Chapter II
Lithostratigraphy

II. Lithostratigraphy

This chapter deals with the detailed lithostratigraphic description and classification of the well exposed Upper Cretaceous-Lower Eocene succession in the Farafra Oasis. The succession exhibits many distinct lateral and vertical variations in facies and thickness (Fig. 2.1). The exposed thickness of the Upper Cretaceous–Lower Eocene succession is in the range of 250m. This succession contains different varieties of lithology including chalks, chalky limestones, argillaceous limestones, shales, mudstones, dolostones, sandstones and evaporites.

The stratigraphic succession of the Farafra Oasis ranges in age from Santonian to the Early Eocene. It corresponds to seven well-established formations. These are from older to younger: El-Hefhuf, Khoman, Dakhla, Tarawan, Esna and its lateral equivalent Ain Dalla, and Farafra formations, respectively. The segregation of these formations is based mainly on field relations and observations, the lithologic characteristics and correlation with the neighboring areas. The aerial distribution of the recorded formations is illustrated in figure 2.2, a photogeologic map at a scale of 1: 1000 000 based on aerial photographs, landsat image and field check was prepared. The structural elements are also delineated and demarcated. Fourteen surface stratigraphic sections are measured and sampled in the eastern and western parts of the Farafra Oasis (Table 2.1, Fig. 2.3). These sections are chosen to represent the obvious lateral and vertical facies and thickness variations marking the Upper Cretaceous-Lower Eocene succession in the Farafra Oasis. Some of these sections are studied for the first time such as those measured in Qur Hadida and southeast Qur Hadida.

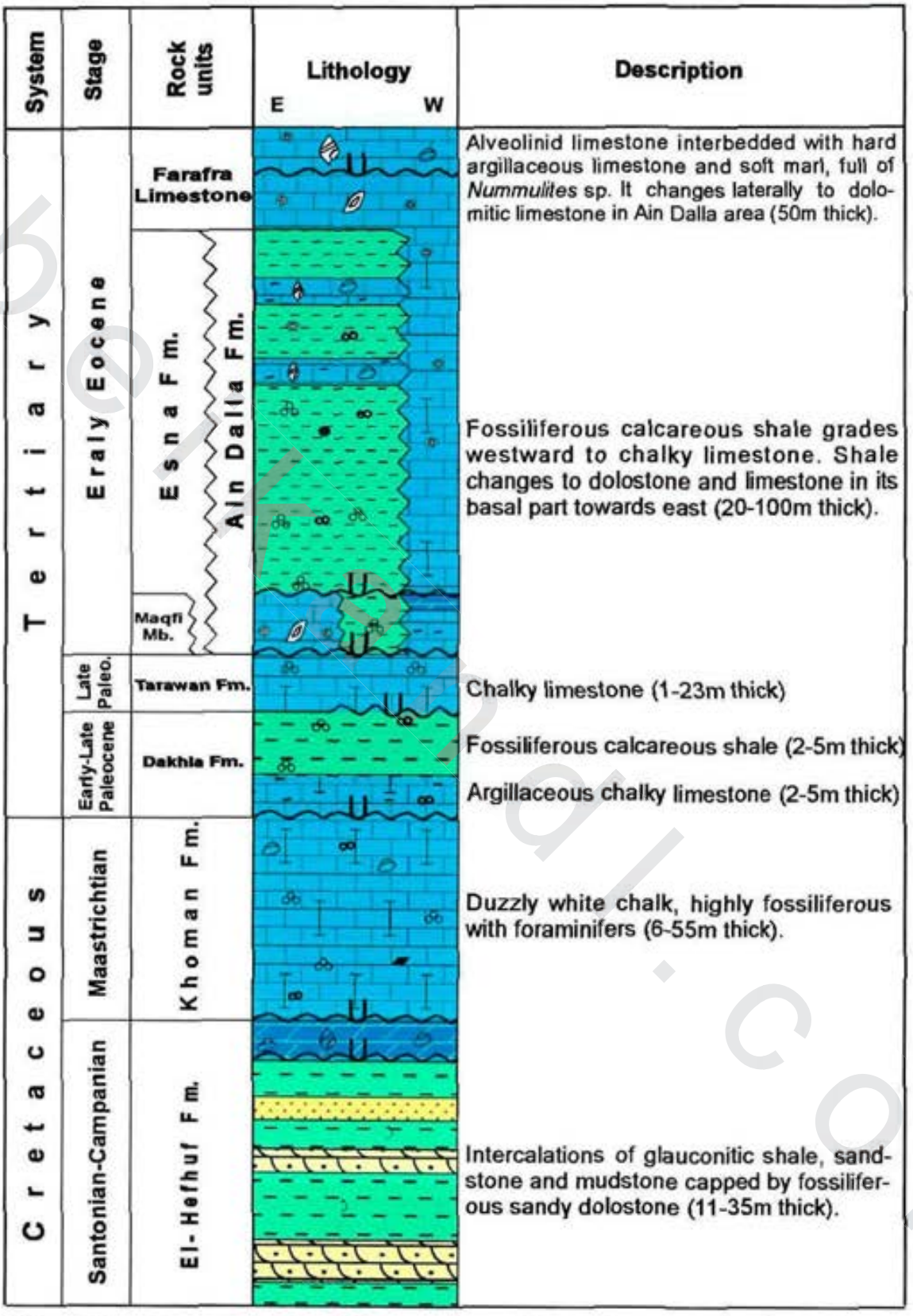


Fig. 2.1 Generalized lithostratigraphic column of the Upper Cretaceous-Lower Eocene succession exposed in the Farafra Oasis. Not to scale.

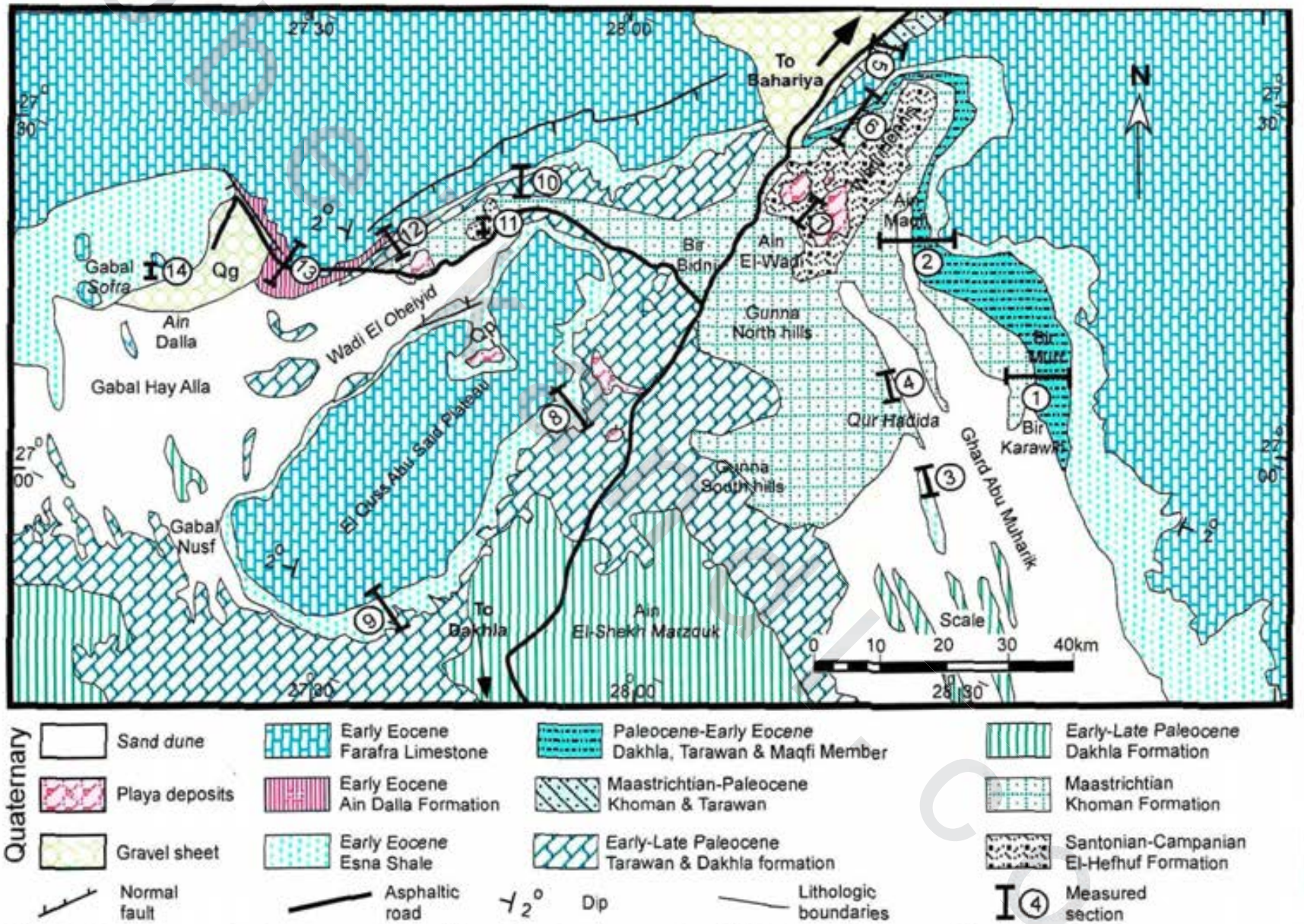


Fig. 2.2 Photogeologic map of the Farafra Oasis, central Western Desert, Egypt.

Table 2.1 The location of the studied sections in the Farafra Oasis.

Measured sections	Location
1. Bir Murr section	Lat. 27° 11′ 24″
	Long. 28° 37′ 7″
2. Ain Maqfi section	Lat. 27° 23′ 59″
	Long. 28° 27′ 44.5″
3. Qur Hadida section	Lat. 27° 7′ 15″
	Long. 28° 19′ 13″
4. Southeast Qur Hadida section	Lat. 27° 00′ 57″
	Long. 28° 24′ 1″
5. South Qaret Sheikh Abd Alla section	Lat. 27° 38′ 40″
	Long. 28° 24′ 43″
6. Northwest Ain Maqfi	Lat. 27° 31′ 04″
	Long. 28° 21′ 34″
7. Wadi Hennis section	Lat . 27° 18′ 43″
	Long. 28° 13′ 45″
8. Northern slope of El Quss Abu Said section	Lat. 27° 6′ 23″
	Long. 27° 51′ 33″
9. Southern slope of El Quss Abu Said section	Lat. 27° 49′ 35″
	Long. 27° 34′ 25″
10. Northwest Bir Bidni (about 30km in Farafra-Ain Dalla road).	Lat. 27° 22′ 48″
	Long. 27° 49′ 42″
11. East Shakhs El-Obeiyid section	Lat. 27° 20′ 56″
	Long. 27° 44′ 52″
12. Shakhs El-Obeiyid section	Lat. 27° 17′ 42″
	Long. 27° 35′ 23″
13. Ain Dalla section	Lat. 27° 23′ 37″
	Long. 28° 23′ 39″
14. Gabal Sofra section	Lat. 27° 17′ 8″
	Long. 28° 13′ 49″

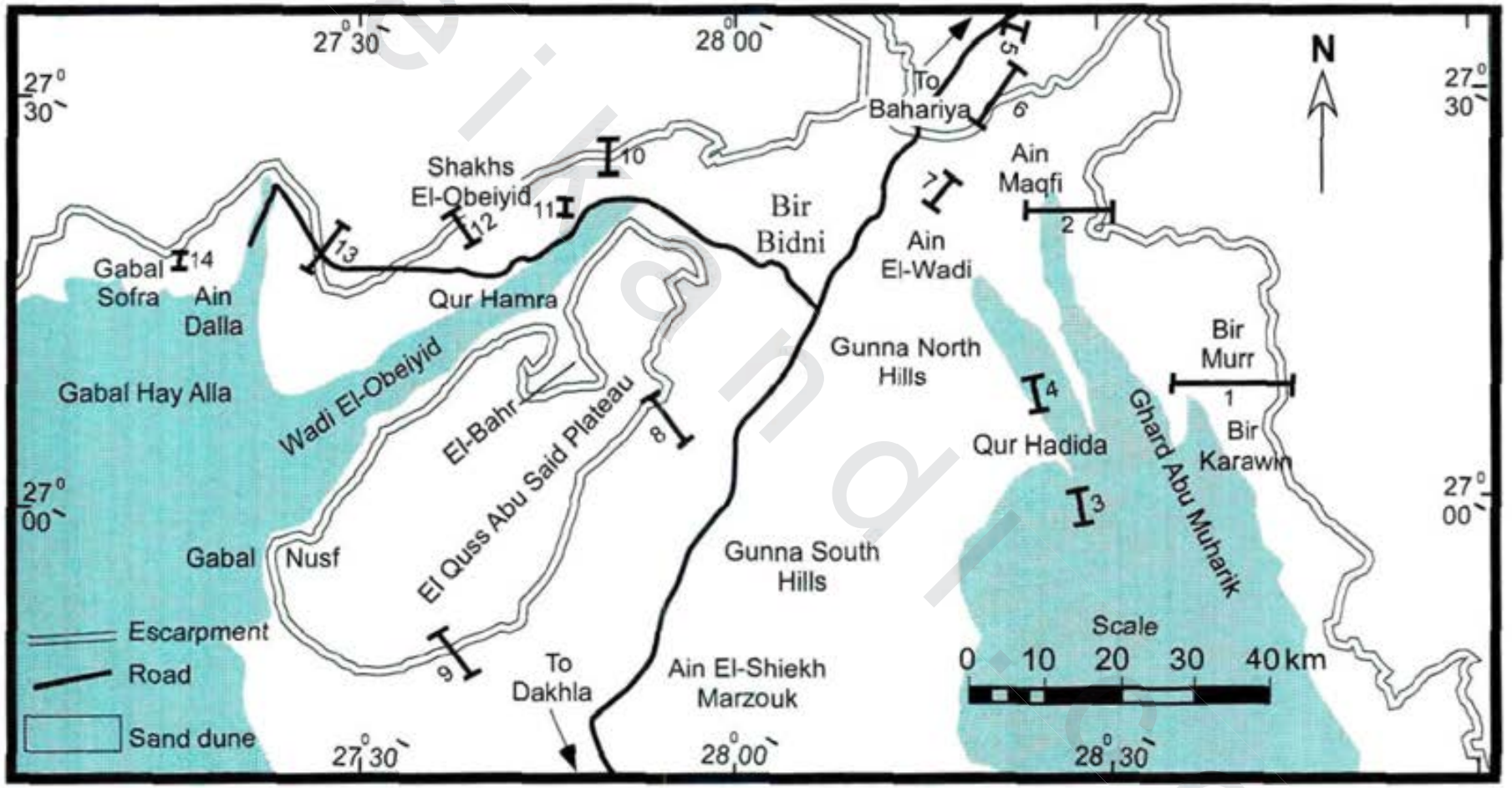


Fig. 2.3 Location map of the Farafra Oasis showing the measured stratigraphic sections.

The following is a detailed lithostratigraphic description of the detected Upper Cretaceous-Lower Eocene formations in the Farafra Oasis, given from older to younger:

II.1 El-Hefhuf Formation

Author: The predominantly clastic succession exposed at the base of Gabal El-Hefhuf, Bahariya Oasis, was first described by Lebling (1919), who dated it to the Santonian. The term El-Hefhuf Formation was later introduced by Said (1962), El-Akkad and Issawi (1963), Hermina (1990) and Issawi *et al.* (1996) to designate this succession.

Type area: Gabal El-Hefhuf, Bahariya Oasis.

Thickness at the study area: The maximum exposed thickness of El-Hefhuf Formation in the Farafra Oasis is 34m at south Wadi Hennis, which decreases to about 15m thick at the north of Wadi Hennis, forming low hillocks, while the exposed thickness at east Shakhs El-Obeiyid is only 11m.

Age assignment and correlation: A Turonian–Santonian age was suggested to El–Hefhuf Formation by Said (1962), Franks (1982), Abu El-Hassan (1994), Ibrahim and Abdel–Kireem (1997) and Abdel Mohsen (2002). El-Akkad and Issawi (1963), Ismail and Abdel–kireem (1985) and Klitzsch and Hermina (1989) gave a Campanian age to this formation. Khalifa *et al.* (2002b) dated a Turonian–Santonian age to the clastic bed underling the upper dolostone bed of Campanian–Maastrichtian age. In the present study and according to the macrofossil content, shark teeth and the stratigraphic position, the clastic deposits of El-Hefhuf Formation assigned this unit to the Santonian age, which is terminated with phosphatic sandy dolostone and fossil bank of a proper Campanian age. Weiler (1935) identified nine fish teeth species in

the phosphatic beds at El–Hefhuf area and argued that seven of these species are common in the phosphatic deposits widely exposed at several localities in the Eastern Desert of Egypt.

The top part of El–Hefhuf Formation is equivalent to the 10m thick compact dolomitized limestone bed described by Barakat and Abd El–Hamid (1973) in the Farafra subsurface succession. It is most likely to correlate the clastic sediments of El-Hefhuf Formation in the Farafra area with the upper part of its middle member given by El–Akkad and Issawi (1963) in its type locality. The top carbonate sediments may be correlated with the upper member of El-Hefhuf Formation in its type locality and partly with the Duwi Formation in the Dakhla and Kharga oases, south Western Desert. The studied sections of El–Hefhuf Formation also correlate with Ain Giffara Formation established by Khalifa (1977) in Gabal El–Hefhuf, Bahariya Oasis. El–Hefhuf Formation is equivalent to the lower Santonian-Campanian part of the subsurface Khoman Formation in the north Western Desert.

Lithology: El-Hefhuf Formation represents the oldest exposed rocks in the Farafra Oasis (Fig. 2.1). El-Akkad and Issawi (1963) gave a detailed description for El-Hefhuf Formation in its type locality in the Bahariya Oasis. There, it consists of three members. The basal member is made up of brecciated, siliceous dolostone, the middle member consists of alternating argillaceous and arenaceous beds with phosphatic grit toward its top, and the upper member is composed of hard siliceous dolostone occasionally phosphatic at its base. They stated that this formation extends far beyond the Bahariya Oasis, having been noticed to cover parts of the Bahariya-Farafra road and from several outcrops especially at the descent to Ain El-Khadr, Ain El-Wadi and the adjacent areas.

