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STRUCTURE OF THE NORTHEASTERN PLATEAU OF THE BAHARIYA OASIS, WESTERN DESERT, EGYPT[1]

ABDOU ABDOU ELBASSYONY[2]

ABSTRACT

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The structural studies of the northeastern plateau concern two fold axes trending NE-SW. The first fold axis runs through the ElHarra and ElGedida areas. The second fold axis runs through the Gebel Ghorabi and Dumbell's Hill areas. Between these two fold axes lies the plunge of the northeast anticline (Ghorabi anticline) of the Bahariya high.

Two periods of deformation have affected the investigated area. The first one is considered to be a part of the Syrian arc system (of the Laramide cycle) that extends in post-Cenomanian – pre-Campanian time from Bahariya to Abu Rawash near Cairo. The second one is considered to be a part of the Alpine cycle. It affects the Eocene and Oligocene sediments.

Faulting accompanied both periods of deformation. The fault systems: NE-SW (aualitic), E-W (Tethyan) and NW-SE (African) are recognized.

INTRODUCTION

In the heart of the Western Desert, at a distance of about 270 km to the southwest of Cairo, lies Bahariya oasis (Fig. 1) in a great depression that is almost completely surrounded by escarpments.

The area under investigation is the northeastern plateau of this depression. It includes three localities of economically important iron ore deposits, namely: the ElGedida, ElHarra, and Gebel Ghorabi areas. BALL & BEADNELL (1903) recorded the ferruginous sandstone of Gebel Ghorabi, ElHarra, ElHeiz and Gara ElHamra. The ElGedida iron ore area was described by the present author (1961).

BALL & BEADNELL (1903) were the pioneers who described the regional geology of the Bahariya oasis. Their work was continued by different authors (see references) who contributed to the geology of Bahariya (Fig. 2). Table I shows the different formation names given by various authors for the units in the Bahariya oasis and their correlation with the area under investigation.

The Bahariya anticline is oval in shape and resembles a brachy-anticline. It is formed of two major anticlines lying on the same axis, with a NE-SW trend. The one to the northeast, the Ghorabi anticline is the highest and the other at the extreme southwest end of the oasis is the Khoman anticline. Between the Ghorabi and Khoman anticlines a group of hills is believed to lie on the same axis (Fig. 2). This folding forms a part of the major structural Laramide high that extended in post-Cenomanian – pre-Campanian time from Bahariya to Abu Rawash near Cairo.

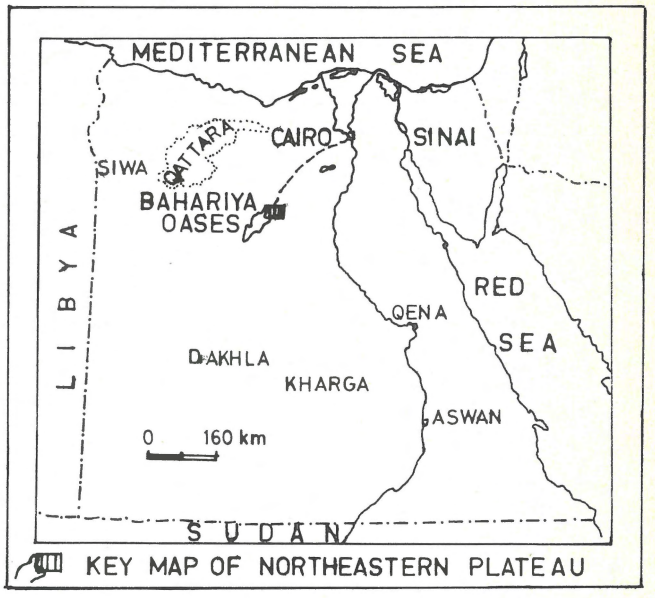

Fig. 1
Key map of the Northeastern Plateau of the Bahariya Oasis, Western Desert, Egypt.

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[2] The Egyptian Geological Survey and Mining Authority. 3, Salah Salem Street, Abbasia, CAIRO, Egypt.
Present address: 26A Mohammed Adli Kafafi Street, HELIOPOLIS,Egypt.

