

## **Preliminary Review of the Stratigraphy of the Outcropping Mesozoic Erathem in the Republic of Yemen**

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**ABSTRACT.** In Yemen, the surface exposed Mesozoic Erathem is represented by the Jurassic and Cretaceous systems. The Jurassic includes the Affar Formation (Early Jurassic) and the Surdud Group (Middle-Late Jurassic). The Affar is the upper formation of the Kohlan Group (Permian-Early Jurassic) and consists of sandstone. The Surdud Group is subdivided into the Amran (limestone), Madbi (marl), Sabatayn (evaporites), and Nayfa (limestone) formations. The Cretaceous System includes the Ghiras Member and the Ghiras/Mahra Groups.

The Ghiras Member is the lower unit of the Tawilah Formation (Cretaceous-Paleocene). It occurs in the northern provinces of Yemen, and it consists of sandstone. The Ghiras/Mahra Groups are well developed in the western and eastern regions of the southern provinces, respectively, and they are laterally equivalent. The Ghiras Group consists of elastics. It includes the Qishn (limestone), Harshiyat (sandstone), and Mukalla (sandstone and shale) formations. The Mahra Group was divided into the Qishn (limestone), Harshiyat (sandstone), Fartaq (limestone and marl), Mukalla (sandstone), and Sharwayn (marl and limestone) formations.

The Republic of Yemen embraces the southwestern corner of the Arabian Peninsula bordering the Red Sea and the Gulf of Aden (Fig. 1). It is a new country that resulted from the union of the former "Yemen Arab Republic" (North Yemen), and the former "People's Democratic Republic of Yemen" (South Yemen). In many cases, rock units in the two parts of Yemen represent a continuous natural sequence. The present work aims to compile the available information on the Mesozoic Erathem in

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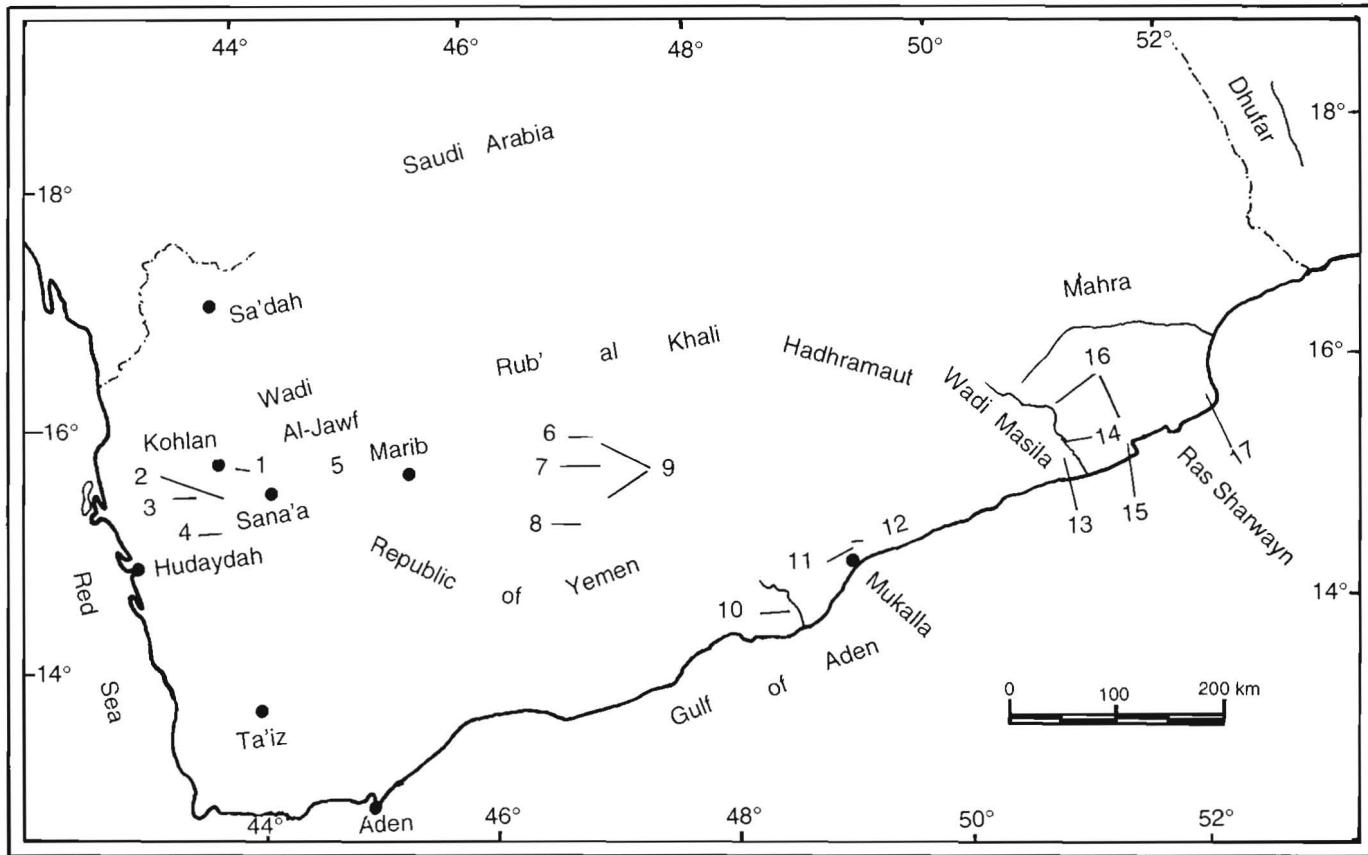


Fig. 1. Index map showing locations of the stratotypes of the Mesozoic lithostratigraphic units in the Republic of Yemen (after Beydoun 1964, 1966, Beydoun and Greenwood 1968, Beydoun *et al.* 1993, El-Nakhal 1987, 1988, 1990a):

- 1: The type area of the Kohlan Group, and the type sections of the Affar Formation, Azzan, Souq, and Hessen members.
- 2: The type section of the Tawilah Formation.
- 3: The type area of the Amran Formation.
- 4: The type section of the Surdud Group.
- 5: The type section of the Ghiras Member (Tawilah Formation).
- 6: The type section of the M'qah Member (Sabatayn Formation).
- 7: The type section of the Shabwa and Layadim members (Sabatayn Formation).
- 8: The type section of the 'Ayad Member (Sabatayn Formation).
- 9: The type area of the Sabatayn Formation.
- 10: The type sections of the Madbi and Nayfa Formations.
- 11: The type sections of the Mukalla Formation, Harshiyat Formation, Rays Member (Harshiyat Formation), and the reference section of the Qishn Formation in the western parts of the southern provinces.
- 12: The type sections of the Sufla Member (Harshiyat Formation), and Lusb Member (Mukalla Formation).
- 13: The type section of the Maqrat Member (Fartaq Formation).
- 14: The type sections of the Tihayr and Dha Sohis members (Fartaq Formation), and the reference section of the Harshiyat Formation in the eastern parts of the southern provinces.
- 15: The type sections of the Qishn and Sharwayn formations.
- 16: The type area of the Mahra Group.
- 17: The type section of the Fartaq Formation.

