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D5.1 – Input specifications for seismic hazard computation

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Dissemination Level		
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PP	Restricted to other programme participants (including the Commission Services)	x
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1 Introduction

One of the major challenges to harmonize probabilistic seismic hazard assessment (PSHA) across national borders in the European-Mediterranean region is to assemble the existing and new data in a homogeneous and harmonized manner. To achieve this, the data provided to the seismic hazard engine (SHE) has to follow guidelines so that all source model typologies can be processed. The difficulty to harmonize the data sets arises from the fact of different philosophies that have been pursued in the many former projects and are partly also the result of the restrictions formerly used software posed on the definition of the source typologies. As a second reason, it was often considered to only apply a subgroup of source typologies, e.g. only areal seismic source zones, as the knowledge of active faults was not warranted by the data. Within SHARE, all types of possible sources in state-of-the-art PSHA need to be digested and processed; therefore, it is an essential task to suggest community accepted source typologies to set the standard for the current and future seismic hazard studies on this or larger scales.

1.1 Purpose of the document

The purpose of this document is to specify seismic source model typologies to be used in SHARE and to outline standard source model typologies for future seismic hazard analyses. In particular for SHARE it is intended to assure that:

- Efforts under WP3 will be focused on deriving the information that will be incorporated in the SHARE community based authoritative hazard model under WP5 and WP6.
- Inputs and outputs of SHARE are compatible with those of the Global Earthquake Model (GEM, www.globalearthquakemodel.org).

2 Source model typologies

The definition of source model typologies follows some basic assumption:

- The seismicity temporal occurrence model follows a Poisson process for all the typologies
- Annual rates of occurrence for discrete intervals of magnitude describe the seismicity occurrence properties; usually evenly spaced magnitude intervals are used. This description admits flexibility and generality. This unique representation allows the description of various frequency-magnitude distribution (FMD) models.

The source model typologies share some basic parameters (i.e, location, maximum magnitude - Mmax - and earthquakes reccurence) and some particular/specific properties (style-of-faulting, fault orientation, depth distribution). This document outlines the description of the seismic source characterization from a scientific point of view. The translation into parameters of the seismic hazard engine is documented in deliverable D6.1.

The SHARE logic tree (described in D5.2) may include branches for the following seismicity models as regionally appropriate:

- Area seismic source zone models,
- Smoothed seismicity models,
- Hybrid models that combine any of the above models and include seismogenic sources and/or individual faults.

Based on these seismicity models, we define the following source types:

- Areal source zone,
- Smoothed seismicity model,
- Fault source,
- Subduction zone.

In the following subsections the basic parameters that characterize each of the above seismic source typologies are summarized.

2.1 Area source zones

Area sources are the most common typology used in the PSHA input model for SHARE. Area sources generally represent regions exhibiting the same seismotectonic regime and seismicity occurrence features. In PSHA, area sources are often modelled assuming that the seismicity is homogeneously distributed over their extent. It is common use that, for each area, the occurrence parameters are calculated by processing the subset of events (from regional, national or international catalogues) occurring within the polygon. This procedure frequently creates a trade-off between the need for small areas, so as to guarantee homogeneity in the underlying seismogenic process, and the necessity for large area sources so as to select large sets of events and – therefore – reliably compute the seismicity occurrence parameters. For cases with few earthquakes certain parameters such as b-values and Mmax can be calculated within a larger region of similar characteristics as the source zone.

The use of areal sources is frequent because of the lack of information needed to consistently define more accurate representations of seismic sources and of the corresponding seismogenic process. A disadvantage to area sources is their sometimes subjective choice through the definition of their geometry.Area source zones represent homogeneous seismicity in terms earthquake activity rates and FMD. Ruptures will not be allowed to extend outside of source zone boundaries. This is called **area source** in deliverable D6.1.

