We attribute the remaining 25% of swell bathymetry and 35% of gravity anomaly to an eastward reduction of mantle density above an effective compensation depth, constrained to be 50-200 km. Simple melting calculations assuming passive mantle upwelling predict that the observed crustal thickenning is consistent with a small eastward increase in mantle temperature of 15-25 °C. This thermal anomaly produces an eastward decrease in mantle density due to thermal expansion and the subsequent along-axis variation in melt depletion. For preferred mantle compensation depths of 50-150 km the thermal effects can explain 40 to 70% of the mantle density anomaly required by the geophysical observations. Therefore, our results require the existence of compositionally-buoyant mantle beneath the GCS near the Galápagos plume. We will discuss plausible origins for the mantle anomaly such as depleted mantle by the upwelling plume, melt retention, or a mantle source enriched in incompatible elements and volatiles [*Cushman et al.*, this meeting], and their implications for melting beneath the Galápagos plume-ridge system.

T41D-04 0915h INVITED

Upper Mantle Structure Beneath the Galpagos Archipelago From Body Wave Data

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We report on the initial results from an ongoing broadband seismic experiment conducted in the Galpagos Islands. The Galpagos offer an advantageous site for a reconnaissance seismic study of an oceanic hotspot, because the islands cover nearly the entire bathymetric swell or surface signature of the presumed underlying plume. In September 1999 we deployed 10 three-component broadband seismometers, which augment an existing GSN site and a telemetered array of high-frequency seismometers. The combined seismic networks record data suitable for imaging upper mantle structure, constraining crustal thickness variations, and characterizing local seismic activity associated with tectonic and volcanic processes. The resulting elliptically shaped array is 300 km by 200 km in aperture (east-west/north-south, respectively); stations are spaced 50-70 km apart. A primary goal of the experiment is to define the first-order characteristics of the upper mantle structure beneath the Galpagos hotspot in order to ascertain if the hotspot is associated with a plume-like feature in the upper mantle. To do so, we are inverting the delay times of teleseismic P and S body waves. The Galpagos hotspot is well situated with respect to regional and teleseismic earthquake sources, and the region displays remarkably low seismic noise, as it is located in the doldrums with calm winds (<5 m/s) over 60% of the time (90% of the time from February through April). Examination of our data and plots of magnitude versus epicentral distance indicates that teleseismic earthquakes with mb>5.5 and regional earthquakes with mb>4.2 provide useful data. P waves often show excellent signal-to-noise ratios in the frequency band 0.3 to 2 Hz. These phases can be picked, using waveform alignment, to an accuracy of 20 ms. The spectral content of the larger events is broad, with teleseismic earthquakes generating signals at frequencies up to 5 Hz, as well as at lower frequencies (< 0.1 Hz). The S wave data are also of excellent quality, with good signal to noise and coherent waveforms across the array. We observe S waves from events at 30° to 40° distance with good energy at frequencies approaching 1 Hz (wavelengths of about 4 km). Initial measurements indicate that the mean S wave delay varies by nearly 2 s across the array, with greater delays to the northwest. For a given station, the variation with respect to the mean is 0.5 to 1.0 s, a figure much greater than the error in an individual delay (∼0.1 s). The variation, for a given station, indicates that as the back azimuth and distance of the event vary, different anomalous structures are being interrogated. These observations suggest that the underlying structure is indeed three-dimensional.

