S32A-05 1135h

Improving the Level of Seismic Hazard Parameters in Saudi Arabia Using Earthquake Location and Magnitude Calibration

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Saudi Arabia is an area, which is characterized very poorly seismically and for which little existing data is available. While for the most parts, particularly, Arabian Shield and Arabian Platform are aseismic, the area is ringed with regional seismic sources in the tectonically active areas of Iran and Turkey to the northeast, the Red Sea Rift bordering the Shield to the southwest, and the Dead Sea Transform fault zone to the north. Therefore, this paper aims to improve the level of seismic hazard parameters by improving earthquake location and magnitude estimates with the Saudi Arabian National Digital Seismic Network (SANDSN). We analyzed earthquake data, travel times and seismic waveform data from the SANDSN. KACST operates the 38 station SANDSN, consisting of 27 broadband and 11 short-period stations. The SANDSN has good signal detection capabilities because the sites are relatively quiet. Noise surveys at a few stations indicate that seismic noise levels at SANDSN stations are quite low for frequencies between 0.1 and 1.0 Hz, however cultural noise appears to affect some stations at frequencies above 1.0 Hz. Locations of regional earthquakes estimated by KACST were compared with locations from global bulletins. Large differences between KACST and global catalog locations are likely the result of inadequacies of the global average earth model (iasp91) used by the KACST system. While this model is probably adequate for locating distant (teleseismic) events in continental regions, it leads to large location errors, as much as 50-100 km, for regional events. We present detailed analysis of some events and Dead Sea explosions where we found gross errors in estimated locations. Velocity models are presented that should improve estimated locations of regional events in three specific regions: 1. Gulf of Aqabah - Dead Sea region 2. Arabian Shield and 3. Arabian Platform. Recently, these models are applied to the SANDSN to improve local and teleseismic event locations and to develop an accurate magnitude scale for Saudi Arabia.

S32A-06 1150h

Stress and Metamorphic Conditions for Warm-slab Earthquakes: Geiyo Area, Southwest Japan

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The M = 6.7 2001 Geiyo earthquake occurred at the northern tip of a narrow band of high intraslab seismicity that extends from eastern Kyushu to the Geiyo area in Southwest Japan. We use JMA focal mechanism solutions to infer stress conditions as controlled by regional geodynamics in the Geiyo area, and we use a double-difference (DD) algorithm to refine the location of the 2001 Geiyo earthquake relative to the background seismicity. The slab experiences maximum E-W stretching and sharp bending in this area and is thus in a stress environment favoring large earthquakes. The DD relocation results in insignificant readjustments of earthquake locations, indicating a high accuracy of the original locations in the JMA catalogue. The Geiyo earthquake is deeper than most of the background seismicity. We also find that the magnitude of the background earthquakes increases with (slab-normal) depth and peaks at about 8 km below the top envelope of the intraslab seismicity. This distribution is consistent with the following conceptual model. Rock densification during pervasive dehydration reactions "shatters" the top part of the subducting crust, discouraging large earthquakes. The more uniform lower crust and mantle, under tectonic stress and with local dehydration along deep faults, can host much larger events such as the 2001 Geiyo earthquake. How deep inside the slab can earthquakes occur may depend on the state of mantle serpentinization prior to subduction.

S33A CC: 220 C-E Wednesday 1330h

POLARIS and Related Studies
Posters *(joint with G, GP, T, SEDI)*

Presiding: **D Eaton,** University of Western Ontario**; I Ferguson,** University of Manitoba

S33A-01 1330h POSTER

Crustal Seismic Velocity Model of Southern Ontario

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Knowledge of crustal thickness and velocity is important to obtain precise hypocenter locations, as well as to constrain tectonic interpretations for a particular region. In southern Ontario, the installation of the POLARIS network started in 2001. At present, there are 23 broad-band stations installed in this region. Together with the information from the Southern Ontario Seismic Network (SOSN), which operated with short-period sensors between 1990-2000, more than 200 recorded events (earthquakes and quarry blast) are available for velocity modeling. The arrival-time data from local events and some well recorded quarry blasts are used for a preliminary estimation of the 1-D and 3-D velocity model of southwestern Ontario. For 1-D velocity tomography the method of Kissling (1984) (VELEST program) is applied. Different initial models are used to obtain a robust result. The Moho depth is constrained independently using results of receiver-function analysis and gravity inversion. . The obtained 1-D optimum' velocity model is used as the initial model for a subsequent 3-D local tomography using the Thurber inversion' (Thurber, 1981, 1983, 1993) (SIMULPS program). New hypocenter locations for all local events in southwestern Ontario in 1990-2003 have been calculated using the new 1-D and 3-D velocity models.

