The spectrum of primitive mafic magma compositions within the European volcanic province ranges from melilite nephelinites and melilitites, through basanites and alkali basalts to subalkaline tholeiites; these are considered to be the products of variable degrees of partial melting of a relatively homogeneous HIMU-like reservoir within the upper mantle, the European Asthenospheric Reservoir or EAR. Variations in the trace element and Sr-Nd-Pb isotopic characteristics of magmas are consistent with mixing of partial melts from both lithospheric and asthenospheric mantle sources. A component geochemically similar to the EAR also exists within the Icelandic plume system; this is preferentially sampled by relatively rare, small degree, partial melts (nephelinites and alkali basalts). Thus both geophysical and geochemical data can be used to support a geodynamic link between the Paleocene-Recent activity of the Icelandic mantle plume system and the magmatism much further to the south in western and central Europe.

S71D-12 1155h INVITED

Constraining the Iceland Low-velocity Anomaly to Test Causal Hypotheses

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For several decades the mantle plume hypothesis has been the most prevalent model cited as the cause of the geophysical and geochemical anomalies around Iceland. Recently the hypothesis has come under increasing pressure as various workers argue that the apparent anomalies are not particularly anomalous, and alternative models, operating entirely within the upper mantle, are presented as the causal mechanism.

Seismic tomography provides the only method of "imaging" 3D mantle structure in situ, and three seismograph networks have been deployed across Iceland to collect the necessary data. Several velocity images of the Icelandic mantle using traveltime delays recorded by these regional networks have been published; all use ray-theoretical tomographic inversion techniques. To first-order they are consistent, showing a low velocity anomaly with a horizontal width of a few hundred kilometers, and extending from the surface to the maximum depth of resolution around ∼400 km. However, small variations in the structure imaged, and inherent distortions associated with the inversion techniques, have provided for a range of interpretations.

Here we present constraints on the geometry and amplitude of the low-velocity anomaly beneath Iceland. They are the results of tests using both ray-theoretical and full 3D wave propagation methods designed to test the extent to which the anomaly can be bent and squeezed. Ray-theoretical tests to squeeze the low-velocity anomaly both horizontally and vertically show that low-velocities are required to at least 350 km depth. They also suggest that the traveltime dataset could be satisfied by a narrow low velocity column, 100 km in diameter. Using the Spectral Element Method (SEM) we calculate synthetic waveforms and traveltime delays for stations across Iceland given various anomaly geometries. The SEM delay maps show a much broader delay footprint than ray-theoretical calculations would predict, implying that the Iceland anomaly could be about half the width of the ray-theoretical tomography results. However, the amplitude of the delays is also significantly reduced for narrow anomalies. We conclude that the Iceland low-velocity anomaly must extent to at least 350 km depth, is 100 to 200 km wide and does not extend laterally along the North Atlantic Ridge.

URL: http://www.geology.wisc.edu/∼rallen

S71E MCC: 121 Sunday 0830h

Radiated Energy and Apparent Stress: Constant or Nonconstant Scaling? I

Presiding: **K M Mayeda,** Lawrence Livermore National Laboratory**; R Abercrombie,** Boston University

S71E-01 0830h INVITED

Earthquake Apparent Stress Scaling

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There is currently a disagreement within the geophysical community on the way earthquake energy scales with magnitude. One set of recent papers finds evidence that energy release per seismic moment (apparent stress) is constant (e.g. Choy and Boatwright, 1995; McGarr, 1999; Ide and Beroza, 2001). Another set of recent papers finds the apparent stress increases with magnitude (e.g. Kanamori et al., 1993 Abercrombie, 1995; Mayeda and Walter, 1996; Izutani and Kanamori, 2001). The resolution of this issue is complicated by the difficulty of accurately accounting for and determining the seismic energy radiated by earthquakes over a wide range of event sizes in a consistent manner. We have just started a project to reexamine this issue by analyzing aftershock sequences in the Western U.S. and Turkey using two different techniques. First we examine the observed regional S-wave spectra by fitting with a parametric model (Walter and Taylor, 2002) with and without variable stress drop scaling. Because the aftershock sequences have common stations and paths we can examine the S-wave spectra of events by size to determine what type of apparent stress scaling, if any, is most consistent with the data. Second we use regional coda envelope techniques (e.g. Mayeda and Walter, 1996; Mayeda et al, 2002) on the same events to directly measure energy and moment. The coda techniques corrects for path and site effects using an empirical Green function technique and independent calibration with surface wave derived moments. Our hope is that by carefully analyzing a very large number of events in a consistent manner using two different techniques we can start to resolve this apparent stress scaling issue.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

S71E-02 0850h INVITED

Are Large and Small Earthquakes Dynamically Different?

