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► To cite this version:

Caroline Kaub, Laurent Bollinger, Laurent Geoffroy, Julie Perrot, Pascal P. Le Roy, et al.. The M6 1799 Vendée earthquake (France) : a multidisciplinary investigation of the active fault. Rencontres scientifiques et techniques RESIF 2019, Nov 2019, Biarritz, France. hal-02446624

HAL Id: hal-02446624

<https://hal.science/hal-02446624>

Submitted on 21 Jan 2020

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

Session 2



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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.

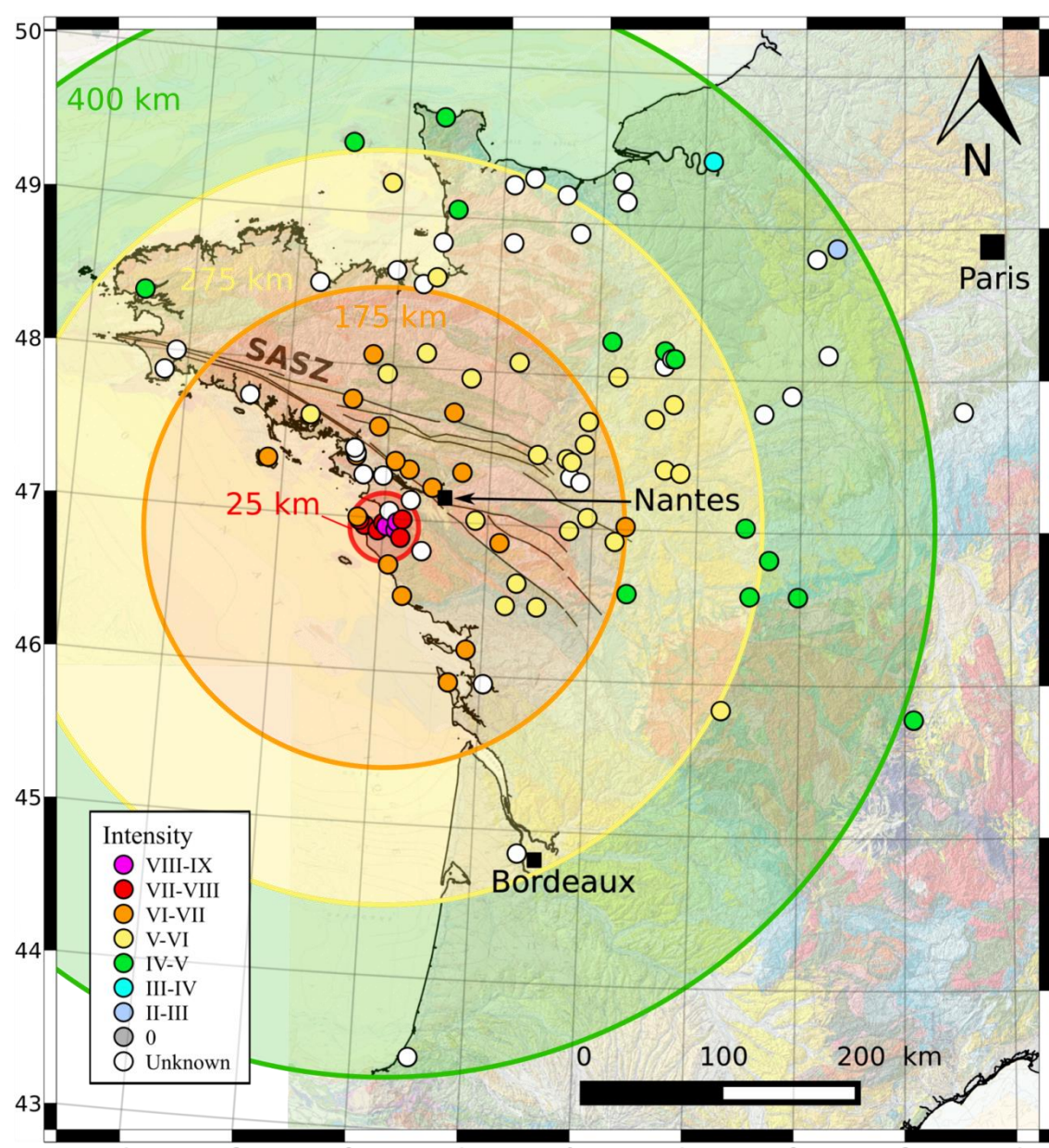


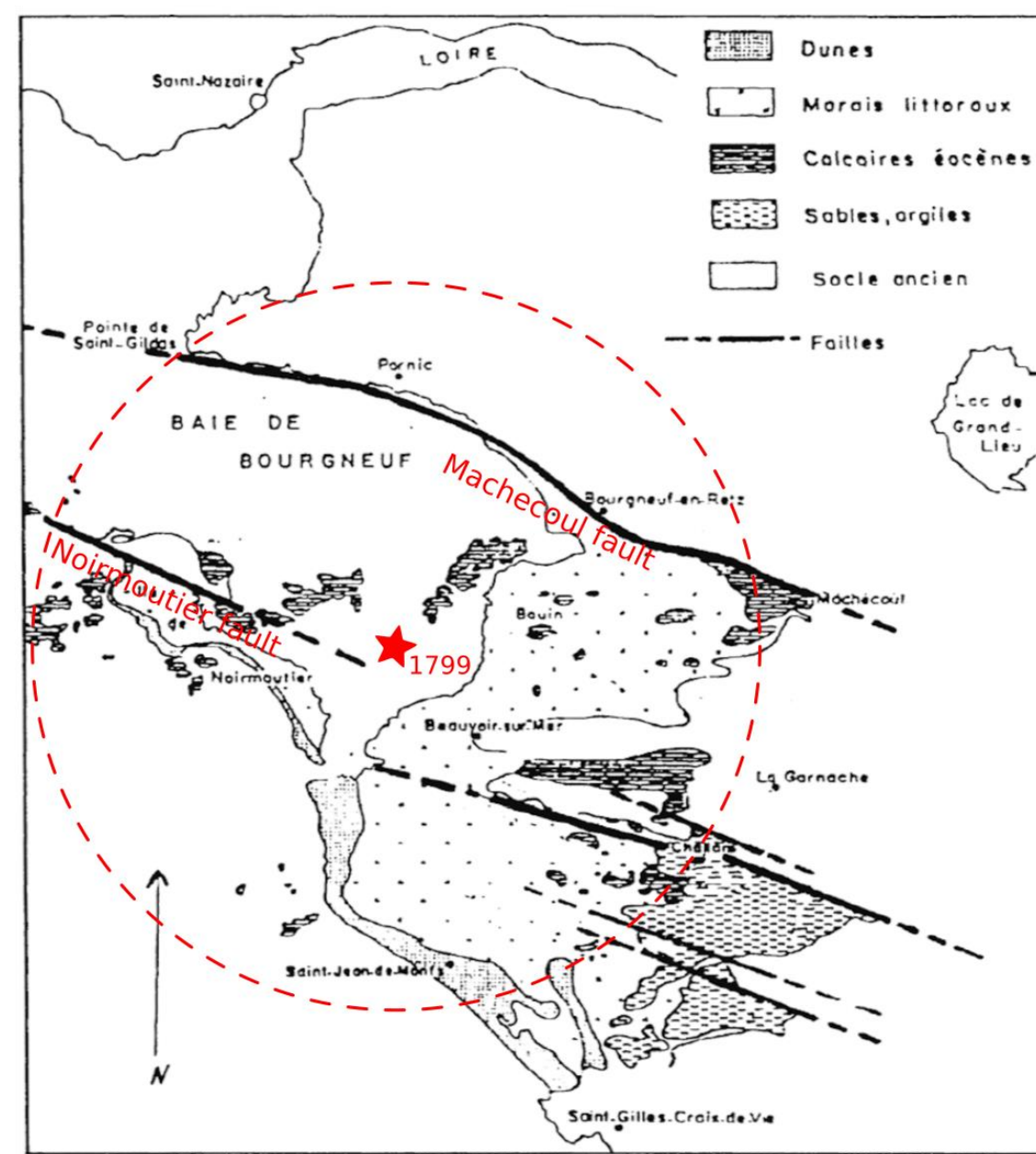
Fig. 1: Macroseismic intensity of the M6 1799 earthquake.

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).

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 mesoseismic 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).



