T42F-07 1535h

Bonneville, Lahontan, and Minchin: New estimates of crust and upper mantle viscosity and density structure from large lake loads

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Sufficiently large paleolakes are useful probes of crust and upper mantle strength. Each of the shorelines formed by the lakes was horizontal when they formed, but are now found at higher elevations near the basin center, due to isostatic response to the removal of the water load represented by the former lake. Improvements in the input data and in the modeling strategy for three significant paleolakes are reported.

At their maximum extents, lakes Bonneville, Lahontan, and Minchin respectively occupied areas of (49, 22, 56) 10^3 km^2, and water volumes of (8.9, 2.0, 4.5) 10^3 km^3 in western Utah, western Nevada, and western Bolivia, all at nearly the same time. Peak elevations in each case occurred 14-15 kyr BP.

In order to use the shoreline elevation pattern of a paleolake to provide constraints on Earth structure, several ingredients are necessary. In most cases, the easiest to obtain is the spatial pattern of shoreline elevations, and the most difficult to obtain is the temporal pattern of lake surface elevation variations.

In previous analyses of these three basins, the elastic structure (density, rigidity, and bulk modulus) has been held fixed at seismically determined values, and only the viscosity has been adjusted to match the observed rebound pattern. In the present analyses, viscosity and density were both varied in each layer. Small changes in density structure removed long wavelength residuals which were present in the previous analyses.

The Bonneville data set includes slight revisions in loading history, and incorporates elevations from the Bonneville (1550 m), Provo (1440 m), Stansbury (1350) and Gilbert (1300 m) shorelines. Previous analyses have not used the Stansbury data.

The Lahontan data set includes minor revisions to loading history, and incorporates 180 elevations from the highest (Sehoo) shoreline.

The Minchin data set includes substantial recent revisions to the previously used loading history, and corrects a misidentified elevation at one of the survey sites. This error had lead to the suggestion of a basin-wide tilt signal, which is now seen to be spurious.

T42F-08 1550h INVITED

Modeling GPS Observations of the 3D Crustal Deformation Field in Fennoscandia

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Observations of 3-D crustal motion in Fennoscandia obtained via Project BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea Level and Tectonics) show a pattern that is clearly related to the on-going glacial isostatic adjustment (GIA) of the region. To predict the deformation field we adopt a GIA forward model comprised of a spherically symmetric, self-gravitating, compressible, viscoelastic earth model; a number of recent models of the Fennoscandian ice history; and an ocean load computed by solving a recently improved form of the sea-level equation. The contribution to the deformation field from GIA-induced perturbations in the model earth's rotation vector is also incorporated in the predictions. Comparison between the GIA predictions and the GPS-derived observations show a strong correlation, verifying that GIA is by far the dominant contributor to the observed deformation pattern. A series of forward predictions that sample an extensive range of viscosity parameter space yield models that are compatible with those inferred from recent analyses of Fennoscandian relative sea-level data. For example, the viscosity model preferred by this exercise is characterized by a 120 km elastic lithosphere, upper mantle viscosities in the range 5 x 10^{20} to 10^{21} Pa s, and lower mantle viscosities in the range 5 x 10^{21} to 5 x 10^{22} Pa s. We compute a residual deformation pattern by subtracting a best-fitting GIA model prediction from the observed rates. The residual field suggests that that non-GIA processes, such as neotectonics, produce motions of magnitude around 1 mm/yr (in the rsm sense) or less in the region.

T42F-09 1605h

Effects of Laterally Varying Mantle Viscosity on Post-Glacial Rebound from Spherical Finite Element Models

