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Transposing an active fault database into a seismic hazard fault model for nuclear facilities

Part A: Building a database of potentially active faults (BDFA) for metropolitan France

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Abstract

The French Radioprotection and Nuclear Safety Institute (IRSN), with the support of the Ministry of Environment, compiled a database (BDFA) in order to define and characterize known potentially active faults of metropolitan France. The general structure of BDFA is presented in this paper. BDFA contains to date a total of 136 faults and represent a first step toward the implementation of seismic source models that would be used for both deterministic and probabilistic hazard calculations. An example transposing BDFA into a fault source model for PSHA (Probabilistic Seismic Hazard Analysis) calculation is presented for the Upper Rhine Graben (Eastern France); and exploited in the parent paper (part B) in order to illustrate ongoing challenges for probabilistic fault-based seismic hazard calculations.

1 Introduction

The practice acquired in nuclear regulation over the last decade as well as the feedback arisen from recent earthquake consequences on Nuclear Power Plants (e.g., Kashiwazaki-Kariwa in 2007, Fukushima and North-Anna in 2011), have challenged the expertise of the IRSN (French Radioprotection and Nuclear Safety Institute). Hence, IRSN's researches related to the geological aspects of Seismic Hazard Analysis (SHA) have been focused on 3 principal axes: (1) updating national seismotectonic zoning pattern (Baize et al., 2013); (2) performing and publishing collaborative studies on specific French active faults (cf. Cushing et al. 2008, Baize et al., 2011; Garcia Moreno et al., 2015, De La Taille et al., 2015); and (3) implementing the BDFA, a database concerning the potentially active fault of the Metropolitan France. These issues directly follow key aspects reported in the International recommendations for SHA in Site Evaluation dedicated guides (cf. International Atomic Energy Agency, 2010) where matters linked with both seismic motions and surface faulting are

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addressed; and meets the requirements of the French deterministic Fundamental Safety Rule (RFS 2001-01) for the determination of ground motions at sites as well.

The above mentioned third axis started in 2009 and consists in the on-going BDFA project (Palumbo et al., 2013); funded by the IRSN and the French Ministry for environment. It represents a first step to support SHA calculation that needs a collection of seismic sources information.

This paper introduces the BDFA framework & principles (BDFA from the French terms of *Base de Données des Failles Actives* which means Active Faults DataBase). Currently, the project focuses on faults longer than 10km (roughly capable of producing M≥6 events according to Wells & Coppersmith, 1994) and crossing a 50-km-circular area having its radius centred on French nuclear facilities (Fig. 1). Future implementations of BDFA should address larger areas of investigation at the entire country scale.

BDFA aims at representing a first step toward the constitution of a seismic sources catalogue that can be later used in SHA as well as PFDHA (Probabilistic Fault Displacement Hazard Analyses) calculations. An outlook of BDFA in the upper Rhine Graben and its transcription into a source model for PSHA calculation is presented in the final part of this paper.

2 Rationale behind BDFA

Despite its distance to active plate boundaries and relatively low to moderate seismotectonic activity (intraplate domain), research activities proved that in metropolitan France both significant earthquakes (e.g. historical catalogue, www.sisfrance.net) and surface faulting (e.g. Sébrier et al., 1997, Chardon et al., 2005) have occurred in the past.
BDFA rely on some previous works dealing with similar issues, namely ; 1) the seismotectonic map released by Grellet et al. (1993) and the active fault database of southeastern France (Terrier, 2004), 2) the IRSN catalogue of faulting evidences affecting Quaternary deposits (Baize et al., 2002), and, 3) the French catalogue of neotectonic evidences (available online at www.neopal.net). Those previous works are based upon both a catalogue of published (scientific articles, PhD thesis…) and unpublished reports (technical reports, student works…) as well as an important interpretation phase performed by the authors.
BDFA aims at reflecting as much as possible the available datasets, either for the establishment of fault mapping, or for the description of their activity. Because various opinions may have been proposed by different authors, at different times and at different scales, we have compiled their interpretations/data, in a specific form for each fault complementing the BDFA. Our own choices on fault parameters and associated uncertainties are therefore tracked and referenced to the aforementioned form. These forms are written in French and available on request as well as neotectonic and structural syntheses compiled at regional scales (ie. Alps, Britany, Jura Mountains…).

Among the parameters compiled in the database, we focused on the two following critical points.

