

THE DEMISE STAGE OF RUDIST BEARING MISHRIF FORMATION (LATE CENOMANIAN – EARLY TURONIAN), SOUTHERN IRAQ

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ABSTRACT

The Cretaceous carbonates are of unique significance in the stratigraphic succession of the Middle East, because much of the discovered prolific carbonate reservoir facies are in the rudist bearing formations. The Late Cretaceous carbonates of the Mishrif Formation are one of these prolific reservoir facies, which extends along the southern parts of Iraq and the Arabian Gulf.

Five subsurface sections were selected from wells of three fields in south and southeastern parts of Iraq, including West Qurna 21, 57 and 215, Tuba 4 and Nasiriyah 2, to determine the radiation and the demise of the rudists in the Mishrif Formation.

This study showed that the rudists of the Mishrif Formation were affected in two stages of demise. The first (Fd) took place during the early Late Cenomanian, recorded by a drastic decline in the abundant occurrence of the recumbent rudists (Caprinidae and Ichthysarcolitidae), which together represent Cenomanian species of the Mishrif Formation. Consequently, the followed Cenomanian – Turonian transition was not only a significant crisis in the abundance of the rudists, but also the benthic foraminifera were affected. The second demise of the rudists was recorded by the disappearance of elevator Hippuritidae and Radiolitidae; represented by these species: *Durania araudi*, *Sauvagesia sharpie*, *Praeradiolites echennesis*, *Praeradiolites sarladensis* and benthic foraminifera, specially Miliolids, with abundance of planktonic foraminifera of the Khasib Formation, this demise took place during the late Early Turonian.

مرحلة زوال الرودست في تكوين المشرف (السينومياني المتأخر – التوروني المبكر)، جنوب العراق

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المستخلص

تعتبر الصخور الجيرية للعصر الطباشيري ذات أهمية كبيرة في التتابع الطباق للشرق الأوسط، وذلك لاكتشاف وفرة عالية من الصخور الجيرية الخازنة للنفط في التكوينات الحاوية للروست، ويعتبر تكوين المشرف أحد تلك المستودعات النفطية الهامة والتي تمتد من جنوب العراق باتجاه الخليج العربي.

تم دراسة خمسة مقاطع تحت سطحية من ابار نفطية هي: 21 Wq، 57، 215، 4 Tu، 2 Ns والتي اختيرت من ثلاثة حقول نفطية في جنوب وجنوب شرق العراق، وذلك لتحديد فترات ازدهار وزوال الروست في تكوين المشرف.

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لقد أظهرت نتائج هذا البحث بأن الرودست في تكوين المشرف تعرض الى مرحلتين من الزوال. الأول حدث خلال الفترة المبكرة من السينومانيان المتأخر، وهذا الحدث سجل بالانخفاض الحاد في وفرة الرودست من نوع المضطجع والمتمثل بالعائلتين Caprinidae and Ichthysarcolitidae والتي تواجدت أنواعهما في الجزء السينوماني من التكوين والتي انقرضت في الفترة المبكرة من السينومانيان المتأخر. تبعت تلك الفترة مرحلة انتقالية بين السينومانيان – التورونيان والتي لم تتميز فقط بما سجله التحول المهم للرودست، لكن سجل تأثرا الفورامنيفرا القاعية أيضا. أما الزوال الثاني للرودست، فقد سجل باختفاء تام للرودست من نوع الصواعد المتماثلة بالعائلتين Radiolitidae and Hippuritidae والتي تمثلت بالأنواع التالية: *Praeradiolites echennesis Sauvagesia sharpie*, *Durania araudi* و *Praeradiolites sarladensis*. إضافة الى الفورامنيفرا القاعية وبشكل خاص عائلة الملبوليدي، مع ظهور الفورامنيفرا الطافية التي تمثل تكوين الخصيب. إن الزوال الثاني للرودست حصل في الفترة المتأخرة من التورونيان المبكر.

INTRODUCTION

The sessile epibenthic rudist bivalves (superfamily Hippuritacea; Late Jurassic – Maastrichtian) were dominated constituents of many Cretaceous Tethyan shallow marine benthic communities (Ross and Skelton, 1993 and Gili *et al.*, 1995) and were among the important carbonate producer in both calcareous and siliciclastic depositional system (Steuber, 1998 and Steuber and Löser, 2000). The distribution of the rudist has also a considerable economic importance, as rudist limestone hosts many significant hydrocarbon resources worldwide, in particular in the Middle East and around the Gulf of Mexico (Scott *et al.*, 1993).

▪ Previous Studies

Many authors have emphasized the oceanographic crisis of the Mishrif carbonate (Cenomanian – Early Turonian), and its lithostratigraphic, biostratigraphic, sedimentological and sequence stratigraphic consequences. Very detailed studies have been carried out concerning lithostratigraphy and biostratigraphy, and discussed by Owen and Nasr (1958); Al-Naqib (1967); Al-Khersan (1975); Al-Siddiki (1978), and Al-Sayab and Al-Jassim, (1996). Sedimentological studies, which include microfacies analysis and depositional environment models, were given by Elf-Iraq (1970); Gaddo (1971); Reulet (1982); Belarabi (1982); Sherwani (1983); Aqrabi *et al.* (1998) and Al-Jumaily (2001). The sequence stratigraphic aspects of the Mishrif Formation have been studied by Aqrabi *et al.* (1998); Sherwani (1998); Mahdi (2004); Al-Rubaiy (2004); Al-Ubaidy (2004) and Al-Badry (2005). In contrast, few papers have been devoted to the rudist communities of the Mishrif Formation (Owen and Nasr, 1958 and Bellen *et al.*, 1959). The aim of this study is to shed light on new data on this topic.

▪ Location

The area studied is located in the southeastern part of Iraq. It runs along the sum of five wells, these are Nasiriyah 2 (Ns), West Qurna 21, 57 and 215 (Wq), and Tuba 4 (Tu). These wells extend from northwest to southeast direction (Fig.1).

TECTONIC AND GEOLOGICAL SETTINGS

The Mishrif Formation is a part of the Cenomanian – Early Turonian sequence, which consists of four formations in the studied area (M'sad, Ahmadi, Rumaila, and Mishrif formations).

Tectonically, the studied area is located in the Unstable Shelf, the Mesopotamian Zone; Samawa – Nasiriyah and Zubair Subzones (Al-Kadhimi *et al.*, 1996, and Jassim and Goff, 2006), where the Samawa – Nasiriyah Subzone includes well Nasiriyah (Ns 2) and Zubair Subzone includes West Qurna oilfield (Wq 21, 57 and 215), and Tuba oilfield (Tu 4).

