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Chapter

Perspective Chapter: History and Classification of Gold Mineralization in Egypt

Refaey El-Wardany and Jiangan Jiao

Abstract

Gold deposits and occurrences are spread over a large number of sites which covered by Precambrian the basement rocks in the Eastern Desert of Egypt, and the gold exploration and mining activities had been districted since ancient times. The ancient Egyptians extracted gold from quartz veins of various dimensions in open pits and underground workings. Consequently, gold production in Egypt seems to have started as early as the predynastic times (about 6000 BCE) from Pre-and Early Dynastic times to Early Arab Period. In the modern days, Egyptian mineral resource authority announced many big international bid-rounds for Gold Exploration and associated minerals was launched to open the minerals sector to foreign investment in the mining industry. Many studies have been achieved to classify the gold deposits in Egypt based on various characteristics such as the nature, occurrences, type of host rock, tectonic setting, metal association, fluid inclusion, and the tectonic environment of mineralization. Gold deposit in Egypt still need more geological and mining studies to understand the gold system types, additionally, to get answers regarding to source, transportation, traps, and host rocks, as well as the whole challenges in mining sectors.

Keywords: gold deposit, Eastern Desert, gold exploration, classification of gold, ancient Egyptians

1. Introduction

The Arabian-Nubian Shield (ANS) is one of the largest and best-recorded outcrops of Neoproterozoic Juvenile rocks on the Earth (950–450 Ma), the ANS developed during the collision between East and West Gondwana with the closure of the Mozambique Ocean (Pacific-sized Ocean) at the north part of the East African orogen (EAO) (**Figure 1a** and **b**). The East African Orogen is a part of the Pan-African orogenic cycle that extends from the north by ANS to the south of the Mozambique belt. The Pan-African Orogeny was a period of major crustal accretion and a part of the Neoproterozoic Gondwana supercontinent; it affected Gondwana and several regions in Laurasia [2, 5–9]. The Egyptian Nubian Shield (ENS), the basement rocks of Egypt comprise covers 100,000 km² (about 10% of the total area of the country), exposed mainly in the southern Sinai Peninsula, the Eastern Desert parallel to the eastern flank of the Red Sea coast, and the Western Desert at Gabal Oweinat. Commonly, the Eastern Desert are divided into three distinct lithotectonic

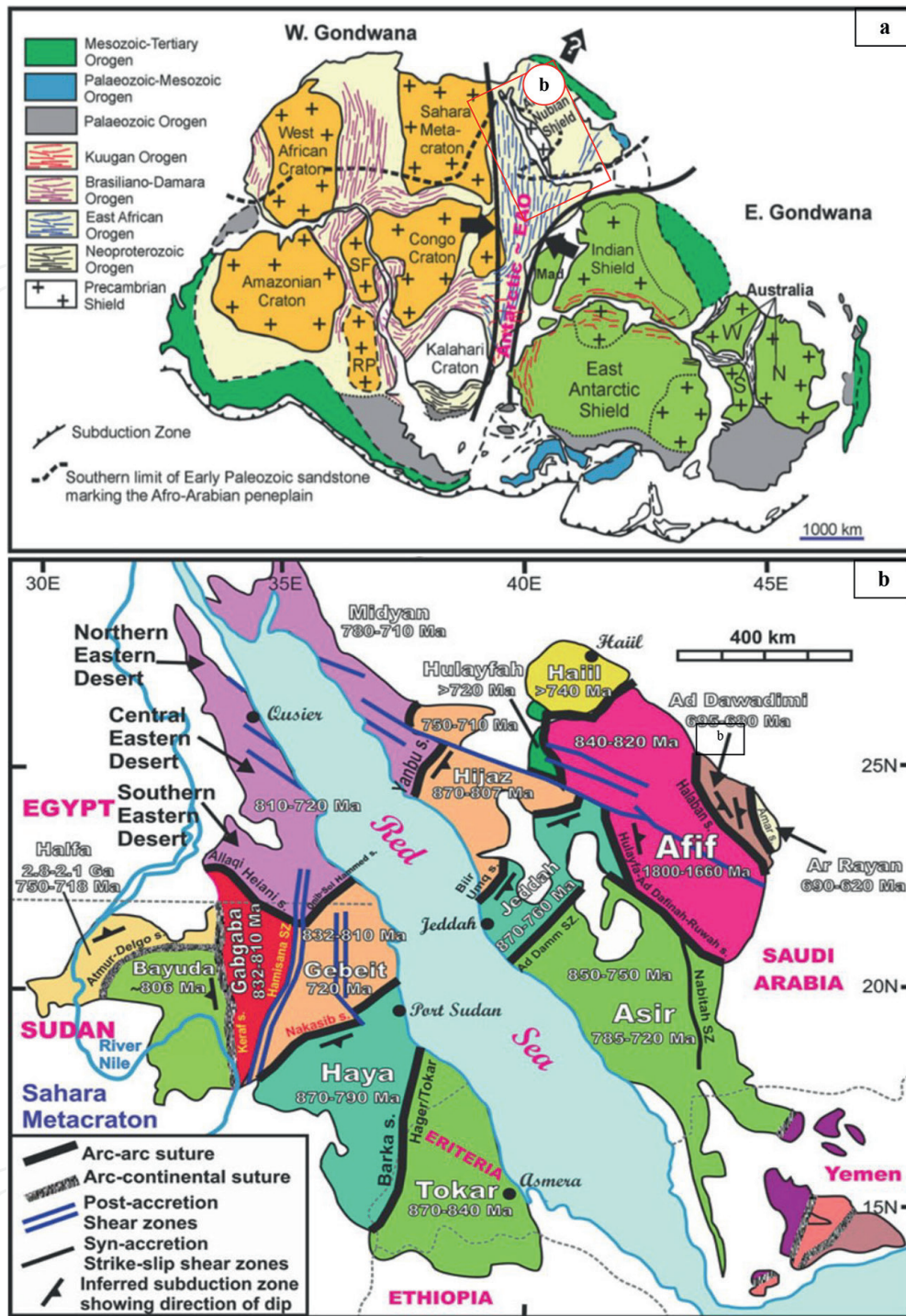


Figure 1. (a) Showing the Gondwanaland supercontinent after [1], (b) Showing locations, terranes, and sutures of Arabian-Nubian shield after [1-4].