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 - RET22) and topography (RGEALTI, IGN) data
 - Machecoul fault morphology
- 700 km of new seismic profiles (Sparker source single channel streamer, CHIRP echo sounder - RET21 & 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

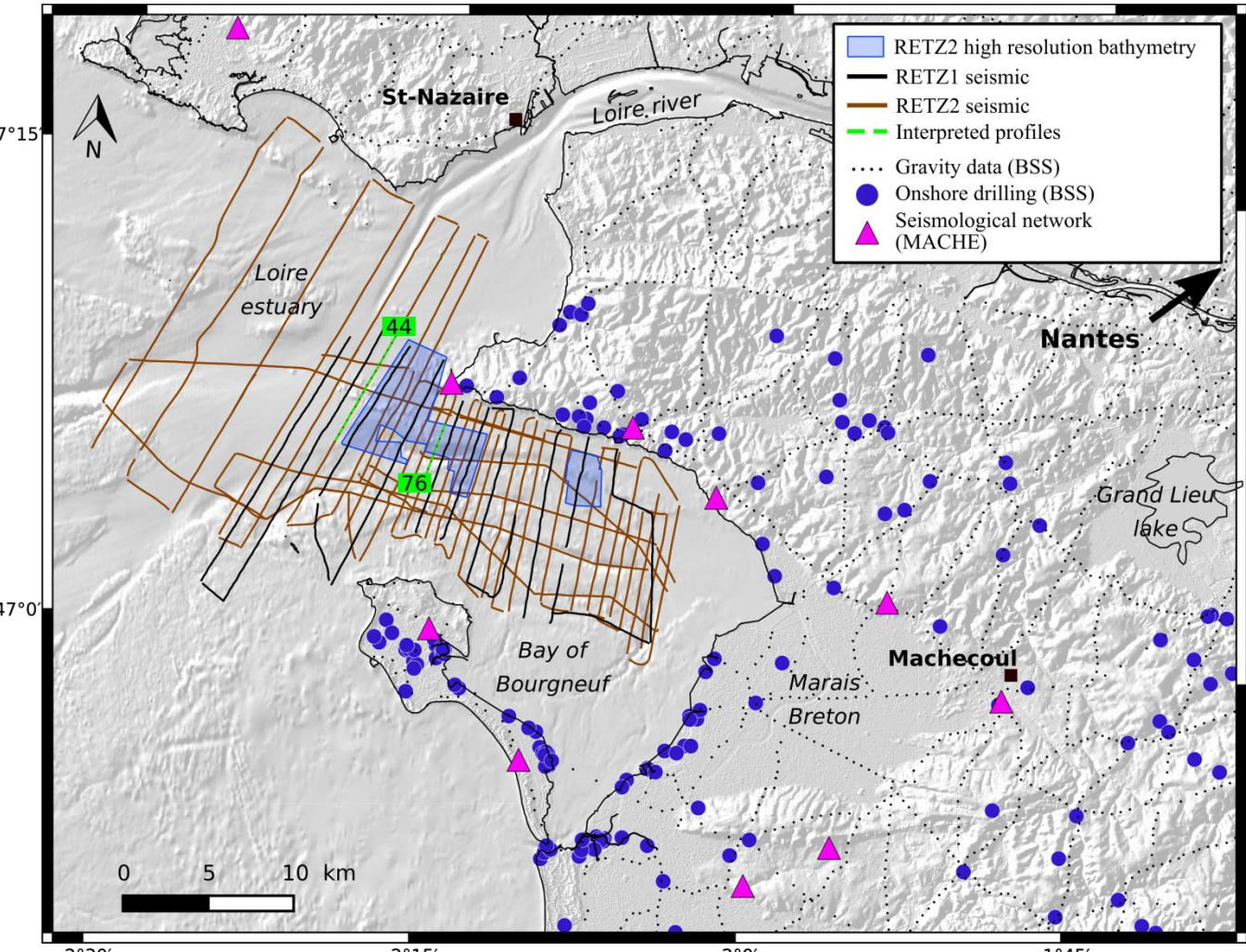
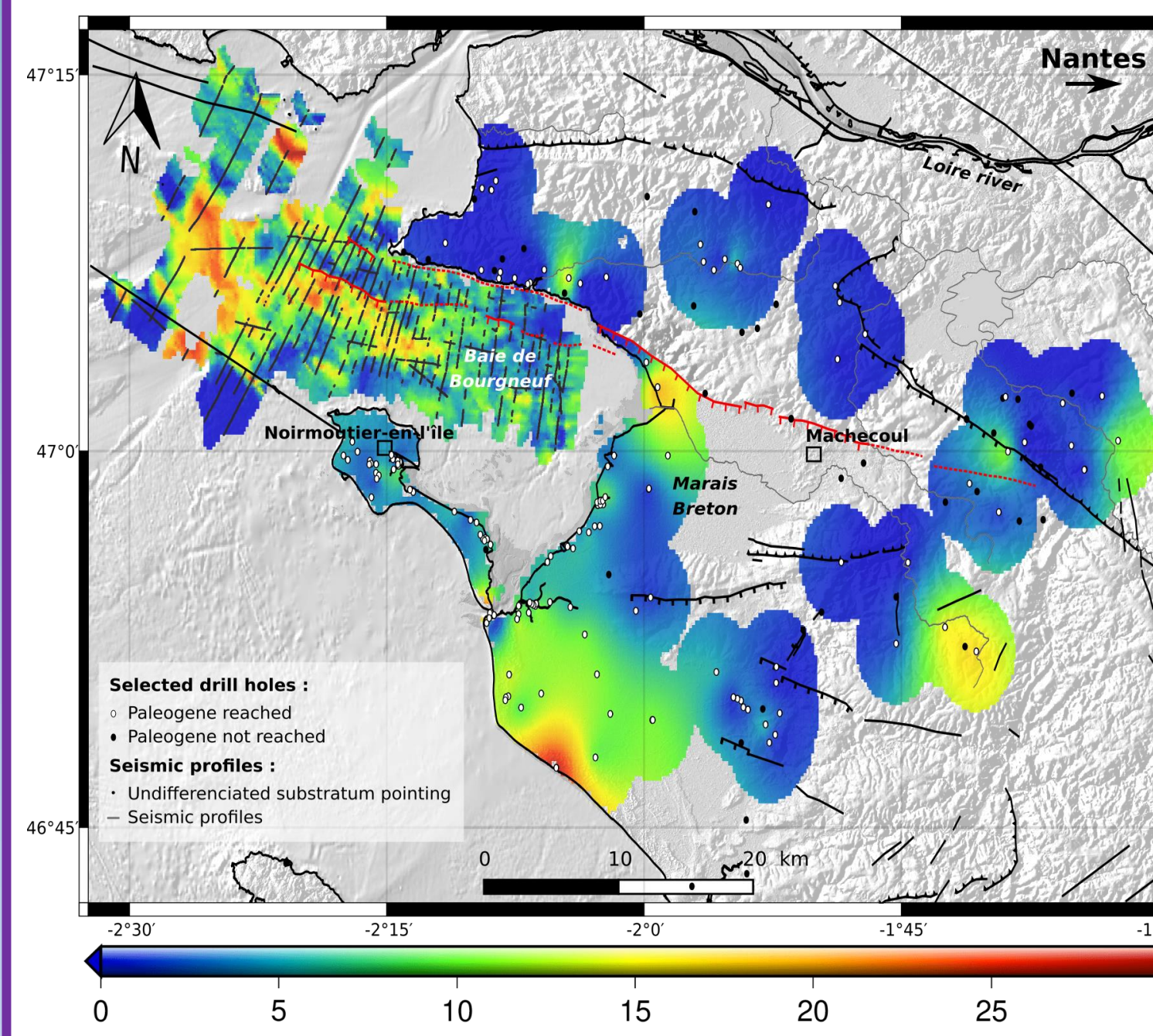


