



Seismic Hazard Harmonization in Europe (SHARE)

Work Package 3, Tasks 3.2 and 3.4

Iberian Region Workshop: Meeting Minutes

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Location: Hotel Vila Monte, Sitio dos Calicos, Moncarapacho, Olhão, Portugal

Date: 14-16 January 2010

Organizing Commission: Susana Vilanova, IST (chair); Julián García-Mayordomo, IGME; Eliza Nemser, IST; José Martinez Diaz, UCM; Glenda Besana-Ostman, IST; João Fonseca, IST

Workshop Goals:

- Introduction of project SHARE to regional experts to convey the type and quality of data that is being solicited from regional experts for the SHARE seismic source model.
- Description of the DISS database and related terminology and concepts (e.g. composite seismogenic sources) that have been established as the standard for project SHARE.
- Description and discussion of the implementation of SSHAC level 3 methodology in project SHARE.
- Presentations on active faulting data within the Iberian region, including Northern Africa.
- Presentations on existing seismic source zone models within the Iberian region.
- Discussion of epistemic uncertainty with respect to fault and source zone data and how epistemic uncertainty will be handled in the SHARE source model.
- Identification and discussion of controversial issues/sources.
- Iberian fault-based seismic source characterization and integrated, updated source zone model.

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TECHNICAL AGENDA	
Thursday, January 14	
08:00 – 09:30	Registration
09:30 – 09:45	Introductory Remarks: Susana Vilanova (IST)
09:45 – 10:00	Gianluca Valensise (INGV), SHARE WP3
10:00 – 10:30	Ronald Arvidsson (GFZ), SHARE WP3.4
10:30 – 11:30	Keynote lectures: João Cabral (FCUL) and Julián Garcia-Mayordomo (IGME) Overview of active faulting in Portugal and Spain
11:30 – 11:50	Coffee break
11:50 – 12:10	Roberto Basili (INGV), Database of seismogenic sources
12:10 – 12:40	Ivan Wong (URS), SSHAC methodology
12:40 – 13:10	Kuvvet Atakan (UiB), Active faults and uncertainties in hazard assessment
13:10 – 14:10	Lunch break
14:10 – 14:30	Regional Seismicity and Seismotectonics
14:30 – 15:00	Galicia and Cantabria
15:00 – 15:10	DISCUSSION
15:10 – 15:30	Northern Portugal
15:30 – 16:00	Pyrenees and Catalan Coastal Range
16:00 – 16:10	DISCUSSION
16:10 – 16:30	Coffee break
16:30 – 17:30	Lower Tagus Valley
17:30 – 17:40	DISCUSSION
17:40 – 18:00	Iberian Massif
18:00 – 18:10	DISCUSSION
18:10 – 18:40	Iberian Chain
18:40 – 19:30	DISCUSSION
Friday, January 15	
09:00 – 09:30	Pilar Villamor (GNS), Active tectonics at transpressional plate boundaries
09:30 – 10:20	Southern Portugal
10:20 – 10:30	DISCUSSION
10:30 – 10:50	Western Betics and Rif
10:50 – 11:00	DISCUSSION
11:00 – 11:20	Coffee break
11:20 – 12:10	Eastern Betics
12:10 – 12:30	DISCUSSION
12:30 – 13:00	Offshore
13:00 – 13:10	DISCUSSION
13:10 – 14:10	Lunch break
14:10 – 14:20	Offshore
14:20 – 14:30	DISCUSSION
14:30 – 15:00	North Africa
15:00 – 15:10	DISCUSSION
15:10 – 15:40	Azores
15:40 – 15:50	DISCUSSION
15:50 – 16:10	Coffee break
16:10 – 16:50	Existing PSHA zonations
16:50 – 17:00	DISCUSSION
17:00 – 17:20	Large scale zonation
17:20 – 19:00	DISCUSSION
19:30	Workshop Dinner

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Saturday, January 16	
08:00 – 13:00	Fieldtrip to the Quarteira and Carcavai Loulé faults

**Note: Many of these presentations will be made available for download from the project SHARE website (www.milliarium.gabo.de) in the following directory:
SHARE>WP3>meetings>20100114_Faro**

14 January (Morning Session, 09:30-13:10)

Susana Vilanova (IST), Organizing Commission Chair

Vilanova began the workshop with some introductory remarks, welcoming the attendees, providing an overview of Project SHARE and WP3 (particularly WP3.2 and WP3.4), and outlining the workshop goals. She provided a brief overview of the SSHAC methodology and welcomed the external experts. Finally, she expressed that all workshop participants, who collectively form a Working Group on Iberian Seismogenic Sources (WGISS), would share the products of the workshop.

Gianluca Valensise (INGV), SHARE WP3 Leader

Valensise outlined some general characteristics of WP3, ‘Earthquake sources and activity rates’. He went on to describe goals for WP3 from the project SHARE DoW and to explain the context of WP3 within project SHARE. Valensise provided some background for project SHARE (e.g. FAUST), an overview of each task within WP3, and some WP3 challenges (e.g. ambitious in scope, with limited time and financing). He closed by explaining the context of the Iberian regional meeting within SHARE.