Ball & Beadnell (1903)			Hermina et al. (1957)			El-Bassyony (1961) ElGedida Area		Said (1962)		El-Akkad & Issawi (1963)		Said & Issawi (1964) Northern Plateau		El-Bassyony (1972) Northeastern Plateau		
Post-Eoc. Oligocene		3-Ferruginous sandstone and iron ores	Post-Oligocene		Black ferruginous grits and conglomerates	Oligocene?	Ferruginous sandstone & grits	Oligocene	Ferruginous grits	Oligocene	Radwan Formation	Oligocene	Radwan Formation	Oligocene		Radwan Formation
Eocene	U.Libyan-L.Mokattam	4-Limestone	Upper Eocene		Limestone Beds	L. Middle Eocene	Limestone / Iron ore	L.Middle Eocene	Plateau Limestone (Iron ore)	L.Middle Eocene	Plateau Limeston (Iron ore)	Middle Eocene: U.Eo.	Bart.	U. Eocene	Bartonian	Teetotum* Formation
			Middle Eocene	U.Lut.	Limestone, calcareous sandstone							Upper	El Hamra* Formation / El Qazzun Formation	M. Eocene	L.Lutetian	Naqb Formation / Iron ore
				L.Lutetian	Limestone							Lower	Naqb Formation / Iron ore			
Upper Cretaceous	Danian	5-White chalk and crystalline limestone	Upper Cretaceous	Maestricht.	Khoman** Chalk	Cenomanian	Variegated sandstone and sandy clays	Maestr.	Chalk**	Maestricht.	Chalk** Formation	Lower Cenomanian	Bahariya Formation	Upper Cretaceaus	Campanian	Iron ore / El Hefhuf Formation
	Turon. Senon.	7–Sandstone, clays and marls		Turon. Senon.	Heiz Beds			Turo.-Sen.	El Hefhuf Formation	Camp.	El Hefhuf Formation					
										U.Cen.	El Heiz Formation				U.Ceno.	El Heiz Formation
	Cenomanian	6–Limestone and variegated sandstone		Cenomanian	Bahariya Beds			Cenom.	Bahariya sandstone & variegated shales	L.Cenom.	Bahariya Formation				L.Cen.	Bahariya Formation

Table I:
Different formations given by various authors for the Bahariya oasis.

* The present author likes to designate the Abu Moharik Formation, after Ghard Abu Moharik, to UpperEocene beds which are displayed in Bahariya vicinity.

** Also the present author assigns the Khoman Formation to the Chalk Beds given above. Both formations rectifying are plotted on the geological map of the Bahariya oasis (Fig. 2).

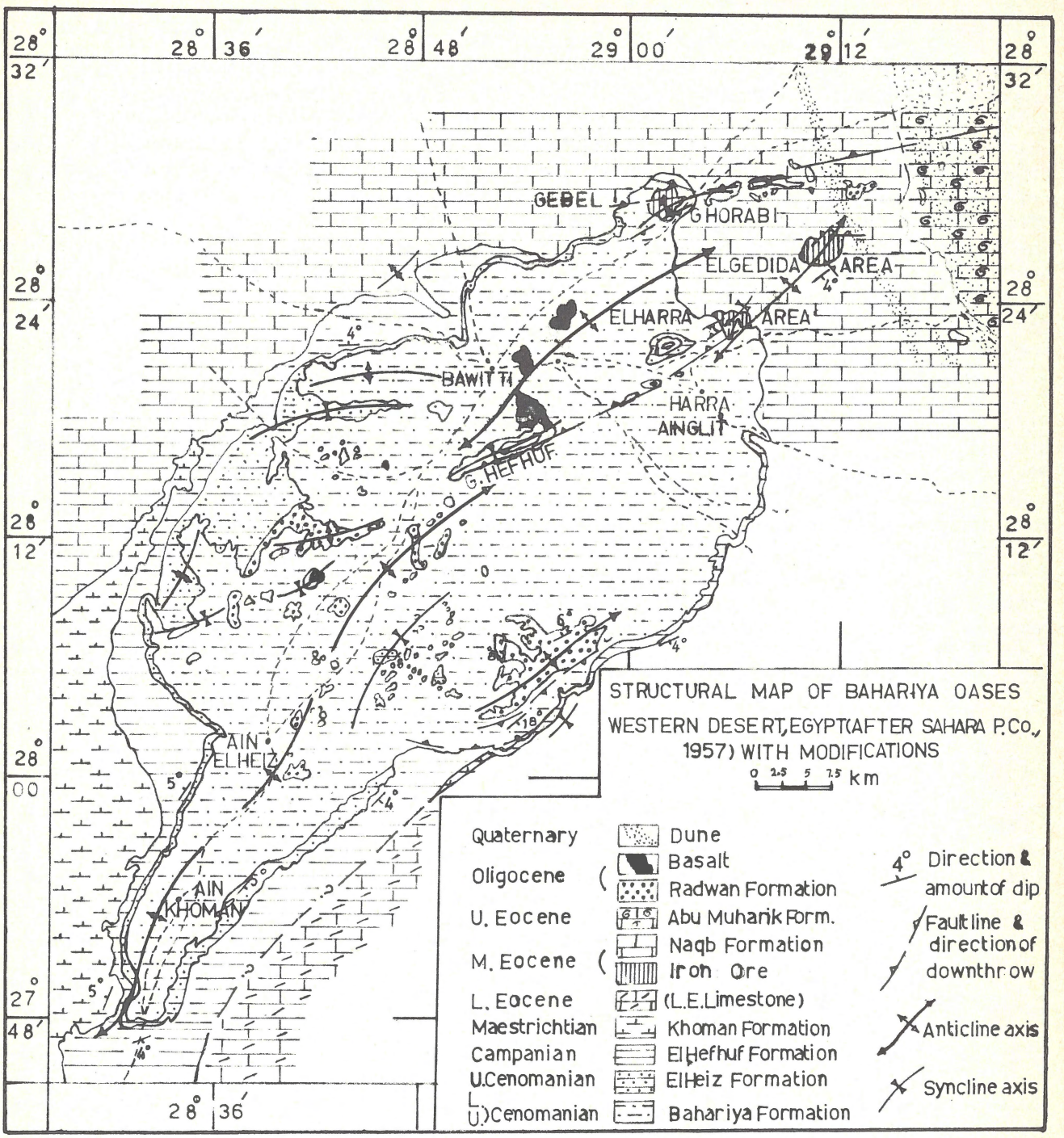

Fig. 2.
Structural map of the Bahariya Oasis, Western Desert.

