T52F MCC: 3005 Friday 1600h

Lithospheric Structure and Dynamics II *(joint with S)*

Presiding: **B Guest,** University of California, Los Angeles

T52F-01 1600h

The Angular Velocity of Nubia Relative to Somalia and the Location of the Nubia-Somalia-Antarctica Triple Junction

Benjamin C Horner-Johnson[1]

Richard G Gordon[1] (rgg@rice.edu)

Sara M. Cowles[1]

Donald F. Argus[2]

[1]Department of Earth Science, Rice University, Houston, TX 77005, United States

[2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, United States

A new analysis of geologically current plate motion across the Southwest Indian Ridge and of the current location of the Nubia-Antarctica-Somalia triple junction is presented. We estimate spreading rates averaged over the past 3.2 Myr from 103 well-distributed, nearly ridge-perpendicular profiles crossing the Southwest Indian Ridge. We evaluate all available bathymetric data to estimate the azimuths and uncertainties of transform faults; six are estimated from multi-beam data and twelve from precision depth recorder data. If the Nubia-Somalia boundary is narrow where it intersects the Southwest Indian Ridge, that intersection lies between about 26° E and 32° E. This places it either along the spreading ridge segment just west of the Andrew Bain transform fault complex or along the transform fault complex itself. These limits are narrower than, and contained within, limits of about 24° E to 33° E previously found by Lemaux et al. (2002) from an analysis of the locations of magnetic anomaly 5. The data are consistent with a narrow boundary, but also consistent with a diffuse boundary as wide as about 700 km. The new Nubia-Somalia pole of rotation lies southwest of southern Africa and differs significantly from previously estimated poles, including that from data in the Red Sea and Gulf of Aden. The new pole indicates displacement rates of Somalia relative to Nubia of 3.4 ± 1.3 mm yr^{-1} (95% confidence limits) towards 176.8° between Somalia and Nubia near the Southwest Indian Ridge, and of 8.4 ± 1.3 mm yr^{-1} (95% confidence limits) towards 118.5° near Afar.

T52F-02 1615h

Diffuse Oceanic Plate Boundaries: Mapping the Relationship Between Angular Velocity and Torque as a Function of Assumed Rheology

Kartik Mutnuri[1] (713-348-4159; mutnuri@rice.edu)

Richard G Gordon[1] (rgg@rice.edu)

[1]Rice University, Dept. of Earth Sciences 6100 Main Street MS 126, Houston, TX 77251-1892, United States

Diffuse plate boundaries comprise about 15% of Earth's surface. The poles of rotation across diffuse oceanic plate boundaries, which are roughly 1,000 to 2,000 km in cross-strike width, tend to lie within the plate boundary themselves. Zatman et al. (2001) showed that this is a predictable consequence of plate geometry and simple physics if component plates are strongly coupled across the diffuse oceanic plate boundaries that separate them. Here we build on the work of Zatman et al. (2001) and of Zatman & Gordon (2003) to construct maps of torque orientation. On these maps we plot the boundary between torque orientations that produce poles of rotation in the diffuse plate boundary and torque orientations that produce poles of rotation outside the diffuse plate boundary. We assume that the upper lithosphere fails at a specific yield strength and that the lower lithosphere deforms by creeping flow. Acting in parallel, the integrated or averaged behavior of these two layers can be approximated as a power-law viscous fluid. The value of the power-law exponent, n, ranges from 3 (if the lower layer dominates) to infinity (if the upper layer dominates). We calculate maps for exponents of 3, 10, 30, and 100. All the maps closely resemble one another, providing further support to the conclusion that the mapping from pole of rotation to torque orientation is insensitive to rheology (Zatman & Gordon 2003). Moreover, the maps show that it is very unlikely ($p < 2\%$) that the pole of rotation will lie outside of the boundary in the along-strike direction. There is a higher probability ($p \approx 20\%$ assuming that all orientations of torque are equally likely) that the pole of rotation will lie outside the boundary in the across-strike direction. Implications will be discussed for the India-Capricorn, Capricorn-Australia, North America-South America, Nubia-Somalia, and Nubia-Eurasia diffuse plate boundaries.