Ronald Arvidsson (GFZ), Representative from SHARE Task 3.4

Arvidsson’s presentation was entitled ‘The current state of the seismic source zone model in SHARE’. He explained that the goal of regional workshops is an integrated Euro-Med source model. He outlined the three different types of models that will be implemented in project SHARE (diffuse source zones, area source zones, and a fault-based model), and confirmed that the latter two are to be discussed in regional workshops. Arvidsson presented the outcome of other regional workshops with respect to seismic source zones, and described how to create seismic source models (using existing national models, data from the SESAME project, etc.). He also outlined general guidelines for defining seismic source models (avoid wavy boundaries, use a simple source zone geometry, and avoid background sources).

Some questions followed, such as:

Q: What to do where there is no fault? How to account for activity outside of faults? A: all of Europe will have area source zones, while only some regions will have faults, though it is not clear how this will be implemented.

Q: How do you constrain the detailed geometry of source zone boundaries? A: Because of the scale involved (all of Europe), the details are not important.

Q: What weights go to each type of branch? A: Not clear yet, but the impact of having irregular boundaries will be smoothed.

Q: What are the criteria for drawing boundaries? A: Geology (significant changes in tectonic regime) and seismicity.

Q: There is confusion about the instruction “Avoid background sources”. A: Activity within seismic source zones will be described using a statistical distribution. Also, source zones are described by Mmax values. Area source zones will be continuous.

João Cabral (FCUL), Invited Keynote Speaker

Cabral provided an overview of neotectonics in Mainland Portugal and the regional dynamical setting. He discussed the regional seismicity, important historical seismicity, and the present stress regime (S_{hmax} = NW-SE, in keeping with the convergence vector). He offered a definition for “Neotectonics” that is geodynamical, not operational: deformation within the current tectonic regime, in this case **3.5 Ma to present**. He stressed that due to vertical movements, river incision that postdates the deposition of upper Pliocene plateau conglomerates can be used as a proxy for regional uplift; based on raised marine terraces, vertical incision indicates an average uplift of **0.1-0.2 mm/yr** over a long time scale. Cabral emphasized that Mainland Portugal is characterized by structures with low slip rates (“silent faults”), so there is a need to focus on all structures with a potential to produce earthquakes.

Cabral provided an overview of the geology in Mainland Portugal, and explained that many faults are reactivated ancient faults in Variscian basement, and that it is challenging to distinguish neotectonic activity from Cenozoic activity. Generally, geologists rely on structural deformation affecting upper Pliocene to Quaternary sediments (this requires the presence of young rocks, and the stratigraphy can be challenging). Due to uplift and incision, there is a lot of erosion, and not a lot of deposition and therefore young faulted contacts are rare, so clear evidence for recent activity is lacking. Geomorphic evidence of active faulting is widely used, (e.g. fault scarps, deformed terraces), though there tend to be problems distinguishing between erosional and tectonic effects on the geomorphology. Cabral stressed that due to the level of seismicity (low to moderate), and the poor earthquake locations, it is difficult to correlate known earthquakes with active faults in this region.

Next, Cabral introduced his Neotectonic Map of Portugal (from 1988), which includes faults that have been active during the past 3Ma. With reference to this map, he noted the prevalence of E-W to NE-SW faults with a reverse-slip component and N-S to NNE-SSW left-lateral faults. He stated that with respect to seismogenic potential, slip rates in this region tend to be low, with long average return periods, and fault segment lengths on the order of tens of km (which might correspond with magnitude 6.5 events). He also emphasized the need for more data due to the very limited amount of paleoseismic data (presently only along the Ferrel fault, the Lower Tagus Valley fault, the Vilariça fault, and the Aljezur fault). Lastly, Cabral described his progress in creating a GIS seismotectonic database of Portugal; his intent was to incorporate this data into a larger European database and he has generously offered the use of this database in project SHARE.

Julián García-Mayordomo (IGME), Invited Keynote Speaker

García-Mayordomo provided an overview of active fault and seismic hazard studies in Spain. He explained that prior to 2002, sources were zones, and he presented the unpublished Neotectonic Map of Spain (1994), which he stated needs to be refined to include only “active

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faults". He outlined the rapid development of seismic hazard studies from 2002-2005 motivated by changes to the civil protection law. Garcia-Mayordomo also raised some issues that arise from using geological data for the purposes of seismic hazard studies, including: 1) what is the definition of an active fault?; 2) slip rate estimates are obtained in different ways for different time periods; 3) since magnitude is often calculated using length, there must be a rigorous criteria for measuring length; and 4) there is a great disparity in recurrence interval data because of the scarcity of paleoseismic data. He referred to a "boom in active faulting studies" from 2005 to the present and outlined current challenges (to collect and assess the information, assess quality, and to develop a database. Finally, he provided an overview of contributed talks from Spanish researchers.

