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Comment & Reply — Tectonics, Tectonophysics

Reply to comment by El Ouardi et al. on *The Cu–Pb–Zn-bearing veins of the Bou Skour deposit (Eastern Anti-Atlas, Morocco): structural control and tectonic evolution*

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Abstract. This note is a reply to the "Comment on *The Cu-Pb-Zn-bearing veins of the Bou Skour deposit (Eastern Anti-Atlas, Morocco): structural control and tectonic evolution*" by Hmidou El Ouardi et al., published in Comptes Rendus Géoscience in Volume 354, 2022, pages 119–123 (https://doi.org/10.5802/crgeos.115). It concerns the article "The Cu-Pb-Zn-bearing veins of the Bou Skour deposit (Eastern Anti-Atlas, Morocco): structural control and tectonic evolution" by Aabi et al., published online on May 04, 2021, in Comptes Rendus Geoscience in Volume 353, 2021, pages 81–99 (https://doi.org/10.5802/crgeos.54).

Keywords. structural model, Copper bearing mineralization, Bouskour, Anti Atlas, Morocco.

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1. Introduction

We thank El Ouardi et al. [2022] for the attention they paid to our work on the Bou Skour mineralization and for the discussion they initiated through their comment. Our valuable colleagues have been alarmed by the alleged equivalence between the model we presented for the Bou Skour polymetallic deposit [Aabi et al., 2021] and the model they had previously presented for part of the Bou Skour deposit, namely the Patte d'Oie district [El Ouardi et al., 2016].

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In the following, we try to answer point-by-point to the comments by El Ouardi et al. [2022], arguing for the validity of our findings and data, and providing opportunities to clarify some controversial ideas.

2. Structural model of the Bou Skour vein-type deposit

El Ouardi et al. [2022] claim that their proposed structural model of the Bou Skour veins emplacement was omitted [El Ouardi et al., 2016] or appears to have been misunderstood and not cited enough. In addition, they argue that the dextral reactivation of the main vein (Filon Principal: FP) should not disrupt their structural model since the reactivation was documented outside the southern "Patte d'Oie" district of the Bou Skour deposit.

The structural model proposed by El Ouardi et al. [2016] (p. 50) indicates only one kinematics for the Bou Skour shear fault, i.e., a sinistral movement displacing the rhyolitic dykes, and affirms that the emplacement of the mineralized veins postdates that of the dyke swarm. However, based on our field mapping data, there is no evidence confirming this interpretation at the scale of the Bou Skour deposit. On the contrary, we confirmed [Aabi et al., 2021] the occurrence of (at least) a twofold kinematic event (Figure 1A). The first event is a sinistral movement [Figure 1B; cf. Figures 5A–F and 11, Aabi et al., 2021], which is responsible for the vein system formation [574.9 ± 2.4 Ma; Bouabdellah et al., 2016] predating the Ediacaran dyke occurrence [564 ± 7 Ma; Walsh et al., 2008a] and interpreted to be contemporaneous to or immediately postdating the emplacement of the host 570 ± 5 Ma Bou Skour granite [Clavel and Tixeront, 1971, Bouabdellah et al., 2016, Aabi et al., 2021]. The second event reactivates the Bou Skour kilometric fault in a dextral brittle regime dissecting a great number of the NNE-trending dyke swarm [Figure 5G,H; cf. Figure 9A, Aabi et al., 2021].

Contrary to what is suggested by El Ouardi et al. [2022], this polyphase kinematics was not only observed in the northern part of the deposit, but also in its southern part where the dykes are also offset (Figure 1C), which indicates a widespread reactivation throughout the kilometric Bou Skour shear zone. Therefore, the structural model of El Ouardi et al. [2016] was not taken into account and was arguably criticized by Aabi et al. [2021, p. 92].

Furthermore, El Ouardi et al. [2022] argue that the Bou Skour mining district appears to be well studied from a structural, magmatic and geochemical point of view, contrary to what was reported by Aabi et al. [2021].

