International Workshop on "Active tectonics and dating"

September 14 – 16, 2021

Hybrid format

(Praz-sur-Arly, France - Belambra Club "L'Alisier" & online)

©Riccardo VASSALLO

RESIF-FACT round table

Paleoseismological investigations of the La Rouvière fault, unexpected source of the 11-11-2019, Mw4.9 Le Teil surface rupturing earthquake (Cévennes fault system, France)

J-F Ritz [1], S. Baize [2], M. Ferry [1], E. Hannouz [3], M. Riesner [4,7], L. Bollinger [4], C. Larroque [5], L. Audin [3], K. Manchuel [6], M. Rizza [7], H. Jomard [2], C. Sue [3], P. Arroucau [6], J. Billant [5]

(1) Géosciences Montpellier
(2) IRSN, Fontenay-aux-Roses
(3) ISTerre , Grenoble
(4) CEA, Bruyeres le Chatel
(5) Géoazur, Nice–Sophia-Antipolis
(6) EDF, Aix-en-Provence
(7) CEREGE, Aix-en-Provence

The 11-11-2019 Le Teil earthquake (Mw4.9), located in the Rhône river valley occurred along the La Rouvière fault (LRF) within the NE termination of the Cévennes faults system (CFS). This very shallow moderate magnitude and reverse-faulting event inverted an Oligocene normal fault which was not assessed to be potentially active, causing surface rupture and strong ground shaking. Its morphology shows no evidence of cumulative reverse faulting during the Quaternary. These observations lead to the question whether the fault was reactivated for the first time since the Oligocene during the Teil earthquake, or if it had broken the surface before, during the Quaternary period, but could not be detected.

To answer these questions, we launched paleoseismic investigations along the LRF to analyze and characterize evidences of paleo-ruptures in Quaternary deposits. 11 trenches were dug along the section that broke in 2019. Five trenches yielded favorable Quaternary deposits (slope colluvium and eolian deposits) lying against the ancient LRF normal fault mirror carved in the Barremian limestones to document past-coseismic deformations. The radiocarbon and OSL dates (from “bulks” collected into colluvium clayey-silty matrices) within 2 trenches, LR1 and LR4, located in the central and southern parts of the LRF, respectively, suggest that at least one event prior 2019, and maybe, more occurred in the past 17 Ka. The radiocarbon dates within trench LR6, located in the northern part of the 2019 rupture suggests that a penultimate event occurred between the end of the 15th century and the beginning of the 17th century with kinematic characteristics similar to the 2019 event (sense of movement, amount of displacement). The fact that these events are not preserved in the morphology is explained by the small amount of displacement and a long return period, consistent with the low strain rate measured by GPS in this region ($0.5 – 1.0 \times 10^{-9}$ yr^{-1}). Our study shows that it is therefore fundamental to carry out more detailed paleoseismological investigations in metropolitan France, especially along ancient faults favorably oriented with respect to the present stress field. Those are already planned in the next coming months along other segments of the CFS.

. .

Workshop "Active Tectonics & Dating"

FACT in Northern Alps: Questions and approaches

Laurence Audin[1], Riccardo Vassallo[1], et al. [2]

[1]*Isterre*

[2]*Alpes du Nord FACT group*

☒ Talk
☐ Poster

The Alpine region is one of the most seismically active areas in France (Drouet et al., 2020). If the actual horizontal velocity deduced from GPS is very low in the western Alps (Nocquet et al., 2016), the exhumation of about 2 mm/yr in the study area points out the active tectonic context (Sternai et al., 2019). For example, the Belledonne Massif is today affected by recurrent active but deep deformation, demonstrated by historical seismicity (Wilhelm et al., 2016), instrumental data (Thouvenot et al., 2003) and geodetic data (Walpersdorf et al., 2015). However, as elsewhere in the Alps, most of the seismicity is a background seismic activity highlighted by local and recurrent swarms. Compared to others swarms in the French Alps, the Maurienne unprecedented swarm (Gueguen et al., 2021) is similar to Vallorcine swarm (Cara et al., 2017) and to the Ubaye swarm (De Barros et al., 2019) in terms of tectonic and geological position: somehow linked with the reactivated Hercynian and/or Alpine structures and triggered in the crystalline basement. In parallel, in terms of tectonic geomorphology in the the Alps, kilometers scale recent scarps with normal motion are linked with gravitational movement and identified as gravitational sackungs (Hippolyte et al., 2006, Le Roux et al., 2009). They must be triggered by a debuttressing process controlled by glacial retreat and gravity but are distinct from “real” active tectonic features. Anyhow, in order to discuss the tectonic activity, the slip rates have to be quantified and few dating studies have been carried out to estimate those in the northern Alps yet. In both cases of geomorphic evidences or seismic evidences of active faulting in our region, the same major key issue remain to be addressed by both scientists and local authorities for risk management: What fault is activated, re activated? What may be the maximum magnitude on these structures? What may be the expected consequences on infrastructures in case of localized surface ruptures? What is the best dating methods to apply? Are paeloseismic studies worth for such post glacial features? These questions also arise in post-L’Aquila or Le Teil contexts where seismic hazard assessment in slow deforming regions is demonstrated to be a new challenge.

