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## Karablands in Sudan: Pedological and Geomorphological Study

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### Abstract

Karablands (Typical badlands) which lie along the banks of the River Atbara and its tributaries represent a unique phenomenon in the area, therefore it has been investigated thoroughly well. After a geomorphological and pedological studies, it appeared that, the karablands were a former in-land lake formed by the River Atbara which ended at that time (~ 7000 years approximately), at Goz Rajab village. The river deposited its load in that lake, by time the River Atbara reached The River Nile and made its way in its former deposits, due to climatic change towards drier periods which enhanced erosional processes that formed the karablands.

**Keywords:** River Atbara; Badlands; Pedology; Geomorphology; Climatic change; Palaeolake.

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### 1. Introduction:

The River Atbara originates from the Ethiopian high lands north of Lake Tana. In the Sudan, two tributaries, Setit and Basalam join the River Atbara (Fig 1.A). The river Atbara course has been controlled by the pre-existing NW Basement shear zone similar to the Blue Nile. The length of Atbara river is about 600 km with an average width of 1 Km, and in some reaches the river varies in width. Due to the high gradient the river speed during the flood is estimated to be about 22 m/sec (Abdel Ati, 1985). River Atbara is contributing about 13.3 percent of the Nile water, mostly between July and October (Hurst, 1952). During the rest of the year the river dries in the lower reaches except for some pools and swamps. Rainy season extends from June to September in the upper reaches with an average annual

rainfall range between 500 to 800 mm, while in the lower reaches the average rainfall is under 75 mm mostly in August and September. The geological formation consists of extensive Pre-Cambrian Basement Complex, mainly of igneous and metamorphic rocks. In the southern part of the area, the river incises upstream vast areas of Tertiary basalt, Jurassic sandstone and mudstone of the Gadaref formation. Thick units of Quaternary, mostly heavy cracking clays, mainly covers the rocks of all formations except in the north in semi-desert land, where it is covered by medium and coarse textured materials: Geomorphologically, the southern part is covered by undulating degraded clay plain,

while New Halfa Irrigated Agricultural Scheme (NHAS) is slightly flat aggradational plain. The natural vegetation is mainly *Talh* trees (*Acacia seyal*) and *kiter* trees (*Acacia mellifera*), with tall grasses in the semi-arid zone; *Samar* trees (*Acacia tortilis*) dominates in the arid zone. Khashm El-Girba dam was constructed in 1964 to generate hydropower and to provide irrigation water to the immigrant people of Wadi Halfa of northern Sudan due to the construction of Aswan High Dam.

A geomorphologic characteristic feature in the study area is that, the Atbara river basin and the related Karablands (typically badlands) are below the level of the clay plain (Plate 1. A). The occurrence of old river terraces at height of 25m from today's river bed level most probably indicates that the river bed was about that height during the more humid climatic conditions of the middle Pleistocene (Said, 1993). The Karablands (typical Badlands) dominate in the middle and the upper reaches of the River Atbara and they cover about 3000 km<sup>2</sup>. They are characterized by thinly vegetated, desiccated rugged terrain and usually dissected by rills and gullies (Plate 2). On the basis of fossil dating the age of the karablands is found to be in lower Pleistocene (Chialvo, 1975).

### Methodology:

In order to achieve this study, many sources of information were used such as satellite images, maps, references, reports, and laboratory work (soil analysis). Ground check (field work) was also utilized for comparing information on the satellite images with the existing features on the ground (visual interpretation). For thin section preparation, the soil samples were decanted to get rid of the clay particles then they were dried in an oven at 40 °C over night. The samples were put in a resin blue-dyed epoxy to make them hard blocks, then they were put again in an oven at 40 °C over night.

Using a cutting diamond saw, blocks of about 2 mm were made, using an astra machine these blocks were grained and by adhesive material were put in a thin section glass, again the graining was done till they reached a thickness of 35 micron which is the standard thickness for a thin section. A polarizing microscope was used to examine the thin sections, while the interesting areas in the thin section were photographed by a mounting camera under plane polarizing light (PPL), and cross polarizing light (XPL).

Soil auger samples were analyzed to determine the soil texture (Sand, Silt and Clay), using Bouyocos method (Hydrometer), while Dry combustion (Resistance furnace) was used to determine organic carbon using Walkely-Blach method. Then the organic matter is calculated by the formula:

$$\% \text{ Organic matter} = 0.35 + (1.80 \times \% \text{ Organic carbon})$$

Nitrogen and Phosphorus determined using Kjeldahl and Olsen NaHCO<sub>3</sub> methods respectively.