S33A-02 1330h POSTER

Relations of Pipe-to Soil Potential to the Local Geomagnetic and Telluric Activity

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Magnetic disturbances cause electric currents in long pipelines, which can contribute to corrosion of the pipeline. To protect the pipeline a cathodic protection system is used to maintain the pipeline at a constant negative potential with respect to surrounding soil that inhibits the corrosion reactions. However induced currents in the pipeline create variations in the pipe-to-soil potential taking. Knowing where and how often these potential variations occur is necessary for assessing the corrosion risk for a pipeline. Large pipe-to-soil potential variations have been observed on a pipeline from Armprior to Kemptville in eastern Ontario. We present observations and analysis of pipe-to-soil potential variations made in October 2003 to investigate why this area experienced such large fluctuations. Geomagnetic field recordings from the nearby Ottawa magnetic observatory were used with a 1-D multi-layered conductivity model of the Earth to calculate the electric field at the Earth surface. Comparison between the pipe-to-soil potential variations and the electric field variations gave correlation coefficients up to 90%. The pipe-to-soil potential recordings and calculated electric fields were used to determine a transfer function representing the pipe/earth response at each site. Comparison of these transfer functions from site to site shows where the peak response occurs. We examine the factors in the pipe structure and in the earth conductivity structure that could be the cause of these localized effects on the pipeline.

S33A-03 1330h POSTER

Possible Subcrustal Anisotropic Fabric Beneath the Grenville Orogen

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The Proterozoic Grenville Orogen, which forms the southeastern edge of the Canadian Shield, is the result of extensive crustal shortening and deformation during the interval 1.3-0.98 Ga. The degree to which this crustal deformation is reflected in the underlying mantle is uncertain, though LITHOPROBE detection of a preserved subduction zone (Calvert et al., 1995) in adjacent Archean terranes indicates that relict Precambrian features are preserved below the crust. A number of permanent CNSN stations (e.g., SADO, GAC, KGNO, etc.) are located on or near the Grenville, and have large archives of teleseismic data available; the more recent deployment of the dense Ontario POLARIS network provides additional constraints. We examine teleseismic receiver functions from POLARIS and CNSN stations for transverse-component energy beneath the Moho; early results indicate a complex structure involving multiple anisotropic domains that do not correlate with SKS splitting results.

S33A-04 1330h POSTER

Crustal thickness in Southern Ontario from constrained linearized gravity inversion

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We use crustal thickness estimates for POLARIS Southern Ontario stations as constraints in a linearized inversion of gridded Bouguer gravity data for topography of the crust-mantle boundary. Estimates of crustal thickness from receiver function analysis varies from 37 to 43 km; the thinnest crust is found in a SW-NE trending belt between Georgian Bay and Lake Ontario. Our gravity inversion assumes a constant density contrast between crust and mantle, and parameterizes the topography of the crust-mantle boundary as discrete rectangular blocks sitting at a reference depth. By assuming that the mass of one block is concentrated at its base, we obtain a linear relationship between the height of the block and the vertical component of gravity measured at the surface. For realistic Moho topography our forward model compares well with more accurate non-linear approaches that either distribute the mass across each discrete block or use a Fourier expansion in the wavenumber domain to parameterize the surface. To the resulting system of linear equations we add additional constraint equations provided by the teleseismically derived thicknesses at the appropriate grid locations. Our preliminary results show long-wavelength undulations in Moho topography. Residual gravity maps display mainly short wavelength features that are presumed to be caused by shallow anomalies. A comparison of the results with tectonic boundaries mapped at the surface show a thick crust underlying the Central Metasedimentary Belt, and thinner crust just SE of the Grenville Front.

S33A-05 1330h POSTER

A Comparison of Teleseismic Receiver Functions for TW∼ST and Polaris Stations in the Western Superior Province, Canada

