receiver function analysis. A receiver function analysis was previously performed on the MOBC seismometer in the QCI. The study revealed a low velocity zone (LVZ) dipping eastwards at 20° beneath the continental Moho, with a depth of 34 km, a thickness of 10 km, and velocities consistent with oceanic crust. Receiver functions have recently been calculated from waveform data recorded at 6 temporary seismometers installed on the QCI during the summer of 1999. Preliminary results indicate a structure similar to that observed under MOBC with a LVZ increasing in depth eastwards across the QCI, consistent with an underthrust slab of Pacific plate. The largest recorded earthquakes in the region are dextral strike-slip events along the QCF; however, if underthrusting is confirmed, as suggested by the receiver function results, then megathrust earthquakes to M ∼8 will also be expected beneath the margin.

T31C-03 0900h INVITED

Could a Complex Earthquake like the 2002 Denali Fault Event hit the Los Angeles area?

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The Denali Fault earthquake sequence began with the 23 October 2002 Mw6.7 Nenana Mountain foreshock, followed on 3 November 2002 by the Mw7.9 Denali Fault mainshock. The transfer of slip from the Susitna Glacier fault to the Denali fault during the mainshock demonstrated that rupture of secondary thrust faults can trigger nearby strike-slip faults, highlighting the possibility that such dangerous earthquakes could occur in more densely populated regions with similar tectonics. For example, previous workers [Eberhart-Phillips et al., 2003] have suggested that an earthquake similar to the Denali Fault mainshock could occur in the Los Angeles metropolitan region, home to more than 13 million people. We have tested this proposal of intraevent triggering by first creating a dynamic rupture model of the Denali Fault earthquake that replicates the transition of rupture from the Susitna Glacier fault to the Denali fault. From this model, we find that the geometry of the faults and the orientation of the regional stress field explain why slip on the Susitna Glacier fault triggered rupture on the Denali fault. We then applied the same methodology to study these short term interactions, as well as static modeling to examine longer term interactions (foreshock/mainshock triggering), between the Sierra Madre-Cucamonga thrust and San Andreas/San Jacinto strike-slip fault systems near Los Angeles. We find that the comparison between these faults and the Denali Fault mainshock breaks down due to differences in background stress and fault geometry. In particular, rupture of the Sierra Madre-Cucamonga system is unlikely to trigger immediate rupture of either the San Andreas or San Jacinto fault, as the Susitna Glacier fault triggered the Denali fault during the 2002 event. However, our modeling suggests that under rare circumstances, a large earthquake on the northern San Jacinto fault could immediately trigger a cascading rupture of the Sierra Madre-Cucamonga system, potentially growing into a dangerous Mw7.5-7.8 earthquake on the edge of the heavily populated Los Angeles metropolitan region. The static modeling yields similar results, suggesting longer term triggering of events is more favorable for events originating on the strike-slip systems.

T31C-04 0915h

Forearc Slivers, Arcs, and Migrating Terranes: Strain Partitioning in a Sandbox

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Using automated image analysis, we determine displacements and strains throughout an analog experiment, for comparison with other models and with structural, geodetic and seismic data from active convergent margins. The rate at which a model forearc sliver or accreted block moves depends upon the geometry of the convergence and the yield criterion, and experiments with frictional blocks are sensitive to many of the same rate and wear-dependent aspect of friction that complicate the behavior of frictional faults in nature. Nonetheless, they illustrate the expected overall behavior, with a minimum obliquity angle below which there is no margin-parallel slip. With moderate to large convergence obliquity, sand experiments with rigid forearc slivers show substantial, but not total, partitioning of the margin-parallel convergence to along the strike-slip boundary between the sliver and the overlying plate. The degree of such partitioning decreases with smaller convergence obliquity and, less so, with increasing quantities of accreted sediment or with the buttressing effects of thrusting at the leading edge of the sliver as it moves parallel to the margin. Without such a rigid sliver and with small convergence obliquities, the margin-parallel component of convergence is broadly diffused throughout the deforming critical wedge, with thrusts throughout the wedge accommodating a small strike-slip component of motion, along with the dominant dip slip. At moderate obliquities, increasingly large portions of that margin-parallel motion are accommodated toward the rear of the wedge, over the backstop formed by the front of the overlying plate. At high obliquities, that region develops distinct strike-slip faults and other structures clearly related to accommodating the margin-parallel part of convergence. Arcuate frictional model margins display all of these features, as obliquity varies around the margin. Those with a nearly Newtonian viscous rheology display a less localized progression of strain distributions including true extension, reflecting stresses due to both plate convergence and topography. A sliver of small aspect ratio, essentially a migrating terrane, produces sweeping lobate features. The extreme partitioning of strain in such a case can lead to the formation of orogens with pronounced reentrants and foldbelts that display nearly pure dip slip faulting in a direction normal to the overall plate convergence vector, features that are absent when the terrane is docked instead of migrating.

