

Middle Jurassic–Early Cretaceous foraminiferal biozonation of the Amran Group, eastern Sana’a Basin, Yemen

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Abstract

Two sections of strata assigned to the Amran Group at Jabal Salab and Jabal Yam in the eastern Sana’a governorate were sampled and correlated. These sections are part of a carbonate platform that extends from the city of Marib in the east to Naqil Ibn Ghailan, 20 km east of the city of Sana’a to the west. Palaeontological analysis of samples recovered has resulted in identification of 123 foraminiferal species, which are used to subdivide the sequence of the Amran Group into five biostratigraphic zones, aged between Bathonian (Middle Jurassic) and Berriasian (Early Cretaceous). The proposed biozones are those of *Riyadhella rotundata*, *Kurnubia jurassica*, *Ammomarginulina sinaica*, *Alveosepta jaccardi* and *Pseudocyclammina sulaiyana/Furitilla caspienseis*. These biozones were constructed and correlated with the equivalent zones reported from several localities.

Key words: Biostratigraphy, Bathonian, Berriasian, Jabal Salab, Jabal Yam

1. Introduction

The Amran Group is considered to be one of the most important rock units in Yemen and in the Arabian Peninsula due to its economic potentiality as main hydrocarbon system in the Marib, Al-Jawf and Shabwa basins, as well as its mineralisations (lead, zinc, copper and silver) in the Jabali area (Al-Ganad et al., 1993). The Amran Group was introduced by Lamare (1923) and Lamare et al. (1930) as the ‘Amran Series’ to describe carbonate rocks that conformably overlay the Kuhlan Formation near the town of Amran, about 40 km northwest of Sana’a. Those authors dated it as Dogger-Malm on the

basis of fossils on record from the Amran-Kuhlan area. The rank of this rock unit was emended to that of a group by Beydoun (1964, 1966), who subdivided it into four formations: Shuqra, Madbi, Sabatain and Naifa (Table 1) and dated the Group as Middle Jurassic (Callovian) to Early Cretaceous (Berriasian) on the basis of fossil content.

The lithostratigraphy of the Amran Group in different areas of Yemen was discussed in detail in several published papers and unpublished works such as those by Botez (1912), Lamare (1923), Lamare et al. (1930), Basse et al. (1954), Beydoun (1964), Geukense (1966), El-Anbaawy (1984), El-Nakhal (1990), Al-Wosabi (1993, 2001, 2005), Simmons & Al-Thour

Table 1. Main lithostratigraphic subdivisions of the Amran Group in Yemen and the study area.

Age		Author	Lamare (1930)	Beydoun (1964, 1966) & Beydoun et al. (1998)	El-Anbaawy (1984)
Cretaceous	Early	Berriasian	Transition Series	Naifa Fm	Jabal Salab/Wadi Al-Ahjur
Jurassic	Late	Tithonian	Amran Series	Madbi Fm/Sabatain Fm	Shuqra Fm
		Kimmeridgian		Shuqra Fm	Shuqra Fm
	Middle	Oxfordian			
		Callovian			
		Bathonian		Kuhlan Fm	Kuhlan Fm
Early	Bajocian				
			Kuhlan Series		

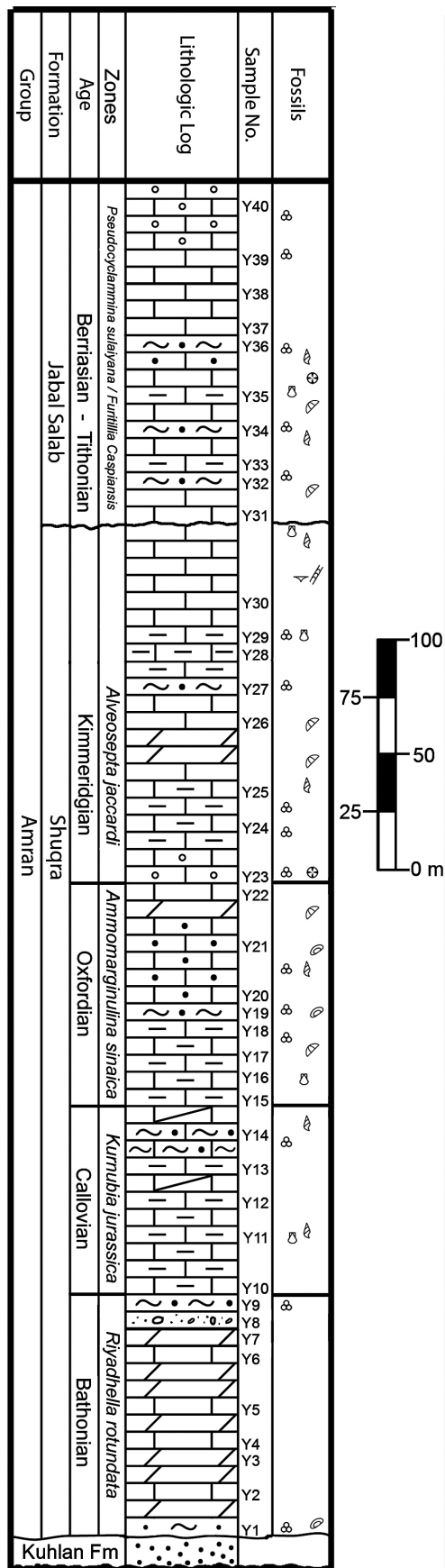
(1994) and Howarth & Morris (1998). Finally, Beydoun et al. (1998) discussed the position of the group when they introduced the lithostratigraphic subdivisions of Yemen in the international Lexicon of Stratigraphy. They subdivided the Amran Group into four formations: Shuqra, Madbi, Sabatain and Naifa (Table 1). Brown et al. (1989) studied this rock unit in the shield area of western Saudi Arabia. The biostratigraphy of the Amran Group has not been discussed by these researchers, with the exception of Al-Wosabi (1993, 2001) and Simmons & Al-Thour (1994).