Defining the surface fault trace

After Fourniguet (1978), Grellet et al. (1993) first attempted to synthetize neotectonic and active faults over France at the 1:1 000 000 scale; hence it is the main cartographic reference of BDFA. This fault mapping suffered many simplifications and a rough cartographic representation, so that it cannot be operated at a more precise scale. Our first objective was then to improve this mapping through the analysis of a broad literature including geological and thematic maps at different scales (down to 1:50 000 geological maps), the use of increasingly accurate Digital Elevation Models, availability of aerial photographs and specific publications containing maps at various scales. BDFA was developed under a GIS structure, considering four degrees of uncertainty (reliable, uncertain, hidden, and suspect) to reflect the status of knowledge of each segment. The fault traces are paired with explicit tables; therefore, fault segments are coupled with several data whose original sources can be traced.

Discriminating whether a fault is considered active or not

This task represents a key point of the database, however, not straightforward to determine, because of both technical and regulation (against what do we want to protect themselves?) purposes.

From a technical point of view, when no sign of current activity is recorded along a fault (from seismic, geodetic measurements), which is often the case in intraplate domains, determining whether a fault is active or not is based upon the age of the youngest observed deformation. The bottom line being that the younger the deformation is, the more likely it will generate earthquakes in the future. Hence, discerning which segment is active or not will be based upon a temporal threshold.

From a political point of view, national and international may differ in defining temporal limits to be taken into account to define active faulting and related ground motions. Concerning the determination of ground motion at sites, the French ASN (Nuclear Safety Authority) rule (RFS 2001-01) stipulate for example that if a paleo-earthquake is evidenced along a fault, then the ground motion associated to an event whose return time would be a few tens of thousands of years should be taken into account along this fault. Concerning the fault displacement hazard, the International nuclear safety guidelines (IAEA, 2010) indicate that fault capability (i.e. capacity of a fault to rupture the surface during an earthquake) should be assessed by collecting information's through Plio-Quaternary time span for intraplate domains (the temporal threshold to account for should then be 5.3 Myr). It is in comparison significantly larger than the one proposed by the US Nuclear Regulatory Commission (US-NRC) which advises to set this limit at 35ky for faults that ruptured once at or near the surface or 0.5 Myr for faults highlighting recurring earthquakes.

In France, the tectonic stress field has not experienced changes since the end of Miocene, with the persistence of the convergence between Africa and Eurasia (Baize et al., 2013). In parallel, the age of Plio-Quaternary sediments that may

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attest for active faulting are often absent or poorly constrained. In this context, we considered reactivations of past structures as possible and build the BDFA as a potentially active fault database, thus including late Miocene to Quaternary structures (Figure 1).

