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Scope

The Jordan Journal of Natural History is an open access scientific publication published by the Conservation Monitoring Center at the Royal Society for the Conservation of Nature. The aim of the journal is to enrich knowledge on the regional fauna and flora of the Arabian countries of the Middle East (Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen). This includes fauna, flora (Systematics, taxonomy, Phylogenetics, Genetics, Morphology, Conservation, Ecology, Biogeography, and Palaeontology) and Geology. Monographs will be published as a supplementary issue.

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CONTENTS

Geological evolution of the Azraq basin, eastern Jordan: An overview

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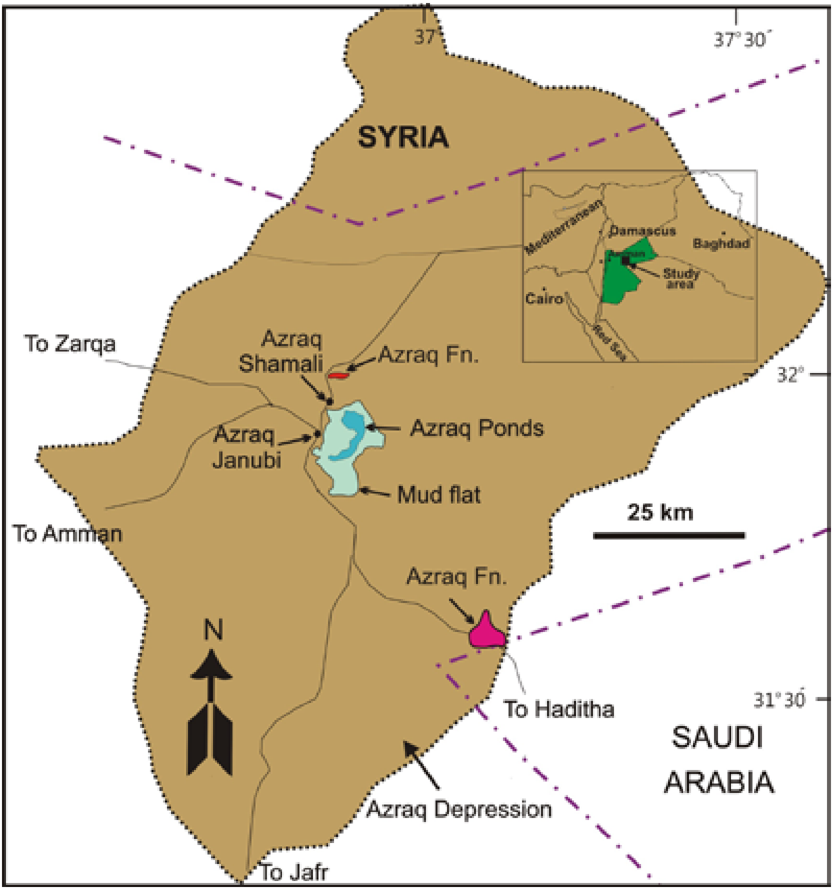
ABSTRACT

The Azraq basin is some 100 Km east of Amman, the capital of Jordan. Hydrologically, it occupies ~12700Km^2, mostly in Jordan, but it also extends to southern Syrian and NW Saudi Arabia. The Azraq area seems to have developed as a basin during the Paleozoic testified by the total thickness of both Ram and Khreim Groups in the Azraq subsurface being slightly less than twice those in the southern outcrops. In this case, the Azraq basin is similar to the Wadi Sirhan basin. From the Carboniferous, Late Paleozoic, to the top Ajlun Group, Mid Cretaceous, no basinal development took place in the Azraq area. Dramatic changes seem to have taken place in the Azraq basin during the deposition of the Belqa Group. Northwest-trending faults became active since the Coniacian? such as the Fuluk Fault and Rajil Fault. A subsiding graben, called Hamza Graben, was the scene for a thick, fast sedimentation of more than 2000m during the Coniacian-Campanian represented by the Rajil, Hamza and Hazim Formation which are dominated by carbonates. This is explained by synsedimentary deposition in a subsiding basin. The basin continued up till the Eocene albeit being at a slower rate during the rest of the Belqa Group. By the end of the Eocene, the Neo-Tethys Ocean had migrated from the eastern Mediterranean and the Azraq area, as well as almost all Jordan, and the area became terrestrial, and subjected to erosion. The Azraq basin continued as a depression where lake deposits formed from the Miocene onwards. The large recharging area of the Azraq depression seems to have ensured enough water for the marches and springs of the Azraq oasis even in the driest climates in the past, which made the oasis a refugia for hominins and animals throughout the Pleistocene time.

Keywords: Azraq basin, evolution, paleoclimate, hominins

INTRODUCTION

The Azraq Basin is situated some 100 km east of Amman. It drains an area slightly more than 12700 km^2 in Jordan, southern Syria and northern Saudi Arabia (Fig. 1). It is an endorheic or closed basin located in the Jordanian Plateau where all the drainage is collected at Qa ‘Al-Azraq at 500m above mean sea level (amsl), a flat sabkha or salt flat which is dry but seasonally flooded with rain water. In the near past, several springs were present at and around this Ga' such as 'Ayn Qasiyya,'Ayn Sawda, and the Lion's Spring, in addition to groundwater recharging the permanent marches at the cenrte of the Ga'. Consequently, this area became an oasis within a vast desert area at the cross roads with Iraq, Syria and Saudi Arabia. Two permanent settlements were established; Azraq Druze in the north and Azraq Shishan in the south. During the 1980s, the oasis became dry because of the overpumping of fresh, groundwater to the major cities of Jordan especially to the capital Amman (El-Naqa, 2010). The Royal Society for the Conservation of Nature (RSCN) have reclaimed and maintained the newly formed, much smaller (2 Km^2), southern wetland at Azraq Shishan (France, 2010).



Figuer 1: Location map of the Azraq basin

The Azraq oasis and the paleolakes formed within the Azraq basin during the warm, wet periods of the Pleistocene (the last 2 million years or so) were, most probably, an important route for the migration of hominins and animals, eastwards to SE Asia and northwards to Europe (e.g. Abed et al., 2008; Cordova et al., 2012; Ames et al., 2013). The Azraq paleolakes and other paleolakes in Jordan, were an important link with the similar water bodies along Wadi Sirhan and further east and southeast in northern Arabia. Thus, it is not unusual to find a rich hominin remains in the Azraq basin, indicating its importance in the archeological, paleoclimate and paleoemvironmental research (e.g. Ahmad and Davies, 2017).

On the other hand, the Azraq basin is mostly covered by Quaternary to recent sediment, especially within the Azraq Ga', as well as by basaltic rocks of the Tertiary-Holocene times. This is different from the fully exposed older geological units along the Rift valley in the west and the wadis tributing it such as Wadi Mujib (e.g. Bender, 1974; Abed 2017). Thanks to the oil wells drilled in the basin, especially the Hamza oil field where rock units down to the Precambrian were penetrated and studied (Core Lab, 1987; Andrews, 1991).

The aim of this paper is to provide an overview of the geological evolution of the Azraq basin, especially oasis and its surroundings such as Hamza oil field and Dahikiyeh, from the Precambrian to Recent with some emphasis on the paleohydrology/paleoclimate during the Pleistocene-Holocene times in relation with hominin presence.

2. CLIMATE

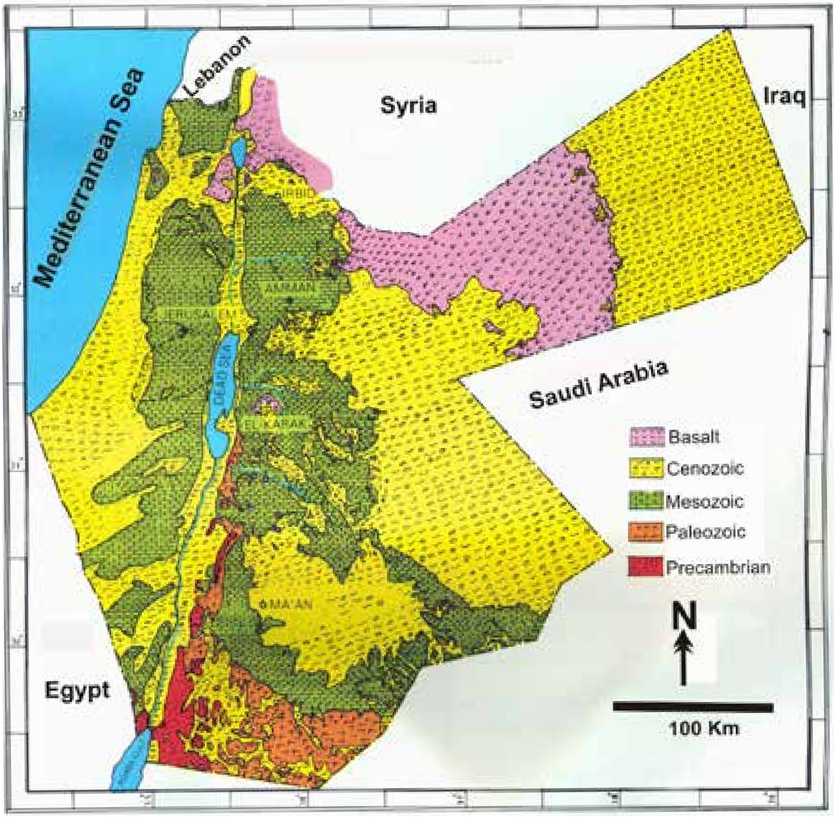
Both areas are located within the eastern desert of Jordan. Average annual rainfall, as short duration storms, is 150 mm in the northern part of the basin decreases to 60 mm in the south. The weather is recognized by two defined seasons; hot, dry, dusty and comparatively strong northwesterly wind in summer (May-October), and cold, semi dry, windy in winter (November-April) (Ayed, 1986).

The Azraq oasis was thriving in this eastern desert until late 1980s when it dried out because of over pumping of the shallow groundwater aquifer. Since then, migrating birds had changed routes.

Most of the vegetations in the area are desert shrubs (salt tolerant plants), grasses along wadis and few palms and other type of trees near the Azraq ponds. Farms are developed near the two Azraq towns and east of the mudflat irrigated by shallow wells of acceptable salinity (Fig. 1).

3. PRECAMBRIAN BASEMENT

Cropping out Precambrian rocks in Jordan span the period 800-540 million years (Ma). They form northermost exposure of the Arabian Shield which covers western Arabia.



Figuer 2: General geological map of Jordan showing the Precambrian basement in SW Jordan (red) and covered by the Phanerozoic sedimentary sequence.

In Jordan, the Precambrian basement is subdivided into an older complex called the Aqaba Complex (800-600Ma) made essentially of granitoids exposed around Aqaba and further east and north. The other subdivision is the younger Araba Complex (600-540 Ma) with abundant volcanic rocks, metasedimentary rocks mainly conglomerates, and minor granitoids (McCourt and Ibrahim, 1989). The Precambrian rocks suffered an extensive erosional phase at the Ram unconformity; that is before the deposition of the overlying Paleozoic sandstones. Consequently, the surface of the basement at the Ram unconformity consists of varying types of rocks such as the metamorphic rocks, granitoids, volcanics, conglomerates and sandstones, depending on the depth of erosion.

The exposed surface of the Precambrian basement in the south dips around 5° to the SE, E, NE and N directions, disappears and becomes deeper into the subsurface below the Phanerozoic sedimentary cover away from the outcrops

(Fig. 2). Within the Azraq basin, no deep borehole penetrated the basement except the Safra well-1 (SA-1), nearby Qasr Al-Kharraneh, few 10s of kilometers west of Azraq oasis, total depth is 2582.0 and of granite basement (Andrews, 1991). The Safra-1 well is situated at the western borders of the basin. It is an old well drilled in 1957 in upfaulted block (Safra fault) or an anticlinal structure according to Bender (1974). Consequently, its total depth to the basement is much shallower than the boreholes nearer to the centre of the basin such as Hamza oil field where the total depth of Hamza-4. For example, reached 3984.0 without reaching the basement. Thus, the depth to the basement in the Hamza Graben is in excess of 5.5 km becoming shallower away from the graben.

4. PALEOZOIC SEQUENCE

4.1 The exposed Paleozoic of Jordan

The Paleozoic sequence crops out nicely in south Jordan and along the eastern shoulders of Wadi Araba up to the southeastern tip of the Dead Sea (Fig. 2). Contrary to this, all the Paleozoic rocks are deeply buried in the Azraq basin, and the following description is taken from the deep boreholes drilled during the chase for oil and gas, especially in the Hamza oil field drilled by the Natural Resources Authority (NRA). Geologists have subdivided the exposed Paleozoic sequence of Jordan into groups and formations shown in Table 1 (e.g. Bender, 1974; Powell, 1989a). The exposed Paleozoic rocks represent the lower Paleozoic only; i.e. The Cambrian, Ordovician and lower Silurian Periods, from 541-441 Ma, and a small section of the upper Permian. In other words, the lower 100 Ma out of 290 Ma making the whole Paleozoic Era, are present in Jordan. This point is discussed below.

The exposed rocks are briefly described in the following two paragraphs. It should be mentioned, first, that the whole sequence is divided into two groups: Lower (older) called the Ram Group and upper (younger) called the Khreim Group.

4.1.1 Ram Group

The lower half of the Paleozoic rocks in Jordan consists of sandstone types varying in colour, mineralogy, sedimentary structures, hardness and the like. Collectively, the whole sequence is called Ram Group because these sandstones are the back bone of the Ram area. These sandstones are ~ 1000 m thick and are divided into four rock units (formations); from older to younger: Saleb, Umm Ishrin, Disi and Umm Sahm Formations (Table 1) and Fig. 3.

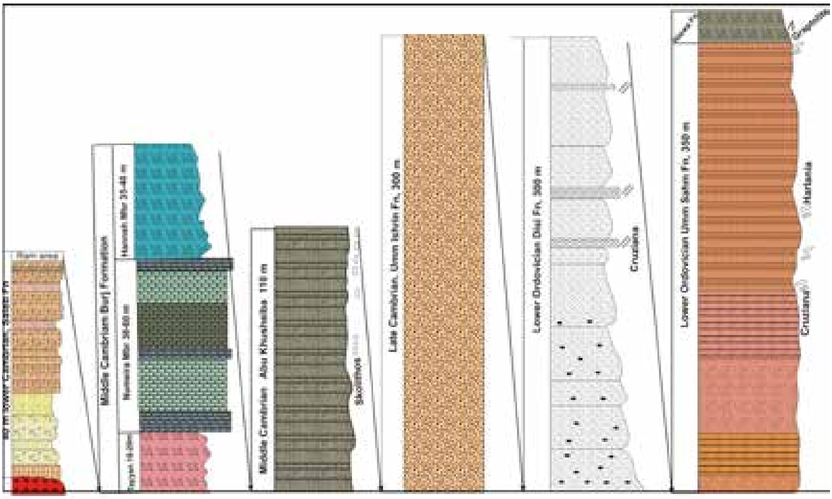
Saleb Formation is lower Cambrian in age, overlies the Precambrian basement, consists of yellowish, arkosic sandstone (quartz plus minor feldspar), and 60 m thick in Ram area and exceeds 200 m in the Dead Sea basin. It is of braided rivers origin.

Umm Ishrin Formation is of late Cambrian, overlies Saleb Formation, consists of quartz sandstone, and is about 300 m thick. It is characterized by its reddish brown colour due to hematite cements, long vertical joints and consequently columns, and long vertical cliffs in excess of 300 m. Umm Ishrin is certainly the single-most beauty element in Ram and Petra. It is of braided rivers origin.

Disi Formation is of early Ordovician, overlies Umm Ishrin formation, and consists of around 300 m thick white quartz sandstone. Pure silica (SiO_2) can reach 99%, mainly as quartz. This is the glass sand of Jordan. Weathering produces dome-shaped attractive features. Trace fossils such as *Cruziana* are abundant in the few meters thick marine shale horizon in its upper part, otherwise, it is of braided rivers origin.

Age العمر		Formation تكوين		Group مجموعة
Silurian سيلوري		أصبحت ضمن السعودية		خريم KHREIM
Silurian سيلوري	لاندوفري Llandovrian	الخشة Khushsha		خريم KHREIM
Silurian سيلوري	لاندوفري Llandovrian	Ratia راطية	المدورة Mudawwara	خريم KHREIM
Silurian سيلوري	لاندوفري Llandovrian	Batra البترا	المدورة Mudawwara	خريم KHREIM
Ordovician أوردوفيشي	أشجيلي Ashgilian كرادوسي Caradocian	Tubeiliyat طبيليات	جليديات عمار Ammar glaciale; المدورة Mudawwara	خريم KHREIM
Ordovician أوردوفيشي	لانديلي Llandeilian	ديبدب Dubaydib		خريم KHREIM
Ordovician أوردوفيشي	لانفرني Llanvirnian	الحسوة Hiswa		خريم KHREIM
Ordovician أوردوفيشي	أرينيجي Arenigian	أم سحم Umm Sahm		رم Ram
Ordovician أوردوفيشي	تريمادوسي Tremadocian	ديسة Disi		رم Ram
Cambrian كمبري	كمبري أعلى Upper Cambrian	أم عشرين Umm Ishrin		رم Ram
Cambrian كمبري	كمبري أوسط Middle Cambrian	Abu Hhusheiba أبو خشيبة		رم Ram
Cambrian كمبري	كمبري أوسط Middle Cambrian	Tayyan طيان	البرج Burj	رم Ram
Cambrian كمبري	كمبري أوسط Middle Cambrian	Numeira نميرة	البرج Burj	رم Ram
Cambrian كمبري	كمبري أوسط Middle Cambrian	Hanneh حنة	البرج Burj	رم Ram
Cambrian كمبري	كمبري أسفل Lower Cambrian	سلب Saleb		رم Ram
ما قبل الكمبري Precambrian		Basement rocks صخور القاعدة		

Table 1: Nomenclature of the Paleozoic rock units in south Jordan and Wadi Araba Dead Sea.



Figuer 3: Lithology of the formations making the Ram Group

Umm Sahm Formation is the uppermost formation in this sandstone group. It is a 350 m thick, early Ordovician, reddish and indurated, cliff-making quartz sandstone and of transitional marine environment with the indicative fossils and trace fossils.

This is the story in the Ram area. However, two more rock units are added in central and north Wadi Araba and the Dead Sea basin, namely the marine **Burj formation** which consists mainly of carbonates and abundant fossils and their traces, and **Abu Khusheiba Formation** which is made of marine, white, fine quartz sandstone and vertical burrows, *Skolithos* indicating a tidal marine environment. Both formations are present between Saleb and Umm Ishrin formations (Table 1).

4.1.2 Khreim Group

The Khreim Group overlies the Ram Group and consists mainly of shale, but the sandstone rocks are still important. The group is almost completely of marine deposition with fossils such as Graptolites, Brachiopods, *Conularia* and trace fossils such as; *Skolithos* and *Cruziana*. It is subdivided into four formations; they are from older to younger: Hiswa, Dubaydib, Mudawwara and Khushsha. The total thickness of the group is in excess of 550 m. See Table 1 and Fig. 4 where the formations and their ages are shown.

The **Hiswa Formation** consists of 80 m thick offshore marine shale becoming more sandy and shallower upwards, it is of middle Ordovician age. The **Dubaydib Formation** is around 130 m in thickness of alternating sandstone and greenish shale with *Skilithos* burrows especially in the sandstone. It is of middle Ordovician. **Mudawwara Formation** is around 220 m thick similar in lithology with the underlying Dubaydib Formation, except for its middle part **(Batra Member)** where an 80 m thick, offshore marine shale with Graptolite is present. **The Khushsha Formation** is the uppermost unit of the Khreim with a lithology similar to upper part of the Mudawwara Formation.

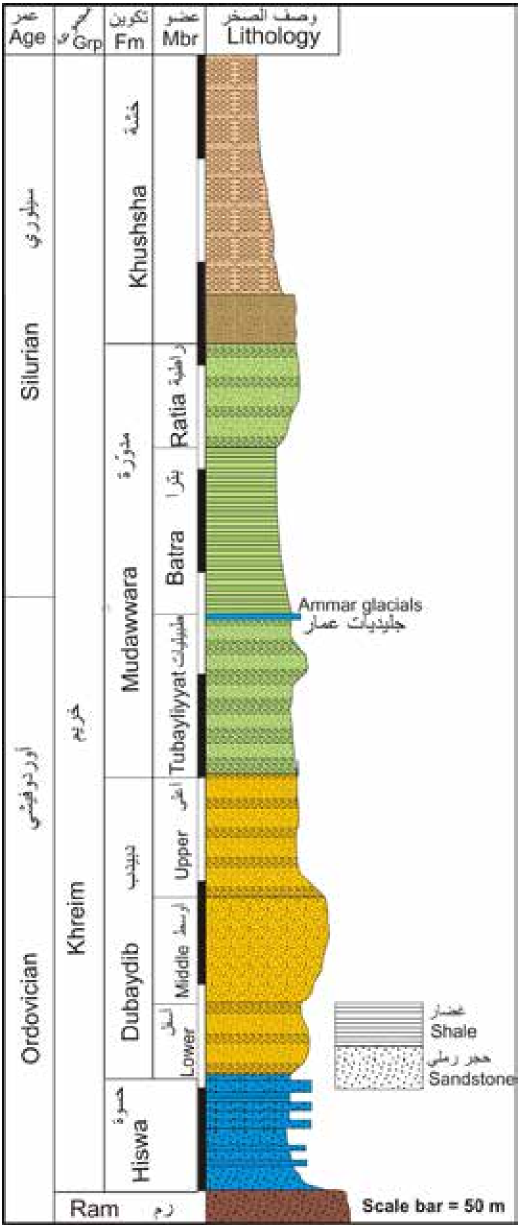
4.2 Paleozoic in the Azraq basin subsurface

No Paleozoic rock is cropping out in the Azraq basin. They are deeply buried in the subsurface. Thus, these rocks are studied from the boreholes drilled in the basin, especially within the Hamza oil field in the eastern part of the basin. In general, the exposed Paleozoic succession in the south, described above, is also present in the subsurface of the Azraq basin. However, two main points should be mentioned. First, the thickness of the formations increases in a northeastern direction compared with the outcrops in the south. Second, there is a systematic omission of Paleozoic strata in a westward direction. Both points are discussed below.

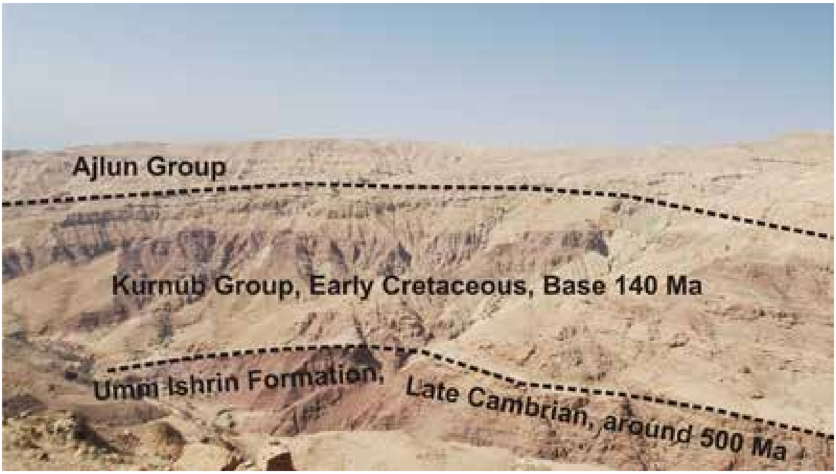
The total thickness of the exposed sequence in the south is ~1550 m, including all the cropping out formations from the base of Saleb Formation of the Ram Group to the top of the Khushsha Formation of the Khreim Group. This is lower than the total thickness of the same sequence in the Azraq basin, but this depends on the position within the basin where this is not the case. One of the major reasons for the changes in total thickness of the Paleozoic is the systematic omission or erosion of formation during the Hercynian Orogeny which took place during the Middle Carboniferous, discussed below.