The Amran Group consists mainly of limestone, marly limestone, shale beds and thick beds of evaporites (salt rocks and gypsum), characterised as the Sabatain Formation in Shabwa "surface outcrops" and Safer "subsurface" areas. The Shuqra Formation consists mainly of limestone with thin shale, siltstone and marl interbeds at several horizons, deposited in a shallow-marine environment. The Madbi and Sabatain formations are lateral equivalents. The former consists of marly clastics which were deposited in an open, shallow-marine en-

vironment, while the latter comprises evaporites (gypsum and rock salt) and black shales which were deposited in isolated basins. In the present paper, the subdivision by El-Anbaawy (1984) will be used. He subdivided the Amran Group in northern parts of Yemen, in particular the eastern and western Sana'a basin and neighbouring areas. He introduced the Shuqra and Jabal Salab formations in the eastern parts and Shuqra and Wadi Al-Ahjur formations in the western parts. The Jabal Salab and Wadi Al-Ahjur formations are equivalent with the Naifa Formation of Beydoun (1964) in eastern and southeastern parts of the country (Table 1). The Jabal Salab Formation consists mainly of marl-argillite, bioclastic sandstone and pisolitic limestone, whilst the Wadi Al-Ahjur Formation is characterised by thick beds of marly limestone intercalated with limestone beds.

The present study aims to introduce a foraminiferal biozonation of the Amran Group in the study area and to compare this with equivalent strata in Yemen as well as from other localities.

**Fig. 1.** Location map of the sections studied.



4. Palaeontology

The Amran Group is a highly fossiliferous limestone sequence. Invertebrate fossils recorded during fieldwork including bivalves, gastropods, ammonites, belemnites and brachiopods. Micro-palaeontological analysis of collected samples from studied sections has led to the identification of 123 foraminiferal species as well as sponge spicules, algal species (e.g., *Acicularia* sp., *Salpingoporella* sp. and *Revularia* sp.), bryozoans and ostracods. The recorded foraminiferal species are listed in Table 2 and their distribution in the Amran Group is shown in Table 3. The recorded foraminiferal species are represented by 67.4% textulariines, 0.81 miliolines, 25.2% lagenines, 2.43% involutines, 2.43% spirillines and 1.62% robertines (Table 2). The identified foraminiferal assemblage is characterised by a predominance of simple arenaceous and nodosariid species, a rarity of miliolines and the absence of planktonic forms (Table 2). This distribution is consistent with the distribution of foraminifera of the Middle Jurassic in the Middle East (Al-Saad, 2008).

The lower part of the sequence, which constitutes the lower part of the Shuqra Formation (*Riyadhella rotundata* Zone), contains arenaceous species with simple interiors. This, in addition to the rarity of calcareous forms, indicates that this part of the Shuqra Formation was deposited in a shallow, near-shore environment (Bandy, 1960, 1963; Gordon, 1970; Bhalla & Abbas, 1978; Grigelis & Ascoli, 1995; Grigelis & Norling, 1999). The middle portions of the Shuqra Formation (*Kurnubia jurassica* and *Ammomarginulina siraiica* zones) and the upper part (*Alveosepta jaccardi* Zone) are rich in both arenaceous and nodosariid species which suggests a moderately deep, open marine environment (Norton, 1930; Natland, 1933; Glaessner, 1945; Bielecka & Pożaryski, 1954; Wall, 1960; Redmond, 1964a, b; Bhalla & Abbas, 1978; Banner & Simmons, 1994; Grigelis & Ascoli, 1995; Grigelis & Norling, 1999). The uppermost part of the *Alveosepta jaccardi* Zone (upper part of the Shuqra Formation) and the *Pseudocyclammina sulaiyana/Furitillia caspiensis* Zone (Jabal Salab Formation), which constitute the upper part of the Amran Group, are characterised by a predominance of simple arenaceous forms and a rarity of calcareous ones which suggests a shallow, near-shore environment.

