Ceramics, Oxides, Geomaterials

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SEM observation of gold in quartz vein from Atud ancient gold mine in central Eastern Desert of Egypt

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The wealth of gold in Pharaonic Egypt is legendary. The Eastern Desert of Egypt was long known as a gold mining district of the empire providing the precious metal since ancient times. Gold mining in this area dates back to predynastic times (*ca* 3500 BC) and continued during Old to New Pharaonic dynastic Kingdoms (2700 to 1070 BC) and later different times throughout the history of Egypt. This area is belonging geologically to the Precambrian basement of the Arabian Nubian shield which extends from the river Nile eastwards towards the Arabian Peninsula. It extends as a belt parallel to the Red Sea coast for a distance of about 800 km along Egypt's eastern edge hosting all the known locations of gold deposits in Egypt which is about 250 gold mining sites spread over the whole area [1].

The gold was extracted from quartz veins of various dimensions in open-pit and underground workings. The quartz veins are sheet like body of crystallized silica precipitated from hydrothermal fluids in shear zones, faults and fractures within the metasidements and related rock of basaltic and dioritic origin [2]. The native gold is spatially associated with these veins and occurs in most cases as minute specks and discrete scattered flakes within the vein or as small inclusions in sulphides particularly pyrite and arsenopyrite [3].

The Atud area (latitude 25° 00' 10" N and longitude 34° 24' 10" E) located at 638 km (as the crow flies) south east of Cairo and 58 km west of the town of Mersa Alam on the Red Sea coast "Figure 1a." is one of several ancient dominant gold vein deposits in central Eastern Desert of Egypt. This area is centred on *Jabal* (hill) Atud shown from a bird's eye view perspective in "Figure 1b." and a corresponding geological map in "Figure 1c." and depicted in a photograph in "Figure 1d.". In this area a number of gold-bearing quartz veins are concentrated mainly in three localities, referred to as the main Atud. The average thickness of the veins in Atud is about 70 cm. The gold content of the mineralized veins varies considerably even in the same vein, it may reach a maximum of 467–1203 ppm. However, the average does not usually exceed 11–30 ppm [4]. The mine was first excavated during Pharonic time but no ore is produced since then, between 1953 and 1969, the Egyptian Geologic Survey and Mining Authorities (EGSMA) performed underground prospecting work in the main Atud site through three expeditions [5].

In this study we report SEM and EDS investigation of a sample cut using a geological hammer and crowbar from a quartz vein "Figure 1e." which cropped out inside surface of the first level entered from the northern side of the mine shown in "Figure 1f.". The samples for microscopic observations were cut from the bulk sample then grind, polished and ultrasonically cleaned. The SEM used in this study is FEI Inspect-S50 supplied with Quantx Bruker EDS spectrometer. The samples were observed at low vacuum of 0.45 Torr and the SEM operated at 20 keV accelerating voltage.

Depicted in "Figure 2a." illustrating gold specks of various morphologies, our observations showed that these specks ranged in maximum-lengths from 3.4 μm to 9.2 μm. A typical obtained EDS spectrum from such specks is shown in "Figure 2b.". However, due to the erratic presence of specks and their distribution of sizes, more specks must be measured to obtain a reliable histogram. In addition we should not exclude that gold may occur in "invisible form" as solid solution or submicron specks which is harder to observe. The possible origin of this gold mineralization in Atud area was related to fluid phase separation, sulphidization and carbonatization of the host dioritic rocks during hydrothermal alteration and mineralization [5]. In conclusion, we had demonstrated the versatility of using SEM-EDS in the assessment of a gold bearing quartz vein in Atud ancient mine.

