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D3.1 – Compilation of existing regional and national seismic source zones

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Revision: 1

Dissemination Level

PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1. Introduction

The goal of the current report is to present a new European areal seismic source zone model (SSZM) covering the SHARE project area (Figure 1) which in the west stretches from Iceland, the mid-Atlantic ridge, the Azores, to, in the east, Romania and Turkey. In the north from Scandinavia to, in the south, Algeria and Cyprus. The current source model is an areal source zone model with use of some additional line sources in Turkey. This report is not intended as a complete scientific description of the model but rather a description of work and principles upon which the model is based. An accompanying scientific paper describing the model in detail is planned. The here presented source model reports on the status of the SHARE source model, resulting from the SHARE WP5 model building workshop of October 2010.

As a part of the model building in SHARE a seismic source zone model, also called area source model, has been constructed. The model is built upon available local and regional models as well as newly constructed source zones. The model has been constructed during eight separate workshops (Table 1) throughout Europe as subdivided by the SHARE consortium. Almost 80 experts from the informed European-Mediterranean seismological community have participated in building the model (Table 2).

The model consists of two separate parts. The first part corresponds to crustal seismicity and covers all of the study area. The second part of the model contains zones that cover areas of significant intermediate seismicity.

The here presented model is a community-based consensus model for Europe engaging experts throughout the SHARE region. In total almost 80 experts from 28 countries were involved in the construction leading to a high degree of homogenization across national borders. The participation largely exceeds the number of participants in SHARE that receive financial support from the EC – this underlines the communities interest and need for a model as targeted in SHARE.

The first European SSZM was the GSHAP model (Grünthal et al., 1999a, 1999b) followed in the southern portion of the Euro-Mediterranean region by the SESAME model (Jimenez et al., 2001). North of 44^{o} the SESAME model is identical to the GSHAP zonation north with some adjustments mostly of minor nature (Jimenez et al., 2003). Thus the GSHAP and SESAME models, according to WP5 model building workshop, are of the first generation of European source models. Consequently, the SHARE SSZM, a second generation European SSZM, will be denoted version 2.0.

New areas covered by the seismic source model compared to previous models are, the Azores, Iceland, the North Atlantic Ridge, smaller islands at sea and intermediate depth seismicity in the Cyprean Arc. One difference from the SESAME model (Jimeney et al., 2001) is that the entire study area is covered by source zones.

A collection of references for European, regional scale, national and local models can be found in Appendix 1. This collection is rather comprehensive but do not cover all published source zonation studies throughout Europe but aims at selecting important and recent works throughout the SHARE region. Selected models will be made available as GIS files.

The SHARE SSZM model, v2.0, which is supplied together with this report, is here provided as an ESRI shape file but will also be made available as ASCII files.

2. Principles of model construction

The principle for seismic source zones, which is also used here, is that they represent enclosed areas within which, a uniform seismicity distribution and maximum magnitude is expected. Background sources have been avoided in the sense that all areas have been covered by seismic sources, i.e., even very low seismicity areas are covered with areal source zones.

The principles along which seismic source zones in the current model have been constructed are based on information from geological structures on different scales, tectonics and seismicity. One challenge in the construction has been the varied seismotectonic environments, stretching from the old stable continental regional (SCR) shield areas, younger SCR of Central Europe, the active mountain building of the Pyrenee's, the Alpine belt and the Carpathians, the mid-Atlantic Ridge and the current collision and subduction areas of the Mediterranean. In the older SCR shield and platform regions of northern Europe very few recent active structures are known. In these areas, available information from seismicity and older structures has been the basis for the current model. Pronounced structures, like the Rhein Graben in Central Europe, are well defined by the source zonation and are constructed with a higher detail than the above described large structures like the Baltic Shield. In the Mediterranean area the active structures have played a major role in the model construction. Seismicity also follows these structures well, e.g., as can be seen along the North Anatolian fault, the Gulf of Corinth and in the Hellenic Arc. Use of fault source information has also been made in the construction of the source zones; especially in the case of the construction of the sources for Balkans, Greece and Turkey, Italy and Portugal.