### Results:

#### Bedding and Beds:

Beds are the characteristics of sediments that resulted from the spreading out of sedimentary material. Each bed consists of materials having consistent properties. These beds are a function of the ways in which particles are distributed in sediment. The gross size or composition of particles may change from one bed to the next. For example, a bed of pebbles may lie next to a bed of sand. Even in the fine sediments beds are found (Plates 1.C and 1.D). The thickness of beds is functions of the size of the sedimentary particles, the availability of particles, and the mechanics of particles deposition. Obviously, the limiting minimum thickness of a layer is diameter of its most abundant particles

**Plate (1)**

(A) Karablands below the level of the surrounding clay plain.



(B) Rills, Gullies and thinly vegetated cover characterize the Karablands.



(C) Beds of the Karablands.



(D) Recent sediments of the River Atbara.



(E) Calcium carbonate concretions scattered on the Karablands slope.



(F) Rounded shape of Karablands sediments (i.e. long distance transported).



(G) Fine particles are dominant in the northern part of the Karablands at Goz Rajab village.



(H) Fine sediments are existing far away from the recent river channel.





According to Abdel-Latif (1997), the litho-faces analysis of the Karabland sediments have revealed several faces classified according to the faces codes of Miall (1978):

1- Massive to horizontally stratified matrix supported polymictic gravels (GM), surrounded by basal contents. This face is usually overlain by through cross-stratified, moderately sorted, pebbly sand facies (ST).

2- Horizontally stratified sand (Sh) and horizontally laminated silt (F1), which interbedded with thin beds of calcrete (c). Different types of calcrete are encountered within the facies sequences they are whitish to gray in color and range from nodular to powdery to indurated and honey comb types. Boulder calcrete formed by the disintegration of hardpan calcrete are found usually scattered on the slope (Plate 1.E) they give the Karabland their unique color (gray).

Finally, the top of the facies sequence is usually occupied by desiccated laminated mud facies (m) which contains rootlets (Fig. 1.B).

### Shape of Sediments:

An important attribute of particles is their shapes. Shape describes the geometric form of particles, and this form reflects the origin, history, and internal lattice structure of the particles. During transport, as particles collision with one another or with bedrocks, their edges and corners wear off so that an angular particles may ultimately become round. From the field observation, the sediment particles are rounded shape, particularly pebble and sand grains (Plate 1.D).

Therefore it could be stated that, these sediments are transported by the running water from the Ethiopian High lands with the slope to its recent place, because wind cannot carry or rolls great sizes of pebbles like the sediments of the Karabland (Plate 1.D), particularly that the climate in the Quaternary and early Pleistocene were more wetter than it is now. The transportation and sedimentation occurred when water passed the steep gradient and reached the gentle gradient (Fig 1.C).

### Size Distribution:

The movement of wind and water commonly separate particles by their sizes; thus many sedimentary deposits consist of pure sand, silt, or clay, however, where sediments from contrasting parent deposits converge, mixture of size are common (Friedman et. al 1926).

The size distribution of sediments particles in the Karabland is identified where the vertical depths according to the difference of sizes in the sediment layers. It was observed that, the clay soil or sandy clay where clay is the dominant particles (Plate 1.F and 1.G), due to the relatively low discharge and slow speed which decreases the ability of stream to carry or rolls larger sizes of sediment for long distance.

Mixture of sizes, gravel consisting of particles that individually may be boulders, cobbles, or pebbles, sand, which may be very coarse, coarse, medium, fine, or very fine, and mud, which may consist of clay and various size classes of silt. Plate (1.C) is the best case of this type of size mixture in the Karabland sediments. This type may reflect the different discharge and different speeds (flow) for the stream and their fluctuations.

There are also longitudinal distributions of particle size mainly due to the decreases in the river flow, which decrease its ability to carry sediments. Therefore, in the Southern part of the area (Sofi village) the particle size is larger, then it decreases northward till Goz Rajab village where the particle size is finer.

Another characteristic of the Karabland deposits is that it becomes wider as we move northward. Due to the channel slope, i.e there is an adverse relationship between slope and the width of the Karabland (Fig. 1.A and 1.B). As a result of the variation in deposit particle's size, the erosion process is more active in removing the fine particles (clay and silt) and leaving the coarser materials (pebbles and gravels) covering the top of the Karabland in the most of the area (Plate 1.E).