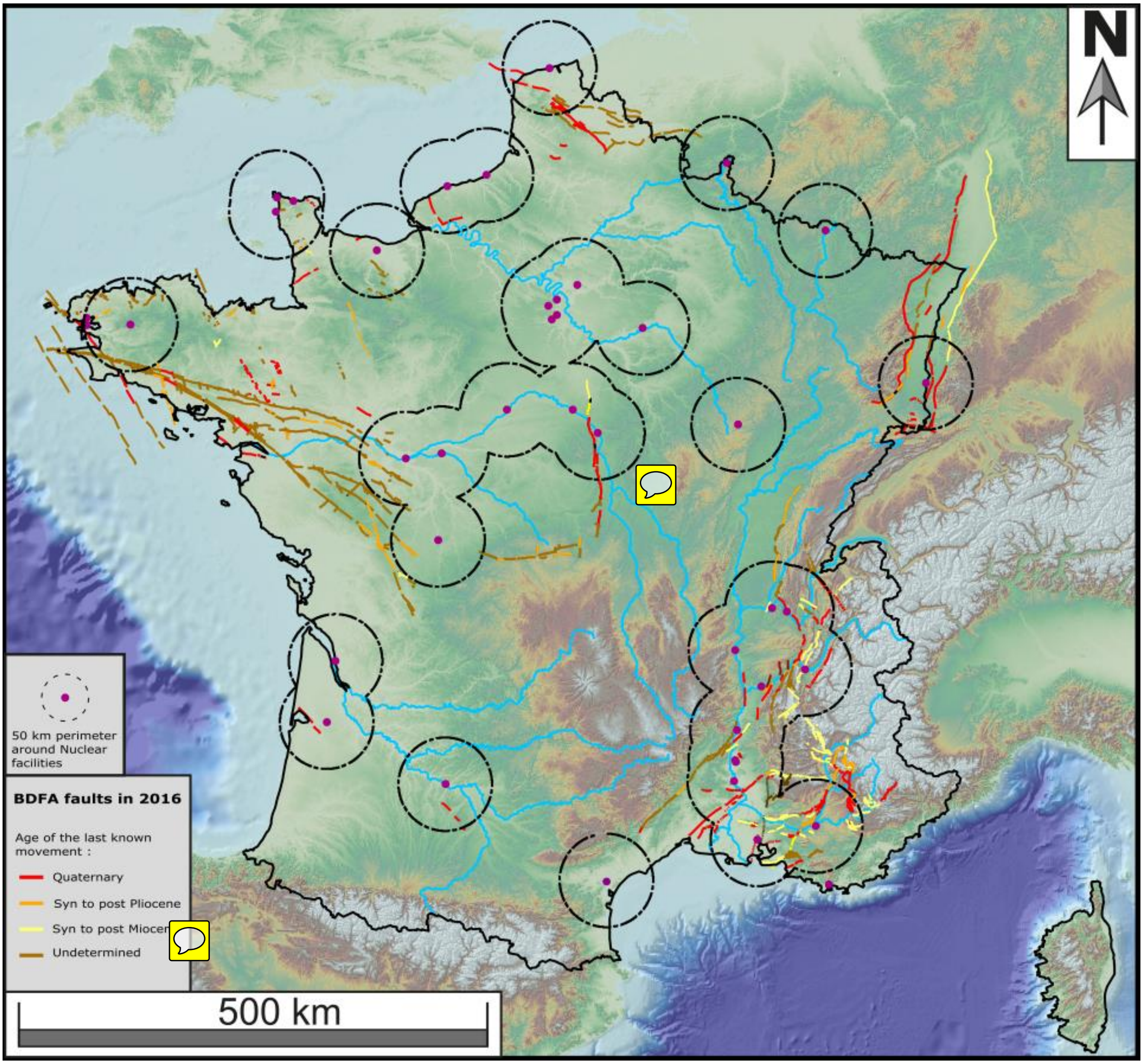

Figure 1: Map of BDFA (Google earth kml file provided in annexes) at the scale of metropolitan France. Faults coloured by the age of the last known movements. Black circles represent a 50km perimeter around each nuclear facility.

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3 The Database structure & statistics

The database structure (see Annexes) was inspired by other databases' developed in the world, such the ones from ~~as the~~ USA (QFAULT, Haller et al., 2004), New-Zealand (NZAFD, Langridge et al., 2016), Japan (AIST from the geological survey of Japan), Italy (Michetti et al., 2000) or Iberia (QAFI, García-Mayordomo et al., 2012). The proposed map for France is associated with a relational database describing the state of knowledge for each fault segment. This database is composed of several thematic tables (designed in Microsoft Excel spreadsheets) linked together with an identification key.

The identification key for each fault system described in BDFA (ID_Fault - IDF) corresponds to the one referenced in the French Geological survey (BRGM) fault database related to the 1:1 000 000 geological map. A new identification key has been produced to give a unique reference to each fault segment (ID_UNIQUE - UID). These two identification keys allow to link together following tables:

- The MAIN TABLE contains all gathered fault parameters with associated uncertainties when available (i.e. map characteristics, geometry, neotectonics~~,~~ ages and kinematics, calculation of a robustness index, editing notes);
- The "INDEX-REF" & "REFERENCES" tables list the publications used to characterize the active fault system;
- The "INDEX-EVIDENCES" table includes all neotectonic evidences reported in the NEOPAL and IRSN databases (respectively www.neopal.net and Baize et al., 2002);
- The "INDEX-SEISMIC" reports largest earthquakes, essentially events described in the historical archives (www.sisfrance.net) for which magnitude values are proposed by Baumont and Scotti (2011);

All fields are explained in the BDFA-table enclosed in annexes. Most of them are manually implemented, while we took advantage of GIS capabilities to implement cartographic parameters such as length, azimuth, tips coordinates.

3.1 Fault traces and segmentation

Fault segmentation and location are key parameters in seismic hazard assessment (Wesnousky, 1986, Biasi & Wesnousky, 2016, Field et al., 2015). When building-up the french BDFA, we gave priority to the published fault traces and segmentations. However, few active or potentially active faults have been studied in detail in France. We therefore proposed, when the available data cannot be considered as reliable, a new mapping including fault segmentation as following:

- Regarding the definition of the surface trace of the fault, priority was given at available large scales geological maps (1:50 000) and then, if not available, at lower scales maps (1:250 000 & 1:1 000 000). As a last resort, Digital Elevation Models (DEM) and derived slope maps, as well as air photos, were analysed to propose fault traces based

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on their topographic signature. Finally, each proposed fault trace goes along with a reliability index (TRA: reliable, uncertain, hidden, or suspect),

- The basic unit is the (fault) segment. Segments are grouped into a (fault) system or (fault) family. A fault system is composed of segments having similar characteristics (notably their direction) and forming a discontinuous trace at surface,
- Fault segments were generally archived into 4 families (Major, M; Parallel, P; Oblique, OB and Orthogonal, OX). This distinction accounts for the relative strike of the subordinate segments with respect to the major fault (M): 0-15° = P; between 15 and 70 ° = OB, between 71 ° and 90 ° = OX,
- Fault segments smaller than 5km are gathered to their neighborest segment when they present a similar strike,
- Two fault segments presenting a similar direction have to be gathered if their tips are at a distance less than 1km,
- A fault that presents a rather small (<15°) or regular change in direction is not segmented; conversely, when linear faults present direction changes higher than 15°, the fault is segmented.