Yemen and correlate the equivalent rock units applying the same terminology in its two parts whenever this is possible. In this study I shall refer to the former "Yemen Arab Republic" as the northern provinces, and the former "People's Democratic Republic of Yemen" as the southern provinces.

#### **Stratigraphic development:**

Geological studies on the northern provinces of Yemen commenced with the work of Botez (1912), Beneyton (1913), Lamare (1923a, b, 1936, 1955) and Roman (1925). Detailed stratigraphical work was carried out by Lamare *et al.* (1930) who introduced the Kohlan, Amran, and Tawilah "Series" which were assigned to the Early Jurassic, Middle-Late Jurassic, and Cretaceous, respectively. Geukens (1960, 1966) traversed the country, measured sections, named formations and compiled the available information on the geology of the northern provinces. Since the 1980s the staff members of the Department of Geology, University of Sana'a, have carried out more detailed stratigraphical and sedimentological studies on the different Mesozoic rocks of the northern provinces (Abou-Khadrah 1982, Abou-Khadrah *et al.* 1983, Aboul-Ela 1983, El-Anbaawy 1984, El-Nakhal 1985, 1987, 1988, 1990a, El-Anbaawy and Al-Thour 1989).

In the southern provinces, the first geological studies were by Carter (1852), and Kossmat (1907). In (1908) Newton and Crick published faunal determinations of Jurassic molluscs. Little (1925) provided the first stratigraphical and paleontological account for the Mukalla area of this part of Yemen. Detailed stratigraphical studies were made by Wetzel and Morton for the Iraq Petroleum Co. group in unpublished reports during the period 1948-1950 (Beydoun 1964, 1966, Beydoun and Greenwood 1968). The currently used stratigraphy of the southern provinces was established by Beydoun (1964) who described group, formation, and member divisions of lithostratigraphic units, revised nomenclature by Wetzel and Morton, and incorporated new names.

### The Mesozoic Erathem in Yemen

The Mesozoic rocks in Yemen consist of nonmarine and marine clastics and carbonates which are included within the Affar Sandstone, the Surdud Group, the Ghiras Sandstone Member, and the Ghiras/Mahra Groups. The Affar Formation is the upper unit of the Kohlan Group, and the Ghiras is the lower member of the Tawilah Formation. These units are shown in (Table 1).

**Table 1:** Lithostratigraphic units belonging to the Mesozoic Erathem in the Republic of Yemen

Age		Nothern Provinces		Southern Provinces
Cenozoic	Tertiary	Tawilah Formation	Medj-Zir Sandstone Member	Umm er Radhuma Formation
	Paleocene			
Mesozoic	Cretaceous	Tawilah Formation	Ghiras Sandstone Member	Ghiras / Mahra Group Group
	Middle-Late Jurassic	Surdud Group		
	Early Jurassic Triassic?	Kohlan Group	Affar Formation	Kohlan Formation
Permian	Kooli Formation (= Akbara Shale)			

### Kohlan Group:

The term Kohlan "Series" was originally introduced by Lamare *et al.* (1930) to describe the shales and sandstones which extend between the basement rocks below, and the Amran Limestone (Middle-Late Jurassic) above in the Kohlan area (Fig. 1). On the basis of the occurrence of Liassic plant fossils in its upper parts, the Kohlan "Series" was dated as Early Jurassic (Carpentier and Lamara 1932). As the shales which constitute the lower part of the Kohlan "Series" exhibit definitive features of glacial origin (Roland 1978, Kruck and Thiele 1983, El-Nakhal 1984, 1987, 1992), they were correlated with the Late Paleozoic Gondwana glacial deposits. Accordingly, the lower age range of the "series" has been expanded to the Permian and the age of the Kohlan sequence was considered by El-Nakhal (1984, 1987, 1989, 1990a, 1992) to be Permian-? Triassic to Early Jurassic.

El-Nakhal (1987) treated the Kohlan in the northern provinces as a group which he subdivided into two formations and five members which are shown in (Table 2).