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Large and small earthquakes are generally believed to be similar because of the "constant-static-stress-drop ($\Delta\sigma_s$)" scaling relation. Here, we address this question in light of other seismological parameters. First, is $\Delta\sigma_s$ really scale independent, as is generally believed? The estimate of $\Delta\sigma_s$ depends critically on the length scale of the source, $\tilde{L}$. For large events, $\tilde{L}$ is usually well determined, and the estimates of $\Delta\sigma_s$ is probably reliable. For small earthquakes, however, $\tilde{L}$ is not determined directly, but is inferred from the corner frequency or duration of an earthquake, with the implicit assumption that rupture speed, V, is comparable to S wave speed, β. Although V is close to β for large earthquakes, V is not known for small earthquakes. If V is smaller (or larger) for small earthquakes, then $\Delta\sigma_s$ can be larger (or smaller) than generally believed. The fast rupture speed for large earthquakes is in striking contrast with the slow rupture speed, $V \leq 0.4\ \beta$, measured for laboratory samples. The ratio, $\tilde{e}$, of radiated energy, E_R, to seismic moment, M_0 (this ratio multiplied by rigidity, μ, is traditionally called "apparent stress") exhibits large variations among different data sets. Estimates of $\tilde{e}$, especially for small earthquakes, are subject to large uncertainties mainly because of the difficulty in estimating E_R accurately. Some variations are attributed to inaccurate estimates of E_R, but existing data still seem to suggest that small earthquakes have generally smaller $\tilde{e}$ than large earthquakes. However, the ratio, $\tilde{e}$, alone does not necessarily represent the dynamical property of earthquakes. A better parameter is the fracture energy, E_G, or the radiation efficiency, $\eta_R = E_R/(E_R + E_G) = 2\tilde{e}/(\Delta\sigma_s/\mu)$. For large earthquakes, η_R and E_G can be estimated fairly accurately from macroscopic source parameters such as E_R, M_0, and $\Delta\sigma_s$. The values of η_R estimated for most large earthquakes are larger than 0.3, which means that the fracture energy, E_G, is smaller than, or comparable to E_R. This is consistent with the observed high rupture speed, V. For small earthquakes, if V is smaller than that for large earthquakes, then $\Delta\sigma_s$ is larger, and η_R is smaller, even if $\tilde{e}$ is about the same between large and small earthquakes. In this case, the slower rupture speed V is consistent with the smaller η_R. These results, together with the various lubrication mechanisms that may work at large fault slip and slip velocity, suggest that large earthquake ruptures are more likely to run away. Also, the dynamics of faulting can be significantly different between large and small earthquakes, which means that ground motions of large earthquakes cannot be estimated from those of small earthquakes by direct extrapolation. However, this question is far from being resolved, and more precise determinations of rupture speed, source dimension and radiated energy, are required to resolve it.

S71E-03 0910h INVITED

How Good are our Source Parameter Estimates for Small Earthquakes?

