Tectonophysics

T11A MCC: 3007 Monday 0800h

Earthquake Geology and Hazards of East Asia I *(joint with S)*

Presiding: **Y Chen,** National Taiwan University**; K Mueller,** University of Colorado**; Y Sugiyama,** National Institute of Advanced Industrial Science and Technology

T11A-01 0800h INVITED

Deep geometry and evolution of the northern part of Itoigwa-Shizuoka Tectonic Line active fault system, Central Japan, revealed by Seismic profiling

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The northern Fossa Magna (NFM) is a Miocene rift system produced in the final stages of the opening of the Sea of Japan. It divides the major structure of Japan into SW and NE portions. The Itoigawa-Shizuoka Tectonic Line (ISTL) bounds the western part of the northern Fossa Magna and forms an active fault system showing the one of the largest slip rates in the Japanese islands. Based on the paleo-seismological data, the ISTL active fault system was evaluated to have the highest seismic risk among active faults within inland Japan. A quantitative understanding of active tectonic processes, including crustal deformation and related destructive earthquakes, is important in reducing seismic hazards through precise estimation of strong ground motions. The structure of the crust, especially the deep geometry of active fault systems, is the most important piece information required to construct such a dynamic model. In this context, the seismic reflection profiling was performed across the northern part of the ISTL active fault system by three seismic lines. Obtained seismic sections are interpreted based on the pattern of reflectors, surface geology and velocity model by refraction analysis, using the balanced cross section technique. The 68-km-long Itoshizu 2002 seismic section across the northern middle part of the ISTL active fault system suggest that the Miocene NFM basin was formed by an east dipping normal fault with shallow flat (6 km), deeper ramp (6 <ETH> 15 km) and deeper flat at 15 km in depth. This unique geometry is interpreted that this low-angle normal fault was produced by Miocene high thermal regime, estimated from the thick volcanic rocks at the base of the basin fill. Namely, the normal fault reflects the brittle-ductile boundary in Miocene. Consequently, since the Pliocene, the basin fill was strongly folded by the reverse faulting along the pre-existing normal faults in the Pre-Neogene rocks. The reverse faults in the basin fill produced fault-related folds on their hanging wall. Westward migration of thrusting is recognized by shallow high-resolution seismic section and tectonic geomorphology. The ISTL active fault is an emergent thrust dipping 30 degrees to the east and no evidence is observed showing late Quaternary faulting along the fault, runs parallel to the ISTL and located east of it. Based on the balanced geologic cross-section, the total amount of Miocene extension is ca. 45 km and the total amount of shortening is ca. 25 km. If we assume that the shortening deformation has continued since 5 Ma at constant rate, the horizontal slip rate is calculated as 5 mm/y. The late Quaternary slip rate in the northern part of the ISTL active fault system based on very shallow seismic profiling and drilling shows similar value. The 7-km-long seismic section (Matsumoto 2002) across the middle part of ISTL active fault system also suggests that east-dipping fault geometry at gentle dip. To summarize deep geometry of the ISTL active fault system is strongly controlled by the Miocene extensional structure.

T11A-02 0820h

A Holocene Seismic Event and Earthquake Potential of the Uemachi Fault in Metropolitan Osaka, Estimated From High-resolution Analyses of Continuously Cored Boreholes and Seismic Reflection Profiles

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We completed a high-resolution stratigraphic correlation of five continuously cored boreholes and identified a probable earthquake event dated as 9,200 to 9,500 calibrated 14C years BP on the 45-km-long Uemachi fault system traversing Metropolitan Osaka. The 50 to 75 m-spaced, 37 to 50 m-long five cores were extracted from a subsurface flexure zone of the northern part of the Uemachi fault, a main strand of the fault system. Correlation of the five cores were carefully undertaken based on densely measured vertical change of density, magnetic susceptibility, brightness, hue, pH, electric conductivity and pollen assemblage. Depth distribution of recognized correlation surfaces through the five cores indicates an about 2 m vertical uplift during the earthquake event in early Holocene time, and lack of postdating faulting events. High-resolution S-wave seismic reflection profiling across the 450-m-wide subsurface flexure has revealed that the flexure deformation associated with the last event is concentrated within the approximately 50-m-wide foremost part of the flexure zone. The seismic profile linked with the five borehole data also suggests the advancement of the front of flexure deformation at the time of the last faulting event. An average uplift rate of 0.3 m/ky in the past 3 My is estimated for the northern part of the Uemachi fault from 800 m vertical offset of the basal surface of the Plio-Pleistocene Osaka Group. The displaced basal surface is clearly imaged on the two existing deep seismic profiles (P-wave and S-wave profiles) across the entire flexure zone. An average uplift rate larger than 0.2 m/ky in the past 0.6 my is also estimated from the existing deep boreholes named OD-5 and OD-8, which are located on the downthrown side and in the midst of the flexure zone, respectively. If we assume average uplift rate to be 0.3 m/ky and coseismic uplift to be 2 m for the northern part of the Uemachi fault, the mean recurrence interval of the fault is estimated to be around 7,000 years. The elapsed time ratio of the Uemachi fault may have already exceeded 100 percent, and earthquake potential of the fault may be raised to nearly the same level as the Nojima fault immediately before the 1995 Kobe earthquake.