The stratigraphical study of the exposed formations reveals the following breaks in sedimentation in the area under consideration:

(1) Cenomanian – Campanian unconformity;
(2) Campanian – Middle Eocene unconformity;
(3) Middle Eocene – Upper Eocene unconformity;
(4) Middle Eocene – Oligocene unconformity.

STRUCTURES OF THE NORTHEASTERN PLATEAU

The structural study of the area investigated reveals two lines of folding lying along the flanks of the Bahariya anticline. The first one to the east comprises two prominent anticlines, namely the ElGedida and ElHarra anticlines. The second one to the west includes a series of high structures with low structures between them.

The study of the first line of folding proves that the ElGedida and ElHarra anticlines lie on the same axis of folding. The ElGedida and ElHarra areas were studied in detail and mapped on a scale of 1 : 10,000, using a plane-table and a self reducing theodolite of the Kern-type. Figures 3 and 4 are versions of these two maps.

The following is a brief description of these two structures.

The ElHarra Anticline

This anticline represents a periclinal fold trending northeast-southwest, with a length of 2.6 km, an average width of more than one kilometre and a maximum elevation of 268.9 m above sea level.

The ElHarra anticline has the blocky sandstone member of the Lower Cenomanian Bahariya Formation at its core. The northwest flank of the anticline culminates in a fault (AA′ on Fig. 3). It has a sharp plunge to the southwest, while to the northeast it is unconformably covered by the ElGedida iron ore member of Lower Lutetian age.

The ElGedida anticline

The ElGedida anticline forms the high central part of ElGedida area (Fig. 4). Its axis has a general trend in a northeast-southwest direction, and a sharp plunge to the northeast. This anticline has a massive sandstone belonging to the Lower Cenomanian Bahariya Formation at its core which is unconformably overlain by the ElGedida iron ore member of Lower Lutetian age.

The ElGedida anticline has a length of 5 km, an average width of 3 km and its crest has a maximum altitude of 255 m above sea level.

The ElGedida anticline falls on the same axis as the ElHarra anticline, forming a brachy-anticline trending northeast-southwest. This fold system was formed by the movement that occurred in post-Cenomanian – pre-Campanian time and is considered to be a part of the Syrian arc. The Syrian arc system extends from the Farafra oasis through the Bahariya oasis to Abu Rawash near Cairo. Regionally it continues in a diagonal direction across the north of Egypt to the Suez area and the centre of Sinai, and a southwest continuation of these structures occurrs in Syria. This Syrian arc forms part of the major structural Laramide cycle.

The structures of the western line of folding are more intricate. They are dissected by faults and are arranged along the same axis of folding. The Gebel Ghorabi and Dumbell's Hill anticlines are the characteristic structures of the western axis of

