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Author Correction: Coincident locations of rupture nucleation during the 2019 Le Teil earthquake, France and maximum stress change from local cement quarrying

Vincenzo De Novellis , Vincenzo Convertito, Sotiris Valkaniotis , Francesco Casu , Riccardo Lanari, Mario Fernando Monterroso Tobar  & Nicola Alessandro Pino 

Correction to: *Communications Earth & Environment* <https://doi.org/10.1038/s43247-020-00021-6>, published online 18 September 2020.

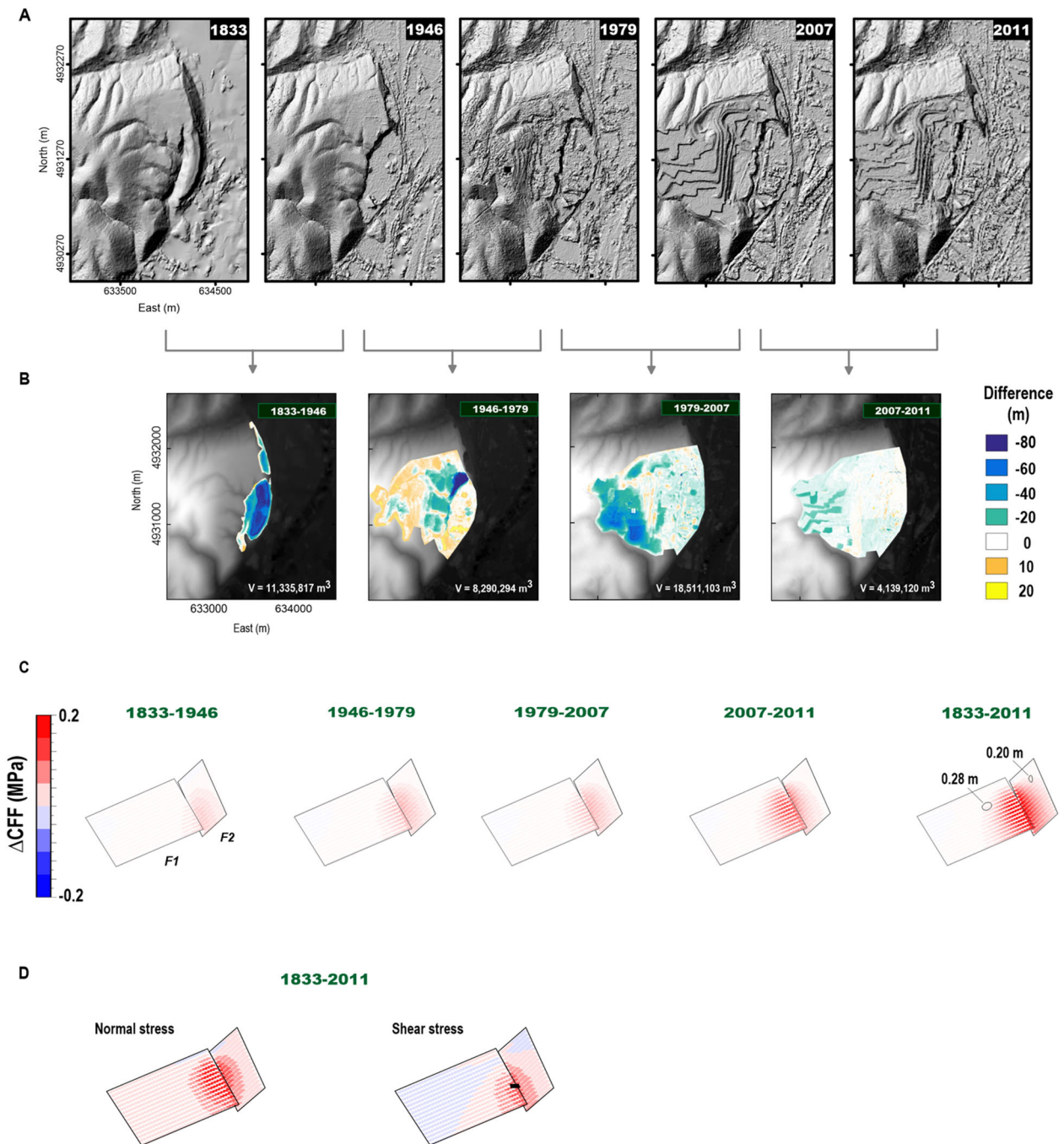
The original version of this article contained errors in the estimated magnitude of the Coulomb stress changes—caused by the removal of mass at a near-by cement quarry—on the faults associated with the November 11, 2019, Le Teil (southern France) earthquake. The errors derived from the use of incorrect values for the volumes of removed material in the stress computation, and led to an overestimate by almost one order of magnitude of the maximum Coulomb stress change that resulted from the quarrying activity on the faults that caused the earthquake. The estimated volumes, indicated in Table 4 of the Supplementary Information, were computed correctly, but then a wrong file was used in the stress calculation.

