the above low velocity zone on the subducting slab, we calculated synthetic waveforms using FDM (Finite Difference Method) with elastodynamic formulation (E3D code, developed by Dr. Shawn Larsen) and the P-wave velocity 2D structure of Kamimura et al. (2002). The E3D uses staggered grid, and 2nd order and 4th order approximation in time and space, respectively. Grid spacing of the calculation is 30 m in x and z, and 1.5 msec in time. Five-Hz and 0-phase Ricker wavelet pressure source was used. Several structure models are used for comparison. One model has no low-Q zone, another one has low-Q zone only just below the serpentine seamount. Other models have low-Q zones just below the serpentine seamount and above the subducting slab, horizontal width of the low-Q zone are different one another. Comparing synthetic waveforms and observed data, we can conclude that there must be a low-Q zone just below the serpentine seamount and on the subducting oceanic slab. The low-Q zone on the slab has ca. 80 km wide east to west and connects to the serpentine seamount. It is very important to understand where serpentinites of the seamounts came from to explain the characteristics of seismicity at the IBSZ. In this presentation we are going to explain an interpretation that serpentine moved through the plate boundary and reached just below the serpentine seamount, using an existence of the low-Q zone. Kamimura, A., Kasahara, J., Masanao S., Hino, R., Shiobara, H., Fujie, G., Kanazawa, T., 2002. Crustal structure study at the Izu-Bonin subduction zone around 31°N: implications of serpentinized materials along the subduction plate boundary, Physics of the Earth and Planetary Interiors, 132, 105-129.

T31A-06 0930h

Geodynamic and Seismic Characterization of Mantle Flow in the Izu-Bonin Subduction System

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The goal of this study is to provide new constraints on mantle flow in subduction zones as inferred by patterns of seismic anisotropy. In particular, we are implementing improved methods of interpreting seismic anisotropy measurements in terms of lattice-preferred orientation (LPO) induced by mantle flow. In this study, we focus on the dynamics of the Izu-Bonin (IB) subduction system, which contains a plate geometry that can be approximated to first order by 2D mantle flow models. This simple configuration, combined with recent new measurements of shear wave splitting in the region [Anglin and Fouch, this session], provides an important opportunity to evaluate the role of water on flow and strain development in a hydrated mantle wedge. Current and previous observations of seismic anisotropy in the IB mantle wedge, suggest convergence-parallel fast polarization directions, consistent with models of deformation in a “dry” mantle system. However, the IB mantle wedge is most likely hydrated, and some models of deformation in a hydrated mantle predict convergence-orthogonal fast polarization directions. This dichotomy thus provides an ideal setting in which to test hypotheses regarding the effect of water on mantle flow, strain, and seismic anisotropy. To this end, we use a finite element approach to calculate kinematic models of flow in the mantle wedge. We use these flow models to calculate LPO in the mantle wedge following the method developed by Kaminski and Ribe [EPSL, 2001] that incorporates the combined effects of intracrystalline slip and dynamic recrystallization on textural development. We utilize the resulting textures to predict shear wave splitting for a range of seismic raypaths by solving the Christoffel equation for each increment of a raypath and integrating the resulting predicted shear wave splitting experienced by each ray. A significant advantage of this approach is the ability to provide more appropriate representation of a range of mantle mineralogies, resulting LPO development, and predicted shear wave splitting for regions within the mantle flow model. While our current modeling efforts utilize an isoviscous mantle rheology, we are developing more appropriate models with temperature-dependent rheologies and hydrated mantle conditions. In addition, we will examine the role of water on LPO development and predicted shear wave splitting. Finally, we will compare the range of results of predicted shear wave splitting with shear wave splitting measurements currently in progress.