Fig. 3. Lithostratigraphic column of the Jabal Yam section, showing provenance of samples and distribution of foraminiferal zones proposed.

Table 2. Foraminiferal species recorded from the sections studied.

Suborders	Species	Species	Species	
Textulariina	<i>Reophax densa</i> Tappan	<i>A. laevigatus</i> Lozo	<i>T. limbata</i> Kalantari	
	<i>R. sp.cf. helveticus</i> Haeusler	<i>A. spongiphillus</i> Seibold & Seibold	<i>T. sp. cf. pullchra</i> Ziegler	
	<i>R. liasica</i> Franke	<i>A. subaequalis</i> Myatliuk	<i>T. robusta</i> Ziegler	
	<i>R. metensis</i> Franke	<i>A. subcretaceous</i> Cushman & Alexander	<i>T. squammata</i> Jones & Paker	
	<i>R. sterkii</i> Haeusler	<i>A. suprajurassicum</i> Schwager	<i>Riyadhella regularis</i> Redmond	
	<i>R. suivicus</i> Franke	<i>A. venustus</i> Loeblich & Tappan	<i>R. rotundata</i> Redmond	
	<i>Evolutinella darwini</i> (Dain)	<i>Ammomarginulina aegyptiaca</i> Osman & Hassanein	<i>Paleogaudyina magharaensis</i> Said & Barakat	
	<i>E. subevoluta</i> Nikitina & Myatliak	<i>Am. baryntica</i> Loeblich & Tappan	<i>Verneuilinoides gracious</i> Dain	
	<i>Haplophragmoides sp.cf. arabicus</i> Hassan & Others	<i>Am. minuta</i> Osman & Hassanein	<i>V. minuta</i> Said & Barakat	
	<i>H. barrowensis</i> Tappan	<i>Am. pullucida</i> Said & Brand	<i>V. neocomiensis</i> Myatliuk	
	<i>H. bartensteni</i> Kalantari	<i>Am. sinaica</i> Osman & Hassanein	<i>V. tryphera</i> Loeblich & Tappan	
	<i>H. barthouxi</i> Said & Barakat	<i>Haplophragmium aequala</i> (Roemer)	<i>V. zerqaensis</i> Basha	
	<i>H. circularis</i> Said and Barakat	<i>Alveosepta jaccardi</i> (Schrodt)	<i>Gaudryina vadaszi</i> Cushman & Glazewski	
	<i>H. hagni</i> Bhalla	<i>Al. Powersi</i> Redmond	<i>Verneuilina anglica</i> Cushman	
	<i>H. kingakensis</i> Tappan	<i>Everticyclammina contorta</i> Redmond	<i>Pfenderina gracilis</i> Redmond	
	<i>H. tryssa</i> Loeblich and Tappan	<i>E. eccentrica</i> Redmond	<i>P. inflata</i> Redmond	
	<i>Nautiloculina oolithica</i> Mohler	<i>Brankampella arabica</i> Redmond	<i>Steinekella steinekei</i> Redmond	
	<i>Ammobaculites alaskensis</i> Tappan	<i>Feuritilla caspiensis</i> Kalantari	<i>Kurnubia jurassica</i> (Henson)	
	<i>A. alexanderi</i> Cushman	<i>Pseudocyclammina rogalia</i> Cushman & Glazewski	<i>K. morissi</i> Redmond	
	<i>A. barrowensis</i> Tappan	<i>P. sulaiyana</i> Redmond	<i>K. palastiniensis</i> Henson	
	<i>A. braunsteini</i> Cushman & Applin	<i>Bimonilina variana</i> Eicher	<i>K. variabilis</i> Redmond	
	<i>A. cobani</i> Loeblich & Tappan	<i>Plectinella aegyptiaca</i> Said & Barakat	<i>Praekurnubia crusi</i> Redmond	
	<i>A. coprolithiformis</i> (Schwager)	<i>Textulariopsis jurassica</i> (Gumbel)	<i>Marssonella oxycona</i> (Reuss)	
	<i>A. crespinae</i> Bhalla	<i>Trochammina bartensteni</i> Said & Barakat	<i>Pseudomarsonella bipartita</i> Redmond	
	<i>A. fontinensis</i> (Tappan)	<i>T. concava</i> Seibold & Seibold	<i>P. reflexa</i> Redmond	
	<i>A. hofkeri</i> Bhalla	<i>T. conningensis</i> Tappan	<i>P. maxima</i> Redmond	
	<i>A. indicus</i> Bhalla	<i>T. gryci</i> Tappan	<i>P. plicata</i> Redmond	
	<i>A. irregulariformis</i> Bartenstein & Brand	<i>T. inflata</i> (Montagu)		
	Involutinina	<i>Trocholina conica</i> (Schlumberger)	<i>T. delicatissima</i> Kalantari	<i>T. nodulsa</i> Seibold & Seibold
	Spirillinina	<i>Spirillina amphicata</i> Loeblich & Tappan	<i>S. infima</i> Strickland	<i>S. polygyrata</i> Gumbel
	Miliolina	<i>Massilina rediclaiffensis</i> Gordon		
	Lagenina	<i>Dentalina plebeia</i> Terquem	<i>Saracenaria cornucopiae</i> (Schwager)	<i>Vaginulina composita</i> Loeblich & Tappan
	<i>Nodosaria fontinensis</i> Terquem	<i>S. triangularis</i> (D'Orbigny)	<i>Eoguttulina amygdalina</i> Loeblich & Tappan	
	<i>N. kuhni</i> Franke	<i>Astacolus aphrastus</i> Loeblich & Tappan	<i>E. bilocularis</i> (Terquem)	
	<i>N. nitidana</i> Brand	<i>A. crepidula</i> (Fichtel & Moll)	<i>E. inovroclaviensis</i> (Bielecka & Pozaryski)	
	<i>Fronicularia dentaliniformis</i> (Terquem)	<i>A. pediacus</i> Tappan	<i>E. liasica</i> (Strickland)	
	<i>Lenticulin audax</i> Loeblich & Tappan	<i>Vaginulinopsis enodis</i> Loeblich & Tappan	<i>E. polygona</i> (Tarquem)	
	<i>L. muensteri</i> (Roemer)	<i>V. epicharis</i> Loeblich & Tappan	<i>E. triloba</i> (Terquem)	
	<i>L. quenstedti</i> (Gumbel)	<i>V. misrensis</i> Said & Barakat	<i>Globulina lacrima</i> (Reuss)	
	<i>L. subalata</i> (Reuss)	<i>Planularia anceps</i> (Terquem)	<i>G. sp. cf. prisca</i> Reuss	
	<i>L. varians</i> (Bornemann)	<i>P. beierana</i> (Gumbel)	<i>Guttulina pera</i> Lalicker	
			<i>G. physalia</i> Loeblich and Tappan	
Robertinina	<i>Epistomina caracolla</i> (Roemer)	<i>Epistomina mosquensis</i> Uhlig		