T52F-03 1630h

Breaking into the Plate: Seismic and Hydroacoustic Analysis of a 7.6 Mw Oceanic Fracture Zone Earthquake Adjacent to the Central Indian Ridge Plate Boundary

DelWayne R Bohnenstiehl[1] (del@ldeo.columbia.edu)

Maya Tolstoy[1]

Emily Chapp[1]

[1]LDEO Columbia Univ., Box 1000, Palisades, NY 10964

Where oceanic spreading segments are offset laterally from one another, the differential motion of the plates is accommodated by strike-slip motion along ridge-perpendicular transform faults. Off-axis from the ridge-transform intersection, no differential motion is require, and the fracture zone trace is thought to be inactive except where reactivated by intra-plate stresses. On 15 July 2003, an earthquake with a magnitude of 7.6 Mw occurred near the northern Central Indian Ridge (CIR), the divergent boundary separating the Somalian plate from the Indian and Australian plates. The size of this event places it within the 99th quantile of magnitude for shallow (< 40 km depth) strike-slip events (null axis plunge >45 deg) within the global Harvard CMT catalog. The earthquake's epicenter is near 2.5 deg S, 68.33 deg E, where the CIR is marked by a series of short (<100 km long) right-stepping transforms that offset the northwest trending spreading segments (20 mm/yr). Seismic signals associated with the mainshock and its largest aftershocks were recorded well by land-based seismic networks. Regional seismic phases (Pn, Sn), as well oceanic T-waves, where also recorded at an IMS hydroacoustic station to the north of the Diego Garcia atoll. T-wave signals recorded at Diego Garcia were cross correlated to determine accurate travel time differences. These traveltime differences were used in a plane wave fitting inversion to determine the horizontal slowness components and estimate the back azimuth to the epicenter. Aftershock locations are derived using the azimuthal information and Pn-T traveltime differences. Together, the seismically- and hydroacoustically-derived epicenters show a linear band of aftershocks extending more than 200 km along the off-axis trace of a right stepping transform. We interpret these aftershock events as delineating the length of the mainshock rupture. As the well-constrain hypocenter of the mainshock lies near the western edge of this aftershock zone and the centroid location lies within its eastern portion, the rupture appears to have propagated from the plate boundary, breaking into the Indian plate along the fracture zone. The moment tensor solution for the mainshock event indicates dominantly right-lateral slip with a near vertical nodal plane striking parallel to the trend of the aftershocks. The right-lateral sense of slip opposes the left-lateral slip along the adjacent active transform and is consistent with reactivation due to north-south extension in association with a diffuse plate boundary that separates the Indian and Australian Plates. Coulomb failure modeling indicates that the right-lateral mainshock should promote left-lateral slip on the active portions of neighboring transforms. Consistent with this prediction, the largest aftershock, a 5.6 Mw left-lateral earthquake, is located on the active portion of a transform approximately 150 km northwest of the mainshock rupture. These models also show that left-lateral slip on the adjacent active transform, extending southwest from mainshock rupture, should be inhibited. No aftershock activity is observed along this active transform. Static stress changes will tend to reduce ridge-normal compressive stresses along the portion of the CIR axis to the north of the mainshock, with an increase in ridge-normal compression to the south. This will promote and impede axis-parallel diking events within these respective regions.

T52F-04 1645h

Global Inversion of Lithospherical Stress and Deformation

Shimin Wang[1,2] (573-882-4449; smwang@pku.edu.cn)

Mian Liu[1] (573-882-3784; lium@missouri.edu)

