

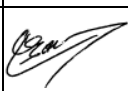

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CATALOGUE OF ISOSEISMAL AREAS FOR XXth CENTURY FRENCH HISTORICAL EARTHQUAKES ($I_0 > VI$)

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Executive Summary

In regions that undergo low deformation rates, the use of macroseismic information is of primary interest when dealing with seismic hazard analysis, in order to be able to characterise large earthquakes that present long return periods. In order to determine seismological parameters of historical earthquakes, Intensity Data Points (IDPs) can be used i) as individual points to calibrate intensity attenuation relations [SIGMA deliverable D1-108 and D1-147 – that will be presented at the SIGMA SC n°9] or ii) through the area of isoseismals. Concerning this second option, an explorative study has already been performed in SIGMA about the automatic drawing of isoseismals and the building of a relation between the magnitude-depth parameters and the isoseismals areas based on well-constrained events of the last century in France (metropolitan) (SIGMA deliverables D1-31 and D1-128). The objective of the deliverable presented here is not to work on magnitude and depth determination for past events, but **to produce an exhaustive atlas of manually drawing isoseismals for events with intensity greater than VI that occur in metropolitan France during the 20th century**. Even if some manual isoseismal drawings were already available for some of the events of interest [Levret et al. 1994] we wanted here to produce a homogeneous dataset of isoseismals based on a unique approach (detailed in the deliverable) and with drawings associated to reliability indexes.

Such dataset could be used in the future as an input for studies that aim at confronting historical data with PSH outputs, by comparing a risk assessment based on historical data and a risk assessment derived from the convolution of hazard and fragility curves [Labbé, 2010; Rota, 2014 – SIGMA deliverable D4-118].

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Methodology for Preparing an Atlas of Isoseismal Maps for Earthquakes Felt in Continental France between 1900 and 2007 with Epicentral Intensities of VI or Greater, Drawn from the SisFrance Database



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1. Objective of the study

Pursuant to a request from the utility Électricité de France (EDF-TEGG-CEIDRE), BRGM, in 2014-2015, in the framework of the SIGMA project, was assigned the mission to produce an Atlas of isoseismal maps, said Atlas comprising the earthquakes drawn from the SisFrance (BRGM, EDF, IRSN / SisFrance) database with epicentral intensities of degree VI (MSK) or greater, occurring over the period 1900 to 2007, and felt in continental France or its immediate vicinity. Thus this study concerns all seismic events with epicenters either directly within the borders of continental France (departments 01 to 95) or in adjoining countries (catalogue references 110 to 115 in SisFrance, representing successively Belgium, Luxembourg and the Netherlands (110), Germany (111), Switzerland (112), Italy and the Mediterranean (113), Spain (114) and Great Britain, the Atlantic Ocean and the English Channel (115).

Associated with maps edited in “image” format¹, the Atlas is also companioned separately and in digital format by the results of the plots of the isoseismals and their characteristics (degree, surface area, reliability indices) interpreted by BRGM. These data are provided in Mapinfo format².

2. Definition of the main terms used

Epicenter: The point situated on the ground surface directly above the earthquake hypocenter. The effects of the event are generally strongest surrounding the epicenter.

Macroseismic intensity: macroseismic intensity is the quantification of the earthquake’s strength at a specific point on the ground surface, obtained from a statistical estimate of the effects produced at this spot on persons, buildings and the environment.

Epicentral intensity: the intensity at the earthquake’s epicenter.

Macroseismic map: the mapped values of macroseismic intensity compiled for a given earthquake.

Isoseismal: a curve plotted on a macroseismic map surrounding points with equal values of intensity.


Meizoseismal area: on a macroseismic map, an area enclosed by the isoseismal corresponding to the strongest intensity.

3. Concerning SisFrance data used to prepare an Atlas of isoseismal maps

In constituting the Atlas, EDF identified 212 earthquakes³ (Appendix 1) drawn exclusively from the SisFrance database (BRGM-EDF-IRSN, 2014) devoted to French historical macroseismicity. Since this base

¹ Paper map in color, A4 format

² Mapping software Mapinfo Professional, version 8.5 b

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(BD) is updated annually, the version used in the framework of this study (2014) corresponds to the most recent version, integrating a small number of modifications involving epicentral coordinates and/or the epicentral intensity for a few events revised by BRGM on this occasion and concerning the 2015 version.

To describe the SisFrance database succinctly, it is organized into different Tables that supply for a given event: i) its spatio-temporal characteristics (date, hour location, main shock, foreshock, aftershock, earthquake swarm), (ii) its epicentral characteristics (geographic coordinates of the epicenter, epicentral intensity on the MSK scale with reliability indices and most recent update), (iii) the associated macroseismic observations (place names, geographic coordinates, intensity observed in the locality with reliability indices and most recent update) and, lastly, (iiii) a documentary and bibliographic table.

In preparing the isoseismal maps for the Atlas, two main tables were used: the Table of Characteristics of point Observations (OBSIRENE) and that of the Epicentral Characteristics (EPCSIRENE). A single link makes possible the association between each table, the “Numevt”, a numerical key assigned to each individual earthquake. The content of these tables is outlined below.

- **3.1 Evaluating an individual macroseismic intensity associated with a locality (OBSIRENE)**

For a point observation, the intensity evaluation of macroseismic effects is performed based on a synthesis of documentary data and on an in-depth critical examination of these latter. The more descriptive and precise these documents are, the more reliable the corresponding intensity will be. In any event, the document judged to be the most reliable takes precedence over the others.

Defining the macroseismic intensity associated with a locality accordingly consists in assigning a degree to the effects described for this place using the MSK 1964 intensity scale (cf. Appendix 2).


- **3.2 Reliability indices for individual intensity (QIOBS)**

In SisFrance, each point intensity degree is systematically assigned a reliability index (Qiobs) that expresses the level of certainty or uncertainty of the corresponding evaluation. Three types of index are used:

- Qiobs A: a point intensity that is certain, based on a detailed description of the macroseismic effects.
- Qiobs B: a point intensity that is fairly certain, based on a description of the macroseismic effects that appears plausible.
- Qiobs C: an imprecise point intensity based on a description of the macroseismic effects that is sparse or contradictory.

In the event that the degree of intensity cannot be defined for lack of detail, there is still the reliability index alone (Qiobs A, B or C), which attests to the fact that the earthquake was indeed “felt” in that locality with a varying degree of certainty. The reliability index assigned to each point intensity does have a certain

³ List supplied by EDF (Appendix 1, SisFrance, 2014 version) and modified by BRGM (2015, Appendix 2)

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degree of importance for drawing the isoseismals, as these latter precisely call on the reliability of the intensities reported in the localities.

- 3.3 Using degrees on the MSK 1964 Intensity Scale

To transpose the degrees of the MSK Intensity scale, SisFrance uses the following values:

- degree 0: zero effects, earthquake described as “not felt” at the locality,
- degrees 2 to 12: effects ranging from very weak to extremely violent.

Degree 1 on the scale is not used.

- 3.4 Expressing point intensities

The expression of the intensity may be represented by one or by two figures (i.e., A 6 or A 6.5). In the first case, A 6 means that the intensity of degree VI on the MSK scale has been reached with certainty (code A); in the second, A 6.5 indicates that degree VI has been reached in all cases and degree VII for a portion of them.

- 3.5 The macroseismic epicenter and its coordinates (EPCSIRENE)


In SisFrance, the macroseismic epicenter (the point at the ground surface directly above the hypocenter) is mostly placed on the “barycenter” of the meizoseismal area, itself contained within the isoseismal of the strongest intensity. The coordinates of the epicenter are thus established using a macroseismic map produced by the Mapinfo mapping software.

The epicentral coordinates are calculated by clicking the computer mouse on the macroseismic map once the isoseismal areas have been plotted, and the meizoseismal area in particular.

However, the epicentral coordinates may at times be associated with the coordinates of the observation in the case where the earthquake is described by just one observation.

Also, when a meizoseismal area cannot be determined (observations too rare or incomplete), the epicentral coordinates are then placed on, or in the neighborhood of, the macroseismic intensities having the strongest value, and are assigned a reliability index reflecting this uncertainty.

On the screen, the epicentral coordinates are calculated based on the French Lambert projection system (extended Lambert II, metric values), which are then converted in the table of epicenters of the base into geographical coordinates (longitude and latitude) expressed in sexagesimal degrees and minutes.

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- 3.6 Reliability indices for epicentral location (QPOS)

In SisFrance, the epicentral determination, assessed on the basis of knowledge of the meizoseismal area, is rated *via* different reliability indices (Qpos)⁴:

- Qpos A: Well-established coordinates (a few km); precise epicentral determination inside an area of maximum intensity that is precisely circumscribed by an isoseismal.
- Qpos B: Fairly reliable coordinates (uncertainty on the order of 10 km); epicentral location acceptably constrained in an area of maximum intensity relatively well contained by an isoseismal.
- Qpos C: Uncertain coordinates (between 10 and 20 km); epicentral location uncertain within an area of maximum intensity bounded by an isoseismal.
- Code D: Assumed coordinates (ranging from some to 50 km); epicentral location suppositional within an area of macroseismic intensity uncontained by an isoseismal.
- Code E: Arbitrary coordinates (uncertainty greater than 50 km); epicentral location arbitrary in view of widely scattered point observations.
- Code I: "Isolated" coordinates; earthquake recognized in a single observation point; the epicenter takes on the coordinates of the locality together with the intensity ascribed thereto.

- 3.7 Reliability indices for the value of epicentral intensity (QIE)


After the epicentral coordinates, the epicentral intensity itself is then determined based either on the intensity values in the localities situated at the epicenter or immediately next to it, or by estimating a probable value in instances where the localities lie far from the position of the epicenter. Thus, the epicentral intensity does not systematically correspond to the maximum observed intensity: it may be greater. It is assessed using various methods that relate the existence or absence of a meizoseismal area more or less well circumscribed by an isoseismal and the level of proximity of the points of macroseismic intensity surrounding the epicenter.

The codification for the reliability of the epicentral intensity estimate (Qie) is associated with the following conditions⁵:

- Qie A: Well-established epicentral intensity, dense distribution and precise value of the highest point intensities.
- Qie B: Fairly certain epicentral intensity, distribution not as dense and precise value of the highest point intensities.
- Qie C: Uncertain epicentral intensity, sparse distribution and imprecise value of the point intensities.

⁴ In Lambert, J., Levret-Albaret, A. (Dir.): Milles ans de séismes en France, Ouest Éditions, Nantes, 1996, p. 21

⁵ Idem.

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- Qie K: Relatively certain epicentral intensity obtained from a computation based on an attenuation law (Sponheuer).
- Qie E: Debatable epicentral intensity in view of the small number of point intensities and their distance.
- Qie I: Isolated epicentral intensity, based on a single reference point and having the same coordinates as the locality.

4. Principles adopted for assembling an Atlas of isoseismal maps

- 4.1 Steps and methodology for constructing the isoseismal maps of the Atlas

Described hereinafter are the steps and processes implemented, starting with the preparation of the macroseismic map on down to plotting the isoseismals.