Finally, we assign a unique identification number (ID-UNIQUE) to each fault segment. This identification number is obtained by concatenating the ID_FAULT, the segment family (M, P, OB, OX) and the number of the segment.

3.2 Age of deformations & slip rates

The age of the youngest deformed geological horizon is also a key parameter because it will conditions whether the causative fault is considered in hazard calculation or not (RFS 2001-01, IAEA, US-NRC). A good constraint on the age of the most recent deformations allows, when a total amount of slip can be determined over the period considered, to calculate a fault slip rate, but they are rarely reported in the original consulted documents. Even the published slip rates values were systematically controlled before integration into the database, because of sometimes ambiguous, vague or inconsistent information in terms of chronology and stratigraphy. Conversely, in case no slip rate are given by authors but good constraints are provided in terms of chronology and amount of slip, we propose a slip rate based on their observations.

We defined the following parameters to be filled in the database (Figure 2):

- DCHR: Deformed CHronostratigraphic Unit. Local terminology indicating the most recent chronostratigraphic units involved by faulting,
- DCHRT (in years): age DCHR Top. Numerical value which gives the upper limit (geochronological) of the unit involved in the deformation,
- NWEU: Terminology indicating the most recent North West European Chronostratigraphic units which is involved by fault. If for example in literature is reported Würm, it will report Weichselian,

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- UCHR: Undeformed CHronostratigraphic Unit. Local terminology indicating the most recent chronostratigraphic units not involved by faulting,
- DCHRB (in years): age DCHR Base. Numerical value which gives the lower limit (geochronological) of the younger unit involved in the deformation. If dating doesn't exist, it could be esteemed through chronostratigraphic correspondent,
- DM: Dating Method used to establish DCHRT and DCHRB; 3 predefined terms: radiometric, relative (stratigraphic principles, biostratigraphy), indirect (facies),
- OST (in years): Offset Span Time. Time span representing the value used for calculate slip (rate),
- AR: Age of the chronostratigraphic Units used for determining slip Rates (restraining OST).

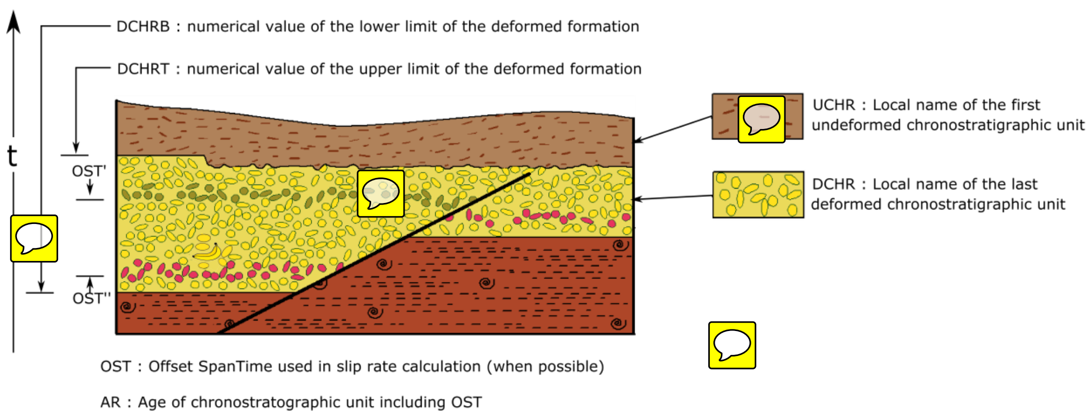

Figure 2: Stratigraphic relationships considered to feed quantitative neotectonic (Age) table of BDFA.

3.3 Robustness index

The current version of the database includes 136 faults with a total of 581 fault segments. Among these 581 segments, 118 are qualified as active during the Quaternary. We provide a "robustness index" (RI), estimated for each segment. This index aims at providing a ranking of the fault population in terms of activity reliability. RI follows the empirical expression modified from Baize et al., (2013)

$$RI = (S + 0.1) \times (S + Age + M + 3H + 4I + 2G)$$

Where:

- S: Structural knowledge. It may be valued 0 or 1, according to well-known or unknown tectonic structures, respectively,
- Age: time of last recognized displacement. It may be valued 1, 2, or 3 for Paleogene, Neogene, and Quaternary, respectively,

- M: Morphological expression of the fault. It may be valued 0 or 1, according to negligible or prominent surficial expression, respectively,
- H: historical seismicity parameters. It may be valued 0 or 1. The value 1 is adopted when a significant historical earthquake (epicentral intensity ≥ V, according to www.sisfrance.net) occured ~~inside an area widening~~ 5 km ~~of~~ the fault trace,
- I: instrumental seismicity parameters. It may be valued 0 or 1. The value 1 is adopted when significant instrumental activity (either significant earthquakes with Ml ≥ 4 or swarms/alignments of low magnitude events) occured ~~inside an area widening~~ 5 km ~~of~~ the fault trace,
- G: geodetical data indicating displacement along the fault. It may be valued 0 or 1, according to lack or recognised movement, respectively.

