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Comment on: The La Lucette Sb-Au-(W) vein-deposit (Armorican Massif, France): New time and genetic constraints to decipher the 310–295 Ma Sb-Au metallogenic peak in the Variscan Belt by Cheval-Garabédian et al. (2023)

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ABSTRACT

Recently, Cheval-Garabédian et al. (2023) published a paper in Ore Geology Reviews entitled “The La Lucette Sb-Au-(W) vein-deposit (Armorican Massif, France): new time and genetic constraints to decipher the 310–295 Ma Sb-Au metallogenic peak in the Variscan Belt.” Studies on Sb mineralisation are highly welcomed, especially in France, where there is a lack of updated data hindering a comprehensive understanding of this mineral system. The paper provides new mineralogical, fluid inclusion and geochronological data from historical collection samples of La Lucette mine, a mining site no more accessible since at least 40 years (Serment, 1978). These data, together with structural data from literature, lead the authors to build a metallogenic model related to dextral shear zone during the Carboniferous-Permian transition. The authors further argue for a single and unique 310–295 Ma Sb-Au metallogenic peak in the European Variscan Belt, a late Variscan hydrothermal event coeval with post-thickening tectonics (Munoz et al., 1992; Bouchot et al., 1997, 2005). This assertion is not correct. In this comment, we highlight that (i) several errors and approximations question the validity of their model, and (ii) the authors omit certain information that contradicts their metallogenic model. In our view, their data do not fully support the existence of a generalised and unique Late Carboniferous Sb-Au metallogenic peak in the French Variscan Belt. Furthermore, the idea defended by the authors that ore deposits occurred during dextral strike-slip tectonics that affected the area may better support a possible long-lived history during Palaeozoic times.

1. Errors, approximations and contradictions in constructing the metallogenic model

A careful examination of the article reveals several inaccuracies and omissions. First and foremost, the authors assert that the emplacement depth of the La Lucette Sb-Au-(W) deposit is comprised between 3.5 and 6 km, whereas their metallogenic model (as seen in the graphical abstract and Fig. 15 in Cheval-Garabédian et al. (2023)) indicates that this deposit is located at a depth of approximately 2 km. Furthermore, the thickness of the sedimentary sequence (i.e., from lower Ordovician to late Carboniferous) that constitute the Laval basin have been estimated at about 3.1 km (Le Gall et al., 2011). Since the deposit is mainly located

within the Silurian *meta*-sedimentary rocks and there is at least an erosional gap (hiatus) from Middle to Upper Devonian, the graphical abstract and Fig. 15 contradict the emplacement depth proposed by the authors in their abstract. This is a major inconsistency, which questions an interpretation of fluid pressure regime and pressure correction applied to fluid inclusion data, especially since the authors record supralithostatic fluid overpressure. Another confusing aspect is the structural framework depicted in Figure 3 from Cheval-Garabédian et al. (2023). The C-D cross-section of Fig. 3C in Cheval-Garabédian et al. (2023) is inaccurate in its current state and should be corrected. This cross-section is taken from Bastit (1930) and is parallel to the mineralised Georges vein and cuts a NW-SE trending unmineralised fault. The

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red line depicted in Fig. 3B from Cheval-Garabédian et al. (2023) is an interpreted non-mineralised fault, not marked in the mining plan, but incorrectly labeled “Mineralized Veins”. This kind of mistake may have harmful consequences in further mining exploration.

The metallogenic model proposed in the paper is widely based on a single U-Pb date obtain on apatite grains. We are well aware that absolute dating of such type of mineralisation is not an easy task and we do not question the validity of the U-Pb date. However, its significance in terms of Sb-Au ore deposition age should require a detailed discussion, which is not found in Cheval-Garabédian et al. (2023):

- The samples studied are coming from historical and museum collections, but their exact locations are not specified with respect to the 12 recognised lodes at La Lucette (Guiollard, 1995). Indeed, the use of samples from historical collections does not always allow for a rigorous contextualization of its mode of occurrence (i.e., only partial information are frequently available for each sample). Moreover, historical samples generally have a more spectacular nature than usual. Most of the lode veins of La Lucette seem to have geodic texture (Bellanger, 1921) and resemble to extensional vein (Pochon, 2014, 2017). Thus, the scheelite-stibnite-bearing breccia (dated in this paper) appears as a peculiar and uncommon ore facies, especially since the scheelite mineralisation was discovered by BRGM drill cutting in 1970s (i.e. at least 40 years after mine closure, Guigues, 1978) and are not located through the historically exploited veins of La Lucette. The structural features attached to the dated sample are unknown and consequently the representativeness of such brecciated facies for the whole mineralising system is doubtful. Is it a brecciated mineralised tension gash, a hybrid or a shear vein?
- The authors observed, for the first time, apatite grains in a quartz vein from the early stage of tungsten deposition. Apatite seems to postdate scheelite crystallisation (Fig. 5 from Cheval-Garabédian et al. (2023)) but shows no clear relationship with the other mineralised stages. The authors do not demonstrate the textural relationships between apatite and stibnite or gold. Furthermore, they do not show the relations between scheelite and the As-Fe stage. Consequently, the exact timing of apatite growth in the paragenetic sequence is not clearly identified, according to the authors’ own admission (see section 4.2): “...*Its more accurate position in the paragenetic succession remains difficult to estimate...*”.
- According to Douxami (1907) and Bellanger (1921), WNW-ESE oriented barren quartz veins subsequently crosscuts mineralised veins. The authors do not mention the presence of such late hydrothermal event and neglect to discuss its potential influence on isotopic resetting, which may affect mineralised veins. This oversight may have consequences for the interpretation of their age.