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Observations of isostatic adjustment of the earth's surface due to transient loading provide important constraints on the mantle viscosity structure. However, most studies of this response have assumed a spherically symmetric earth. Seismic observations indicate that the visco-elastic properties of the mantle may include significant lateral variations. Therefore, it is important to study the sensitivity of surface uplift to lateral variations in viscosity structure. To study such effects, we have used 2-D and 3-D spherical finite element software CitcomSVE [Zhong, 2001]. For earth models with spherically symmetric viscosity structure, we were able to test the reliability of the finite element results by comparing against the traditional analytic method for models with a realistic (in space and time) glacitaion-deglacitation model, similar to the history of the Laurentide ice sheet. Having determined that, for sufficiently high space and time resolution, these two methods yielded surface responses that agreed to within 0.5%, we have explored the effects of the size of the updating time-step and self-gravitation in the finite element calculations. We have found that the largest permissible time-step size is $\sim 0.3\eta/\mu$ (where η and μ are the viscosity and shear modulus for the lower mantle) for models with either an isoviscous mantle or a radially stratified mantle where the upper mantle's viscosity is 10 times smaller. The effects of self-gravity are examined with calculations that include different numbers of spherical harmonic degrees in the perturbed gravitational potential (from $l_{max} = 0$ for no self-gravitation, to $l_{max} = 10$, 20, and 32). While self-gravitation has relatively small ($< 2\%$) effects on the vertical motion at the center of the ice disk, its effects at the peripheral bulge are rather significant. The relative difference between the finite element and exact models at the bulge is 15% and 9% for $l_{max} = 2$ and 10, respectively. However, we found that $l_{max} = 20$ seems to be sufficient to represent the self-gravitation. We will use the results of this model to discuss the effects of lateral variations in viscosity on surface response, particularly the sensitivity of the response to the distribution of viscosity anomalies.

T42F-10 1620h

Modeling the Response of a Three-Dimensional, Viscoelastic Earth

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We describe a finite-element numerical scheme for modeling the response of a viscoelastic Earth. The scheme has been developed to consider problems on either global or regional scales and thus has application to both post-glacial rebound and post-seismic relaxation. The method provides a time-domain, fully three-dimensional solution which honors both seismic discontinuities and lateral variations in the viscoelasticity of the mantle and lithosphere.

At each time step, the numerical procedure simultaneously solves for material displacements and the perturbed gravitational potential. Our preliminary calculations adopt the Cowling approximation for the perturbed gravity and assume a Maxwell viscoelastic rheology. We have developed a special tetrahedral grid for regional problems that allows for the treatment of explicit PREM-like discontinuities. The discretization is based on a finite volume approach, combined with a standard linear interpolation within each grid element. This combination results in a fast assembly and an efficiently designed system matrix. The resulting algebraic system is solved based upon an ILU-preconditioned, generalized minimal residual method.

We review the theoretical aspects of the scheme and discuss the results of a series of benchmarks.

T42F-11 1635h

Tectonic Plate Coupling and Elastic Thickness Using a Viscoelastic Model of Crustal Deformation in Southern North Island, New Zealand

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The crustal deformation in the Wellington region of North Island, New Zealand has been studied by inverting GPS-derived crustal velocities using a steady-state viscoelastic model of oblique plate convergence. The deformation is driven by pseudo-backslip on the locked Pacific-Australia plate interface. Finite element techniques are used to calculate effective Green functions for the slip elements and slip velocities are determined from a weighted least squares analysis. The parameters of the model are the depth-dependent backslip velocities, v(z), (or equivalently the coupling between the plates, a = abs[v/V] where V is the relative plate velocity), the elastic plate thicknesses, and the elastic moduli. Seismic data indicate that Young's modulus of the Australian crust is about half that of the Pacific plate. In this case, the model best fits the data when the Pacific plate elastic thickness is 40-60 km and the Australia plate elastic thickness is 100-150 km. These elastic thicknesses are greater than those derived from seamount loading data suggesting that the elastic thickness on the geodetic time scale (decades to centuries) is greater than that on a tectonic time scale (millions of years). The elastic thicknesses increase as the modulus contrast is reduced, but decrease if the modulus contrast is greater than that suggested by seismic observations. The elastic thickness estimates are derived by minimizing the reduced chi-squared misfit between the model predictions and observations. We find that there is a broad range of statistically acceptable elastic thicknesses distributed about the optimal value. However, the coupling distribution is more tightly constrained with strong coupling (a= 0.8-1.0) occurring to depths of more than 20 km. We further find that the fit of the viscoelastic model to the data is marginally better than the fit of the ”best” elastic model. Finally we note that most of the information for discriminating between models comes from the trench-normal rather than the trench-parallel components of the horizontal velocities.