- 4.1.1 Reconstructing the macroseismic map (Step 1)

Firstly, the punctual data for each earthquake (OBSIRENE Table) are extracted using the BRGM's SisFrance server. Following a query launched initially *via* ORACLE, then EXCEL, concerning the event's Numevt, the mapping software (Mapinfo) allows all the macroseismic observations concerning the selected earthquake to be displayed on the monitor. The corresponding observations are then materialized by georeferenced points (localities) on which are noted each point intensity (Iobs) and its reliability index (Qiobs). The data window thus obtained enables all the effects of the event to be displayed. This first phase is then completed by a thematic analysis representing the different degrees of intensity reached to be represented by means of symbols on a corresponding color scale (cf. Figure 1).

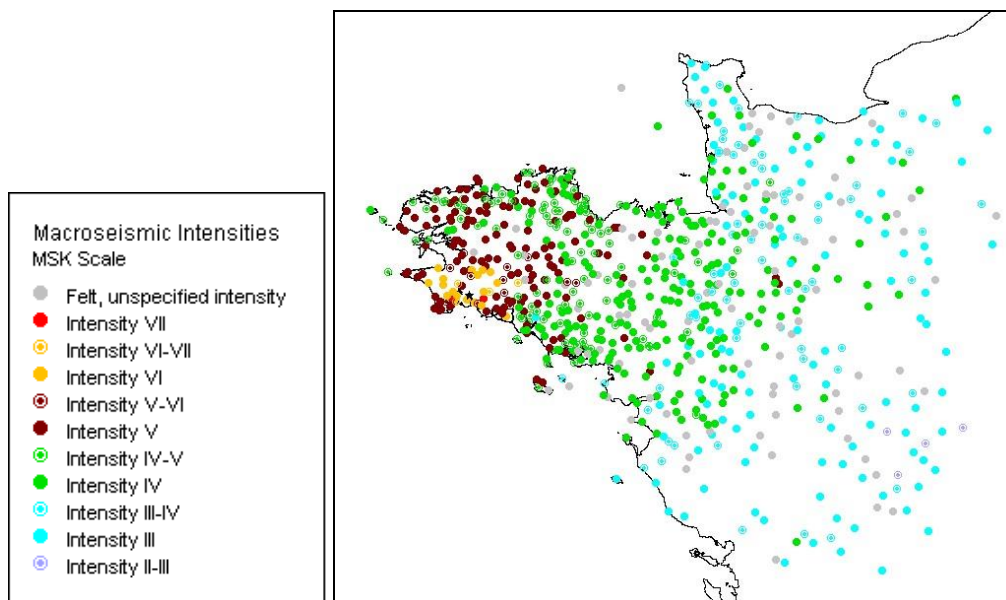


Figure 1. An excerpt from the Mapinfo SIG: a reconstruction of the macroseismic map (reduced view) of the intensities of the January 2, 1959 Brittany earthquake, according to SisFrance, Numevt 290030; a thematic analysis based on the point intensity value.

4.1.2 Defining and characterizing the concept of intensity domain (Step 2)

On an isoseismal map, the intensity zone by principle corresponds to an area that uniformly associates point intensities of a degree that is rigorously identical. In practice, however, such harmony is rarely achieved. Quite often, the very opposite is true. For a given intensity zone, it will not be exceptional to encounter intensities integrated in the same intensity zone, presenting a lower or a higher degree. The reason behind this mainly relates to the description of seismic effects recorded in the documentary sources (archives) when estimating the point intensities. This explains why one may find, in the zone devoted to intensity IV for example, one or more lower intensities of III or III-IV, even of degree II-III or zero (not felt). The same may hold true for one or more higher intensities, V or greater yet, for example. Does not the map (Figure 1) display an intensity V and several points of intensity IV mingled in with many points of intensity III?

For example, during the March 19, 1935 earthquake in the Alps (SisFrance, Numevt 50043), intensities of degree IV or zero are integrated in the intensity V zone, with an intensity VII bordering on this latter zone... Likewise, for the Vercors earthquake of April 25, 1963, intensities of very different levels are found side by side: a VII value near a V one, a zero value “not felt” lying between two positive values of IV and V, a II-III value near a IV one, etc. (Figure 2). And there are innumerable other examples.

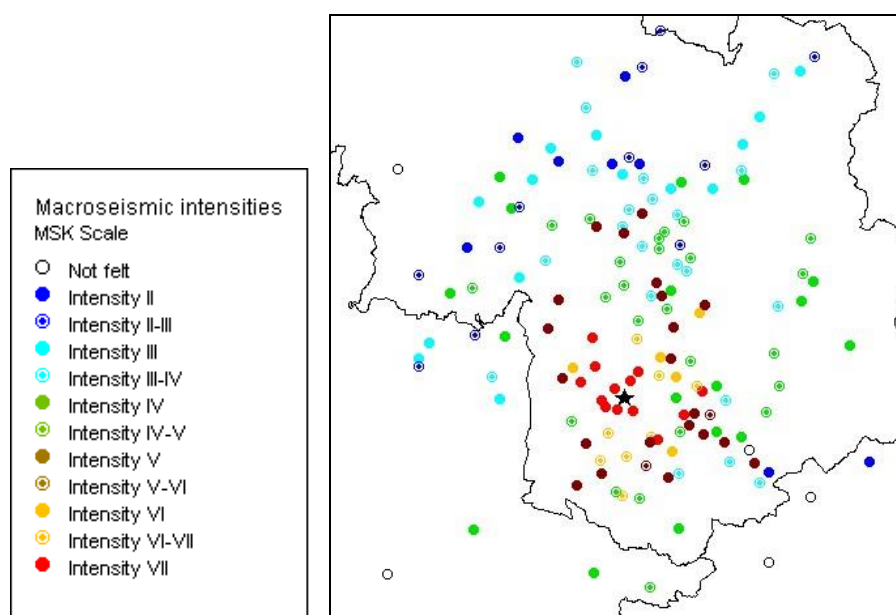



Figure 2. An excerpt from the Mapinfo SIG: a reconstruction of the macroseismic map (reduced view) of the intensities of the April 25, 1963 Vercors earthquake, according to SisFrance, Numevt 380075; a thematic analysis based on the point intensity value. The black star indicates the earthquake’s epicenter.

These apparent disparities thus lead us to admit that each point intensity has its own “weight”, its own representativeness. It should be pointed out that when defining the boundary of the isoseismal, this representativeness is subjected to a critical examination, notably from the standpoint of its reliability index, but also and more particularly by comparing it with the intensities in its immediate vicinity. In other words, the question must be posed, for example, of deciding what weight should be assigned to intensity VII surrounded by a group of intensity V points? Likewise, what would be the weight to assign one or more zero intensities (i.e., not felt) scattered among positive intensities? Etc.

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In our methodology, the fact of including such an apparently underestimated or overestimated intensity in an intensity zone that is different from it should initially have been associated with accordingly proceeds from this critique, which makes it possible to propose a general interpretation, at times precise, and less so at others, of how the isoseismal, and accordingly the boundary of the intensity zone, has been plotted.

In the opposite case, these (under- and/or overestimated) intensities should have been systematically treated as distinct enclosed units of lesser or greater intensity compared to that of the intensity zone considered. This would result in a host of tiny zones of different intensity contained within a zone of uniform intensity, a little like a “mix” of weaker or stronger intensities. This procedure is not compatible with our methodology. On the contrary, we combine, in the interests of a critical objectivity, these different point intensities inside a single zone with a view to causing, not a simplistic view, but a wide tendency, a wide orientation of the different intensity zones to emerge. Thus it represents an interpretation.

The question could always be raised, in the event, to wonder whether these (under- and/or overestimated) intensities might be explained by possible local site effects. As for us, we ascribe these differences - mostly minor (on the order of a degree or half a degree) - to a lack of precise information on the description of the earthquake effects when they were being estimated rather than linking them to any local deceleration or acceleration phenomenon.


In this respect, and on the same line of thinking, a word should be said about the intensities noted 0 (not felt, “zero” value in SisFrance). In many instances, these values do not integrate with the others in a uniform and satisfactory manner to define what could be the actual boundary of the macroseismic zone. How often do we discover a tangle of “zero” degree intensities close by positive point intensities with degrees of II, III, IV, and sometimes V or more... Under such conditions, we consider, based on our experience, that the actual representativeness of the 0 value in the SisFrance BD should be doubted when it lies next to and/or is encircled by many positive values. This is true of many earthquakes. In the event, according to our methodology, it would not be out of the question to register zero values in a zone of positive intensity.

Conversely, we recommend retaining as actual negative values those 0 intensities that concretely appear relatively clustered together. For example, several zero-value intensities that are well constrained geographically and spatially should be taken into account as a relatively reliable “non-felt” zone.

In the Atlas of isoseismal maps, we accept the premise that the intensity zones are, each one, constituted by the value of one whole degree and a half degree above it, with the totality nevertheless integrating the processes detailed above, that is:

- Intensity zone II: includes mainly intensities of degrees II and II-III.
- Intensity zone III: includes mainly intensities of degrees III and III-IV.
- Intensity zone IV: includes mainly intensities of degrees IV and IV-V.
- Intensity zone V: includes mainly intensities of degrees V and V- VI.
- Intensity zone VI: includes mainly intensities of degrees VI and VI- VII.
- Intensity zone VII: includes mainly intensities of degrees VII and VII- VIII.
- Intensity zone VIII: includes mainly intensities of degrees VIII and VIII-IX.
- Intensity zone IX: includes intensities of degree IX.

N.B.: It will be noted, however, that although the majority of the intensity zones calculated for this study do correspond to a whole degree value, it does sometimes occur that the zone in question is associated with an intensity degree plus half. Thus one might encounter the value 65, signifying an intensity zone of degree VI-VII (for instance, event Numevt 340014). Also, values larger than degree IX MSK do not exist in Sis France for the earthquakes concerned by this study.

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- 4.1.3 Plotting the outlines of the isoseismals; closed curves or open lines (Step 3)

Since each earthquake has its own specific characteristics and constitutes a singular case in itself, the plot of each isoseismal is performed manually, taking into account a particular intensity zone and the state of knowledge concerning it. A single expert established the plots for the entire study so as to guarantee the Atlas's overall coherency.

For each event, the general distribution of the point intensities of the earthquake is first rated visually. Going back to the earlier examples (Figures 1 and 2), the thematic analysis of the intensity values (colored symbols) and their geographical distribution make it possible to detect the boundaries of the different intensity zones and, accordingly, the boundary of the corresponding isoseismal or isoseismals. In a second phase, this initial approach is then refined on the screen by zooming in on the map in order to improve the detail on the plot of the contour of the isoseismal in such a way as to ensure it is coherent with spatial distribution of the point intensities.