T31C-05 0930h

Strain Partitioning and the Geometry of Oblique Plate Convergence

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Strain partitioning occurs at convergent margins where oblique subduction takes place, a fact that has been known for a number of years. The geometry of plate subduction controls strain-partitioning mode in the forearc region. Deformation in the forearc depends on the direction of relative plate convergence, earthquake slip vectors, and trench-normal direction. Two basic angles are derived from these vectors: obliquity of plate convergence, the angle of plate motion direction and trench normal, and slip partitioning which is the angle between the earthquake slip vector and trench normal. Traditionally, oblique convergence models consider the trench (convergent margin) a straight line on a flat Earth. This is correct for small-scale (in the order of a few kilometers) models. However, earthquakes along convergent margins often have fault lengths of tens and even hundreds (for magnitude 7 or greater) of kilometers. On the other hand, the direction normal to the trench is usually calculated averaging contiguous points along the deepest part of the digitized bathymetry, yielding the local trend of the trench. The direction normal to the trench thus calculated varies greatly along a specific trench. In this work we propose an alternate treatment of the geometry of the trench. On a spherical Earth, trench segments form arcs of small circles. Usually, a trench of interest will contain a few (three-five) such segments, which can be fitted (in a least-squares sense) with small circles with a known center of curvature (or pole) on the surface of the Earth. Also known are the initial and final points. Instead of the standard direction normal to the trench, we use the average azimuth from the segment of small circle to its corresponding pole. We use this direction instead of trench normal and calculate obliquity of plate convergence. We test our model along the western Sunda arc, from the eastern Himalayan sintaxis to Sumatra. Five contiguos small circles were fitted to the trench: one along the Indoburman ranges, two on the Andaman sea, and two offshore Sumatra. Direction of forearc deformation appears to be governed by the angle between the vector of plate convergence and the average direction of the trench, with earthquake slip vectors playing no role whatsoever. In fact, along the Indoburman ranges there are are no shallow, thrust-faulting earthquakes, although there is a subducted slab.

T31C-06 0945h

Current deformation in eastern Alaska and northwestern Canada related to the Yakutat collision: constraints from GPS and seismicity

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The northern Canadian Cordillera is very tectonically active with exceptionally high seismicity in southwestern Yukon and neighboring Alaska, and surprisingly high seismicity 800 km to the northeast in the Mackenzie and Richardson mountains adjacent to the craton. The Yakutat block has been colliding with North America in the corner of the Gulf of Alaska for the last *sim*5 m.y. The oblique collision results in partitioning of strain into strike-slip (e.g., Denali Fault) and convergent components. The intense seismicity occurs in the collision zone, where deformation is taken up mainly by thrust and strike-slip faulting in the Chugach-Saint-Elias Mountains. Some of the convergent component of strain is transferred across the Cordillera to the northeast, where seismicity rates and Global Positioning System (GPS) vectors indicate that motion is taken up in a broad zone of the fold-and-thrust belt, with little internal deformation of the intervening Cordillera. Simple numerical models for the collisional deformation and strain transfer show the development of both a coastal mountain belt and a foreland thrust front. The high crustal temperatures inferred from high heat flow measured in the northern Cordillera facilitate decoupling in the weak lower crust, allowing the upper crust to transfer stress across the Cordillera to be taken up in the weak foreland sedimentary belt. The strong craton acts as a backstop. Ongoing GPS and seismicity studies are in progress to determine the nature of the internal deformation of the Cordillera.

T31D CC: 516 D Wednesday 0830h

The Structure and Formation of Atlantic Rifted Margins: Observations and Numerical Models I

(joint with GP, S, V, NS)

Presiding: **K E Louden,** Dalhousie University**; R S Huismans,** Dalhousie University

T31D-01 0830h INVITED

30 Years of Volcanic Margin Research: From Conceptual Process Oriented Thinking to Present day 3D Reality’

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Over the past 30 years the Norwegian segment of the NE Atlantic continental margin has been a focus area for both continental margin research and hydrocarbon exploration. A gradually improving data coverage and quality, combined with an increasing number of people involved in interpretation and geological evaluation, has resulted in a more advanced understanding of the margin structure and its geodynamic development. The aims of this presentation are (1) to review the exploration history of the Norwegian margin, (2) to address the links between conceptual and process oriented research in the past with the present day 3D reality’, and (3) to point towards type of challenges that likely characterise most volcanic margins globally. The Norwegian margin can be used to understand how large-scale lithospheric processes are coupled to temporal and spatial changes in vertical motions, development of rift structures and the nature of igneous activity. This is due to the fact that the volcanic cover adjacent to the Continent Ocean Boundary (COB) is sufficiently narrow to allow seismic imaging of a highly attenuated rift zone, a broad zone of intrusive complexes, and a resolvable stratigraphy for the syn- and post-rift sedimentary succession. Today we can review the accumulated knowledge in the framework of detailed observations from 3D seismic surveys. In particular, extensional faults, intrusive igneous complexes, and a large number of hydrothermal vent complexes associated with the igneous activity are exceptionally well imaged on the 3D data. The 3D data reveal a coupled system that 2D data never could resolve. Linking the

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3D images to the deep crustal structures provides additional constraints on how to improve the understanding of the driving' geodynamic processes.