5. Age and biostratigraphy

The biostratigraphy of the Amran Group in Yemen was studied by Al-Wosabi (1993), who used the foraminiferal species that were recorded from the Jabali area, east of Sana'a, and by Simmons & Al-Thour (1994), who constructed a biozonal scheme on the basis of foraminiferal and algal contents from the western areas of Sana'a region. The succession of the Amran Group in the sections studied includes the Shuqra and Jabal Salab formations. The total count of identified foraminiferal species from the two studied sections reaches 123. Ninety-eight species are recorded from Jabal Yam and one hundred and three from Jabal Salab with some duplication. The stratigraphical range of these species was restricted between Bathonian (Middle Jurassic) and Berriasian (Early Cretaceous) (Table 3). Biostratigraphic subdivision of the Amran Group based on foraminiferal data does not provide high-resolution zones which is a result of the slower rate of evolution of Jurassic foraminifera, which is substantiated by rather long geological ranges for most of the species. However, within a basin, local associations and their distribution provide a fair basis for biostratigraphic classification. Few of the recorded species displayed a wide range; two examples are *Reophax suevica* Franke "Rhaetian-Tithonian" and *Lenticulina muensteri* (Roemer) "Rhaetian-Hauterivian". Several of the recorded species were considered index species ranging in age from Late Jurassic to earliest Cretaceous, particularly in Middle East countries, including *Bramkampella arabica* Redmond and *Pseudocyclammina sulaiyana* Redmond. On the other hand, there are many species which recorded as an index fossils of the Middle-Late Jurassic such as *Kurnubia jurassica* Henson, *K. palastinensis* Henson, *K. morissi* Redmond, *K. variabilis* Redmond, *Pfenderina gracilis* Redmond, *P. inflata* Redmond, *Stienekella stienekii* Redmond, *Pseudomarssonella bipartita* Redmond, *P. maxima* Redmond, *P. plicata* Redmond, *P. reflexa* Redmond, *Riyadhella regularis* Redmond, *R. rotundata* Redmond, *Reophax helveticus* Häusler, *Haplophragmoides arabicus* Hassan, Hassanien & Abd El-Shafy, *H. barthoxi* Said & Barakat, *H. circularis* Said & Barakat, *Ammomarginulina pullucida* Said & Barakat, *Plectinella aegyptiaca* (Said & Barakat), *Vaginulina misrensis* Said & Barakat, *Ammobaculites braunsteini* Cushman and Applin, *A. cobhani* Loeblich & Tappan, *A. venustus* Loeblich & Tappan, *Ammomarginulina baryntica* Loeblich & Tappan, *Astacolus aphrastus* Loeblich & Tappan, *Vaginulina composita* Loeblich and Tappan, *Eoguttulina amygdalina* Loeblich and Tappan, *Alveosepta jaccardi* (Schrodt), *A. powersi* Redmond, *Ammomarginulina aegyptiaca* Said and Barakat, *A. minuta* Osman & Hassanein, *A. sinai-*