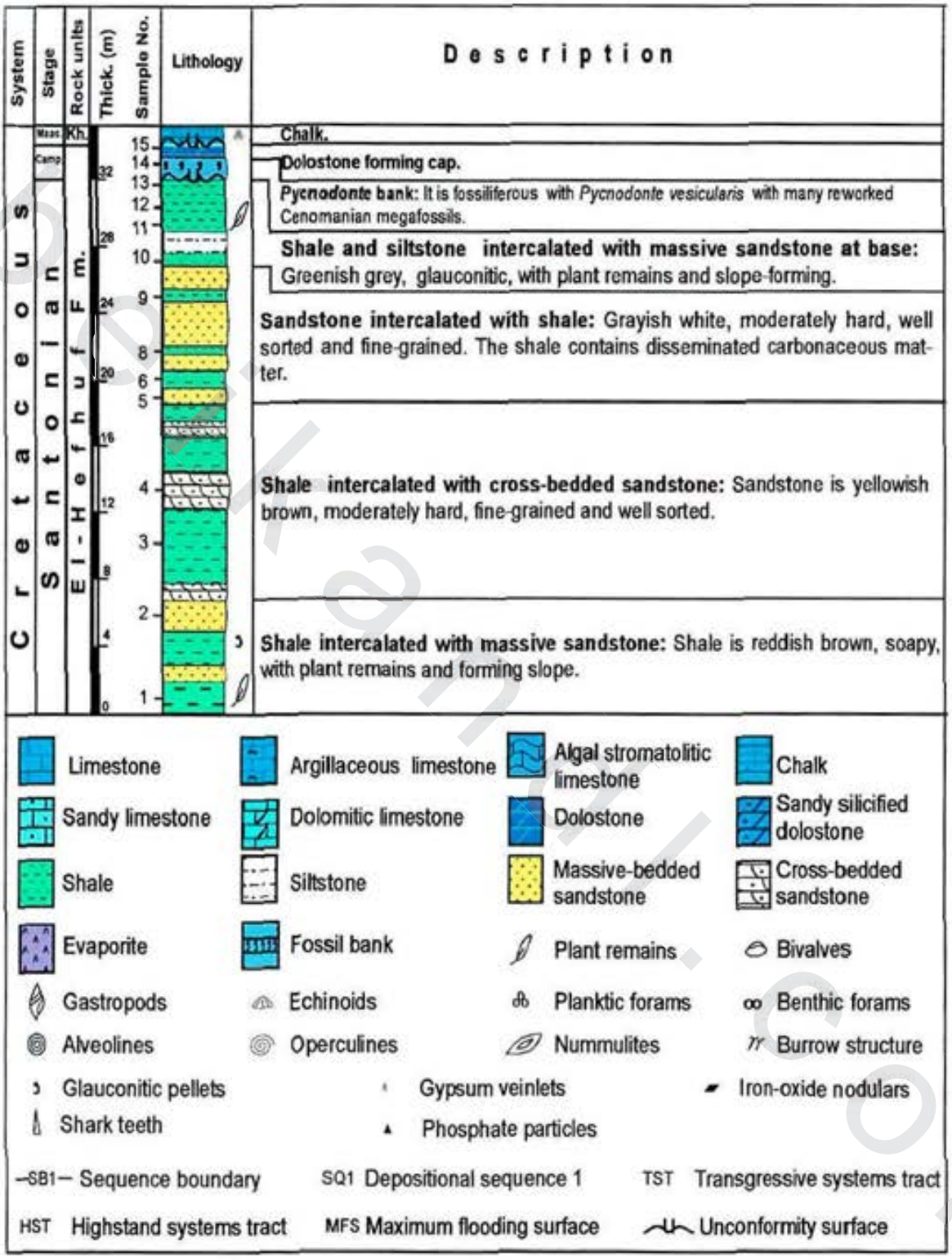


Fig. 2.4 Stratigraphic succession of the Santonian-Maastrichtian rocks exposed in Wadi Hennis, northeast Farafra Oasis.

At Wadi Hennis, El-Hefhuf Formation is composed of a clastic sequence of sandstone, shale and siltstone partly glauconitic, which is terminated with a bank of *Pycnodonte vesicularis* followed by a dolostone bed (Fig. 2.4). The sandstone is grayish white to yellowish brown, moderately hard, fine-grained, well sorted, ferruginous and massive to cross-bedded with inclinations up to 20°. Cross bedding is a common feature in the lower part of the calstic sequence. The shale and mudstone are reddish brown, greenish gray, slope forming, soapy, fissile and partly glauconitic (Fig. 2.5). They occasionally contain disseminated carbonaceous matter and plant remains. This clastic sediment is barren of foraminiferal content and megafossils.

Fig. 2.5 The siliciclastic deposits of El-Hefhuf Formation in Wadi Hennis. Photo is looking northeast.

The topmost part of El-Hefhuf Formation consists of 2m thick fossil bank and phosphatic sandy dolostone (Fig. 2.4). It is highly fossiliferous with large, well preserved bivalves of *Pycnodonte vesicularis* (Lamarck), 4cm in height and 7cm in

length (Fig. 2.6). Fauna is commonly found in random orientation. There is some evidence of reworking whereas disseminated fossils of Cenomanian age such as *Ilymatogyra* (*Afrogyra*) *africana* (Lamarck) and *Ceratostreon flabellatum* (Goldfuss) are present with the *Pycnodonte vesicularis* (Lamarck). This indicates that Wadi Hennis was an ancient topographic low and received reworked Cenomanian fauna from the surrounding high of the Bahariya and El-Heiz formations during deposition of the *Pycnodonte vesicularis* (Lamarck). The dolostone forming the cap rocks of El-Hefhuf Formation is pale brown to yellowish brown, very hard, massive, cavernous, fractured and partly ferruginated with iron-oxide spots together with manganese dendrites (Fig. 2.7).

In east Shakhs El-Obeiyid, the upper part of El-Hefhuf Formation form isolated hillocks (Figs. 2.8 & 2.9). It is composed of two units with a sharp contact inbetween. The lower unit is consists of 2.5m thick fissile shale with gypsum veinlets. The upper unit, 8m thick, starts with phosphatic sandy dolostone with common shark teeth and burrows. The latter have different straight, bifurcated and flask shapes. At the top part of this bed, there are iron nodules, oxidized porifera and other badly preserved fossils. It is followed by intercalated soft and hard sandy argillaceous limestone. The top part of this unit is marked by 1.5 m thick dolostone and fossil bank enriched in casts of *Pycnodonte vesicularis* (Fig. 2.8). Shark teeth are found at different levels in this section but decrease in abundance upward. The shark teeth may reach up to 3-4cm in length. It is worth mentioning that the 6.5m thick sandy argillaceous limestone beds below the fossil bank and dolostone are not recorded in Wadi Hennis area; most probably eroded away before deposition of the fossil bank.

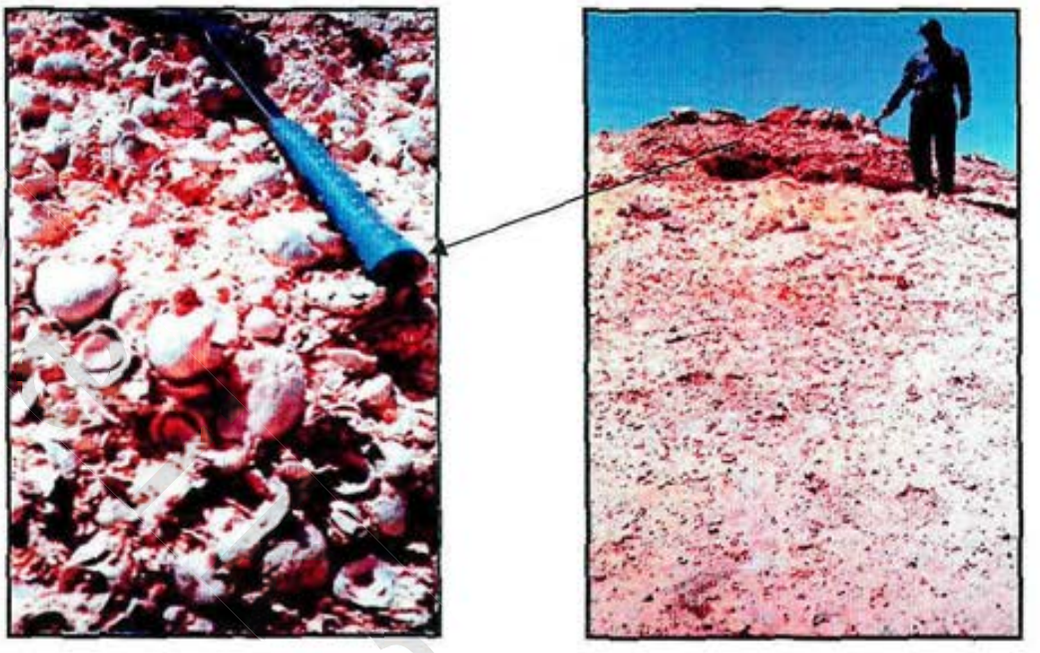


Fig. 2.6 Oyster bank mainly formed of *Pycnodonte vesicularis* (Lamarck) overlying soft shale in the topmost part of El-Hefhuf Formation, in Wadi Hennis.

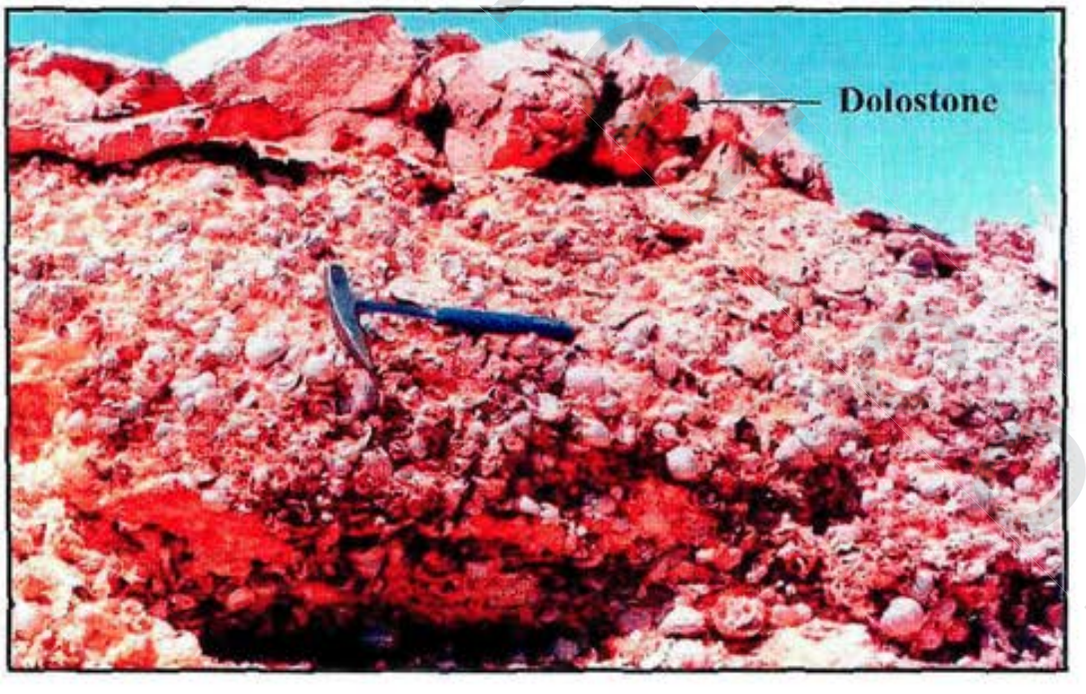


Fig. 2.7 Hard dolostone bed capped the *Pycnodonte vesicularis* fossil bank in the topmost part of El-Hefhuf Formation, Wadi Hennis.

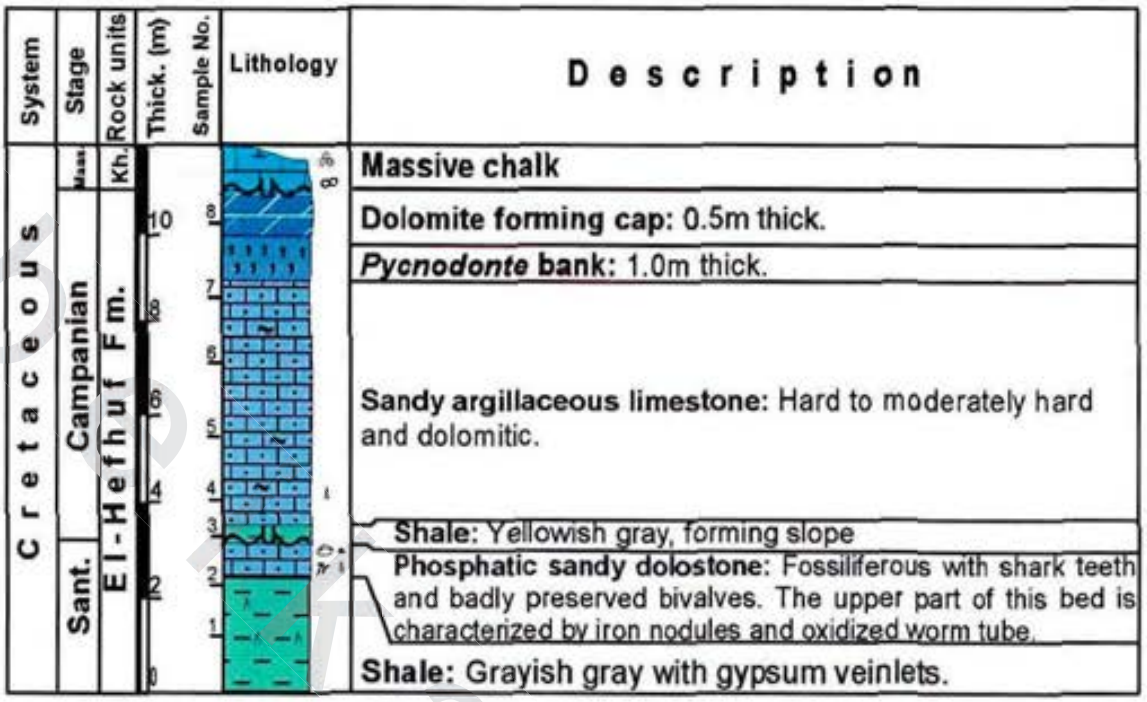


Fig. 2.8 Stratigraphic succession of the Santonian-Maastrichtian rocks exposed in east Shakhs El-Obeiyid, northwest Farafra Oasis.

Fig. 2.9 Isolated hillock forming the top part of El-Hefhuf Formation that crops out to the east of Shakhs El-Obeiyid. Photo is looking west.

Stratigraphic limits: Issawi *et al.* (1999) mentioned that the contact between El-Hefhuf Formation and the overlying Khoman Chalk is very gradational and conformable. This contact is sharp irregular in the Farafra Oasis.

Areal distribution: El-Hefhuf Formation is widely distributed in the Bahariya Oasis. It is only exposed in Wadi Hennis and east Shakhs El-Obeiyid in the Farafra Oasis.

Important fossil elements: The bivalves recorded in the topmost part of El-Hefhuf Formation are: *Pycnodonte vesicularis* (Lamarck), *Neithea coquendi* (Péron) and reworked Cenomanian fossils of *Ilymatogyra* (*Afrogyra*) *africana* (Lamarck) and *Ceratostreon flabellatum* (Goldfuss). In addition, some gastropods as *Cerithium tenouklense* (Coquand), porifera, ammonites, shark teeth and skeletal fish remains are recorded.

Discussion: The following discussion shows the multitude of the formational names and ages given by different authors to describe the oldest exposed rocks in the Farafra Oasis.

The clastic rocks of El-Hefhuf Formation represent the Nubia Group of Omara *et al.* (1970) and Barakat and Abdel Hamid (1974) and the Wadi Hennis Formation of Dominik (1985). While the topmost part of El-Hefhuf Formation invokes Ain El Wadi Limestone of Omara *et al.* (1970) and the compact dolomitized limestone of Barakat and Abdel Hamid (1974).

Recently, Khalifa and Zaghloul (1989) named the clastic sediments at Wadi Hennis the Nubia Formation (Santonian-Campanian) and mentioned that these sediments are followed by 1.5m thick phosphatic sandstone and then 1m thick sandy dolostone. They termed the latter two beds as Ain Giffara Formation (Campanian-Maastrichtian). The Ain Giffara

Formation was first introduced by Khalifa (1977) at Gabal El-Hefhuf, Bahariya Oasis. He pointed out that Ain Giffara Formation simply represents the upper member of El-Hefhuf Formation of El-Akkad and Issawi (1963) and marks an unconformable contact between Ain Giffara Formation and the underlying two units of El-Hefhuf Formation. Khalifa *et al.* (2002a) used the term Ain Giffara Formation again at Wadi Hennis to include both the clastic sediments and the overlying dolostone of Campanian-Maastrichtian age. In the same year, Khalifa *et al.* (2002b) named the clastic beds as Naqb El Sellim Formation (Turonian-Santonian) and the upper phosphatic dolostone bed as Ain Giffara Formation. The present paleontological analysis and the stratigraphic position prove that El-Hefhuf Formation is dated as Santonian-Campanian and equivalent to the middle and upper parts of El-Hefhuf Formation at its type locality, Bahariya Oasis.

II.2 Khoman Formation

Author: Zittel (1883) and Beadnell (1901) established the term white chalk for the Danian sediments. Ball and Beadnell (1903) used the name chalk and gave number 5 to this unit in the succession of the Bahariya Depression. Said and Kerdany (1961) and said (1962) used the term Chalk, while El-Akkad and Issawi (1963) used the name Chalk Formation for the Maastrichtian rocks. The term Khoman Chalk is applied by Beckman *et al.* (1967), while Youssef and Abdel El-Aziz (1971) coined the Farafra Chalk as a new name to these rocks.

Type area: No exact location is given; generally, the scarp face to the west of Ain Khoman, south Bahariya Oasis, is used as the type locality.

Thickness: The thickness of the Khoman Formation varies from one locality to other. It reaches its maximum thickness in the northern escarpment of the Farafra Oasis where the thickness is in excess of 55m (Table 2.2). In other parts of the Farafra Oasis, only the topmost part of the Khoman Formation is exposed such as in east Qaret Sheikh Abd Alla, Ain Maqfi, Bir Murr, NE Bir Bidni, Shakhs El-Obeiyid and Qur Hadida.

Table 2.2 The varied thickness of the Khoman Formation in the Farafra Oasis.

Locality	East Qaret Sheikh Abd Alla	NW Ain Maqfi	Ain Maqfi	Bir Murr	NE Bir Bidni	Shakhs El-Obeiyid	Qur Hadida
Thickness	6m	55m	4m	6m	30m	5m	15m

Age assignment and correlation: Hewaidy and Strougo (2001) and Khalil and El-Younsy (2003) considered the Khoman Formation to range in age from Early Maastrichtian to Danian. In the present work, a Maastrichtian age is given to the Khoman Formation. It is possible to correlate the Khoman Formation in the Farafra Oasis with the Mawhoob Shale and Beris Mudstone members of the Dakhla Formation in the Dakhla Oasis and with the Sudr Formation in the Sinai and Eastern Desert of Egypt. The Khoman Formation is equivalent to the subsurface Khoman-A Member in the north Western Desert.

Lithology: The Khoman Formation is made up of snow-white chalk, which is moderately hard, massive, fine-grained and fractured with calcite fillings and limonitic concretions. The fundamental lithologic characteristics of this formation are the lack of any terrigenous components and the rather homogeneous lithology all over the study area (Fig. 2.10). The chalk is highly fossiliferous with foraminiferal assemblage, which may contain rare macrofossils.

