PANORAMIC OF PALEOHABITATS OF PLIOCENE SAHABI FORMATION AND RECENT AS-SAHABI AREA, NORTHERN LIBYA

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ABSTRACT

*As-Sahabi area is located to the south of Ajdabiyah city in Sirt Basin, Libya. This area considered as a spectacular open Museum of vertebrate remains (i.e. teeth, bones, skulls and skeletons) of mammals, reptiles, aves and fish. This paper presents the methods used during the excavation and lists most of the documented taxa and finally compare these paleo-habitats with the corresponding present-day habitat of As-Sahabi. The As-Sahabi fossils played important role in delineating the paleohabitats and in understanding the migration routes as well as in tracing their evolutionary trends. These remains are preserved in continental deposits (mainly sands and clays) since 5 million years ago. Six paleo-habitats have been suggested "Salt neritic water, Eo-Sahabi River, Riverine forest and river edge, Water's edge and Eo-Sahabi estuary habitats, Savana habitat, and Arid Desert-like habitat. As-Sahabi vertebrates (e.g. crocodiles, hippos, hyena, etc..) are considered to be the ancestral taxa of the descendant vertebrates exist today in other parts of the world. However, some are found to be indigenous taxa due to migration failure such as the gigantic size, Mastodon (*Stegotetrabeledon lybicus*) and shovel-tusker Proposcidean (*Amebelodon cyrenaicus*) or medium-sized with short-legged *Anthracothere* (*Libycosaurus petrocchii*).*

Keywords: As-Sahabi; Vertebrates; Proposcidean; Continental; Libya

INTRODUCTION

The well-known Neogene paleontological site in Libya, As Sahabi (Fig. 1) has attracted not only paleontologists for its open natural museum of Neogene vertebrates, but also tourists for its fascinating scenery and impressive desert landscape panorama. During the 1920's, Italian soldiers noted by accident the presence of mammal fossil bones in the vicinity of the Qasr as Sahabi, a now-ruined fort dating from Roman times, located at the southern part of the present paleontological site. In the early 1930's, the famed Italian geologist and paleontologist Ardito Desio, with Professor G. D' Erasmio from Naples and geologist G. Stefanini from the University of Pisa, conducted the first geological and paleontological investigation in the As Sahabi area (Petrocchi, 1934). Carlo Petrocchi,

a young paleontologist recruited in the 1935 by Desio to study As Sahabi, would become involved for decades in As Sahabi (and Libya), and make discoveries that rendered As Sahabi the most famous Libyan fossil site. Among his first finds (via excavations also), were the skull of the four-tusked elephantid *Stegotetrabelodon syrticus* and the skull and the *in-situ* skeleton of a cetacean, a whale (Petrocchi 1934, 1936 and 1941). For more on the discovery of the As Sahabi site, see Rook (2008); for a general presentation of the paleontological site, see Boaz (2008).

The as Sahabi area is located in the northeastern part of Sirt Basin, covering an area of about 375 km² (Fig. 1). It is bounded by longitudes 20°48'08" to 20°54'45" E and latitudes 30°10'58" to 30°17'36" N, within a tectonic province called the Ajdabiyah Trough. The productive samples in terms of vertebrates came from scattered exposures aligned in a N30°E-trending manner and bounded by the Sabkhat al Qunayyin from the west (Fig. 1). However, the western part of the As Sahabi area is called the Sabkhat Al Qunayyin (Fig. 1).

Fig. 1: Index map shows the location of As Sahabi (modified after Muftah, 2013)

MATERIALS AND METHODS

The Field Work

The visited stratigraphic outcrops in As Sahabi area for this study consist of two profiles named P10 and P28 (Fig. 2). P10 (Jabal Shagig): Coordinates: Latitudes (30°11'12.58" N) and Longitudes

(20°49'24.14" E). The measured thickness of this profile is 46 meters, represented by all members of Sahabi Formation (Fig. 2). P28 (Elephant hill): Coordinates: Latitudes (30°13'56.69" N) and Longitudes (20°51'26.71" E). The measured thickness of this profile is 22 m. This section represents by four members of Sahabi Formation, from bottom to top U1 member, UD member, and V member. At this locality a possible complete skeleton of the Mastodon *Stegotetralodon* is buried, from which the name of the hill was derived. An amazing petrified forest is situated in front of this hill (Fig. 2).