By convention, between two reliable intensities (Qjobs A or B) of different levels, the boundary of the isoseismal is plotted at equal distance between these two values: for instance, between the degree IV value and the degree V value. This principle of equidistance, however, will not be systematically adopted should the intensities be unreliable (Qjobs C) or their spatial distribution vague, ill constrained, or poorly informed. Accordingly, two types of plots of boundaries of isoseismals will be presented in the Atlas: the closed curve (type 1) or the open line (type 2), each depending on the state of knowledge relative to the earthquake, i.e., the density, number, spatial distribution and reliability of the point observations plotted on the macroseismic map. Moreover, although SisFrance admits it is seeking the characteristics of the meizoseismic areas (those where the intensity is strongest) in order to satisfy the precision of the epicentral coordinates, it does occur nevertheless that these zones cannot be systematically characterized by an isoseismal boundary for want of sufficient information. Several earthquakes in this study fall into this category, mainly "foreign" ones (with an epicenter outside of France), for which the meizoseismic area will not be determined.

- 4.1.3.1 The closed curve and its reliability indices (Type 1)

The closed curve is represented by a closed polygon which allows a surface area⁶ to be calculated, associated with an intensity domain. In this study, several reliability indices (codes) are used to reflect the reliability of the trace:

- Code A: a closed curve having a reliable trace associated with a uniform and closely-spaced distribution of the intensities; the isoseismal is well constrained, making it possible to establish a reliable boundary between the two intensity zones.
- Code B: a closed curve with a relatively certain trace associated with a less well organized and closely spaced distribution of intensities; the isoseismal is nevertheless constrained, thereby allowing a boundary to be drawn between the two zones.
- Code C: a closed curve with an uncertain trace associated with a less well organized and sparse distribution of intensities; the isoseismal is poorly constrained due to the scatter of the reference points. The absence of intensity points over the whole of the trace must not exceed 25% of its length.

⁶ The result of the surface area calculation of the isoseismals is attached to the GIS appended to this study; it is not directly displayed on the macroseismic maps in the Atlas.

- Code D: a closed curve with a presumed trace within a poorly constrained zone determined by: i) the presence of at least two strong intensities, supposing the epicenter within a poorly substantiated macroseismic zone (a few reference points); ii) absence of macroseismic “landmarks” over 25% to 50% of the outer boundary of the concerned isoseismal. In this case, the boundary of the trace is in part established by analogy with the contour of the isoseismal for the next higher intensity.
- Code E: a closed curve with an arbitrary boundary, essentially virtual, surrounding a zone with little or no information, conforming over more than 50% of its outer border around an almost total absence of reference points (e.g., boundaries of isoseismals at sea, a poorly known earthquake); the plot of the corresponding isoseismal is most often adapted to the contour of the isoseismal of the next higher intensity, by analogy.

The maps below, relative to the June 11, 1909 Provence earthquake (Figures 3 and 4) display, by way of example, a succession of closed curves characterized by different levels of reliability index: A, B, C, D and E. These indices are not shown on the paper Atlas, but do appear in the Mapinfo GIS.

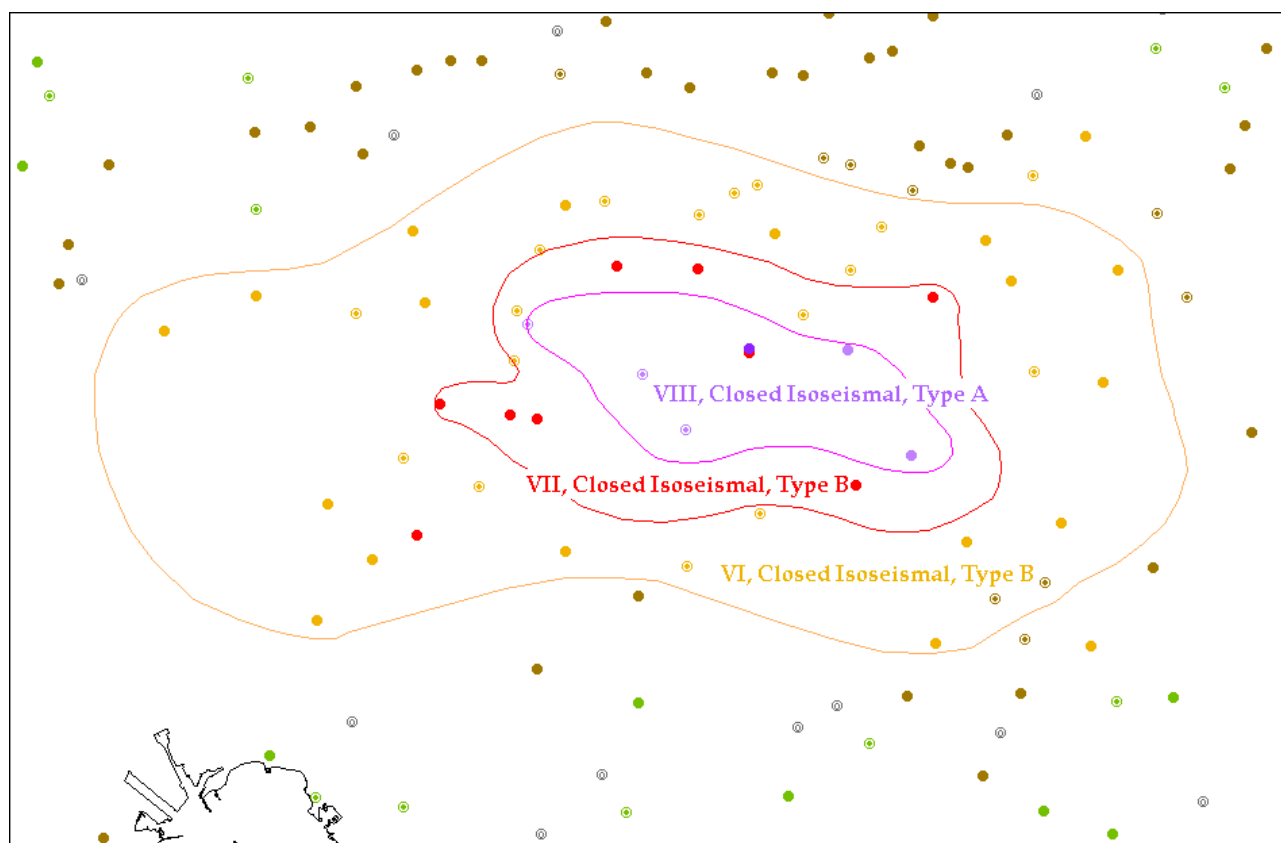


Figure 3. Example drawn from the Mapinfo GIS: the June 11, 1909 Provence earthquake, SisFrance, Numevt 130057; thematic analysis on the value of point intensity. Intensity zones VI to IX materialized by closed curves (closed isoseismals), their type expressing the reliability index assigned to the plot of the isoseismal: closed type A isoseismal: Zone VIII: boundary well constrained by the surrounding intensities, plot reliable; closed type B isoseismals: Zones VII; VI: plots relatively certain but not well constrained due to a less concentrated distribution of observations.

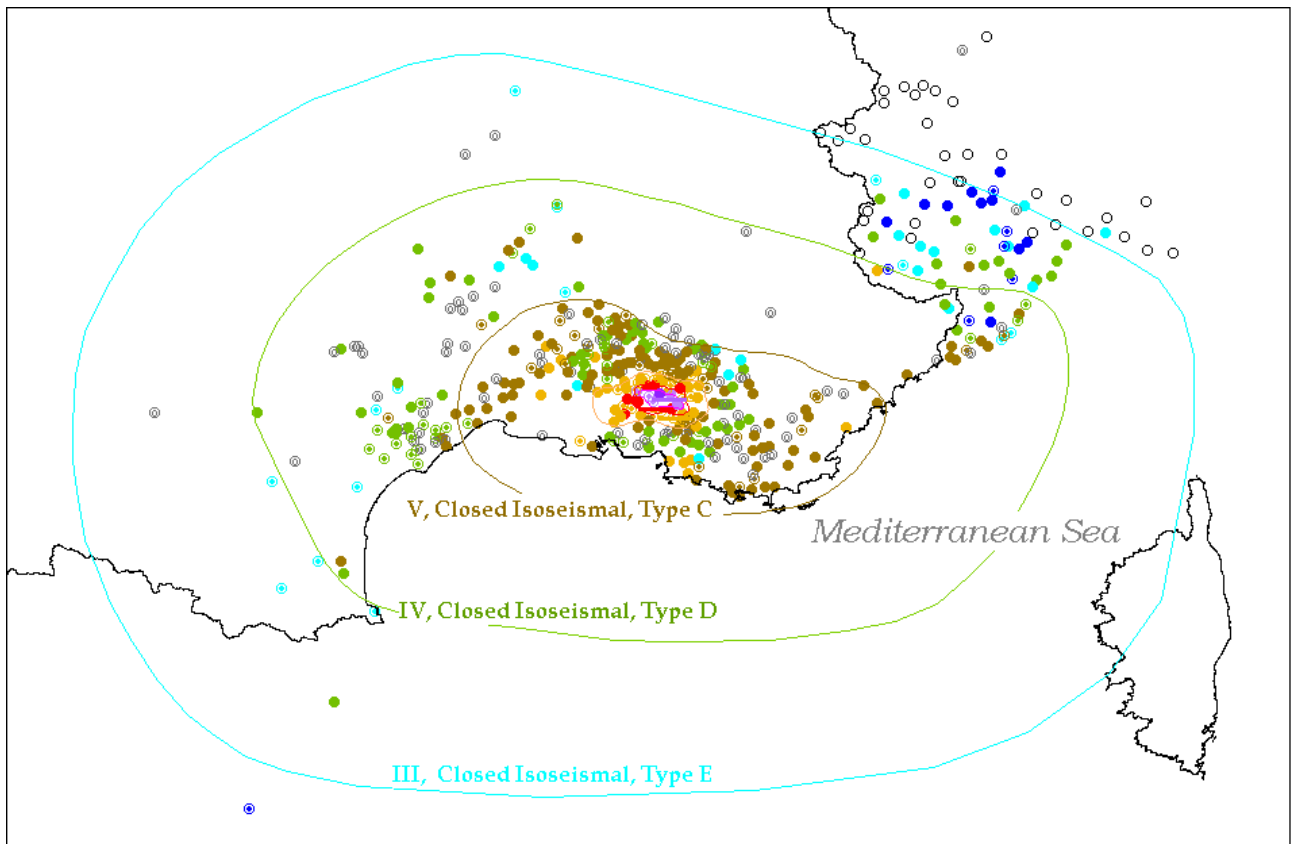



Figure 4. Example drawn from the Mapinfo GIS: the June 11, 1909 Provence earthquake, SisFrance, Numevt 130057; thematic analysis on the value of point intensity. Zones of intensities III to V suggested by closed curves, the type of which expresses the reliability index assigned to the boundaries of the isoseismal plot: Closed type C isoseismal: Zone V : poorly constrained boundary imputable to scattered intensities or with gaps over less than 25% of the total length of the plot; Closed type D isoseismal : Zone IV: presumed plot in a poorly constrained zone presenting gaps over 25 to 50% of the total length of the plot; Closed type E isoseismal: Zone III: arbitrary plot presenting large gaps over more than 50% of the total length of the plot of the isoseismal; curve drafted by analogy with the isoseismal of the next higher intensity degree.