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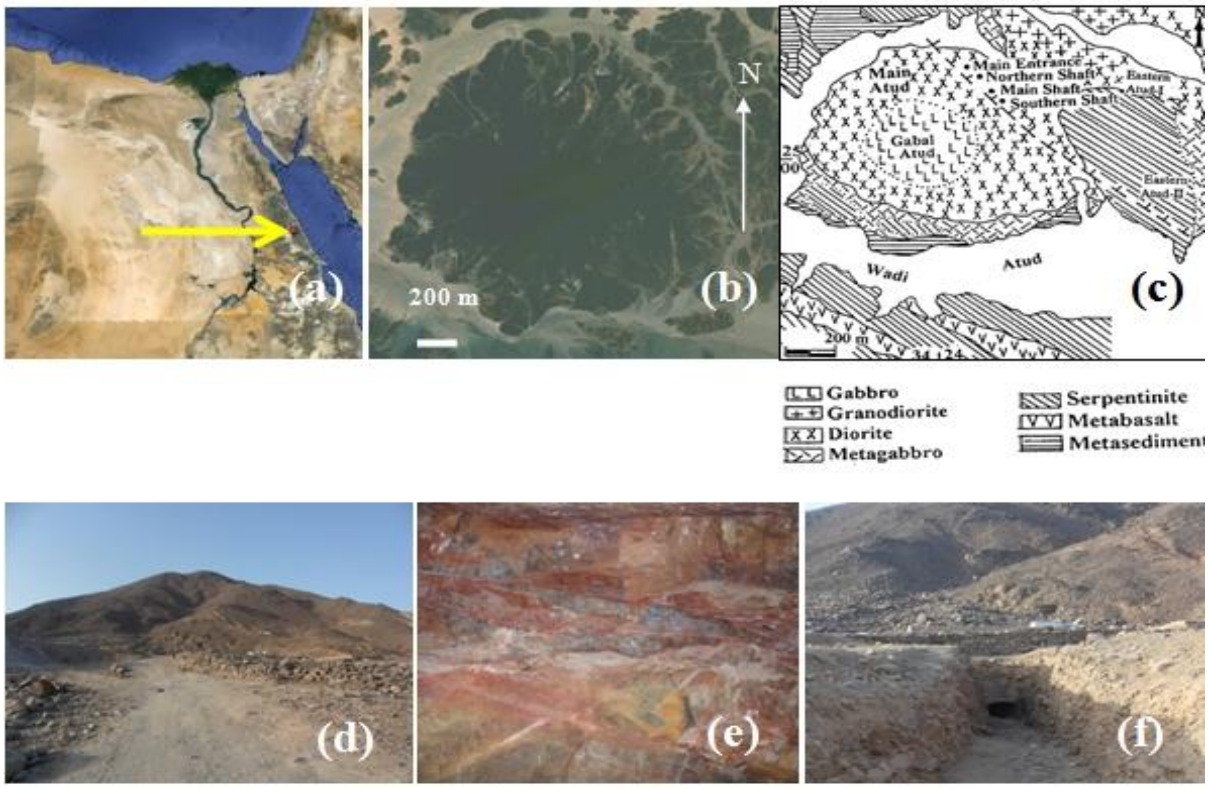

Figure 1. (a) A location map of Egypt with an arrow pointing to the Atud area in central Eastern Desert (Google Maps). In (b) a view at eye altitude of 6 km of the *Jabal* Atud (Google Earth) and in (c) a geological map of *Jabal* Atud [5]. In (d) the north side of *Jabal* Atud and in (e) the gold bearing quartz vein from the first level entered from the northern entrance shown in (f).

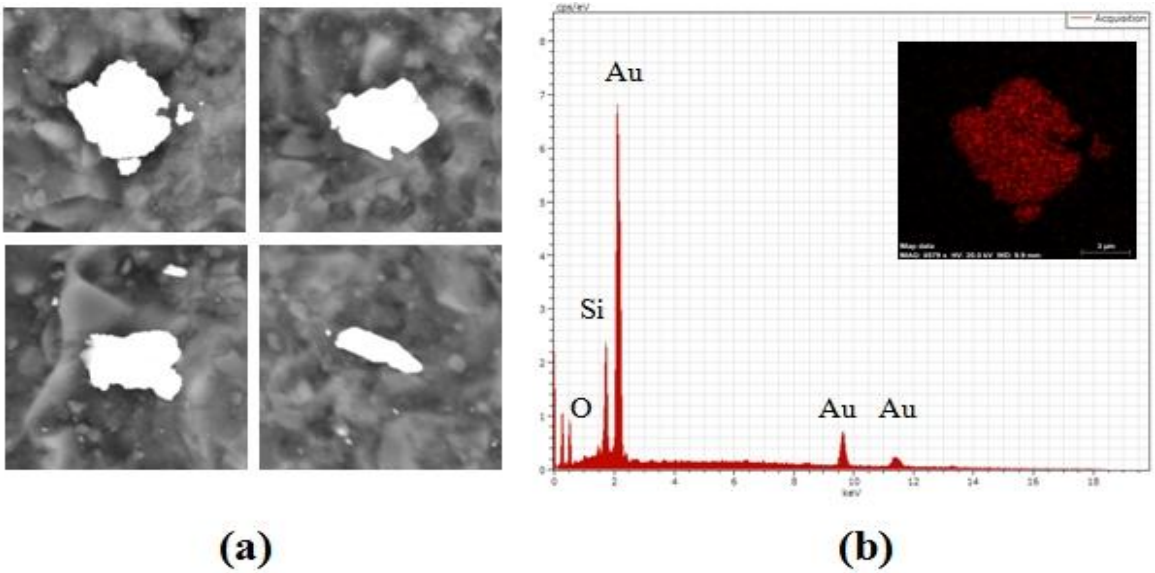

Figure 2. In (a) backscattered electron micrographs each has a side of 20μm (magnification of x5000) depicting the different morphologies of observed gold specks and in (b) EDS spectra obtained from the gold speck shown in the first micrograph in (a), with the inset showing the Au elemental mapping of this speck