This index is subjective by nature. It gives a higher weight to "dynamic" criteria like seismicity, because we consider that it is the most relevant criterion to prove seismotectonic activity. The total population of the database was classified within equally-separated RI classes (Figure 3). It highlights that a relatively small part of BDFA fault segments are reliably active (82 segments with an RI > 10, corresponding to 42 faults over 136) and may then help pointing out the needs for future data acquisitions.

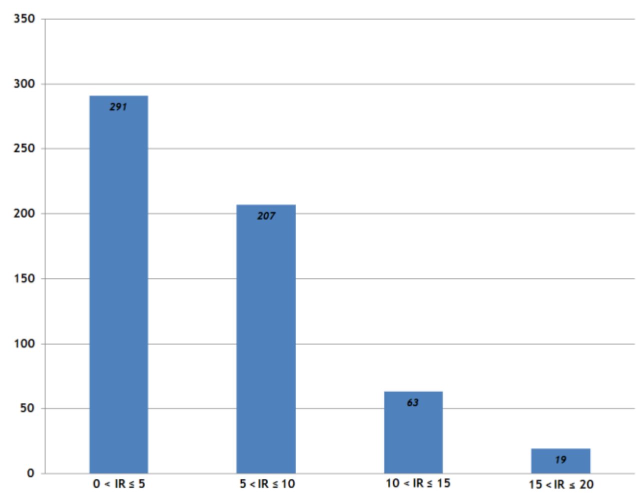

Figure 3: Robustness index (RI) distribution.

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4 Transposing BDFA into a fault seismic source model for SHA, an exercise in eastern France

The southern part of the Upper Rhine Graben (URG) straddling the border between France and Germany from northern Switzerland north to Mainz in Western Germany, presents a significant seismic activity for an intraplate area (Bonjer et al., 1984, Barth et al., 2015). A magnitude 4 or greater shakes the URG every ≈10 years (Barth et al., 2015) and in 1356 a magnitude ≈6.5 struck the city of Basel. This event is the largest regional earthquake that is registered in the Swiss, German and French archives. Macroseismic intensities, based on reported damages, reached VIII-IX in the epicentral area according to the French macroseismic catalog. No historical information about a surface faulting is recorded in the manuscripts and the fault source of this earthquake is still debated.

Previous investigations have supported the hypotheses that the 1356 historical earthquake might be due either to the activity of West trending buried faults (e.g. Meyer et al., 1994), or to a North trending Rhenish structure (e.g. Meghraoui et al., 2001). Nivière et al. (2008) investigated the NS “rhenish” structures (e.g. Rhine River Fault, see figure 4) and concluded from morphological evidences that these structures are potentially able to generate earthquakes as strong as M=6.6-6.8, (in the magnitude range of the 1356 Basel earthquake) in a time frame of several ten thousand years.

Because of their closeness to the French nuclear power plant (NPP) of Fessenheim (<10 km), these potential active faults might be hazardous for the NPP safety. We hereafter propose to derive a fault source model from the BDFA, in order to feed an exercise which goal is to assess the fault parameters that influence most the results of PSHA calculations at short distance from a site (developed in the parent paper).

In the BDFA, the three faults closest to the NPP are the West Rhenish, the Rhine River and the Black Forest Faults (“*faille Rhénane Ouest*”, “Faille du Rhin” and faille de la “Forêt Noire” in BDFA respectively). Only their closest segments to the NPP are considered here (figure 4) and used in the PSHA exercises (see parent paper, part B). Our knowledge about the considered fault segments is highlighted by Robustness Indexes varying from RI=4.4 up to RI=15.4 (Figure 4), mostly dependent here on the presence/absence of spatially captured historical/instrumental seismicity. However, for the purpose of the PSHA exercise performed in the parent paper, the Reliability Index has not been exploited to weigh the activity of the fault segments. The table in figure 4c summarizes how the BDFA parameters were considered for PSHA calculations:

- Faults lengths: BDFA surficial traces were taken into account and digitized in PSHA CRISIS software V1.2 (Ordaz et al., 2014 - Figure 4). Lengths may slightly differ due to a rough digitization in PSHA software. In BDFA, surficial fault traces (figure 4c) of the three considered fault systems were directly derived from the literature,
- Faults depths: BDFA gives priority to depths characterized through geophysical prospections. Concerning the West Rhenish fault for example, segments’ depths in BDFA are derived from the interpretation of reprocessed high

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resolution industrial seismic profiles by Rotstein & Schaming (2008). For the PSHA fault model, we retain depths derived from the analysis of regional seismicity at depth (Edel et al., 2006) and the interpretation of a crustal scale seismic profile (DEKORP-ECORS, Brun et al., 1991). Two depth values will be tested for PSHA calculations: 15 and 20km,

- Faults dips: we keep the BDFA values, except for the Black Forest fault, where a higher angle, equal to the Rhine River fault was assigned (70±10°) as proposed in Nivière et al. (2008). This is due to the fact that dip values in BDFA (50±10°) are derived from very surficial geophysical data (Rotstein & Schaming, 2008), posing geometrical problems at depths with the neighboring Rhine River fault (Rhine River and Black Forest faults will crosscut themselves at depth taking into account dip values from BDFA and considering depths of 15 and 20km),
- Faults slip-rates: we considered slip-rates contained in BDFA (lower and upper bounds). For the Rhine River and the Black Forest faults, slip-rates are available in the literature for only one segment of each fault system; we then attributed coherent values to all segments for which no value has been proposed in the literature. Slip-rates along these fault segments were deduced from the analysis of post-Pliocene geological markers (Nivière et al., 2008). For the West Rhenish Fault, considered in BDFA as active during the Pliocene and possibly during Quaternary, no slip rates were found in the literature. We then attributed an upper bound of slip-rate equal to the lower slip-rate determined for both the Rhine River and Black Forest faults; and a lower bound of slip rate coherent with lower fault-slip rates determined in the Lower Rhine Graben following Vanneste et al., 2013.

It is worth mentioning that in this part of the Rhine Graben, all fault slip-rates available in the literature are vertical slip-rates, leading us to assume a normal faulting kinematic for the considered fault. However, data from seismicity (Edel et al., 2006), geodesy (Tesauro et al., 2005) as well as long term regional stresses (Rotstein and Schaming, 2011) suggest a possible strike slip component along faults in the Fessenheim area. Field data to confirm and quantify this strike slip component (possibly dominant) along faults are missing today, but it is clear that such an hypothesis should be explored for future hazard assessment.

This exercise of translating the database into a fault model shows that even if the database has been designed to integrate parameters required for the construction of a PSHA fault model, its transcription is not straightforward and it is then still necessary to make assumptions and account for alternatives when data are either lacking, not consistent with each other, or of insufficient quality.

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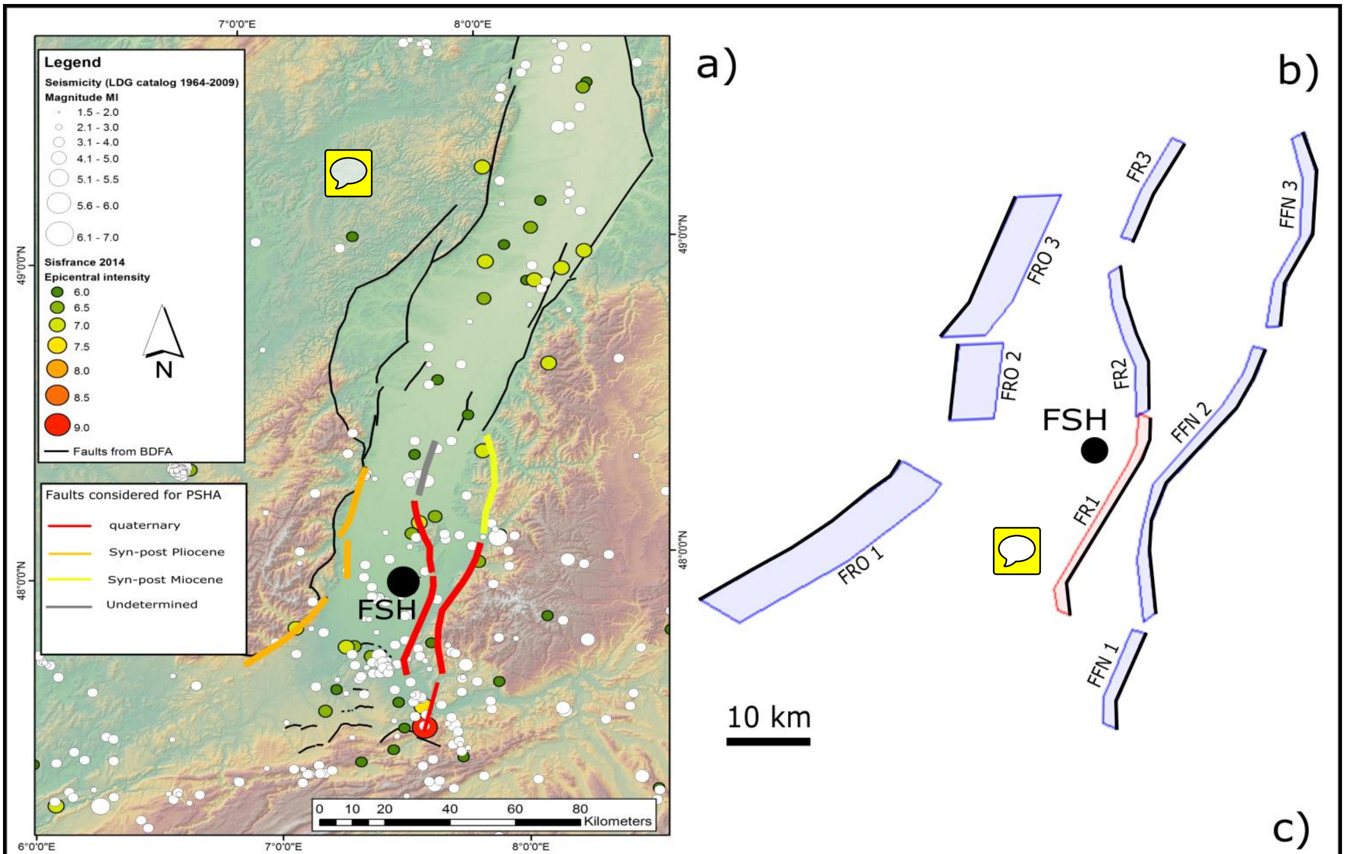