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Measuring reliable and accurate source parameters for small earthquakes (M<3) is a long term goal for seismologists. Small earthquakes are important as they bridge the gap between laboratory measurements of stick-slip sliding and large damaging earthquakes. They also provide insights into the nucleation process of unstable slip. Unfortunately, uncertainties in such parameters as the stress drop and radiated energy of small earthquakes are as large as an order of magnitude. This is a consequence of the high frequency radiation (> 100 Hz) needed to resolve the source process. High frequency energy is severely attenuated and distorted along the ray path. The best records of small earthquakes are from deep (> 1km) boreholes and mines, where the waves are recorded before passing through the near-surface rocks. Abercrombie (1995) and Prejean & Ellsworth (2001) used such deep recordings to investigate source scaling and discovered that the radiated energy is a significantly smaller fraction of the total energy than for larger earthquakes. Richardson & Jordan (2002) obtained a similar result from seismograms recorded in deep mines. Ide & Beroza (2001) investigated the effect of limited recording bandwidth in such studies and found that there was evidence of selection bias. Recalculating the source parameters of earthquakes recorded in the Cajon Pass borehole, correcting for the limited bandwidth, does not remove the scale dependence. Ide *etal.* (2002) used empirical Greens function methods to improve source parameter estimates, and found that even deep borehole recording is not a guarantee of negligible site effects. Another problem is that the lack of multiple recordings of small earthquakes means that very simple source models have to be used to calculate source parameters. The rupture velocity must also be assumed. There are still significant differences (nearly a factor of 10 in stress drop) between the predictions of even the simple models commonly in use. Here I assess the uncertainties in available estimates of source parameters for small earthquakes and consider the implications that they have for earthquake rupture dynamics and nucleation.

S71E-04 0925h INVITED

Progress Towards More Reliable Seismic Energy Estimates

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The radiated seismic energy density of an earthquake is peaked around the corner frequency of the earthquake. Since earthquake corner frequencies vary with earthquake size, seismic energy is distributed over a wide range of frequencies. It can be difficult to discern the nature of scaling of seismic energy because seismic energy estimates must account for the wave propagation effects this same wide range of frequencies. Despite the difficulties, studies in recent years have shown that many of the discrepancies between, for example, regional and teleseismic energy estimates for the same earthquake can be resolved if propagation effects are properly accounted for. In some instances, simply accounting for site response has resolved large discrepencies between estimates based on regional versus teleseismic data. In others, accounting for propagation effects empirically, either by empirical Green's function deconvolution or by spectral ratio analysis, has greatly reduced previous discrepancies in radiated energy.

Improved energy estimates should more clearly illuminate the nature of the scaling of energy with seismic moment. For example, Ide and Beroza [Does apparent stress vary with earthquake size?, Geophys. Res. Lett., 3349-3352, 2001] suggested that the scaling of radiated energy of microearthquakes reported in some studies might be an artifact of magnitude-dependent biases in the analysis. Better energy estimates should also help shed light on a related issue of whether observed large

variations in apparent stress for earthquakes of a given size are real and if so, what these variations reveal about the earthquake source.

URL: http://pangea.stanford.edu/~beroza/energy.html

S71E-05 0945h

Estimates of radiated energy from global shallow subduction zone earthquakes

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Previous studies used seismic energy to moment ratios for datasets of large earthquakes as a useful discriminant for tsunami earthquakes. We extend this idea of a "slowness" discriminant to a large dataset of subduction zone underthrusting earthquakes. We determined estimates of energy release in these shallow earthquakes using a large dataset of source time functions. This dataset contains source time functions for 418 shallow (< 70 km depth) earthquakes ranging from Mw 5.5 - 8.0 from 14 circum-Pacific subduction zones. Also included are tsunami earthquakes for which source time functions are available. We calculate energy using two methods, a substitution of a simplified triangle and integration of the original source time function. In the first method, we use a triangle substitution of peak moment and duration to find a minimum estimate of energy. The other method incorporates more of the source time function information and can be influenced by source time function complexity. We examine patterns in source time function complexity with respect to the energy estimates. For comparison with other earthquake parameters, it is useful to remove the effect of seismic moment on the energy estimates. We use the seismic energy to moment ratio (E/Mo) to highlight variations with depth, moment, and subduction zone. There is significant scatter in this ratio using both methods of energy calculation. We observe a slight increase in E/Mo with increasing Mw. There is not much variation in E/Mo with depth seen in entire dataset. However, a slight increase in E/Mo with depth is apparent in a few subduction zones such as Alaska, Central America, and Peru. An average E/Mo of 5x10e-6 roughly characterizes this shallow earthquake dataset, although with a factor of 10 scatter. This value is within about a factor of 2 of E/Mo ratios determined by Choy and Boatwright (1995). Tsunami earthquakes suggest an average E/Mo of 2x10e-7, significantly lower than the average for the shallow earthquake dataset. In addition, we also examine several large shallow earthquakes with relatively low E/Mo in order to compare these events with tsunami earthquakes as well as characteristics of the subduction underthrust zone.

