



HAL
open science

Post-publication careers: ground ruptured, community united

Stéphane Baize, Jean-François Ritz

► **To cite this version:**

Stéphane Baize, Jean-François Ritz. Post-publication careers: ground ruptured, community united. Communications Earth & Environment, 2022, 3 (61), 10.1038/s43247-022-00392-y . insu-03661240

HAL Id: insu-03661240

<https://insu.hal.science/insu-03661240>

Submitted on 6 May 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Post-publication careers: ground ruptured, community united

Stéphane Baize ¹✉ & Jean-François Ritz ²

When an earthquake in southern France caused the ground to rupture—a phenomenon not known during the last 25 years in the region—the earthquake science community worked together to determine the implications for hazard assessment. Now we must maintain that spirit of co-operation for the future.

In the most destructive French earthquake since 1967, the ground ruptured at the surface (Fig. 1)—just a few kilometers from a nuclear power plant. The event occurred near the small town of Le Teil, southeastern France on November 11, 2019, and constitutes a phenomenon that had not previously been described in France. At Mw 4.9, the quake was only moderate in magnitude, but occurred at a depth between 1 and 2 km, then lead to the ground rupture.

The event captured our interest along with that of the French scientific community, and we published an early account that identified and described this surface rupture in *Communications Earth & Environment* in late August 2020¹. French society, unaccustomed to such destructive earthquakes in metropolitan France joined the conversation.

Bridging disciplines

In the wake of the quake, the community of geologists interested in earthquakes and in the characterization of faults in France has come together to take action. Two PhD theses have been assigned to investigate the Cévennes Fault that was responsible for the Le Teil earthquake, supported by industrial and governmental agencies. In a separate project, existing data are being made available at the national level, beyond the existing synthesis², and updated with regional input. Interdisciplinary cooperation has sprung up between geologists, seismologists and geophysicists from academic circles, to develop temporary instrumental networks and propose analyses of the earthquake and consequences^{3–7}.

Field geologists have continued to investigate where possible, despite the lockdowns and curfews resulting from the COVID-19 pandemic, and the motivation of our group has remained strong. Importantly, we were able to excavate a dozen paleoseismological trenches that demonstrate earlier incidences of ground rupture. Some trenches are still open for 2021/2022 scientific conferences, field trips and for teaching: they are a crucial resource in a country where such events and research opportunities are not so common. All this was made possible thanks to the positive and enthusiastic response of land owners, a welcome behavioral trait in freshly earthquake-shaken areas.

We have adapted our way of working to meet pandemic-related health requirements, an easier task in outdoor activity. We also had to satisfy the needs of co-working: we concentrated field efforts, as well as external media visits when restrictions allowed, and moved online conferences to exchange ideas to the phases of lockdown. Ultimately, we found that these adaptations allowed us to continue to carry out our time-sensitive work effectively.

¹IRSN, Institut de Radioprotection et Sûreté Nucléaire, PSE-ENV/SCAN/BERSIN, Fontenay-Aux-Roses, France. ²Géosciences Montpellier, Université de Montpellier, CNRS, Université des Antilles, Montpellier, France. ✉email: stephane.baize@irsn.fr



Fig. 1 This tiny scarp on the La Rouvière tar road was the first evidence of Le Teil earthquake-related ground rupture uncovered by the field team (2 days after the event). The equipment is a laser scanner to image accurately the offset.



Fig. 2 Detail picture of a trench wall excavated across the causative fault. This is from the first trench out of a dozen that was dug during the 2020 spring; notice the fracture in the colluvium related to a pre-historical activity, with the two authors for scale.

Change in focus

Our own careers and personal trajectories have been affected as well as those of our colleagues. The Le Teil earthquake has turned the research community's attention and activity to seismic hazard and seismicity in intraplate areas and particularly in France. A few fundamental scientific questions now need to be addressed.

Identification of other unknown but potentially active faults.

