward increasing field as one approaches true seafloor spreading in the Gulf of Aden, and crustal thickness decreases. Quite remarkably, the magmatic segment boundaries, where data coverage is good, are marked by 15-25 mGal steps. The amplitude of the along-axis steps, as well as their across-axis characteristics, indicate that magmatic intrusion and ca. 2 km relief at the crust-mantle interface contribute to the steps. We use inverse and forward models of gravity data constrained by existing seismic and petrological data to evaluate models for the along-axis steps. EAGLE seismic data will be acquired across and along the magmatic segments to improve our understanding of breakup processes.

T52A-0907 1330h POSTER

EAGLE Design of 2003 Controlled Source Seismic Profile Across the Ethiopian Rift

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The Ethiopia Afar Geoscientific Lithospheric Experiment (EAGLE) is a project to image the crust and upper mantle just prior to break-up in the northern Ethiopian Rift, where the transition from continental rifting to incipient sea-floor spreading is captured. A major component of EAGLE is a 400km cross-rift controlled source profile involving the detonation of 8 borehole shots into a nominal 450 recorders distributed along the line. The principal objective of this part of the project is to provide a cross-rift P-wave velocity model of the crust and upper mantle across a transitional rift segment. The results will be used: (1) to constrain the volume of magmatic material that has been added to the crust across the rift; (2) to determine the distribution of crustal strain; (3) to identify pre-rift variations in lithospheric properties that may have influenced high strain location; and (4) to provide high resolution crustal velocity control to enhance interpretation of teleseismic and local earthquake data recorded on the linked EAGLE passive array projects. A planning visit to Ethiopia in 2001 resulted in 7 of the 8 borehole sites being provisionally identified. Information concerning population distribution and environmental risk, water table depths and restrictions on the use of underwater shots will limit the distance to which seismic energy can be observed from each shotpoint. Results from previous surveys both in Ethiopia and in the Kenya Rift enable expected amplitude-distance relations to be estimated. Using (1) the optimum crustal seismic velocity model consistent with available gravity data, (2) the proposed distribution of shots and recording stations, (3) the range to which energy from each shot should be observed, and(4) field and remote sensing constraints on major rift structures and volcanic centres, 2-D forward modelling of first arrival travel times is being undertaken to enable tighter control on the experiment design in line with the defined experiment objectives.

T52A-0908 1330h POSTER

Tectonics and Evolution of the Conjugate Passive Margins of the Eastern Gulf of Aden (Encens-Sheba cruise)

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The gulf of Aden is one of the few oceanic basins in the world where the two conjugate passive margins are preserved beneath a thin post-rift sedimentary cover and can be correlated within a lateral error smaller than 10 km. It is also one of the few basins where the structures can be followed from the oceanic ridge to the margins. It is therefore an adequate site to compare conjugate margins and to study the oceanisation process from the continental break-up to the emplacement of an active spreading ridge.

The geophysical data set of the Encens-Sheba cruise in the eastern Gulf of Aden and previous experiment, allow us to define the structure of the two conjugate passive margin in this area. These data show that the basement can be divided into three domains from east to west, with distinct morphologic and sedimentary character. (1) an area of rifted continental crust exhibiting one or two parallel horst blocks trending N110∼E (2) a 20-30km long continent-ocean transition and (3) an oceanic crust with rough basement but smoother relief than the rifted crust. The two conjugate margins are narrow and asymmetrical. The northern margin (southern Yemen and Oman) is steep whereas the southern one (northern and western of Socotra island) is broad. Titled blocks, horsts and grabens bounded by faults dipping towards the ocean or the continent compose the northern margin, whereas a deep basin near the continental slope in the vicinity of the continent-ocean transition characterizes the southern margin. The continent-ocean transition is marked by a negative gradient of the free-air gravity anomalies. The two conjugate margins are divided by transfer faults in 3 major segments. This segmentation that occurs during the continental rifting seems to be directly correlated to the segmentation of the inception oceanic spreading center. The first identifiable magnetic anomalies is the An 5C-An 5D that gives an age of opening of the Gulf of Aden as 16-17Ma ago.

T52A-0909 1330h POSTER

The SHEBA Ridge : a Particular Spreading Center or an End-member of the Slow Spreading Processes ?

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We analyze multibeam bathymetry, acoustic imagery, magnetic and gravity data collected during the Encens-Sheba cruise of the NO Marion Dufresne. The survey covered the axis and the flanks up to the continental margins of the Sheba Ridge between 52°E and 54°30'E, at the oriental extremity of the Aden gulf. The full spreading rate in this young oceanic basin is about 2 cmy since the continental rifting. Three second-order segments, one presenting an anomalously shallow axis, characterize this part of the Sheba ridge. The new bathymetry data reveal a particular fabric on the flanks and at the axis for the long (120 km) and shallow spreading center. The flanks, like the ridge axis, are marked by large, more or less circular, volcanic domes. They are built by a few large volcanoes (5-10 km diameter) and by several smaller (1-2 km diameter) edifices. Many of these volcanoes present a well-developed caldera. These volcanic constructions are well developed in the southern part of the axis. Close to the axis, the higher reliefs culminate at a depth of 1000 m. Tectonic scarps limit a deep axial valley at the extremities of this long segment. The deformation, diffuse at the ends, becomes more focused toward the center of this segment and is arranged in an hourglass pattern. A negative mantle Bouguer anomaly elongated in the spreading direction marks this segment. The differences in MBA (70 mgals) and in depth (more than 2 km) between the center and the ends of this segment are the largest, highest of the slow spreading ridges. Acoustic imagery, axial magnetic and mantle Bouguer anomalies generally permit to precise the location of the spreading axis. In this segment, if the axial area is clearly defined, the neovolcanic zone is more difficult to localize. This suggests a diffuse volcanism at the center of the segment at the origin of the numerous small volcanoes. The other segments of the Sheba ridge present a more typical slow spreading axial valley. The discontinuities display large nodal basins, the deeper and larger being located at the intersection between the ridge axis and the Socotra fracture zone.

These new geophysical data in this region raise new questions. One is whether this particular segment of the Sheba ridge is the expression of a specific spreading process or it corresponds to an end-member of the slow spreading processes (2-3 cmy). A second is whether the most well developed volcanic domes in the southern part of the ridge are due to off axis volcanism or to asymmetric spreading.

