Geodesy

G21A CC: 220 C-E Tuesday 0830h

The Mechanics of Shallow Subduction Zones I Posters *(joint with S, T, SEDI)*

Presiding: **J Sauber,** NASA Goddard Space Flight Center**; S Mazzotti,** Geological Survey of Canada**; R Dmowska,** Harvard University

G21A-01 0830h POSTER

The effects of deformation partitioning on the same intersection lineations preserved within, adjacent to, and further away from porphyroblasts

Hyunwoo Lee[1] (82-42-868-0576; heanu@kins.re.kr)

Yundeuk Jang[2] (82-53-950-5358; jangyd@bh.knu.ac.kr)

Tim H Bell[3] (61-7-4781-4766; tim.bell@jcu.edu.au)

[1]Korea Institute of Nuclear Safety, 19 Guseong Yuseong, Daejeon 305-338, Korea, Republic of

[2]Dept. of Geology Kyungpook National University, 1370 Sankyuk Buk-gu, Daegu 701-702, Korea, Republic of

[3]School of Earth Sciences James Cook University, Townsville, Townsville, QLD 4811, Australia

Late development of N-S trending folds in Daecheong reservoir area in South Korea fold all previously developed matrix structures. However well developed curving inclusion trails in garnet porphyroblasts preserve a history of earlier deformation and foliation development that remains unaffected by these younger folds. The foliations and intersection lineations preserved in garnet porphyroblasts show consistent orientations on both limbs and hinge of the younger N-S-trending D6 fold. This suggests that the porphyroblasts have not been rotated by development of the fold. Although the growth of porphyroblasts prior to development of the young N-S trending folds has preserved linear structures within the porphyroblasts from the effects of younger deformation, this has not been the case in the matrix. The same linear structures preserved within the strain shadows of garnet porphyroblasts as those preserved in the rim of the garnet porphyroblasts, are less affected and rotated on the fold limbs than the hinge where the deformation is more intense for this structure. They are also less rotated than the equivalent structures in less protected matrix. The hinge of the fold was a zone of high strain during the development of the late N-S trending folds and resulted from a dextral shear (looking north) on the axial plane differentiated crenulation cleavage, predominantly in section, but also in plan.

G21A-02 0830h POSTER

Further Evidence for an Anisotropic Detachment Zone Within the Cascadia Subduction Zone

Xi Luo[1] ((203) 432-9809; xi.luo@yale.edu)

Jeffrey Park[1] (203 432 4172; jeffrey.park@yale.edu)

[1]Yale University , Dept. of Geology and Geophysics, New Haven, CT 06520-8109, United States

The structure of the Cascadia region is important because anisotropy and abnormal structures have been reported by numerous seismic studies associated with the Juan de Fuca subduction zone. Recent GPS observations addressed the movement of the Siletz terrane, which suggest a northward migration of the North American forearc margin, a puzzling intra-terrane deformation. So it is very interesting to know what anisotropy orientation is produced by the movement of slab and the forearc terrane above it. An earlier receiver function study of GSN station COR (Corvallis, Oregon) showed that two-lobed back azimuth variation in Ps amplitude and polarity indicates anisotropy with a tilted symmetry axis within a dipping anisotropic layer that lies above the subducting oceanic crust. This is a possible detachment zone for the northward slippage of the Siletz forearc terrace along the top of the descending slab. Attempts to model the converted wave amplitude suggest that serpentinite is involved in the anisotropic layer above the slab. We have analyzed 5 additional broadband stations (GNW, LON, LTY, TTW, WVOR) of the Pacific Northwest Regional Seismic Network (UW), which have operated between 1990 to 2003 and provided between 100 and 300 P-waves for study, depending on the station. We observe at these stations a Ps phase corresponding to a slab-conversion. We observe on the transverse receiver function that the slab-converted wave has a polarity reversal at north-south direction in some stations, which is consistent with observations at COR, suggesting a broader detachment zone associated with north-south GPS motion. We will model structure for each station to determine if a similar thin velocity layer exists above the slab in this area. This will is considered in our tectonic model and related to the GPS study.