S71E-06 1000h

THE DEFICIENT T WAVES OF TSUNAMI EARTHQUAKES

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We develop an algorithm quantifying the energy flux of T phases recorded at island stations following major teleseismic events, which we further scale by the seismic moment of the earthquake, to define a T-phase efficiency, GAMMA. We apply this concept to a set of six recognized tsunami earthquakes, which generated tsunamis larger than expected from their conventional seismic waves. Through comparison with nearby reference events whose T waves were recorded at the same sites, we find that the tsunami earthquakes exhibit a deficiency in GAMMA ranging from 1.5 to 2.5 orders of magnitude. This result settles a 50-year old controversy on the possible correlation between T-wave generation and tsunami genesis. The deficient character of the T waves from tsunami earthquakes readily supports the proposed model of an exceedingly slow rupture velocity for this class of events, and the close examination of T wavetrains supports the concept of a jerky rupture in at least two cases. We also show that T waves observed in Hawaii after the great 1946 Aleutian earthquake are too late, by about 29 minutes to be attributed to the mainshock, but rather were generated by anaftershock. This is in line with the extremely slow character of the mainshock as a charter "tsunami earthquake". The computation of GAMMA is straightforward in real time, and could become a valuable contribution to real-time tsunami warning in the far field.

S71E-07 1035h

Direct Seismic Energy Modeling and Application to the 1979 Imperial Valley Earthqu ake.

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The seismic energy associated with an earthquake has two representations: the work of the seismic waves done against a distant surface or a fault representation. For a fault subject to slip-weakening friction, the energy density is the difference between an elastostatic work and a work density spent in fracture and relaxation. We apply this to a dynamic simulation of the 1979 Imperial Valley earthquake, whose initial conditions are inspired by previous kinematic studies. A large area of the fault has a negative energy density, and the emission of energy is roughly confined to small parts of the fault with large positive energy density. We compute the work of the seismic waves against the surface of a sphere enclosing the source, and we find the same amount of energy. We produce a map of energy directivity that shows that 40 % of the energy passes through only 6.5 % of the sphere.

S71E-08 1050h

A Transportable & Stable Regional Magnitude Based on Coda Envelopes

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We have developed a magnitude calibration methodology for sparsely distributed regional stations using narrow band coda envelopes. This approach has most recently been applied to IMS stations located in Israel, Jordan and Egypt for events which span local and near regional distances with magnitudes ranging between Mw 3.0 to 5.0. Our preliminary results show that a magnitude estimate from one station using the coda is equivalent to a network average of roughly 9 stations when using traditional magnitudes (e.g., mb(P), ML, Md). The stability of the coda comes from measuring a long length of coda using a calibrated synthetic envelope as an empirical metric. We relate the non-dimensional coda amplitudes to an absolute scale by tying them to independent moment estimates from larger waveform-modeled events. Unlike most narrow band magnitudes, this approach yields an azimuthally-averaged moment-rate spectrum that is completely corrected for path and site effects. The resultant magnitudes from the spectra (e.g., Mw and mb) are fully transportable and do not suffer from regional bias. For small regional events (mb < 4.5), a stable, accurate magnitude is essential in the development of realistic detection threshold curves, formation of an Ms:mb discriminant, and accurate yield determination. Our calibration methodology is purely empirical. Rather than rely on the numerous assumptions that are built into the myriad of coda scattering models, we empirically find the distance-dependent velocity and coda shape factors. Since our events span both local and regional distances there is good reason not to assume that coda energy is homogeneously distributed in space, a common assumption in previous local distance coda studies. For the narrow band envelopes, we parameterize the peak S (or Lg) velocity as a function of distance as well as coda envelope shape factors. We find that for a given source, the coda amplitude is virtually constant for the first 100 to 150 km from the source but then decays with increasing distance. This is likely a result of the scattered waves transitioning from a 3-D (local S waves) to 2-D waveguide (Lg coda waves). This observation is consistent with previous local distance (< 150 km) coda studies that concluded that the coda energy is homogeneously distributed in space behind the direct wave front.