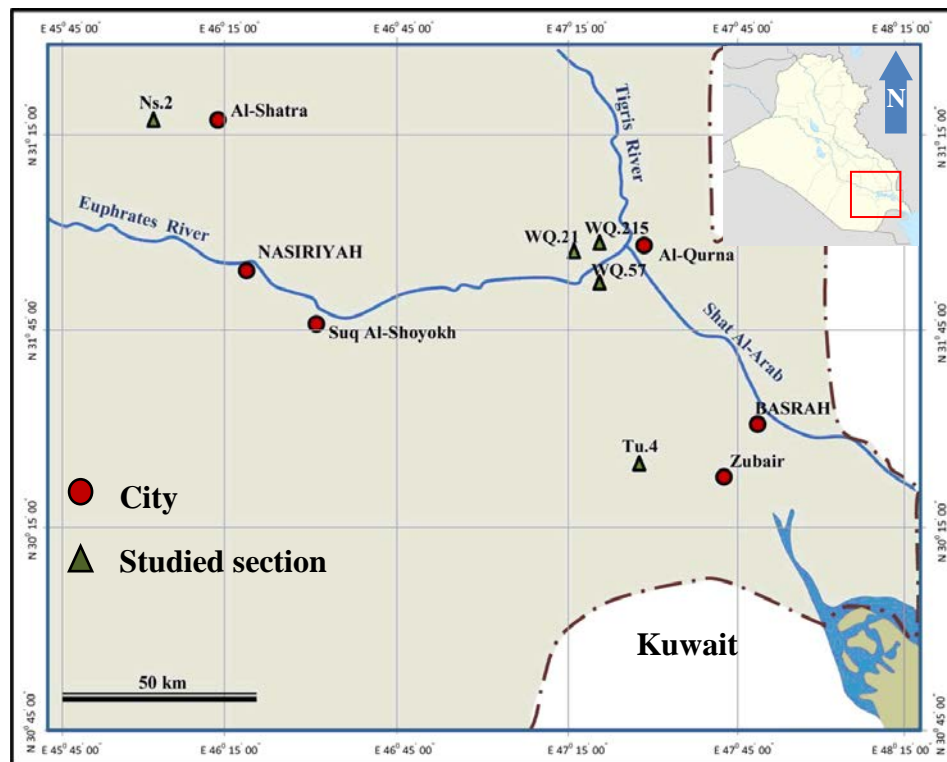


Fig.1: Location map of the studied sections

The Mishrif Formation consists of fine-grained, limonitic fresh water limestone containing Charophyta, followed by grey-white, dense, fractured or stylolitic algal limestone, with gastropods and shell fragments. Then followed by brown, detrital, porous, partly very shelly and foraminiferal limestone, with banks of rudists; this limestone grades downwards into a compacted marly limestone (Owen and Nasr, 1958). The Formation is in conformable contact with the underlying Rumaila Formation, where changes from oligosteginal – globigerinal limestones, below, to neritic limestone, with miliolids, *Begia* spp., and larger foraminifera, above (Bellen *et al.*, 1959), and the Khasib Formation disconformably overlies the Mishrif Formation (Owen and Nasr, 1958).

▪ Palaeogeography

During the Late Cenomanian, carbonate platforms extended broadly along the northern and southern borders of the Tethyan Realm on the passive margins of the Eurasian, African and American Plates. In both extremities, the Tethys was joined with the Pacific Ocean; a general East – Westward oceanic circulation governed the palaeogeographic distribution of the rudists (Philip, 1982). Patterns of species richness along the northern and northeastern shores of the Afro – Arabian Plate (Fig.2) are much different from those of the central and northern Tethyan domains. In Libya, Egypt and Lebanon, rudists are predominantly found in Cenomanian – Turonian deposits (Fig.2). Records of post-Coniacian rudists are scarce, and almost exclusively related to *Duraniafara frabensis* Douville (Lewy, 1993). Several species of *Durania* are apparently eurytopic, and this genus is frequently found as a pioneer along the northern and southern limits of the groups' distribution, or in environments that are otherwise unfavorable for other rudist species (Cobban *et al.*, 1991; Reitner, 1991 and Steubar and Löser, 2000). Data from Arabian countries, except Oman are to scarce, but rudist occurrences are apparently widespread in Syria (Dubertret, 1966) and UAE (Morris and Skelton, 1995).