T52A-0910 1330h POSTER

Magnetic Signature of a Volcanic to non-Volcanic Margin Transition off Atlantic Canada

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The volcanic rifted margin along the Atlantic coast of Eastern North America is characterized by a strong, linear magnetic anomaly from the Blake Spur fracture zone to Nova Scotia. This anomaly, the East Coast Magnetic Anomaly (ECMA), has been shown to coincide at several locations with a thick layer of igneous material emplaced at the continent-ocean transition. Off Nova Scotia, the anomaly changes character, becoming disjointed and lower in amplitude until it fades to the northeast into the regional background level. This region may mark the transition from a volcanic to a non-volcanic style of rifted margin.

Seismic reflection data across this transition region off Nova Scotia show that, in the southwest, the ECMA coincides with a zone of seaward dipping reflections in igneous basement. Further to the northeast, basement is obscured by an overlying complex zone of salt diapirs. Modelling of the magnetic anomaly indicates that the highest amplitude peak coincides with the seaward edge of an igneous body near the ocean-continent boundary. Just north of the New England Seamounts, the anomaly peak is 50 km wide and of moderate amplitude (+280 nT), consistent with a wide unit of volcanic material buried at 7 km depth beneath the sediments. Further to the northeast, the anomaly becomes narrower and more subdued, reflecting a source body that is smaller and deeper.

The interpreted cessation of volcanism off Nova Scotia may be linked to a change in rifting style, mantle thermal conditions, or reduction in the lateral flow of magma from a distant hot spot. Seismic transects and magnetic data for different parts of the US Atlantic margin show that crustal thinning occurred across a much broader width of continental crust in the north than elsewhere along the margin. The calculated isostatic gravity anomaly for this part of the margin should help to determine the presence of anomalous crustal structure or uncompensated loading in this region. We will evaluate possible explanations for the observed variations in rifting style and volcanism using available seismic and potential field data.

T52A-0911 1330h POSTER

Structure and Mechanisms of Extension at the Galicia Interior Basin, West of Iberia

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We have studied a classical non-volcanic margin, the West Iberia margin, to understand the evolution of the deformation with increasing extension. We present a coincident pre-stack depth-migrated seismic section and wide-angle profile across an abandoned rift, the Galicia Interior Basin, that shows the structure of the basin and gives insight regarding changes in the rheology of the crust and mode of deformation from the little extended rift flanks, stretching factors of 1.5, to the center of the basin, stretching factors of 4-5.5. The data show that the basin has an asymmetric structure with major faults dipping to the east. The velocity structure is also asymmetric and consists of 3 velocity layers beneath the east flank of the basin and 2 beneath the center of the basin and at the west flank, suggesting that the basin probably formed along a terrain boundary. Towards the center of the basin, fault-block size and spacing decreases as faults reach progressively deeper lower crustal levels, indicating a switch from ductile to brittle behavior of lower crustal rocks. At stretching factors of 4 faults cut deep into the lower crust and appear to bring lower crustal rocks to shallow levels in the crust. The ratio of upper to lower crustal thickness yields information on the amount of differential stretching. At the rift flanks, (stretching factors of 2), the ratio is fairly constant indicating that stretching of the upper and lower crust was uniform. However, towards the basin center the distribution of upper and lower crust is uneven. At fault block scale, there is an excess of lower crust at the footwall of deep penetrating faults and a deficit at their hangingwall. We interpret that initially, large scale extension occurred by pure shear but as extension increased it switched to simple shear at fault-block scale as the lower crust was entering the brittle regime. Simple shear along deep penetrating faults might have been accompanied by small scale flow (40 km) of the deepest crust in order to accommodate fault offsets, resulting in a smooth Moho topography.

T52A-0912 1330h POSTER

Segmentation of Volcanic Passive Margins: a Record of the Transition From Mechanical Extension of the Lithosphere to Plate Divergence by Magmatic Accretion

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Passive continental margins record the history of extensional faulting and sedimentation in isolated rift basins followed by strain localisation and magmatism at incipient seafloor spreading centres. Unlike many margins where the early record is buried by thick post - rift sequences, southern Red Sea structures are exposed onshore. The western escarpment to the southern Red Sea Rift in Ethiopia is a volcanic passive margin that has developed over the past 30 Ma above or near a mantle plume. Owing to changes in plate boundaries since 30 Ma, in this locally unstable triple junction, the synrift units of the margin have remained above sea level and are therefore exposed for field and remote sensing studies. Moreover, the synrift units of the margin are almost exclusively volcanic, making the margin particularly suitable for the study of the interactions of faulting and magmatism during extension. Integration of field data and processed Landsat-5 TM and Landsat-7 ETM + imagery shows that there are two major phases of Oligo-Miocene rifting separated by a riftward shift in the locus of synrift magmatism. The architecture of early synrift sequences (25 - 20 Ma) is defined at the largest scale by long border faults, arranged sub - parallel with the now inactive rift margin, along which basin development was diachronous. Early synrift sequences underwent extension and margin normal flexure before riftward emplacement of later synrift sequences with a segmentation defined in outcrop by the extent of volcanic constructs. This volcanic segmentation represents the transition between segmentation controlled by major basin bounding faults and structural processes and slow spreading mid-ocean ridge segmentation controlled by asthenospheric processes. Our new and existing field, 40Ar /39Ar and geophysical studies are used to compare these transitional segments with those elsewhere in Afar and along slow - spreading ridges.