Legend of the degrees of macroseismic intensity, MSK scale; June 11, 1909 Provence earthquake.

- | | |
|---|-----------------------------|
| 1909, June 11, SisFrance, Numevt 130057 | |
| Macroseismic intensities (MSK) | |
| ○ | Not felt |
| ● | Intensity II |
| ⊙ | Intensity II-III |
| ○ | Intensity III |
| ⊙ | Intensity III-IV |
| ● | Intensity IV |
| ⊙ | Intensity IV-V |
| ● | Intensity V |
| ⊙ | Intensity V-VI |
| ● | Intensity VI |
| ⊙ | Intensity VI-VII |
| ● | Intensity VII |
| ⊙ | Intensity VIII |
| ● | Intensity VIII-IX |
| ● | Intensity IX |
| ⊙ | Felt, unspecified intensity |

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- 4.1.3.2 The open line and its reliability indices (Type 2)

The open line is called upon to represent the “beginnings” of an isoseismal or isoseismals due to the too massive lack of references at short as well as intermediate and long distance from the epicenter and which would not allow a closed isoseismal to be obtained, even virtual. This incipient isoseismal notably coincides with the following criteria:

- Rarity or lack of point observations. Even in an arbitrary or virtual manner, the boundaries or contours of the isoseismal cannot be extrapolated for the assessment criteria are insufficient.
- An earthquake attested at a single point. SisFrance sometimes records the existence of an event that is materialized by just one point observation; yet this is accepted as being the epicenter (Qpos value = 1, isolated). For example, the Provence earthquake of September 30, 1937 (Numevt 40140) exemplifies such a case; the open line, unreliable, will be preferred, for no argument could substantiate a closed isoseismal curve.
- Gaps in information concerning various intensity zones situated between the epicenter and the outer limit of the known macroseismic area. For example, the July 10, 1923 event (cf. Figure 5) in Navarre, Spain (Numevt 1140048) is characterized in SisFrance by a marked absence of macroseismic data in Spain, both near the epicenter and at distance.

The reliability indices of the open line are characterized by two codes, D and E.

- Code D: the limit of the open line (incipient part of the isoseismal) is constrained by the presence of a sufficient number of point intensities to announce a suppositional plot;
- Code E: the limit of the open line (incipient part of the isoseismal) is constrained by the rarity or lack of point intensities announcing an arbitrary plot.

Attention should be drawn to the fact that the “open line” mode, unlike the closed curve, does not allow a surface area to be computed.

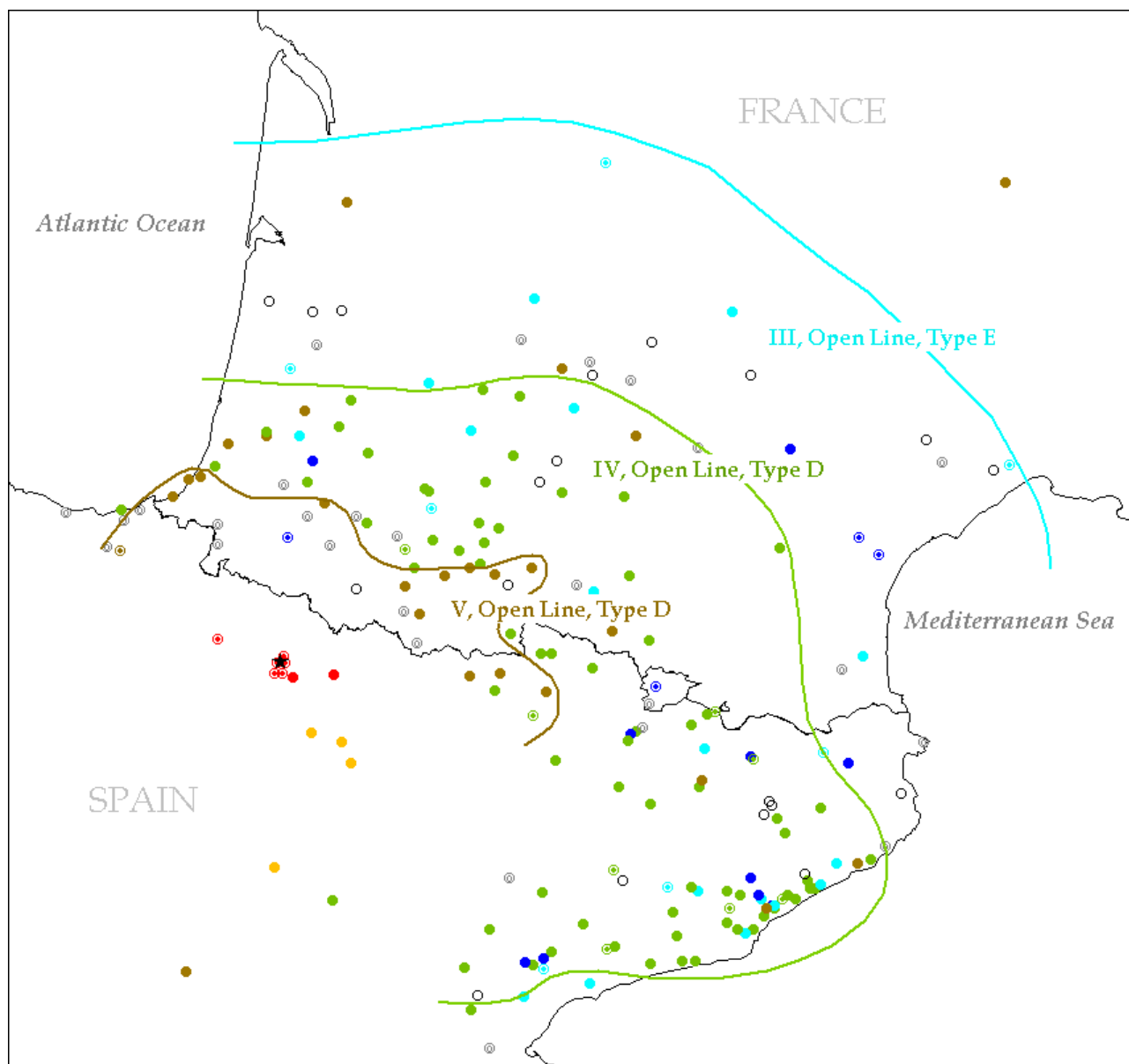



Figure 5. Example drawn from the Mapinfo GIS: the July 10, 1923 earthquake in Navarre (Spain), according to SisFrance, Numevt 1140048; a thematic analysis on the value of point intensity. Open line plots of the boundaries of intensity III isoseismals: open type E isoseismal, with the boundary of the plot little or not constrained by references; of intensity IV and V: open type D isoseismals, plot boundary defined based on the existence of relatively large numbers of references.

- 4.1.4 Smoothing the outlines of the isoseismal (Step 4)

The physical nature of the propagation of seismic waves does not allow them to decrease in broken lines of the “knife cut” type. Actually, what we imagine for propagation is a more or less strong attenuation of waves versus distance, taking on the appearance of curves with variably sized radii, more or less rounded, with no sharp angles. In this study, we have respected this principle by manually drawing curves and/or lines, the contours of which have been adapted following some smoothing intended to eliminate angular points that the raw distribution of the point intensities might reproduce. Naturally the smoothing is still adapted to the context of the spatial distribution of the observation points, as well as their reliability.

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- 5. Reconstituting the isoseismal maps in the Atlas (“image” format)

The Atlas of isoseismals includes the mapping of isoseismals relative to 212 earthquakes with intensities of MSK VI or more, taken from the SisFrance BD for the period 1900 to 2007 (Appendix 1). The version of the data corresponds to the year 2014, and has been partially completed and updated for 2015 by BRGM in the course of the work undertaken during the present study. It is this latest version that should be preferred, insofar as BRGM’s modifications have been communicated to EDF.

Each isoseismal map is presented in color in “image” format (A4) and is printed on paper. Each map contains a succession of headings including:

- 5.1 The map’s title bar (contents)

- The Numevt (numerical key) of the earthquake,
- The earthquake date (day, month, year),
- The designation of the regional location,
- The coordinates of the epicenter in longitude and latitude expressed in sexagesimal degrees and minutes,
- The reliability index of the epicentral coordinates (Qpos),
- The value of epicentral intensity expressed on the MSK 1964 Scale,
- The reliability index of the epicentral intensity (Qie).


- 5.2 The isoseismal map (contents)

On the image version of the map, the presence of isoseismals is materialized:



- a) Either by solid color infills materializing one or more intensity zones (closed curves), with an associated legend;
- b) Or by dashed lines in color indicating the beginnings of an isoseismal (open line), with an associated legend.

The map also contains:

- The geographical position of the SisFrance epicenter;
- The graphic representation of the reliability indices of the intensities associated with the point observations;
- The presence of geographical references (mapbox, names of important towns or cities), a scale in kilometers, a hydrographic network and the compass rose;
- A mini situation map of the earthquake on the scale of France;
- The SisFrance, SIGMA, EDF and BRGM logos

	<p style="text-align: center;">Research and Development Programme on Seismic Ground Motion</p> <p style="text-align: center;">CONFIDENTIAL <i>Restricted to SIGMA scientific partners and members of the consortium, please do not pass around</i></p>	<p>Ref : SIGMA-2015-D1-148 Version : 01</p> <hr/> <p>Date : May 22, 2015 Page : 33 pp</p>
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On the export CD of the Image version of the maps, the referencing of each earthquake is materialized by a designation that corresponds to the SisFrance Numevt. It takes the following form:

-  SEISME_EVT_560027.png
-  SEISME_EVT_560027z.png

N.B.: For certain maps, the level of detail in the epicentral zone is magnified. In these instances, the letter “z” (for zoom) is added to the identification code of the corresponding map following the Numevt. See an example of the final map in image format for the entire January 9, 1930 event, Numevt 560027, and the image format with a zoom on the epicentral zone.