4.2.1 Hercynian Orogeny

A major tectonic event seems to have occurred, most probably, during the Middle Carboniferous throughout Belad Ash Sham and its surroundings **(Gvirtzman and Weissbrod, 1984)**. A major geanticline was formed in the area where its maximum uplift and curvature was near Gaza and northern Sinai. The Paleozoic strata older than the event (Carboniferous), i.e. Cambrian, Ordovician, Silurian and Devonian became accordingly emerged and dip away from the apex of the geanticline. Thus, the more distance from the apex to the east and southeast, the lower the strata became. Consequently, erosion and removal of the preexisting formation was less severe towards the east and south east. For this reason, more Paleozoic material was preserved in Tabouk and Aleppo compared with Jordan.



Figuer 4: Columnar section for the formations making the Khreim Group In the outcrops.

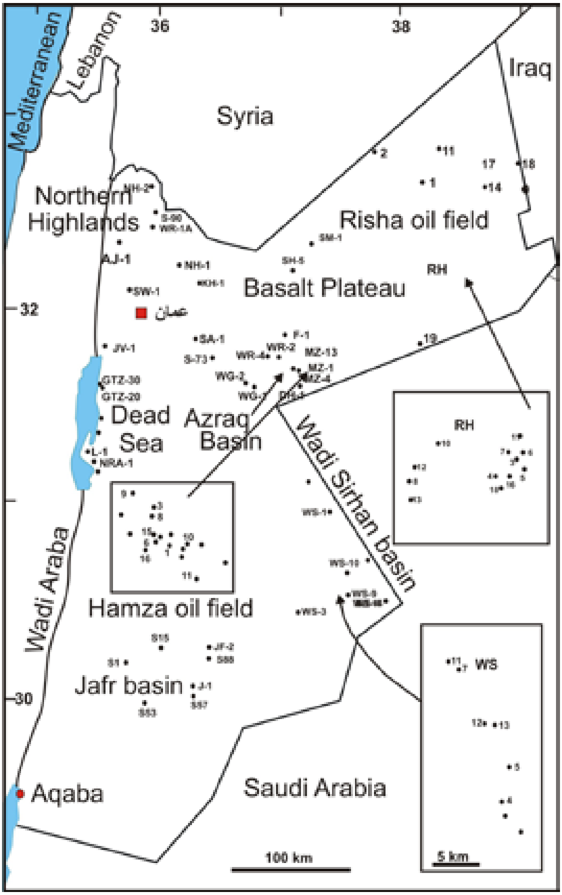


Figuer 5: Field photo from Wadi Karak showing the unconformity between Umm Ishrin Formation overlain by the Early Cretaceous Kurnub Group.

In Jordan, erosion and omission of the Paleozoic formations is greatest in the west throughout the outcrops along Wadi Araba-Dead Sea coast. For example, the outcrops at Wadi Al-Karak till Wadi Al-Mujib preserve only the Cambrian formations: Saleb, Burj and Umm Ishrin, while the rest of the Ram Group and all the Khreim Group were removed by erosion (Fig. 5).

Nothing like such outcrops can be seen to the east throughout the Jordanian plateau, and the deep oil wells are used to show the extent of the Hercynian Orogeny on Paleozoic formations. More than 100 boreholes (Fig. 6), mostly by the NRA during the 1980s - early 1990s, were employed by Andrews (1991) and his colleagues to study this phenomenon in the subsurface of Jordan. Their effort produced Fig. 7 which shows the distribution of the Paleozoic formation throughout Jordan. It clearly shows, despite being an approximation, that the more and more formations have escaped erosion exists in an eastward direction. On the map Fig. 7, the area where the name of the formation is written indicates its presence in part, in the subsurface under that area and further east, but it is not present (eroded) west of that.

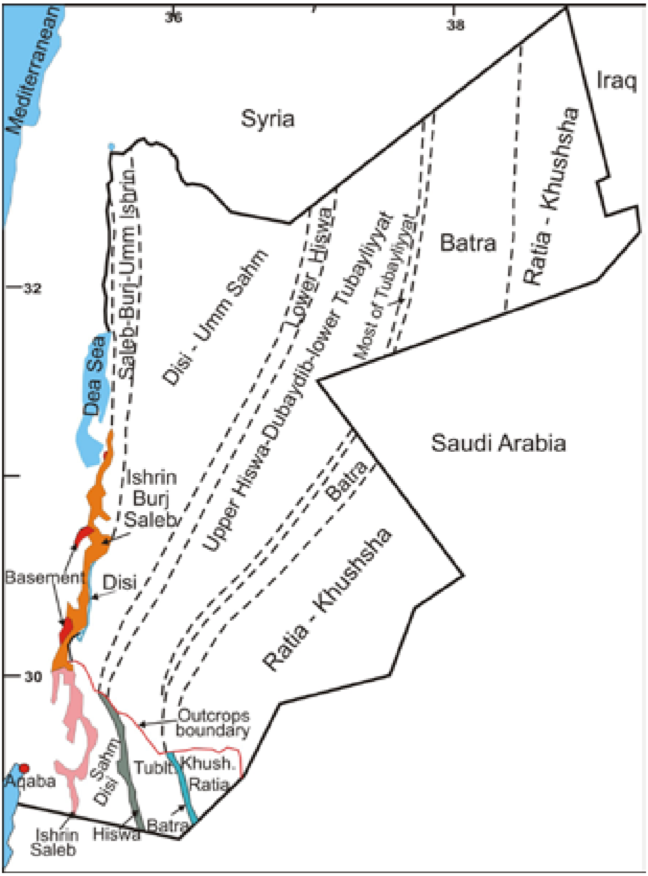
For example, in the western parts of the Azraq basin, Safra well (SA-1), the Khreim Group is completely removed, in addition to the upper parts of Ram Group (Umm Sahm and most of Umm Ishrin where only 40 m exist) (Fig. 6). The total thickness of the Paleozoic in this well is 280m only. In the eastern parts of the basin, such as the Dahikiyeh area and east of the Fuluk fault, removed material includes the upper Mudawwara Formation (Batra and Ratia Members) as well as all overlying strata.



Figuer 6: Shows the location of the oil wells drilled in Jordan

4.2.2 Formations details

Starting with the **Ram Group**, and despite more than 25 wells were drilled in the Azraq basin, two wells only penetrated the whole succession down to the **Saleb Formation**. They are Safra well (SA-1) and Wadi Ghadaf-2 well (WG-2). Well WG-2 did not reach the Precambrian basement andthe Saleb Formation was not fully penetrated. However, the penetrated thickness was 115.0 and 70+ m in SA-1 and WG-2 respectively **(Andrews, 1991)**. It consists of arkosic sandstones with some pebbly horizons deposited in a continental environment by braided rivers similar to what has been mentioned in the outcrops, possibly with less pebbles due to being distal compared with the southern outcrops.



Figuer 7: Distribution of the Paleozoic formations in the in the subsurface and the outcrops (south of the red line) (Modified after Andrews, 1991).

Andrews (1991), in his isopach map for the Saleb Formation, indicated that the total thickness of the Saleb Formation in the Azraq basin should be more than 750m. This is based on the finding of such thickness in boreholes in nearby basin, e.g. Wadi Sirhan well-3 (WS-3) =750m, Sweileh-1 (SW-1)=931.0m, Northern Highlands-1 (NH-1)=531.0m, Hammar well-1 (HM-1)=1100m and GTZ-3D Dead Sea coast=401.5+. Some of these boreholes were studied by **Amireh and Abed (2000) and Amireh et al., (2008)** in cores and cuttings to develop criteria to distinguish the Saleb Formation from the underlying Umm Ghadah Formation (UGF). The latter formation is of Ediacaran age (Late Precambrian). Petrographically, UGF is distinguished from the Saleb by having abundant rhyolite lithic fragments compared with more feldspar in Saleb Formation. It was easily proved that the lower parts of most of these well consist of UGF while the upper part is Saleb. For example, in WS-1 the lower 327m belongs to UGF, HM-1 the lower 475m belongs to UGF. Consequently, the 750m thickness of Saleb Formation in the Azraq basin, according to **Andrews (1991)**, cannot be accepted. However, the thickness of Saleb in SA-1 is twice as much as in the southern outcrops, but it is only half the thickness in the Dead Sea basin **(Powell, 1989a).**

The **Burj Formation** is of lower middle Cambrian age; it overlies the Saleb Formation of the lower Cambrian. The Burj Formation is fully marine where it was deposited in shallow marine environments with abundant fossils and trace fossils that can be seen in the wadis along the southern Dead Sea **(Amireh et al., 1994).** It was not deposited in southern Jordan, but starts from central wadi Araba in the outcrop and Jafr basin in the subsurface and continues northwards. The thickness of the Burj is almost uniform throughout the surface and the subsurface and varies within a small range from 100- 135m (SA-1, 135 m; WG-2, 118.3m; **Andrews, 1991**). Likewise, the **Umm Ishrin Formation** has a subsurface thickness in the Azraq basin (226m in WG-2) comparable with the southern outcrops (230-320 m) without great changes. The 40 m+ in SA-1 is due to truncation by the Hercynian Orogeny as discussed above. The lithology and depositional environments are essentially the same as those of the southern outcrops. **Disi and Umm Sahm Formations** are not easily separable in the subsurface. In the southern outcrops, both formations consist of quartz sandstones with varying degrees of cementation and induration as discussed above with a total thickness of both formation ranging 460-635 m **(Powell, 1989a; Andrews, 1991)**. Total thickness of the two formations increases in a northeastern direction relative to the southern outcrops. The thickness almost doubled in the Azraq basin. This is indicated by the presence 1270m thickness in WG-2, the only borehole that penetrated the whole sequence. Similarly, WS-1 in Wadi Sirhan to the south the thickness reported is 1191m and 1204m in the Jafr basin JF-1. More fine materials are reported in the subsurface compared with the southern outcrops. However, the depositional environments are essentially similar. This is the end of the Ram Group.

The Khreim Group begins with the offshore marine shale of the **lower Hiswa Formation** with Graptolite. In the southern outcrops the thickness is 30 m becoming 100.0+ m in WG-2, 146.0 m in DH-1. No more wells penetrated this formation in the Azraq basin. The upper part in WG-2 was truncated at the Hercynian Orogeny keeping 100 m of the formation, while in DH-1 the formation is fully preserved because it is more to the east. The presence of the planktonic graptolites indicates an offshore marine environment rich in organic matter.

The overlying sedimentary interval includes **most of Hiswa + all Dubaydib formation + some parts of lower Tubeiliyat**.; that is essentially Dubaydib Formation of the middle Ordovician, but with some Late Ordovician. It was named by **Andrews (1991)** in the subsurface Umm Tarifa Formation. This unit was penetrated by many wells in Wadi Sirhan and Risha area, but not in the Azraq basin. In the Azraq basin, it is eroded in SA-1 and WG-2, both being to the west. It is penetrated in two well in the Hamza oil field, MZ-4= 118.0+ m and MZ-13=69.0+ m. In both wells the upper part is eroded. In the Dahikiyeh well DH-1 further east, its thickness = 494.0+ m, the upper contact is eroded.

Two wells in Wadi Rajil, WR-2= 90.0+ m and WR-4=47.0+ m, both wells are truncated by the Hercynian Orogeny. For the location of the mentioned wells, see Fig. 6 above. To give an idea about the depositional thickness before erosion, this unit is 560m in JF- 1 to the southwest and 1114m in RH-3 (Risha area to the northeast). The Azraq basin is midway between the two basins, and the thickness in the Azraq basin might have been around 800 m before erosion. However, the preserved thickness after the Hercynian erosion in the Azraq basin increases eastwards towards the Dahikiyeh area from 47.0 m to 494 m. The age of this unit is Llandeilo-Caradoc-Ashgill (Middle to Late Ordovician). Lithologically, the complete well in the Risha and Sirhan basin shows that this formation consists of a lower silty unit, an interbedded unit of siltstone and sandstone, and an upper silty unit. Trace fossils are similar to the southern outcrops. The rest of the Khreim Group from the upper Tubeiliyat to the top Khushsha are all eroded in the Azraq basin and well not be discussed further. However, they can be studied in the Risha basin northeast of the Azraq basin to those who wanted to do so, see **Andrews (1991)**.

To conclude, the total thickness of the Ram Group in the southern outcrops is ~ 1000m becoming ~1750m in the Azraq subsurface. The preserved lower Khreim Group in the Azraq subsurface is ~640m compared with ~400m of the equivalent sequence in the southern outcrops. Consequently, there is an increase in the thickness of the Paleozoic rocks in the Azraq subsurface, which would indicate the presence of a basin during the Paleozoic similar to the Wadi Sirhan area.

5. TRIASSIC SEQUENCE

5.1 General

The Triassic Period is the 1st period in the Mesozoic Era following the Paleozoic Era. It extends from 250-203 Ma; that is 47 million years. In Jordan, the Triassic rocks crop out along the northeastern coasts of the Dead Sea, starting from Wadi Mujib northwards till north of Wadi Hisban **(e.g. Cox, 1923, 1925; Wagner, 1934)**. Two separate outcrops are present in Wadi Al-Bahhath, to the west of Na'ur, and a 3rd isolated exposure of, the Late Triassic, is present at the Zarqa River, west of King Talal Dam or north of Al- Subeihi town. No Triassic rocks are exposed in any part of Jordan except those mentioned above in western Jordan **(Abed, 2017; Bender, 1974; Bandel and Khouri, 1981; Powell, 1989b)**.

The Exposed Triassic rocks mentioned above are called collectively the **Zarqa Ma'in Group**. The Triassic sequence along the Dead Sea coasts was subjected to erosion at the Early Cretaceous Kurnub Group unconformity. Thus, there is no complete Triassic succession within the outcrops along the NE Dead Sea. Erosion and removal of the Zarqa Ma'in Group increases southwards until the whole group disappears completely at Wadi Mujib. No Triassic rocks are present south of Wadi Mujib including all of central and southern Jordan **(e.g. Makhlouf, 1987; Powell, 1989b; Andrews, 1992a)**. The absence of the Triassic rocks in most Jordan (central and south) is not all erosional, but it is depositional. There is an agreement among the workers in the geology of the area that the paleoshore lines of the Triassic was along Wadi Mujib; meaning that the Neo-Tethys Ocean shore line was at the Mujib during the Triassic and the rest of Jordan was emerged where Triassic sediments were not deposited **(e.g. Bender, 1974)**. So, Triassic rocks were not originally deposited in central and south Jordan, but were deposited north of the shore line where marine environment was present (Fig. 8). The deposited sequence north of Mujib was later subjected to erosion and removal at the Early Cretaceous Kurnub unconformity.

5.2 Subsurface Triassic in the Azraq basin

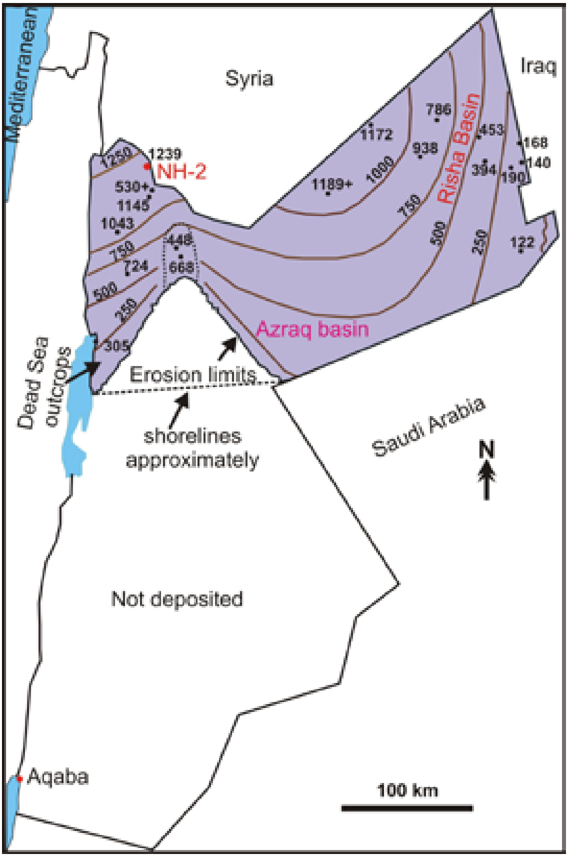
From the foregoing, it is clear that the Triassic rocks were deposited in north Jordan, north of the Triassic shore line extending, approximately, from the Mujib to the Azraq basin. These rocks were partially or completely removed in north Jordan during the Early Cretaceous (Fig. 8).

It is said previously that the exposed Triassic rocks are collectively grouped as Zarqa Ma'in, but **Andrews (1992a)** gave it a new name called the **Ramtha Group**. He also gave new names for the subsurface formations. In this article the former name is kept throughout.

Fig. 8 shows that the Triassic deposits are thickest in the Northern Highland well NH-2 near Ramtha city, where 1239m compared with a total thickness of around 300 m in the Dead Sea outcrops. These deposits were penetrated in more than 36 wells indicating, as shown in the isopach map, that the total thickness of the Zarqa Ma'in Group is thinning towards the ESE.

In the Azraq basin, Triassic rocks were penetrated in many wells, especially in the Hamza oil field, many are closely spaced. However, 7 wells only penetrated the whole Triassic sequence. These are:

DH-1	269.0m	Dahikiyeh
F-!	443.0m	Fuluk Fault area
MZ-4	295.0m	Hamza, 14m dolerite
MZ-13	265.5m	Hamza
WH-1	310.0m	Wadi Hazim
WR-2	339.0m	Wadi Rajel
WR-4	285.5m	Wadi Rajel

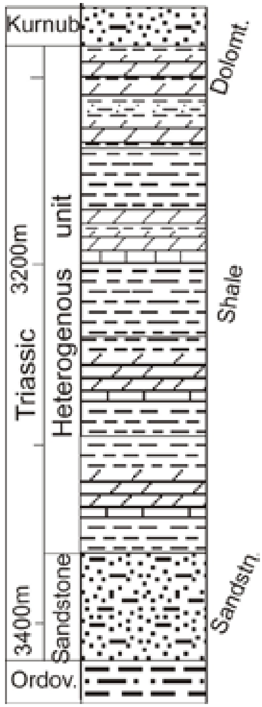


Figuer 8: Isopach map of the Triassic rocks in Jordan both surface and subsurface (Modified after Andrews, 1992a).

The total thickness of the whole Triassic sequence in the Azraq basin ranges between 265-443m. This is far below the thickness in NH-2. Thus, it was not possible to differentiate the sequence into formations. It can be divided into two facies (Fig. 9).

- A sandstone facies at the base of the sequence: colorless to pale-grey made of coarse to fine-grained sandstone. Some thin streaks of dark grey silty shale are scattered in the sandstone. Some glauconite is also seen,
- An interbedded dolomite-shale-sandstone unit overlies the previous facies up to the top of the sequence. Dolomite beds can reach 7 m in thickness. A typical facies is the dolomitized bioclast grainstone. Shale beds are grey to black Limestone is rare.

The age of the sequence in DH-1, MZ-4 and WR-2is Carnian (Late Triassic, while in WR-4 it is Mid-Late Triassic **(Core Lab, 1987)**. These facies seem to have been deposited in a slightly restricted, shallow marine shelf (intretidal-subtidal). The bioclasts, oolite and coated grains indicate a high energy regime while the shale might indicate a calm subtidal environment.



Figuer 9: Triassic sequence in well WR-2 (Wadi Rajel) in the subsurface of the Azraq basin (After Andrews 1992)

It should be emphasized that the Triassic rocks in the Azraq basin are overlain by the Early Cretaceous Kurnub Group sandstone. Also, No Permian rocks are present in the Azraq basin. They were not deposited there.

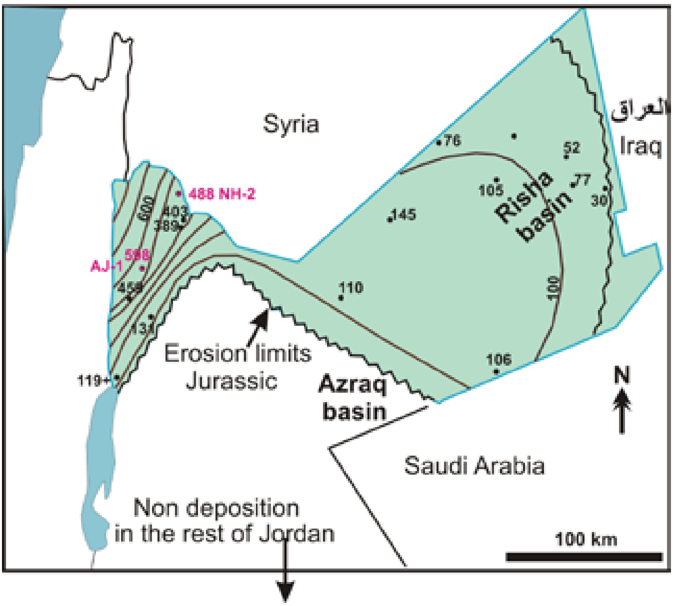
6. THE JURASSIC PERIOD

The Jurassic represents the 2nd period of the Mesozoic Era which extends 203-140 MA; a duration of 63 million years. It is widely distributing in the surrounding countries and it is a major source rock for oil in the Arabian Gulf and Iraq. In Jordan, however, it is restricted to northern Jordan from its shore line passing roughly from Amman eastwards and southwestwards. The outcrops are present near Mahis, Baqa', west of As-Salt, A'rda, and Zarqa

River **(Bender, 1974; Abed, 1987; Powell, 1989b)**. They are designated **Azab Group** and also in the subsurface. Total thickness in the outcrops is 400 m, while in the subsurface in Ajlun well (AJ-1) it is 598 m and NH-2 = 488m. Thus, the Jurassic basin centre is to the northwest of Jordan because it is much thicker in the adjacent countries. It thins towards the east and southeast to few 10s of metres (Fig. 10). It consists of alternating horizons of carbonates and siliciclastics with abundant fossils and trace fossils as well as primary sedimentary structures indicative of the shallow marine depositional environments. Unfortunately, the Jurassic Period has no rocks deposited in the Azraq basin, simply because the Azraq basin was above sea level at that time; i.e. within the land and not the sea as shown in Fig. 10. The Triassic rocks in the Azraq basin are overlain by the Early Cretaceous Kurnub sandstones with no Jurassic rocks intervening.