T52A-0913 1330h POSTER

Extensional Tectonism of the Ayu Trough, Southern Philippine Sea: Transition from Rifting to Seafloor Spreading

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The Ayu Trough, located in the southern end Philippine Sea, represents a divergent boundary between the Philippine Sea and Caroline Plates. This oceanic basin is unique because it is the only segment along the entire Philippine Sea Plate that is without a subduction zone. Previous studies suggest that the Ayu Trough is an ultra-slow-spreading ridge with the rate of opening increasing to the south. However, the difficulty in determining the exact spreading rate of the Ayu Trough is compounded by the fact that it lies near the magnetic equator. In May of 2000 and 2001, we carried out detailed geological and geophysical surveys of the Ayu Trough onboard R/V *Onnuri*. These included multibeam echosounding, measurements of marine gravity and magnetic fields, and multichannel seismic profiles taken between the equator and 3°30'N. A composite bathymetric map of the region south of the Palau Island was produced by combining our data sets with existing ones. According to our analyses, the Ayu Trough is divided into three parts: the northern (0°-1°30'N), middle (1°30'-4°N), and southern (4°-6°30'N) sections. The northern section is marked by a relatively shallow axial region, which suggests that this is the most magmatically robust among the sections. A sharp break in the trend of the trough axis occurs at 4°N, between the middle and southern sections. The seafloor within the middle section is characterized by features asymmetric with respect to the axis. They were probably produced by NW-SE and WNW-ESE extensions and thus support the argument that the opening of the Ayu Trough occurred in complicated and oblique fashion. Farther south, a long transform fault defines the boundary between middle and southern sections. The axial depth makes a stepwise decrease to the south of 1°30'N. The analyses of magnetic field data reveal that, while the region beyond 100 km exhibits considerable variations, the magnetic anomalies within 100 km from the trough axis are very much subdued. This observation suggests that the opening of the Ayu Trough involved an initial stage of rifting of existing volcanic arcs, followed by production of new seafloor.

T52A-0914 1330h POSTER

Fault Network Evolution in the Whakatane Graben, New Zealand

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The Whakatane Graben in the Bay of Plenty, New Zealand, is a zone of active extensional growth faulting and rapid subsidence within the back-arc region of the Pacific-Australia plate boundary. The sedimentation in the graben is rapid enough to keep pace with the tectonic subsidence and so provides a high fidelity record of the fault motions. Over 100 closely spaced multichannel seismic reflection profiles and high resolution chirp and boomer sediment profiles have been collected, defining a pseudo-3D seismic volume which includes the highly active Rangitaiki and White Island faults. Within the sediments imaged in these profiles are several readily identifiable high amplitude reflectors including stillstand terraces and volcanic ash layers. The age control of these layers is such that quantitative measurements of fault displacements and growth rates can be made, thereby providing an insight into the development of this young and highly active back-arc basin.

Analysis of the multichannel seismic profiles reveal that in the 7.5 km strike distance covered the Rangitaiki fault comprises five major interacting segments. Displacements of up to 1 km are measured on these faults across three subsurface horizons with estimated ages of 246 ± 45ka, 611 ± 91ka and 1033 ± 143ka. The fault interactions observed include examples of single faults bifurcating upwards and independent fault segments becoming increasingly linked through time. Interactions between faults are seen to affect fault growth, with shallowing of fault dip angle before faults become hard-linked, and fault trace curvature in fully linked faults.

The chirp and boomer profiles achieve up to 50 m of subsurface penetration and image four of the post-glacial erosion surfaces, providing excellent temporal controls. Measurements of fault displacements across these layers and changes in the sedimentary thickness between them will be used to constrain, on a timescale of a few thousand years, the partitioning of fault displacement between the interacting segments of the Rangitaiki and White Island faults.

T52A-0915 1330h POSTER

From Core Complex to Wide Rift Mode: Modeling the Evolution of the Basin and Range.

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From Triassic to late Cretaceous the Basin and Range province underwent uplift, thrusting and magmatism. In the Cenozoic two phases of extensional tectonics occurred; the first phase began in the early Neogene and continued until mid-Miocene time and was associated with large amount of localized extension on single normal faults as it is observed in the core complex belt. The second extensional phase lasted from the mid-Miocene to the end of the Miocene and was associated with broadly distributed extension on multiple normal faults which produced the Basin and Range morphology. Before extension began in the Neogene the previous phases of convergent tectonics and uplift determined the initial geometry and rheology of the basin. Thickened crust and features such as major preexisting thrust faults, possible rheological contrast between the lower and upper plate of the orogeny, as well as the presence of weak lower crust or lower density magmatic bodies are likely to have influenced the style of extensional tectonics observed in the Basin and Range Province.

Here, I present 2D numerical models of the extension of a thickened visco-elasto plastic lithosphere in which the effect of preexisting structures on the evolution of the basin is analyzed. The brittle parts of the lithosphere are modeled as a frictional and cohesional material. The ductile lithosphere is modeled as a non-Newtonian Maxwell visco-elastic material. Faults in the brittle parts of the model are formed by locally decreasing the cohesion as a function of plastic strain. The rheological structure of the model is controlled by the initial temperature distribution and the temperature boundary conditions. Model results show that the presence of a preexisting major thrust boundary, the possible rheological contrast between the upper and lower plate of the orogeny and the presence of a weaker, lighter (molten) lower crust could help localize the deformation on a single graben as observed in the core complex extensional phase. The presence of a preexisting major thrust boundary also enables the asymmetric thinning of the crust by viscous flow in the lower crust. After this first phase of very localized extension thinning of the crust generates enough buoyancy to delocalize the extension. This leads to a second phase of broadly distributed extension and to the well known Basin and Range morphology.

T52A-0916 1330h POSTER

Geologic and geomorphic evidence for the magnitude of rift-related subsidence of northeastern Baja California

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Present elevation of the eastern Peninsular Ranges of northern Baja California is 1 to 2.5 km higher than the adjacent Gulf of California Extensional Province. A pre-rift erosion surface and the distribution and facies of pre-rift sedimentary and volcaniclastic rocks indicate that prior to rifting, elevation was similar across northeastern Baja California. Eocene(?) through Miocene fluvial systems and volcaniclastic deposits of an Early to Middle Miocene volcanic arc flowed from what is now the Gulf Extensional Province westward across the southern Sierra San Pedro Mártir. These drainage systems were later occupied by a welded ash-flow tuff, the ~12.6 Ma Tuff of San Felipe, which erupted from a vent in western Sonora prior to opening of the Gulf of California. Approximately $\frac{1}{3}$ of the elevation of a pre-rift erosion surface on the eastern Peninsular Ranges closely follows the structure of adjacent rift basins, suggesting that this topography is supported by flexure of the upper continental crust with an effective elastic thickness, $T_c \approx 5$ km. After removing these local topographic anomalies, a regional 1 to 1.5 km elevation difference remains between the Peninsular Ranges and the Gulf of California. Recently published geophysical studies indicate that northeastern Baja California is comprised of 33–40 km-thick crust beneath the Sierra San Pedro Mártir and 15–18 km-thick crust beneath the rifted margin of the Gulf of California. Elevation differences between these areas are consistent with regional Airy-type isostatic compensation of rift-related crustal thickness changes with support of locally high topography of the eastern Peninsular Ranges by flexure of the upper continental crust.