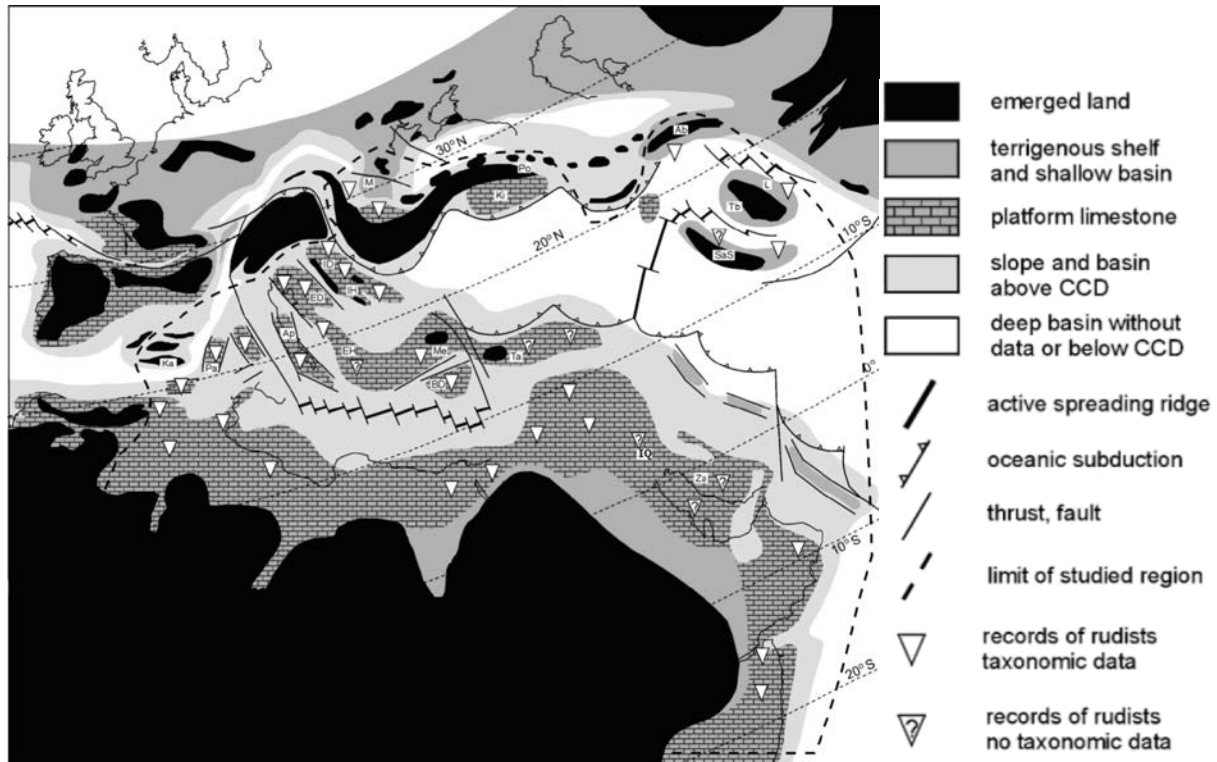


Fig.2: Cenomanian palaeogeography of the Mediterranean and Middle East Tethys (modified from Philip *et al.*, 1993). Ab, Alburz; Ap, Apulia; BD, Bey Daglari; ED, External Dinarids; EH, External Hellenids; ID, Internal Dinarids; IQ, Iraq; Ka, KabyliaKi, Kirsehir; L, Lut; M, Moesia; Me, Menderes; P, Parnassus; Pa, Panormides; Po, Pontides; SaS, Sanandaj – Sirjan Zone; T, Tunisia; Ta, Taurus; Tb, Tabas; Za, Zagros.

The Cenomanian – Lower Turonian Mishrif Formation in subsurface section from UAE has been described to contain abundant rudist associations on a prograding platform margin that borders the intracratonic Rub Al-Khali Basin (Burchett and Britton, 1985). Such Cenomanian – Turonian Platforms are also known in subsurface sections of Iraq and, to a limited extent, in Saudi Arabia, and crop out at the Zagros Range of Iran (Sarvak Formation), but systematic descriptions of rudist are absent (except in Iraq, in this study). Abundant Cenomanian – Turonian associations have been mentioned from the Natih Formation (Philip *et al.*, 1995 and Buchem *et al.*, 1996), but specific descriptions are rare. In Algeria and Tunisia, rudists have been reported from all Cretaceous stages; since the Barremian, although species richness is lower than in Northern and Central Tethyan Realms (Steuber and Löser, 2000). There is an emphasis on the Cenomanian – Turonian occurrences, similar to North African countries further to the east, but the overall evolution of species richness is similar to that of Central and Northern Tethys.

THE MISHRIF FORMATION RUDISTS AND BIOLOGICAL EVENTS (DISCUSSION AND CONCLUSION)

The Mishrif carbonate contains mollusca fragments, bioclastic packstone to grainstone, miliolid and non-rudist bivalves in muddy limestone and rudist (mainly Capronidae and Radiolitidae) rudstone, and with fragmented rudists mixed with wackestone lithoclasts. Rudist buildups at the Mishrif Formation are not as numerous as those of the Shuaiba Formation, although they contain significant amount of hydrocarbons in offshore U.A.E, Oman and

southeastern Iraq (Al-Sharhan, 1995). The most typical occurrence of rudist's genera was found in all studied wells; most of them occur as large broken arcuate shape with pallial canals' structures (Fig.3). These structures are well developed in Caprinidae, Ichthyosarcotitidae families (Skelton and Gili, 1991), with few fragments of Hippuritidae. But, we were able to observe important features from well preserved specimens; such as radial bands, and occurrence of fine rectangular celluloprismatic structures on the outer shell layer. These features are known only in Radiolitidae (Sanders and Pones, 1999; Skelton and Smith, 2000, and Pones and Vicens, 2008).

The abundance of rudists in the Mishrif Formation increases considerably at the middle to upper parts of the formation (Figs.4, 5, 6, 7 and 8). These fauna are dominated by Caprinidae, Ichthyosarcotitidae and Radiolitidae, while other families are of only minor importance. The Caprinidae and Ichthyosarcotitidae were particularly widespread during Cenomanian, and much recorded in the Arabian Gulf (Steuber, 1999, and Steuber and Löser, 2000); such as in Natih Formation in Oman (Philip *et al.*, 1995; Al-Sharhan, 1995 and Buchem *et al.*, 1996). A drastic decline in abundance of rudists occurred at the Cenomanian – Turonian boundary, the Caprinidae and Ichthyosarcotitidae, which together represent all Cenomanian species in Mishrif Formation, become extinct, while there is only a slight reduction in the abundance and an increase in the species richness of Radiolitidae.

The rudists in Mishrif Formation had affected in two demises. The first demise of the Caprinidae and Ichthyosarcotitidae may have been even more dramatic, taking into consideration that their predominantly aragonitic shells are prone to early diagenetic dissolution, which certainly introduces a preservational bias to the record of these families as compared with Radiolitidae having predominantly calcite shells (Steuber and Löser, 2000). Consequently, the Cenomanian – Turonian transition was not only a significant crisis in the abundance of rudist, but also marks an important faunal disappearance, which mainly involved benthic foraminifera of the Mishrif Formation. The benthic foraminifera were affected in two steps. The species, *Praeolvinacretacea*, *Ovalveolina ovum*, *Dohiaplanta*, *Cisvalveolinafallax*, *Multispierianairanensis*, *Chrysalidinadecorata*, *Pseudolitounellareichelix*, *Biconcava* sp., *Taberinabingstani* and *Pseudorhipidonina* sp., disappeared with the first demise of rudist. Subsequently, *Dicyclina* sp. *Qataria dukhani*, *Rotalia* sp. and *Textularia* sp., disappeared at the Late Cenomanian (Figs.9 and 10).

The first demise, which affected the rudistidae, and the reef ecosystem, are generally correlative with the mass extinction episodes mentioned by Raup and Sepkoski (1984 and 1986) and may be related to global causes, such as meteorite/ comet impact, eustatic lowering, giant volcanic eruptions, or oceanic anoxia. But, each of these rudistidae extinction occurs earlier than the main part of the mass extinction and its associated perturbations, by 0.25 to one million years (Johnson and Kauffman, 1990). This rudist extinction may thus have been due to independent causes, or to early phases of environmental decline linked to mass extinction interval (Kauffman, 1988).