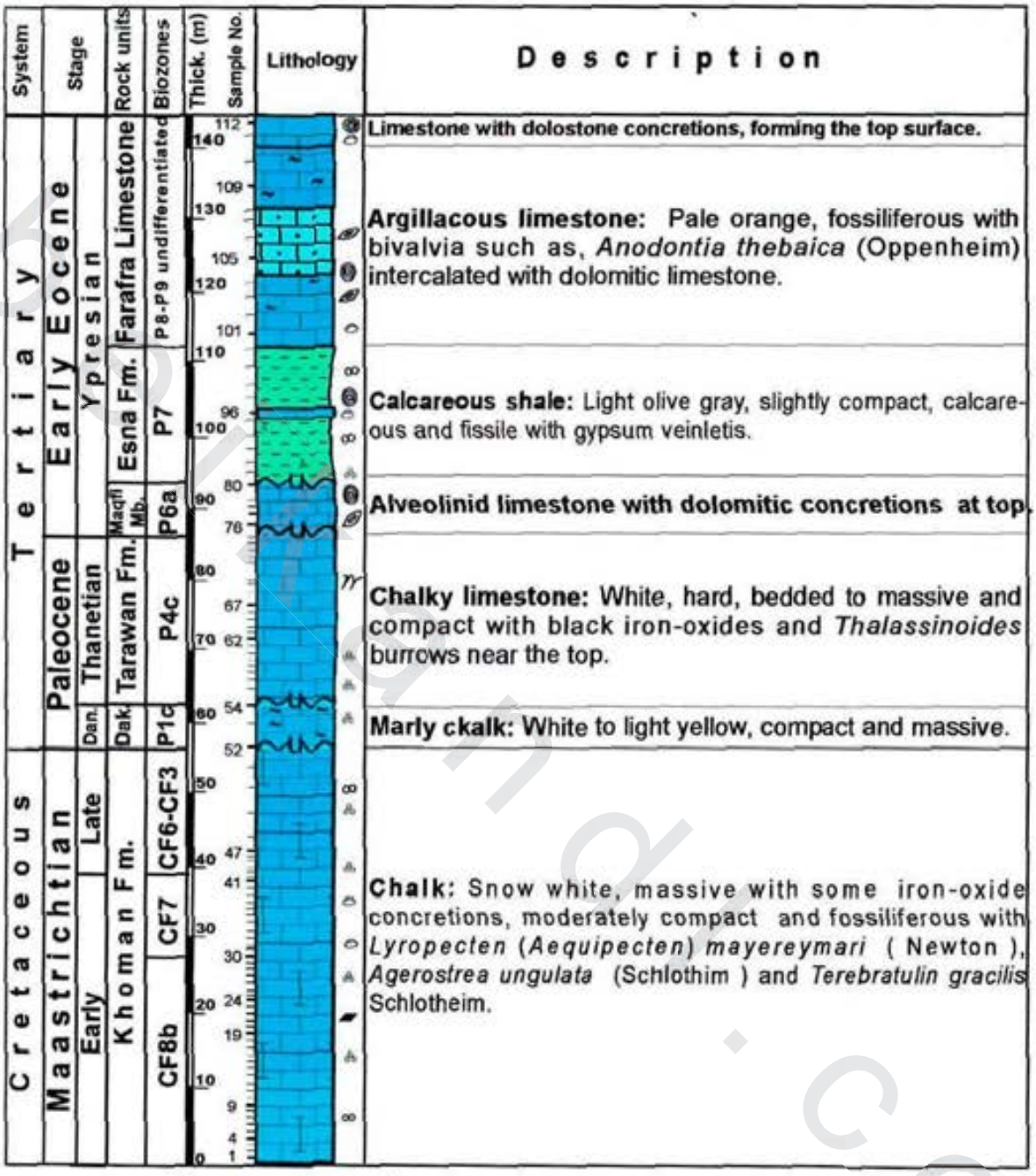


Fig. 2.10 Stratigraphic succession of the Maastrichtian-Lower Eocene rocks exposed in northwest Ain Maqfi area, northeast Farafra Oasis.

In some instances, fine limonitic grains are disseminated in the chalk. The plain at the foot of the chalk sediments is sometimes covered by loose small iron-oxide nodules, which are separated from the easy eroded chalk. Intrakarstic deposits formed

by hidden valleys are recorded stand against the Khoman Formation in north Ain El-Wadi area (Fig. 1.8). Another intrakarstic dolostone deposits are traced to overlie the Khoman Formation toward the northeastern escarpment (Fig. 1.9). These deposits have a wide areal distribution in the northeastern part of the Farafra Oasis.

At Qur Hadida area, the chalk of the Khoman Formation is followed by a succession of dolostone intercalated with mudstone (Figs. 2.11 & 2.12). Dolostone is ledge-forming, iron-rich and rarely burrowed. It contains algal stromatolites at different levels near the top part of Qur Hadida hills (Fig. 2.13). The algal stromatolites are of domal shape, rarely low crenulated with 20-30cm height, 30-40cm width and laminae thickness ranging from 1–4mm. The top part of the Khoman Formation in Qur Hadida area is partly fossiliferous with badly-preserved pelecypods, benthics and planktics (*Heterohelix* and *Rugoglobigerina*). This

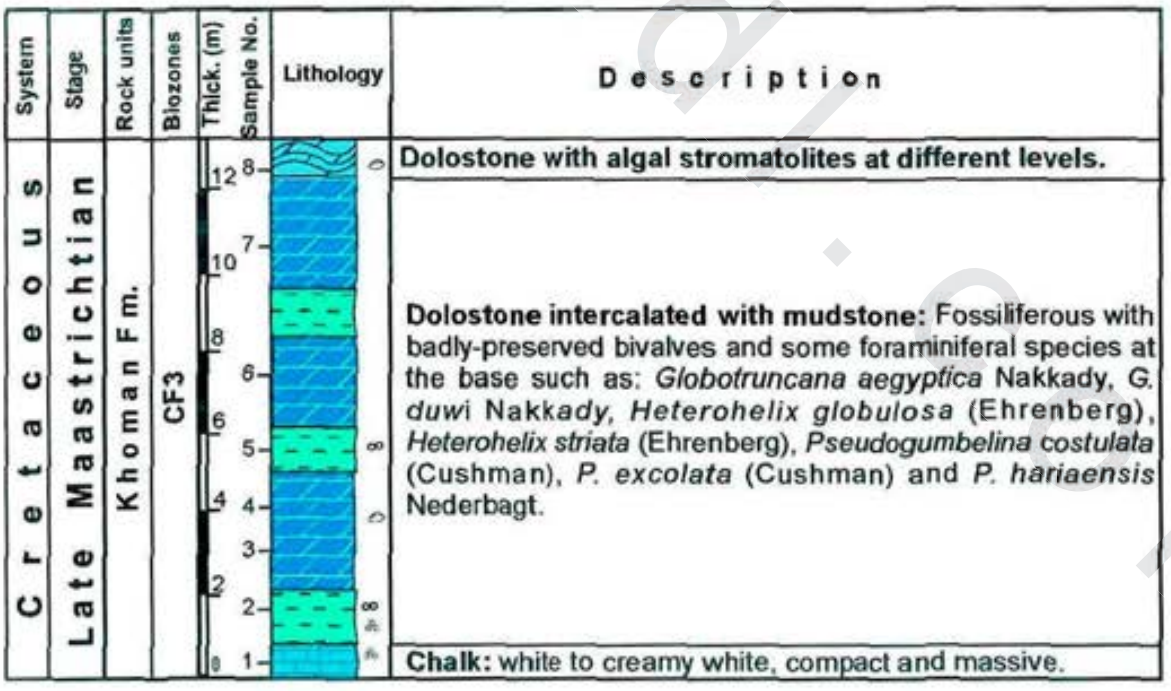


Fig. 2.11 Stratigraphic succession of the Upper Maastrichtian rocks exposed in Qur Hadida area, east Farafra Oasis.

Fig. 2.12 General view of the succession measured at Our Hadida area showing the alternating dolostone and mudstone beds capping the Khoman Chalk. Photo is looking north.

Fig. 2.13 Low-domed algal stromatolites forming the top of the Khoman Formation at Our Hadida area.

fauna is often crushed due to the agitation in the very shallow regime under which these deposits have been formed. In the Bahariya Oasis, the top part of the Khoman Formation is also composed of hard dolomitic limestone beds (Issawi *et al.*, 1999).

The Khoman Formation changes laterally and gradually into the Dakhla Formation at Abu Minqar and Dakhla Oasis to the south of the Farafra Oasis. It is completely replaced by the shale of the Dakhla Formation in the Dakhla and Kharga oases.

Stratigraphic limits: An important disconformity surface exists between the Early-Late Maastrichtian and the Early Paleocene in the Farafra Oasis. This disconformity, however, cannot be easily recognized in the field and is only demarcated by a faunal break. It marks the top part of the Khoman Formation. This disconformity surface denotes a sedimentation break between the Lower-Upper Maastrichtian Khoman Formation and the Lower-Middle Paleocene Dakhla Formation. The top of the Khoman Formation in Ain Maqfi area coincides with the major extinction of the Cretaceous planktic species at the Cretaceous/Tertiary boundary. Along this unconformable boundary, the chalk changes upward into more argillaceous chalk with a yellowish white color; quite different from the underlying snow-white color.

At the northern descent to the Farafra depression, the Cretaceous-Paleocene disconformity consists of an interval, 10-15cm thick, of reworked chalk pebbles, littered with burrows. At Gunna North, thick burrowed interval is identified at the top of the Khoman Formation. It covers the floor of the northern part of the Farafra depression. In Wadi Hennis, the Khoman Formation unconformably overlies El-Hefhuf Formation. The contact is sharp irregular separating between the topmost dolostone bed of El-Hefhuf Formation and the chalk of the Khoman Formation.

In south Qaret Sheikh Abd Alla, the Khoman Formation is directly overlain by the Upper Paleocene Tarawan Formation. While in the Bahariya Oasis, the Upper Cretaceous sediments are unconformably overlain by the Lower Eocene carbonate sediments (Issawi *et al.*, 1999).

Kerdany and Cherif (1990) regarded the absence of the uppermost Maastrichtian sediments at the top part of the Khoman Formation in many localities of the north Western Desert as a probable reflection of the Late Cretaceous to Paleocene tectonic movement (Laramide tectonic phase).

Areal distribution: The Khoman Formation is widely distributed throughout the floor of the Farafra Oasis. It extends over a wide area especially in the northern part of the depression. The formation makes up the foot slopes of the Gunna North inselbergs and the eastern scarp of the Farafra Oasis as well as in the floor of the Farafra till Qur Hamra.

Important fossil elements: A rich planktic foraminiferal assemblage is recorded in the Khoman Formation such as *Globotruncana aegyptiaca* Nakkady, *G. arca* (Cushman), *Globotruncanita stuarti* (de Lapparent) and *Rugoglobigerina macrocephala* Brönneimnn. These in addition; to the macrofossil assemblage of *Lyropecten* (*Aequipecten*) *mayereymari* (Newton), *Agerostrea ungulata* (Schlotheim) and *Pycnodonte* (*Pycnodonte*) *vesicularis* (Lamarck). *Terebratulina gracilis* Schlotheim is the most characteristic faunal element in the top part of the Khoman Formation.

Discussion: A great confusion exists in the past concerning the stratigraphic position of the chalk cropping out in and around the floor of the Farafra Oasis and its correlation with other districts.

LeRoy (1953) correlated the chalk at the base of Ain Maqfi

section (unit A) with that forming the floor at El Quss Abu Said and with the white chalk in the Dakhla and Kharga oases, and considered this unit of Late Cretaceous (Maastrichtian).

Issawi (1972) considered the chalk in the Farafra Oasis to be stratigraphically and paleontologically lower than the Tarawan Chalk, which is equivalent to the Dakhla Shale of the southern oases of the Western Desert.

Youssef and Abdel Aziz (1971) assigned to the chalk forming the floor of the Farafra depression a new name, the Farafra Chalk, and gave it a Maastrichtian (probably Middle Maastrichtian–Late Danian) age, while the upper one or two meters yielded a Late Danian fauna. The term Farafra Chalk is synonymous with the present Khoman Formation.

Barthel and Herrmann-Degen (1981) extended the concept of the Tarawan Chalk (which is Late Paleocene throughout Egypt) to include the Maastrichtian part of the chalk exposed in the Farafra Oasis. They mentioned that the Tarawan Formation covers the time span from at least Late Maastrichtian with faunal assemblage such as *Gansserina gansseri* Bolli, *Globotruncana conica* White and *Globotruncana aegyptiaca* Nakkady to Thanetian with faunal assemblage as *Igorina pusill* (Bolli) and *Morozovella angulata* (White). In the present work, the Dakhla Formation separates the Khoman Formation from the Tarawan Formation.

II.3 Dakhla Formation

Author: The term "Dakhla Shale" was firstly introduced by Said (1961).

Type area: Gabal Gifata in the Dakhla Oasis.

Thickness: The Dakhla Formation in the Farafra Oasis is represented by a thickness of a few meters, ranging from 1-10m thick.

Age assignment and correlation: Mansour *et al.* (1982) and Tantawy *et al.* (2001) mentioned that the Dakhla Formation is of Maastrichtian to Early Paleocene age at the Dakhla Oasis. El-Azabi and El-Araby (2000) gave a Late Maastrichtian-Middle Paleocene age to the Dakhla Formation. In the present work, an Early to Middle Paleocene age (Danian-Selandian) is given to the Dakhla Formation in the Farafra Oasis. The Dakhla Formation in the Farafra Oasis is represented by the uppermost part of the Kharga Shale Member of the Dakhla Shale at its type locality, Dakhla Oasis.

Lithology: The Dakhla Formation is subdivided by Mansour *et al.* (1982) from base upward into the Mawhoob Shale, the Beris Mudstone, the Kharge Shale and the Qur El Malik sandstone members. In the present study, the Dakhla Formation is only represented by the uppermost part of its Kharga Shale Member, whereas the other lower subdivisions are replaced by the Khoman Formation. Generally, the Maastrichtian Mawhoob Shale and Beris Mudstone members change laterally into Khoman Formation north of Latitude 27° 00′. The Dakhla Formation in the Farafra Oasis consists of two units (Fig. 2.14); the lower unit consists of argialleous chalk with reworked foraminiferal fossils of Maastrichtian age in its lowermost part. This indicates the presence of an unconformity at the base of the Dakhla Formation. The upper unit, on the other hand, is formed of fissile calcareous shale with many gypsum veinlets. In north Ain El-Wadi, the Dakhla Formation is marked by 2m thick argillaceous chalk of Early Paleocene.

In the desert area lying to the southeast of Abu Minqar, the upper part of the Dakhla Formation is represented by a very peculiar facies. It consists of a brown sandy limestone packed with vermetid (gastropod) shells and a rich assemblage of other molluscs. This peculiar facies has been first noticed by Barthel

and Herrmann-Degen (1981). The thickness of this vermetid facies decreases from 14m in the southeast to pinch out in the northwest; over a stretch of about, 5km pinching out occurs approximately 1km northwest of the Farafra-Abu Minqar road where it descends from the scarp. Barthel and Herrmann-Degen (1981) identified the *Morozovella uncinata* and *Morozovella angulata* zones from sample immediately below the base of the vermetid marls.

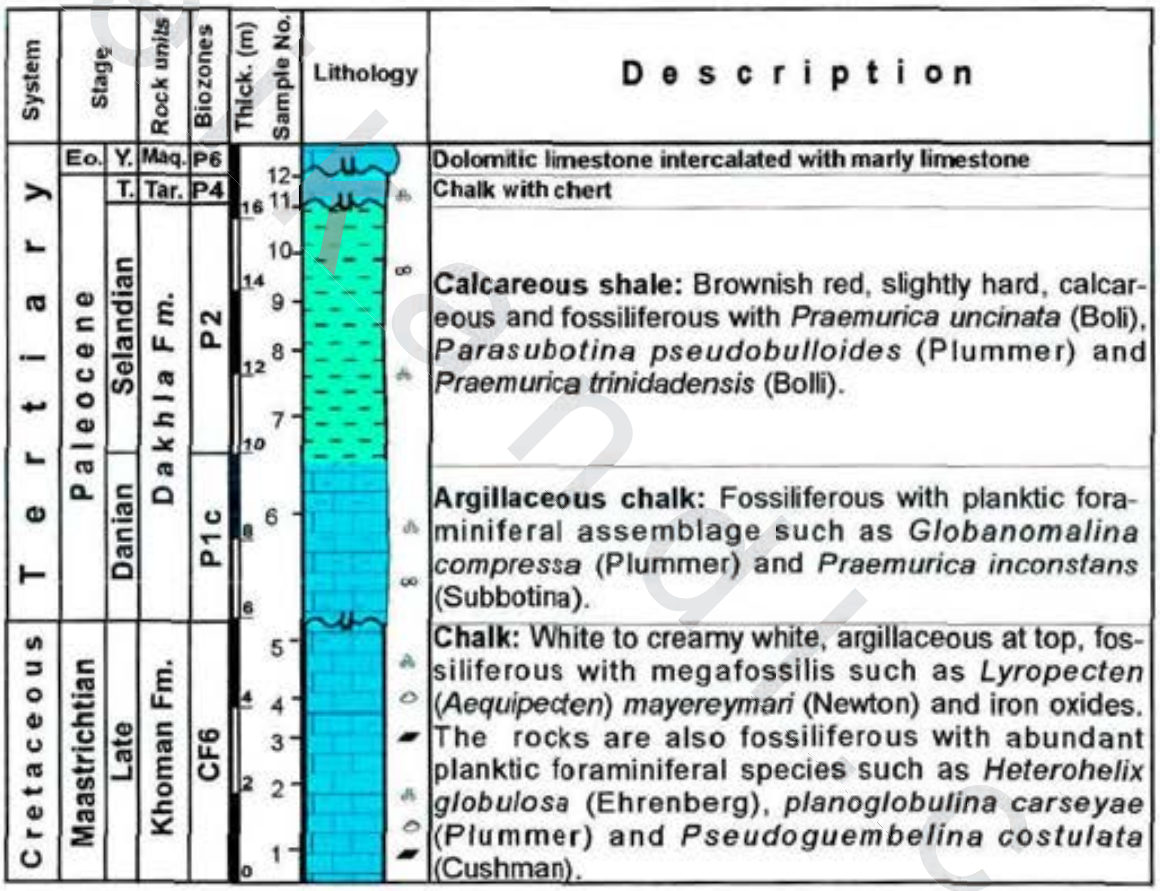


Fig. 2.14 Stratigraphic succession of the Upper Maastrichtian-Lower Eocene rocks exposed in Bir Murr area, east Farafra Oasis.

Stratigraphic limits: The Dakhla Formation unconformably overlies the Khoman Formation and unconformably underlies the Tarawan Formation (Fig. 2.15). In the eastern escarpment of the Farafra Oasis, the unconformable contact between the Dakhla Formation and the overlying Tarawan Formation is detected due to the absence of some foraminiferal zones such as in Bir Murr

and Ain Maqfi areas. While, in some other areas of the Farafra Oasis (e.g. northwest Bir Bidni and Gunna North) a conformable contact exists between the Dakhla Formation and the Tarawan Formation (Fig. 2.15 & 2.16).

Areal distribution: The Dakhla Formation is widely distributed in the central and southern parts of the Western and Eastern Deserts of Egypt. In the Farafra Oasis, the formation is absent in south Qaret Sheikh Abd Alla (Fig. 2.17), perhaps due to uplift of this area during deposition of the Dakhla Formation.