For a given source zone, the following information is required:

- Coordinates defining the polygon of the source zone (ordered clockwise or counter-clockwise).
- Activity rates and FMD (several sets of values with associated weights, see also Figure 1):
    - To allow flexibility, activity rates and FMD should be provided as a list of magnitude-rate pairs (magnitude, annual rate) for the interval M_{min}-M_{max}. As a standard, the rates will be referred to the centre of each magnitude bin.
    - Alternatively, information can be provided in terms of the parameters of a Gutenberg-Richter (G-R) recurrence relationship (a,b or α,β along with information about type of G-R relation (cumulative or non-cumulative, log or $\log_{10}$)).
- M_{max} (preferably several values with associated weights).
- Focal depth distribution functions.
- Predominant style of faulting (one or several with associated weights) and optionally with associated strike, dip and rake (errors can be included)..
- Magnitude-rupture length and magnitude-rupture width (or magnitude-area) scaling relationships (one or several with associated weights). This will be used to account for source finiteness. If not provided, a standard relation may be adopted (e.g., Wells and Coppersmith, 1994).

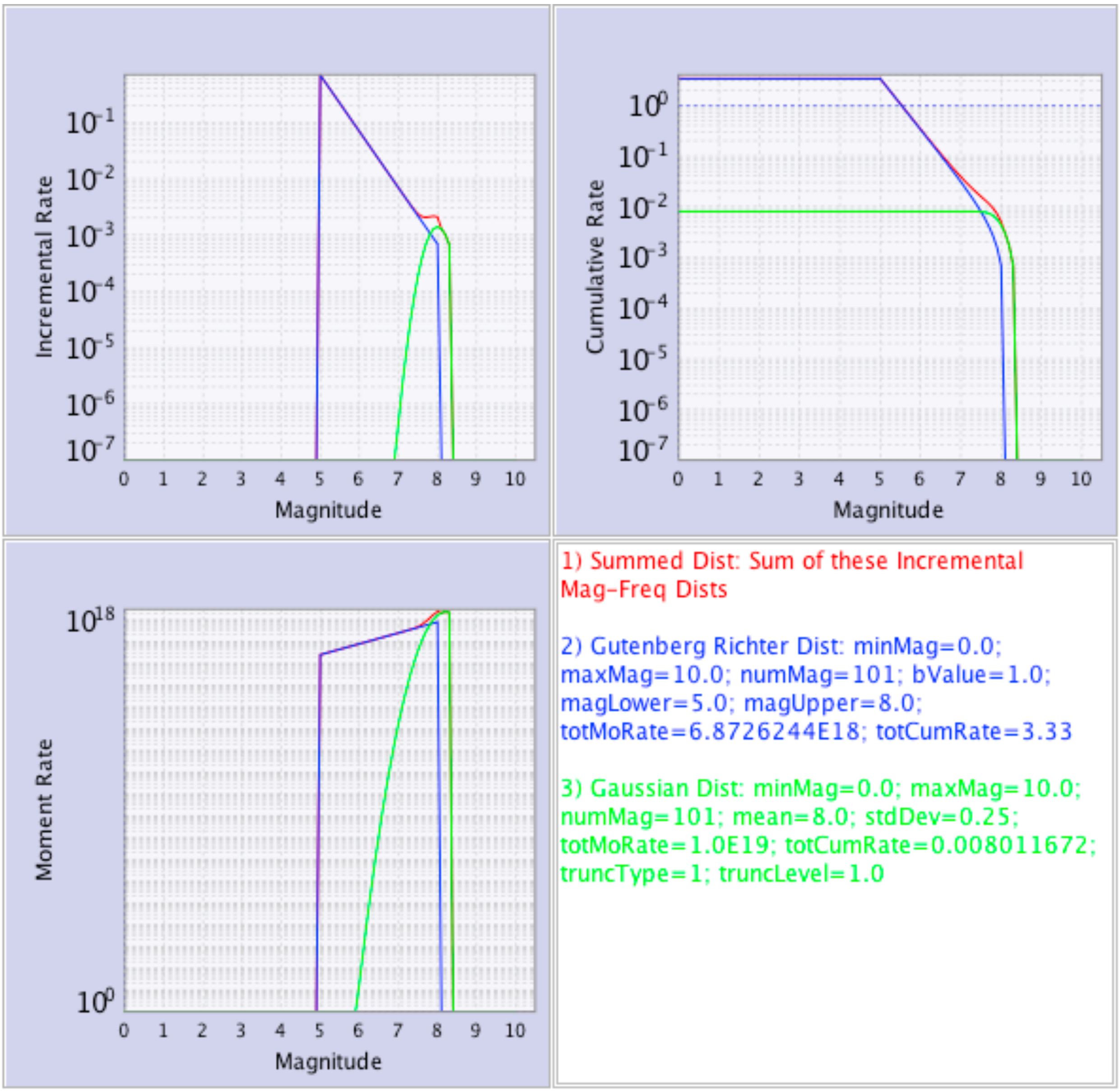

Figure 1 - Schematic illustration of the combination of a Gutenberg-Richter model with a characteristic earthquake model (obtained using the OpenSHA MagFreqDistApp441.jar applet – available at http://www.opensha.org).

2.2 Smoothed seismicity model

Smoothed seismicity approaches are based on rates of earthquake occurrence defined on a regular or irregular grid. In most cases, seismicity rates will be obtained by redistributing earthquakes contained in the SHARE catalogue. This source model typology is also called **grid source** in deliverable D6.3.

A smoothed seismicity model can be represented in one of the following ways:

