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Slab melting in some young and hot subduction zones has been reported from geochemical observations and thermal modeling, but there was still no seismic evidence to confirm it. Also the detailed geometry in the deep part of the melting slab is often ambiguous in that the intraslab earthquakes within the Wadati-Benioff zone are only limited to shallower depths. To improve the understanding of both the seismic features and the geometry found in a young and hot subducted slab, we analyze an anomalous moonquake-like seismogram that was generated by an intermediate-depth earthquake recorded in central Japan. Since the subducted Philippine Sea plate in central Japan is extremely young (0-2 Ma) and therefore hot, strong partial melting might have taken place to produce abundant melting spots in the subducted slab. Melting spots, identified as bright spot, could efficiently reflect or scatter much seismic energy and then generate many later phases with large amplitudes. As a result, slab melting can be identified in the deep bending part of the subducted Philippine Sea plate from strong seismic scattering.

S11F MCC: Level 1 Monday 0830h

Scale-Frequency Phenomena and Earth Structure Posters *(joint with NG)*

Presiding: **D A Wiens,** Washington University**; Y Zeng,** Seismological Laboratory, University of Nevada

S11F-0356 0830h POSTER

Fractal Model of Elastic and Electrical Properties of Porous Rock

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A theoretical model of elastic and electrical properties of porous rock was developed for quantitative joint analysis of collocated seismic velocity tomography and magnetotelluric (MT) experiments. A fractal model applied to elastic properties of rock by Spangengerg (1998) was extended to describe electrical properties of porous rock with the same microstructure for a percolation case. An inverted geometrical model of pore spaces and matrix was also developed to consider isolated pores and a system staying near percolation. The simulation results of electrical properties were compared with the empirical Archie's law and former theoretical models of electrical properties of porous rock for special cases of ellipsoidal isolated pores and for interconnected pore geometries, such as a system of tubes along cubic grain edges or films surrounding cubic grains. This comparison shows that the present model is consistent with the former models for special cases. The main advantage of the present model against other theoretical models is possibility to describe both elastic and electrical properties of rock with a single model for a wide range of microstructures including 3D grains and pore anisotropy and various degrees of pore interconnection. It provides us a simple way to obtain the dependency of a resistivity against a seismic velocity for an arbitrary microstructure. Obtained theoretical dependencies of seismic velocity vs. resistivity allow us to estimate a liquid fraction in a structure from explored seicmic velocity and resistivity distribution. Based on the developed model, an attempt have been successfully made to elaborate a quantitative method for solving the problem whether the variation of resistivity and seismic velocities in a region can be attributed to presence of liquid only or whether other causes should be considered. The developed model can be used for parameterization of a joint MT and seismic inverse problem in a variety of geological settings.

S11F-0357 0830h POSTER

Elastic wave velocities anisotropy and dispersion in cracked rocks

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In the static regime (when cracks do not propagate), the simplest hypothesis that can be made is to neglect crack interactions. In fact, we show that such hypothesis takes better into account the interactions than most interactive models (especially the self-consistent and Hudson's approaches) because of the geometrical compensation of interactions that exist when cracks are distributed randomly or in parallel. Kachanov's [1993] non interactive model of solids with many cracks enables us to predict elastic wave velocity anisotropy for non-randomly orientated distribution of cracks. In the transversely isotropic case, we show that P wave anisotropy and S wave birefringence can be very different in the dry and saturated regimes. This model also enables us to quantify the damage in a rock in terms of crack density, as well as preferential orientation of the crack distribution and saturation using laboratory elastic wave velocity measurement data. Predictions are in agreement with microstructural analysis up to crack densities higher than 0.5. By coupling such a model to poroelasticity, we can also predict dispersion between high frequency and low frequency measurements in the saturated regime due to "squirt flow" mechanisms. Dispersion is lower when cracks are not parallel. However, when they are parallel, dispersion can be very high and therefore elastic wave velocity anisotropy observed on the field (at low frequency, i.e.$<$1KHz) can be very different than the one observed in the laboratory (at high frequency, i.e. 1MHz). S wave birefringence is particularly sensitive to saturation and thus to frequency.