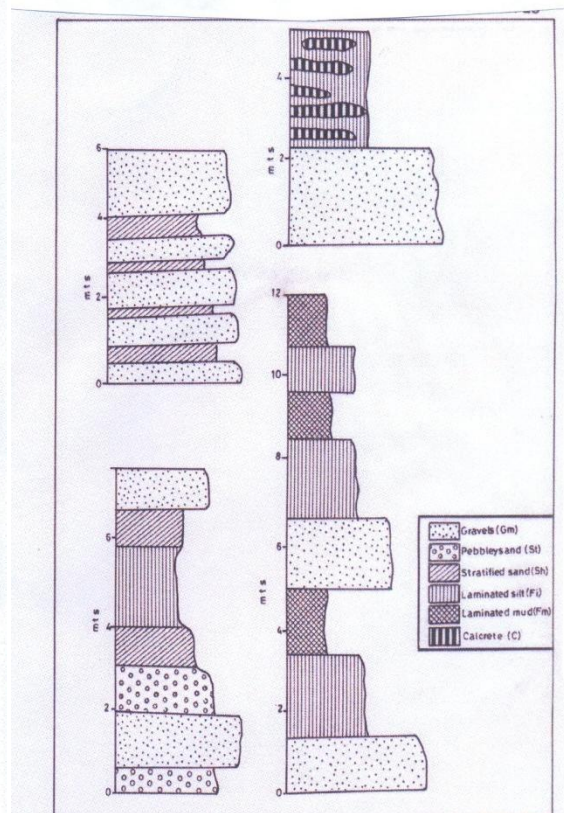
Figure (1)

(A) Karablands along the River Atbara



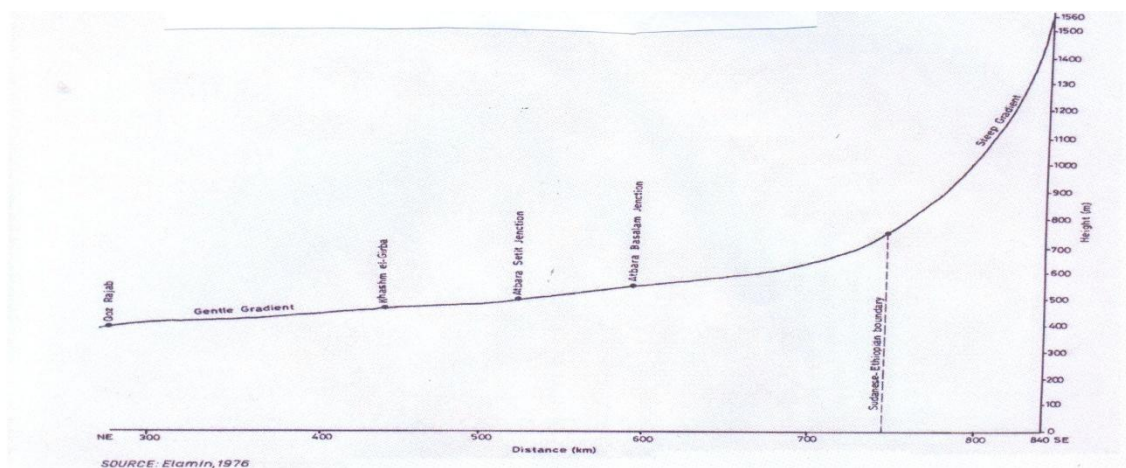
Source: Nasr (2004)

(B) Vertical profiles in Karabland main faces types



Source: Abdellatif (1997)

(C) Slope of the River Atbara channel



Source: El amin ( 1976 )

### Mineralogy:

Casual examination of soil sample illustrates that; the inorganic portion is variable in size and composition. It is normally composed of small rock fragments and minerals of various kinds. The rock fragments are remnants of massive rocks from which the regolith and in turn the soil has been formed by weathering ; they are usually quite coarse. The minerals on the other hand, are extremely variable in sizes, some are large as smaller rock fragments; others, such as colloidal clay particles, are so small that they can't be seen with the aid of an ordinary microscope. An electron microscope must be used.

Minerals such as quartz and other so-called primary minerals have persisted more or less unchanged in composition from the original mother rock, other minerals such as the silicate clays and iron oxides have been formed by the weathering of less-resistant minerals as the regolith developed and soil formation progressed. These minerals are called secondary minerals. In general, the primary minerals tend to dominate the coarser fractions of soil, whereas secondary minerals are most prominent in the fine materials, especially in clays.

