Hercynian Granite and Related Mineralisation in Beni Snouss, Western Algeria

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Abstract. The purpose of this research is to describe the mineralisation related to the Hercynian granite located in western Algeria by combining geologic, tectonic, mineralogical and fluid inclusion studies. Quartz veins bearing sulphides occur in close spatial association with granitoids, which, representing hydrothermal activities associated with them. Visible but rare gold occurs in a very small quantity connected with arsenopyrite. Barite veins and stock works are developed in the granites where are observed at Mallal and Bouabdous. The vein varies in thickness from a few centimetres up to 2 meters, and their length varies from 10 up to up 100 m. Most of veins are N50 - N75 and 60 to 90 dip.

1. Introduction
Unlike European deposits whose mineralogy, fluid chemistry and age of emplacement are well-established, North African deposits, and more specifically those of Algeria, remain poorly understood owing to the lack of geochronological, fluid inclusion, and isotopic data.

The Beni-Snouss monzogranitic intrusion is a part of the Oranian magmatic Province [1], which is mainly characterized by several Late-Hercynian post-collisional granitic intrusions. The granite plutons selected for this study are associated with the late Hercynian phase and intrudes the Lower Silurian metasediments, which were affected by the major Hercynian folding phases [2]. Granitic rocks are mainly represented by two small bodies, about 1 km² each one, called from West to East: Tairet granite and Bouabdouss granite. Contact metamorphism is marked by the transformation of pelitic sediments to spotted hornfels showing quartz, biotite, muscovite, andalusite and cordierite association. Dikes of aplites, pegmatites and anodesites have been reported in the Beni Snouss area. These dikes postdate the calc-alkaline granite. In the Beni Snouss massif (Western Algeria), gold – quartz vein is linked with Hercynian granites and pegmatites. Here, free native gold is preponderant, while visible gold occurs in a very small arsenopyrite minerals, veinlets and echelon tension gash fillings.

The mineralized structures which consist mostly of quartz and barite occur principally as N110° to N140, and E-W-trending trans-tensional steeply dipping veins.

2. Geological Setting
The study region is located in the oriental part of the Ghar Rouban Massif. According to Lucas [2], the main geologic units (Figure 1) are Hercynian granites (late to post-tectonic 297 ± 1 Ma) and (ii) Silurian metasediments (mostly schists with subordinate quartzite and carbonaceous slates). The Tairet and...
Bouabdouss granites have been classified as alkaline granites [1]. The most important formations are Jurassic sedimentary rocks that show their maximum thickness along the oriental part of Ghar Rouban. The structural evolution of the district has been described by Elmi [2].

**Figure 1.** Geological map of Ghar Rouban district with the location of Pb-Zn-(Cu) and Ba deposits [1]

### 3. Petrography and Geochemistry

The petrography and geochemistry of the Beni Snouss batholith have been well described through multiple investigations [1, 3].

The Beni-Snouss monzogranitic intrusion is a part of the Oranian magmatic Province, which is mainly characterized by several Late-Hercynian post-collisional granitic intrusions. The composite massif consists of two different units of biotite-rich porphyritic granite: the coarse-grained monzogranite of Tairet and the medium grained monzogranite of Bouabdous with abundant microgranular enclaves, which are rare in Tairet.

They exhibit aporphyritic hypidiomorphic granular texture and contain a typically interstitial quartz and show undulatary extinction, perthitic K feldspar (orthoclase and microcline), plagioclase (oligoclase-andesine) biotite and some muscovite, tourmaline. Apatite, zircon and topaz are found as accessory minerals. Tourmaline is abundant in Tairet granite, (Figure 2).

The studied intrusion, represented by a composite association of granites with dark microgranular enclaves, has a typical high-K calc-alkaline evolution, with peraluminous trend. This association consists of crustal granitic magma and a dark, but felsic magma that had preserved a previous isotopic mantle source signature. Furthermore, this intrusion was affected by post-magmatic hydrothermal alterations, which developed greisenization effects.
4. Mineral deposits

The Beni Snouss district displays two types of mineral deposits:

- Quartz veins with Au occurrences, striking N50 E to N80E and dipping N to NW (average 65),
- Widely distributed and exploited Ba (Pb - Zn) veins (Bouabdouss.). These veins are hosted by Paleozoic sediments, and cut across the granitic stocks.

4.1. Quartz veins

The quartz-tourmaline veins and veinlets are typically either N110 -150 or E-W trending, with thicknesses ranging from 1 to 3 m and lengths of a few hundred meters. The veins are milky white (Figure 2D) to light grey. Several quartz occurrences are observed: grey and microcrystalline; white macrocrystalline and translucent with palissadic textures; or locally pyramidal. The ore minerals are mainly arsenopyrite and rare gold.

The hematite-bearing quartz veins are mainly composed of massive and euhedral quartz and hematite with minor amounts of pyrite and pyrrhotite. Locally, some mineralized veins occur as conjugate vein pairs and “en echelon” tension gash. Texturally, the veins display comb, laminated, breccia and crack and seal textures, suggesting that episodic, multiple mechanisms were important for trans-tensional vein formation. Small vug-filling disseminations of sulphides also occur within the quartz (Figure 3).