G21A-03 0830h POSTER

Determination of Vertical Surface Deformation From Repeated Historical Leveling in Cascadia

David Verdonck (dverdonck@eglab.org)

Eastern Geodynamics Laboratory, 60 Larchmont Road, Elmira, NY 14905, United States

Over the last decade, surface deformation studies at subduction zones have focused primarily on GPS determined horizontal deformation. The emphasis on horizontal deformation is because GPS determined vertical deformation rates do not have sufficient precision to constrain subduction models. In order to include active vertical deformation data as constraints on subduction models, we need to utilize uplift rates determined from sources other than GPS. In this study, I estimate vertical deformation rates for Washington, Oregon, and northern California from historical repeated differential leveling and tide gauge data. The data distribution is more than adequate to constrain first order subduction models. Since 1904, more than 5500 benchmarks have been leveled to more than once yielding nearly 200 independent uplift rate profiles. The leveling data are corrected for systematic errors and reviewed for suitability. Uplift rate profiles are calculated by differencing elevations from repeated leveling lines. The uplift rate profiles are locally smoothed using a robust, locally weighted, technique. The smoothing is used to remove short wavelength features and reduce the effects of local benchmark instabilities and leveling blunders. The smoothed rates are adjusted and are tied to tide gauge data using a least square technique. A regional pattern of interseismic uplift is then determined by fitting a surface to the adjusted uplift profiles. Tests with synthetic data show the method provides adequate resolution and precision.

G21A-04 0830h POSTER

Long Period Co-Seismic Gravity Modeling of Silent Slip Earthquakes Along the Cascadia Subduction Zone

Tyler J Hayes (thayes@uwo.ca)

The Cascadia Subduction Zone (CSZ) is an area of large and potentially catastrophic seismic events which occur as large magnitude ($M_m > 8$) events. The mitigation of such hazards within highly populated areas presents a difficult problem which is dependent upon such observations as plate motion and strain accumulation. Long period Bouguer anomalies may act as a proxy for permanent strain deformation at depth. To date there are no large scale models that successfully model the temporal gravity signal over extended spatial regions encompassing more than one fault. These deep slip events typically last for days to weeks which would generate a long period signal. The highly periodic (13–16 months) silent slip events along the Cascadia Subduction Zone (CSZ) present a ideal location for the observation of such long period signals. Models of co-seismic gravity changes based on the analytical solutions of Okada (1985) and Okubo (1992), which act as an upper limit, are in the range of $30\mu gals$–$800\mu gals$. These amplitudes are well within the range of land based observations and potentially within the observable limits of several remote sensing satellites designed specifically for gravity data (e.g. GRACE, CHAMP, GEOS). This same technique should be applicable to any mechanism in which deformation occurs such as volcanic activity or glacial rebound.

G21A-05 0830h POSTER

Ground Level Surface Deformations and Earthquakes at West Yunnan During 1985-1998

Zheng-Xin Li (+86-21-64386191; lzx@center.shao.ac.cn)

Shanghai Observatory, Chinese Academy of Sciences, 80 Nandan Road, Shanghai 200030, China

Based on the repeated measurements of the gravimetric network at West Yunnan, China during 1985-1998, the non-tidal Plumb Line Variations (PLV) and the Deformations of the Ground Level Surface (GLSD) in this area have been determined. Interesting phenomena have been discovered in using these measurements, which are the first time being determined successfully, to study the earthquakes happened nearby. It appeals that there is usually a raised GLSD around the epicenter before an earthquake, but a contrary GLSD afterwards. In taking the determined GLSD as an index, the 15 earthquakes (Ms > 4.6) happened in this area during 1985-1998 have been studied. By the timing of the GLSD change, including the raised GLSD as well as the depressed one, the course of an earthquake event has been described. The topography of the GLSD, including the size, the maximum height, and the location of the summit has also been measured. The consistency of the description of these earthquakes not only demonstrates the applicability of this new approach in earthquake studying, but also the reality of the existence of non-tidal plumb line variations and ground level surface deformation in this area.

