УДК 553.41:32

Late-orogenic gold deposits in the north-eastern part of the Arabian-Nubian Shield

Hani E. Sharafeldin

Abstract The Arabian-Nubian Shield, located at the northern end of the East African Orogen, is an extensive Neoproterozoic collision zone of thrusts that forms a tectonic zone formed by rocks of the ophiolite association and volcanogenic-metasedimentary deposits. Gold ore mineralization is associated with quartz veins in granites. In all quartz gold-bearing veins, gold is in association with pyrite or with aggregates of pyrite and arsenopyrite. The zones of the veins consist of massive quartz with scattered gold and sulfide minerals. Among the rocks containing mineralized veins, sometimes serpentinized ultramafics, metamorphosed volcanic and sedimentary rocks with intrusive gabbroids and granitoids predominate.

Keywords: Arabian-Nubian Shield, collision zone, East African Orogen , gold-quartz-sulfide formations, gold-quartz veins, Late Proterozoic, volcanogenic-metasedimentarydeposits.

1. Introduction

The Arabian-Nubian Shield occupies the northeastern part of Africa and the western part of the Arabian Peninsula) (Fig. 1). There is now general agreement that the Arabian-Nubian Shield represents one of the best documented examples of Late Proterozoic to Early Paleozoic 950-450 Ma age; The Late Proterozoic Pan-African rocks occupy about one tenth of the land surface of Egypt. They form mountainous terrains in the Eastern Desert and south Sinai, as well as a limited area in the southwestern corner of the Western Desert (Oweinat area).

2. Evolution of the Nubian Shield in Egypt

The gold-bearing territory of Egypt lies within the north-eastern part of the African platform. Most of the territory is composed of rocks of the Nubian-Arabian shield. The Arabian-Nubian Shield is located at the northern end of the East African orogenic area and is an extensive Neoproterozoic conflict zone. The rocks of the foundation of the Arabian-Nubian Shield in the region of the Eastern Desert of Egypt between the Nile valley and the Red Sea coast form a tectonic wedge of northern latitude. They are represented by ophiolite and island-arc associations of rocks and intrusive complexes formed in the conditions of the continental margins (andesitic-rhyolites) and under platform conditions (tonalite-granodiorites) (Fig. 2).

Hani Elsayed Sharafeldin, Post-graduate Student at Russian State Geological Prospecting University n. a. Sergo Ordzhonikidze (MGRI-RSGPU), Moscow Russia, ,hanisharfeldin@gmail.com

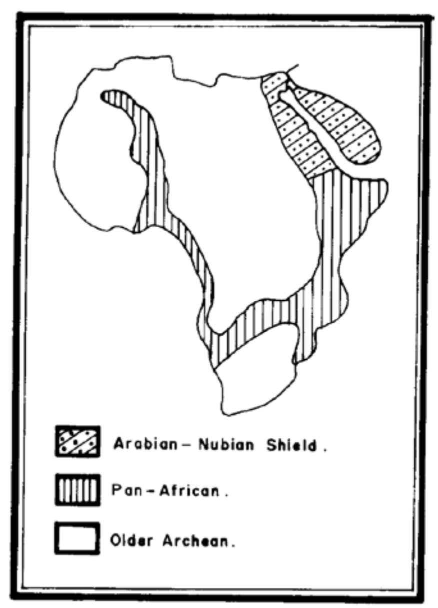

Fig. 1 Distribution of the Pan-African rocks [3].