T31A-07 0945h

Mantle Seismic Anisotropy in the Izu-Bonin Subduction System

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The objective of this study is to determine the location and extent of seismic anisotropy within the Izu-Bonin (IB) subduction system to constrain mantle flow dynamics in the region. Of particular importance is an improved understanding of the role of water in strain development and seismic anisotropy in hydrated mantle. The IB system is a key location in which to evaluate this problem as it presumably contains a hydrated mantle wedge and is a viable candidate for relatively simple 2D mantle flow. However, the dearth of seismic stations in IB presents significant challenges in measuring shear wave splitting in the region. We therefore apply a unique approach for imaging mantle seismic anisotropy to provide new constraints on patterns of strain and mantle flow in the IB system. We apply an analysis technique that determines residual splitting between teleseismic S and sS for intermediate- and deep-focus events. In this method, we estimate receiver-side anisotropy by applying particle motion analysis to teleseismic S. To limit the receiver-side anisotropic effect on the sS waveform, we use the resulting splitting parameters (fast polarization direction and relative delay time) from the S phase to apply particle motion corrections to the sS phase. We then evaluate shear wave splitting in sS to provide an estimate of seismic anisotropy recorded by sS within the upper mantle on the source side of the raypath. In our current dataset, we have examined residual sS splitting in waveforms in which no discernible splitting is evident on teleseismic S, thus limiting the potential effect of receiver-side upper mantle anisotropy on sS. Preliminary results from analysis of several source-receiver pairs exhibit fast polarization directions oriented E-W (i.e., convergence-parallel) and splitting times ranging from 1.75 s to 2.75 s. These results are consistent with the limited body of existing shear wave splitting analyses of local S phases for northernmost regions of the IB mantle wedge; however, splitting times from the current study are roughly double those estimated by previous work, as expected given the extended path length of sS relative to local S within the mantle wedge. While we emphasize that these results are preliminary, analysis of our dataset will continue to provide new constraints on the lateral and depth distribution of seismic anisotropy beneath the Izu-Bonin region.

T31B MCC: 3005 Wednesday 0800h

Causes and Consequences of Lateral Heterogeneity in the Earth's Mantle I

(joint with S, V, MR, DI)

Presiding: **C Lithgow-Bertelloni,** University of Michigan**; L Stixrude,** University of Michigan

T31B-01 0800h INVITED

The Production and Destruction of Chemical and Lithological Heterogeneities in the Mantle

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Gast, Tilton and Hedge first showed that Earth's mantle was isotopically heterogeneous in 1964. Since that time, work on the isotopic taxonomy of Earth's mantle has delineated 5 chemical species (domains): DMM (depleted MORB mantle), FOZO (Focus zone depleted mantle), HIMU (high U/Pb mantle), EM1 and EM2 (enriched mantles). Despite decades of debate, the mode of formation and placement of these domains in the mantle is still contentious. DMM is certainly the upper mantle, and FOZO is likely the deep mantle. The “Standard Model” of Hofmann and White ascribes the other three domains to subduction and long-term storage of the oceanic lithosphere, followed by recycling to surface hotspots via plumes. The HIMU and EM domains reflect mantle containing ocean crust and/or sediment components. The challenge is to translate the arguably miniscule isotopic heterogeneities of this isotopic zoo into a macroscopic view of the mantle. What is the variability in major element composition? What are the scale-lengths of these heterogeneities? Are there mafic lithologies as well as peridotitic lithologies? Do these heterogeneities imply bulk chemical and thermal variations that are important in seismological and dynamical studies of the mantle? The Standard Model creates heterogeneities in both lithology (eclogite and peridotite) and chemistry (mafic and ultramafic) on only 10-km scale lengths. Can these survive mixing, stirring and storage for billions of years? Can they be imaged tomographically? Do they provide dynamically significant chemical or thermal buoyancy? Is the Standard Model even operative? One weakness of this model is its requirement for arbitrary and ad hoc chemical processing during subduction of the lithosphere, in order to provide the right protoliths for evolution of the mantle zoo. We have probed this weakness using the classic example of an EM2 mantle domain, the Samoa hotspot. Basalt with the most extreme Sr (0.7089) in the oceans shows a very smooth trace element pattern with only slight negative anomalies at Ti and Ba. This spidergram is inconsistent with the standard model that invokes a sediment component to explain the enrichment of the EM2 mantle source. Furthermore, it is highly unlikely that any chemical processing during subduction would “smooth out” the typically jagged spidergram of oceanic sediment. We propose instead that EM2 mantle represents the bottom, not the top, of the oceanic lithosphere. The enriched character results from a metasomatic melt/rock reaction process involving small-degree partial melts percolating up from underlying partially molten asthenosphere. This causes the lower regions (tens of kilometers?) of all oceanic lithosphere to become trace-element enriched as a matter of course; subduction and long-term storage then generates the EM2 isotope signature, and recycling in plumes/hotspots provides us the witness. The model EM2 source will have a major element composition inconsequentially different from that of DMM mantle, but with a heat production some 10 times higher (11 pW/kg versus 0.9 pW/kg).