T52A-0917 1330h POSTER

Origin of Regional Uplift Across Southern California and Northern Baja California

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We use models of a free-end elastic plate to predict observed patterns of uplift across the Peninsular Range Province in southern California and northern Baja California. Gravity profiles, seismic refraction profiles and tomography constrain our flexure models. Vertical deformation of the elastic plate results from a buoyant force (1.5 x 1012 kg/m across southern California and 2.5 x 1012 kg/m across Baja California) derived from a low density (3.1 g/cm3) mantle anomaly and Vening Meinesz uplift. A flexural model oriented ENE across southern California through San Diego County shows total uplift at the rift shoulder crest of 1800 m, uplift at the Pacific coast of 100 m, and a half-wavelength of 175 km. Another ENE-oriented flexural model across northern Baja California shows total uplift at the rift shoulder crest of 3080 m, uplift at the Pacific coast of 130 m, and a half-wavelength of 177 km. Uplift in each numerical model closely matches topography. We argue the Sierra Juarez and Sierra San Pedro Martir are distinct rift shoulder segments truncated by the Matom and Sierra La Tinaja accommodation zones. These models suggest flexural uplift across the region may account for 65-83% of total uplift along the Pacific coastline recorded in raised marine terraces in the northern rift segment and 83-100% of uplift in the southern rift segment. Our models indicate regional uplift is largely, but not entirely, produced by a regional aseismic process that is unrelated to uplift above blind thrust faults or other local structures.

T52A-0918 1330h POSTER

First Results from EW0108 Marine Seismic Survey of the Gulf of Corinth

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We report preliminary results from R/V MAURICE EWING cruise 2001-08 on which we imaged the bathymetry, stratigraphy and structure of the active rift in the Gulf of Corinth. Initial processing of the 240-channel seismic data (6- and 3-km streamer) through DMO and post-stack migration was performed onboard and ashore using ProMAX software. We also collected and processed swath bathymetry (Hydrosweep DS2) and free air gravity data.

Deformation accompanying the 10-15 mm/yr stretching is focused beneath the Gulf of Corinth and causes major earthquakes. The bounding faults are high-angle near the surface but may, in the center of the Gulf, have low and perhaps very low dips in the seismogenic zone at 5-11-km depth. We sought, with 16.3-second MCS records, to directly image the fault geometry at depth, and thereby to distinguish between competing models of the deformation. Ongoing processing is aimed at suppressing the out-of-plane reflections from the basin margins in order to image the true reflectors at depth.

We successfully recorded 8 long strike lines and 33 dip lines across the Gulf, providing the first systematic grid of seismic data that everywhere images to basement. Shots from the 8445 cu in 20-airgun array were also recorded by our regional array of 40 seismometers on land, plus 30 existing stations, as well as by our two linear arrays of 75 (Derveni) and 25 (Itea) geophones.

T52A-0919 1330h POSTER

A New Look at the Structure and Stratigraphy of the Gulf of Corinth

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EW0108 marine seismic, bathymetric and acoustic imagery data, coupled with Landsat ETM+ data, provide an integrated offshore-onshore view of the upper-crustal faulting and sedimentation in the actively-rifting Gulf of Corinth.

Modern sediment delivery to the central basin floor at 860 mbsl occurs via canyons and channels that incise the steep, fault-controlled, basin edges. The basin bounding faults trend east and are right-stepping en echelon. Many of the channels traverse lateral ramps between the steps in the bounding faults, but some have grown with the faults and cut across their face and uplifted footwalls. An axial channel feeds sediments eastward from the less than 400-mbsl-deep basin west of Aigion into the central basin. The depocenter has narrowed through time: the subsidence of the basin center has outpaced deposition.

The Gulf of Corinth is an asymmetric graben. The master bounding faults are on the south side, east of 22.25 degrees, but are more symmetric and/or on the north side further west. The latter pattern extended further east in the past, indicating lateral migration of the dominant offset on opposing bounding faults. In the north, shallow platforms in the subsidiary Gulfs of Itea and Andikiron are underlain by thin sediments (few hundred meters). The northern basement is flexed and serially faulted down southward into the axial trough, where sediment thickness exceeds 2 km, and then steps abruptly up the master fault system to the southern shore. A complex array of synthetic and antithetic normal faults cut the basin fill. These include crestal graben in oppositely-vergent hangingwall anticlines north of Derveni and south of Akra Pagkalos. The eastern Gulf is similarly complex where, for example, the western apex of the Perehora Peninsula is bounded by intersecting coast-parallel faults with offshore (opposing) dips.

T52A-0920 1330h POSTER

Morphology and Gravity Variations Along Lau Basin Spreading Centers Indicate Mantle Wedge Control on Backarc Crustal Accretion

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We examine the effects of the backarc mantle wedge on crustal accretion in the Lau Basin using morphologic and geophysical observations of its main spreading centers. The Lau spreading centers transect the basin from 40-180 km from the arc volcanic front sampling the mantle wedge in an area showing large gradients in arc influence. Spreading rates on these axes vary from 40-95 mm/yr. The spreading centers display marked changes in morphology and mantle Bouguer anomalies (MBAs) indicating large variations in magmatic state and crustal thickness. From south to north the spreading centers exhibit indications of enhanced, to depleted, to normal magma supply. The variations, however, do not follow spreading rate trends observed at mid-ocean ridges. The southernmost spreading centers closest to the arc volcanic front have axial highs although spreading rates are slow. Northward and farther from the volcanic front, the spreading centers deepen and form axial valleys with relatively higher MBAs, indicating thinning crust despite faster spreading rates. The northernmost spreading centers farthest from the volcanic front are propagating southward and exhibit normal fast-spreading characteristics consistent with their spreading rate. To explain these observations we propose that the spreading centers experience enhanced melt delivery when near the volcanic front in part due to lowering of the melt solidus by mantle hydration from the slab, but also due to capturing part of the arc magmatic budget. Farther from the volcanic front depleted mantle, generated by melt extraction by the arc and by the spreading centers themselves, is overturned and re-introduced beneath the spreading centers as a result of subduction-induced mantle corner flow. The spreading centers in this position over the mantle wedge have in part self-depleted their melt source and are magma starved. Sufficiently far from the wedge corner undepleted fertile mantle is horizontally advected by slab rollback and by corner flow into the mantle wedge. Spreading centers in this position thus exhibit normal characteristics for their spreading rate. The observations from the Lau Basin spreading centers indicate fundamental differences in controls on crustal accretion between back-arc and mid-ocean settings resulting from the mantle wedge environment.

