S72B-1148 1330h POSTER

Strain Energy Flow and the Accumulation of Large Earthquake Energies in the Island Arc-Trench Dynamics (NE Japan Arc)

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A gravitational shear flow of the island-arc rock-mass was newly revealed under the Japan trench inner slope on the artifact-free and distortion-free seismic reflection profiles (Nagumo and Tsuru (2001), Eos. Trans. AGU82(47), Fall.Meet. Suppl. Abstract T12D-0934). Based on such a shear flow phenomena, I envision a picture of the island arc-trench dynamics as below. The hot upper mantle under the volcanic arc generates buoyancy, and uplifts the volcanic arc. The uplifted island arc rock-mass gains excess gravitational potential energy. The surface inclination from the central arc towards the trench axis generates horizontal driving force within the arc mass, and generates shear stresses, shear deformations, and shear strain energies.

In the deep part of the crust, such shear stresses exceed the critical value, and the rock-masses are in a state of shear flow. Because of rather hot thermal regime, such a shear flow of rock-masses predominates within the ductile intermediate zone of the crust, which ranges from the basal granitic layer to the upper part of the basaltic layer.

The shear flow carries the whole island-arc mass towards trench axis from the central volcanic arc and transports the strain energies, which are involved within the deformed rock-mass, and forms a flow of strain energy. Such a gravitational flow of the rock-mass is a behavior of viscous fluids in a long time scale.

When the strain energy flow is obstructed by some mechanism, a part of the strain energy flow is trapped, and stored around the obstacles. The stored energies accumulate with elapse of time, and results in an occurrence of large earthquake.

I postulate that the occurrence condition of a large earthquake is such that the average density of the accumulated strain energy within the volume of the self-adjoined domain attains a certain critical level. Then, we can estimate the earthquake radiation energy by the product of the critical strain energy and the volume of the self-adjoined domain. The gravitational potential energy is sufficient enough to generate the large earthquake energies in the forearc region. The energy supply by the subducting oceanic plate is not required.

Such a view of strain energy accumulation process may relate to the variety of the asperity, repetition interval of occurrence, and the types of earthquakes, such as main shock type, swarm type and etc. The above picture of the island arc-trench dynamics does not require subduction-accretion tectonics.

S72B-1149 1330h POSTER

Source Characteristics of Shallow Intraslab Earthquakes from Strong Motion Data

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Large shallow intraslab earthquakes, occurring within subducting slabs at 30-100km depths, generate earthquake damages by strong ground motions (e.g. the 1993 Kushiro-oki earthquake, the 2001 Geiyo earthquake, and the 2001 Nisqually earthquake). Source characteristics of intraslab earthquakes have been pointed out to have some different features compared to those of inland crustal earthquakes and interplate earthquakes by some researchers. We examined six shallow intraslab earthquakes that recently occurred around Japan ($M_{JMA}5.1-7.0$) using dense strong motion network data.

The observed peak ground accelerations at K-NET stations for the 2001 Geiyo earthquake in near distance are about 3 times larger than those expected from the attenuation relation based on inland crustal earthquakes proposed by Fukushima and Tanaka (1992). For other intraslab events, the observed peak ground accelerations are also larger than the expected values. These seem to be related with high stress drop in source as well as low attenuation along the propagation path in case of intraslab earthquakes.

We carried out strong motion simulation based on the empirical Green's function method to investigate the source characteristics of intraslab earthquakes. Using the empirical Green's function method, we can construct the source model to explain observed waveforms in broadband frequency range (Irikura, 1986; Miyake et al., 1999). We used the observed waveforms of a small event occurring at each source region as the empirical Green's function, and estimated the number, size, and location of asperity (strong motion generation area), rise time, and rupture propagation velocity of target events by forward modeling.