Fig. 3: Location map of all the techniques.

4. Basin infilling



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

Plio-quaternary depocenter repartition study :

- Poorly represented 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).

3. Machecoul Fault trace and morphology

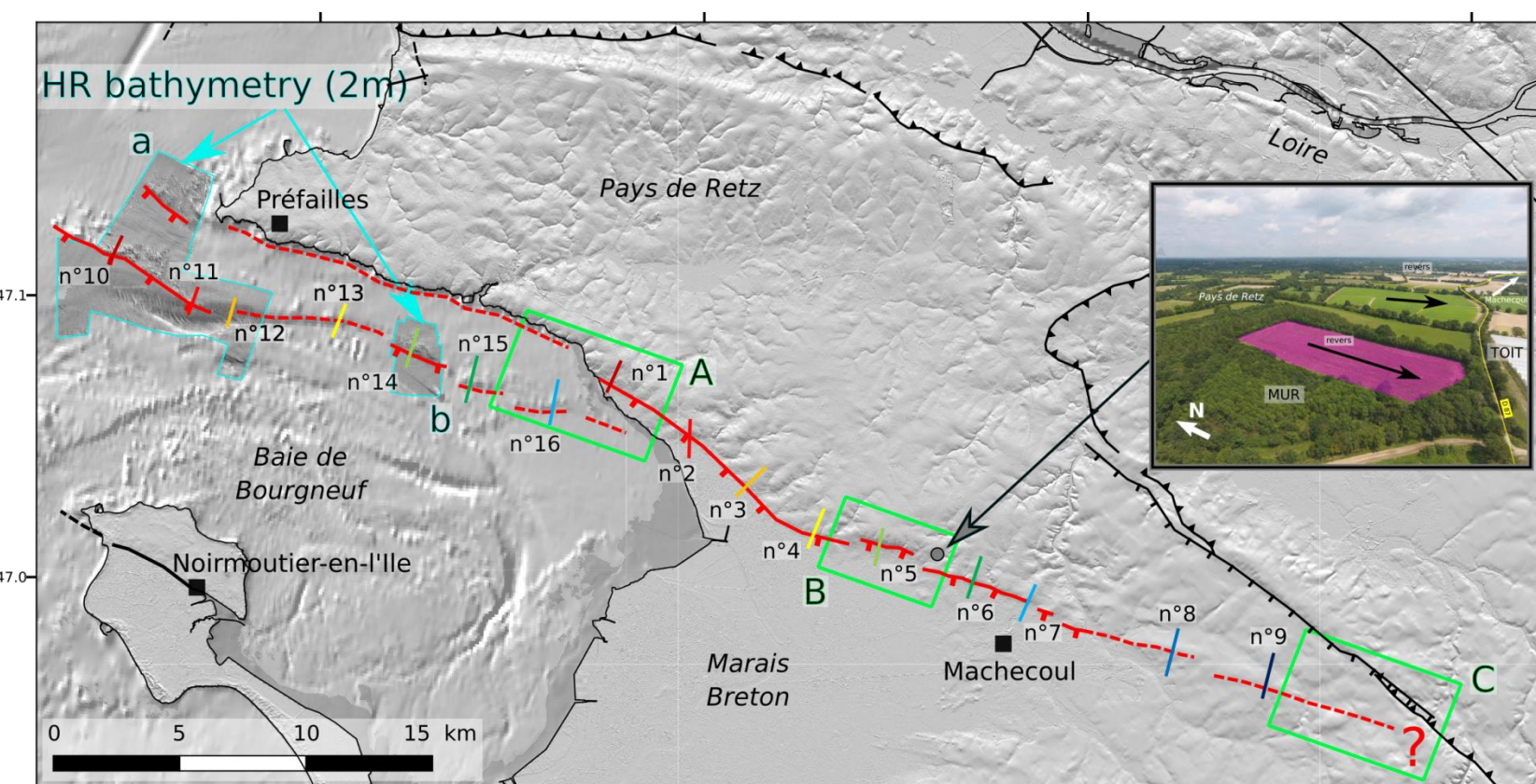


Fig. 4: Onshore-offshore extension of the Machecoul fault signature.

