0EGYPTIAN PHANEROZOIC STRATABOUND ORE DEPOSITS

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Hussein and El Sharkawi (1990) reviewed the different genetic classifications of the Egyptian ore deposits including those occurring within the Phanerozoic strata. El Aref (1996) discussed the geological settings and modes of formations of the Phanerozoic deposits and provides a new and an integrated genetic scheme. The ore deposits under consideration include varieties of stratabound and stratiform ore types. The development of these deposits coincided well with the paleogeographic evolutional pattern of the Phanerozoic shorelines and the related distributions of paleohighs, as well as paleoclimatic conditions and the sea level cycles, which prevailed. The stratiform deposits show conspicuous depositional and diagenetic features and are hosted within certain lithostratigraphic units of shallow near-shore environments of regional or local magnitudes. The stratabound deposits are intimately related to paleoerosion surfaces and comprise an integral part of the related weathering profile. The geological settings of these deposits and their main characteristics and modes of formations are given in the following. The detailed description of each ore type is included in the related literature(s).

CLASSIFICATION OF THE EGYPTIAN STRATABOUND DEPOSITS

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A. Cambrian Stratabound Th-U Conglomerates

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1. Beach placers

2. Alluvial placers

PALEOZOIC ORE DEPOSITS

Among the Paleozoic stratabound ore deposits are the following types:

A- Cambrian Stratabound Th-U Conglomerates

This type builds up the basal polymictic conglomerates of the proximal fluvial clastics of the Cambrian Araba Formation, Gabal Nukhul, Um Bogma region, Sinai (Aita, 1996).

B- Cambrian Stratiform Malachite in Shoreface Clastics, Araba Formation, Um Bogma, Sinai

This type is correlated with the Cambrian cupriferous sediments of Timna, Israel and Wadi Dana, Jordan. The geometry of the malachite, together with the paleotopographic position and environment of the host sediments suggest that Cu has been leached from nearby copper bearing Precambrian paleohighs and transported into the basin of deposition as bicarbonate or mobile complexes, and diagenetically recrystallized into malachite during the drying out of the marine host sediments (El Sharkawi *et al*., 1990a).

C. Carboniferous Stratabound to Stratiform Mn Deposits, Um Bogma, Sinai

The lowermost Early Carboniferous sediments of Um Bogma Formation of Um Bogma region hosts stratiform and stratabound Mn ores (El Sharkawi *et al.,* 1990b). El Aref and Abdel Motelib (1996) recognize the following three general ore facies, which intertongue from east to west:

a) Stratiform continental Mn conglomerates, sandstones and mudstones of fining-upward pattern, representing proximal facies of braided streams, well represented in the extreme eastern part of Um Bogma region, e.g., Gabal Ghorabi, Gabal Sheikh Hebbos and Gabal Adedia.

b) Stratiform lagoonal to swampy intercalated manganiferous mudstone and dolostone, prevailing in the central part of Um Bogma region; and

c) Near-shore pisolitic/oolitic ore of coarsening-upward tendency of relatively high energy (storm-dominated) depositional environment, e.g., Wadi Abu Thor and Gabal Sid El Banat.

Westwards, these Mn ore facies change into open marine carbonate facies. Stratabound karst Mn ore and the related paleosol overprint the latter two facies as a result of intra-Carboniferous (intra-Um Bogma) paleokarstification processes. These ore varieties, together with the coeval carbonates, are truncated by the marine shales and dolostones of the overlying upper members of Um Bogma Formation and/or the clastics of the Abu Thora Formation.

The facies distribution of the Mn deposits suggest that Mn and Fe were derived from eastern hinterlands as clasts and suspensions that deposited in channels along the coastal zone and debauched into the Carboniferous sea depositing lagoon to shallow marine manganiferous ore types. A subsequent phase of uplifting and sea regression accompanied with karstification of the already formed manganiferous dolostones and mudstones led to the leaching and redistribution of the Mn and its concentration in the subsoil horizon of the resulted paleokarst profile. Cu and U bearing phosphate, vanadate, sulphate, halide, silicate and carbonate minerals together with kaolinite, gibbsite and alunite are concentrated in the fossilized lateritic topsoil (organic-rich) horizon of the intra-Carboniferous paleokarst profile.