Some questions followed, such as:

Q: Uplift and slip rates are similar, is it possible that only the vertical component of fault slip is captured? A: Yes, this is true.

Q: What do you make of the Negredo et al. (2002) figure with strain rates? A: Based on current research we have a very different picture for Portugal offshore.

Roberto Basili (INGV), SHARE WP3.2 Task Leader

Basili began with an overview of fault-related hazards, including ground shaking, surface deformation, and surface rupture. He then reviewed published earthquake source databases, and explained that the goal of SHARE is to expand European coverage. He defined important terminology and parameters for seismogenic sources, including ISS- Individual seismogenic sources, CSS- Composite seismogenic sources, and DSS- Debated seismogenic sources. He also addressed the issue of how/where to terminate a CSS (either the fault clearly terminates or there is a major change in geometry or slip rate). He expressed the goal to have a database for all of Europe, where regional partners will manage the "back-end". Finally, he stressed that the intent is to empower the database user community by soliciting input from users.

One question followed, but since Basili ran out of time, his presentation was continued the next morning.

Q: What if you have a fault with trenches all along and based on paleoseismology you have a paleoearthquake, is it an ISS or CSS? A: That depends, it could be either.

Ivan Wong (URS), Invited External Expert Panelist

Wong provided an introduction and overview to the methodology developed by the SSHAC (senior seismic hazard analysis committee) for PSHA; project SHARE follows a SSHAC level 3 methodology. He explained that according to SSHAC, the ownership of results is by the community, and while consensus is not necessarily reached, the goal is to capture the full range of legitimate interpretations. SSHAC was introduced because PSHA evolved to a point where the process was complex and guidelines needed to be established. The goal of the regional workshop stated in SSHAC jargon is to capture the best judgments of those within the informed technical community (informed technical community represents the participants of the meeting). SSHAC recognizes that there is no consensus and no single correct model and instead aims to capture epistemic uncertainty (uncertainty due to a lack of knowledge; different interpretations define the range of epistemic uncertainty). Any model that is supported by data is credible, whereas models that are not supported by data are not included in the model. The goal is to represent the center, body, and range of interpretations.

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Wong introduced the concept of Probability of Activity $P(a)$, an example of epistemic uncertainty that is used when we do not know whether a fault is seismogenic. $P(a)$ is a judgment that treats the likelihood of whether or not a fault is active in a probabilistic manner. He went on to explain that the "Technical Integrators" (in SSHAC terminology) are the regional leaders in project SHARE; in this case João Fonseca, Susana Vilanova and Eliza Nemser from IST. The role of the regional experts is that of "proponents", who have developed a model, support a model, and advocate for that model. "Evaluators" are tasked with stepping back, looking at everyone else's model, and assigning appropriate weights to different models based on their relative credibility. "Resource experts" present information, these same participants act as "proponents" later. He explained that peer review and documentation are very important in SSHAC. Finally, he cautioned that experts tend to underestimate uncertainty and that it is always useful to include faults, just important to capture the uncertainty; also, particularly in the estimation of slip rates, uncertainty is very important.

14 January (Afternoon Session, 14:00-19:30)

Kuvvet Atakan (UiB), Invited External Expert Panelist

Atakan provided an overview of SHA, both deterministic and probabilistic, which was very useful for participants who are geologists with little or no seismic hazard experience. He showed examples of PGA maps that show ground motion distribution, and explained different models such as the characteristic earthquake model, and Poissonian vs. time dependent recurrence models. He stressed that it is always a challenge when studying a particular fault to know where we are presently in the recurrence interval (earthquake cycle). Atakan then moved to a discussion of uncertainties, and the distinction between analytical and numerical uncertainties, and uncertainties related to the interpretation of the data. He then outlined various sources of uncertainty. For example, in active faulting investigations, you have data from the regional scale, the local scale and the site scale, and you introduce and propagate uncertainties when you extrapolate from one scale to another. When you use trench data to extrapolate to the rest of the fault, you also introduce uncertainty. He proposed a method whereby you can apply a logic tree approach to paleoseismic analysis, and for each stage introduce two branches: 1) your favored model, and 2) other alternatives. He ended on an optimistic note, suggesting that future paleoseismic data may be able to provide constraints on parameters such as location of the asperities, rupture size, initiation point, and directivity effects.

Seismicity and Seismotectonics of the Plate Boundary Region

Mourad Bezzeghoud (UE), Invited Regional Expert

Bezzeghoud provided an overview of the seismicity and seismotectonics of the plate boundary region. He discussed major historical events, instrumental seismicity, and the total seismic moment tensor at the western part of the Eurasian-Nubian plate boundary.

Seismicity and Seismotectonics of Portugal and the Azores

José Borges (UE), Invited Regional Expert

Borges presented work by himself, M. Bezzeghoud, and B. Caldeira on the seismicity and seismotectonics of Portugal and the Azores. He detailed Azores-Gibraltar instrumental

seismicity, and discussed the most likely source for the 1755 earthquake based on modeling (Gorringe Bank). With respect to the seismotectonics of the Azores region, he presented focal mechanism data from Borges et al (2007), and he described two different zones, each with different slip rates, that are consistent with geodetic data.