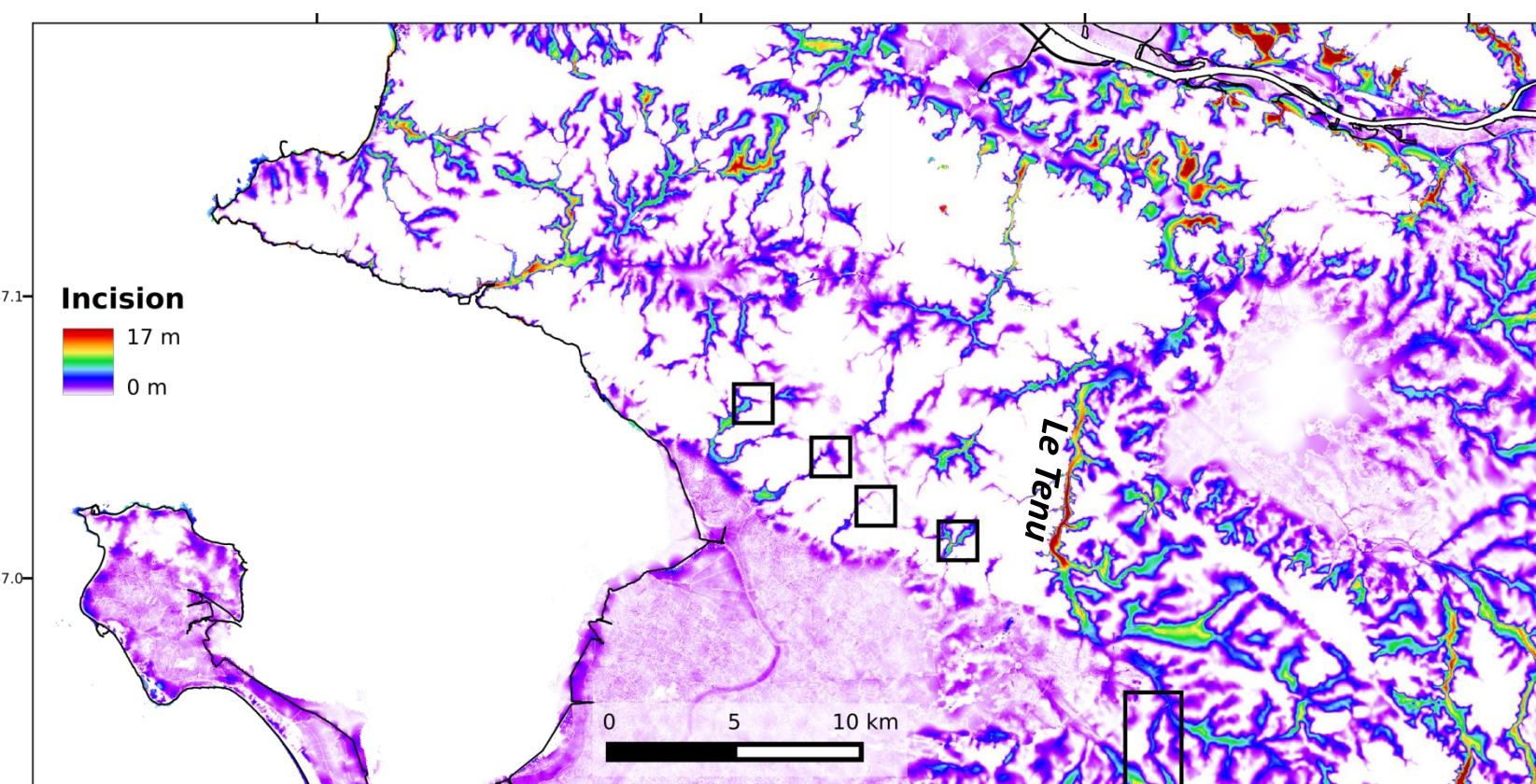


Fig. 5: Incision and captures of the footwall and hanging wall.

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 upward 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]

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).