1. A gridded seismicity model (one or several with associated weights) defines the annual rate of seismicity as a function of magnitude on each node of a specified grid (regular or irregular). Such smoothed seismicity models may be derived by approaches such as Kagan and Jackson (1994), Stock and Smith (2002a, 2002b), and Zechar and Jordan (2010)
2. An earthquake catalogue that contains for each event longitude, latitude, depth and moment magnitude, including uncertainty estimates, can be provided. For reliable implementation, moment magnitudes should be homogeneous. The catalogue has to be associated with a space-time varying completeness magnitude model, and should be supplemented by kernel smoothing parameters and associated with appropriate ground-motion prediction equations for the given approach. In some cases, when for example the smoothing parameters are unavailable, the model building scientists may derive the smoothing parameters.

Considering non-homogeneity in the magnitude of completeness records of the European earthquake catalogue, as well as differences in attenuation and bandwidth function, applying a hybrid model (for example the hybrid zone-less approach of Chan and Grünthal, 2008) may be more appropriate for the European region. In this case, the following additional information is needed:

- Large-scale zonation based on the geological architecture. This zonation should accommodate separate areas where large differences in the earthquake source process occur, regional differences in catalogue completeness history are obvious and/or attenuation differences are expected. An example of a zonation is included in Figure 2.
- Optionally, information regarding the predominant faulting style in each zone (one or several with associated weights) can also be provided together with associated strike, dip and rake (errors optional). This information can be introduced at the catalog level (method 2 above).