MESOZOIC ORE DEPOSITS

These deposits are associated with the general southward transgressive trend of the Tethyan sea and contemporaneous lateritization on the hinterlands (El Aref, 1996). They include:

A) Jurassic Coal and Jurassic-Lower Cretaceous Stratiform Ironstones

During the Jurassic-Lower Cretaceous transgressive–regressive cycles on the Northern Sinai, the southern hinterlands were under intensive erosion and deposition of the continental clastics and the associated currently quarried kaolin-rich laterites and paleosoles of the Raqaba, Temmariya and Malha formations in the southern Sinai and the Gulf of Suez and the equivalent continental clastics of the Gilf Kebir, Six Hill and Sabaya formations in the Southern Western Desert. Paralic facies associations were dominated in the northern part of Egypt. The thickest Jurassic sequence crops out in Northern Sinai at Gabal El Maghara. Its paralic facies associations include coal seams and ironstone bands (El Sharkawi *et al.,* 1989). Albian-Aptian shallow marine carbonates including oolitic ironstone bands are also exposed in Gabal Manzur, east of Gabal El Maghara. The Jurassic sediments of Gabal El Maghara, north Sinai include the main economic coal seams of Egypt. These seams are confined to the Bathonian sediments and predominated by vitrinite and clarain (Al Far, 1966 and Adindani and Shakhov, 1970). Exposed coal deposits are also recorded in Um Bogma district associating with Carboniferous sediments. Subsurface coal seams and coaly sediments have been recorded in some oil wells in the Gulf of Suez region, i.e. Ayun Musa, Sinai and in the Western Desert (Adindani and Shakhov, 1970).

B) Cenomanian Stratiform Ironstone

The paralic Bahariya Formation Cropping out in El Bahariya region, Western Desert, includes within its lower and upper members glauconitic ironstone bands and lenses, 15-150 cm thick, well exposed in El Bahariya depression as a result of repeated tectonic pulses of the Upper Cretaceous-Lower Tertiary ("Laramide") tectonic event. Economic Cenomanian ironstone bands of considerable thickness are well represented in El Harra and Nasser mine areas (IEP,1993-1997).

C) Turonian Stratabound Laterites

A major regressive phase has been established during the Middle Turonian, accompanying an important pulse of the "Laramide" movement which elevated Southern Egypt, El Bahariya arc and numerous structures across Northern Egypt and Sinai (Said, 1990). The extreme southern hinterlands were subjected to deep weathering processes including lateritization and received simultaneous fluvial sedimentation constituting the lower part of the Taref Formation of north Kharga and the Turonian laterite bearing Abu Aggag Formation of northeast Aswan (Germann *et al.*,1987, Mesaed,1995 & El Sharkawi, *et al.,*1996). Southwest Aswan at Wadi Kalabsha, the probably concomitant 9 m kaolin member of Said and Mansour (1971) and Said *et al.*, (1976) is overlain and underlain by fluvial conglomeratic sandstones similar in composition and textures to those of the Abu Aggag Formation. Eastward of Aswan at Wadi Natash, the upper part of the Abu Aggag Formation intercalates with the Natash volcanic sheets and their lateritic caps.

D) Coniacian-Santonian Stratiform Ironstone

Southward transgression of shallow Coniacian-Santonian Tethyan sea extended until Northern Sudan, depositing near-shore sediments along a restricted NS trending basin, i.e. the Timsah Formation, at the vicinity of Aswan and the Hawashiya Formation at Central Wadi Qena. Stratiform oolitic ironstone bands are confined to these formations. Meanwhile, genuine marine sediments were deposited in the structural laws of northern Egypt and the Gulf of Suez area (El Sharkawi,*et al.* & 1996; El Aref, *et al*., 1996). The host Timsah Formation of east and southeast Aswan is formed of four large-scale coarsening up-ward sedimentary cycles, representing deposition under a repeated shoaling conditions accompanied with acceleration to current and wave activities during a gradual progradation of linear tidal sand/ooid bars on a shelf mud. The oolitic ironstone bands reflect deposition in highly agitated conditions along the bar flanks and bar crests during regressive events terminating short-lived small-scale progradation regimes (IEP, 1993-1997, Mesaed, 1995; El Sharkawi *et al*, 1996 & El Aref *et al*., 1996).