SEISME_NUMEVT_560027

9-1-1930 LANDES DE LANVAUX (MEUCON) - LAT : 47°44'N LONG : 2°48'W - QPOS : A ; IEPC : 7 ; QIE : A

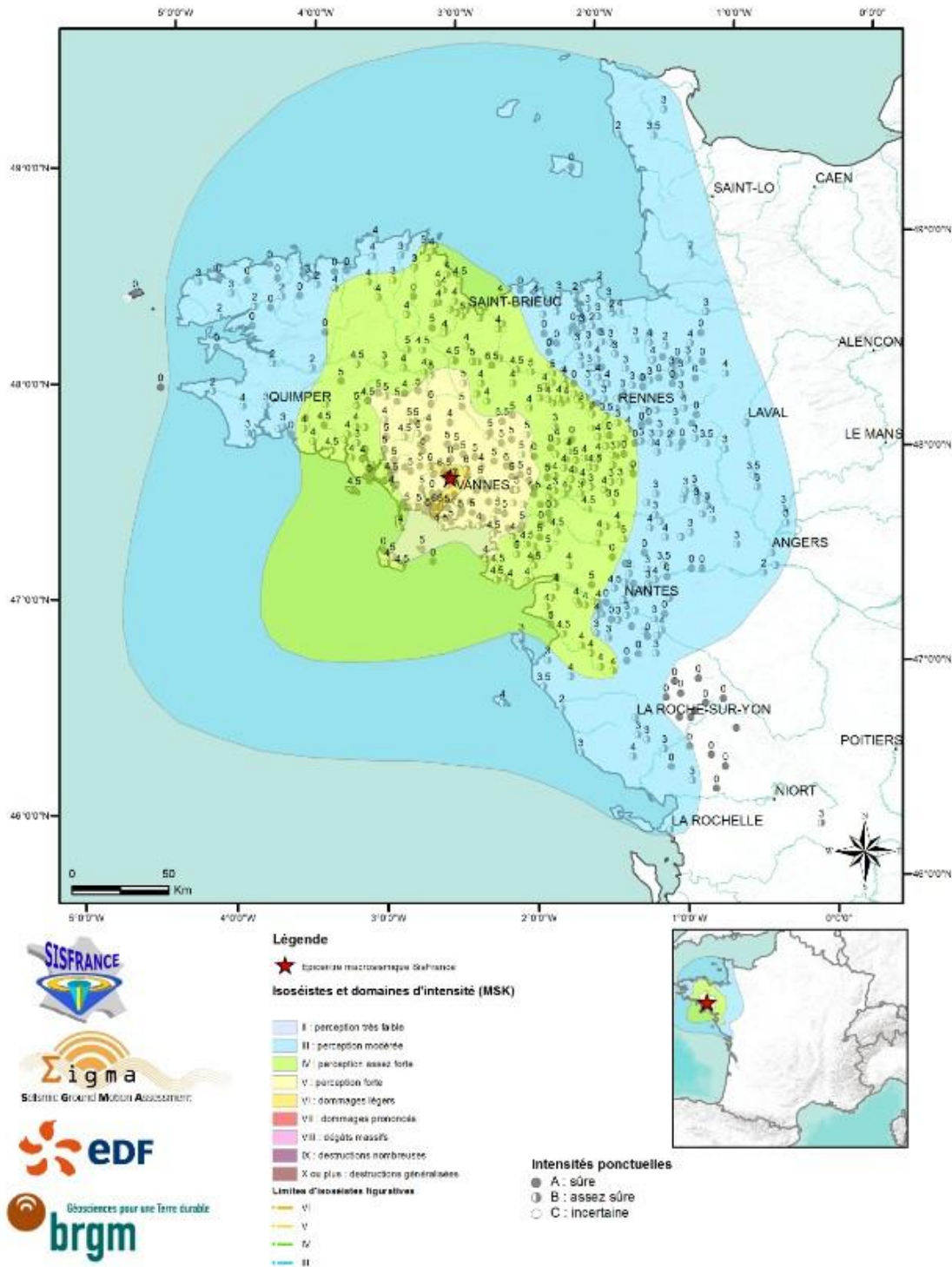


Figure 6. Final reconstitution (small-scale view) of the isoseismal map (closed curves) for the January 9, 1930 Brittany earthquake, SisFrance, Numevt 560027; original A4 paper format in the Atlas.

SEISME_NUMEVT_560027

9-1-1930 LANDES DE LANVAUX (MEUCON) - LAT : 47°44'N LONG : 2°48'W - QPOS : A ; IEPC : 7 ; QIE : A

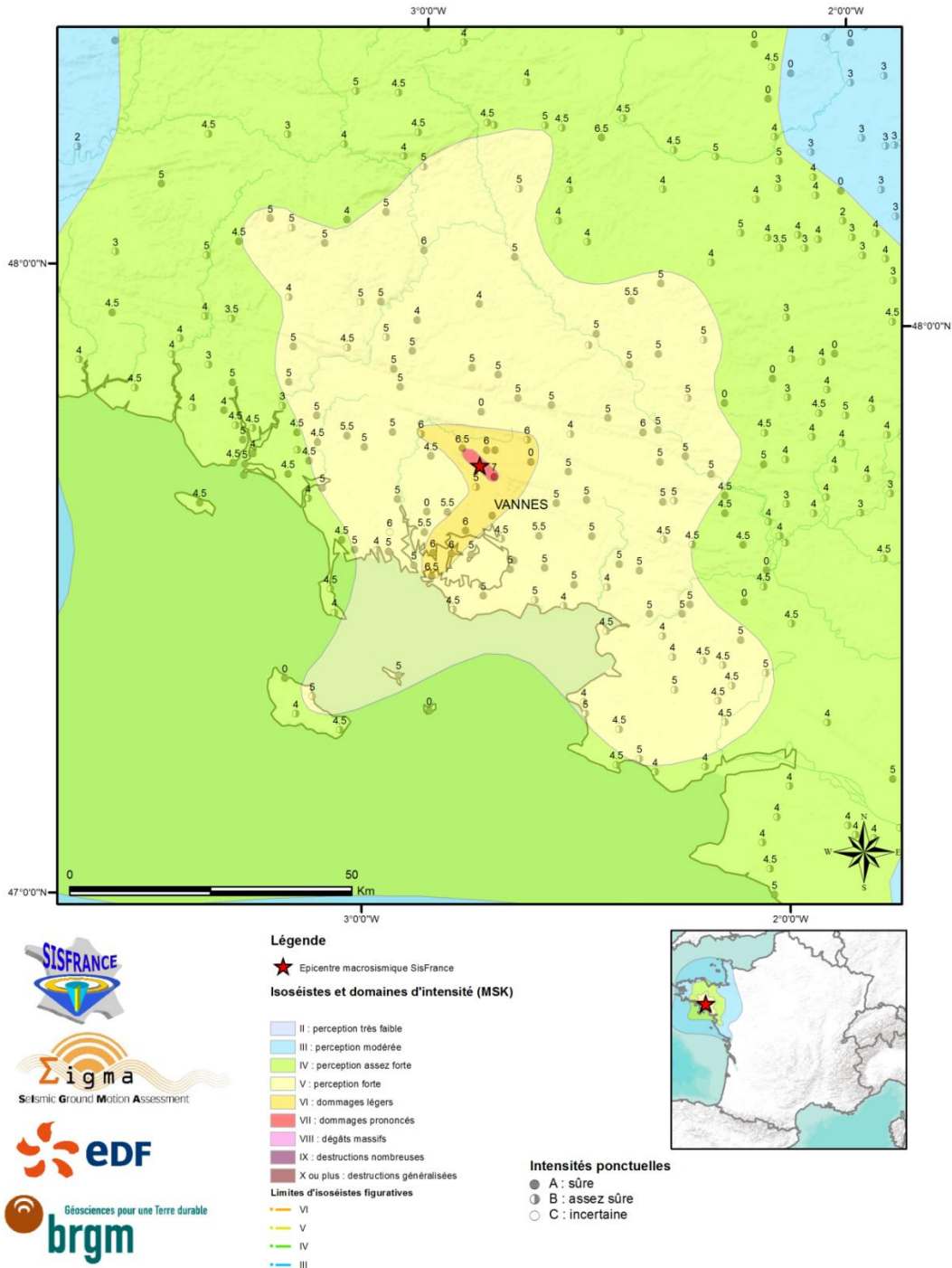



Figure 7. Final reconstitution of the details of the epicentral zone (zoomed view) for the January 9, 1930 Brittany earthquake, SisFrance, Numevt 560027; original A4 paper format in the Atlas.

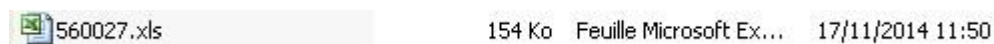
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- 6. Reconstituting the characteristics of the isoseismals (Mapinfo CD)

The present study includes a computer-related section devoted to the characteristics of the isoseismals materialized on the image maps. This section comprises two associated exports: an Excel export and a Mapinfo export. We will be illustrating the material presented with an example: the export of the January 9, 1930 Brittany earthquake, assigned the identification (numerical key) in SisFrance of 560027.

- 6.1 The EXCEL export

The Excel format consists in a file containing the export of point data associated with the chosen event: localities, geographical coordinates, individual macroseismic intensity, and the intensity's reliability index (A, B or C). The Excel export has the same numerical key as the corresponding earthquake in the SisFrance BD. This file is subsequently exploited under Mapinfo.



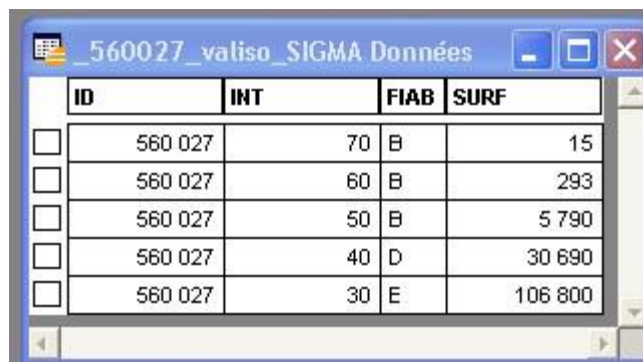
- 6.2 The MAPINFO export

The data under the Mapinfo format are assembled from the Excel file, allowing them to be reconstituted on a map. Each event processed under Mapinfo is accompanied by four files, each of which has its own extension (DAT, ID, MAP and TAB):

560027_valiso_SIGMA.DAT	1 Ko Fichier DAT	03/03/2015 15:30
560027_valiso_SIGMA.ID	1 Ko MapInfo Table File	03/03/2015 15:29
560027_valiso_SIGMA.MAP	5 Ko MapInfo Table File	03/03/2015 15:29
560027_valiso_SIGMA.TAB	1 Ko MapInfo Table	03/03/2015 15:30

Opening these files in conjunction with each other reconstitutes the characteristics of the isoseismals on the computer screen in table form (Figure 8) including:

- The earthquake's identification (Numevt): "ID" column;
- The value of the degree of the intensity zone for which the surface area computation is being performed: "INT" column. The values are expressed in Arabic numerals; i.e., "70" means the intensity VII zone, "50", that of intensity V, "65" that of VI-VII, etc.;
- The reliability index associated with the contour of the closed isoseismal (A, B, C, D, E) and/or of the open line (D, E); "FIAB" column;
- The surface area expressed in square kilometers (km²) for closed isoseismals only: "SURF" column. The surface area computation is performed automatically by Mapinfo provided the isoseismal is associated with a closed polygon. The value zero (0) is systematically assigned for open-line isoseismals.