ca Osman & Marzouk, *Textulariopsis jurassica* (Gümbel) and many other species.

Based on the vertical distribution of the recorded foraminifera, i.e., first appearance, last disappearance of a certain species and abundance of some species in the sequence, five biozones were recognised (Table 3). In ascending order, these zones are: *Riyadhella rotundata* Zone, *Kurnubia jurassica* Zone, *Ammomarginulina sinaica* Zone, *Alveosepta jaccardi* Zone and *Pseudocyclammina sulaiyana/Furtillia caspiensis* Zone. The proposed zones find confirmation in earlier papers by different researchers such as Kalantari (1969), Souaya (1976), Hassan et al. (1978), Kalia & Chowdhury (1983), Abd El-Shafy (1984), Williams et al. (1990), Al-Wosabi (1993, 2001, 2005), Simmons & Al-Thour (1994), Kuznetsova et al. (1996), Hewaidy & Al-Saad (2000), Al-Saad (2008) and Sarfi & Yazdi-Moghadam (2016).

5.1. *Riyadhella rotundata* Zone

This zone was introduced by Kalia & Chowdhury (1983) in the Bathonian of India. The base of the *Riyadhella rotundata* Zone equates with the first appearance of *Riyadhella rotundata* Redmond, while the top is marked by the disappearance of the foraminiferal species of the *Riyadhella rotundata* Zone and the first appearance of *Kurnubia palastinensis* Henson. Conspicuous species in this zone are *Astacolus pediacus* Tappan, *Nodosaria fontinensis* Terquem, *N. kuhni* Franke, *Dentalina plebae* Terquem, *Trochammina bartensteini* Said & Barakat, *T. robusta* Ziegler, *Ammobaculites braunsteini* Cushman & Applin, *Trocholina delicatissima* Kalantari, *Riyadhella regularis*, *Haplophragmoides barthoxi*, *H. barrowensis* Tappan, *Reophax liasica* Terquem, *R. suevica* Franke, *Paleogaudryina magharaensis* Said & Barakat, *Pfenderina inflata* Redmond, *Verneuilinoides zerqaensis* Basha, *V. minuta* Said & Barakat, *Eoguttulina bilocularis* (Terquem), *Lenticulina varians* Bornemann, *Fronicularia dentaliniformis* (Terquem), *Ammobaculites venustus* Loeblich and Tappan, *A. suprajurassicum* (Schwager), *A. fontinensis* (Terquem), *A. barrowensis* Tappan, *A. alaskensis* Tappan, *A. cobhani*, *Planularia beierana* (Gümbel) and *Pseudomarssonella reflexa* Redmond. This zone represents the lower part of the Shuqra Formation in the sections studied and is of Bathonian age (Table 3).

5.2. *Kurnubia jurassica* Zone

The base of this zone equates with the first appearance of *Kurnubia* species, which is considered

an index species of the Middle-Upper Jurassic in the Middle East. The upper limit of this zone is taken at the disappearance of *Kurnubia jurassica* and the first appearance of *Ammomarginulina sinaica* Osman and Hassanein. This zone is rich in *Kurnubia palastinensis* Henson, *K. jurassica*, *K. variabilis* Redmond, *Planularia anceps* (Terquem), *Astacolus crepidula* (Fichtel & Mole), *Guttulina pera* Lalicker, *Vaginulinopsis misrensis* Said & Barakat, *Lenticulina subalata* Reuss, *Nodosaria nitidana* Brand, *Ammomarginulina aegyptiaca* Said and Barakat, *A. minuta*, *T. inflata* (Montagu), *Trochammina* sp. cf. *pullchra* Ziegler, *Trocholina conica* Schlumberger, *Plectinella aegyptiaca* (Said &

Barakat), *Haplophragmoides* sp. cf. *arabicus* Hassan, Hassanein and Abd El-Shafy, *H. circularis*, *Pfenderina gracilis* Redmond, *Praekurnubia crusi* Redmond, *Pseudomarssonella bipartita*, *P. maxima*, *P. plicata* Redmond and *Reophax densa* Tappan.