S11F-0358 0830h POSTER

Quasi-Cylindrical FDM: an Ultra-Fast 2.5D Waveform Modeling Method for Explosion Seismic Experiments

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We propose a new efficient method for modeling 2.5D wavefields of explosion seismic surveys. The most common form of seismic exploration remains a nearly linear survey with data acquisition lines including the source and receivers. The interpretation of amplitude and waveform information for such linear acquisition requires consideration of 3D seismic wavefields. In many scenarios the structure is approximately 2D, but still modeling is needed for point sources. Recently 2.5D modeling methods have been developed for the simulation of 3D seismic wavefields in media varying in two dimensions, which require a storage only slightly larger than those of the corresponding 2D calculations. However, they require long computation times comparable to that of the corresponding 3D calculations, which is a major obstacle in routinely applying these conventional 2.5D methods to seismic surveys. To overcome this computation time problem, we have considered a new approach for modeling 2.5D seismic wavefields using a quasi-cylindrical representation, and implemented this approach using a velocity-stress finite-difference method (FDM). Our method requires similar computation time and storage as for 2D calculations, so that, with moderate computational resources, we may apply the method to routine analysis of seismic surveys where a number of trials of waveform modeling are inevitable. In this presentation we show some numerical examples to demonstrate the validity and feasibility of our method, with a simulation of a realistic large-scale onshore-offshore seismic experiment.

S11F-0359 0830h POSTER

Self-Affine Fracture Surface Topography and its Implications on Seismic Wave Propagation

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Over the past two decades, many field and laboratory observations have been made on the self-affine (fractal) properties of fracture surface geometry. In many cases, particularly for fractures in crystalline and granular rocks, the power spectrum of a fracture surface can be described by the power law with exponents limited to a relatively narrow range (e.g., Schmittbuhl et al., 1995). This number is directly related to the Hurst exponent which characterizes the self-affine properties of the fracture, i.e., the scaling relationship of the surface topography between the fracture-normal coordinate and the fracture-parallel coordinates. In this presentation, we will discuss the effect of self-affine fracture geometry on the scaling relationships of fracture compliance and, therefore, on the reflection and transmission of seismic (elastic) waves. The opening width of the fracture is assumed to have either 1) the same self-affine distribution as the fracture surfaces or 2) a distribution resulting from shear displacement across the fracture. Fracture compliances of three-dimensional, self-affine fractures subjected to stress are computed using a numerical model modified from the work of Hopkins (2000). Our preliminary study showed that for a self-affine fracture, normal fracture compliance is proportional to the scale of the fracture in the fracture-normal direction, and hence the fracture compliance follows a scaling relationship log(S/S0)=H log(L/L0). Here, S and L are the normal fracture compliance and the characteristic length of observation, respectively, H is the Hurst exponent, and 0 indicates the quantities measured at the reference scale L0. By introducing this relationship to the seismic displacement discontinuity model (Schoenberg, 1980; Pyrak-Nolte et al., 1990), transmission and reflection coefficients of fractures at different scales and frequencies can be computed. The scaling relationship of fracture properties as shown in this paper is significant because it allows us to estimate the geometry and constitutive relationships of fractures in the field from laboratory measurements on small core and block samples. Once this is done, properties of interests such as stress state and gas and fluid contents of the fractures can be evaluated from field seismic measurements on the fractures.

S11F-0360 0830h POSTER

Optimum Time-Frequency Decomposition For Seismic Data Using Continuous Wavelet Transform

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Time-frequency decomposition is an important signal analysis tool for seismic data. The overall frequency content of a signal can be obtained from the Fourier transform. However, for a non-stationary signal, such as seismic signal, whose frequency content varies with time, 1D transformation in frequency is not sufficient. Traditionally, 2D representation in time and frequency space for a 1D signal is achieved by taking Fourier transform over a short-time window. This method is commonly known as short-time Fourier transform (STFT). Time-frequency resolution in STFT is limited by the choice of a window length. Windowing problem in time-frequency analysis is absent in the continuous wavelet transform (CWT) method. CWT utilizes the property of dilation and translation of a wavelet and produces time-scale map where scale, defined in terms of length of time support of a wavelet, represents a frequency band. However, scale can be converted to frequency and the time-frequency map thus produced is called TFCWT. It is produced from CWT in two steps: 1. producing time-scale map, and 2. converting the scale to frequency. TFCWT has optimum time-frequency resolution, i.e. higher frequency resolution at lower frequencies and higher time resolution at higher frequencies, which makes it useful for seismic data interpretation. Visualization and interpretation of seismic sections in frequency space using single frequencies from the TFCWT spectra can be utilized to enhance low frequency shadows caused by hydrocarbon reservoirs. This idea can also be extended in interpreting time slices from 3D seismic data in frequency space. This method has been used to identify thin beds below tuning thickness.

