SUMMARY AND CONCLUSIONS

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The geological history of the area studied is controlled by its geographic location as well as by the stratigraphic setting of the rocks in question and their structural development during a span of time extending from the Precambrian till the Quaternary.

The area is located in north east Africa, at the northern edge of the great African Shield which protrudes north east of the area, nearly bordering east Egypt in what is known as the Red Sea Hills. The roots of the basement rocks encircle south Egypt and extend south in Sudan forming the main core of the African Shield nearly uninterrupted except in small localized areas where platform sediments crop out masking the basement rocks beneath. The many igneous and metamorphic rocks in south west Egypt e.g. Tarfawi, Cepheren-Um Shaghir; Gebel Kamel and Uweinat are outcroping vestiges of the main African Shield uplifted intermittently during the Phanerozoic. The blanket of sediments above the shield extends from the Red Sea Hills sloping gently to the north and west forming a huge questa occupying almost $\frac{3}{4}$ of the total area of Egypt. In the area studied, the sediments thin out southward over the Shield, but again more thickness when proceeding north i.e. at the dip slope of the exhumed Shield. However within this general theme superimposed over the area because of its geomorphic location, structural feature since the Precambrian and during the Phanerozoic had developed a topographic model by which several intercratonic basins were created. In these basins, comparatively thick sediments were deposited hence diversified stratigraphic units were identified.

Issawi (1978) assumed that the area to the east of Tarfawi high was positive during the Paleozoic and most of the Cenozoic. The discovery of Devonian strata at Um Shaghir (present work) and of Devonian and Carboniferous rocks at Aswan area (Issawi and Jux, 1982 and Jux and Issawi, 1983) necessitates a new insight on the history of south Egypt.

During the Early Paleozoic, the area east of Tarfawi including the present area was a stable part of the north African Shield, whereas west of Tarfawi a huge basin, the Dakhla basin, was developed in Egypt initiated by the rising of the Uweinat-Gilf high in the west and Tarfawi high in the east. The Uweinat high bordered at that time another basin to the west namely Kufra basin. The two basins Dakhla and Kufra were hewed within the Precambrian rocks and were filled by clastic sediments from the eastern high Nubia massif. The Dakhla basin however might be slightly younger than the Kufra basin which received older Cambrian and Ordovician sediments, the Dakhla probably started in the Silurian or at maximum during the Late Ordovician (Burollet, 1963, Mahrholz 1965, Issawi 1978, Issawi and Jux 1982, Jux and Issawi 1983).

The Devonian witnessed a great unstability in the area where many grooves and low areas were developed east of Tarfawi, most probably by the rising of the Chephren high manifested in a huge basement area south and south east of Um Shaghir hill. Again, most probably another basement uplift took place at the present Nile course where a basement area was uplifted developing an intercratonic basin to the east of Aswan extending south east fingering the basement rocks of the Egyptian Eastern Desert. In summation, the configuration of the basement attested the development of the many intercratonic basins stretching along the northern flanks of Gondwana from Tabuk in Saudi Arabia passing by Sinai and the Eastern Desert basin, east and south east of Aswan basin, Um Shaghir sub-basin, Dakhla basin, Kufra basin and Murzuq basin; the last two are found in Libya (Bellini and Massa, 1981; Issawi and Jux, 1982; Al-Laaboun, 1982 and Jux and Issawi, 1983). The western and eastern most basins were entrenched much deeper within the basement rocks, hence receiving much thick and older sediments i.e. since the Cambrian whereas both Aswan and Um Shaghir areas were shallow troughs only, developed since the Devonian.

Klitzsch (1984) gave an account on the presence of Paleozoic sediments in the Dakhla basin reaching 3000 m, considering Nubia (including the study area) a marginal shelf to a continental foreland over which deposition of very shallow Paleozoic marine sediments interbedded with fluvio - continental to deltaic clastics took place. He also stated that "This Paleozoic cover, however, was removed from Nubia and bordering areas further north and west during the followig phase of structural development" (Klitzsch, 1984 p. 27). In 1990 Klitzsch (p. 398 and 399) and Klitzsch and Wycisk (1987) indicated that both the Devonian and Carboniferous sediments never crop out in Nubia or Aswan areas. The work of Zaghloul et al. (1983), Issawi and Jux (1982) and Jux and Issawi (1983) proved the presence of Devonian strata at Wadi Abu Agag to the east of Aswan, also the two last authors described Carboniferous plant remains from Wadi Abu Agag. The mapping of the area south east of Aswan by the staff members of the geological survey of Egypt also proves the presence of Upper Paleozoic sediments in this area (M. Hinnawi, Personal Communication, 1992).