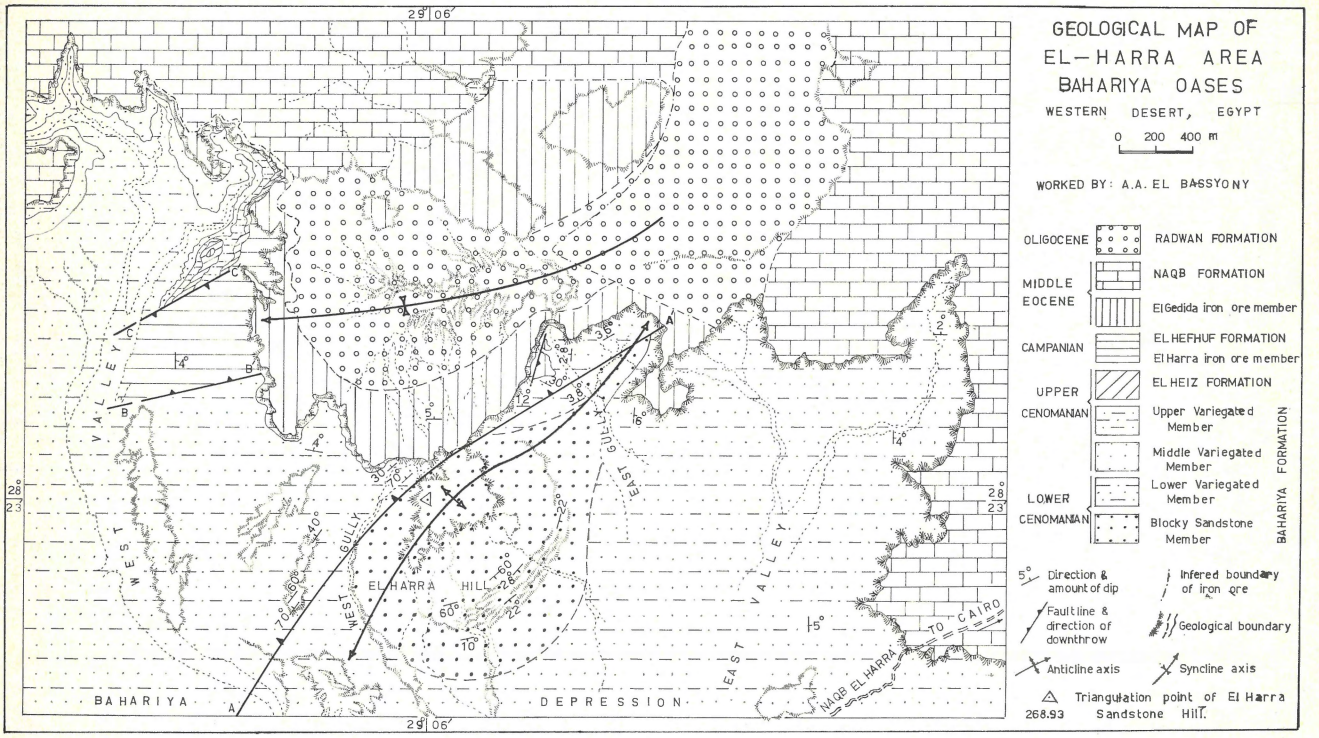

Fig. 3
Geological map of the ElHarra area, Bahariya Oasis, Desert, Egypt.

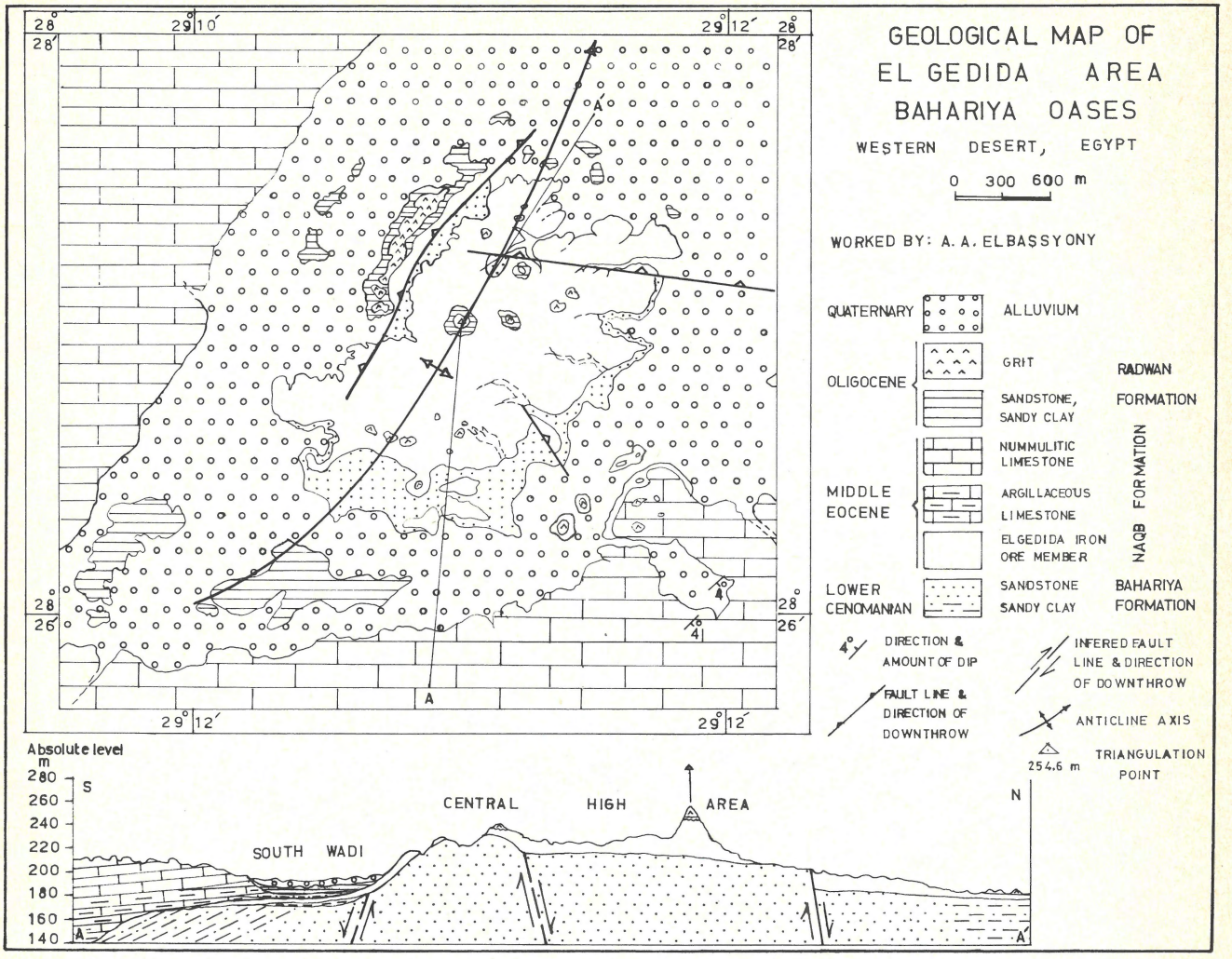

Fig. 4
Geological map of the ElGedida area, Bahariya Oasis, Western Desert, Egypt.

folding. The geological map, scale 1 : 100,000 of the northeastern plateau was prepared from the aerial photographs, scale 1 : 40,000 (Fig. 5).