T11A-03 0835h

Reverse faulting Events of the Ohchigata Fault Zone, Central Japan

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The Ohchi plain is one of the NE-SW trending tectonic depressions located at the base of the Noto Peninsula protruding into the Japan Sea. Tectonic setting of this area has been changed from the tensional stress field related to the opening of the Japan Sea during Miocene into the compressional stress field after Pliocene. Geologists in 1930's discussed that geological structure of the both margins of this plain are controlled by normal faults or folds. In 1970's, geomorphologists referred that those are reverse faults and active during late Quaternary period based on the study on the terrace deformations. Our seismic reflection profiling surveys in 2001 and 2002 clearly imaged thrust faults dipping approximately 30 degrees to the mountain side beneath both of the margins of this plain. In 2003, we excavated a trench on the fault along the southwestern plain margin. The result shows that this fault has repeatedly been reactivated during late Pleistocene and the last faulting occurred around 3,000 years ago. Active faults along the margins of this plain are called the Ohchigata Fault Zone. Based on the topographic study using the aero-photographs, several tectonic landforms are identified on the alluvial terraces traversed by the Sekidosan fault along the southern margin of this plain. This fault strikes N45E and has produced a scarp about 2 m high at Mijiro site. In order to obtain the information on faulting history, we excavated a trench across the fault scarp at this site. On the trench walls, a reverse fault dipping 10 to 45 degrees to the southeast was exposed. On the upthrown side of the fault, thin terrace deposits in Holocene overlie late Pleistocene beds intercalating 2 layers of widespread volcanic ash, that may correspond to AT (29 ka) and Aso-4 (85-90 ka), respectively. The Pleistocene beds are extensively deformed and partly overturned near the fault. On the downthrown side, a layer of sand and gravel dated at around 3,000 yrs BP by 14C dating method (AMS) is vertically displaced about 2.2 m by this fault.

T11A-04 0850h

Significant contributions from shallow sediments to PKP travel time delays and the implications: an example from Taiwan and its nearby islands

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PKP waves, which penetrate the Earth's core and arrive back at the Earth's surface at near vertical incident angles, are generally regarded as invaluable when it comes to probing deep Earth structures. Such observations provide an ideal opportunity to measure individual travel time residuals and thereby independently examine either seismic velocity models from different approaches or regional tectonic models based on a variety of geodynamic hypotheses. However, the contribution of travel time delays from shallow geological structures to PKP travel time residuals is, however, quite general undefined in any seismic array, and accordingly, their implications have rarely been discussed. Relative PKP travel time residuals determined in the Taiwan region vary from -2.5 to +2.0 seconds, a range greater than the highest teleseismic travel time delays from deep earth. These data were used in this study to evaluate two three-dimensional crustal models of Taiwan derived from updated tomographic inversion studies. It is found that the tomographic models are able to predict PKP delay times of less than 40% and the PKP residuals are indeed consistent with the values of station corrections used in determining local earthquakes. Employing detailed gravity measurements, we interpreted these data to infer lateral heterogeneity beneath Taiwan. It is to be noted that the observed PKP residuals in Taiwan are strongly affected by the travel time delays of shallow sediments and that both of the 3-D regional crustal models failed to consider this low velocity layer. The implications of this study are that the time delays from shallow sediments obstruct the seismic inversion of deep earth structures when teleseismic waves are used and that local earthquake locations beneath thick sediments cannot, therefore, be accurately determined.