G21A-06 0830h POSTER

Deep Structures of the Ecuador Convergent Margin and the Adjacent Carnegie Ridge: Possible Effect on Coupling and Great Earthquakes Recurrence Interval ?

David Graindorge[1] (845 365 8577; graindor@ldeo.columbia.edu); Audrey Gailler[2] (gailler@oceane.obs-vlfr.fr); Alcinoe Calahorrano[2] (calahorr@oceane.obs-vlfr.fr); Philippe Charvis[2] (philippe.charvis@obs-vlfr.fr); Jean-Yves Collot[2] (collot@obs-vlfr.fr); Nicole Bethoux[2] (nbethoux@oceane.obs-vlfr.fr)

[1]Lamont Doherty Earth Observatory of Columbia University, P.O. Box 1000 61 ROUTE 9W, Palisades, NY 10964-8000, United States

[2]UMR Geosciences Azur, BP 48 Quai de la Darse, Villefranche sur Mer 06235, France

The Ecuadorian margin located between 2.5°S and 1°N is underthrust by the Carnegie Ridge (CR), a prominent volcanic relief on the Nazca Plate. According to its history of great subduction earthquakes, the margin in contact with CR can be divided in two segments. Immediately north of 0.5°S, the 1906 and 1942, earthquakes ruptured the plate boundary adjacent to the northern flank of CR, whereas between 0.5°S and 2.2°S, the poorly defined 1901 event (Ms=7.8, SISRA catalogue) occurred somewhere at the junction between the trench and the southern flank of CR. Although scarce, these observations suggest an apparent greater earthquake recurrence interval where the bulk of CR is subducting. Recent GPS results show that elastic strain has been equally accumulating across both margin segments, indicating that the plate interface is partially locked in this area. Deep crustal structure of the margin and adjacent CR was explored using on-shore off-shore wide-angle seimics. Crustal models obtained by 2-D inversion of traveltimes reveals the overthickened (14 km) oceanic crust of the CR that underthrusts the high velocity (> 6 km/s) basement of the upper plate margin wedge, interpreted as part of the accreted oceanic terranes described on-shore. The plate interface dips 4° to 10° east from the trench to a depth of 15 km. Shadow zones observed on the margin OBS records are interpreted as a low velocity zone consisting of a thin layer of underthrust sediments, and the 3-km-thick CR layer 2, whose average seismic velocity of 5.1 km/s is slower than that of the margin wedge. Consequently, we suggest that stronger normal stress related to the CR buoyancy, together with a larger CR surface involved in the subduction locked zone between 0.5°S and 2.2°S would locally enhance the mechanical coupling between the plates and would therefore be responsible for the observed increase in the recurrence interval of large earthquakes.

G21A-07 0830h POSTER

Intraslab Seismicity and Thermal Stress in the Subducted Cocos Plate beneath Central Mexico

Vlad MANEA[1] (vlady@ollin.igeofcu.unam.mx)

Marina MANEA[1] (mary@ollin.igeofcu.unam.mx)

Vladimir KOSTOGLODOV[1] (vladimir@ollin.igeofcu.unam.mx)

Granville SEWELL[2] (sewell@math.utep.edu)

Shri Krishna Singh[1] (krishna@ollin.igeofcu.unam.mx)

[1]Instituto de Geofisica, Universidad Nacional Autónoma de México (UNAM), México, Ciudad Universitaria, Circ. de la Inv. Cientifica,, Mexico, df 04510, Mexico

[2]University of Texas, El Paso, Math Dept, El Paso, tex 799137, United States

With a maximum depth extent of 80 km, an important particularity of the intraslab earthquakes beneath Guerrero, is their exclusively normal fault mechanism. Based on the new developed thermal models for