Keywords : swarms and scarps, active faults, alps, seismic hazards

Workshop "Active Tectonics & Dating"

The potentially active Marche fault in NW Massif Central : preliminary field observations, topography and drainage characteristics (Region 6 working group of the FACT axis - ATS-Resif)

Y. Gaudemer[1], Y. Klinger[1], R. Lacassin[1], E. d'Acremont[2], A. Rabaute[2]

[1] IPGP - 1 rue Jussieu - 75238 Paris Cedex 05
[2] ISTEP - 4 place Jussieu - 75252 Paris Cedex 05

☐ Talk
☒ Poster

In the framework of the « Failles ACTives » (FACT) axis of the Action Transverse Sismicité of the consortium RESIF (https://www.resif.fr/actions/action-transverse-sismicite/), the R6 region is devoted to the study of potential actives faults in central France (Bassin de Paris and its surroundings). Among interesting targets, the Marche fault, in the NW corner of Massif Central, is probably inherited from the Variscan (upper Palaeozoic) orogeny. Its present morphology is that of a ≈ 100 km-long, roughly E-W trending scarp. In its eastern two thirds, from the village of Colondannes to the Montluçon Basin, it appears on average resolution (25-30 m) DEMs as a rather sharp, continuous feature. This, combined with low-to-moderate seismicity has led to classify it as a potentially active fault.

On higher resolution (5 m) DEMs, and in the field however, the fault has a more subdued, discontinuous morphology, with scarp slopes mostly gentler than 10°. Some rivers crossing the fault exhibit knickpoints in their longitudinal profile, but these are upstream from the fault, while the river bed itself is not clearly vertically offset by the fault. Besides, the local landscape is clearly marked by human activity, mostly agriculture, centuries of which may have obscured any sign of tectonic activity.

The Marche fault thus bears little evidence of present-day faulting. The key to assessing its level of activity is probably paleoseismology in trenches dug across the fault where it cuts through Quaternary deposits. This requires first to accurately locate the fault trace, by means of surface geophysics, e.g. high-resolution seismic reflection.

Workshop "Active Tectonics & Dating"

Activities of the RESIF-ATS-FACT group for Northern France region R7 to improve the knowledge on potential active faults

GRAVELEAU Fabien[1], Pierre ANTOINE[2], Hervé JOMARD[3], Thierry CAMELBEECK[4], Thomas LECOCQ[4], Kevin MANCHUEL[5], AVERBUCH Olivier[1], Aurore LAURENT[1], F., MEILLIEZ[1], Laurent BECCALETTO[6], CHANIER Frank[1], WATREMEZ Louise[1], GAULLIER Virginie[1], LAURENCIN Muriel[1], Anne DUPERRET[7], Sara VANDYCKE[8], Pierre ARROUCAU[5], Françoise BERGERAT[9], Jean-Luc LOCHT[2]

[1] *Univ. Lille, CNRS, Univ. Littoral Côte d'Opale, UMR 8187 - LOG - Laboratoire d'Océanologie et de Géosciences, 59000 Lille, France,*
[2] *UMR 8591 - LGP - Laboratoire de Géographie Physique, 92195 Meudon, France,*
[3] *IRSN, Institute of Radiological protection and Nuclear Safety, BP17, 92262 Fontenay-aux-roses, France,*
[4] *Royal Observatory of Belgium, Seismology, Avenue Circulaire 3, 1180 Uccle, Belgium,*
[5] *EDF-DIPNN-CEIDRE-TEGG, 905 avenue du Camp de Menthe, 13097 Aix-en-Provence Cedex 02, France,*
[6] *BRGM, Orléans, France,*
[7] *UMR 6294 CNRS Laboratoire Ondes et Milieux Complexes, Université Le Havre - Normandie, 53 rue de Prony, 76058 Le Havre cedex, France,*
[8] *Génie Minier, Faculté Polytechnique de Mons, 9 rue de Houdain, 7000 Mons, Belgium,*
[9] *UMR 7193, Institut des Sciences de la Terre de Paris (ISTeP), Sorbonne Université-CNRS, 4 place Jussieu, 75005 Paris, France.*