The present work substantiates the allocation of Devonian and Carboniferous sandstone in Nubia.

At Um Shaghir, a clastic section 31.0 m thick was measured including *Bifungites sp.* which proves a Devonian age for this unit. The basal nonfossiliferous sediments (66.0 m thick) exhibit fining upward, ranging from basal conglomerate through sandstone to siltstone. The lithofacies and sedimentary structures indicate deposition in braided fluvial systems. Channel fill deposits are also common. In general, the Pre-Devonian or Early Devonian sediments in the area reflect fluvial activity over south Egypt most probably flowing from south to north, draining the high shield in the south to the north or north west as the direction of the cross beds indicate.

The Devonian clastics show parallel lamination, intensive bioturbations. The Bifungites point to marine invasions within an overwhelming fluvial sand and silt beds. The fluvial regime dominated over the area in Early Devonian or Pre Devonian continued during the Devonian with minor marine incursions. The Devonian shore line extended from west of Gilf Kebir (Issawi, 1978) passing by Um Shaghir and continued further east south of Aswan and crossing the present site of the Red Sea south of Hurgada. Drilling for oil in Hurgada area proved the presence of a thick clastic section which the oil geologists in Egypt named Nubia "A" (Hantar, 1990). This section might be Paleozoic and has nothing to do with the prefix Nubia (Sandstone). Also drilling at Wadi Araba some 120 km south of Suez (Hermina et al. (1983) reported on the presence of a thick clastic section below the Carboniferous which they considered Devonian in part. In general the Devonian shore line crossed south Egypt from west to east and continued north amid the present Red Sea Hills before the initation of the Red Sea and bends near south Sinai to the south again froming the western flank of Tabuk basin in Saudi Arabia. The picture presented here is totally different from that shown by Klitzsch (1990 p. 398).

The Carboniferous Gilf Formation has a thickness of 72.0 m, mostly represented by massive sandstone beds deposited as a result of rapid sediment dumping from high energy fluvial systems. Water carried clay particles from channel banks and also trea trunks. No marine Carboniferous sediments are known from the study area. The recognition of Carboniferous in the present area is made possible by the finding of floral remains within sediments of this system.

The initial break up of Gondwana began during the Permo-Carboniferous and Triassic. Rifting concentrated in widely separated areas stretching from the eastern margin