T11A-05 0905h INVITED

Tectonics of the Ailao Shan-Red River Fault Belt in East Asia

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The Ailao Shan-Red River (ASRR) fault belt is one of the most profound active strike-slip faults in East Asia. It is generally believed that the Cenozoic India-Eurasia collision caused the southeastward extrusion of Indochina along the ASRR fault belt (left-lateral displacement) in mid Tertiary. However, geomorphologic evidences and earthquake focal mechanism solutions do indicate a present-day right-lateral slip of the ASRR. Structural analyses and field observation along the ASRR in northern Vietnam revealed that the ASRR has undergone multiple phases and styles of deformation (three ductile folding events with a younger brittle deformation) possibly since Triassic to Pliocene. The deformation history, combined with offshore exploration data and igneous activities, enabled us to better constrain the tectonic evolution of the ASRR. A previously unrecognized deformation event (D1) with foliations showing dextral sense of shear possibly formed during the Triassic Indosinian orogeny or during Eocene post India-Eurasia collision. D2 is the strongest deformation event within the ASRR forming large-scale horizontal folds possibly commenced since Eocene-Oligocene as the thickened ductile crust flowed eastwardly away from the Tibetan Plateau under SE Asia, and extended to Early Miocene till termination of sinsitral strike-slip movement of the ASRR. D3 continuously uplifted most of the ASRR and formed current antiformal domes in northern Vietnam with NW-SE subvertical fold axial planes parallel to the trend of ASRR, possibly due to the right-lateral movement of the ASRR during Late Miocene to Pliocene. Continuous denudation uplifted the ASRR crossing the brittle-ductile transition zone forming brittle structures (D4) as the right-lateral movement of the ASRR continued.

T11A-06 0925h

Paleoseimology deduced from the Fengyuan trench on the northern part of the Chelungpu Fault, central Taiwan: an example of very low angle reverse fault

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We carried out the trenching and boring at the western margin of the lowest terrace, east of Fengyuan City, in order to know the nature and frequency of the faulting, on the northern part of the Chelungpu fault, central Taiwan. At this trench, we found that in addition to the 1999 earthquake fault which is characterized by the very low angle reverse fault with overturning of the younger strata, the penultimate earthquake event, which occurred between ca. 1400 yr BP and 2000 yr BP. The age of the lower part of the terrace gravel (Bed E) is ca. 4000 yr BP, thus two faulting events occurred during the past ca.4000 years. The amount of horizontal shortening and vertical displacement of the penultimate event are twice of those of the 1999 earthquake, supporting the presence of two events. The age of the penultimate earthquake at the Fengyuan site is the oldest record within the Chelungpu fault so far and suggests this part of the Chelungpu fault represents an independent segment from the central and southern part.

T11B MCC: 3005 Monday 0800h

Observational and Theoretical Insights Into the Structure and Dynamics of Mid-Ocean Ridges I

(joint with V)

Presiding: **W H Smith,** NOAA Laboratory for Satellite Altimetry**; J A Goff,** Institute for Geophysics, University of Texas

T11B-01 0800h

Correlating the textures of altimetric gravity and multibeam bathymetry

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We compare the tectonic fabric textures seen in altimetric gravity and multibeam bathymetry at sites on the flanks of slow- and fast-spreading ridges, midplate, and back-arc basin areas. Our aim is to correlate altimetric and bathymetric textures, to determine the limits of resolution of current altimetric data, and to characterize the seafloor texture signals that should be recoverable with a future altimetric mission having a lower noise floor than existing data. Multibeam data we compiled for this analysis are from the RIDGE synthesis, the NGDC coastal and global relief projects and other holdings, and data contributed by other investigators. Altimetric data are gravity version 11.1 (18 km filter) and topography "polish" version 8.2. All our data are available at http://ibis.grdl.noaa.gov/SAT/Bathy.intro.html Areas with dense multibeam swath coverage are necessarily small, and the wavelengths our data sets resolve are mostly in the uncompensated band. Simple forward models of gravity assuming uncompensated seafloor topography agree well with altimetric gravity in amplitude and spectral roll-off, except at the shortest wavelengths where altimetric fields are too smooth. Where abyssal hill amplitudes and wavelengths are large enough, gravity texture shows clear ridge-parallel lineations.