During the feedback process local experts have been given opportunity to suggest changes after model construction in local workshops. This has in several parts of the model lead to changes. A draft model was presented and discussed during the SHARE Rome 2010 1st annual meeting. Further feedback was received from the review made during the WP5 model building workshop in Potsdam, October 2010.

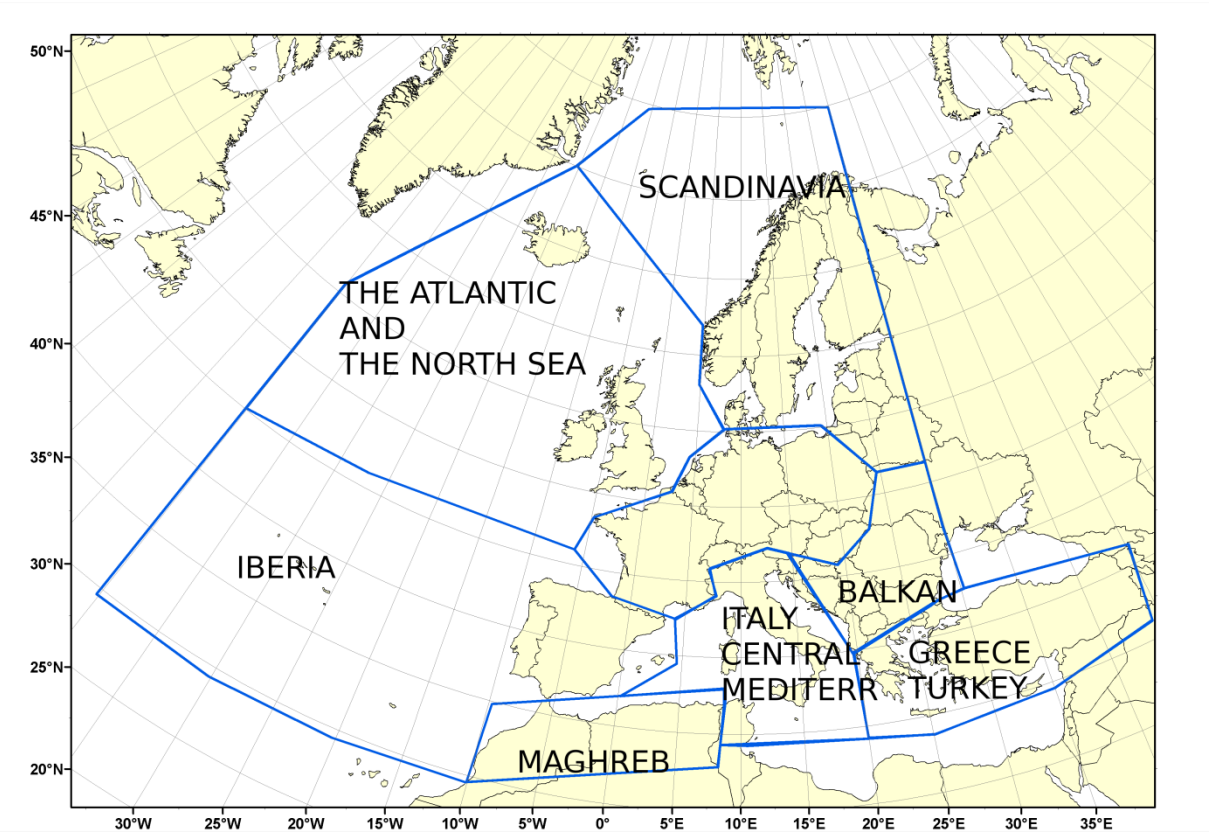

Figure 1. SHARE regional division for task T3.4 on areal seismic source model. The area was later modified to cover all of Turkey on request of the Turkish delegates.

3. Overview of completeness of information

The here presented model is complete as to being delivered from each subregion. All significant intermediate depth seismicity areas are also present, i.e., Vrancea, the Hellenic Arc and the Cyprean Arc. The interface of the subduction zone is currently not included but might be included in a later state. The model is extended compared to Figure 1 after request from the EMME project, thus covering the whole of Turkey.