The *Kurnubia jurassica* Zone can be correlated with *Trocholina* spp / *Kurnubia palestinensis* of Simmons & Al-Thour (1994), which were identified in the upper Callovian of the Sana'a region and with the *Kurnubia variabilis* Zone of Al-Wosabi (1993). In addition, this zone is equivalent to the *Kurnubia jurassica* Zone (Hassan et al., 1978; Abd El-Shafy, 1984), the *Kurnubia palastinensis* Zone (El-Badry et

Table 3. Foraminiferal biozonation of the Amran Group in the study area.

Foraminiferal species	Age		Jurassic		Cretaceous		Biozones
	Middle		Late		Lower		
	Bathonian	Callovian	Oxfordian	Kimmeridgian	Tithonian	Berriasian	
<i>Ammobaculites</i> sp. cf. <i>crepinae</i>							<i>Pseudocyclammina sulaiyana</i> / <i>Furtilia caspiensis</i>
<i>A. irregulariformis</i>							
<i>Haplophragmium aequala</i>							
<i>Everticyclammina contorta</i>							
<i>E. eccentrica</i>							
<i>Feurtillia caspiensis</i>							
<i>Trochammina limbata</i>							
<i>Globulina</i> sp. cf. <i>lacrima</i>							
<i>G. sp. cf. Prisca</i>							
<i>Epistomina caracolla</i>							
<i>Ammobaculites hofkeri</i>							
<i>A. indicus</i>							
<i>A. subcretaceous</i>							
<i>Bramkampella arabica</i>							
<i>Pseudocyclammina sulaiyana</i>							
<i>Bimonilina variana</i>							
<i>Trochammina conningensis</i>							
<i>T. squammata</i>							
<i>Verneulinoides</i> sp. cf. <i>neocomiensis</i>							
<i>Marssonella oxycona</i>							
<i>Saracenaria triangularis</i>							<i>Alveosepta jaccardi</i>
<i>Saracenaria cornucopiae</i>							
<i>Evolutinella darwini</i>							
<i>E. subevoluta</i>							
<i>Ammobaculites alexanderi</i>							
<i>A. coprolithiformis</i>							
<i>Textulariopsis jurassica</i>							
<i>Haplophragmoids hagni</i>							
<i>Ammobaculites laevigatus</i>							
<i>Eoguttulina liasica</i>							
<i>Gaudryina vadaszi</i>							
<i>Ammobaculites subaequalis</i>							
<i>Alveosepta jaccardi</i>							
<i>Verneuilina anglica</i>							
<i>Kurnubia morissi</i>							

Foraminiferal species	Age	Jurassic			Cretaceous		Biozones
		Middle		Late	Lower		
		Bathonian	Callovian	Oxfordian	Kimmeridgian	Tithonian	
<i>Lenticulina muensteri</i>							<i>Ammomarginulina sinaica</i>
<i>Eoguttulina inovroclaviensis</i>							
<i>E. polygona</i>							
<i>Spirillina infima</i>							
<i>Verneuilinoides tryphera</i>							
<i>Spirillina amphilocata</i>							
<i>S. polygyrata</i>							
<i>Eoguttulina amygdalina</i>							
<i>E. triloba</i>							
<i>Guttulina physalia</i>							
<i>Nautiloculina oolithica</i>							
<i>Ammomarginulina pullucida</i>							
<i>Pseudocyclammina rogalia</i>							
<i>Epistomina mosquensis</i>							
<i>Masselina rediclaensis</i>							
<i>Lenticulina audax</i>							
<i>L. quenstedti</i>							
<i>Astacolus aphrastus</i>							
<i>Vaginulinopsis enodis</i>							
<i>V. epicharis</i>							
<i>Ammomarginulina sinaica</i>							
<i>Vaginulina composita</i>							
<i>Reophax sp. cf. helveticus</i>							
<i>R. metensis</i>							
<i>R. sterkii</i>							
<i>Haplophragmoides bartensteni</i>							
<i>H. kingakensis</i>							
<i>H. tryssa</i>							
<i>Ammobaculites spongiphillus</i>							
<i>Ammomarginulina baryntica</i>							
<i>Alveosepta powersi</i>							
<i>Trochammina concava</i>							
<i>T. gryci</i>							
<i>Verneuilinoides graciosus</i>							
<i>Steinekella steinkei</i>							
<i>Trocholina nodulosa</i>							
<i>Trochammina inflata</i>							
<i>Reophax densa</i>							
<i>Ammomarginulina aegyptiaca</i>							<i>Kurnubia jurassica</i>
<i>Am. minuta</i>							
<i>Trochammina sp. cf. pullchra</i>							
<i>Trocholina conica</i>							
<i>Nodosaria nitidana</i>							
<i>Lenticulina subalata</i>							
<i>Vaginolinopsis misrensis</i>							
<i>Guttulina pera</i>							
<i>Plectinella aegyptiaca</i>							
<i>Haplophragmoides sp. cf. arabicus</i>							
<i>H. circularis</i>							
<i>Pfenderina gracilis</i>							

