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.

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In a recent article, De Novellis et al. (2020, hereafter referred to as DN20) studied the effect of mass extraction from a quarry on the occurrence of the M_w 4.9 Le Teil, France, earthquake of November 11 2019. This topic is of great importance regionally due to the damage caused by the earthquake in its vicinity, and globally due to its implications on hazard assessment in low seismicity regions. This topic is also the focus of the French working group mandated by CNRS INSU ("Groupe de Travail Teil" of Institut National des Sciences de l'Univers du Centre National de la Recherche Scientifique) to assess the possibility of an anthropic origin of the Le Teil earthquake. Their report was made public in the month after the earthquake (Delouis et al, 2019, hereafter D19; the corresponding author of this comment is the current chair of that expert group; both authors contributed stress change calculations to D19).

The conclusions of these two independent research efforts, despite using similar data and methods, are contrasting. While both D19 and DN20 concluded the earthquake was possibly a triggered event (i.e. its initiation was possibly promoted by the quarry activity but its further rupture growth was primarily enabled by natural pre-existing stresses), DN20 deemed realistic the hypothesis that the earthquake was an induced event (i.e. both the earthquake initiation and its further growth, up to its final size, were caused by the quarry activity). This distinction is critical for our understanding of future anthropogenic hazards in the region and in similar settings elsewhere, and may have significant social, economical and legal repercussions. Here, we show that a severe error in the modeling done by DN20 undermines their conclusion.

The volume of material extracted from the quarry that is reported in DN20 is about 7 times smaller than the volume the authors used in their computations of the Coulomb stress changes induced by the quarry on the local faults involved in the 2019 Le Teil earthquake. The latter are documented in the code and input files provided to us by the authors upon request, with which we have reproduced the stress values reported in their figures 3C and 3D. Table 1 reports the differences between the extracted-volume values published in the Supplementary Table 4 of DN20 and those used for the stress computations in figures 3 and 4 of DN20.

As a consequence of the error in source volume described above, the Coulomb stress changes reported in DN20 (e.g. their figure 3) are overestimated by a factor of about 7. After re-scaling the volumes of the computation input files of DN20 to match the total volumes for each period reported in their Supplementary Table 4, and re-running the computation with their code, the resulting stress change values (Figure 1-bottom) are similar to those reported by Delouis et al (2019; see their figures QC2 and QC3).

The large overestimation of stress values by DN20 undermines their core argument to qualify the Le Teil earthquake as an induced event rather than a triggered event. DN20 use their erroneous stress estimates to argue the time-advance caused by the quarry is comparable to the natural recurrence of earthquakes in the area, which in turn they claim supports the induction hypothesis. This conclusion hinges on comparing the values of Coulomb stress change and earthquake stress drop, which DN20 report to be similar. However, the corrected values of Coulomb stress changes (Figure 1-bottom) are not similar to the earthquake's stress drop (of order 1 MPa), but about one order of magnitude smaller. Thus, the stresses induced on the faults by the exploitation of the quarry are not sufficient to account for the stresses released by the earthquake. Based on this evidence, even though the event could have been triggered, it cannot be qualified as induced.

DN20 also "suggest that further mass removal in the area might lead to even stronger earthquakes, by activating deeper sectors of the same fault plane" under "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". It is fair to note that, given the current state of knowledge, the opposite scenario is also mechanically plausible: the same material properties that led to the 2019 rupture not propagating deeper, possibly associated to the ductile behavior of the marly layers at the base of the rupture (Ritz et al., 2020; Cornou et al., 2020), could buffer the deeper fault portions from the effects of quarry activity. This important question is one of the subjects of current investigations by the CNRS/INSU Working Group Teil.

Time period	Volume removed as reported in Supplementary Table 4 of DN20 (10^6 m^3)	Volume removed used for stress calculations by DN20 (10^6 m^3)	Ratio between used volume and reported volume
1833 - 1946	11.3	54.1	4.8
1946 - 1979	8.3	75	9
1979 - 2007	18.5	115.5	6.2
2007 - 2011	4.1	54.7	13.3
1833 - 2011	42.3	299.4	7.1

Table 1. Two estimates of volumes removed from the quarry, reported by DN20 and actually used in their stress calculations, and their ratio for 4 different time periods and their sum.

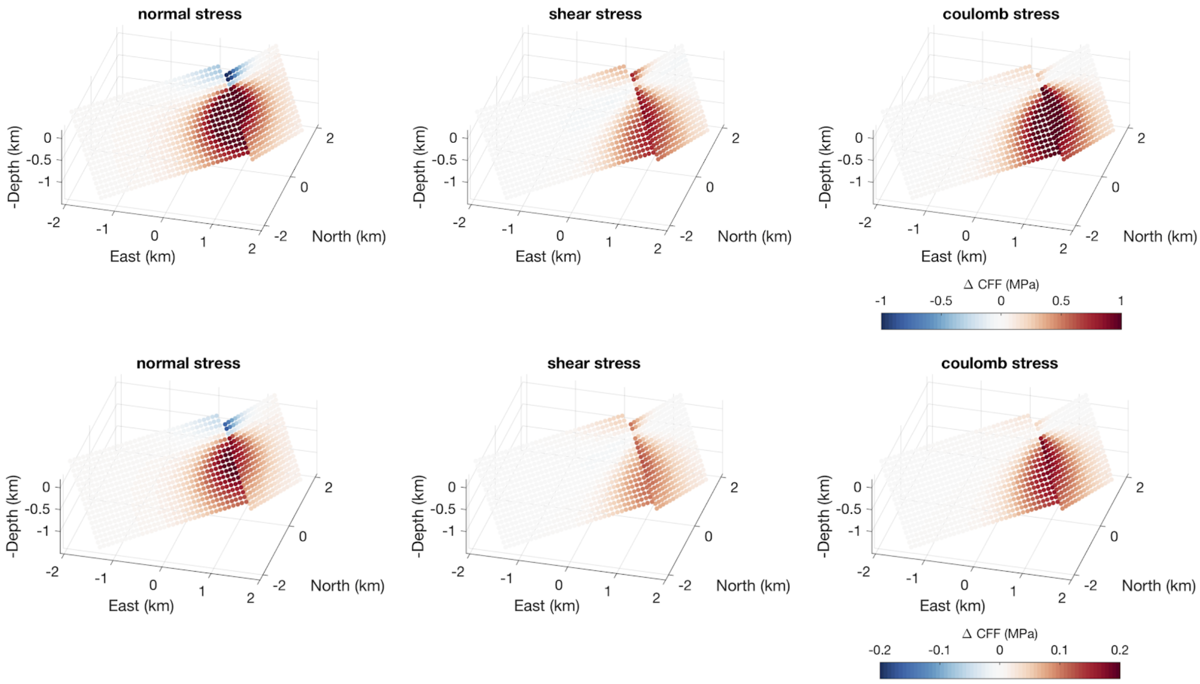

Figure 1. Normal stress, shear stress and Coulomb stress changes on the causative faults of the 2019 Le Teil earthquake using the fault geometry, friction coefficient of 0.4 and density of 2300 kg/m3 assumed by DN20, using (top) the extracted-volume values used by DN20 in their calculation as shown in Fig. 3 of the main text, and (bottom) those values re-scaled to match the volumes reported in the Supplementary Table 4 of DN20.

Author contribution statement

JPA designed the study and drafted the manuscript. CL conducted the calculations, prepared the figure and reviewed the manuscript.

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