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# The Bi'r Tawilah deposit, central western Saudi Arabia: Supergene enrichment of a Pan-African epithermal gold mineralization

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ABSTRACT

The Bi'r Tawilah gold deposit in central western Saudi Arabia represents a Pan-African example of gold mineralization in which both hypogene and supergene ores are recorded. The sulphidic gold ore is hosted in intermediate to felsic intrusions that occur along the N–S trending thrust-fault zone within the so-called "Nabitah orogenic zone". There are four rock units present (from oldest to youngest): serpentinites and related listwaenites, diorites, granitic rocks and porphyries. Hydrothermal alteration consists of chloritization, sericitization, carbonatization and silicification and affects all rock types. Chloritization of biotite results in abundant rutile, whereas sulphidization coincides with carbonatization. The Bi'r Tawilah ore is confined to NW-trending shears (Riedel fractures) related to N–S slip of the pre-existing Tawilah thrust due to activation within the Najd fault system. Samples from the boreholes show macro- and microscopic evidence of shearing such as micro-shear planes and strain shadows of pyrite. Sulphides and gold are present in most rock types. Paragenetically, the sulphides consist of abundant pyrite and relatively lesser amounts of arsenopyrite, in addition to very minor chalcopyrite, sphalerite and galena. In all boreholes, it was noticed that the abundance of arsenopyrite increases with depth.

The elevated silver content of electrum (~13–22 wt%) at Bi'r Tawilah is typical of gold deposits and low-sulphidation epithermal deposits. The early mineralization stage took place in proximity to hydrothermally altered intermediate to felsic intrusions. The aerially restricted hydrothermal alteration by carbon-aqueous fluids led to ore remobilization in which gold amounts up to 4.3 g/t. Finally, gold enrichment (up to 5.4 g/t) resulted from supergene alteration that took place during weathering above the water table at a depth of ~20–25 m.



## 1. Introduction

Gold mineralization in the late Proterozoic Pan-African Arabian–Nubian Shield is of great interest for understanding the relationship of ore genesis and tectonics of the orogeny. In the Nubian Shield in Egypt and northern Sudan, gold mineralization in the Pan-African belt has different genetic types where the noble metal is encountered in different lithologies (e.g. carbonated ultramafics, gabbro-granite contacts, exhalative volcanic and associated VMS) that are all characterized by multiple metal sources (e.g. Surour et al., 2001; Kusky and Ramadan, 2002; Zoheir, 2008, 2011; Gabr et al., 2010). Recently, gold has been of particular interest for exploration and mining in the Arabian Shield of Saudi Arabia. Gold occurrences in the Arabian shield are widespread and most of these occurrences are known as sites of old workings developed on gold-bearing quartz veins, gossans and, rarely, placers (Botros, 2004). Some of these gold occurrences are ranked as ore deposits of economic significance and have been mined or are under evaluation, e.g. Mahd Ad Dahab, Sukhaybarat, Bulghah, Al Hajar, Jadmah, Hamdah, Ad Duwayhi and Bi'r Tawilah by the Saudi Mining Company (Ma'aden) and the Shayban prospect (CITADEL, 2008, 2009) (Fig. 1).

Primary gold mineralization in the Arabian shield can be grouped into three main types based on tectonic settings and host rocks (Harbi et al., 2006). The first type is associated with volcano-sedimentary sequences (e.g. the Siham Group or the early Hulyfah Group), including volcanogenic massive sulphide deposits (VMS) and epithermal base- and precious-metal deposits. Gold in some of the VMS deposits may have been re-worked by the Najd Fault System (transcurrent deformation, Fleck et al., 1976) where epithermal mineralizations are associated with some massive sulphide deposits (e.g. Mahd Ad Dhahab and Al Amar). The gold-bearing zones at Al Hajar gold mine were subjected to some