Thin sections investigation of sand minerals showed that, quartz (sub- rounded to angular) is the dominant in the black cotton soils while calcium carbonate nodules rarely occurred, Polycrystalline quartz, feldspars and, plagioclase (which are dominant in metamorphic rocks) are also seen (Plates 1.H, 2.A and 2.B). River flood plain mainly consists of heavy minerals especially Apatite, Zircon, Iron oxide, Ilmenite, and Rutile, while quartz is rarely existed, that is mainly due to the variation of the specific gravity among minerals. Heavy minerals are deposited inside the bed of the river channel or close to it, while light minerals like Quartz and Feldspars are deposited far away from the River channel (Plate 2.C, 2.D and 2.E).

Thin section, which is prepared from the Karabland, showed that calcium carbonate is

dominant (in nodules or cementing other materials like rock fragments or quartz) (Plates 2.F, 2.G and 2.H). Sometimes calcium carbonates occur in layers. Heavy minerals are rarely occurred in this sample but some also exist. Therefore it could be stated that, sand minerals in the three categories (Black cotton soil – Karabland – River flood plain) are quite different. Black cotton soils have mainly light minerals (Quartz and feldspars), while river floodplain is mainly heavy minerals beside little amount of carbonates.

The little amount of heavy minerals which are occurring in Karabland and little amount of calcium carbonates that exist in the river flood plain indicate that these soils are genetically similar together (i.e. they are of the same parent material). The formation of the Karablands by the river resulted in considerable amount of water in them, which later evaporated resulting in salts accumulation which formed the carbonate that characterize these lands, while the absence of common minerals between Black Cotton Soil and Karabland or river flood plain, indicated that the Black Cotton Soil is locally developed while others are transported soils.

### Discussion:

#### Age of Karabland:

Arkell (1949) recorded fossil mammal bones and chellean-type artifacts from the 33-ft terrace at the River Atbara on the left bank upstream from the Butana Bridge. He also recorded terraces at 21 ft and 14 ft. L. Berry and Whiteman in 1966 studied sections exposed on the east bank of the river. It is undoubted that Paleolithic implements were found and they were unable to spend sufficient time in the area to obtain a complete picture. The Atbara River is now cutting into a thick series of sands, gravels and clays exposed from the bridge upon to the plain extending toward Kassala town. Terraces are present near the river as Arkell mentioned, but the terrace features that occur on either sides of the river as it arises out of the valley are erosion feature produced by hard and soft

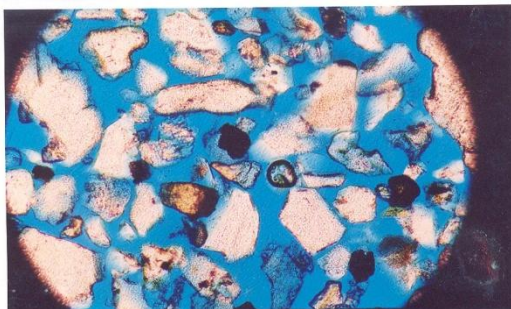


**Plate (2)**

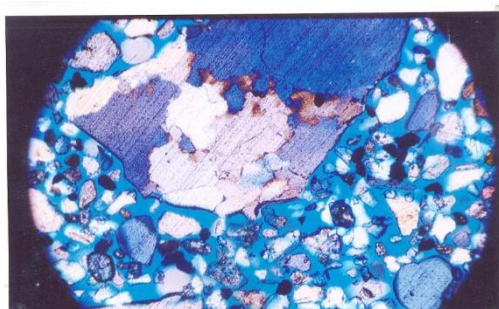
(A) Sediments of different sizes are dominant Cotton soil.



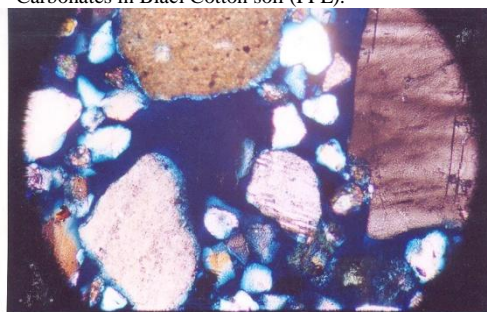
(B) Quartz and some ironoxides in the Black in the Karablands.



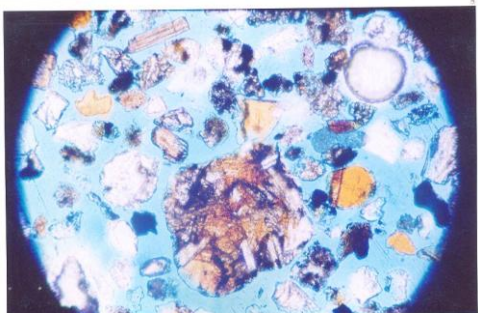
(C) Polycrystalline Quartz (mainly from etamorphic rocks) in Black Cotton soil(XPL).