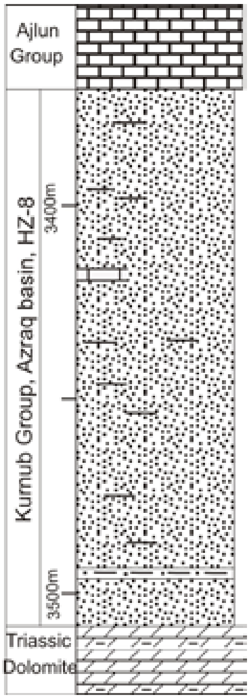
7. KURNUB GROUP, EARLY CRETACEOUS

The Kurnub Group is of Early Cretaceous age (~140-98 Ma); a duration of around 40 million years. Kurnub is an Arabic word for the Kurnub structure in eastern Nagab (Negev) in Palestine and was introduced to the geology of Jordan by **Quennell (1951)**. The group consists essentially of friable, fluvial quartz sandstones throughout Jordan, except for some shallow marine



Figuer 10: Isopach map for thickness distribution of the Jurassic rocks in Jordan (Modified after Andrews, 1992a)

interbeds in northwestern Jordan. It crops out in many parts of Jordan, in particular, the deep wadis crossing the mountain range to the Rift valley in the west. It is characterized by its massive, white sandstone at the base and varicolored sandstone in the upper part. The Kurnub Group thickness varies up to 350m to the NW of Amman. It thins to the east and SE becoming absent in the extreme SE **(e.g. Bender, 1974; Amireh, 1999; Amireh and Abed, 1999; Powell, 1989b)**. This is all from the exposed deposits.



Figuer 11: Columnar section in the Kurnub Group in HZ-8, Hamza oil field in the Azraq basin, dominantly sandstones.

7.1 Subsurface of the Azraq basin

In the Azraq basin, the sandy facies has previously been partly interpreted as to the Azab Group Jurassic), but it is reinterpreted as a Kurnub succession with rare reworked Jurassic microfossil **(Core Lab, 1987; Andrews, 1992)**; e.g. Hamza-well-8. The Kurnub sandstone consists of white and light grey, friable, porous, fine- to coarse-grained sandstone interbedded with grey-green siltstone and shale and thin streaks of limestone (Fig. 11). It overlies the Triassic sequence and is overlain by the limestones of the Ajlun Group of the mid Cretaceous.

The Kurnub Group in the Azraq basin was penetrated in around 20 boreholes, where the thickness is much less than in western Jordan and has a range

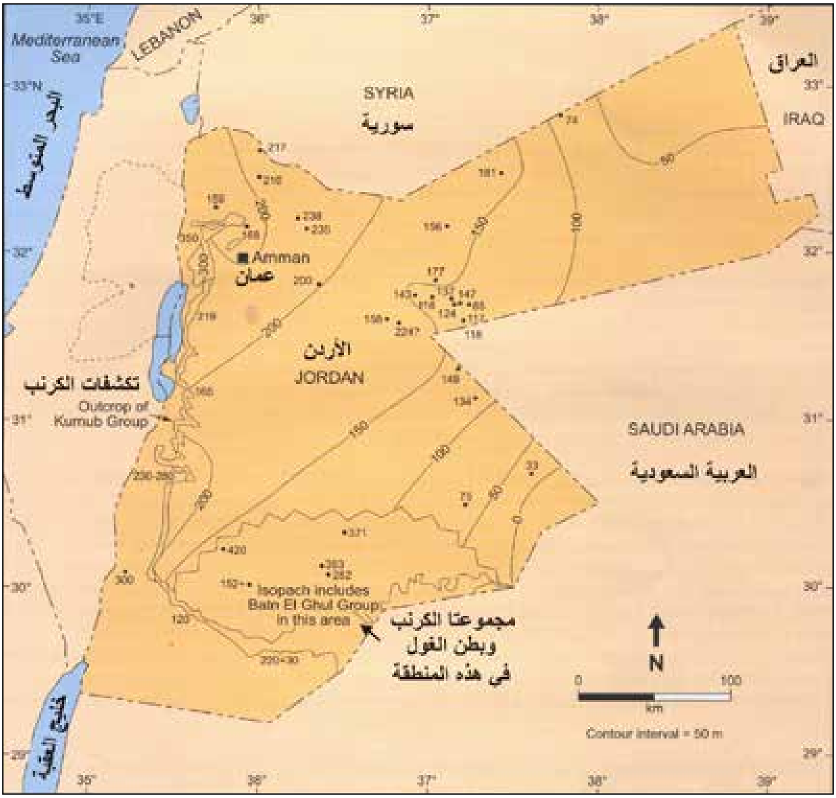
120-180m compared up to 350m (Fig. 12). It thins further east in the Risha basin to 25-60m. Few microfossils were found in these boreholes indicating an Albian-Aptian age of the Early Cretaceous **(Core Lab, 1987)**.

The Kurnub sandstones were deposited by braided rivers grading upwards into meandering rivers. Sparse palynomorph microfauna suggest a basin wedge, intertidal-supratidal environments with a more marine influence in Wadi Hazim well WH-1 **(Core Lab, 1987; Andrews, 1992a)**.

8. THE AJLUN GROUP, MID CRETACEOUS

8.1 General

The age of the Ajlun Group in the exposed rocks in Jordan is mid Cretaceous involving two stages: Cenomanian-Turonian; 100.5-89.8 Ma, a duration of ~11million years. The Mid Cretaceous was one the warmest periods in Earth's geological history where all the ice on Earth was melted and returned to the



Figuer 12 Distribution of thicknesses (isopach map) of the Kurnub Group throughout Jordan with the thicknesses in some borehole such as the Azraq basin (after Powell and Moh'd, 2011)

ocean as liquid water, the resultant was a global eustatic sea level rise 200-250m higher than today. Sea water transgressed and covered the continental margins with shallow epicontinental seas. Consequently, most of the eastern Mediterranean was submerged including almost all the Jordanian land. Thus, Jordan was covered with a warm, shallow continental shelf sea water where limestone and marl were the principle deposits with abundant fauna such Mollusca (Cephalopods, Gastropods, Bivalves), Echinoderms, Foraminifera, ostracods, and others **(e.g. Wetzel and Morton, 1959; Bender, 1974; Powell, 1989b; Powell and Moh'd, 2011)**.

In Jordan, the exposed rocks of the Ajlun Group are in excess of 600m of marl and limestone. They are subdivided into five formations. They are from older to younger: Na'ur, Fuheis, Hummar Shueib, and Wadi Es Sir (Masri, 1963). See Fig. 13 and Table 2 for more details.

In general, the thickness of the group decreases southwards, sandstones increase and carbonates decrease until the group becomes made of sandstones and siliciclastics in Batn El Ghoul area some 70 km south of Ma'an. The group seems to have been deposited in a rimmed marine platform (Powell and Moh'd, 2011).

Wadi Es Sir Formation, called also A7, forms the lower part of the shallow Wadi Es Sir-Amman aquifer (A7-B2). It might have been a reservoir in the Hamza oil field, and it is a major source for building stones marl horizons, especially the Fuheis Formation marl, is used for the cement industry.

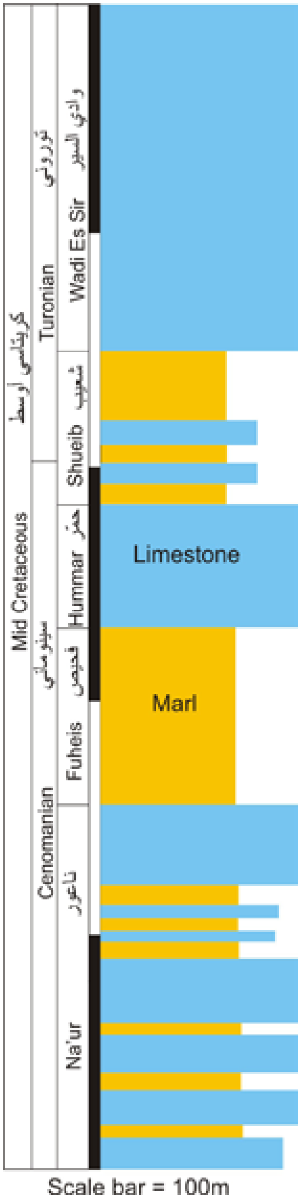
8.2 Ajlun Group in the Azraq basin

The Ajlun Group was deposited throughput Jordan except the extreme south and southeast as shown in Fig. 14. Many well were drilled in the Azraq basin in search for hydrocarbons, where the following brief description of the Ajlun Group in the subsurface is taken from.

The Ajlun Group in the Azraq subsurface is essentially similar to the outcrops in northern Jordan. The group in both areas consists of alternating horizons of limestone and marl/shale with abundant fossils as said above. The age of the group in Azraq is the same as in the outcrop; i.e. Cenomanian-Turonian of the Mid-Cretaceous, but, there are differences (Fig. 15).

a) The boundaries between the lower four formations are not as clear as in the outcrops in north Jordan. So, the lower sequence was divided into five informal units for the sake of correlation between wells. The Wadi Es Sir Formation is distinct.

b) The lower sequence ends by a sandstone horizon, not present in each and every well, but it is 12-24 m thick of fine-medium, glauconitic, argillaceous calcareous sandstone.



Figuer 13: Generalized columnar section of the Ajlun Group from its exposed rocks showing the formations and their thicknesses in north Jordan.

c) At least one thick anhydrite horizon, up to 7 m thick, is present at the base of Wadi Es Sir Formation. other beds are also present. Which is not present in the outcrops.

d) Glauconitic dolomite is not uncommon in Wadi Es Sir Formation which is not the case in outcrops.

e) Furthermore, the equivalent of the Hummar and Shueib Formations have some horizons rich in organic matter, thought to be the source for the local oil in some wells.

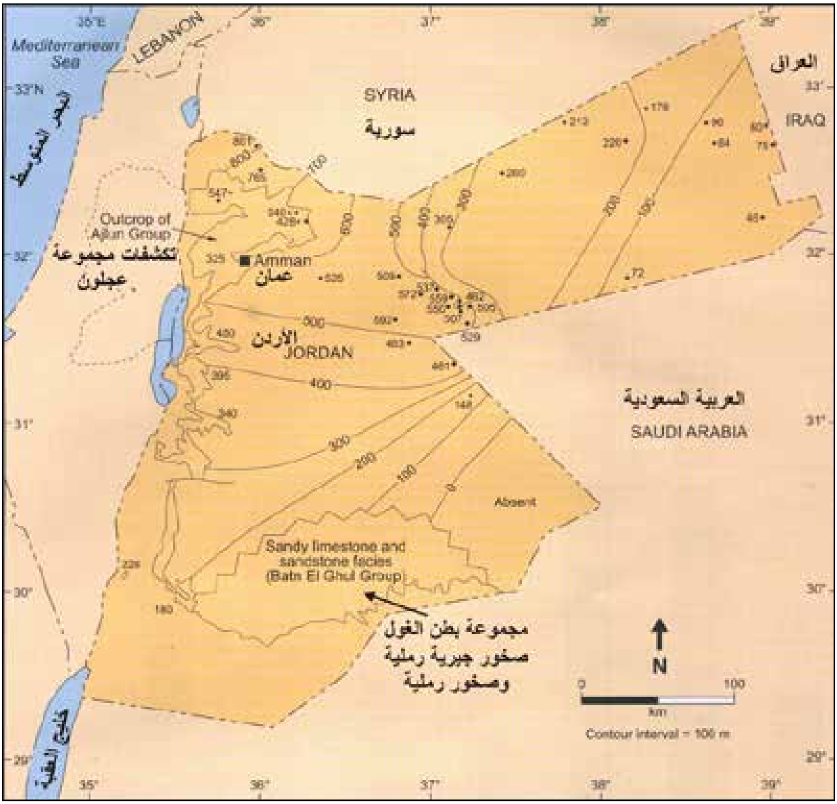
f) Wadi Es Formation is capped by another sandstone horizon called Rajil Sandstone which is not the case in the outcrops in north and central Jordan where the same formation is overlain by chalk. The presence of this sandstone horizon is taken to indicate an unconformity between the Ajlun Group and the Belqa Group with some omitted material from the latter group. Similarly, there is an unconformity (disconformity) between both group in the outcrops (Core Lab, 1987; Powell, 1989b; Andrews, 1992b).

Age		Group	Formation	Member
Tertiary	Eocene	Belqa	Shallaleh	
			Umm Rijam Chert Limestone	
	Paleocene		Muwaqqar Chalk Marl (MCM)	
Late Cretaceous	Maastrichtian		Al Hisa Phosphorite (AHP)	Qatrana Phosphorite
				Bahiyya Coquina
				Sultani Phosphorite
	Campanian		Amman Silicified Limestone	
	Santonian			
	Coniacian		Ghudran	Dhiban Chalk
				Tafila
				Mujib Chalk
	Turonian	Ajlun	Wadi Es Sir	
	Cenomanian		Shueib	
			Hummar	
			Fuheis	
			Na'ur	
Early Cretaceous	Aptian-Albian		Kurnub (Hathira) Sandstone Group	

Table 2: Nomenclature of the Ajlun and Belqa Groups (El-Hiari, 1986; Powell, 1989b)

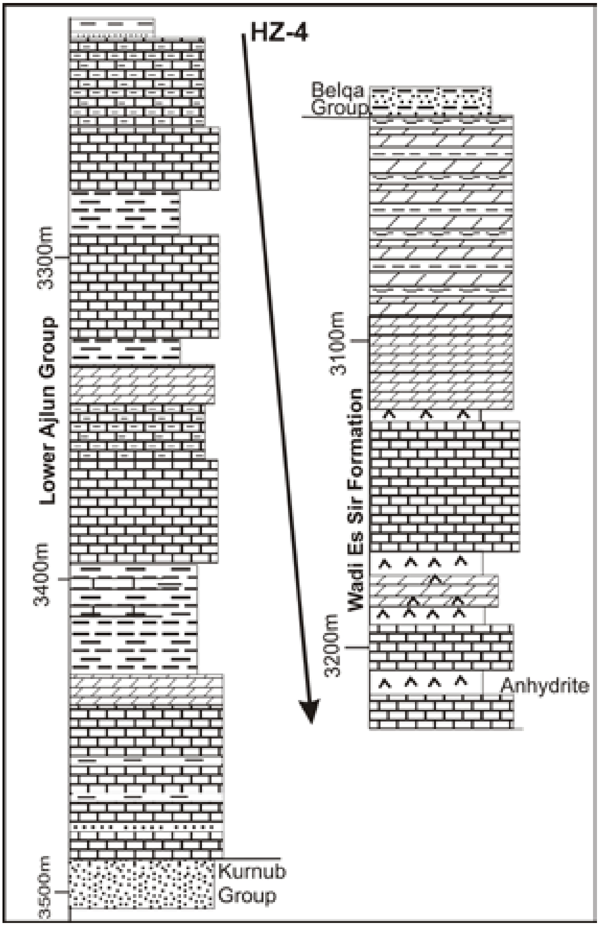
The thickness of the Ajlun Group is not constant in all wells. The thickness of lower part of the sequence up to the base of Wadi Es Sir has a range between 225-329m, it seems to increase westward. Wadi Es Sir Formation thickness varies between 85-290m, with a typical thickness in most wells 240-250m. Total thickness can slightly be more than 600m, which is comparable with the north Jordan outcrops.

The depositional environments are comparable with the outcrops of being a rimmed platform with depositional environments varying from deep subtidal (open shelf) especially in the marl horizons, to intertidal-supratidal. The Anhydrite beds in Wadi Es Sir Formation is interpreted as a sabkha environment in the Azraq subsurface. A similar sabkha environment was described by Abed and El-Hiari (1986) extending from Wadi Mujib and



Figuer 14: Isopach map showing the distribution of thicknesses for the Ajlun Group throughout Jordan in the surface and subsurface (After Powell and Moh'd, 2011)

further south, but it is gypsum not anhydrite. It is Turonian in age, that is possibly why it was considered as part of Wadi Es Sir Formation in the Azraq basin, because all Turonian rocks are added to the Wadi Es Sir Formation.



Figuer 15: Hamza- 4 well log showing the lithology of the Azraq Group. Left, lower Ajlun Group up t the base of Wadi Es Sir Formation; right, Wadi Es Sir Formation (From Andrews, 1992b).

9. BELQA GROUP, LATE CRETACEOUS-PALEOGENE

9.1 Exposed formations

The Belqa Group is the last marine group which was deposited throughout Jordan from the Neo-Tethys Ocean. By its end at around the Late Eocene, the ocean migrated from the eastern Mediterranean and never back again. Since then, Jordan became the scene for erosion and sporadic deposition in the low-lying areas such as the Rift valley and the Azraq basin.

The formations constituting the Belqa Group crop out in more than 60% of the country. These formations are from older to younger: Ghudran, Amman, Al-Hisa, Muwaqqar, Rijam and Shallaleh (Table 2 and Fig. 16). These formations consist of exotic (not common) rocks such as phosphate, bedded chert, porcellanite, and oil shale. Such rocks are believed to have been deposited from cold, upwelling currents flowing westwards along the southern shelfs of the Neo-Tethys Ocean (e.g. Abed, 2013). The total thickness of the exposed Belqa Group is ~ 550m, but it varies considerably because of the highs and lows at the ocean floor during the time of deposition, because of the compression associated with the subduction then collision between the Arabian Plate and the Eurasian Plate (e.g. Powell and Moh'd, 2012; Abed, 2013; Abed et al., 2012, 2016). For example, the Muwaqqar Formation is in excess of 300m in the Yarmouk basin while it is around 100m in central Jordan (e.g. Yassini, 1979; Abed et al., 2005). Al-Hisa Formation (phosphate-bearing) is 65m and ~10m thick in Central Jordan and Al-Kora basin west of Irbid respectively (Abed and Sadaqah, 1998; Abed et al., 2016).

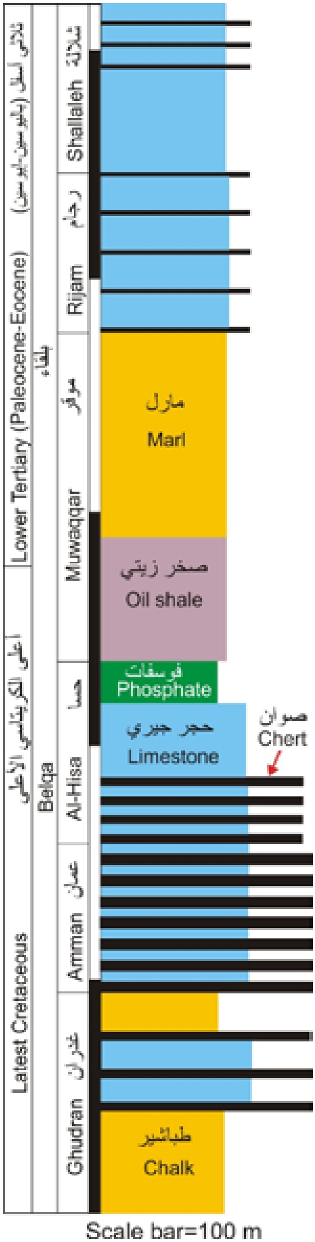
The Belqa Group is the source for economic deposits which are playing an important role in the development in Jordan. Most important among them are the phosphates, the oil shale, building stones, and pure carbonates.

9.2.1 Structural overview

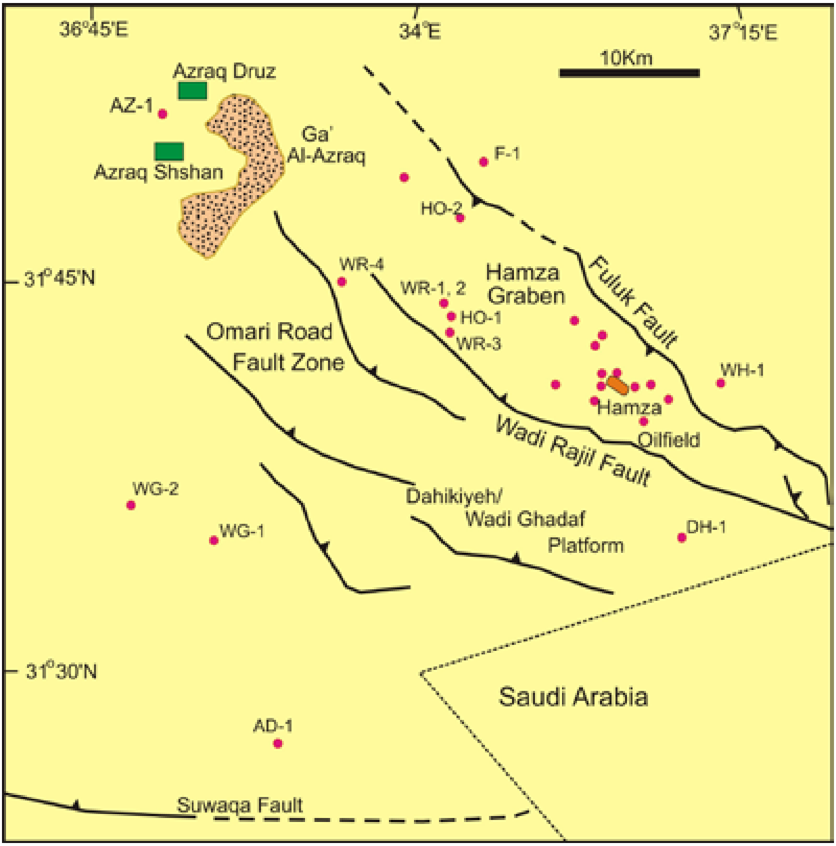
The major factor affecting sedimentation the in Hamza oilfield and its vicinity is tectonics. Two faults were synsedimentary active during the Late cretaceous, Coniacian-Maastrichtian: the Fuluk Fault in the NE and Wadi Rajil Fault is the SW. They created the Hamza Graben (Fig. 17) where around 3000m of sediments were deposited. According to Core Lab (1987) interpretation, three structural units were formed in and outside the graben (Fig. 17):

- The Hamza Oilfield within the graben where the thickest sediment accumulation in the Late Cretaceous.
- Hamza High within the graben but shallower than the Hamza Oilfield. This is evident from the shallow water faunas, secondary dolomites and evaporites and, in some cases, thinning of section.
- Dahikiyeh-Wadi Al-Ghadaf Platform to the west and southwest of the graben and possibly extending southwestwards to Suwaqa Fault.

All these faults are trending NW and most probably they form part of the Wadi Sirhan Fault Zone.



Figuer 16: General composite columnar section for the Belqa Group in the outcrops



Figuer 17: General structural map of the Hamza area (Core Labe, 1987)

9.2.2 Belqa Group subsurface Stratigraphy

The lowermost part of the Belqa Group is supposed to start with the relatively thick chalk horizons of the Ghudran Formation, as it is the case in the outcrops. No chalk is present overlying the Ajlun Group and underlying the chert of the Amman Formation throughout the Hamza area. Instead three different facies are introduced here, all below the chert of the Amman formation. They are from older to younger.

Rajil Formation is the oldest formation, it overlies the limestone of the Wadi Es Sir Formation of the Ajlun Group and is well below the Amman Formation. In the Hamza Oilfield, it consists of a lower sandstone unit, mainly made of sandstone with minor interbedded claystone, chalky and dolomitic limestones. Thickness of the unit in HZ-2 is 158m. The upper unit, claystone-limestone unit, consists of silty claystone, pyritic shale, chalky limestone and pyritic dolomitic limestone. Nodules of chert and lenses of anhydrite are present towards the unit base. Total thickness in HZ-2 is 260m. Maximum thickness of the Rajil Formation is 551m found in HZ-3 in the Hamza Oilfield. The sandstone content decreases northwards in the well HO-2, within the graben, (Fig. 17) has only 49m sandstone. Sandstone also decreases westward towards WR-4 where substantial sandstone is still present.