4. The SHARE areal seismic source zone model

For each sub-region of the SHARE area, except the Maghreb, local SHARE SSZM workshops have been held (Table 1.). Totally eight workshops have been held. Further information can be found in the minutes from each workshop. A brief description of progress of work for each subregion is given below in sections 5.1-5.8. The resulting SHARE SSZM can be seen in Figure 2.

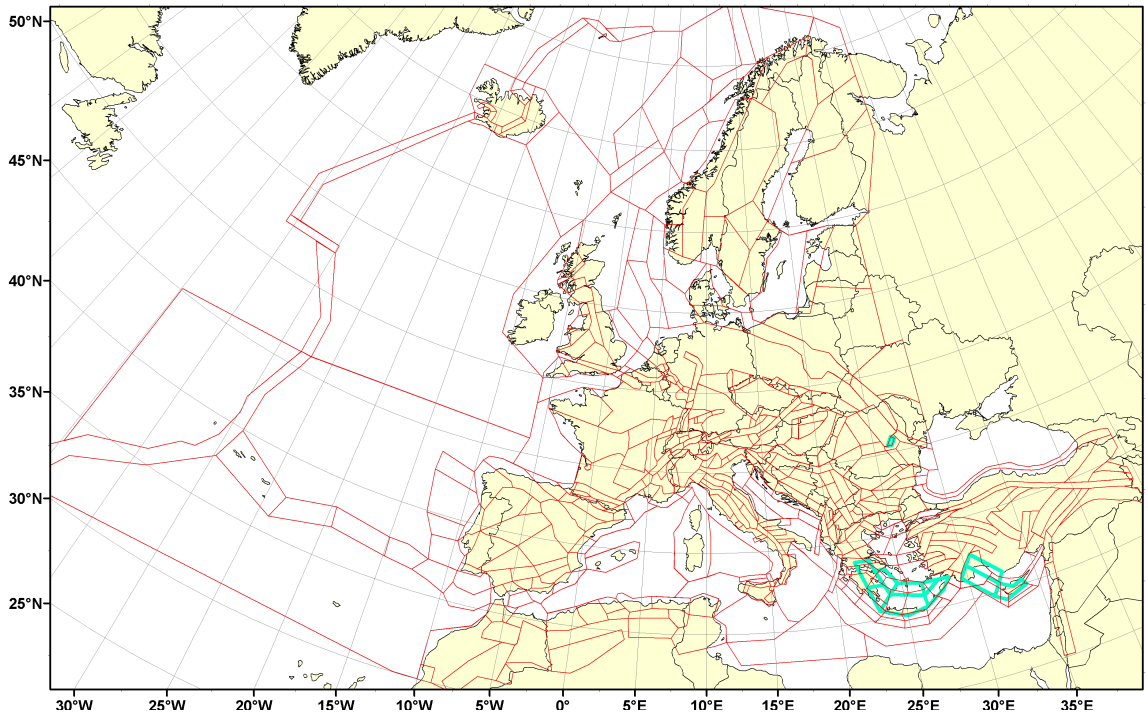

Figure 2. The SHARE seismic source zone model as of November 30, 2010. Intermediate source are highlighted in green.

4.1 Scandinavia

The Scandinavian model is by large based upon the NORSAR and NGI (1998) and GSHAP (Grünthal et al., 1999) models. Further GSHAP was used in the SESAME model for this part of Europe. The current model has after the Oslo workshop received major changes compared to the previous models. Firstly, the Baltic Sea, the Baltic countries and Finland have to large part been reworked so that the zonation corresponding better to large scale tectonic features and seismicity. Parts of Norway and the North Sea have newly updated zonation according to similar principles. The model has been controlled by the participants who has had possibilities to add comments and suggest further changes. This was done in emails from the regional leader, NORSAR, to the local experts from every country in the sub-area.