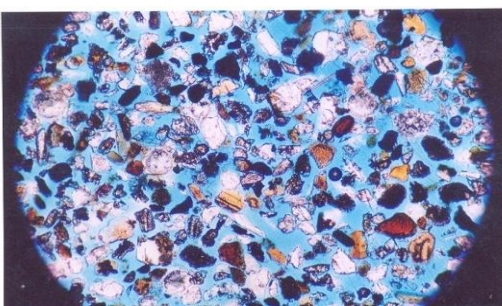
(D) Quartz and Feldspar beside some calcium Carbonates in Blacl Cotton soil (PPL).



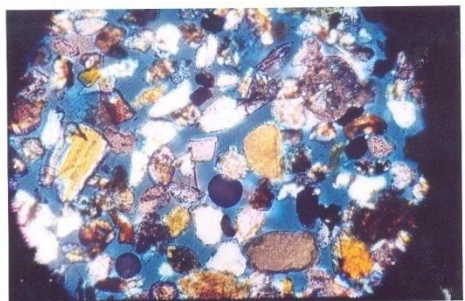
(E) Heavy minerals (Iron oxides and Aptite) and Rocks fragments in river flood plain soil (XPL).



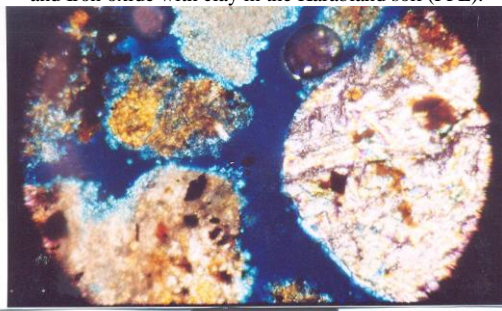
(F) Heavy minerals (Aptite,Zircon and Iron) 400 u in the River flood plain soil(XPL).



(G) Heavy minerals (Iron oxides, Zircon and Amphiboles) in the river flood plain soil (XPL).



(H) Volcanic rocks fragment , calcium carbonate and Iron oxide with clay in the Karabland soil (PPL).





bands in the unconsolidated deposition. These stretch eastward and in the Whiteman's views (1971) are part of the Pleistocene deposits.

Snails collected from a soil pit dug in the Khashum El Girba area in connection with the irrigation scheme gave a radiocarbon age of  $12150 \pm 375$  years B.P. (Whiteman, 1971). The shells were obtained from a depth of 185 cm. from a clay layer ( $15^{\circ} 48' N$ ,  $35^{\circ} 24' 30'' E$ ). Then the Karablands deposits, (including the terrace system of the River Atbara) may be older than 12150 years B.P. The Karabland also intensively investigated by Abbate *et al.* (2010), according to the investigation the area yielded vertebrate remains and many Acheulean artifacts and was deposited from the late Early Pleistocene to the early Middle Pleistocene.

### **Climatic change:**

During the Triassic Africa was part of the great continent of Gondwanaland, which also included Australia, Antarctica, India and Southern America. By Jurassic times west Gondwanaland, comprising Africa and South America, had separated from east Gondwanaland, comprising Australia, Antarctica, and India. Separation of earth of the constituent continental segments of former Gondwanaland began during the Cretaceous.

A slow clockwise rotation and northward movement of the African continent took place during the ensuing 75 million years of Cenozoic time. One result of these movements was a change in the position of Africa relative to the equator. During the Cretaceous Africa was positioned such that the equator extended from S.W. Nigeria, through central Chad, into N.W. Sudan and Saudi Arabia (Habicht, 1979).

By early Tertiary time Africa was only a few degrees south of its present position. During the Miocene and Pliocene a slight clockwise rotation brought Africa into contact with Europe, the resultant crustal deformation was accompanied by considerable uplift in the Atlas, and by volcanism and updoming in the Hoggar, Tibesti, and Jebel Marra mountains (Vincent 1960, Rognon 1967, Girod 1971; and

Vail 1972). Another outcome of the slow northward drift of Africa during Palaeozoic time was a progressive southward shift of the equatorial forest belt, which once extended diagonally across the Sahara from S.W. to NE. Associated with the late Tertiary built up of ice in high latitudes were major changes in the vegetation of northern Africa during the early Tertiary (Paleocene and Eocene), conditions in the southern sector of the present Sahara were dominantly equatorial and widespread deep weathering was characteristic of this time (Faure, 1976, Greigent and Pognet 1967). At the onset of the Oligocene, sea surface temperature fell sharply. From Oligocene to Miocene time Sudano- Guinean woodland and Sudanian Savanna woodland covered much of what is now the Sahara (Maley, 1980).