*This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48. UCRL-JC-141977 Abs

S71E-09 1105h

Energy Budget of the 1999 Chichi, Taiwan Earthquake

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We examined the energy balance of the 1999 Chichi, Taiwan earthquake (Mw 7.6) using several estimates of radiated and thermal energy. Estimates of radiated energy from regional seismograms give a value of about 1.0×10^{16} joules. The static stress drop from the total moment and the fault area is about 3 MPa. Temperature measurements from 2 shallow boreholes in the northern and southern sections of the fault show temperature profiles that increase across the narrow fault zone. If we assume this temperature increase was caused by frictional heating during faulting of the earthquake, thermal modeling gives the results that the fault generated 2.5 $\times 10^6$ joules per square meter in the north and 4.5 x 10^6 joules per square meter in the south. If these frictional values are extrapolated to depth, using higher normal pressure, we estimate that the earthquake produced a total of about 2 x 10^{17} joules of frictional heat. Adding the radiated and thermal energy gives a total energy of the earthquake (neglecting the fracture energy) of about 2.1 x 10^{17} joules. This implies an average seismic efficiency is about 5%.

The average energy values for the earthquake can be quite different from the energy balance on smaller portions of the fault. For example, most of the radiated energy is generated by a large asperity on the northern part of the fault, which has an area that is about 20% of the whole fault surface. For this region of large slip, it has been suggested that the dynamic friction may be very low. If we use a value of 0.2 for the coefficient of friction, which is consistent with the borehole temperature data, the thermal energy for region of the asperity will be about 3×10^{16} joules and the seismic efficiency for the asperity is about 30%, which is much higher than the average value for the whole earthquake.

S71E-10 1120h

Apparent Stress Scaling Relations for Mining-Induced Seismicity

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Mining-induced seismicity provides an important link between the laboratory and natural tectonic processes because it includes both fresh-fracturing events and those dominated by frictional slip. We have studied a dataset of such events that occurred between 1994-1999 in the Far West Rand gold-mining region of South Africa, approximately 80 km southwest of Johannesburg, at depths between 1.5 - 4 km. This depth range is comparable to that of borehole studies in California and to the target depth of the SAFOD experiment. These mining-induced events were recorded by five networks of 109 three-component geophones installed at depth throughout the active mining environment.

Using the method of Andrews (1986), we calculated source parameters for 228 mining-induced events in the range of $-0.7 \leq M \leq 2.8$ in which M is moment-magnitude. We find that fracturing and frictional events have distinctly different source scaling properties. The apparent stress of fracturing events decreases with seismic moment, and the apparent stress of friction-dominated events scales as $M^{1/6}$ up to $M \approx 5$. From these observations of apparent stress and of "apparent" stress drop, we develop a quasistatic model of earthquake nucleation and rupture for friction-dominated events in which fracture energy scales with stress intensity factor at the crack tip. Assuming slip weakening conditions and constant stress drop, this model predicts an increase in rupture velocity with event size, which is corroborrated by measurements of maximum particle velocity in the near field.

