Volume n° 1 - from PR01 to B15

Field Trip Guide Book - B01

Florence - Italy
August 20-28, 2004

32nd INTERNATIONAL
GEOLOGICAL CONGRESS

GEOLOGY AND ARCHEOLOGY OF CYRENAICA NORTH EASTERN LIBYA

Leader: A.S. El-Hawat

Associate Leader: E.O. Abdulsamad

Pre-Congress

B01

The scientific content of this guide is under the total responsibility of the Authors

Published by:
APAT – Italian Agency for the Environmental Protection and Technical Services - Via Vitaliano Brancati, 48 - 00144 Roma - Italy

APAT
Italian Agency for Environment Protection and Technical Services

Series Editors:
Luca Guerrieri, Irene Rischia and Leonello Serva (APAT, Roma)

English Desk-copy Editors:
Paul Mazza (Università di Firenze), Jessica Ann Thonn (Università di Firenze), Nathalie Marléne Adams (Università di Firenze), Miriam Friedman (Università di Firenze), Kate Eadie (Freelance indipendent professional)

Field Trip Committee:
Leonello Serva (APAT, Roma), Alessandro Michetti (Università dell'Insubria, Como), Giulio Pavia (Università di Torino), Raffaele Pignone (Servizio Geologico Regione Emilia-Romagna, Bologna) and Riccardo Polino (CNR, Torino)

Acknowledgments:
The 32nd IGC Organizing Committee is grateful to Roberto Pompili and Elisa Brustia (APAT, Roma) for their collaboration in editing.

Graphic project:
Full snc - Firenze

Layout and press:
Lito Terrazzi srl - Firenze

Volume n°1 - from PR01 to B15

32nd INTERNATIONAL GEOLOGICAL CONGRESS

THE GEOLOGY AND ARCHAEOLOGY OF CYRENAICA

AUTHORS:
A.S. El-Hawat (Garyounis University Benghazi - Libya)
E.O. Abdulsamad (Garyounis University Benghazi - Libya)

Florence - Italy
August 20-28, 2004

Pre-Congress

B01

Front Cover:
A view at wadi al Athrun mouth sea-cliff exposure showing Maastrichtian chalk slump structure. It is a testament of the ongoing tectonic activities of Cyrenaica due to the compressive forces induced by the conversion of Eurasian and African plates that also led to inversion and development of Al Jabal al Akhdar anticlinorium.

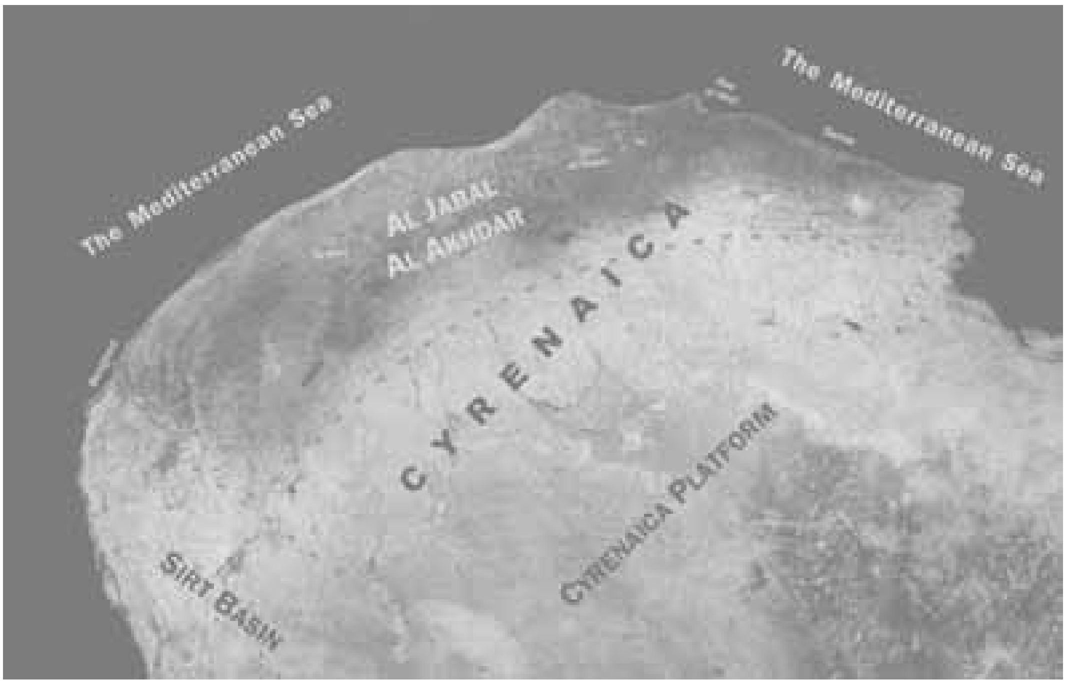
Leader: A.S. El-Hawat
Associate Leader: E.O. Abdulsamad

Introduction

General: Cyrenaica is located in northeastern Libya and forms a prominent promontory on the North African coast that covers about 150,000 km^2 (Figure 1). It consists of two distinct tectonic provinces separated by a hinge line called the Cyrenaican fault system. These provinces are the mobile north Cyrenaica inverted basin, referred to as Al Jabal al Akhdar; and the more stable Cyrenaica platform to the south (Figure 2). The northern mobile belt area, where the fieldtrip will be conducted, has been influenced by the Tethys tectonic activities and events since its opening during the Jurassic. It was subsequently shaped by the reversal of the Eurasian and African plate movement that led to subduction of the latter beneath the former from the Upper Cretaceous to the present. The goal of the fieldtrip is to examine a complete and gently deformed Cenozoic carbonate succession and the associated Upper Cretaceous - Paleocene inversion inliers (Figure 3) in a typical southern Tethyan setting.

In the framework of the history of northern Cyrenaica in relation to the Tethys, this field trip will deal with the sedimentology, biostratigraphy and the hallmarks of the eustatic and inversion tectonic events that influenced the Mediterranean. Sequences to be examined exhibit a complete spectrum of carbonate ramp facies complexes that include bathyal planktonic foraminiferal limestone, outer ramp deep neritic mudstone clinoforms, and large foraminiferal and coralgal-reefal build-ups, as well as oolitic and large foraminiferal shoals, up to the Messinian salina deposits. The impact of eustatic and tectonic events on the sedimentary and biostratigraphic history of the succession will be demonstrated and evaluated. Unconformities, syndepositional mass movements, and reworking of sediments and fossils together with issues of palaeontological versus physical stratigraphic boundaries will be discussed in the field in light of the geologic and tectonic setting in Cyrenaica. A visit to the well-preserved ancient city of Cyrene (631 B.C.), where the first Greek settlers came to North Africa is planned, as well. The geologic and hydrogeological factors that led to the establishment of Cyrene (the place with a hole in the heavens), and the history of its destruction by tectonically induced seismic events will be a point of interest.

Figure 1 - LandSat image of northern Cyrenaica.



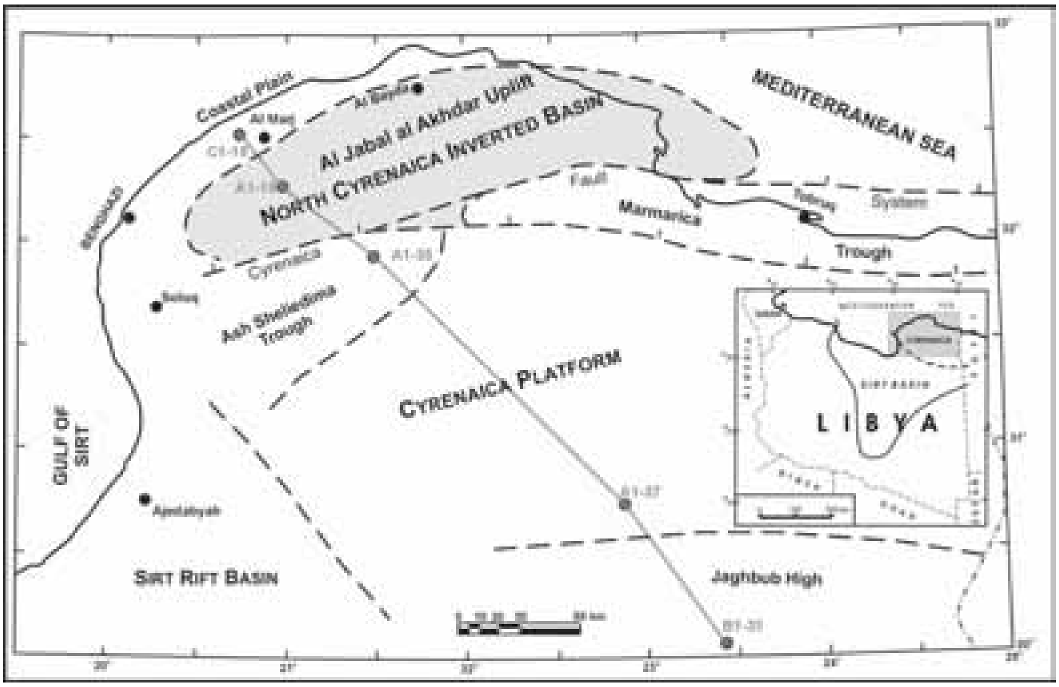


Figure 2 - Location map of the tectonic provinces of Cyrenaica and location of the regional cross section. (source: El Hawat et al., in press.)

Logistics:
After the arrival of the participants at Benghazi they will be housed in one of Benghazi's hotels, where an introductory lecture will be given. The field trip will start early the next day. Libya is connected by an excellent paved road network that offers good accessibility to all the outcrops in the field trip area. Transport will be mainly by small buses and vehicles. The new roadcuts and quarries of Cyrenaica (See back cover) present well-exposed and complete Upper Cretaceous and Cenozoic successions. The undeformed nature of the succession permits a clear tracing of the carbonate sequences that shall be visited over the course of the field trip, enabling a clear understanding of the vertical and lateral facies changes in relationship to the inversion Cretaceous structure of Al Jabal al Akhdar anticlinorium. Depositional models and sub-models of the same sequence in different
structurally controlled palaeotopographic settings shall also be described. The area offers an excellent opportunity for specialists to discuss the Cenozoic palaeontology, palaeoecology and biostratigraphy of larger foraminifera.

August weather in Cyrenaica is hot. Temperature reaches 30 to 35°C during the day. Participants are advised to wear field clothes, sun hats and shades and use plenty of sun block. We also recommend drinking plenty of fluids, even if not thirsty. The physical intensity of the field work, however, is light to moderate, as most outcrops are close to paved roads.

Field References:

1. Guidebooks:

El Hawat. A.S. and Shelmani, M.A., 1993. Short notes and guidebook on the geology of Al Jabal la Akhdar, Cyrenaica NE Libya. Interprint, Malta. 70 pages.

El Hawat, A.S. and Abdulsamad, E.O., in press. The Geology of Cyrenaica: A Field Seminar. Earth Science Society of Libya, Tripoli.

2. Topographic Maps:

Topographic maps of Cyrenaica, NE Libya, scale 1: 50,000 based on aerial photos taken in 1964, prepared by the Army Map Service, Corps of Engineers, US Army, Washington, D.C. and printed in 1967. Updated in 1977by the Survey Department of Libya

based on 1:250 000 scale Landsat images.

3. Geologic maps:

Contant, L.C. and Goudarzi, G.H., 1964. Geologic map of Libya, scale 1:2,000,000. U.S Geol. Survey, Map I-350 A.

Francis, M. and Issawi, B., 1977. Geological map of Libya; 1:250,000, Sheet NH 34-2, Soluq, and explanatory booklet. Ind. Res. Cent., Tripoli, 86 pp.

Geological Map of Libya, scale 1:1,000,000. Industrial Research Center, geological research & mining department, Tripoli, Libya. (1985).

Klen, L., 1974. Geological map of Libya; 1:250, 000. Sheet NI 34-14, Bengahzi, and explanatory booklet. Indust. Resear. Cent., Tripoli, 56 pp.

Rohlich, P., 1974. Geological map of Libya; 1:250,000 sheet, Al Bayda sheet NI34-15, explanatory booklet. Indust. Resear. Cent., Tripoli, 70 pp.

Zert, B., 1974. Geologic map of Libya, 1:250,000, Dernah sheet NI 34-I6, explanatory booklet. Indst. Resear. Cent., Tripoli, 49 pp.0

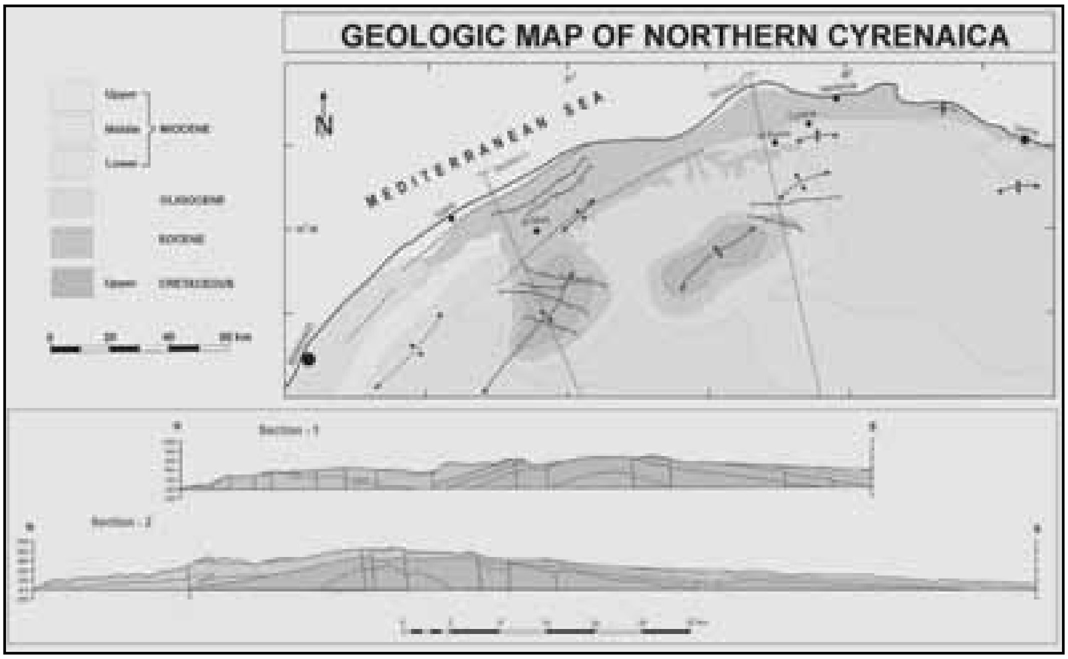
Regional geologic setting

General:

The Cyrenaican promontory is bound to the west and south by extensions of the Sirt rift complex and stretches to the east into the Marmarica platform of the Western Desert of Egypt. South of the inverted basin of Al Jabal al Akhdar, two elongated Tertiary depositional troughs separate the north from tectonically stable provinces of Cyrenaica to the south. These are the Marmarica and Ash-Sheliedima troughs that dip toward their relative depocenters to the northeast and southwest respectively along the Cyrenaica fault system. Al Jaghbub High, which forms the southern extension of the Cyrenaica platform, is separated from the eastern extension of the Sirt basin, which is called the Al Hameimat trough, along the southern Cyrenaica fault system (Figure2).