T31B-02 0815h INVITED

Constraints on Mantle Flow Through Joint Inversions of Seismic and Geodynamic Data

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Recent progress in global seismic tomography is yielding three-dimensional (3-D) images of mantle structure with greatly improved resolution on length scales ranging from a few hundred to several thousand kilometers. All seismic models agree on several large scale structures although seismic models from different groups still differ in many regions indicating issues of resolution remain. Furthermore, there is still debate on fundamental questions concerning the nature of mantle flow and chemical reservoirs in the mantle. Even as seismic models of the mantle improve, it is likely debate will remain concerning their interpretation in terms of mantle layering. Mantle flow has an observable signature in several geophysical fields including global gravity anomalies, plate motions, and dynamic surface topography. Given a density field of the mantle and a mantle viscosity structure, these geodynamic observables can be computed by calculating the instantaneous flow in the mantle. The dynamic response functions relating a given density anomaly to a given geophysical observable depend upon the existence of any chemical or phase change boundaries that impede vertical mass transport across the mantle. With knowledge of the three-dimensional variation in mantle density, we may thus discriminate among models with and without flow boundaries at different depths in the mantle using global geodynamic surface observables. Using various scalings between seismic velocity and density, we present joint inversions for 3D seismic velocity (density) mantle structure, plate motions, global free-air gravity anomalies, global dynamic surface topography, and dynamic ellipticity of the core-mantle boundary for a layered and un-layered mantle. The mantle flow models employ new mantle viscosity profiles that are optimized for each inversion. The seismic data consist of over 40000 S, multi-bounce S, ScS, multibounce ScS, SKS, and SKKS travel times. The joint inversions to date indicate that whole mantle flow is favored over a model with a barrier to flow near 660 km depth. We will also present results showing how these joint inversions can explicitly test the hypothesis of a negative or null correlation between anomalies of density and seismic shear velocity in the bottom half of the lower mantle. Such hypothesis tests provide insight on the relative importance of thermal and chemical contributions to lower-mantle density and seismic anomalies.

T31B-03 0830h

Mantle flow, mantle plumes and hotspot motion: The cause of the bend of the Hawaiian hotspot track

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Flow in the mantle has been modelled using seismically inferred density anomalies in the mantle and recent plate motions. Using past plate motions and advecting the density anomalies backward in time allows the models to be extended back to ∼ 100 My. The flow distorts and moves mantle plumes, causing the hotspots to move. Previous models of this by Steinberger and O'Connell have predicted the southward motion of the Hawaiian hotspot. Recently published paleomagnetic results by Tarduno et al [Science, 301,1064(2003)] have confirmed this prediction, and refined models have reproduced the measured motion of the hotspot. A related problem is the plate circuit that connects the African and Pacific hotspots: The Hawaiian hotspot track predicted from published plate circuits, assuming stationary hotspots, does not fit the observed track. The discrepancy steadily increases for the Hawaiian chain, and the predicted track does not show a bend. Our model of plumes distorted by global mantle flow can explain the misfit for times after the bend. For the Hawaiian hotspot, computations consistently predict a S to SE motion of about 1000 km during the past 80 Ma, which explains the discrepancy for the Hawaiian chain, although not the bend and the trend of the Emperor chain. However, a combination of modeled hotspot motion and a relatively modest motion at an unrecognized plate boundary — about 13 degrees clockwise rotation of W vs. E Antarctica around an axis near the E–W–Antarctic boundary between ∼ 83 and 44 Ma, plus possibly some deformation between the Pacific plate and the Campbell Plateau between ∼ 83 and 63 Ma — allows a simultaneous fit to all hotspot tracks from ∼ 83 to 47 My. The required deformation is not in conflict with, but supported by geologic evidence. The motion, and its cessation, may be related to tractions on the base of the plates (which are also calculated from the flow models), and the growth of strong oceanic lithosphere that inhibited the separate motion after 47 My ago.