Galicia and Cantabria

Fidel Martín González (URJC), Invited Regional Expert

González presented work by himself, J. Giner-Robles, J. Martínez Díaz, and J. Insua Arévalo. He explained that in Galicia (the NW Iberian peninsula), there is a lack of markers for dating, and very little work has been done in this region. There are reactivated Alpine structures; the 1995 and 1997 Lugo seismic sequences reactivated Alpine faults. González described structures that include NE-SW left-lateral faults, NW-SE right lateral faults, and NW-verging thrusts, and provided estimated Mmax values for faults that fall into these categories. In the absence of slip rate data for the short period, long-term estimates are used.

Northern Portugal

João Cabral (FCUL), Invited Regional Expert

Cabral presented data on the Penacova-Régua Verim (PRV) and the Manteigas-Vilariça-Bragança (MVB) faults in northern Portugal, which are sub-parallel, ~200 km long each, ~60 km apart, and both reactivated left-lateral faults. He presented evidence for reactivation and information about historical and instrumental seismicity surrounding these faults. He also presented paleoseismic data from the Vilariça fault, including slip rate estimates. Cabral presented work published in Cabral (2005) and Rockwell et al. (2009).

Pyrenees and Catalan-Coastal Range

Julián García Mayordomo (IGME), Invited Regional Expert

García-Mayordomo provided an overview of data on faults in the Pyrenees, including the Leyre, Lourdes, Coronas, Maladeta, Sud-Tet Cerdagne, Tech, and Amer faults.

Juan Insua Arévalo (UCMadrid), Invited Regional Expert

Arévalo presented data on the Leyre fault in the south Pyrenees, near Pampalona. There is no seismicity associated with this fault; he presented the results of a morphotectonic study. Arévalo provided seismogenic parameters for the Leyre fault, including rupture area, surface rupture length, dip, Mmax, and slip rate data.

Hector Perea (FCUL), Invited Regional Expert

Perea presented data from the central Pyrenees, including historical seismicity and data on the Coronas fault. For the Coronas fault, he presented parameters including displacement, length, slip sense, slip rate, and Mmax. He also explained the gravitational component of slip on this fault, and the glacial effects. He also described the northern Maladeta fault, and provided focal mechanism data, slip sense, length, slip rates, and Mmax values. In the eastern Pyrenees, he described the Tet-Cerdanya fault, and provided slip sense, age, length, strike, dip, and slip rate data. Perea also described the Ribes-Camprodon thrust, the Vallfogna thrust, and the Amer fault. For the Amer fault, he provided detailed fault parameters. In the western Mediterranean, Perea described the extensional basin, and the two systems of normal faults, trending NW-SE and NE-SW. In this region he indicated there is a detachment depth between 10-15 km and there are 17 faults with characteristics of activity. He provided a table showing

seismogenic parameters, including estimates of M_{max} , based on Wells and Coppersmith (1994) relations.

Lower Tagus Valley

João Fonseca (IST), Invited Regional Expert (and Iberian Regional Leader)

Fonseca presented work by himself, S. Vilanova, and G. Besana-Ostman. He began with a brief overview of the geologic history of the Lower Tagus Valley (LTV) fault and early studies on the LTV fault. He then described recent paleoseismic and active tectonics studies. After Besana-Ostman presented new active tectonics data, Fonseca discussed the compatibility between plate boundary slip rates (from Serpelloni et al, 2007) and LTV slip rates.

Glenda Besana-Ostman (IST), Invited Regional Expert

Besana-Ostman presented new mapping of a tectonic scarp in the LTV (near Entrocamento) based on aerial photos and geomorphic mapping. She presented preliminary displacement values and slip rate estimates from this ongoing study.

Matthieu Ferry (UE), Invited Regional Expert

Ferry presented no data but introduced a new project being undertaken by himself, J. Carvalho, J. Borges, and D. Fitzenz on seismogenic sources in the LTV (called the ATESTA project). He provided an overview of historical seismicity on the LTV, an overview of neotectonic studies, and proposed that the Basel-Reinach fault in Switzerland may be considered an analog to the LTV.

Pedro Cunha (UCoimbra), Invited Regional Expert

Cunha presented research by himself, A. Martins, and J. Cabral. He provided an overview of the geology of the Tagus Valley region, and presented data acquired by mapping and dating fluvial terraces. He also presented OSL dates from the terraces, argued for differential uplift of opposite sides of the valley, and provided a comparison of the incision rates of different terrace staircases.

João Carvalho (INETI), Invited Regional Expert

Carvalho presented work by himself, R. Ghose, T. Rabeh, J. Cabral, M. Costa, C. Pinto, F. Carrilho, M. Bielik, L. Matias, S. Heleno, M. Silva, J. Borges, and M. Ferry on geophysical data that has been applied to the characterization of potential seismogenic faults in the LTV. He described available oil industry data in the region, some of which has been reprocessed and reinterpreted. He showed sample seismic and potential-field interpretations, and presented a preliminary map of potential seismogenic sources that is undergoing revision. He announced plans to acquire high-resolution data to improve visualization of shallow deformation. There are three published papers on this topic by this author: Carvalho et al. (2005), *Marine and Petroleum Geology*; Carvalho et al. (2006), *Tectonophysics*; Carvalho et al. (2008), *Geophysical Journal International*.

