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Philippe Hervé Leloup. Comment on the paper “Structural and petrological characteristics of a Jurassic detachment fault from the Mont-Blanc massif (Col du Bonhomme area, France) ” by Dall’Asta et al. Published in Journal of structural Geology 159 (2022). Journal of Structural Geology, 2023, 168, pp.104811. 10.1016/j.jsg.2023.104811 . hal-04192742

HAL Id: hal-04192742

<https://hal.science/hal-04192742v1>

Submitted on 31 Aug 2023

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Comment on the paper “Structural and petrological characteristics of a Jurassic detachment fault from the Mont-Blanc massif (Col du Bonhomme area, France) » by Dall’Asta et al. published in *Journal of structural Geology* 159 (2022).

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Building on a paper previously published by Ribes et al. (2020), Dall’Asta et al. (2022) claim to document a main detachment fault in the Col du Bonhomme area in the southern part of the Mont-Blanc range. This SE dipping detachment would connect with the Valaisan rift and make of the Mont-Blanc external crystalline range a Jurassic extensional core complex. This detachment would be the best-preserved example of large Mesozoic syn-rift normal faults within the external crystalline ranges of the Mont-Blanc and Aiguilles Rouges. However, we show below that this publication does not demonstrate in any way the existence of such a major Jurassic extensional detachment.

The authors propose that in the Col de la Croix du Bonhomme area, the top of the Variscan basement (migmatitic gneiss, granite, and rhyolite) is brecciated in a ~40 m thick damage zone topped by cataclasite and a black indurated fault gouge below the Mesozoic sedimentary rocks. This ≤ 1 m thick fault gouge, rich in phyllosilicates, would constitute the core zone of the suspected detachment. A key point is thus to constrain the geometry and kinematics of that gouge. On the map provided in their figure 2 the black gouge, would in fact outcrop only sporadically (dashed lines), with continuous outcrops (continuous lines) being found only at a few places. The absence of any coordinates on the map precludes a precise georeferencing, but coordinates given for some illustrations allow locating some key observation stations.

The authors provide a stereographic plot of the main structures, with two main orientations for the detachment fault (their figure 3G - centre). They acknowledge that they could measure very few lineations / striations within the gouge / cataclasite but that they mostly trend ~N-S, and that they found shear criteria at only four locations all showing top to the south shear senses (their figure 3G - right). They further show two examples supposed to illustrate top to the south shear (their figures 3D and S6C). The scarcity of lineation / striation and of shear criteria cast doubts on the intensity of simple-shear deformation in the decollement, while very intense deformation would be expected in such a thin zone absorbing a large amount of motion. During our investigations we did not find any clear N-S stretching lineation or striation nor top to the south shear criteria. Further, figure S6C illustrate a top to the north shear criteria (not top to the south), while that of figure 3D could not be checked in the field as it is most likely mislocated because its position ($45^{\circ}46'13.36''\text{N}/6^{\circ}43'46.17''\text{E}$) is localized within basement rocks 3.5km north outside of the map.

The largest continuous outcrop of the putative detachment is supposed to occur in the footwall of the NW-SE trending normal /right lateral Faille Des Fours (their figure 5, also see Fig. 4a, b in Ribes et al., 2020). At that location (station AR2232 $45^{\circ}43'47.30''\text{N}/6^{\circ}43'54.16''\text{E}$), a black layer is indeed visible at the transition between the Triassic dolostone and the basement (Fig. 1a, b). However, a closer look at the outcrop reveals that the black colour is a manganese/iron rich coating (Fig. 1c), and that the rocks are not black gouge, but quartzite (Fig. 1c). In this zone, the Triassic dolostones do not directly rest on the basement through a detachment. Instead, the usual autochthonous Triassic stratigraphy succession is present with quartzite in between the dolostone (Fig. 1d) and the basement (in that case weakly fractured rhyolites). Whilst the sandstones are locally altered and vesicular, they are not intensively deformed nor underlain by a gouge layer (Fig. 1e). The dolostone layers are affected by a series

of normal faults oblique to the faille des Fours (Fig. 1a) that have not been reported on any published map. These normal faults do offset the basal contact of the sandstones but not the highest dolostone beds (Fig. 1a) and are thus probably Triassic syn-sedimentary faults. A major Liassic detachment should have offset these faults which is not the case. Note that further northeast along the same postulated detachment, at the base of the Amône outcrop, Ribes et al., (2020) already misinterpreted the basal unconformity of the grès singuliers conglomerate as black fault-gouge and cataclasite.