T31B-04 0845h

Estimate of the Temperature Field of the Mantle and its Contribution to the Lateral Heterogeneity of the Earth's Interior

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The origin of lateral heterogeneity is important for understanding many aspects of the Earth's interior, including mantle flow and viscosity structure, the gravity field, and dynamic topography at the surface. These lateral variations can be ascribed to three main causes: temperature, bulk composition, and phase assemblage. Modeling the temperature field is an important step in understanding the relative contributions of these variations. Down-welling slabs are the most important source of density heterogeneity in the mantle. We assume the temperature field to be largely the product of subduction and neglect the contributions due to active upwellings. We use a model of the history of subduction for the last ∼120 Myr to derive a density field for the mantle, from which we compute a three-dimensional velocity field by solving Stokes equation for an incompressible Newtonian fluid. Using a commercial finite-element software package called Abaqus we solve for the temperature field by solving the advection-diffusion equation in steady state. We choose free-slip, 3000 K velocity-temperature boundary conditions at the core-mantle boundary, and at the surface we constrain velocities to be plate velocities and temperatures to be 300 K. We recover the half-space cooling behavior in the lithosphere and obtain reasonable values of the heat flow, indicating that our predicted temperature field behaves as expected. We use our predicted temperature fields to compute the expected phase assemblage for a mantle of constant bulk composition. We will focus our discussion on the expected topography on major seismic discontinuities (410 and 660) and comparisons to three-dimensional seismological observations.

T31B-05 0900h INVITED

Constraints on the Thermochemical Structure of the Earth's Deep Mantle Using Seismic, Geodynamic and Mineral Physics Data

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The integration of seismic, geodynamic and mineral physics data to constrain the large scale composition and dynamics of the Earth's mantle is a widely stated goal of global geophysics; however, the appropriate methodology for this integration is a matter of debate. In recent work [Forte and Mitrovica, Phil. Trans., 2002] we outlined, atleast for a simple compositional model of the mantle, an approach for combining joint (shear and bulk sound) seismic models, seismic velocity derivatives obtained from results in mineral physics, and convection related observations (plate motions, gravity anomalies and the excess ellipticity of the CMB). Our inversions yielded a mantle viscosity profile characterized by two viscosity maxima within the lower mantle. The deepest of the two, at 2000 km depth, suppresses all but the longest horizontal wavelengths of the present-day flow in the bottom 1000 km of the lower mantle, thereby providing a simple interpretation for the 'red' spectrum of seismically-inferred heterogeneity in this region. The integration also suggested that while chemical anomalies in the lower-most mantle are required to explain seismic observations, these anomalies are unable to inhibit the dominant thermal buoyancy of the deep-mantle megaplumes below the Pacific and Africa. In this talk we describe the results of a large set of new inversions that: (1) extend the viscosity inferences to include a suite of data related to glacial isostatic adjustment (GIA; these data include site-specific post-glacial decay times from Fennoscandia and Hudson Bay, and a relaxation spectrum which provides the decay time versus wavelength of Fennoscandian deformation); and (2) map out, using Monte-Carlo simulations, plausible variations in thermochemical structure (summarized by the so-called buoyancy ratio) associated with uncertainties in the seismic models, mineral physics data and mantle viscosity (including the presence of the lateral variations). The GIA data provide an important, independent constraint on absolute viscosity and significantly improve the resolution of the resulting viscosity inferences, particularly in the transition zone and top half of the lower mantle. However, the viscosity peak at 2000 km depth remains a robust feature of these new inversions, reinforcing our earlier conclusion that this structure plays a pre-eminent role in deep mantle flow dynamics. Furthermore, the Monte-Carlo simulations indicate a positive correlation between density and shear wave velocity in the deep mantle and thus a dominance of thermal buoyancy within that region.

T31B-06 0915h INVITED

Inferring Chemical, Thermal and Mechanical Heterogeneities in the Upper Mantle From Seismological Observations