T42G MC: 309 Thursday 1330h

Initiation of Subduction: Constraints From the Field and From Modeling II

(joint with OS)

Presiding: **J Encarnacion,** Saint Louis University**;** **M A House,** California Institute of Technology

T42G-01 1330h INVITED

Spontaneous Nucleation of Subduction Zones in the Western Pacific During Middle Eocene Time: Evidence From the IBM Forearc Ophiolite

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Subduction zones nucleate in two fundamentally different ways. Induced nucleation is a response to continuing plate convergence following a collision event and requires the lithosphere to fail under compression; no change in plate motion is expected. Spontaneous nucleation of a subduction zone (SNSZ) manifests failure of old lithosphere due to gravitation instability. SNSZ doesnt require plate convergence to occur but major changes in plate motion are expected. SNSZ is possible where old oceanic lithosphere is unusually dense (old continental margins) or weak (along fracture zones). The western edge of the Pacific plate spontaneously reorganized as a convergent margin during Middle Eocene time (~50-42 Ma) and is the best known example of SNSZ. The unusual nature of this episode is preserved in the Izu-Bonin-Mariana (IBM) forearc, where pillow basalts, dyke complexes, gabbro, and harzburgitic mantle define an in situ ophiolite. The IBM forearc ophiolite requires that SNSZ was accompanied by a strongly magmatic episode of seafloor spreading. Spreading so close to the present trench requires asthenospheric upwelling where strong mantle downwelling now occurs. Abundant boninite, formed by melting harzburgite, in IBM forearc sections further demonstrates the unique nature of the IBM subduction initiation event. IBM SNSZ spans the period from beginning of magmatic construction of the IBM forearc ophiolite about 50 Ma to the change in Pacific Plate motion at 43 Ma marking the start of true subduction. Events during this stage are very poorly understood but can only be explained by subsidence of part of the lithosphere to a depth such that asthenosphere flowed over it. Stern and Bloomer (1992 BGSA 104, 1621-1636) argue that this occurred along a zone of weakness associated with a N-S fracture zone but this has been criticized on the basis of paleomagnetic models requiring $\sim$90 ° CW rotation of the Philippine Sea Plate (PSP) since 43Ma. The youngest parts of the paleomagnetic reconstructions fail because geologic evidence refutes arguments for significant rotations since 15 Ma. Regardless of paleogeographic controvesies, the essential geologic evidence for IBM SNSZ are robust. Furthermore, the prediction that SNSZ will simultaneously develop along the entire margin of the affected plate is satisfied. Development of physical models are now required in order to make further advances in understanding SNSZ.

T42G-02 1345h

Initiation of Subduction and Forced Changes in Absolute Plate Motion: A Pacific Perspective

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In the process of inspecting Pacific Basin reconstructions and new absolute plate motion (APM) models, e.g., Engebretson et al. (1985), Scotese et al. (1988), Yan and Kroenke (1993), Lee and Lawver (1995), Kroenke (1996), Wessel and Kroenke (1997, 1998) and Sterling et al.(2000), it unexpectedly became evident that the initial alignment of all subduction zones, i.e., the strike of the newly formed trench axis, consistently seemed to roughly parallel the APM of the adjoining oceanic plate during the time the zone was being formed. Every major subduction zone, whose original alignment relative to APM could be established, invariably exhibited this relationship. Furthermore, two types of subduction zone initiation could be recognized: A) those that preceded, and may have been responsible for subsequent, major, long-lived changes in APM and B) those that followed major changes in the APM, whose development may have enabled the accomodation of the ensuing convergent stress buildup following the change. In the latter situation, APM changes appeared to have occurred concomitant with terrane collision and/or accretion and, although sometimes impressive, were often short-lived. In both situations, however, subduction zone alignment roughly paralled plate motion during the initiation of subduction. We examine the tectonic initiation of Pacific margin subduction zones in the context of absolute motions of the ocean plates as determined in the hotspot frame of reference. The primary plate motion driving force is assumed to be the pull of the descending lithospheric slab. The cause and effect of changes in plate motion, as well as the timing of these changes, will be considered in relation to the tectonic initiation and development of subduction zones.