In fact, in the introduction section of our paper [Aabi et al., 2021, p. 82], we have cited all previous work, including that of El Ouardi et al. [2016], pointing out that their studies have improved the geological knowledge of the deposit and guided the exploration activities in this area up to now. However, the structural analysis remains insufficient as long as El Ouardi et al.'s [2016] work is limited to the southern part of the deposit "Patte d'Oie district" without taking into account the structural framework and tectonic events at the regional scale. Based on our extensive field survey that integrated the available microstructural and geological data, we have provided, for the first time, a new structural map of the entire deposit, thereby upgrading and revising the structural knowledge of this mining area [cf. Figure 4, Aabi et al., 2021].

3. Stratigraphic control and age of the mineralized veins

El Ouardi et al. [2022] explain why their structural study [El Ouardi et al., 2016] was not integrated into a regional and global geodynamic framework by citing the lack of isotopic dates of the Bou Skour mineralization, at that time. They consider that the only stratigraphic marker was the rhyolitic dykes dated at 564 ± 7 Ma [Walsh et al., 2008a]. Instead, crucial well-dated outcrops occur in the southern flank of the Bou Skour district that were already available in the 1:50,000 Bou Skour map [Walsh et al., 2008a]. These outcrops expose conglomerates with interbedded mafic and felsic volcanic formations of the Upper Ouarzazate Group [556–548 Ma; Walsh et al., 2008b] in the hanging wall of the Tagmout normal fault above the rhyolitic dykes and the mineralized structures (NTGF; Figures 1A and 2A,B). This limits the age of mineralization to Ediacaran times and supports the claim that ore emplacement occurred during the latest phase of the Pan-African event [Bouabdellah et al., 2016, Aabi et al., 2021], thus excluding the post-Pan-African, Variscan or Alpine ages proposed by El Ouardi et al. [2016] and by previous au-