The Al Jabal al Akhdar inverse anticlinorium was down faulted to form the northern coastal plain, that extends into the steep, narrow, and intensely faulted and folded continental margin offshore. It is separated from the Mediterranean Ridge by a deep, , narrow and elongated furrow at 2500 to 3000 meters of depth. This represents the line of the noth Cyrenaica fault system (NCFS). Meanwhile, the Cyrenaican continental slope to the south, is being differentially overthrusted by the Mediterranean Ridge, in what is regarded as an incipient continental collision process (Huguen and Mascle, 2001). Whereas the northern

Figure 3 - Geological map and cross ections of northern Cyrenaica. (Sources: El Hawat and Shelmani, 1993;



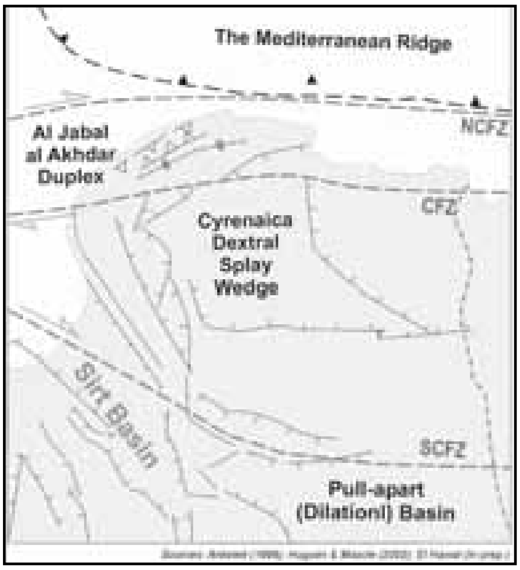


Figure 4 - Tectonic provinces of Cyrenaica (Sources: Anketell, 1996; Huguen and Muscle, 2001; El Hawat et al., in press).

tip of the Cyrenaican promontory exemplifies the maximum compressive effect of the Mediterranean Ridge due the convergence between the African – European and Aegean plates, the Al Jabal al Akhdar anticlinorium represents an inverted early Mesozoic subsiding basin of northern Cyrenaica on land. The highest topographic areas of Al Jabal al Akhdar running along the structural axis of the Upper Cretaceous inliers (Figure 3), corresponds to the axis of maximum subsidence of the Cyrenaican basin prior to inversion.

Apart from the presence of post-depositional Upper Cretaceous deformation structures, stratigraphic signatures observed in northern Cyrenaica indicate repeated and persistent compressive events in this part of the Mediterranean. Evidence of repeated syndepositional mass movements of sediments and unconformities attest to recurring compressive events throughout time. Major slump structures, slides, debris flows and turbidites are commonly observed in outcrops in sections ranging in age from the Upper Cretaceous to the present. Also, the presence of a series

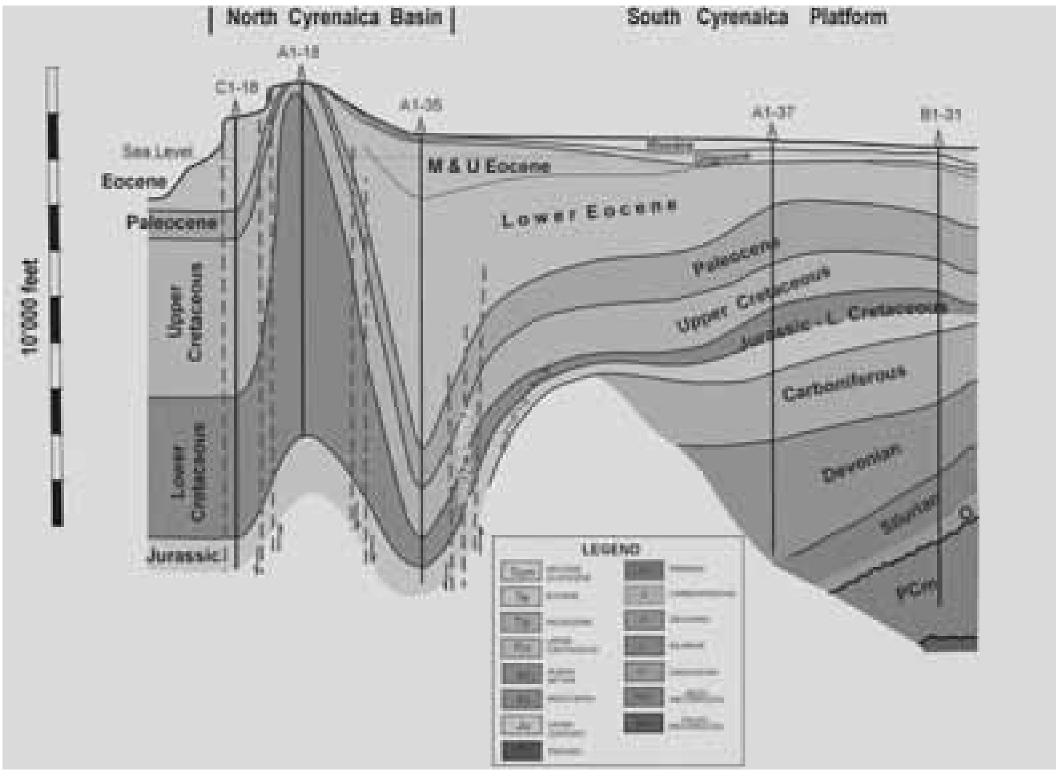


Figure 6 - Regional geologic cross section of Cyrenaica Sources: El Hawat and Shelmani, 1993; El Hawat et al., in press).

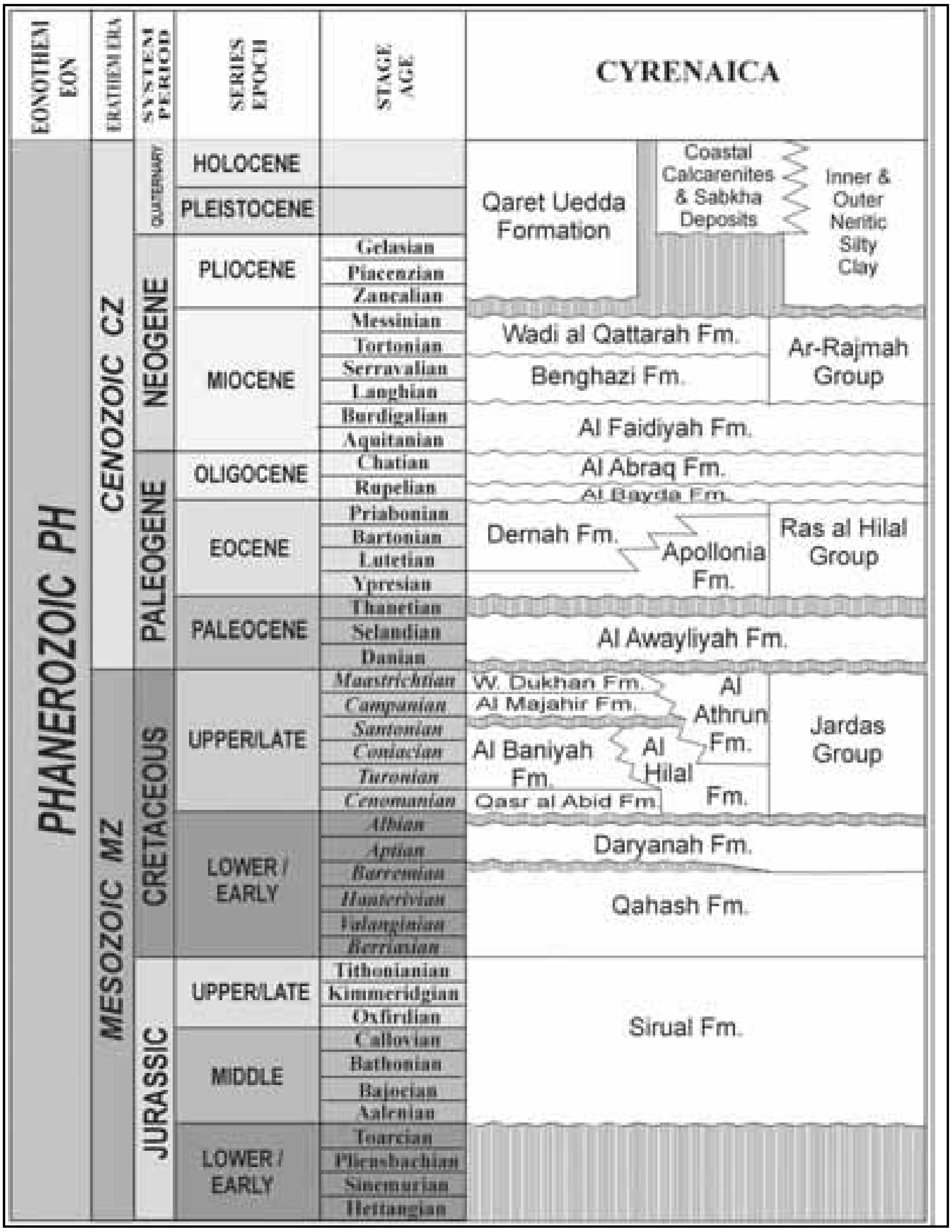


Figure 5 - Stratigraphic chart of northern Cyrenaica (sources: El Hawat et al., in press).

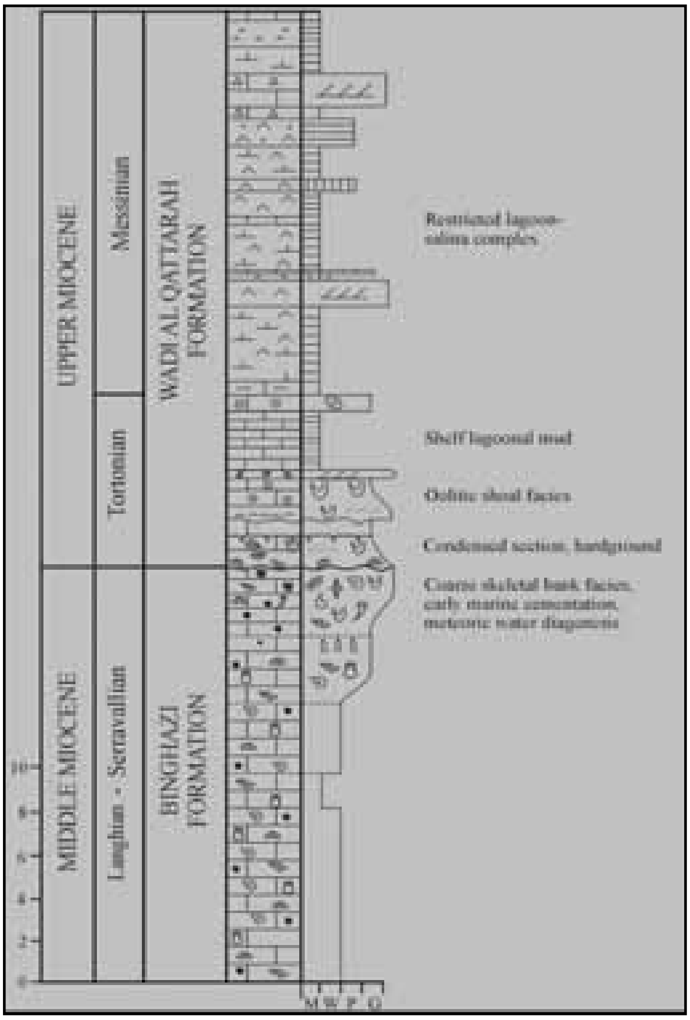


Figure 7 - Stratigraphic log of the Soluq-Abyar roadcut, showing outcrop sequence of the Langhian-Serravalian, Tortonian and Messinian successions.

of elevated Pleistocene wave-cut erosional terraces along the northern coastal margin of Cyrenaica, as well as ancient archaeological sites destroyed by earthquakes and presently submerged along the coast are evidence of neotectonic activities. In his recent tectonic analysis of the sedimentary basins of Libya Anketell (1996) postulated that whereas the Sirt basin represents a pull-apart extensional basin within a dextral wrench setting, the Cyrenaica platform was formed within a splay wedge. Furthermore, the Al Jabal al Akhdar inverse anticlinorium represents a dextral contractional duplex bound by northern Cyrenaica, Cyrenaica and southern Cyrenaica dextral wrench fault systems (Figure 4).

The timing of the northern Cyrenaica tectonic events suggests that subsidence along the Cyrenaica fault and development of northern Cyrenaica basin was initiated during the Triassic, when Pangea started to break-up. The process then accelerated during the Middle Jurassic-Lower Cretaceous with the opening of the Tethys. A major angular unconformity with variable but extensive stratigraphic hiatuses, as shown by seismic, drilling and surface geologic data, strongly suggests that the inversion of the northern Cyrenaica basin and the deformation of its continental margin started during the Turonian. This was then followed by major inversion pulses during the Santonian, Palaeocene, Lower-Middle Eocene, Oligocene and, finally, at the end of the Miocene (El Hawat and Shelmani, 1993; El Hawat *et al.*, in press). However, if we group these events we notice that the inversion of northern Cyrenaica occurred in two main tectonic phases. First, compression forces induced by Upper-Cretaceous-to-Miocene right lateral wrenching set off the initial phase of the northern Cyrenaica inversion. Second, at the end of the Miocene the increased compressive influence of the Mediterranean Ridge caused dominant vertical uplifting tectonics in Cyrenaica that overprinted the earlier wrench tectonic signatures. Figure 5 is the stratigraphic chart of the Mesozoic and Cenozoic successions of northern Cyrenaica, complete with formation names and unconformities. The regional lithostratigraphic and tectonic cross section (Figure 6) summarises the geological history of Cyrenaica.

Field itinerary

DAY 1

On the first day of the field trip we'll stop to see outcrops showing the passage of the southern extension of the Al Jabal al Akhdar anticlinorium

Figure 8 - View of the outcrop exposed on the opposite side of the Soluq-Abyar road cut, showing the clearly defined Middle-Upper Miocene boundary.

towards the Sirt rift complex of central Libya. We will then examine outcrops of Middle-Upper Miocene rocks, and follow this section into older Neogene and Palaeogene portions as we go northwards towards the Jabal al Akhdar axis. To do this we will drive south from Benghazi towards the village of Soluq and then take a north-easterly road to the town of Abyar.

Stop 1:

Starting along the roadcut at the base of Al Jabal al Akhdar's first escarpment we will examine the Miocene section where the Middle -Upper Miocene boundary is exposed (Figure 7). The whole section had been previously ascribed to the Middle Miocene, but the discovery of the boundary (El Hawat and Salem, 1985; 1987), which eventually was correlated with outcrops in central and western Libya (El Hawat *et al*., 1993), led to labelling the upper half of the section as Tortonian and Messinian.

The boundary is clearly defined on both sides of the roadcut (Figure 8), where it separates shallowing up-cyclesof massive bedded, coarse skeletal limestone of the Langhian-Serravalian Benghazi Formation from the Tortonian-Messinian Wadi al Qattarah Formation. ,—The latter formation is represented by cross-bedded ooskeletal limestone overlain by mudstone and crystalline gypsum facies . Close examination of the unconformity reveals the lithological contrast between the two formations. Also, the sharply-defined, bored, burrowed and truncated surface that is followed by transgressive lag dominated by *Echinolamps* sp shell concentration(Figure 9), forms the basal transgressive system tract of the W. al Qattarah Fm.

A condensed section lies a few decimetres above the unconformity surface. This consists of cross-laminated foraminiferal grainstone and packstone, capped by a lithified hardground with sponge and *Lithophaga* borings, and open and partially-filled burrows. The upper surface of the hardground is encrusted with small oysters, serpulids and bryozoa (Figure 10). This CS discontinuity surface is correlatable for up to 60 km northward along the depositional strike.

Walking up the road_along the roadcut we will examine the rest of the Tortonian section which is dominated by the ooskeletal shoal facies. These are interrupted at the top by a thick partially-restricted lagoonal mudstone facies, and an oolitic limestone unit exhibiting soft sediment deformation.