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Inferring heterogeneity in the mantle is critical for our understanding of evolution and dynamics of this planet. Most previous efforts in this direction have been concerned with mapping anomalies in temperature, partial melting and/or major element chemistry. We show that in addition to these anomalies, anomalies in trace elements such as hydrogen (water) and the stress level can now be mapped using seismological observations when combined with the latest results of mineral physics. The effects of hydrogen on seismic wave propagation are mostly through its effects on attenuation (Q) and anisotropy. A theoretical analysis shows that the effects of water on attenuation and seismic wave velocities can be parameterized using the rheologically effective temperature (Karato, 2003). This formulation predicts that the velocity heterogeneity caused by anomalies in temperature or water content must have correlation with anomalies in Q. Furthermore the slopes of correlation between Q and velocity anomalies are different between thermal and water origin. Consequently a comparison of anomalies in average seismic wave velocities and Q provides a useful tool to identify the cause of these anomalies. Such an analysis on wedge mantle in the western Pacific suggests that significant heterogeneity in major element chemistry is present in the shallow (<200km) upper mantle whereas anomalies in the deep upper mantle are most likely attributed to the heterogeneity in water content (Shito and Shibutani, 2003). Recent laboratory studies also show that the nature of seismic anisotropy is sensitive to various parameters including water content, temperature and stress magnitude (Jung and Karato, 2001; Katayama et al., 2003). A commonly observed trend of fast shear wave polarization (trench parallel near trench to trench normal anisotropy away from trench) can be attributed to the regional variation in stress level (and water content) in the subduction zone: high stress (plus high water content) near slabs (leading type-B lattice preferred orientation of olivine) and low stress (low water content) away from slabs (type-A or C). Deviations from this trend may imply different stress distributions caused by different temperature and/or water content.

T31B-07 0930h

Lateral Variation in Upper Mantle Viscosity: Role of Water

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Differences in the viscosity of the earth's upper mantle beneath the western US (10^{17}-10^{19} Pa-s) and global average values based on glacial isostatic adjustment and other data (10^{20}-10^{21} Pa-s) are generally ascribed to differences in temperature. We compile geochemical data on the water contents of western US lavas and mantle xenoliths, together with calculations of water solubility in olivine and its influence on effective viscosity using a power law creep rheological model, and suggest that the low viscosities for the western US upper mantle reflect the combined effect of high water concentration (essentially at or near the saturation value for olivine) and moderately elevated temperature. The high water contents of the western US upper mantle may reflect the long history of Farallon plate subduction, including flat slab subduction, which effectively advected water into the upper mantle as far inland as the Colorado Plateau.

T31B-08 0945h

Physical property of a chemical heterogeneity in the mid-mantle: seismic evidence for an oceanic crust in the mid-mantle

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A clear later phase approximately 80 s after the direct P-wave is observed in most of individual seismograms recorded by a short-period seismometer network in Japan (J-array) from a cluster of deep earthquakes that occurred at the northern Mariana subduction zone. This phase 1) shows a P-wave particle motion; 2) arrives later from earthquakes with shallower focal depths; 3) has a steeper incident angle than that of P wave; and 4) shows a deviation of a few degrees in the arrival azimuth from that of P wave. We interpret it as an S to P converted wave which takes off downward from the source and is reflected at a velocity discontinuity (reflector) below the earthquakes. Applying an inversion technique to the data set shows that the seismic reflector dips toward southwest by about 20 at 24.25~N 144.75~E, and at a depth of 1115 km with a lateral extension at least 100 x 100 km. The location corresponds to the lower edge of a high-velocity anomaly in global tomographic models. Amplitude and

waveform analyses suggest a decrease of S-wave velocity by 2-6% and an increase of density by 2-9% within the reflector. There is almost no difference in P-wave velocity (<1%) between the reflector and the surrounding mantle. The estimated thickness of the reflector is about 12 km. These observations indicate that the observed seismic structure is more likely to be a chemical reservoir rather than a purely thermal anomaly. The seismic reflector might be a piece of subducted oceanic crust, as suggested by a previous study. It also could be related to the break down of the D-phase of dense hydrous magnesium silicates (DHMS) at mid-mantle pressure condition reported by recent mineral physics studies. Both scenarios imply that either mechanical or chemical segregation might occur within the subducted slab at mid-mantle condition.