Since the combined area of asperities obtained for each earthquake is about 14-66% of values predicted by the empirical relation for inland crustal earthquakes proposed by Somerville et al. (1999), the stress drops on asperity of shallow intraslab earthquakes are higher than those of inland crustal earthquakes. The ratios between the combined area of asperities obtained in this study and the value predicted from the empirical relation decrease with focal depth. The stress drops on asperity of shallow intraslab earthquakes increase with focal depth.

We used the strong motion data from K-NET, KiK-net, and F-net operated by the National Research Institute for Earth Science and Disaster Prevention (NIED) and the CMT solutions by F-net and Harvard University. We also used the hypocentral information provided by the Japan Meteorological Agency (JMA).

S72B-1150 1330h POSTER

Calibration for Coda Derived Moment Magnitude Using Berkeley Complete Waveform Moment-Tensor Solutions

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The method of seismic moment-tensor determination using complete waveforms (Dreger and Helmberger, 1993; Pasyanos et al., 1996) provides stable solutions for local and regional events if the data propagation paths are well-calibrated to calculate Green's functions. However, this waveform modeling approach has a limitation to apply to smaller events with the cut-off magnitude of approximately 3.5 due to reduction of S/N ratios in the passband employed. We carried out an experiment to extend the moment magnitude scale to smaller events (M<3.5) in northern California using an empirical method of coda derived moment magnitude (M_w(coda)) calibration (Mayeda et al., 2002). The basic assumption of this approach is that the coda spectra are the results of scatters from randomly distributed inhomogeneities in the crust and represent seismic energy propagation, independent of the source radiation pattern, as a function of propagation distance with a specific attenuation rule. In practice we found that when the data propagation paths cross a wide range of different structural areas, the standard deviation of the parameters is large and the parameter estimation is less coherent. Thus, in the course of calibration the entire northern California is divided into several tectonic subregions, in each of which the calibration parameters are relatively coherent. The present study suggests a conservative application of the coda envelope calibration method to estimate M_w(coda) that avoids ambiguities.

URL: http://www.sci.hiroshima-u.ac.jp/

S72C MCC: 133 Sunday 1330h

Plumes, Hot Spots, and Calderas II

(joint with G, GP, OS, T, V, DI)

Presiding: **U Achauer,** Institute de Physique du Globe (IPG)**; G Ito,** University of Hawaii

S72C-01 1330h

En Echelon Volcanic Ridges Along Seamount Chains Result from Episodic Changes In Stress Orientations That Open Cracks to the Asthenosphere and Permit Magma Ascent: They do not Require Plumes

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An alternative to the plume/hotspot hypothesis for seamount chains is formation via cracks through the lithosphere. Many Pacific Cenozoic seamount chains comprise intermittently spaced volcanic ridges aligned en echelon to the overall trend of the chain, a pattern that reflects tensional stresses in the lithospheric plate at angles to the trend. The overall trend is a line of incipient cracking close to the average direction of plate motion in the fixed-Antarctica reference frame. The ridges mark episodic, relatively local deviations in the orientation of the stress field, permitting the incipient tensional cracks to open through the lithosphere to the asthenosphere. The upper parts of the asthenosphere are at the solidus temperature, as manifested in lower seismic velocities indicating the presence of small fractions of melt, such that through-going cracks allow magmas to form and ascend toward the surface where they erupt to form the volcanoes and en echelon ridges. High fertility of the source region favors increased volumes of magma. Cracks typically break though in the younger parts of the lithosphere, which is thinner and weaker than older lithosphere, but cracking is possible anywhere along the volcanic trend where the lithosphere is thin or weak. Cracking is common, for example, along the thinned lithosphere of the boudinage-like structures imaged on regional gravity maps, as in the Pukapuka chain, which follows one of the regional gravity lows. There, the time sequence of volcanic ridges is not progressive. The markedly different orientation of the youngest parts of the Hawaiian chain, compared to the long-term average trend of the chain, may record a change in regional stress orientations in the Pacific plate beginning about 3-4 Ma, reflected also in the Marquesas and younger parts of the Society Islands.