T41D-05 0930h INVITED

Lithospheric Evolution of Galapagos Magmas

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The volcanoes of the western Galapagos are of two types: monotonous systems, which erupt lavas with a narrow compositional range, and variable systems, which erupt a wide range of compositions. Fernandina, Sierra Negra, and Wolf volcanoes are monotonous systems, with Mg# $= 44 \pm 4$ for all but a few lavas. These compositions correspond to a narrow range of eruption temperature, typically 1130 ± 20 degrees. Cerro Azul, Alcedo, and Roca Redonda are variable systems; lavas range from picrites (Mg# > 70) to rhyolites, representing hundreds of degrees of difference in eruption temperature. Volcan Ecuador used to be a monotonous system but has changed to a variable one since it underwent sector collapse. Monotony is attributed to thermochemical buffering in the plumbing system beneath the caldera of each volcano. GPS and Insar deformation modeling indicate that the top of the "magma chamber" is < 2 km deep for the monotonous systems, with a sill-like shape. Cerro Azul is the only variable system that is well-modeled by geodetic data, and the active chamber there is at least 5 km deep. Compositional variations of both kinds of suites indicate that most magmas undergo cpx-dominated fractionation in the deep crust. All of the monotonous magmas and some of the variable ones undergo a shallow plagioclase-dominated phase, probably in the subcaldera sill. Extreme compositional variation in the 1998 Cerro Azul lava indicates that disaggregation of cumulates and magma mixing can be important in the variable systems. We present two hypotheses for the thermal and compositional steady state of the monotonous volcanoes. In one, a large (same diameter as the caldera; hundreds of meters thick) liquid chamber serves as a homogenizer, intercepting most batches of magmas. In the second, a thin sill (< 100 m thick; same diameter as the caldera) overlies a thick pile of olivine-gabbroic and wehrlitic cumulates, and each batch of magma reacts with the cumulates before a final stage of fractionation in the sill. Geochemical modeling indicates that the liquid reservoirs have volumes of only a few cubic kilometers, hence the second geometry is preferred. The variable systems are believed to be transient, which can develop as a volcano is still in a juvenile phase (Cerro Azul and Roca Redonda), a dying phase (Alcedo), or after severe disruption (Ecuador).

T41D-06 0945h INVITED

New Perspectives on the Structure and Morphology of the Submarine Flanks of Galápagos Volcanoes- Fernandina and Isabela

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The submarine flanks of oceanic volcanoes are dynamic environments that reflect the history of volcanic construction and mass-wasting. The submarine slopes of the Galápagos had only been investigated during two modern research cruises - the 1990 PLUME 2 cruise and during the 2000 AHA-Nemo cruise. These data provide the backdrop for a recent sonar mapping and dredging cruise, carried out in Aug-Sept., 2001 on board R/V *Revelle*, over the southwestern and western edge of the Galápagos platform. The survey included detailed MR1 side-scan sonar imagery (gridded at 8 m pixel resolution) and EM120 multibeam bathymetry (gridded at 100 m pixel resolution), which provided the basis for detailed dredging and towed camera investigations of the submarine flanks of Fernandina and Isabela.

The principal geologic provinces delineated by the MR1 sonar imagery include submarine rift zones, major landslides between the rifts, and inferred young lava flows at 3000-3500 m depth located 10-20 km west of the islands. Prominent submarine terraces extend for tens of kilometers along the platform edge south of Isabela and west of Floreana, and in the bight between Fernandina and Cerro Azul volcanoes. The depth range for the terraces is variable between 2000-3300 m.

Galápagos submarine rift zones are characterized by mottled backscatter reflectivity seen elsewhere on seamounts, Hawaiian submarine rifts, and the mid-ocean ridge, and are interpreted as constructional submarine volcanic terrain comprising pillow and lobate lava. Extensive spatial variability in acoustic contrast is visible in the MR1 sonar data and is interpreted as complex inter-fingering of submarine eruptive units. These areas of presumably young, high reflectivity flows are located away from the submarine rifts and appear to overlie sediment. These flows cover distances as great as ∼10-15 km and are located 10-20 km from the nearest coastline. These large submarine flows may relate to large subaerial events such as the 1968 Fernandina caldera collapse which was unaccompanied by subaerial eruptions.

Four prominent terraces characterize the slope south of Isabela and west of Floreana, covering an area of ∼600 km^2 between ∼1500-3000 m, and roughly occur at ∼400m depth intervals (2200m, 2500m, 2900m and 3300m). Landslides and sculpting of the platform edge by mass-wasting are imaged in the sidescan sonar data as down slope streaming of light/dark acoustic patterns. This contrasts with the western edge of the platform, north of Isabela and west of Fernandina, that is dominated by submarine rift zones and is interpreted as younger volcanic terrain. The complexity of the morphology and variability of constructional and erosional terrains along the western margin of the platform are clear indicators of the more youthful terrain immediately north and west of Fernandina, the leading edge of the Galápagos hotspot.