T52A-0921 1330h POSTER

Magma Piracy in the Southern Mariana Backarc

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Since 1997 the southern Mariana convergent margin system has been mapped with Hydrosweep, MR-1, and SeaBeam swath sonar systems on five cruises resulting in 168,500 km^2 of bathymetry data and 186,800 km^2 of sidescan data, revealing anomalous processes relative to the rest of the Mariana region. Most of the Mariana Arc is characterized by arc volcanism dominated by large, central volcanoes located at the boundary between a backarc basin with slow-spreading ridge morphology and a nonaccretionary forearc composed of Eocene volcanic arc rocks But southwest of Tracey Seamount, the southernmost large central arc volcano, the character of the arc and backarc changes dramatically. The arc volcanoes become small or nonexistent, but those that do occur lie along relict spreading fabric within the backarc basin. Furthermore, the spreading center appears to have an inflated, fast-spreading morphology, including dueling propagator fabric, and this southern backarc basin forms a shallow plateau overall. The spreading center then becomes less well-defined west of 143^{o}E, and the volcanism appears to cease altogether west of 142^{o}E in an area of amagmatic rifting, an observation supported by earthquake focal mechanisms and magnetics.

The inflated morphology of the spreading axis, along with the absence or reduced size of nearby arc volcanoes suggests that arc magmas have been entrained into the backarc-spreading magmatic system. This "magma piracy" would result in arc magma being erupted at the backarc spreading center, therefore the backarc crust would be formed in part from arc magmas. Dredge samples from along the active ridge show compositions consistent with this suggestion. We suggest that this magma piracy has dominated the southern backarc basin for at least the last 3 m.y. since the robust spreading began. We suggest that the apparently higher magma production rate and the hybridized crust could account for the shallowness of the basin, as the more evolved arc-lavas would be generally more buoyant than backarc basin basalt alone.

T52A-0922 1330h POSTER

Multi-channel Seismic Reflection Imaging of a Magma Chamber Beneath the East Scotia Ridge

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The East Scotia Ridge (ESR) is an active backarc spreading centre located in the Scotia Sea (western South Atlantic). It separates the Scotia plate from the eastward-migrating Sandwich plate, which includes the South Sandwich volcanic arc. Regional mapping has shown that the ESR is composed of nine ridge segments (E1-E9), separated by non-transform discontinuities, and that it has a full spreading rate of 65-70 mm/yr. We present analyses of the first multi-channel seismic reflection (MCS) profiles from the ESR, collected during RRS James Clark Ross cruise JR18 as part of the British Antarctic Survey Sandwich Lithospheric and Crustal Experiment (SLICE). These new data extend across segment E2 (centred on 56°05'S) where an earlier geophysical survey revealed a prominent magma chamber reflection (MCR) beneath an axial volcanic high. The JR18 profiles were collected using an airgun source with a combined chamber capacity of 61.8 l, and a streamer with an active length of 2400 m. They show the acoustic architecture of the crustal magma chamber in detail. The MCR lies at 1.1 s two-way-time (TWT) below sea floor beneath the summit of the axial high, increasing to 1.8 s TWT below sea floor with increasing water depth along the ridge axis. Analyses of common-mid-point gathers suggest that this is equivalent to a sub-bottom depth of 2.6 ± 1.4 km beneath the apex of the high. We can trace the MCR > 23 km along axis, although it is faint beneath much of the high, and has a highly variable seismic character. At the summit of the high, the MCR shows a bright, comparatively simple waveform, which is inverted in polarity relative to the overlying sea-floor reflection. Nearby however, the MCR is more complex, and shows vertical offsets and bifurcation of the waveform.

T52A-0923 1330h POSTER

First Survey For Submarine Hydrothermal Vents In NE Sulawesi, Indonesia

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The IASSHA-2001 cruise (Indonesia-Australia Survey for Submarine Hydrothermal Activity) was successfully conducted from June 1 to June 29 on board Baruna Jaya VIII. Preliminary results are reported of the first expedition to locate and study submarine hydrothermal activity in north east Sulawesi.

Leg A focussed on Tomini Bay, a virtually unexplored Neogene sedimentary basin. Its objective was to test whether modern sediment-hosted hydrothermal activity occurred on the sea floor. The results of new bathymetric mapping, sediment coring and CTD/transmissometer hydrocasts negate the likely presence in central Tomini Bay of large-scale modern analogues of hydrothermal massive sulfide environments involving hydrothermal venting of basinal or magma-derived fluids into reduced sediments. It is possible that the heat engine required to drive circulation of basinal and hydrothermal fluids is today too weak.

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Surveys around Colo volcano indicate that it may be in its final stage of evolution.

Leg B studied the arc and behind-arc sectors of the Sangihe volcanic island chain extending northwards from Quaternary volcanoes on the northeastern tip of Sulawesis North Arm, near Manado. West of the main active chain and extending northwards from Manado there is a subparallel ridge surmounted by a number of high (>2000 m) seamounts of uncertain age.

Fifteen relatively high-standing submarine edifices were crossed during this leg, of which nine were tested for hydrothermal activity by hydrocast and dredging. Eight sites were known from previous bathymetric surveys, and seven are new discoveries made by narrow-beam or multibeam echo sounding. Two submarine edifices at least 1000 m high were discovered in the strait immediately north of Awu volcano on Sangihe Island. One, with crest at 206 m, is surrounded by a circular platform 300m deep which we infer to be a foundered fringing reef to a formerly emergent island. The other, lacking such a platform, appears relatively young and may be parasitic to Awu volcano. It has a summit crater or small caldera, about 800 m across and breached to the northwest. A dredge hauled within the caldera returned numerous un-abraded fragments of fresh pumiceous dacite glass with prominent phenocrysts of plagioclase, orthopyroxene and clinopyroxene, plus small angular fragments of a similar but less vesicular lithology. Coatings of soft ferruginous deposit on some fragments suggest that the caldera is hydrothermally active.