ISSN 2229-5518

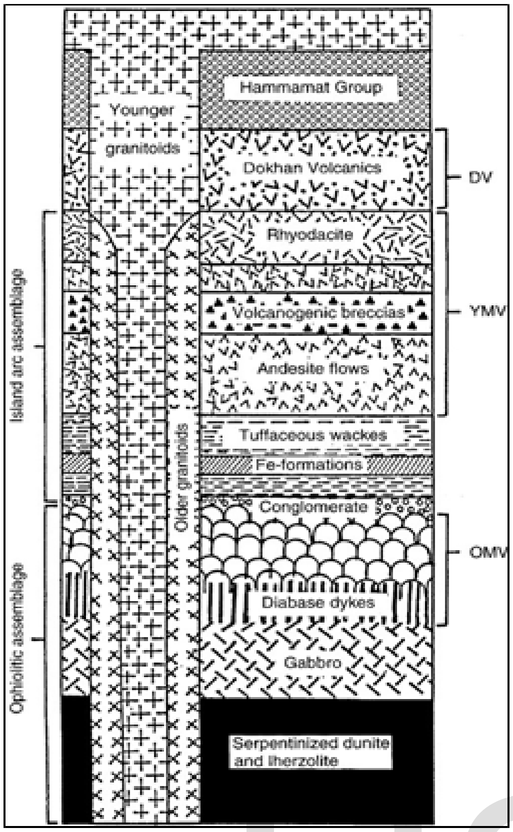

Fig. 2. Formations of rocks of the Eastern Desert of Egypt: OMV - Early Proterozoic metavolcanic, YMV - Middle Proterozoic metavolcanic, DV - Neoproterozoic volcanogenic rocks of the Dokhan formation. [7].

Among the faults are faults of the north-western, north-eastern, latitudinal and meridional directions. The faults that limit the grabens of the Red Sea, the Suez and the Gulf of Aqaba belong to the fault system of the East African rift zone, which extends from Egypt along the Red Sea coast and further to the south. The rift zone is characterized by complex tectonic development and represents a re-activated by the Riphean movements the block of the Proterozoic basement of the African platform, formed in a trough that covered the south-western part of Saudi Arabia and the eastern part of Egypt. This Riphean folded belt in which the granitoid massifs are widely developed is a large thrusting tectonic structure with an eccentric arrangement of the plates of ancient metamorphic volcanogenic and clastic rocks, complicated by left-side shear dislocations (Fig. 3).

The ultramafic rocks associated with ophiolites are mainly converted into serpentinites and rocks of a chlorite-carbonate composition. Serpentinites and talc shales with interlayers of phyllites and graphite schists are serpentinite melange, characteristic of ophiolite complexes of the ancient oceanic crust.

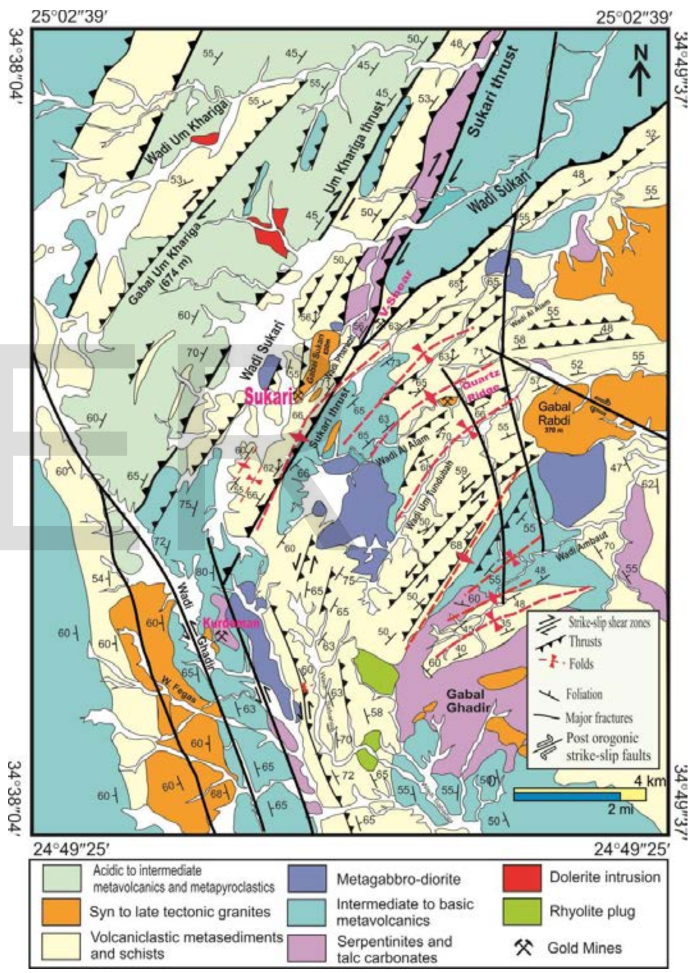

Fig.3. Geological map of the gold ore region of the Eastern Desert of the Arabian-Nubian Shield [8]