Total thickness of Rajil Formation is 419-566m in the Hamza Oilfield, becomes thinner in the Hamza High, and much thinner in the platform as in Dahikiyeh DH-1 181-299m. No fossils are found in the formation except the fresh-water algae *Characeae*, thus, the depositional environment is terrestrial, probably in deltas (Core Lab, 1987). Because Wadi Rajil Formation is well below the Amman formation, its age is most probably Coniacian? Santonian? up to Campanian? (See Andrews, 1992b). The Wadi Rajil Formation is not reported anywhere in Jordan except in the Hamza area.

Hamza Formation is present only in the graben and the platform, but not reported in the outcrops elsewhere in Jordan. It overlies Rajil Formation and consists mainly of dolomite, minor chalky limestone, sandy and sandstone towards its base, and abundant nodules of chert. Near the top of the formation, a zone 65-110m thick contains layers with residual oil and asphalt. It is thickest in the graben to 467-840m, with the greatest thickness northwards near the Fuluk Fault in HZ-4, 2, thins in the platform to 249-294m and absent NE of the Fuluk F-1. The high thickness of the Hamza Formation can be explained by the continuous subsidence during its time of deposition. No fossils are found within this formation, possibly due to dolomitization. The age is put as Santonian-Campanian.

Hazim Formation (after Wadi Al-Hazim) is also restricted to this part of the Azraq basin and is not reported any where in Jordan in the outcrops. The Hazim Formation Mainly of limestone variously argillaceous, marly, chalky, dolomitic, fossiliferous, pyritic and glauconitic. Anhydrite beds are present throughout, being up to 4m towards the top of the formation. HZ-14 has a 30m thick halite horizon. The uppermost 50m are highly variable with interbedded limestone, dolomite, marl and anhydrite. Its top ends where indurated limestone with chert begins (the Amman Formation).

The Hazim thickness is highest in the graben 413-608m nearby the Fuluk Fault, while in the platform it is thins to 155-255m. It is Absent NE of the Fuluk F-1. On the bases of not so much useful Ostracoda (*Bairdia sp.* and *Cytherella sp,*) and foraminifera (*Elphidium*), the Hazim Formation was given an Early Maastrichtian age (Al-Harithi et al., 1987). The above-mentioned fossils as well as presence of halite, anhydrite and anhydritic dolomite point out to a shallow, calm, marine lagoonal depositional environment.

The three discussed formations, Rajil, Hamza and Hazim, may be correlated in the outcrops by the disconformity above Wadi Es Sir Formation and the

Ghudran Formation. The remaining formations of the Belqa Group in the Azraq subsurface, Amman through Shallaleh (Table 2 and Fig. 13), retain their names and will be discussed briefly below.

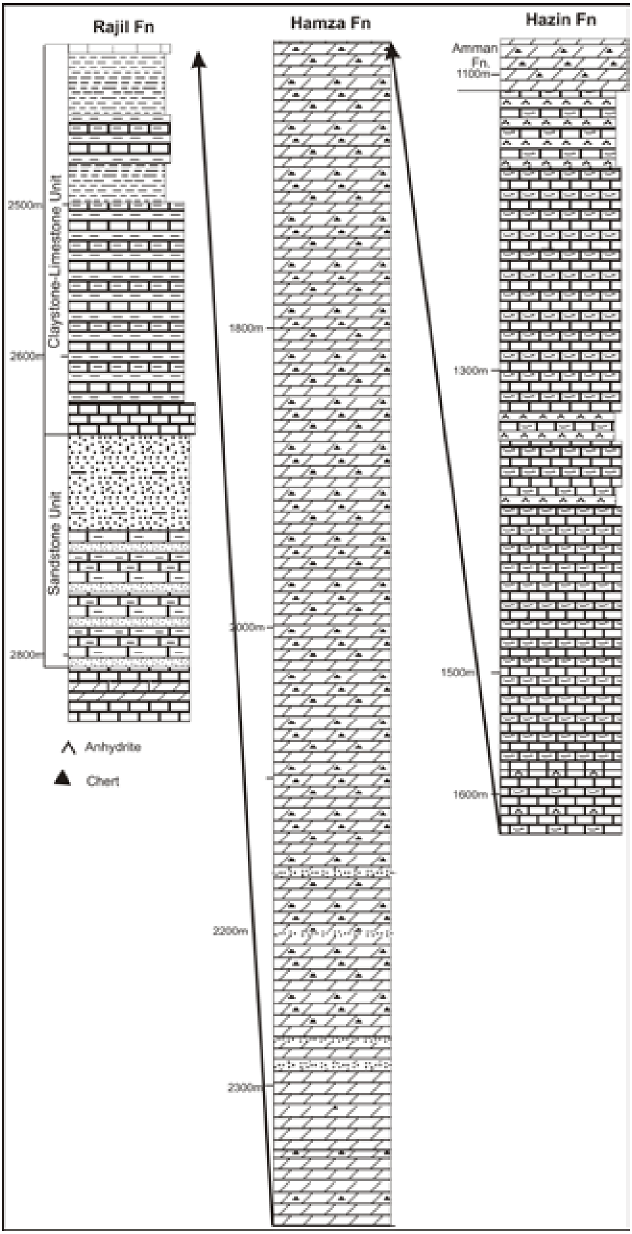
Amman and Al-Hisa Formations are grouped together because of the difficulty to recognize the boundary between them in the surface and subsurface alike (e.g. Powell, 1989b; Abed and Sadaqah, 1998). The lower part, Amman formation, consists of predominant chert and minor chalk limestone. Anhydrite is also present in the lower part. Higher up, very high radioactivity was interpreted as due to the presence of phosphates/ phosphatic chert in a horizon 1-15m thick. This is the principle zone where bitumen and asphalt are reported in the Hamza Oilfield such as HZ-13 with asphalt filling the fractures and cavities in a brecciated dolomite. Al-Hisa Formation consists of phosphatic and bituminous limestone with the chert being below (Fig. 19).

Due to inconsistency of defining the Amma/Al-Hisa in the subsurface, the reported thickness varied greatly. Core Lab (1987) added all strata belonging to the Campanian to Amman Formation and the resultant thickness was 1313m. This is too high compared with outcrops. On lithology and geophysical logging, Andrews (1992b) redefined the two formation despite their age in the wells on the basis of lithology and geophysics. Accordingly, the maximum thickness in Hamza Oilfield is 138.5m in HZ-11.

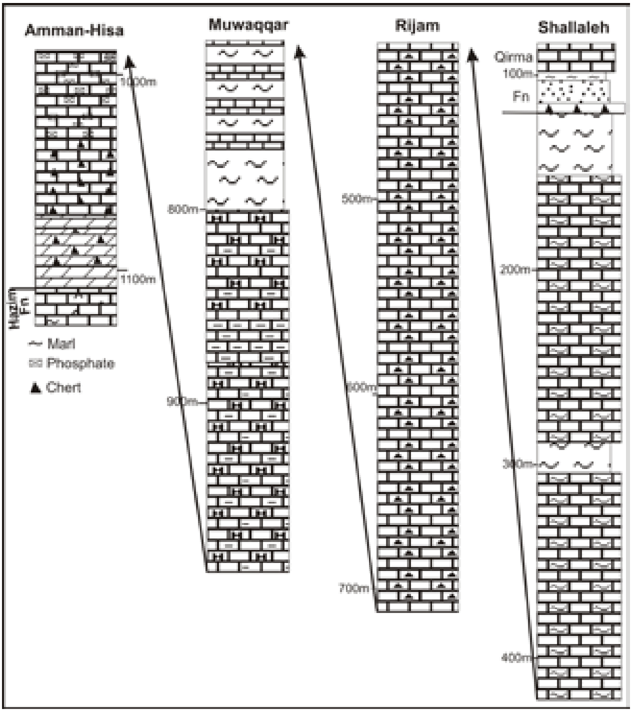
In the up thrown side of the Fuluk Fault, Al-Hisa is called Usaykhim Formation with sandy phosphatic facies with a maximum of 87m in Hazim well WH-1.
The age of both formations in the Azraq subsurface is most probably Maastrichtian (Dilley, 1985). Consequently, the age and thickness of both formations are comparable with the outcrops.

The **Muwaqqar Formation** is well-known in the outcrops, throughout Jordan, by being made of soft marl and oil shale. Andrews (1992b) used the same out crops terminology for the subsurface and made the Muwaqqar Formation equal to Ghareb, Taqiye and Sara Formations, frequently used in the NRA reports. The Muwaqqar in the Hamza Oilfield, as in HZ-2, consists of argillaceous, phosphatic, locally fossiliferous and part1y marly limestones with rare chert nodules are overlain by soft marl interbedded with partly fossiliferous, argillaceous or chalky limestones (Andrews, 1992b) (Fig. 19).

Accordingly, the total thickness of the formation in the Hamza Oilfield is 128.0 (AZ-1)-288.0 (HZ-4). This thickness is comparable to outcrops and there is no need for extensive subsidence envisaged by those who defined the Muwaqqar Formation according to age (Maastrichtian-Paleogene), where the total thickness reached 975 m, and explained that by continuous subsidence (Core Lab, 1987). Depositional environments are similar to the outcrops.



Figuer 18: Columnar sections for the Rajil, Hamza and Hazin Formation at the base of the Belqa Group (Modified from Andrews, 1992b)



Figuer 19: Well HZ-2 log showing the lithology of the Amman through Shallaleh Formations in the Azraq subsurface.

Rijam Formation crops out in many parts of the Azraq basin with a similar definition of the other outcrops in Jordan. It consists of bedded chert and limestone to marly limestone with some phosphate. There seems to be no differences in lithology between the outcrops and the Azraq subsurface. The thickness of Rijam Formation in the outcrop near Irbid is 220m, decreasing southwards. In the Azraq subsurface, it has a maximum of 311m in HZ-1 and early to middle Eocene age. Otherwise, it is similar to the outcrops.

Shallaleh Formation crops out mostly in eastern and northern Jordan as it is the case in the Azraq basin. The formation crops out at Faydat Al-Dahikiyeh area where it consists of 60-70m of marl and 30 m of limestone with chert concretions and marl. The marl contains bitumen, glauconite and phosphate (Bender, 1974). A sandstone horizon is present at its top in this area. In the subsurface of Hamza Oilfield, represented by well HZ-2, the formation consists of marly limestone and marl with chert concretions (Fig. 19). The thickness of the outcrops in the Azraq basin is around 55m where the base is not seen. However, in the Hamza Graben, the thickness increases towards the Fuluk Fault from 160m to 428m in well HZ-16. It is given an age of early- to middle Eocene in the Azraq area (Core Lab, 1987). It was deposited in mid to outer shelf marine environment.

10. POST NEO-TETHYS DEPOSITS

The Neo-Tethys Ocean, which submerged Jordan during Late Cretaceous-Eocene, had migrated from the area during the Late Eocene or possibly the very Early Oligocene; i.e. at around 35 Ma ago. The migration was due to the compression and uplift of the area caused by subduction and later the collision of the Afro-Arabian Plate with the Eurasian Plate, through the continuous northward movement of the former plate (e.g. Abed, 2013 and the references therein). Consequently, Jordan became almost completely emerged and subjected to erosion of the previously deposited Belqa Group. Deposition was restricted to low-lying areas such as the Rift valley in the west and the Jafr, Azraq basin and the like in the east. Known deposits in the Azraq basin are described below.

10.1 Qirma Formation

The name is after Tell Qirma to the southeast of the Azraq towns. The formation consists, mainly, of quartz sandstone sometimes burrowed, but micritic limestone and dolomite with algal mud cracks are also reported (Ibrahim, 1996). See Fig. 20 for full description of the Formation. The thickness of the formation is 38-44m in the outcrop, but reaches 211m in the Hamza Oilfield. Its base is the unconformity with the basalt of the Wisad Group and its top is also the unconformity with the basalt of the Safawi Group.

The age of the Qirma is Miocene (Tutonian), according to the presence of the *Discerbinella montereyansis* and *Valuylineria casitasensis* described by Baker and Harza (1958) in water wills in the basin. The Miocene age is also confirmed by the absolute age dating of the underlying Wisad basalt at 13 Ma while the overlying Safawi basalt is 8 Ma. The Qirma Formation, most probably, was deposited from a brackish lake, despite some advocating marine origin.

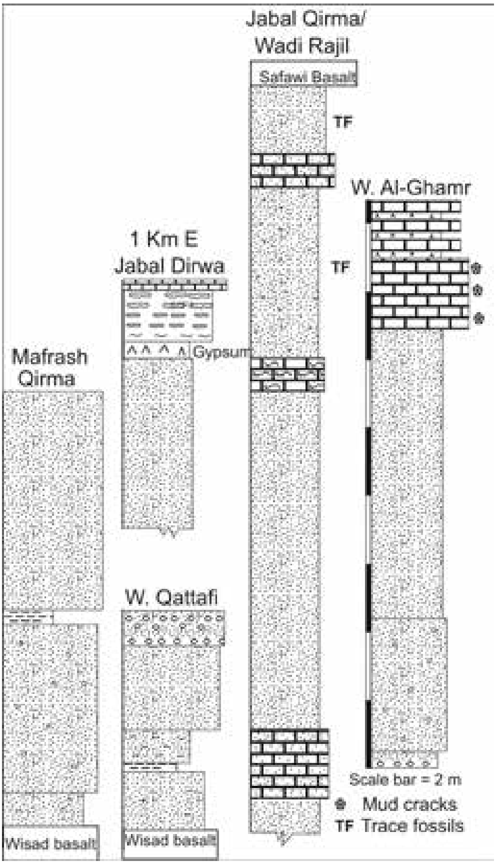
10.2 Azraq Formation

The Azraq Formation crops out around the Azraq towns and continues south and east up till the Saudi borders. It consists of soft, gently sloping sediments which does allow the exposure of the whole thickness of the formation. Furthermore, varying lithologies were described from different parts of the basin. For example, the rocks present in the Umari area are, sandstone, conglomerates, limestone with abundant fossils (Figs. 21, 22), Fig. 23 shows the columnar section in Umari area. In other localities, limestone, gypsum beds, gypcrete, gypsiferous marl and rare halite are present.

At the oasis, boreholes were drilled for bentonite exploration by the NRA to a depth of 80m. The following description is taken from Alali and Abu Salah (1993) and Ibrahim (1996).

- Gypsiferous clays and clay layers (a few meters thick in the upper parts of some boreholes).

- Gray, white dolomite and dolomitic limestone (less than 2 m thick) (in few boreholes).
- Brown to green, yellowish brown, gray to light gray clay layers (14 to 30 m thick), occasionally silty, gypsiferous, calcareous and diatomaceous.
- Gray to dark green diatomaceous clay, soft and massive (4.5-31 m thick) (in two levels).
- Gypsum layers as intercalations with gypsiferous clays and clay layers (a few meters thick in the upper parts of some boreholes).
- Loose sand, silt and gravel intercalations.
- Whitish gray to white sandstone beds, calcareous-cemented, intercalated within clay layers.
- Basalt flows and tuft layers occur within clay layers (found in three boreholes in Al Bayda area).



Figuer 20: Sections in Qirma Formation (Ibrahim, 1996)

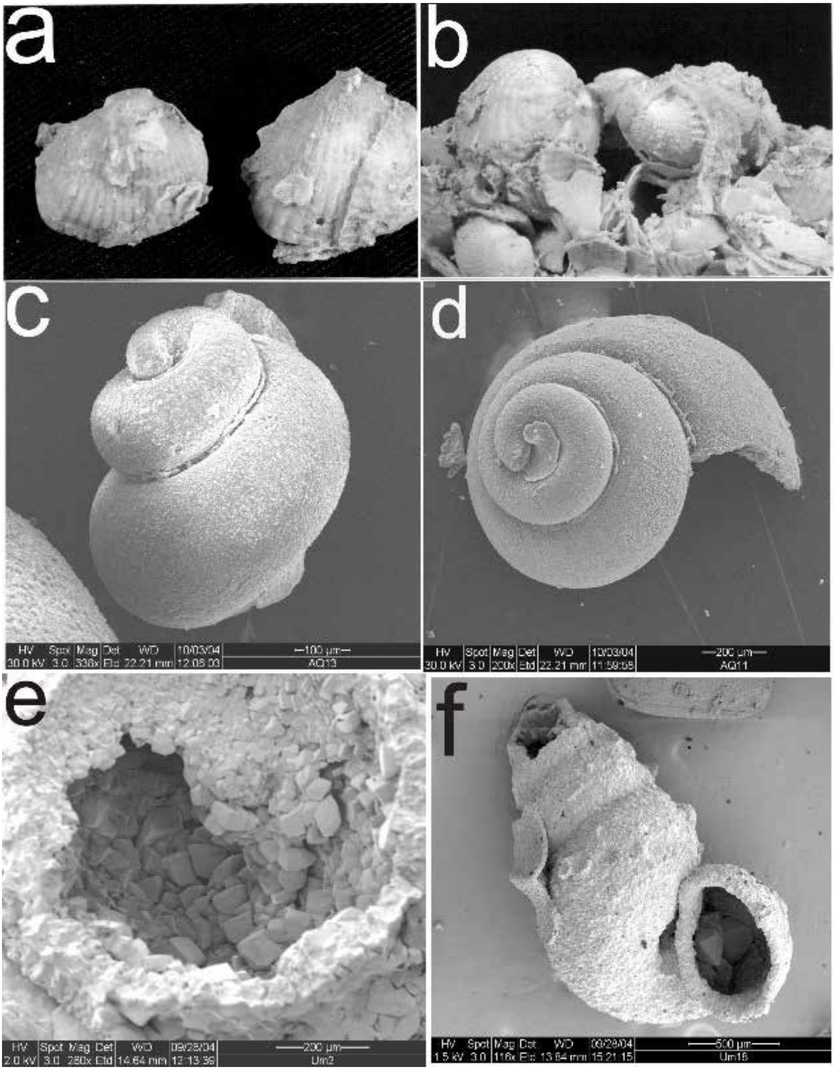


Figure 21: Mulluscan fossils from the Umari area. a. Cardium shell from Azraq. b. Cardium shell from Al Umari. c. Bythinia sp. d. Gyraulus sp. e. Highly diagenetic gastropod shell. f. Hydrobia sp. (Abed et al., 2008)

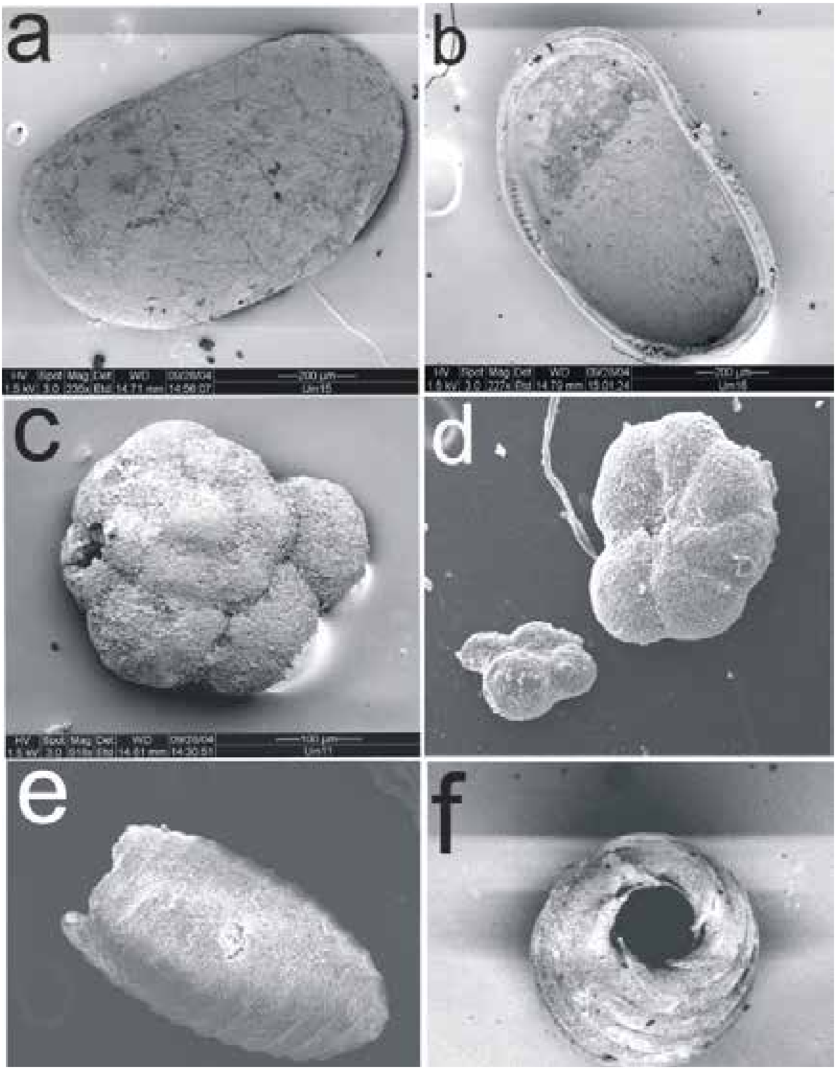


Figure 22: Ostracods and Charophyte fossils. a. Cyprideis torosa gr., smooth and sieve like, exterior right valve. b. Cyprideis torosa gr.enterior left valve. c. Ammonia beccarii tepida ventral view. d. Ammonia beccarii tepida dorsal view. e. Charophyte gyrogonite of Croftiella cf escheri. f. Charophyte top view (Abed et al., 2008).

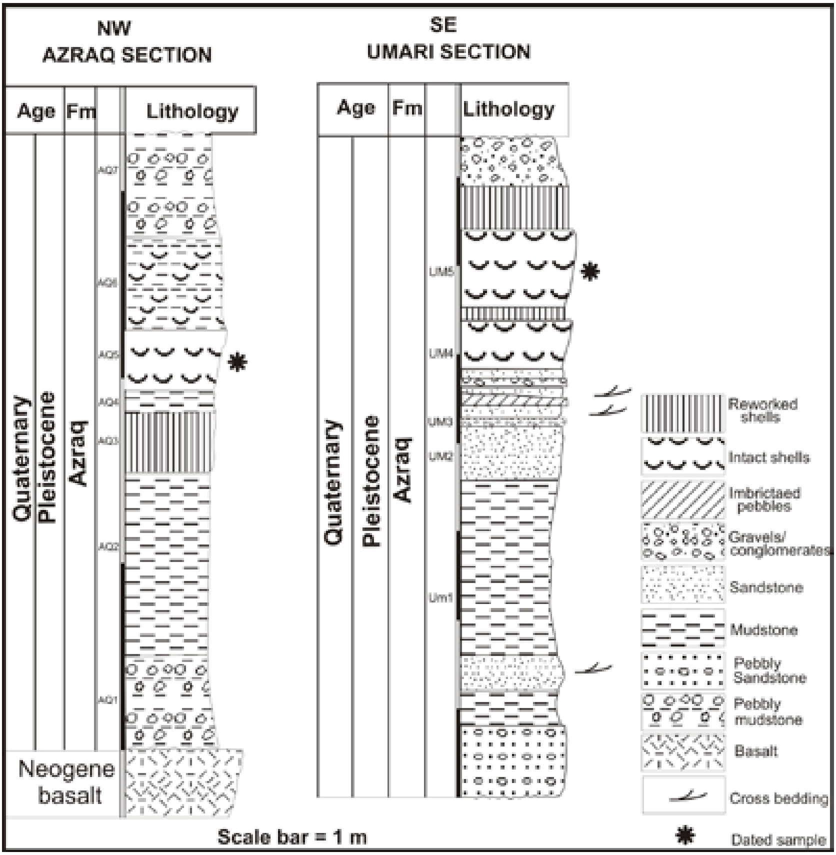


Figure 23: Two columnar sections showing the lithology of the Azraq and Umari sites where fossils were found (Abed et al., 2008).