domains as specific: Northern Eastern Desert (NED), Central Eastern Desert (CED), and the Southern Eastern Desert (SED) (Figure 2a) [11-15]. The basement complex in the Eastern Desert is composed of a heterogeneous rock assemblage; it can be classified into two major units (Figure 2b). The lower tectonostratigraphic unit (infrastructural unit) of the old continental margin comprises medium to high-grade metamorphic gneisses and migmatites, psammitic schists (e.g., Meatiq, Migif-Hafafit, Sibai, and El-Shalul domes) [16-19]. The upper tectonostratigraphic unit (suprastructural unit) [13, 18-21], which is represented by ophiolites, magmatic-arc related island-arc volcanic, and volcanoclastic

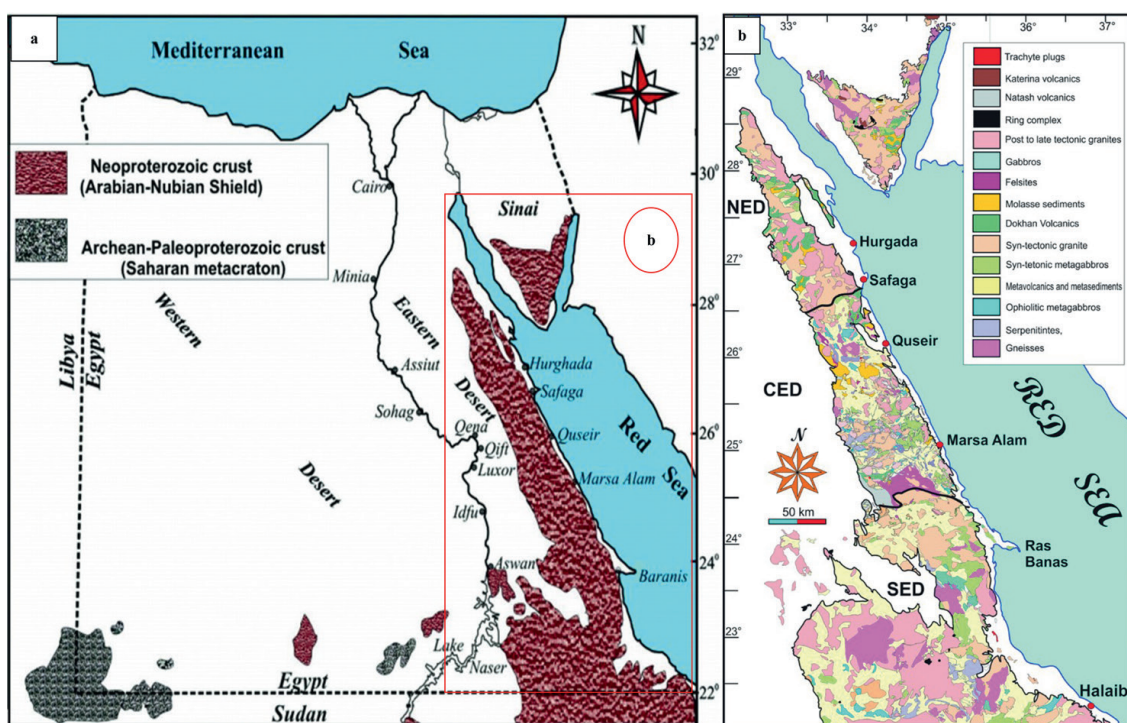


Figure 2. (a) Distribution of Neoproterozoic basement rocks in Egypt [10], (b) Geologic map of the Eastern Desert and Sinai [1].

intruded by Syn to late tectonic calc-alkaline and alkaline granites, metagabbro-diorite complexes, Dokhan volcanics, and molasse sediments intruded by post tectonic granitic intrusions and dike [10, 13, 22–28].

2. History of gold mining in Egypt

The history of gold mining in Egypt can be divided into two main times: ancient time and modern time.

2.1 History of ancient gold mining

The production and mining activities of gold deposits have been carried out from the Eastern Desert of Egypt since ancient times, more than 240 gold deposits and occurrences are spread over the whole area covered by the basement rocks of the Precambrian age.

In most mines, the ancient Egyptians extracted gold from quartz veins of various dimensions in open pits and underground workings. Gold production in Egypt seems to have started as early as the predynastic times (about 4000 BC) and continued in different periods up to the sixth century when the gold mines lost their importance [29–35]. Mond and Winkler published a preliminary report in the season 1937–1938; they noted that the historical time of gold production was started with the accumulation of the nugget gold from the grounds of some wadis in the middle of 5000 BC, which dated by the evidence in production sites of by the “Earliest Hunters” [36].

Harrell, 1992, submitted an article about the Turin papyrus map one of the oldest maps and the oldest map that illustrates the topography and geology of Wadi Hammamat in the Central Eastern Desert of Egypt (**Figure 3**). However,