Pollen spectra from scattered localities in northern Africa show that many elements of the present Saharan flora were already present during the Pliocene, suggesting that replacement of tropical woodland by plant adapted to aridity was in progress during the late Miocene and early Pliocene. The consequences of these changes were predictable and dramatic. Major rivers, which had previously eroded large valleys, dwindled and dried up, valleys became choked with alluvium and with colluviums washed off the previously vegetated and stable slopes. Wind no longer stopped by vegetation but mobilized the alluvium and formed some of it into dunes of silt and clay particles which were blown and from the land to the sea. Now in the arid Hoggar Mountains at southern Algeria; there seems to have several phases during the late Pliocene or early Pleistocene when the mountain valleys had tropical freshwater lakes, which subsequently dried out (Rognon, 1967).

In western Sudan lake diatomite's of probable early Pleistocene age occupy a lava dammed valley northwest of Jebel Marra (Williams *et al.*, 1982), and in the Afar desert of Ethiopia and Djibouti lakes occupied now arid fault-troughs on a number of occasions during the

late Pliocene and early Pleistocene (Gasse, 1975, Gasse et al; 1980).

Pollen spectra from fluvio-deltaic sediments of the Ome River in southern Ethiopia revealed a decrease in rainfall between 3.0 and 2.0 million years ago, leading to extension of the *Antrocaryan* flora and culminating in a drier-than present climatic phase between 2.35 and 2.10 million years ago (Bonnefille, 1979). The moist interval toward 6.500-4.500 B.P. which is evident on both margins of the Sahara as well as in now hyper – arid parts of Libya, Egypt and the Sudan, evidenced a vast expansion of Neolithic nomads throughout the desert of Northern Africa, followed by a great migrations to the less arid margins and to the Nile valley after about 4.500 B.P. (Clark, 1980).

#### **Evolution of Karabland:**

The faces and the stacked fining upward sequence testify the deposition within channels, bars and overbank environments of low-sinuosity stream under higher discharge, larger sediment load and humid climatic condition than those occurring today. The formation of the Karablands testifies to gradual change in the fluvial style from a aggradational to degradational regime in response to both outocyclic and allocyclic process operating since lower Pleistocene (Abdel latif, 1993).

The Karablands appear to have developed in response to extreme erosion in the river basin caused by base – level change in the river system, which was triggered by late Tertiary climatic change toward drier conditions. The climatic change and its influence on the river system and the fluvial styles are reported from the Blue and White Niles in the Sudan (Williams et al, 1982). Moreover Campbell (1989) has reported from Mexico and Alberta, Similar cases of badlands developments in response to extreme rapid evolution in stream systems due to Holocene climatic fluctuation. In Sudan both natural and man-made causes have contributed to badlands development in

the river basin. The prolonged drought periods, destruction of vegetation and the desertification all have resulted in a high rate of erosion. The limited cover of vegetation and the favorable erodable lithologies contributed also to that development.

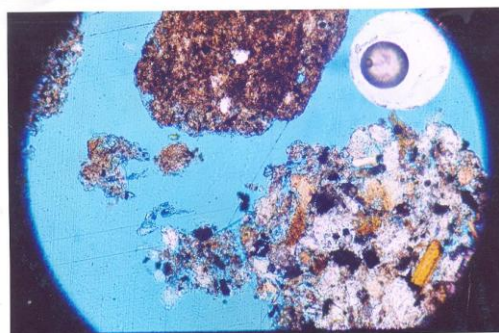
The Karablands with their clastic sediments provide an endless supply of easily erodable sediments. The frequency and magnitude of the seasonal fluvial events as well as the physical and chemical characteristics of the badlands facies limit erosion on the Karablands. The differential erosion and weathering are well manifested in the fluvial facies sequences. The well-developed gullies cutting deep in the clay sediments indicate the highly erodable nature of these sediments (Plate 3.A). These erodable sediments eventually find their way to the river channel choking the channel with a huge sediment load. Higher sedimentation is one of several environmental aspects in the River Atbara basin, (Abdel Ati, 1985; Khallafalla and Osman, 1986; Ahmed and Hamed, 1986). The high erosion rates have produced high sedimentation yield. Prior to the construction of Khashm El- Girba Dam, the silt content was estimated around 3 kg per cubic meter of the river water (Elshami, 1976). Recently, a random sample of river water is found to contain 30 percent silt by volume mainly due to the removal of vegetation especially for mechanized rain-fed agriculture.