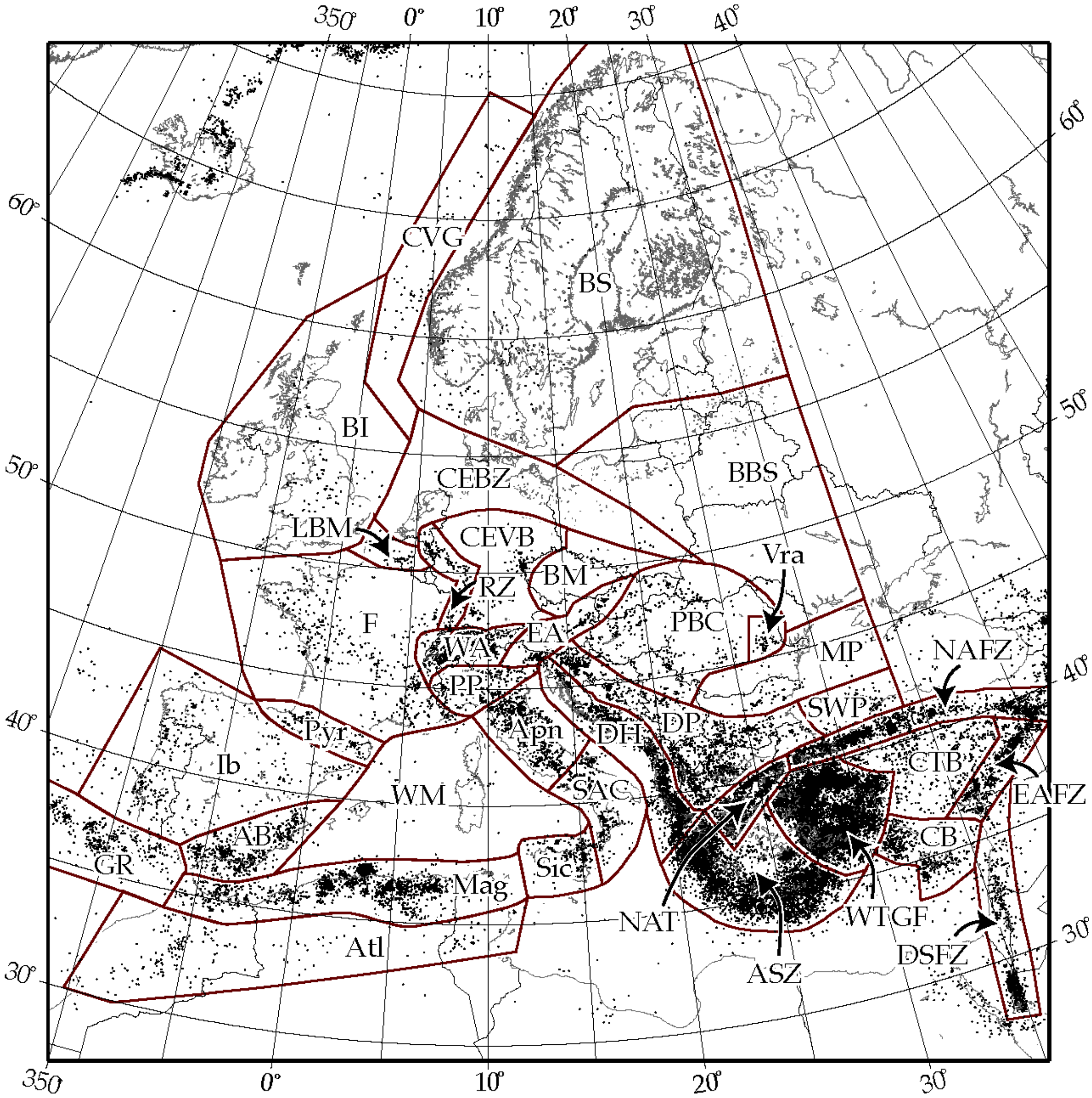

Figure 2 – Large-scale zonation used in the implementation of the hybrid zone-less approach of Chan and Grünthal (2008). The large scale zonation considers not only the large scale tectonic architecture but also accommodates differences in the catalogue completeness and in the bandwitdh functions used in the zoneless approach.

2.3 Fault sources

Fault sources represent the more elaborate way to describe seismic sources; however, their correct definition in terms of geometry and recurrence parameters necessitate an amount of information currently only available in areas with clear surface evidences of faulting activity and high seismicity occurrence rates (e.g California, Japan, Turkey, Italy, Greece). Usage of fault sources is only desired if fault structures or networks can adequately be implemented in the SHE without too large uncertainties. In the SHARE hazard assessment process, individual seismogenic sources are collected in WP3 and clearly defined seismogenic sources will be included in the hazard calculation. In the source data model, there are two fault source typologies; the first is normally used to describe simple shallow faults (Figure 3) while the second one is used to model subduction interface faults (Figure 4). Deliverable D6.1 defines the technical implementation of these parameters. Fault ruptures are distributed homogeneously over the fault surface and will not be allowed to extend outside the fault.