A highlight of the expedition was a visit to Banua Wuhu, classed as an active volcano (eruption in 1919) whose summit is just exposed at low tide. Gas bubbling, subsurface sonic activity, and venting of hydrothermal fluids with temperatures around 50C are known to occur on the summit at around 10 m depth, and ferruginous oxide deposits several mm thick are common. A multibeam bathymetric chart to 1000 m was prepared and deeper narrow-beam echo sounding show that Banua Wuhu is a parasitic feature on the north-western side of adjacent Mahenetang Island, also a volcanic construction, the combined edifice exceeding 3000 m in height. We recovered thoroughly altered porphyritc andesite containing disseminated pyrite and a carbonate-chlorite-clay mineral assemblage.

In summary, while the IASSHA cruise located only a single but potentially significant example of modern seafloor hydrothermal activity, we collected much valuable new geological and oceanographic data on two contrasted areas in northeastern Sulawesi that with on going post-cruise processing will greatly expand our knowledge of these regions.

Binns and Permana Co-Chief Scientists

T52A-0924 1330h POSTER

Structure of a Young Oceanic Basin: Results of the Encens-Sheba Cruise in the Eastern Gulf of Aden

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The Encens-Sheba cruise was carried out in July 2000 aboard R/V Marion Dufresne in the eastern part of the Gulf of Aden. It produced a complete swath bathymetry, gravity and magnetic data set between southern Oman (Dhofar) and Yemen in the north and Socotra island in the south, and between Alula-Fartak fracture zone in the west and the Socotra fracture zone in the east. The new data set shows a complete section of a young oceanic basin from conjugate passive continental margins up to the oceanic spreading center. On the conjugate passive margins, single channel seismic data have been also collected.

The two conjugate margins are steep, narrow and asymmetric. Titled blocks, horsts and grabens bounded by faults dipping towards the ocean or the continent compose the northern margin, whereas a deep basin near the continental slope in the vicinity of the continent-ocean transition characterizes the southern margin. The two margins are divided by transfer faults in 3 major segments. The continent-ocean transition is marked by a negative gradient of the free-air gravity anomalies.

The present Sheba ridge is divided by discontinuities in 3 segments from 20 to 100 km long. The central part of the 100-km-long western segment is characterized by an axial uplift reflecting a large magmatic activity. The two other shorter segments display axial valley more classical for a slow spreading ridge (1.1cm/a). Although the magnetic anomalies show a complex history of oceanic accretion, the evolution of the segmentation can be followed. Indeed, the segmentation of the conjugate passive margins seems to be correlated with the location of early traces of identifiable Sheba ridge offset. The oldest anomalies are identified as an5C-an5D. The Gulf of Aden in this area thus opened 16-17Ma ago, which is significantly older than the 12-13 Ma suggested by previous studies.

T52A-0925 1330h POSTER

Controls on the Asymmetry of Lithosphere Extension: the Role of Frictional-Plastic Strain Softening

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Are rifts and conjugate passive margins fundamentally asymmetric, and if so, what controls the asymmetry? The deep structure of continental rifts and passive margins, as constrained by seismic data, has been interpreted both in terms of symmetric and asymmetric rifting models. Whether the inferred asymmetries stem from whole lithosphere faults and shear zones remains a central question. Although a range of kinematic models has been proposed, including pure shear, simple shear and combinations of these models, kinematic models provide little insight into extensional processes. Most dynamical models predict symmetric extension of a uniformly layered lithosphere and, therefore, the origin of possible asymmetry remains enigmatic, although it is always possible to appeal to inherited in-homogeneity of the lithosphere. We use plane-strain thermo-mechanical finite element model experiments of lithospheric extension to investigate the effects of strain softening in the frictional-plastic regime on the asymmetry of extension. Strain softening is considered in cases where the crust is either strongly or weakly coupled to the mantle, and as the extension velocity varies from 0.3 to 30 cm/yr. In the absence of strain softening extension is symmetric (SS mode). When strain softening takes the form of a reduction in the internal angle of friction with increasing strain, lithospheric extension may be asymmetric at a lithospheric scale (AA mode), or exhibit crustal asymmetry concomitant with mantle symmetry (AS mode). The different styles depend on the relative control of the system by the frictional-plastic and ductile layers, which promote asymmetry and symmetry, respectively. High extension velocities and weak ductile crust-mantle coupling tend to suppress the fundamental asymmetry induced by frictional strain softening. This is because they, respectively, increase the effective strength of the lower lithosphere and decrease the control by frictional plasticity. We tested the sensitivity of our model results to variations in rate and amount of frictional weakening, thickness of the lower crustal channel and to the initial friction.

T52A-0926 1330h POSTER

Seismic velocity structure of the margins of the southern and southeastern Tsushima Basin in the Japan Sea using ocean bottom seiemometers and airguns

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The Tsushima Basin is located in the southwestern Japan Sea, which is a back-arc basin in the northwestern Pacific. Although, some geophysical surveys had been conducted to investigate the formation process of Tsushima Basin, it has not been revealed yet. In 1998 and 2000, to obtain data for the formation process about the Japan Sea including the Tsushima Basin, seismic velocity structure surveys with ocean bottom seismometers (OBSs) and airguns were carried out at the southern Tsushima Basin and the margins which are supposed to the transition zones of the crustal structure of Korean Peninsula and Japan island arc. In 1998fs experiment, the survey had two lines, one was a 130-km-long from the southern Tsushima basin off Pfohang in Korea toward Korean Peninsula (P-1 line) and the other was a 126-km-long through the basin and Korean straits which is continental shelf (P-2 line). In 2000fs experiment, the survey line was a 89-km-long from the southeastern Tsushima basin off western Oki islands toward southwest Japan arc (SE line). The P-1 and SE lines are on the opposite side of the Tsushima Basin. In this presentation, we discuss the seismic velocity structure beneath the southern and southeastern Tsushima basin and marginal area of P-1, P-2 and SE lines to clarify the formation process in the Tsushima Basin. The results show that the crustal thickness of the marginal area of the southern Tsushima Basin beneath the P-1 and P-2 line is about 20km including about 1km thick sedimentary layer and about 23km including about 3km thick sedimentary layer, respectively. In SE line, the crustal thickness under the Tsushima Basin is about 17km including about 5km thick sedimentary layer and about 20km including about 1.5km thick sedimentary layer under the marginal area. From the result of the SE line, the whole crustal thickness and the thickness of the upper part of the crust increase towards the land. On the other hand, thickness of the lower part of the crust seems more uniform than the upper layers. The crust in the basin area has about 6km/s layer with the large velocity gradient. These features under the SE line near southwest Japan arc are similar to those of P-1 and P-2 lines near Korean Peninsula.