E) Campanian-Maastrichtian Stratiform Phosphorite Deposit

Economic phosphate strata are confined to the Upper Cretaceous shoreline successions of the Quseir variegated shales or Mut Formation (Campanian) and the Duwi Formation (Campanian-Maastrichtian). These two units comprise the phosphorite Duwi Group of Glenn and Arthur (1990) and are best exposed in a generally E-W trending belt, extending along the middle latitude of Egypt. The Duwi Group strata consist of a relatively sediment-starved heterogeneous mixture that were deposited in a generally shallow epicontinental sea, resulted during Campanian-Maastrichtian trangressive event, and extended across the northern margin of the Arabo-Nubian Craton and deepened towards the North. Northwards, chalky limestones of open marine condition (the lower part of the Sudr Formation, Sinai and the Khoman B in the Western Desert) were accumulated. The economic phosphate deposits of the Duwi Group are well represented in three main regions: a) Red Sea Coast, including the Quseir Group of mines (i.e. Hamadat, Atshan, Duwi, Anz, Abu Tundub & Hamrawein) and the Safaga Group of mines (i.e. Um El Howeitat, Gasus, Wasif & Mohamed Rabah); b) Nile Valley (i.e. several occurrences locating between Esna and Idfu, and c) Abu Tartur plateau, Western Desert. According to Philobbos (1996), The Egyptian Campanian-Maastrichtian phosphorites were deposited in very shallow restricted conditions just off an oyster bank that developed on the highs created by the tilted blocks. The economic phosphorites were deposited on the gentle ramp of the southern tilted block which was bounded from the north by a syn-sedimentary ENE faulting.

CENOZOIC ORE DEPOSITS

Two groups of Cenozoic stratabound and stratiform ore deposits can be distinguished, based on their stratigraphic set-up:

A) Paleogene Fe Ore Deposits and Karst -Related Calcareous Deposits (Egyptian Alabaster)

B) Neogene Rift-Related Deposits

A) Paleogene Fe Ore Deposits and Karst-Related Calcareous Deposits "Egyptian Alabaster"

The Paleogene stratabound deposits include:

1) Intra-Eocene stratiform and stratabound Fe deposits

Since Upper Lower Eocene time, a major regressive phase started; the Middle Eocene shoreline was approximately along the south Minia-El Bahariya latitude. This northward retreat of the Tethyan paleoshoreline was accompanied by the culmination of the Syrian arc tectonic event which led to the uplifting of the Cretaceous strata in El Bahariya region. Intra-Eocene stratiform and stratabound ironstones were developed along the Middle Eocene paleoshoreline on Cretaceous paleohighs and are represented by the following successive ore types (Khalil,1995;El Aref,1996; IEP,1993-1997 & El Aref, *et al.*, 1999):

a) Stratabound iron and manganese rich laterite hosting kaolinite and alunite nodules, developed along the Cretaceous-Eocene boundary in El Harra and El Gedida mine areas.

b) Middle Eocene (Lutetian) stratiform oolitic-pisolitic (oncolitic) ironstone representing deposition during shallowing regimes along Lutetian paleoshreline. This ore type constitutes the lowermost part of the iron ore sequence of El Hara and El Gedida mine areas and is related to shallow marine deposition on Cretaceous paleohighs.

c) Middle Eocene stratiform ferruginous mudstones and dolostones of restricted lagoonal conditions comprising the upper portion of the Lutetian sequence (i.e. Naqb & Qazzun formations).

d) Lutetian-Bartonian stratabound karst ore resulting from paleokarstification of type c during Lutetian-Bartonian uplifting phase, sea-level fall and deep weathering processes (El Aref & Lotfy, 1989, El Aref *et al.*, 1999).

e) Stratiform channel-fill ore conglomerates truncating the karst ore and debauching into Bartonian sea (El Gedida mine)

f) Bartonian iron laterite developed during the intermittent lateritization of Bartonian glauconitic sequences (El Gedida mine, El Sharkawi & Khalil, 1977).

2. Upper Cretaceous- post-Eocene Fe-rich lateritic blankets (surficial ferricrite duricrusts)

These deposits were generated during the morphologic evolution of El Bahariya depression, Western Desert. The most promising ferricrete type is high-lying, forming an indurated and dissected surficial crusts (9-16m thick) of constant altitude (270-320m, above sea level), capping the beveled summits of isolated conehills, inselbergs and flat-topped mesas. Such topographically high crusts denote remnants of an old continuous erosion surface or peneplain (El Aref *et al.*, 1991) and delineate the level of paleo-watertable. These lateritic blankets represent the products of *in situ* deep weathering processes (involving karstification). These processes acted upon the exposed Cenomanian clastics and the related ironstones of the southern part of El Bahariya depression (e.g. El Heiz area, Gabal Radwan and Sandstone Hill, (El Aref *et al.*, 1991) and the Middle Eocene Fe-bearing carbonates (Naqb & Qazzun formations) of the northwestern corner of the depression (e.g. Gabal Ghorabi, El Aref & Lotfy, 1989).