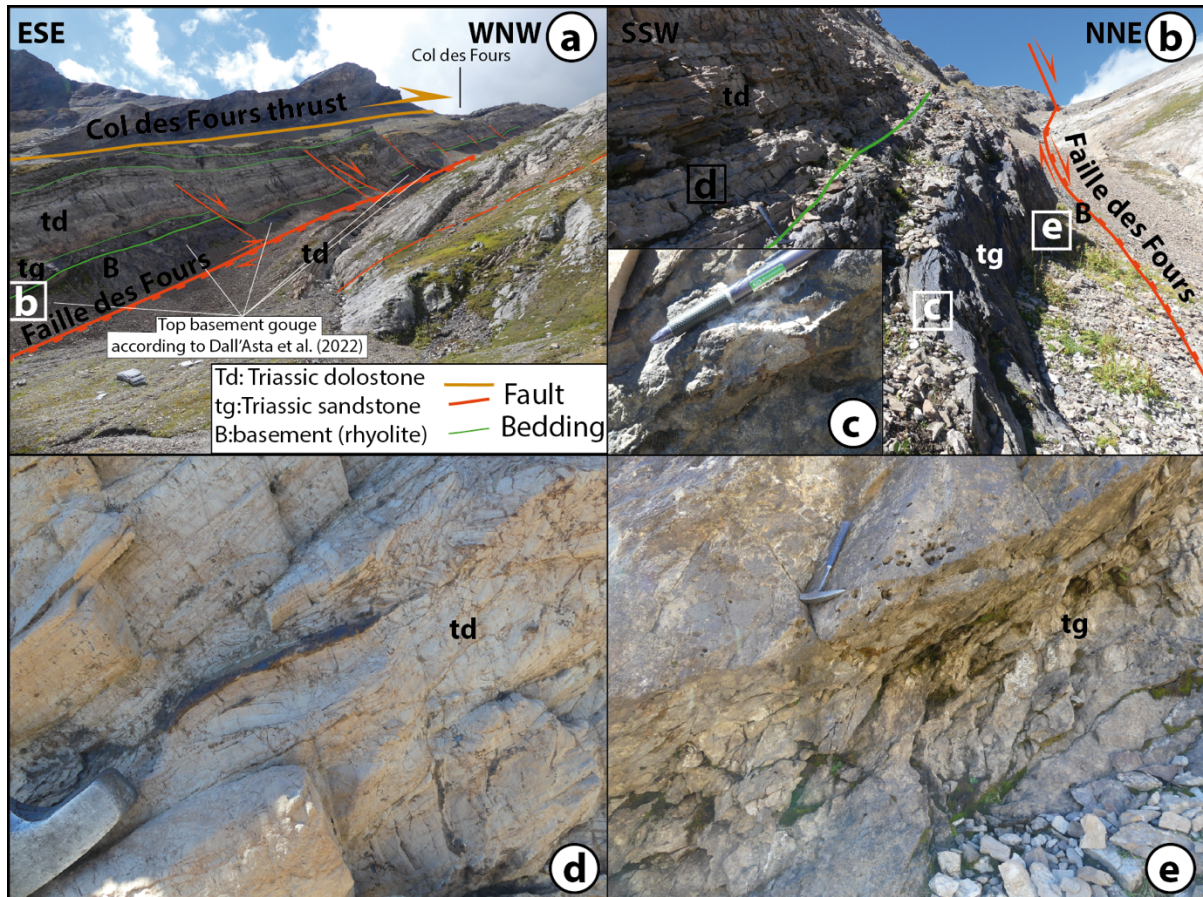


Fig. 1 The postulated detachment (top basement gouge) in the hanging wall of the faille des fours. a) General view from the ESE. b) Station AR2232. Triassic dolostone rest on top of the Triassic sandstones, themselves lying on top of the basement. Squares locate the figures. c) Detail of the white Triassic sandstone seen behind the black manganese / iron coating. d) Detail of the Triassic dolostone with syn-sedimentary breccia and a manganese / iron level. e) Bottom of the Triassic sandstones.