The early granites, which are part of the Precambrian basement, and young granites of the Early Cambrian and younger age, were formed in the zones of tectonomagmatic activation. Many rare metal deposits of tantalum, niobium, and lithium are associated with the ancient cyanogenic rocks (1000 million years old). The massifs of the rapacious granites (540-435 million years) are confined to tectonic zones of Upper Riphean activation and are characterized by increased alkalinity. There is a spatial relationship between the metasomatic halos of the carbonatization of ultramafic rocks, granite intrusions embedded in them, and the mineralization of gold.

Granite intrusions that were formed on contact with ultramafic rocks acted as a source of heat flow, which facilitated the migration of fluids. These fluids leached gold from the enclosing rocks and deposited gold within the permeable tectonic zones [10]. The concentration of gold in carbonatized metavolcanic rocks is three orders of magnitude higher than in unaltered ultramafics, which indicates the role of alkaline carbonate metasomatism in the formation of gold deposits.

3. Gold deposits in the Eastern Desert of Egypt

More than 110 gold deposits are known in the Northeast of the territory of the Arabian-Nubian Shield (Figure 4). Gold mineralization is common in the rocks of the crystalline basement throughout the Eastern Desert of Egypt, with the exception of the extreme northern part. Almost all authors note the spatial relationship of gold mineralization in the Eastern desert with granitoid rocks, among the Archean mafic and ultramafics. The age of calcium-alkaline granitoids is determined to be 559 ± 6 Ma. [1, 2]. Deposits of gold-quartz-sulfide ores in small magmatic bodies determine the metallogeny of gold from the Arabian-Nubian Shield.

It is established that the vast majority of gold deposits are confined to metasomatically altered granite plutons and Carbonatized Precambrian volcanic-sedimentary rocks of the Pan-African cover. Deposits of gold are usually localized in faults, feathering deep faults of the northwest orientation [5].

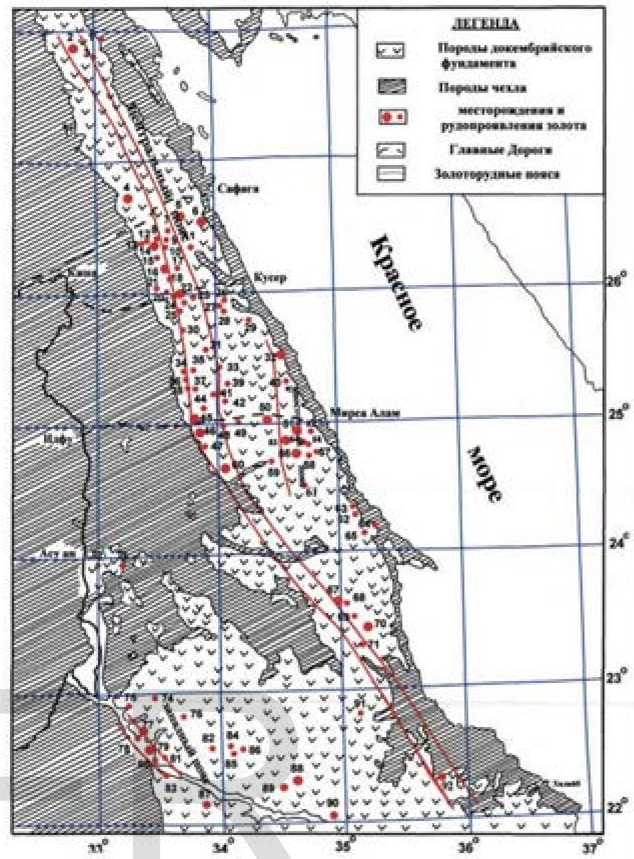

Fig. 4. The scheme of the location of deposits and ore occurrences of gold in the Eastern Desert of Egypt [7].