**Table 2:** Subdivisions of the Kohlan Group in the northern provinces of the Republic of Yemen (after El-Nakhal 1987)

Age	Group	Formation	Member
Early Jurassic	Kohlan Group	Affar Formation	Hessn Sandstone Mem.
↑			Souq Sandstone Mem.
Triassic ?		Kooli Formation (= Akbara Shale)	Azzan Sandstone Mem.
~~~~~			Khalaqah Shale Mem.
Permian			Sharas Siltstone Mem.

As the present study is concerned with the Mesozoic sequence in Yemen, the Affar Formation will be discussed below, whereas the Kooli Formation (= Akbara Shale) being of Permian age will not be treated here.

### Affar Formation:

The Affar is the upper Formation of the Kohlan Group, the lower being the Kooli (= Akbara Shale). The term was introduced by El-Nakhal (1987) to accommodate the fluvial sandstones which form the upper parts of the Kohlan Group. It replaces the informal term "Kohlan Sandstone" of Roland (1979) in the

northern provinces. The type locality lies in the Kohlan area and it was named after Kohlan Affar town (lat. 15° 43' 47' N, long. 43° 42' 13' E). In its type locality, the Affar consists of about 190 m of fine to medium, whitish, and brownish sandstones, with numerous thin, green and brownish claystone siltstone interbeds, and occasional conglomeratic beds particularly in the middle parts. The lower contact with the Kooli Formation (= Akbara Shale) is unconformable, and the upper contact with the Amran Formation is gradational and conformable.

The upper parts of the Affar Formation have yielded a group of plant fossils of Liassic age (Carpentier and Lamare 1932). These include: *Pagiophyllum* sp. cf. *P. peregrinum*, *Dictyophyllum* sp., *Laccopteris* sp., *Cladophlebis* sp. Also, El-Nakhal (1987) recorded trace fossils in the form of tracks and burrows in the upper parts of this rock unit in the Kohlan area. On the above basis the Affar Formation was assigned to the Liassic (Early Jurassic). This age assignment was substantiated by the record of *Coskinolinopsis primaevus* (of Liassic age) in a thin exposure of similar deposits outcropping above the basement in Dhufar (Oman) in Beydoun and Greenwood (1968), and the occurrence of Bajocian (earliest Middle Jurassic) benthic foraminifera in the basal parts of the conformably overlying Amran Formation (El-Nakhal 1990a).

As the Affar Formation unconformably overlies the Kooli Formation (Permian) (= Akbara Shale), and as the beds surrounding the contact on both sides do not bear diagnostic fossils, it is not known whether the Triassic System is represented within the Affar or not.

The Affar Formation is well exposed in the northwestern regions of the Republic of Yemen. Its equivalents are recognized in the southern provinces and they were included within the Kohlan Formation whose exposures are present in all Jurassic sections in this part of Yemen (Beydoun 1966, Beydoun and Greenwood 1968).

El-Nakhal (1987) subdivided the Affar Formation into three sandstone members which are in ascending order, the Azzan, Souq, and Hessn members (Table 2).

*Azzan Sandstone Member:* This unit was introduced by El-Nakhal (1987). It includes the lower part of the Affar Formation, and consists of fine-medium, white, and yellow sandstones, with numerous green claystone and thin siltstone, interbeds. The type section lies near Kohlan Affar town (lat. 15° 43' 57' N, long. 43° 42' 13' E), and it was named after Azzan Village. In that locality, it begins with a thin basal conglomeratic bed, and attains a thickness of 55 m.

No fossils were recorded but on stratigraphical grounds it was assigned to the Early Jurassic (El-Nakhal 1987). The Azzan Member unconformably overlies the Khalaqah Shale Member (of the Kooli Formation, = Akbara Shale), and conformably underlies the Souq Sandstone Member.

*Souq Sandstone Member:* The Souq Sandstone Member was suggested by El-Nakhal (1987) to include the middle part of the Affar Formation which consists of brownish, ferruginous, fine-medium sandstones, with thin brownish claystone and siltstone interbeds.

Its middle part includes a brownish gravelly siltstone bed very rich in basement rock boulders reaching a maximum diameter of 1.5 m. This bed has a thickness of about 2 m and it is considered here as representing a mud flow. The type locality lies near Kohlan Affar town (lat. 15° 43' 57' N, long. 43° 42' 13' E) and it was named after the Souq of Kohlan (= market of Kohlan). In the type area, the Souq Member attains a thickness of about 60 m, and exhibits numerous polygonal cracks which were attributed to the effect of cooling and frost action during the Pleistocene Epoch (El-Nakhal 1985, 1987, 1990b, 1993).

The Souq Member has yielded no fossils but on stratigraphical grounds it was assigned to the Early Jurassic. It lies conformably between the underlying Azzan and the overlying Hessn members.

*Hessn Sandstone Member:* This is the uppermost member of the Affar Formation. It was introduced by El-Nakhal (1987). Its type section lies near Kohlan Affar town (lat. 15° 43' 57' N, long. 43° 42' 13' E) and it was named after Hessn Kohlan (= castle of Kohlan). It consists of about 75 m of fine-medium, white, and yellow sandstones with thin greenish claystone interbeds.

The plant and trace fossils which were recorded in the Affar Formation (Carpentier and Lamare 1932, El-Nakhal 1987) were found in the Hessn Member. On the basis of these, the member is dated as Liassic. The lower contact with the Souq Member, and the upper contact with the Amran Formation are conformable.

### **Surdud Group:**

This group includes the limestones, marly clastics, shales, and evaporites of Middle-Late Jurassic age which constitute the Amran, and Madbi/Sabatayn Formations, and lie between the Affar Formation (Early Jurassic) and the Tawilah Formation (Cretaceous-Paleocene) in the northern provinces of Yemen. It was introduced by El-Nakhal (1990a). The type section lies in Wadi Surdud near its

junction with Wadi Al-Ahjur (lat. 15° 10' N, long. 43° 42' E), where it attains a thickness of 360 m. This rock unit has yielded a rich assemblage of micro- and macrofossils (see details under individual formations and members) which indicates a Bajocian-Kimmeridgian age for the group (El-Nakhal 1990a).

The equivalents of the Surdud Group in the southern provinces were included within the Amran Group. The Surdud Group was subdivided by El-Nakhal (1990a) into the Amran, and the Madbi/Sabatayn formations, whereas the Amran Group was subdivided into the Shuqra, Madbi/Sabatayn, and Nayfa formations. However, the Amran "Series" was originally introduced to include the calcareous sequence which lies between the Kohlan "Series" below and the equivalents of the transitional beds (= Madbi/Sabatayn Formations) above (Lamare *et al.* 1930, p. 52, 53, Fig. 17). Accordingly, the attachments of the Madbi/Sabatayn, and Nayfa Formation to the Amran does not conform with its original definition. On the other hand, the Shuqra Formation in the southern provinces is correlatable with the Amran Formation in the northern provinces. As the Amran was introduced in 1930 (Lamare *et al.* 1930), and the Shuqra in 1950, in an unpublished report prepared by Heybrock (cited in Hudson 1954), the Amran has a date priority over the Shuqra.

On the basis of the above-mentioned points it is suggested that:

- (a) To use the term Amran within its original definition.
- (b) To stop using the term Amran Group in the southern provinces, and replace it with the term Surdud Group.
- (c) To treat the Shuqra Formation as a junior synonym of the Amran Formation, and drop it from the Jurassic stratigraphy of Yemen.
- (d) To consider the Nayfa as the uppermost formation of the Surdud Group. This does not contradict with the original definition of the Surdud Group which accommodates the sedimentary sequence lying between the Affar Formation below and the Tawilah Formation above.
- (e) To expand the upper range of the Surdud Group to the Portlandian (= Tithonian).

