The M6 1799 Vendée earthquake (France) : a multidisciplinary investigation of the active fault

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Session 2

1. Context of the M6 1799 Vendée intraplate earthquake

The coastal Vendée (France) is located to the south of a main structure of the Armorican Massif, the 600-km-long South Armorican crustal Shear Zone (SASZ) (1) ***[fig. 1]***. This "stable continental region" (2) is affected by a system of dominantly NW-SE trending shear zones and faults, inherited from a long and polyphased tectonic history since Variscan times.

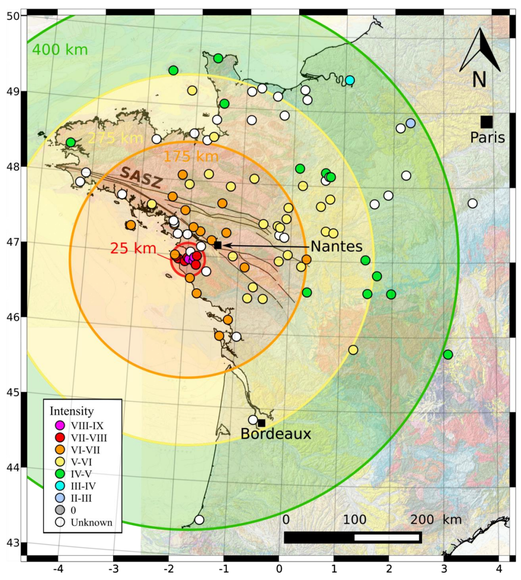


Fig. 1: Macroseismic intensity of the M6 1799 earthquake.

This area currently presents a moderate background seismic activity, but was affected by a significant historical earthquake (magnitude M ~ 6) on the 25th of January 1799. The mesoseismal area probably influenced by strong site effects in the nearby Neogene basin (Marais Breton) is located along an onshore/offshore discontinuity bounding northward the basin, the Machecoul fault (MF) ***[fig. 2]***.

The perception area stretched from Paris to Bordeaux and made this event the largest documented in the western part of France ***[fig. 1]***. Earthquake parameters have been determined from macroseismic data (3) and present a wide variability of magnitude and depth couples : from Mw 5.8 to 6.6 and depth around 20 km (*4 and 5*).

Can we connect this main earthquake to a specific fault ?

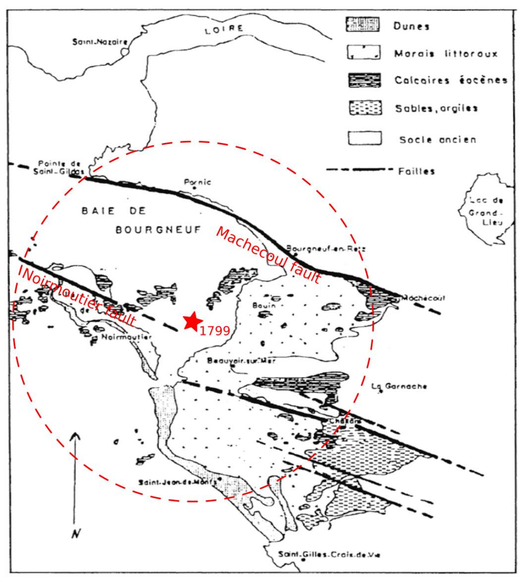


Fig. 2: Main faults of the Marais Breton and Baie de Bourgneuf and epicentral location (3), modified from (6) .

2. An onshore/offshore multidisciplinary approach

Investigation of the epicentral area of the 1799 earthquake to identify active faults potentially responsible for this event and quantify their recent activity combining outcomes from ***[fig. 3]*** :

- **40 km²** of new HR bathymetry (Geoswath interferometric sonar - **RETZ2**) and topography (RGEALTI, IGN) data
  - ➢ Machecoul fault morphology
- **700 km** of new seismic profiles (Sparker source single channel streamer, CHIRP echo sounder – **RETZ1** & **2**)
- Existing onshore drill database (**BSS**, (7)) to stress Neogene depot centers in the Marais Breton.
- Available onshore gravity data (**BGI**, (8)) to calculate Bouguer anomaly and 2D modeling near the MF
  - ➢ basin geometry & sediment infilling.
- **10 stations** temporary seismological experiment (**MACHE**) to complement 4 years of regional catalog
  - ➢ current seismicity