Fault_Name	Segment_Name	*Segment name PSHA*	Dip (°)	± Dip	Dip PSHA	Depth (km)	± Depth	*Depth PSHA*	Length (km)	*Length PSHA*	Neotectonic_Age	slip rate (mm/yr)	*Slip rate PSHA*	Robustness (IR)	Bibliography for BDFA
Rhine River Fault	FRR-1	*FR1*	65	15	70 ± 10	15	5	*15 to 20*	35	*36*	Quaternary	UnDef	*0,04 to 0,1*	15.4	Segmentation & geometry (Rotstein et al., 2005 ; Nivière et al., 2008 ; Behrmann, 2003) - Slip rate (Nivière et al., 2008)
	FRR-2	*FR2*	65	15	70 ± 10	15	5	*15 to 20*	25	*27*	Quaternary	0,04 - 0,09	*0,04 to 0,1*	11	
	FRR-3	*FR3*	70	99	70 ± 10	15	5	*15 to 20*	20	*20*	Undetermined	< 0,1	*0,04 to 0,1*	4.4	
West Rhenish Fault	Belfort-Guebwiller	*FR01*	50	99	50 ± 10	3.5	99	*15 to 20*	36	*36*	Pliocene	UnDef	*0,01 to 0,05*	14.3	Segmentation & geometry (Rotstein et Schaming., 2008, Ford et al., 2007, Bertrand, 2005) - Slip rate (Nivière et al., 2008 ; Cornu et Bertrand 2005)
	Guebwiller-Colmar	*FR02*	55	99	50 ± 10	2.5	99	*15 to 20*	16	*16*	Pliocene	UnDef	*0,01 to 0,05*	6.6	
	Colmar-Sélestat	*FR03*	60	99	50 ± 10	1.5	99	*15 to 20*	27	*27*	Pliocene	UnDef	*0,01 to 0,05*	6.6	
Black Forest Fault	FFN-1	*FFN1*	40	99	70 ± 10	15	5	*15 to 20*	20	*15*	Quaternary	UnDef	*0,05 to 0,15*	11	Segmentation & geometry (Behrmann et al., 2003 ; Nivière et al., 2008) - Slip rate (Nivière et al., 2008)
	FFN-2	*FFN2*	50	99	70 ± 10	15	5	*15 to 20*	50	*50*	Quaternary	0,07 - 0,18	*0,05 to 0,15*	11	
	FFN-3	*FFN3*	40	99	70 ± 10	15	5	*15 to 20*	35	*35*	Miocene	UnDef	*0,05 to 0,15*	8.8	

Figure 4: a) Potentially active faults from BDFA (in black), selected segments for PSHA calculation in colour (depending on the age of the last movement on the fault). b) Fault model as produced for PSHA. Black lines correspond to the surficial trace of the faults, in light blue the projection of fault planes at the surface (taking into account a 15km depth and the max. dip angle), in light red the closest fault to FSH (Fessenheim NPP). c) Table containing principal parameters as exported from BDFA (gray and white columns) table and their transposition into the parametric PSHA fault model (light green columns).