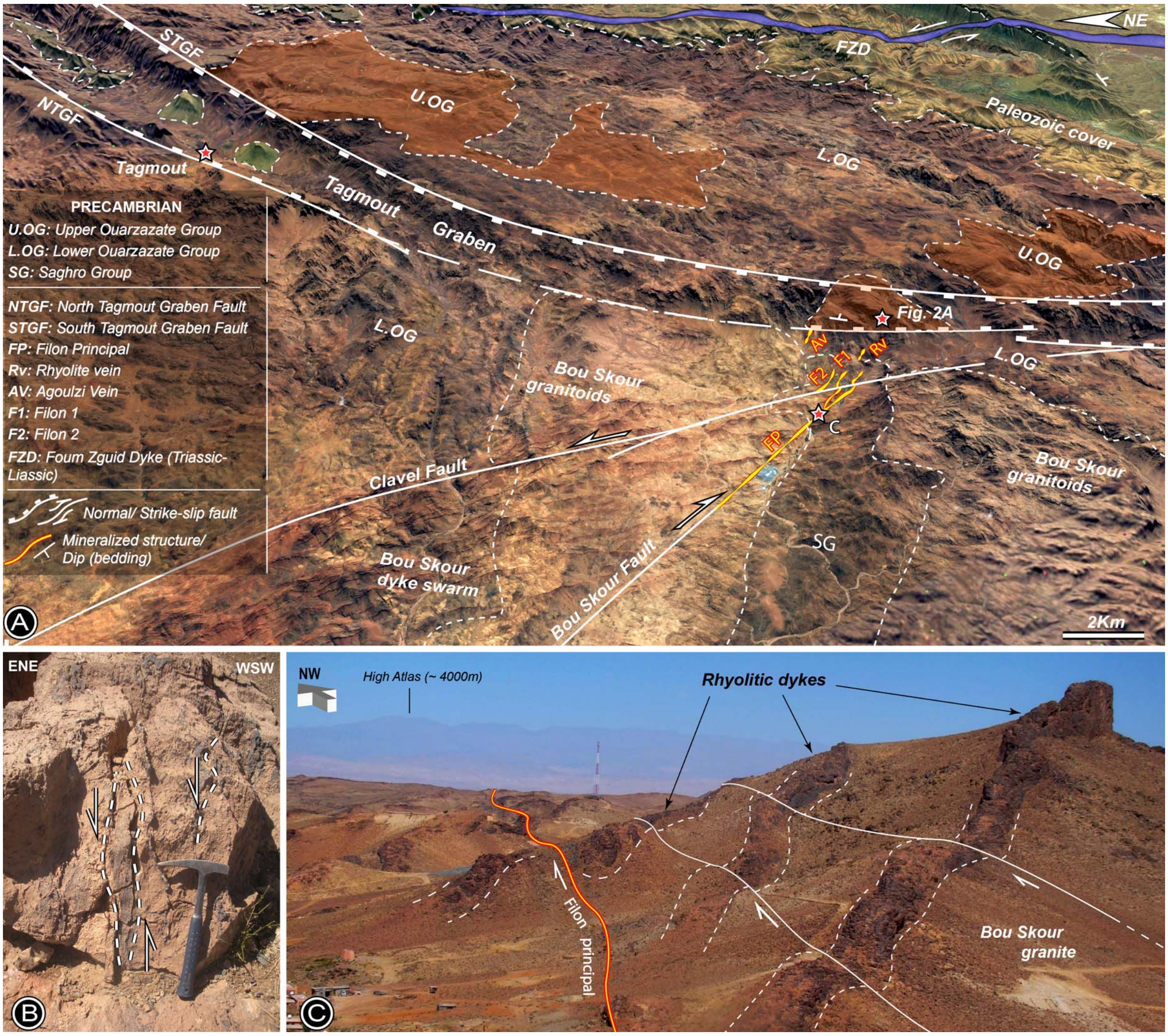

Figure 1. (A) Interpreted oblique "Google Earth" image of the Bou Skour–Tagmout faulted zone showing the distribution of NE to ENE major faults and their relationship with the NNW-trending Bou Skour mineralized structures. (B) Hydrothermal tension-gashes within the "Filon1" recording the first sinistral movement of the Bou Skour shear zone. (C) Ediacaran rhyolitic dyke dissected along the NNW-FP and its satellite faults showing the right-lateral strike-slip reactivation (southern "Chapeau de Fer" district). See "A" for location.

thors [Startsyne et al., 1975, Harfin, 1984, Maacha et al., 2011, El Azmi et al., 2014].

4. Late reactivation of the Bou Skour deposit, implications and conclusion

The late reactivation of the mineralized structures and any attempt of integration of the Bou Skour tectonics in the regional framework are considered by El Ouardi et al. [2022] as "two subsidiary points" that would not be mentioned to contradict their earlier results [El Ouardi et al., 2016].

However, unraveling the late tectonic evolution and its effect on the mineralized veins in the Bou Skour area should not be considered as a secondary and incidental result, as it makes available a well-