T52A-0927 1330h POSTER

Crustal Structure of Northenmost part of Okinawa Trough by Ocean Bottom Seismographic Observation

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The Okinawa Trough is placed between the Ryukyu Island arc and the China mainland as the back-arc region of the Ryukyu arc. From the previous geophysical and geological studies, the Okinawa Trough is considered to be in an early stage of back-arc spreading. Many seismic experiments have been performed in the Okinawa Trough region, however there is no deep seismic survey using Ocean Bottom Seismometers (OBSs) in the northernmost part of the Okinawa Trough. It is important for understanding tectonics of back-arc spreading to obtain a seismic structure beneath the area of East China, west of Kyushu, which is considered as the northernmost part of the Okinawa Trough. In addition, a seismic structure beneath the area is useful for consideration of tectonics of the Kyushu Island.

A seismic survey with OBSs was carried out in west of Kyushu in fall of 1999. The profile is 300 km long and 20 OBS were deployed at an interval of 15 km. We used airguns and explosives as controlled sources. During shooting of the airguns, reflection waves were recorded by 24-ch hydrophone streamer towed from the shooting ship.

The obtained seismic reflection profile shows large lateral heterogeneities in the upper crustal structure in spite of the smooth seafloor topography of the surveyed area. On the distance-time sections of OBSs, apparent velocities of first arrivals vary due to the heterogeneities. A@seismic velocity model for the shallow structure at each of the OBS locations is derived by using a tau-p inversion of the indivisual OBS record. On the other hand, a deep structure beneath the profile is estimated by a forward modeling using a two-dimensional ray tracing.

The sedimentary section model consists of two layers. The upper sedimentary layer has a thickness of 200-500m with P-wave velocity of 1.7 - 1.9 km/s. A vertical velocity gradient of the upper layer is small.@The

lower sedimentary layer has P-wave velocity of 2.0 - 3.5 km/s with relatively large vertical velocity gradient. The thickness of the lower layer has large variety from 800 m to 3500 m. The upper crust is large lateral heterogeneity and is also divided into two layers. Velocity at the top of the upper crust vary from 3.0 - 4.9 km/s. The lower layer of the upper crust has velocity of 5.6 - 6.0 km/s. The thickness of the upper crust changes from 3 km to 9 km. The boundary between the upper crust and lower crust is about 10 km deep below the sea surface. The lower crust has velocity of 6.5 - 6.7 km/s. Compared with the upper crust, the lower crust is relatively homogeneous. A thickness of the lower crust is about 15 km. The crust has a thickness of about 25 km in total and the Pn velocity is estimated to be 7.7 -7.8 km/s.

The distribution of the P-wave velocity and the thickness of the crust indicates that the crust of the northernmost part of Okinawa Trough is similar to that of an island arc than to that of an ocean. The obtained seismic structure suggests that the northernmost part of the Okinawa Trough is in the incipient stage of the back-arc rifting.

T52B MC: Hall D Friday 1330h

Syn-Convergent Extension in the Apennines, Italy II *(joint with G, S, V)*

Presiding: **S Willett,** University of Washington

T52B-0928 1330h INVITED POSTER

Quantifying Exhumation History Across the Northern Apennines

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Exhumation of Northern Apennines has been investigated through low-temperature geochronometric data (apatite fission-track analysis, AFT; U-Th/He on apatite and zircon). Results show a different thermotectonic evolution for the drainage divide area (Mt. Falterona, MF) and the metamorphic complex of the Apuane Alps (AA) on the Tyrrhenian side. Throughout the late Middle and Late Miocene, the AA were exhumed at a constant rate of 1.5 mm/y, whilst the MF area was rapidly subsiding, buried by foreland turbidites and eventually by the Ligurian unit. Exhumation in the AA abruptly dropped to 0.5 mm/y at the Early Pliocene. At that time, the MF started to be exhumed at a rate of 0.7 mm/y. No evidence for pronounced topography exists. With those rates, erosion could keep the pace with uplift. From Middle Pliocene onward, coarse-grained sedimentation in intramontane basins documents growing relief, with the final development of the present-day topography. The uplift rates increased to values of 1.4 mm/y in the MF and 0.8 mm/y in the AA. The MF became the most elevated area, therefore creating the present watershed.

T52B-0929 1330h POSTER

Time to Steady State in Emergent Convergent Wedges: Olympic Mountains of the Washington Cascadia Margin, and the Apennines of Northern Italy

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The Olympic Mountains of NW Washington State and the Apennines of Northern Italy show a similar history in their emergence and transition to a flux steady state. The Olympics represent the forearc high of the Cascadia subduction wedge; the Juan de Fuca plate is subducting at ~35 km/m.y. beneath this wedge, driving accretion of a 2-3 km thick sedimentary cover. The modern accretionary flux is ~63 km^2/m.y, which is similar to the long-term erosional outflux of ~51 km^2/m.y. Cooling ages show steady erosion rates from the core of the orogen over the last 14 m.y., indicating a flux steady state, where the accretionary and erosional fluxes are equal. What is remarkable is that the Olympics came into a flux steady state within 4 m.y. after initial emergence above sea level. The Olympic sector of the Cascadia wedge is currently 230 km wide and 30 km deep at its thickest point, equal to a cross section of 3450 km^2. If the wedge reached its present steady state size solely by accretionary growth, it would have had to increase its cross section by 1055 km^2, which implies a growth rate of >264 km^2/m.y. given the <4 m.y. time for transition to a flux steady state. This flux is too fast to be drive by accretion alone. Some other process must be involved.