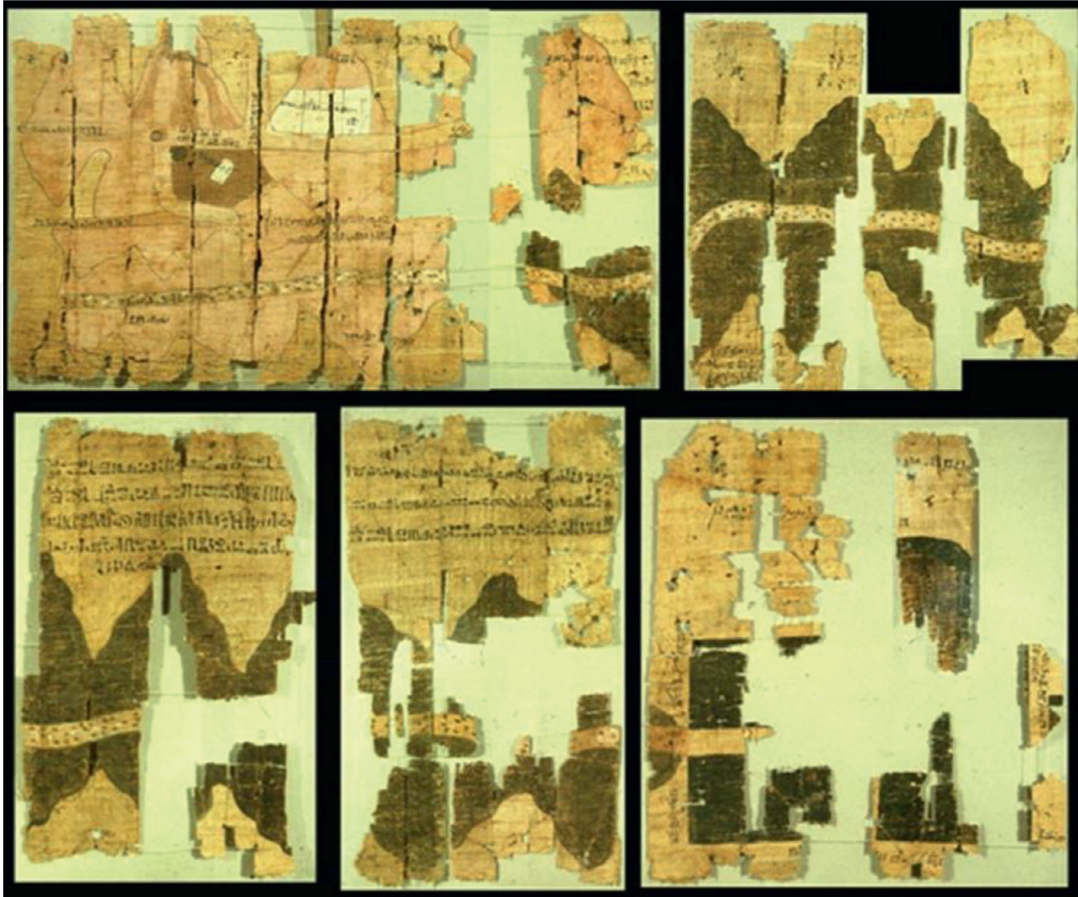


Figure 3.
The Turin papyrus map illustrates the topography, geology and gold working at Wadi Hammamat during the reign of Ramesses IV (1151–1145 B.C.) [37].

it shows gold-working settlements during the ancient time at Bir Umm Fawakhir and “bekhen-stone” quarry regions. He noted that the map was drawn by the chief administrative officer (“Scribe of the Tomb” Amennakhte, son of Ipuuy) of the village of Deir El-Medina during the reign of Ramesses IV (1151–1145 BC) to record the king’s bekhen-stone quarrying expedition to Wadi Hammamat late in the third year of his reign [37]. Generally, the gold production periods in Egypt can be classified into eight periods: Pre- and Early Dynastic times (~3500–2700 BC), Old and Middle Kingdom (2700–2160 and 2119–1794 BC, respectively), New Kingdom times to the Third Intermediate Period (1550–1070 BC), Ptolemaic (Greek) times (~300–30 BC), Kingdoms of Kushitic times (800–400 BC and to 100 AD), Roman and Byzantine Period times (~30 BC–641 AD), Early Arab Period (~990–1350 AD), and modern mining time. Each period includes certain techniques and equipment [26, 34–39].

2.2 Modern gold mining history

In the nineteenth century, Egyptian gold attracted increasing attention, and at the beginning of the present century, most of the gold deposits were rediscovered and worked. However, by the end of 1918, gold mining practically stopped [29, 40]. The period between 1932 and 1958 represents a new stage of gold exploration in Egypt, during which several deposits were examined and the major ones, such as Sukari, Um Ud, Hangaliya, Um Rus, Barramiya, El Sid, Um Garaiyat, and others, were put under exploitation. From 1902 to 1958, the amount of pure gold recovered in Egypt

was about 7 tons [1, 40]. The last stage in the history of gold mining is the prospecting work that was carried out at Atud deposits in 1953–1954 [41] and 1963–1964 [42]. In 1967, the gold deposits of Semna, Atalla, El Sid, Um Rus, Barramiya, Atud, Sukari, Um Ud, Hangaliya, Kurdeman, Hamish, Um Garaiyat, and others were examined by [43]. Gold deposits and occurrences in Egypt have been reviewed in many publications, some data on the gold deposits were presented in the reports of the Mining Guidance, 1935–1958, reports of Mines and Quarries Department 1906–1960, reports of the Egyptian Mining and prospecting Co., 1955–1962 and Hunting Ltd., 1967. There are many different views concerning the stages of gold development and the relations of gold mineralization with various magmatic complexes. In the period from 1983 to 1989 a new stage in the history of gold mining when the work was carried out at many gold mines in the Eastern Desert by Minex Company. The Geological Survey of Egypt played an important role in the prospecting work done by Minex Company and gave the most accurate and complete data on many gold mines, for example, Abu Marrawat, El Barramiya, HI Fawkhir, and Semena.

In 1990, the Pharaonic Company begins to prospect gold in Egypt depending on modern theories and using more accurate techniques for analysis, depending on data collected by Minex. Nowadays, Cryst International Company seeks gold in the Eastern Desert depending on modern theories. Cryst International Company is interested in gold associated with pyrite in many locations, especially in the Hammata area. In 1995, many companies invested in gold exploration in Egypt (i.e., Centamin, Aton Resources Inc. (formerly Alexander Nubia), Thani Dubai, Mica Star, SMW,

