occurs within the crustal portion of the subducting slab. Dehydration embrittlement associated with the basalt to eclogite phase transition within the subducting oceanic crust offers a plausible physical mechanism to explain these earthquakes. While this region is seismically very active, earthquake magnitudes seldom exceed M 4.5. In contrast, the south Puget Sound region has been shaken by several larger intraslab earthquakes including the 2001 magnitude 6.8 Nisqually earthquake which occurred near (perhaps at the same place as) the 1949 M 7.1 Olympia earthquake and within a few fault lengths of the 1965 M 6.5 Seatac earthquake. These three events lie on a line with the 1999 M 5.8 Satsop earthquake and several anomalously deep small earthquakes to the east. A main goal of this study is to determine whether these larger events are also confined to the crustal portion of the subducting plate or whether they rupture into the mantle, perhaps requiring an alternative explanation. The details of the older events are not well constrained so we focus on the Nisqually event. We suggest that this event nucleated at or very near the subducted Moho because it seems to be located near the base of the well located surrounding microseismicity. In addition, a strong reflector, interpreted to be the subducted Moho has been imaged at the base of the microseismicity in central Puget Sound. We invert nearly two dozen three-component strong-motion seismograms, generally within 100 km of the epicenter, to constrain the rupture process of the Nisqually earthquake. The data are not sufficient to distinguish between the two potential fault planes (one nearly vertical, striking north) and the dipping gently to the west. For either fault plane, rupture propagates unilaterally to the North, on a fault that is elongated north-south along slab strike. As a result of this geometry, if the near horizontal plane is the fault plane then the entire rupture occurred within the crust of the subducting slab. Indeed, an earthquake up to 2 times larger in spatial dimensions and in total slip, (having nearly an order of magnitude larger moment) would still fit within the subducted crust. In contrast, rupture on the vertical plane has a slight downward propagation such that the entire rupture would be confined to the mantle portion of the slab.

S42D-11 1640h

The Vrancea Zone, Romania: Intermediate Depth Seismicity in Search of a Viable Subduction Zone

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While intermediate depth seismicity remains an enigma of subduction zones, the Vrancea zone of Romania stands out as an enigmatic case of intermediate depth seismicity. Vrancea seismicity is characterized by high recurrence rates of strong, intermediate depth, volumetrically confined earthquakes, and is commonly interpreted as the final stages of oceanic subduction during formation of the Carpathian orogen. Several aspects of the Vrancea zone suggest the subduction model may not be viable here, and that intermediate depth seismicity may result from delamination of the continental lithospheric mantle. The seismogenic region is laterally restricted (70 km along strike) and dips steeply (60-70 degrees NNW) beneath the foreland of the orogen. Accordingly, Vrancea seismicity is not readily correlatable in either position or orientation with inferred suture zones of the Carpathian hinterland. Subduction models appeal to either (1) detachment and lateral migration of a subducted slab, or (2) roll-back of an oceanic slab (SSE) roughly orthogonal to the direction of inferred subduction (WSW). The Eastern Carpathians formed as a result of major deformations in Late Cretaceous and early to middle Miocene time, ending about 10 Mya. While ophiolites mark the closure of an ocean basin in Cretaceous time, geologic evidence for a younger ocean basin remains equivocal. Any remnant slab from either event must have remained in the upper mantle for at least 10 Ma, and is only now foundering. A new multinational effort, with investigators from Romania, Germany, The Netherlands, and the U.S., is focused on resolution of the Vrancea enigma through new geophysical experiments. The southeastern Carpathians may prove to be one of the best places to distinguish between these two proposed sources of upper mantle seismicity, and establish evidence either for active lithospheric delamination, or a very unusual case of slab subduction.

S42E MC: 307 Thursday 1330h

Structure of the Mediterranean and Iberian Pennisula *(joint with T)*

Presiding: **R Carbonell,** Dept. Geophysics, Inst. Earth Sciences "Jaume Almera"-CSIC**; S van der Lee,** Inst. of Geophysics