☐ Talk
☒ Poster

Northern France is a moderately active seismotectonic region in which several potential active structures are identified onshore (*e.g.,* along the Artois hills) and offshore (*e.g.,* along Dover Strait). In the framework of the "*Faille Actives*" axis (FACT) of the *Action Transverse Sismicité* (ATS) of the French Consortium Resif, a group of academics from Universities, CNRS Laboratories, Observatories and industrial companies from France and Belgium was created in 2019 to critically assess, update and complete the potentially active fault database (BDFA) compiled by the IRSN (Jomard *et al.*, 2017). The group met twice in mid-October 2019 and 2020, and started to share ideas and informations about published works, datasets, field observations, etc. One of the strength of the group is its interdisciplinarity (geologists, geophysicists, geomorphologists, quaternarists), on land and at sea, and its cross-border partnership.

During 2020 meeting, a small online workshop has been organized to allow participants to present their past and present research works in the Hauts-de-France region (North of France). Presentations concerned not only the shallow geology and landscape analyses but also recent researches about deep basement inherited structures that are potentially involved in the active tectonics processes. Northern France geology is indeed governed primarily by a Meso-Cenozoic sedimentary cover overlying unconformably a deep basement which has been severely deformed (faulted and folded) during the Variscan orogeny and reactivated during the Pyrenean-Alpine orogeny. Understanding the relationship between the ancient basement structures and recent surface structures is an important target to understand and characterize the potential active faults in the region.

In the present contribution, we present synthetic results (field observations, topographic/bathymetric landforms and geophysical results) about seismotectonics and structural investigations across the Strait of Dover, the Artois Hills, the Bray region, the Mélantois area and the Nord - Pas-de-Calais coal basin.

Keywords : Northern France, Seismic Hazard, Active faults,

Workshop "Active Tectonics & Dating"

The Maladeta-Bedous Fault System in the Pyrenees

Pierre Lacan[1]; Maria Ortuño[2]; Charlotte Fillon[3]; Marc Viaplana[4]

[1] Centro de Geociencias, Universidad Nacional Autónoma de México, Blvd. Juriquilla, 3001, 76230, Juriquilla, Querétaro, México
[2] RISKNAT group, Geomodels institute, Earth and Ocean Dynamics Department, Universitat de Barcelona, C/ Martí i Franquès s/n, 08028, Barcelona, Spain.
[3]Total EP, R&D Nexts, Avenue Larribau, 64018 Pau, France.
[4]Group of Dynamics of the Lithosphere (GDL), Institute of Earth Sciences Jaume Almera (ICTJA-CSIC) C/ Lluís Solé i Sabarís s/n, 08028 Barcelona, Spain.

☐ Talk
☒ Poster

The Maladeta-Bedous Fault System is a 150 km long structures extending between the Aspe valley in the Atlantic Pyrenees and the Aran valley in Catalonia and accommodating late Miocene to present vertical movements in the high range of the Pyrenees. Individual faults within the system were identified through geomorphological evidence such as the displacement of high-elevation low-relief surfaces, knickpoint and differential incision of valleys and ridges. Their coincidence with the main Pyrenean thrusts led to propose that they correspond to a single system that results from the inversion of major alpine thrusts. The model matches well with the location and kinematics of instrumental seismicity as with the location of some historical earthquakes. The characterization of the Maladeta-Bedous System has benefited from the analysis of digital elevation models with 25 m of resolution combined with field observations. Significant uplift along the axial zone is also attested in Miocene times by paleontological data, low-temperature thermochronological data and by InSAR mapping. These latter results take advantage of the recent advances in mapping vertical motions by the emergence of satellite imaging with Sentinel-1 fleet deployment where no GPS data is available. They resolve mm-scale differential vertical displacement between the High Chain and the Northern Pyrenean Zone located at the level of these faults. The origin of these vertical displacements is still under discussion, but some processes have been suggested as faulting accommodating differential erosional isostatic rebound, removal of lithospheric mantle.