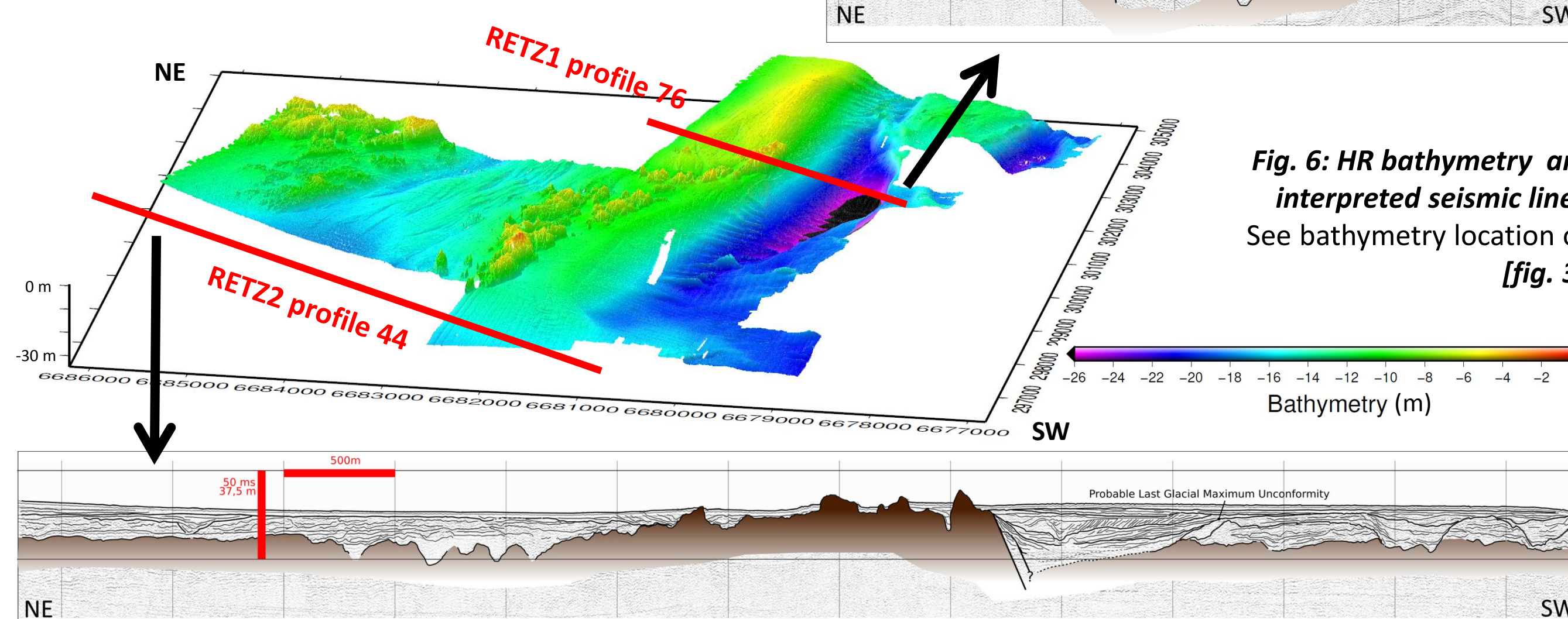


Fig. 6: HR bathymetry and interpreted seismic lines. See bathymetry location on [fig. 3].