The following is a brief description of the most interesting structures of the western axis of folding.

The Gebel Ghorabi Anticline

Gebel Ghorabi is an elongated high structure, with a length of 6 km, an average width of 4 km, and maximum relief of 265 m above sea level. It plunges in a northeast direction, at Naqb ElQadeim.

The core of the Gebel Ghorabi structure is made up of the upper variegated member of the Upper Cenomanian Bahariya Formation (ELBASSYONY, 1972: p. 70, Table III). This is followed unconformably by the ElGedida iron ore member of Lower Lutetian age.

The Gebel Ghorabi anticline is mentioned in previous literature as part of a major anticline (Ghorabi anticline) extending from the centre of the Bahariya depression with a north-northeast trend.

The Naqb ElQadeim Anticline

This anticline is elongated and plunges to the northeast. It lies just northeast of the Gebel Ghorabi anticline and is on the same anticlinal axis. Its crest area is completely excavated down to its core. Only the limbs of Middle Eocene limestone are preserved. The core of the structure consists of the Bahariya Formation, which is covered by alluvium and blown sands.

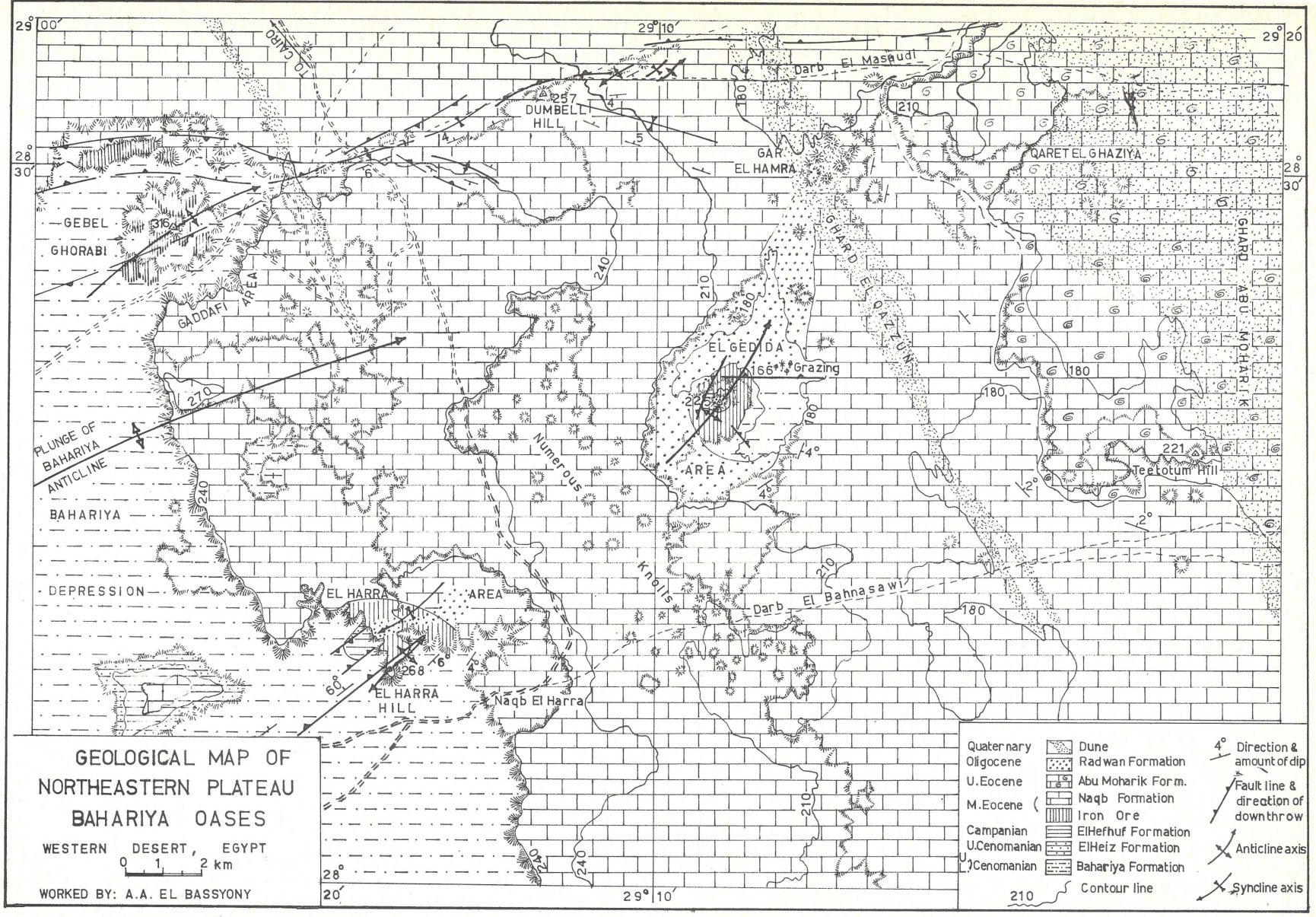

Fig. 5
Geological map of the Northeastern Plateau, Bahariya Oasis, Western Desert, Egypt.