The en echelon crack mechanism requires no excessive "hotspot" temperatures and no plumes.

S72C-02 1345h INVITED

Seismic Evidence for a Plume Beneath the Galápagos Hotspot

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The Galápagos hotspot and Galápagos Spreading Center system provide a promising environment for testing further the plume hypothesis and for developing a comprehensive model of hotspot magmatism and hotspot-ridge dynamics. The near-ridge setting of the Galápagos hotspot and its location with respect to seismic sources provide unparalled opportunities to image upper-mantle anomalies associated with hotspots and ridges. Here we report on a reconnaissance, land-based seismic experiment designed to image the structure of the crust and upper mantle beneath the archipelago. The data comprise broadband, three-component seismograms recorded at twelve sites; the aperture of the seismic network is 300 km.

Initial results indicate that the Galápagos hotspot is underlain by an anomalously thin transition zone and by an upper-mantle low-velocity anomaly consistent with a mantle plume. The transition-zone structure of the Galápagos region in general is similar to that of the Pacific basin in areas removed from hotspots and to sites within the western U.S. However, a subset of data that sample a region centered to the west-southwest of Isabela indicates a 45-km thinning of the mantle transition zone. To produce this thinning by a plume that penetrates the transition zone requires a temperature anomaly of as much as 300 K relative to the average Pacific basin or tectonically active North American sites. This value is similar to the temperature anomaly inferred by others for the Hawaiian plume and is twice as large as the thermal anomaly inferred for Iceland. Tomographic inversion of body-wave delay times reveals a pronounced low-velocity anomaly centered near the southwestern corner of Isabela, above the area of thinned transition zone. This anomaly, which we interpret to be the axis of the plume, is narrower than the anomaly imaged beneath Iceland. At depths less than 150 km the region of lowest seismic velocities, inferred to be plume-derived material, is deflected first to the northeast beneath the central archipelago and then to the north-northwest along the Wolf-Darwin

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lineament. There is little evidence of hot plume material pancaking beneath the lithosphere, particularly beneath the northern islands of Pinta, Marchena, or Genovesa, which appear to be underlain by mantle that is seismically fast in comparison with mantle beneath the Wolf-Darwin lineament. The delivery of plume material to the ridge axis along the Wolf-Darwin lineament, as our initial results suggest, cannot be the result of simple thermal erosion at the base of the lithosphere by a fixed plume because the geometry is not that expected from plate kinematics. Our results contradict many predictions of previous studies, including that the plume is (i) located beneath Fernandina, (ii) wet (not hot), and (iii) spreading out radially toward the Galápagos Spreading Center.

S72C-03 1400h INVITED

Réunion (Indian Ocean) Oceanic Island Volcanism: Seismic Structure and Heterogeneity of the Upper Lithosphere

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Réunion island in the Indian Ocean is commonly considered as the recent and active expression of the hotspot that formed the Deccan traps, although both the hypothesis of recent small hotspots for both Reunion and Mauritius, or of relation with the plate heterogeneity have been proposed. Structural studies by seismic methods, from the scale of the upper cone of the active Fournaise volcano to that of the crust 100 km around, have been carried out. At this scale significant departures appear from the Hawaiian case to which it is traditionally compared, with the seismic signature of active volcanism showing differences too. Refraction-reflection seismics do not see a geometry of the top of the underlying plate towards the island, expected in plate flexure modelling by analogy with other hotspot island. Where it is sampled, doming is suggested instead. There appears to be less magmatic products than if there was a large amount buried in a flexural depression. The velocity structure resolved for the volcanic island, apart from high velocity cores under the volcanoes leads to smaller overall density than usually considered in flexure modelling. The same appears to hold for the material of the cone of about 120 km radius rising above the regional sea-bottom level to the 30 km radius island, from coincident reflection and refraction seismics on several lines radial to the south-eastern half of the island. At the crust-mantle level, there is evidence from reflection-refraction line extending 150 km either side of the island for a layer of velocity intermediate between normal crust and mantle values. Two radial reflection line to the SSW, close to each other detect a differences in depth of the oceanic basement. This may coincide with a fracture zone suggested from the reconstruction of the sea-floor spreading history from the magnetic anomaly pattern. The latter has been interpreted previously to indicate that the western part of Réunion developed atop a Paleogene fossil accretionary center. This has also been suggested for Mauritius island, the two fossil accretionary center having been active on different sides of a triple junction, and carried away from each other along the later fracture zone in-between. The available seismic data sample only from the top of the island to the top of the mantle. At this scale they evidence a departure of Réunion from an idealized oceanic hotspot volcanic islands model, as well as the relation of its location with a structural heterogeneity of the underlying lithosphere that appears inherited from its complex origin. These partly unexpected results suggest that the case deserves further sampling at the broader regional scale including Mauritius, and deeper into the mantle