T41E MC: 310 Thursday 0830h

Active Tectonics of Taiwan II *(joint with G, S)*

Presiding: **C M Rubin,** Central Washington University**; Y Chen,** National Taiwan Univ.**; J Suppe,** Princeton University

T41E-01 0830h INVITED

Seismic Strain Field in Taiwan

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Centroid-moment-tensor (CMT) solutions determined by inverting waveform data of Broadband Array in Taiwan for Seismology (BATS) are collected for earthquakes that occurred in the Taiwan region. In total, the dataset contains more than 300 events that scattered across an area of 400 km by 400 km, including the devastating 1999 Chi-Chi earthquake sequence. The entire region is divided into 3 layers (0-40 km, 40-70 km, and greater than 70 km) with blocks of 0.2 degree by 0.2 degree in lateral dimension. Seismic moment tensors of all earthquakes that occurred inside each block are summed to give the strain tensor characterizing the corresponding seismic deformation. We calculate the eigenvalues and eigenvectors of the resulted strain tensor for each block and project the normalized maximum compressional (P) and extensional (T) axes on horizontal plane to resolve the strain field in Taiwan associated with regional seismic activities. For the majority of events with depths less than 40 km (i.e., at crustal scale), the strain field is characterized by nearly E-W compression along the eastern coastline and immediately offshore east of Taiwan. Once inland, clear fan-shaped trajectories of P-axes are observed, ranging from NW-SE in the northwest to NE-SW in the southwest. The Ryukyu and Luzon subduction systems show compression in the forearc region and extension in the backarc and outerrise regions. For depths greater than 40 km, a clear pattern of lateral compression is observed within the subducted Philippine Sea plate to the northeast of Taiwan. It is doubtless that the "slab-continent" collision is predominant at deeper depths near the junction between the Ryukyu arc and Taiwan Collision Zone, whereas the "arc-continent" collision is predominant in the central and southern Taiwan.

T41E-02 0845h INVITED

Paleoseismic Study of the Southern Part of the Chelungpu Fault

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The Chi-Chi earthquake ruptures frequently followed the preexisting Holocene terrace scarps that have already been recognized as a Holocene fault scarp. Uplifted Holocene terraces are important indicators of active tectonics, and its presence can be interpreted as a geomorphic expression of active faulting. Therefore, the Quaternary fold-and-thrust belts along the Chelungpu fault are one of the best areas for neotectonic studies. In this study, we are to discuss paleoseismicity of the Chelungpu fault with the help of careful observation based on the trenching study. These trenching sites are located on the southern part of the Chelungpu fault occurring vertical displacement ranging from 0.2 m to 3 m during the Chi-Chi earthquake. Through the paleoseismic investigation, the deformation pattern of surface rupture can be subdivided into fault and fold ruptures. Prehistoric ruptures for six trenching sites have been produced the vertical displacement ranging from 0.4 to 1.7 m. The evaluated data is approximately similar to the observations from the paleoseismic rupture and the Chi-Chi earthquake ruptures. In the Chushan, Wanfung, and Pineapple field sits, the paleoseismic analysis reveals clear evidence of recurrence timing of the Chelungpu fault occurring younger than 200 yr BP by 14C dating. Based on the historical earthquake record, 1792 A.D. and 1848 A.D. earthquakes were the two markedly damaging earthquakes striking central Taiwan. We suggest that one of the strong earthquakes may have caused the last paleoseismic event.

T41E-03 0900h

Seismic Deformation in the Footwall of the Chelungpu Fault Before and After the 1999 Chi-Chi, Taiwan Earthquake