By considering the correct volumes, the maximum Coulomb stress changes (ΔCFF) on the La Rouvière (LRf) and La Chade (LCf) faults that we had erroneously indicated as 1.10 MPa and 1.15 MPa are actually only 0.19 MPa and 0.18 MPa, respectively. They are therefore almost one order of magnitude smaller than the earthquake stress drop of 1.3 MPa. Based on the corrected values, we conclude that the quarry activity did not induce the 2019 Le Teil earthquake. The corrected Coulomb stress change estimates do support our conclusion that the earthquake was triggered by the mass removed from the quarry. However, based on the corrected Coulomb stress changes, we infer that the occurrence of the earthquake was hastened by only about 18,000 years, and not by about 110,000 years, as we had inferred from the erroneous values.

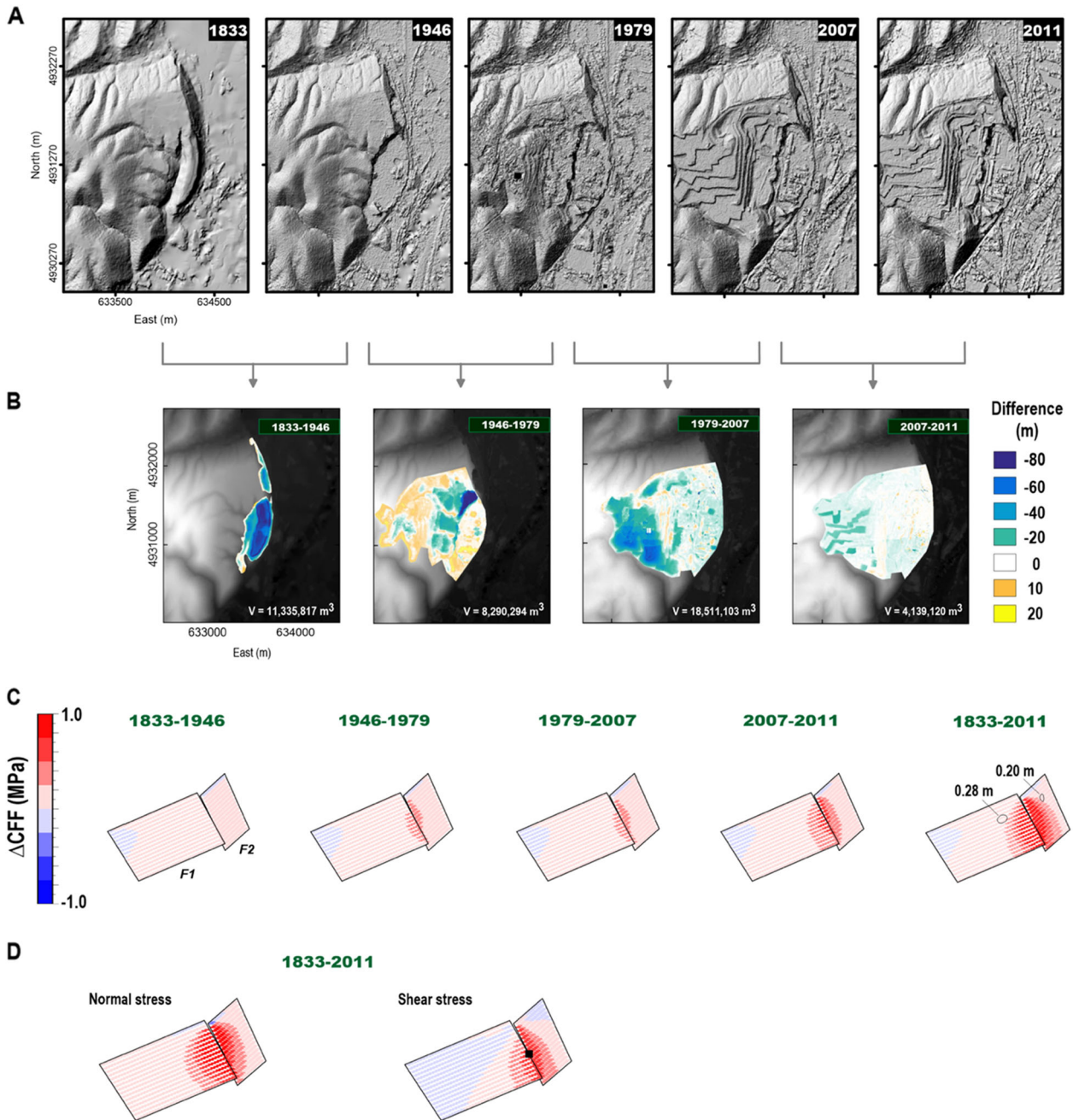
We would like to warmly thank Chao Liang and Jean-Paul Ampuero, from Université Côte d'Azur (France), for bringing the mistake to our attention, by checking the coherence of the stress computation with the estimated volumes.