S72C-04 1415h INVITED

Geodynamics of the Yellowstone Hotspot: Plume or Not?

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A collaborative research project has focused study on the Yellowstone hotspot to understand its geodynamic processes and to assess whether it has a deep mantle source. The study includes seismic and GPS investigations over a large portion of northwestern U.S., focusing on the possible plume-plate interaction that is hypothesized for the Yellowstone-Snake River Plain (YSRP) volcanic field. Regional deformation reveals dominant NE-SW extension of the entire system. Seismic tomography reveals low-velocity crustal bodies beneath Yellowstone and an upper mantle P- and S-wave low-velocity anomaly flanked by high velocities. The mantle low-velocity body extends in depth from 90 km to 200 km and is indicative of partial melt beneath the plain and basalt depletion extending laterally outward beneath the tectonic parabola. Kinematic models reveal a fan-shaped, opening of the northern Basin-Range extending westward from Yellowstone toward the Pacific Northwest.These observations suggest a plume interpretation with melt-driven convection ascending beneath the hotspot and residuum spreading laterally away from the SRP and allow a plume interpretation in which a deep source supplies hot fertile mantle beneath the hotspot. Alternatively, a non-plume hypothesis has convective rolls resulting from asthenospheric upflow behind the mass of depleted residuum moving with North America. In either case, these observations suggest mantle flow beneath the hotspot delivers magma to the crust creating the basalt-rhyolite crustal volcanism and a resulting in a basalt-depleted mantle residuum. Notably, mantle anisotropy reveals relatively uniform NE-SW fast-axes consistent with strain expected for uninterrupted SW plate motion. This strain field does not indicate a plume source. However models of global mantle flow suggest a plume located 1000+ km W of Yellowstone that has a pronounced NE upward geometry entrained in mantle flow (Steinberger and OConnell, 2000). Such a bending plume conduit could produce uniform horizontal flow beneath Yellowstone. At present viable plume and non-plume models are consistent with available observations.

URL: http://www.mines.utah.edu/~ggcmpsem/UUSATRG/CD-Yel/ys-geodyn.html

S72C-05 1430h INVITED

High Resolution Seismic Imaging of the Campi Flegrei Caldera, Southern Italy

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[9]see abstract EGS02-A-06808, EGS XXVII General Assembly, Nice,, April 2002, France