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We analyze the seismicity pattern and style of earthquake faulting in the footwall of the Chelungpu fault before and after the 20 September 1999 Mw 7.6 Chi-Chi, Taiwan earthquake. The earthquakes occurred in the footwall of the Chelungpu fault covering January 1991 to May 2001, were relocated using the double difference algorithm (Waldhauser and Ellsworth, 2000). Focal mechanisms ($2.2 < M_L < 4.7$) are determined by P-wave polarity data and SH/P amplitude ratios based on relocated hypocentral locations. The relocated seismicity defines a NW-SE-trending lineament with width and length of 8 km and 35 km, respectively. The seismicity are also loosely separated by two clusters: one cluster covers mainly the pre-Chi-Chi events located just ∼4 km west of the Chi-Chi main shock, and the other contains mostly post-Chi-Chi events and is separated from the Chi-Chi main shock by 20 km. The pre-Chi-Chi events is marked by two depth levels: one is a cluster of earthquakes in the depth range of 9-14 km, and the other includes earthquakes in the deeper zone spread within 17-28 km depths. The post-Chi-Chi events, on the contrary, are concentrated only in the depth range of 11-15 km. In the pre-Chi-Chi events area, the style of earthquake faulting shows alternating thrust and normal mechanisms in the shallow depth, while the deeper zone is dominated by thrust faulting. The normal faults in the shallow depth have their T-axes mostly trending NW-SE, whereas the directions of P-axes of thrust events in the shallow level are rather random. On the other hand, the thrust events in the deeper zone have mainly E-W-trending P-axes. For the post-Chi-Chi events cluster, normal faults with E-W-trending T-axes apparently are the dominated style of earthquake faulting. The normal faults with E-W-trending T-axes located in the post-Chi-Chi events area are most likely occurred in pre-existing weak zones, and can be readily explained by the post-seismic relaxation in the footwall of the Chi-Chi thrust event. For the pre-Chi-Chi events area, the thrust events with E-W-trending P-axes in the deeper zone apparently are the results of present-day regional Philippine Sea plate convergence. The origin of the alternating thrust and normal mechanisms in the shallow depth is not that obvious, although the normal faulting with NW-SE-trending T-axes could be the long-delayed post-seismic relaxation in the footwall of previous large events, for example, the 1916 Nantou earthquake sequence (M 6.8 for the main shock), located ∼15 km NE of Chi-Chi main shock.

T41E-04 0915h

Aftershock Distribution of the 1999 Chi-Chi, Taiwan, Earthquake and Crustal Structure in the Source Region from an Explosion Reflection Survey

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We have conducted an active and a passive seismic experiment in central Taiwan in 1999 and 2001 to understand an active tectonics associated with the 1999 Chi-Chi, Taiwan, Earthquake. First, we carried out aftershock observations of the 20 September 1999 Chi-Chi, Taiwan, Earthquake beginning 15 days after the main shock. We deployed 20 seismographs twice in a 100 km by 100 km area around the focal area of the main shock. Each observation period lasted one month. There are three particular trends in the east-west cross-section: an east-dipping plane, a nearly flat plane distribution, and a deeper cluster. These trends correspond to the fault plane of the main shock, the hypothesized decollement between the accretionary wedge, and the upper boundary of the Eurasian Plate, and intra-plate activity respectively.

The second seismic experiment was conducted from March to May 2001. It includes a 12-km-long reflection profiling and a 150-km-long passive experiment. The latter observes earthquakes to image entire crustal structure of the Taiwan Island. We deployed 58 offline seismic stations along the lines.The shot gather obtained by two 50-kg dynamites clearly demonstrates the flat reflector at 4 to 5 seconds (TWT), interpreted as the decollement mentioned above and many horizontal reflectors from 5 to 15 seconds (TWT), interpreted as crustal reflectors of the Eurasian Plate.

The geological structure is characterized by a well-developed fold-and-thrust belt very similar to that found along the trench slope of subducted plate. Thrusting due to the eastward subduction of the Eurasian Plate has thickened sedimentary material. The westward migration of the thrust front is well recorded in the sedimentary successions in western Taiwan. Aftershock distribution suggests that the 1999 Chi-Chi, Taiwan, Earthquake occurred along the base of the accreted material and cuts to the surface on a thrust fault (Suppe, 1981, Sato and Hirata, 1999). We observed active seismicity at a depth of 10 km, which may correspond to the decollement between the Eurasian Plate and the accretionary wedge.

T41E-05 0930h

Rupture Behavior of 1999 Chi-Chi Earthquake Associated With Background Seismicity and Tectonics

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Spatial and temporal slip models of 1999 Chi-Chi earthquake reveal that significant fault slip occurred at the northern end of the rupture, where the faulting bent sharply from N 3 E to N 80 E. Up to 10 m of slip occurred simultaneously on both sides of the bend at about 18-21 sec after rupture initiated. Before the occurrence of 1999 Chi-Chi earthquake, background seismicity in the region defined a NW-SE trending seismogenic zone, that coincides well with the bending of surface rupture of the 1999 Chi-Chi earthquake. It is not associated with any identified active fault. Detail crustal structure modeling, using generalized ray and 2-D finite-difference methods to match earthquake seismograms in that region reveal a four layer structure associated with soft and hard sediment, and a SE dipping Conrad and Moho discontinuities. The coincidence of the bend in the Chelungpu fault, the NW-SE trending seismic zone and SE dipping of Conrad and Moho structure in that region suggest an association between the deep structure and the Chelungpu fault rupture. We are using the double-difference algorithm to relocate both the aftershocks of the Chi-Chi earthquake and the earthquakes in the NW-SE zone. By combining the results of high-resolution earthquake locations and previous studies we hope to be able to understand the possible association between the NE bend of the Chelungpu fault rupture and the regional tectonic elements.