[1]University of Missouri, 101 Geology, Columbia, MO 65211, United States

[2]Peking University, Department of Geophysics, Beijing 100871, China

We have derived a global model of lithospheric stress and deformation using numerical inversion. The lithosphere is divided into 14 plates and represented by thin spherical shells of Newtonian fluid in our finite element model. The relative velocity between two plates at divergent plate boundaries is prescribed according to the Nuvel-1A plate motion model, which provides good fit to observed sea-floor spreading rates and the azimuth of transform faults. Large transform boundaries are modeled as rheologic weak zones. A set of free parameters describing the regional variation of plate viscosity as well as the external forces at convergent plate boundaries and on the base of the plates are determined by least-square fitting the VLBI and principal stress orientation data. The optimal model predicts a global stress field and intraplate deformation that are generally consistent with geological observations. The modeling results indicate that continental lithosphere is about 5 times as viscous as oceanic lithosphere which, in turn, is 2 orders of magnitude more viscous than lithosphere at transform boundaries. The predicted convergent rates are 20% slower for the India-Asia continental collision boundaries, and 7 % slower for the Nazca-South American subduction boundary than those predicted by the Nuvel-1A model. Our model also suggests that dragging forces by the underlying mantle on the base of both continental and oceanic lithosphere are resistant to absolute plate motions, and basal drag under continental lithosphere is 3 times stronger than that under oceanic lithosphere.

T52F-05 1700h

Making Room for the Pacific: Southward Migration of Pacific Subduction Beneath New Zealand and Tectonic Consequences of Delaminating the Australian Lithosphere

Peter J J Kamp[1] (64 7 838 4876; p.kamp@waikato.ac.nz)

Kevin P Furlong[2] (814 863 0567; kevin@geodyn.psu.edu)

[1]Universty of Waikato, Dept Earth Sciences, Hamilton 2001, New Zealand

[2]Penn State University, Geodynamics Research Group, University Park, PA 16802, United States

Over the past 20 Ma, as a consequence of the substantial obliquity to plate motions, the southwestern edge of the subducting Pacific slab has migrated southward sweeping beneath the North Island of New Zealand to its present position beneath the northern South Island. In many locations where a well-defined slab edge migrates, such as northern California where the Gorda slab migrates with triple junction motion, the slab edge is on the trailing edge of the plate leaving a slab window in its wake. In contrast, in the New Zealand case, the slab edge is the leading edge of the plate and thus it is moving into a region with a pre-existing lithospheric structure that needs to be modified and/or removed to allow the slab to migrate. Present day lithospheric structure in the vicinity of the slab edge and the record of vertical motions preserved in the geologic record provide the key to unraveling the tectonic response of New Zealand to this slab migration. Associated with the slab migration is the development of a series of ephemeral basins that trail the slab edge. These range from the 20 Ma Waitemata Basin in the Auckland region to the present day Wanganui Basin, whose active depocenter lies between the North and South Islands of New Zealand. These basins are characterized by rapid subsidence/deposition following passage of the slab edge, followed by more gradual uplift and exhumation. An analysis of seismicity in the vicinity of the present slab edge identifies a near vertical region of deep seismicity, spatially distinct from the slab, which we interpret to be a delaminated sliver of the mantle lithosphere of the Australian plate. The delaminated sliver appears to initiate in the region where the edge of the slab interacts at shallow levels (30-80 km), in a style akin to a chisel, with the Australian lithosphere. The tectonic consequences of this active delamination and subsequent sinking of the detached mantle lithosphere include localized uplift in the vicinity of the slab edge, rapid subsidence and basin formation, followed by more gradual inversion of the basins. The vertical motions recorded in the history of the basins are inferred to be driven by viscous coupling between the sinking sliver and the base of crust. The spatial and temporal scales of evolution of these basins provide constraints on the extent of this viscous coupling. The transition from a transform to subduction boundary in the northern South Island of New Zealand represents an ideal location to study the processes by which lithosphere adapts to abrupt changes in plate interactions.