Along the trail between the Nan des Lotharets and the Col du Bonhomme, Dall'Asta et al. (2022) map three traces of the décollement, and they suggest that it is because it has been affected by an anticline with a NE-SW axis (their figures 2 and 3G). However, field observations are quite different, with all sedimentary formations dipping to the south and being offset by several faults. The most important of these faults, the Bonhomme fault, appears on the BRGM geological map at scale 1/50 000 (Mennessier et al., 1977) as a ~1.7km long NE-SW fault, dipping to the NW and lowering the NW compartment. The fault offsets the basement and the Triassic sediments by several meters. At station AR504 (45°43'39.18"N, 6°42'39.77"E) the Bonhomme fault separates cataclastic granites from sandstone and brecciated dolostones (Fig. 2a, b) and strikes N40°, 30°NW on average (Fig. 2d). The exact same fault outcrop is depicted in both papers by Ribes et al. (2020) and Dall'Asta et al. (2022, their Figure 3C), where

it is attributed to the detachment, but without orientation on the figures and without indicating to what trace of the detachment it would correspond. Deformed rocks below the dolostone correspond to the description of the black gouge, and presumably furnished most samples studied in detail in the paper as it is the only location where we found such rocks. Samples from that fault zone exhibit clear striations (Fig. 2c) that trend $N80^\circ$ to $N100^\circ$ (Fig. 2d), almost perpendicular to the lineations reported by Dall'Asta et al., (2021). A nearly horizontal schistosity and shear criteria (Fig. 2a, c), both suggest that the fault is normal (top to the west) in good accordance with the map relationships. In that zone, all stratifications dip to the south, unless the ones directly on top of the Bonhomme fault (Fig. 1a) that correspond to a local fault-bend with a NE-SW axis which is compatible with the normal motion of the fault. Dall'Asta et al., (2021) consider that the Bonhomme fault does not exist and that the black gouges constitute the limb1 of an anticline affecting the décollement with all other stratifications constituting the limb2 (their figure 3G). However, this anticline does not exist, and the only significant fold is the fold-bend syncline linked to the Bonhomme fault described above. A major issue would have been to justify how a west dipping normal fault with top to the west motion could be the main evidence for a major detachment dipping to the southeast with top to the south motion. In that area it is however true that the base of the Triassic series and the top of the basement are deformed. That deformation is poorly defined, but the cleavage appears parallel to the bedding (Dall'Asta et al., 2021). Similar deformation is also locally observed within the Triassic dolostone, at the base of the Grès Singuliers and at their top immediately below the Col des Fours thrust. There, the lineation trends $N90^\circ$ and shear criteria implies top to the west simple shearing parallel to the stratification. Such deformation is compatible with thrusting at the base of the Helvetic nappes in the Miocene (Eltchaninoff et al., 1982; Leloup et al., 2005; Egli et Mancktelow, 2013).