T31D-02 0855h INVITED

Volcanic Productivity During Continental Breakup from Numerical Models of Mantle Convection with Application to Atlantic Rifted Margins

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One of the most remarkable results of several decades of rifted margin research in the Atlantic has been the recognition that these margins show extreme variability in magmatic productivity at the time of breakup, ranging from essentially none along Newfoundland-Iberia to more than 30 km thick new igneous crust along Greenland and Norway. The underlying causes and processes responsible for this diversity remain the subject of intense debate. While mantle potential temperature is clearly one dominant parameter other factors have also been proposed. In this contribution we use a numerical model of mantle convection and a rifting lithosphere to investigate melt productivity during breakup and the establishment of a steady-state, passive seafloor spreading system. The model incorporates a non-Newtonian, temperature dependent viscosity that includes the feedback from melting on the physical properties of the mantle. The models show that some small-scale convection can occur during breakup, but that only modest excess productivity results from models that evolve naturally into steady-state mid-ocean ridge-like accretion. We use the model to quantify the spatial and temporal scales of volcanism associated with continental breakup under a variety of different assumptions about the viscosity, density, and thermal structure of the upper mantle. The implications of these results for understanding melt productivity observed along the Greenland margins and the Newfoundland-Iberian margins is then discussed.

T31D-03 0915h

Refraction Seismic Study in Davis Strait: The Nature of the Crust at the Transform-Rifted Margin Between Baffin Island and Greenland

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Understanding the crustal structure within Davis Strait is important for assessing the early history of mantle plume dynamics in the North Atlantic and the formation of a rifted transform margin between North America and Greenland. In August/September 2003, the NUGGET (NUnavut to Greenland GEophysical Transect) experiment was carried out in Davis Strait. The purpose of the refraction seismic study was to determine the nature of the crust in southern Davis Strait at the transition from non-volcanic style continental margins in Labrador Sea to a volcanic transform-rifted margin between Baffin Island (Canada) and West Greenland. The experiment consisted of two lines utilizing a 104-liter tuned airgun array and ocean bottom seismometers (OBS) equipped with three-component geophones and a hydrophone. Line 1 is a 620-km long East-West transect running from southern Baffin Island to Nuuk, Greenland, crossing four exploration wells. 28 OBS were deployed along the line and the data are of excellent quality. The large Ungava transform fault system crosses this line and the velocity model will provide information on the identification of possible magmatic underplating and how this fault interacted with the Greenland-Iceland plume. Line 2 is a 185-km long North-South transect running from Davis Strait into Labrador Sea, where it lies within the transitional crust of the Greenland margin. 15 OBS were deployed along Line 2 and initial analysis of the data indicates a significant lateral velocity change from north to south. The northern part of the line probably consists of thinned continental crust. The southern part, however, consists of a 12-km thick layer with P-wave velocities ranging from 6.8 to 7.0 km/s, below a 3.5-km thick layer with velocities >4.4 km/s. The depth to Moho is ~19 km. This velocity model probably indicates that there is over-thickened oceanic crust in the transition zone of the Greenland margin, which suggests that volcanic activity in Davis Strait extended farther south than previously thought.

T31D-04 0930h

The Limit of Volcanic Rifting: A Structural Model Across the Volcanic to Non-volcanic Transition off Nova Scotia

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The rifted continental margin along much of the Atlantic coast of eastern North America is classified as volcanic, with thick sequences of igneous material emplaced at the continent-ocean transition during Late Triassic to Early Jurassic rifting. A strong, linear magnetic anomaly (ECMA) is observed along the margin from the Blake Spur fracture zone to the Scotian margin, coincident with seismic images of seaward dipping reflectors (SDRs). Along the SW Scotian Margin, the anomaly changes character, becoming lower in amplitude, disjointed and weaker as it fades to the east into the regional background level. The loss of magnetic signature and disappearance of SDRs have suggested that most of the Scotian margin is primarily non-volcanic, with the transition starting northeast of the New England seamounts. Three wide-angle seismic reflection / refraction lines were collected in 2001 across the continental margin and deep sedimentary basin offshore Nova Scotia to investigate the transition in rifting style. Line 3 crossed the ECMA at the SW end of the margin, where sediment thickness is less than 10 km. The velocity model shows a 120 km-wide transition zone separating thinned continental crust from oceanic crust. P-wave velocities in the upper and lower layers of the transition zone average 6.2 and 7.2 km/s, consistent with velocities for the transition zone off the US Atlantic margin where the volcanic nature has been well-established. The upper surface of the transitional crust is coincident with SDRs, and magnetic models also support an interpretation of volcanic origin. However, total thickness of the transitional crust is only 10 km, significantly thinner than the interpreted 15 to 20+ km of igneous material interpreted off the US. Oceanic crust adjacent to the transition zone is less than 6 km thick, suggesting a change to conditions that inhibited melting during the early stages of formation of oceanic crust. These observations allude to considerable complexity associated with the gradual reduction in volcanism, and eventual transition to a non-volcanic style of rifting, along the Scotian margin.