A better characterization of the quaternary activity of the Maladeta-Bedous fault System will require an effort in detecting offsets of more recent landforms and sediments. The analysis of high-resolution LiDAR-derived earth Digital elevation models, progressively available in the Pyrenees, is regarded as a promising tool to locate young sediments along the trace of the fault system, allowing for trenching analysis and the identification of fault bedrock scarps suitable for exposure dating. Additionally, the study of the lacustrine record preserved in the neighboring lakes could contribute to understand the recurrence of moderate-large earthquakes in the area.

Keywords : Pyrenees, Active faulting, neotectonic, Maladeta-Bedous Fault System

Workshop "Active Tectonics & Dating"

Active tectonic in the SE France (region n°3) in the framework of the FACT axis (RESIF)

Christophe Larroque, Frédérique Leclerc, Jérémy Billant, Bruno Scalabrino

Géoazur Université Côte d'Azur-CNRS, France

☐ Talk
☒ Poster

Within the framework of the "Failles ACTives" axis (FACT) of the Action Transverse Sismicité of the consortium RESIF, the Region 3 working group (Geoazur, IsTerre, IRSN) is in charge of studying and characterizing the active structures in the area of the Southwestern Alps, the Ligurian Sea and Corsica.

Priority has been given to the investigation of submarine escarpments identified as being related to the Ligurian fault system at the origin of major historical earthquakes such as that of 23 February 1887. We performed a dive using the Hybrid-ROV Ariane (Ifremer) operated from the R/V L'Europe, during the scientific cruise TELEPRESENCE (PIs: O. Soubigou and F. Leclerc) along the Marcel fault scarp, belonging to the western part of the Ligurian faults system. The HROV dive lasted 3h at a mean depth of 2280 m b.s.l., and was recorded by two cameras. It proceeded at 1.5-2 m above the seafloor and zigzagging across the fault scarp. Overall, the seafloor is covered by hemipelagic sediments. The target scarp is hardly visible but revealed by a 15-20 m bathymetric smooth change recorded by the HROV. However, we did not identify any morphology of tectonic origin along this scarp. The only noticeable features are submetric form, probably of biologic origin. Ce travail confirme la difficulté des analyses de la tectonique active en mer et en particulier le problème du passage de l'échelle des données géophysiques à celle du terrain. We have planned a new diving campaign in november 2021 off the coast of Imperia on the eastern part of the Ligurian faults system where deformation trhough quaternary deposits seems is better expressed.

Other targets are also being worked on: (i) in the lower Var valley, northeast of Nice, with the reanalysis of Pleistocene terraces and fractures associated with the Donareo fault as well as (ii) recent structures in the Ubaye and Stura valleys that could be related to the Barcelonnette seismicity swarms.

Workshop "Active Tectonics & Dating"

Perspectives in studying active faults in metropolitan France: looking for markers of activity of major inherited structures in the Armorican Massif (R8 FACT region)

Clément Perrin[1], Julie Perrot[2] and the members of the R8 FACT region

[1] Laboratoire de Planétologie et Géodynamique, UMR6112, Observatoire des Sciences de l'Univers de Nantes Atlantique, UMS3281, Université de Nantes, CNRS, 2 rue de la Houssinière - BP 92208, 44322 Nantes Cedex 3, France
[2] Geosciences Océan, UMR 6538, IUEM-UBO, Place Nicolas Copernic, F-29280 Plouzané, France.

☐ Talk
☒ Poster

The northwestern part of France is characterized by a various set of major faults and shear zones, mostly inherited from past Protero-Paleozoic orogens (Cadomian, Variscan), and extensional (Meso-Cenozoic) and compressional (Cenozoic) events. Currently the region is located far from plate tectonic boundaries and is submitted to very low strain rates. Still, a fairly high activity of moderate size instrumental earthquakes (M~3-4) has been recorded in the region, which has also experienced several large historical earthquakes in the past. Among them, the large M6 1799 Vendée earthquake has been recently revisited by recent studies, raising the question of the potential activity of the Machecoul fault as a source of the earthquake.
Kaub et al., (2021) carried out a multidisciplinary study in the epicentral region, onshore and offshore, and better characterized the lateral segmentation of the Machecoul fault, basins geometry and sediment infilling in the Baie of Bourgneuf, and inferred the Neogene and Quaternary sediment thickness. The offshore Plio-Quaternary units infill paleovalleys and seem to increase in thickness westward. The deposition of these units appears to be controlled by the southern escarpment of the Machecoul Fault. The planar contact between the Plio-Quaternary sediments and the basement along the fault trace as well as the thickening of these sedimentary units near this contact suggests tectonic control rather than erosion. Onshore, the Machecoul fault trace is tenuous and gradually fading out eastwards. Even if the new observations suggest a recent activity of the Machecoul fault bounding the basin to the North, a Holocene activity cannot be firmly demonstrated. Upcoming studies, involving subsurface geophysics, neotectonics and paleo-seismological survey will be performed to eventually demonstrate the relation between the fault and the earthquake.