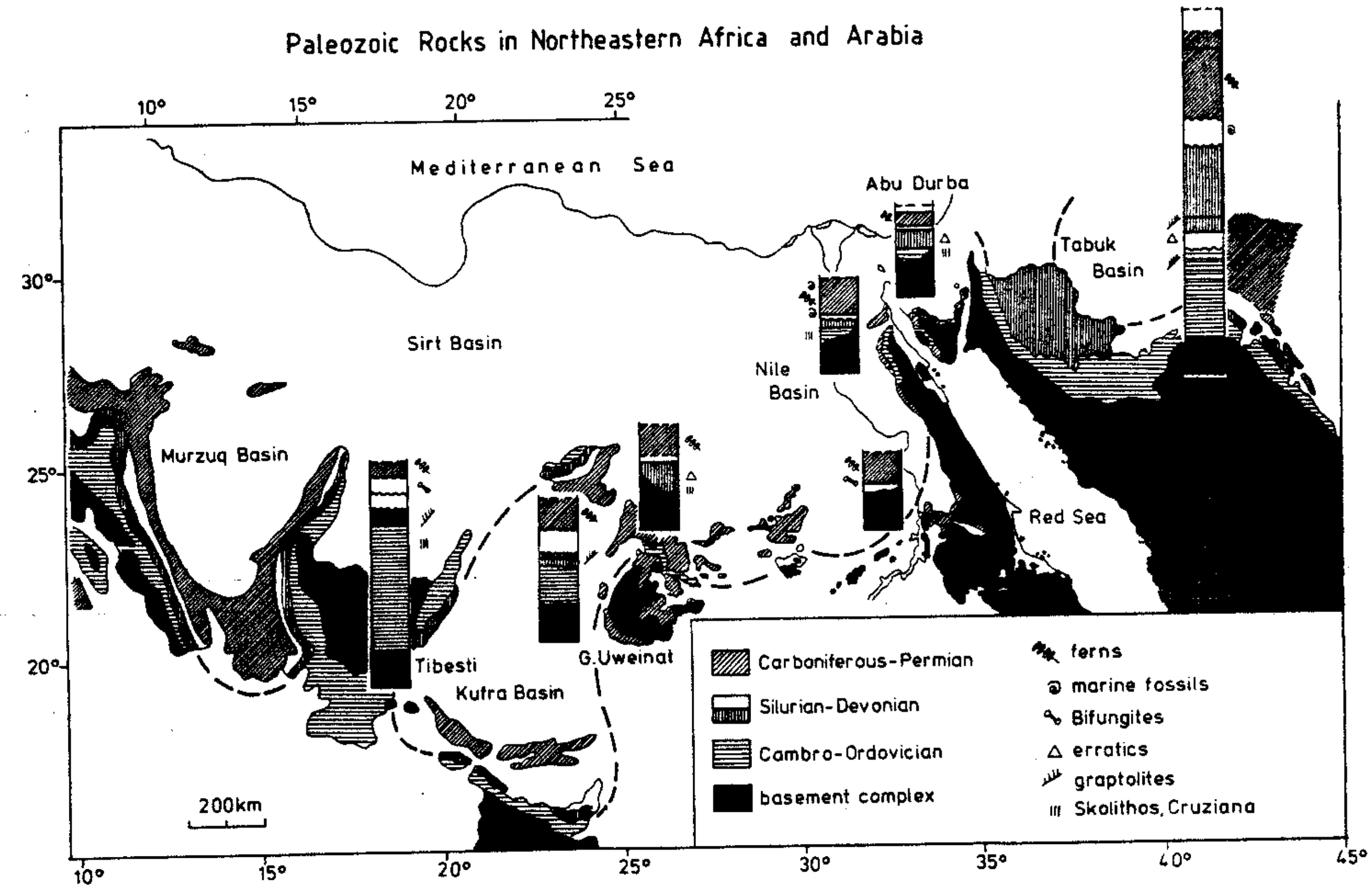

FIGURE 19. Surface exposures of Paleozoic sediments in Libya, Egypt, and Saudi Arabia in part from Bellini and Massa 1981; Issawi ans Jux, 1982; Al Laboun, 1982).

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of Africa to the axis of the future Central Atlantic ocean in the west and in the Tethys domain (Guiraud et al., 1991). In these areas rift related magmatic events are common. Along the north western margin of Africa rifting commenced during Middle Triassic and culminated at the Triassic/Jurassic transition time with the intrusion of extensive dolerite dykes and sills (Guiraud et al. 1991). In the Central Mediterranean Tethys domain rifting commenced during the Permian and propagated westward during the Triassic; rift related magmatism peaked in the area of Morocco and Algeria during the Late Triassic - Early Jurassic, prior to Middle Jurassic crustal separation between North Africa and Europe (Ziegler, 1988, 1992). At the west coast of the Gulf of Suez, Abdallah et al. (1963 described many basalt dykes injected through Jurassic beds, but the Lower Cretaceous sediments were not affected.

The effect of breaking of Gondwana resulted in a major uplift of most of south Egypt and the intrusion of alkalic rhyolites in Gebel Nusub el Balgum 216±5 Ma (Schandelmeir and Darbyshire, 1984) north of Bir Safsaf, in the area of Chephren quarries south of Um Shaghir and in the Carboniferous section of Gebel Uweinat and further north. In addition, the reactivation of the many fault lines in Nubia created a landscape with many positive and negative features. The presence of conglomerate and paleosol bands on top of the Gilf Formation reflects this unstable tectonic episode; a phase of the Hercynian orogeny. The uplifted basement rock masses i.e. Tarfawi and Chephren highs assumed a north to north east trend almost perpendicular to the most common east-west faults affecting the whole of south Egypt.