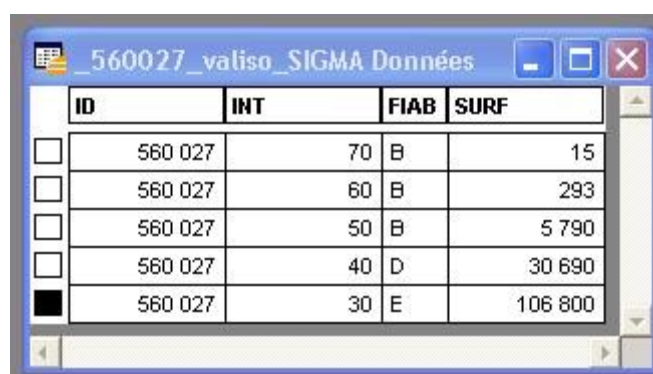


	ID	INT	FIAB	SURF
<input type="checkbox"/>	560 027	70	B	15
<input type="checkbox"/>	560 027	60	B	293
<input type="checkbox"/>	560 027	50	B	5 790
<input type="checkbox"/>	560 027	40	D	30 690
<input type="checkbox"/>	560 027	30	E	106 800

Figure 8. The data set obtained under Mapinfo corresponding to the characteristics of the January 9, 1930 Brittany earthquake, SisFrance Numevt 560027; ID col. = earthquake identification; INT col. = the value of the degree of the intensity zone (70 = VII); FIAB col. = the reliability index of the isoseismal contour; SURF col. = the surface area expressed in km² for the corresponding isoseismal.

After the table of data, Mapinfo opens an isoseismal map (closed curves and/or open lines) by double-clicking on the .TAB. Then each level of intensity associated with a closed isoseismal and/or an open line is selected individually using the computer mouse.

On the screen, the data appear in the following form (Figure 9). The selection of the MSK intensity III isoseismal (value 30 in the table) is reconstituted on the map (Figure 10), where the isoseismal is activated.



	ID	INT	FIAB	SURF
<input type="checkbox"/>	560 027	70	B	15
<input type="checkbox"/>	560 027	60	B	293
<input type="checkbox"/>	560 027	50	B	5 790
<input type="checkbox"/>	560 027	40	D	30 690
<input checked="" type="checkbox"/>	560 027	30	E	106 800

Figure 9. The January 9, 1930 earthquake, SisFrance Numevt 560027, according to the Mapinfo dataset. The selection of the MSK intensity III isoseismal (closed curve, value 30 in the table) is reconstituted and is active on the map on Figure 10.

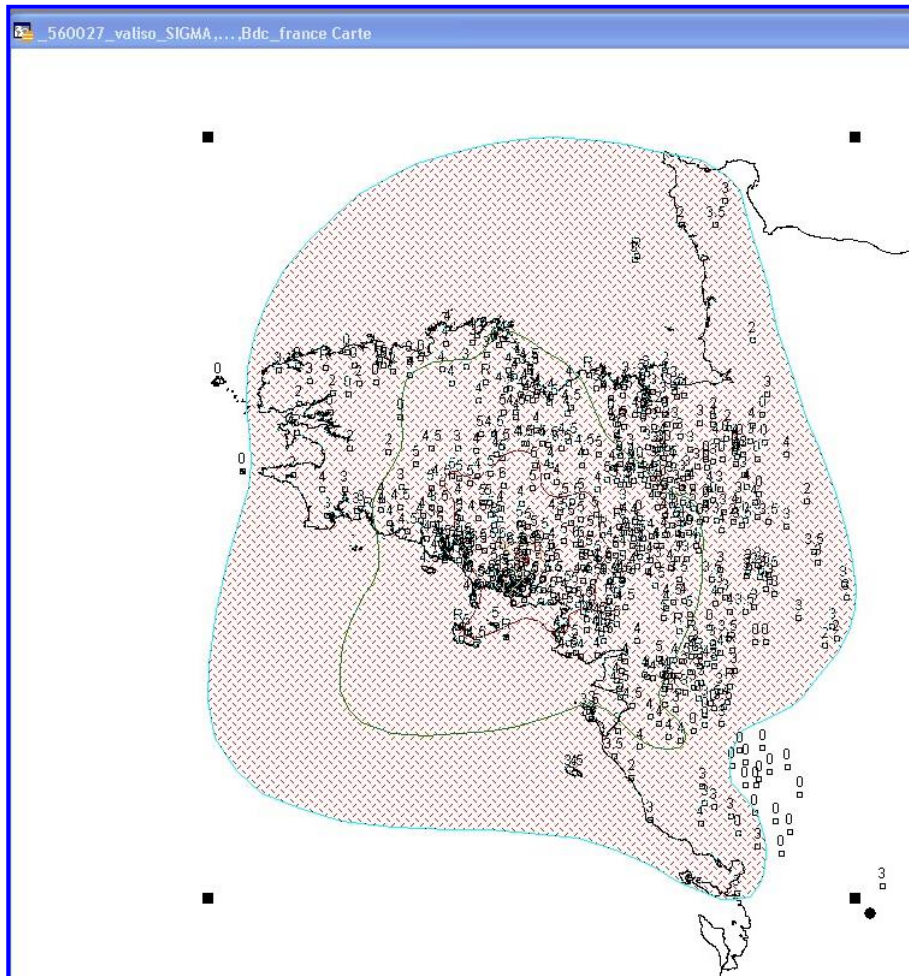



Figure 10. The January 9, 1930 Brittany earthquake, SisFrance Numevt 560027, according to the Mapinfo dataset. The selection of the MSK intensity III isoseismal (closed curve, value 30 in the table on Figure 9) is active on the map.

For isoseismals associated with open lines (Figure 11), the identifying elements in the Mapinfo GIS use the same identification criteria, but alone: surface area values are not supplied (value 0).

ID	INT	FIAB	SURF
<input type="checkbox"/> 1 140 048	50	D	0
<input type="checkbox"/> 1 140 048	40	D	0
<input type="checkbox"/> 1 140 048	30	E	0

Figure 11. The Mapinfo dataset of the isoseismals (open lines) of the July 10, 1923 Navarre earthquake, SisFrance Numevt 1140048; the surface area values (SURF col.) are not supplied (cf. the map, Figure 5, p. 19).

All the mapped data constituted under Excel and Mapinfo are, in the framework of this study, exported on a CD.

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- Appendix 1 – SIGMA Project; EDF list of earthquakes of the Atlas of isoseismals derived from SisFrance (Oct. 2014)

lo	QIE	max_l	n_i	Nobs	AN1	appelation	x	y	
40065	6	C	6	3	6	1912	EMBRUNAIS (ST-ANDRE)	933300	1962500
40067	7,5	A	7,5	4	5	1913	MOYENNE-DURANCE (VOLX)	882500	1882100
40082	6,5	A	6,5	16	17	1933	UBAYE (LE LAUZET)	929000	1943700
40092	6	A	6	72	72	1949	UBAYE (LE LAUZET)	920800	1947000
40099	7,5	A	7,5	112	118	1951	HAUT-VERDON (CHASTEUIL)	928500	1876900
40109	7,5	B	7,5	169	207	1959	UBAYE (ST-PAUL)	956100	1958200
40140	6	I	6	1	1	1937	MOYENNE-DURANCE (LURS)	884800	1891400
40176	6	A	6	29	32	1984	PREALPES DE DIGNE (AIGLUN)	905800	1901700
40203	6	B	6	90	90	1997	PREALPES DE DIGNE (PRADS-HAUTE-BLEONE)	930500	1924800
50032	7	A	7	30	32	1904	BRIANCONNAIS (BRIANCON)	941800	2000100
50043	7	A	7,5	232	254	1935	EMBRUNAIS (ST-CLEMENT)	941200	1962900
50050	6	C	6	55	64	1937	QUEYRAS (GUILLESTRE)	947300	1972500
50052	6	C	6	49	52	1938	EMBRUNAIS (CHATEAUROUX)	934400	1966300
50057	6,5	B	7	351	381	1938	QUEYRAS (GUILLESTRE)	938100	1972000
50099	6	B	6	66	68	1991	BRIANCONNAIS (BRIANCON)	943000	1993900
110005	6,5	K	7	48	67	1950	CORBIERES (CAMPLONG-D'AUDE)	624100	1792300
120003	6	B	6	65	113	1939	VALLEE DE L'AVEYRON (SEVERAC-LE-CHATEAU)	660800	1929800
130057	8,5	A	9	392	475	1909	TREVARESSE (LAMBESC)	840600	1854400
130059	6	C	6	4	15	1909	TREVARESSE (LAMBESC)	840000	1855400
130064	6	C	6	5	6	1909	TREVARESSE (LAMBESC)	839300	1854300
130118	6	A	6	173	183	1984	BASSE-PROVENCE (MIMET)	856500	1829000
160012	7	A	7	616	647	1935	ANGOUMOIS (ROUILLAC)	415600	2087900
170069	6	B	6	5	6	1903	AUNIS (LA ROCHELLE)	332400	2142900
170077	6	A	6	380	411	1958	ILE D'OLERON	314500	2117800
170079	7	A	7	436	446	1972	ILE D'OLERON	324400	2108100
180010	6,5	A	7	328	399	1925	MARCHE-BOISCHAUT (CHATEAUMEILLANT-LA CHATRE)	583100	2170400
200013	6	B	6	64	66	1978	CASTAGNICCIA (CERVIONE)	1191900	1722800
230010	6	B	6	130	146	1925	MARCHE-BOISCHAUT (LA CHATRE)	580500	2172200
260097	7	B	7	14	15	1901	BAS-PLATEAUX DAUPHINOIS (MANAS)	811500	1959000
260120	6	A	6,5	67	70	1934	TRICASTIN (ROUSSAS)	793700	1934400
260122	7	A	7	42	50	1934	TRICASTIN (VALAURIE)	795000	1936200
260126	6	A	6,5	93	101	1934	TRICASTIN (VALAURIE)	799000	1936400
260127	6	A	6	7	40	1934	TRICASTIN (BOUCHET)	799200	1929000
260138	6	A	6	28	28	1934	TRICASTIN (VALAURIE)	796300	1938100
260142	6	A	6	7	10	1934	TRICASTIN (VALAURIE)	796300	1938100
260150	6	A	6	64	69	1936	TRICASTIN (LA GARDE-ADHEMAR)	792300	1936200
260175	7	A	7	72	74	1952	BARONNIES (PIERRELONGUE)	830100	1920700
290030	7	B	7	682	784	1959	CORNOUAILLE (MELGVEN)	126900	2345100
300014	6,5	B	7	17	18	1946	COSTIERE (LE PONT-DU-GARD)	780700	1878300
310037	6	A	6,5	551	606	1999	HAUT-COMMINGES (CIERP)	460800	1771700
380053	6	A	6	32	33	1938	BAS-PLATEAUX DAUPHINOIS (LA SONE)	833200	2017300
380058	6	A	6	124	134	1941	BAS-PLATEAUX DAUPHINOIS (LA COTE-SAINT-ANDRE)	832100	2045100
380070	7,5	A	7,5	489	506	1962	VERCORS (CORRENCON-EN-VERCORS)	854700	2005200
380075	7	A	7	156	156	1963	VERCORS (MONTEYNARD)	862900	1998100
380080	7	A	7	36	57	1963	VERCORS (MONTEYNARD)	861500	1998000
380083	6	A	6	19	33	1963	VERCORS (CORRENCON-EN-VERCORS)	855800	2008900
380084	6	B	6	6	14	1963	VERCORS (CORRENCON-EN-VERCORS)	853300	2005100
380085	6	B	6	7	12	1963	VERCORS (CORRENCON-EN-VERCORS)	850500	2010600
380099	6	A	6	90	93	1979	VERCORS (MONTEYNARD)	860400	1994300