The Dumbell's Hill Anticline

This is a series of high structures trending northeast-southwest. The nearest two anticlines to Dumbell's Hill lie on the same anticlinal axis as the Naqb ElQadeim structure, with a plunge to the southwest. These two anticlines are drawn on Fig. 5 as one brachy-anticline, having a general northeast-southwest trend. This anticline consists of nummulitic limestone of the Lower Middle Eocene Naqb Formation. Its crest is deformed by the continuation of a fault that runs along the northeastern side of Dumbell's Hill. The fault crosses the crest of the structure and then swings northeastward, with a downthrow towards the north-northwest. This deformation may have resulted in the separation of this anticline into two high structures.

The structures of this western axis of folding, except for the Gebel Ghorabi anticline, are due to post-Eocene movement. This movement disrupted the Oligocene sediments in the Gebel Ghorabi and ElGedida areas. It may be assigned to a post-Oligocene age. It forms part of the Alpine movement that affected North Africa and the East Mediterranean.

FAULTS

The tectonic study of the area in question gives rise to the recognition of three fault systems. A northeast-southwest trending fault system with a throw of 40-174 m belongs to the Upper Cretaceous movement. Another northeast-southwest trending pattern of faults with an average throw of 40 m belongs to the post-Eocene movement. A second fault system trending northwest-southwest with an average throw of 30 m belongs to post-Eocene or even post-Oligocene movement. A third hinge pattern of faults trending east-west with a variable displacement, belongs to post-Oligocene movement.

These fault systems could be clearly detected in the aerial photographs used (scale 1:40,000). The northeast-southwest fault system is the dominant one. Fault swinging and bifurcation in the western part of the map area exhibit changes in fault trends and throws.

These faults have the following characteristics: they are all normal gravity faults; their planes have moderate to high angles of dip; they change their courses and bend from their original directions; they are of hinge faults type.

The ElHarra area is the most interesting from a structural point of view. The Block-faulted structure is formed above the ElHarra Upper-Cenomanian scarp. This graben (block faulted) structure is filled by several beds of basal Campanian rocks, which do not extend on either side (Figs. 6 and 7). Later beds, however, extend uninterruptedly above the depression which was submerged by the Campanian sea (Fig. 8).

The presence of this graben filled by the Campanian rocks proves the transgression of the Campanian sea, although previous workers had mentioned its absence in this area.

The lower Middle Eocene sediments show a similar northeast-southwest trending structural low. This synclinal fold may be due to rejuvenation in post-Eocene time, mainly along the old lines of folding.

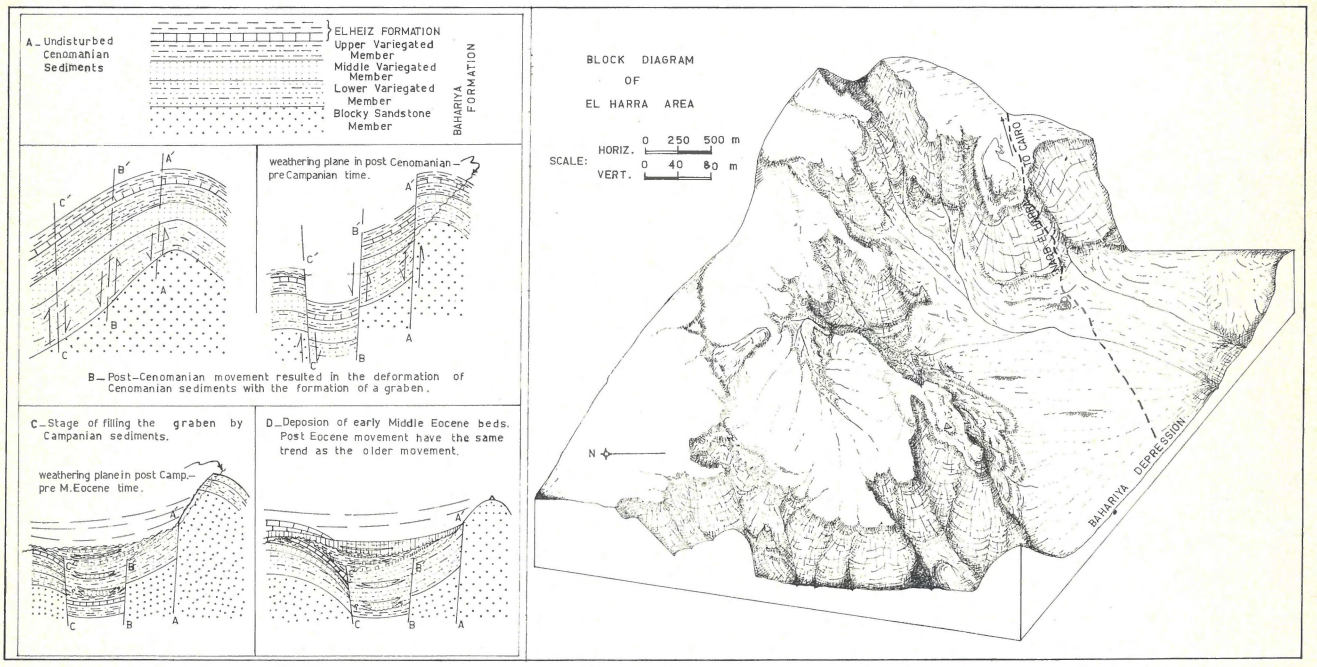

Fig. 6
Schematic illustration of the geological history and structural evolution of the western scarp of the ElHarra area (are shown on figure 3, between the faults BB′ and CC′). Block diagram of the ElHarra area.