The known gold deposits are mainly represented by gold-quartz veins with sulfide mineralization. Gold-quartz veins cross the various rocks of the Precambrian basement, which forms part of the Arabian-Nubian mountain massif. Since most known gold deposits are confined to quartz veins, historically researchers have focused on this type of deposits. Deposits are combined into goldore belts of the north-western direction. The eastern belt adjoins the contact of the basement rocks and is confined to the gold deposits of Umm Rasa, Atida, Sukari, Khangali, Umm Ida and a number of ore occurrences.

An example of the manifestation of gold-quartz-sulfide formation has the Sukari deposit. The deposit of Sukari has

ISSN 2229-5518

located 15 km to the west-southwest from the coast of the Red Sea. It is localized in the border area of the folded Riphean belt of the late Proterozoic rocks (900-650 Ma) of the Arabian Nubian Shield [5]. Formation and stabilization of the rocks of the folded belt cover the entire period of Pan-African orogeny.

The ore deposit of the Sukari deposit is composed of volcanic-terrigenous rocks and granite massifs. The ore-bearing array of calcium-alkaline granitoids is located in a thick stratum of comparatively plastic shales, andesite and dacite tuffs, subordinate lavas, and also small lenses and bodies of serpentinites. (Fig. 5). In this case, the separation of granitoid bodies corresponds to the stratification of sedimentary rocks, which is connected with the granitization of the enclosing rocks.

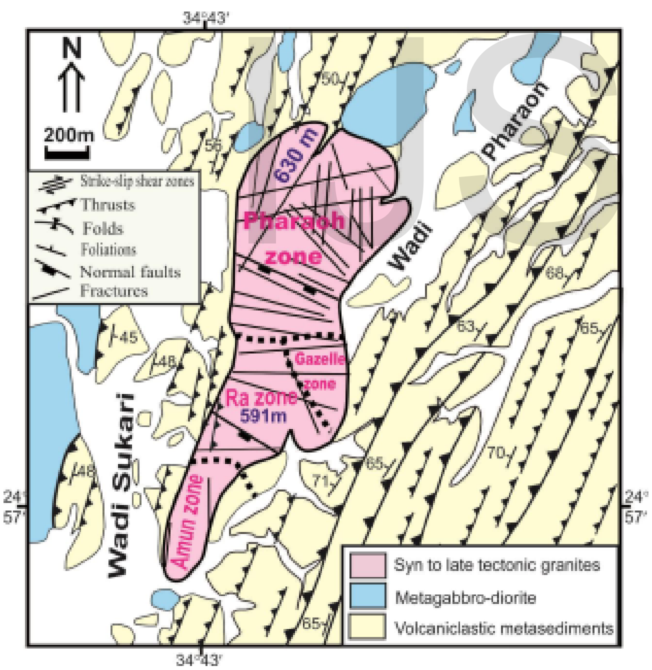

Fig.5. Geological map of Sukari intrusive massif [8]

Granitization of rocks is associated with the ore-bearing granitoid massifs, which is observed in some gold deposits of the world. Granitoid massifs are located between the two junction faults of the submeridional and northeastern directions, as well as associated contact discontinuities, which serve as local ore-controlling disturbances. The granitoid massif extends from the north-north-east to the southsouthwest by 2.3 km. In the northern, the widest part of its diameter reaches 700-800 m, in the south, it is reduced to 100-150 m [9].

Gold mineralization is localized in array of Late Proterozoic granites, whose age is 559 + 6 million years. At the same time, according to the rubidium-strontium analysis, the age of gold mineralization dates back to 522 + 12 million years [4].

The granitoids are intersected by pre-ore, but slightly mineralized, discontinuities of the sublatitudinal series. They are located less than 30-50 m from each other. In addition, cracked disturbances of the submeridional direction are manifested. Quartz veins with sulfides also gravitate to discontinuous structures inside granitoid bodies.

It is in this structural lattice, between relatively densely located pre-ore disturbances, that ore bearing fissured bundles and mineralized zones of gold-quartz veins were formed.

The veins consist mainly of a massive with a milky hue or gray-white quartz. In many cases, quartz is two generations; the early breccia of milky quartz, which usually does not contain gold and late gray quartz, in cement debris which is usually gold-bearing.