T31D-05 0945h

The Nature of the Passive Margin in the Area of the Canary Islands, Central Atlantic Ocean

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The Canary Islands (CI) form a roughly E-W trending island chain normal to the coast of Africa. The base of the continental slope lies only 30-40 km east of the easternmost island, Fuerteventura. The oceanic lithosphere beneath CI formed about 180-150 Ma ago, during the earliest stages of opening of the central Atlantic Ocean (e.g. Roest et al., 1992). The CI hotspot has been active during the last 60-70 million years (Geldmacher et al., 2001). Detailed studies of mantle and crustal xenoliths from different islands, including point analyses of trace elements and 87Sr/86Sr isotopic ratios in minerals, show that the lithosphere beneath CI consists of highly depleted oceanic crust and upper mantle that have been metasomatized to different degrees during the CI intraplate event. The original composition of the upper mantle is best preserved in the REE concentrations in ol and opx porphyroclasts and in cpx neoblasts in the most refractory spinel harzburgite xenoliths. These are strongly depleted in MREE relative to HREE. LAM-MC-ICPMS Sr isotope analyses of cpx in these xenoliths give 87Sr/86Sr ratios of 0.7027-0.7028. This is within the range of N-MORB and significantly below the range of CI basaltic rocks (=0.7030). Modeling based on major and trace elements in the most refractory sp harzburgites suggests that the lithospheric mantle beneath CI represents the residue after about 25 percent depletion relative to the Primordial Mantle. Such a high degree of partial melting results in complete exhaustion of cpx. In these rocks cpx appears mainly as small neoblasts along the boundaries of opx porphyroclasts, and is believed to be the results of exsolution of opx, followed by recrystallization. Cpx in more highly metasomatized peridotites give 87Sr/86Sr ratios in the range 0.7029-0.7033, and have flat to LREE-enriched REE patterns. Two types of gabbroic xenoliths have been retrieved. One type, dominated by augite+plag+hornblende+mt+-ol, is interpreted as cumulates formed from alkali basaltic Canarian magmas. The other type (opx-gabbros) is mildly deformed and consists of ol+cpx+plag+-opx. Some of these show evidence of reactions with enriched magmas. Cpx and opx in the most pristine opx-gabbros have strongly depleted REE patterns. Estimates indicate formation of the opx-gabbros from N-MORB parent melts with (La/Sm)N=0.16 and (Sm/Yb)N=0.52; that is among the lowest ones recorded for MORB magmas. We conclude that in the area of CI, the oldest oceanic lithosphere was highly depleted. There is no evidence that transitional melts were involved in the formation of the oldest oceanic crust in this part of the Atlantic Ocean. Furthermore, there is no evidence that continental lithosphere is present anywhere beneath the Canary Islands. The continent-ocean transition in the area of the Canary Islands thus appears to be quite sharp, located just east of the easternmost CI, and to be quite different from the 80-130 km wide continent-ocean transition zone found further north in the Iberia Abyssal Plain (e.g. Whitmarsh and Sawyer, 1996).

Geldmacher et al., 2001. J. Volc. Geotherm. Res. 111, 55-87 Roest et al., 1992. Marine Geophys. Res. 14, 1-24 Whitmarsh and Sawyer, 1996. Proc. ODP Scientific Res. 149, 713-733

T32A CC: 516 B Wednesday 1030h

Mineral Physics Perspectives on the Structure, Composition, and Dynamics of Earth's Deep Interior

(joint with S, V, MR, SEDI)

Presiding: **J Badro,** Institut de Physique du Globe, Universite Paris VI**;** **D Farber,** Lawrence Livermore National Laboratory

T32A-01 1030h INVITED

Direct measurements of sound velocities of iron with nuclear resonant inelastic x-ray scattering under high pressure and temperature

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Iron is the most abundant component in the Earth's core. Understanding the physical properties of Fe under core conditions is crucial for interpreting the seismological and geomagnetic observations deep in the Earth's interior. The physical properties of Fe have been extensively studied by dynamic and static high-pressure experiments and theoretical calculations, but direct static measurements of the sound velocities of