In turn, these terms are overlain by a Messinian

Figure 9 - Close-up of the Middle-Upper Miocene unconformity showing a sharply-defined bored surface followed by transgressive lag of Echinolamps sp. at the base of the Tortonian.

sequence consisting of slightly_folded and channelled units of marl with dwarfed oyster banks, mudstone, algal stromatolites, and lenses of coarsely crystalline gypsum. After a short drive along the road the section transitions into deltaic and estuarine sand and clay facies showing calcareous sandstone, evidence of bioturbation, plant rootlets, and dwarfed oysters, overlain by a unit of rippled, fine-grained lagoonal gypsarenites that shift into gyps-stromatolites and, finally, swallow-tail twinned coarsely crystalline gypsum.

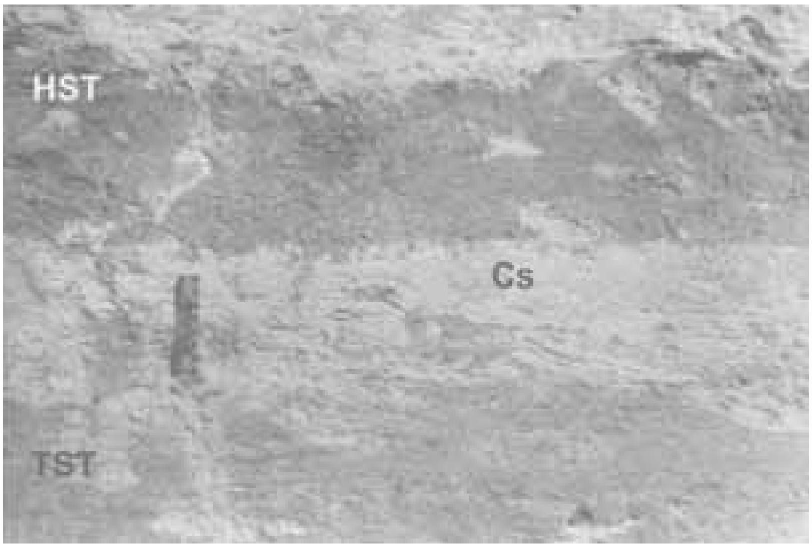


Figure 10 - Close up of the bored hardground forming the condensed section (CS) at the top of the transgressive system tract (TST) at the base of the Tortonian.

Stop 2:

We are now at a higher altitude than the last stop, and are located further to the northeast along the road to Al Abyar. The outcrop at this stop consists of massive Middle Miocene Porites reefal facies overlain by a well- bedded lagoonal lime mudstone with ostracods. These basal layers are separated by a Middle – Upper Miocene major erosional unconformity (Figure 11). The patch reefs are the landward equivalent of the shallow marine coarse skeletal bank deposits observed at stop 1. They form a belt extending 50 km northward to Al Abyar, and one hundred kilometres southward to the western margin of the Sirt rift basin. The reef belt formed a rim around the Al Jabal al Akhdar anticlinorium during the Middle Miocene.

The presence of these reefs at these higher elevations is attributable to several causes. First regression in the Middle Miocene, then transgression over the sloping Middle Miocene sea floor in the Tortonian produced an offlap relationship (El Hawat and Salem, 1985; 1987). These palaeotopographic and eustatic causes, however, were subsequently overprinted by the tectonic uplift of Al Jabal al Akhdar and Cyrenaica due to the compressive forces induced by the subduction of the North African plate, which peaked at the end of the Miocene (El Hawat *et al*., in press).

Figure 11 - Elevated exposure of massive, bedded, Langhian-Serravalian Porites patch reef, followed by well-bedded Upper Miocene, ostracods-rich, mudstone facies. The boundary between the two units forms a prominent erosional unconformity.

Stop 3:

At the Hawa al Barraq quarry we shall examine a typical Messinian salina lake's carbonate and gypsum deposits (Figure 12, 13). This locality is further north than the siliciclastics issued out from the Messinian basin

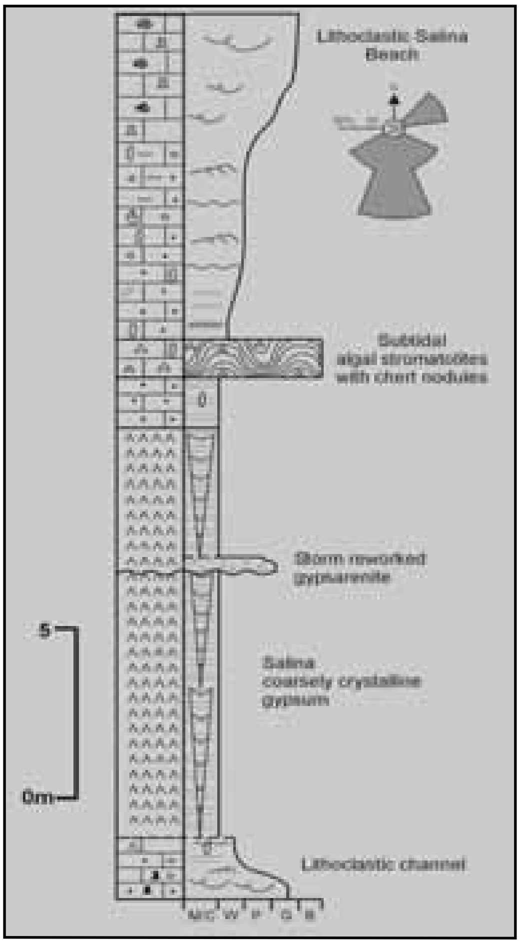


Figure 12 - A lithologic log of a typical Messinian section exposed at the Hawa al Barraq gypsum quarry, showing one of the salina lake facies typified by giant crystalline gypsum interrupted by a storm-induced gypsarenite layer, carbonate channel-beach facies and algal stromatolites.

at the Sirt rift system. Conditions in this area led to the development of thick, coarsely crystalline gypsum lenses, algal stromatolites, coarse channel-beach storm deposits, and salina lake margin evaporite-solution collapse breccia associated with tepee structures and bedded chert with pseudomorphs after gypsum (El Hawat, 1980).

These Messinian facies are the youngest deposits on the southern flank the Al Jabal al Akhdar structure. These salinas were developed in a syncline on the northern flank of the main axis of the anticlinorium. Although the whole Miocene sequence in this locality is thick, it tapers out to the north, as the Middle Miocene beds pinch out and the Tortonian oolitic shoal facies onlap the Palaeogene beds in a narrow, structurally-controlled belt (Figure 14).

Stop 4:

Outcrops along the Al Abyar-Deryana roadcut (Figure 15) are exposed on the southern extension of an anticlinal structure, where beds dip a few degrees to the southwest. This section consists of Eocene, Oligocene and Miocene beds. The Eocene ~~terms~~ at the base of the section are covered by Pleistocene beach-dune deposits at 120 m a.s.l. These remnants of the Mediterranean Pleistocene eustatic sea-level change were tectonically uplifted as a result of the Quaternary and present-day uplift of Cyrenaica (El Hawat *et al*., in press).

In this roadcut we shall examine: 1) Lower Oligocene Algal limestone, Al Bayda Fm.; 2) Middle to Upper Oligocene beds, Al Abraq Fm.; 3) Lower Miocene beds, Al Faidiyah Fm.; 4) the Miocene Benghazi Fm; and 5) Upper Miocene beds Wadi al Qattarah

Figure 13 - A view of the Messinian giant crystalline gypsum facies exposed at the Hawa al Barraq gypsum quarry and a layer of gypsarenites interrupting the crystalline sequence (arrows), suggesting reworking during a storm event.

Fm. of the Ar Rajmah group (Figure14). All of these stratigraphic units are separated from each other by unconformities, and each forms a single shallowing-up sequence, reflecting the interplaying of eustasy

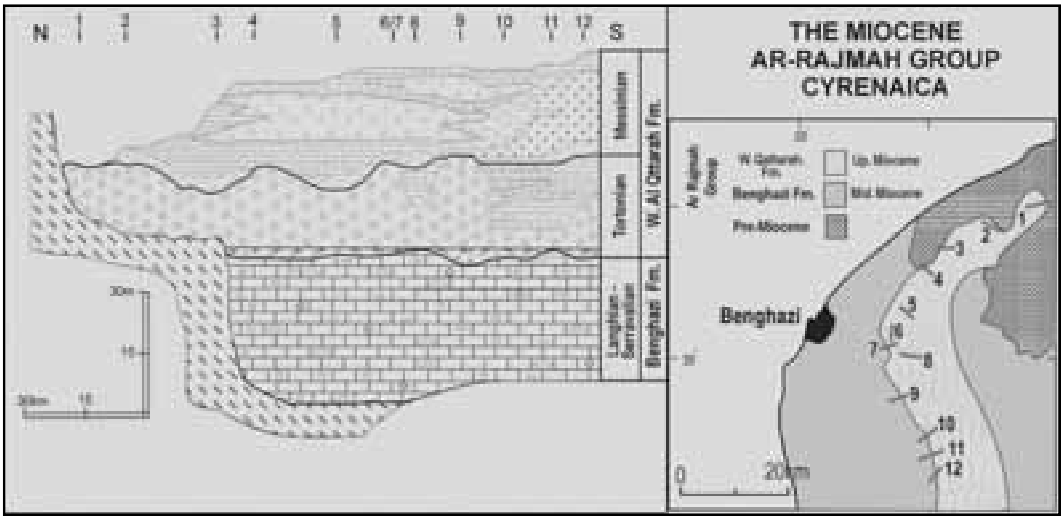


Figure 14 - Geological map and cross section of the Miocene, the Ar-Rajmah Group is exposed along the first escarpment of Al Jabal al Akhdar.

and Al Jabal al Akhdar tectonics.

Stop 5:

The Wadi Al Bacur roadcut stop coincides with the general location of the Farzugha anticline's crest, which we will see as we drive north from the previous stop. The outcrops consist of soft, well-bedded Eocene, Lutetian (El Khoudary, 1976, 1980; Helmdach and El Khoudary, 1980), chalky limestone that is gently inclined a few degrees to the north. Close examination reveals that these beds consist of delicate, small-scale, cross laminated, occasionally bioturbated calcisiltite as well as very fine calcarenite (Figure 16), which also contains occasional polished and reworked limestone coarse sand and granules.

These beds grade upsection along the roadcut into hard calcilutite and calcisiltite

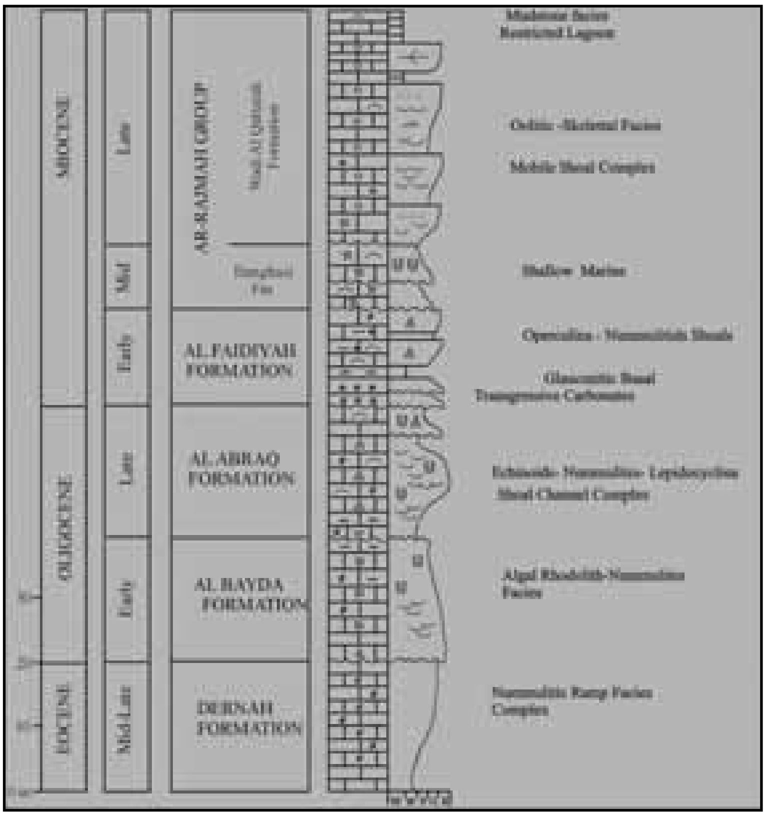


Figure 15 - Lithologic log of the Daryanah-Abyar roadcut showing the Palaeogene-Neogene succession.

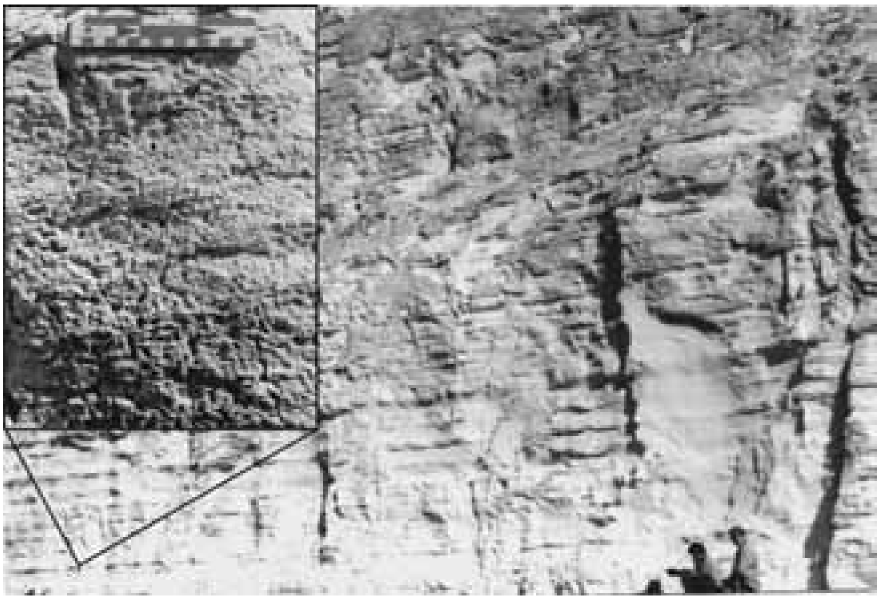
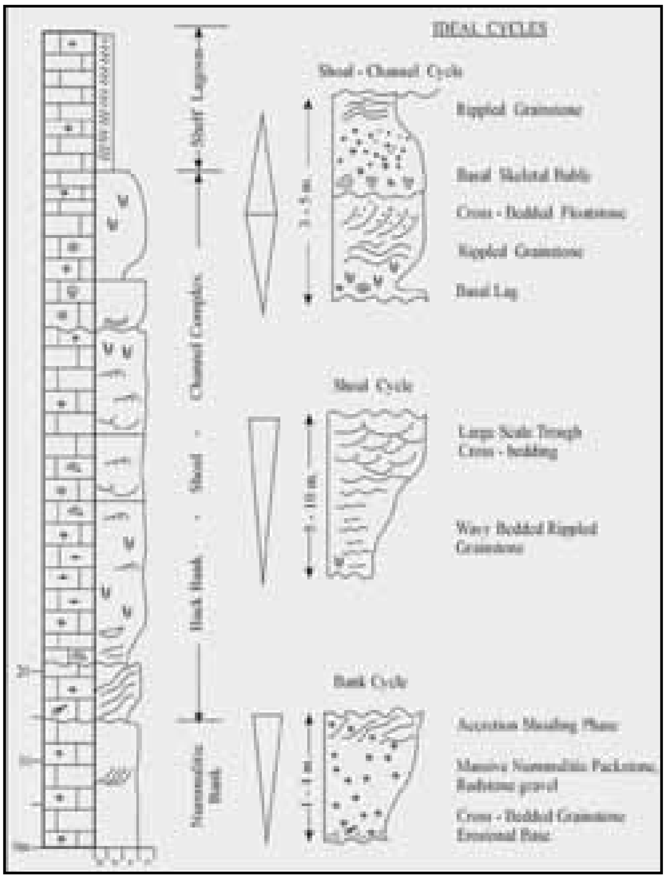


Figure 16
A view of the Eocene outer ramp exposure of the Apollonia Fm. along the Tukrah roadcut. Beds are slightly inclined to the north and consist of well-bedded, chalky calcisiltite, and very fine calcarenite that exhibits small-scale current structures and bioturbation.



mudstone associated with chert and interbedded with chalk. These in turn change into calcisiltite and fine calcarenite at the top of the roadcut. The succession is interpreted as deep neritic outer ramp facies that were deposited on the northern limb of the Al Jabal al Akhdar anticlinorium. These facies belong to the Apollonia Formation, and as we shall see later they transition upward and laterally into mid-ramp diachronous nummulite bioaccumulations. The cross lamination observed in the muddy facies of these outcrops are a result of the fine-grained carbonates being reworked by deep shelf currents (El Hawat, 1986a, 1986b).