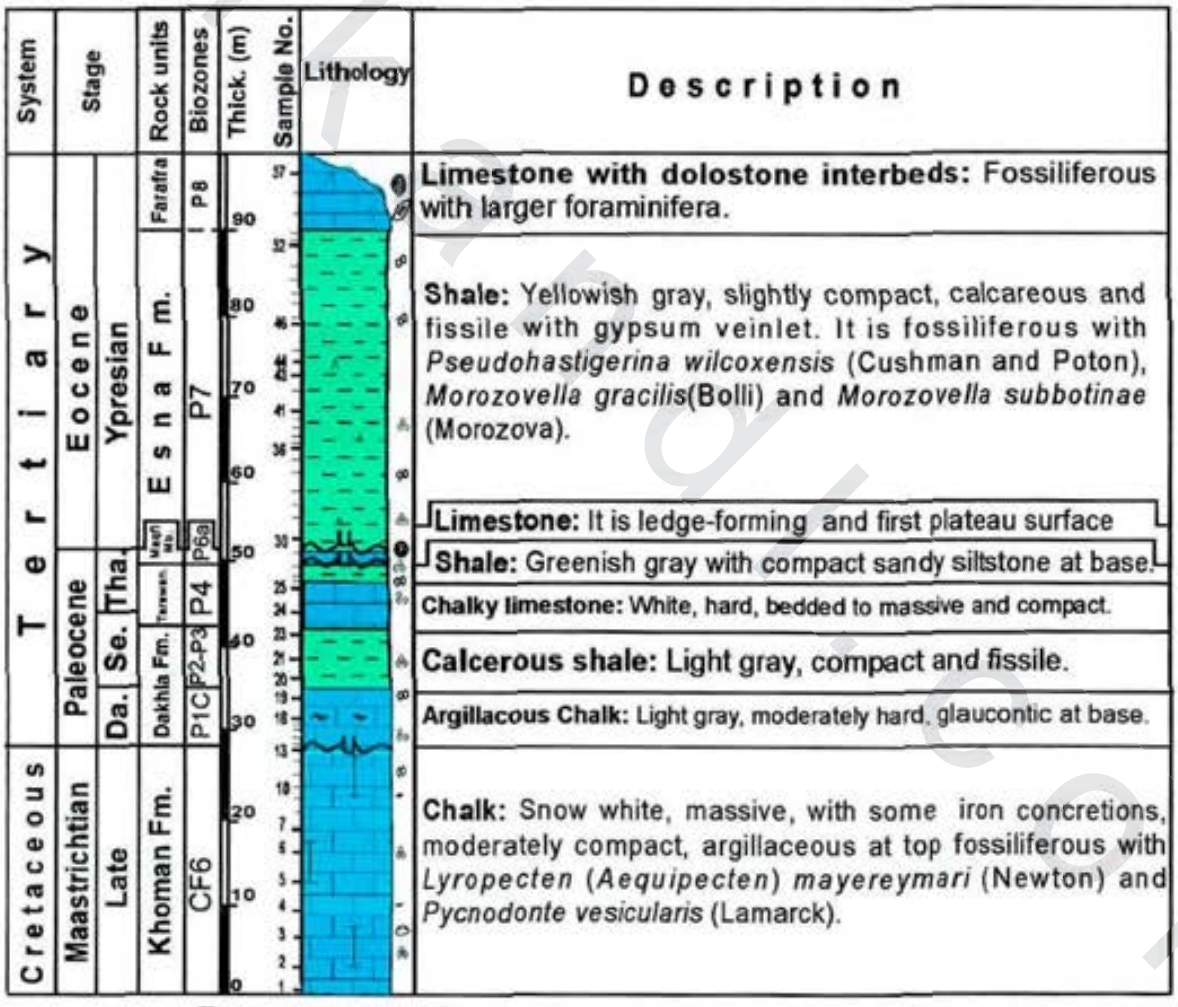


Fig. 2.15 Stratigraphic succession of the Upper Maastrichtian-Lower Eocene rocks exposed in northwest Bir Bidni (about 30km from Farafra-Ain Dalla passage), northwest Farafra Oasis.

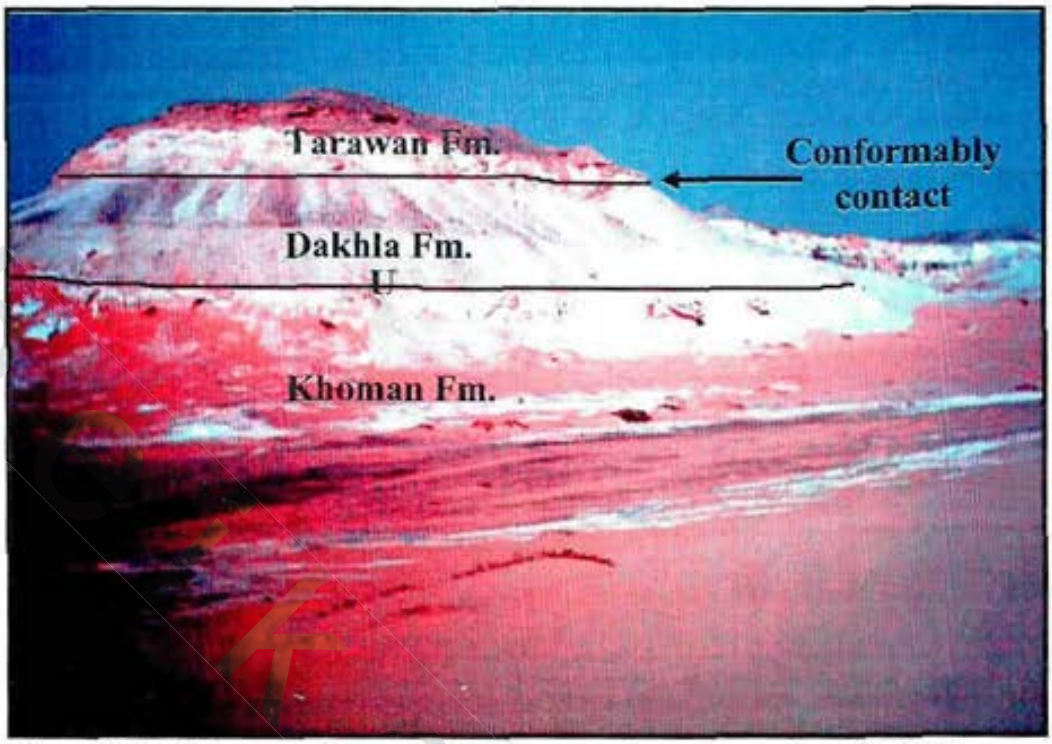


Fig. 2.16 The conformable contact between the Dakhla and Tarawan formations at northwest Bir Bidni. Photo is looking north.

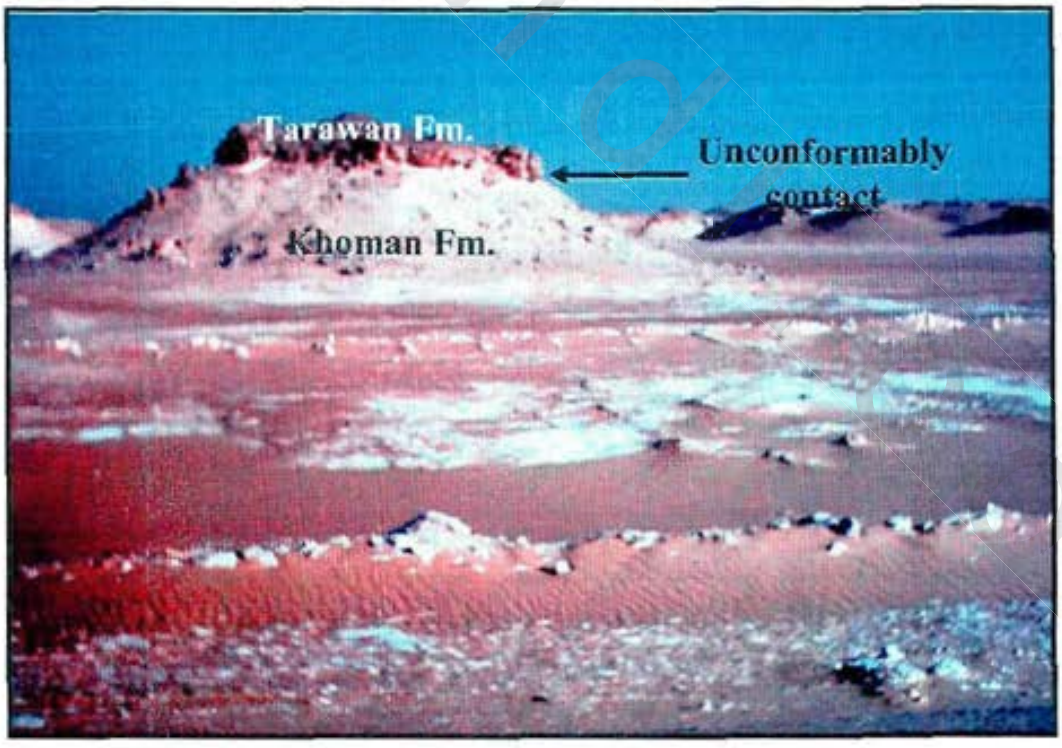


Fig. 2.17 The irregular unconformable contact between the Khoman and Tarawan formations marking the absence of the Dakhla Formation in south Qaret Sheikh. Photo is looking northeast.

Important fossil elements: A rich microfossil assemblage is recorded in the Dakhla Formation including *Parasubbotina pseudobulloides* (Plummer), *Praemurica trinidadensis* (Bolli), *P. uncinata* (Subbotina), and *P. inconstans* (Subbotina), *Morozovella angulata* (White), *M. conicotruncata* (Subbotina, 1947) and *Igorina pusilla* (Bolli). Brachiopods are the most characteristic megafossil elements in the lower part of the Dakhla Formation in the Farafra Oasis.

Discussion: Youssef and Abdel-Aziz (1971) mentioned that the 4.5m thick shale between the Tarawan Chalk above and the chalk forming the base of the succession in the Gunna North belongs to the Dakhla Shale. The lower three meters are of Late Danian age while the top part of the shale attributes to the Late Paleocene. The Middle Paleocene is missing.

Barthel and Herrmann-Degen (1981) pointed out that the Dakhla Formation in Ain Maqfi area lies between the Tarawan Formation of Maastrichtian–Paleocene age and considered both Khoman and Dakhla formations as a lower part of their Tarawan Formation.

II.4 Tarawan Formation

Author: The term Tarawan Formation was first introduced by Awad and Ghobrial (1965). LeRoy (1945) coined the term Abdalla Limestone to describe the Upper Paleocene rocks that crop out at Qaret Sheikh Abd Alla, which is considered as a synonymous with the Tarawan Formation (Issawi *et al.*, 1999).

Type area: Gabal Tarawan, Kharga Oasis, Western Desert.

Thickness: The Tarawan Formation varies considerably in thickness from 1m in Bir Murr to 23m in northwest Ain Maqfi (Table 2.3).

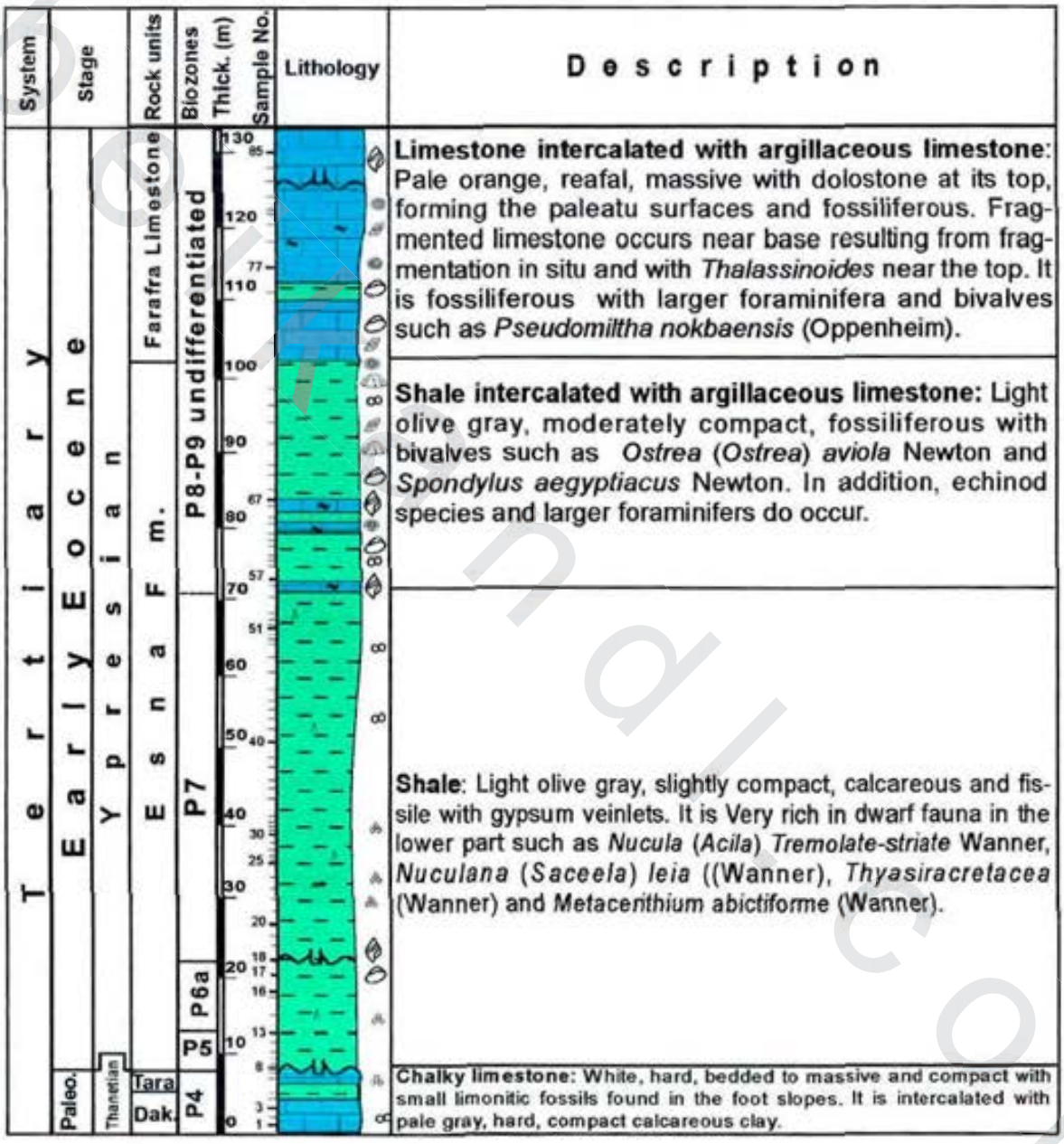
Table 2.3 The thickness variations of the Tarawan Formation in the Farafra Oasis.

Locality	East Qaret Sheikh Abd Aila	NW Ain Maqfi	Ain Maqfi	Bir Murr	NE Bir Bidni	Shakhs El-Obeiyid	El Quss Abu Said
Thickness	6m	23m	2m	1m	9m	34m	0.5-5m

Age assignment and correlation: The Tarawan Formation is assigned to the Late Paleocene (Thanetian) due to the presence of the *Globanomalina Pseudomenardii* (Bolli). It interfingers with the Kurkur Formation and the basal part of the Garra Formation in Abu Tartur-Kharafish Plateau and in south Kharga Oasis (Hermina *et al.*, 1990).

Lithology: The Tarawan Formation in the Farafra area has more or less the same lithology as in the Dakhla and Kharga oases. It is mainly composed of chalky limestone with intercalations of compact calcareous clay at the middle part in El Quss Abu Said (Fig. 2.18 & 19) and arenaceous limestone with chert bands, at its top part in the northwest Ain Maqfi. In north Farafra-Ain Dalla passage, the topmost part of the Tarawan Formation is composed of calcareous fissile shale with a sharp lithological contact at the base (Fig. 2.20). The formation is followed by a hard limestone ledge of the Maqfi Member. The chalk of the Tarawan Formation is white, hard to moderately hard, compact and thick-bedded to massive. Limonite is invariably present and imparts a light yellow color to the Tarawan Formation in the southern part of El Quss Abu Said Plateau and northwest Ain El-Wadi. The Tarawan Formation exhibits intensive burrowing by *Thalassinoides* near its top part in northwest Ain Maqfi (Fig. 2.21). In some areas in the Farafra Oasis such as Shakhs El-Obeiyid and northwest Ain Maqfi, the Tarawan Formation becomes thicker and its topmost part being dolostone. The increased thickness of the Tarawan Formation is associated with a decrease in thickness of the overlying Esna Formation.

In the northwestern part of Ain Maqfi (Lat. 27° 29` 59`` N and Long. 28° 20` 47`` E), the Tarawan Formation is recorded to dip in all directions which might indicate a tectonic disturbance after its deposition (Fig. 2.22).



Base unexposed

Fig. 2.18 Stratigraphic succession of the Upper Paleocene-Lower Eocene rocks exposed in northern slope of El Quss Abu Said.

Fig. 2.21 ***Thalassinoides*** **burrows near the top part of the Tarawan Formation in northwest Ain Maqfi.**

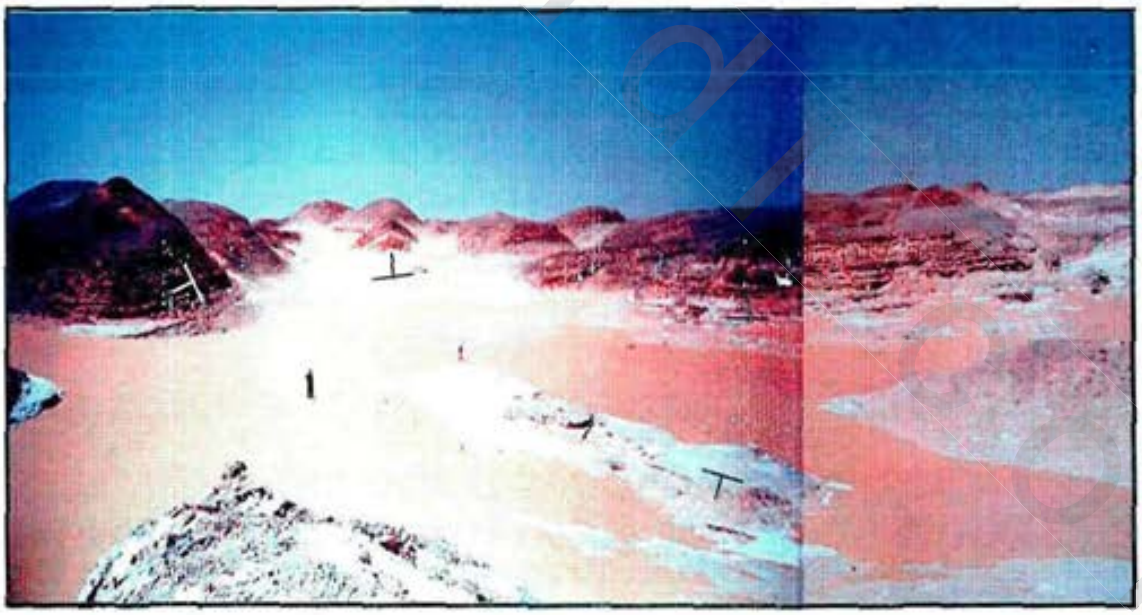


Fig. 2.22 The Tarawan Formation exposed in the northwestern part of Ain Maqfi showing dipping in all directions. Photo is looking southeast.