The application of these suggestions would facilitate the subdivision and correlation of the Middle-Upper Jurassic succession in both the northern and southern provinces, as it is shown in (Table 3).



**Table 3:** Subdivisions of the Middle-Upper Jurassic succession in the Republic of Yemen

Group	Formation	Member	Age
Surdud Group	Nayfa Formation	—	Portlandian (= Tithonian)
	Madbi / Sabatayn Form. Form.	'Ayad Mem. / M'qah Mem.	Late Kimmeridgian
		Layadim Member	
		Shabwa Member	
Amran Formation	—	Early Kimmeridgian ↑ Bajocian	

**Amran Formation:**

This lithostratigraphic term was introduced by Lamare *et al.* (1930) as the Amran "Series" to include the Jurassic calcareous sequence lying between the Kohlan "Series" below and the equivalents of the transitional beds above. As this unit is not divisible into mappable smaller units, El-Nakhal (1990a) gave it a formational rank. The type section of Amran "Series" was not precisely located by Lamare *et al.* (1930), but Geukens (1960, 1966) deduced that its type locality lies in the southern side of Wadi La'ah. In the type locality it consists of about 320 m of light grey limestone, with shale and marl interbeds. In the southern provinces, the junior synonym of the Amran Formation (Shuqra Formation) consists of 39-80 m of fossiliferous limestones and marls. In southwestern Saudi Arabia, the Amran Formation consists of 20-720 m of crystalline, blue-grey limestone and dolomite, locally silicified and brecciated, with minor beds of shale and tuff near top (Brown *et al.* (1989). The exposures of the Amran Limestone are widely distributed in the northern and southern provinces of Yemen as well as in southwestern Saudi Arabia. In the centres of the Jurassic sedimentary basins, the lower contact with the Affar Formation, and the upper contact with the Madbi/Sabatayn Formations are gradational and conformable. In localities lying near the margins of the sedimentary basins, one or both contacts may be unconformable (El-Nakhal 1990a).

The exposures of the Amran Limestone in the northern provinces, southern provinces, and southwestern Saudi Arabia have yielded numerous fossils (for details see Basse *et al.* 1955, Geukens 1960, 1966, Schott *et al.* 1960, Beydoun 1964, 1966,

Greenwood and Bleackley 1967, Beydoun and Greenwood 1968, Brown *et al.* 1989, El-Nakhal 1990a), which date the Amran and its junior synonym the "Shuqra Formation" as Bajocian-Kimmeridgian. However, as the Amran conformably underlies the Madbi Formation which contains fossils of Kimmeridgian age, the Amran Formation is dated as Bajocian-Early Kimmeridgian (Middle-Late Jurassic), (El-Nakhal 1990a).

#### **Remarks:**

El-Anbaawy (1984), recognized in the Amran sequence of the northern provinces of Yemen, seventeen facies associations which he included in four formations and two members. El-Anbaawy (1984) suggested the Wadi Al-Ahjur Formation, Jabal Salab Formation. Thoma Member and Wadi Naham Member as new units. However, he delineated his new units on the basis of their inferred facies characteristics; this however, violates the rules of stratigraphic nomenclature (North American Stratigraphic Code 1983, Articles 22a, d, and 24,b). Accordingly, all the new units suggested by El-Anbaawy (1984) are informal, and thus invalid and they are therefore, rejected in the present study.

El-Anbaawy and Al-Thour (1989) studied the sedimentological evolution of the "Thoma Member" of El-Anbaawy (1984) in the eastern parts of the northern provinces. In this informal member, El-Anbaawy and Al-Thour (1989) recognized three megafacies. Proceeding from the shore landwards they were as follows: ooid bank, shelf lagoon, and alluvial coastal plain.

#### **Madbi/Sabatayn Formations:**

The Madbi and Sabatayn were considered by Beydoun (1964, 1966) to be laterally equivalent formations deposited in two different depositional environments. The Madbi consists predominantly of marl deposited in a shallow to open-marine environment, whereas the Sabatayn consists of evaporites laid down in an isolated basin (or basins).

#### **Madbi Formation:**

This formation name was introduced by Beydoun (1964). Its type section lies in the southern provinces of Yemen, in Jabal Madbi (lat. 14° 22' N, long. 48° 06' E). In its type locality, the Madbi Formation consists of 233 m of fossiliferous grey marls, occasionally gypsiferous, locally bituminous, with thin fossiliferous, rubbly, marly limestone interbeds. In the northern provinces, the Madbi Formation is represented by a widely variable lithology. In Wadi Surdud it includes sandy beds and shale with marl interbeds. To the west, in the Arida-Mujabjib area it is composed of shale including gypsum and limestone interbeds. In the southern slopes of Wadi La'ah it

is represented by shale with sandstone interbeds. In the north around the Sa'dah area, the formation consists of fossiliferous sandstones, gypsum lenses and sandy limestone interbeds.

In the southern provinces, the Madbi Formation conformably overlies the Amran Formation, and underlies the Nayfa Formation. Similarly, in the northern provinces its lower contact with the Amran Limestone, and upper contact with the Tawilah Sandstone are conformable.

In both the southern and northern provinces, the Madbi Formation has yielded a rich assemblage of fossils (Geukens 1960, Beydoun 1964, 1966, Beydoun and Greenwood 1968).

On the basis of its fossil content, Beydoun (1966) assigned the Madbi Formation to the Kimmeridgian with the probability that the age may extend from the Early Oxfordian (Argovian) to the Late Kimmeridgian. Beydoun and Greenwood (1968) dated it as Late Oxfordian to Late Kimmeridgian, whereas El-Nakhal (1990a) assigned it to the Late Kimmeridgian.

#### **Sabatayn Formation:**

The Sabatayn is thought to be the lateral equivalent of the Madbi Formation (Beydoun 1964, 1966). The formation was introduced by Wetzel and Morton in 1950 in an unpublished report (cited in Beydoun 1964, 1966, Beydoun and Greenwood 1968). It was named after Ramlat as Sabatayn area, and its type locality lies in the southern provinces of Yemen in the Jurassic salt-dome area. In both the southern and northern provinces, the Sabatayn consists of lower halite (base not seen) followed upwards by black shales, and gypsum which grades laterally into sandstone and shale. Its thickness is variable, the maximum being about 300 m. In the southern provinces its lower contact is not exposed, whereas its upper contact with the Nayfa Formation is conformable. Similarly, the lower contact in the northern provinces is not exposed and the upper contact with the Tawilah Formation is conformable. Fish remains and pollen grains occur at certain levels (see details under specific members). On paleontological basis it was considered to be of Late Jurassic age by Beydoun (1966) and Beydoun and Greenwood (1968), whereas El-Nakhal (1990a) assigned it to the Late Kimmeridgian.

Beydoun (1964, 1966) subdivided the Sabatayn Formation in the southern provinces into four members which are in ascending order: the Shabwa, Layadim, 'Ayad, and M'qah; the last two members are laterally equivalent and interfinger. El-Nakhal (1990a) recognized these members in the northern provinces and applied the same names.

*Shabwa Salt Member:* This is the lowest member of the outcropping Sabatayn Formation and it occurs in all Jurassic salt domes in both the southern and northern provinces of Yemen. It was introduced by Wetzel and Morton 1950, in an unpublished report (Beydoun 1964, 1966, Beydoun and Greenwood 1968). The base of the Shabwa Member is not exposed and generally only the upper 10-20 m are seen. This Member consists of rock salt which has a layered structure, grey striations and bituminous stains. The name was given after the Shabwa Salt Dome in the southern provinces (lat. 15° 22' N, long. 47° 02' E); the Layadim Shale Member conformably overlies it (Beydoun 1964, 1966, Beydoun and Greenwood 1968). In the northern provinces, the Shabwa Salt Member is exposed in the Safir Salt Dome (15° 41' N, long. 46° 09' E). It has a similar lithology to that of the type section. In the Al-Ghiras area near Sana'a, this Member is seemingly not present. Field observations as well as the information collected from the citizens who dug water wells in this area, support that it is most probably not represented at this locality. Beydoun (1964, 1966) and Beydoun and Greenwood (1968) dated the Shabwa Member as Late Jurassic, whereas El-Nakhal (1990a) considered it to be of Late Kimmeridgian age.