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5 Discussion and perspectives

In areas covered by the BDFA, the database represents to date the most complete source of information available in the literature. It is however clear that the database needs to be extended to the entire country (metropolitan as well as neighboring regions) for a wider use than seismic hazards related to nuclear facilities.

However, for the time being, we are aware that the data contained in the database are mostly of low resolution as expressed through the robustness index. In metropolitan France, the main reasons for this situation are the following:

- Dating: because surficial deposits were strongly subjected to human reworking and erosion (mostly linked to glaciations), few markers are available to characterize the recent activity of faults (age, slip-rates etc…). In parallel, few quaternary formations have been the subject of absolute dating campaigns and the question of the age of deformations is often questionable. In this light, projects aiming at developing methodologies (such as the *Proyecto Dataciòn* performed in Spain, 2001) would help reducing dating uncertainties,
- Paloeseismic evidences and seismic activity: due to the very long return periods of surface rupturing earthquakes, and because tectonic deformation rates are in the order, or even lower than erosion rates, very few paleoseismic evidences have been identified so far in France. Then, the best way we currently have to estimate the activity of faults is to be able to associate earthquakes, either instrumental or historic. Yet, apart from some temporary local seismic networks (Courboulex et al., 2003), we are rarely able to associate the registered seismicity to a specific structure. It is then understandable that such time/cost consuming studies are not sufficiently profitable for researchers in a context of scientific competition. In parallel, new ideas regarding the seismic behavior of stable continental regions (Calais et al., 2016) are sprouting, with the idea that the classical seismic cycle on a fault may not be the most plausible hypothesis and that the seismic potential could be more distributed in space and time. Then, questions related to the definition of what is a stable continental region and how to differentiate faults that would have the potential to produce major earthquakes from faults that haven't are of growing importance. In any case, there is a crucial need of funding data gathering in metropolitan France, but also in regions with comparable geodynamical context in order to properly address and argument future seismic hazard analysis;
- Hidden & blind faults: some faults and fault segments without outcropping signatures have been recognized (such as the Belledone fault, Thouvenot et al., 2003) and integrated into the database. However, studies conducted to highlight them are few in number. In this respect, studies leading to the reprocessing of industrial seismic profiles are likely to complete our knowledge, as well as accurate relocation of instrumental seismicity (Thouvenot et al., 2003, Courboulex et al., 2003).

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The BDFA project, although it represents the "state of the art" of published studies, is inherently incomplete. It is hoped that it will be useful for identifying and programming the scientific campaigns that will be necessary for site specific seismic hazard assessment studies. In this paper we proposed a PSHA fault model based on the transposition of BDFA data in order to conduct an exercise in the Upper Rhine Graben (developed in the parent paper – part B), aiming at quantifying the relative influence of fault parameters on the hazard at a specific site. We underline here that industrial seismic data reprocessed from the GEORG project (http://www.geopotenziale.org/) shows a more complex tectonic pattern in comparison to BDFA, illustrating the need to take into account structures that are not visible at the surface and potentially important to take into account in future hazard analyses. The reason such dataset could not be included in the BDFA is that additional work, beyond the scope of this study, needs to be done to interpret the structural pattern inferred by GEORG into BDFA parameters.

We also point out that according to international safety guides, the capable fault issue should be explored for facilities located in the vicinity of potentially active faults. The capable fault issue examination requires a detailed and local dataset as well, that BDFA clearly does not fulfil, but which again represents a guide for future investigations.

Finally, the ongoing post 2011 Tohoku earthquake discussions have led to envisage extreme events as scenarios against which Nuclear Power Plants need to be prepared. One possible way to foresee these events for SHA purposes may be evaluating the maximum magnitude derived from the sizes of potential earthquake sources (i.e. the active faults). In that sense, the presented database may be useful but additional discussions on criteria to define fault segmentation and consecutively the potential for multi-segment ruptures is needed.

6 Conclusion

In this paper, we present a first release of a potentially active fault database (BDFA) that defines and characterizes faults in their current state of knowledge. This database may be used during the elaboration of fault-based models for future Seismic Hazard Assessment (SHA), either deterministic or probabilistic. In this light, BDFA was designed to include appropriate seismotectonic parameters to do so (geometry, segmentation, slip rate, etc). However, BDFA must not be considered as a complete database and therefore cannot substitute for the necessary in-depth studies required to evaluate the hazard at a specific site.

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Despite all the care we have taken in the development of this database, it is possible that some errors remain here and there. We then would like to thank in advance all the persons that will contact us in order to share their experience and favor the development and quality of the database.

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