We have had to adapt our usual reconnaissance strategy: the Le Teil earthquake source was only 5 km long, previously not known to be active, and located in an area a priori unfavorable for morphological analyses. Following our ambitious and successful field campaign, it is now clear that the fault in question has been active in the Quaternary, probably in the form of repeated reactivation of an originally Oligocene age structure⁸ (Fig. 2). It is worrying to think that other faults not yet studied, could, in fact, be just as active. There is potentially a lot of work to be done in the longer term. We need to build a clear picture of seismic

hazard. The paramount lesson that we learned this year is that paleoseismological investigation, namely trenching, is a powerful tool to document past fault activity, even in unexpected areas.

Potential threats from surface rupture and their mitigation.

The Le Teil earthquake has focused the attention on surface faulting and the acute risks it poses to infrastructure: it occurred not only just a few kilometres from a nuclear power plant, but also in one of the most industrialized regions of France. Methodologies to evaluate the surface faulting risk to infrastructure have been improving for a few years in an international framework^{9–11}. This hazard has become a concern for sensitive facilities^{12, 13}, and has only now erupted onto the French scene. If other sensitive sites are threatened by earthquake-related surface ruptures, we need to identify and mitigate these risks.

Causes of intraplate seismicity. Plate tectonics classically leads to the assumption that the cyclic buildup of stress on faults leading to earthquakes is essentially controlled by distant tectonics, i.e. in the case of France, the convergence of Africa and Eurasia, the counter-clockwise rotation of the Adria microplate and extension in the Atlantic Ocean. This is still a commonly accepted model for active areas, including in the French Alps¹⁴. However, alternatives have been suggested for intraplate areas that involve different internal and external geodynamic processes at regional and local scales, such as climatic or even anthropogenic factors^{15–18}. Geological and paleoseismological data—the only data that can provide long-term constraints on the timing of tectonic deformation—will be essential for gaining a clearer picture of the responsible driving forces.

Build on the insights

Substantial media coverage of the earthquake and its impact put us and our colleagues in the spotlight, following the publication in *Communications Earth & Environment*. We had media interest from national television and radio reports and live broadcasts on the anniversary of the earthquake, national or regional press articles, as well as specialized magazine reports. Aftershock activity has been weak, seismologically speaking, but the media reverberated.

Public and scientific interest in seismic risk has thus been revived and, two years after the quake, we have made good progress. However, the acquisition of the data necessary to inform seismic risk requires long-term commitment, and we must remain determined to ensure that this initial impetus is maintained in the years to come.

Acquiring paleoseismological data in a short time and at the scale of the country is a daunting task and further steps to achieve scientific goals will require close collaboration between geologists, geophysicists, geodynamicists, and modelers. As a scientific community that mobilized so effectively after the Le Teil Earthquake, we must now work to keep up the collaborations we have forged. The FACT (“*Fautes Actives*”) task force of the now well-established ATS group (“*Action Transverse Sismicité*”) from the RESIF national network of Geodesy and Seismicity^{8, 19} is the relevant framework to address this challenge.

Received: 13 January 2022; Accepted: 14 February 2022;

Published online: 15 March 2022

References

1. Ritz, J.-F. et al. Surface rupture and shallow fault reactivation during the 2019 Mw 4.9 Le Teil earthquake, France. *Commun. Earth Environ.* **1**, 10 (2020).
2. Jomard, H. et al. Transposing an active fault database into a seismic hazard fault model for nuclear facilities – Part 1: Building a database of potentially