Stop 6:

As we approach the town of Al Marj we will make a brief stop to examine at the first appearance of the Lutetian

Figure 17 - Lithological log of the Middle Eocene Dernah Formation in Al Marj limestone quarry. The base of the section consists of midramp Nummulite gizehensis banks, followed by inner ramp skeletal shoals and shelf lagoonal mudstone and wackestone that exhibit soft sediments deformation.

Nummulite gizehensis, which represents the forebank facies of the mid-ramp bioaccumulation. This outcrop suggests that we are looking at the Dernah Formation. The Dernah-Apollonia boundary is transitional, as there is a continuum in sedimentation between the outer and mid-ramp settings. This is a fossil collection stop, as nummulite shells are scattered loosely on the ground as a result of differential weathering of the soft matrix. Refer to Abdulsamad (1999, 2000) and Abdulsamad and Barbieri (1999) for the palaeontology of the larger foraminifera in Al Jabal al Akhdar.

Figure 18 - Close up of the channel structures in the inner ramp skeletal shoal facies, Al Marj limestone quarry.

Stop 7:

The Al Marj limestone quarry is located on an up-faulted block on the northern margin of the Jardas al Abid Cretaceous inlier overlooking Al Marj agriculture plain, which forms the downthrown side of this major transpression fault system.

We are on a higher palaeoslope point on the Eocene ramp than the outcrops at the previous two stops. In this outcrop the succession (Figure 17) consists of one depositional sequence. It starts with midramp *Nummulite gizehensis* packstone at the base of the quarry, turning into a complex sequence of inner ramp, coarse-grained skeletal grainstone and rudstone (Figure 18), forming a nummulitic bank-channel-shoal system. These then change upwards into inner-ramp, shelf, lagoonal facies consisting of a mudstone and molluscan skeletal wackestone section at the top of the quarry. This succession includes a unit exhibiting soft sediment deformation structures that were produced as a result of a tectonically-induced seismic shock; it is a common feature that is observed throughout the stratigraphy of Cyrenaica from the Cretaceous on.

The Eocene nummulitic banks and its association with coarse-grained shoal facies in this exposure are part of a rim of high-energy deposits that surrounded an island of tinverted Cretaceous rocks of the Jardas al Abid inlier.

DAY 2

Today we will drive south form the town of Al Marj up the second plateau towards the core of one of the Cretaceous inliers that are aligned ENE-WSW in northern Cyrenaica (Figure 4). The core of the inversion structure is located around the Jardas al Abid village. In the inlier we shall examine the Upper Cenomanian exposures of the Qasr al Abid marl Formation, the Al Baniyah limestone Formation (Turonian-Coniacian-early Santonian), the Al Majahir limestone Formation (Campanian) and the Wadi al Dukhan dolomite Formation (Maastrichtian).

These will be followed by a quick stop at Uwayliah, to visit another inversion structure where eroded remnants of the Palaeocene (Landenian) outcrops' inlier chalks are exposed, and then drive to the ancient Greek city of Cyrene, where we will spend the afternoon among the well-preserved ruins. Along the way we will make short stops to have a look at the Oligocene outcrops located on the northern margin of the anticlinorium. The Oligocene and Lower Miocene succession of marls and carbonates was important to the development of the fountain of Apollo, that led to the establishment of Cyrene. We shall have time to visit this archaeological site.

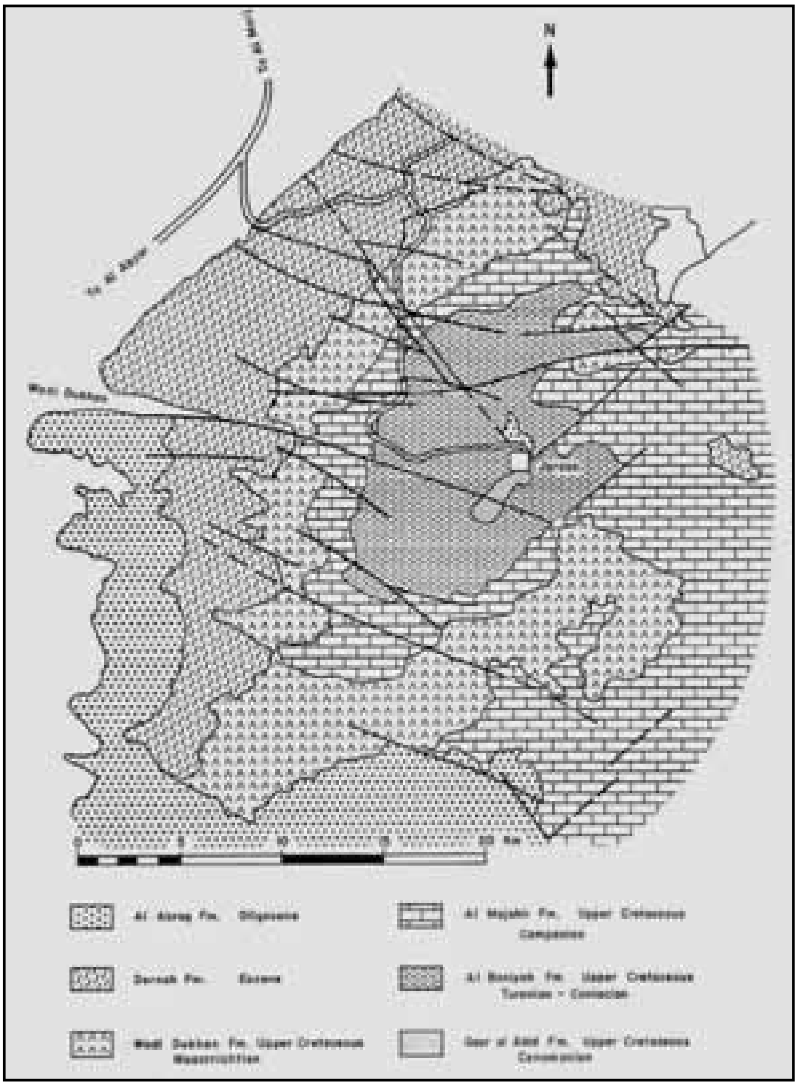


Figure 19 - Geological map of the Jardas Al Abid inlier (source: El Hawat and Shelmani, 1993).

Stop 1:

Drive from the hotel to the Al Marj-Abyar road, where we will then turn at the eastern branch of the fork leading to the village of Jardas al Abid, at the core of the Cretaceous inlier (Figure 19). After crossing the Eocene outcrops we shall stop at the Maastrichtian outcrops of the Wadi al Dukhan Formation. Looking west, we will observe a spectacular panorama that shows the unconformable relationship between the Cretaceous and the Tertiary strata.

Stop 2:

A short stop at the boundary between the Al Majahir (Campanian) and Al Baniyah (Turonian-Coniacian) Formations. We shall take a short walk to examine these formations in roadcuts and quarries; then, a walk up the (Majahir Fm.) hill will offer a bird's eye view of the inlier (Figure 20). According to the mapping of the area, the boundary between the Al Baniyah (Turonian

Figure 20. Panorama showing the northern part of the Jardas Al Abid inlier, with the Eocene Dernah Fm. to the north and the Turonian – Santonian, Al Baniyah Fm. to the south.

Figure 21 - Exposure of lenticular rudist bioherm in the Campanian Al Majahir Formation.

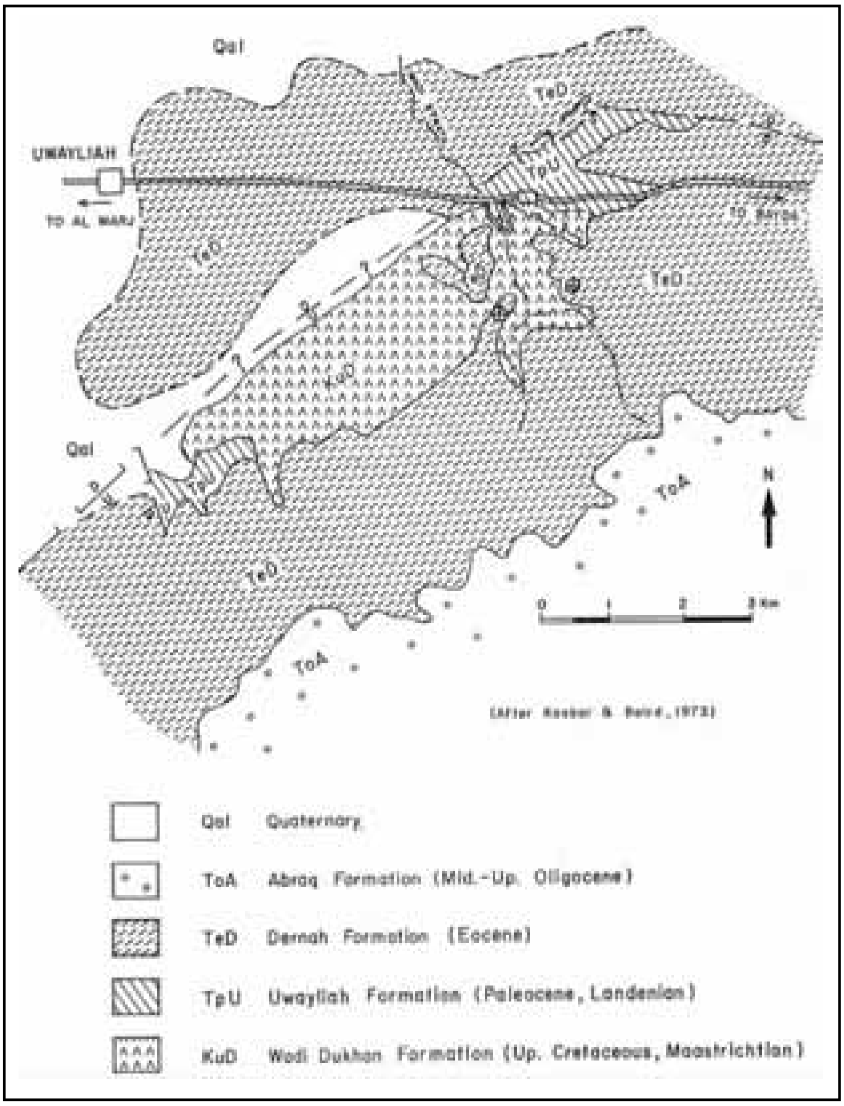


Figure 22 - Geological Map of the Uwayliah inlier. (source: Kaabar and Baird, 1973).

to early Santonian) and Al Majahir (Campanian) formations is marked by an unconformity. This coincides with the intra-Santonian tectonic event that led to the main inversion of the northern Cyrenaica inliers (Rohlich *et al*., 1996). As we drive along the road towards Jardas we shall observe some faulted blocks that consist of inclined Cretaceous beds of the Al Baniyah, Al Majahir and Wadi al Dukhan formations.

Stop 3:

A quick stop at a roadcut to examine a newly- discovered rudist site (Figure 21). This rudist, identified as *Durania sp*, suggests a Campanian dating for the Al Majahir Formation (El Hawat and Shelmani, 1993). This is the third recorded rudist site in Al Jabal al Akhdar. The

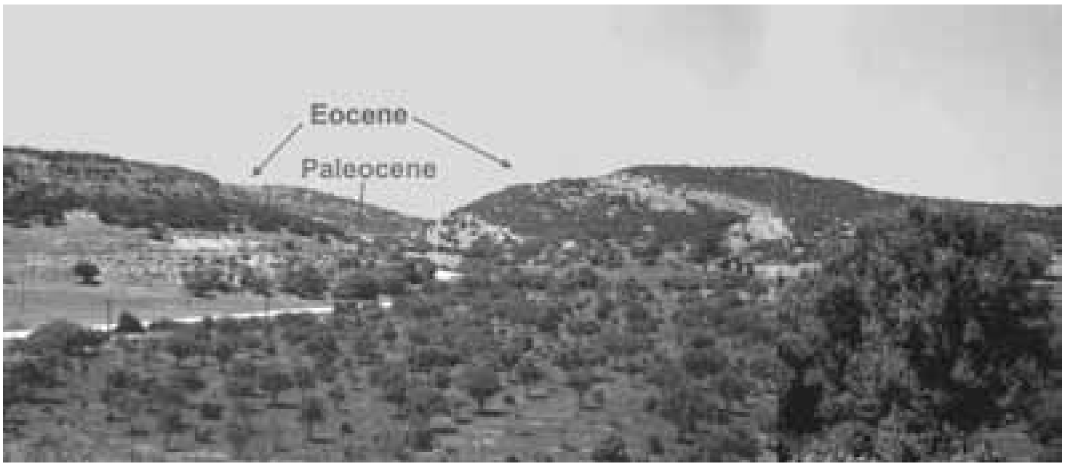


Figure 23 - View of the Uwayliah inlier looking west. The road passes almost parallel to a major fault zone where the Palaeocene Uwayliah Fm. is exposed. The over laying bed of the Eocene Dernah Fm. is almost horizontal south of the fault, but dips at a higher angle to the north towards the Al Marj trough.

first is found in Wadi al Dukhan (Maastrichtian) outcrops in the Uwayliah inlier, which was reported in unpublished AGIP field notes during 1960. The second locality is reported south of the Al Majahir fortress in the Al Baniyah Formation (Rohlich, 1974). The rudist build-up at this locality occurred in a shallowing up cycle, where rudists form a lenticular body dominated by skeletal rudstone debris around a small bioherm of rudist boundstone, suggesting that rudists are often preserved as skeletal debris rather than true reefal build-ups.

Stop 4:

Passing the Jardas al Abid Fort on the left (elevation 650 m), we shall drive on to the village school where the Qasr al Abid Formation is exposed. According to Barr (1968), the oldest beds exposed in the vicinity are of Upper Cenomanian age. The base of the unit is reported to be in well A1-18, 700 feet below the surface. The Cenomanian at this site consists of a shallow water fauna of oysters, echinoids, benthonic foraminifera and ostracods, in addition to a small percentage of planktonic forams. In contrast, the Cenomanian in Ras al Hilal, on the coastal area, which presents deeper marine traits, and is dominated by planktonic fauna. Before we depart from the Jardas al Abid inlier, it is worth mentioning that the area was the site of the first oil well drilled in Libya (A1-18), by the Libyan – American Oil Company back in 1956. Remnants of this historical exploration site are still observable today. We shall pay a visit to the well site, if time permits.

Stop 5:

Driving east from Al Marj, 2.5km east of Uwayliah village we will see the second Cretaceous-Palaeocene inversion inlier (Figure 22). This area is strongly faulted and structurally complex. Here there is a possible element of wrench tectonics as it lies along the margin of the Al Marj trough and north

Figure 24 - A view of the Palaeocene-Eocene section south of the fault.

of the larger inlier that we have just seen at the last stop. In this locality the Paleocene is overlain by the Maastrichtian Wadi al Dukhan Dolomites that were pushed up by a reverse fault. No fossils have been reported from these massive dolomites in this area; however, rudist reefs were reported in the old AGIP field notes referred to earlier. Dips of up to 15 degrees have been measured in the dolomite beds. This Cretaceous – Palaeocene sequence is unconformably overlain by the Eocene Dernah Formation (Figure 23).