4.2 North Sea and the Atlantic

The regional SSZM is for the mainland of UK based on the Eurocode 8 zonation for UK with modifications (Musson and Sargeant, 2007). This model was constructed upon criterias of tectonic structures as well as seismicity patterns (Musson and Sargeant, 2007). One addition in the current model is that the whole region has been tesselated. The Atlantic ridge is based

upon Musson et al. (1993) whereas the North Sea, though reworked, is based on the NORSAR and NGI (1998) model. The Icelandic model was not a product of the regional workshop in Oslo but was provided from Iceland by R. Sigbjörnsson (personal communication). This model has a degree of complexity which is not seen in other parts of the SHARE model. Following recommendations from the WP5 model building workshop, Potsdam October 2010, the Icelandic SSZM was therefore simplified to conform to the standards of the SHARE SSZM. The southeastern border towards Central and Western Europe was modified after a series of email and telephone discussions between the Belgian representatives and SHARE T3.4 task leaders.

4.3 Central and Western Europe

The zonation for Central and Western Europe was constructed using first a draft model produced by the regional leader. This was then modified during the workshop. Source models from France (Working Group EPAS, 1998), Belgium (Leynaud et al., 2009, Verveer et al., 2009, Vanneste, personal communication), Germany (Grünthal et al. 2009, Burkhard and Grünthal, 2009), Switzerland (Wiemer et al., 2009), the Czech Republic, Poland, and Slovakia (Schenk et al., 2000) and Hungary (Toth et al., 2006) were used as background material. In the draft model the TECTO model was inserted for Switzerland (Wiemer et al., 2009) but was after requests from the Swiss experts substituted for the SEIS model (Wiemer et. al., 2009). For Austria, the initial model used was the Lenhardt and Günthal model described in Grünthal et al. (2007). This model was subsequently modified after consultations with the responsible expert for the Austrian zonation (W. Lenhardt) and input given at the WP5 model building workshop, October 2010, Potsdam.

Homogenization along the borders towards the North, and East was seamless. The northern boundary was adopted after suggestions from the Oslo workshop. The eastern boundary was provided to the Balkan workshop in Podgorica where it was accepted. The boundary towards Italy was substituted as a consequence of suggestions made at the Rome, May 2010, workshop, after consultations between experts of respective region.

The boundary towards the North Sea and the Atlantic provided from the Oslo, November 2009, workshop, was discussed and changed as a result of several in depth email and telephone discussions in May 2009.

4.4 Iberia

In Iberia the most recent local models were those of (Vilanova and Fonseca, 2007) for Portugal and the SESAME model for Spain (Jimenez et al., 2001). However, the regional experts decided that a new model was needed. During three workshops, Faro, Lisbon and Madrid, the model was drafted. The working model from these workshops was then circulated among local experts and consensus was achieved after modifications. This was done in several rounds whereof the last model was received end of November. Feedback on the model was received from the Rome 2010 SHARE annual meeting, in which certain zones were described as to large and thus diluting seismic hazard whereas the zone containing the Lisbon 1755 earthquake was too small to contain a M8+ earthquake. The model has already been discussed at Iberian conferences (Garcia-Mayordomo et al., 2010, Vilanova et al., 2010).

4.5 The Balkans

The Balkan model was constructed as cooperation between the SHARE project and the BSHAP project. The SHARE contact partners within the BSHAP project are Dr. B. Glavatovic and Dr. M. Radulian. The resulting model of the Podgorica workshop was based

upon the SESAME model, the Slovenian model of Zivcic et al. (2002) and the Albanic national model (Aliaj et al., 2004). This model was to a large extent changed in the workshop in Podgorica. The model derived in the workshop was made available to the participants of the workshop and has had several changes discussed in a series of email discussion, two meetings with each of the regional representatives. The homogenization towards Turkey was done after email discussion with the Turkish delegates, T3.4 scientist in charge, and WP3 representatives. The fit towards Italy was adopted at the Podgorica workshop together with Italian colleagues.