G

Guerrero subduction zone, the thermal stress due to nonuniform temperature distribution in the subducting slab is calculated using finite element method. The calculation results revealed that the first shallow part of the subducting slab is characterized by low deviatoric compressional thermal stresses in its central part (0.25 Kbars); then the stress field changes to a extensional behavior for the core of the slab with maximum values of 0.4 Kbars for the flat region and 0.75 Kbars deeper. An important feature for the central Mexican subduction zone is its shallow subhorizontal plate contact; significant thermal compressional stresses (0.65 kbars) arisen in the upper and lower part of the slab are not consistent with the normal fault intraplate earthquake focal mechanism. Since the Cocos plate dips into the asthenosphere at angle of 20°, pressure forces due to the induced flow in the mantle wedge are partially balanced by the gravitational body forces. A net clockwise torque might exist at the hinge point and its value is set in such way that the compressional stresses for the flat part of the plate vanishes. For the lower part of the slab, ductile behavior is assumed, the compressional stresses decreasing exponentially with depth. According with the thermal models for Guerrero, the temperature range of 700°C-800°C is in good agreement with the maximum depth extent of the intraplate earthquakes and with the maximum extent of the tensional stresses in the subhorisontal part of the slab, being considered as cutoff temperature range.

G21A-08 0830h POSTER

Structural studies beneath Honshu and Hokkaido Japan using receiver function analysis.

R. Alex J. Smith (81-457-78-5397; asmith@jamstec.go.jp)

IFREE (JAMSTEC), Japan Marine Science and Technology Center (JAMSTEC) Showa-machi 3175-25, Kanazawa-ku, Yokohama 236-0001, Japan

Combining land seismic, offshore seismic, and receiver function structure, allows delineation of the main structural discontinuities beneath the Japanese Islands. The location of the subducting Pacific and Philippine Sea Plates can also be discerned. The focus areas of study are beneath Hokkaido, Northern Japan and the Tokai Region, Southwest/Central Japan. Both regions have detailed offshore/onshore seismic reflection and refraction studies that have been carried out by JAMSTEC (Japanese Marine Science and Technology Center). In this study the seismic crustal study is supplemented with analysis of teleseismic events. Teleseismic data is obtained from NIED (Natural Research Institute for Earth Science and Disaster Prevention) F-net broadband network. Combining the receiver function study with velocity structure from the seismic experiments allows determination of Moho depths and depth to the subducting plate more accurately. The non-uniqueness of the receiver function study is removed by using wide-angle information to constrain upper crustal structure. For the Hokkaido region, the focus is to determine possible velocity variations within the double seismic zone that may be caused by dehydration reactions. For the Tokai region, where intraslab seismicity terminates at about 60 km depth, we hope to map out the subducting plate to greater depth and try to delineate possible subducted ridge structures. Finally we hope to include analysis of data from the denser HINET network. This is a first step in construction of a more accurate 3D structural velocity model for future modeling of geologic processes and earthquake relocation for the Japanese Islands region.

G21B CC: 220 C-E Tuesday 0830h

New Advances in Global Plate Kinematics and Dynamics From Space Geodesy I Posters *(joint with S, T, SEDI)*

Presiding: **T Dixon,** University of Miami**; C Kreemer,** Collge de France**; W Holt,** State University of New York at Stony Brook

G21B-01 0830h POSTER

Estimates of Continental Plate Motions Derived From Continuous GPS Measurements of Station Coordinates and Velocities, 1996-2004

David A. Hutchison (613-995-4379; hutch@geod.nrcan.gc.ca)