The following parameters must be defined:

- Fault geometry (simple fault plane or composite set of planes). Fault geometry can be defined as in Figure 3
- Coordinates (lon, lat) for the fault plane nodes spanning the fault (along strike), defined at fixed depths at the top and the bottom of the seismogenic layer. It must be checked that the four nodes defining a sub-plane are on the same plane.
- Coordinates (lon, lat) of the fault trace (at the surface), along with dip for each sub-plane. The fault surface will be defined by projecting the fault trace along an average dip derived from the specified dip values, and will be constrained between the minimum and maximum depth.
- Minimum and maximum depth (depth to the top and bottom of the seismogenic zone).
- Activity rates and FMD (several sets of values with associated weights, see also Figure 1):
    - To allow flexibility, activity rates and FMD should be provided as a list of magnitude-rate pairs (magnitude, annual rate) for the interval M_{min}-M_{max}.
    - Alternatively, information can be provided in terms of the parameters of a G-R recurrence relationship (a,b or α,β along with information about type of G-R relation (cumulative or non-cumulative, log or $\log_{10}$)).
    - A characteristic earthquake model provided as the activity rate and a truncated Gaussian distribution specifying mean magnitude, standard deviation and truncation in terms of number of standard deviations.
    - If both types (Gutenberg-Richter and characteristic earthquake) of models are provided, the final activity rate will be the sum of the two (Figure 1).
    - Example reference providing multiple representations of activity rates: Bungum (2007)
- Predominant focal mechanism (one or several with associated weights) and associated variability ($rake_{min}$, $rake_{max}$ – strike and dip are fixed by the fault source geometry). For details on standard definitions, see Basili et al., 2009. Alternatively, a style of

faulting can be used (e.g. normal, reverse) provided that a classification is specified (e.g. Abrahamson et al., 2008, Table 4, page 51).

- Magnitude-rupture length and magnitude-rupture width (or magnitude-area) scaling relationship (one or several with associated weights). This will be used to account for source finiteness. If not provided, a standard relation may be adopted (e.g., Wells and Coppersmith, 1994).

Fault sources will only be implemented in SHARE in cases where all required parameters have been estimated in a reliable manner.

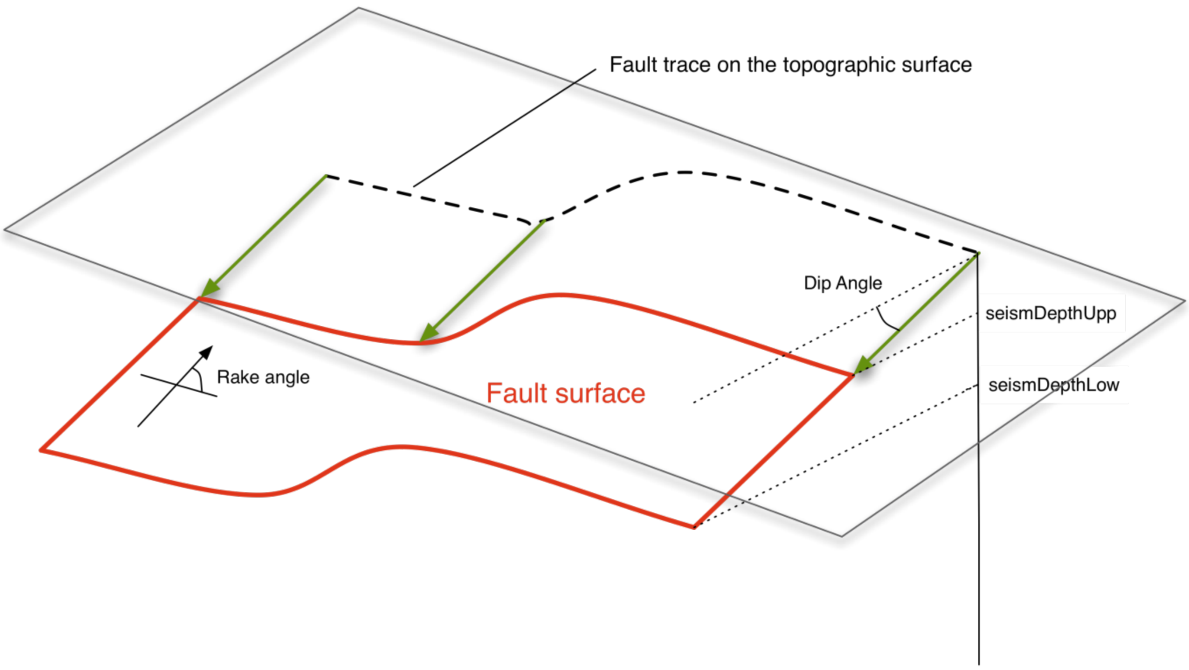

Figure 3 – Schema of a simple fault representation in the SHE. The black dashed line is the fault trace at the surface. The red lines are the borders of the fault surface. The green arrow shows the dip angle. On the right side of the picture the lower seismogenic depth and the upper seismogenic depth are appropriately placed.