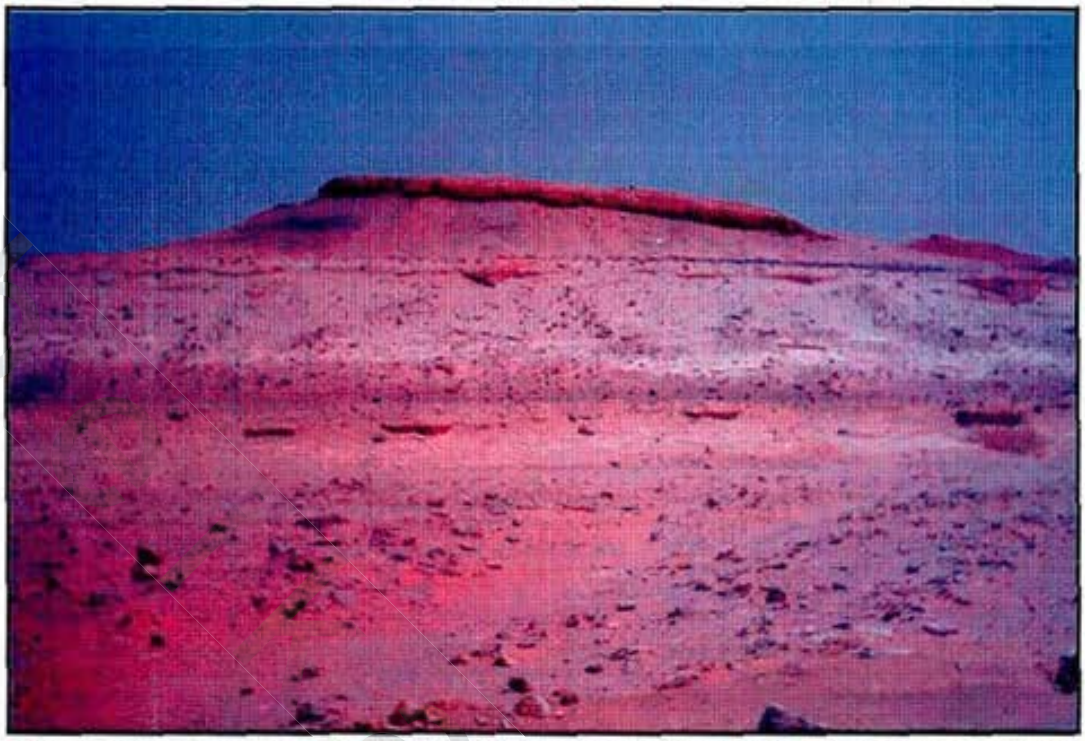


Fig. 2.19 General view of the Tarawan Formation in the northern part of El Quss Abu Said showing its calcareous clay near the top. Photo is looking northeast.

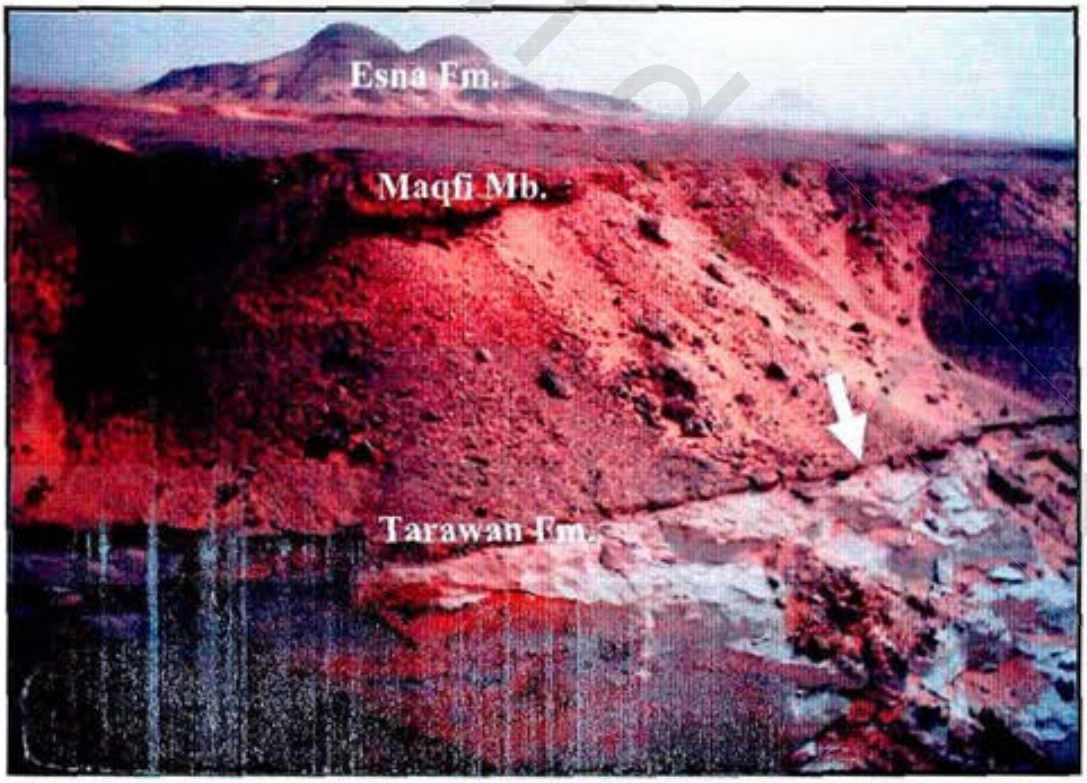


Fig. 2.20 A sharp lithological contact between the chalky limestone and the shale facies near the top part of the Tarawan Formation in NW Bir Bidni. Photo is looking northeast.

Stratigraphic boundaries: The Tarawan Formation could be easily separated from the underling calcareous shale of the Dakhla Formation. The contact, however, is conformable in some area such as northwest Bir Bidni and Gunna North (Fig. 2.15&2.16). In north Ain El-Wadi, the Tarawan Formation is separated from the snow white chalk of the Khoman Formation by a yellowish gray argillaceous chalk of the Dakhla Formation with a clear unconformably contacts between them. Further north in the extreme northeastern part of the Farafra Oasis at southeast Qaret Sheikh Abd Alla, the Tarawan Formation lies directly over the Khoman Formation with a clear and irregular erossional contact, due the absence of the Dakhla Formation (Fig. 2.23). The upper boundary of the Tarawan Formation, on the other hand, is easily traced where it changes abruptly into calcareous shale of the Esna Formation in El Quss Abu Said Plateau (Fig. 2.24). A sharp erosional contact also exists between the Tarawan Formation and the Maqfi Member of the Esna Formation (Fig. 2.25). The latter consists of Alveolinid limestone with reworked clasts in the eastern part of the Farafra Oasis.

Areal distribution: The Tarawan Formation is widely distributed in the Farafra, Dakhla and north Kharga oases of south and central Western Desert and in the upper Nile Valley as well as in the Red Sea region (Quseir-Safaga).

Important fossil elements: A rich planktic foraminiferal assemblage is recorded in the Tarawan Formation such as *Globanomalina Pseudomenardii* (Bolli), *Morozovella acuta* (Toulmin), *M. aequa* (Cushman & Renz), *M. apanthesma*, *M. velascoensis* (Cushman) and *Acarinina mckannai* (White). In addition, dwarf fossils are recorded which often form a floating material upon the lower slope of the Tarawan exposures.

Discussion: LeRoy (1953) subdivided the sediments in Ain Maqfi section into unit A of Late Cretaceous that is followed by units IV,

III, II and I of Early Eocene. He did not record the Tarawan Formation. In the present study, the Upper Paleocene Tarawan Formation is proved to underlie the Lower Eocene Maqfi Member. Said and Kerdany (1961) recorded the Esna Shale cutting through the lower part of the Maqfi Member which lies directly over the Maastrichtian Khoman Formation They didn't record the Tarawan Formation in Ain Maqfi area.

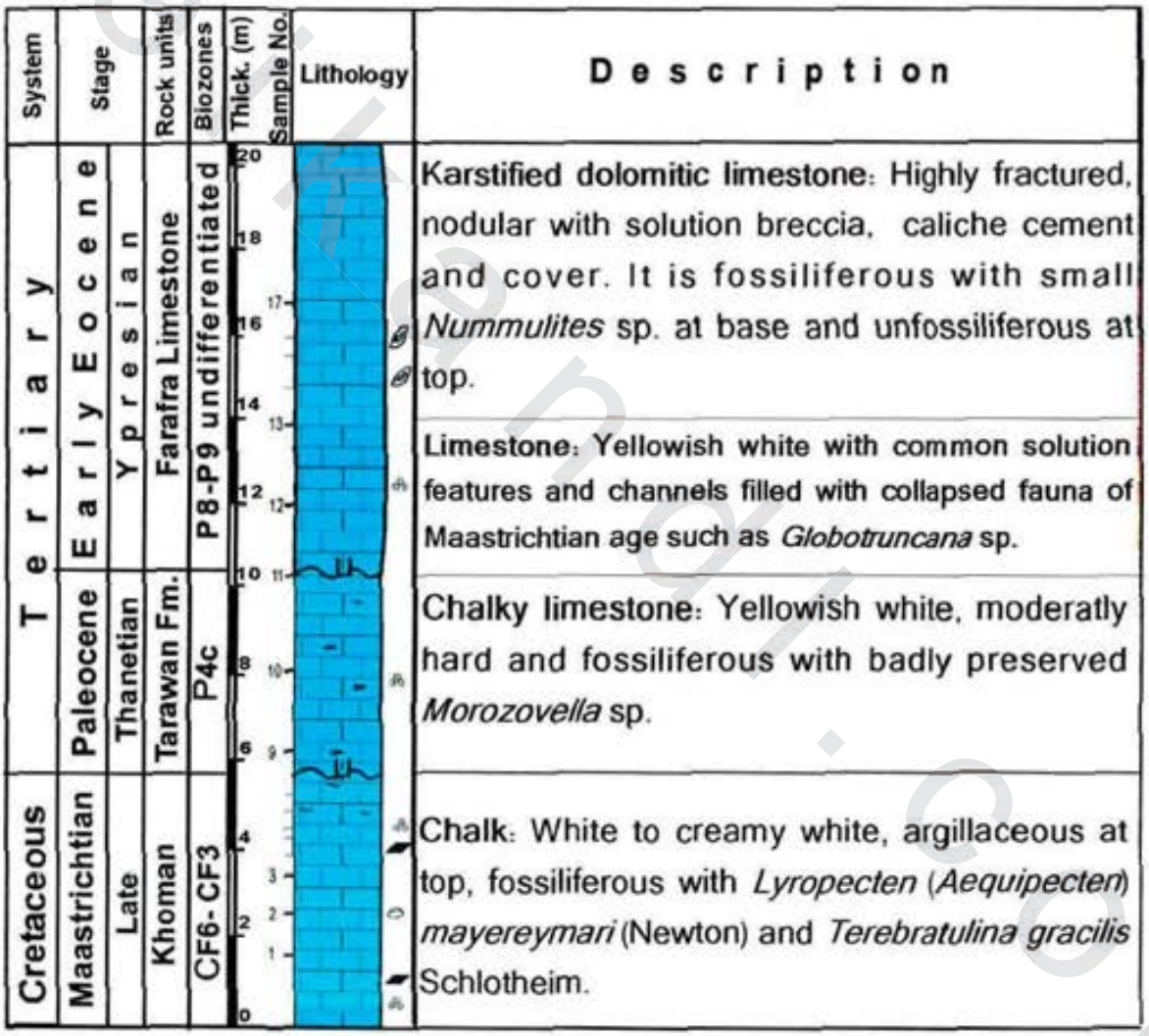


Fig. 2.23 Stratigraphic succession of the Upper Maastrichtian-Lower Eocene rocks exposed in Qaret Sheikh Abd Alla, north east Farafra Oasis.

Fig. 2.24 The unconformable contact between the Tarawan and Esna formations in the northern slope of El Quss Abu Said Plateau. Photo is looking northeast.

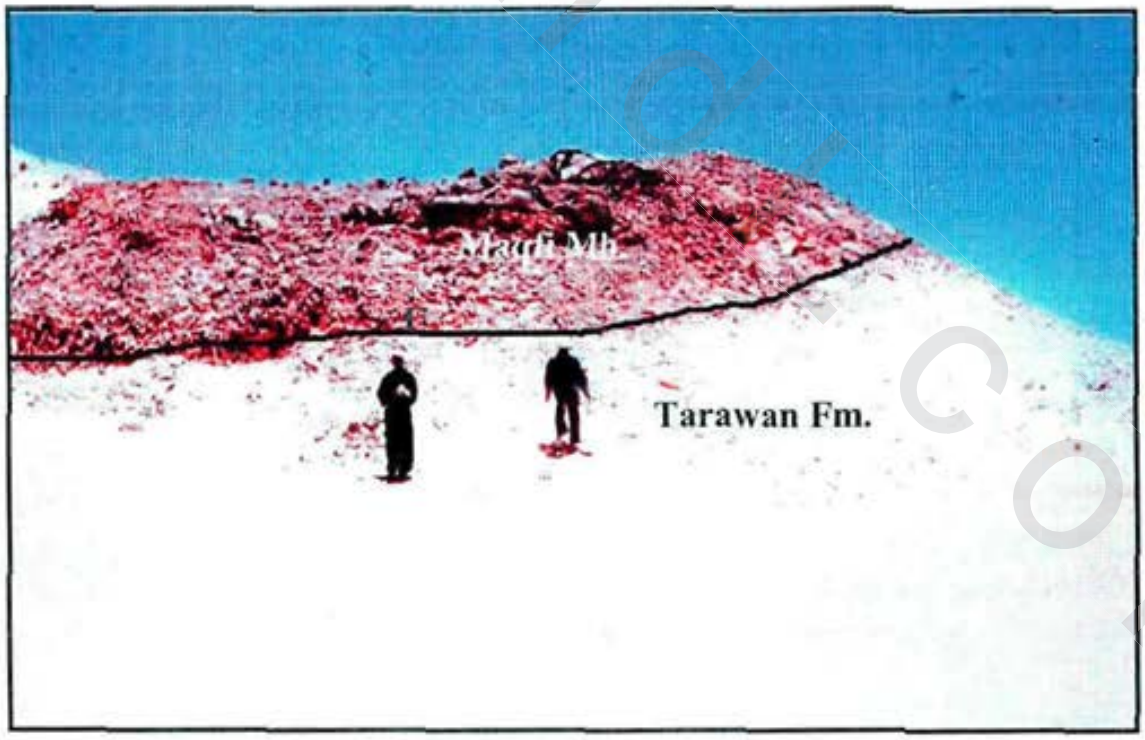


Fig. 2.25 A sharp erasional contact between the Tarawan Formation and the overlying Maqfi Member of the Esna Formation in the northwest Ain Maqfi. Photo is looking southeast.

Barthel and Herrman–Degen (1981) mentioned that the top part of the Tarawan Formation yield a Latest Thanetian or Earliest Ilerdian microfauna of *Morozovela Pseudomenardii* (Bolli) and *Morozovela velascoensis* (Cushman, 1925). In the eastern narrows of the passage from Qasr El–Farafra to Ain Dalla, they neglected completely the term Khoman Formation and it has lumped, all the Chalk sediments of Maastrichtian–Paleocene age to the Tarawan Formation. Khalifa and Zaghloul (1989) named the chalk above the Khoman Formation as Abdalla Limestone-Tarawan Chalk and assigned to it a Late Maastrichtian age. They mentioned that the Abdalla Limestone is equivalent to the Tarawan Chalk due to the great similarities in facies and fossil content and also because both units have the same stratigraphic position. In the present study, the Abdalla Limestone is considered as synonymous with the Tarawan Formation of Late Paleocene age.

II.5 Esna Formation

Author: The term Esna Shale was firstly introduced by Beadnell (1901). Later, Said (1962) amended the term Esna Shale and restricted its usage to the shale beds above the Tarawan Formation and below the Thebes Limestone. The present author follows Said (op. cit.) and Dupuis *et al.* (2003) in using the term Esna Formation for the unit occupying the same stratigraphic position.

Type area: Gabal Oweina, southeast of Esna area, Nile Valley.

Thickness: The Esna Formation exhibits obvious lateral facies and thickness changes in the Farafra Oasis depending on the palaeotopographic setting of the depositional regime. In the palaeostructural highs, the formation is represented by a reduced thickness of about 20m in northeast Ain Maqfi, while in the palaeostructural lows, the formation thickness reaches up to 130-150m as in El Quss Abu Said and Ain Maqfi areas (Table 2.4). These areas, in fact, represent the central part of the Farafra basin.

Table 2.4 shows the variations in thickness of Esna Formation in the Farafra Oasis.

Locality	Gabal Sofra	NW Ain Maqfi	Ain Maqfi	North El Quss Abu Said	South El Quss Abu Said	NE Bir Bidni	SE Qur Hadida
thickness	80m	20m	130m	110m	94m	40m	26m

Age assignment and correlation: The Esna Formation is assigned to the Early Eocene. The formation starts in the eastern escarpment of the Farafra Oasis with its basal Maqfi Member, which lies directly over the Tarawan Formation, This member, contains abundant larger benthics of alveolines, nummulites and operculines. There is no evidence to the present-day indicating that the genus *Nummulites* ever appeared in Egypt prior to the Early Eocene. Therefore, the present author assigns an Early Eocene age to the Maqfi Member in the eastern escarpment of the Farafra Oasis. The Esna Formation changes laterally into Garra Formation in north Kharga-Naqb El Rhumi, to the east of Gabal Shawshaw and in west Gabal Haishan northeast of Qur El Malik (Hermina, 1990). It also changes laterally into Ain Dalla Formation in the northwestern part of the Farafra Oasis.

Lithology: The Esna Formation is mainly composed of green shale and mudstone intercalated in its upper part with argillaceous limestone (Fig. 2.26). The latter is fossiliferous with larger foraminifers. The shale is the dominant lithofacies type in these clastic-dominated sediments. It makes up a substantial proportion of the overall thickness, about 80% of the total sediments. The lithofacies characters of the Esna Formation show a rapid variation epically in its basal part from the eastern and western escarpment of the Farafra Oasis.

In the eastern and northeastern approaches of the Farafra Oasis, the Esna Formation starts at the base with the Maqfi Member which consists of a hard limestone partly conglomeratic

at the base, with large nodular dolostone at the top (Figs. 2.27-2.29). It is rich in alveolines, nummulites and operculines. This member lies directly over the Tarawan Formation.