The importance of this site lays in the exposure of the Al Uwayliah Formation, found on the right side of the road (Figure 24). This is one of two confirmed Paleocene exposures in Al Jabal al Akhdar. This exposure is Landenian in age, whilst the other, at Jardas al Jarari is Danian. The age difference between these localities is ascribable to differences in pre-Paleocene palaeotopographic configuration, as well as subsequent tectonics and erosion during inversion.

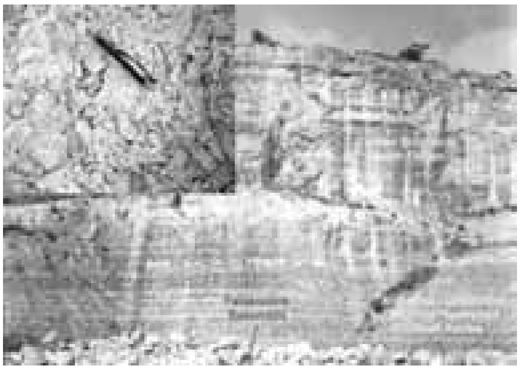


Figure 25 - East of the Uwayliah Eocene section consists of well-bedded, lagoonal, orbitolite-rich mudstone and wackestone, overlain by coarse bio-skeletal high-energy debris of the windward beach-shoal complex.

Stop 6: [Optional]

A glance at the Eocene outcrops on the left of the road as we drive to Cyrene. Facies in this quarry of the Dernah Formation is a lateral equivalent of the inner ramp shoal facies we have already seen at the Al Marj quarry (first day, stop 7). However, this facies is coarser, skeletal whole-shell calcirudite associated with small nummulites and coral fragments that occur in massive beds (Figure 25). It was deposited in a very high energy setting. Since all shoals formed a rim around the Cretaceous inliers, these higher energy facies are interpreted as representing the windward shoals, whereas the Al Marj shoals to the west were deposited on the leeward side of the Cretaceous islands. We will be discussing the windward vs. leeward carbonate sedimentation on the larger scale of the whole Al Jabal al Akhdar anticlinorium, where the nummulitic bioaccumulation facies of Cyrenaica changes into coral-coralgal dominated facies on the eastern outcrops of the anticlinorium, which we are going to see tomorrow.

Stop 7:

A quick stop along the Al Marj-Al Bayda-Cyrene road at Zawiet al Argoub, where we can see the Shahat Marl Member's Lower Oligocene unit of the Al Bayda Formation, exhibiting syndepositional slump structures. In itself the slump is not that spectacular, but it demonstrates the persistent tectonics in Cyrenaica due to the ongoing inversion process, and their signature in the sedimentary record. These slumps are commonly observed in the Cretaceous (see cover page), Eocene, Oligocene, as well as, the Miocene and in recent time.

In the offshore area of the Sirt basin, the occurrence of extensive submarine fans and slump structures are associated with a substantial thickening of the Oligocene sequence, as a result of rapid subsidence (Smith and Karky, 1993), during the time that northern Cyrenaica was being differentially uplifted. The Oligocene indeed, was a time of greater North African events; with the regional tectonics involving the uplifting of the African plate that led to the end of the carbonate depositions in North Africa with the influx of siliciclastics towards the Tethys (El Hawat, 1997).

Stop 8:

Another quick stop at Wadi al Kuf to enjoy the Al Jabal al Akhdar landscape of Eocene limestone cliffs and Mediterranean vegetation. The Eocene-Oligocene boundary coincides with the level of the bridge seen crossing the top of the wadi above us. Structurally, we are in the middle of the Al Marj trough where there was higher subsidence during the Eocene. Eocene outcrop lithology in the area consists of muddy, shelf lagoonal facies with small nummulites, as compared with the higher energy, midramp facies which occur around the structurally higher areas to the south (stop 7, day 1), and to the north (stop 1, day 3).

Stop 9:

Driving past the town of Al Bayda, going east towards the smaller town of Shahat where the ancient city of Cyrene was founded. We shall spend the rest of the afternoon amid the ruins of the birthplace of the man that helped Christ to carry the cross on his way to crucifixion, Simon the Cyrenian.

The area of ancient Cyrene is large and complex, and

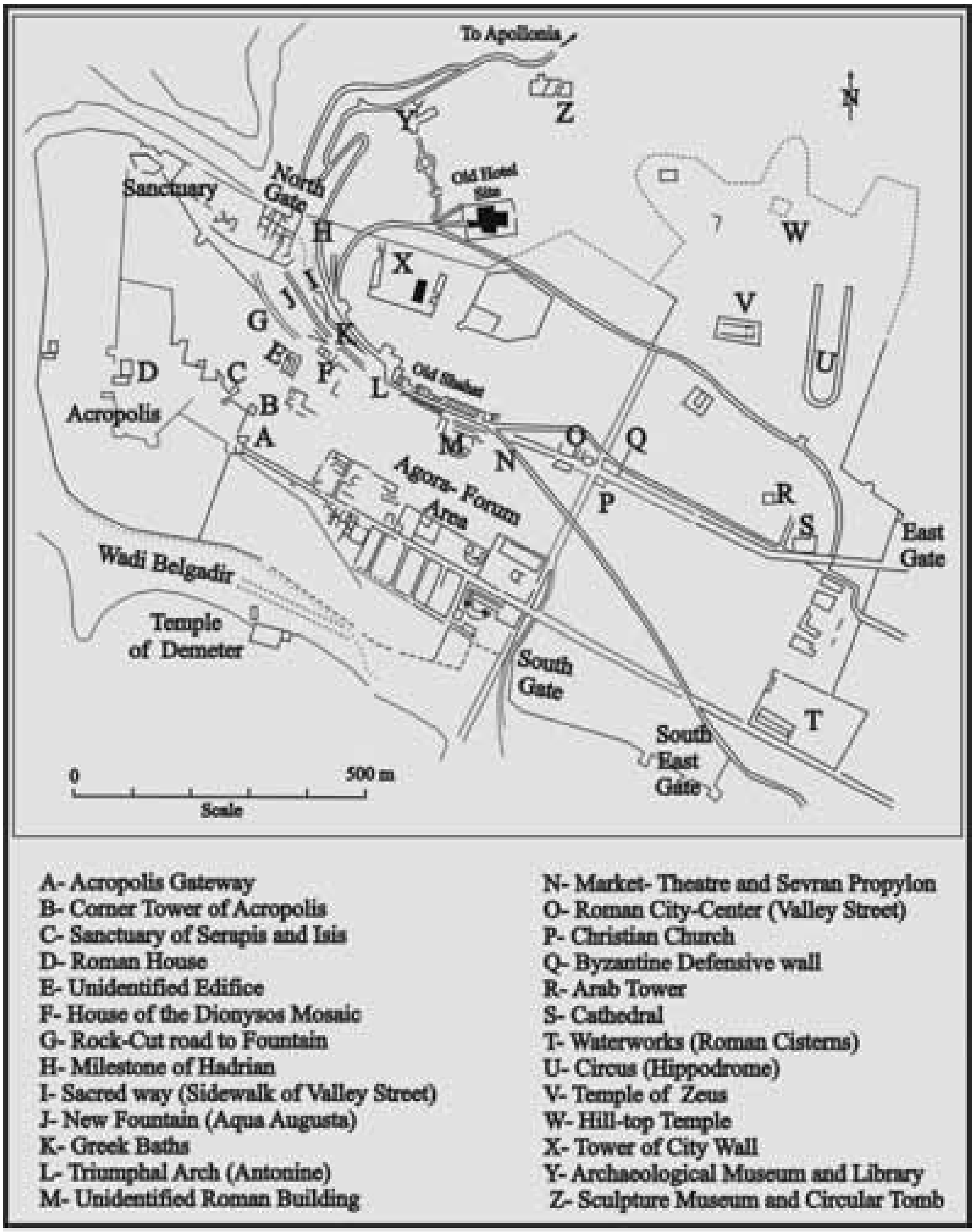


Figure 26 - General map showing the ancient city of Cyrene (source: Goodchild,1970).

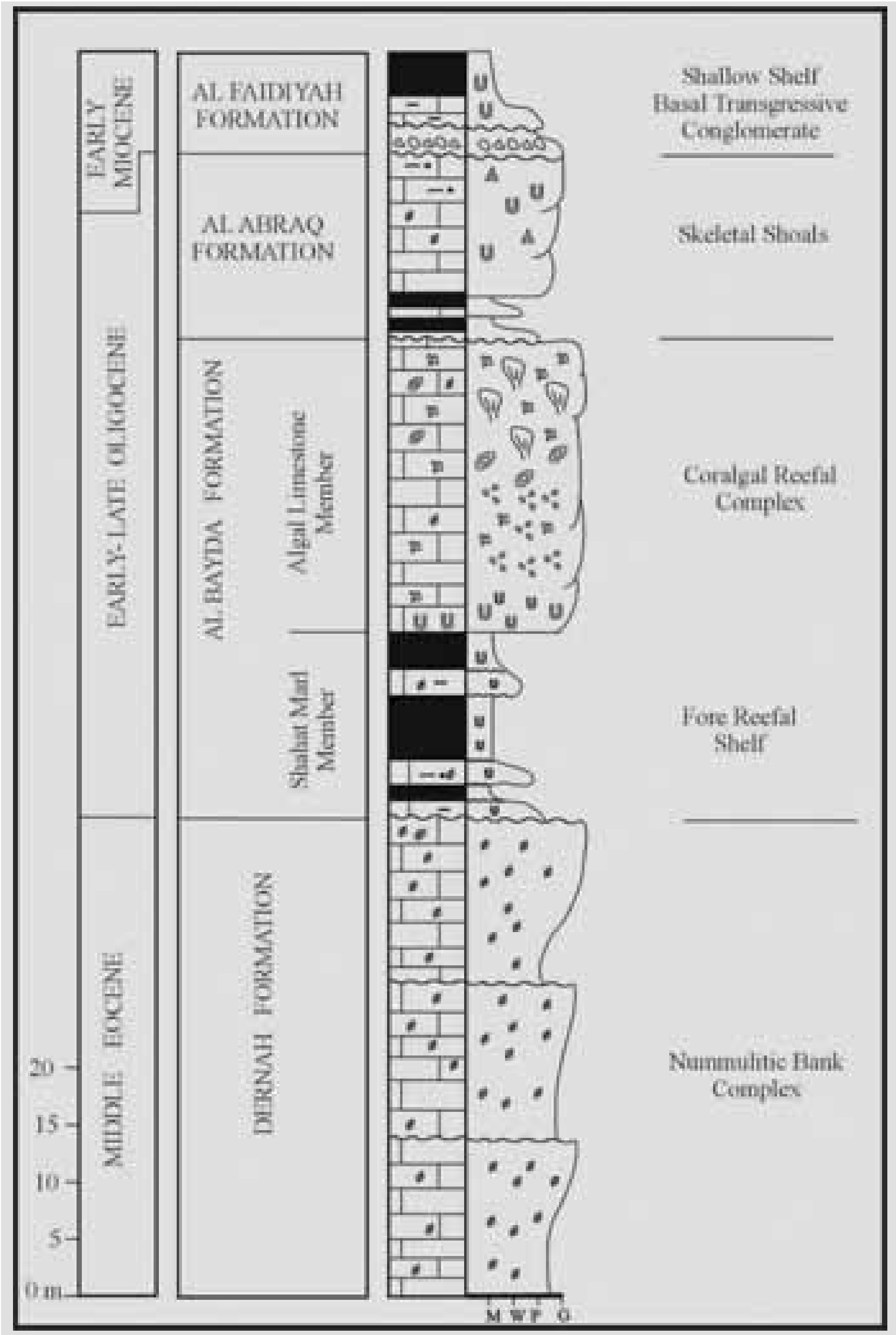


Figure 27 - Lithological log of the Cyrene road cut (source: El Hawat & Shelmani, 1993).

to explain its history we would need a specialized guide. However, as an introduction guide to the ruins of the ancient city of Cyrene, a general map of the city, including maps of the Agora-Forum and of the Fountain and Sanctuary areas, are here provided (Figure 26). The following brief account and map are derived from a historical guide published by the Libyan Department of Antiquities (Goodchild, 1970).

The Founding of Cyrene

The story of the foundation of Cyrene as a colony of Greek immigrants from the island of Thera (modern Santorini) has been handed down to us as a mixture of legend and history. The date usually assigned to this event is 631 B.C. It seems that towards the middle of the seventh century B.C. a crisis due to overpopulation arose on the small Aegean island, and a seven-year period of drought caused such distress that forced emigration seemed the only solution. So the leaders of the community consulted the famed Oracle of Apollo at Delphi, and were told to found a colony in Libya. An expedition was organized and entrusted to a certain "Aristoteles", who later took the name of Battus and became the first king of Cyrene. Some 200 young men were nominated to accompany Battus, and from Thera they sailed to Crete where they found a pilot to lead them to the shores of Africa. They founded the first settlement on a small island called Platea in the Gulf of Bumba, on the eastern outskirts of the fertile Cyrenaican plateau. The first settlement on the island of Platea was not successful. The isle was small and there was little water. After two years the settlers decided to consult the Oracle again and were advised to go to the mainland. Convinced that they had yet to find the true Libya, the settlers returned to Africa and moved their settlement from the arid Platea to a more favourable site called Aziris, situated on the mainland between Bomba and Dernah, at the mouth of Wadi Kalij. Here they remained another six years, in the course of which they learned that even better sites lay on the high plateau farther to the west. Friendly Libyans offered to guide them to a place where they could establish their permanent settlement. These guides were, however, anxious to prevent the Greeks from seeing IRASA, the finest part of the country. This place is perhaps Dernah itself on Ain Mara. So the march was made at night and when dawn broke the travellers found themselves on the future site of Cyrene. "Here, O Greeks," said their guides, "ye may fitly dwell, for in this place there is a hole in the heavens". The Libyans referred , of course, to the abundant rainfall of the Cyrene area. Their own numbers were small, and the country was large; in all probability they themselves were only thinly scattered on the upper plateau, finding its winter climate too harsh for their African blood. But the Greeks were captivated by a landscape not unlike the Greek mainland, and relatively free from those droughts which they had suffered on Thera. There was good arable soil and ample pasture; most important of all, the Libyans were friendly and willing to give their daughters in marriage to these foreigners who had arrived without their womenfolk. King Battus ruled for forty years over his tiny immigrant community, and by all accounts he ruled wisely and moderately. Although still a minute nucleus, in comparison with the city that was to develop in later years, Cyrene began to take shape. A temple of Apollo the "founder" was erected close to the spring which was named after the nymph Cyrene (Kura or Kurana), and a straight approach road was laid down on the plain. When Battus died his tomb was venerated and a public place of assembly, the later Agora, grew up around it.

Figure 28 - The upper sequence of the mid-ramp nummulite succession of the Dernah Fm., Cyrene road cut. Note the accretionary arrangements of the nummulite bodies (arrows), and the Eocene-Oligocene boundary (dashed line).

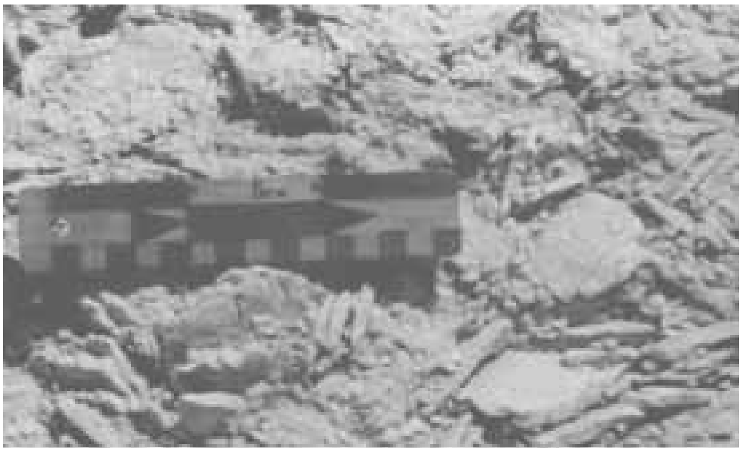


Figure 29 - Close-up of the Middle Eocene, Nummulites gizehensis, Cyrene roadcut.