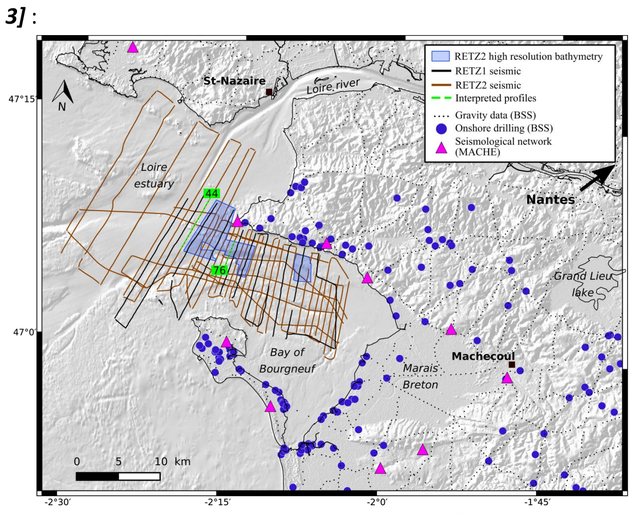


Fig. 3: Location map of all the techniques.

3. Machecoul Fault trace and morphology

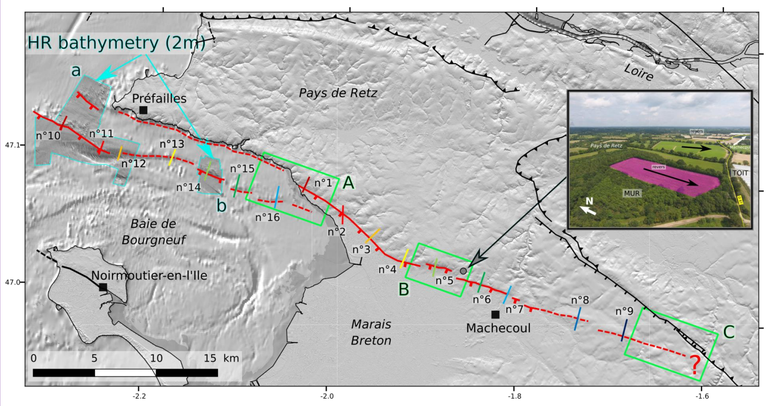


Fig. 4: Onshore-offshore extension of the Machecoul fault signature.

Complex fault system geometry ***[fig. 4 & 6]*** :

- Onshore morphological trace very **tenuous**, disappearing gradually eastward
- Slope break highly **anthropized**
- **Relay structures**
- Offshore signature expressed up to the seafloor, with two parallel faults and uppward flexured HW ***[fig. 6]***
- **Segmentation** : several N110 trending segments ranging from 2.5 to 12.5 km length onshore, and a maximum 7.5 km length offshore
- **SW dipping normal faults system** : no accurate estimation of onshore dip, around 60° dip for the main segment offshore ***[fig. 6]***

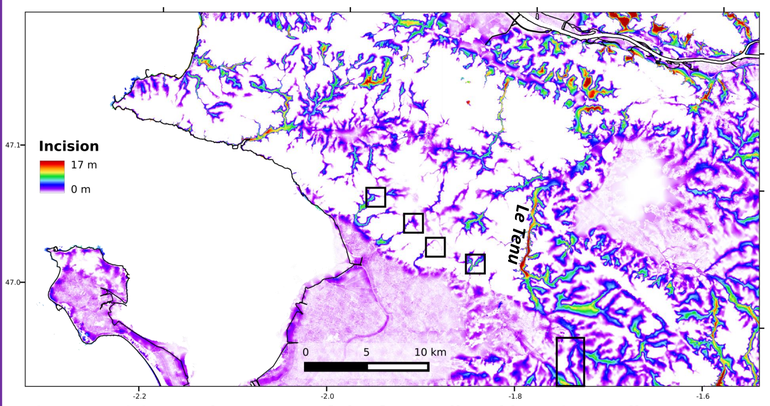


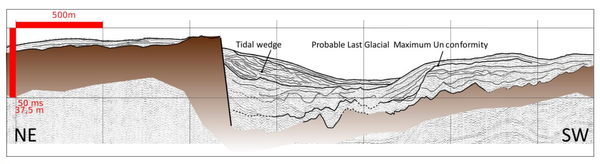
Fig. 5: Incision and captures of the footwall and hanging wall.