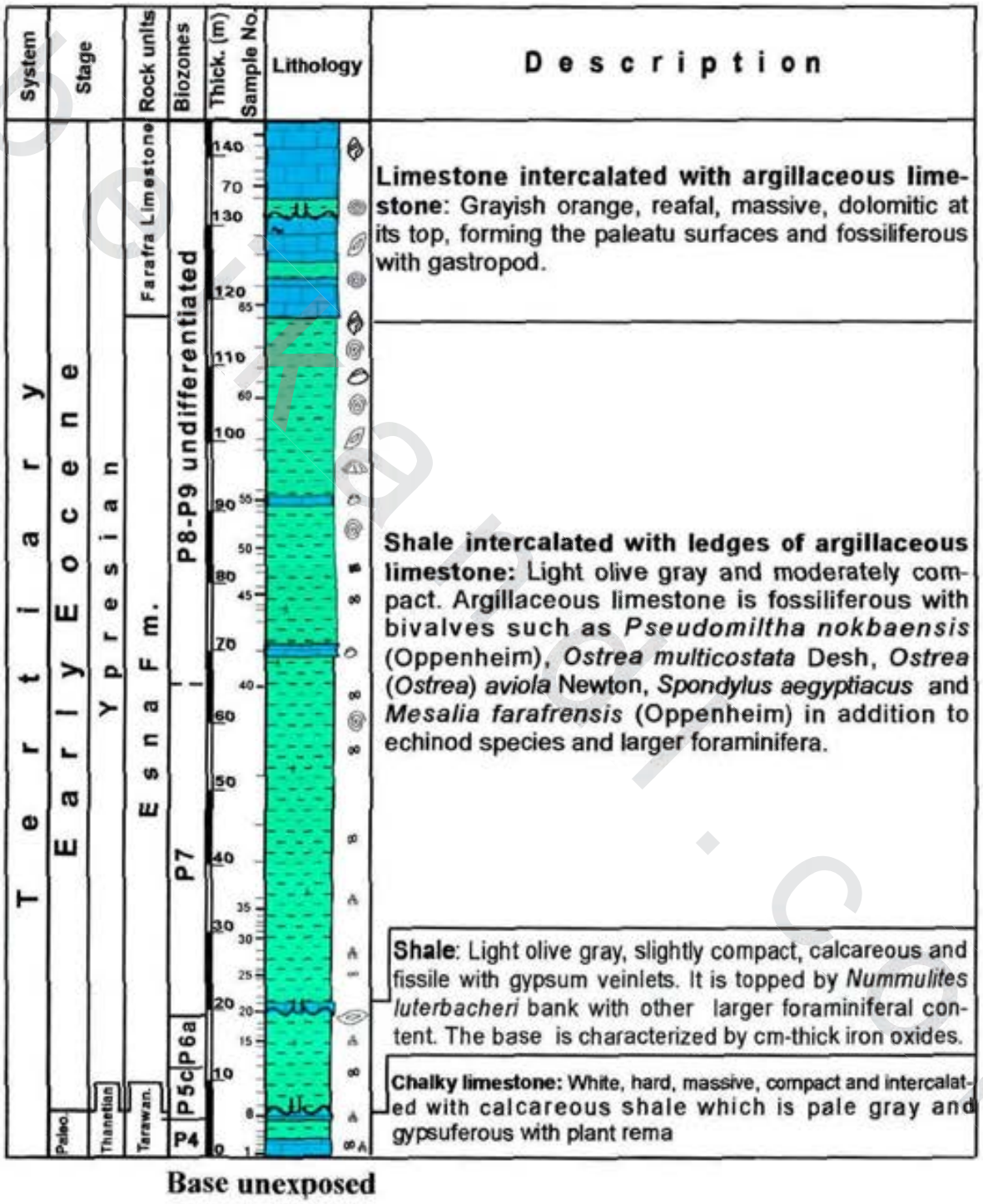
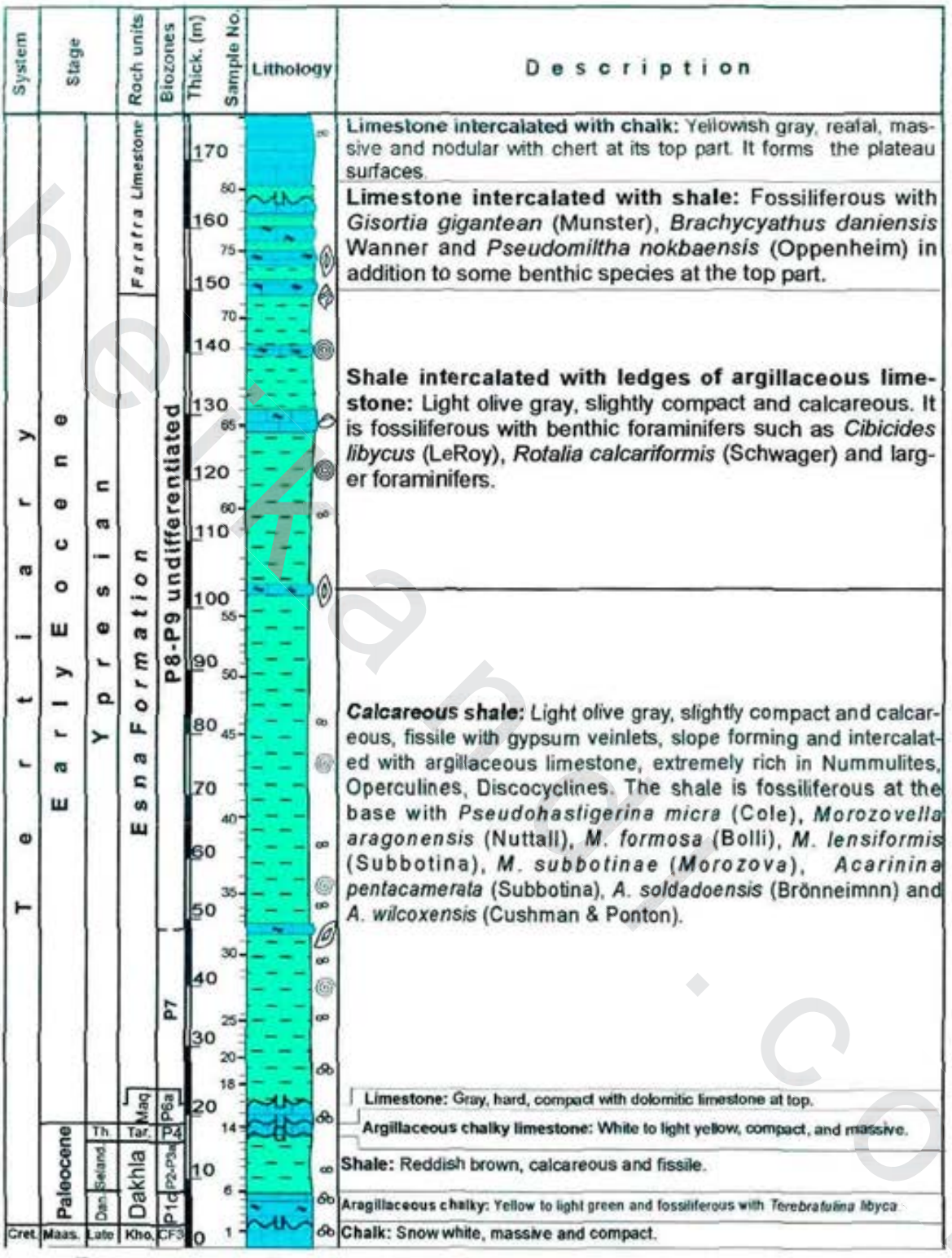


Fig. 2.26 Stratigraphic succession of the Upper Paleocene-Lower Eocene rocks exposed in the southern slope of El Quss Abu Said.



Base unexposed

Fig. 2.27 Stratigraphic succession of the Upper Maastrichtian-Lower Eocene rocks exposed in Ain Maqfi, east Farafra Oasis.

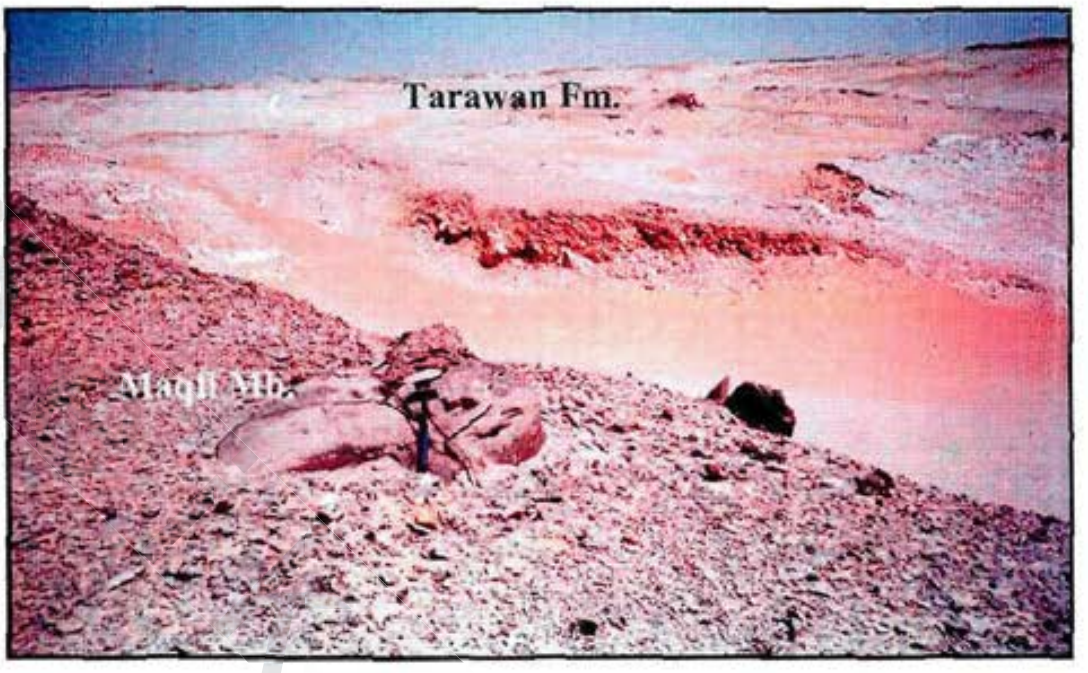


Fig. 2.28 The nodular dolostone in the top part of the Maqfi Member, which unconformably overlies the Tarawan Formation at northwest Ain Maqfi. Photo is looking north.

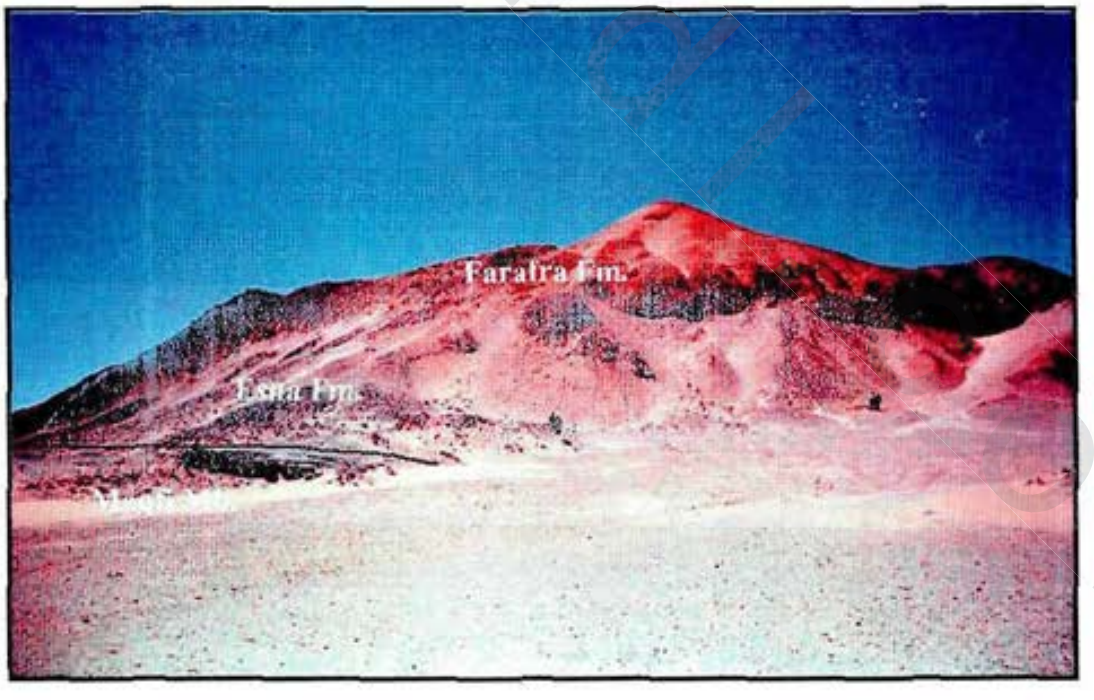


Fig 2.29 The Maqfi Member forming the base of the Esna Formation at northwest Ain Maqfi. Photo is looking north.

Said (1962) considered the alveolines and nummulites of the Maqfi Member as the oldest known forms of alveolinidae and nummulitidae and classified them as belonging to the base of the evolutionary lineages. Cuvillier (1930) considered this unit as the type locality of the oldest Eocene in Egypt (Montian). While, Said and Kerdany (1961) gave a Landenian age to the Esna Formation which overlies the Maastrichtian Chalk. Consequently, they included the Dakhla and Tarawn formations within the Esna Formation. The Maqfi Member is missing in the western approaches of the Farafra Oasis such as in El Quss Abu Said, Gunna North and Gabal Sofra. Said (1962) correlated the shale at El Quss Abu Said Plateau which contains dwarf fossils with the Maqfi Member of the north and east Farafra Oasis. Wielandt (1996) believed that the *Nummulites* bank, which is recorded overlying the basal shale facies of the Esna Formation corresponds to Ain Maqfi Member, exposed in the northeastern part of the Farafra Oasis.

The presence of an unconformity surface between the Upper Paleocene and the overlying Lower Eocene sediments in Ain Maqfi area and the presence of shallow water reefal deposits of the Maqfi Member indicate that the northeastern and eastern areas of the Farafra Oasis were paleo-structural highs. It is known that after deposition of the Cretaceous sediments the Bahariya region formed a push-up structure. Therefore, the Esna Formation is missed over there. The Esna Formation exhibits a quite distinctive change in lithology toward the submerged palaeo-structura highs forming carbonate facies in Ain Dalla area, while in southeast Qur Hadida it consists of sabkha, shale and sandstone capped by unfossiliferous limestone (Fig. 2.30).

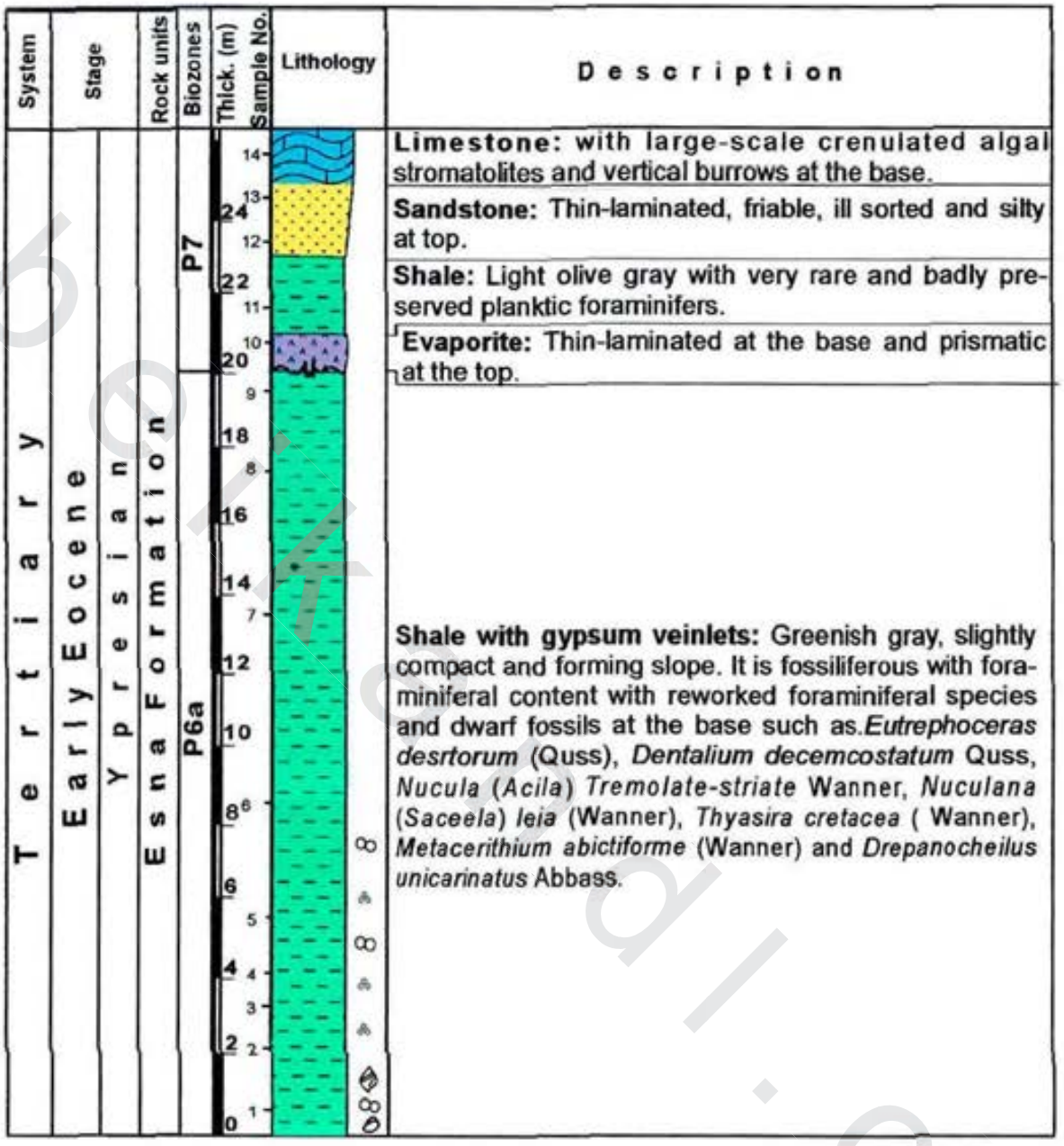


Fig. 2.30 Stratigraphic succession of the Lower Eocene rocks exposed in southeast Qur Hadida, east Farafra Oasis.

In southeast Qur Hadida, the Esna Formation is characterized by abundant and well-preserved planktic foraminiferal content in its lower part with *Morozovella subbotinae* and *Acarinina soldadoensis* of Early Eocene age. It yields dwarf fossils at the base. The lower shale is followed by evaporite, shale, sandstone and then limestone (Figs. 2.31 & 2.32) which indicate obvious

shallowing conditions in the depositional regime. The evaporite is characterized by the following features:

- The base is thin-laminated anhydrite intercalating with claystone. The lamina thickness is 1mm-2cm with a total thickness of about 15cm.
- Large prismatic anhydrite intercalating in part with thin-laminated evaporite. Prismatic crystals may reach up to 7cm in length and 1.5 cm in width. They are oriented upward in different directions, forming the main bulk of this bed, about 85cm thick.

Boukhary *et al.* (1995) introduced a new formational name, the Nusf Formation, for the top part of the Esna Formation in El Quss Abu Said due to the presence of abundant larger foraminifera and to its more calcareous nature than in the type section (Fig. 2.33).

The upper part of the Esna Formation in El Quss Abu Said Plateau is characterized by the presence of *Ostrea* (*Ostrea*) *aviolai*, which is recorded in the southern slope building several thin to thick, laterally persistent. The shalls of these biostromes are usually crowded forming thick encrustations.

In the eastern reach of the Farafra Oasis at Bir Karawin, the shale of the upper part of the Esna Formation is frequently intercalated with limestone interbeds (1-3m thick, Fig. 2.34).

In fact, the Esna Formation thins out northward and completely missing along the northern scarp of the Farafra Oasis most probably due to its later erosion on the uplifted area. Along the extreme northern part of the Farafra Oasis, the Tarawan Formation is directly overlain by the Farafra Formation at Qaret Sheikh Abd Alla (Fig. 2.23).

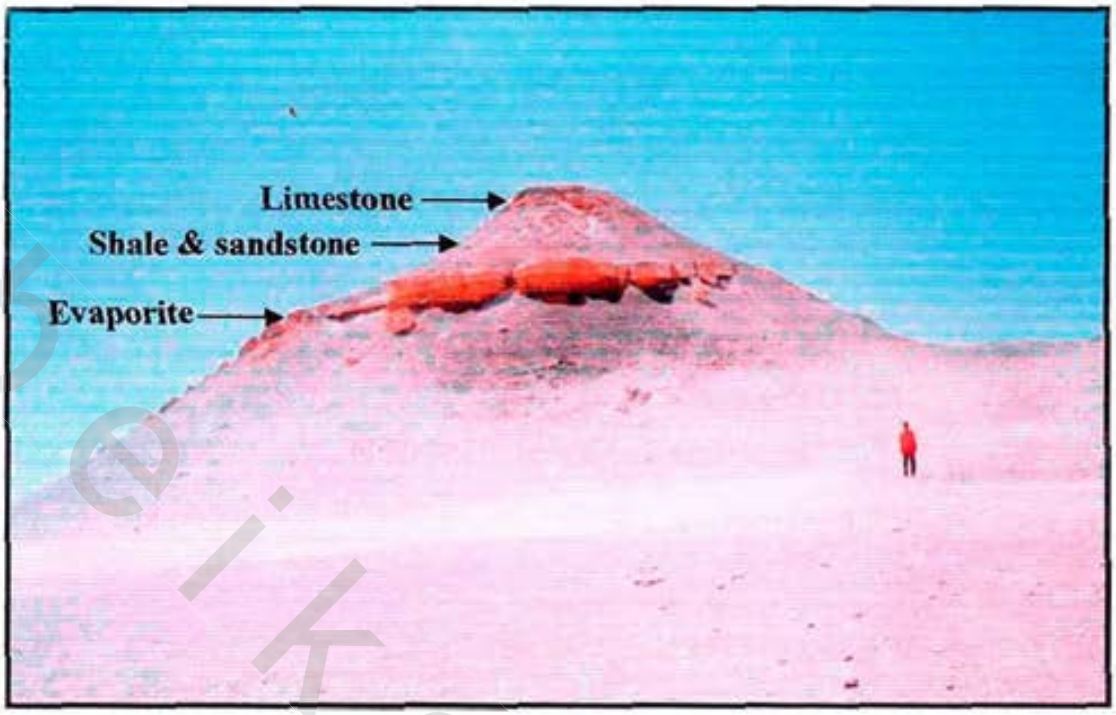


Fig. 2.31 Thin sequence of evaporite, shale, sandstone and limestone terminates the Esna Formation in southeast Our Hadida, east Farafra Oasis. Photo is looking southeast.