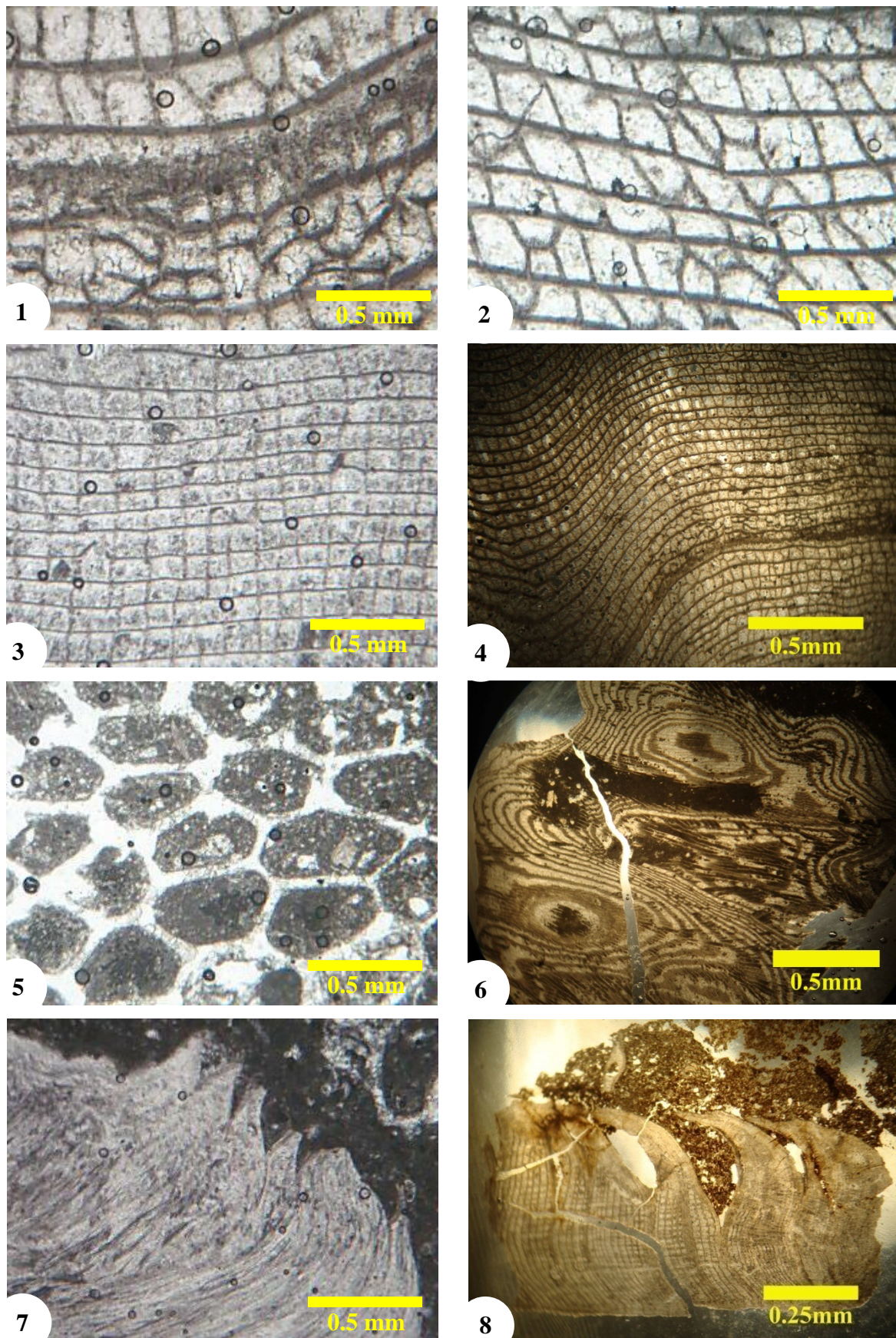


Fig.3

Fig.3:

Durania arnaudi (Choffat)
Non-compact, normal cellular structure

1 and 2) Transverse section of attached valves (WQ 57, at depth 2407 m)

3) Tangential section of attached valve (WQ 215, at depth 2523 m)

4) Radial section of attached valve (Tu 4, at depth 2445 m)

Sauvagesia sharpie (Bayle)
Non-compact, normal cellular structure

5) Transverse section of attached valves (WQ 21, at depth 2465 m)

Praeradiolites sarladensis Toucas
Non-compact, normal cellular structure with radially elongate cells

6) Transverse section of attached valves, showing the folding of the growth lamellae in the outer shell layer (WQ 215, at depth 2515 m)

7) Radial section of attached valve (Ns 2, at depth 1930 m)

Praeradiolites echennensis Astre
Inclination, concentric folding and stacking of the growth lamellae in the outer shell layer

8) Anti dorsal radial section (WQ 215, at depth 2515 m)