*Layadim Shale Member:* This name was introduced by Wetzel and Morton in an unpublished report prepared in 1950 (Beydoun 1964, 1966). It consists of variegated shales, commonly black, papery, bituminous, occasionally sandy, micaceous, with thin marl, shaly limestone, dolomitic limestone, and gilsonite thin interbeds. In some salt domes this unit becomes marly, locally shaly and contains salt streaks. Its thickness varies from 7 to 68.5 m. It is conformably underlain and overlain by the Shabwa and 'Ayad (or M'qah) members, respectively (Beydoun 1964, 1966, Beydoun and Greenwood 1968). The Member is recognized in all Jurassic salt domes in the southern provinces of Yemen and was named after Al 'Ayadim Salt Dome, while its type section is in the Shabwa Salt Dome in the southern provinces. This member also occurs in the Al-Ghiras area near Sana'a (in the northern provinces) where only the upper 0.5-1 m is exposed and there it consists of black, papery, bituminous shale with occasional pyrite crystals. The Layadim Member has yielded abundant *Estheria* and *Sponistroma* of Late Jurassic age, and a rich assemblage of fossils fish, spores and pollens (for details see Basse *et al.* 1955, Schott *et al.* 1960, Geukens 1960, Beydoun 1964, 1966, Beydoun and Greenwood 1968, El-Nakhal 1990a). On the basis of its fossil content and stratigraphical position the Layadim Member was assigned to the Late Jurassic by Beydoun (1964, 1966) and Beydoun and Greenwood (1968), and to the Late Kimmeridgian by El-Nakhal (1990a).

*'Ayad Gypsum Member:* This is one of the upper two units of the Sabatayn Formation the other being the M'qah Sandstone Member which is its lateral variant. It was introduced by Wetzel and Morton in 1950 in an unpublished report (cited in Beydoun 1964, 1966). This rock unit consists of white to yellow bedded gypsum, with occasional thin dolomite, argillaceous and biyuminous limestone interbeds. It conformably overlies the Layadim Shale Member, and generally underlies the Nayfa Limestone. Its thickness is variable being 230 m at its maximum development at the 'Iyadh Dome. In most other domes, the member is incompletely preserved or absent owing to erosion, and only at the 'Iyadh Salt Dome in the southern provinces (its type section, lat. 14° 59' N, long. 46° 49' E) is in actual contact with the overlying Nayfa Formation (Beydoun 1964, 1966, Beydoun and Greenwood 1968). In the northern provinces the 'Ayad Member is well developed in the Al-Ghiras area where it is represented by thick gypsum lenses. In this part of Yemen, it consists of about 60 m of gypsum with marl and clay interbeds, and it conformably extends between the underlying Layadim Shale Member and the overlying Ghiras Sandstone Member (of the Tawilah Formation). At the Safir Salt Dome, this member is incompletely preserved and it is replaced by its laterally equivalent, the M'qah Sandstone Member. On stratigraphical grounds the 'Ayad Member was assigned to the Late Jurassic (Beydoun 1964, 1966, Beydoun and Greenwood 1968), and to the Late Kimmeridgian (El-Nakhal 1990a).

*M'qah Sandstone Member:* The M'qah Member is regarded as the lateral equivalent of the 'Ayad Gypsum Member. It was named by Wetzel and Morton in an unpublished report prepared in 1950 (Beydoun 1964, 1966). This member occurs in the Milh Maq'ah dome and it is partly represented in the Shabwa Dome as a tongue in the 'Ayad Member. At its type section (Milh Maq'ah Dome) the member consists of about 150 m of coarse, greenish, ripple-marked sandstone alternating with micaceous shales with plant remains. Beds of clayey limestone, dolomite and marl are found at various levels, and gypsum is present at the base and top and in bands at various levels within the clastic sequence (Beydoun 1964, 1966, Beydoun and Greenwood 1968). In the northern provinces, the M'qah Member is exposed in the Safer Dome where it attains a thickness of 150 m and consists of clayey sandstone which is very rich in gypsum, followed upwards by alternating grey, sandy shale and purple sandstone. The upper parts are covered with Recent dunes. Beydoun (1964, 1966) and Beydoun and Greenwood (1968) assigned this member to the Late Jurassic, whereas El-Nakhal (1990a) considered it to be of Late Kimmeridgian age.

#### **Naya Formation:**

The Nayfa is the uppermost formation of the Surdud Group. It is recognized in the southern provinces both in the coastal regions and the salt-domes area, but is

absent in the northern provinces. The term was introduced by Pike and Wofford in 1939, in an unpublished report (Beydoun 1964, Beydoun and Greenwood 1968). The stratotype lies in the southern provinces in Jabal Madbi, Wadi Hajar, near Ma'abir (lat. 14° 22' N, long. 48° 06' E). The formation consists of thin-bedded, porcelaneous limestones with platy dolomites and marly layers. It lies conformably on the Madbi/Sabatayn Formations, and is unconformably overlain by the Qishn Formation. Lithologically, the Nayfa is divisible into two parts. The lower part consists of a sequence of thin-bedded, microcrystalline to porcelaneous limestones with common thin interbeds of platy dolomite, dolomitic shale, rubbly marly limestone or marl. This sequence is widely distributed and ranges in thickness from 50 to 446 m. It contains several conglomeratic limestone zones marking intraformational breaks within the formation. The upper part consists of a sequence of marly generally grey and yellow, commonly shaly and in places gypsiferous or silty and containing interbeds of marly, rubbly to fissile, microcrystalline, locally shelly, grey limestones. A maximum thickness of 78 m for this part was measured at the Al Ma'abir section (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

The Nayfa Formation has yielded numerous macro- and microfossils which date the formation as Portlandian (= Tithonian, latest Jurassic) to possible Berriasian (Earliest Cretaceous), (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

The Nayfa Formation is restricted in its occurrence to the southern provinces. This indicates that the south-to-north Nayfa marine transgression which deposited the limestone, following the Madbi/Sabatayn deposition, did not reach the northern provinces. Instead, continental conditions prevailed and gravelly sandstones of the Ghiras Member (of the Tawilah Formation) were deposited (Beydoun 1964, 1966, El-Nakhal 1990a). This also suggests that the lower part of the Ghiras Sandstone Member (Early Cretaceous) is equivalent to the Nayfa Formation.

#### **Tawilah Formation:**

The term Tawilah was introduced as Tawilah "Series" by Lamara *et al.* (1930) in which they included the sandstone sequence lying between the Middle-Late Jurassic Amran "Series", and the Tertiary volcanic rocks. Also, Lamara *et al.* (1930) included within their Tawilah "Series" the underlying marls, siltstones, shales, which form the Transitional Beds (= Madbi/ Sabatayn Formations). At that time the Tawilah "Series" was believed to be nonfossiliferous, and on stratigraphical grounds it was dated as Cretaceous. In 1960, Geukens recorded marine fossils of Eocene or Paleocene age in the upper parts of the Tawilah "Series". Accordingly, he subdivided the Tawilah "Series" into a lower part corresponding to the continental sandstones, and an upper part corresponding to the marine sandstones. That author,