João Cabral (FCUL), Invited Regional Expert

Cabral continued the presentations on the LTV fault zone, describing the effects of distant seismicity and the regional historical and instrumental seismicity. He also discussed the geologic history of the basin and provided evidence for recent surface faulting that affects

upper Pliocene sediments. He also provided seismogenic parameters for the Azambuja fault, based on the Cabral et al. (2004) *Journal of Seismology* publication.

Iberian Massif

Raúl Pérez López (IGME), Invited Regional Expert

Pérez López presented work by himself, Giner-Robles, Rodríguez-Pascua, and Silva. He gave an overview of the seismotectonic setting of the Madrid basin. He described micro- and macro-structural, paleoseismic, and focal mechanism data from normal faults affecting Late-Middle Pleistocene fluvial sediments. He also provided an overview of the instrumental seismicity in the basin. The question debated was whether the South Border Fault of the Spanish Central System (~150 km long) can be assumed to behave as an unsegmented fault with a slip rate of 0.01 mm/yr from Cenozoic geological markers. Pérez López described evidence for liquefaction that can be related with paleoearthquakes with magnitude greater than 5.5. Relevant publications include Carreño et al. (2008) *Seismological Research Letters* and Silva et al. (1998) *Terra Nova*.

Iberian Chain

Paloma Lafuente Tomás (UNIZAR), Invited Regional Expert

Tomás presented work by herself, J.L. Simón, L.E. Arlegui, and C.L. Liesa on the neotectonic and seismotectonic setting of the Iberian Chain and a paleoseismic study of the Concud fault. She provided an overview of the neotectonic setting of the central, central-eastern, and eastern sectors of the Iberian Chain. She then presented data from ongoing paleoseismic investigations along the Concud fault at the eastern boundary of the Jiloca graben. Relevant publications include Simón et al. (2005), Lafuente et al. (2008, 2010).

Pedro Lucha (UNIZAR) + Alvaro Gonzalez (UNIZAR), Invited Regional Experts

Lucha presented work by F. Gutiérrez and P. Lucha, providing a geomorphological perspective on active faults in the Iberian Range (NE Spain). In addition to describing the tectonic geomorphology of the Iberian Range, the authors presented a paleoseismic study of the Munebrega West Fault and a geomorphological cartography of the Río Grío Graben; these neotectonic structures have been discovered recently thanks to regional geomorphic studies. Lucha also described existing sources of information (mostly unpublished) that can be used to compile a database of active faults in the Iberian Range. Relevant publications by these authors include: Gracia et al. (2002) *Geomorphology*; Gracia et al. (2008) *Geological Magazine*; Gutiérrez et al. (2008) *Geomorphology*; Gutiérrez et al. (2009a) *Archeoseismology and Palaeoseismology in the Alpine-Himalayan collisional zone. 1st INQUA-IGCP-567 International Workshop on Earthquake Archaeology and Palaeoseismology, Baelo Claudia, Spain*; Gutiérrez et al. (2009b) *International Journal of Earth Science*.

15 January (Morning Session, 08:30-13:30)

Roberto Basili (INGV), SHARE WP3.2 Task Leader

Basili continued his presentation from the day before, and discussed default activity rates and possible recurrence models (ISS: strictly periodic; CSS: moment rate balanced G-R). He discussed how penetrable boundaries will be handled in the SHARE source model, and how the potential for ruptures to jump segment boundaries will be accounted for. He presented a code that was written to check the proximity of endpoints of neighboring faults. He also

continued to explain general features of the DISS database, such as each parameter in the DISS database has a qualifier to explain the source of the data. With regard to how the DISS database/project SHARE will handle epistemic uncertainty about whether or not a fault is active, he presented a scheme that assigns a quality factor to fault data.

Pilar Villamor (GNS), Invited External Expert Panelist

Villamor presented a talk on active tectonics at transpressional plate boundaries. She described faults from New Zealand, an example of a transpressive plate boundary. She wowed the audience with incredible photos of active faults in New Zealand, including the Alpine fault, the Wellington fault, the Otago and Nelson reverse faults, and the Central Taupo Rift. She also discussed the extent to which this orogen may be considered an analog for the tectonics in Iberia.

Southern Portugal

Antonio Brum da Silva (FCUL), Invited Regional Expert

Brum da Silva described the neotectonic activity in the Moura region, and the seismicity of the Alentejo region of SE Portugal. He presented data on the seismogenic parameters of the Vidigueira-Moura fault (VMF), and the Alqueva fault (AF) from a published paper by himself, J. Cabral, H. Perea, and A. Ribeiro (2009), *Tectonophysics*.