S

S71E-11 1135h

Observations that Constrain the Scaling of Apparent Stress

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Slip models developed for major earthquakes are composed of distributions of fault slip, rupture time, and slip velocity time function over the rupture surface, as divided into many smaller subfaults. Using a recently-developed technique, the seismic energy radiated from each subfault can be estimated from the time history of slip there and the average rupture velocity. Total seismic energies, calculated by summing contributions from all of the subfaults, agree reasonably well with independent estimates based on seismic energy flux in the far-field at regional or teleseismic distances. Two recent examples are the 1999 Izmit, Turkey and the 1999 Hector Mine, California earthquakes for which the NEIS teleseismic measurements of radiated energy agree fairly closely with seismic energy estimates from several different slip models, developed by others, for each of these events. Similar remarks apply to the 1989 Loma Prieta, 1992 Landers, and 1995 Kobe earthquakes. Apparent stresses calculated from these energy and moment results do not indicate any moment or magnitude dependence. The distributions of both fault slip and seismic energy radiation over the rupture surfaces of earthquakes are highly inhomogeneous. These results from slip models, combined with underground and seismic observations of slip for much smaller mining-induced earthquakes, can provide stronger constraint on the possible scaling of apparent stress with moment magnitude **M** or seismic moment. Slip models for major earthquakes in the range **M**6.2 to **M**7.4 show maximum slips ranging from 1.6 to 8 m. Mining-induced earthquakes at depths near 2000 m in South Africa are associated with peak slips of 0.2 to 0.37 m for events of **M**4.4 to **M**4.6. These maximum slips, whether derived from a slip model or directly observed underground in a deep gold mine, scale quite definitively as the cube root of the seismic moment. In contrast, peak slip rates (maximum subfault slip/rise time) appear to be scale invariant. A 1.25 m/s slip rate for one of the mining-induced earthquakes was estimated by dividing the corresponding slip observed at depth by the duration of the seismically-recorded slip pulse. Peak slip rates determined from the slip models for the major earthquakes are similar, ranging from about 0.8 to 4.8 m/s. Thus, for earthquakes in the moment magnitude range 4.4 to 7.4, the peak slip rate shows no dependence on **M**. Whatever variation there is in slip rate is probably due to factors related to the strength of the seismogenic rock mass such as depth. These observations support the idea that apparent stress does not vary systematically with seismic moment inasmuch as the apparent stress is determined by slip rate. Indeed, our finding that fault behavior of **M**4.4 earthquakes can be scaled readily to events of **M** greater than 7 with slips up to about 8 m suggests, quite persuasively, that the source physics for crustal earthquakes is much the same over this magnitude range. Interestingly, the mining-induced earthquakes involved brittle failure across very old pre-existing faults for which the cohesive strength is high and the pore pressure is zero, due to mining operations.

S71E-12 1150h

Energy Released by an Asperity Model of an Earthquake

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Estimating the energy released by an earthquake is a difficult problem because reliable data for the entire frequency spectrum of the source are generally not available. This difficulty is often circumvented by making various assumptions about the source and its spectrum, the most common being that stress, slip, and hence energy release are rather uniformly distributed over the fault surface. However, recent empirical and theoretical studies of small and moderate sized repeating earthquakes have raised questions about this general assumption of a homogeneous earthquake source. Observations that the repeat times for small repeating earthquakes along the San Andreas fault near Parkfield and Stone Canyon scale with the scalar moment to the 1/6 power can be explained by an asperity model of an earthquake based upon the analytical solution to the exterior crack problem. A characteristic of this asperity model is a very heterogeneous stress field, one that can not be described by a single parameter such as stress drop. This asperity model has been extended to include an estimate of energy release and it has been found that energy scales with the scalar moment to the - 1/3 power. This appears to argue for nonconstant scaling of apparent stress with moment, although the scaling of energy release could be offset by an opposite scaling of seismic efficiency, a parameter not constrained by our approach. Another interesting possibility suggested by the asperity model is that the moment and energy observed in the far field may have derived their major contributions from rather different parts of the fault.

S72A MCC: Hall C Sunday 1330h

Shallow, Near-Surface Imaging Posters

Presiding: **F Scherbaum,** University of Potsdam**; R Gritto,** Lawrence Berkeley National Laboratory

S72A-1124 1330h POSTER

Detecting low Velocity Anomalies Combining Seismic Reflection With First Arrival Seismic Tomography

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In the present study seismic reflection techniques and high resolution seismic tomography are combined to determine location and geometry of shallow low velocity anomalies. Underground cavities (mines), water flows (formation with loose sand), etc. are geologic features characterized by slow seismic velocities and are targets of considerable social interest. Theoretical considerations (Snell's law) suggest that low velocity anomalies are undersampled and therefore badly resolved by ray tracing methods. A series of synthetics simulations have been carried out to asses the resolving power of the different methodologies. A 400m$\times$50m two dimensional velocity model consisting of a background velocity gradient in depth from 3000 to 4000 m/s which included a rectangular low velocity anomaly (300 m/s). This anomaly was placed between 10m and 30m in depth and between 180m and 220m in length. The synthetic data calculation and the tomographic inversion have been done with absolutely independent programs. The data has been created using a 2D finite differences wave propagation acoustic algorithm. The tomographic inversion has been performed using two different software packages. The first one uses a combination of ray tracing a finite differences schemes to estimate the forward problem and an iterative conjugate gradient matrix solver to calculate the inverse. The second software package uses a modified Vidale scheme (Eikonal equation) to solve the forward problem and a LSQR to solve the inverse problem. The synthetic data were used for the inversions and for the generation of a conventional stacked section simulating a high resolution seismic reflection transect along the velocity model. The conventional stack images the diffractions caused by the velocity anomaly, which provided the location and extent of the low velocity anomaly. The inversions schemes provided estimates of the velocities, however, the tomograms and the ray tracing diagrams indicated a low resolution for the anomaly.