Total thickness in the outcrops is around 15m, while in the boreholes in the centre of Qa' Al-Azraq it is 80m (Ibrahim, 1996). The age of the formation is certainly Pleistocene, not Pliocene, as indicated by others (e.g. Ibrahim, 1996 and the references there in). The Pleistocene age is based on U-Th age dating of the Umari section at 331 Ka by Abed et al., 2008), and OSL dating for a sandstone horizon further north at 656 Ka by Turner and Makhlouf (2005).

The Azraq Formation was deposited in a lake/lakes occupying the Azraq depression partly or wholly depending on the paleoclimate. The abundance of clays and diatoms at the centre of the basin, (Ga' Al-Azraq), may indicate the permanent presence of relatively deep and fresh water. During times of dry paleoclimate, the lake shrinks and gypsum, and possibly halite, can form at certain parts of the lake. During Marine Isotope Stage 9 (MIS9), at

331 Ka, which was a wet and warm period of the Pleistocene, the lake/lakes was/were occupying the basin from the Umari in the east till Azraq Druze in the north (Fig. 24) (Abed et al., 2008).

More recent deposits of the Late Pleistocene to the Holocene are also present. They are younger than the Azraq Formation and include: the Dashaha silt dunes up to 10m high at the periphery of the Ga', the abundant gravels at the mouths of the major wadis recharging the Ga', and the desert pavement.

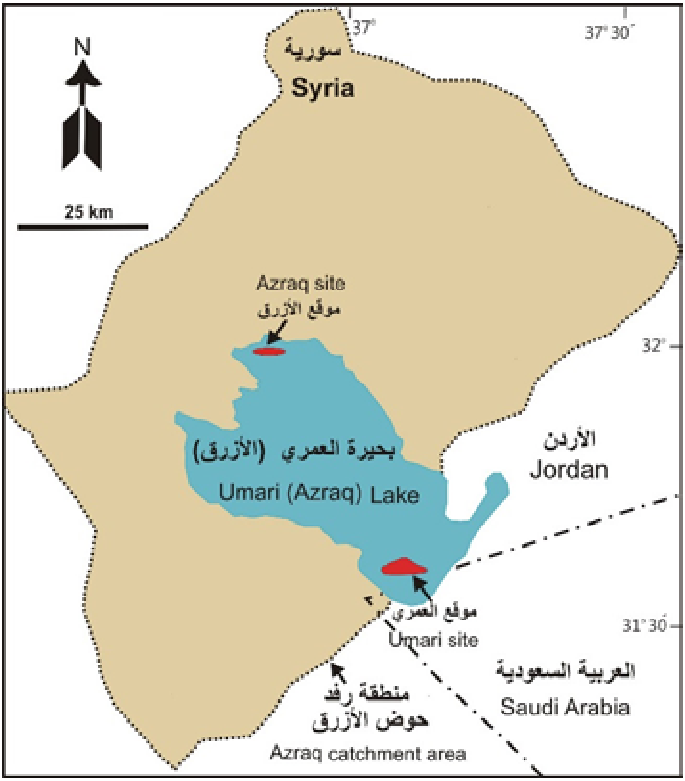


Figure 24: The extent of the Azraq paleolake at 330 Ka BP. The shoreline of the paleolake is drawn at the 540 m contour above sea level (Abed et al., 2008)

Figure 25: Basalt overlying Shallaleh Fn in W. Uwayned west of Azraq

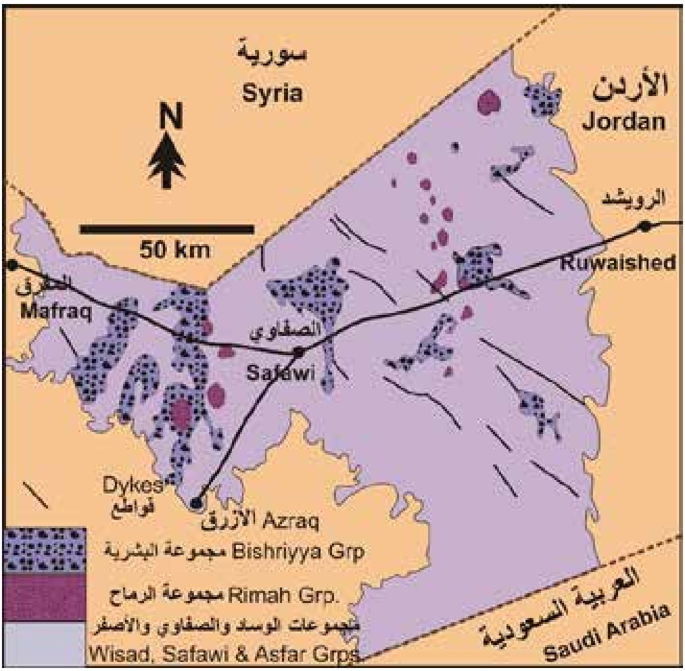


Figure 26: Map showing Harrat Esh Sham in Jordan with the basalt groups

11. VOLCANIC ROCKS

Remarkable volcanic activities took place during the Cenozoic. Since the Early Miocene, 25 Ma ago, up till 100Ka in the Azraq area, Jordan and its surroundings witnessed abundant volcanic eruptions in the form of fissure eruptions along faults or as cone eruptions. This event, both tectonic and volcanic, took place during the release of stress in the Afro-Arabian Plate after colliding with the Eurasian Plate at about 25 Ma, which led to the formation of the Syrian-East African Rift system including the Red Sea (e.g. Abed, 2017).

A huge basaltic plateau or field, 45000 km2 was formed in Southern Syria, Palestine, NE Jordan (11000 km2) and Saudi Arabia. Collectively, this basaltic field is known as Harrat Esh Sham Supergroup. Harrat Esh Sham consists mainly of the black basalt (Fig. 25) erupted along faults and fissures parallel to the Res Sea; i.e. in a NW-SE direction. The other type of material are the cinder cones where pyroclastic material were produced as volcanic bombs and ashes such as in Jabal Aritain, Tell Hassan and Tell Rimah.

In Jordan, cropping out Harrat Esh Sham is divided into 5 major groups. They are from older to younger: Wisad, Safawi, Asfar, Rimah, and Bishriyya (Fig. 26). Older eruptions are also present in the subsurface. The maximum thickness in Jordan near Jabal Druze in southern Syria is 400 m. Paleosoil is reported between the groups. This is a major topic that needs to be discussed separately.

12. EVOLUTION OF THE AZRAQ BASIN

The Azraq area, especially the Hamza oilfield area, seems to have been a basin during the Paleozoic. The Ram Group thickness in the subsurface is slightly less than twice the thickness of the southern outcrops. This is also true for the preserved parts of the Khreim Group. This might be due to the position of the Azraq basin as a continuation of Wadi Sirhan basin, where the NW-trending Sirhan Fault Zone crosses Sirhan basin. Although the Sirhan Fault Zone is a Tertiary feature, it might have been a reactivate Najd Faults, which have the same trend. Its Activity was later subdued until it was active again during the Tertiary as discussed below (e.g. Abed, 1985; Amireh and Abed, 2008, Powell et al., 2014).

Since the Carboniferous up till the end of the Ajlun Group, no basinal development had taken place in the Azraq area. The relatively thin, marine Triassic deposits in the Azraq basin do not indicate basin formation. The Triassic basin is in fact in northwestern Jordan. The Jurassic was not deposited there and the Kurnub Group of the Early Cretaceous is terrestrial sandstone. The total thickness of the Ajlun Group, despite being marine, as well as the thickness of each formation in the group, are essentially similar to those in the outcrop. Consequently, there are no sign of a basin developed at the time of deposition during the Mid Cretaceous (Cenomanian-Turonian).

Dramatic changes seem to have taken place in the Azraq basin during the deposition of the Belqa Group. Northwest-trending fault became active since the Coniacian? such as the Fuluk Fault and Rajil Fault (Fig. 17). A subsiding graben, called Hamza Graben, formed in between the two fault and a relatively thick sequence of sediments was deposited. It includes the Rajil, Hamza and Hazim Formation, Coniacian-Campanian, with a total maximum thickness of 2000 m of sandstone at the base becoming carbonates with some chert and evaporates up section as discussed above (Andrews, 1992b). There is nothing like that in the outcrops, except for 100m of equivalent Ghudran Formation in central Jordan. The overlying formations in the Belqa Group, Amman through Shallaleh Formation, have a comparable thicknesses and lithology with the outcrops in northern Jordan, albeit being slightly higher in thickness and reach a total thickness ~1200m; thus making the total thickness of the Belqa Group in the Hamza oilfield up to 3200m (Fig. 27).

The thick sedimentation in the Hamza Oilfield can be explained by synsedimentary deposition associated with active subsidence along, especially, the Fuluk Fault. The Fuluk Fault and other faults involved in creating the Hamza Graben, are trending NW, and can be considered as a rejuvenation of the Precambrian Najd Faults oriented in the same direction (Abed, 1985; Amireh and Abed, 2008; Powell et al., 2014). The NW- trending faults in Jordan are younger than the formation of the Hamza Graben, most probably they are Miocene in age; e.g. the Karak-Fayha Fault zone (Bareri et al., 1979). In the opinion of the present author, the Wadi Sirhan Fault zone, which has the same trend and involves the same area, is also Miocene in age. This is because no volcanic activity occurred along the Sirhan Fault Zone before the Miocene, documented by the age of the basalt erupted along these fault; i.e. 26-Recent (e.g. Al Kwatli, et al., 2014; Ibrahim et al., 1998). So, the formation of the Fuluk Fault and the Hamza Graben may be considered as an earlier rejuvenation event along the Sirhan Fault Zone.

Since the Late Eocene-Oligocene, the interior eastern Mediterranean underwent a process of uplift, in advance of the formation of the Dead Sea Transform (DST). This uplift process led to the migration of the Neo-Tethys Ocean westwards and northward (e.g. Bender, 1974; Abed, 2013). Consequently, almost all the interior eastern Mediterranean, including almost all of Jordan, became terrestrial. Thus, no marine strata have been deposited within the Azraq area after the Eocene. However, lacustrine deposits formed from lakes such the Miocene Qirma Formation, the Middle Pleistocene Azraq-Umari lake/lakes and the Azraq Pleistocene-Recent lake (Ibrahim, 1996; Abed etal., 2008).

Since its emergence at around the end of the Eocene, the Azraq Basin has existed as a depression. Non-marine strata deposited during this time interval is about 150 m thick at the centre of the basin and consists of sandstone, marl, mud rocks with diatomites and limestone (Core Lab, 1987; Ahmad and Davies, 2017). Towards the periphery of the basin, the younger parts of these terrestrial sediments crop out and are designated as the Azraq Formation. Although the Azraq Formation is dominated by sandstones, it has a variable lithology difficult to correlate because of the lack of well-established dates (Ibrahim, 1996; Rabba'a, 1998).

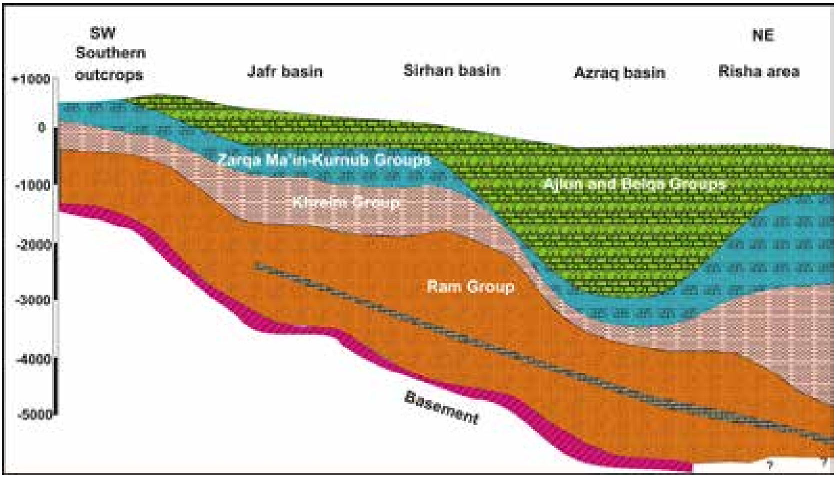


Figure 27: A SW-NE cross section from southern Jordan to the Risha area showing approximately the Azraq basin deposits and other basins.

12. HOMININ REFUGIA IN THE AZRAQ BASIN

The Azraq basin, especially Ga' Al-Azraq or the oasis, was occupied by a cyclic wet and dry climate sediments, dominated by wet periods (Ahmad and Davies, 2017), throughout the Pleistocene. (Ames et al., 2013). Thus, the Azraq basin worked as bridge in the migration routes for hominins and animals between Africa, Arabia and SE Asia on one hand, and Asia and Europe on the other hand. The large area of the Azraq basin, ~ 12700 km^2 , ensures enough precipitation and then groundwater for the Azraq marches and springs to survive for thousands of years. The presence of several springs in the oasis, as well as the emergence of groundwater to the surface, make the Ga' small area a pocket in an otherwise a harsh environment (Cordova et al., 2012).

Abundant research work on the archaeology of the Azraq basin is present since the early 20th century. All major Paleolithic, Epipaleolithic and Neolithic archaeological sites are well represented in the Azraq basin, especially in and around the oasis. Consequently, hominin population, paleoenvironments and paleoclimates at the time, within the Azraq basin, are now better understood, sometimes at a detailed scale (e.g. Cordova et al., 2012; Ames et al., 2013 and the literature therein).

In general words, it can be concluded from the published archaeological works that the Azraq oasis has had an almost continuous presence of water as ponds, even in the driest paleoclimatic conditions where the elevated areas are dry. This conclusion is supported by the large recharge area constituting the Azraq basin (Cordova et al., 2012; Ames et al., 2013; Ahmad and Davies, 2017 amongst others). These pond were serving as a refugia for hominins and animals during these harsh climates. During wet climates hominins would disperse and use the higher lands and the many wadi courses tributing the Ga'. For example, the Middle Paleolithic seems to have been a harsh, dry environment where the hominins moved to the ponds in the oasis. This dry period corresponds with the glacial Marine Isotope Stage (MIS) 6, around 250-130Ka. Paleoclimate became wetter and warmer during the MIS 5a and 5c in the Azraq basin and hominins remains are found in higher areas like Wadi Enoqiyya (Hours. 1989; Shea, 2008; Cordova et al., 2009). This may indicate that hominin population was less vulnerable to contractions and extinctions in the Azraq area compared with other parts of the eastern Mediterranean (Ames et al., 2013). This is in agreement with the findings of Abed et al., (2008) that warm periods in the Pleistocene climate were wetter than the cold , glacial periods.

REFERENCES

Abed, A. M., 2017. Geology of Jordan, its water and environment. Dar Wael, Amman (In Arabic.

Abed, A. M.., 2013. The Eastern Mediterranean phosphorite giants: An interplay between tectonics and upwelling. GeoArabia, V. 18, no. 2, p. 67-94, Gulf PetroLink, Bahrain.

Abed , A. M., 1985. On the supposed Precambrian palaeosuture along the Dead Sea rift, Jordan. J. Geol. Soc. London, 142, 527-531.

Abed, A. N., 1987. New occurrence of the Jurassic in the Baqa’a depression. Dirasat, 14, 265-274.

Abed, A. M. & El-Hiayri, M., 1986. Depositional environments and paleogeography of the Cretaceous gypsum horizon in west-central Jordan. Sed. Geol., 47, 109-123.

Abed, A. M.& Sadaqah, R., 1998. Role of oyster buildups in the deposition and accumulation of Late Cretaceous phosphorites in central Jordan. J. Sedimentary Research, 68A, 1009-1020.

Abed, A.M., Yasin, S., Sadaqa, R., Al-Hawari, Z., 2008. The paleoclimate of the eastern desert of Jordan during marine isotope stage 9. Quaternary Research, 69, 458- 468.

Abed, A. M. and Arouri, KH, and Boreham, C. J. 2005 Source Rock Potential of the Phosphorite-Bituminous Chalk-Marl Sequence in Jordan. Marine and Petroleum Geology, 22, 413-425. Elsevier.

Abed, A. M. Yasin, S. and Sadaqah, R. 2008. On the paleoclimate of the eastern Desert of Jordan during the isotope stage 9. Quaternary Research, 69, 458-468 , Elsivier.

Abed, A. M., Abu Hamad, A., Abul Khair, H. and Kraishan, G., 2012 Development of calcrete and clinoforms during emergence and flooding of the Late Cenomanian carbonate platform, Jordan. Facies (Springer) DOI 10.1007/s10347-012-0333-1.

Abed, A. M and others, 2016. Development of calcrete of the Late Cretaceous carbonate platform, northern Jordan, and its tectonic implications. Arab Journal of Geosciences, 9, 87-. DOI: 10.1007/s12517-016-2627-z.

Abed, A. M., Al-Kuisi, M. Jaber, O. and Sadaqah, R., 2016. Rare earth elements and uranium geochemistry in the Al-Kora phosphorite province, Late Cretaceous, northwestern Jordan. Arab Journal of Geosciences (Springer), 9, 187. DOI:10.1007/s12517-015-2135-6.

Ahmad, K. and Davies, C., 2017. Stable isotope ($\delta^{13}C$ and $\delta^{15}N$) based interpretation of organic matter source and paleoenvironmental conditions in Al-Azraq basin, Jordan. Applied Geochemistry, 78, 49-60.

Alali, J. and Abu Salah, A., 1993. Exploration for bentonite and other minerals in Azraq Depression. Natural Resources Authority, Unpublished Economic Geology Division Report. Bentonite Project, Amman, 101p.

Al-Harithi, T., Abu Azzam, H. and Rousan, M. 1987. Micropaleontological analysis of well HZ-14, interval B70-3040m. Biostratigraphic and Petroleum Geochemistry Section, Petroleum Laboratory Division, NRA, Amman.

Al Kwatli MA, Gillot PY, Lefèvre JC, Hildenbrand A, Kluska JM (2014). Magma genesis controlled by tectonic styles in the northern part of the Arabia plate during the Cenozoic. Spec Publ Geol Soc, Lond. 392:61–91.

Ames, C., Nowell, A, Cordova, C., Pokines, J. and Bisson, M., 2013. Paleoenvironmental change and settlement dynamics in the Druze Marsh: Results of recent excavation at an open-air Paleolithic site. Quaternary International, p 1- 14. http://dx.doi.org/10.1016/j.quaint.2013.04.016.

Amireh, B.S., Schneider, W., Abed, A.M., 1994. Evolving fluvial-transitional-marine deposition through the Cambrian sequence of Jordan. Sedimentary Geology 89, 65–90.

Amireh, B. S., 1999. The Early Cretaceous Kurnub Group of Jordan: Subdivision, characterization and depositional environment development. N. Jh. Geol. Palaont. Mh., , 289-300.

Amireh, B. S. and Abed A. M., 1999. Depositional environmentss of the Kurnub Group (Early Cretaceous) in northern Jordan Journal of African Earth Sciences, 29, 449-468.

Amireh, B. and Abed, A. M., 2000. Surface and subsurface occurrences of the new Infracambrian Umm Ghaddah Formation in Jordan: Tectonic implications. Dirasat, 27, 143-168.

Amireh, B., Amaireh, M, and abed, A. M., 2008. Tectono-sedimentary evolution of Umm Ghaddah Formation (Late Ediacaran-Early Cambrian) in Jordan. Journal of Asian Earth Science, 33, 194-218.

Andrews, I., 1991. Paleozoic lithostratigraphy in the subsurface of Jordan. Natural Resources Authority Subsurface Geology Bull., 2.

Andrews I. J., 1992a. Permian, Triassic and Jurassic lithostratigraphy in the subsurface of Jordan. NRA, Subsurface Geol. Bull., 4, 60p.

Andrews, I., 1992b. Cretaceous and Paleogene lithostratigraphy in the subsurface of Jordan. NRA, Subsurface Geology Bull., 5, 60p.

Ayed, R.,1986. Surface Water Resources in the Azraq Basin. Unpubl. Report, Water Authority, Amman, Jordan. 196p.

Baker Jr., M. INC and Harza Eng. Co., 1958. Princess Project: Definitive Plan Report. Amman, 188p.

Bandel, K. and Khoury, H., 1981. Lithostratigraphy of the Triassic in Jordan. Facies, 4, 1-26.

Barberi, F., Capaldi, P.,Gasperini, G., Marinelli, G., Santacroce, Treuil M. and Varet, j.,1979: "Recent Basaltic Volcanism of jordan and its implication on the Geodynamic history fo the Dead sea Shear Zone". In:Ternat. Symp.Geodynamic Evol. Of the Afro Arabian Rift system.Rome.

Bender, F., 1974. Geology of Jordan. Brontraeger, Berlin, 119p.

Cordova, C.E., Nowell, A., Bisson, M.S., Pokines, J., Ames, C.J.H., al-Nahar, M., 2009. The Druze Marsh paleolithic project, north Azraq Jordan stratigraphic se- quences from the 2008 and 2009 seasons. Annual of the Department of An- tiquities of Jordan 53, 311-320.

Cordova, C.E., Nowell, A., Bisson, M.S., Ames, C.J.H., Pokines, J., Chang, M., al-Nahar, M., 2012. Interglacial and glacial desert refugia and the middle paleolithic of the Azraq Oasis, Jordan. Quaternary International.

Core Lab, 1987. Azraq Basin study. Internal report for the Natural Resources Authority, Amman.

Cox, J. R., 1925. A Bajocian-Bathonian outcrop in the Jordan valley and its molluscan remains. Ann. Mag. Nat. Hist. Ser., 9, 69-181, London.

Cox, J. R., 1932. Further notes on the Transjordan Triassic. Ann. Mag. Nat. Hist. Ser., 10, 93-113, London.

Dilley, F.E. 1985. Cretaceous correlations in the Hamza wells Nos. 1 to 5. Palaeontology Report No.6, NRA,Amman.

El-Hiayri, M., 1985. The geology of Jabal El-Mutarammil, map sheet No. 3252 III. NRA, Mapping Project Bull. 1, 51p.

El-Naqa, A., 2010. Study of Salt Water Intrusion in the Upper Aquifer in Azraq Basin Jordan. International Union for the Conservation of Nature (IUCN) and the University of Jordan, Amman.