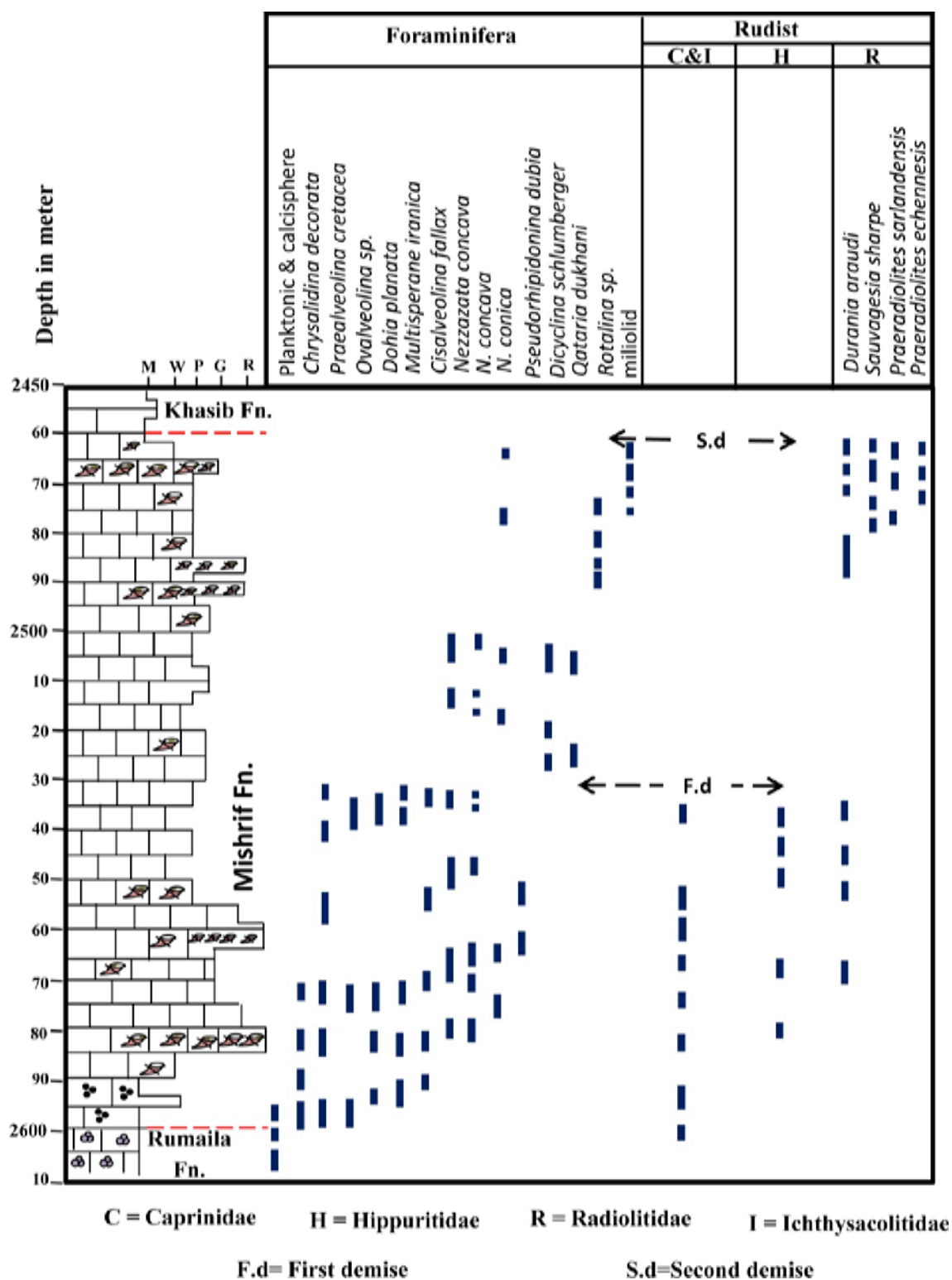


Fig.4: Distribution of rudist and benthic foraminifera, Mishrif Formation, West Qurna well 21

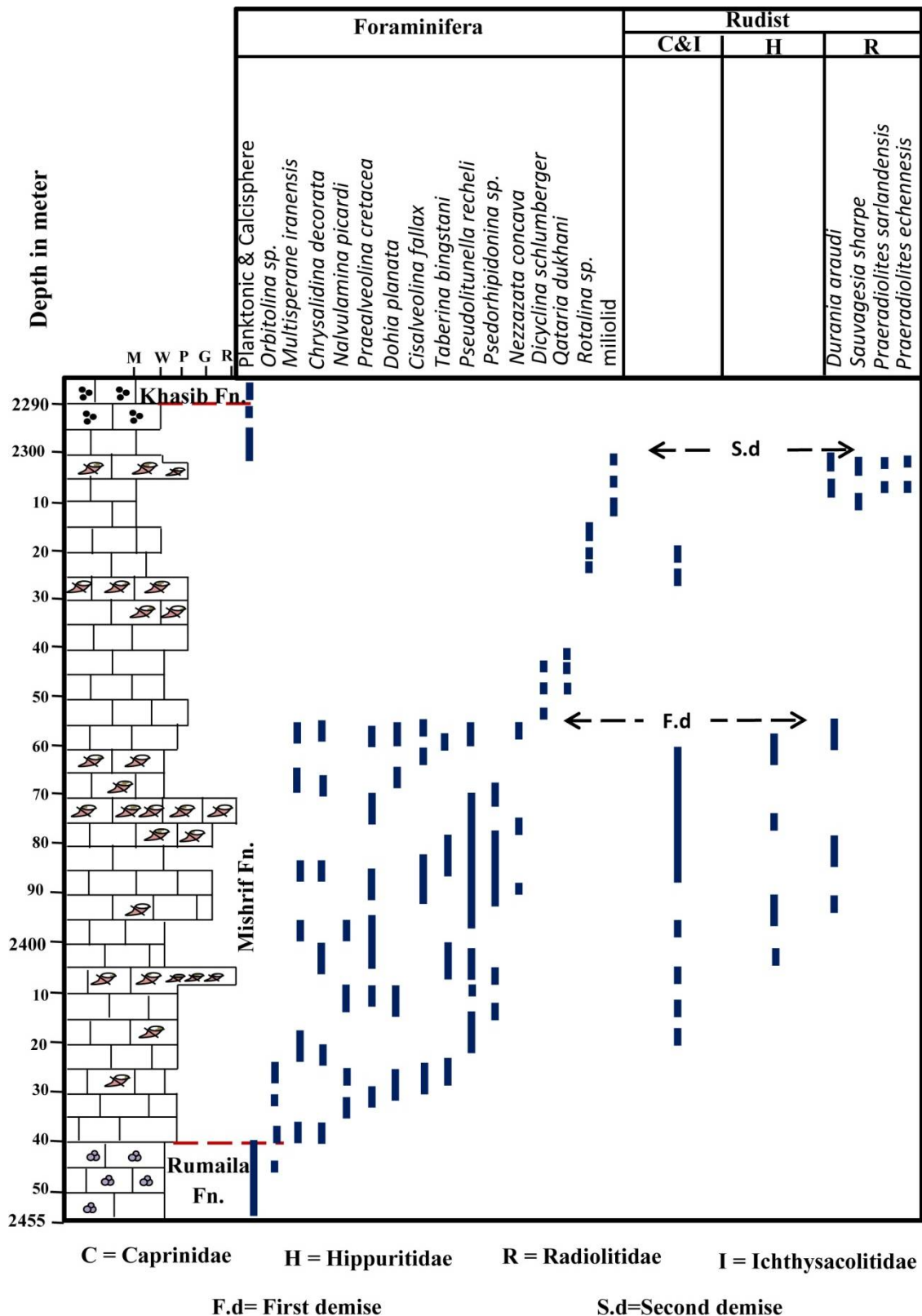


Fig.5: Distribution of rudist and benthic foraminifera, Mishrif Formation, West Qurna well 57