DAY 3

We will continue to examine the geology of the upper escarpment where Cyrene was founded, then drive down to the coast to view the town of Apollonia (Susa) from the first escarpment, if our schedule permits it we will stop at the archaeological sites. We will then drive along the coastal road to Ras al Hilal- Athrun where the last Mesozoic inliers in Al Jabal al Akhdar in this excursion may be seen. In this area the Upper Cretaceous sequence is exposed on the coastal plain and is overlain by a mixed sequence of wadi and beach Quaternary deposits. This sequence is also exposed in beach cliffs and wadi cuts. The western part of the inlier coincides with the widened coastal plain of ~~Mersa~~Marsa Ras al Hilal, and is composed largely of the Al Hilal shale Formation. To the east, in the narrower coastal plain, Cretaceous sediments are dominated by the Al Athrun limestone Formation. The presence of the Cretaceous exposures are attributable to the occurrence of a fold, the axis of which is trending in a NE-SW direction. This is another structure on the northern limb of the Al Jabal al Akhdar anticlinorium. The crest of this fold coincides with Wadi al Qalah, located immediately south of the village of Ras al Hilal . Several stratigraphic units are missing over this area. The boundary between the Al Hilal shales and Al Athrun limestone is gradational. On the crest of the inversion anticlinorium in the Jardas inlier to the south, the equivalent Upper Cretaceous sequences are of shallower water origin, and are interrupted by the intra-Santonian unconformity. To the west, in Benghazi offshore, Al Hilal - Athrun sequence is interrupted by a shallow water unit of the Al Majahir Formation. To the east in the Gulf of Bumba, the Upper Cretaceous sequence is missing altogether.

We will be examining these sequences and facies in roadcuts and beach cliffs in a spectacular setting today. At the village of Al Athrun we shall see the Cretaceous-Eocene unconformities and sequences with slump features representing submarine mass movements in the lower part of the outer Eocene ramp. The top part of the ramp succession, which is to be seen later in the afternoon, consists of shallower marine mid-ramp facies associated with forebank turbidite feeder channels. On our drive back to Benghazi we shall make two other important stops. First, at the west Dernah roadcut where we will see the windward reefal equivalent of the Eocene nummulite bioaccumulation to the west, and the associated Oligocene debris flow channel. Then, at the Ain Ad-Dabusseyah roadcut, we can examine the Palaeogene sequence, including the Oligocene coralgal reefal complex.

Figure 30 - Faulted Eocene beds showing knee fold on the footwall (left of centre). The hanging wall exhibits tectonically elevated wave-cut terracing. The lower edge of the terrace is at 120 m a.s.l. (centre). Susa village (Apollonia) is to the left.

Stop 1:

The CYRENE-APOLLONIA ROADCUT.

The new roadcut along the Shahat (Cyrene)- Susa (Apollonia) highway offers a good opportunity to

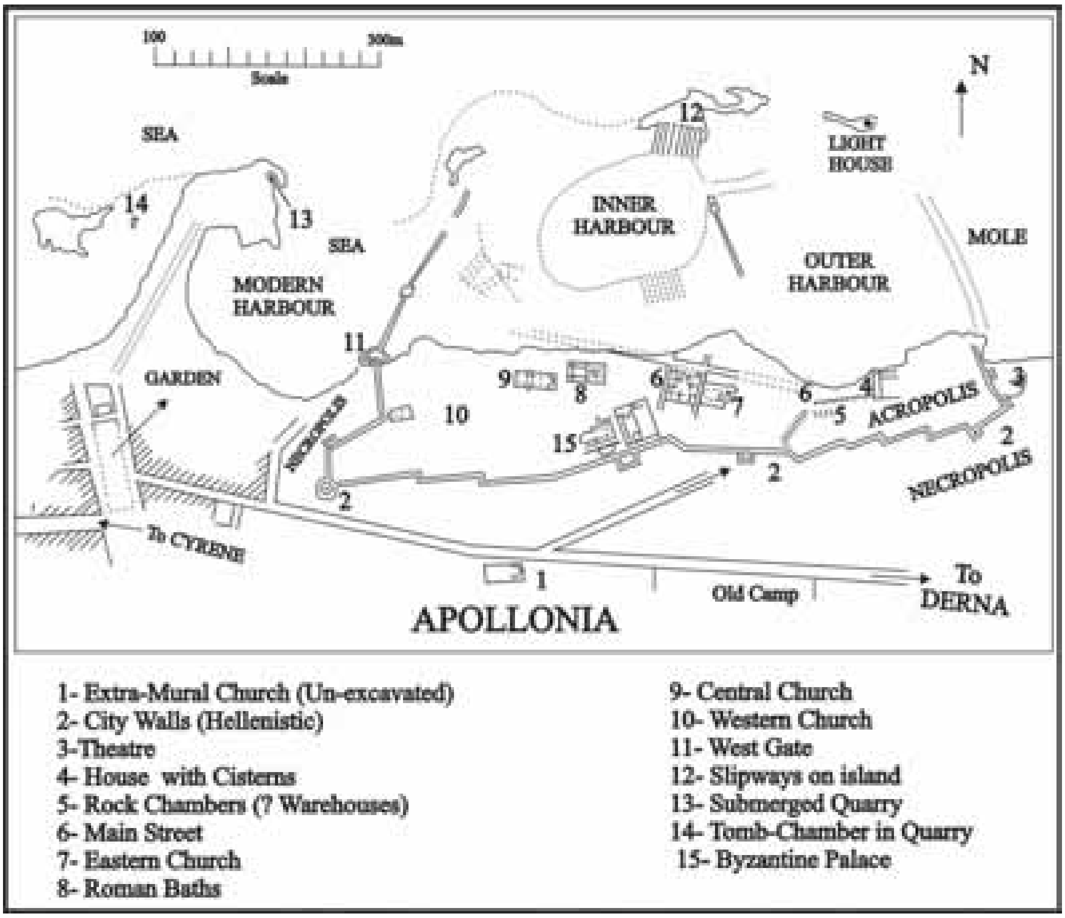


Figure 31 - General map of the ancient city and port of Apollonia (Susa). (source: Goodchild, 1970).

examine the complete Eocene-Oligocene-Miocene section (Figure 27), which makes up the second Al Jabal al Akhdar escarpment. The roadcut also offers one of the best locations to study larger foraminifera (Abdulsamad, 1999, 2000). The base of the section consists of massive units of the Middle Eocene Dernah Formation. The nummulitic bank complex is underlain by back-bank, Orbitolite wackestone and mudstone facies forming the top of the Eocene middle sequence.

The bank com-plex consists of a series of lenticular nummulitic bodies that exhibit coarsening up vertical sequences.

These bodies are stacked on top of one another and also, develop large-scale, prograding, sigmoidal, trough and draping primary structures (Figs. 28, 29). The Lower Oligocene Al Bayda Formation also displays a single shallowing up depositional cycle, unconformably underlain by the Eocene (Figure 28). This cycle was a result of progradation of the shallow water coralgal-reefal carbonate facies over the deeper Shahat marl Member neritic shelf muds . The Al Abraq and Faidiyah Formations present similar shallowing-up sequences. It is important to re-emphasise that the Al Jabal al Akhdar tectonics were active during sedimentation of these sequences. These tectonic activities influenced sedimentation and the facies thickness distribution. We shall talk more about that later.

Stop 2:

We will derive down the upper escarpment, the first plateau, and as we are midway along the first escarpment we could make an optional stop to enjoy the view of the coast where Apollonia, the harbour of Cyrenaica was founded. Looking eastward along the escarpment note the prominent terrace: this is an elevated Pleistocene wave-cut terrace (Figure 30).

Figure 32 - Panoramic view taken from the Ras al Hilal headland looking south towards the Cretaceous-Eocene inlier forming the cliff in the background.

The seaward edge of this feature has an elevation of about 120 meters.

Hey (1956) demonstrated that the Quaternary shoreline deposits of northern Cyrenaica occur at, 15 – 25, 35 – 40, 44 – 55, 70 – 90 and 140 – 190 meters above sea-level. Whereas the lowest one, 6 meters, is constant throughout Cyrenaica, the higher ones suggest that tectonic warping overprinted eustatic events. Some of the higher terraces however may have eroded away, and hence the number of terraces may vary from place to place. The terraces and associated beach-dune calcarenite complexes are partially covered by calcite-cemented fluvial gravel, which may often be covered in turn by more recent alluvium. These features are associated with fault-controlled wave-cut cliffs that exhibit knee folding of the footwalls, where the beds often exhibit anomalous dips. These are a result of the vertical tectonic movements that have affected northern Cyrenaica since the end of the Miocene . This is due to the ongoing compressive influences induced by the conversion of the African and Eurasian plates, which has also led to the development of the Mediterranean ridge on the Cyrenaican offshore (El Hawat *et al.*, in press).

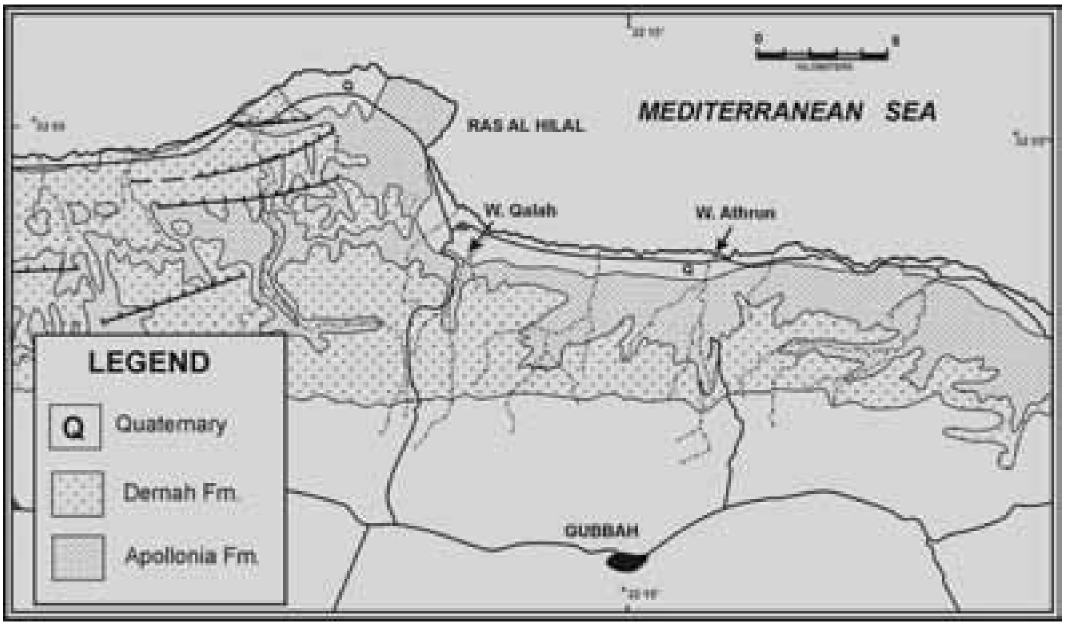


Figure 33 - Geological map of the Ras al Hilal area. The Cretaceous beds are shown on the map as they form outcrops in the sea cliffs and are covered by Quaternary rocks in the narrow coastal area (source: Rohlich, 1974).

Stop 3:
APOLLONIA

This is an optional stop. Drive down the escarpment to Susa, to look at the ancient ruins of Apollonia (Figure 31). The following are extracts from Goodchild (1970).

Marsa Susa (Apollonia) is located on the Mediterranean coast, twenty kilometres north of Shahat (Cyrene). Ancient Apollonia was Cyrene's port for over a thousand years, and its ruins form an essential part of the whole archaeological complex. The modern Cyrene-Apollonia road follows the course of the ancient highway linking the city to the port. Originally constructed by the Greeks, it was later improved in A.D. 100, to be partly destroyed fifteen years later, by the Jewish insurgents. After further repairs it remained in use until the Arab conquest of Libya. The highway was chiselled squarely into the Eocene rocks, with sidewalks on either side, it passed through Cyrene's northern necropolis. The construction of the new asphalt road after 1914 has changed its appearance. Modern Susa (Apollonia) was founded in 1897 as a colony of Moslem refugees from Crete. It was extensively rebuilt in the Italian occupation as a port for coastal shipping and an administrative centre. The ancient town of Apollonia is fairly well preserved, as it lies almost entirely outside the modern day Susa. The principal damage to the ruins has been caused by the sea, following a subsidence of the coastal area during the late antiquity periods due to the ongoing tectonics of Cyrenaica. Apollonia was given its name in honour of the patron god who brought the Greeks to Libya, but in Christian times it was commonly called "Sozusa", from which has developed the Arab name "Susa". Although Apollonia was the port of Cyrene, its prosperity was such as to give it autonomy during the Roman period, when it was recognized as one of the five cities of the Pentapolis of Libya (Goodchild, 1970).

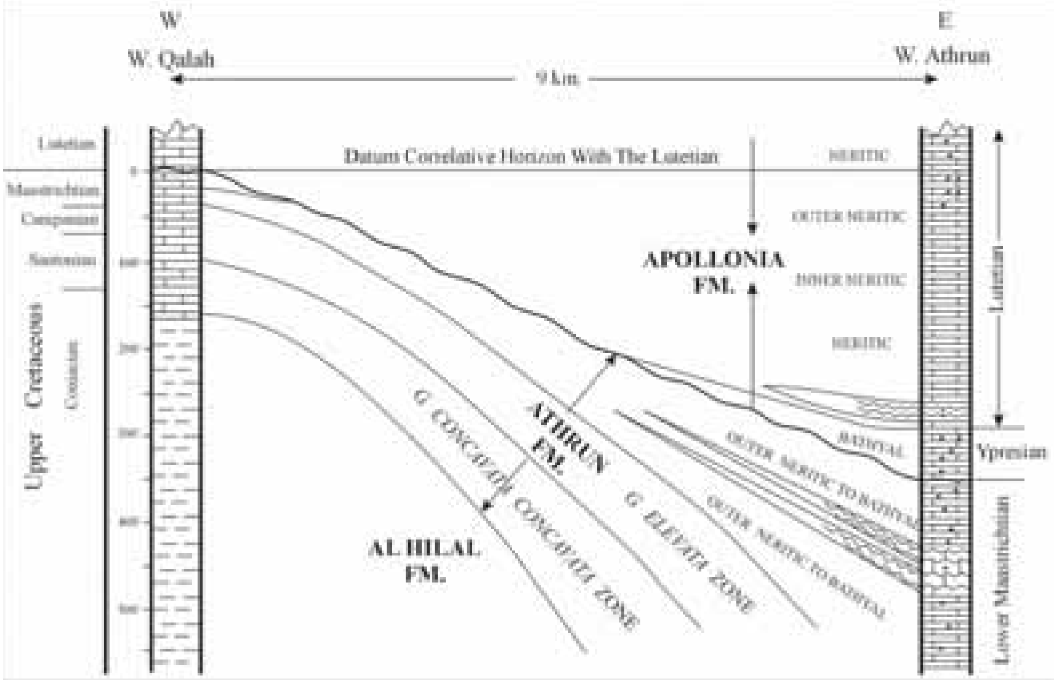


Figure 34 - Cross-section in the wadi Qala - wadi Athrun area located in Figure 3, showing the Cretaceous - Eocene inlier at the Ras al Hilal area. (source: Barr & Berggren, 1980).