#### **Ancient Lake:**

There is a hypotheses probably that, the Karablands areas was an ancient lake (Atbara palaeolake) where the running water accumulated for long time in the Midle Tertiary eras when a series of earth quakes occurred in Sudan and some faults resulted which led to lowering of the basic rocks and Nubian sandstone, then the river Atbara had been captured by the Nile. In the late Tertiary and early Quaternary the tectonic movement was familiar which resulted in earth mass movement down ward and upward, then the

### Plate (3)

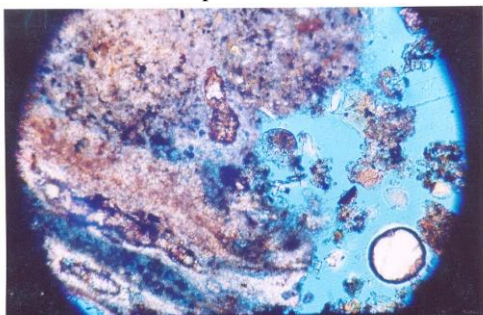
(A) Rock fragments cemented by carbonate and clay in Karabland soil



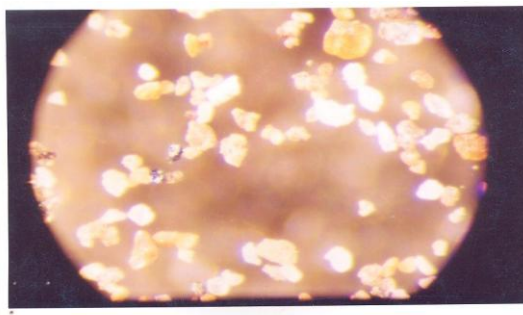
(B) The nature of the Karabland resulted from deep gullies due to high erodability of the clay soil.



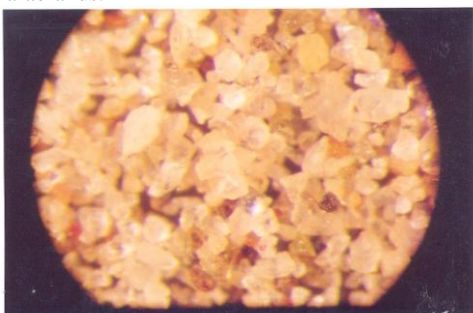
(C) Calcium carbonate in the Karabland in the soil of the river plain.



(D) Heavy minerals (iron oxides) and Quartz soil (PPL).



(E) Quartz in the Black Cotton soil.



(F) Calcium Carbonate concentration is the dominant mineral in the Karablands.



(G) Vegetated water inlets decrease water Materials.



(H) Utilization of Karabland sediments as Erosivity. building Materials.





African rift and the Ethiopian plateau appeared, beside some longitudinal faults which formed the water drainage of the upper Atbara, upper Blue Nile, Sobat, Dinder, and Rahad rivers. This tectonic movement also removed the natural barrier, which hindered the river Atbara to reach the River Nile and destroyed the mountainous masses forming Khashm El-Girba cataract in distance of 475 meters and height of 430 meters above sea level.

The previous actions followed by climatic change and arrival of huge amount of water from the Ethiopian plateau in the late Miocene and early Pleistocene, the river Nile captured the River Atbara, Blue Nile and, white Nile in the late Pleistocene therefore the River Atbara valley with its recent shape was formed in Pleistocene.

Before removal of the barrier that hindered the River Atbara to connect with, the River Nile, River Atbara deposited its suspended and bed loads inside the lake (the depression between Goz Rajab village and the Sudanese Ethiopian boundaries). After removal of the barrier, due to occurrence of some faults as a result of tectonic reformation prior to the Pleistocene, El Bedri et-al (2006), simultaneously with the change in the base level and drained of dammed water, the equilibrium of the river activity changed, the river began to erode a new channel on its former deposits. Due to the nature of the Karabland (i.e. the high erodibility), the river's channel become deeper and top of the deposits exceeded 25 meters which led to increase the running water's speed and consequently its erosivity. Due to the high rate of erosion on the top of the karabland it carried into a fantastic regime of gullies and gorges (Plate 1.A) at the western and eastern banks of the river, but its dominant on the left side due to the slope factor. There are some observational as well as analytical factors could be used as evidences for the occurrence of the former lake in the site of the recent Karabland areas.