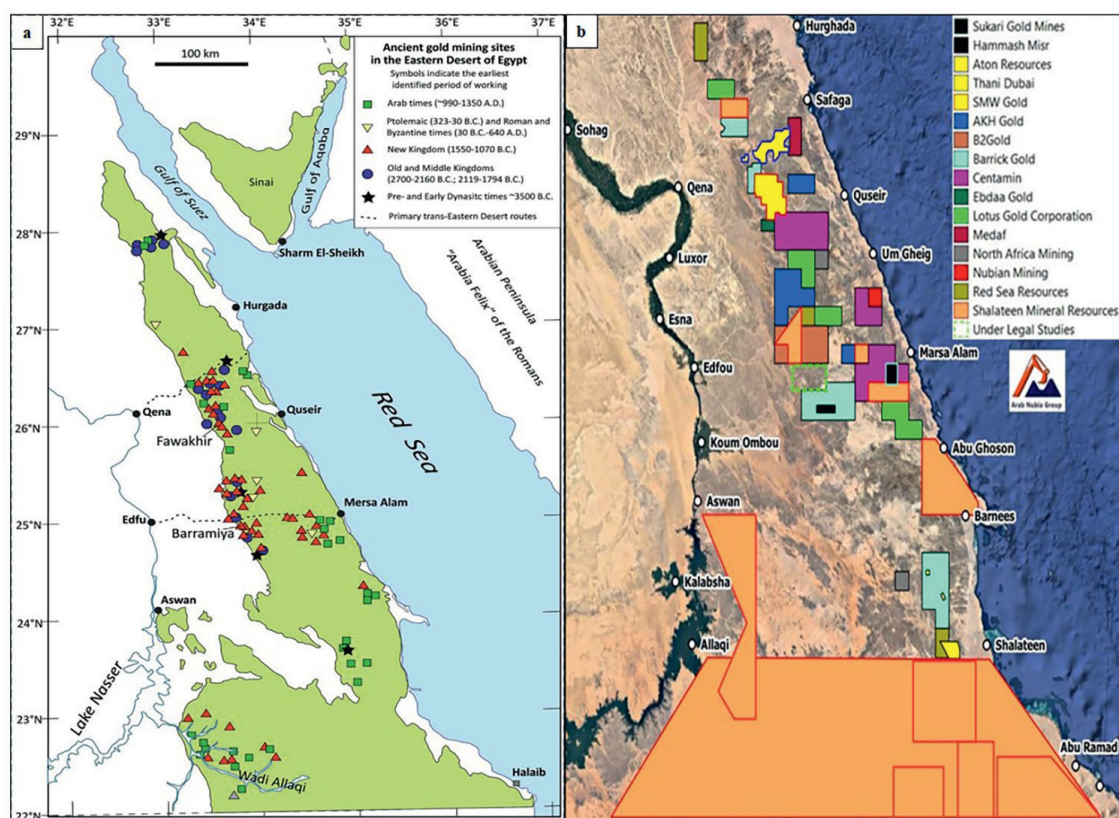


Figure 4.
 (a) Map shows the historical regions of gold in the Eastern Desert according to the earliest known ancient periods working [40], and (b) concession of the international and Egyptian companies in 2020 (after Arab Nubian group <https://www.linkedin.com/company/5013242/admin/>).

6	Wadi Nasb Area	75	Um Soleimat	144	Hamash	213	Betam
7	South Wadi El Shalal	76	El Sid	145	Geili	214	El Hoteib
8	Abu Rahab	77	El Shihimiya Um Hargal	146	Khashab	215	Um Egat – 1
9	Wadi Madsus	78	El Nur	147	North Gabal El Khellah	216	Um Egat – II
10	Um Zariq – I	79	Zeidon	148	Gabal Abu Himimid	217	Egat Mine
11	South Wadi Nasb	80	Makhyt	149	Kab El Rayan	218	Shanaiyet
12	Um Zariq – II	81	Shughief	150	El Qulan	219	Al Fawi – 1
13	Wadi El Kid	82	Wadi Zeidon	151	Wadi El Homer	220	Al Fawi – II
14	Wadi Qabila	83	Hadarba	152	Shialek	221	Al Fawi – III
15	Wadi El Samra	84	WadiUmAash	153	Abu Rahaya	222	Wadi Beida
16	Wadi Um Toleihat	85	Maiser	154	Kortonos	223	Wadi El Abied
17	Gabal Dara	86	Perevalny	155	El Hudy	224	Korbai
18	Wadi Zobeir	87	Wadi Manih	156	Wadi I Hi Mikan	225	Um Radam
19	Um Balad	88	El Heir	157	Zergat Naam	226	North Gabal Gerf
20	Ruh A1 Hadid	89	Tigelny (Wadi El Heir)	158	Gabal Nikeiba	227	El Direib
21	Wadi Dara	90	Wadi El Moilh	159	Urf Abu Humar	228	Madarai
22	Um Mongul	91	Daghbag	160	Abu Gurdi	229	Wadi Oregium
23	Wadi El Urf	92	Deghig	161	Salib El Abied	230	El Qurun
24	Wadi Dib	93	Tila Gadalla	162	Betan – 1	231	Romeit
25	Talat A1 Zarqa	94	Fella Godalla	163	Um Eleiga	232	Groore
26	Um Tweir	95	El Hisinat	164	Ourga El Rayan – 1	233	Abu Hireig
27	El Helliev	96	El Mayia (El Bakriya)	165	Orgarian	234	Gabal Abu Hodied
28	Abu Morrat	97	Um Salatite	166	Hutit	235	W. Meisah
29	Um Tagher	98	Um Selim	167	Um Kalib	236	Gabal Heianai – 1
30	Wadi Fatira El Zarqa	99	Al Barramiya	168	Ourga El Rayan – II	237	Heianai – II
31	Fatiri El Beida	100	Bokari-I	169	Wadi Khuda	238	Gabal Suruk
32	El Ghozah	101	Bokari-II	170	El Anbat	239	Soorib (Gudir)
33	Fatiri	102	Abu Mouawad	171	Southwest Gabal Sirsir	240	Wadi El Qurat
34	Wadi El Dob	103	Kap El Abiad	172	Gabal Nazar area-I	241	Gabal Shiab

35	Abu Shehat	104	Tarfawi	173	Gabal Nazar area-I I	242	Gabal Hamida
36	El Bolh	105	Wadi Kareim	174	Gabal Nazar area-I 11	243	Gabal Elba
37	Gray	106	Wadi Kareim-BIF	175	Gabal Nazar area-VI	244	Sul Hamid
38	Safaga	107	El Dabbah	176	North Gabal Peter and Paul	245	Qash Amir
39	Abu Marawat	108	Hamrat ghannam	177	Southwest Gabal Nazar	246	Oseir Irab
40	Semna	109	Sharm El Bahari	178	Gabal Kamel		
41	Massaghat El Gukh	110	Abu mureiwa	179	South Gabal Kamel		
42	Gabal Semna	111	Nusla	180	Hisayrbah		
43	E 1 Eredeia	112	Um Grifate	181	Hariari		
44	Bohlog	113	Atwi	182	Um Araka		
45	Gidami	114	Um Ghamis	183	Um Ashirah		
46	Abu Qarahish	115	Sigdit	184	Nekib		
47	Wadi Gasus	116	UmRus	185	Abu Swayel		
48	Wadi Abu Shigeili	117	WadiMurin	186	Middle Wadi Haimur		
49	Wadi Queih	118	AbuDabbab	187	Haimur		
50	Wadi Queih	119	UmNar	188	Wadi El Nile		
51	Sagi	120	Gabal El Hadid	189	Atshan		
52	Wadi Hemeiriya	121	Um Samra-I	190	Murra		
53	Kap Amiri	122	Um Samra-II	191	Korsco		
54	A1 Areifia	123	Abu Quraiya	192	Atshani		
55	Hamama-I	124	Beizah	193	Maraheib		
56	Hamama-II	125	Atud 193	194	Um Garaiyat		
57	Abu Had	126	UrfElFahd	195	South Kalabsha		
58	Atalla El Mor	127	Abu Mireiwa	196	Fillat		
59	Kap El Abse	128	Dungash West	197	Um Doma		
60	Rabshi	129	Dungash East	198	Abu Fass		
61	Wadi Sodmein	130	Um Dalalil	199	Eneigit – 1		
62	El Haramiya	131	Samut	200	Eneigit – II		
63	North Wadi Atalla	132	Um Tundebe	201	Seiga – 1		
64	Wadi Nabsh El Qadim	133	Sukari	202	Seiga – II		
65	Atalla	134	Am Baut	203	Um Shashoba		