Natural Resources Canada, 452-615 Booth St., Ottawa, ON K1A 0E9, Canada

Analysis Centres of the International GPS Service (IGS) currently compute daily Earth Rotation Parameters (ERPs) and weekly precise coordinates for over 200 globally distributed tracking stations. These estimates are made available to the scientific community in the Solution Independent Exchange (SINEX) format, developed for exchange and analysis of position estimates from techniques such as SLR, LLR, VLBI, DORIS and GPS. On behalf of the IGS, National Resources Canada (NRCan) has been combining, officially since 1999, all weekly SINEX files from the ACs to form weekly and cumulative solutions. The weekly solution (named igsyyPwwww, yy = 2-digit year, wwww = 4-digit GPS week) contains estimates of station coordinates, ERPs and geocentre pertaining to the GPS week, and the cumulative solution (named IGSyyPWW, WW = 2-digit week number, 01 to 52, within the year) comprises station coordinates and velocities in a common reference epoch, Jan. 1, 1998. For example, two solutions produced for week 1253 (2nd week of year 2004) were igs04P1253 (weekly) and IGS04P02 (cumulative). Since week 1253, all IGS solutions have been aligned to IGb00, a realization of IGS's most recent International Terrestrial Reference Frame, ITRF2000. IGb00 was obtained from coordinates and velocities of 99 globally distributed reference stations by alignment to ITRF2000 at GPS week 1231 of cumulative solution IGS03P33. Before week 1143, a realization of IGS's previous reference frame, ITRF97, was used instead. Using the cumulative solution from any given week, the rotation components of any continental plate with at least two stations are estimated and compared with published results. These include three known plate models: NNR NUVEL 1, NNR NUVEL 1A and the most recent REVEL 2000 aligned to ITRF97. The findings can be summarized as follows: Continental rotations derived from IGS04P02 are shown to be significantly different at 99% confidence level from NNR NUVEL 1A's estimates for North American, Eurasian, Australian, Pacific, Antarctic, Indian, Nazca and Nubian (the latter compared to NNR NUVEL 1A African) plates. In addition, certain plates previously regarded as belonging to an adjacent, larger continent in NNR NUVEL 1 or 1A are now seen to move significantly differently; e.g., Amurian distinct from Eurasian, Adriatic and Sinai distinct from NNR NUVEL 1A African. North American, Eurasian, Australian and Pacific plates show significantly different rotations in IGS04P02 than predicted by REVEL 2000, yet not from the alignment of REVEL 2000 to IGb00. Certain pairs of adjacent plates show relative Euler poles near their plate boundaries; e.g., Eurasian and North American, Amurian and Eurasian, Amurian and South-China, Adriatic and Eurasian, Arabian and Nubian, Sinai and Nubian, Sinai and Arabian, Nubian and Somali. This phenomenon can be expected when bordering plates show no subduction or obduction. RMS difference between velocities of stations used in Euler pole calculation in IGS04P02 and those expected from NNR NUVEL 1A rise to 4.3 mm/yr in the horizontal component and 8.7 mm/yr in the vertical. The horizontal RMS velocity difference decreases significantly to 2.4 mm/yr when IGS04P02 is compared with REVEL 2000.

G21B-02 0830h POSTER

Interactive Web Interface to the Global Strain Rate Map Project

Charles M Meertens[1] (303-581-7465; meertens@unavco.org)

Louis Estey[1] (303-581-7456; estey@unavco.org)

Corné Kreemer[2] (33-4-42908546; kreemer@cdf.u-3mrs.fr)

William Holt[3] (631-632-8215; wholt@mantle.geo.sunysb.edu)

[1]UNAVCO, Inc., 6350 Nautilus Drive, Boulder, CO 80301, United States

[2]Geodynamics Lab, College de France, Europole de l'Arbois, BP 80 Batiment LAENNEC, France

[3]Department of Geosciences, SUNY, Stony Brook, NY 11794-2100, United States

An interactive web interface allows users to explore the results of a global strain rate and velocity model and to compare them to other geophysical observations. The most recent model, an updated version of Kreemer et al., 2003, has 25 independent rigid plate-like regions separated by deformable boundaries covered by about 25,000 grid areas. A least-squares fit was made to 4900 geodetic velocities from 79 different geodetic studies. In addition, Quaternary fault slip rate data are used to infer geologic strain rate estimates (currently only for central Asia). Information about the style and direction of expected strain rate is inferred from the principal axes of the seismic strain rate field. The current model, as well as source data, references and an interactive map tool, are located at the International Lithosphere Program (ILP) "A Global Strain Rate Map (ILP II-8)" project website: http://www-world-strain-map.org. The purpose of the ILP GSRM project is to provide new information from this, and other investigations, that will contribute to a better understanding of continental dynamics and to the quantification of seismic hazards. A unique aspect of the GSRM interactive Java map tool is that the user can zoom in and make custom views of the model grid and results for any area of the globe selecting strain rate and style contour plots and principal axes, observed and model velocity fields in specified frames of reference, and geologic fault data. The results can be displayed with other data sets such Harvard CMT earthquake focal mechanisms, stress directions from the ILP World Stress Map Project, and topography. With the GSRM Java map tool, the user views custom maps generated by a Generic Mapping Tool (GMT) server. These interactive capabilities greatly extend what is possible to present in a published paper. A JavaScript version, using pre-constructed maps, as well as a related information site have also been created for broader education and outreach access. The GSRM map tool will be demonstrated and latest model GSRM 1.1 results, containing important new data for Asia, Iran, western Pacific, and Southern California, will be presented.