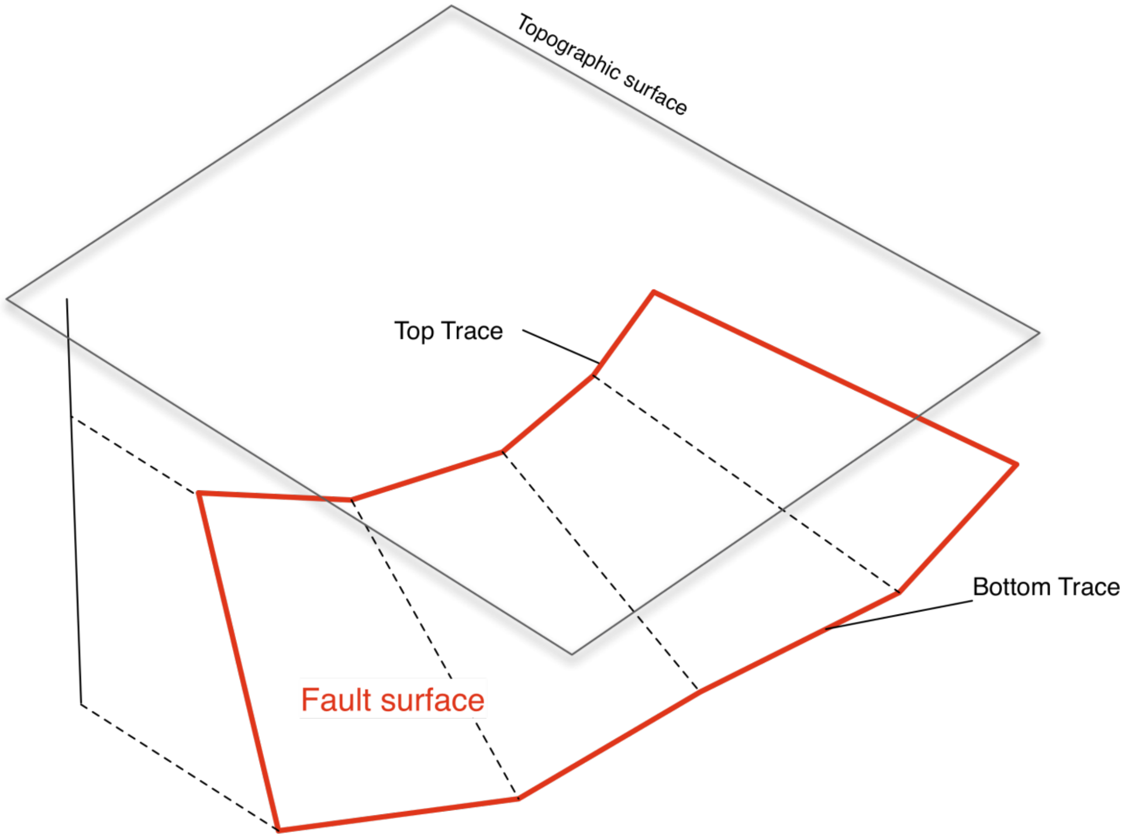

Figure 4 – Schematic representation of a subduction interface fault.

2.4 Subduction sources

Subduction sources can be divided into two categories, interface sources and intra-slab sources.

- Interface sources are fault sources described under fault sources. These sources are typically located in the uppermost parts of the subduction zones.
- Intra-slab sources are sources below the crustal level. Earthquakes occur here within the plates and not at the border interface fault. These sources can be described as a dipping volume source or planar area sources with an appropriate depth distribution.
    - sources also depth for each polygon point.
- One special intraplate source type is a tear fault. A tear fault is characterized by earthquakes occurring on vertical tears within the subducting slab and are due to their location considered in the intraplate/in-slab environment. Tear faults can be described as fault sources.

3 References

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