S72A-1125 1330h POSTER

Imaging Brittle Fracture Zones:Tomo-Datuming in a Granitic Pluton

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Wave equation datuming was used as a substitute to conventional refraction static corrections. This resulted in improved 2-dimensional high resolution seismic reflection images. A high resolution seismic reflection data set forms a multi-seismic data acquisition experiment in southwestern Iberian Peninsula that was used to test this processing scheme. The data was acquired with the aim of characterizing and mapping the fracturation of a granitic body (Albala pluton). An accurate near surface velocity model was derived from high-resolution seismic tomography using the traveltimes and the locations of sources and receivers as initial parameters. The tomographic algorithm uses a forward travel time calculation based on a finite difference algorithm and solves the linearized inverse problem by iterative conjugate gradient matrix solvers. The advantage of using wave equation datuming over refraction statics it properly propagates the recorded wavefield to the new datum, instead of applying vertical time shift to the data traces. This fact improves the signal-to-noise (S/N) ratio of the shot gathers and restores reflections and diffractions, providing better seismic images. The study area is characterized by strongly variable near-surface velocities and rugged surface topography. The stacked sections show a prominent dipping reflector that correlates with the main structure of the study area, North Fault. The diffractions correlate with subvertical structures (i.e.dikes) identified at surface.

S72A-1126 1330h POSTER

A Trial of the Delineation of Gas Hydrate Bearing Zones using Seismic Methods Offshore Tokai Japan

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MITI Research Well 'Nankai Trough' was drilled at offshore Tokai Japan in 1999/2000 and the existence of gas hydrate was confirmed by various proofs through borehole measurement or coring. It gave so big impact to the view of Japanfs future energy resources and other scientific interests.The METI, Ministry of Economy, Trade and Industry, has started the national project "Methane Hydrate Exploration study" in Japan since the fall 2001.

Bottom Simulating Reflectors (BSRs) were widely found on the marine seismic data acquired offshore Japan especially in the shelf-slope near Nankai Trough. BSRs are thought to be the bottom of gas hydrate stability zones, we cannot, however, get the information of gas hydrate bearing zones, such as the height of those, the porosity, the gas hydrate saturation etc, only from BSRs. In order to estimate the amount of gas hydrate accurately, we have to get those reservoir parameters of gas hydrate bearing zones from marine seismic data. The velocity of these zones is greater than that of the surrounding sediment, because pure gas hydrate has high velocity that is more than 3,000 m/s. This means the interval velocity is the key for exploration of gas hydrate.

First, we have tried to image the gas hydrate bearing zones from seismic stacking velocity analysis. After the conversion to interval velocity from NMO velocity by Dix's equation, we imaged the P-wave velocity section through 2D seismic line. We successfully imaged high velocity zones above BSRs and low velocity zones beneath BSRs on P-wave velocity section. But the resolution of the section from the velocity analysis is not so high. Although we have only two adjacent well log data on the seismic line, in order to make more detailed map, we tried to execute the seismic impedance inversion with MITI Nankai Trough Well data. We made a simple initial model and inverted to seismic impedance value. We got the good impedance section and delineated the gas hydrate bearing zones through it. JNOC, Japan National Oil Corporation, and METI conducted three 3D seismic surveys at offshore Tokai Japan in 2002 and they will drilled some research well at the same area from 2003 to 2004. We hope to image 3D gas hydrate bearing layers from the 3D seismic data and well results. To image the gas hydrate bearing zones, we will try to detect interval velocities from seismic data and to resolve much higher, we are planning to execute the multi-seismic attribute analysis and AVO inversion.

S72A-1127 1330h POSTER

Shallow Crustal Structure of Chicxulub Impact Crater Imaged With Seismic, Gravity and Magnetotelluric Data: Structure of the Central Uplift and Origin of the Cenotes Ring.

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