Corrections have been made in both the PDF and HTML versions of the Article, and the HTML has been updated to include a corrected version of the Supplementary Information. These corrections are:

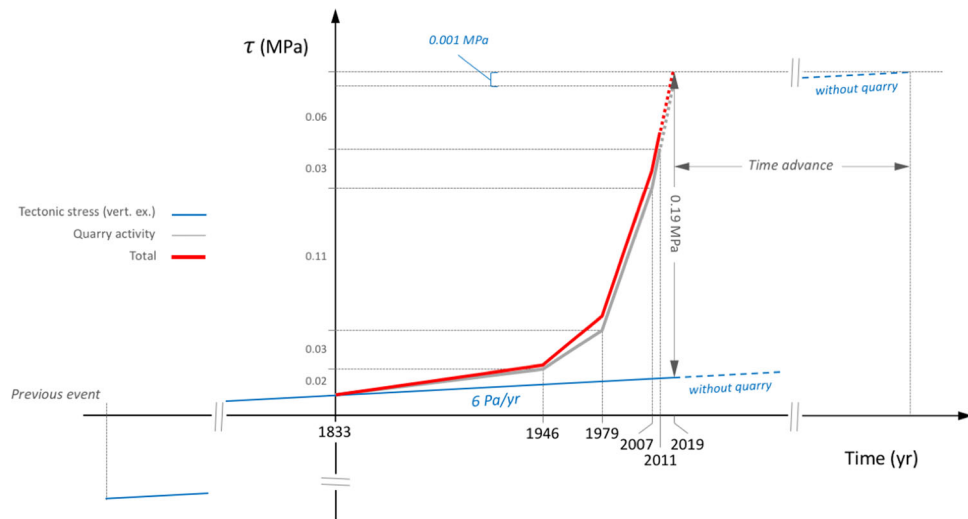
The error described above affected the original versions of Figs. 3 and 4, and Supplementary Fig. 10. The correct version of Fig. 3 is:



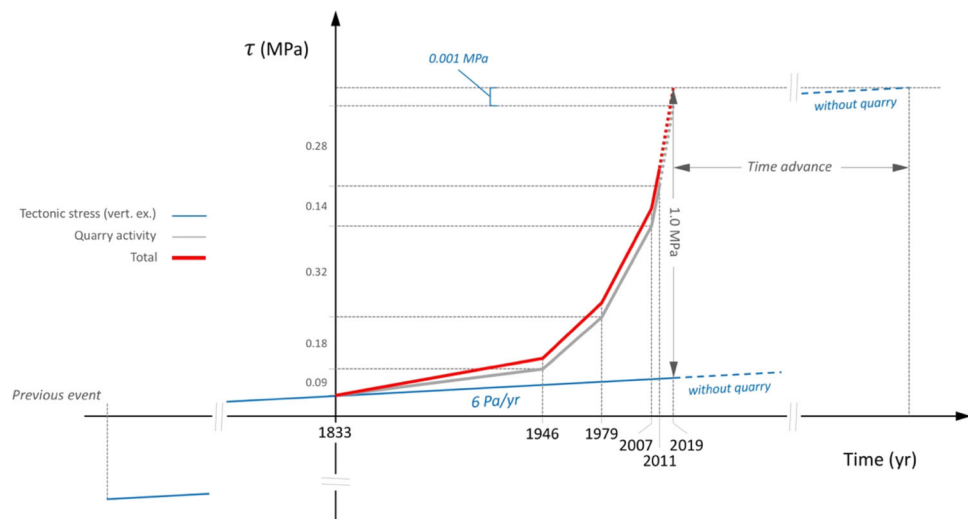
Which replaces the previous incorrect version:



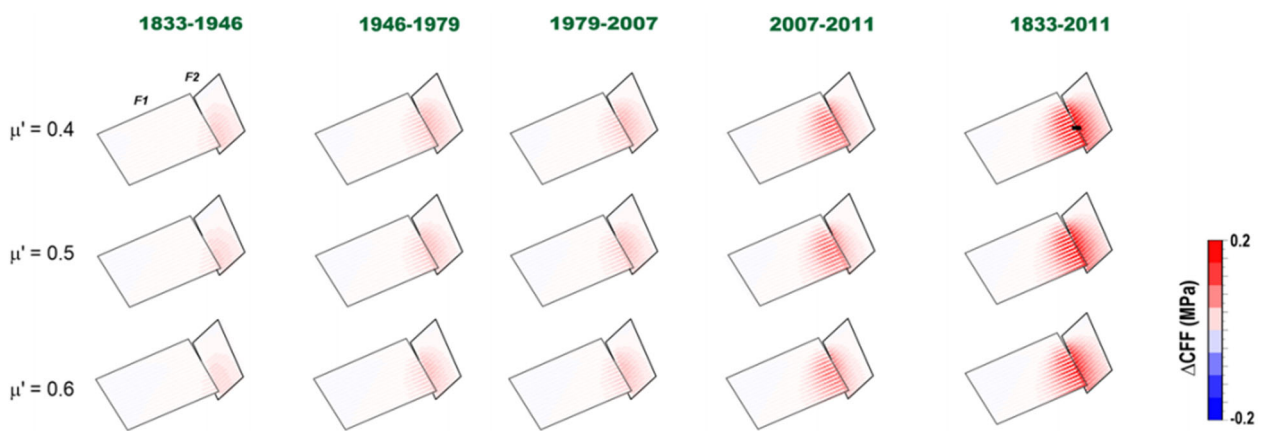
The correct version of Fig. 4 is:



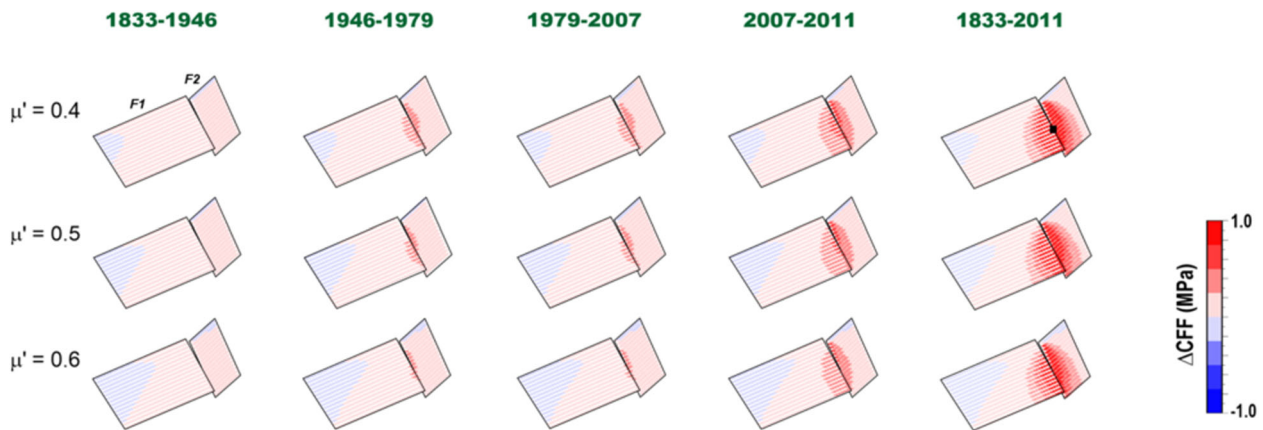
Which replaces the previous incorrect version:



The correct version of Supplementary Fig. 10 is:



Which replaces the previous incorrect version:



The fifth sentence of the abstract originally incorrectly read “We find that almost two centuries of mass removal at a nearby cement quarry likely provided the required stress change to either induce the Le Teil earthquake, or hasten its occurrence by more than 100,000 years”. The correct version reads “We find that almost two centuries of mass removal at a nearby cement quarry likely provided the required stress change to hasten the occurrence of the Le Teil earthquake by more than 18,000 years”.

The final sentence of the second paragraph of the Introduction originally read “Nevertheless, no evidence of cumulative compressional deformation has been detected along the ruptures associated with the 2019 earthquake.” In the correct version “and, remarkably, the geologic evidences suggest that the La Rouvière fault could have been inactive since million years” has been added to the end of this sentence.

The second and third sentences of the third paragraph of the Introduction originally incorrectly read “Our results indicate that the extraction activity could have induced or at least triggered the Le Teil earthquake. In this latter case, we estimate a clock advance larger than 100,000 years.” The correct version reads “Our results indicate that the extraction activity could have triggered the Le Teil earthquake. In this case, we estimate a clock advance larger than 18,000 years”.

The second sentence of the second paragraph in the “Stress change caused by the quarry activity” section of the Results originally incorrectly read “In particular, a large patch of stress increase resulted on the northern half of the LRF, with maximum corresponding to 1.10 MPa, while the Coulomb stress increased on most of the LCF, reaching a maximum change of 1.15 MPa.” The correct version states “0.19” instead of “1.10” and “0.18” instead of “1.15”.

The third sentence of the same paragraph originally incorrectly read “These values are very similar to the stress drop $\Delta\sigma = 1.3$ MPa estimated for the 2019 earthquake (see “Methods” section).” The correct version now states “less than one order of magnitude smaller than” instead of “very similar to”.

The eighth sentence of the first paragraph of the Discussion originally incorrectly read “The estimated cumulative maximum Coulomb stress change on the fault due to the total mass subtraction is 1.10 MPa by 2011, corresponding to maximum normal $\Delta\sigma_n = 0.87$ MPa and shear stress $\Delta\tau = 0.67$ MPa.” The correct version states “0.19”, “0.21” and “0.11” instead of “1.10”, “0.87” and “0.67” respectively.

The first sentence of the second paragraph of the Discussion originally incorrectly read “The shear stress value resulting from the quarry activity is comparable with the stress drop of the earthquake (~ 1 MPa), pointing to an anthropogenic origin of the seismic event.” The correct version reads “The shear stress value resulting from the quarry activity is one order of magnitude larger than what typically considered sufficient to trigger an earthquake (0.01 MPa), pointing to an anthropogenic effect on the origin of the seismic event”.

The second sentence of the second paragraph of the Discussion originally incorrectly read “In fact, these results allow stating that the rock extraction from the quarry likely have induced the 2019 Le Teil earthquake or, alternatively, triggered it by dramatically accelerating the loading of the fault and hastening its unlocking.” In the correct version “induced” has been replaced with “triggered” and “or, alternatively, triggered it” has been removed.