S42E-01 1330h

Investigation of Crust and Upper Mantle in the Western Mediterranean

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Seismic data from all available broadband stations in the western Mediterranean were used to study the structure of the crust and upper mantle across the Alboran Sea with the receiver function method. Most stations close to the plate boundary are part of the GEOFON network, jointly operated by ROA, UCM and GFZ. P to S converted teleseismic waves at the Moho underneath each station and their multiples are used to determine the crustal thickness and the average crustal Vp/Vs ratio. The Moho depth at all stations close to the coast is near 20 km and increases further inland to about 30 km. In the central part of the Betics, the Moho seems to be distorted, but a strong converter in the upper mantle could possibly support the lithospheric delamination hypothesis derived from seismicity and other data. There are also indications of a north dipping structure underneath the coast of Morocco extending down to about 120 km and correlating well with the seismicity. At most stations around the Alboran Sea, the 410 is poorly visible and the 660 seems at its normal position. These results, although preliminary, could indicate that the entire upper mantle down to 660 km is distorted due to lithospheric delamination. To improve this image, GFZ takes presently part in the TEDESE (Terremotos y Deformacion Cortical en el Sur de Espana) project of UCM and ROA. As part of this project, a temporary network of additional broad-band seismological stations will be installed in south Spain and northern Morocco in October 2001 for a one year period. The aim is to carry out an integrated evaluation of seismic risk in south Spain from the study of the characteristics of the occurrence of earthquakes and their focal mechanisms together with measurements of crustal deformation using geodetic GPS and SLR techniques, to improve the receiver function sampling and to analyze heterogeneities of structures and effects of anisotropy in the crust and asthenosphere. From this studies, seismotectonic models and maps will be elaborated and seismic risk in the zone will be evaluated.

S42E-02 1345h

Crust and upper-mantle discontinuities from analysis of broadband seismological data in the Mediterranean region

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We have analyzed receiver functions to derive simple crustal models for a total of 17 permanent and temporary 3-component broadband seismological stations in the Mediterranean region. The 12 studied temporary stations have been operated under the MIDSEA project. To determine an accurate Moho depth we have reduced the trade-off between crustal velocities and discontinuity depth by using a new grid search method, which is an extension of recently published methods to determine crustal thickness. The values we find for Moho depth range from around 20 km for intra-oceanic islands and extended continental margins to near 45 km in regions where the Eurasian and African continents have collided. The relatively stable north-eastern African margin shows crustal thicknesses close to a standard value of 35 km while the relatively tectonically disturbed margin of north-western Africa shows significantly thinner crust. Modeling of crustal structure shows that all stacked receiver functions can be explained within standard deviations by a 2- or 3-layer model containing a sedimentary layer and/or a mid-crustal discontinuity. Both receiver function analysis and cross-correlation are powerful tools to reveal interfaces in the upper-mantle. For studying upper-mantle discontinuities we use both these methods. We transform the processed signals to the slowness-time domain to highlight P-to-S conversions from interfaces at different depths. The tectonic complexity of the Mediterranean region is found to extend down to the transition zone.

S42E-03 1400h

New 3-D Upper-Mantle S-Velocity Model for the Mediterranean Region

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A new 3-D S-velocity model for the uppermost mantle beneath the Mediterranean and surrounding regions as well as a Moho map, have been developed using broadband seismograms recorded at portable and permanent seismic stations in Europe, Northern Africa and on Mediterranean islands. Following the partitioned waveform inversion method, the waveforms of S- and surface wave trains of about 730 vertical component seismograms from 145 earthquakes recorded at 94 different seismic stations have been interactively fitted. The linear constraints on upper mantle S-velocity structure provided by the waveform fits have been combined with independent estimates of Moho depth obtained from receiver function analysis (Van der Meijde et al., 2001), seismic refraction/reflection surveys and gravity data studies in a linear damped least-squares inversion for S-velocity and for crustal thickness. The obtained solution is stable and does not depend on the starting model. The resulting 3-D S-velocity model shows a degree of complexity comparable with the surface observations characterizing the plate boundary region. Our model confirms the existence of an extensive low-velocity layer beneath the area. While the western Mediterranean is characterized by a shallow low-velocity layer, which does not reach 200 km depth, the low-velocity anomalies beneath eastern Europe and Turkey extend deeper in the upper mantle. High velocity anomalies, which could be related to past or still ongoing subduction, are present beneath the Hellenic arc, Italy and the Alps. High velocities are also observed at 300 km depth beneath eastern Spain. The obtained crustal thicknesses range from 20 km beneath the western Mediterranean region and the Canary islands, through 30 km for continental Europe and the eastern Mediterranean Sea to over 40 km beneath Turkey and along continental collision zones such as the Alps and Dinarides. The resolving power of the data set depends strongly on the density of available wave paths and varies as a function of geographical position. Interpretation of the imaged velocity anomalies is aided by testing the resolution of realistic structures as well as of basic patterns of different sizes and orientations.

S42E-04 1415h

Tomography of the Mediterranean Basin, 1: Phase and Group Velocities of Surface Waves.