also restricted the term Tawilah "Series" to the lower continental part, and he introduced the term Medj-Zir "Series" to accommodate the upper marine sandstone. El-Nakhal (1988) revised the original definition of the Tawilah "Series", restricted it to the sandstone sequence lying between the Transitional Beds (= Madbi/Sabatayn Formations) below, and the Tertiary volcanics above. He also gave the Tawilah a formational rank, and subdivided it into the Ghiras Sandstone Member which includes the continental sandstones (of Cretaceous age), and the Medj-Zir Sandstone Member which includes the marine sandstones (of Paleocene age), and this is followed in the present study. The Ghiras Member is discussed below, whereas the Medj-Zir Member being of Paleocene age, will not be treated here.

The type section of the Tawilah Formation lies in Jabal Al-Tawilah about 50 km northwest of Sana'a (lat. 15° 30' N, long. 43° 42' E). In its type locality the formation consists of about 300 m of white, yellow, occasionally brown, fine to coarse-grained, usually gravelly, cross-bedded sandstones, with clay, shale and siltstone interbeds, and occasional hematitic nodules. The sequence is cut by numerous fissures and dikes fed by the Tertiary volcanism. The lower contact of the Tawilah Formation with the Madbi/Sabatayn Formations is conformable. Its upper contact with the Yemen Volcanics was considered to be unconformable by El-Nakhal (1988), and diachronous and conformable by Menzies *et al.* (1990). The continental lower sandstones which constitute the Ghiras Member contain fragments of silicified wood, and trace fossils, whereas the sandstones of the Medj-Zir Member yielded an assemblage of marine fossils including benthic foraminifera and trace fossils (mainly *Thalassinoides*). The stratigraphical position and fossil contents of the Tawilah Sandstone indicate a Cretaceous-Paleocene age (El-Nakhal 1988).

#### Remarks:

The Tawilah sequence is widely distributed in Yemen, and its exposures are known in both the northern and southern provinces. Abou-Khadrah (1982) divided the Tawilah Formation into two informal members: lower and upper. Similarly, Aboul Ela (1983) informally divided this unit into lower, middle, and upper units. Abou-Khadrah *et al.* (1983) following Geukens (1960, 1966), used the term Tawilah within its restricted sense (*i.e.* applied it for the continental sandstones of Cretaceous age only) which they subdivided into Thula, Shebam, and Kawkaban members. This usage however, does not agree with the original definition of the formation (Lamare *et al.* 1930) nor with its revised definition (El-Nakhal 1988), and violates the rules of stratigraphic nomenclature (1983, Article 19, Remark g). Furthermore, field observations show that both the Tawilah Formation (in its restricted sense) and the overlying Medj-Zir sequence, which are exposed in Sana'a area, cannot be mapped separately. These observations are substantiated by: (a) Geukens (1960, 1966)

recognized the Medj-Zir "Series" on the basis of its fossil content and geological age rather than its lithologic characteristics; and (b) Grolier and Overstreet (1978), Kruck (1984), and Kruck *et al.* (1984), mapped these two rock units collectively together as a one unit. Accordingly, none of these two rock units can be given a formational rank but they may be considered as two members within the same formation. Therefore, the Tawilah Formation in its restricted sense, should be treated as a member, and its subdivision into members is here rejected (North American Stratigraphic Code 1983, Article 25, Remark d).

In the southern provinces, the equivalents of the Ghiras Sandstone Member are represented by two main facies: (a) a clastic facies which is well developed in the west, and was included within the Tawilah Group; and (b) a carbonate facies which is well developed in the east, and was included within the Mahra Group. Both the Tawilah and Mahra groups were assigned to the Cretaceous. Beydoun (1964, 1966) subdivided the Tawilah Group into the Qishn, Harshiyat, and Mukalla formations, and the Mahra Group into the Qishn, Harshiyat, Fartaq, Mukalla, and Sharwayn formations. However, as mentioned above the restriction of the term Tawilah to the Cretaceous sequence does not conform with its original definition (Lamare *et al.* 1930) nor with its revised definition (El-Nakhal 1988). Therefore, it is suggested to replace it with the term Ghiras Group. Accordingly, the classification of the Cretaceous System in both the northern and southern provinces of Yemen is modified as shown in (Table 4).

*Ghiras Sandstone Member:* This member was introduced by El-Nakhal (1988) to accommodate the continental sandstones which form the lower parts of the Tawilah Formation, and lie between the Madbi/Sabatayn Formations (Late Jurassic) and the Medj-Zir Sandstone Member (Paleocene). Its stratotype lies in Jabal Zi Marmer in Al-Ghiras area, about 20 km northeast of Sana'a (lat. 15° 35' N, long. 44° 24' E). In its type area it consists of 250 m of white and brown, usually medium to coarse-grained, gravelly, ferruginous sandstones, with siltstone, clay and shale interbeds. It is characterized by the abundance of fissures and joints. In some localities, the Ghiras Member includes in its middle part a brownish, ferruginous sandstone interval with a thickness ranging from few meters to about 60 m. However, as this interval constitutes a part of a member with a relatively restricted geographical distribution, it is here considered as a key bed of local importance.

The Ghiras Member extends conformably between the Madbi/Sabatayn Formations below, and the Medj-Zir Sandstone Member above. Only silicified wood and trace fossils were recorded in the Ghiras Member. On the basis of its stratigraphical position between the Madbi/Sabatayn Formations (Late Jurassic), and



**Table 4:** Classification and correlation of the Cretaceous System in the northern and southern provinces of the Republic of Yemen

Northern Provinces		Southern Provinces			Age				
		West		East					
<b>Tawilah Formation</b>	Medj-Zir Sandstone Member	Umm er Radhuma Formation			Paleocene				
	Ghiras Sandstone Member	Chiras Group	Mukalla Formation	Lusb Mem.	Sharwayn Formation	Masstrichtian			
				Harshiyat Formation	Makra Group	Fartaq Formation	Maqrat Member	Senonian	Campanian
			Sufla Mem.						Tihayr Member
		Rays Mem.	Dha Sohis Member						
		Qishn Formation	Harshiyat Formation	Qishn Formation	? Turonian –				
					Cenomanian				
					Albian				
		Aptian and Barremian							

the Medj-Zir Member (Paleocene), the Ghiras Member was dated as Cretaceous (El-Nakhal 1988). As mentioned above, the Nayfa Formation of the southern provinces, and the lower parts of the Ghiras Sandstone member are coeval.

### **Ghiras Mahra Groups:**

In the southern provinces, the Cretaceous System is included within the Ghiras and Mahra groups which are laterally equivalent and interfinger. The name Ghiras Group is a readaptation of El-Nakhal's Ghiras Member (El-Nakhal 1988) of the northern provinces. The Ghiras Group replaces the term Tawilah Group of Beydoun (1964, 1966) and subsequent authors, which does not agree with both the original (Lamare *et al.* 1930) and revised (El-Nakhal 1988) definitions of the Tawilah. It is a shallow-water to lagoonal-marine sequence consisting dominantly of varicolored, ferruginous, locally cross-bedded sandstone, siltstone, marl, and shale, with abundant conglomerates and scattered lenses of limestone containing fossils of Barremian to Maastrichtian age. The group is well exposed in the western parts, and is unconformably underlain by the Amran Formation or the Precambrian basement, and overlain by the Umm er Radhumah Formation. Beydoun (1964, 1966) subdivided the sequence embraced by the Ghiras Group into the Qishn, Harshiyat, and Mukalla formations.