URL: http://ibis.grdl.noaa.gov/SAT/Bathy.intro.html

T11B-02 0815h

The Correspondence of Altimetric Gravity Texture to Abyssal Hill Morphology

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We examine the possible relationship between altimetric and abyssal hill textures along the flanks of Southeast Indian Ridge, where previous studies observed a progressive west-to-east increase in abyssal hill roughness and scales. Such a relationship is often considered unlikely because abyssal hills are typically smaller than upward continuation filter scales. Nevertheless our analysis, which carefully avoids inclusion of fracture zones and major propagator psuedofaults, also demonstrates a west-to-east increase in gravity rms roughness and scale. The rms exhibits the most well resolved variations. Characteristic scales and aspect ratios also increase to the east, although less resolvably. At the roughest gravity textures, ∼ridge-parallel lineaments can be resolved, suggesting that this texture is directly responding to abyssal hill morphology. We suggest that the westernmost gravity texture samples, adjacent to axial high regions, represent a base noise level. The rms roughness of these data is ∼4 mgals with a characteristic scale of ∼9 km. We demonstrate, using synthetic realizations, how a filtered product such as altimetric gravity could be responsive to variations in the unfiltered substrate from which it was derived at scales smaller than the length of the filter. We first compare the roughness and characteristic scales from filtered and unfiltered profiles. Filtered profile scales are weakly dependent on unfiltered scale where the latter are smaller than the filter size, but possibly resolvable enough so the lineated fabric of larger abyssal hills could be evident in the altimetry data. The roughness of the filtered profiles is found to be strongly dependent on both the roughness and scale of the unfiltered profiles. Altimetric roughness may thus be very sensitive to gross changes in abyssal hills, even those too small to be directly resolved. A reduction in the noise level by future altimetry missions would greatly enhance this response. Our follow-up investigations will focus on predictions of altimetry texture based on upward continuation of 2-D abyssal hill morphology and realistic renderings of altimetric noise.

T11B-03 0830h

Evidence for Highly Focused Magmatic Accretion Along the Ultra-Slow Southwest Indian Ridge

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The Southwest Indian Ridge (SWIR) spreads at effective slow to ultra-slow rates of only 8-15 mm/yr at the 7°-16°E region, depending on its local obliquity. During Dec. 2000-Jan. 2001 and Jan.-Feb. 2003, we carried out an extensive SeaBeam bathymetry, gravity, and magnetic survey, as well as rock dredging, of a 400-km-long section of the SWIR, including the Shaka transform. The results reveal dramatic variations in seafloor morphology, residual gravity anomaly, crustal magnetization, and rock types within the surveyed region. A 50-km-long segment centered on 14°30' E, which we call the "Narrowgate" segment, has a well-defined narrow axial rift valley, a bull-eye-shaped mantle Bouguer gravity low with along-axis amplitude of 25 mGal, and clear off-axis record of magnetic stripes to crustal age of 7 Ma. These ridge-axis features resemble a classic slow-spreading ridge segment in the northern Mid-Atlantic Ridge. However, this ridge segment appears to be less robust prior to 7 Ma. To the west, a 200-km-long stretch of the ridge axis at 11°45'-14°15'E lies obliquely to the spreading direction, resulting in effective ultra-slow full spreading rates of only 8 mm/yr. The relatively deep rift valley, systematically positive mantle Bouguer gravity, and extremely low amplitude of crustal magnetization suggest that while lithosphere is formed there, it has very little magmatic crust. Such interpretation is collaborated by the abundance of ultramafic rocks dredged on this stretch of the ridge. Further westward, an apparently robust ridge segment, called the Joseph Mayes Seamount segment, is found near 11°20'E. This 40-km-long ridge segment is associated with major mantle Bouguer anomaly with along-axis amplitude of 40 mGal as well as strong crustal magnetization. However, this ridge segment appears to have become magmatically robust only 3-4 Ma. Together the above evidence suggests that magma accretion along this stretch of the SWIR axis is highly focused in space and time. We propose a model in which the overall low magma supply rate and dominant lithospheric cooling at a slow/ultra-slow ridge will result in temporal centers of highly focused magma accretion. The extremely heterogeneous thermal and rheological boundaries in the lithosphere should help lateral migration of melts to be pooled towards such temporal centers of magmatic accretion.

T11B-04 0845h

Correlation of Shallow Seismic Structure and Observed Geologic Boundaries of Fast-Spreading Crust Exposed Near Hess Deep

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In July 2003 we conducted a seismic survey over fast-spreading crust adjacent to the Hess Deep rift. The program acquired 16 MCS profiles parallel to the scarp