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The Mediterranean Basin is a geodynamically complex area, governed by the slow collision between Africa and Eurasia. The boundary between the two plates is not well defined. Although there is clear geodetic and seismic evidence of Northward subduction under the Hellenic and Calabrian arcs, diffuse seismicity around the Adriatic Sea and Western Mediterranean requires a more complex description of plate interaction. Tomographic studies play an important role in this context.

In recent years, high-resolution seismic images of the Mediterranean Basin have been derived from observations of body-wave travel times, mostly based on the ISC catalog. This type of data does not provide a thorough coverage of the upper mantle, whose structure is best constrained by measurements of surface-wave velocity anomalies. Our group has assembled a large data set of Love and Rayleigh wave phase anomaly observations (e.g., *Ekström, Tromp and Larson*, 1997). We complement it with a regional set of group velocity measurements, collected by the Lawrence Livermore National Laboratory, associated with earthquakes and stations distributed in and around the Mediterranean/Northern African area.

We investigate the capability of our data set to resolve detailed structure in the Mediterranean Basin, finding–by least-squares inversion– 2-D images of lateral variations in phase and group velocities, at selected periods (30 to 300 s). We employ local, alternatively block or cubic spline parameterization of laterally variable nominal resolution, highest in the region of interest.

To test the consistency of our recent work in upper mantle tomography, we also calculate "theoretical" lateral variations in phase and group velocities from our recent upper mantle model (*Boschi*, 2001). Although this model is based only on measurements of surface-wave phase velocity, both the group and phase velocity maps derived from it are clearly consistent with our results, and effectively reduce the variance of the corresponding data.

URL: http://www.seismology.harvard.edu

S42E-05 1430h

Tomography of the Mediterranean Basin, 2: Compressional Velocity from ISC Travel Times.

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Seismic images of the Mediterranean Basin, based on measurements of P-wave travel time from the ISC bullettins, have recently been published by researchers at University of Utrecht (e.g., *Wortel and Spakman*, 2000) and at I.N.G.V. in Italy (e.g., *Piromallo and Morelli*, 1997). The Italian group has strictly focused on the region of interest, while the Dutch group has derived a high resolution regional model within the framework of a variable resolution model encompassing the whole globe.

We propose an alternative 3-D global image of P-wave velocity anomalies in the mantle, described by a spline parameterization that is denser throughout the Mediterranean area. A comparison between our results and those of other workers is worthwile for various reasons; (1) a cubic spline parameterization is more effective than a block one in resolving detailed structure with a limited number of free parameters; (2) we have independently relocated, before the inversion, the seismic sources associated with the ISC measurements; (3) we have corrected the residuals for the effects of the crust using the recent *Mooney et al.*'s (1998) Crust-5.1 crustal model.

The appropriate choice of a ray-tracing algorithm is another important factor affecting the effective resolution of tomographic images; particularly if regional-distance body-wave observations are to be used to investigate the upper mantle structure, where triplications occur. Also, if a 3-D solution model is chosen as a starting model for a new inversion, deviations of the theoretical ray paths from their first-order, planar shape should be taken into account. We investigate the possibility of overcoming such difficulties by application of the "pseudo-bending" ray-tracing algorithm in our formulation of the forward and inverse problems; we verify the accuracy of the technique, tested on 1-D, 3-D, isotropic and transversely isotropic Earth models.

URL: http://www.seismology.harvard.edu

S42E-06 1445h

A Contribution to the Understanding of the Regional Seismic Structure in the Eastern Mediterranean

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Regional earthquakes recorded by two digital broadband stations (BGIO and KEG) located in the Eastern Mediterranean have been analyzed in order to study the seismic structure in this region. The area consists of different tectonic provinces, which complicate the modeling of the seismic wave propagation. We have modeled the Pnl arrivals using the FK-integration technique (Saikia, 1994) along different paths at the two stations, at several distances, ranging from 400 to 1500 km. Comparing the synthetics obtained by using several models compiled by other authors, we have constructed a velocity model, considering the informations deriving from group velocity distribution, in order to determine the finer structure in the analyzed paths. The model has been perturbed by trial and error until a compressional velocity profile has been found producing the shape of the observed waveforms. The crustal thickness, upper mantle P-wave velocity and 410-km discontinuity determine the shape of the observed waveform portions.