Foraminiferal species	Age	Jurassic				Cretaceous		Biozones
		Middle		Late		Lower		
		Bathonian	Callovian	Oxfordian	Kimmeridgian	Tithonian	Berriassian	
<i>Kurnubia jurassica</i>							<i>Kurnubia jurassica</i>	
<i>K. palastiniensis</i>								
<i>K. variabilis</i>								
<i>Prækurnubia crusi</i>								
<i>Pseudomarssonella bipartita</i>								
<i>P. maxima</i>								
<i>P. plicata</i>								
<i>Astacolus crepidula</i>								
<i>Planularia anceps</i>								
<i>P. beierana</i>								
<i>Reophax suivicus</i>							<i>Riyadhella rotundata</i>	
<i>Ammobaculites cobbani</i>								
<i>A. alaskensis</i>								
<i>A. barrowensis</i>								
<i>A. fontinensis</i>								
<i>A. suprajurassicum</i>								
<i>A. venustus</i>								
<i>Verneuilinoides minuta</i>								
<i>Nodosaria kuhni</i>								
<i>Frondicularia dentaliniformis</i>								
<i>Lenticulina varians</i>								
<i>Eoguttulina bilocularis</i>								
<i>Verneuilinoides zerqaensis</i>								
<i>Pfenderina inflata</i>								
<i>Paleogaudryina magharaensis</i>								
<i>Reophax liasica</i>								
<i>Haplophragmoides barrowensis</i>								
<i>H. barthouxi</i>								
<i>Trochammina robusta</i>								
<i>Riyadhella regularis</i>								
<i>Trocholina delicatissima</i>								
<i>Ammobaculites braunsteini</i>								
<i>Trochammina bartensteni</i>								
<i>Riyadhella rotundata</i>								
<i>Pseudomarssonella reflexa</i>								
<i>Dentalina plebeia</i>								
<i>Nodosaria fontinensis</i>								
<i>Astacolus pediacus</i>								

al., 1981) and the *Kurnubia gigantea* Zone (Abd El-Shafy & Ibrahim, 1987) in Egypt. This zone represents the beginning of the middle part of the Shuqra Formation and is of Callovian age (Table 3).

5.3. *Ammomarginulina sinaica* Zone

The present zone was established by Hassan et al. (1978) in Egypt and later also documented by El-Badry et al. (1981) and Abd El-Shafy (1984). The

Ammomarginulina sinaica Zone is of Oxfordian age in the study area. It starts with the first appearance of *Ammomarginulina asinaica*. This is the richest zone as far as foraminiferal content is concerned in the sections studied. Some species, which appeared in the underlying zones, are still present in this zone together with newly appearing forms. The foraminiferal species which characterise this zone include *Trocholina nodulosa* Seibold & Seibold, *Steinekel-la steinekei* Redmond, *Verneuilinoides graciosus* Dain, *V. tryphera* Loeblich & Tappan, *Trochammina concava*

Seibold & Seibold, *T. gryci* Tappan, *Ammomarginulina baryntica* Loeblich & Tappan, *A. pullucida* Said & Barakat, *Ammobaculites spongiphilus* Seibold & Seibold, *Haplophragmoides tryssa* Loeblich & Tappan, *H. kingakensis* Tappan, *H. bartensteini* Kalantari, *Reophax sterkei* Häusler, *R. metensis* Franke, *R. sp. cf. helveticus* Häusler, *Pseudocyclammina rogalai* Cushman & Glazewski, *Nautiloculina oolithica* Mohler, *Eoguttulina inovooclaviensis* (Bielicka & Pożaryski), *E. polygona* (Terquem), *Lenticulina muensteri* (Roemer), *L. audax* Loeblich & Tappan, *L. quenstedti* (Gümbel), *Spirillina amphilocata* Loeblich & Tappan, *S. polygyrata* Gümbel, *S. infima* (Strickland), *Massilina rediclaensis* Gordon, *Astacolus aphrastus* Loeblich & Tappan, *Vaginulinopsis enodis* Loeblich & Tappan and *V. epicharis* Loeblich & Tappan.