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The ∼2.7 Ga Superior Province is one of the largest preserved Archean crustal blocks in the world. To better understand its tectonic evolution by examining the seismic velocity structure of the crust and upper mantle beneath the Western Superior Province (WSP), a portable array of 17 broadband 3-component stations was deployed between May and November of 1997. Data recorded by these stations, part of LITHOPROBE's Teleseismic Western Superior Transect (or TW∼ST), have been used in the past for shear wave splitting, surface wave, and seismic tomography studies. Our study looks at differences in crustal and uppermantle structure, as determined from receiver functions, in the central region of the WSP and near its northern margin with the Proterozoic Trans-Hudson Orogen (THO). The exact location of the northern boundary between WSP and THO cannot be delineated on the basis of surface geology as it lies buried beneath Phanerozoic cover rocks of the Hudson Bay Lowlands. Teleseismic receiver functions are time series that effectively image P- to S-wave conversions occurring at interfaces across which there is a significant contrast in seismic (particularly shear wave) velocity. Signals on transverse receiver functions may be indicative of dipping interfaces, out-of-plane scattering introduced by local 3-D structure, or the presence of anisotropy. Here, receiver function results for two stations (B14 and BPW) from the 1997 TW∼ST dataset are compared to preliminary receiver function results obtained from the newly deployed (June 2003) Polaris stations at Musselwhite Mine (MUMO; located in the WSP near Pickle Lake, northern Ontario, and close to TW∼ST station B14), and on the Sutton Inlier (SILO; located about 60 km SE of Peawanuck – and TW∼ST station BPW – near the southern shore of Hudson Bay). The Moho *Ps* converted phase is associated with a distinct, positive peak at ∼4.5 seconds on the radial receiver functions for all four stations. Prior to this, centered at around 2 seconds, a double-peaked positive arrival, with an amplitude roughly comparable to that of the later Moho arrival, is observed on radial receiver functions for stations MUMO and B14. This double peaked positive arrival is also observed on the radial receiver functions for SILO and BPW, but is associated with a much lower amplitude (roughly half that of the very distinct Moho *Ps* arrival). In contrast to the radial receiver function waveforms, for which there seem to be many common characteristics between the four stations, there are significant differences in the transverse receiver function waveforms for stations located close to the THO margin (SILO and BPW) as opposed to those located in the central part of the WSP (MUMO and B14). The transverse receiver functions for both MUMO and B14 feature a number of crustal reverberations for the first 10 seconds, with amplitudes comparable to those observed on the radial receiver functions. Amplitudes observed on the transverse receiver functions for SILO and BPW, however, are considerably lower than those observed on their radial counterparts. This agrees generally with results from previous shear wave splitting and surface wave studies, both of which indicate that higher levels of anisotropy exist in the central parts of the WSP than near the margins of the cratonic block and in the neighboring THO.

S33A-06 1330h POSTER

Upper Mantle Structure of the Slave Craton from Teleseismic Body-Wave Tomography

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Cratons form the core of the majority of Earths continents and offer a unique window into the evolution of continents and plate tectonics over geological time. The dynamics that led to the evolution and stabilization of cratons over one billion years ago, however, remains poorly understood. The Archean Slave province, located in the NW Canadian Shield, is an ideal site to study the formation of cratons due to its high degree of preservation and evidence that its lithosphere possesses a distinct stratification resulting from cratonic assembly. In addition, numerous geochemical and petrological analyses have been performed over the past 15 years on xenoliths sampling the Slaves lithosphere, yielding important constraints on mantle state and composition. In this study, we investigate upper mantle velocities beneath the Slave craton using body-wave travel time tomography. The region is well situated relative to global seismicity, making it an ideal craton to study using seismic tomography. Velocity models are generated by inversion of body-wave travel-time delays for isotropic slowness perturbations with respect to the iasp91 radial Earth model. Our primary data set consists of 2345 teleseismic travel-times from 204 events recorded over three years (2000-2003) by the Northwest Territories component of the POLARIS broadband seismic network. Results from the inversion of these data agree with those from a reconnaissance study conducted by Bank et al [2000], but add greater resolution across the Lac de Gras kimberlite field. To increase the overall resolution, a more comprehensive inversion is performed on the combined POLARIS and reconnaissance data sets. Preliminary results from this inversion suggest a >1.0% lateral velocity contrast that coincides with the western edge of the craton, pointing to differences in lithospheric evolution of the Slave province and the surrounding Proterozoic terranes. The model suggests two additional features of interest: first, a lateral SW-NE trend in alternating positive/negative velocity regions, whose outlines coincide with those of an ultra-depleted mantle region previously inferred from geochemical, petrological and MT studies; second, a low velocity anomaly centered to the south of the Lac de Gras kimberlite field and observed between 50-150 km depth. This latter anomaly has a radius of 50 km, it exhibits a 2.8

S33A-07 1330h POSTER

POLARIS Consortium Status Report

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POLARIS (www.polarisnet.ca) infrastructure is now in its fourth and final year of construction. Currently 69 Libra VSAT geophysical observatories are installed in three arrays in Ontario, BC and the NWT and transmit live broad-band seismic data to two central Hubs in London and Ottawa Ontario. Geological Survey of Canada (GSC) has recently obtained additional funding to expand the research scope of POLARIS in Ontario, particularly in relation to diamond exploration. The BC array construction is completed with 18 installed observatories. In the NWT, 22 observatories are currently installed and a final two are planned for this year. In Ontario, 29 are installed, and a final 14 (including 8 POLARIS and 6 GSC) are planned for this year. In a shift of focus, another 5 observatories are planned for Hudson Bay for installation later this year. Before the end of 2004, the total installed POLARIS observatories including those funded by GSC should reach the POLARIS target of 90. The magnetotelluric (MT) component of POLARIS has made considerable progress in the past year and MT soundings already completed for parts of Ontario and BC arrays and planned for the NWT this year. In addition, the first 5 long-period MT systems will be co-installed at 5 NWT VSAT locations this year. POLARIS installations in the NWT have been both challenging and rewarding. The robust solar-powered stations have performed well and some continued to transmit data even during dark days of winter with extreme low temperatures.