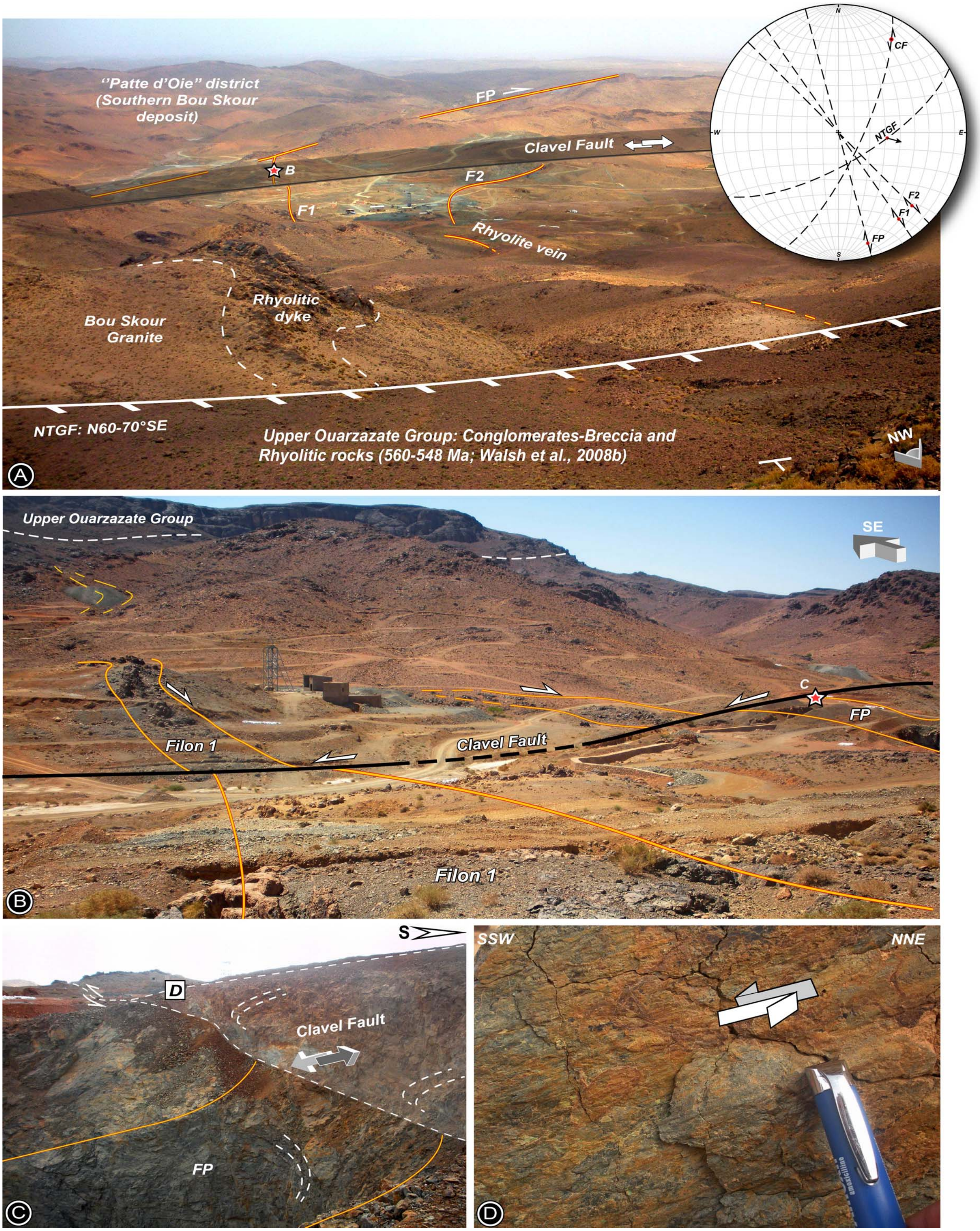

Figure 2. Caption continued on next page.

Figure 2 (cont.). (A) Panoramic view of the southern extension of the Bou Skour mineralized structures as well as the rhyolitic dykes hidden beneath the Upper Ouarzazate Group formations; stereographic representation of normal and strike-slip major structures (equal-angle, lower hemisphere); CF: Clavel Fault, NTGF: North Tagmout Graben Fault, FP: Filon Principal, F1: Filon 1, F2: Filon 2. See Figure 1A for location. (B) Post-mineralization deformation along the NNE-Clavel fault showing a left-lateral strike-slip movement (C) associated with subhorizontal slickensides (D). See Figures 2A and 2B for location of (B) and (C, D), respectively.

described example for a better analysis of the whole Saghro Precambrian domain. As a contribution to our project on the Saghro Massif [Aabi et al., 2017, 2019a,b, Hejja et al., 2020, Hejja, 2021], our recently published paper [Aabi et al., 2021] provides new ideas on the Bou Skour ore emplacement and related tectonic events and updates the assessment of its tectono-metallogenic context. The proposed late Pan-African tectonic control of the Bou Skour structures and the related structural criteria may have significant implications for further mining exploration in the wide Precambrian outcrops of the Saghro Massif as well as in the entire Anti-Atlas Pan-African belt. Describing the remobilization and deformation of the Precambrian mineralized structures along the major normal, reverse and strike-slip faults (e.g., Clavel fault; Figure 2A–D) offers a better understanding of the process of fault/vein networks during the superimposed orogenic cycles (Pan-African, Variscan and Alpine) in this part of the West African Craton.

To conclude, in their comment, El Ouardi et al. [2022] do not provide additional detailed fieldwork across the entire deposit than what was presented in their former paper [El Ouardi et al., 2016]. Likewise, they do not take into account the available stratigraphic control of the age of the mineralization [Walsh et al., 2008a,b, 2012, Aabi et al., 2021], and they unduly minimize the interest of unraveling the late regional deformation phases.

Conflicts of interest

Authors have no conflict of interest to declare.

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