Mophometric analysis ***[fig. 5]*** :

- Low incision and residual relief of the FW
  - ➢ **preserved Pliocene paleosurface ?**
- Epigenic river (Le Tenu) : FW **uplift** ?
- 4 minor captures in the FW ***[fig. 5]***
- 1 main capture in the HW ***[fig. 5]***

- 2 km wide offshore sub-basin

This pattern of active fault and basin orientation is observed all along the north French Atlantic coast and could be connected to tectonic activity since early Cenozoic (9).



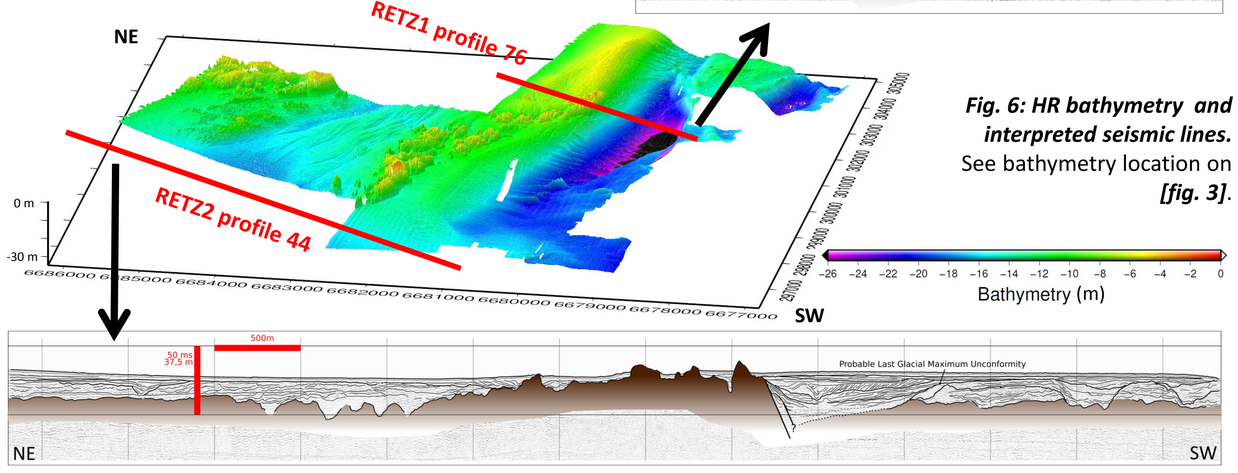
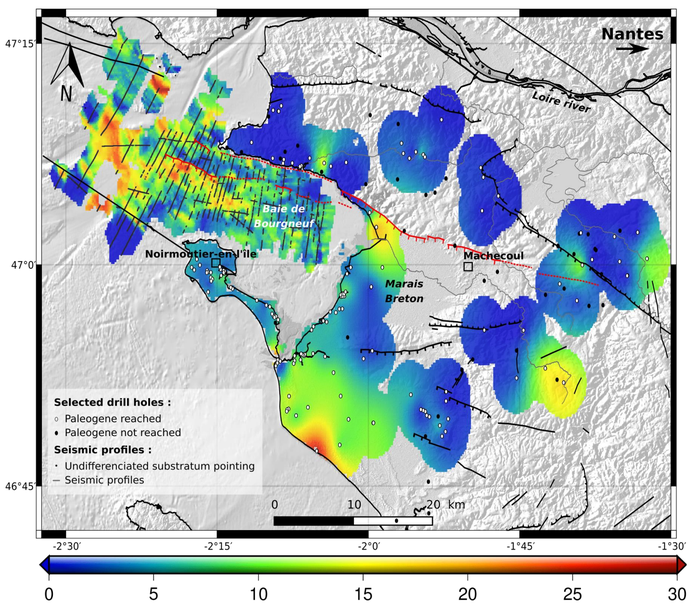


Fig. 6: HR bathymetry and interpreted seismic lines.
See bathymetry location on ***[fig. 3]***.

4. Basin infilling



- 5 mGal negative Bouguer anomaly in the Marais Breton
  - ➢ **Shallow sedimentary basin**

Plio-quaternary depocenter repartition study :

- Poorly representated onshore, widely offshore ***[fig. 7]***
- Thickness gradient both toward the MF and westward along the MF
- No syntectonic deformation figures observed on seismic reflexion profiles ***[fig. 6]***
  - ➢ **Pre-existing topography passively filled during the Neogene or tectonic control of the sedimentation by the MF ?**

Fig. 7: Neogene to Quaternary sedimentary thickness (m).