S33A-08 1330h POSTER

A Re-interpreted Seismic Velocity Model Beneath Vancouver Island, Canada: a Shallower Subducting Slab?

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Seismic refraction data collected in 1980 across the Cascadia margin of Vancouver Island have been reinterpreted, since a recent re-evaluation of LITHOPROBE reflection profiles across the margin suggested that the subducting oceanic slab is much shallower than previously thought. Of primary interest on the reflection profiles is the regionally extensive E-reflection band in the lower continental crust. Recently, relocated seismicity, tomographic velocities and reflection images suggested that the E-reflection band lies directly above the subducting oceanic slab. This positions the subducting oceanic slab approximately 6 km shallower than previously interpreted from the refraction data. Using 2D traveltime inversion and synthetic seismograms, we have modeled high-amplitude secondary arrivals as wide-angle reflections from the Moho of the subducting plate, and not as continental Moho reflections. The reflection interface occurs at a depth of 35-37 km beneath central Vancouver Island, so that the top of the subducting slab is at 30 km depth, just below the E-reflection band. Thus, the revised velocity model with a relocated oceanic slab fits the refraction observations as well as or better than former interpretations.

S33A-09 1330h POSTER

Earthquake Site Response Studies in Victoria, B.C. Using Weak Motion Recordings, Microtremor Data, and SHAKE Modelling

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We have examined the earthquake site response across greater Victoria, British Columbia. The surface geology across this region varies significantly and is dominated by thin soils situated on crystalline rock with a number of deeper pockets of soft clay soils. Detailed geological and geophysical data are available for most of the city. We have utilized a variety of techniques and data sets to estimate seismic site response and compare our results with the predicted amplification based on surface geology. Recordings of six recent earthquakes, including the Mw=6.8 Nisqually, Washington event (150 km from Victoria), provide weak motion data with peak horizontal acceleration varying from 1%g to 3.5%g. These events were recorded on a variety of geological conditions including bedrock, thin (<3 m) soft soil (NEHRP class E), and thick (5-12 m clay and till) soil (NEHRP class C and E). Microtremor measurements were also made at each of these sites. Earthquake site response was estimated using standard spectral ratios (bedrock reference sites) and H/V ratios. The results from the two techniques at each site are remarkably similar both in frequency and, notably, in amplitude. H/V ratios of the microtremor data were in good agreement with those of the earthquake data. Overall, sites with < 3 m of soil exhibit a relatively flat site response at frequencies < 10 Hz. Sites with 5-12 m of clay show peak amplification up to six times that of bedrock at frequencies of 2-5 Hz. SHAKE modelling of the observed Fourier amplitude spectra demonstrated that the peak amplification at each site could be attributed to the local geology amplifying the ground motion. A flat site response <10 Hz occured for < 2.5 m of soil, and peak amplification between 2-5 Hz was modelled by 10 m of clay, thicker amounts of Pleistocene till, or a combination of both.

S33A-10 1330h POSTER

Green's Functions, Source Signatures and the Normalization of Teleseismic Wavefields

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We examine the canonical source/Green's function separation problem in the context of teleseismic *P*-wave scattering from receiver-side crust and upper mantle structure. Conventional "receiver function" analysis represents a leading order approximation to the *S*-component of the Green's function but affords no information on *P*-to-*P* scattering. We demonstrate that an improved estimate of the 3-D Earth's Green's function, including scattered *P* contributions, can be achieved through consideration of its theoretical spectral characteristics. Under conditions typical of the real Earth, the *P*-component of the Green's function can be shown to be minimum phase. This property is responsible for the success of receiver functions in mantle/lithospheric studies. The minimum-phase constraint enables implementation of multichannel, multicomponent, separation of Green's function and source spectra within the log-spectral domain. We construct a highly redundant system of equations incorporating the cross-spectra of the data to determine the response of the receiver-side structure. We will present both synthetic and data examples to demonstrate the efficacy of this methodology in recovering all three (*P*, *SV*, and *SH*) components of the teleseismic *P*-wave Green's function.

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