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

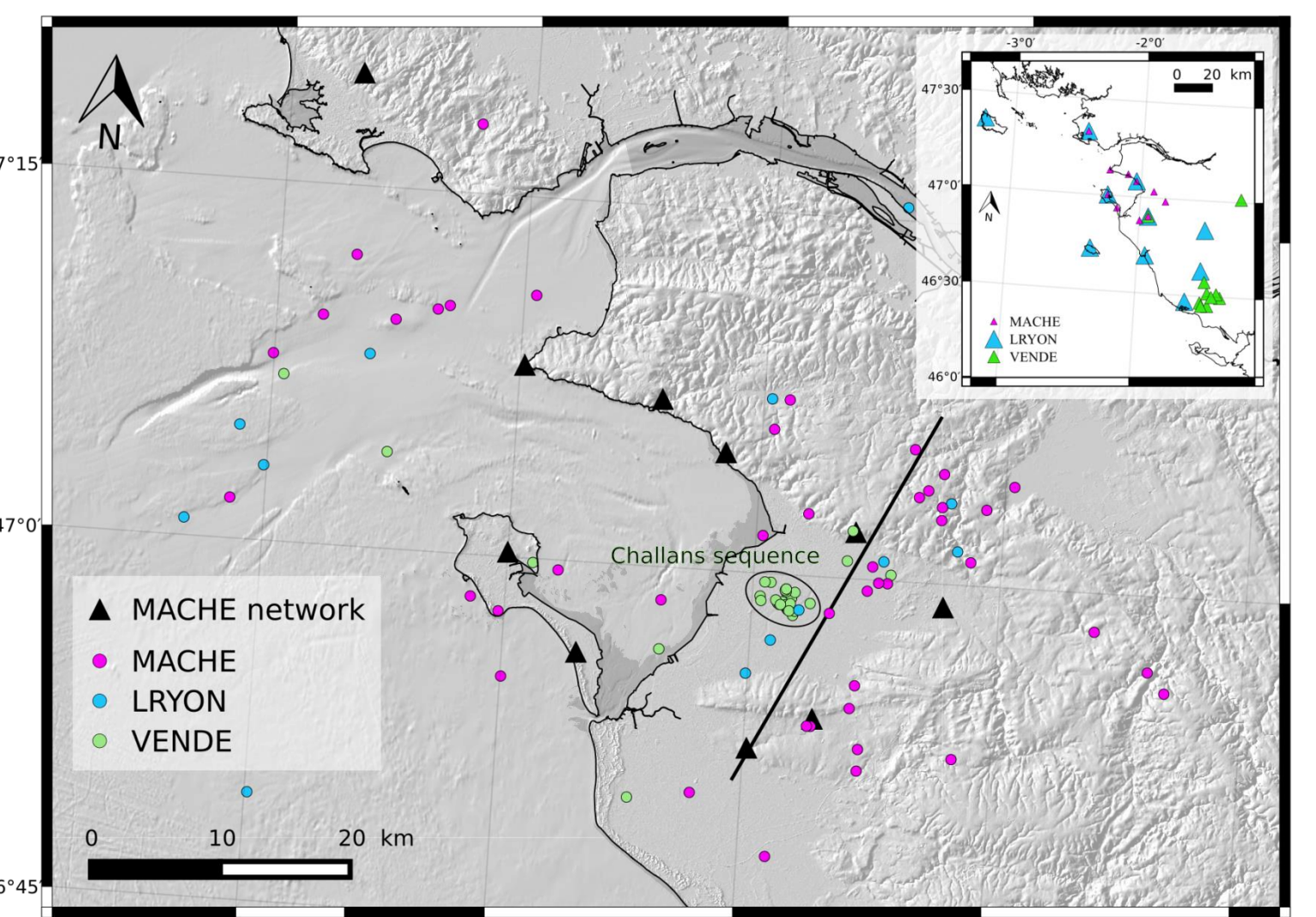
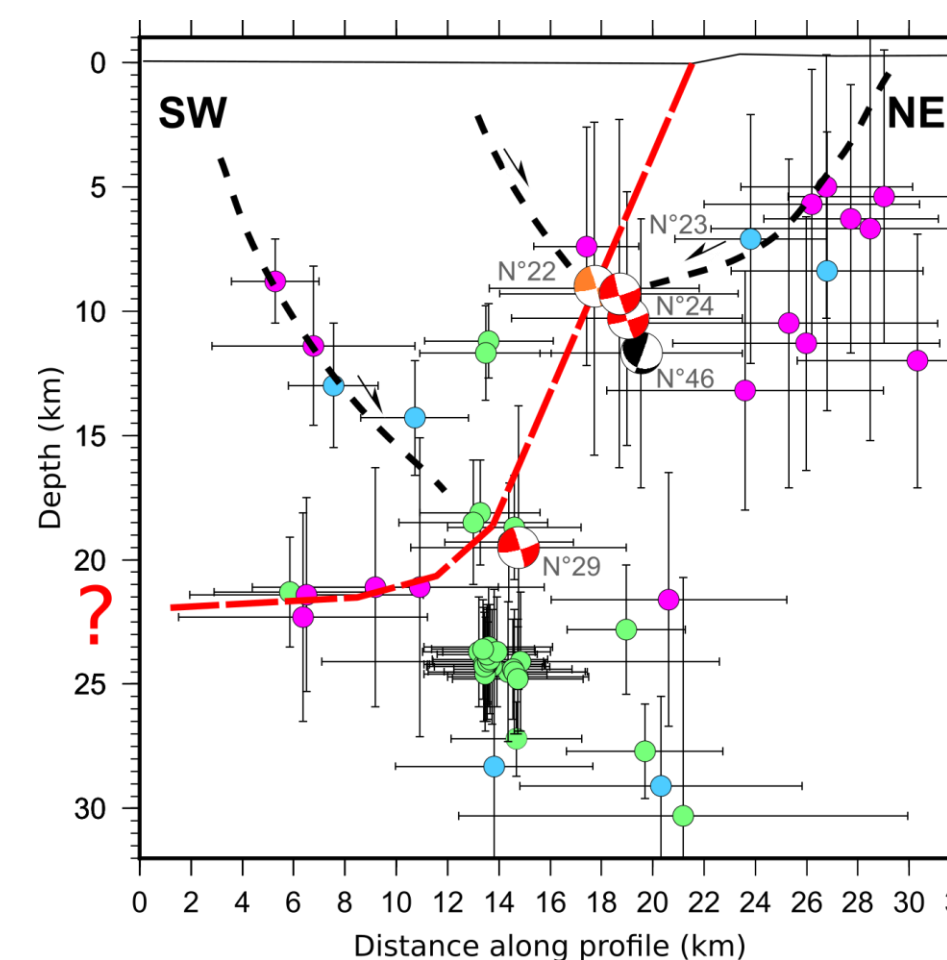


Fig. 8: Seismicity characterized by 3 different network of 10 stations (2011-2017).



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-negligible 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)

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