66	A1 Fawakheir	135	Sabahia	204	Gabal Kulyeit – 1
67	Hammamat – I	136	El Lawi	205	Gabal Kulyeit – II
68	Hammamat – II	137	Leweiwi (Um Gamil)	206	South Mashbih
69	Um Had	138	Kurdman	207	Gabal Anweib

Table 1.
 Locations of gold deposits and occurrences in Eastern Desert, Egypt.

resources at 11 Moz with a lifetime of 15 years [38–41]. The gold production started from the open pit mine in 2010 and underground started from 2011 to nowadays. The random mining or illegal gold rushers phenomena (they are called Dahaba) have been widely distributed along the whole Eastern Desert. Even though they represented some advantages in gold exploration on different scales but they display enormous harmful impacts by destroying the old mine and having a great environmental impact; at the first, they used a metal detector in exploration, but now they developed their techniques by using crushers, panning, and grinding; in addition, they used mercury and even cyanide to extract and refractory gold. In the Southern Eastern Desert, Shalateen Mineral Resources Company (SMRC), a governmental company is working to control these phenomena by giving licenses to the rushers to explore legally. In 2018, new recommendations for policies were announced by the Egyptian government to encourage global investment in mining. In August 2019, the law of mineral resources was modified and published in January 2020. In 2020, a big international bid-round No (1) for gold exploration and associated minerals was launched to open the minerals sector to foreign investment in the mining industry. At the end of 2020, EMRA announced that 11 international and Egyptian companies (Hammash Misr, Aton Resources, Thani Dubai, SMW Gold, AKH Gold, B2Gold, Barrick Gold, Centamin, Ebdaa Gold, Lotus Gold Corporation, Medaf, North Africa Mining, Nubian Mining, Red Sea Resources, and Shalateen Mineral Resources) win 82 gold exploration areas in Egypt (**Figure 4**). More than 195 gold deposits and occurrences are situated in the Eastern Desert of Egypt since ancient times until modern days (**Figure 5** and **Table 1**).

3. Classification of the gold deposits in Egypt

Many studies classified the gold deposits in Egypt based on different characteristics (e.g., the nature, occurrences, type of host rock, tectonic setting, metal association, and the tectonic environment of mineralization). Hume [29] believed that the formation of gold took place in two different stages and related the main gold mineralization to the second stage of hydrothermal activity that accompanied the development of the dioritic intrusion of the Metarchean age (i.e., Proterozoic) [33]. He grouped the mineral deposits into four categories: (1) gold occurrences; (2) group occurrences of silver, copper, zinc, molybdenum, tungsten, iron, chromium, nickel, lead, tin, platinum, and graphite; (3) precious and semiprecious minerals; and (4) ornamental stones. Kochine and Bassyuni [46] classified the gold mineralization depending on the mode of occurrences and the

nature of mineralization into three distinguished types of gold dykes, veins, and placer deposits. El Ramly et al. [47] added that most gold deposits are confined either to the intrusive masses of granodiorites and diorites or to the schists in the close vicinity of these masses. On the other hand, he stated that there are more than 95 locations of different gold deposits and occurrences that are hosted by variable rock composition including, schists, mudstone-greywacke-conglomerates, granites, granodiorite (gabbros, metavolcanics, and dyke like felsite porphyries and trachytes, diorites). Sabet et al. [48] identified four main epochs based on the time of mineralization and formation of gold: Preorogenic epoch, Syn to late-orogenic epoch, Riphean-lower Paleozoic epoch, and Mesozoic-Cenozoic epoch. Also classified the major gold “Formations” in the Eastern Desert into: (1) gold-sulfide “Formation”, (2) gold-bearing iron quartzite “Formation”, and (3) gold-bearing quartz veins “Formation”. Sabet and Bordonosov [49] classified the occurrences of gold in Egypt into three types, namely, gold-sulfide, skarn gold-ferruginous quartzite, and gold quartz veins formations. The gold quartz vein formation was subdivided according to the metal and mineral associations into: gold-arsenic, gold-pyrite, gold-polymetal, gold-copper, gold-mercury, and gold-antimony types. Botros