During our drive east of Susa we will point out an important archaeological site about 7 kms east of the town. A karstic cave can be observed in the face of a low lying northern-facing Eocene rock scarp, located east of wadi al Hira. This is the world famous "Haua Fteah" cave. The site was made famous by archaeological, palaeontological, climatological and geological publications by several researchers (McBurney and Hey, 1955; McBurney, 1967). This is one of the most important prehistoric sites in North Africa. Deposits of unknown thickness have been excavated to a depth of 13 meters in the cave. The oldest C14 age obtained has been 46,000 years BP. This was from a sample depth of 7.5 meters in the cave floor deposits. Fro the acquired data sets, cyclic climatic phases have been interpreted.

Figure 35 - A view of Cretaceous-Eocene section in wadi Athrun. Note unconformities (arrows), nanno-planktonic zones. (source: El Hawat, in press).

Stop 4:

As we continue to drive east we can observe on the south side of the road Apollonia Formation outcrops. These exhibit prominent syndepositional slide scars, faulting and tilting of beds, as well as pronounced incised wadies. All these features evolved due to tectonics at one time or another. Further along, the Ras al Hilal (the Crescent Head) headland appears on the north side. A view from the headland looking south will show an impressive panorama of the escarpment of the Ras al Hilal Cretaceous-Eocene inlier and the village on the coast (Figure 32). This headland is the tip of the Cyrenaican promontory, and the most forward-jutting point of the Libyan coastline into the Mediterranean. It is also the closest to the Mediterranean ridge where compressive forces are at work.

The geological map (Figure 33) and cross section (Figure 34) demonstrate the development of the Ras al Hilal – Athrun Cretaceous inlier. To examine its rock we'll enter the Ras al Hilal Motel, east of the village, and walk down the sea-cliff where the Cenomanian, Al Hilal shale Formation is exposed. These shales form the core of the Ras al Hilal inlier. They were discovered by Barr and Hammuda (1971), and were dated Upper Cenomanian to Coniacian. These exposures are the deep-water equivalent of the Qasr al Abid and Al Baniyah Formations observed in the Jardas al Abid inlier at the axis of the anticlinorium to the south. These shales were deposited north of a submarine barrier that separated the Cyrenaican trough from the Tethys.

Stop 5:

After driving east to the village of Al Athrun (derived from the Greek name *Erythrum*), we shall walk down to the shallow bottom of wadi al Athrun to treat ourselves to spectacular geologic scenery and history. The eastern wall of the wadi presents a unique two dimensional panorama of the Upper Cretaceous-Lower Tertiary sequence (Figure 35). At the base, the Cretaceous beds are white and have a very slight dip to the south. These are overlain by a thin, tan, marly zone which marks the contact between the Cretaceous and the overlying tan-coloured beds of the Lower Eocene, Apollonia Formation. The Paleocene is missing in this sequence. However, in places, the Upper Cretaceous-Lower Tertiary boundary (Figure 36) is marked by a pebbly zone with Paleocene lithoclasts. This has caused some palaeontologists to believe that there actually are Paleocene beds at the base of the section. The overlying Eocene sequence has produced

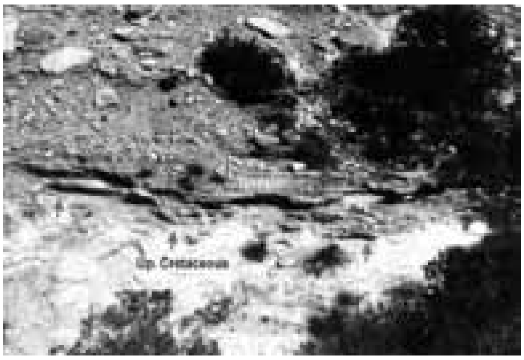


Figure 36 - Close-up of the light-coloured chalk of the Upper Cretaceous (Maastrichtian) Athrun Formation, and tan-coloured Lower Eocene (Ypresian) rocks. The K/T unconformity is overlain by a shaley layer containing reworked Palaeocene pebbles (source: El Hawat, in press).

planktonic forams and nannofossils of Ypresian age. It is followed by a Lutetian slump unit. A few meters upsection, below the slump unit, an unconformity within the Ypresian is marked by a glauconitic, pebbly bed. This form eustatic unconformity marking the boundary between Nannofossil zones NP13 and NP14. The following base of the slump, on the other hand, marks the Ypresian-Lutetian unconformity boundary between NP14a and NP14b (Figure 37), with a hiatus of about 3 million years, and suggests a eustatic event overprinted by tectonics (El Hawat, in Press). The planktonic foraminifera packstone bed below this unconformity was deposited in a bathyal environment. The slump section above the unconformity is 10m thick and consists of shallow neritic mid-ramp nummulitic wackestones facies. This sequence is followed by normal, well-bedded, deep neritic, outer-ramp Apollonia facies. Clearly, the slump unit indicates submarine mass movements of shallow- water nummulitic facies into a deep water setting (El Hawat, 1985 & in press). Ideas concerning this section are currently in the process of being published. The interplay between global eustasy and local tectonics will be discussed.

Stop 6:

This is an optional stop at the sea-cliff exposed at the mouth of Wadi al Athrun (See cover page). Exposures of the Al Athrun limestone Formation are overlain by Quaternary deposits. The section is part of the Barr and Hammuda (1971) type section. This beach cliff

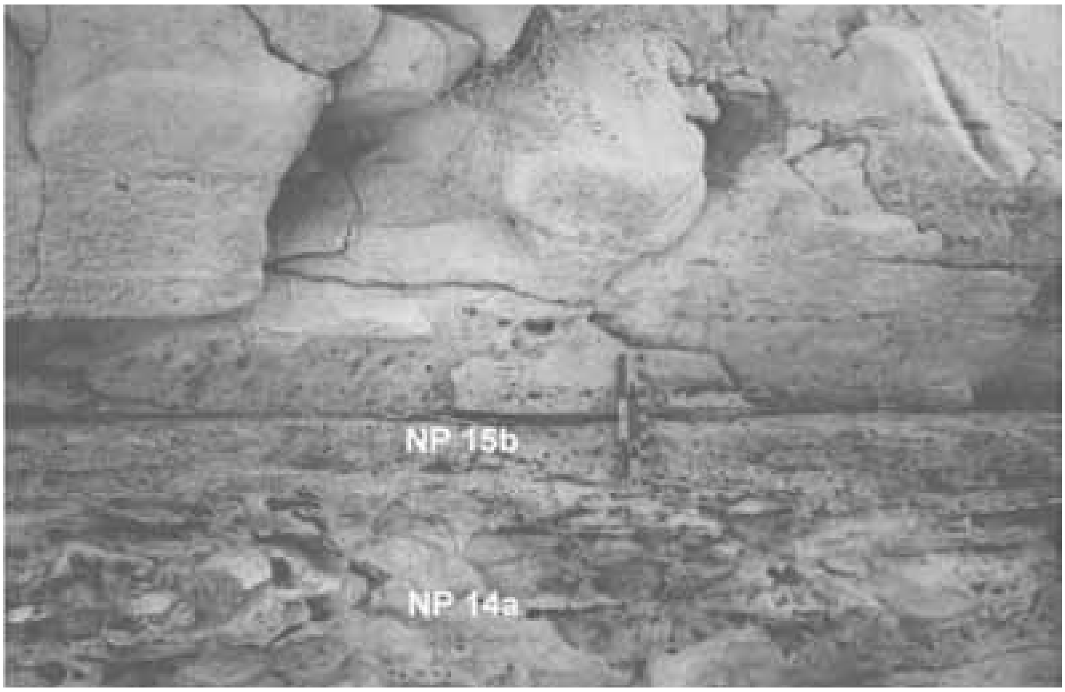
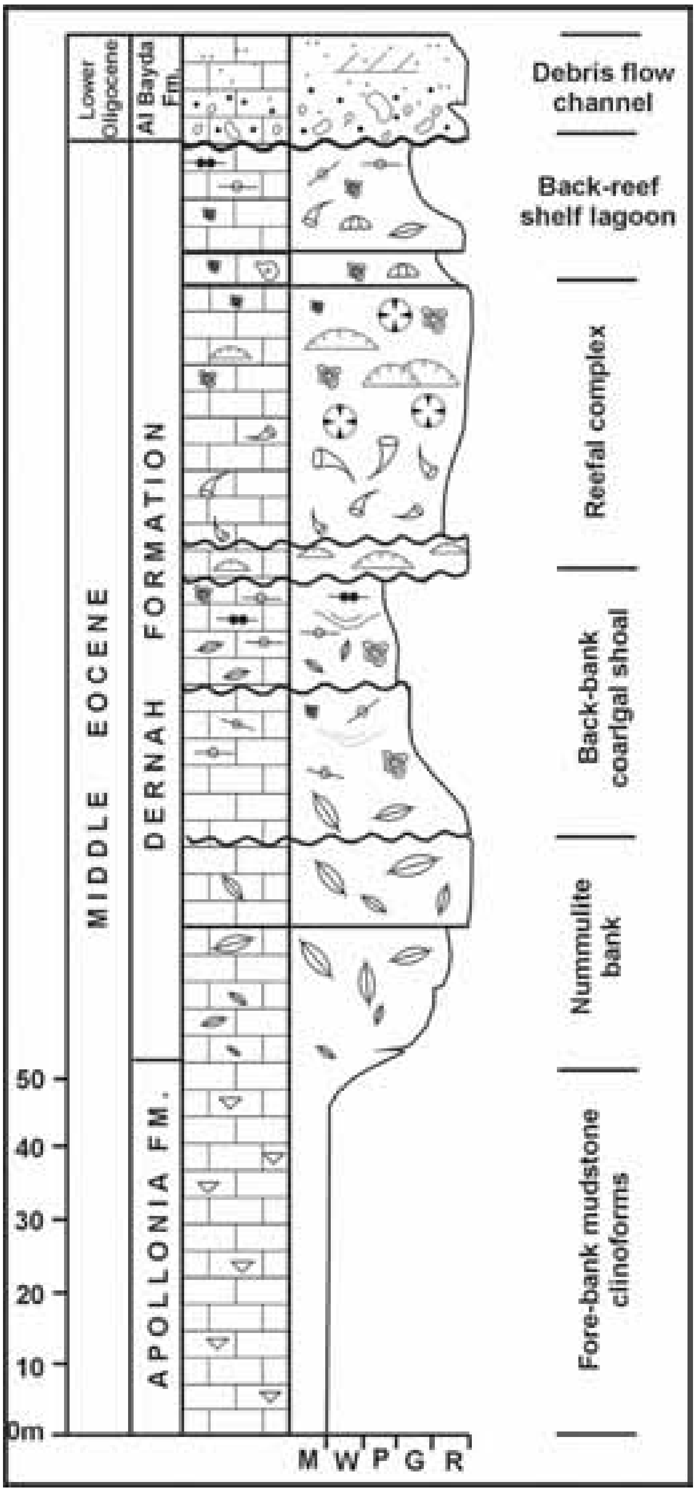


Figure 37 - Close-up of the Ypresian-Lutetian boundary below the slump unit. The boundary represents a hiatus of about 3 million years (source: El Hawat, in press).



exposure shows a good example of slump structures which are common in the formation. These are related to tectonic events that were taking place at the axis of the anticlinorium. As indicated earlier, the intra-Santonian tectonic events include uplifting and wrenching. The latter is indicated by the occurrence of fault flower structures which are recognized along seismic lines.

Al Athrun chalks are rich in planktonic forams, *Inoceramus* fragments, as well as such ichnofauna as *Zoophycos and Chondrites*. These indicate deep-marine, lower-slope sedimentation ranging from deep neritic to bathyal conditions.

Stop 7:

Drive to the western approaches of Dernah and turn right at the road that winds up the escarpment to examine the west Dernah roadcut. This roadcut offers a major change from the Eocene facies we have examined so far. It forms the eastern edge of the Al Jabal al Akhdar anticlinorium before it plunges eastwards into the Mediterranean. It is believed to represent the windward side of the Al Jabal al Akhdar structure during the Eocene (El Hawat *et al*., 2002; In press). We shall examine the Eocene nummulite-reefal facies association first described in detail by Hammuda (1973). The section in this roadcut is about 200m thick and represents a shallowing up succession of Apollonia outer-ramp mudstones, grading into the high-energy, shallow-water, mid-ramp nummulitic bank facies of the Dernah Formation (Figure

Figure 38 - Lithological log of the west Dernah road cut. (source: El Hawat and Shelmani, 1993).

38). This section is reduced in thickness when compared to other sections to the west. This facies passes into a back-bank, inner-ramp, coralgal-discocyclinid carbonate sand shoal-channel facies complex that, in turn, grades into a succession of restricted inner-shelf lagoonal facies which exhibit intensive dolomitization, dissolution discontinuity surfaces, and other features consistent with subaerial exposure.

The upper part of the cycle shows early development of patch reefs with intermittent phases of subaerial exposure, followed by a thick sequence of solitary corals, then topped by a succession of massive corals. The overlaying sequence is dominated by a back reef, coralgal-discocyclinid, sand shoal complex. The Eocene-Oligocene boundary is marked by intensively bioturbated hardground that develop a nodular appearance, and is followed by paleosols and terra rossa development (Figure 39). These features suggest the end of the Eocene tectonic uplift and subaerial exposure prior to the deposition of the Lower Oligocene, where the Shahat marl Member of the Al Bayda Formation is missing, and the overlying algal limestone member consists of a single unit. The Eocene-Oligocene boundary is followed by up to 20m of a thick, massive, fining-up, debris flow channel unit that contains olistoliths of reworked Eocene mixed with Oligocene facies. It suggests that the tectonic conditions that uplifted the area at the end of the Eocene also continued to overprint the Lower Oligocene transgression.

Figure 39 - A view of the Eocene-Oligocene unconformity. The top of the Eocene section shows the development of a nodular lithified hardground followed by a brown-coloured paleosoil horizon. The Lower Oligocene consists of debris flow olistoliths derived from the Eocene (source: El Hawat et al., in press)

Stop 8:

As we drive back to Benghazi along the main highway to Qubbah we will make an optional stop at the Ain Ad-Dabusseyah roadcut. In this roadcut (Figure 40) again we shall examine the Eocene-Oligocene sequence in order to improve our facies models of the Palaeogene sequence. We are on the highest southern point of Ras al Hilal. However, in this section, the Dernah Fm. is nummulite-dominated with no reefal development to speak of. Facies belts are fairly well defined with forebank gravity slope mass movement and turbidites (remember the slump at the base of the section at stop 5) followed by high energy midramp nummulitic bank facies that exhibit large-scale prograding features. These deposits are reduced to thin units that exhibit a sharp sequence boundary on top. These are the upper ramp facies, a continuation from the lower ramp sequence examined earlier at Al Athrun.

Again the Oligocene Shahat marl is missing at the base of the Al Bayda Fm. in this section, as at the west Dernah roadcut. However, the red paleosoil is also missing. The Algal limestone member exhibits a shallowing-up cycle of sedimentation. It starts with a cross-bedded *Lepidocyclina*-coralgal shoal-channel complex, which grades upwards into reefal-coralgal bioherms. The Lower-Middle Oligocene boundary is sharply marked by a dolomitized, orbitoid wackestone unit. The overlying Al Abraq shoal calcarenites are characteristically soft, yellowish, bioturbated, thick bedded, echinoid-*Operculina-Heterostegina*-rich, and in places contain reworked nummulites. Apparently, these were the rocks preferred by the ancient Romans to dig and establish archaeological sites, compared to the hard reefal limestone below. The overlying Al Faidiyah Formation on the other hand, produces the black soil that covers the upper plateau. This colour is a result of the release and oxidation of ferrous iron from the basal glauconitic marl.