S11F-0361 0830h POSTER

Usage of Fractal Model of Elastic and Electrical Properties of Porous Rock for Recognition of Liquid-Saturated Pore Zones From Collocated Seismic and Magnetotelluric Experiments: Deep Extension of Nagamachi-Rifu Fault Case

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A theoretical model was involved for quantitative joint analysis of collocated seismic velocity tomography and electromagnetic experiments. The main advantage of the present model against other theoretical models is possibility to describe both elastic and electrical properties of rock with a single model for a wide range of microstructures including 3D grain and pore anisotropy and different interconnection extend from isolated to interconnected pores. Based on the developed model, an attempt have been made to elaborate a quantitative method for solving the problem whether the variation of resistivity and seismic velocities in a region can be attributed to presence of liquid only or whether another assumption should be involved. The suggested method was applied for analyzing a collocated seismic velocity tomography and MT experiment carried out across the active Nagamachi-Rifu fault running through Sendai city, Northeastern Japan. Several zones, where the perturbation of both velocity and resistivity can be explained with several percentage of liquid fraction, were recognized in the region, namely, a caldera and a deep extension of the Nagamachi-Rifu fault. In the caldera region at the shallow depth of 3 km, the reduction of the seismic velocities up to 10% and the low resistivity about several ohm were explained by about 3% of porosity. At the depth of 15 km a zone of the low velocity of 5-10% decrease and of the low resistivity about tens of ohm were explained by about 2% of porosity and interpreted as the deep extension of the Nagamachi-Rifu fault. The developed model allows involving in quantitative analysis of 3 independent parameters: compressional and shear velocities and resistivity and can be used for parameterization of a joint MT and seismic inverse problem in a variety of geological settings.

S11F-0362 0830h POSTER

Application of Fractal Model of Electrical and Elastic Properties of Porous Rock to Hirabayashi Borehole Data

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To investigate microstructure of fault core and damaged zones, a fractal model for elastic and electrical properties of porous rock was applied to logging data of the Hirabayashi borehole, a 746 m deep borehole penetrating the Nojima fault, the main fault responsible for the Kobe earthquake at 1995. The main advantage of the present model against other theoretical models is possibility to describe both elastic and electrical properties of rock with a single model for a wide range of microstructures including 3D grains and pore anisotropy and various degrees of pore interconnection. Dependencies of the conductivity and the seismic velocities against the porosity were successfully simulated for all zones detected by core analysis: from the outside fault zone (152-426 m) to the upper and lower damaged zones (426-611 m and 641-746 m respectively) and the fault core zone (611-641 m). An interesting feature is that while the number of fractures observed by Fullbore Formation MicroImager (FMI) in the outside fault zone (4.2 fracture/meter) is 2-5% more than in the upper damaged and core zones (3.99 and 4.08) and only 12.5% less than in the outside fault zone (4.8 fracture/meter), the resistivity and seismic velocities in the fault zone are remarkably lower. This seeming discrepancy was explained by increasing number of microcracks that might be not detected by FMI. The seismic velocities and resistivity measured by logging at the depth 152-426 m were successfully simulated under assumption, that porosity of microcracks does not exceed 0.73%, the lowest porosity throughout the depths. At upper and lower damaged zones the experimental data were effectively simulated with porosity of microcrackes of 2.28%. These results are in a good agreement with the porosity measurements of core analysis, namely, 0.67% for the samples taken from the outside fault zone and 2.29% for the samples from the upper and lower damaged zones. The application of the fractal model of electrical and elastic properties of porous rock is demonstrated to be useful for recognizing a rock microstructure using porosity, resistivity and seismic velocities, which are measured in boreholes.

S11G MCC: 2002-2004 Monday 1020h

Theories of Earth's Interior II *(joint with T, V)*

Presiding: **L Kellogg,** University of California, Davis**; T Lay,** University of California, Santa Cruz