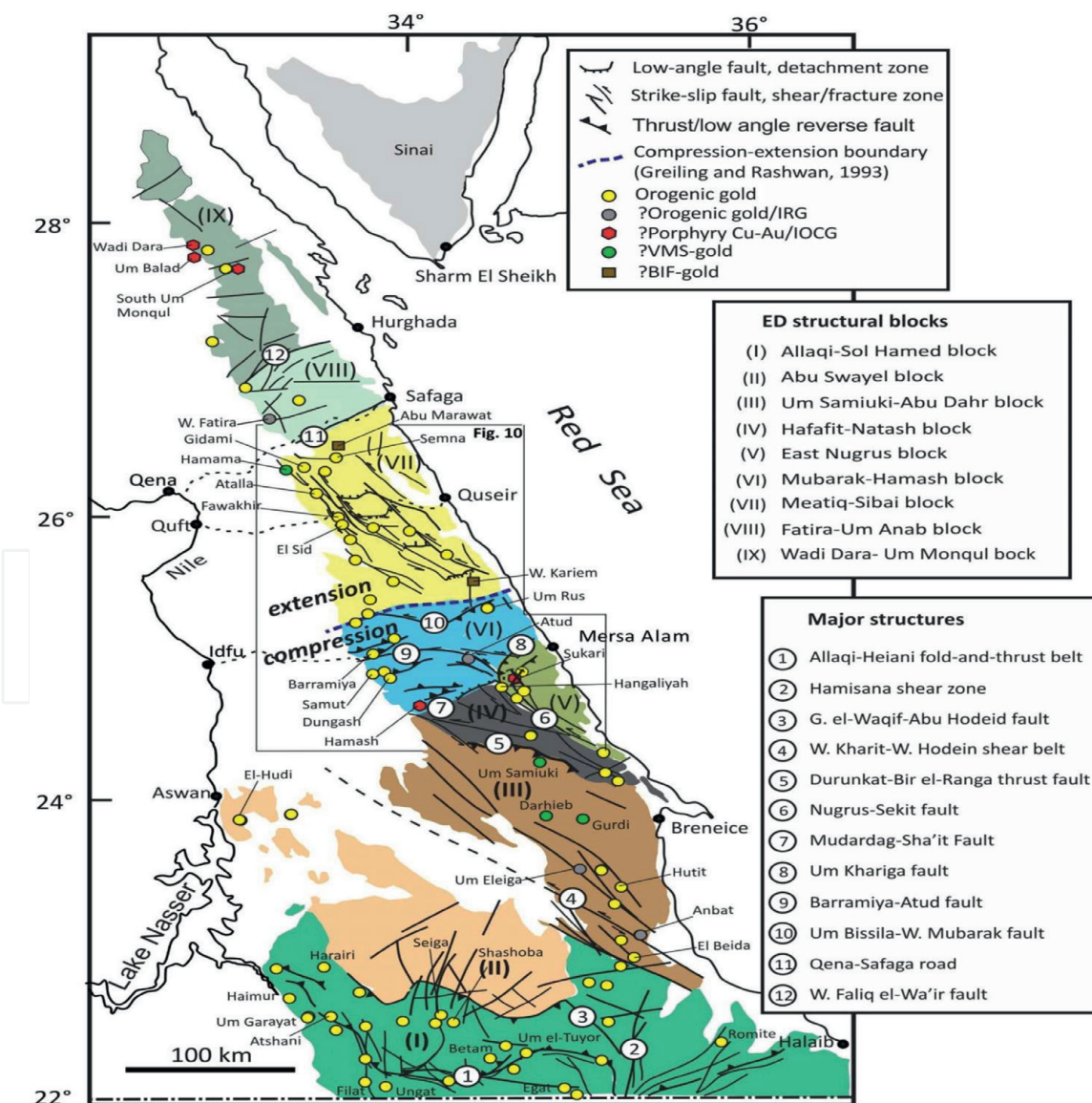


Figure 6. Gold occurrences and structural blocks in ED [39].

[50] classified the gold mineralization in the Eastern Desert depending on their related tectonic environment into three main classes and subdivided these classes depending mainly on the type of the host rock as follows: gold hosted in the island-arc stage (such as BIF and tuffaceous metasedimentary rocks), gold hosted in the orogenic stage (such as gold mineralization along the sheared contacts of the ophiolitic serpentinites, associated with porphyry copper mineralization, and auriferous quartz veins intruded gabbros and granodiorite, and the third type is gold mineralization going with the post-orogenic stage. Botros [37], according to the tectonic-magmatic evolution of the Nubian shield, modified his classification of gold deposits to new threefold gold deposits. (1) Stratabound deposits are subdivided into three main types: gold-bearing Algoma-type banded iron formation, gold-bearing tuffaceous sediments, and gold-bearing volcanogenic massive sulfide deposits; (2) non-stratabound deposits are divided into two main types: vein-type mineralization hosted in a wide range of rocks and disseminated-type mineralization hosted in hydrothermally altered rocks (alteration zones); and (3) placer deposits are divided into modern placers and lithified placers. Zoheir et al. [39] noted that the Eastern Desert is divided into nine structure blocks, which are the Allaqi-Sol Hamed block, Abu Swayel block, Um Samiuki-Abu Dahr block, Hafafit-Natash block, East Nugrus block, Mubarak-Hamash block, Meatiq-Sibai block, Fatira-Um Anab block, and Wadi Dara-Um Monqul bock (**Figure 6**). They reviewed that the gold deposits in Egypt are mainly orogenic gold systems, but some other gold systems with some dough and limited distribution have been studied as volcanic massive sulfide (VMS), porphyry systems, Fe-oxide-Cu-Au (IOCG) systems, and intrusion-related system. On the other hand, they mentioned that the gold deposits are controlled by structure and just five that controlled the orogenic gold occurrences are Allaqi-Sol, Hamed block, Um Samiuki-Abu Dahr block, East Nugrus block, Mubarak-Hamash block, and Meatiq-Sibai block. El Aref et al. [51] believed that most of the gold deposits in the Eastern Desert are related to orogenic gold deposits and are structurally controlled. They noted that there is some evidence of VMS system, associated high-sulfidation Au-Cu-Mo mineralization and porphyry type, while they mentioned that there is no evidence in support of the presence of iron oxide copper-gold (IOCG) or even intrusion-related in the Eastern Desert.

4. Conclusion

The Arabian-Nubian Shield (ANS) is one of the largest and best-recorded outcrops of Neoproterozoic Juvenile rocks on the Earth; the basement rocks extend in the Eastern Desert are divided into three distinct lithotectonic domains as specific: Northern Eastern Desert (NED), the Central Eastern Desert (CED), and the Southern Eastern Desert (SED). The basement complex in the Eastern Desert is composed of a heterogeneous rock assemblage; it can be classified into the lower tectonostratigraphic unit or infrastructural and the upper tectonostratigraphic unit or suprastructural. The production and mining activities of gold deposits have been conducted in the Eastern Desert of Egypt since ancient times; nowadays, the random mining or illegal gold rushers phenomena (they are called Dahaba) have been widely distributed along the whole Eastern Desert. Many studies classified the gold deposits in Egypt based on distinctive characteristics, such as nature, occurrences, type of host rock, tectonic setting, metal association, and the tectonic environment of mineralization. Still, there are many challenges in the geologic exploration and mining studies of gold in Egypt.

Acknowledgements

The authors would like to thank the National Science Foundation of China (NSFC: 92162213). They express their gratitude to the group of School of Earth Science and Resources, Chang'an University for their support during this research. Refaey El-Wardany is very grateful to Prof. Ibrahim Abu El-Leil, Prof. Basem Zohair, Prof. Yonggang Feng, Dr. Amr Abdelnasser, in addition, the Geology Department Faculty of Science Al-Azhar University (Assiut Branch) and the China Scholarship Council, for help and supporting his research. The editor and the anonymous reviewers are acknowledged for their many insightful comments and suggestions that improved many interpretations.