4.6 Greece and Turkey

The SSZM for Greece and Turkey was initially established in the Athens meeting, March 2010 (Table 1) and this is the form that is presented within the current model release. It should be added that we received a new model for Greece at the beginning of November. This last release was produced from cooperation between local Greek experts and subsequently discussed in several telephone and mail conferences with the scientist in charge of T3.4. This model will be inserted into the SHARE SSZM when approved. It is currently undergoing homogenization between the Turkish, the Greek experts and T3.4 responsible scientist.

The model consists of one of the most complex environments in Europe since it contains plate boundaries, North Anatolian Fault, the Cyprean Arc and the Hellenic Arc, large scale intraplate deformation in the shallow part of the western Aegean plate and a diffuse plate boundary to the north. The type of deformation changes radically from the eastern part of the Aegean plate to the western part leading to sometimes more dispersed zonation in the western part and in the east dominated by the long stretching east and north Anatolian fault zones. To the south prominent structures like the Hellenic Arc and the Cyprean Arc dominate the architecture of the model.

The model contains two layers of sources. Shallow sources covering the whole region and intermediate depth sources covering relevant parts of the Hellenic and Cyprean Arcs.
The model in the Greek and Cyprean area build to a large extent upon the previous works of Papiouannou and Papazachos, (2000) and Papiouannou (2001).

The Turkish model (Demircioglou et. al., 2007, Demircioglou, 2010) was provided as cooperation between the EMME project and SHARE. It is intended that the EMME model and the SHARE models to be seamlessly integrated at the borders of respective project. The Turkish model is further a hybrid model in the sense that the area sources have been constructed with respect to integrated line sources for the main faults like the north and east Anatolian faults.

4.7 Italy and Central Mediterranean

The Italian model is a revised version of the ZS9 model (Meletti et al., 2008) and is a result of the May 2010 Rome workshop. The model was further revisited during the WP5 model building workshop in Potsdam with improvements in the southern part of the Mediterranean. Adaptations of borders towards the surrounding regions were made during the Rome workshop and in workshops for regions surrounding the Italian and Central Mediterranean area.

4.8 Maghreb

For the Maghreb area no workshop has been held but consultation was made with the regional representative A. Yelles at the SHARE annual meeting, Rome, 2010. The current valid model

for Algeria (Pelaez et al., 2005, Hamdache et al., 1998) was adopted whereas for Morocco the SESAME model (Jimenez et al., 2001) was used.

5. Outlook for further developments

The source model is complete in coverage of the SHARE study area. A version of the SHARE model, adapted for use as background source zones in combination with fault sources, will be delivered at a later date. The reasons for this are that the most recent fault information has not yet been made available and the last part of the areal source zone model was received too late to adapt to the fault model.

The region Greece and Turkey has recently come up with a new model for Greece. This model is currently being homogenized together with the Turkish model. As soon as this has been done the source model can be updated.

Focal depth information and faulting style information are not primarily belonging to T3.4. During the Potsdam WP5 model building workshop it was decided that GFZ will provide these data in addition to the original commitments. This information is still under processing. Most focal estimates regarding range of focal depths have been gathered from the regional representatives. Some focal depth estimates are still missing. Also focal depth estimation using the SHARE catalog has as yet not been made possible since this catalog has at time of writing not been made available for use. Focal depth information from the SHARE catalog will be inserted into the source model as soon as it is complete.

Faulting style information has also not been inserted since updates of the source model came in at a very late stage. When the source model is complete with updates from Greece and Turkey this can be done. This information will be retrieved from the world stress map database.