T41E-06 0945h

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The study of the Nankai subduction zone has revealed the important role played by splay faults in the ruptures of large subduction earthquakes. Because it is subaerial in a zone heavily instrumented, the Chi-Chi earthquake is the best-documented evidence for the rupture of a splay fault within an active accretionary wedge. Several models of the Chi-Chi rupture have now been obtained on the basis of dense geodetic data as well as Spot images (see Loevenbruck and Cattin in the same session). These show that the rupture only affected the eastward dipping Chelungpu fault and that it did not extend along the decollement on which this fault is rooted. They show further that the rupture amount increased approximately linearly in the direction of plate motion from very little at its basis near the decollement to a maximum at the surface. Modeled interseismic elastic deformation indicates that the decollement to the west is slipping continuously at a rate of about 45 mm/yr. This suggests that it acts as a ductile level and this ductility can be understood in view of the estimated temperature of about 350°C where the splay fault branches. We discuss some of the obvious implications of this simple model. The increasing rupture upward on the splay fault may be the result of the dynamics of dip slip faulting on a reverse fault that intersects the surface. Whatever the cause, this asymmetric distribution of motion on the splay fault cannot be maintained over a complete seismic cycle. The downward increasing deficit of slip must be compensated. This compensation does not appear to occur during the post-seismic phase. Alternatively a later rupture that would not reach the surface might compensate it.

T41E-07 1020h

Detail Shear Velocity Structure Beneath Taiwan Derived from Dense Strong Motion Waveforms

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We investigated detail crustal velocity structure of Taiwan, using generalized ray and 2-D finite-difference methods to match earthquake seismograms recorded by Taiwan Strong Motion Network (TSMN). We first examined the earthquakes and waveforms at west-central Taiwan region, where a NW-SE seismogenic zone, named as Sanyi-Puli seismic zone, was well recognized. Our results reveal four-layer structure associated with soft and hard sediment and SE dipping Conrad and Moho discontinuities. The depth of Moho varies across the NW-SE seismogenic zone, suggesting the correlation of the seismogenic zone with background tectonic setting of Taiwan. We also examine the longitudinal valley in eastern Taiwan, a region generally accepted as a convergence boundary of Eurasia Plate and Philippine Sea Plate. Direct, reflected, and refracted phases corresponding to waves traveling within the crust, mantle and collision boundary were clearly observed for the stations in coastal range region. For the stations with distances greater than 10 km from the edge of the collision boundary and with certian amount of velocity contrast of crust to mantle, these phases can be clearly modeled. These phases are crucial for understanding the structure beneath the collision region. Our results delineated a collision of Philippine Sea Plate subducted underneath Eurasian Plate and showed a significant reflector at depth of about 10 km beneath coastal range. Further detail waveform modeling of other corresponding regions will be addressed to delineate detail velocity structure beneath Taiwan. This will be important for basic understanding of Taiwan velocity structure for better earthquake locations and further 3-D waveform propagation modeling.