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References

- [1] Abd El-Wahed M, Hamimi Z. The Egyptian Nubian Shield Within the Frame of the Arabian–Nubian Shield. In: Hamimi Z, Arai S, Fowler AR, El-Bialy MZ, editors. *The Geology of the Egyptian Nubian Shield*. Cham: Springer; 2021. DOI: 10.1007/978-3-030-49771-2_2
- [2] Johnson PR, Woldehaimanot B. Development of the Arabian-Nubian Shield. Perspectives on accretion and deformation in the northern East African Orogen and the assembly of Gondwana. In: Yoshida M, Windley BF, Dasgupta S, editors. *Proterozoic East Gondwana, Supercontinent Assembly and Breakup*. London: Geological Society; 2003. pp. 290-325
- [3] Hargrove US, Stern RJ, Kimura J-I, Manton WI, Johnson PR. How juvenile is the Arabian–Nubian Shield? Evidence from Nd isotopes and pre-Neoproterozoic inherited zircon in the Bi'r Umq suture zone, Saudi Arabia. *Earth Planet Science Letters*. 2006;252(34):308-326
- [4] Abdelsalam MG. Quantifying 3D post-accretionary tectonic strain in the Arabian-Nubian Shield: superimposition of the Oko Shear Zone on the Nakasib Suture, Red Sea Hills, Sudan. *Journal of African Earth Sciences*. 2010;56(4-5):167-178. DOI: 10.1016/j.jafrearsci.2009.07.003
- [5] Johnson P, Abdelsalam M, Stern B. The Bi'r Umq-Nakasib Suture Zone in the Arabian-Nubian Shield: A Key to Understanding Crustal Growth in the East African Orogen. *Gondwana Research*. 2003;6:523-530. DOI: 10.1016/S1342-937X(05)71003-0
- [6] Stern RJ, Johnson PR, Kroner A, Yibas B. Neoproterozoic ophiolites of the Arabian-Nubian Shield. *Developments in Precambrian Geology*. 2004;13:95-128
- [7] Ali KA, Stern RJ, Manton WI, Johnson PR, Mukherjee SK. Neoproterozoic diamictite in the Eastern Desert of Egypt and northern Saudi Arabia: evidence of *750 Ma glaciation in the Arabian-Nubian Shield? *International Journal of Earth Sciences*. 2010;99:705-726
- [8] Fritz H, Abdelsalam M, Ali K, Bingen B, Collins A, Fowler A, et al. Orogen styles in the East African Orogen: A review of the Neoproterozoic to Cambrian tectonic evolution. *Journal of African Earth Sciences*. 2013;86:65-106. DOI: 10.1016/j.jafrearsci.2013.06.004
- [9] Eliwa HA, Breitzkreuz C, El-Gameel K, Khalaf IM. Ediacaran Post-collisional Volcanosedimentary Successions in Egypt. In: Hamimi Z, Arai S, Fowler AR, El-Bialy MZ, editors. *The Geology of the Egyptian Nubian Shield: Regional Geology Reviews*. Cham: Springer; 2021. DOI: 10.1007/978-3-030-49771-2_7
- [10] El-Bialy MZ. Precambrian basement complex of Egypt. Cham: Springer; 2020. pp. 37-79
- [11] Akaad MK, El Ramly MF. Geological history and classification of the basement complex in the Central Eastern Desert of Egypt. *Geo-Survey Egypt*. 1960;9:1-24
- [12] El Shazly EM. On the Classification of the Precambrian and Other Rocks of Mapnatic Affiliation in Egypt Intern Geol. India; 1964
- [13] Ries AC, Shackelton RM, Graham RH, Fitches WR. Pan-African structures, ophiolites and mélangé in the Eastern Desert of Egypt, a traverse at 26°

- N London. *Journal of Geological Society*. 1983;**140**:75-95
- [14] el Gaby S, el Nady OM, Khudier AA. Tectonic evolution of the basement complex in the Central Eastern Desert of Egypt. *Geologtsche Rundschau*. 1984;**73**:1019-1036
- [15] Ragab AI, El-Alfy Z. Arc-arc collision model and its implications on a proposed classification of the Pan-African rocks of the Eastern Desert of Egypt. *MERC Ain Shams University, Earth Science Series*. 1996;**10**:89-101
- [16] Neumayr P, Hoinkes G, Puhl J, Mogessie A, Khudeir AA. The Meatiq dome (Eastern Desert, Egypt) a Precambrian metamorphic core complex: petrological and geological evidence. *Journal of Metamorphic Geology*. 1998;**16**:259-279
- [17] Habib ME, Ahmed AA, El-Nady OM. Two orogenies in the Meatiq area of the Central Eastern Desert Egypt. *Precambrian Research*. 1985;**30**:83-111
- [18] Bennett JD, Mosley PN. Tiered tectonics and evolution, E Desert and Sinai, Egypt. In: Matheis G, Schandelmeier H, editors. *Current Research in African Earth Sciences*. Rotterdam: Balkema; 1987. pp. 79-82
- [19] El-Gaby S, List FK, Tehrani R. Geology, evolution and metallogenesis of the Pan-African Belt in Egypt. In: El-Gaby S, Greiling RO, editors. *The Pan-African belt of Northeast Africa and adjacent areas*. Weisbaden: Vieweg & Sohn; 1988. pp. 17-68
- [20] Shackleton RM, Ries AC, Graham RH, Fitches WR. Late Precambrian ophiolitic melange in the Eastern Desert of Egypt. *Nature*. 1980;**285**:472-474
- [21] Bregar M, Bauernhofer A, Pelz K, Kloetzli U, Fritz H, Neumayr P. A late Neoproterozoic magmatic core complex in the Eastern Desert of Egypt; emplacement of granitoids in a wrench-tectonic setting. *Precambrian Research*. 2002;**118**:59-82
- [22] Stern RJ. Late Precambrian ensimatic volcanism in the Central Eastern desert of Egypt. San Diego: University of California; 1979. p. 210
- [23] Stern RJ. Petrogenesis and tectonic setting of Late Precambrian ensimatic volcanic rocks, Central Eastern Desert of Egypt. *Precambrian Research*. 1981;**16**:195-230
- [24] Sturchio NC, Sultan M, Batiza R. Geology and origin of Meatiq dome, Egypt: A Precambrian metamorphic core complex? *Geology*. 1983;**11**:72-76
- [25] Stern RJ, Hedge CE. Geochronologic and isotopic constraints on late Precambrian crustal evolution in the Eastern Desert of Egypt. *American Journal of Science*. 1985;**285**:97-127
- [26] Johnson P, Andresen A, Collins A, Fowler A-R, Fritz H, Ghebreab W, et al. Late Cryogenian-Ediacaran history of the Arabian-Nubian Shield: A review of depositional, plutonic, structural, and tectonic events in the closing stages of the northern East African Orogen. *Journal of African Earth Sciences*. 2011;**61**:167-232. DOI: 10.1016/j.jafrearsci.2011.07.003
- [27] Thurmond AK, Stern RJ, Abdelsalam MG, Nielsen KC, Abdeen MM, Hinz E. The Nubian Swell. *Journal of African Earth Sciences*. 2004;**39**(3-5):P401-P407. DOI: 10.1016/j.jafrearsci.2004.07.027
- [28] Stern RJ, Ali K. Crustal evolution of the Egyptian Precambrian rocks. In: Hamimi Z, El-Barkooky A,