T52F-06 1715h

High-Velocity Lid Structure of East Antarctica and its Implication

Keiko Kuge[1] (keiko@kugi.kyoto-u.ac.jp)

Yoshio Fukao[2] (fukao@eri.u-tokyo.ac.jp)

[1]Dept. Geophysics, Kyoto University, Sakyo, Kyoto 606-8502, Japan

[2]ERI, University of Tokyo, Bunkyo, Tokyo 113-0032, Japan

We determined velocity structure of both P and S waves beneath East Antactica by modeling waveforms of P, PP, S, and SS waves which travel from shallow strike-slip earthquakes in the southwest of New Zealand to broadband stations in Antarctica. In the distance range from 25 to 35 degree, significant phases are observed in the vertical and transverse components of the records, ahead of IASP91 travel times of PP and SS waves, respectively. Our study of travel times and waveforms suggests that the significant phases consist of P (S) wave bottoming at depth shallower than 400 km and PP (SS) waves bouncing at the Moho and Earth surface. The existence of high-velocity lid beneath East Antarctica, which reaches around depth of 200 km, can explain the observed waveforms. By modifying the velocity models of the Canadian shield to fit our observations, we obtained Vp and Vs models of East Antarctica. The velocity of the lid is a few percent slower than that of the Canadian shield. In our observations, S waves bottoming above 400 km are observed at farther distances than P waves. This implies that there can be a difference in the velocity profile between P and S waves. The value of Vp/Vs in our velocity models is around 1.76 for the lid, and larger than 1.8 for the mantle below it. From the velocity models, we examined mantle temperatures, based on the finite strain theory. We used the attenuation model and elastic parameters of Goes et al. (2000). Effect of the anelasticity changes not only Vp and Vs but also Vp/Vs as the functions of temperature and depth. Comparison of Vp/Vs between the calculation and our velocity models shows that the temperatures at the mid depths of the lid and underlying asthenospheric mantle are approximately 500-1000 and 1200-1500 C, respectively. When olivine-rich composition is used, the temperatures tend to be high. Mantle temperatures were also calculated from our Vp and Vs models separately. The temperatures separately obtained from Vp and Vs are in agreement with each other.

T52F-07 1730h

Composite Anisotropies Revealed by P-Wave Velocity Data Under the Approximation of 2nd Rank Tensor

Laurent Louis[1] (+33 1 3425 4998; laurent.louis@geol.u-cergy.fr)

Christian David[1] (+33 1 3425 4985)

Philippe Robion[1] (+33 1 3425 4910; philippe.robion@geol.u-cergy.fr)

[1]UMR CNRS 7072 Univ. Cergy-Pontoise, Av.du Parc - Le Campus - Bat I, Cergy-Pontoise 95031, France

From diagenesis to tectonic stress induced deformation, rock microstructures always present some anisotropy associated with a preferential orientation, shape or spatial arrangement of its constituents. Considering the consequences this anisotropy has on directional transport and mechanical properties, as the geological history it carries, its 3D characterisation has received a particular attention in numerous works. A fast and simple way to give an overall estimation of the microstructural state of a rock sample is the determination of some physical property fabrics, provided that one is able to assign the measured anisotropies to one or more microstructural features. In non porous metamorphic and igneous rocks that often present a strong textural anisotropy, the relations between shape or lattice preferred orientation and acoustic or magnetic properties are quite well established. However, this is not the case for weakly anisotropic granular media in which the recognition of a microstructural anisotropy implies a statistical analysis on thin sections. In this latter case, anisotropy of magnetic susceptibility (AMS) has been intensively used in structural studies, providing a mid-scale (cm) tool to infer different stages of deformation depending on the position in the studied structure, but leading to an unresolved interpretation problem in terms of microstructures since the origin of the magnetic signal rarely fits a directly observable feature. In the work that will be presented, we propose to complete the classical AMS approach with the estimation of P-wave velocity anisotropies (APV), assuming that this property, like the magnetic susceptibility, supports also a tensorial notation as a first order approximation. Through a careful study of samples retrieved from different deformed structures, we show that P-wave velocities reveal a strong sensitivity to all observable anisotropic microstructural features, which is used to highlight evidences for location-dependence of grain-scale fabrics.

Reference Style for Abstracts

When referencing a meeting abstract, please use the following format, which indicates that this abstract volume is a supplement to the regular *Eos* issue. This format meets all AGU requirements for a complete reference.

Pfister, R. G., and M. S. Nestler, Sharing community data, services and tools using the EOS clearinghouse (ECHO), *Eos Trans. AGU, 84*(46), Fall Meet. Suppl., Abstract U41B-0006, 2003.