Fig. 2: Jabal Shagig (P10); and Elephant hill (P28)

Excavation Procedures

- 1- Sediments (sands) are removed from around the specimen (Fig. 3A) using painting brush with intensive care, because the "skeleton" is very fragile and will be collapsed easily if subjected to very little force (Fig. 3B).
- 2- when most of the skeleton is exposed (Fig. 3C) the surface covered with thin Paraloid – B72 or any alternative glue and left this cover for many hours (up to 24 hours) to infiltrate and fill the bone tissue (pores) to hardening the skeleton.
- 3- The glued skeleton is coated with Aluminium foil and covered with wet cloth. All exposed skeleton coated with Gypsum amalgom and left this for 24 hours to solidify (Fig. 3D).
- 4- The coated and solidified skeleton is turned upside down (Fig. 3E) with care, then the specimen transported to the Laboratory. The gypsum cover is removed in the laboratory to undergoes the required measurements and identifications by the concerned specialists.

Fig. 3: The excavation steps of *Chelonia* from AS Sahabi area near the petrified forest at P28

RESULTS AND DISCUSSION

Geological Settings

Stratigraphy

The As Sahabi area was mapped by De Heinzelin and El-Arnautil (1983&1987); Muftah et al. (2008); Muftah (2013). Recently, El-Shawaihdi et al. (2014), El-Shawaihdi et al. (2016) amended the lithostratigraphic nomenclatures of the As Sahabi area based on stable isotopes dating of few samples to modify formation "M" and regional correlation to introduced new "lower member" and "upper member" of Sahabi Formation, Qarrat Waddah Formation and Z Formation, the latest version (Fig. 4) the composite columnar section having adopted four superimposed formations composing the substratum:

1- M Formation: Semiconsolidated bioclasts exposed in floor of the Sebkhat, totally or partially decalcified and gypsified. Erosional relief of shallow reefs "MR" with corals, echinoids, pelecypods and gastropods (De Heinzelin and El-Arnautil, 1987) (Fig. 4).

2- Sahabi Formation: It can be subdivided into two members: i) the lower member ($\approx$ De Heinzelin and El-Arnautil's P member and lowermost part of T member) characterized by semi-consolidated sandy, gypsiferous, and dolomitic limestone. Presence of a large network of fractures ($\sim$ 5 m deep) filled with selenitic gypsum is also a characteristic feature. ii) the upper member ($\approx$ De Heinzelin and El-Arnautil's T, U1, UD, and U2 members of Sahabi Formation) and uppermost part of T member) characterized by Sand with abundant marine fauna in places. Often bioturbated, and containing fish teeth and sirenian skeletons with land mammals. Followed by sands with clay lenses and clay balls incorporating well preserved bones. A transgressive bar, followed by interbedding of sand, clay and

dolomitic crusts generally bounded between two dolomite beds, the lower one is highly bioturbated (Fig. 4).

3- Qarat Weddah Formation ($\approx$ De Heinzelin and El- Arnauti's V member): Composes mainly of medium-coarse sands and sandy clays with lenses of dolomite and gypsum crystals (Fig. 4).

4- Z Formation ($\approx$ De Heinzelin and El- Arnauti's Z member): Very complex fossil soil capping the Sahabi Formation (Fig. 4).

Paleontology Flora

The Sahabi fossil flora is largely African in nature, as judged by comparative anatomy of the collected fossil wood with the living African species (Dechamps, 1987a; 1987b; Dechamps & Maes, 1987). These include *Acacia mellifera*, *A. nilotica*, *A. tortilus*, *Ekebergia rueppeliana*, *Sterculia setigera*, *Adenia gummifera*, *Cryptosepalum pseudotaxus*, *Hyphaene thebaica*, and *Phoenix dactylifera*. Evidence of fossil diatoms undigested within coprolites is also recorded from the Sahabi Formation (Burckle, 1982).