S11G-01 1020h

Subduction Drive of Plate Tectonics

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Don Anderson emphasizes that plate tectonics is self-organizing and is driven by subduction, which rights the density inversion generated as oceanic lithosphere forms by cooling of asthenosphere from the top. The following synthesis owes much to many discussions with him. Hinge rollback is the key to kinematics, and, like the rest of actual plate behavior, is incompatible with bottom-up convection drive. Subduction hinges (which are under, not in front of, thin leading parts of arcs and overriding plates) roll back into subducting plates. The Pacific shrinks because bounding hinges roll back into it. Colliding arcs, increasing arc curvatures, back-arc spreading, and advance of small arcs into large plates also require rollback. Forearcs of overriding plates commonly bear basins which preclude shortening of thin plate fronts throughout periods recorded by basin strata (100 Ma for Cretaceous and Paleogene California). This requires subequal rates of advance and rollback, and control of both by subduction. Convergence rate is equal to rates of rollback and advance in many systems but is greater in others. Plate-related circulation probably is closed above 650 km. Despite the popularity of concepts of plumes from, and subduction into, lower mantle, there is no convincing evidence for, and much evidence against, penetration of the 650 in either direction. That barrier not only has a crossing-inhibiting negative Clapeyron slope but also is a compositional boundary between fractionated (not "primitive"), sluggish lower mantle and fertile, mobile upper mantle. Slabs sink more steeply than they dip. Slabs older than about 60 Ma when their subduction began sink to, and lie down on and depress, the 650-km discontinuity, and are overpassed, whereas younger slabs become neutrally buoyant in mid-upper mantle, into which they are mixed as they too are overpassed. Broadside-sinking old slabs push all upper mantle, from base of oceanic lithosphere down to the 650, back under shrinking oceans, forcing rapid Pacific spreading. Slabs suck forward overriding arcs and continental lithosphere, plus most subjacent mantle above the transition zone. Changes in sizes of oceans result primarily from transfer of oceanic lithosphere, so backarcs and expanding oceans spread only slowly. Lithosphere parked in, or displaced from, the transition zone, or mixed into mid-upper mantle, is ultimately recycled, and regional variations in age of that submerged lithosphere may account for some regional contrasts in MORB. Plate motions make no kinematic sense in either the "hotspot" reference frame (HS; the notion of fixed plumes is easily disproved) or the no-net-rotation frame (NNR) In both, for example, many hinges roll forward, impossible with gravity drive. Subduction-drive predictions are fulfilled, and paleomagnetic data are satisfied (as they are not in HS and NNR), in the alternative framework of propulsionless Antarctica fixed relative to sluggish lower mantle. Passive ridges migrate away from Antarctica on all sides, and migration of these and other ridges permits tapping fresh asthenosphere. (HS and NNR tend to fix ridges). Ridge migration and spreading rates accord with subduction drive. All trenches roll back when allowance is made for back-arc spreading and intracontinental deformation. Africa rotates slowly toward subduction systems in the NE, instead of moving rapidly E as in HS and NNR. Stable NW Eurasia is nearly stationary, instead of also moving rapidly, and S and E Eurasian deformation relates to subduction and rollback. The Americas move Pacificward at almost the full spreading rates of passive ridges behind them. Lithosphere has a slow net westward drift. Reference: W.B. Hamilton, An alternative Earth, GSA Today, in press.

S11G-02 1035h

Stability of Subduction Zones in Numerical Models of Mantle Convection With Plate Tectonics

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During geological time, the Earth's surface has been marked by several cycles of opening-closing of oceans and collision-breakup of continents related to mantle dynamics and location of subduction zones.
indent Here we present a 3-D spherical model of mantle convection which incorporates surface surface tectonic plates which are dynamically coupled to the buoyancy-driven mantle flow. The formalism used to take into account the plates is the same as the one used by Monnereau and Quéré (2001). These time-dependent convection models reveal a cyclical re-organization of the subduction zones, alternating between two stable configurations. The principal input to this convection model is a multi-layer viscosity profile, with a low-viscosity channel at the bottom of the upper mantle, inferred by Forte and Mitrovica (2003) from simultaneous inversions of convection and glacial isostatic adjustment (GIA) data.
indent In these numerical convection simulations, the cycling between the two stable subduction zone configurations is characterized by a period between 500 and 700 Ma. This periodic behaviour is manifested in a relatively restricted range of model parameter space. For example, we have also used the same viscosity profile with differing internal and bottom heating inputs and we found that the cyclical behaviour was suppressed or entirely absent. For these alternative heating configurations, the convection simulations instead yielded a classical polygonal cell pattern usually obtained in free-slip models with upwellings surrounded by cold downwellings. It appears that the configuration of the mantle (e.g., relative importance between internal and bottom heating at the core-mantle boundary) plays a role in determining the appearance of steady, periodic variations in subduction zone configuration. Oscillations in bottom heat flux will enable the convective process to cycle back and forth between its two stable plate subduction patterns. We speculate that geological inferences of periodic variations in subduction zone configuration may provide a possible constraint on the style of mantle convection and in particular on viscosity structure and/or heating configuration.

S11G-03 1050h

Understanding the Mantle Through the Curious Topography on the 410 Discontinuity

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Our understanding of the 410 km and 660 km seismic discontinuities has grown tremendously over the past 15 years. The debate regarding whether the seismic discontinuities arise from chemical or phase changes seemingly has been put to rest by the multitude of seismic and mineralogical evidence supporting phase transformations in the olivine component at these depths. Assuming that the discontinuities are indeed due to mineral phase transformations, there is much that can be learned about the composition and dynamics of the mantle. The depth and sharpness of the discontinuities depends on composition, temperature, water content, and attenuation. The Clapeyron slopes (the gradient of the phase boundary in pressure/temperature space) of the olivine to wadsleyite transition at the 410 and the ringwoodite to perovskite and magnesiowüstite transition at the 660 are similar in magnitude but opposite in sign. Therefore, the topography of the two discontinuities should be anticorrelated in the presence of vertically coherent thermal anomalies. While this is observed in some subduction zones and hot spots, many global and regional studies do not observe the expected anti-correlation of topography. This lack of anti-correlation can be explained in some instances where the subducting slab broadens at the 660, causing a more extensive thermal anomaly

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