The ore veins are in contact with granitoids (mainly granodiorites) with mafic-ultramafic rocks or in granites, where they are confined to shear zones that complicate tectonic contacts. Gold-quartz veins are structurally controlled by fault planes or zones of intense fracturing. They can be localized as a series of veins inside the barrel with clamps. The main veins have a thickness of 0.6 to 5 m, always accompanied by a series of parallel veins and form ore zones of considerable power compared to veins (Fig. 6).

In all quartz gold-bearing veins, gold is in association with pyrite or with aggregates of pyrite and arsenopyrite. The zones of the veins consist of massive quartz with scattered gold and sulfide minerals. Among rocks that contain mineralized veins, sometimes serpentinized ultramafics, metamorphosed volcanic and sedimentary rocks with magmatic rocks can be found. In the vein zones, local aureoles of hydrothermal changes with a thickness of 1-2 m on either side of the veins are noted and they are represented by sericitation, chloritization, and pyritization. Hydrothermally altered rocks belong to the metasomatic formation of berezites and are also gold-bearing. Gold in the ore is mainly in native form or is present in gold-bearing pyrite. The gold content is variable in one vein. A noticeable increase in the gold content was noted where veins or host rocks are filled with finely dispersed aggregates of graphite.

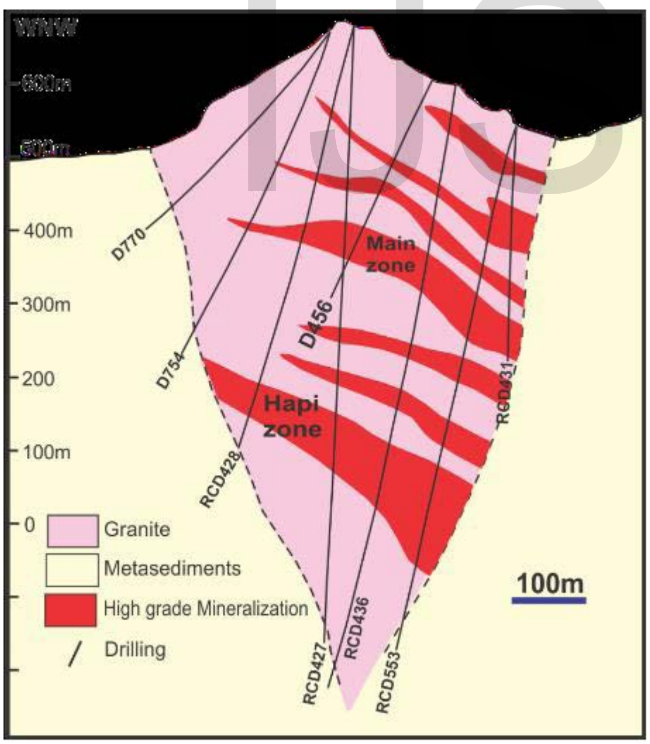

Fig. 6. Geological section of the ore zone 'Ra' of the Sukari deposit [8]

The average gold content is 11 to 30 g / t. Silver is always present in association with gold. In ore veins, there is a perceptible amount of sulfide ore minerals, mainly pyrite, arsenopyrite, sphalerite, chalcopyrite, galena and pyrrhotite [Kochen and El Basuni, 1968]. Pyrite is the most common sulfide and predominates over arsenopyrite. The high content of gold in the ore is associated with an increased concentration of arsenopyrite. Submicroscopic crystals and thin sulfide and gold deposits are noted in quartz veins, cracks, and tectonic breccias. Pyrite is found in all mineralized zones. Pyrite crystals are sometimes found in the 'shirt' of brown goethite and hydrogeothite in the pores of rocks or in open fissures that have undergone superficial chemical weathering. Arsenopyrite is a common mineral in the mineralized zones with high gold content and is usually present in the ore body and in the areas of tectonic brecciation of rocks. Arsenopyrite partially consists of open cavities of cracks and small quartz veins, where arsenopyrite forms idiomorphic crystals (sometimes in the form of needles in crosssection) in thin quartz fringe veins and in fringing breccia fragments.

Minerographic studies of ores have shown that the inclusion of pyrite in arsenopyrite and/or microinclusions of arsenopyrite in pyrite indicate that they belong to a single paragenesis [5]. Minerals contain numerous inclusions of rutile, which suggests their formation as a result of sulfidization of preexisting rocks at the hydrothermal stage. In the mineral aggregates of pyrite and arsenopyrite, micro deformations, as well as breccia textures, are manifested.