2. A generalised and unique Late Carboniferous Sb-Au metallogenic peak in the French Variscan Belt is not supported by the published data

The authors used the orientation of mineralised veins and their crosscutting relationships to demonstrate that all the Sb occurrences were emplaced between 310 and 295 Ma, as they state that their metallogenic model for the La Lucette deposit can be applied to all the other deposits in the Armorican Massif. However, several approximations and lack of consistency lead to some misunderstanding and an incomplete discussion, strongly impacting their interpretations and conclusions. Some key points are detailed below.

- Firstly, based on old underground mining plans, the authors interpreted the main Sb-bearing veins of the La Lucette deposit as en-échelon array of N25°E trend tension gashes developed along an N130°E striking dextral strike-slip fault. It is obvious that some of the mined veins have geodic textures (e.g., the Georges vein or their Fig. 4A) but without wall-rocks exposures, typology of veins (e.g.

extensional, hybrid shear extensional or shear) cannot be established yet. Describing the typology of a vein based solely on its orientation in mining galleries is a geological nonsense. Therefore, with their current structural data, the authors cannot assert that their samples came only from extensional veins. Moreover, the SE-directed dip of the La Lucette vein array presented in the Fig. 3B&C from Cheval-Garabédian et al. (2023) does not match vertical en-échelon extensional veins expected in a dextral strike slip regime. Moreover, other mechanisms than the simple shearing regional context might be evoked to explain the formation of these vein systems. Unfortunately, no other mechanisms are proposed nor discussed.

- Secondly, in Figure 14, it is essential for the authors to provide an explanation why the shortening direction aligns systematically with the mineralised veins of La Lucette, Ty Gardien, La Bellière, Les Brouzils, and Rochetréjoux Sb deposits (excluding the Le Semnon deposit). Are all those veins pure extensional veins? This has not been demonstrated in the cited literature. The kinematic reconstruction of Gumiaux et al. (2004) indicates that the Central Armorican domain (CAD) underwent a bulk N120-125°E oriented dextral simple shearing regime in which the finite shortening direction rotated clockwise from early (355 Ma) to late (300 Ma) Carboniferous. In such non-coaxial strain, the direction of principal infinitesimal shortening is of N165-170°E, and the latest tension gashes developed should strike parallel to this – and not N25°E-directed as these authors claim – as they must not have rotate after the ~ 300 Ma age proposed. Another trend, for late-Variscan tension gashes (earliest are deformed and rotated), may underline a control by a local principal stress direction. Thus, in the Variscan simple shearing tectonic setting, systematically aligning the shortening direction with Sb veins for almost all Sb deposits (as depicted in their Fig. 14A) is undoubtedly a mistake.
- Finally, in section 7.4, the authors are challenging the metallogenic model of the Le Semnon Sb-Au deposit from Pochon et al. (2016a, b, 2018). In our study, the timing of Sb ore deposition is interpreted as bracketed between 360 Ma (coinciding with the emplacement age of the dolerite dyke) and 335 Ma (the maximum age of the subsequent resetting). We do not understand why the authors want to challenge this age and refute our interpretation, as their data are not sufficient to do that. The authors seem to suggest that the La Lucette Sb-Au-(W) and Le Semnon Sb-Au deposits have the same emplacement age around 310–295 Ma. This assertion is wrong, as the mineralised veins in the La Lucette Sb-Au-(W) deposit cut across the regional cleavage, as reported by Douxami (1907); whereas the mineralised veins in the Le Semnon Sb-Au deposit are affected by the Variscan regional cleavage, as shown by Pochon et al. (2018). This first-order difference demonstrates that these two deposits cannot be contemporaneous.

Additionally, the authors have omitted important details that further weaken their interpretation. The authors ignore the emplacement age of two Sb occurrences. The age of the Saint-Aubin-des-Châteaux base metal-Sb-Au occurrence at ca. 359 Ma (Gloaguen et al., 2007; Pochon et al., 2019) is missing in their discussion, as well as the age of ca. 326–323 Ma of the Beslé Au-Sb occurrence (Pochon, 2017). These ages clearly indicate that all the Sb-Au deposits in the Armorican Massif were not emplaced during the same mineralising event around 310–295 Ma, as argued by the authors. Furthermore, recent literature (Tartèse et al., 2015; Tuduri et al., 2023) clearly demonstrated several fluid circulation events between ~ 405 Ma and 345 Ma in the CAD, precisely where the Le Semnon Sb-Au deposit and the Saint-Aubin-des-Châteaux occurrence are located. All the data are actually compatible with the occurrence of several Sb and/or Au mineralising events between 360 and 300 Ma, rather than with one single event between 310 and 295 Ma. This is further consistent with the long-lasting Paleozoic simple shearing event suffered by the CAD (Gumiaux et al., 2004).

In summary, the authors are using one single date obtained on a

single museum sample that cannot be accurately located within the La Lucette ore deposit to deny several pieces of evidence showing the existence of older Sb-Au deposits in the region. Such misuse of relevant data is for us a major scientific mistake.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Gloaguen reports financial support was provided by French National Research Agency. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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