T42G-03 1400h

Subduction Initiation by Extrusion Tectonics? Evidence From the Palawan Ophiolite, Philippines

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There are few well-constrained geologic examples that can provide insight to the conditions under which subduction initiated. The Palawan ophiolite preserves evidence bearing on the initiation of subduction that can be linked with tectonic events in the surrounding areas. We report a 34 Ma crystallization age for the Palawan ophiolite obtained by zircon U-Pb dating on plagiogranite. Previous hornblende and white mica Ar-40/Ar-39 dates from the high T and P metamorphic sole are indistinguishable from the crystallization age of the ophiolite. New major and trace element geochemical data from pillow basalts and mafic dikes from five separate areas of the ophiolite all indicate a predominantly N-MORB-like source for the ophiolite, although some trace element ratios are transitional to IAT (e.g., Hf/Ta and Th/Hf). Differentiation trends on plots of MgO vs. TiO2 and MgO vs. Al2O3 deviate from MORB trends and are more akin to trends for the Mariana and Lau backarc basins. The available evidence suggests that the ophiolite formed in latest Eocene-earliest Oligocene time in a "mature" backarc basin that opened within Early Cretaceous oceanic lithosphere (now preserved beneath the ophiolite). The concordance between the times of ophiolite and high T-P sole formation indicate that the ophiolite was detached at, or close to, the spreading axis. The transition from spreading to convergence requires that far-field compressional stresses were applied to the area of the ridge axis. Previous work has shown that this zone of convergence evolved into a subduction zone that spawned the Cagayan arc-Sulu Sea backarc system. This implies that the presence of the old, dense Early Cretaceous oceanic lithosphere was insufficient for subduction to begin and that external forces were required to initiate subduction. The new data, combined with recent thermochronologic data from the Red River Shear zone indicating shearing beginning at 33 Ma and seafloor spreading of the South China Sea at 32 Ma suggest a scenario wherein extrusion of Indochina into the proto-South China Sea area caused compression in the Palawan back arc basin, ophiolite detachment and initiation of subduction.

T42G-04 1415h

From Spreading and Transform Fault to Subduction: Examples from the Boundaries of the Caroline Plate

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The Caroline Plate is an oceanic plate which lies near the equator in the western Pacific. It is surrounded by three major plates: the Pacific Plate to the north and to the east, Philippine Sea Plate to the west, and Australian Plate to the south. Early studies suggest that the Caroline Plate has undergone a counterclockwise rotation with respect to the Philippine Sea Plate. However, the history of seafloor spreading within the Caroline Plate and its interaction with neighboring plates are not well constrained. In recent years, Korea Ocean Research and Development Institute performed a number of detailed bathymetric mapping and geophysical surveys along the margins of Caroline Plate using R/V *Onnuri*. These investigations reveal that the Caroline Plate holds at least two classical examples of transition from divergent and/or transform fault boundaries to convergent boundary. The first example of this type is found along the western edge of the Caroline Plate where it comes into contact with the Philippine Sea Plate. An abrupt change occurs from an ultra-slow-spreading ridge (Ayu Trough) to deep trenches (Palau and Yap Trenches) toward north along this boundary. Furthermore, our multibeam bathymetric data show that, contrary to previous notions, the opening of Ayu Trough occurred in an oblique manner. The second case of transition into a subduction zone can be observed along the northern and eastern margins of the Caroline Plate. Unlike the first case, the transition is gradual in this case. In the northern section of the Caroline Plate, Sorol Trough divides the Caroline Ridge into two sections. A number of evidences suggest that the motion between Caroline and Pacific Plates along the Sorol Trough is transtensional. Farther to the east, the boundary between the Caroline and Pacific Plates becomes somewhat obscure on regional scale. However, our bathymetric transects of this region suggests that increasing compression from north to south has led to a change in the fault pattern on the seafloor and subsequently to a subduction. For instance, the seafloor under moderate compression in the north is marked by a multitude of regularly spaced thrust faults. This region appears to be more than 120 km wide at 7 °N and 135 °E. However, with increasing convergence to the south, the thrust faults begin to interaction with one another, which leads to a preferential growth of one or more faults. With further localization of strain, the margin develops into a trench.