The Mahra Group on the other hand, was introduced by Wetzel and Morton in 1948, in an unpublished report (cited in Beydoun and Greenwood 1968). In its full development, it includes the marine carbonate equivalent of the Ghiras Group of the western parts. It thickens and grades from sandstones to predominantly carbonates eastwards. This group is fossiliferous and on paleontological evidence it was dated as Barremian-Maastrichtian. It is unconformably underlain by the Nayfa Formation, and overlain by the Umm er Radhumah Formation. Beydoun (1964, 1966) subdivided the Mahra Group into the Qishn, Harshiyat, Fartaq, Mukalla, and Sharwayn formations.

### **Qishn Formation:**

This is the lowest exposed formation for both the Ghiras and Mahra groups. It varies laterally between the eastern and western regions of the southern provinces, being thinner in the west with clastics forming its lower part. The Qishn Formation was introduced by Wetzel and Morton in an unpublished report prepared in 1948 (cited in Beydoun 1964, 1966, Beydoun and Greenwood 1968). Its type section lies in the Mahra Province at Ras Sharwayn, near Qishn (lat. 15° 25' N, long. 51° 37' E). A reference section for the formation in the western regions was designated at Jabal ar Rays near Al-Mukalla (lat. 14° 35' N, long. 49° 08' E), (Beydoun 1964, 1966, Beydoun and Greenwood 1968, Beydoun *et al.* 1993). At its type section, the Qishn

Formation consists of 411 m of fossiliferous limestone with marl interbeds. It begins with 5 m of brecciated limestone which was taken as evidence of an unconformity. It rests (probably unconformably) on the Nayfa Formation (Tithonian to possible Berriasian). In the western regions, the reference section of the present formation attains a thickness of about 32 m. The sequence includes a basal conglomeratic sandstone, this is followed by marl and fossiliferous, sandy, shaly, massive to well bedded limestone. Its lower contact with the Precambrian basement, or with the Upper Jurassic rocks is unconformable, whereas its upper contact with the Harshiyat Formation is conformable (Beydoun 1964, 1966, Beydoun and Greenwood 1968). The Qishn Formation outcrops in several localities along the coastal regions of the southern province between the border with Oman and about long. 47° 10' E. It was also detected in the subsurface of both the offshore and onshore areas of the southern provinces where it reflects the same characteristic features of the formation in outcrop (Beydoun *et al.* 1993). However, Beydoun *et al.* (1993) pointed out that in the subsurface of the Wadi Hadhramaut area, the Qishn Formation sand development was much greater and thicker than anticipated in an interval previously thought most likely to be dominated by carbonates and shale.

The Qishn Formation has yielded numerous fossils which date it as Barremian-Aptian (Beydoun 1966, Beydoun and Greenwood 1968, Beydoun *et al.* 1993). Beydoun *et al.* (1993) equated the present formation with both the upper Kahma Group of Oman, and the upper Thamama Group of Saudi Arabia and the Gulf area.

#### **Harshiyat Formation:**

The Harshiyat Formation is represented in both the eastern and western parts of the southern provinces of Yemen. The name was introduced by Wetzel and Morton in 1948, in an unpublished report (Beydoun 1964, 1966). Its type section lies in the western parts in Hadhramaut, at Jabal al Rays (lat. 14° 35' N, long. 49° 08' E). A reference section for the Harshiyat Formation in the eastern parts was designated in Mahra at Wadi Masila, Tihayr area (lat. 15° 42' N, long. 50° 44' E). In its type area the formation consists of 293 m of fine to coarse, ferruginous, calcareous, friable to hard, well bedded to massive, cross bedded sandstones with siltstone, shale, marl, dolomitic limestone, and recrystallized, fossiliferous limestone interbeds. This sequence of clastics contains two persistent limestone or dolomitic limestone interbeds. The lower occurs within the lower sequence of the clastics and forms the Rays Member. The upper caps the upper part of the clastics and forms the Sulfa Member which separate the Harshiyat from the overlying and lithologically similar Mukalla Formation. Both members pinch out westwards (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

The reference section of the Harshiyat Formation in the eastern parts in Wadi Masila, consists of 195 m of green, purple, brown, fossiliferous shale, and varicolored, partly calcareous, fine to medium grained, cross bedded, fossiliferous sandstone with marl and shale interbeds.

This formation extends conformably between the underlying Qishn Formation, and the overlying Mukalla Formation. In its upper parts, the rock unit bears numerous fossils such as molluscs, echinoderms, foraminifers and plant remains (see details in individual members). On paleontological and stratigraphical grounds the Harshiyat Formation was dated as Albian-Cenomanian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

The Harshiyat Formation includes two limestone members which are in ascending order, the Rays and Sufla.

*Rays Limestone Member:* It was introduced by Beydoun (1964) to accommodate a persistent limestone interval that lies in the lower part of the Harshiyat Formation. Its type section lies at Jabal Al-Rays near Mukalla, Hadhramaut (lat. 14° 35' N, long. 49° 08' E). The stratotype consists of 9 m of grey to brown, bedded to semi-massive, coarsely recrystallized, partly dolomitic, occasionally slightly sandy, ferruginous, weathered reddish brown limestone. This member thins westwards and pinches out some 80 or 90 km west of Al-Mukalla. Due to recrystallization, no recognizable fossils have been preserved other than possible crinoid fragments. On the basis of its stratigraphical position the Rays Member was assigned to the Albian (Beydoun and Greenwood 1968).

*Sufla Limestone Member:* This Member was described by Wetzel and Morton in an unpublished report prepared in 1950 (Beydoun 1964). The stratotype lies at Ath Thil'ah as Sufla, 12 km northeast of Mukalla, Hadhramaut (lat. 14° 37' N, long. 49° 10' E). It consists of 16 m of grey, crystalline, fine to coarse grained, massive, fossiliferous limestone, occurring at the top of the clastics of the Harshiyat Formation, which thin westwards. On the basis of the occurrence of a diagnostic assemblage of fossils, the Sufla Member was dated as Cenomanian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

#### **Fartaq Formation:**

The occurrence of the Fartaq Formation is restricted to the eastern regions of the southern provinces. It is a limestone-marl succession that is the lateral equivalent of the upper horizons of the Harshiyat clastics of the western regions. This rock unit was introduced by Wetzel and Morton in an unpublished report prepared in 1948

(Beydoun 1964, Beydoun and Greenwood 1968). Its stratotype lies at Ras Fartaq, Mahra Province (lat. 15° 56' N, long. 52° 09' E), where it consists of 510 m of fossiliferous limestone and marl, with a basal shale bed. This formation is conformably underlain by the Qishn Formation, and overlain by the Mukalla Formation. The Fartaq Formation has yielded a rich assemblage of fossils which dates it as Albian to Cenomanian, to probable Turonian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

In Wadi Al-Masila, the Fartaq Formation attains a thickness of 206 m which represent the upper part of the carbonate type section indicative of the diachronous nature of the marine transgressive. In this locality, the formation is divisible into three distinct units which were treated as members. These are in ascending order, the Dha Sohis, Tihayr, and Maqrat Members.