References

Kaub, C., Geoffroy, L., Bollinger, L., Perrot, J., Le Roy, P., Authemayou, C., 2021. Is the Machecoul fault the source of the ~M6 1799 Vendée earthquake (France)?. Geophys. J. Int. 225 (3), 2035–2059, doi:10.1093/gji/ggab076

Workshop "Active Tectonics & Dating"

Morphotectonics (high resolution / LIDAR) and paleoseismology of the Trevaresse Fault (FACT axis Region 2 working group)

Rizza Magali[1], Bollinger Laurent[2], Manzanares Pablo[1,2], Klinger Yann[3], Bellier Olivier[1], Siame Lionel[1], Quesnel Yoann[1], Uehara Minoru[1], Fleury Jules[1], Rinalducci Véronique[1], Baize Stéphane[4].

[1] *Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France*
[2] *CEA, DAM, DIF, F-91297 Arpajon, France.*
[3] *Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Université Paris Diderot, CNRS, Paris, France.*
[4] *Institut de Radioprotection et Sûreté Nucléaire, Fontenay-aux-Roses, France*

☐ Talk
☒ Poster

This research project is part of the "Active faults - France" (FACT) action carried out by the RESIF consortium, one of whose objectives is to better understand seismotectonics and processes that control active deformation and seismic hazard in metropolitan France. In addition, the FACT action also aims to improve the temporal resolution of past earthquakes by developing paleoseismological investigations (trenches in Quaternary deposits), involving also sub-surface geophysical methods to locate potentially active structures under Quaternary sedimentary deposits. Within the framework of the RESIF consortium, we wish to re-launch work in Provence, which is one of the target areas of the FACT action and for which CEREGE is the regional coordinator (region 2).

One of the proposed axes of our research project is to continue morphotectonic analyses in Provence by using new tools of very high resolution topography such as LiDAR imagery or SfM photogrammetry by drone. We first focus on the Trévaresse fault, whose historical reactivation was responsible for the Lambesc earthquake in 1909, one of the most destructive shaking in recent history in France, with strong damage to the villages. One of the advantages of this study area is that the morphology, surface rupture and fault segmentation associated with the activity of the geological structures have been partly evidenced by studies in the 2000s (Chardon & Bellier., 2003). Moreover, the surface rupture of the 1909 earthquake was identified in an open trench (Chardon et al., 2005) and the quaternary sediments excavated there were affected by multiple earthquakes. However, none of the formations in this trench have been dated and we therefore have no knowledge of the return times on this fault system.

Our objective is to refine first the mapping of quaternary morphological surfaces and tectonic scarps. In 2021, our work focused on the morphological expression of active fault segments and geomorphological anomalies identified by exploiting high-resolution (1 meter) topography surveyed with airborne LiDAR by a team from the University of Caen (Thomas, 2018). These data have been complemented by field observations and new structural geology data and some geophysical surveys. In addition, photogrammetric surveys by drones were performed to complete very high-resolution topographic data (<10cm/pixel). In the near future (2022), we would like to open 1 to 2 paleoseismic trenches to confirm or not the presence of surface ruptures on other fault segments of the Trevaresse linked to the past occurrence of major earthquakes. If the potential sites seem too limited, we will reopen a trench in the area already excavated by Chardon et al. (2005) to date the affected deposits and eventually document more evidence of past earthquakes.

Finally, this work aims at dating Quaternary morphological markers and paleoseismic events identified in the trenches. This step will be carried out by means of appropriate dating methods in the sedimentological context of the alluvial terraces of the Durance, by using the cosmogenic isotope technique (36Cl), and optical luminescence (OSL), these two methods being widely used at CEREGE.

Keywords : Active faults, Provence, LiDAR, paleoseismology