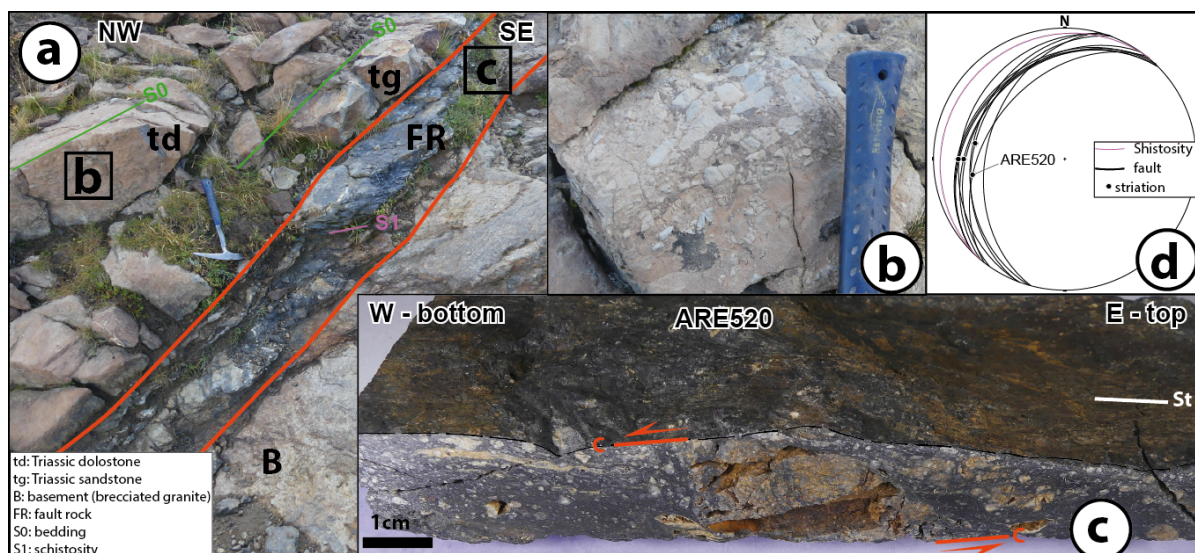


Fig. 2. The Bonhomme NW dipping normal fault. a) Station AR504 outcrop. Squares locate figures. b) Detail of the brecciated dolostone. c) Oblique view of the fault rock sample ARE520 with well-defined striation (St), and asymmetric tails on a clast suggesting top to the west (normal) motion. d) Stereonet of the fault planes and striations within the fault rocks.

At both locations described above the dolostones are brecciated (Figs. 1d, 2b). Similar breccia is found at other locations far from the postulated detachment, and locally in pockets within the dolostones. In both cases, the breccia formation occurred while the sediments were not lithified yet (Egli et al., 2013), thus during the Triassic, and they are not fault rock but could

represent seismite. In any case they do not represent hydraulic breccia directly linked to the deformation within a major Liassic detachment.

Our conclusion is that the most spectacular outcrop of the major Liassic detachment proposed by Dall'Asta et al. (2022) corresponds to a small normal fault with rather different geometry and kinematics than that assumed for the extensional detachment. The age of that west dipping normal fault still needs to be determined. At other locations deformation on the postulated detachment is not yet well characterized and could possibly have formed during alpine deformation with top to the west shearing as is documented ~100m higher in the stratigraphy at the base of the Helvetic nappes. Even if some normal faults have locally been preserved despite the alpine deformation in the external crystalline ranges, the presence of a major southeast dipping Liassic detachment in the Mont-Blanc that would connect with the Valaisan rift still awaits any convincing field evidence.

Acknowledgments

Review by S. Schmidt helped to clarify the text.

Comment on the reply by Dall'Asta et al., (2023)

Fig. 3C of Dall'Asta et al., (2022) and Fig. 5D of Ribes et al., (2020) are pictures of a similar fault with black gouge but without orientation. In its comment Leloup (2023) shows in its fig. 2a a picture of the very same outcrop (station AR504, 45°43'39.18"N, 6°42'39.77"E) with the fault clearly dipping to the NW (N40°, 30°NW on average). That dip is opposite to what would be expected for the detachment inferred by Dall'Asta et al., (2022) and Ribes et al., (2020). In their Reply, Dall'Asta et al., (2023) show in their Fig. 1B another picture of that same outcrop, but this time oriented. However, this orientation is erroneous and misleading as it would imply the fault dips toward the SE, in contradiction with the field and the authors own stereographic plot that clearly show gouge dipping to the NW (green great circle), and their text.

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