### **Observational Evidences:**

- 1- Karablands consist of clay soil, sandy soil, regolith, pebbles and gravels transported by running water (i.e. transported soil) surrounded by the black cotton soil which formed in situ (El-Amin, 1976).
- 2- The highest peaks of the Karbland do not exceed 30 meters above the riverbed and below the level of the surrounding black cotton soils. Those peaks slope toward the river channel (Plate 1.B).
- 3- The edge of the Karabland formation follows the contour line 500 meters above sea level i.e. all or most edges are of the same height.
- 4- The existence of lateral beds of sediments and its expansion to the west and east of the river channel in the same level indicates that, these beds were sedimented at the same time of the same flood (discharge).
- 5- Sequences of the gravels size from the Sudanese-Ethiopian boundaries Northwest ward to Goz Rajab village i.e. sediments size start bigger at Gallabat town, and start to decrease toward Goz Rajab village.
- 6- The width of Karabland increases as we move northwesterly from few meters at Gallabat town to more than 10 km at Goz Rajab village (Fig 1.A), i.e. there is adverse relationship between the width of the Karabland and degree of slope.
- 7- Karabland covered by gravels and rock fragments which are dominant in the recent river channel.
- 8- Whiteman (1971) proved that, the geological history of the river Atbara channel and Karabland formation are of the Pleistocene formation, accordingly, they are simultaneous phenomena.
- 9- Existence of some parallel faults is observed at the end of the Karabland north Goz Rajab village; that could be considered as important observational evidence.

**Analytical Evidences:**

1. Analysis of the black cotton soil under different land uses (cropping, forest, and pasture) showed that the sand percentage in the top soil is slightly higher than the lower depths mainly due to the erosional activity, while the Karablad is totally different, due to the nonsystematic distribution of the particle size within the strata.

2. Soil analysis also showed that, the Karabland have a relatively low fertility particularly in the organic matter content, that is mainly due to the coarse particles of sediments which allow more water to infiltrate and high content of air which accelerate the oxidation of organic matter.

3. Thin sections investigation for Karabland, black cotton soil and river flood plain showed that, the dominant minerals are calcium carbonate, quartz and heavy minerals respectively (Plates 3.B, 3.C, 3.D and 3.E). There are some links between badland (Karabland) and river flood plain, which are the existence of calcium carbonate and heavy minerals in both of them (i.e. they are of the same source). The considerable amount of calcium carbonate in the Karabland indicated that, this soil was rich in water content, then water evaporated leaving the carbonates.

From these investigations, it can be concluded that, the Karabland is a transported soil carried by the River Atbara from the Ethiopian high lands and deposited in the lake (depression) between Gallabat town at the Sudanese-Ethiopian boundaries and Goz-Rajab village (16° 15' N) during the Pleistocene.

**Conclusion:**

Karabland covers about 3000 km<sup>2</sup> of less-fertile soil, which cannot be used for agricultural production despite the availability of the water for irrigation that is mainly due to its irregular topography (Plates 1.A and 1.B). As pasture, Karablands is a good source of fodders for camels and goats (especially in remote areas), where animals browsing trees and shrubs grow at both sides of the water inlets (Plate 3.F).

Karabland deposits also used as a building materials, fine materials (clay and silt) used to make building blocks while pebbles and gravels sieved to be used with cement and sand for concrete (Plate 3.G). As a resource potential, groundwater exploration has revealed that the Karabland facies which border the river, represent a major and important ground water aquifer which is annually recharged from the river floods, that is mainly due to the sediments properties which contain a considerable amount of sand, gravels with CaCO<sub>3</sub> concretion overlying Basement complex. This water is mainly used for drinking by nomads and their animals. The Karabland resulted in response to extreme water erosion activity, caused by base level change. This change was triggered by the late climatic changes toward drier conditions. The karabland facies indicate that the deposition occurred by low-sinuosity streams under rather higher discharges, larger sediment loads and more humid climatic conditions than those occurring today.

The prolonged drought, the lack of vegetation cover and the nature of the easily erodable sediments all have resulted in accelerated erosion of the ancient sediments and then resulted the recent morphology of the Karabland, Erosion of the Karabland together with erosion of the river catchment area resulted in high sedimentation yields, that eventually deposited in the river channel and Khashm El-Girba reservoir leading to significant reduction in the storage capacity,

decline in hydropower generation and, decreasing in the total irrigated area in Kashm El-Girba Agricultural Scheme.

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