Paula Figueiredo (FCUL), Invited Regional Expert

Figueiredo presented ongoing work by herself, J. Cabral, and T. Rockwell from the S. Teotónio-Aljezur-Sinceira fault system SW of Lisbon. She provided evidence for activity, and some fault parameters. She also described the historical seismicity (which is not well known) and related instrumental seismicity. She discussed mapped faults offshore and concluded by presenting results from trenching studies at the Alfambras trough.

João Carvalho (INETI), Invited Regional Expert

Carvalho presented work by himself, R. Dias, E. Ramalho, C. Pinto, R. Ressureição, J. Leote on geophysical data applied to the characterization of the San Marcos-Quarteira (SMQ) and Carcavai faults (CF). He provided an overview of the neotectonics and seismicity in southern Portugal. He then presented geophysical results that confirm the activity and orientation of the SMQ. He also described geophysical data from the CF. There is one published article on this topic by this author: Carvalho et al. (2006), *Journal of Applied Geophysics*; there is also an abstract, Carvalho et al. (2007), *AGU*.

Ruben Dias (INETI), Invited Regional Expert

Dias presented work by himself, J. Cabral, and R. Ressureição on the seismotectonics of the Algarve region. Dias provided an overview of the historical seismicity, and described the deformation that is observed (folded Plio-Pleistocene sediments, fractures, faults, joints). He described several faults, including the Martinhal, Lagos, Quita dos Pocos fault, S. Marcos Quarteira, Loule, Odiáxere, and Boliqueime faults. He presented a table of fault parameters that includes Mmax estimates. Related published work referred to in his abstract includes Dias and Cabral (2000), Dias (2001) [PhD Thesis], Dias and Cabral (2002), Dias et al. (2004), Dias et al. (2009), Ressureição (2009) [MSc thesis].

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After Dias's presentation, Pedro Terrinha told of a new (unpublished) database as a result of project NEAREST that includes these faults in addition to offshore structures.

Western Betics and Rif

Patricia Ruano (UGR), Invited Regional Expert

Ruano presented data on the Balanegra, Baza, and Zafarraya faults. Some of the faults she described are short faults, which elicited the question of whether they are continuous. Ruano responded that they are probably not, as you cannot trace them in seismic profiles.

Juan Insua Arévalo (UCMadrid), Invited Regional Expert

Arévalo presented data from the Malega Basin in the Western Betics. He described the historical and instrumental seismicity, and indicated that the scattered seismicity shows no clear relationship with faults. He presented gravimetry data and a morphotectonic analysis, and provided slip rate estimates and Mmax values. He then switched gears to a different talk on active faults and seismicity in the Granada Basin, during which he provided detailed parameters for the Granada Fault.

Domenico Giardini (ETH-Zurich) Project SHARE Coordinator

Giardini made just a few general comments on project SHARE. He explained that SHARE was designed so that scientists can see how their data is fed into seismic hazard study. He also explained that insofar as Ibero-Magreb is part of Europe and Europe is part of the world, this really is part of a global effort. He also indicated that it would have been ideal to include researchers from every country as part of project SHARE, but that it was not possible. As a result of this limitation, he explained that SHARE relies heavily on contributions from researchers that are not directly associated with the project. Finally, he thanked everyone for their participation.

Eastern Betics

Julián García-Mayordomo (IGME), Invited Regional Expert

García-Mayordomo began by presenting historical seismicity data from the Eastern Betics. He then presented data on the Alhama de Murcia fault, including segmentation data, with a table summarizing the seismogenic parameters of each segment. He also discussed the Albox, Guadalenum, and Carrascoy faults. He then changed topics and discussed the Bajo Segura anticlinorium, and presented a table showing the seismogenic parameters for this structure.

Miguel Ángel Rodríguez-Pascua (IGME), Invited Regional Expert

Rodríguez-Pascua presented work conducted by himself, R. Pérez-López, J. Bischoff, V.H. Garduño-Monroy, and J.L. Giner-Robles from the intraplate province of Albacete, in the Prebetic External Zone in the SE of Spain. He showed ground deformation and large scarps along the Pozohondo fault, a Holocene active, segmented structure that bounds the Cordovilla Basin but has scarce associated instrumental seismicity. He also provided paleoseismic data and seismogenic parameters for the Pozohondo fault. The estimated slip rate is 0.09 mm/yr for the active segment of Tobarra-Cordovilla of the Pozohondo fault and the estimated maximum magnitude is between 6-6.2. Archaeoseismic evidence suggests an historic earthquake of magnitude close to 6 that affected Roman buildings. There are two published studies that were referred to in this presentation: Rodríguez-Pascua et al. (2008), *Geomorphology*; and Rodríguez-Pascua et al. (2009), *Sedimentary Geology*.

Ximena Moreno (CSIC/UTM), Invited Regional Expert

Moreno presented work by herself, E. Masana, E. Gràcia, A. Rodés, R. Bartolomé, and R. Pallàs on the Eastern Betic Shear Zone (EBSZ). She presented geomorphic data and paleoseismic data on the onshore portion of the Carboneras fault, and marine geophysical data on the offshore portion. She also presented seismogenic parameters from their ongoing study to characterize the activity and segmentation of the Carboneras fault zone.

