NEW SEISMIC SOURCE ZONE MODEL FOR PORTUGAL AND AZORES

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ABSTRACT

The development of seismogenic source models is one of the first steps in seismic hazard assessment. In seismic hazard terminology, seismic source zones (SSZ) are polygons (or volumes) that delineate areas with homogeneous characteristics of seismicity. The importance of using knowledge on geology, seismicity and tectonics in the definition of source zones has been recognized for a long time [1]. However, the definition of SSZ tends to be subjective and controversial. Using SSZ based on broad geology, by spreading the seismicity

clusters throughout the areal extent of a zone, provides a way to account for possible long-term non-stationary seismicity behavior [2,3]. This approach effectively increases seismicity rates in regions with no significant historical or instrumental seismicity, while decreasing seismicity rates in regions that display higher rates of seismicity. In contrast, the use of SSZ based on concentrations of seismicity or spatial smoothing results in stationary behavior [4]. In the FP7 Project SHARE (Seismic Hazard Harmonization in Europe), seismic hazard will be assessed with a logic tree approach that allows for three types of branches for seismicity models: a) smoothed seismicity, b) SSZ, c) SSZ and faults. In this context, a large-scale zonation model for use in the smoothed seismicity branch, and a new consensus SSZ model for Portugal and Azores have been developed. The new models were achieved with the participation of regional experts by combining and adapting existing models and incorporating new regional knowledge of the earthquake potential. The main criteria used for delineating the SSZ include distribution of seismicity, broad geological architecture, crustal characteristics (oceanic versus continental, tectonically active versus stable, etc.), historical catalogue completeness, and the characteristics of active or potentially-active faults. This model will be integrated into an Iberian model of SSZ to be used in the Project SHARE seismic hazard assessment.

1. INTRODUCTION

Project SHARE (Seismic Hazard Harmonization in Europe) of the 7th Framework Program of the European Commission aims to evaluate European seismic hazards using an integrated, standardized approach. Work Package 3 specifically involves the identification and characterization of the earthquake sources to be used in the European source model. Towards this objective Task 3.2 is to compile a European database of active faults and seismogenic sources and Task 3.4 is to develop a seismic source zone model. To accomplish the objectives of Project SHARE, Europe has been divided into seven regions, and Instituto Superior Tecnico (IST) has been tasked with integrating data from the Iberian Peninsula, Maghreb region and the Azores.

Project SHARE will utilize a level-3 SSHAC methodology [5], wherein various regional experts come together in a workshop setting to present the results of relevant research to integrators and external experts. Subsequently, the integrators and expert panel will evaluate the data and determine how to integrate the various contributions using a logic tree approach.

In order to comply with the SSHAC level-3 methodology, a SHARE-IBERIA workshop was held in January 2010 in Olhão, Portugal, with the participation of a large number of regional experts. The discussions focused on the locations, geometries, segmentation behaviors, slip rates, and recurrence intervals of faults in Iberia and Azores, which are considered to be active in the current stress regime. The panel of external experts included Kuvvet Atakan (University of Bergen), Ivan Wong (URS Corporation), and Pilar Villamor (GNS, New Zealand). At this workshop, a first draft of a seismic source zone model for Portugal and Azores was developed. The model was further discussed in February 2010, during a meeting in Lisbon where a small group worked on a preliminary model that could be distributed and discussed by the regional community. The resulting first-iteration-model, together with a preliminary justification of the boundaries, was sent out for discussion to the regional experts and external experts. In June 2010 at the annual meeting of the Project SHARE, the integrators presented the models and new input was received from the participants and task leaders. The second-iteration model, and the corresponding boundary justifications will be distributed for a second round of feedback from the regional and external experts.

2. METHODOLOGY FOR DEVELOPING SEISMIC SOURCE ZONES

In Project SHARE, the logic tree will allow three types of branches for seismicity models: a) smoothed seismicity models, b) seismic source zone models, and c) seismic source zone models and faults, as stated in the document entitled “Specification of source models to be used in SHARE” by Sørensen, Grünthal, Pagani and Woessner. The seismic source zones (SSZ), which are the subject of the present paper, are geographic polygons that delineate areas with homogeneous characteristics of seismicity. The characteristics of seismicity that must remain uniform within a SSZ are the maximum magnitudes, the seismogenic thickness, the probability of activity or probability of existence, and the activity rates. The characteristics of the earthquake catalogues, in particular the detection threshold or completeness, should also be an input for the SSZ model [6].