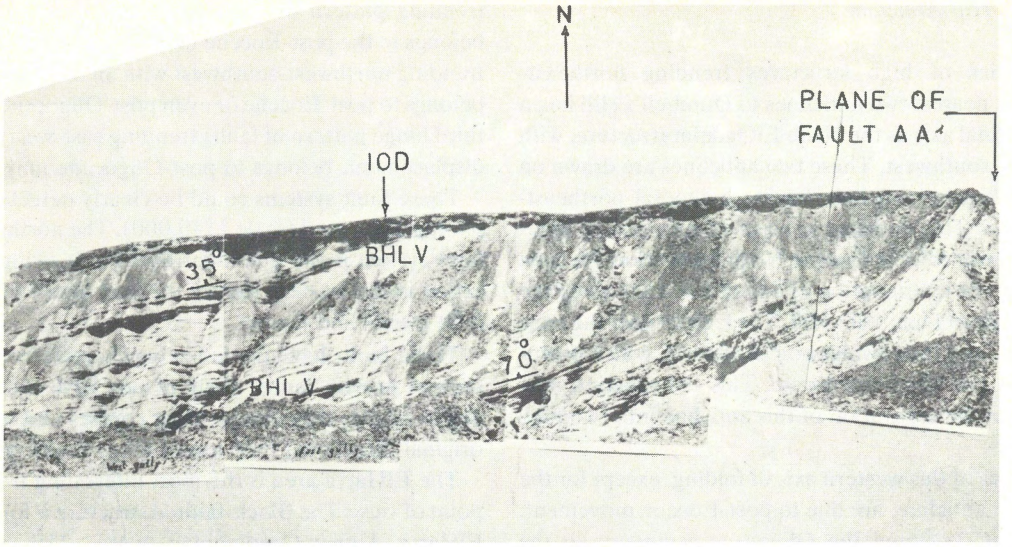

Fig. 7
Panorama showing fault AA′ on figure 6. Iron ore deposits (IOD) unconformably overlying the highly faulted lower variegated member of the Bahariya Formation (BHLV).

The block diagram of the ElHarra area given on Figure 6 is drawn from the ElHarra contour map with a scale of 1 : 25,000, looking eastward. The front scarp in the drawing is that of the western scarp. The block diagram shows the topography of the ElHarra area.

CORRECTING THE TREND OF THE GHORABI ANTICLINE PLUNGE

HERMINA ET AL. (1957) used the ElHeiz-Bahariya contact as the reference datum for constructing the Bahariya structural contour map, with proper intervals determined for its projection in the northeastern area where the ElHeiz Formation is absent, and the Middle Eocene limestone lies unconformably on the Bahariya Formation. The stratigraphical map of Bahariya worked by Hermina shows the ElHeiz Formation outcropping along the scraps from the east to the northeast scarp, between ElHarra and the Gebel Ghorabi scarp. On the stratigraphical map of Bahariya (Fig. 2), the ElHeiz Formation outcrops at the eastern scarp as far south as Naqb LeGlit, while it outcrops on the western scarp up to the west of south Gebel Ghorabi. ELBASSYONY (1972) recorded the occurrence of the ElHeiz and ElHefhuf Formations in the ElHarra area; also the occurrence of ElHeiz limestone in the Gaddafi area (Fig. 9). The ElHeiz limestone does not occur along the northeastern scarp, between the ElHarra and Gebel Ghorabi areas, except at these localities.

Accordingly, the calculations of HERMINA ET AL. (1957) for constructing the Bahariya structural contour map are not valid for its representation at the northeastern scarp of Bahariya. The absence of the ElHeiz limestone at the northeastern scarp of Bahariya and its occurrence at both flanks, the Gebel Ghorabi and ElHarra areas, shows that this northeastern scarp of Bahariya is still structurally high since the deposition of this formation. This is also confirmed by the occurrence of *Alveolina frumentiformis* and *Operculina discoidea* in the Gebel Ghorabi and ElHarra areas while they are absent in the area in between. So the plunge of the northeast anticline (Ghorabi anticline) of the Bahariya high can be corrected to a northeast direction across the scarp between the ElHarra and Gebel Ghorabi areas.

CONCLUSIONS

The stratigraphical data and the structural study prove that the northeastern plateau of the Bahariya oasis has been structurally high since the deposition of the ElHeiz Formation (Upper Cenomanian). This has enabled the correction of the plunge of the northeast anticline (Ghorabi anticline) of the Bahariya high to a due NE trend, between the ElHarra and Gebel Ghorabi areas. The plunge of the Ghorabi anticline was plotted through Gebel Ghorabi in a north-northeast direction in previous literature.