Native gold, as later, fills veins and micropores in deformed aggregates of pyrite and arsenopyrite. Other sulfides, such as galena, chalcopyrite, sphalerite, pyrrhotite in the ore are secondary. Some pyrite crystals contain relicts of pyrrhotite and chalcopyrite, which presupposes the formation of pyritization haloes over the previously existing pyrrhotite and, probably, chalcopyrite. Galena is rarely present in the form of large crystals in milky white quartz veins and areas with gold mineralization. Sphalerite is sometimes more extensive than other sulfide minerals. Chalcopyrite grains are randomly distributed in sphalerite aggregates. The sphalerite-chalcopyrite association fills and replaces earlier pyrite precipitates. The galena observed in pyrite appears to belong to the one-aged to sphalerite and chalcopyrite mineral association.

4. Conclusions:

The predominant type of Precambrian gold mineralization of the Northeastern part of the Arabian-Nubian Shield is gold-quartz and gold-sulfide-quartz ore veins associated with zones of increased tectonic permeability of the crust and the presence of rocks - derivatives of acid magmas and sulfide fluid systems. In this connection, the following factors that determine gold-quartz-sulfide mineralization can be:

- an important role of granitization or magmatic replacement in the areas of ancient rifting, which led to the formation of gold-bearing granite-greenstone ore-bearing belts of the Arabian-Nubian Shield;
- Precambrian gold deposits have passed the stages of metasomatic calcium-alkaline changes, and ore - regeneration in successive epochs and phases of Riphean tectonic ore formation and formation belonging to deposits.

5. References

[1] Amin M.S. Geology and mineral deposits of Umm Rus sheet; Geological Survey of Egypt, Cairo. 1955.

[2] El Shazly, E.M., Classification of the Egyptian mineral deposits, Egypt. Egyptian Journal of Geology, 1957. Vol. 1: pp. 1-20. Cairo

[3] Engel, A.E.J., Dixon, T.H. and Stern, R.J., 1980. Late Precambrian evolution of Afro-- Arabian crust from ocean-arc to craton. Geol. Soc. Am. Bull., 91: 699--706.

[4] Ghoneim, M.F., Bjørlykke, A., Harraz, H.Z., Rb–Sr and Sm/Nd Isotopic Systems of El Sukkari Granite, Eastern Desert, Egypt. 1st International Conference on the Geology of Africa, Assiut, Egypt, 1999.1, pp. 281–282.

[5] Helmy, H.M., Kaindl, R., Fritz, H., The Sukari gold mine, Eastern Desert-Egypt: structural setting, mineralogy, and fluid inclusion study. Mineralium Deposita, 2004. 39, pp. 495–511.

[6] Kochin G.G., Bassiouni F.A. The mineral resources of the UAR, Report on generalization of geological data on mineral resources of the UAR carried put under contract 1247 in 1966-1968, part I, Metallic minerals: Internal report, Geol. Surv. of Egypt, 18/1968.

[7] Mohamed, F.H., Moghazi, A.M. and Hassanen, M.A., Geochemistry, petrogenesis and tectonic setting of late Neoproterozoic Dokhan-type volcanic rocks in the Fatira area, eastern Egypt. International Journal of Earth Sciences, 2000.88, pp. 764-777.

[8] Mohamed A. Abd El-Wahed, H. Harraz, M. H. El-Behairy, Transpressional imbricate thrust zones controlling gold mineralization in the Central Eastern Desert of Egypt., Ore Geology Reviews. 2016.78, pp. 424–446.

[9] Nekrasov E. M., Dorozhkina L. A., Dudkin N. In. Features of Geology and structure of the largest gold deposits of endogenous class. Moscow: Astrea-centre, 2015. - 192 p.

[10] Takla, M.A., El Dougdoug, A.A., Rasmay, A.H., Gad, A.A., El Tabbal, H.K., Origin of Um Eleiga gold mineralization, south Eastern Desert, Egypt. Egypt. 1990. Mineral. 2, pp. 3– 20.