T42G-05 1430h

Late Miocene Re-initiation of Subduction Beneath SW Japan: Implications from Late Cenozoic volcanism

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SW Japan was the site of arc magmatic activity during Cretaceous and early Tertiary time, as part of the Eurasia continent. Arc magmatism ceased about 45 Ma, probably due to initiation of subduction along the Izu-Bonin-Mariana margin to the east. A remarkable progression of eruptive products, beginning in Middle Miocene time ($\sim$20 Ma), signaled re-initiation of Philippine Sea plate subduction. Subductin reinitiation is also related to opening of the Japan Sea back arc basin at this time. Late Cenozoic arc volcanism in SW Japan is characterized by alignment of distinctive magmatic suites parallel to the trench, beginning with a large volcano-plutonic felsic suite (17-13 Ma) in the Outer Zone near the trench. This was associated with alkali basalt and calc-alkaline acid volcanic provinces in the back arc region (20-13 Ma). Outer Zone activity consisted mostly of S-type felsic magmas suggesting melting of the lower crust, perhaps related to subduction of very young Shikoku Basin crust. Farther inland along the Setouchi belt, high magnesian andesite (HMA) occurred about this time (15-12 Ma) again aligned parallel to the trench. This HMA originated from slab sediment melts reacting with overlying mantle wedge peridotite. Outer Zone and Setouchi belt volcanism ended at 12 Ma, and monogenetic alkali basalt volcanism was established in the back arc region (12-0.2 Ma). Distribution of the younger alkali basalt activity (2.5-0 Ma) has been restricted further to the back arc. Eruption of Adakites (1.7-0 Ma) has been superimposed on earlier sites of alkali basalt activity. Alkali basalts were melts of depleted asthenosphere and enriched lithosphere. SW Japan Adakites appear to be melts of subducted Philippine Sea basaltic crust. Subduction re-initiation beneath SW Japan appears to have begun after back-arc basin opening based on ODP drilling results but paleomag rotations suggest that rotation of SW Japan is younger. Mantle wedge was heated by upwelling associated with opening of the Japan Sea at the same time that subduction of the young hot Shikoku Basin crust led to melting of Shimanto Belt sediments in the Outer Zone. Subducted sediments could have melted when injected into this hot region and reacted with forearc mantle to produce HMA. Further penetration of the slab gradually cooled the forearc mantle wedge, so that the volcanic arc narrowed and migrated away from the trench. When the slab reached the depth of eclogite stability, dehydration melting produced Quaternary adakites. The area where adakites occur lies along the extension of the Shikoku Basin ridge, supporting the model of melting of a hot slab.

T42G-06 1505h

The Elastic Properties of the Lithosphere Beneath Scotian Basin

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To assess the possibility that the North Atlantic Ocean may subduct at Scotian basin east of Canada, we investigate the present compensation state of this deep basin. A Fourier domain analysis of the bathymetry, depth to basement and observed gravity anomalies over the oceanic area east of Nova Scotia indicates that the basin is not isostatically compensated. Moreover, the analysis emphasizes that density perturbations in excess to sediments exist beneath the basin. The load produced by the sediments and these density perturbations must have been supported by the lithosphere. We simulate the flexure of the lithosphere under this load by that of a thin elastic plate overlying an inviscid interior. It is shown that a plate with a uniform rigidity does not adequately represent the lithosphere beneath the basin as well as the oceanic lithosphere far from the basin, rather the rigidity of the lithosphere directly beneath the basin is about one to two orders of magnitude smaller than elsewhere. We relate this weakening to the thermal blanketing effects of the thick sediments and the fact that the lithosphere has a temperature dependent rheology. We suggest that this weak zone would have a controlling effect on the reactivation of normal faults at the hinge zone of the basin, that were formed during the break-up of Africa and North America and were locked in the early stages after the break-up. The weak zone would facilitate reactivation of the faults if tensional stresses were produced by possible reorientation of the spreading direction of the North Atlantic Ocean in the future. The reactivation of the faults would create a free boundary condition at the hinge zone, allowing further bending of the lithosphere beneath the basin and juxtaposition of that to the mantle beneath the continent. This may provide a favorable situation for initiation of slow subduction due to subsequent compressional forces.

T42G-07 1520h

Subduction Initiation: Criticality by Addition of Water?