G21B-03 0830h POSTER

Terrestrial Reference Frames for Current Plate Motion

Ravi R. Kumar[1] (713-348-2247; rkumar@rice.edu)

David L. Andrews[1] (713-348-2247; dandrews@rice.edu)

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

[1]Rice University, Dept. of Earth Science 6100 Main Street, MS-126, Houston, TX 77005, United States

We examine recent estimates of plate motions relative to the hotspots with a view to better understanding both the hotspot and no-net-rotation frames. In recent years, two independent studies of present plate motion relative to the hotspots reached very different conclusions. On the one hand, Gripp & Gordon [2002] used trends and rates from volcanic edifices formed during the past 6 Myr to estimate the HS3-NUVEL1A set of angular velocities relative to the hotspots. Their angular velocities are constrained to consistency with the relative plate angular velocities of NUVEL-1A. They found that only eleven hotspot trends and two volcanic propagation rates met their minimum reliability criteria. They combined these and found that the rates and trends were mutually consistent. They find that the lithosphere has a relatively rapid net rotation of 0.44 ± 0.11 degs/Myr (95% confidence limits), which is much faster than the net rotation of the lithosphere over the past 47 Myr of about 0.15 degs/Myr. One the other hand, Wang & Wang [2001] use twice as many (22) trend data and no rate data to estimate the T22A set of current angular velocities of plates relative to hotspots, which is also constrained to consistency with NUVEL-1A. They find that their angular velocities are inconsistent with volcanic propagation rate data and hypothesize that this is due to motion of hotspots relative to the mantle in a direction opposite to that of plate motion at a rate about one-fourth of the plate velocity. They hypothesize, for example, that Pacific hotspots move about 20 mm/yr to the east-southeast. This hypothesis, if correct, has several profound implications, one of which is that the net rotation of the lithosphere implied by their angular velocities is about half the size of that implied by HS3-NUVEL1A. Key to their result is the acceptance of trends that can only be estimated by averaging over the locations of volcanic edifices spanning several tens of millions of years in age. They assert that hotspot tracks with volcanic propagation rates pertinent to the last 10 Myr exhibit no significant change in trend in at least the past 30 Myr. In this talk we will take a fresh look at the trend data used by both groups to evaluate their applicability to motion during the past 6 Myr. Moreover, we will use plate reconstructions over longer intervals of time to more rigorously test both the fixed-hotspot and 25%-of-plate-speed moving-hotspot hypotheses. We will furthermore examine whether either frame of reference can be reconciled with the no-net-rotation frame of reference.

G21B-04 0830h POSTER

Seafloor Geodetic Measurements of Nazca-South America Plate Stick-Slip Behavior

Katie L Gagnon[1] (858-822-1836; kgagnon@ucsd.edu)

Dave Chadwell[1] (858-534-2663; cchadwell@ucsd.edu)

Edmundo Norabuena[2] (305-361-4928; enorab@rsmas.miami.edu)

[1]Scripps Institution of Oceanography, UCSD, 9500 Gilman Dr, 0205, La Jolla, CA 92093-0205, United States

[2]Rosenstiel School for Marine and Atmospheric Sciences, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, United States

A combination of GPS and acoustic travel time measurements were taken from the R/V Roger Revelle in