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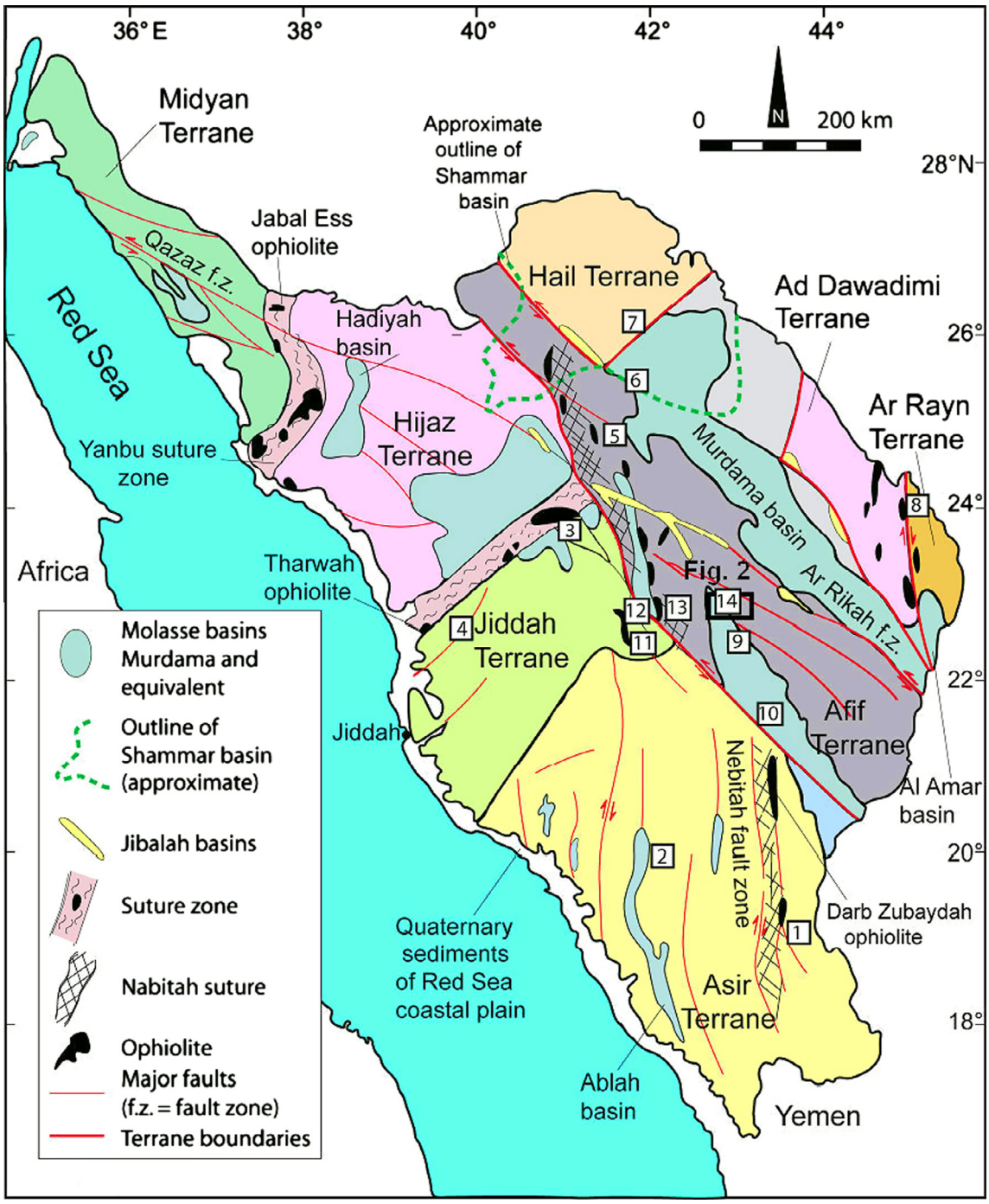


**Fig. 1.** General geologic map of the Arabian Shield showing major tectonostratigraphic terranes, ophiolite belts, sutures, fault zones, post-accretionary basins in the Arabian Shield of western Saudi Arabia (from Nehlig et al., 2002 with modifications by Johnson and Woldehaimanot, 2003; Stern and Johnson, 2010). Numbers represent locations of the major gold deposits as follows: (1) Hamdah, (2) Al Hajar and Jadmah, (3) Mahd ad Dhahab, (4) Jabal Shayban, (5) Humaymah, (6) Bulghah, (7) Sukhaybarat, (8) Al Amar, (9) Ad Duwayhi, (10) Um Matierah, (11) Ar Rjum, (12) Ash Shakhtaliya, (13) Zalm, (14) Bi'r Tawilah (including Jabal Ghadarah, Al Mansourah and Masarah).

supergene enrichment processes and gold was enriched in the oxidation zones that almost lack any sulphides. Dubé et al. (2007) distinguished two genetic models for Au-rich VMS deposits: (1) conventional syngenetic volcanic-hosted Au-poor VMS mineralization overprinted during regional deformation by Au mineralization; and (2) syngenetic VMS deposits characterized by an anomalous fluid chemistry (with magmatic input) and/or deposition within a shallow-water to subaerial volcanic setting equivalent to epithermal conditions. Lack of detailed mineralogical and microfabric studies for the Saudi VMS-related gold deposits does not allow researchers to affiliate them to one or both of the genetic models of Dubé et al. (2007). Recently, Mercier-Langevin et al. (2010) defined in their review a geometric mean gold grade for 513 VMS deposits worldwide of 0.76 g/t, and deposits with more than 3.46 g/t Au (geometric mean plus one geometric standard deviation) are considered auriferous. This latter category also includes some examples from Saudi Arabia such as the Nuqrah deposit with a gold grade of 3.80 g/t Au.

The second type of gold deposits is spatially associated with carbonatized ophiolitic ultramafic rocks (listwaenites), which