In comparison, the Apennines convergent wedge has formed by subduction of thinned continental crust of the Adriatic plate. Convergence rates are slower, at ~4 to 5 km/m.y. since 30 Ma. The accreted sedimentary cover, however, is much thicker, ~12 km, which gives an accretionary flux of ~40 to 50 km^2/m.y. Integration of erosion rates across the orogen indicate an erosional outflux of ~40 km^2/m.y. This balance between accretionary and erosion fluxes is consistent with fission-track and He cooling ages that indicate steady erosion rates in the core of the orogen, starting at ~5 Ma. Like the Olympics, the onset of steady state seems to have occurred shortly after emergence at ~5 Ma, and at fast rates, inconsistent with growth by accretion alone.

In the both the Olympics and the Apennines, some process other than accretion is needed to account for a fast transition to a flux steady state, following emergence of the wedge above sea level. Some have argued for slab breakoff as a mechanism to drive rapid uplift in the Apennines, but tomographic images show that the subducted slab is still present beneath the northern Apennines. I propose that in both cases, rapid uplift was caused by changes in the subducting plate. In the Olympics, there is good evidence that the present concave-outward shape of the trench formed at ~15 Ma, in association with extension across the Basin and Range. This change caused an arch to form in the slab beneath the Olympics. For the Apennines, rapid uplift appears to be the result of the wedge overriding a passive margin ramp. Prior to 5 Ma, the Northern Apennine wedge was overriding highly thinned Adriatic crust (~7 km thick below the accreted sedimentary cover), whereas now that equivalent crustal section is ~22 km thick.

T52B-0930 1330h POSTER

Numerical Modeling of Continental Subduction in Apennines-Style Context

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We performed numerical experiments of early stages of continental subduction and slab detachment at the mantle scale, using a 2D thermo-mechanical model which accounts for brittle-elasto-ductile behaviour and for surface processes.

Our goal is to study the influence of various parameters on subduction-related orogens (for instance the Apennines) such as density contrasts, convergence rate, thermal state and intensity of surface processes.

The model reproduces the subduction cycle from early stages to penetration of the slab to the 660 km boundary. Depending of the parameters' combination, the evolution of the initiated slab varies from rapid detachment to stagnation of the subduction. An important feature of our experiments is the almost systematic occurrence of underplating of the lower plate crust beneath the upper plate, leading to formation of double-Moho like structures. It appears that the subducted upper crust and sediments may play a role of lubrication layer, like the low friction coefficients used in some previous models.

The results show that the main controlling parameter of slab evolution is the density contrast between the slab, subducted crust, and surrounding asthenosphere : for instance, when the contrast between the slab and the asthenosphere is larger than 0.02, the sinking rate of the slab is high, and slab detachment can occur within the first million years after onset of subduction. The rate of convergence appears to be a second-order parameter, a high rate being able to prevent detachment. The intensity of surface processes predominantly controls the surface topography, and also seems to be able to influence deep processes such as the sinking rate. Thus, the same topography can be maintained for completely different subduction scenarios.

T52B-0931 1330h POSTER

Extensional Structures on the Po Valley Side of the Northern Apennines

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The present-day tectonics of the Northern Apennines is characterized by extension in the inner Tyrrhenian side and compression in the outer Po Valley-Adriatic side. The boundary separating the two domains, extensional and compressional, is still largely undetermined and mainly based on geophysical data (focal mechanisms of earthquakes). Map-scale extensional structures have been studied only along the Tyrrhenian side of the Northern Apennines (Tuscany), while along the Po Valley-Adriatic area the field studies concentrated on compressional features. A new, detailed field mapping of the Po Valley side of the Northern Apennines carried out in the last ten years within the Emilia Romagna Geological Mapping Program has shown the presence of a large extensional fault crossing the high Bologna-Modena-Reggio Emilia provinces, from the Sillaro to the Val Secchia valleys. This Sillaro-Val Secchia Normal Fault (SVSNF) is NW-SE trending, NE dipping and about 80 km long. The age, based on the younger displaced deposits, is post-Miocene. The SVSNF is a primary regional structure separating the Tuscan foredeep units from the Ligurian Units in the south-east sector of the Northern Apennines, and it is responsible for the exhumation of the Tuscan foredeep units along the Apennine water divide. The subvertical, SW-NE trending faults, formerly interpreted as strike slip, are transfer faults associated to the extensional structure. A geological cross-section across the SVSNF testifies a former thickness reduction and lamination of the Ligurian Units, as documented in the field, in the innermost areas of the Bologna-Modena-Reggio Emilia hills, implying the occurrence of a former extensional fault. These data indicate that the NE side of the water divide has already gone under extension reducing the compressional domain to the Po Valley foothills and plain. They can also help in interpreting the complex Apennines kinematics.

T52B-0932 1330h POSTER

A Comparison of Structural Data and Seismic Images For Low-Angle Normal Faults in the Northern Apennines (Central Italy): Constraints on Geometry and Activity

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During the last 20 Myr extensional tectonics in the Northern Apennines have moved from the Tyrrhenian sea toward east. Much of the extension is due to low-angle east-dipping normal faults now exhumed in the Tyrrhenian islands and Tuscany, while still accommodating deformation in the Apenninic chain (Umbria region 200 km eastward). This tectonic framework provide an example where exhumed structures can be compared with active extensional structures and processes affecting the Umbria region. It is here proposed the case study of two of these low angle normal faults, the Zuccale fault (Zf), cropping out in the Elba island and the Altotiberina fault (ATF) mainly detected by seismic profiles crossing the Umbria region. The Zf in the eastern part of the Elba island juxtaposes along a gently (~ 10°) eastward dipping contact, the Upper Cretaceous Helminthoid flysch in its hangingwall over the Permian-Triassic (?) phyllitic basement in its footwall. Structural analysis of the brittle structures that characterise the fault zone has been used to constraint the state of stress under which the fault slipped. From the N-S trending vertical vein system perpendicular to the slickenlines of the fault plane and from the Andersonian normal faults present within the fault gouge, some of them rotated according to a top to the east movement, we infer that (1) the maximum principal stress was sub vertical during the fault activity (2) the fault accommodate slip under low values of differential stress and at dips similar to its present flat geometry (3) local fluid overpressures were attained during the fault activity favoured by a thick fault gouge. The geological scenario described in the Elba island shows similarities with the active deformation of the Umbria region. Seismic profiles crossing this area matched with surface geology highlight the presence of an east-dipping low-angle (~ 20°) normal fault, the Altotiberina fault (ATF), and antithetic seismogenic structures bounding the intramountain basins (Upper Pliocene-Quaternary). The

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