Fig. 2.32 Thin-laminated anhydrite at the base intercalated with claystone laminae followed by large prismatic anhydrite at the top, upper part of the Esna Formation at southeast Our Hadida, east Farafra Oasis.

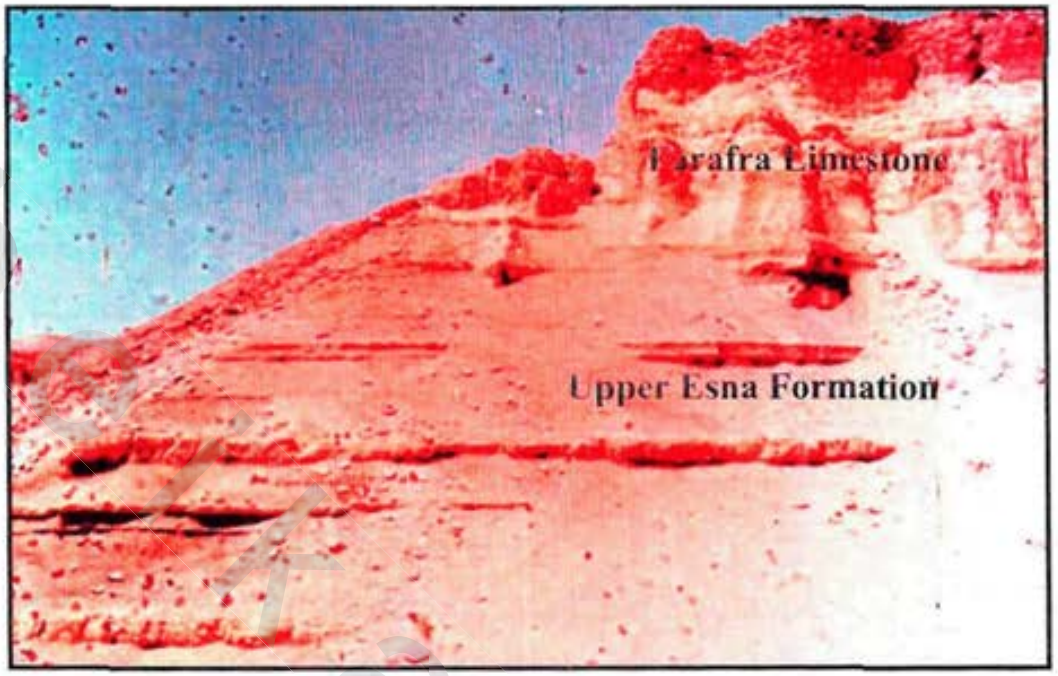


Fig. 2.33 Frequent limestone interbeds present in the shale of the upper part of the Esna Formation in El Quss Abu Said escarpment, west of Qasr El-Farafra. Photo is looking west

Fig. 2.34 Frequent limestone interbeds in the upper part of the Esna Formation at Ain Maqfi-Bir Karawin escarpment. Photo is looking northeast.

Based on the megafossil content, Strougo (1996) divided the Esna Formation into three informal members in El Quss Abu Said. These members are from base to top:

Libyan 1 (b1): It comprises the lower part of the Esna Shale and consists of calcareous shale with horizon of dwarf fauna occurs some 20-30m above the base of the Esna Formation. In the present study, the dwarf fauna are commonly found as floating material upon the slopes of the Tarawan and Esna formations in the Farafra Oasis. He also defined the stratigraphic position of the Dwarf fauna at Gabal Gunna inselberge, suggesting that it falls around the boundary between the *Morozovella subbotina* Zone and the *Morozovella aragonensis* Zone of Abdel-Kireem and Samir (1995). The upper limit of b1 is traced at the first appearance of the larger foraminifera and macroinvertebrates.

Libyan 2 (b2): It forms the middle part of the Esna Shale. The Esna Shale of this level is intercalated with two or three prominent, buff marly layers containing an abundant fossil association.

Libyan 3 (b3): It comprises the upper part of the Esna Shale along the northern, eastern, and southern scarps of El Quss Abu Said. According to strougo (1996), the lower boundary of b3 is traced at the first occurrence of *Carolia blanfordiana* (Cox). While, the upper boundary is the Esna Shale/Farafra Limestone contact, which is characterized by the massive appearance of Alveolines, together with large-size Lucinids. The present author believes that such subdivision is hardly applied in east Farafra succession due to its rarity and low diversity megafossil content.

Stratigraphic boundaries: In the western scarp of the Farafra Oasis, the Esna Formation overlies the Tarawan Formation with a

minor submarine break and conformably underlies the Farafra Limestone (Figs 18 & 24). This unconformabl contact is observed along the scarp of El Quss Abu Said. While in the eastern escarpment of the Farafra Oasis, the limestone of the Maqfi Member marking the base of the Esna Formation is found to overlie the Tarawan Formation with a sharp unconformable contact (Figs. 2.25&2.27). This member is followed by the overlying shale of the Esna Formation with another unconformable contact.

Areal distribution: The Esna Formation is widely distributed in the Farafra Oasis along its eastern and western escarpments. The formation missing at Naqb El Selim area in the northern part of the Farafra Oasis but can be traced southward to the Dakhla Oasis. In some areas in west Dakhla Oasis, the Thebes Formation unconformably overlies the Tarawan Formation; where as the Esna Formation is totally missing. The Esna Formation is traced at the western face of El Quss Abu Said in El-Bahr and Gabal Nusf areas. It is also recorded in the area to the west of Ain Dalla (Gabal Sofra) where the Formation it extends westward till it is covered by the sand dunes of the Great Sand Sea.

Important fossil elements: A rich magafossil assemblage is recorded at the top part of the Esna Formation including bivalves such as *Pycnodonte aviculina* (Oppenheim), *spondylus aegyptiacus* Newton, *Ostrea* (*ostrea*) *aviola* Newton, *Ostrea multicostata* Desh, *"Limea" delanouei* Oppenheim and *Glyptoactis* (*Claibornicardia*) *aff. Corpulenta* Strougo. These in addition to the larger foraminifers such as *Alveolina pasticillata* (Schwager), *Nummulites deserti* DE LA Harpe and *Operculina libyca* Schwager. The formation is also fossiliferous with echinoid and gastropod species in its top part. While, the lower and middle

parts of the Esna Formation are fossiliferous with abundant planktic foraminiferal content such as *Morozovella subbotinae* (Morozova), *M. gracilis* (Bolli), *M. formosa* (Bolli), *M. aragonensis* (Nuttall), *Acarinina pentacamerata* (Subbotina) and *A. soldadoensis* (Brönneimnn).

Discussion: The Maqfi Member can be easily depicted in the stratigraphic log of LeRoy (1953), where it is situated between units IV and II. He identified the *Gyroidina girardana* and *Morozovella velascoensis* (Cushman) from the unit IV though he questioned the position of the *Morozovella velascoensis* in the Egyptian stratigraphy until the Egyptian Paleocene is more specifically correlated in terms of the European section. LeRoy (op. cit.) favored allocating this unit to the basal Eocene.

Youssef and Abdel-Aziz (1971) did not identify the Maqfi Member in the Maqfi section. However, this interval appears clearly in their stratigraphic log, some 11-12m above the Tarawan Chalk (their sample 10) where they reported the presence of larger foraminiferal assemblage such as *Discocylina nudimargo, Operculina libyca, Nummulites deserti, Nummulites solitorius* and *Nummulites fraasi.*

Neither Said and Kerdany (1961) nor Youssef and Abdel-Aziz (1971) commented on the disconformities that bounded LeRoy unit III (the Maqfi Limestone Member). This is critical because the present author strongly believes that the Paleocene/Eocene boundary lies at the base of this unit.

II.6 Ain Dalla Formation

Author: The term Ain Dalla Formation was first introduced by Barthel and Herrmann–Degen (1981), while Issawi *et al.* (1999) and Issawi and Osman (2000) used the name Dalla Chalk.

Type area: Scarp-spur 10km north of Ain Dalla.

Thickness: Ain Dalla Formation attains a total thickness of about 80m in Ain Dalla-Shakhs El-Obeiyid area.

Age assignment and correlation: Barthel and Herrmann–Degen (1981) gave a Middle Ilerdian age to Ain Dalla Formation. In the present work, an Early Eocene age is given to this formation.

Lithology: Ain Dalla Formation is composed of yellowish white, well-bedded chalky limestone with chert bands at the top (Figs. 2.35 & 2.36). The average thickness of the single bed is 15 cm. The limestone in the lower part of Ain Dalla Formation is intercalated with burrowed intervals, which are topped by sandy dolostone. The basal part of Ain Dalla Formation is made up of soft argillaceous chalky limestone with chert nodules at the top, which is closely similar to the Thebes Formation recorded by many authors in the west Dakhla area (e.g. Mansour *et al.*, 1982).

In Bir El-Obeiyid, the present author records the occurrence of a few shale beds enriched in *Pseudohastigerina wilcoxensis/Morozovella velascoensis* Subzone P5c. These shale beds unconformably overlie the Tarawan Formation (P4) with a clear erossional contact (Fig. 2.37). They are followed by argillaceous limestone with larger foraminifers. In Shakhs El-Obeiyid, the Ain Dalla Formation is terminated with about 20m thick calcareous shale, which is overlain by the Farafra Limestone (Fig. 38 & 39). The presence of shale bed, at the base of Ain Dalla Formation in Bir El-Obeiyid and at its top in Shakhs El-Obeiyid indicates that this area represents a transitional zone between the Esna and Ain Dalla formations.

In contrary to the observation of the present author, Barthel and Hermann-Degen (1981) stated that Gabal Sofra, about 12km

west of Ain Dalla, is stratigraphically rather similar to Ain Dalla area and mentioned that the Ain Dalla Formation rests on the greenish gray marl of the Dakhla Formation. The present study proves that Gabal Sofra a normal succession forming of Esna and Farafra formation (Figs. 2.41 & 2.42). A normal succession of Tarawan, Esna and Farafra formations is also recorded in Qur Hamra just to the south of the Farafra-Ain Dalla road (Fig. 2.43).

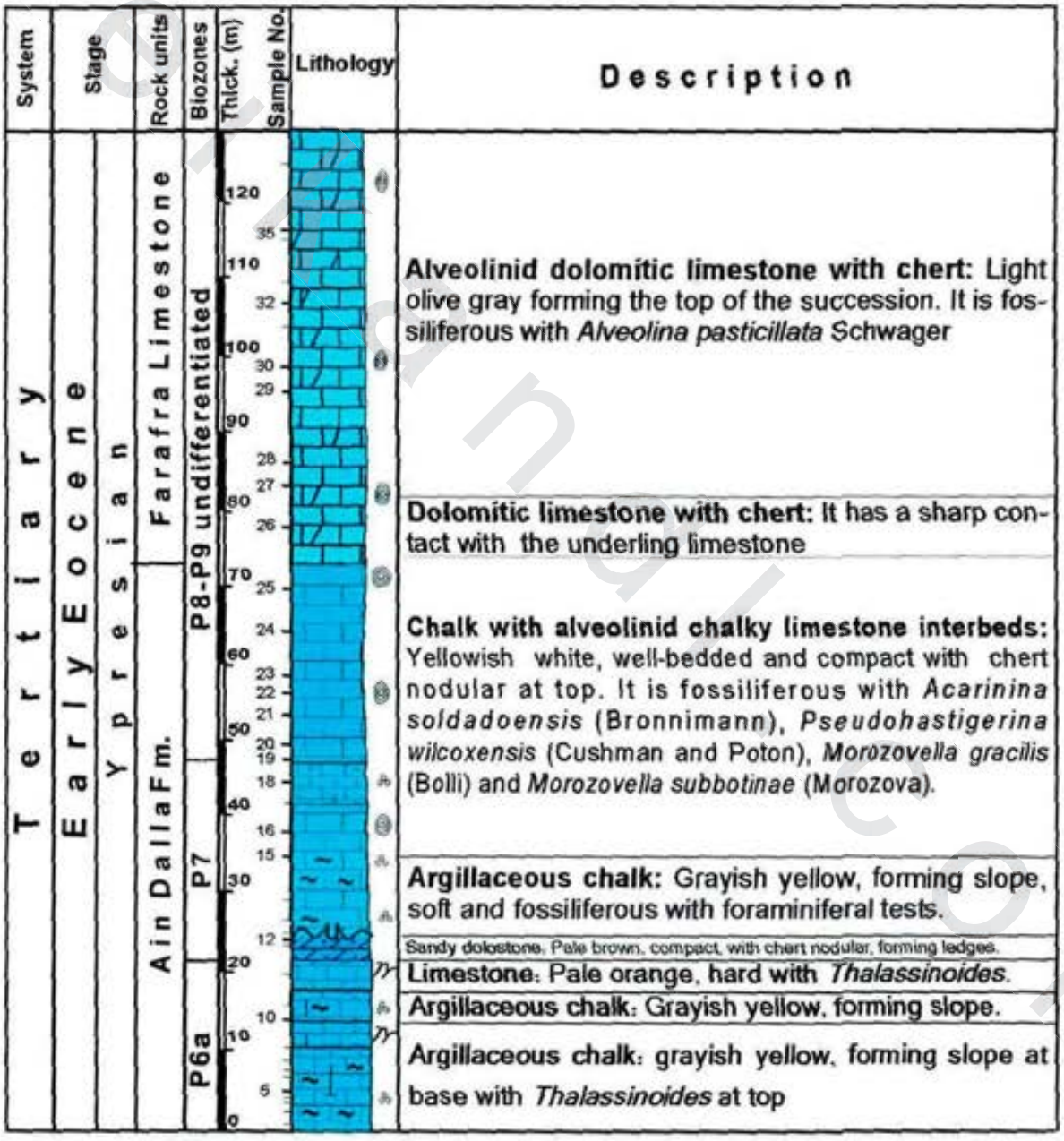


Fig. 2.35 Stratigraphic succession of the Lower Eocene rocks exposed in northeast Ain Dalla, west Farafra Oasis.

Fig. 2.36 The Ain Dalla Formation exposed in northeast Ain Dalla depression, northwest Farafra Oasis. Photo is looking northwest.

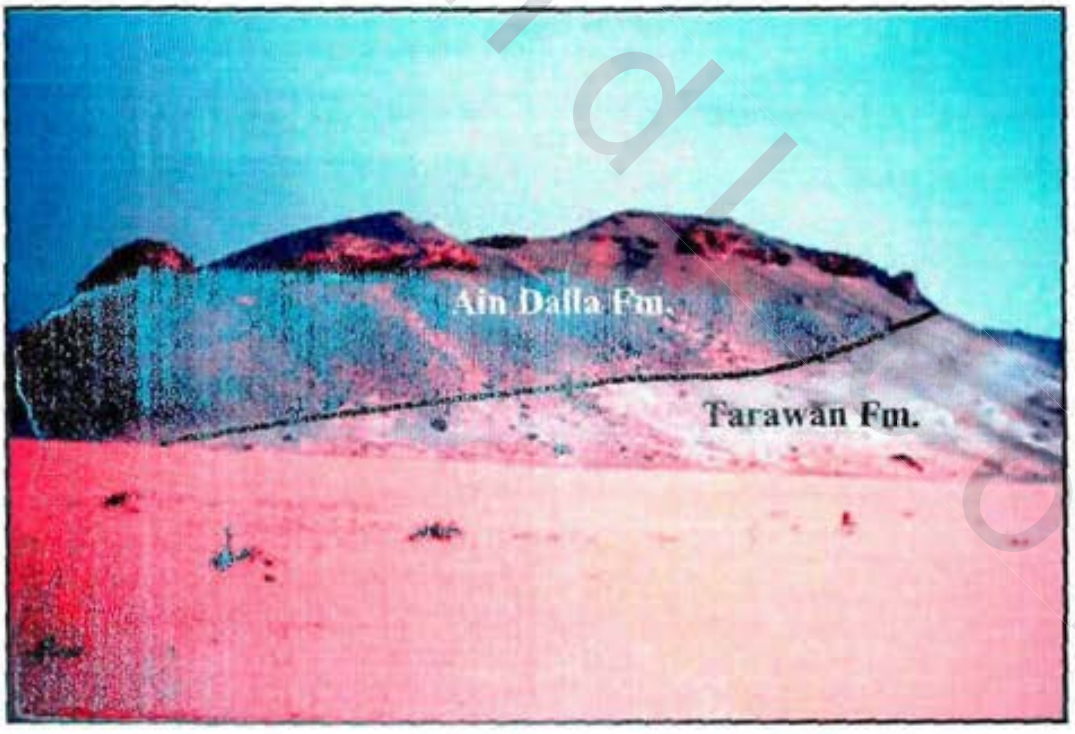
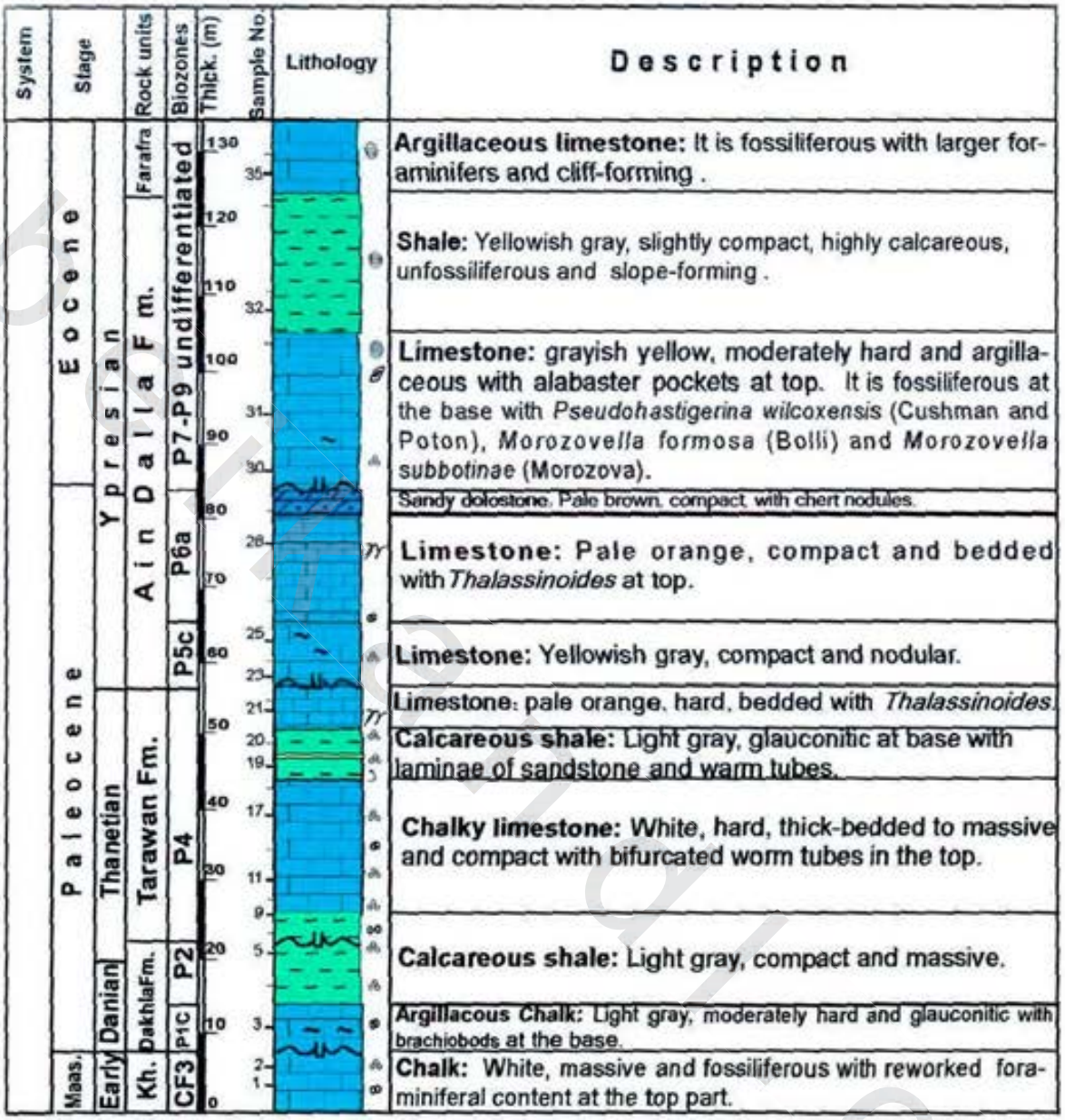


Fig. 2.37 General view of the Tarawan and Ain Dalla formations that exposed in Bir El-Obeiyid showing the shale at base of Ain Dalla Formation. Photo is looking northeast.