Campi Flegrei is one of the main unrest calderas in the world. Several hundred thousansd people live within its borders. This makes very high the volcanic risk associated even to a minor eruption. The caldera formed as a consequence of a huge ignimbrite eruption around 40000 year b.p. In the last ten thousand years , the volcanic activity has been characterized by the occurrence of explosive eruptions with a return period of thousands year. The last one occured in 1538 , giving rise to an about 130 m, spatter cone.The bottom of the caldera has been continously sinking with an average speed of about 1 cm per year, from 1538 till 1970. Two resurgency episodes occurred in 1970-1972 and 1982-1984 with a nearly simmetrical, up-lift with a maximum of about 3.8 m at the town of Pozzuoli. Then the ground has slowly sinking down and it did not recover its level in 1970. In the past the structure of the caldera has been mainly investigated by a few km deep drillings, earthquake seismic tomography, gravity and magnetic surveys and sporadic observations of teleseismic and wide angle seismic data. The whole geophysical information indicate the following features: a) the evidence of sharp temperature gradients at shallow depths (450 degrees measured at 3km depth) b) the presence of a few km thick, inner basin characterized by low V_P, high V_P/V_S and high Q_P; c) the shape of this basin is consistent with the gravity low anomaly and appear to be the site where most of deformation is concentrated during the recent ground uplift episodes; d) the possible occurrence of a magmatic reservoir at about 4-5 km depth from teleseismic observations and extrapolation of thermal data. Relevant open questions still remain to be answered, mainly concerning the depth and lateral extension of the shallow magmatic reservoir and the possible existence of intra-crustal magmatic sill as it has been found in the nearby Mt.Vesuvius. With the aim to provide new insights on the caldera structure and location of its feeding system, a dense and extended active seismic survey has been performed during September 2001,in the gulfs of Naples and Pozzuoli in the framework of the so called SERAPIS project. 60 three-component stations have been installed on-land in the areas of Campi Flegrei, Mt.Vesuvius and on the islands of Ischia and Procida and 72 sea bottom seismographs (OBS) have been installed in the gulfs of Naples and Pozzuoli. A denser 2D network of 35 OBSs has been deployed in the bay of Pozzuoli aimed at detecting and modeling reflected/converted waves from the possible shallow to deep discontinuities beneath the Campi Flegrei caldera. About 5000 shots have been performed during the SERAPIS experiment, at an average spatial spacing of 125 m, for a total ship travel path of 620 km. We present preliminary results based on the processing and analysis of the SERAPIS and microearthquake data sets, with a particular focusing on the upper crustal structure by seismic tomography, reflection and receiver function methods.

S72C-06 1445h INVITED

Roots of the Long Valley Caldera ? Mono Craters Volcanic Field

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The Long Valley Caldera-Mono Craters volcanic field is a large, bi-modal (basaltic-rhyolitic) system residing in an extensional tectonic setting between the stable Sierra Nevada block on the west and the Basin and Range province on the east. A small eruption at the north end of the Mono Craters as recently as 250 years ago and persistent unrest within Long Valley caldera over the past two decades emphasize that this volcanic field is underlain by an active magmatic system. Seismic and deformation data suggest that the shallow portion of the magmatic system consists of relatively small pockets of melt or partial melt (diameters < 5 km) in the upper 10 to 15 km of the crust beneath the resurgent dome, the south moat, Mammoth Mountain, and perhaps the Mono Craters. Carbon dioxide and helium emissions from Mammoth Mountain have isotopic signatures characteristic of an upper mantle source. Geophysical images of the roots of the magmatic system, however, remain blurred. Indeed, in the vicinity of the volcanic field, the depth to and geometry of the base of the crust and the structural transition from the central Sierra Nevada to the Basin and Range province are still poorly known. Published seismic tomographic inversions indicate that both the caldera and Mono Craters are underlain by volumes of anomalously low P-wave velocities and high S-wave attenuation extending from depths of less than 10 km to lower-crustal depths of 30 to 40 km, although the results of individual inversion differ significantly on important details. Important insights on the roots of the volcanic field come from the mineralogy and chemistry of basaltic over the past 4 million years. Most basalts that erupted prior to the caldera-forming eruption 760,000 ybp have a lithospheric mantle signature while the post-caldera basalt signatures resemble that of the mafic lower-crust global average. This pattern is consistent with a model in which an asthenospheric mantle welt has been rising through an extending and thinning lithospheric mantle along the western edge of the Basin and Range province providing sufficient heat to melt and erode the lithospheric mantle to the base of the lower crust. Aside from these glimmerings, the deep roots of the Long Valley Caldera-Mono Craters system remain in deep shadow.