Offshore

Pedro Terrinha (INETI), Invited Regional Expert

Terrinha described ongoing work by himself, L. Matias, L. Noiva, J. Vicente, S. Silva, L. Batista, N. Lourenço, G. Carrara, T. Cunha, J. Duarte, F. Rosas, V. Valadares, E. Gràcia, and N. Zitellini on active faults offshore between the Gibraltar Straits and the Tore-Madeira Rise. First, he presented an overview of the distribution of seismic profiles from various sources since 1974. He then presented the results of processing and interpretation of seismic data, multibeam bathymetry, and OBS data, including data on the Marquês de Pombal thrust, the Horseshoe Fault, the SWIM fault zone, and the Gulf of Cadiz Accretionary Wedge. Terrinha then presented a map of active faults, and a corresponding table of active fault parameters, including kinematics, length, and Mmax estimates. He then presented various tectonic models for the plate boundary region, including a new model based on the SWIM fault zone. He also briefly described the results of analog and numerical models that reproduce the observed deformation.

Sónia Silva (FCUL), Invited Regional Expert

Silva presented work by herself, L. Matias, M. Romsdorf, W. Geissler, P. Terrinha, and the NEAREST Working Group on instrumental seismicity in the Gulf of Cadiz based on NEAREST OBS ocean bottom network data. She presented an overview of historical and instrumental seismicity in the Gulf of Cadiz. She then showed preliminary results from analyzed earthquake events showing the depth distribution of hypocenters and focal mechanism data.

Luis Matias (FCUL), Invited Regional Expert

Matias presented work by himself, M.A. Baptista, F. Carrilho, A. Annunziato, and the NEAREST Team on scaling laws for tsunamigenic earthquakes in the Gulf of Cadiz. He introduced the Portuguese tsunami warning system, which relies on pre-computed scenarios and tsunamigenic source zones.

15 January (Afternoon Session, 14:30-19:00)

Offshore

Hector Perea (FCUL), Invited Regional Expert

Perea presented work by himself, E. Gràcia, E. Masana, R. Bartolomé, and P. Santanach on active faults in the Mediterranean offshore. He discussed data from the Bajo Segura offshore basin and the València trough. He also discussed the historical and instrumental seismicity of the Bajo Segura basin, and presented marine geophysical data with evidence for Quaternary deformation. He described four extensional faults with Quaternary activity from the

València trough, and presented seismic profiles through these structures. He closed by providing a table of seismogenic parameters for the València trough extensional faults.

North Africa

Mourad Bezzeghoud (UE), Invited Regional Expert

Bezzeghoud presented a talk entitled “Seismogenic sources along the western Eurasia-Africa plate boundary: Morocco and Algeria”. He provided an overview of historical and instrumental seismicity for the Ibero-Maghrebian region, along with focal mechanism data from Bezzeghoud et al. (2008) and Bufoin et al., (2004). He also discussed the total seismic moment tensor, also from Bezzeghoud et al. (2008). He described in detail the data from several major earthquakes, including the Alhoceima earthquake (Bezzeghoud and Bufoin, 1999), Melilla earthquake (Bezzeghoud and Bufoin, 1999), Mascara earthquake (Bezzeghoud and Bufoin, 1999), Al Asnam earthquake (Bezzeghoud et al., 1995), Tipaza earthquake (Bounif et al., 2003), Zemmouri-Boumerdes earthquake, and Constantine earthquake (Deschamps et al., 1991).

Azores

José Madeira (FCUL), Invited Regional Expert

Madeira presented work by himself and A. Brum da Silveira on the neotectonics of the Azores central group of islands. He began by describing the geodynamic setting of the Azores at the triple junction between the North American, Eurasian, and African plates. Active transtensional deformation in the Azores is believed to result from differential spreading rates north and south of the triple junction; hot spot-related volcanism is believed to be tectonically controlled. Madeira presented data from historical seismicity and instrumental seismicity, including some focal mechanism data (instrumental seismicity is only available after the 1980 M7.2 earthquake). He then presented results from neotectonic studies in the Central Group of Islands, including Terceira, S. Jorge, Pico, and Faial Islands. Active faults in this region are characterized by clear fault scarps, geomorphic features, and aligned volcanic centres. Fault lengths are not well known, as there is limited information about the offshore extent of many faults. Slip rate estimates were presented based on neotectonic methods and paleoseismic data. Mmax values were calculated using relationships from Wells and Coppersmith (1994) and are consistent with values from historical and instrumental seismicity. Relevant publications by this author include Madeira and Brum da Silveira, (2003), *Annals of Geophysics*.