Table 1. SHARE Workshops on seismic source zone model construction

Region and Place	Dates
The region Scandinavia and the region North Sea and the Atlantic, Oslo, Norway	November 24, 2009
Central and Western Europe, Potsdam, Germany	December 2-3, 2009
Iberia, Faro, Portugal	January 14-16, 2010
Iberia, Lisbon, Portugal	February 18, 2010
The Balkans, Podgorica, Montenegro	March 9-11, 2010
Greece and Turkey, Athens, Greece	March 16-17, 2010
Iberia, Madrid, Spain.	April 27, 2010
Italy and Central Mediterranean, Rome, Italy	May 3-4, 2010

Table 2. Participants in the SHARE Working Group on the Seismic Source Zone Model

Region	Country	Participant	Affiliation
Scandinavia	Norway	H. Bungum	NORSAR
	Sweden	E. Carlsson	UU
	Finland	P. Mäntyniemi	HU
	Russia	B. Assinovskaya	PAO
	Latvia	V. Nikulin	EGMA, Riga
	Lituania	A. Pacesa	IGG, Vilnius
	Netherlands	B. Dost	KNMI
North Sea and the Atlantic	UK, Ireland and Faroes	R. M. W. Musson	BGS
	Iceland	R. Sigbjörnsson	UI
Central and Western Europe	Germany	R. Arvidsson	GFZ
	Germany	G. Grünthal	GFZ
	Germany	M. Sørensen	GFZ
	The Czech Republic	P. Hrubcova	CAS
	The Czech Republic	Z. Jechumtalova	CAS
	The Czech Republic	V. Schenk	CAS
	Poland	B. Plesiewics	PAS
	Poland	J. Trojanowics	PAS
	Hungary	L. Toth	HAS
	Belgium	K. Vanneste	ROB
	Belgium	T. Camelbeeck	ROB
	Netherlands	B. Dost	KNMI
	Austria	W. Lenhardt	ZAMG
	France	C. Martin	GEOTER
	France	S. Baize	IRS
	Switzerland	D. Girardini	ETH
	Switzerland	J. Woessner	ETH
Iberia	Portugal	S. Vilanova	IST
	Portugal	E. Nemser	IST
	Portugal	J. Fonscea	IST
	Portugal	G. Besana-Ostman	IST
	Portugal	A. Brum de Silveira	UL
	Portugal	J. Madeira	UL

	Portugal	J. Cabral	UL
	Portugal	J. F. Borges	UE
	Portugal	J. Carvalho	LNEG
	Portugal	P. P. Cunha	UC
	Portugal	R. P. Dias	LNEG
	Portugal	F. Carlos Lopes	UC
	Portugal	H. Perea	UL
	Spain	J. Garcia-Mayordomo	IGME
	Spain	J. M. Insua-Arévalo	UCM
	Spain	J. J. Martínez-Díaz	UCM
	Spain	J. A. Álvarez-Gómez	UdC
	Spain	F. Martín- González	URJCM
	Spain	Á. González	UZ
	Spain	P. Lafuente	UZ
	Spain	R. Pérez-López	IGME
	Spain	M. A. Rodríguez-Pascua	IGME
	Spain	J. Giner-Robles	UAM
	Spain	J. M. Azañón	UG
	Spain	E. Masana	UB
	Spain	X. Moreno	CSIC
The Balkans	Montenegro	B. Glavatovic	MSO
	Montenegro	L. Vucic	MSO
	Montenegro	J. Mihailjevic	MSO
	Slovenia	M. Zivcic	ARSO
	Romania	M. Radulian	NIEP
	Bulgaria	S. Shanov	BAS
	Bulgaria	A. Radulov	BAS
	Bulgaria	I. Petrov	BAS
	Albania	L. Duni	GIT
	Albania	D. Kuci	GIT
	Austria	K. Decker	UV
Italy and Central Mediterranean	Italy	G. Valensise	INGV
	Italy	R. Basili	INGV
	Italy	V. Kastelic	INGV

	Italy	C. Meletti	INGV
	Italy	M. Stucchi	INGV
Maghreb	Algeria	A. K. Yelles-Chaouche	CRAAG
Greece - Turkey	Turkey	M. Erdik	BU
		M. Demircioglou	BU
		K. Sesetyan	BU
		L. Gülen	SU
	Greece	K. Makropoulos	UOA
		C. Papaiouannou	ITSAK
		S. Pavlides	AUTH
	Italy	R. Caputo	UBP

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Appendix 1. Sources for the collection of national and regional area source zones

North Atlantic

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