France, R., 2010. Rehabilitation of a Historic Wetland: Jordan's Azraq Oasis. In: Restorative Redevelopment of Devastated Ecocultural Landscapes. CRC Press, pp. 85-115, http://www.crcnetbase.com/doi/pdf/10.1201/EBK0415952255-c7.

Gvirtzman, G. and Weissbrod, T., 1984. The Hercynian geanticline of Helez and the late Paleozoic history of the Levant. In: The Geological Evolution of the Eastern Mediterranean edited by J. E. Dixon and A. F. Robertson. Geol. Soc. London Spec. Publ. 17, 177-186.

Hours, F., 1989. The paleolithic industries of Wadi Enoqiyya, Azraq. In: Copeland, L.,

Hours, F. (Eds.), The Hammer on the Rock: Studies in the Early Palaeolithic of Azraq, Jordan. British Archaeological Reports, pp. 403e450. Oxford.

Ibrahim, K. 1996. The Regional Geology of Al Azraq Area (Map Sheet No. 35531). Natural Resources Authority, Bulletin 36. 67p.

Ibrahim, K. M., Harlavan, Y., Tarawneh, K., Ilani, S., Rabba, I., Weinberger, R., & Steinitz, G. (1998). Dating (K–Ar) the Harrat Ash-Shaam Basaltic Super-Group sequence of NE Jordan. Initial results of phase I. Report GSI/21/98, Geological Survey of Israel, Israel.

Makhlouf, I., 1987. The stratigraphy and sedimentation of Upper Middle Cambrian, Permo-triassic, and Lower Triassic rocks along the northeastern margin of the Dead Sea basin. Unpubl. Ph. D thesis, Newcastle Upon Tyne Univ., 315p.

Masri, M., 1963. The Geology of the Amman-Zerqa area, 74 pp. (Central Water Authority, Amman, Jordan, Unpublished Report).

McCourt, W.J. and K. Ibrahim 1989. The geology, geochemistry and tectonic setting of the granitic rocks of Southwest Jordan. Bulletin 10, Natural Resources Authority, Amman.

Powell, J., 1989a. Stratigraphy and sedimentation of the Phanerozoic rocks in central and south Jordan, Part A: Ram and Khreim Groups. Geol. Map. Div. Bull. 11. NRA, Amman, 92p.

Powell, J. H., 1989b. Stratigraphy and sedimentation of the Phanerozoic rocks in central and south Jordan, part B: Kurnub, Ajlun and Belqa Groups. (Geology Directorate, Natural Resources Authority, Amman, Jordan), Bulliten 11, 130 pp.

Powell, J. and B.K Moh'd, 2011. Evolution of Cretaceous to Eocene alluvial and carbonate platform sequences in central and south Jordan. GeoArabia, v. 16, no. 4, p. 29-82.

Powell, J.H., and B.K. Moh'd, 2012. Early diagenesis of Late Cretaceous chalk-chert-phosphorite hardgrounds in Jordan; Implications for sedimentation on a Coniacian–Campanian pelagic ramp. GeoArabia, v. 17, no. 4, p 17-38.

Powell, J.H., Abed, a. M. and LeNindre , Y. 2014. Cambrian startigraphy in Jordan. Geoarabia, 19 (3), 81-134.

Quennell, A. M., 1951. The geology and mineral resorces of the (former) Transjordan. Colonial Geology and Mineral Resources, London, 2, 85-115.

Rabba'a, I., 1998. The Geology of Al Umari (Abar Al Hazim) (Map Sheet No. 3453- III). Natural Resources Authority, Bulletin 43.

Shea, J.J., 2008. The lower and middle paleolithic in the Middle East and neigh-boring regions. Evolutionary Anthropology: Issues, News, and Reviews 17, 205- 207.http://dx.doi.org/10.1002/evan.20183.

Wagner G., 1934. Deutcher Muschelkalk am Toten Meer. Natur U. Volk, 62, 449-454, Frankfort.

Wetzel, R. & Morton, D. M., 1959. Contribution a la geologie de la Transjordanie. Notes et Memoirs sur le Moyen Orient 7, 95-191.

Yassini, I., 1979. Maastrichtian-Lowe Eocene biostratigraphy and the planktonic foraminiferal biozonation in Jordan. Rev. Esp. Micropal., 11, 5-57.

Macrofaunal Fossil Assemblage from Beit Ummar, Hebron, Palestine

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ABSTRACT

Eighteen molluscan and echinoderm elements comprising eleven Bivalvia, three Gastropoda, two Cephalopoda and two Echinoidea are described from a marl bed outcropping in the northern part of Beit Ummar, Hebron District, Palestine. This fossil community belongs to the Middle Cenomanian time and is similar to nearby macrofaunal assemblages in the Eastern Mediterranean region. The species extracted indicate a shallow marine warm environmental condition that prevailed in the sea at that time frame in what is now the Hebron Hills.

Keywords: Palestine, Hebron, Macrofauna, Middle Cenomanian.

INTRODUCTION

Palestinian geologic studies proliferated with the increased interests of Europeans in Palestine in the second half of the 19th century (see Benzinger1895; Blanckenhorn, 1896; Lartet 1873; Lynch, 1852; Russell 1888). Recent literature showed that the tectonic movements resulted in multiple openings and closing of the sea basins and uplifts that produced the rich fossil fauna of the Eastern Mediterranean region (Lewy 1990; Ben-Avraham et al. 2002). Of the various geologic eras studied in our region, the Mid Cretaceous (particularly Cenomanian 93-100 MYA) provided an interesting assemblage of geological and paleontological material (Braun and Hirsch 1994; Philip 1978). Geological studies, made by Palestinians are rare and we chose to study the areas of the occupied Palestinian territories near Hebron because of its rich fossil beds. Research and development in our area lags behind nearby areas (Qumsiyeh and Issac, 2012). This study focused on one area near Hebron to understand the assemblage of Cenomanian fossils.

MATERIALS AND METHODS

The area selected for study is located in the town of Beit Ummar approximately 15 km north of Hebron city with coordinates 31°37'50.1"N 35°06'38.3"E (31.630593, 35.110633). The main outcropping rocks here are the marls of Yatta Formation (Fig. 1) according to the adopted Palestinian Stratigraphic Nomenclature (Abed and Wishahee, 1999); intercalated within these marls are some medium hard marlstone and hard dolomitic limestone that are highly fractured and broken due to the intensive ancient earthquakes that affected the whole region in late Cenozoic times and lead to the formation of the greatest on Earth Afro-Arabian rift system which extends from Mozambique in the far south to Anatolia in the north.

This hilly area is a part of a geologic anticline which extends from Beer Saba' in the south to the Samaritan and Galilee hills in the north.

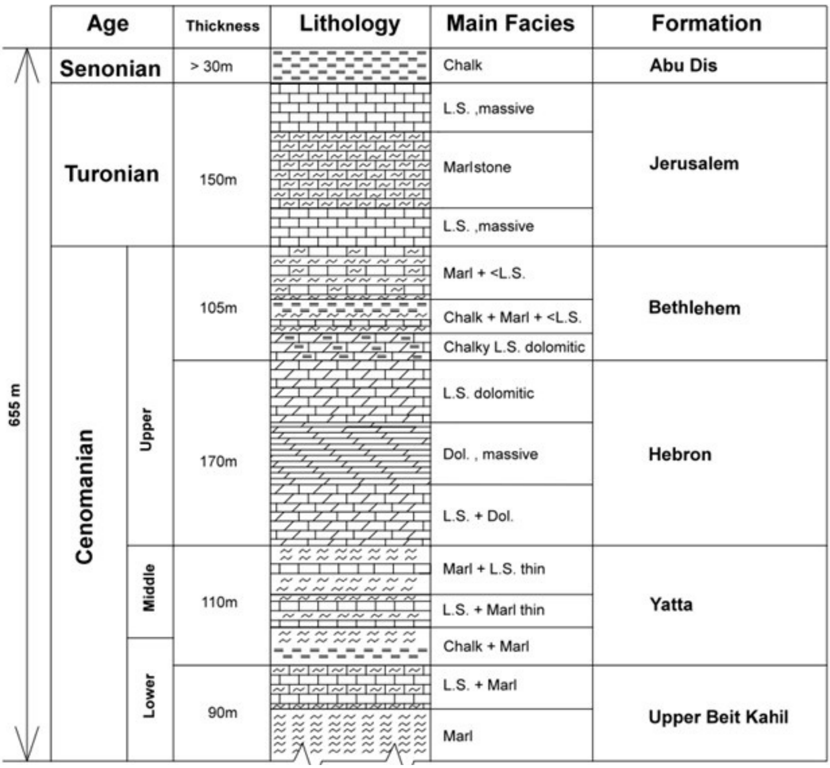

Figure 1: Lithological section of Cenomanian outcrops in Hebron area and vicinity showing the lithology, age and approx. thickness of Yatta Formation rocks (modified after Abed & Wishahee, 1999).

Due to the uplifting of the central mountain regions of Palestine and the syntectonical erosional forces especially during the many ice ages accompanied by intensive rainfalls causing erosion of the landscape. The formation that the locality belongs to is termed the Yatta formation (Abed and Wishahee, 1999). From the hydrogeological point of view, the Yatta formation is considered an aquiclude but it contains locally some economic deposits of kaolinite (a mineral essential for cement, pottery and ceramics industries mined especially in Dura area).

Rock facies dominating the site are soft beige marls and the medium hard whitish marlstone inter-beds (140 m) with some dolomitic limestone inclusions. The fossils were collected from within the excavated rock beds. The selected fossils were cleansed and catalogued at the Palestine Museum of Natural History Geology/paleontology collection (PMNHG numbers assigned) at Bethlehem University.

RESULTS

This study documented over 18 species of Cenomnian fossils from one locality near Beit Ummar, West Bank, Palestine. Hereby we describe the material collected which included members of three molluscan classes (Bivalvia, Gastropoda, and Cephalopoda) and one of the Phylum Echinodermata.

Class Bivalvia Linnaeus 1758
Order Veneroida Adams & adams, 1856
Family Cardiidae Lamarck, 1809

Cardium sp. Fig. 2 B&D
<u>Material</u>: **PMNHG053, PMNHG079, PMNHG083, PMNHG126.**
<u>Remarks:</u> This is noted in the western part of upper Galilee, in some cases of having difficulties in distinguished identification between *Cerastoderma glaucum* and *Acanthocardia tuberculata* they use to name it *Cradium sp.* (Bar-Yosef Mayer, 1997).

Order Anomalodesmata Dall, 1889
Family Pholadomyidae Dall, 1905

Pholadomya cf decorate Fig. 2 C&E
<u>Material</u>: **PMNHG034, PMNHG116**
<u>Remarks</u>: This species of Bivalvia was recorded in the Eilat area from Palestine (Bartov et al., 1972). Our specimens are suspected to be *Pholadomya decorate* which is found in many locations in Europe and Palestine (Hirsch, 1980).

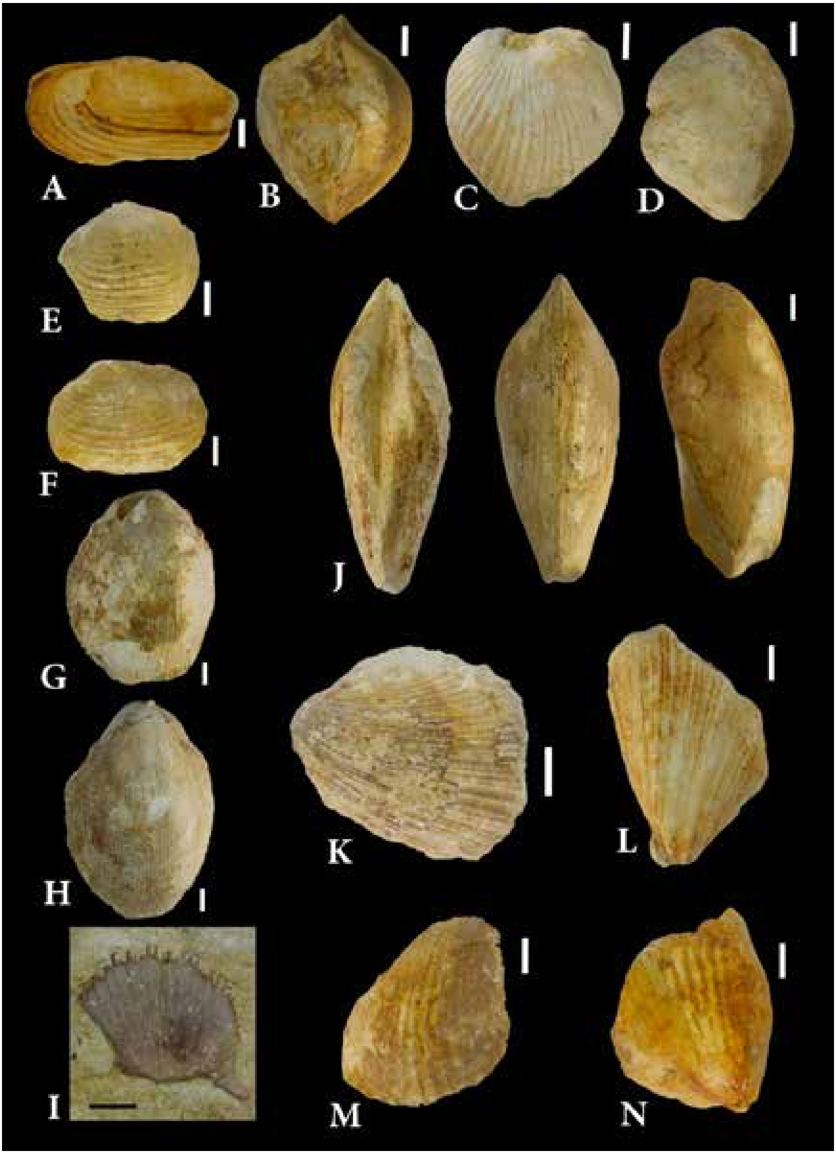

Figure 2: **A & F**: *Panopea sp*. **B & D**: *Cardium sp.1.* **C + E**: *Pholadomya sp.* **G & H**: *Mytiloides sp.* **I:** Remains of a shell of undeterminable *Neithea sp.* within a mother rock. **J**: (the 3 photos) *Arca (Eonavicula) sp.* **K**: *Neithea duturgei.* **L&M&N**: *Neithea quinquecostata.* Bar scale 5mm.

Order Arcoida Stoliczka,1871
Family Arcidae Lamarck, 1809

Arca (Eonavicula) sp. Fig. 2J
Material: **PMNHG008, PMNHG018, PMNHG111, PMNHG114, PMNHG118, PMNHG123, PMNHG131, PMNHG133, PMNHG140, PMNHG142, PMNHG143.**
Remarks: It is a species from the Middle Jurassic to Recent of Western Europe, found in Jordan in the Middle Cenomanian rocks (Perrilliat et al., 2006).

Family Limopsidae Dall 1895

Limopsis sp.
Material: **PMNHG211**
Remarks: A specimen similar to our specimen was collected from the Cenomanian of India (Kendrick & Vartak 2007). The globally distributed limopsid clade had its earliest occurrences in the Early Cretaceous of Europe and New Zealand (Brown et.al. 2011).

Order Ostreoida F'erussac,1822
Family Pectinidae Refinesque,1815

Neithea duturgei (Conquand, 1862) Fig. 2K
Material: **PMNHG121, PMNHG196.**
Remarks: It is noted from the late Cenomanian of Jordan (Perrilliat et al. 2006)
Neithea quinquecostata **(SOWERBY, 1814) Fig 2 L M N**
Material: **PMNHG036, PMNHG038, PMNHG188, PMNHG232.**
Remarks: mentioned from the Cenomanian of South India (Kendrick & Vartak 2007) and Egypt as *Pecten quinquecostata* (Mekawy 2007).
Neithea sp. Fig. 2I
Material: **PMNHG150**
Remarks: One specimen of an unidentified Neithea (previously *Pecten sp*) was collected

Order Myoida Stoliczka, 1870
Family Hiatellidae Gray, 1824

Panopea sp. Fig. 2 A&F
Material: **PMNHG044, PMNHG128, PMNHG203**.
Remarks: We could not reach to the species identification for the bad preservation of the specimens. In general it is recorded in Jordan (Perrilliat et al., 2006).

Order Mytiloida Ferussac, 1822
Family: Inoceramidae Giebel, 1852

Mytiloides sp. Fg. 2 G & H
Material: **PMNHG002, PMNHG005, PMNHG013, PMNHG015, PMNHG057,**

PMNHG063, PMNHG081, PMNHG107.
Remarks: This species mentioned from the Cenomanian of Jordan (Perrilliat et al. 2006). All specimens that collected are molds and identification is difficult.

Order Ostreida Fërussac 1822
Family Ostreidae Rafinesque, 1815

Ceratostreon flabellatum (Goldfuss, 1833)
Material: **PMNHG006, PMNHG016, PMNHG020, PMNHG031, PMNHG033, PMNHG051, PMNHG056, PMNHG061, PMNHG064, PMNHG068, PMNHG075, PMNHG087, PMNHG089, PMNHG108, PMNHG120, PMNHG122, PMNHG145, PMNHG147, PMNHG162, PMNHG173, PMNHG191, PMNHG195, PMNHG197, PMNHG199, PMNHG201, PMNHG206, PMNHG207, PMNHG210, PMNHG218.**
Remarks: *Ceratostreon* is noted from the Cenomanian rocks of Libya (El Qot et al. 2013),Egypt (Gawad 2007 and Khalil 2007), Marocoo, Algeria, Tunisia, Algeria and Jordan (Dhondt et al., 1999). Abdel-Gawad etal., (2006) mentioned that this is a wide distributed species in the southern part of Palestine.

Order Venerida Rafinesque, 1815
Family Fimbriidae Nicol, 1950

Fimbria sp.
Material: **PMNHG 001, PMNHG 035, PMNHG043, PMNHG043, PMNHG046, PMNHG071, PMNHG085, PMNHG088, PMNHG101, PMNHG110, PMNHG113, PMNHG124, PMNHG134, PMNHG151, PMNHG182, PMNHG209, PMNHG220.**
Remarks: is noted from the Cenomanian rocks of Libya (El Qot et al. 2013) and as *Protocardia hillana* (Sow., 1813) from Middle Cenomanian to Santonian of Egypt (Mekawi 2007).

Class Gastropoda Cuvier, 1795
Order Stromboidea Rafinesque, 1815
Family Tylostomatidae Stoliczka, 1868

Tylostoma (s.str.) pallaryi (Peron & Fourtau, 1904) Fig. 3 A-D&F
Material: **PMNHG041, PMNHG86, PMNHG194.**
Remarks: This ammonite is mentioned from the Cenomanian of Algeria (need ref). and Tunisia under the name *Aporrhais dutrugei* (Conquand) reported from Late Cenomanian (Kennedy & Gale 2015).
Pterodonta sp. Fig 3 G
Material: **PMNHG029, PMNHG049.**
Remarks: Noted previously from Upper Albian/Cenomanian rocks of Egypt (Kiel 2001). From Middle Cenomanian of eastern Sinai (Ayoub-Hannaa 2011). And found in the argillaceous limestone in southern part of the Historic Palestine (Bartov et al., 1972).

Order Architectibranchia Haszprunar 1985

Family Acteonellidae Gill, 1871
Trochactaeon sp. Fig. 3 H
Material: **PMNHG052, PMNHG106.**
Remarks: Reported from the Egypt under the name *Colombellina fusiformis* (Douville', 1916) from the Middle Cen. of Sinai (Mekawy 2007).

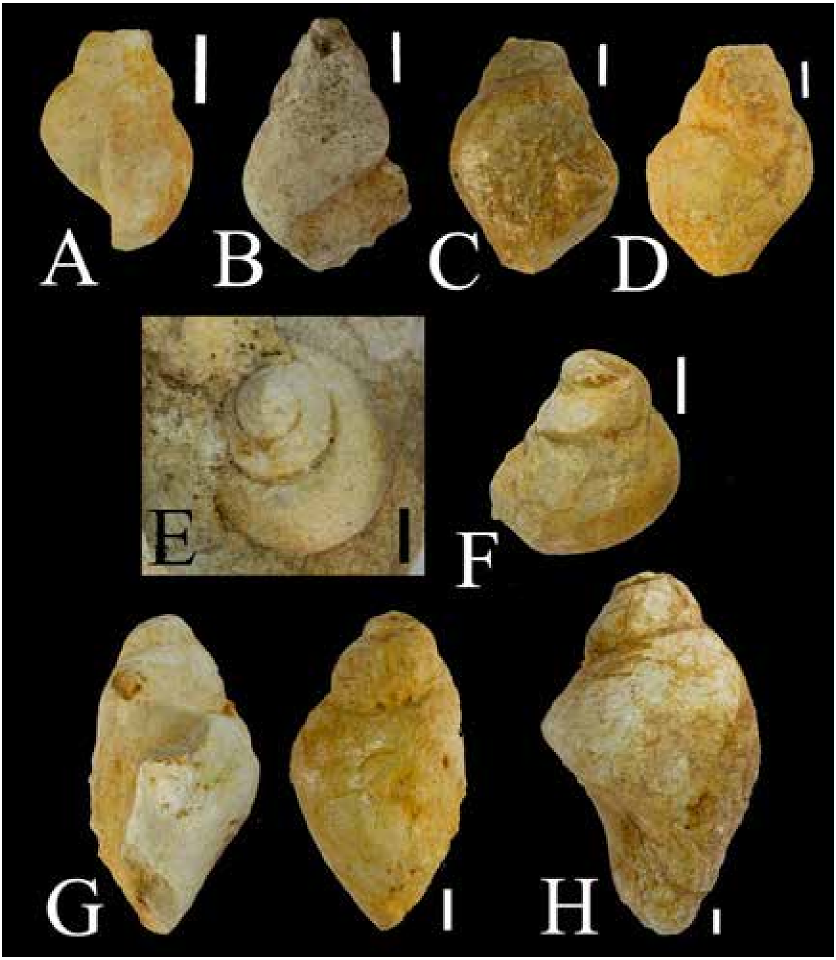

Figure 3: A - F: *Tylostoma (s.str.) pallaryi.* **E**: Internal mold of undetermined Gastropode in mother rock; similar to our specimen can be seen in Žítt et al from the Cenomanian of Czech republic. **G**: *Pterodonta sp.* **H**: *Trochoacteon sp.* Bar scale 5mm.

Class Cephalopoda Cuvier, 1797
Order Ammonoidea Zittel, 1884
Family: Acanthoceratidae Grossouvre 1894

Metoicoceras geslinianum D'Orbigny Fig. 4 A&B
Material: **PMNHG019, PMNHG028, PMNHG062, PMNHG099, PMNHG109, PMNHG129, PMNHG161.**
Remarks: Mentioned from the Lower Upper Cenomanian rocks of Germany (Owen & Smith 1991). But it is also similar to material described as *Neolobites vibrayeanus* (D'Orbig., 1841) from the Cenomanian rocks of Egypt (Nagm & Wilmsen 2012) and Tunias (Al-Sabbagh et al. 2011; Kennedy & Gale 2015). It is reported from the Negev' Cenomanian (Lewy et al., 1984).
Family: Vascoceratidae Douvillé 1912
Vascoceras cauvini Chudeau Fig. 4C
Material: **PMNHG104**
Remarks: This species is reported in association with *Metoicoceras geslinianum* fossils in the same layers as ours in the Negev (Lewy et al., 1984).