390016	7	A	7	74	75	1971	JURA (VAUX-LES-SAINT-CLAUDE)	860000	2157400
440040	6	C	6	13	27	1907	PAYS DE CHATEAUBRIANT (TREFFIEUX)	309100	2297900
450009	6	A	6	33	43	1933	VAL DE LOIRE (TIGY)	587200	2311200
560019	6	B	6	3	4	1902	ILE DE BELLE-ILE (LE PALAIS)	187500	2282900
560027	7	A	7	519	543	1930	LANDES DE LANVAUX (MEUCON)	214900	2316300
610009	6	A	6	553	586	1927	BOCAGE NORMAND (FLERS)	386600	2426300
630059	6	C	6	2	14	1913	COMBRAILLE (PIONSAT)	624200	2120400
630069	6	A	6	240	261	1957	LIMAGNE (RANDAN)	686100	2117200
640001	7,5	A	7,5	1291	1323	1980	OSSAU (ARUDY)	382100	1788600
640003	6	E	5,5	21	40	1980	OSSAU (ARUDY)	382100	1788600
640028	6	E	4,5	29	50	1980	OSSAU (ARUDY)	382100	1788600
640272	7	B	7	59	107	1902	BEARN (LURBE-SAINT-CHRISTAU)	355000	1793300
640284	7	C	7	6	21	1902	BEARN (OLORON-SAINTE-MARIE)	360800	1802300
640292	7	B	7	26	61	1911	BEARN (BENEJACQ-COARRAZE)	390700	1801300
640330	6	B	6	50	62	1952	BEARN (ARETTE)	348600	1793100
640362	8	A	8	803	839	1967	BEARN (ARETTE)	346924	1793410
640375	6,5	B	6,5	141	154	1973	BEARN (NAY-BOURDETTES)	387800	1797700
640385	6,5	C	6,5	8	9	1977	PAYS BASQUE (STE-ENGRACE)	337000	1784700
640417	6	A	6,5	158	162	1981	BEARN (NAVARRENX)	352200	1824900
640431	6,5	B	6,5	364	377	1982	PAYS BASQUE (ST-JEAN-LE-VIEUX)	325200	1796300
640444	6	C	6	151	153	1982	BEARN (S. ARTHEZ-D'ASSON)	384700	1784800
640462	6	B	6	125	135	1984	PAYS BASQUE (BAIGORRY)	302300	1801100
650221	7	A	7	60	87	1904	BIGORRE (BAGNERES-DE-BIGORRE)	418800	1787400
650244	7	E	6,5	6	11	1905	BIGORRE (BAGNERES-DE-BIGORRE)	417000	1770800
650273	6,5	E	5	21	24	1912	ARAGON (JACA ?)	362400	1735400
650287	7	A	7	392	450	1924	BEARN (S. ARTHEZ-D'ASSON)	385000	1787100
650324	6	B	6	40	49	1930	LAVEDAN (ARGELES-GAZOST)	405700	1785600
650361	6	B	6	79	97	1948	BIGORRE (CHEUST-JUNCALAS)	410600	1785800
650366	7	B	7	147	159	1950	BIGORRE (CAMPAN)	422600	1776200
650374	6	B	6	82	87	1952	LAVEDAN (ARGELES-GAZOST)	414300	1774600
650377	6	B	6,5	112	122	1953	BIGORRE (CAMPAN)	429500	1782900
650382	6,5	B	6,5	389	450	1958	BIGORRE (HECHES)	439000	1779500
650398	6	B	6	24	30	1966	HAUT-COMMINGES (GOURDAN-POLIGNAN)	447000	1771900
650500	6	B	6	244	251	2002	LAVEDAN (AUCUN)	394000	1777100
650505	6	A	6	524	605	2006	BIGORRE (GAZOST)	408900	1783000
660061	6	E	7	5	19	1920	FENOUILLEDES (ST-PAUL-DE-FENOUILLET)	610600	1755200
660068	6,5	A	6,5	9	30	1922	FENOUILLEDES (ST-PAUL-DE-FENOUILLET)	613300	1758900
660073	6	A	6	19	22	1922	PLAINE DU ROUSSILLON (MILLAS)	628400	1746000
660095	6	A	6	807	856	1996	FENOUILLEDES (ST-PAUL-DE-FENOUILLET)	619300	1748400
670096	6,5	B	6,5	112	125	1952	OUTRE-FORET (WISSEMBOURG)	1013200	2440900
670102	7	A	7	70	87	1952	OUTRE-FORET (WISSEMBOURG)	1013500	2453900
670106	6	A	6	79	81	1959	PLAINE DE BASSE-ALSACE (ERSTEIN)	992400	2385600
680065	6	A	6	32	44	1901	PLAINE DE HAUTE-ALSACE (ST-LOUIS)	988200	2298000
680091	6,5	B	6,5	450	467	1980	PLAINE DE HAUTE-ALSACE (HABSHEIM)	979600	2314100
700013	6	B	6	38	43	1955	AVANT-PAYS JURASSIEN (MONTARLOT-LES-RIOZ)	876300	2275000
700017	6	A	6	44	47	1955	AVANT-PAYS JURASSIEN (MONTARLOT-LES-RIOZ)	875000	2274900
730165	6	A	6	22	28	1947	LAC DU BOURGET (JONGIEUX)	868700	2088000
730174	6,5	K	7	108	119	1958	LAC DU BOURGET (CONJUX)	869300	2091100
730177	6	A	6	40	43	1958	BUGEY (LA BALME-DE-SILLINGY)	863100	2083400
740060	7,5	B	7,5	227	302	1905	MASSIF DU MONT-BLANC (LAC D'EMOSSON)	952700	2130600
740067	7	B	7	10	24	1905	MASSIF DU MONT-BLANC (CHAMONIX)	961800	2119900
740069	6	B	6	6	12	1909	CHABLAIS (ABONDANCE)	937600	2151600
740079	7	A	7	89	100	1936	AVANT-PAYS SAVOYARD (FRANGY)	878200	2123000
740094	6,5	B	6,5	21	21	1968	CHABLAIS (ABONDANCE)	939900	2152100
740097	7	A	7	18	32	1968	CHABLAIS (ABONDANCE)	941100	2154000
740119	6,5	B	6,5	287	292	1980	BAUGES (FAVERGES)	908200	2092900
740150	6	A	6	516	522	1994	GENEVOIS (LES VILLARDS-SUR-THONES)	912700	2109900
740153	7	A	7	763	782	1996	AVANT-PAYS SAVOYARD (EPAGNY-ANNECY)	891500	2109200


830006	6	E	5,5	114	123	1932	MEDITERRANEE (S. MARSEILLE)	828100	1790800
840066	7	A	7	10	10	1905	BARONNIES (VAISON-LA-ROMAINE)	812700	1923800
840068	6,5	C	6,5	2	4	1924	COMTAT (CADEROUSSE)	793400	1902800
840074	7	B	7	39	43	1927	BARONNIES (MALAUCENE)	829000	1915100
860021	6	B	6	19	23	1901	BRANDES DU HAUT-POITOU (CHARROUX)	446500	2127800
880053	6	A	6	219	234	1984	HAUTES-VOSGES (ELOYES-REMIREMONT)	917600	2349400
880077	6,5	A	6,5	3853	3959	2003	PAYS FORESTIER SOUS-VOSGIEN (RAMBERVILLERS)	923500	2378700
1100014	7	A	7	1380	1449	1938	FLANDRES (RENAIX-OUDENAARDE)	692600	2641900
1100022	7,5	A	7,5	41	67	1983	PAYS DE LIEGE (LIEGE)	827700	2631200
1100078	7	C	7	8	13	1949	HAINAUT (HAVRE)	720700	2609300
1100079	7	C	7	20	20	1965	HAINAUT (MAURAGE)	726700	2605700
1100080	7	C	7	25	25	1965	PAYS DE LIEGE (HERSTAL-LIEGE)	831300	2631400
1100081	6	C	6	13	13	1966	HAINAUT (HAINE-SAINT-PIERRE)	732600	2607700
1100082	6	C	6	12	12	1966	HAINAUT (CARNIERES)	736200	2605900
1100083	7	C	7	30	30	1966	HAINAUT (CARNIERES)	738500	2607800
1100094	6	B	6	8	25	1911	HAINAUT (RANSART)	752700	2610100
1100107	6	A	6	44	88	1925	LIMBOURG (BILZEN)	828600	2656900
1100110	6,5	A	6,5	1265	1348	1992	LIMBOURG (ROERMOND)	859100	2694000
1100119	6	C	6	49	53	1928	HAUTES-FAGNES (VERVIERS)	853036	2630231
1110017	7	B	7	653	736	1926	VALLEE DU RHIN (KAISERSTUHL)	994000	2361500
1110019	6	C	6	9	11	1957	JURA SOUABE (TAILFINGEN)	1094000	2385900
1110021	6	C	6	31	36	1965	FORET NOIRE (ST-BLASIEN)	1033700	2329000
1110022	6	C	6	63	70	1974	FORET NOIRE (WEHR)	1019100	2305700
1110059	6,5	B	6,5	93	111	1903	VALLEE DU RHIN (KARLSRUHE)	1028000	2467200
1110061	8,5	K	8	368	480	1911	JURA SOUABE (EBINGEN)	1090100	2385500
1110062	6	B	6,5	140	218	1913	JURA SOUABE (TUBINGEN)	1097000	2433100
1110063	7	E	5,5	6	24	1915	JURA FRANCONIEN (INGOLSTADT ?)	1258300	2473100
1110064	6	C	6	1	9	1917	BODENSEE (KONSTANZ ?)	1112300	2318600
1110065	6,5	C	6,5	64	101	1924	JURA SOUABE (EBINGEN)	1103400	2392300
1110066	6,5	E	4,5	36	50	1924	JURA SOUABE (EBINGEN)	1103400	2392300
1110068	7	C	7	17	35	1930	ALPES BAVAROISES (NAMLOS)	1228000	2296300
1110069	7	A	7	446	499	1933	VALLEE DU RHIN (RASTATT)	1028600	2447600
1110070	6	E	4	14	24	1933	JURA SOUABE (PFEFFINGEN ?)	1090800	2380000
1110074	7,5	C	7,5	404	442	1935	JURA SOUABE (KAPPEL)	1139400	2365700
1110075	6	E	5	312	365	1935	VALLEE DU RHIN (OFFENBURG)	1033300	2418200
1110076	7	K	7	763	834	1935	VALLEE DU RHIN (OFFENBURG)	1033300	2418200
1110077	7	B	7	29	47	1943	JURA SOUABE (EBINGEN)	1089400	2381800
1110078	7	B	7	49	53	1943	JURA SOUABE (BALINGEN)	1089200	2383600
1110079	6	E	5	23	39	1947	JURA SOUABE (EBINGEN)	1094200	2384000
1110080	6,5	E	3,5	2	8	1947	JURA SOUABE (ONSMETTINGEN)	1094200	2384000
1110083	7	B	7	126	147	1948	VALLEE DU RHIN (KARLSRUHE)	1043800	2458100
1110085	6,5	B	7	108	120	1952	VALLEE DU RHIN (LUDWIGSHAFEN)	1043000	2515700
1110086	7	B	7	4	16	1969	JURA SOUABE (TAILFINGEN)	1096500	2386100
1110087	7	B	7	111	125	1970	JURA SOUABE (ONSMETTINGEN)	1095100	2387800
1110091	7,5	A	7,5	449	467	1978	JURA SOUABE (ONSMETTINGEN)	1094300	2382200
1110096	7,5	B	7,5	21	32	1951	HAUTES-FAGNES (EUSKIRCHEN)	911500	2635300
1110197	6,5	B	6,5	2	12	1950	HAUTES-FAGNES (EUSKIRCHEN)	915100	2635500
1110221	6	C	5	803	819	2004	BADEN-WURTTENBERG (WALDKIRCH)	1019100	2357700
1120023	7	B	7	9	12	1924	VALAIS (VISP)	1027200	2155800
1120028	7,5	A	7,5	464	476	1946	VALAIS (CHALAIS)	1001400	2155900
1120031	7	E	5	2	185	1946	VALAIS (CHALAIS)	1001400	2155900
1120033	7	B	7	365	388	1946	VALAIS (CHALAIS)	1001400	2155900
1120035	7	B	7	104	120	1954	VALAIS (N-W. SION)	973500	2150400
1120037	6,5	B	6,5	119	131	1954	VALAIS (MONTANA)	998700	2157600
1120038	7	B	7	211	256	1960	VALAIS (BRIG)	1035800	2162000
1120044	6,5	B	6,5	156	207	1925	JURA SUISSE (ORBE-LIGNEROLLE)	914700	2200100
1120077	6	B	6,5	166	223	1910	JURA SUISSE (LAUFEN)	986900	2281300