The third sentence of the second paragraph of the Discussion originally incorrectly read “Incidentally, we note that even considering the upper extreme for the stress drop ($\Delta\tau = 2.0$ MPa, see “Methods” section), it would be of the same order of magnitude of the calculated shear stress change and the hypothesis of an anthropogenic origin for the earthquake is still strongly supported.” The correct version reads “Incidentally, we note that even considering the upper extreme for the stress drop ($\Delta\tau=2.0$ MPa, see Methods section), this would not change our conclusion and the hypothesis of an anthropogenic effect on the origin for the earthquake still holds.”

The first sentence of the third paragraph of the Discussion originally incorrectly read “In case of triggering, the time advance can be estimated by dividing the cumulative stress change associated with the quarry activity by the tectonic stress rate”. In the correct version

“In case of triggering,” has been removed from the start of this sentence.

The second sentence of the third paragraph of the Discussion originally incorrectly read “About 111,000 years is the time required for the tectonic forces to load on the fault a stress amount similar to the change produced by ~180 years of rock extraction from the quarry (Fig. 4)”. The correct version states “18,000” instead of “111,000”.

The fourth sentence of the third paragraph of the Discussion originally incorrectly read “Assuming for 2011–2019 the same average extraction rate calculated for the period 2007–2011 (and the same location), the total normal and shear stress change would be $\Delta\sigma_n = 1.3$ MPa and $\Delta\tau = 1.0$ MPa, respectively, corresponding to a time advance of $\sim 1.6 \times 10^5$ years, making the induction hypothesis even more realistic, in agreement with the geologic evidences suggesting that the LRF could have been inactive since million years.” In the correct version “1.3”, “1.0” and “ 1.6×10^5 ” have been replaced with “0.26”, “0.15” and “25,000” respectively, “induction” has been replaced with “triggering” and “in agreement with the geologic evidences suggesting that the LRF could have been inactive since million years” has been removed from the end of the sentence.

The second sentence of the fifth paragraph of the Discussion originally incorrectly read “In the hypothesis of a linear increase of the fault strength with depth and especially if on deeper portions of the fault there is near-critical preexisting tectonic stress, additional future mass removal might trigger deeper slip, possibly causing a stronger earthquake than the one that occurred on November 11, 2019.” In the correct version “these” has been replaced with “this” and “of a linear increase of the fault strength with depth” has been removed.

The third sentence of the fifth paragraph of the “Calculation of the rock volume extracted from the quarry” section of the Methods originally incorrectly read “Original DSM raster files were clipped and resampled into a common pixel size (3 m for 1833–1946 and 2 m for the rest) and then converted into point clouds.” In the correct version “for 1833–1946 and 2 m for the rest” has been removed.

The original version of this Article contained an error in Ref. 8, which contained an incorrect spelling of the first author’s name as:

Gonzales, P. J., Tiampo, K. F., Palano, M., Cannavò, F. & Fernandez, J. The 2011 Lorca earthquake slip distribution controlled by groundwater crustal unloading. *Nat. Geosci.* 5, 821–825 (2012).

The correct form of Ref. 8 is:

González, P. J., Tiampo, K. F., Palano, M., Cannavò, F. & Fernandez, J. The 2011 Lorca earthquake slip distribution controlled by groundwater crustal unloading. *Nat. Geosci.* 5, 821–825 (2012).

The first sentence of the caption of Fig. 4 originally incorrectly stated “The increment of the shear stress on the faults of the 2019 earthquake caused by the tectonic forces (blue line; exaggerated vertical scale), starting from the previous (unknown) earthquake, and by the Le Teil quarry activity (1 MPa; gray line).” The correct version states “0.19” instead of “1”.

The values in the fourth column of Supplementary Table 4 titled “ ΔCFF^* (MPa)” originally read “0.14”, “0.27”, “0.45”, “0.19” and “1.05”. In the correct version these values are replaced by “0.02”, “0.04”, “0.11”, “0.03” and “0.19” respectively.

The caption of Supplementary Table 4 originally incorrectly read “* ΔCFF is computed at the point indicated in Supplementary Fig. 9”. The correct version states “Supplementary Fig. 10” instead of “Supplementary Fig. 9”.

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Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s43247-021-00109-7>.



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