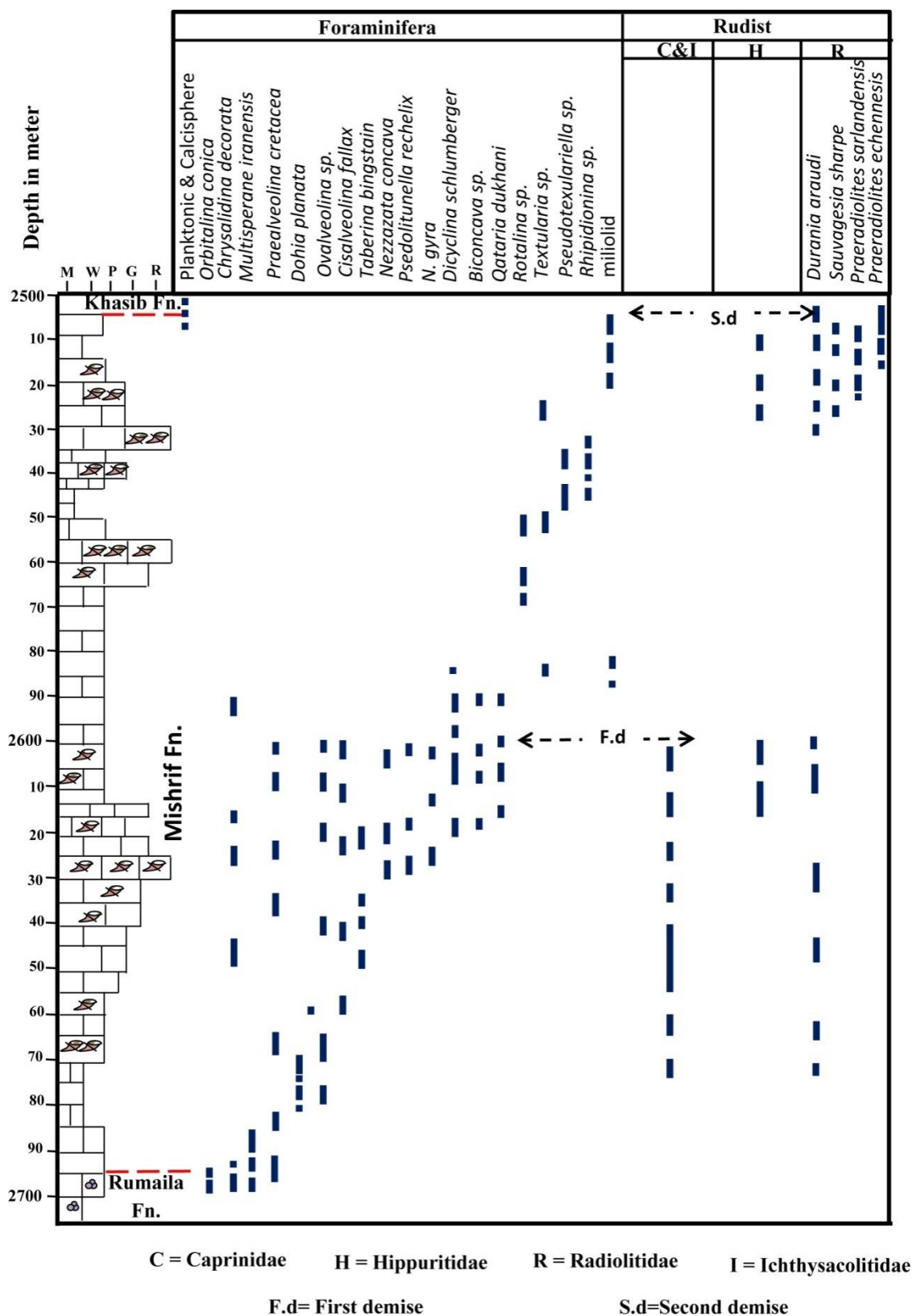


Fig.6: Distribution of rudist and benthic foraminifera, Mishrif Formation, West Qurna well 215

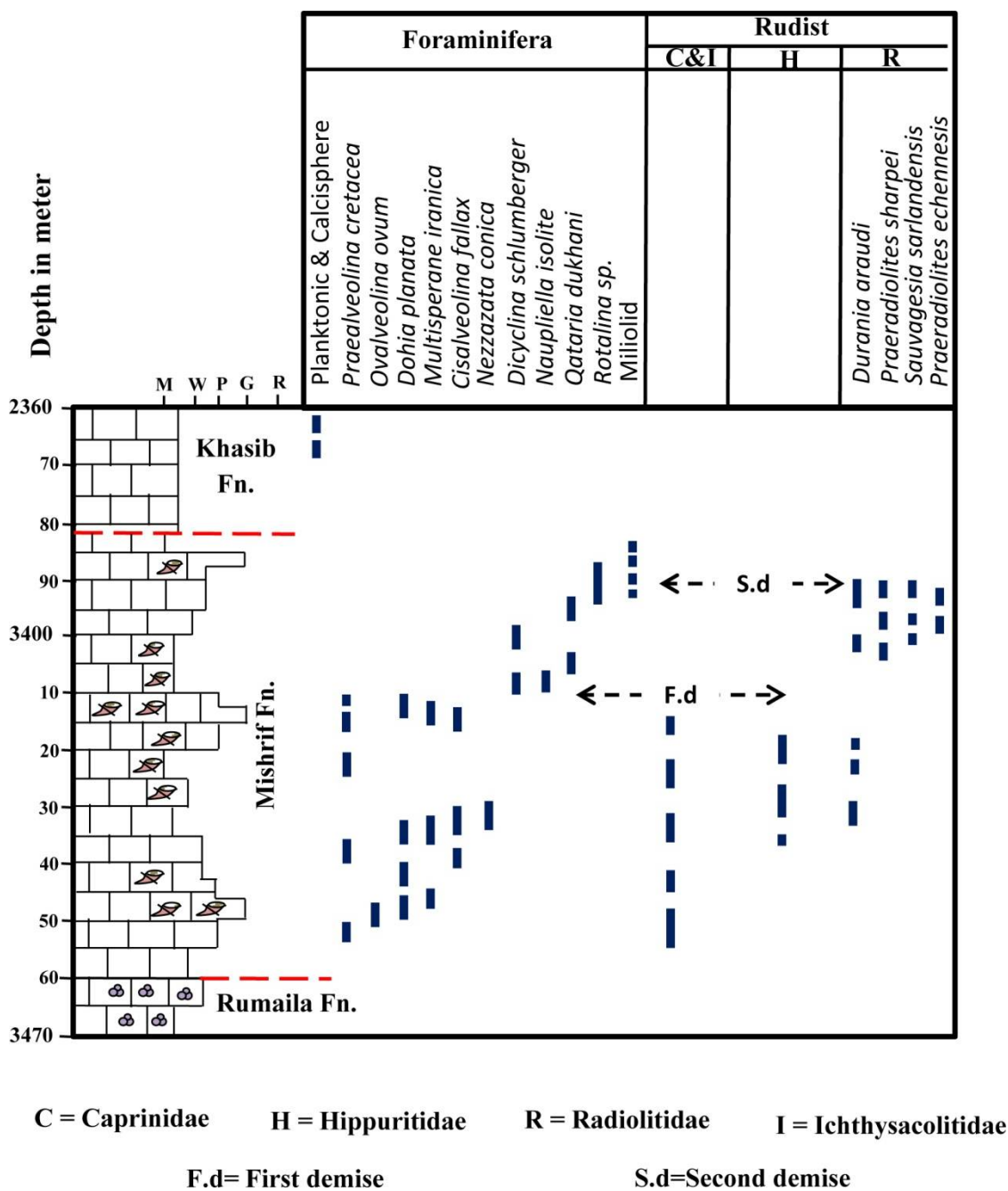


Fig.7: Distribution of rudist and benthic foraminifera, Mishrif Formation, Tuba well 4