*Dha Sohis Limestone Member:* This rock unit was introduced by Wetzel and Morton in 1948, in an unpublished report (cited in Beydoun 1964, Beydoun and Greenwood 1968). The stratotype lies in the Tihayr area, Wadi Masila, Mahra Province (lat. 15° 44' N, long. 50° 45' E). It consists of 41.5 m of fossiliferous marly, rubbly, yellowish, pale green, limestone with green, gypsiferous shale, and glauconitic marl interbeds, and chert nodules at the top. It is conformably underlain by the Harshiyat Formation, and overlain by the Tihayr Shale Member. On the basis of its fossil content and stratigraphical position, the Dha Sohis Member was assigned to the Cenomanian. Beydoun (1964) partially, correlated this Member with the Sufla Member of the Harshiyat Formation in the western parts.

*Tihayr Shale Member:* This term was proposed by Beydoun (1964). Its stratotype lies in the Tihayr area of the Wadi Masila, in Mahra Province. It consists of 69 m of a series of fossiliferous green and purple shales, locally gypsiferous, and containing some bands of marly limestone and an interval of colored sandstone near the top. The lower contact with the Dha Sohis Member is conformable, and its contact with the overlying Maqrat Member is also conformable. The Tihayr Member has yielded a diagnostic fossil assemblage on the basis of which it was dated as Cenomanian to possible Turonian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

*Maqrat Limestone Member:* This member was described by Wetzel and Morton in an unpublished report prepared in 1948 (Beydoun 1964, 1966, Beydoun and Greenwood 1968). The type section lies in the Maqrat area, Wadi Masila, Mahra Province. It consists of 99 m of fossiliferous limestone. Near the base it passes into dolomitic limestone, and in the top it becomes coarse-grained with thin streaks of

marl. It extends conformably between the underlying Tihayr Member, and the overlying Mukalla Formation. On the basis of its fossil content and stratigraphical position it was dated as Cenomanian to probable Turonian.

#### **Mukalla Formation:**

The Mukalla Formation is recognized in both the western and eastern parts of the southern provinces. It is the only formation which persists in the two parts without any significant changes in its lithological characteristics. The Mukalla Formation was introduced by Wetzel and Morton in an unpublished report prepared in 1948, to include the clastic sequence directly underlying the Tertiary rocks in Hadhramaut. The stratotype lies in the western parts near Mukalla, at Jabal Al-Rays (lat. 14° 35' N, long. 49° 08' E). The stratotype consists of 165 m of colored, locally fossiliferous, fine to coarse, pebbly, cross bedded, friable to hard sandstone with marl and siltstone interbeds. At Ath Thil'ah as Sufla, this formation includes a thin fossiliferous limestone bed underlain by a sequence of marls, and these form Lusb Member. The Mukalla Formation thickens westwards. It overlies the Harshiyat Formation and underlies the Umm er Radhuma Formation with an apparent conformity. The lower parts of the Mukalla Formation bear an assemblage of Campanian fossils (Beydoun 1964, 1966, Beydoun and Greenwood 1968). On stratigraphical and paleontological evidence, this formation was considered to be of Senonian (probably Campanian) to Maastrichtian age.

*Lusb Member:* The term was introduced by Wetzel and Morton in 1948, in an unpublished report as the Lusb Formation separating the Mukalla and Harshiyat formations. It was emended by Beydoun (1964), who treated it as a member within the Mukalla Formation. The Lusb is a local member recognized only in its type locality at the Ath Thil'ah as Sufla, 12 km northeast of Mukalla (lat. 14° 37' N, long 49° 10' E). It consists of 45 m of yellowish green and ochreous, gypsiferous and soft marl, with marly sandstone interbeds, overlain by 5 m of fine to medium grained, yellow, nodular weathering reddish brown, fossiliferous limestone. It conformably extends within the sandstones of the Mukalla Formation. On the basis of its fossil contents the Lusb was dated as Campanian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

#### **Sharwayn Formation:**

The Sharwayn is the top formation of the Mahra Group in the eastern parts of the southern provinces. It is not recognized as a separate formation in the equivalent Ghiras Group in the western parts. The formation grades westwards from limestone, through marl and limestone, to a marl sequence. It was described in an unpublished report by Wetzel and Morton in 1948, and emended by Beydoun (1964). Its

stratotype lies in Mahra at Ras Sharwayn (lat. 15° 22' N, long. 51° 56' E), where it consists of 66 m of fossiliferous, yellow brown to olive green, soft marl, and shale with harder calcareous concretions, overlain by fossiliferous marly, crystalline, locally nodular, grey, hard limestone. It is conformably underlain by the Mukalla Formation, and overlain by the Umm er Radhuma Formation with probable disconformity. The Formation has yielded numerous fossils which date it as Maastrichtian (Beydoun 1964, 1966, Beydoun and Greenwood 1968).

### Summary and Conclusions

The above preliminary revision of the exposed (outcrop) stratigraphy of the Mesozoic Erathem in the Republic of Yemen has led to the following conclusions:

1. The Mesozoic Erathem is represented by only the Jurassic and Cretaceous systems, whereas the Triassic System is most probably absent. The Permian glacial episode which affected the area, was followed by a continental period that led to nondeposition/or removal of the Triassic System.
2. The Mesozoic sequence begins with the fluvial sandstones of the Affar Formation, Kohlan Group which were laid down during the Liassic (Early Jurassic).
3. Subsequently, a major marine transgression took place during the Middle-Late Jurassic when the sea covered most of Arabia including the Yemen and southwestern Saudi Arabia. This episode led to the deposition of typical marine sediments of the Surdud Group which represents a major transgressive marine sedimentation cycle which is preceded and followed by littoral to continental sediments. It begins with the carbonates of the Amran Formation (Middle-Late Jurassic). This is followed by the marls and evaporites of the Madbi/Sabatayn Formations (Late Jurassic). In the latest Jurassic, a restricted marine advance occurred in the southern provinces where the limestones of the Nayfa Formation (Tithonian to possible Berriasian) were laid down, but continental conditions prevailed in the northern part of Yemen.
4. The latest Jurassic continental conditions continued during the Cretaceous Period in the northern provinces where the gravelly sandstones of the Ghiras Member, Tawilah Formation, were laid down. In the southern provinces, a shallow marine environment prevailed in the west where the mainly

arenaceous Ghiras Group was deposited; a relatively deeper open marine environment occurred in the east where the coeval principally calcareous Mahra Group was deposited.



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(Received 27/12/1993;  
in revised form 07/10/1995)

## مراجعة مبدئية لطبقة صخور حقبة الحياة المتوسطة في الجمهورية اليمنية

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يمثل حقبة الحياة المتوسطة في اليمن بالعصرين الجوارسي والطباشيري . يضم العصر الجوارسي تكوين العفّار (أوائل الجوارسي) ومجموعة سرّدد (وسط - أواخر الجوارسي) . العفّار هو التكوين العلوي في مجموعة كحلان (البرمي - أوائل الجوارسي) وهو يتكون من صخور رملية . أما مجموعة سردد فتقسم إلى تكوينات العمران (حجر جيرى) ، والمدبي (مارل) ، والسبعين (متبخرات) ، والنيفع (حجر جيرى) .

أما العصر الطباشيري فيشمل فرد الغراس الرملي ومجموعتي الغراس / المهرة . فرد الغراس هو الوحدة السفلية في تكوين الطويلة (طباشيري - باليوسين) ويوجد في محافظات اليمن الشمالية ويتكون من صخور رملية . أما مجموعتي الغراس / المهرة فتوجدان في المحافظات الجنوبية . توجد مجموعة الغراس في الاجزاء الغربية بينما توجد مجموعة المهرة في الاجزاء الشرقية من

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المحافظات الجنوبية ، وهاتان المجموعتان متكافئتان ومتناظرتان جانبياً . تتكون مجموعة الغراس من فتاتيات رسوبية وتضم تكوينات قشن (حجر جيرى) وحرشيات (حجر رملى) والمكلا (حجر جيرى وطين صفائحي) . أما مجموعة المهرة فتشمل تكوينات قشن (حجر جيرى) ، حرشيات (حجر رملى) ، فرتك (حجر جيرى ومارل) ، والمكلا (حجر رملى) ، شروين (حجر جيرى ومارل) .