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We have employed high-resolution finite-element (100k) models based on new rheological data of the lithosphere to investigate the role played by water on initiating subduction. Models of subduction require the formation of a weak zone to initiate subduction. This first instability ruptures the mechanical coherence of the lithosphere by localized plastic yielding. With plastic failure, fluid-dynamical approaches have succeeded in producing near vertical slab like features of negatively buoyant viscous lithosphere. However, the yield strength of the lithosphere has been assigned arbitrarily and the significance of elastic bending stresses has been neglected. Elasticity counteracts near vertical dripping slabs and creates distinct asymmetry. Hence, an elastic-fluid-thermo-mechanical instability is needed to drive a cold, stiff, and negatively buoyant lithosphere into the mantle. This instability can be triggered slowly by sedimentary loading over a time span of 100 Myrs. Our results indicate that subduction can proceed by a double feedback mechanism (thermo-elastic-rheological) promoted by lubrication due to water. An Atlantic-type continental margin would thus reach criticality upon the steady addition of sediments, if an average sediment load of 10 km thickness is reached. Plummeting of such a gravitationally and mechanically unstable lithosphere into the mantle is possible through many subsequent mechanisms.

T42G-08 1535h

Can Convective Instability of a Thickened Passive Margin Help Initiate Subduction?

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A fundamental part of plate tectonic theory is that plates are generated at spreading ridges and consumed at subduction zones. High density phase changes in the subducting slab help to pull the plate into the convecting mantle. McKenzie (1977) formulated expressions for the driving and resisting forces at a subduction zone and showed that at least 130 km of slab, moving at a rate of at least 1.3 cm/yr, would be required to subduct before the process would be self-sustaining. It was unclear from this work, or in more recent studies, how subduction is initiated in the first place. We propose that initiation of subduction at a passive margin may be aided by convective instability of a thickened igneous crustal section that was emplaced during initial rifting of the margin, such as is observed along much of the eastern boundary of the North Atlantic. We performed calculations of subsolidus phase equilibria of mafic and ultramafic lower crustal compositions that show that at the base of the crust at a thickened passive margin, high density phase transitions cause the density of the crust to exceed that of the underlying mantle at sub-Moho pressures by 50-100 kg^3. Following recent work on convective instability of dense lower crust (Jull and Kelemen, JGR, 2001), we propose that colder temperatures at passive margins inhibit rapid convective removal of dense lower crust, and that initially only the deeper, ductile portions of the crust flow downwards via diffusion creep, allowing the density instability to continue. This results in subsidence and related sedimentation, which cause more and more of the lower crust to reach pressures where high density mineral phases form. Using a two-dimensional finite element model for the development of a convective instability, we evaluate this idea and determine the timescales and range of temperatures and pressures at which a thickened passive margin can produce a significant negative buoyancy force on the plate margin. A key component of this idea is that the phase transformations occur faster than the viscous root can “drip” off the bottom. This requires that the kinetics of reactions forming dense phases such as garnet are rapid compared to the time scale for convective instability, and that the reactions occur within geologically relevant times. Alternatively, if the lower crustal load cannot overcome the elastic strength of the plate (along with ridge push + sediment load), then the lower crust could eventually fall off and allow asthenospheric upwelling/heating/weakening, thus decreasing the elastic thickness of the plate so that ridge push and sediment load can overcome shear resistance at the plate margin and initiate subduction.

T42G-09 1550h

A Coupled Thermomechanical Model of Continental Collision in Alpine-Type Mountain Belts

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A fully coupled numerical thermomechanical model that accounts for strain localization, surface processes, phase changes and high viscosity contrasts is used to test different mechanisms of subduction in continental collision zones. The model considers various end member cases including low and high buoyancy of the subducted crustal material after metamorphic reactions. The low buoyancy model predicts steep subduction with early break-off and 3 levels of metamorphic rock exhumation for the same collision context: the classical corner flow LP-LT exhumation in the accretionary prism; deeper (70 km) HP-HT exhumation for the thickened subducting crustal-sedimentary wedge, and ultra HP-HT exhumation from the lower crustal chamber, forming at the depth of 100-120 km and separated from the upper one by a narrow crustal channel, which width can oscillate in the process of shortening, thus controlling the quantity of the crustal material exchanged between the crustal wedge and the lower crustal chamber. Although both zones of crustal accumulation and the narrow channel between them resemble a vortex-shaped nozzle, this nozzle appears to be too soft to produce any significant overpressures. From the upper crustal wedge, the material is exhumed following the ascending shear flow created by the overriding plate assisted by positive buoyancy of the heated crustal material. From the lower crustal chamber, the material is transported upwards to the upper crustal wedge by a flow induced by the asthenospheric traction and a small scale convective instability forming in the lower crustal chamber due to its heating by the overriding asthenosphere. In the case of high buoyancy, underplating may occur and the latter mechanisms become dominant resulting in fast exhumation of the crust to the surface, accelerated or slowed subduction in case of full or partial crustal decoupling, respectively, and upper plate extension. For all scenarios, the experiments demonstrate the primary importance of the pre- and post-metamorphic density contrasts as well as the importance of the lateral shear flow zones systematically created at the boundaries between the upper and lower crust and lower crust and mantle lithosphere (Moho zone). Shear strain localization is also predicted at the lithosphere asthenosphere boundary.