3. **Fossil pre-rift (Oligocene?) alumino-ferruginous latosol,**
Um Gereifat area, Red Sea coastal zone

This latosol profile comprises three transitional horizons (El Aref, 1993a): a) a basal slightly weathered Precambrian granite, b) a middle saprolite horizon, and c) an upper Al and Fe-rich laterite horizon. The uppermost laterite horizon is truncated by the proto-rift fanglomerates of the Late Oligocene-Early Miocene? Ranga Formation.

4. Karst calcareous deposits ("Egyptian Alabaster")

This deposit type represents the karst-related reprecipitated calcium carbonates and the associated terra-rossa soil (i.e., calcareous cave and surficial sediments) which are known in the Egyptian literature as "Egyptian Alabaster" or travertine. Paleokarstifications of multi-erosion cycles have had significant effects upon the landscape development of the Cretaceous and Eocene carbonates cropping out south of the Upper Eocene-Oligocene paleo-shorelines and on the development of the related calcareous deposits (Abu Khadra *et al.*, 1987; El Aref *et al.*, 1987; Philip *et al.*, ; El Aref, *et al.*, 1996).

B) Neogene Rift-Related Ore Deposits, Red Sea Coastal Zone

The Neogene deposition under the Red Sea rifting dynamic resulted in a series of mixed clastic, carbonate and evaporite facies associations exhibiting variable stratigraphic set-up and lateral distributions (e.g. Montenat *et al.*, 1988; El Aref, 1993b). Numerous small-scale economic and non-economic, stratabound and stratiform Ba and Sr sulphates, Pb, Zn and Fe sulphides, S and Mn oxide and hydroxide are intimately related to some of the syn-rift depositional environments and syn-rift paleokarst surfaces. They include:

1- Stratiform to stratabound galena in the beach sandstones of the basal part of the Middle Miocene Um Mahara Formation, cropping out in Essel and Zug El Bohar mine areas (El Aref and Amstutz, 1983).

2- Stratiform (layered) oolitic/oncolitic Mn ore, up to 80 cm thick, conformable with the upper lagoonal algal limestones of the Um Mahara Formation and cropping out in Gabal Abu Shaar El Qibli (El Aref and Abdel Moteleb, 1992).

3- Stratiform celestite of rhythmic crystallization texture confined to restricted supratidal evaporitic limestones which constitute the upper part of the Middle Miocene Um Mahara Formation at Wadi Essel (El Aref, 1993b).

4- Stratabound intra-karstic celestite (celestite stalagmites and stalactites) related to the paleokarstification of type 3 and its host rocks during the post-Um Mahara pre-Abu Dabbab paleokarst event (El Aref, 1993b).

5- Stratiform barite layers or laminae confined to restricted sabkha facies of the Middle-Late Miocene Abu Dabbab Evaporite (Abdel Wahab and Ahmed, 1987).

6- Stratiform and stratabound biogenic sulfur deposits associated with bituminous materials and/or surface oil seepage. Sulfur is confined to sabkha stromatolitic carbonates and evaporites of the Abu Dabbab Formation (e.g. Ranga and Um Rheiga occurrences, El Aref, 1984; Abdel Wahab and Ahmed, 1987) or the coeval Gemsa

Formation (e.g. Ras Gemsa Gabal El Zeit occurrences, Shukri and Nakhla, 1955; Wali *et al.*, 1989 and Youssef, 1989).

7- Stratabound karstic barite confined to karst features scattering within the Abu Dabbab evaporite sequence (e.g. Gabal Abu Ghorban, El Aref and Ahmed, 1986).

8- Stratabound Pb, Zn and Fe sulfides with varieties of Pb & Zn sulphates, carbonates, chlorides, phosphates, molibdates and silicates as well as Fe-oxides and hydroxides, silica; Ca, Mg, and Fe carbonates, gypsum, anhydrite and kaolinite (e.g., Um Gheig mine area). This mineral assemblage is hosted in a karst fill mass developed along a major NW-SE rift fault as a response of Plio-Pleistocene (post-Um Gheig) paleokarst event (El Aref and Amstutz, 1983; El Aref *et al.*, 1986; El Aref 1993a,b)

9- Surficial manganese and barite deposits, long extracted from Halaib-Elba region, are described in detail by El Shazly (1957), El Shazly and Saleeb Roufaiel (1959) and Basta and Saleeb (1971). They exhibit features and textures of supergene processes that acted upon Precambrian granites and Miocene rocks and most likely related to the Plio-Pleistocene weathering event.

QUATERNARY DEPOSITS

1. **Beach placers**
2. **Alluvial placers**