T41E-08 1035h INVITED

Slip distribution and tectonic implications of the great Chi-Chi earthquake

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Most of the tectonic activities of Taiwan are related to the collision between the Philippine Sea and Eurasian plates. The eastward subducting Eurasian plate underneath the Philippine Sea plate in southern Taiwan has been used as a classical example of the Critical Taper Model. However, the tectonic style in northeast Taiwan reflects the northward subduction of the Philippine Sea plate beneath the Eurasian plate. The recent Chi-Chi earthquake occurred in central Taiwan, near the region where the subduction direction changes. Here we will report on the fault complexity of the Chi-Chi earthquake as obtained by inverting densely and well-distributed static measurements. We show that the slip of the Chi-Chi earthquake was concentrated on the surface of a "wedge shaped" block. The inferred geometric complexity is later proven to be able to satisfy both far field and near field seismic observations simultaneously. This result provides a unique snapshot of tectonic deformation taking place in the form of very large (>10m) displacements of a massive wedge-shaped crustal block. Such large motion is related to the evolutionary stress conditions in the central Taiwan and may provide unique information pertaining to the spatial and temporal patterns of the tectonic processes of the polarity change of the subduction. The hinge line of this block is along the well defined narrow transfer (SanYi-Puli) seismic zone, which sharply separates the local long term GPS velocity field. In contrast, a recent numerical simulation based on the thin-skinned model shows a rather broad deformation pattern (Hu, *et al*, 2001). The sharp features across the SanYi-Puli seismic zone could be caused by bottom driven forces instead of side forces. To test this idea we present numerical models of 2D+1D oblique compression in a visco-elasto-plastic lithosphere. The brittle crust is modeled as a frictional and cohesional material, and the ductile crust is modeled as a non-Newtonian Maxwell visco-elastic material. Faults in the brittle parts of model are formed by locally decreasing the cohesion as a function of plastic strain. When both convergence and strike-slip are driven from the sides of the model (as in the thin skinned model) a broad zone of deformation develops. When oblique compression is driven from the bottom of the model we find that a narrow zone of deformation is generated as seen in the SanYi Puli seismic zone. Such a result is consistent with the 3D physical experiments of Chemenda *et al* (1997), and implies that the complexities of the Chi-Chi event is caused by its location near the vertex of the changeover from overthrusting to subducting motion between the Philippine Sea and the Eurasian plates, and driven from the bottom.

T41E-09 1050h INVITED

The Chi-Chi Earthquake and the Seismic Cycle Associated with Mountain Building in Central Taiwan

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Co-seismic deformation due to the 1999 Chi-Chi earthquake, Mw=7.6, was measured from SPOT satellite images in combination to available co-seismic GPS data. Surface ruptures clearly show off in the measured horizontal displacement field allowing for a detailed cartography and measurement of co-seismic slip along the fault trace. The strike-perpendicular component varies smoothly and indicates 4-5 m thrust on average. The strike-parallel component of about 3-4 m to the south, near the epicenter, gradually increases northward to reach about 7-8 m. This pattern is associated with a general clockwise deviation of surface displacements to the north. Displacements and strain are much larger in the hanging wall than in the footwall. The zone of large co-seismic surface displacement fall within the Sun Moon Lake seismic gap and is bounded to the east by the range front where intense micro-seismic activity was taking place before the earthquake. Co-seismic deformation was modelled using elastic dislocations. The fault geometry was constrained from structural geology. Its geometry and the slip distribution were adjusted to fit both horizontal surface displacements measured from SPOT and vertical displacements measured from GPS. The fault plane makes shallow 20-35° east dipping ramp and roots into a dcollement at a depth of 6 to 8 km. The data are satisfactorily adjusted, assuming a nearly constant slip azimuth on the main fault plane close to the azimuth of plate convergence (N305°E +/-5°) and with most of the co-seismic slip being confined (near the surface) on the shallow ramp. The northward rotation of displacements are well reproduced from the model and thus appear to be an edge effect due to oblique direction of thrusting and to the eastward bend of the fault trace at its northern end. Based on these data, we suggest that the model proposed for the Himalaya of Nepal also apply to some extent to the central range of Taiwan. In the inter-seismic period, aseismic shear, in a direction imposed by the convergence azimuth across the range, takes place below the high topography of the Central Range where ductile deformation is enhanced by relatively high crustal temperatures while the frontal thrust faults remain locked. GPS measurements indicate that this shear zone was creeping at 35-45 mm/yr. before the Chi-Chi earthquake. This process leads to elastic strain and stress build up along the front of the range, triggering micro-seismic activity. On the long term, deformation is accommodated by overthrusting along the foothills, the strain transfer being the results of large earthquakes such as the Chi-Chi earthquake. Surface displacements during the Chi-Chi earthquake indicate however that, the dcollement connecting the ramp with the creeping zone is a zone of slip deficit. Because sufficiently large post-seismic slip there seems improbable this zone probably also breaks during large earthquakes. Finally earthquakes must also occasionally break the most frontal Changhua fault, lying parallel to the Chelungpu fault. Assuming that these range bounding faults are associated with typically M=7 to 7.5 magnitude earthquakes, they would produce such an event every about 150-250 yr. activating either the Changhua, the Chelungpu faults, or the dcollement at depth. There is however a variety of possible scenarii of strain transfer through earthquakes that may invoke infrequent larger earthquakes.