Existing PSHA zonations

Julián García-Mayordomo (IGME)

García-Mayordomo presented the existing seismic source zone models for Spain. He also outlined some problems with seismic source zones in general, including the fact that delineating zones can be highly subjective. Existing source zones that cover the whole Iberian Peninsula include Martín (1984), IGN (1991), Jiménez et al. (1999), Jiménez, Giardini and Grünthal (2001), and Pelaez and López Casado (2001). Additionally, local-scale zonation models exist for the Pyrenees, Northeast Iberia, the Catalan Coastal Range, the Betic Cordillera, the Eastern Betic Cordillera, and the Canary Islands. García-Mayordomo pointed out that for SHARE we need to either 1) produce a composite model from regional-scale models, 2) produce a composite model from local-scale models, or 3) produce a new

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model (though there is little time!). He proposed a hybrid model, wherein source zones are complimentary to fault sources.

Susana Vilanova (IST)

Vilanova presented an overview of instrumental seismicity in Iberia and some major historical earthquakes, with an explanation of how magnitudes were calculated. She also discussed the source zones for historical events based on the distribution of high intensities. She then showed a simplified fault map juxtaposed on the earthquake data and presented the Vilanova and Fonseca (2007) zonation model, which is based on seismicity. She also presented the Pelaez and Casado (2002) zonation model and the Sousa and Costa (2009) zonation model, which is based on gross morphostructural provinces. Lastly, she presented the existing zonation model for the Azores, from Carvalho et al. (2001).

Large-scale zonation

Julián Garcia-Mayordomo (IGME)

Garcia-Mayordomo presented a preliminary large-scale zonation model for Iberia developed for use in the smoothed seismicity branch of the SHARE logic tree. This model is the product of a collaboration within a UCM-IGME Working Group that includes J. Garcia-Mayordomo, J.J. Martínez-Díaz, J.A. Álvarez-Gómez, J. Giner-Robles, J.M. Insua-Arévalo, R. Pérez-López, M.A. Rodríguez-Pascua, and F. Martín-González. Garcia-Mayordomo presented existing zonations in Iberia as the basis for this preliminary map. Additionally, he described the criteria that has been adopted for delineating large-scale zones in project SHARE, as outlined in the document “Specification of source models to be used in SHARE”, authored by Mathilde Sørensen, Gottfried Grünthal, Marco Pagani and Jochen Woessner: 1) large differences in the earthquake source processes, 2) regional differences in catalog completeness time, and/or 3) attenuation differences.

Following these presentations on source zones and large-scale zonation, a general discussion on source zones ensued, moderated by Ronald Arvidsson and Susana Vilanova. It was a challenge to organize the discussion in a systematic way, and Kuvvet Atakan suggested that a systematic approach would be to go through one of the zonation models and have a discussion on each zone boundary. The point was raised that time limitations and a lack of clear criteria for drawing source zones were impeding progress. Pilar Villamor and Ivan Wong highlighted the importance of using geology and crustal characteristics as criteria to delineate source zones. Vilanova pointed out that in the document “Specification of source models to be used in SHARE”, authored by Mathilde Sørensen, Gottfried Grünthal, Marco Pagani and Jochen Woessner, it states that seismicity should be used as the main criteria for source zone models, whereas large-scale zonation models are to be based on geological architecture. Ivan Wong explained that using seismicity as the sole basis for source zone models assumes that seismicity is stationary, and that instrumental/historical records give a complete picture of the spatial distribution of earthquakes.

Jose Madeira suggested that one source zone may be sufficient to cover the whole Azorean region. As a product of this discussion, the participants produced a sketch that includes revisions to existing source zone models. Ronald Arvidsson kept this sketch as a starting point for the new zonation model for Iberia. As a result of this productive discussion, new consultations and meetings have been scheduled for the near future (February 18 in Lisbon

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and another in early March in Madrid) to achieve a source zone model that will then be circulated to achieve consensus.

CLOSING REMARKS

Gianluca Valensise recognized that the workshop represented an historic event for the Spanish and Portuguese scientific communities to come together. He remarked on the very impressive amount of data that has been acquired in Spain and Portugal in the past 10 years. He said that we accomplished more than was anticipated in this workshop. Finally, he pointed out that while the geologists seem to have a strong collaboration, there is more work to be done on seismic source zones.

Domenico Giardini commented that it is sobering to reflect, in light of the recent earthquake destruction in Haiti, on the importance of seismic hazards research. He reminded participants to remember the context of the work, that in Lisbon we saw that kind of destruction in 1755. He closed by saying that it is essential to make sure that the seismogenic models represent the latest science so that we can do a service to society with a representative model.

Representative of the President of the Câmara Municipal de Olhão joined the closing session to welcome the participants, to state the importance of the workshop and his support for similar initiatives. He closed with a few remarks about how the municipality is making efforts in terms of educating the population.

16 January

We concluded this workshop with a fieldtrip led by João Cabral (FCUL) and Ruben Dias (INETI) to view deformation associated with the San Marcos-Quarteira faults. The field guide was authored by J. Cabral, R.P. Dias and R. Ressureição, and provided an extensive overview of the regional geologic setting. The group visited deformed sandstones at the Boliqueime outcrop and the Barrancosa railway outcrop, and we examined beautiful detrital dikes nearby.

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