Paleontology Fauna

A large number of mammalian and other vertebrate remains (more than 5000 specimens), have been so far collected and identified from the Sahabi Formation (lower member in the As Sahabi area, with De Heinzelin and El- Arnauti's member "U1" the most prolific in terms of mammalian, reptilian and avian remains. The most common mammalian representatives in the Sahabi Formation after Boaz et al., (2008) are shown on Table (1). Presence of the vertebrate trace fossils (Coprolites) is also common characteristic in the investigated area, which give a clue to the behavior of these organisms (Fig. 5).

Fig. 4: Geological map and composite stratigraphic column of As Sahabi area shows the studied profiles (Modified after De Heinzelin and El-Arnauti, 1987)

**Table 1: Some of the documented Mammalian faunas from Sahabi Formation
(As Sahabi) (after Boaz et al., 2008)**

Order	Family	Genus	Species
Carnivora	Felidae	<i>Machairodus</i>	sp.
	Ursidae	<i>Indarctos</i>	<i>atticus</i>
	Viverridae	<i>Viverra</i>	sp.
	Hyaenidae	<i>Percrocuta</i>	<i>senyureki</i>
		<i>Hyaenictitherium</i>	sp.
Proboscidea		<i>Euryboas</i>	sp.
	Phocidae	gen. indet	sp. indet
	Gomphotheriidae	<i>Ambelodon</i>	<i>cyrenaicus</i>
		<i>Anacus</i>	<i>petrocchi</i>
	Elphantidae	<i>Stegotetrabelodon</i>	<i>syrticus</i>
Perissodactyla	Rhinocerotidae	<i>Diceros</i>	<i>neumayri</i>
	Equidae	<i>Cremiophipparrion</i>	<i>aff. matthewi</i>
		<i>?Cremihipparion</i>	<i>nikosi</i>
Artiodactyla		<i>"Hipparrion" (Sivalhippus)</i>	sp.
	Suidae	<i>Nyanzachoerus</i>	<i>syrticus</i>
		<i>Nyanzachoerus</i>	<i>cf. devauxi</i>
	Hippopotamidae	<i>Hexaprotodon</i>	<i>sahabiensis</i>
	Anthracotheriidae	<i>Libycosurus</i>	<i>petrocchi</i>
	Giraffidae	<i>Samotherium</i>	sp.
	Bovidae	<i>Gazella</i>	sp.
		<i>Leptobos</i>	<i>syrticus</i>
		<i>Tragoportax</i>	<i>cyrenaicus</i>
		<i>Kobus</i>	<i>darti</i>
		<i>?Hippotragus</i>	sp.
		<i>cf. Damalacra</i>	sp.
		<i>Raphicerus</i>	sp.
		<i>Prostrepsiceros</i>	<i>libycus</i>
Cetacea	Delphinidae	<i>cf. Lagenorhynchus</i>	sp.
	Platanistidae	gen. indet	sp. indet
Sirenia	Dugongidae	<i>Metaxytherium</i>	<i>serresii</i>
Insectivora	Soricidae	gen. indet.	sp. indet
Rodentia	Cricetidae	<i>Abudhabia</i>	<i>yardangi</i>
		<i>Myocricetodon</i>	sp. A
		<i>Myocricetodon</i>	sp. B
	Muridae	<i>Progonomys</i>	sp.
	Ctenodactylidae	<i>Sayimys</i>	sp.
	Sciuridae	<i>cf. Atlantoxerus</i>	<i>getulus</i>
Primates	Cercopithecidae	<i>Macaca</i>	sp.
		<i>cf. Libypithecus</i>	sp.