- active faults (BDFa) for metropolitan France. *Nat. Hazards Earth Syst. Sci.* **17**, 1573–1584 (2017).
3. Causse, M. et al. Exceptional ground motion during the shallow Mw 4.9 2019 Le Teil earthquake, France. *Commun. Earth Environ.* **2**, 14 (2021).
 4. Cornou, C. et al. Rapid response to the M w 4.9 earthquake of November 11, 2019 in Le Teil, Lower Rhône Valley, France. *Comptes. Rendus Géoscience* **353**, 1–23 (2021).
 5. Delouis, B. et al. Constraining the point source parameters of the 11 November 2019 Mw 4.9 Le Teil earthquake using multiple relocation approaches, first motion and full waveform inversions. *Comptes. Rendus Géosci.* **353**, 1–24 (2021).
 6. Marconato, L. et al. Insights on fault reactivation during the 2019 November 11, Mw 4.9 Le Teil earthquake in southeastern France, from a joint 3-D geological model and InSAR time-series analysis. *Geophys. J. Int.* **229**, 758–775 (2022).
 7. Vallage, A. et al. Multitechnology characterization of an unusual surface rupturing intraplate earthquake: the M L 5.4 2019 Le Teil event in France. *Geophys. J. Int.* **226**, 803–813, <https://doi.org/10.1093/gji/ggab136> (2021).
 8. Ritz, J.-F. et al. New perspectives in studying active faults in metropolitan France: the “Active faults France” (FACT/ATS) research axis from the Resif-Epos consortium. *Comptes. Rendus Géosci.* **353**, 381–412 (2021).
 9. Baize, S. et al. A Worldwide and Unified Database of Surface Ruptures (SURE) for Fault Displacement Hazard Analyses. *Seismol. Res. Lett.* **91**, 1 (2020).
 10. Nurminen, F. et al. Probability of Occurrence and Displacement Regression of Distributed Surface Rupturing for Reverse Earthquakes. *Front. Earth Sci.* **8**, 1605 (2020).
 11. Sarmiento, A. et al. Fault Displacement Hazard Initiative Database. Report GIRS-2021-08. *UCLA Natural Hazards Risk And Resiliency Research Center* <https://doi.org/10.34948/N36P48> (2021).
 12. Decker, K., Hintersberger, E., Hirsch, H. NPP PAKS II. Paleoseismological assessment of the Siting Report and the Site License with respect to fault capability. Report, <https://www.umweltbundesamt.at/fileadmin/site/publikationen/rep0759.pdf>, Umweltbundesamt GmbH, Vienna (2021).
 13. Valentini, A. et al. Probabilistic Fault Displacement Hazard Assessment (PFDHA) for Nuclear Installations According to IAEA Safety Standards. *Bull. Seismol. Soc. Am.* **111**, 2661–2672 (2021).
 14. Mathey, M. et al. Present-day geodynamics of the Western Alps: new insights from earthquake mechanisms. *Solid Earth* **12**, 1661–1681 (2021).
 15. De Novellis, V. et al. Author Correction: Coincident locations of rupture nucleation during the 2019 Le Teil earthquake, France and maximum stress change from local cement quarrying. *Commun. Earth Environ.* **2**, 47 (2021).
 16. De Novellis, V. et al. Coincident locations of rupture nucleation during the 2019 Le Teil earthquake, France and maximum stress change from local cement quarrying. *Commun. Earth Environ.* **1**, 20 (2020).
 17. Liang, C. & Ampuero, J.-P. Comment on “Coincident locations of rupture nucleation during the 2019 Le Teil earthquake, France and maximum stress change from local cement quarrying” by De Novellis et al. (preprint). *Geophysics* <https://doi.org/10.1002/essoar.10504400.2> (2020).
 18. Mazzotti, S., Jomard, H. & Masson, F. Processes and deformation rates generating seismicity in metropolitan France and conterminous Western Europe. *Earth Sci. Bull.* **191**, 19 (2020).
 19. Masson, F. et al. The Transversal Seismicity Action RESIF: A Tool to Improve the Distribution of the French Seismicity Products. *Seismol. Res. Lett.* **92**, 1623–1641 (2021).

Author contributions

S.B. and J.-F.R. contributed equally to the conceptualization. S.B. led the writing of the paper, with strong support of J.-F.R.

Competing interests

The authors declare no competing interests.

Additional information

Correspondence and requests for materials should be addressed to Stéphane Baize.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2022