The presence of Permo-Triassic strata as postulated by Klitzsch (1984, 1990), in the area is uncertain in the wake of the uplift mentioned above. This uplift affected most of the land of Egypt, hence no definite marine Permian or Triassic sediments are known in Egypt south of latitude 30° N. Continental sediments belonging to these epoches are present within the clastic section encountered between the Carboniferous and Jurassic strata of Sinai and, the Eastern Desert (Abdallah et al., 1963 and Issawi and Jux, 1982), but there extension in south Egypt is uncertain.

The long period of marine regression over south Egypt during the Permian, the Triassic and probably the Early Jurassic had witnessed intensive erosional bevelling causing almost flat surface of Nubia area and further west. It is only by virtue of magmatic injection during the Triassic and Early Jurassic that the monotony of the flat surface had been broken and a rough physiography was developed.

During the Early Cretaceous, opening of the Atlantic was accompanied by deformations within the African plate much concentrated on pre existing zones of crustal weaknes which form more or less continuous bands defining several blocks (Olevet _et al._, 1984 and Unternehr _et al._, 1988). Of importance to our study is the two blocks constituting North Africa namely the Arabo Nubian block and the West African block (Burke and Deway, 1974 and Guirand and Mourin, 1991). The boundaries between these two blocks correspond to major fracture and rift zones. The Gulf of Guinea fracture zone continued northeastward into the Benu trough and continued in north Sudan and south west Egypt maintaing the same trend, N 35° E (Meyerhoff and Meyerhoff, 1972; Moody, 1973 and Issawi, 1978). The western faults of west Tarafawi basement high at about longitude 29°E belong most probably to this fracture zone. These fractures zones are Precambrian fractures (Meyerhoff and Meyerhoff, 1972) but have been reactivated and extended progressively with time reaching Egypt during the Late Jurassic - Early Cretaceous (Issawi, 1978). These structures separate the Arabo Nubian block from the westerly west African block. Within the Egyptian Arabo

Nubian block, the Late Jurassic - Early Cretaceous seas covered most of the low intercratonic basins depositing a type of facies mostly clastics 50.0 m thick but totally different from the underlying Paleozoic Sandstones. The Abu Ballas Formation belonging to this time span, shows evidences of being deposited under near - shore environment probably under tidal - flat influence ranging from high energy intertidal to low-energy supratidal. Sediments were transported by tidal currents (herringbone cross-bedding) and primary sedimentary structures were partly destroyed during periods of soil formation.

The directions of paleocurrents are perplexing showing northerly and southerly flowing streams. Though the embryonic Tethys was well established by this time and the paleocurrent directions should give evidence of being flowing north yet the southern and western directions are common pointing to a flow in these directions. It might be possible that the Trans African passage following the fracture zone between the Arabo Nubian block and the West African block was intiated by the Late Jurassic - Early Cretaceous and there was connection between the Tethys and the South Atlantic Ocean (Kogbe, 1980) passing by west Egypt. Rivers of south Egypt were also flowing to the south and west.

The following unit, Sabaya Formation, has a thickness of 100 m and represented fluvial deposits. The Sabaya was deposited by braided river systems associated with intensive soil formation during phases of non-deposition coupled by arid climatic conditions; both factors were playing on swampy areas continuously drying hence forming extensive soil horizons.

The continental fluvial conditions dominated over the study area since the last Albian transgression depositing the Abu Ballas continued during the Late Albian and Cenomanian. In the Cenomanian, a rich plant unit was deposited over the Sabaya equated here with the Bahariya Formation. Estuarine conditions became dominant after the last fluvial phases of the Sabaya.

The uplifted Nubia continued as a positive area during most of the remaining Cretaceous time since the Albian except with minor oscillations of the sea covering low areas either along the plate margins or following structural lines hence invading inside parts of the plate especially in areas of intercratonic basins.

The "Santonian event" (Gurioud <u>et</u> <u>al</u>. 1991) is widely known in Africa related to a regional compressional episode affecting many places in west and Central Africa up to the

Chad-Sudan border (Nagangom, 1983, Avbovbo et al., 1986 and Benkhalil et al., 1988). Its extension in Egypt was never understood though the Coniacian and Santonian strata are ill defined (Awad and Issawi, 1974). In Africa the event is associated with folding, conjugate strike-slip faulting, reverse faulting and inversion of some of the deepest Early to Middle Cretaceous basins into shallower ones or vice versa.