Because delineating SSZ involves the use of a wide range of data (geological, geophysical and seismological) and scientific interpretations, zonation models tend to be subjective and controversial (e.g., [1]). SSHAC [5] provides guidelines for establishing seismic source zones for hazard assessment. They distinguish amongst three types of SSZ: concentrated zones, regional zones, and background zones. The main difference between regional zones and background zones is the scale (tens of kilometers for regional area sources and hundreds of kilometers for background area sources).

For the concentrated SSZ the most useful and credible data types are well-located instrumental seismicity and mapped faults in the vicinity of seismicity. Data types with moderate usefulness and credibility include historical or poorly located seismicity and structural features that are parallel to zones of seismicity. For regional SSZ data usefulness/credibility is considered good for criteria that account for changes in the spatial distribution of seismicity and regions of genetically related tectonic history. Data pertaining to changes in structural styles and changes in crustal thickness or composition are considered to have moderate usefulness/credibility. Data types with poor usefulness/credibility include variations in geophysical signature, regional stresses and regional physiography (surface landforms). For background SSZ, data on regional differences in structural styles, tectonic history, physiography and geology are considered to have the most value in terms of usefulness/credibility, whereas data on changes in the character of seismicity are considered poor regarding usefulness/credibility for delineating zone boundaries.

Taking into account Project SHARES's goals and the data available in the Iberian region, the SSZ required for the European source model can be classified as regional SSZ, meaning that they should reflect primarily changes in the spatial distribution of seismicity and differences in tectonic history. In a second level of importance they should reflect changes in structural styles and in crustal thickness, and finally changes in geophysical characteristics, regional stresses and physiography.

Combining SSZ primarily based on seismicity and SSZ primarily based on geology (like background zones in SSHAC terminology) in a logic-tree approach provides a way to account for possible long-term non-stationary behavior of seismicity (e.g, [3]).

3. APPLICATION TO THE BROAD REGION FROM WESTERN IBERIA TO THE AZORES: THE FIRST-ITERATION MODEL

The application of the SSHAC [5] methodology for developing regional SSZ is not straightforward and some SSZ are still under debate. Figure 1 shows the first-iteration model for the studied region.

In this region one example of a good usefulness /credibility criteria is the presence of a passive margin and an aborted rift (the Lusitanian basin) west of Iberia, which in stable continental regions display higher seismicity rates and localize most M>=7.0 earthquakes [7]. The changes in seismicity rates south of the Algarve [8] can also be classified as a good usefulness/credibility criteria, whereas the boundaries between the long NNE-SSW-striking strike-slip faults (Manteigas-Vilariça-Bragança and Penacova-Régua-Verin) and the dip-slip faults (Ponsul and Seia-Lousã [9]) can be justified by using medium usefulness/credibility criteria. In some cases different criteria converge and, in these cases, the SSZ boundaries were delineated in order to satisfy most of these criteria. For instance, the region that encloses the ~500km Messejana fault displays large changes in seismicity rates, which indicates the need to use distinct SSZ that cross the Messejana fault. The delineated E-W boundary across the Messejana fault cuts across the fault in places where there is a structural change in the fault system, thus satisfying both good and moderate usefulness/credibility criterias. However, in some cases the situation is much more complex.

Some major outstanding issues identified at the June 2010 Project SHARE meeting in Rome regarding the first-iteration model presented here that will be addressed in the next iteration are 1) the extent of the zone that includes the Lower Tagus Valley, since that zone is particularly inhomogeneous with respect to the distribution of seismicity rates; 2) the need to accommodate a rupture length compatible with a M8.5 earthquake in the SW

Iberia region; and 3) the change in the completeness time periods of the historical seismicity record across the shoreline.

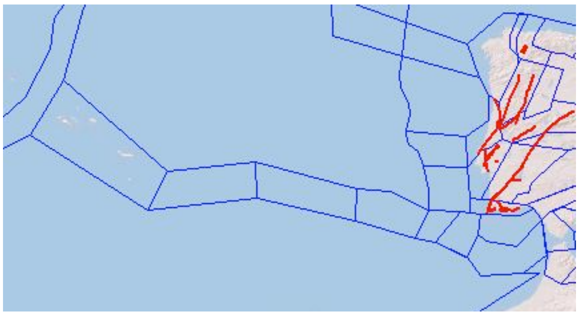

Figure 1: SSZ for Project SHARE: the first-iteration model for Western Iberia and the Azores

4. ACKNOWLEDGEMENTS

Funding was provided by Project SHARE (FP7-226967) financed by the European Commission under the 7th Framework Programme for Research and Technological Development, Area "Environment", Activity 6.1 "Climate Change, Pollution and Risks". The European Commission is not liable for any use that may be made of the information contained therein.

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