5. Seismicity

CHALLANS EARTHQUAKE SEQUENCE (2012)

- 27 April 2012 and located in the Marais Breton ***[fig.8]***
- Approximately 30 events in 17 days, with M_c ranging from 0.5 to 2.2, and a range depth of 20-25 km
- Largest event occurred on 28 April 2012
- No focal mechanisms

MACHE NETWORK (2016 – 2017)

- 58 events located in 22 months with a M_L ranging from 0.3 to 3 ***[fig. 8]***
- Diffuse microseismicity
- Majority of the activity in the HW
- Depth of earthquakes between 5 and 22 km, at least (both intermediate and deep seismicity)
- 8 normal and strike-slip focal mechanisms ***[fig. 8]***
- Stress inversion : **NW-SE $\sigma_{Hmax} = \sigma_1$ or σ_2** and well constrained σ_3

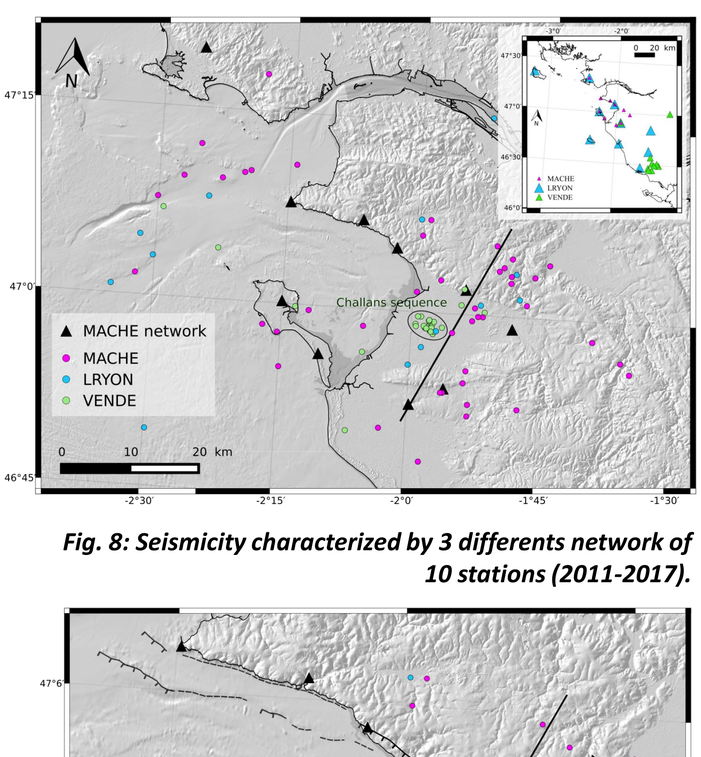


Fig. 8: Seismicity characterized by 3 differents network of 10 stations (2011-2017).

6. Conclusions

- Complex fault geometry : segmentation, relay structures onshore and offshore.
- Apparent tectonic control of Plio-Quaternary depocenters : recent reactivation of an old structure.
- The Machecoul fault is probably an active fault : non-negligeable microseismic activity in Marais Breton.

- **Possible implication of the Machecoul fault in the 1799 event :**
  - ➢ **Noirmoutier fault dips to the SW and is therefore an unlikely source for the 1799 earthquake (6), requiring a macroseismic epicenter several kilometers further South West**
  - ➢ **Foreshock felt only in Machecoul city could indicate a rupture on a fault nearby**
  - ➢ **Machecoul fault segment length compatible with a M6 event**
  - ➢ **Thick seismogenic depth compatible with macroseismic hypocentral estimations (3, 4, 5)**
  - ➢ **MACHE focal solutions compatible with quaternary deformation (10)**

References :
(1) Bitri, A. et al. (2003). C. R. Geosciences. (2) Johnston, A. C. et al. (1994). The earthquakes of stable continental regions. (3) BRGM-EDF-IRSN http://www.sisfrance.net/ (4) Stucchi et al. (2013) Jour. Seism. , 17(2) :523–544 (5) Manchuel, K. et al. (2017). Bull. Earthqu. Eng. (6) Limasset et al. (1992) Ann. Bret. Pays Ouest, vol. 99, 97–116 (7) BRGM http ://infoterre.brgm.fr/page/banque-sol-bss (8) BGI http ://bgi.obs-mip.fr/fr (9) Delanoë Y., 1988. Géol. de la France. (10) Baize, S. et al. (2013). Bull. Soc. Géol. France, 184(3) :225–259.

Aknowledgements : Baltzer A. for bathymetry data exchange of the Loire estuary & Tiberi C. and Plasman M. for their expertise with gravity processing and interpretation.