In Nubia, the effect of such event lies in the development of extensive troughs following the lines of the old submerged Paleozoic basins or the fracture zones along the old Arabo Nubian block. One of the most important troughs in south Egypt is the basin formed east of the Chephren quarries at the present site of the area studied. The basin is limited from the east by the basement rocks of the Aswan area, from the south by the basement of the second Cataract, near Halfa, from the west by the Chephren basement high. The development of this basin reached its final shape at this stage of structural event i.e. Santonian, heralded for the deposition of a thick massive unit partly continental and partly marine namely the Nubia Formation. Though the name has been unfortunately ignored in the work of Klitzsch and his assocaites and also by

Hermina et al. (1983), yet the name is still valied in Egyptian stratigraphy.

The Nubia is divided into Taref Member at the base where the dominant rocks are sandstones and Quseir Member an top where clays become equal or even more developed than the sandstones. In places, where interbedded sandstones and clays make the bulk of the section the unit is described under "undifferentiated Nubia Formation". The base of the Taref Member is characterized by kaolin lenses approaching beds which are of economic value at Kalabsha Kaolin quarries. These lateritic deposits pass gradually into oolitic iron rich kaolinitic sandstones. Both the kaolin and oolite iron lenses are surface pedogenic laterites to lake deposits; their lensoid shape and mode of deposition point to pond environment, arid conditions and pedogenic processes of formation.

The underlying surface of Nubia plays an important role in the type of sediments of this unit and their rapid lateral and vertical facies changes. Several environments of deposition might come near to each other if for instance a huge island made an obstacle in a river course. The type of fluvial sediments reflects braided river system, the many paleosol horizons prove subaerial exposures upon the fine grained sediments, overbank facies are known by fine laminated siltstone with few sandstone interbeds including root casts and plant stems. Aeolian sands on the same level of these fluvial deposits prove active wind carrying sands depositing them on a levee or island in the course of a river depositing its load.

The Quseir Clastic Member was also deposited under the same mode of deposition though the clay particles carried by the rivers in suspension are much greater than in the Taref Sandstone Member. Also very important marine incursions leading to the presence of many diagnoistic Maastrichtian fossils occurred.

To sum up, the Nubia Formation is a magna facies (Teichert, 1958) deposited under several environmental conditions varying from continental to fluvial to fluviomarine to shallow marine, mostly controlled by the uneven surface over which deposition took place during the Campanian - Maastrichtian times.

The flooding of the area by the Maastrichtian Sea was shallow at the begining giving rise to the Quseir Clastics topped by phosphatic lenses representing the well developed northerly Duwi Phosphates. The conditions of deposition were much shallower for well economic phosphate beds to be deposited.

The Maastrichtian Sea transgressed the area reaching north Sudan and proper marine Dakhla Shales were deposited.

The Kurkur Formation is a reefal facies known from the top of the Dakhla and an unconformity surface marks the contact between both units; the Danian is missing (Issawi, 1968).

The reefal facies of the Kurkur is followed by relatively deep marine conditions depositing thick carbonate unit during the Landenian and Early Eocene, Garra Formation at the base and another carbonate and clay unit on top; Dungul Formation of Early Eocene age.

The regression of the Tethys at the close of the Early Eocene from south Egypt was the last episode in the marine history over the area.

It is only during Late Eocene - Oligocene that tensional forces associated the uplift of east Egypt; the movement which preceded the opening of the Red Sea. Tensional forces in Nubia led to the activation of the old structural lines and along some of these faults magmatic eruption took place. It is not uncertain whether the compressional forces leading to thrusting (at Kalabsha) and the many wide domes in the area were antecedent or precedent to the tensional forces. However, in Europe and

North Africa tensional is considered precedent to compression which is believed intra - Eocene 40 Ma. (Fairhead and Binks, 1991). The event is related to a major stage in the collision between the African and European plates, known as the end Lutitiain Pyrenean or Pyrenaen - Atlasic phase (Guiraud, 1986).

The Quaternary sediments reflect several phases of wet and dry climates. During wet climates pond deposits, fresh water limestones, calcite deposits, Tufa and many other types of rocks were formd. On the other hand, dry climate, led to the erosion of the older rocks and the formation of sand dunes and sand sheets.