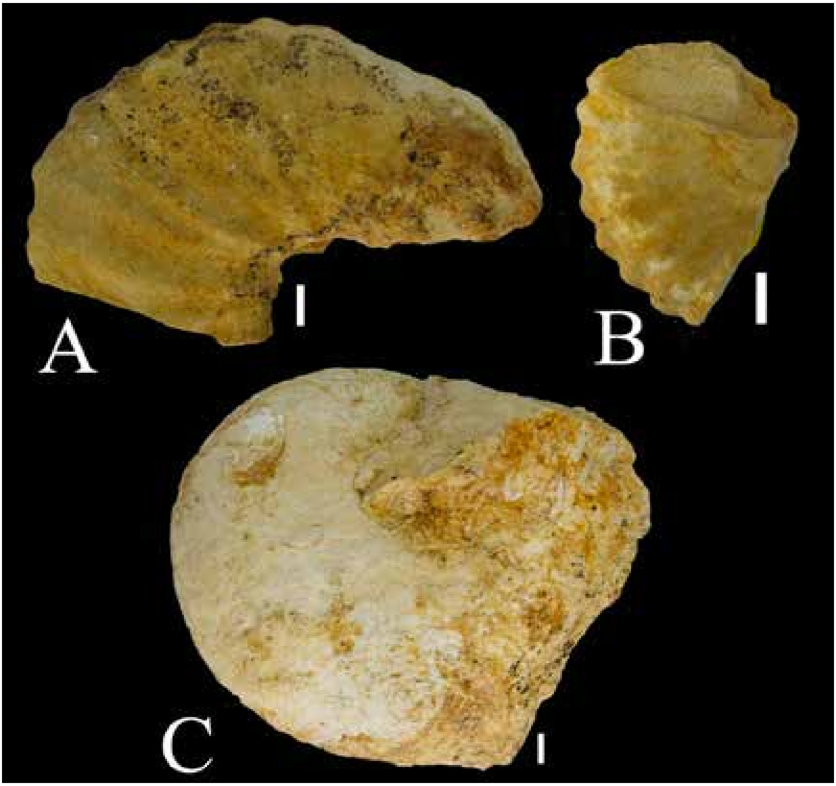

Figure 4: A&B: Ammonite *Metoicoceras geslinianum.* **C**: Ammonite *Vascoceras sp.* Bar scale 5mm.

Phylum Echinodermata
Class Echinoidea
Order Hemicidaroida Beurlen, 1937
Family Pseudodiiadematida Pomel, 1883

Heterodiadema lybicum (Agassiz & Desor 1846) Fig. 5 A
Material: **PMNHG168**
Remarks: Our specimen is very similar to the description given for this species by Néraudeau et al. (1995) as well as Abdelhamid and El-Qot (2016) who both reported it from Saudi Arabia. It is also reported from the cenomanian of Egypt (gawad 2007; El Qot et al. 2013).It is reported from Palestine several times (Blanckenhorn, 1925; Lartet, 1873). Abdelhamid and El-Qot (2016) shows the distribution of this species in three continent (Asia, Africa and Europe).

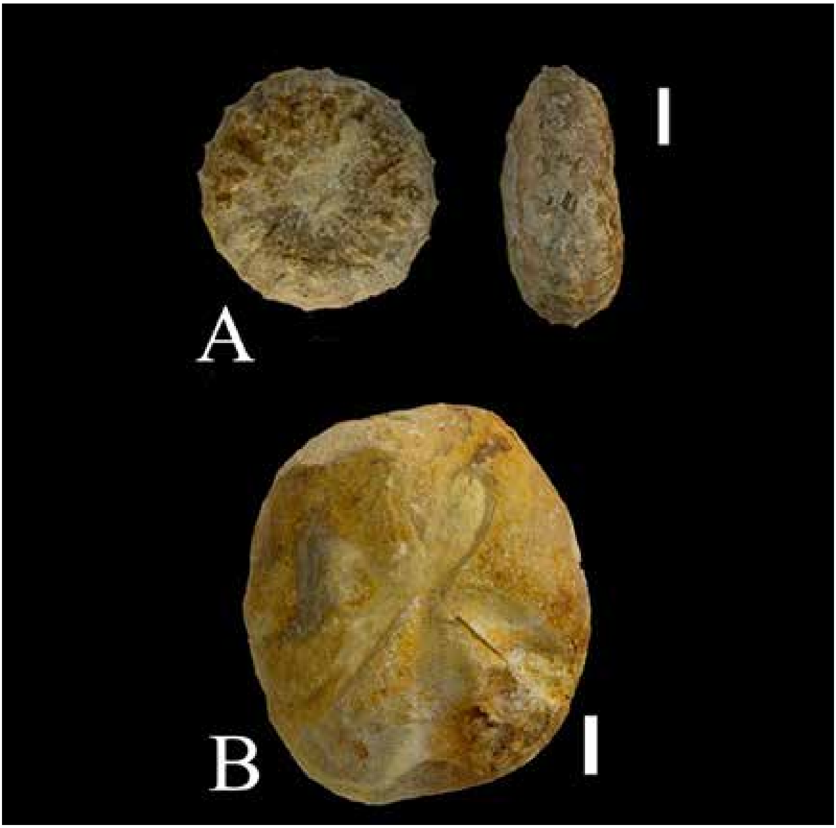

Figure 5: A: *Heterodiadema lybycum.* **B:** *Hemiaster (Hemiaster) cubicus*

Order Spatangoida Claus, 1876
Family Hemiasteridae Clark, 1876

Hemiaster (Hemiaster) cubicus (DESOR,1847) Fig. 5B
Material: **PMNHG022, PMNHG065, PMNHG073, PMNHG153, PMNHG170, PMNHG176.**
Remarks: This is noted from Middle Cenomanian of Egypt both by Gawad (2007) and as *Hemiaster (Hemiaster) syriacus* (Conrad, 1852) from Wadi Quseib by El-Qot et al. (2013). It is also noted from Sinai as *Mecraster batnensis* (Conquand) (Kassab & Abdel-Maksoud 2007).

DISCUSSION

The study of the fossil assemblage proved that the site rocks were deposited under shallow warm sea conditions in the Middle Cenomanian time. A total of 18 species of macro-fauna with nine Bivalves, five Gastropods, two Ammonites and two Echinoids were extracted from a marl bed outcropping in the northern part of Beit Ummar town north of Hebron District of Palestine. There are some notable findings including three species of Neithea, and the presence of *Ceratostreon flabellatum* and *Trochoacteon sp* in these deposits.

Much more paleontological work is needed in this rich area of the Arab world. We also think it important to encourage geologic and paleontologic studies at Arab Universities and other research institutions beyond the usual geologic studies in this region focused on oil exploration. There is a new trend of establishing natural history museums as centers of education and exploration in our region (Qumsiyeh et al. 2017) and we recommend that geology and paleontologic studies should be integral to this. The rich biodiversity evident in this small location and in similar studies portend well for future studies.

REFERENCES

Abdel-Gawad G.I., El-Qot G.M. & Mekawy M.S. 2006. Cenomanian-Turonian Macrobiostratigraphy Of Abu Darag Area, Northern Galala, Eastern Desert,

Egypt. Intern. Conf. Geol. Arab World (Gaw8), Cairo Univ., Giza, Egypt, 2006,pp. 553-568.

Abdelhamid, M.A. & Azab, M. M. 2003. Aptian – Cenomanian Echinoides From Egypt. Rev. Paleobio., Geneve. Pp. 851 – 876.

Abdelhamid, M.A. & El-Qot G. 2016. Revision of the Cretaceous Echinoids Heterodiadema and Trochodiadema, and Description of two new genera from the Middle East and Arabian Peninsula. Cretaceous Research, 57, pp. 1-18.

Abed A. & Wishahee S. 1999. “Geology Of Palestine”. Palestinian HydrologistsGroup, Jerusalem, 461 pp,.

Al-Sabbagh A., Tantawy A., Keller G., Khozyem H., Spangenberg J., Adatte T. & Gertsch B. 2011. Stratigraphy of the Cenomanian - Turonian Oceanic Anoxic Event Oae2 in shallow shelf sequences of NE Egypt. Cretaceous Research, 32, pp.705-722.

Andrade E., Seeling S. , Bengtson P. & Souza-Lima W. 2004. The Bivalve Neithea from the Cretaceous of Brazil. Journal of South American Earth Sciences, 17(1), pp.25-38.

Ayoub-Hannaa W. & Fuersich F. T. 2011. Revision Of Cenomanian-Turonian (Upper Cretaceous) Gastropods From Egypt. Zitteliana, 51, p. 115.

Ayoub-Hannaa W. S. 2011. Taxonomy and palaeoecology of the Cenomanian-Turonian macroinvertebrates from eastern Sinai, Egypt (part A), 418 pp.

Ayoub-Hannaa, W. & Fuersich F. T. 2012. Cenomanian-Turonian Ammonites From Eastern Sinai, Egypt, And Their Biostratigraphic Significance. Beringeria, 42, pp. 57-92.

Bartov, J., Eyal, Y., Garfunkel, Z. and Steinitz, G. 1972. Late Cretaceous and Tertiary stratigraphy and paleogeography of southern Israel. Israel Journal of Earth Sciences, 21, pp.69-97.

Bar-Yosef Mayer, D.E., 1997. The molluscs of Horvat Galil and Nahal Beset. Tel Aviv, 24(2), pp. 223-228.

Ben-Avraham, Z., Ginzburg, A., Makris, J. and Eppelbaum, L. 2002. Crustal structure of the Levant Basin, Eastern Mediterranean. Tectonophysics, 346(1-2), pp. 23-43.

Benzinger, J., 1895. Bericht über neue Erscheinungen auf dem Gebiet der Palästinaliteratur 1894. Zeitschrift des Deutschen Palästina-Vereins (1878-1945), pp.189-236.

Blanckenhorn, M., 1896. Entstehung und Geschichte des Todten Meeres. Ein Beitrag zur Geologie Palästinas. Zeitschrift des Deutschen Palästina-Vereins (1878-1945), pp.1-59.

Blanckenhorn, M., 1925. Die Seeigelfauna der Kreide Palästinas. Palaeontographica (1846-1933), 67, pp.83-114.

Braun, M. and Hirsch, F., 1994. Mid Cretaceous (Albian-Cenomanian) carbonate platforms in Israel. Cuadernos de Geología Ibérica, ’ 18,59-81.

Rowan J. Whittle, K.L. and H.J. Griffiths 2011. The fossil record of Limopsis (Bivalvia: Limopsidae) in Antarctica and the southern high latitudes. Palaeontology, 54(4), pp. 935–952.

Darwish M.H. , Zakhera M.S. , Maksoud N.A. & Obaidalla N.A. 2015. Macro- Biostratigraphy Integration Of The Cenomanian - Turonian Transition At North Eastern Desert And Southestern Sinai, Egypt. The 8th International Conference on The Geology of Africa Assiut- Egypt, pp 99-131.

Dhondt, A.V., Malchus, N., Boumaza, L. and Jaillard, E., 1999. Cretaceous oysters from North Africa; origin and distribution. Bulletin de la Société géologique de France, 170(1), pp.67-76.

El Qot G., Abdulsamad E.O. & Aly M.F. 2013. Upper Cretaceous Macrofossils from Jardas Al'abid Area, Al Jabal Al Akhadar Northeast Libya: A Systematic Palaeontology. Egypt. Journal of Paleontology, 13, pp. 185-254.

El-Qot G.M. , Fürsich F.T., Abdel-Gawad G. & Ayoub-Hannaa W. 2009. Taxonomy And Palaeoecology Of Cenomanian-Turonian (Upper Cretaceous) Echinoids From Eastern Sinai, Egypt. Beringeria, 40, pp. 55-98,

Gale A.S.; Bengston P. & Kennedy W.J. (2005): Ammonites at the Cenomanian–Turonian boundary in the Sergipe Basin, Brazil. Bulletin of The Geological Society Of Denmark, 52, Pp. 167-191.

Gawad G.I.A. (2007): Macrobiostratigraphy Of The Upper Cretaceous Succession From Southern Galala (Egypt). 2nd Internat. Conf. On The Geology of The Tethys, Cairo University, March 2007, pp. 329-349.

Hirsch, F. 1980. Jurassic bivalves and gastropods from northern Sinai and southern Israel. Israel Journal of Earth Sciences, 28, pp.128-163

Imlay, Ralph W. 1961. Characteristic Lower Cretaceous Megafossils From Northern Alaska. Page 121. Geological Survey Professional Paper 335. Us Government Printing Office, Washington.

Kassab A. & Abdel-Maksoud N. 2007. Integrated Macro-Biostratigraphy Of The Cenomanian-Turonian Transition Of Gebel Nezzazat And Gebel Tuwal, Western Sinai, Egypt. 5th Internat. Conf. On The Geology Of Africa; Vol. (1), pp 53-7 5 Assiut-Egypt

Kendrick G.W. & Vartak A.V. 2007. Middle Cretaceous (Cenomanian) Bivalvesfrom the Karai Formation, Uttattur Group, of the Cauvery Basin, South India. The Western Australian Museum Supplement No. 72: 1-101

Kennedy W.J. & Gale A. S. 2015. Upper Albian and Cenomanian Ammonites from Djebel Mrhila, central Tunisia. Revue De Paléobiologie, 34 (2), pp. 235-361.

Kiel S. 2001. Taxonomy and Biogeography Of Late Cretaceous Gastropoda. Dissertation Zur Erlangung Des Doktorgrades Der Naturwissenschaften Im Fachbereich Geowissenschaften Der Universität, Hamburg.

Khalil H.M. 2007. Macrobiostratigraphical, Paleoecological and Palaeobiographical Studies of the Cenomanian/Turonian Transition of Wadi Watir (El Sheikh Attia), Sinai, Egypt. Tanta Univ.

Lartet, L. 1873. Essai sur la Geologie de la Palestine et des contrees avoisinantes telles que l’Egypte et l’Arabie. Deuxieme Partie. Paleontologie (G. Masson), p. 98.

Lewy, Z. 1990. Transgressions, regressions and relative sea level changes onthe Cretaceous shelf of Israel and adjacent countries. A critical evaluation of Cretaceous global sea-level correlations. Paleoceanography, 5, pp. 619-637

Lewy, Z., Kennedy, W.J. and Chancellor, G., 1984. Co-occurrence of Metoicoceras geslinianum (d'Orbigny) and Vascoceras cauvini Chudeau (Cretaceous Ammonoidea) in the southern Negev (Israel) and its stratigraphic implications. Newsletters on Stratigraphy, pp. 67-76.

Lynch, P. W. 1852. Official Report of the United States Expedition to the DeadSea and the River Jordan,” Baltimore, 4, pp. 1–236.

Mekawy M. S. 2007a. Upper Cretaceous Bivalves From Galala Plateaux, North Eastern Desert, Egypt: A Systematic Paleontology. Egypt. Journal of Paleontolology, 7, pp. 197 – 243.

Mekawy M. S. 2007b. Gastropods Of The Cenomanian-Santonian Sequence From North Eastern Desert, Egypt. Egyptian Journal Of Geology, 51, pp. 149-176.

Moghaddam M., Shams P. & Shirazi M. 2016. Systematic Of Albian - Cenomanian Gastropods And Bivalves From The Kazhdumi Formation, Zagros Basin . Journal Of Sciences, Islamic Republic Of Iran 27(3), pp. 237 – 252.

Nagm E. & Wilmsen M. 2012. Late Cenomanian–Turonian (Cretaceous) Ammonites From Wadi Qena, Central Eastern Desert, Egypt: Taxonomy, Biostratigraphy And Palaeobiogeographic Implications. Acta Geologica Polonica, 62(1), pp. 63–89.

Néraudeau, D., David, B. and Al-Muallem, M.S., 1995. The Cretaceous echinoids from central Saudi Arabia. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 197(3), pp.399-424.

Owen, E. & Smith, A. 1991. Kreide – Fossilien: Ein Bestimmungsatlas. 152pp, Germany, Goldschneck Verlag.

Philip, J. 1978. Stratigraphie et paleoecologie des formations a rudistes du Cenomanien: l'exemple de la Province. Geologie Mediterraneene, 5(1), pp. 155-168.

Perrilliat M. De C., Ahmad F. & Vega F.J. 2006. Upper Cretaceous (Cenomanian–Turonian) Bivalves From Northern Jordan, Middle East. Rev. Mex. Cienc. Geol., 23(1), Pp. 96- 106.

Stephenson L.W. 1954. Additions to the Fauna of the Raritan Formation (Cenomanian) of New Jersey. Geological Survey Professional Paper 264-B. United States Government Printing Office, Washington.

Qumsiyeh, M.B., E. Handal, J. Chang, K. Abualia, M. Najajreh, M. Abusarhan. 2017. Role of museums and botanical gardens in ecosystem services in developing countries: Case study and outlook. International Journal of Environmental Studies. 74(2), pp. 340-350.

Russell, I.C., 1888. I. The Jordan-Arabah Depression and the Dead Sea. Geological Magazine, 5(8), pp.337-344.

Žítt1 J. , Kopáčová M. & Nekovařík C. 2003. Epibionts of Mollusc Shells from the Korycany Limestones (Upper Cenomanian, Czech Republic). Bulletin of The Czech Geological Survey, Vol. 78(1), pp. 41–52, 2003.

Status of the Nubian nightjar (*Camprimulgus nubicus*) In Fifa Nature Reserve (Ramsar site)

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ABSTRACT

Fifa Nature Reserve was recently established by the Royal Society for the Conservation of Nature (RSCN) that proves to be an important site for several bird species in the Middle East. The reserve is home to a resident population of the Nubian nightjar (*Caprimulgus nubicus*), which is critically endangered in Jordan. The first and only survey of this species to date was conducted in 2014, three years after the establishment of the reserve. This study provides an updated estimate of the Nubian nightjar population, while assessing some potential factors that may influence activity and breeding habits of the species within the reserve. Using spot counts, we recorded 63 calls of male Nubian nightjars; a 24 % increase from the 2014 study. We also provide the first confirmation of breeding of this species within the reserve by nest observations. Twenty-one nests were located, three of which were proven to be active. Distances to agriculture and vegetation community were not found to influence the number of Nubian nightjar calls recorded. However, all of the nests that we recorded were located in habitat dominated by Tamarix tetragyna and within 100 m of agriculture. Nesting data were too sparse for statistical analyses, however, we suggest that further attention be paid to breeding habits by conducting a more extensive nesting survey during the breeding period.

INTRODUCTION

Fifa Nature Reserve (FNR) is a biodiversity-rich ecosystem that is one of the most important sites for migratory bird species in the Middle East (Ellis, 2017). The reserve was established by the Royal Society for the Conservation of Nature (RSCN) in 2011, mainly to protect two major vegetation types: saline vegetation and tropical vegetation. The reserve was designated as the world's lowest elevation Ramsar Site, lying at 426 meters below sea level. It is considered an important habitat for several rare and endangered bird species at both the local and regional level, including the Nubian nightjar (*Caprimulgus nubicus* and the Dead Sea sparrow *Passer moabiticus* (Al Oshoush and Al-Zoubi, 2017).

Very large numbers of migrant birds pass through the area in spring and autumn. The Nubian nightjar is the smallest nightjar in the Western

Palearctic (Snow & Perrins, 1998). The species is relatively widespread in the arid part of eastern Africa, however, it has been recorded as uncommon and scarce (Perlman, 2008). In the Middle East, it was reported along the Rift Valley in southern Palestine and the Red Sea coast of the southern Arabian Peninsula (Birdlife International, 2012).

FNR is an important site for the Nubian nightjar, containing the largest population within the Middle East. However, information about the behavior and activity of this bird within the reserve is limited to a single previous study (Qaneer 2014), which recorded 45 male calls. Qaneer (2014) reported a positive relationship between tree cover and the number of calls, mostly from Tamarix tetragyna vegetation communities.

The Nubian nightjar is generally regarded as a resident species. However, the northern populations within the Middle East are thought to be predominantly summer visitors, migrating south to eastern Africa for the non-breeding season (Shirihai 1996, Holyoak 2001, Kirwan 2004). The breeding season usually occurs from April to July, and is often influenced by the lunar phase. Nightjars are one group of birds that do not build physical nests, but rather lay their eggs directly on the ground.

The previous survey was conducted only three years after the reserve was established. To determine whether the establishment of the reserve has had an influence on the status of this species, we felt there was a need for an updated study to assess any changes in the Nubian nightjar population over the last five years. Additionally, little is known about the reproductive habits of the Nubian nightjar within the reserve, as no surveys regarding breeding had been conducted.

The current study includes an updated population estimate, as well as documented observations regarding reproductive habits of the Nubian nightjar within FNR.

Study Area

FNR is located at the southwestern part of Jordan, about 33.5 km S-SE of the Dead Sea 157 km north of Aqaba city [UTM East 731366.653, North ,3427479 77] (Figure 1). FNR is located within the Sudanian (Tropical) bio-geographical zone, which is characterized by high temperatures with warm winters and hot summers, combined with low annual rainfall of approximately 100-50 mm/year.

Principal Vegetation types in Fifa Nature Reserve

Two major vegetation types have been recorded in FNR: saline vegetation (19.9 km2) and tropical vegetation (656 km^2), in addition to 0.56 km^2 agricultural land. The area is intersected by wadis and dominated by sparse vegetation of perennial grasses and woody plants such as: *Acacia tortilis,* *Phoenix dactylifera, Nitraria retusa, Tamarix spp. (T. tetragina* and *T. aphylla*) and *Salvadora persica* (RSCN 2011) (Figure 1).

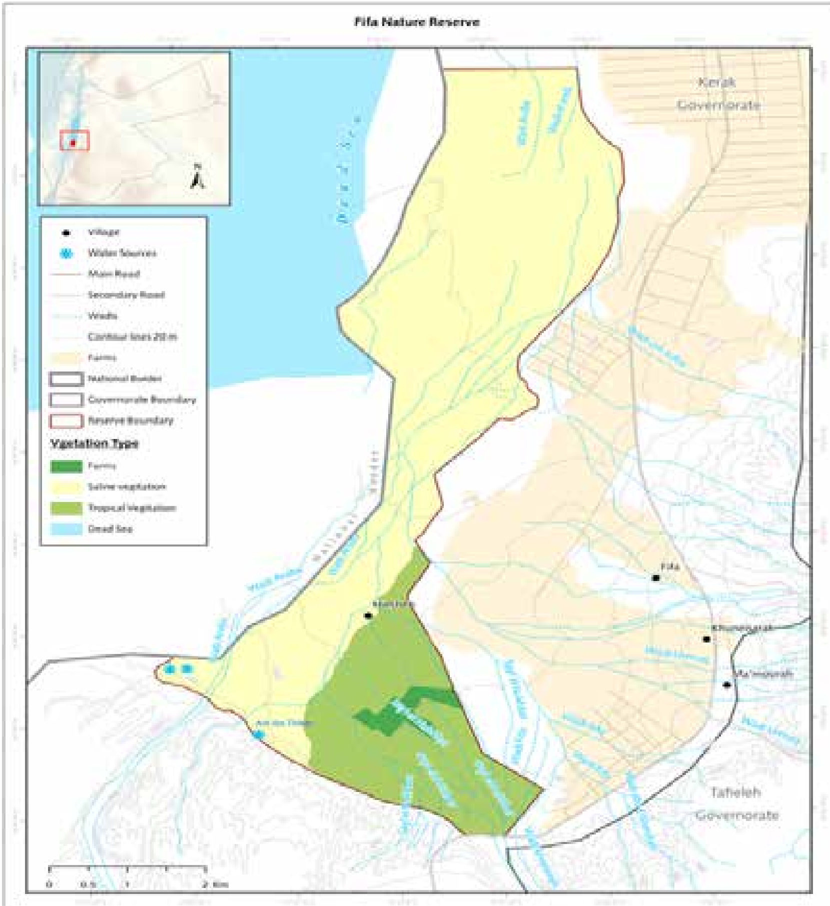

Figure 1. Map of the study area, including vegetation types within Fifa Nature Reserve, as well as the surrounding villages and agricultural land.