- Martínez Frías J, Fritz H, Abd El-Rahman Y, editors. *The Geology of Egypt*. Switzerland: Springer Nature; 2020. pp. 131-151
- [29] Hume WF. *Geology of Egypt, V. II, part III*. Egypt: Geological Survey; 1937
- [30] Newberry P. Beni Hassan II: Archeological Survey of Egypt. London: Kegan Paul; 1893. p. 8
- [31] Meyer C, Heidorn L. Three Seasons at Bir Umm Fawakhir in the Central Eastern Desert. Leiden: Research School CNWS; 1998. pp. 197-209
- [32] Roubet C. The grinding stones of site E-78-3 Wadi Kubbaniye. *The Prehistory of Wadi Kubbaniye*. 1989;3:473-489
- [33] Harrell JA, Brown VM. The Oldest Surviving Topographical Map from Ancient Egypt: (Turin Papyri 1879, 1899, and 1969). *Journal of the American Research Center in Egypt*. 1992;29:81-105. DOI: 10.2307/40000486
- [34] Klemm D, Klemm R, Murr A. Gold of the Pharaohs—6000 years of gold mining in Egypt and Nubia. *Journal of African Earth Sciences*. 2001;33(3):643-659
- [35] Klemm R, Klemm D. Gold and Gold Mining in Ancient Egypt and Nubia, *Geoarchaeology of the Ancient Gold Mining Sites in the Egyptian and Sudanese Eastern Deserts*. Berlin, Heidelberg: Springer-Verlag; 2013. p. 663
- [36] Mond R, Winkler HA. Rock drawings of Southern upper Egypt. ii. *jstor*. 1940
- [37] Botros NS. A new classification of the gold deposits of Egypt. *Ore Geology Reviews*. 2004;25(1):1-37
- [38] Botros NS. Stratiform gold deposits in a Proterozoic BIF, Abu Marawat area, Eastern Desert, Egypt. In: *Eleventh Symposium on Precambrian and Development*. Cairo; 1995
- [39] Basem AZ, Johnson PR, Goldfarb RJ, Klemm DD. Orogenic gold in the Egyptian Eastern Desert: Widespread gold mineralization in the late stages of Neoproterozoic orogeny. *Gondwana Research*. 2019;75:184-217. DOI: 10.1016/j.gr.2019.06.002
- [40] El Alfy EM. Report on the Barramiya gold mine, Eastern Desert. Quseir Phosphate Co., Cairo. EMRA, Internal reports No. 18 / 68-39 / 77-16 / 78-71 / 2003—Al Alfy, E.M., 1951). 1951
- [41] Foda S. Report on Prospecting Work Carried Out by the Mechanical Expedition at Atud, Eastern Desert, 1953-1954. Cairo: Mines and Quarries Dept; 1958
- [42] Rogers BM. An inspection of the ancient gold mining region of the South–Eastern Desert between the Red Sea and the Nile. February 23rd to March 18th 1914. Unpublished report. 1914
- [43] Moharram O, El-Ramly MF, Amer AF, Ivanov SS, Gachechiladze DZ. *Studies on Some Mineral Deposits of Egypt*. Egypt: Geol. Surv, of Egypt; 1970
- [44] Egyptian mineral resources authority 2014, internal report in, No. 35/2014
- [45] Zaghlol K. Structural Control, and Petrology of Gold Occurrences of the Gebel Hamrat Ghannam—Gebel Atawi Stretch, South Quseir, Central Eastern Desert, Egypt. Egypt: Cairo University; 2022
- [46] Kochine G, Bassyuni F. *Mineral Resources of the UAR, Part I, Metallic Minerals*. Egypt: Int. Rep. Geol. Surv; 1968

[47] EI Ramly MF, Ivanov SS, Noehm GC. The Occurrence of Gold in the Eastemdesert of Egypt in Studies on Some Mineral Deposits of Egypt. Part I, Sec. A, Mettalic Minerals. Egypt: Geol. Surv; 1970. pp. 53-63

[48] Sabet AH, Bessonenko VV, Bykov BA. The intrusive complexes of the central Eastern Desert of Egypt. Annals of Geological Survey Egypt. 1976;1976:12

[49] Sabet A, Bordonosov V. "The gold ore formations in the Eastern Desert of Egypt." ("New Occurrence of Gold Mineralization at the Eastern Part of Wadi El ..."). Annals of Geological Survey Egypt. 1984;16:35-42

[50] Botros NS. Metallogeny of gold in relation to the evolution of the Nubian Shield in Egypt. Ore Geology Reviews. 2002;19:137-164

[51] El-Aref M, El-Rahman A, Yasser Z, Basem S, Adel H, Hassan A, et al. Mineral Resources in Egypt (I): Metallic Ores. In: Hamimi Z et al., editors. The Geology of Egypt. ("Prof. Dr. rer. Nat. F. Christoph Breitzkreuz | TU Bergakademie Freiberg") Regional Geology Reviews. Cham: Springer; 2020. pp. 521-587. DOI: 10.1007/978-3-030-15265-9_14