1120078	7	B	7	77	87	1964	UNTERWALD (SARNEN)	1050900	2233700
1120086	6,5	B	6,5	4	7	1929	PLATEAU SUISSE (YVERDON)	937000	2203900
1120109	6	C	6	48	58	1984	ZURICH	1068500	2268500
1120261	6,5	C	6,5	5	11	1915	BAS-VALAIS (MARTIGNY)	966700	2135100
1120271	6,5	B	6,5	1	3	1933	PLATEAU SUISSE (MOUDON)	941200	2196700
1130067	6	B	6	97	100	1905	PIEMONTE (FOSSANO)	1027400	1964500
1130068	6	C	6	81	83	1906	RIVIERA DI PONENTE (TAGGIA)	1043300	1889500
1130070	9	C	9	26	35	1920	TOSCANE (FIVIZZANO)	1232000	1942800
1130078	6	B	6	33	35	1936	PIEMONTE (PIGNA)	1028100	1895800
1130082	6	A	6	100	104	1958	PIEMONTE (VALDIERI)	1006100	1944500
1130085	7	E	4	2	200	1963	MEDITERRANEE (S. IMPERIA)	1073500	1826600
1130086	7,5	E	6	394	412	1963	MEDITERRANEE (S. IMPERIA)	1073500	1826600
1130088	7,5	E	6	6	9	1963	MEDITERRANEE (S. IMPERIA)	1073500	1826600
1130091	6,5	A	6,5	100	101	1966	PIEMONTE (ENTRACQUE)	1004600	1927700
1130092	6	B	6	16	17	1968	RIVIERA DI PONENTE (DIANO MARINA)	1065400	1900300
1130098	6	C	6	37	39	1972	RIVIERA DI PONENTE (PIETRA LIGURE)	1077300	1919800
1130101	8,5	C	8,5	48	52	1976	FRIOUL (UDINE)	1434200	2183500
1130104	6	E	5	90	99	1941	PIEMONTE (PRAZZO ?)	978800	1955800
1130107	7	B	7	46	46	1955	PIEMONTE (STROPPO)	981200	1959700
1130108	7	B	7	95	104	1955	PIEMONTE (PRAZZO)	976300	1953800
1130121	7	B	7	51	67	1914	PIEMONTE (SACRA DI SAN MICHELE)	994400	2023600
1130122	7,5	C	7,5	354	374	1947	PIEMONTE (PRAZZO ?)	992100	1997500
1130129	6	B	6	26	28	1927	PIEMONTE (SUSA)	984900	2028600
1130131	6,5	C	6,5	17	28	1968	VAL D'AOSTE (ARNAZ)	1021800	2084900
1130132	8	C	8	1	22	1901	LOMBARDIE (W. BRESCIA ?)	1237100	2099800
1130133	6	B	6	21	26	1948	SARDAIGNE	1160100	1574500
1130135	7	B	7	479	493	1980	PIEMONTE (PINEROLO)	997600	2014500
1130146	6	E	4	21	25	1981	MEDITERRANEE (S. SAN REMO)	1085100	1818100
1130163	6	B	6	15	15	1901	PIEMONTE (CUNEO)	1010600	1937400
1130164	6	B	6	34	34	1901	PIEMONTE (TORINO)	1025100	1997800
1130184	6	B	6	50	51	1909	RIVIERA DI PONENTE (DIANO MARINA)	1064300	1896500
1130214	6	C	6	15	19	1918	LOMBARDIE (MILANO)	1140200	2088600
1130359	6	C	6	6	6	1956	PIEMONTE (ONCINO)	984200	1976600
1130362	6	C	6	20	20	1938	CANAVESE (LOCANA)	1000000	2059300
1130560	6	C	6	165	191	1995	RIVIERA DI PONENTE (VINTIMILLE)	1022700	1875700
1140018	6	E	6	21	38	1903	CATALOGNE (ROSAS)	702500	1731900
1140020	6	C	6	20	26	1927	CATALOGNE (MONTSENY)	605200	1640100
1140024	8	B	8	467	654	1923	VAL D'ARAN (VIELLA)	476500	1745200
1140026	6	C	6	71	81	1924	VAL D'ARAN (VIELLA)	473700	1745300
1140027	6	C	6	5	6	1950	CATALOGNE (BOREN)	497000	1741200
1140043	6	C	6	1	7	1914	RIBAGORZA (ERISTE)	447400	1732900
1140044	6,5	C	6,5	13	14	1915	RIBAGORZA (CASTANESA)	451300	1723500
1140046	6	B	6	73	82	1919	VAL D'ARAN (BOHI)	476100	1724800
1140048	7,5	B	7,5	177	208	1923	NAVARRRE (BERDUN)	332500	1742200
1140074	6	B	6	1	4	1914	RIBAGORZA (BENASQUE)	451600	1734600
1140126	6	C	6	50	54	2004	CERDAGNE	585900	1703200
1150008	7	E	7	144	167	1931	MER DU NORD (DOGGER BANK)	539100	3003400
1150020	6,5	C	6,5	258	321	1926	JERSEY	274800	2466800

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- Appendix 2 – SIGMA Project; BRGM Modifications made in the list of characteristics of the earthquakes in the EDF Atlas of isoseismals (SisFrance, May 2015) included in the study

Numevt	JJ1	MM1	An1	Qie	Int. Epc	Xlamb	Ylamb
50057	18	7	1938	C	7	941979	1970891
170079	7	9	1972	A	7	314681	2112820
230010	3	12	1925	C	6	580893	2176141
260120	11	5	1934	B	6	794487	1936798
260122	12	5	1934	A	7	796197	1939099
260126	16	5	1934	A	6	796344	1936273
260127	16	5	1934	C	6	799200	1929000
260142	9	12	1934	C	6	796701	1938838
380070	25	4	1962	A	7,5	854362	2008333
380083	4	12	1963	B	6	855155	2007817
380099	22	11	1979	A	6	863297	1995977
390016	21	6	1971	A	7	860095	2157008
610009	19	11	1927	B	6	386054	2424261
630059	16	10	1913	C	6	624200	2120400
640001	29	2	1980	A	7,5	382844	1791047
640028	2	3	1980	E	5	382100	1788600
640362	13	8	1967	A	8	346924	1793410
640431	6	1	1982	B	6,5	322173	1793548
640462	25	2	1984	B	6	299957	1800807
650244	28	7	1905	C	6,5	418735	1778064
650366	31	1	1950	C	7	424476	1774581
650374	5	4	1952	B	6	416434	1769831
660061	28	11	1920	C	7	608355	1747492
670102	8	10	1952	B	6,5	1012064	2451229
670106	4	9	1959	A	6	995807	2388907
680091	15	7	1980	B	6,5	979810	2314900
730165	27	5	1947	A	6	868742	2088978
740079	17	4	1936	B	7	879002	2122583
840066	10	4	1905	B	7	814043	1922758
880053	29	12	1984	A	6	918083	2351409
1100080	21	12	1965	C	7	828856	2632778
1110017	28	6	1926	B	7	997644	2362773
1110059	22	3	1903	B	6,5	1028448	2468228
1110069	8	2	1933	B	7	1028197	2445472
1110083	7	6	1948	B	7	1043800	2458100

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1120077	26	5	1910	B	6	988812	2282898
1130098	18	1	1972	C	6	1075123	1919219
1130184	27	5	1909	B	6	1061760	1894501

N.B. The March 2, 1980 event (SisFrance, Numevt 640028), an aftershock of the February 29, 1980 earthquake in the Ossau Valley (Pyrenees), has been removed from the EDF list, the epicentral intensity having been downgraded from degree VI to degree V (BRGM, 2015).

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- Appendix 3 – The MSK Intensity Scale

Echelle d'intensité MSK (Medvedev, Sponheuer, Karnik, 1964); version simplifiée

Degré I : Secousse non perceptible mais détectée par les instruments.

Degré II : Secousse à peine perceptible, ressentie par des personnes au repos et aux étages élevés de bâtiments.

Degré III : Secousse faible, ressentie de façon partielle ; balancement des objets suspendus.

Degré IV : Secousse largement ressentie dans et hors les habitations, tremblement des objets.

Degré V : Secousse forte, réveil des dormeurs, chutes d'objets, parfois de légères fissures dans les plâtres.

Degré VI : Frayeur de nombreuses personnes, légers dommages, parfois fissures dans les murs.

Degré VII : Dommages aux constructions, chutes de cheminées, larges lézardes dans les murs de nombreuses habitations.

Degré VIII : Destructions des bâtiments, dégâts massifs de tous les types de constructions.

Degré IX : Dommages généralisés aux constructions, même de bonne qualité, chutes de monuments et de colonnes.

Degré X : Destruction générale des bâtiments.

Degré XI : Catastrophe, toutes les constructions sont détruites.

Degré XII : Changement de paysage, vallées barrées, lits de rivières déplacés.