Fig. 5: Close view shows jaw of a mammal and a coprolite (fossilized feces) from the As Sahabi area, Libya

Sahabi Eo-Channel

Carmignani *et al.*, (2009) suggested from remote sensing data that the “Sahabi Channels” of Barr and Walker (1973), which extended by Nicolai (2008) into the Mediterranean Basin by the use of seismic data, represented a late Miocene incursion of the Nile River into Libya. Such a model requires migrate of the Nile from its basin and flow uphill over the higher relief Western Desert to enter the Ajdabya Trough and eventual entry into the Gulf of Sirt. The model is not supported by data on Miocene paleo-relief of western Egypt that would make such a hypothesis plausible, and recent remote sensing data

(Paillou et al. 2009) support a separate Libyan hydrographic drainage pattern distinct from the Nile. Moreover, Muftah et al., (2013) suggested that the source of the river was Chad mega Lake (Fig. 6) based on geochemical analysis of the clay sediments of Member U1 of Sahabi Formation, where, their geochemical composition might also be explained by an origin from Precambrian outcrops within the Ethiopian highlands near Lake Tana in the catchment area of the Blue Nile, paleontological evidence (Table. 1) renders this is an unlikely hypothesis (Muftah et al., 2013).

Fig. 6: Map shows the proposed origin of sediments of the vertebrate bearing member U1 of Sahabi Formation from Chad paleolake (Muftah et al., 2013)

The Palelo-Habitats

Six main paleo-habitats have been interpreted by Boaz (2009) during Pliocene time (i.e. more than 5 million years ago) from the excavated fossil vertebrates (Fig. 7). The main controller event for all these are the Eo-Sahabi river which was discovered by Barr and Walker (1973). These hypothesized paleo-habitats are:

1. Salt water paleo-habita: It was suggested due to the presence of the sea crocodile (*Crocodylus checcchiai*) sea turtles (*Trionyx triungus*); sea cow (*Metaxytherium serresii*); great white shark (*Carcharodon megalodon*); in addition to the birds such as Geese (*Anatidarum* sp.). Meanwhile,

the flora are represented by Doum palm tree (*Hyphaena tehbaica*); Date palm tree (*Phoenix* sp.); and Fig tree (*Myrianthoxylon* sp.) (Fig. 7A) Boaz (2009).

2. Eo-Sahabi River paleo-habitat: It was suggested due to the presence of the long-snouted crocodile (*Euthecodon* sp.); River dolphine (Iniidae sp.); Bottle-noused dolphine (*Lagenorhynchus* sp.); (Platanistadea), reverine fish, Nile Catfish (*Clarias* sp.); Squeaker catfish (*Synodontis* sp.); Crucifix catfish, Widehead cat fish (*Clarotes* sp.); Perch (Percoidea sp.); Nile perch (*Lates nilotica*); Bichir (*Polypterus* sp.) and Sea bream (Sparidae sp.) (Table 1 and Fig. 7B) Boaz (2009).
3. Riverine forest and river edge paleo-habitats: They were suggested due to the presence of the Sixfore-toothed hippopotamus (*Hexaprotodon sahabiensis*); the Four-tusked mastodon- elephant (*Stegotetrabeledon syrticus*); the African bear (*Agriotherium africanum*); Macaque-like cercopithecine monkey (*Parapapio* sp.) and Colobus monkey (Colobinae indet.); in addition to the birds such as Darter (*Anhinga* sp.) and Eagle (Accipitridae sp.). Meanwhile, however, the flora are in form of Sausage tree (*Kigelia africana*); Cape ash tree (*Ekebergia acpensis*); Acacia tree (*Acacia nilotica*); Bush willow tree (*Combretum* sp.) and Doum palm trees (*Phoenix* sp.) as largely learned from the the fossil wood (Fig. 7C) Boaz (2009).
4. Water's edge and Eo- Sahabi estuary Paleo-habitats: They were suggested due to the presence of the Anthracothere (*Libycosaurus petrocchii*); the shovel-tusker proboscidean (*Amebeledon cyrenaicus*) and the predator Sabertooth (*Amphimachairodus aff. kabir*) and the harbor seal (*Monachus* sp.). Meanwhile, the flora are in form of Mangroove tree (*Rhizophora* sp.); tropical chestnut tree (*Sterculina setigera*); Acacia tree (*Acacia tortilis*); Bush willow tree (*Combretum* sp.); Susage tree (*Kigelia africana*) and Date palm trees (*Phoenix* sp.) as largely learned from the the fossil wood (Fig. 7D) Boaz (2009).
5. Savana Paleo-habitat: It was suggested due to the diverse mammalian community consisting of the Hyena (*Percrocuta* sp. & *Chasmaporthetes* sp.); the wild hog (*Nyanzachoerus syrticus*); the bovida antilopes (*Hippotragus libycus*, *Kobus subdulus*, *Gazella* sp., *Dytikodorcus lybicus* and *Raphicerus* sp. and *Miotragocerus cyrenaicus*); the Homonoids (*Sahelanthropus* cf. *tchadensis*); Hippopotamus (*Hexaprotodon sahabiensis*); Three-toed horse (*Cremohipparion* sp.); in addition to the birds Eagle (Accipitricidae sp.) and Darter (*Anhinga* sp.). Meanwhile, the flora are represented by Bushwillow tree (*Combretum* sp.), Cape ash tree (*Ekebergia acpensis*), Acacia tree (*Acacia* sp.), and chestnut tree (*Sterculia setigera*), and Susage tree (*Kigelia africana*) (Table 1 and Fig. 7E) as largely understood from the fossil wood Boaz (2009).
6. Arid Desert-like paleo-habitat: It was suggested due to the presence of the Rodents Gerbil (*Abodabia yardangi*); Ground squirrel (*Atlantoxerus getulus*). Meanwhile, the flora maily represented by Poplar tree (*Populus euphraticus*) (Fig. 7F) Boaz (2009).