T31C MCC: Level 2 Wednesday 0830h

Late Cenozoic Tectonics, Climate, and Topography in the Central and Southern Andes I Posters *(joint with G, H)*

Presiding: **R Allmendinger,** Cornell University**; M Strecker,** University of Potsdam

T31C-0851 0830h POSTER

Tectonic and Climatic Control of Landscape Evolution in the Northern Sierras Pampeanas, Argentina

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Rock uplift, surface uplift and exhumation can be constrained if thermochronologic data can be converted to exhumation and if geological relations provide a datum. In the northern Sierras Pampeanas of Argentina, the Cenozoic Santa María basin, which overlay resistant crystalline basement prior to rapid exhumation, provides an ideal setting to examine the effect of contrasting thermal and erosional regimes. There, tectonically active reverse-fault bounded blocks partly preserve a basement peneplain at elevations >4500 m. Prior to exhumation, the study area was covered by 1 to 1.6 km of ca. 12-6 Ma sediments; this sequence begins with shallow marine deposits immediately overlying the regional erosion surface which are superseded by sandstones and conglomerates. These rapidly deposited sediments have low thermal conductivity and are readily eroded, in contrast to underlying resistant basement. Apatite fission-track data were obtained from two vertical transects in the Calchaquíes and Aconquija ranges bounding the basin. At Cumbres Calchaquíes, erosion leading to the development of the peneplain commenced in the Cretaceous; limited late Neogene cooling is documented by track-length modeling. In contrast, Sierra Aconquija cooled rapidly between 5.5 and 4.5 My. At the onset of this rapid exhumation, sediment was quickly removed, causing fast cooling, but relatively slow rates of surface uplift. Syntectonic conglomerates could only be produced when faulting exposed resistant bedrock; this change in rock erodability lead to enhanced surface uplift rates but decreased exhumation rates. The creation of an orographic barrier after the range had attained sufficient elevation further decreased exhumation rates on the leeward side and increased surface uplift rates. This imbalance cannot be sustained for extended periods of time; either crustal strength or bedrock fluvial incision will ultimately limit the magnitude of relief which can be created before tectonism, and hence rock uplift, migrates to other locations. Differences in the magnitude of exhumation at the two transects are related to both differences in the thickness of the sedimentary basin prior to exhumation and differences in effective precipitation due to an orographic barrier in the foreland.

T31C-0852 0830h POSTER

Testing the Origins of Nonmarine Stratigraphic Sequences, Iglesia Basin, Northwest Argentina

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The Iglesia Basin is an entirely nonmarine Andean foreland basin consisting of approximately 3.5 km of Tertiary strata unconformably overlying Paleozoic basement. Best described as a wedge-top basin, Iglesia Basin is located in San Juan Province, Argentina at S 30-31^{o} between the Frontal Cordillera and Precordillera fold-thrust belt. Interpretations of seismic reflection profiles and field reconnaissance have suggested basin-wide stratigraphic sequences. Additionally, radiometric and magnetostratigraphic data constrain sequence deposition between approximately 17 and 4 Ma. However, a fundamental question remains unanswered: temporal variability of which control caused development of unconformity-bound nonmarine sequences? Prior to this work, hypotheses about the factors at play, notably tectonism and climate change, remained untested, and fieldwork provided only localized information about the nature of the sequences. The present study examines basin lithofacies more broadly and will independently constrain discharge history (a proxy for climate) and intrabasinal tectonics. Thus far, fuller knowledge of the sedimentation patterns, structural expression, and volcanic history of Iglesia Basin is supplied by information from new outcrop localities near the northern paleomargin and basin center, and from reinterpretation of previously studied localities. A substantial volcanic component to the history of the oldest sequences is inferred from age relationships and continuity of deposits in proximity to the Cerro Negro intrabasinal andesitic center. Reassessment of field-assigned sequence boundaries in terms of continuity and expression, both along-strike and across intrabasinal faults, suggests that lithofacies shifts are more prevalent than erosive surfaces. Radiometric dating of additional tuffaceous units in the Tertiary sequences will allow more conclusive correlation among discontinuous outcrops. Floodplain assemblages of Aridosols and Inceptisols indicate notable sedimentary hiatuses, allow pedofacies definition, and provide material for temporally constrained ^{13}C and ^{18}O analysis as a proxy for climate fluctuation. Preliminary interpretation of paleosol micromorphology and isotopic time series suggests minimal diagenesis, as well as an evolution towards moisture-stressed conditions and depletion of heavy isotopes, possibly caused by the orographic effect of the rising Andes. Isotopic signal variability can be compared to sequence chronostratigraphy to test the hypothesis that sequence formation results from stream discharge variations.