MATERIALS AND METHODS

Data Collection

To estimate relative population size and density, we used the spot count technique, as used in the previous study (Qaneer 2014). We randomly selected forty spot count locations within FNR and the adjacent agricultural land. The minimum distance between points was approximately 550 m

(± 126 m), and locations were spread across nine vegetation communities within FNR, at a range of distances to agriculture (mean = 400 m ± 58 m). We obtained a GIS shape file for vegetation communities within FNR from the RSCN GIS unit.

Between March and August 2019, we conducted a single spot count at each location. Counts were performed for 15 minute each, within a period beginning one hour after dusk until one hour before dawn. We identified Nubian nightjars by the distinctive males' calls during the breeding season. The detection radius of calls was estimated at 150 m by playing audio calls from a specific location and walking in a straight-line to a distance that the call could no longer be clearly heard (Qaneer 2014).

We performed a nest count to determine whether Nubian nightjars use FNR as a breeding site. At each spot count location where a bird was heard or observed during the survey, we established a 2 ha plot in the area that the call came from. We then searched each 2 ha plot and recorded whether a nest was present. For any located nests, we took a GPS coordinate and any information that we deemed relevant or important (e.g. number of nests, signs of recent activity). In addition, after a single observation of a female bird with two young resting on the ground (Figure 2), we installed a motion-sensing camera-trap (Bushnell Trophy Cam: Aggressor) for one week to confirm that this was indeed a nesting site.

STATISTICAL ANALYSES

To determine whether vegetation community or distance to agriculture influenced the number of Nubian nightjar calls or nests recorded within the reserve, we conducted a multiple linear regression model for each spatial variable. We also grouped vegetation communities into two distinct categories based on whether or not *T. tetragyna* was the dominant species. All analyses were performed using the statistical software R, ver. 2.15.1 (R Core Team, 2012).

RESULT

A total of 63 Nubian nightjar calls were recorded from 31 spot count locations, which was an increase from 2014, where 45 calls were recorded (Qaneer 2014). The highest number of calls recorded at a single point was five, with a mean of 1.6 (± 0.22). Three nests were confirmed to be currently active at the time of the survey by observing birds or the presence of pellets (Figure 2). However, a total of 21 nests were found near two spot count locations. Nests were found to be clustered in small groups (1 – 3) and locations were recorded for each cluster (Figure 3).

Figure 2. Photograph of two Nubian nightjar nestlings occupying a nest within Fifa Nature Reserve

Effect of vegetation community and distance to farms on Nubian nightjar activity and nesting habits within Fifa Nature Reserve

Nubian nightjar calls were recorded from eight of the nine vegetation communities sampled, while nests were found only in two communities; both of which were dominated by T. tetragyna (Figure 3). Vegetation community had no effect on the number of calls recorded, both when tested by community type (Table 1) and dominant species (Table 1).

It was noted that all nests were found within approximately 100 m (± 8 m) from agriculture (Figure 3). However, data were too sparse to identify any significant factors. The numbers of calls were not influenced by distance to agriculture (Table 1, Figure 4).

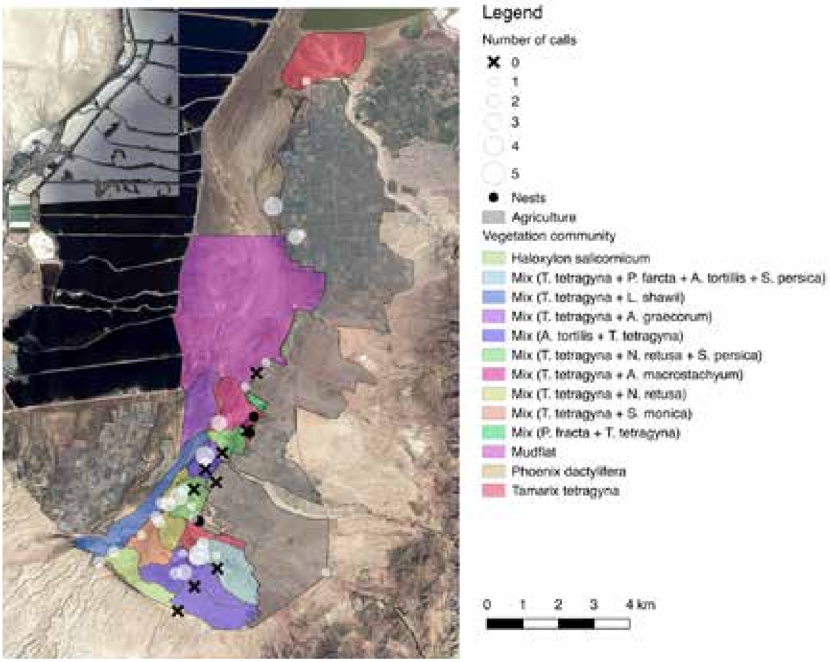

Figure 3. Number of calls and locations of nests in relation to vegetation community and distance to agriculture.

Table 1: Summary of results for the multiple linear regression model

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.5953359	0.7107364	2.245	0.0314**
Vegetation community	0.0004310	0.0006794	0.634	0.5301
Tamarix spp. dominant	-0.0519405	0.0834544	-0.622	0.5378
Distance to agriculture	0.2456098	0.4627642	0.531	0.5990

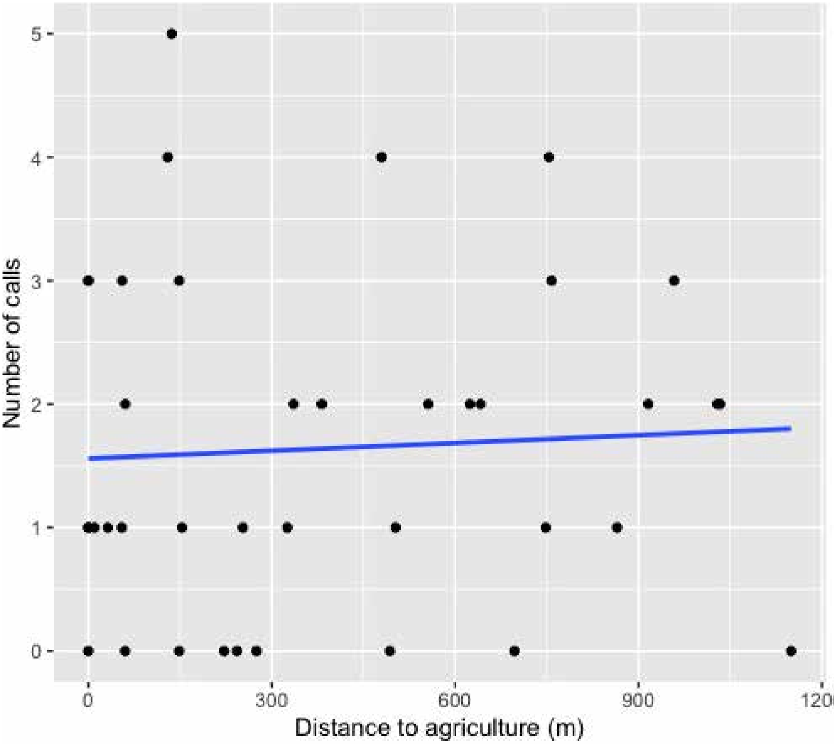

Figure 4. Relationship between the number of Nubian nightjar calls and distance to agriculture.

DISCUSSION

During the five years between the two surveys, we recorded a twenty-five percent increase in the Nubian nightjar population within FNR confirming the status of the reserve as an important location for the Nubian nightjar. This increase is likely related to the fact that the previous study was conducted when the reserve was relatively young, having only been established three years prior to the survey.

Since FNR was established, threats to the Nubian nightjar population have reduced significantly, particularly those involving humans. For example, people are no longer permitted to collect any plant or animal specimens from the reserve; hunting is prohibited; pressure from grazing has reduced; and it is more difficult for the general public to gain access to the area due to military operations.

During the present survey, we recorded the first nesting observation of the Nubian nightjar inside FNR. Camera-trap data confirmed that Nubian nightjars within the reserve tend to lay their eggs on either *T. tetragyna* leaf litter or on bare ground in an open area associated with *T. tetragyna*. Although the data were inconclusive, the only spot count locations where nests were observed were within 100 m of agriculture. This may suggest that Nubian nightjars within FNR prefer to nest in proximity to agriculture, likely due to increased productivity in agricultural areas, and consequently higher food resources.

Similar to the previous study (Qaneer 2014), we did not find any significant relationship between the number of Nubian nightjar calls and distance to agriculture. Qaneer (2014) found a positive relationship between the number of calls and tree cover, and noted that most birds were recorded from *T. tetragyna* tree cover. However, no analyses were conducted comparing the number of calls across the different vegetation communities within the reserve. We found that the number of calls was not influenced by vegetation community, or whether or not *T. tetragyna* was the dominant species.

During the present study, we confirmed that Nubian nightjars are indeed breeding within FNR. Due to the relative sparsity of active nest observations, we suggest further investigation of the nesting habits during the breeding season to determine the long-lasting.

REFERENCES

Al Oshoush and Al-Zoubi 2017. The birds diversity of the wetland habitats in the Fifa Nature Reserve, Jordan. https://www.birdlife.org.

Holyoak, DT. 2001. Nightjars and their Allies. Oxford University Press, UK.

Kirwan, GM. 2004. Remarks on Nubian Nightjar taxonomy. Bulletin of the African Bird Club 11: 117–125.

Perlman, Y. 2008. The natural history of the Nubian Nightjar Caprimulgus nubicus in Israel. Snadgrouse, 30: 117-124.

Qaneer, T. 2014. Ecological study on the Nubian Nightjar, Caprimulgus nubicus, at Fifa Nature Reserve, southern Jordan.

RSCN. 2011. Flora baseline survey at Fifa Protected Area. The Royal Society for the Conservation of Nature. Amman, Jordan. unpublished report.

Shirihai, H. 1996. The Birds of Israel. Academic Press, London.

Short Communication

Shoreline encounter and stranding rates of cetaceans and loggerhead turtles Caretta caretta in North Sinai, Egypt

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Keywords: Common bottlenose dolphin, *Tursiops truncates*, striped dolphin, *Stenella coeruleoalba*, short beaked common dolphin, *Delphinus delphis*, Cuvier's beaked whale, *Ziphius cavirostris*, citizen science, Mediterranean Sea.

ABSTRACT

Eight species of cetaceans and two species of marine turtles regularly occur in the Mediterranean Sea, with the eastern basin of the Mediterranean being considered among the least studied. The objective of this study was to carry out a shoreline cetacean and marine turtle survey in North Sinai, Egypt as part of a citizen science program between 7/2/18 – 8/30/18. We had fifty-five encounters of the common bottlenose dolphin, *Tursiops truncates* in twenty groups with an average of 2.5 (SE + 0.32, Range 1 - 6) individuals seen per group, one striped dolphin, *Stenella coeruleoalba*, and one short beaked common dolphin, *Delphinus delphis*, from the shore. In addition, a fisherman reported an observation of a Cuvier's beaked whale, *Ziphius cavirostris*, from several kilometers from the shore. We observed six stranded common bottlenose dolphins, with a rough average of a stranding occurring every 10 days. We recorded no live observations of loggerhead turtles, *Caretta caretta* but did record nine dead, stranded turtles, for an average of a stranding occurring roughly every seven days. Our shoreline observations of rare cetaceans and the relatively frequent strandings of common bottlenose dolphins and loggerhead turtles suggests that there are resident summer populations and that the eastern basin of the Mediterranean may not be as biologically poor in sea turtle and cetaceans populations as originally thought.

Cetaceans and marine turtles face numerous threats in the Mediterranean Sea such as habitat degradation and loss, by catch, overfishing of prey, disturbance from boats, underwater noise, and chemical and debris pollution (IUCN, 2012, Pace *et al*., 2015). Eight species of cetaceans and two species of marine turtles regularly occur in the Mediterranean Sea, with the eastern basin being considered among the least studied (IUCN, 2012). Data on cetaceans in the coastal waters of Egypt's Mediterranean sea are especially lacking (Boisseau et al., 2010). The objective of this study was to carry out a shoreline cetacean and marine turtle survey in North Sinai, Egypt as part of a citizen science program.

Marine habitats are prohibitively large, mostly inaccessible, expensive and logistically challenging to navigate and often requiring the use of expensive equipment to conduct marine surveys (Clarke *et al*., 2011, 2013). In addition, pelagic species can move long distances, are rare and difficult to observe, and are difficult to observe without specialized equipment as the typical sampling time during any scuba dive is limited to between 30 – 50 minutes.

Observations by enthusiasts who are already in marine habitats, provide observation data that is a low-cost alternative to more costly, standardized, scientific data collection methodologies.

This study occurred between 7/2/18 – 8/30/18 on the public beach of El-Arish (31.1453 N, 33.80297 E) along Egypt's Mediterranean coast. Lifeguards were trained on the identification of the local cetacean and marine turtle species as part of a citizen science program that incorporated volunteers for shore line surveys. Lifeguards were stationed at twenty observation posts located approximately between 200 m – 500 m apart, and from roughly 6:00 am to 6:00 pm for sixty days. In addition, author (BR) regularly visited the lifeguard stations and participated in the surveys. For each observation, we recorded the species, number, date, and time of observation.

We had fifty-five encounters of the common bottlenose dolphin, *Tursiops truncates* in twenty groups with an average of 2.5 (SE ± 0.32, Range 1 - 6) individuals seen per group. Forty-six common bottlenose dolphins were encountered in sixteen groups in July and nine bottlenose dolphins in four groups were encountered in August. One bottlenose dolphin was observed with a calf in August. During the month of July, we also observed one striped dolphin, *Stenella coeruleoalba*, and one short beaked common dolphin, *Delphinus delphis*, from the shore. In addition, a fisherman reported an observation of a Cuvier's beaked whale, *Ziphius cavirostris*, from several kilometers from the shore off the public beach on 7/22/18. We believe that this is a reliable sighting as the individual was able to identify the species from photographs and has participated in past surveys. We observed six stranded common bottlenose dolphins, with a rough average of a stranding occurring every 10 days. Three stranded individuals were observed in July and another three in August. One of the stranded dolphins was alive and returned to sea.

We recorded no live observations of loggerhead turtles, *Caretta caretta* but did record nine dead, stranded turtles, three in July and six in August for an average of a stranding occurring roughly every seven days.

Our citizen science approach was meaningful in obtaining observations of more common and rare species. The four species of cetaceans observed in our survey are listed by the IUCN as either data deficient, vulnerable, or endangered in the Mediterranean Sea (IUCN, 2012). The common bottlenose dolphin (IUCN vulnerable) was the most frequently cetacean observed and stranded, as has been observed in other parts of the eastern Mediterranean basin (Kerem *et al.* 2012). Despite the striped dolphin (IUCN vulnerable) being considered the most abundant cetacean in the Mediterranean Sea, this species was only observed once from the shoreline likely because it is more typically found in the open ocean and is less common in the eastern Mediterranean basin (Boisseau *et al.*, 2010; IUCN 2012). Although striped dolphins can travel in large groups, single individuals are sometimes encountered like we observed (Kerem *et al.*, 2012).

Our observation of the normally open water short beaked common dolphin (IUCN endangered in the Mediterranean), from the shore is a roughly 30 km extension of its known distribution as they have been recorded off the coast of Gaza (Kerem *et a*l., 2012). Although the Cuvier's beaked whale is listed by the IUCN as data deficient and considered rare, it was observed by a fisherman nearshore. This record of Cuvier's beaked whale is the first record from North Sinai since 1968 (Kerem *et al.*, 2012).

Stranding rates usually represent just a small fraction of total mortality and it is not possible to estimate mortality rates without performing drifter experiments (Koch *et al.*, 2013; Flint *et al.*, 2015). However, the number of strandings can still be a useful form of data as strandings often occur in areas of resident or population hotspots (Casale *et al.*, 2010; Koch *et al.*, 2013; Flint *et al.*, 2015). Although we could not identify the source of mortality, relatively frequent rates of a loggerhead sea turtle strandings every seven days and common bottlenose dolphin every ten days suggest that there may be summertime resident populations of each species. Our shoreline observations of rare cetaceans and the relatively frequent strandings of common bottlenose dolphins and loggerhead turtles supports the suggestion that the eastern basin of the Mediterranean may not be as biologically poor in sea turtle and cetaceans populations as originally thought (Kerem *et al.*, 2012; Bradshaw *et al* ., 2017).

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REFERENCES

Boisseau, O., Lacey, C., Lewis, T., Moscrop, A., Danbolt, M., & Mclanaghan, R. (2010). Encounter rates of cetaceans in the Mediterranean Sea and contiguous Atlantic area. *Journal of the Marine Biological Association of the United Kingdom*, 90,1589–1599.

Bradshaw, P. J., Broderick, A. C., Carreras, C., Inger, R., Fuller, W., Snape, R., Stokes, K. L., Godley, B. J. (2017). Satellite tracking and stable isotope analysis highlight differential recruitment among foraging areas in green turtles. *Marine Ecology Progress Series*, 582, 201–214.

Casale, P., Affronte, M,. Isacco, G., Freggi, D., Vallini, C., et al. (2010). Sea turtle strandings reveal high anthropogenic mortality in Italian waters. *Aquatic Conservation*, 20, 611–620.

Clarke, C.R., Lea, J.S.E. & Ormond, R.F.G. 2011. Reef-use and residency patterns of a baited population of silky sharks, Carcharhinus falciformis, in the Red Sea. *Marine and Freshwater Research*, 62, 6, 668–675.

Clarke, C.R., Lea, J.S.E. & Ormond, R.F.G. 2013. Changing relative abundance and behaviour of silky and grey reef sharks baited over 12 years on a Red Sea reef. *Marine and Freshwater Research*, 64, 10, 909–919.

Flint, J., Flint, M., Limpus, C. L., & Mills, P.C. (2015). Trends in Marine Turtle Strandings along the East Queensland, Australia Coast, between 1996 and 2013. *Journal of Marine Biology*, Article ID 848923, 7 pages, 2015. https://doi.org/10.1155/2015/848923.

IUCN. (2012). Marine Mammals and Sea Turtles of the Mediterranean and Black Seas. Gland, Switzerland and Malaga, Spain. *IUCN*, 32 pages.

Kerem, D., Hadar, N., Goffman, O., Scheinin, A., Kent, R., Boisseau, O., & Schattner, U. (2012). Update on the Cetacean Fauna of the Mediterranean Levantine Basin. *The Open Marine Biology Journal*, 6, 6-27.

Koch, V., Peckham, H., Mancini, A., & Eguchi, T. (2013). Estimating At-Sea Mortality of Marine Turtles from Stranding Frequencies and Drifter Experiments. *PLoS ONE*, 8, e56776.

Rabia, B. & Attum, O. (2015). Distribution and status of sea turtle nesting and mortality along the North Sinai coast, Egypt (Reptilia: Cheloniidae). *Zoology in the Middle East*, 61, 26–31.

Short Communication

First record of breeding of the Long-eared Owl, *Asio otus* in Jordan

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The Long-eared Owl (*Asio otus*) is a medium-sized nocturnal species with distinct erect, blackish ear-tufts. It has a broad distribution across the northern latitudes of North America, Europe, Eurasia, and the Levant (Cramp and Simmons, 1985). It prefers forests close to open country, edges of semi-open woodland and urban areas (Cramp and Simmons, 1985). It is known as an opportunist feeder and takes a high diversity of small-sized prey (Birrer, 2009). This owl is considered as an uncommon winter visitor in Jordan (Andrews, 1995). Along its global distribution, diet have been extensively studied in North America and Europe, yet, reports on its ecology and diet within the most southern limits of its distribution are under-represented and far from satisfactory (Birrer, 2009). Only recently, Obuch (2018) reported on the diet of this owl in Jordan, including localities from the Mediterranean bioclimatic region (Amman, Marj al–Hammam, Wasfi Al Tal forest and Dibbin forests), while reported from arid regions including Shaumari and Mafraq Jordan sits at the most southern edge of distribution of the Long-eared Owl, yet no studies have been conducted to establish evidence to its breeding in Jordan.

During July 2018, a Long-eared Owl roost site was spotted on the edge of Mutah University campus (31° 5.792' N, 35° 43.091' E) in southern Jordan. The owl was seen within a plantation of pine trees overlooking open steppe vegetation (Fig. 1). The area sits within the non-forest, dry Mediterranean vegetation. The area is highly degraded by overgrazing and accommodates a suite of urban areas, agricultural farms, and open areas. The majority of the open area is barren and rarely covered by vegetation with a few water run-off-systems (wadis) vegetated by bushes and shrubby microsystems. Later in October of the same year, two sub-adults along with two adults were observed in the same roosting site. The owls fed on several species of birds as well as rodents as their pellets revealed (Abu Baker et al., In press). This report represents the first documentation of breeding of the Long-eared Owl in Jordan as its most southern range for breeding within the southern Mediterranean region.

Figure 1: Long-eared Owl *Asio otus* roosting site at the edge of Mutah University campus (5.792 °31' N, 43.091 °35' E) in southern Jordan.

REFERENCES

Andrews IJ. 1995. The Birds of the Hashemite Kingdom of Jordan. Andrews IJ, Musselburgh.

Birrer S. 2009. Synthesis of 312 studies on the diet of the Long-eared Owl *Asio otus*. Ardea, 97: 615–624.

Cramp S and Simmons KEL. 1985. Handbook of the birds of Europe, the Middle East, and North Africa. The birds of the Western Palearctic. Volume IV. Terns to woodpeckers. Oxford University Press, Oxford.

Obuch J. 2018. On the diet of owls (Strigiformes) in Jordan. *Slovak Raptor* J., 12: 9–40.

Birrer S. 2009. Synthesis of 312 studies on the diet of the Long-eared Owl Asio otus. Ardea, 97: 615–624.

Abu Baker, M.A., Al Oran, R.M. & and Amr, Z.S. In press. Diet composition and prey selection in the Long-eared Owl, *Asio otus* in Jordan: the importance of urban avifauna. Jordan Journal of Biological Sciences.

The Royal Society for the Conservation of Nature

Is a national organization devoted to the conservation of Jordan's wildlife. It was founded in 1966 under the patronage of His Majesty the late King Hussein and has been given responsibility by the government to establish and manage protected areas and enforce environmental laws. As such, it is one of the few non-governmental organizations in the Middle East to be granted such a public service mandate.

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