T41E-10 1105h

The Implications of Unusual High Helium Isotopic Ratios in Non-Volcanic Area of Western Taiwan

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Representative gas samples of fumaroles, springs, mud volcanoes, natural gases were collected from Taiwan for helium isotopes measurement. Samples from northern and eastern Taiwan exhibit higher 3He/4He ratios, which indicates significant mantle-derived signature. The result is not unexpected, since hydrothermal activity is still active at those areas. Nevertheless, some unusual high 3He/4He ratios are obtained from non-volcanic area in western Taiwan. Carbon isotopes of CO2 and CO2/3He ratios in those samples are similar with those from mid-ocean ridge basalts, which believed to be derived from upper mantle. Hence, we are able to conclude that they are mantle-derived. Furthermore, we propose that they are not in-situ mantle-derived volatiles. They may be associated with Miocene magmatism and have been trapped by impermeable formation during the stage of basin subsidence before orogenic event occurred. Consequently, the deep normal faults may be reactivated as reverse faults by continuous compressive stress and cut through the capped rock of the gas reservoir. The old mantle gases, hence, could be released to surface through the leakage.

T41E-11 1120h

Active Continental Growth Under Transpressional Tectonics V Example from Southeastern Taiwan

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Based on structural analysis and recent tectonic motions from the GPS data, we propose that active continental growth in the southeastern Taiwan is resulted from the oblique accretion of the Luzon arc. We found that the deformation structures in the Miocene deposits of the southeastern Central Range exhibit several characteristics of early-stage orogenic processes. These brittle-ductile characteristics indicate tectonic processes including underthrusting, exhumation, and left-lateral transpressional movements. Because the Luzon arc, which is located about 100 km east of the Taiwan island, has not yet to be collided with the southeastern Central Range, it seems evident that the observed deformation structures in the southeastern Central Range occurred before the arc-continental collision. Across the southern Central Range, regional foliation orientations generally display a fan-shaped pattern. In addition, kilometer-scale overturned structures were mapped at the southeastern flank of the Central Range. This overall upward flower structure is consistent with an early-proposed exhumation model, which interprets the presence of higher-grade rocks along the central axis of the mountain belt. Because of the rapid uplifting and erosion rates in Taiwan, it suggests that many early orogenic structures, such as those observed in the southeastern Taiwan, were either obliterated or eroded away in the older mountain belt in the north. Based on previously published GPS data, we estimated the southward propagation rate of the accretion of the Luzon arc along the Longitudinal Valley, to be 7.9 cm/yr. In general, the above kinematics data suggest left-lateral transpressional tectonic movement is currently important process in the southeastern Taiwan. And under such tectonic movement, we highlight the contribution of the Luzon arc accretion to the continental growth of East Asia.

T41E-12 1135h INVITED

Rapid Creeping on the Historic Earthquake Fault in the Chihshang Area: Active Tectonics at the Plate-Suture Between Eurasia and Philippine Sea in Eastern Taiwan

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The Chihshang fault is an active segment of the Longitudinal Valley Fault, the plate suture between the converging Philippine and Eurasian plates. A big earthquake of Mw 7.0 resulted from rupturing of the Chihshang fault in 1951. From that on, no big earthquake greater than M 6 occurred in this area. Instead, the Chihshang fault reveals a creeping behavior at least during the past 15 observation years.

Data from geodetic trilateration network (1986-1988) indicate a horizontal shortening of 22 mm/yr concentrated on the Chihshang fault zone. Leveling of 1987-1988 across the Longitudinal Valley shows a abrupt uplift of 2 cm/yr on the eastern side of the Chihshang fault. GPS measurements of 1992-1999 show a steady horizontal shortening of 30 mm/yr across the Longitudinal Valley in the Chihshang area. Outcrop observation reveals that the surface breaks of the active Chihshang fault are characterized by one or multiple thrust-type ruptures within a narrow zone of 30-100 m wide. Annual outcrop measurements since 1990 show a nearly steady displacement of about 2-3 cm/yr, however, with a seasonal variation from the later biannual measurements since 1996. Combining the above geodetic and geologic data, we can obtain the geometry and kinematics of the Chihshang fault the Chihshang fault strikes N20E, dips 45-55 to the east, and moves as a reverse fault with 1/3 component of left-lateral strike

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