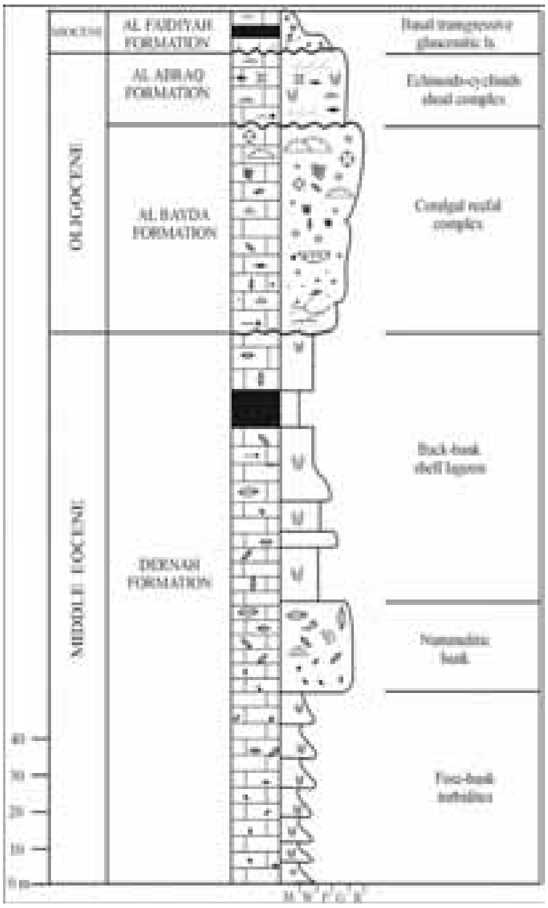


Figure 40 - Lithological log of the Ain Ad-Dabusseyah road cut (source: El Hawat and Shelmani, 1993)

Acknowledgment

We would like to acknowledge the support provided by the Department of Earth Sciences, Faculty of Science and Garyounis University during the preparation of this guidebook.

References

Abdulsamad, E.O., 1999. Stratigraphy and palaeogeography of Tertiary larger foraminifera from Al Jabal la Akhdar (Cyrenaica, NE Libya). Gournale di Geol. Bologna Ser. 3, vol. 61, pp. 75-98.

Abdulsamad, E.O., 2000. Contribution to the Nummulites taxonomy from the Palaeogene sequence of Al Jabal al Akhdar (Cyrenaica, NE Libya). Revue Paleobiol. Geneve, vol 19 (1), pp. 19-45.

Abdulsamad, E.O., and Barbieri, R., 1999. Foraminiferal distribution and palaeoecological interpretation of the Eocene-Miocene carbonates at Al Jabal al Akhdar (northeast Libya). Jour. Micropalaeont., vol 18, pp. 45-65.

Anketell, J.M. 1996. Structural history of Sirt basin and its relationship to the Sabratah basin and Cyrenaica platform, northern Libya. 1st sympo. on the Sediment. basins of Libya. Geology of Sirt Basin. Vol. 3. (M.J.Salem, M.T. Busrewil, A.A. Misallati and M.A. Sola, Ed.) Elsevier, Amsterdam, p. 57-89.

Barr, F.T., 1968. Upper Cretaceous stratigraphy of the Jabal al Akhdar, Northern Cyrenaica. In: F.T. Barr (Ed.) Geology and Archaeology of Northern Cyrenaica, Libya. Petrol. Explor. Soc. Libya, 10th Annu. Field Conference, Tripoli, pp. 131-147.

Barr, F.T. and Berggren, W.A., 1980. Lower Tertiary biostratigraphy and tectonics of northeastern Libya. In: M.J. Salem & M.T. Busrewil (Eds.), Geology of Libya. Academic Press, London, I: 162-192.

Barr, F.T. and Hammuda, O.S., 1971. Biostratigraphy and planktonic zonation of the Upper Cretaceous Atrun Limestone and Hilal Shale, Notheastern Libya. In: A. Farinacci (Ed.), proc. 2nd. Int. conf. Plankt. Microfossils. Rome, 1970, pp. 27-40.

Campbell, A.S., 1968. The Barce (Al Marj) earthquake of 1963. in F.T Barr (editor): The geology and archaeology of northern Cyrenaica, Libya. Petrol. Explor. Soc. of Libya. 10th annual field conference. P. 183-195.

Cavazza, W., Roure, F., Spakman, W., Stampfli, G., Ziegler, P., (Eds.), in press. The TRANSMED Atlas: the Mediterranean Region from Crust to Mantel. Springer-Verlag.

Contant, L.C. and Goudarzi, G.H., 1964. Geologic map of Libya, scale 1:2,000,000. U.S Geol. Survey., Map I-350 A.

Contant, L.C., and Goudarzi, G.H., 1967. Stratigraphic and tectonic framework of Libya. Bull. Amer. Assoc. Petrol. Geol., 51/4: 719-730.

El Hawat, A.S., 1980. Intertidal and storm sedimentation from Wadi al Qattarah Member, Ar-Rajmah Fm., Al Jabal al Akhdar. In: M.J. Salem & M.T. Busrewil (Eds.), Geology of Libya. Academic Press, London, II : 449-462.

El Hawat, A.S. 1986a. Fine-grained current drift carbonates and associated facies in a slope to shelf shoaling-up sequences; the Eocene, NE Libya. In the 7th European I.A.S. Mtg. Ext. Abs. Krakow, Poland, P. 208-210.

El Hawat, A.S., 1986b. Large-scale cross-bedded fine-grained contourites and associated facies; A model from the Eocene of NE Libya. 12th. I.A.S. Congress (Abs.). Canberra, Australia, pp. 94.

El Hawat, A.S., 1997. Sedimentary basins of Egypt: an overview of dynamic stratigraphy. In: K.J. Hsu (editor) Sedimentary basins of the world, vol 3 African Basins (R. C. Selley, ed.),. Elsevier, Amsterdam, p. 39-85.

El Hawat, A.S., In Press. Sedimentology and event stratigraphy of the Lower-Middle Eocene sequence, Apollonia Formation, Cyrenaica, Libya. Earth Science Soc. Libya, Tripoli.

El Hawat, A.S. and Abdulsamad, E.O., in press. The geology of Cyrenaica: a field seminar. Field Guidebook, Earth Science Soc. Libya, Tripoli.

El Hawat, A.S., Abdel Gawad, G.I. and Salem, M.J., 1993. Neogene carbonate discontinuity surfaces in northern Libya. Sedimentary Basins of Libya, Geology of Sirt Basin Symp. Abs. Earth Sci. Soci. Libya, Tripoli. P. 18.

El Hawat A.S. and Argnani A. 2001. Libya and the Pelagian shelf. In: G. Stampfli, G. Borel, W. Cavazza, J. Mosar and P. Ziegler (Editors),The palaeotectonic Atlas of the PeriTethyan Domain . IGCP 369 project CD-ROM. The European Geophysical Society.

El Hawat, A.S., Barghathi, H., Obeidi, . in press. Cyrenaica - Transect VII. In W. Cavazza, W. Roure, F., Spakman, W., Stampfli, G., Ziegler, P (editors), The TRANSMED Atlas: the Mediterranean Region from Crust to Mantel. Springer-Verlag.

El Hawat, A.S., Caline, B., Jorry, S., and Davaud, E., 2002. The Eocene ramp complex of Al Jabal al Akhdar, Cyrenaica, NE Libya: A surface analogue for nummulite reservoir. Abs. AAPG Inter. Petrol. Conf., Cairo. p. A29.

El-Hawat, A.S. and Salem, M.J., 1987. A Case Study of the stratigraphic subdivision of Ar- Rajmah Fm. and its Implication on the Miocene of Northern Libya. In: Proc. VIIIth Cong. Med. Neogene Stratig., Budapest. Ann. Inst. Geol. Publ. Hung., Budapest, LXX : 173-184.

El-Hawat. A.S. and Shelmani, M.A., 1993. Short notes and guidebook on the geology of Al Jabal la Akhdar, Cyrenaica NE Libya. Interprint, Malta. 70 pages.

El Khoudary, R.H., 1976. Contribution to the stratigraphy and micropaleontology of Jabal Al Akhdar; 1. Upper Eocene planktonic Foraminifera from Wadi Bakur, SE Tukrah, NE Libya. Libyan Jour. Sci., 6B : 57-79.

El Khoudary, R.H. 1980. Planktonic foraminifera from the Middle Eocene of the Norhtern escarpment of Al Jabal al Akdar, NE Libya. In: M.J. Salem and M.T. Busrewil (Eds.), The Geology of Libya. Academic Press, London, I : 193-204.

Francis, M. and Issawi, B., 1977. Geological map of Libya; 1:250,000, Sheet NH 34-2, Soluq, and explanatory booklet. Ind. Res. Cent., Tripoli, 86 pp.

Geological Map of Libya, scale 1:1,000,000. Industrial Research Center, geological research & mining department, Tripoli, Libya. (1985).

Goodchild, R.G. 1968a. Graeco-Roman Cyrenaica. in F.T Barr (Ed.): The geology and archaeology of northern Cyrenaica, Libya. Petrol. Explor. Soc. of Libya. 10th annual field conference. P. 23-40.

Goodchild, R.G. 1968b. Earthquakes in ancient Cyrenaica. in F.T Barr (editor): The geology and archaeology of northern Cyrenaica, Libya. Petrol. Explor. Soc. of Libya. 10th annual field conference. P. 41-44.

Goodchild, R.G. 1970. Ancient Cyrene. Libyan Dept. of Antiquities.

Hammuda, O.S., 1973. Eocene biostratigraphy of Derna area, Northeast Libya. Unpub. Ph.D. thesis, Univ. of Colorado, 177 pp.

Hey, R.W., 1956. The geomorphology and tectonics of Gabal Akhdar (Cyrenaica). Geol. Mag., v. 93, no. 1, p. 1-14.

Huguen C., and Mascle, J., 2001. La Margie continentale libyenne, entre 23°30 et 25°30 de longitude est. C.R. Acad. Sci. Paris, Earth and Planetary Sciences, vol. 332, p. 553-560.

Kaabar, S.M. and Baird D.W., 1973. Geological fieldtrip roadlog for Northern Cyrenaica, Libya. Petrol. Explor. Society of Libya , 115 pp.

Klen, L., 1974. Geological map of Libya; 1:250 000. Sheet NI 34-14, Bengahzi, and explanatory booklet. Indust. Resear. Cent., Tripoli, 56 pp.

Mazhar, A. and Issawi, B., 1977. Geological map of Libya: 1:250,000 sheet, Zt. Masus NH- 34-3, explanatory booklet. Indust. Resear. Cent., Tripoli, 80 pp.

McBurnney, C.B.M., 1967. The Haua Fteah (Cyrenaica) and the Stone Age of southeast Mediterranean. Cambridge Univ. Press.

McBurnney, C.B.M., and Hey, R.W. 1955. Pre-history and Pleistocene geology in Cyrenaican Libya. Cambridge Univ. Press.

Rohlich, P., 1974. Geological map of Libya; 1:250,000 sheet, Al Bayda sheet NI34-15, explanatory booklet. Indust. Resear. Cent., Tripoli, 70 pp.

Rohlich, P., 1987. Geological development of Jabal al Akhdar, Libya. Geol. Roundsc., 63/2 : 401-412.

Rohlich, P.; Salaj, J and Troger, K., (1998). Palaeontological dating of the pre-Campanian unconformity in Ghawt Sas area. In M.J. Salem, Mouzughi, A.J., and O.S. Hammuda (editors), Geology of Sirt Basin. Vol. I, p 265-286. Elsevier, Amsterdam.

Smith D.N. and Karki, M., 1993. Basin development of offshore Sirt basin west of Benghazi, Libya. Sedimentary Basins of Libya, Geology of Sirt Basin Symposium (Abs.).

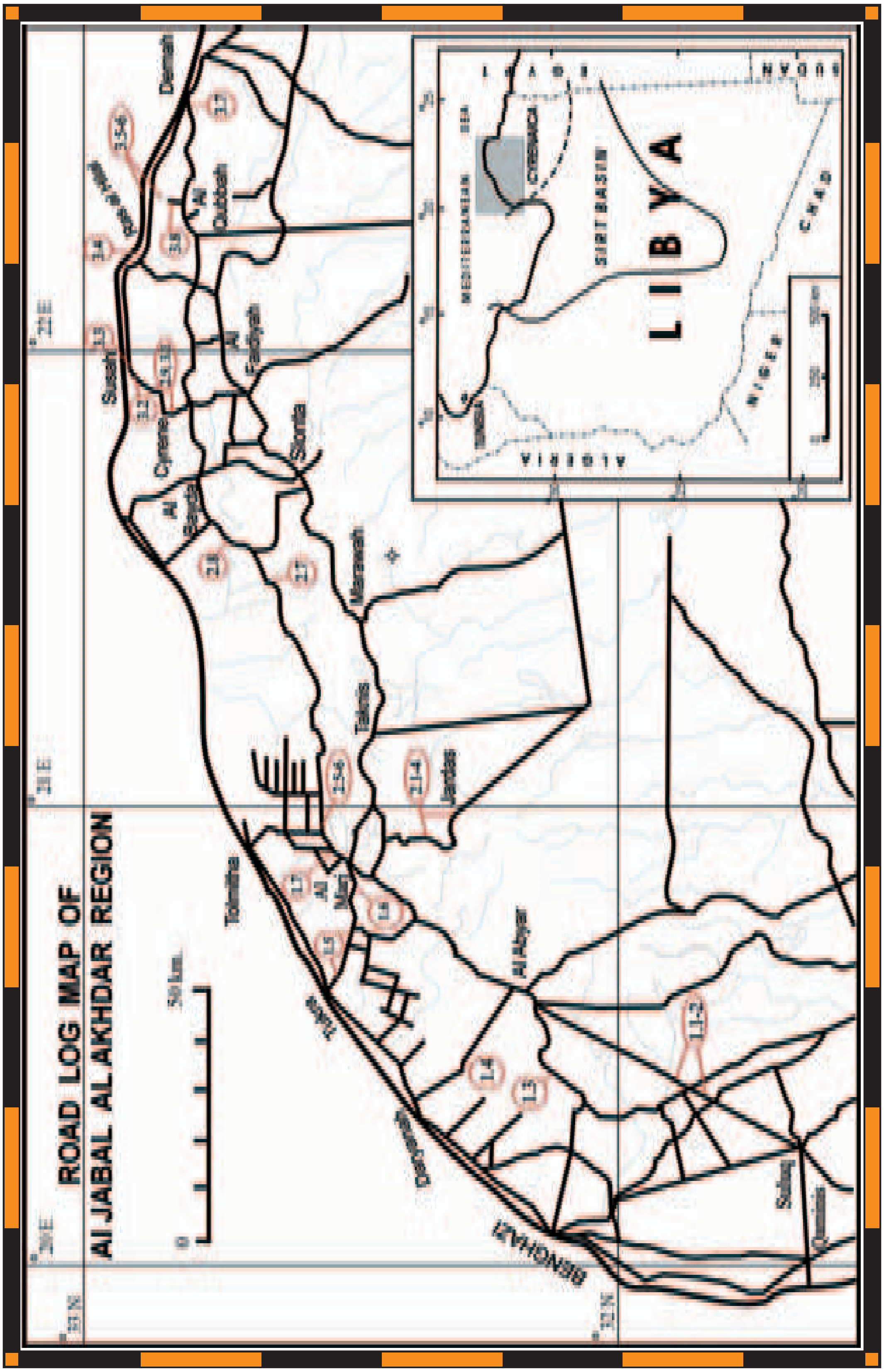
Zert, B., 1974. Geologic map of Libya, 1:250,000, Dernah sheet NI 34-I6, explanatory booklet. Indst. Resear. Cent., Tripoli, 49 pp.

Back Cover:

Road map of Cyrenaica marked by daily stops locations.

32nd INTERNATIONAL GEOLOGICAL CONGRESS

FIELD TRIP MAP



Edited by APAT