Base unexposed

Fig. 2.38 Stratigraphic succession of the Upper Maastrichtian-Lower Eocene rocks exposed in Shakhs El-Obeiyid, northwest Farafra Oasis.

Stratigraphic boundaries: Ain Dalla Formation is found to overlie unconformably the Tarawan Formation (Fig. 2.40) and to conformable underlie the Farafra Limestone.

Areal distribution: Ain Dalla Formation has a limited geographic distribution only found in Ain Dalla area.

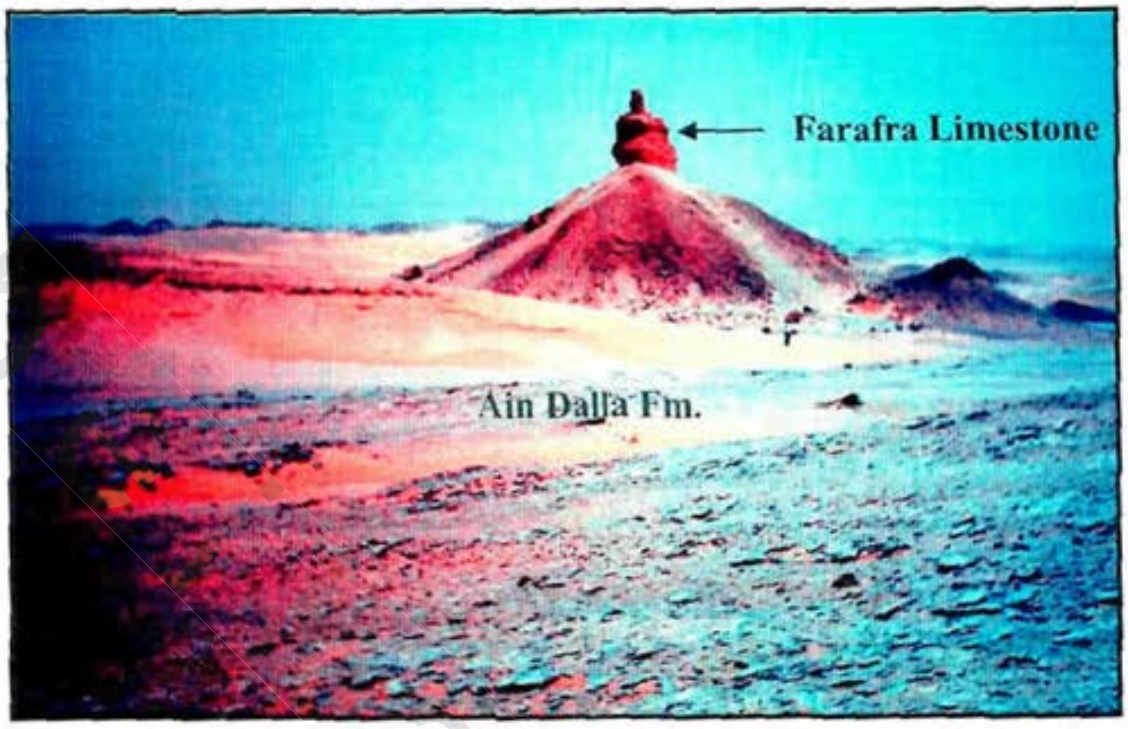


Fig. 2.39 General view of the Shakhs El-Obeiyid land mark showing *the top shale part of Ain Dalla Formation.* Photo is looking northwest.

Fig. 2.40 The unconformable contact between the Tarawan and Ain Dalla formations at Shakhs El-Obeiyid area. Photo is looking northwest.

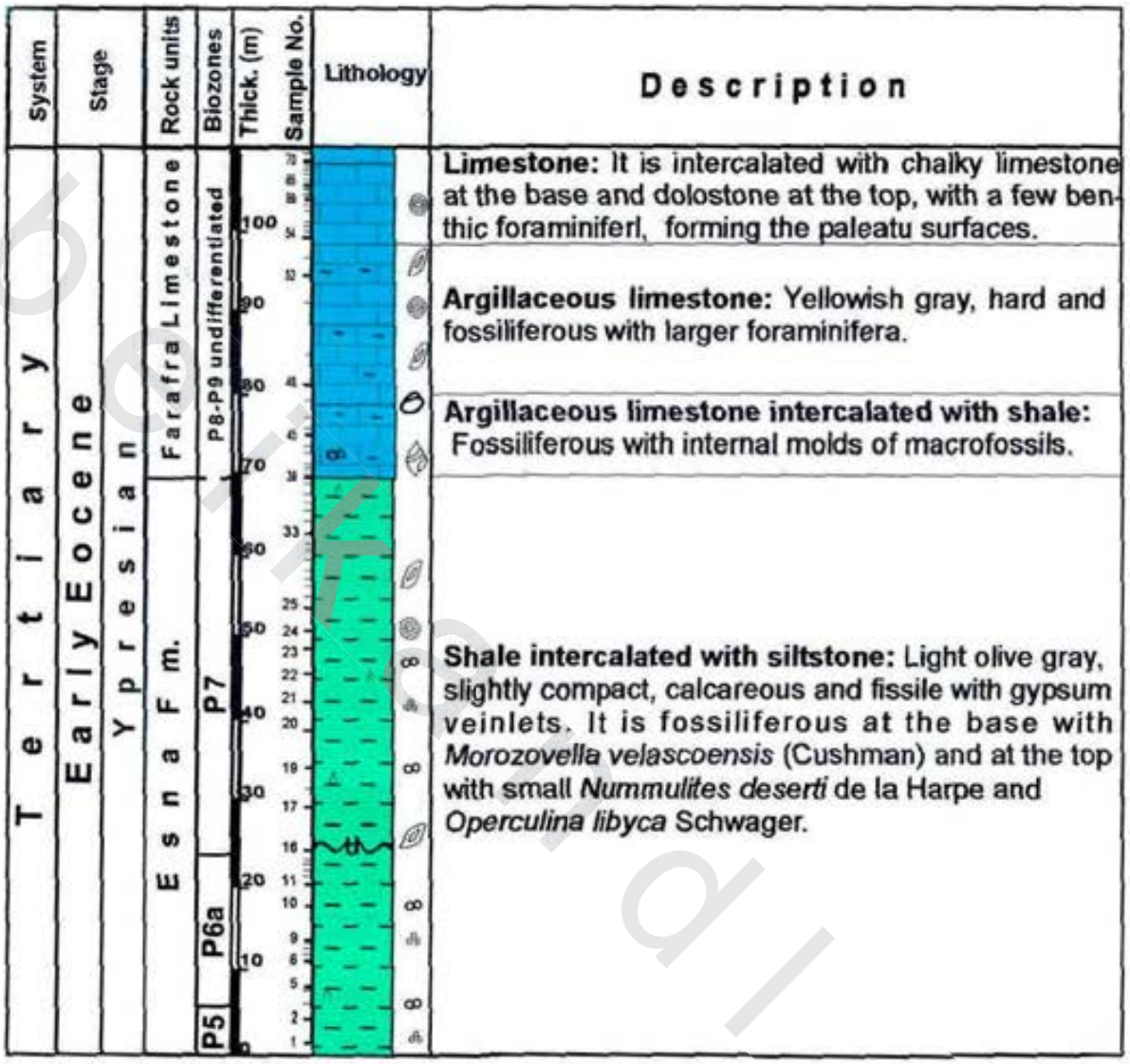


Fig. 2.41 Stratigraphic succession of the Lower Eocene rocks exposed in Gabal Sofra, west Ain Dalla.

Important fossil elements: A rich foraminiferal content is recorded in the lower part of Ain Dalla Formation such as *Morozovella subbotinae* (Morozova), *M. gracilis* (Bolli) and *M. formosa* (Bolli). The top part of this formation is fossiliferous with larger foraminifers.

Discussion: In the geological map of the Geological Survey of Egypt (1982), the Tarawan Formation is drown to underlie

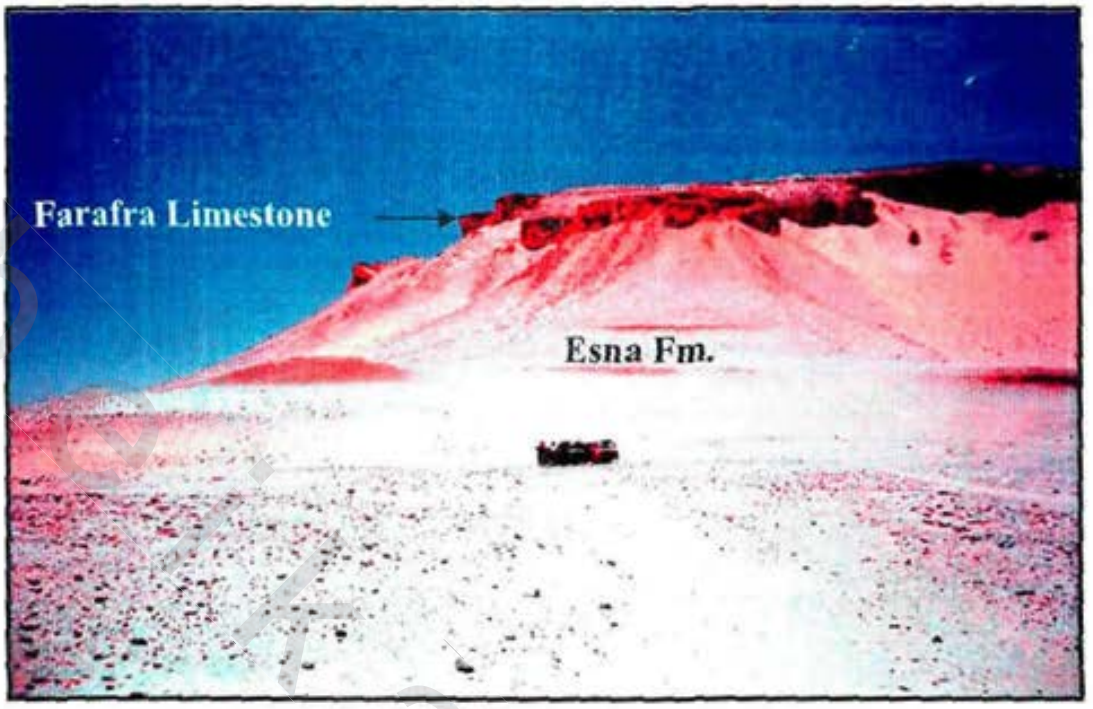


Fig 2.42: General view of Gabal Sofra showing the Esna Formation capped by the Farafra Formation. Photo is looking toward west.

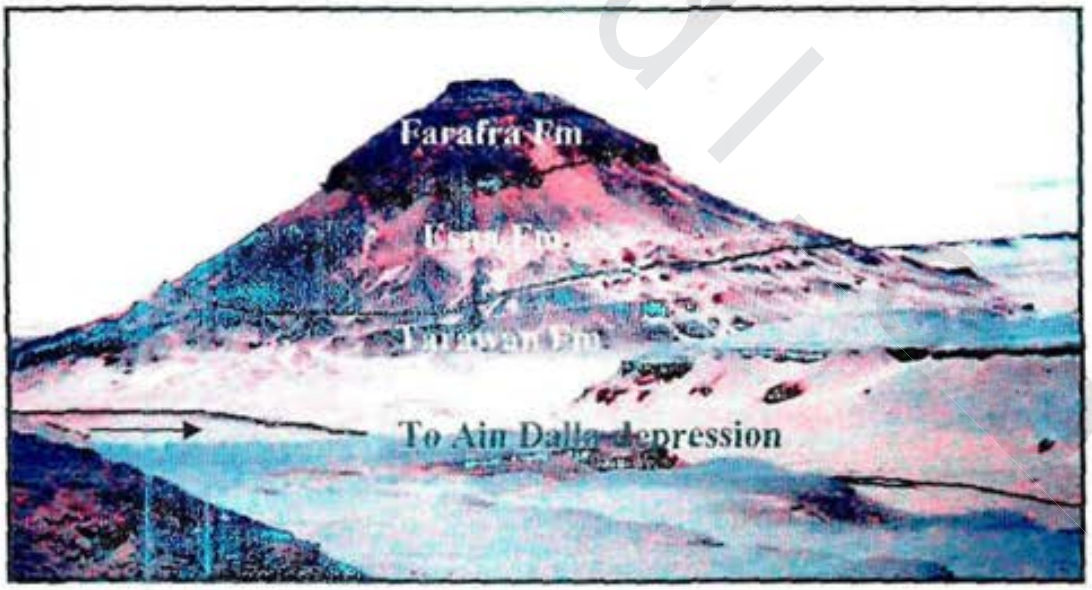


Fig. 2.43: General view of Qur Hamra inselberg showing the exposed Tarawan, Esna and Farafra formations. Photo is looking toward southeast.

directly the Farafra Formation in the Farafra Oasis, while in the Geological map of Egypt given by the EGPC and Conoco (1987) the unit underlying the Farafra Formation is termed Esna Formation. Zaghloul (1983) used the term Abdalla Limestone of Landenian age to represent the rock unit underling the Farafra Formation, while in north Farafra Oasis he recorded the Abdalla Limestone underlying the Esna Formation. Hermina (1990) mentioned that the biogenic limestone at Ain Dalla area is more similar to the Garra Formation known in the south Western Desert than to the deeper facies of the Esna Formation.

II.7 Farafra Limestone

Author: Said (1960) and Said and Kerdany (1961) were the first authors to use the name Farafra Limestone. Whilest, Youssef and Abdel–Aziz (1971) used the term Thebes-Farafra Limestone. Recently, the capping limestone unit in the Farafra Oasis is called Farafra Formation by Hermina (1990), Abdel–Kireem and Samir (1995) and Khalil and El-Younsy (2003).

Type area: El Quss Abu Said Plateau, west Farafra area.

Thickness: The Farafra Limestone attains a maximum thickness of about 50m. The thickness of the formation, however, is far smaller than this amount on the plateau surfaces between Dakhla and Abu-Minqar; being no more than 20m.

Age assignment and correlation: The Farafra Limestone in the Farafra Oasis could be correlated with the Zone P9 of BKSA95 given by Ouda (2003). The formation is dated to the Middle Ilerdian due to the presence of the *Alveolina decipiens* Schwager and *Nummulites deserti* DE LA Harpe. It is also assigned to the Early Eocene by Barthel and Herrmann–Degen (1981) and Hermina (1990). Correlation of the macrofossils of the Farafra

Limestone with those of the Thebes Formation in the Kharga Oasis indicates that the Farafra Limestone is isochronous with the upper part of the Thebes Formation (Omara and Kenawy 1975).

Lithology: The Farafra Formation is composed of grayish yellow limestone intercalated with shale and argillaceous limestone (Figs. 2.10, 2.18, 2.26, 2.27 & 2.40). The upper part of the formation is interbedded with dolostone and some chalk. In Ain Dalla, the Farafra Formation is composed of dark gray to pink dolomitic limestone, very rich in alveolines (Fig. 3.35).

In fact, the Farafra Limestone is very rich in larger foraminifers. The bioclastic nature of this formation indicates deposition under highly turbulent water conditions. Nodular limestone horizon is found about 5m from the base of the Farafra Limestone at El Quss Abu Said due to differented weathering of alternating soft argillaceous limestone and hard limestone interbeds (Fig. 2.44). This resulted in the formation of varied shape clasts, but mostly are oriented parallel to the original bedding plane. The clasts have an average diameter of 10-20cm. The presence of abundant slipped blocks far below their original horizon is a distinct feature of the Farafra Limestone. This is due to the fact that the Farafra Limestone overlies the soft clastic-dominated facies of the Esna Formation. The removal of large quantities of the Esna Formation by erosion resulted in the formation of enormous slipped limestone blocks.

Stratigraphic boundaries: The passage from the Esna Formation into Farafra Limestone is gradational. The shale progressively becomes more calcareous upward passing through marl into hard limestone. The spherical alveolinid appear explosively at the contact between the Esna Formation and the Farafra Limestone

and extend to the top of the formation. However, this boundary is sometimes difficult to trace. In south Qaret El-Sheikh Abd Alla, the Farafra Limestone overlies the Tarawan Formation with a sharp unconformity surface (Fig. 2.23).

Areal distribution: The Farafra Limestone has a great extension, forming the cap rock of El Quss Abu Said Plateau as well as the northern and eastern plateaus (Fig. 2.45). It extends southward to north Kharga Plateau. The Lower Eocene Farafra Limestone is also exposed in the eastern and southern escarpments of the Bahariya Oasis (Said, 1960).

Important fossil elements: The Farafra Limestone yields abundant larger foraminifers including nummulites, operculines and alveolines as well as large-size lucinid species of *Pseudomiltha nokhaensis* (Oppenheim) in very large numbers.

Discussion: Hermina (1990) used the term Naqb Formation in Ain Dalla and mentioned that the Naqb Formation gradually overlies the limestone and chalky limestone of Ain Dalla Formation. In the present study, both rock units are called Farafra Formation to describe the uniform alveolinid dolostone.

Fig. 2.44 Nodular limestone formed due to differential weathering of alternating soft argillaceous limestone and hard limestone interbeds, the lower part of the Farafra Limestone, El Quss Abu Said escarpment, west of Qasr El-Farafra. Photo is looking west.

Fig. 2.45 The Farafra Limestone capping the extreme southern part of El Quss Abu Said Plateau. Photo is looking southeast.