Fig. 7: Hypothetical prevailed paleo-habitats in the As Sahabi area as suggested by Boaz, (2009) Reconstructed by artist Antonio Varelas. (A) Salt water; (B) Eo Sahabi River; (C) Riverine forest and river edge; (D) Water's edge and Eo-Sahabi estuary; (E) Savana; (F) Arid, Desert-like

PRESENT-DAY FAUNA AND FLORA IN AS SAHABI AREA

The only habitat which is predominating the As Sahabi area today by comparison with the paleo-habitats of As Sahabi during Pliocene is the Arid Desert-like, due to the presence of present day Gerbils and the lack of forests (Palm and *Acacia* trees) and other aqueous organisms. The only present day fauna reported in As Sahabi area are represented by:

- 1- Insects: including, Deathstalker Scorpion (*Leiurus quinquestriatus*) (Fig. 8A).; Mammals: including, Camels (Fig. 8B), Gerbils and Fennecs (*Vulpes sp.*).
- 2- Reptiles: including, Lizards (Fig. 8C).
- 3- Red beetle insect (Fig. 8D) and desert Ant.
- 4- Mollusks: including land snails *Helix sp.* (Fig. 8D).

However, flora is mainly of arid desert plants which are mainly restricted to few annual plants and grasses which strictly growing after short time rainfall in wadis and baltas (Fig. 9A-F), the illustrated flora is not classified herein.

CONCLUSIONS

The following are the main conclusions:

- 1- Highlight the Eo-Sahabi river with attention to its possible source and its role in creating the six recognized habitats in Pliocene Sahabi Formation of As-Sahabi area.
- 2- Compare the documented vertebrate fossils remains during the Pliocene time in reconstructing the prevailed habitats in As Sahabi area.

Fig. 8: Desert animals from As Sahabi area, Sirt Basin, Libya (A) Scorpion deathstalker (*Leiurus quinquestriatus*); (B) Camels; (C) Lizard; (D) *Helix* and red beetle insect.

Fig. 9: Desert shrubs from As Sahabi area, Sirt Basin, Libya (A-F not identified)

RECOMMENDATION

- 1- The As Sahabi area is highly recommended to be registered as an international natural heritage site in order to conserve the hidden and the exposed vertebrate fossil remains.
- 2- Protecting vertebrate remains and fossil wood from taking them for any reason.

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