S42E-07 1520h

Deep Seismic Reflection Probing of the Variscan Orogen in Southwest Iberia: IBERSEIS

IBERSEIS Working Group

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The 303 km long deep (20 s) seismic reflection profile, IBERSEIS, has been acquired across the SW Iberian Peninsula, and runs across major tectonic contacts and geological provinces, with the Iberian Pyrite Belt being of the greatest interest. The three major tectonic units sampled are known as the South Portuguese Zone, Ossa Morena Zone and Central Iberian Zone. These zones are separated by sutures and were accreted to one another in Paleozoic times. The transect is part of the EUROPROBE program which is designed to address the fundamental questions about the dynamics of the European lithosphere. Acquisition parameters were designed to favor a high resolution crustal scale image of this orogen. Source signals were generated every 70 m by four 22 ton Vibroseis trucks and were recorded by a 7 km long spread with a receiver spacing of 35 m. The frequency content of the source signal was limited between 8-80 Hz. The seismic profile crosses key elements of the Variscan Orogen, and it offers a unique opportunity to study transpression tectonics. The main scientific results address: a) the characterization of the seismic facies of the SW Iberian lithosphere, with a view to differentiate crustal and lithospheric domains; b) the architecture of the major tectonic contacts; c) the deep geometry of the transpression tectonics seen at surface.

S42E-08 1535h

IBERSEIS: A Seismic Reflection Image of the Variscan Orogen, SW Iberia

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The 303 km long IBERSEIS seismic profile was planned within the framework of the EUROPROBE program to study the deep structure of a transpressive part of the Variscan orogen and answer fundamental questions about the dynamics of the southwestern European lithosphere. Four 22 ton Vibroseis trucks generated an 8-80 Hz source signal which was recorded by a 7 km spread with stations located every 35 m. Shot spacing was 70 m. The close receiver and shot spacing resulted in high resolution images of the crust. Preliminary interpretations of the reflection data show that the highly reflective seismic fabric of the different units of the SW Iberian lithosphere correlate with the major tectonic terranes and contacts mapped at the surface. The two main sutures have been well imaged. The Moho can be identified along the entire transect at 10 to 11 s, indicating a 30-35 km average crustal thickness. The sub-horizontal geometry of the crust-mantle boundary that crosses Variscan sutures suggests a relatively young Moho. Diffractions at Moho depth beneath the southernmost suture zone indicate structure at the crust-mantle boundary.

S42E-09 1550h

The Crustal Structure of the Variscan Transpressive Orogen of SW Iberia

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As part of EUROPROBE's SW Iberia project a deep seismic reflection profile was acquired along one of the most complete transects of the Variscan Orogen (IBERSEIS). The seismic profile crosses two sutures that separate three main tectonic terranes: the South Portuguese Zone, Ossa-Morena Zone and Central Iberian Zone. A preliminary interpretation of the seismic data includes the definition of the geometry of the most prominent sutures such as the Beja-Acebuches ophiolite and Badajoz-Cordoba shear zone. A prominent lower crustal seismic fabric is observed along the involved terranes. The South Portuguese Zone features a typical geometry of a thrust and fold belt architecture. The high resolution achieved by the relatively close receiver and shot spacing has imaged very detailed structures within this thin-skinned tectonic unit, including thrust stacks and duplexes. The Ossa-Morena Zone is characterized by the presence of folded recumbent folds and thrusts. Due to the high resolution, sub-vertical contacts can be identified, helping to understand the strain partitioning of the transpressional tectonics. Furthermore, the seismic data reveal contacts and internal structure of granitic intrusions.

S42E-10 1605h

Thicknesses and Poisson's Ratios in the Iberian Crust as Inferred From Receiver Functions

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During Early Cretaceous times a fragment of the European plate started separating from both the North American and the European plates. The Iberian plate was formed and the former Hercynian Cordillera was destroyed as a consequence of the spreading of the North Atlantic ocean and the opening of the Bay of Biscay. About 80 Ma ago, the Iberian plate inverted its trajectory and converged towards the Eurasian plate, eventually becoming attached again to the European continent. The present Iberian Peninsula, therefore, can be regarded as a Hercynian core surrounded by regions that have experienced Alpine deformation. In this study, we employ the HK receiver function stacking technique to infer crustal thicknesses and Poisson's ratios at several locations in the Iberian Peninsula. The HK stacking [Zhu and Kanamori, 2001] consists of a grid-search for depth and Vp/Vs ratios by summing a weighted combination of amplitudes of the receiver function at the predicted travel times of the Ps, PpPs and PpSs+PsPs phases. We expect that providing new constraints on average seismic properties of the Iberian crust will help understand the evolution of the Hercynian orogen in central Spain or the complex tectonics of the Pyrenees or the Betic Cordillera.

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