This zone can be correlated in part with the *Trocholina* spp./*Kurnubia palastinensis* Zone and with the *Alveosepta jaccardi* Zone of Simmons & Al-Thour (1994) and *Vaginulinopsis epicharis* Zone of Al-Wosabi (1993). This zone is of Oxfordian age in the study area and characterises the middle part of the Shuqra Formation (Table 3).

5.4. *Alveosepta jaccardi* Zone

This zone is equivalent to the *Everticyclammina virgulina* I, *Alveosepta powersi* and *Everticyclammina* II Zone of Simmons and Al-Thour (1994) and to the *Ammobaculites laevigatus* Zone of Al-Wosabi (1993).

The *Alveosepta jaccardi* Zone was used previously by Ascoli (1981, 1988) and Williams et al. (1990) to characterise the Kimmeridgian of Canada and Sarfi & Yazdi-Moghadam (2016) as a late Oxfordian-early Kimmeridgian zone in northwest Iran.

This zone begins with the disappearance of *Ammomarginulina sinaica* and the first appearance of *Alveosepta jaccardi*. The upper limit of this zone equates with the first appearance of *Pseudocyclammina sulaiyana* Redmond and the foraminiferal species that belong to the youngest zone of the Amran Group. Conspicuous foraminiferal species within this zone are *Kurnubia morissi*, *Verneuilina anglica* Cushman, *Alveosepta jaccardi* and *Ammobaculites subaequalis* Myatliuk, *A. laevigatus* Lozo, *A. alexanderi* Cushman, *A. coprolithiformis* Schwager, *Gaudryina vadaszi* Cushman & Glazewski, *Haplophragmoides hagni* Bhalla, *Evolutinella darwini* Dain, *E. subevoluta* Nikitina & Myatliuk, *Textulariopsis jurassica* (Gümbel), *Eoguttulina liasica* (Strickland) and *Saracenaria cornucopiae* (Schwager). Several species represented in this zone continue into the overlying *Pseudocyclammina sulaiyana/Feurtillia caspiensis* Zone. This

zone is of Kimmeridgian age and represents the upper part of Shuqra Formation (Table 3).

5.5. *Pseudocyclammina sulaiyana/Feurtillia caspiensis* Zone

This zone includes many foraminiferal species that are held typical of the uppermost Jurassic and lowermost Cretaceous such as *Pseudocyclammina sulaiyana* Redmond, *Bramkampella arabica* Redmond, *Everticyclammina contorta* Redmond, *E. eccentrica* Redmond, *Trochammina limbata* Kalantari, *Feurtillia caspiensis* Kalantari, *Haplophragmium aequala* (Roemer), *Ammobaculites alexanderi* Cushman, *A. indicus* Bhalla, *A. hofkeri* Bhalla, *A. sp. cf. crespinae* Bhalla, *Epistomina caracolla* (Roemer), *Globulina lacrima* (Reuss), *Evolutinella subevoluta* Nikitina & Myatliuk and *E. darwini* Dain. The base of this zone equates with the appearance of *Pseudocyclammina sulaiyana* and its top is defined by the disappearance of the foraminiferal species of the Amran Group. The age of this zone is latest Jurassic (Tithonian)-earliest Cretaceous (Berriasian) (Table 3).

6. Correlations

The foraminiferal biozonation of the Middle Jurassic–Lower Cretaceous in the study area is correlated with previously proposed foraminiferal biozones by different workers locally in Yemen and regionally in different regions (Table 4). In Yemen, this biozonation often corresponds with that of Al-Wosabi (1993) and Simmons and Al-Thour (1994) which have been based on benthic foraminifera and algal contents. Regional correlation is based on previously published papers for different regions such as Iran (Kalantari, 1969; Sarfi & Yazdi-Moghadam, 2016), Canada (Souaya, 1976; Williams et al., 1990), Egypt (Hassan et al., 1978; Abd El-Shafy, 1984), India (Kalia & Chowdhury, 1983), Syria (Kuznetsova et al., 1996) and eastern Saudi Arabia (Hewaidy & Al-Saad, 2000).

7. Conclusions

The foraminiferal biozonation of the Amran Group in the study area is introduced on the basis of 123 foraminiferal species from the samples collected. These biozones include four taxon range zones (*Riyadhella rotundata*, *Kurnubia jurassica*, *Ammomarginulina asinaica* and *Alveosepta jaccardi* zones) as well as a single assemblage zone, *Pseudocyclam-*

mina sulaiyana/Furitilla caspiensis Zone. These zones are restricted in age between the Bathonian and Berriasian. This biozones are correlated with equivalent zones in Yemen and some Tethyan regions.

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