T42G-10 1605h

A Model for Wilson Cycles

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While the steady state tectonics of subduction are reasonably well understood, the initiation of subduction is not. Theoretical and modeling studies of subduction initiation require large, sustained in-plane stresses to break the continuous oceanic plate and drive the slab into the mantle before a new subduction zone can be self-sustaining. These studies have identified sediment loading and old, dense oceanic lithosphere associated with passive margins as factors favoring the localization of subduction. Old oceanic lithosphere is also quite strong, increasing the stress necessary to break the plate, making passive margins less appealing as a locale for initiation.

In contrast to breaking the plate in-plane, a subduction zone could grow laterally, by crack propagation, extending to join a passive margin. ”Primed” by the bouyancy flux of the pre-existing subduction zone, progressive failure along a passive continental margin would disrupt the oceanic lithosphere and become self-sustaining as the dense plate sank into the mantle, accelerating the tear.

The Caribbean plate provides an example of how a micro-plate might nucleate a subduction zone through stress concentration. As the Caribbean plate advanced, the subduction zone at its leading, eastern edge was progressively channeled to the south as first Cuba and then Hispanola were jammed against the Bahamas platform. The Antilles arc is the current site of active subduction. The Caribbean plate is being over-ridden at the Muertos trough, south of Puerto Rico, and at the northern limit of South America and is over-riding the Pacific plate on the west and the North American plate on the east. The Caribbean plate is pinned between the three surrounding plates, which may provide the necessary stress concentration which could lead to the development of a new active margin on the East coast of North America.

Wilson cycle tectonics, as seen in the Phanerozoic history of North Atlantic passive margins, require that passive margins periodically become active. Since slab pull dominates all other plate boundary forces, changing the geometry of subduction alters the absolute motion of the plate, affecting adjacent plates. Rapid initiation of subduction may offer an explanation of rapid, large-scale re-orientation of plate motions.

T51A MC: Hall D Friday 0830h

The Physics and Mechanics of Compressive Failure: From Faulting to Ductile Flow II *(joint with S, MR, HG)*

Presiding: **C E Renshaw,** Dartmouth College**;** **E M Schulson,** Dartmouth College

T51A-0837 0830h POSTER

Compaction Localization, Fluid Flow and Acoustic Emissions in Porous Rock

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When subjected to non-hydrostatic, compressive stresses, in the brittle-ductile transition regime, sufficiently porous rocks exhibit non-uniform compaction. The compaction occurs as a localization process, analogous to shear localization, but results in a thickening, tabular zone of compaction as opposed to culminating in a shear fracture. Acoustic emission locations were used to track the evolution and propagation of the compaction front while continuous flow permeability measurements were carried out. These experiments showed that compaction localization produced a two-order-of-magnitude decrease in permeability. Because of the inhomogeneous nature of compaction produced by compaction localization, and its temporal evolution, a number of phenomena related to fluid flow are predicted to occur: compaction-induced fluid injection, locally increased pore pressures, and spatial changes in the effective permeability. Understanding these phenomena requires a knowledge of the time-dependent position(s) of the compaction front(s), obtained from acoustic emission locations and upstream and downstream fluid pressures and volumes, obtained from the continuous flow permeability measurements. These effects are analyzed and related experimental results are reported that show the evolution of effective permeability to be linear with respect to the distance the compaction fronts propagated. The presence of multiple compaction bands leads to locally increased pore pressures which will influence compaction localization in a manner similar to dilatancy hardening for shear banding.

T51A-0838 0830h POSTER

Dilational and Compactional Shear Failure: Application to Siliciclastic Petroleum Reservoir rocks.

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