T31C-0853 0830h POSTER

Late Quaternary Sedimentation and Erosion Rates Derived From Luminescence and Cosmogenic Nuclide Dating of Intermontane Basin Sediments, NW Argentine Cordillera

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The easternmost basins of the central Andean cordillera (22^{o}-25^{o}S) are characterised by multiple Late Quaternary and Holocene alluvial fill-cut terraces. Humid phases in the central Andes, interpreted from cores of Late Pleistocene and Holocene lacustrine deposits, have been previously linked to periods of increased frequency of landsliding events. Large landslides lead to rapid increases in local base level and aggradation. Subsequent headward erosion propagates through the basin and produces a characteristic alluvial terrace, common to many active mountain belts. Although climate may be the predominant control on these events, small and young intra-basin faults could also be diverting fluvial systems and reorganising drainage basins and sediment pathways. We have integrated optically stimulated luminescence (OSL) with ^{10}Be cosmogenic nuclide dating techniques to produce a chronology of three of these depositional and erosional sequences in the Quebrada de Humahuaca. From each sequence, multiple OSL samples were collected from the fluvial and (debris flow and stream dominated) alluvial fan deposits to quantify sedimentation rate; four cosmogenic samples were collected from a 1.5 m pit on each terrace surface to quantify surface exposure age, as well as basin-scale erosion rate. Integrating these two dating techniques allows us to test how episodic deposition-erosion events are linked to periods of pronounced climatic variability in the central Andes and to quantify landscape response time to incision events.

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The New ILP Database of Quaternary Faults and Folds in South America

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As part of the International Lithosphere Program's Task Group II-2, we have completed the compilation of Quaternary faults and folds in South America and have established an Internet website for this data. The underpinning maps and reports have been released as electronic U.S. Geological Survey Open-File Reports (pdfs, see poster). The maps show the location, time, sense of slip, and activity rate of major earthquake-related features such as faults and fault-related folds. The maps are accompanied by descriptions of their Quaternary activity. The primary elements of the 10-year project are supervision and interpretation of geologic/tectonic information (Costa and Machette), data compilation (project participants), database design and management (Cisneros), and GIS input and management (Dart). A dozen experts in Quaternary faulting, neotectonics, paleoseismology, and seismology compiled the data: questions about individual faults or additions to the database should be directed to them. Prior to this project, digital maps of Quaternary faults did not exist for any of the South America countries, even though understanding the extent and character of active and older Quaternary faults are critical elements of seismic-hazards analysis. These new data will help extend the relatively short record of instrumental and felt seismicity that is the primary parameter for current seismic-hazard assessments in South American countries. Although some fault data were available for most of the countries (i.e., Venezuela), the degree of completeness varies as a function of the remoteness and vegetation cover (i.e., Brazil). A few faults such as the Bocono have had detailed investigations involving modern paleoseismic techniques. Other faults have been studied in some detail, usually in association with concerns about hazards to urban areas or the safety of critical facilities such as mining operations, oil-and-gas pipelines, or power-generating facilities. However, the general state of knowledge for active faults in South America is probably best described as incomplete and of a reconnaissance nature. With the exception of some historic surface faulting events, little is known about fault chronology and overall rates of fault activityinformation that is difficult to acquire but critical to seismic-hazard assessments.

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Along-Strike Variations in Focal Mechanisms of Central Andean Crustal Earthquakes: Northern Peru through the Argentina Sierras Pampeanas

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120 shallow focal mechanisms in the crust above the subducted Nazca plate were assembled from the Harvard CMT catalog and published studies covering over 40 years of seismicity. The study area included the Andes crust above three major segments of the subducted plate, the Peruvian and Argentinean flat-slab segments and the intervening segment where the subducted Nazca plate dips more steeply. The most seismically active regions continue to be the thick-skinned foreland thrust belts in the eastern Andes of Peru and the Sierras Pampeanas. The earthquakes there are clearly associated with youthful tectonic structures with strong topographic signatures as revealed by the new 90 m SRTM digital elevation models. The mechanisms are dominantly of the thrust type but include a minority of strike-slip orientations. However the P axes remain consistent. The thin-skinned thrust belts east of the central Andean Plateau show significant activity only near Santa Cruz, Bolivia and northern Argentina; most of the Sub-Andean thrust belt of Bolivia and southern Peru remains aseismic. The central Andean plateau itself also remains aseismic except for the region of southern Peru and two earthquakes in the Puna. The crustal seismicity in southern Peru is largely