In the Beni Snouss massif gold – quartz veins are linked with Hercynian granites and pegmatites. Here, free native gold is preponderant, while invisible gold occurs in a very small arsenopyrite minerals. In both cases, the precipitation of invisible gold in arsenopyrite and pyrite by a possible (Fe, Au)3+= (As-S)3- substitution mechanism may have been facilitated by rapid, non-equilibrium conditions involving pressure decreases and wall rock reaction (sulphidation, carbonatisation), [4].

Figure 2. Field photographs of different types of granite showings: (A) grey granite; (B) greisenisation, (C) pink granite with tourmaline. (D) microscopy of pink granite
4.2. Barite veins and stock works

Barite veins and stock works are developed in the granites, and are observed at Mallal and Bouabdous. A few veins contain sulphide mineralization. The vein varies in thickness from a few centimetres up to 2 meters, and their length varies from 10 up to 100 m. Most of veins are N50 - N75 and 60 to 90 dip. They show massive, brecciated and druse textures.

The important minerals of the veins in the order of their abundance are barite, galena, chalcopyrite, pyrite and fluorite secondary malachite and azurite appear locally. Most of the barite is of a white colour but some is pink or even transparent. The pink variety occurs only in Tairet granite. The ore minerals are generally disseminated among barite in the veins. (Figure 4).

Chalcopyrite occurs as large (up to 5 mm in grain size) crystals disseminated in gangue barite or forms massive lumps with galena. Chalcopyrite is found as small grains and contains inclusions of grey copper and shows various oxidation products (covellite, chalcocite). Pyrite is present in minor amounts and occurs as small grains, disseminated among other minerals and has cubic form. Co and Ni, bravoite type.

**Figure 3.** Field photographs of different types of veins of Beni Snouss showings: (A) quartz veinlet; (B) Quartz vein, with hematite, (C) quartz and sulphides. (D) Analyse of quartz
Figure 4. Field photographs showing: (A) pink barite vein (B) microphotography of barite (C) microphotography of pyrite, (D) analyse of pyrite

Figure 5. Microphotographs of representative primary fluid inclusions in barite and quartz showing different shapes and sizes
5. Fluid inclusion study
Following microscopic observations, quartz, barite, were selected in the Beni Snouss area and were prepared as doubly polished using standard techniques. All inclusions were optically studied in order to outline the general characteristics of the fluid inclusion populations (primary, pseudosecondary or secondary) based on criteria proposed by Roedder [5]. Fluid inclusion microthermometric analyses were carried out using a Linkam THS 600 heating freezing stage calibrated using the techniques described in Shepherd et al [6].

The data (Table 1) are presented as last ice-melting temperatures, homogenization temperatures, wt. percent NaCl. Salinity data, expressed as wt. % eq. NaCl was calculated using the computer program.

6. Microthermometry
Microthermometric measurements of fluid inclusions in quartz were performed using a Linkam heating-freezing. The fluid inclusions present in quartz samples are all two-phase (L+V) liquid rich aqueous inclusions. They occur along growth zones (Figure 5) and along annealed fractures in the vein quartz indicating primary and secondary trapping. All the values of the eutectic temperature (Te) or first ice-melting range from -55 to -48 and indicating aqueous solutions of NaCl-CaCl2-H2O system [7] moderately hot with low salinity.

| Host mineral | T_h [°C] | T_e [°C] | T_m_ice [°C] | Salinity (wt % NaCl eq.) |
|--------------|---------|---------|--------------|-----------------------|
| Quartz       | 124 to 178 (40) | -53 to -45 (10) | -4 to -8 (19) | 10.30                |
|              | 178 to 240    |         | -35.5 to -18 (21) | 19.71                |
| Barite       | 120 to 164 (27) | -45 (1) | -14 to -10 (27) | 16.23                |

Notes: Numbers in parentheses refer to numbers of fluid inclusions analyzed; Te = eutectic temperature; T_m_ice = ice-melting temperature; T_h= total homogenization temperature.

7. Results and Discussions
The gold quartz veins are hosted by carboniferous granites. The homogenization temperatures (Th) of the aqueous inclusions range from 178 to 240 °C in quartz. They are ranging between 120 and 164 °C in barite. Data interpretation highlights that the circulation of two kinds of fluids has taken place in the Beni Snouss deposit:
- A fluid characterised by relatively middle temperature (mean 200 °C) and low salinity (15% NaCl eq) for quartz veins.
- A fluid characterised by relatively a low temperature (mean 100 °C) and relatively high salinity (21% NaCl eq) with barite and Pb-Zn sulphides.

8. Conclusions
The gold quartz veins are hosted by Carboniferous granites. Fluids may represent late magmatic fluids associated with greisenisation and mineralisation (Gold and sulphides). Barite veins hosted by granites are probably most recent (post Hercynian).

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