The structural studies of the northeastern plateau concern two axes of folding lying along the flanks of the Bahariya structural high. These two axes of folding are: the ElHarra-ElGedida axis and the Gebel Ghorabi-Dumbell's Hill axis.

Two periods of deformation have affected the northeastern plateau of the Bahariya oasis. The older one belongs to the Laramide cycle and affected the Upper Cretaceous beds. The younger one belongs to the Alpine cycle which deformed the Eocene and Oligocene sediments.

Faulting accompanied both periods of deformation. Three fault systems: NE-SW, E-W, and NW-SE are recognized. The

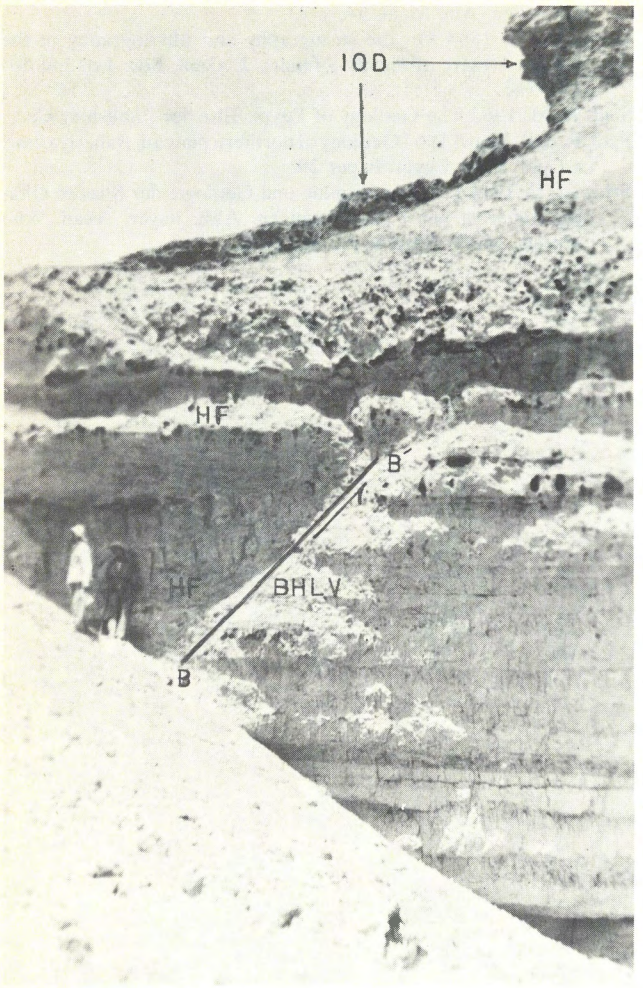

Fig. 8
Stratigraphic position of the ElHefhuf Formation (HF), unconformably overlying the lower variegated member of the Bahariya Formation (BHLV) across the fault plane (BB'). The ElGedida iron ore member (IOD) is shown at the top.

NE-SW trending fault system is the dominant one. They are all normal gravity faults. They bifurcate and exhibit changes in fault trend and throw.

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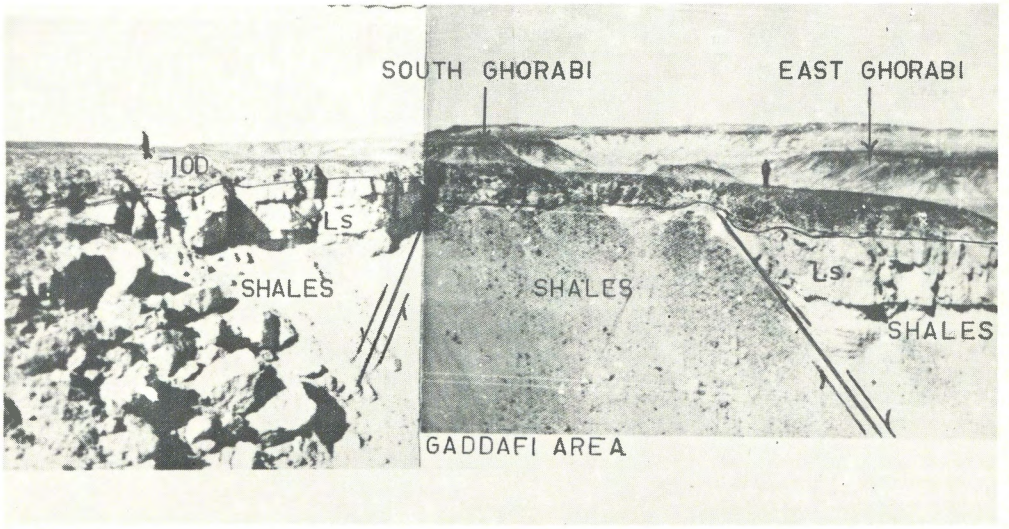

Fig. 9
The ElGedida iron ore member (IOD) unconformably overlies the faulted ElHeiz limestone. The upper beds of the horst are eroded.

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