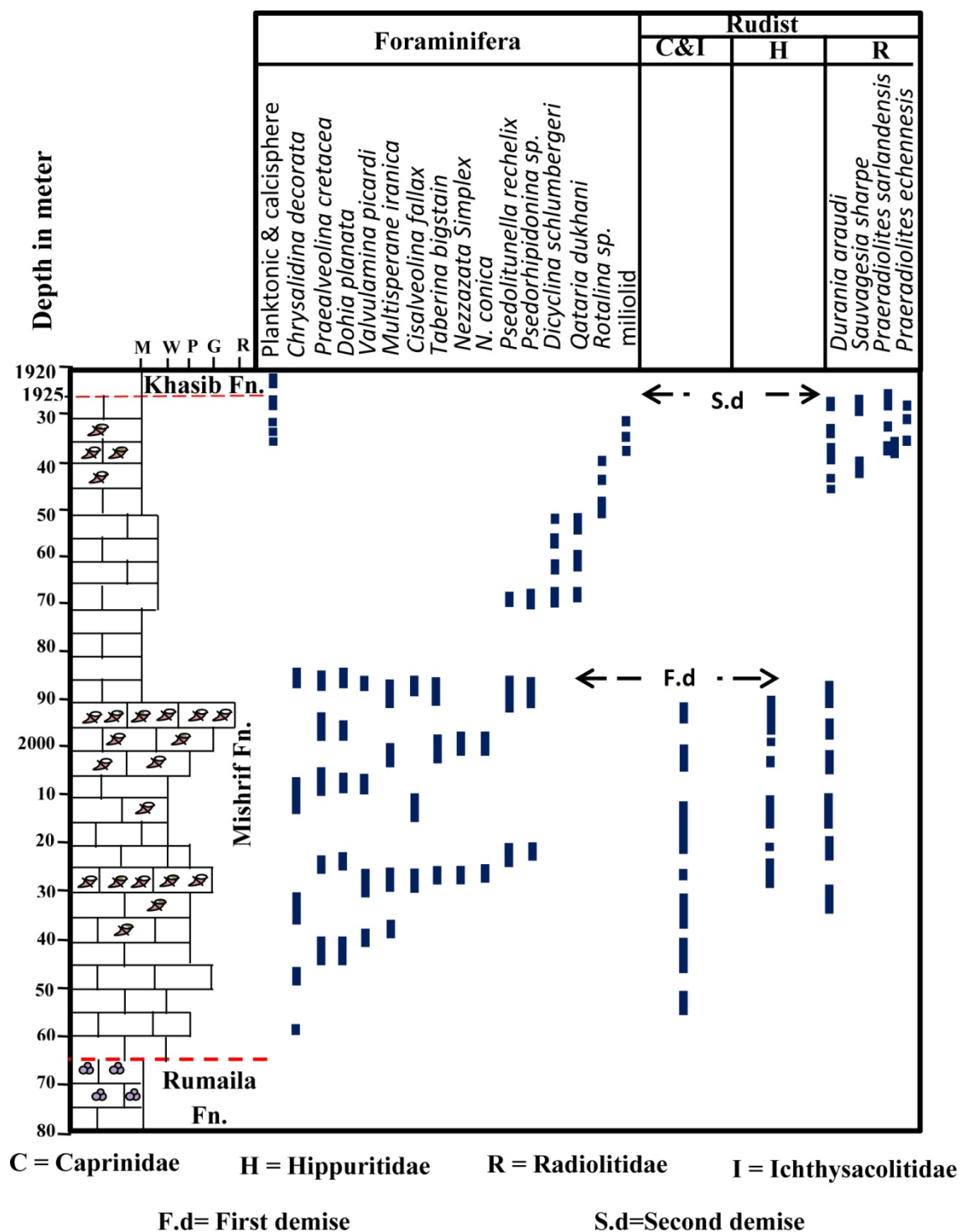


Fig.8: Distribution of rudist and benthic foraminifera, Mishrif Formation, Nasiriyah well 2

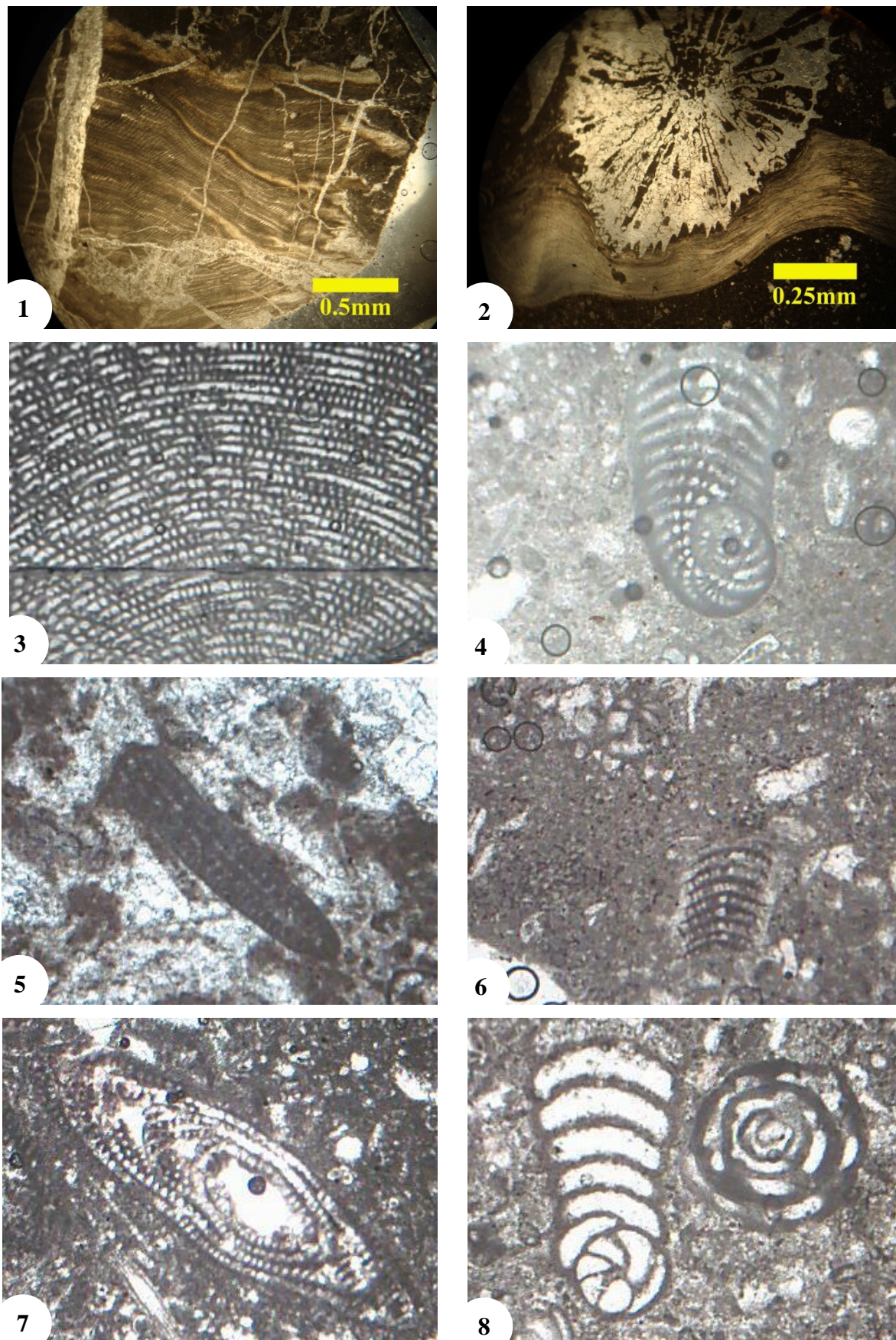


Fig.9

Fig.9:

- 1) *Praeradiolite sechennensis* Astre (WQ 21, at depth 2465 m)
Detail displaying of the outer shell margin.
- 2) Transverse section of coral associated with *Praeradiolites echennensis*
(Ns 2, at depth 2395 m)
- 3) *Multispieriana iranensis* (x40) (WQ 57, at depth 2372 m)
- 4) *Pseudorhipidonina casertana* (x40) (Ns-2, depth 1990 m)
- 5) *Dohia planate* (x50) (Tu-4, at depth 2410.5 m)
- 6) *Taberinabingstani* (x40) (WQ 57, at depth 2360 m)
- 7) *Praealveolinac retacea* (x40) (Ns 2, at depth 2001.5 m)
- 8) *Pseudolituonella reicheli* (x40) (Ns 2, at depth 1985 m)

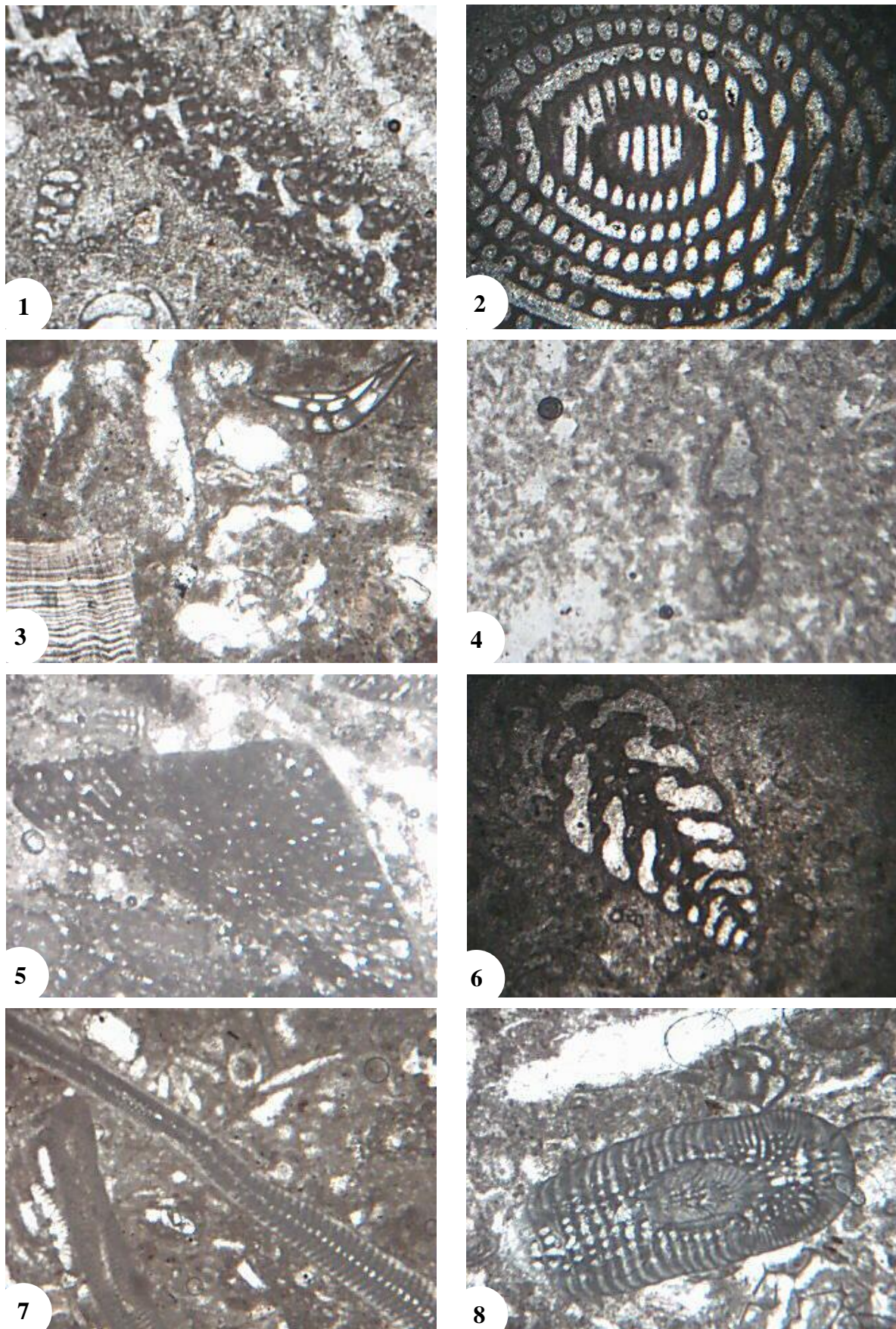


Fig.10

Fig.10:

1. *Dicyclina schlumbergeri* (x40)(WQ 57, at depth 2341 m).
2. *Cisalveolina fallax* (x40) (Tu 4, at depth 2417 m).
- 3) *Nezzazata concava* (x50) (WQ 57, at depth 2370 m).
- 4) *Biconcava* sp. (x50) (WQ 215, at depth 2595 m).
- 5) *Orbitolina conica* (x40) (WQ 215, at depth 2694 m).
- 6) *Chrysalidina decorate* (x40) (WQ 57, at depth 2344 m).
- 7) *Qataria dukhania* (x50) (Tu 4, at depth 2392 m).
- 8) *Pseudotextulariella casertana* (x40) (WQ 215, at depth 2530 m)

The rudistid extinction event of the Late Cenomanian is difficult to be precisely correlated with more resolved temperate zone data in Europe and the Western Interior of the United States, where the stepwise extinction of the *Rotalipora* microfauna (Leckie, 1985) followed by several Mollusca extinctions (Kennedy, 1984 and Elder, 1987) lies within a latest Cenomanian interval of widely fluctuating stable isotope signatures (Pratt, 1985) depicting aperture bed ocean/ climate system, a trace element enrichment interval (including Ir; Orth *et al.*, 1988), and a globalanoxic event (Schlanger and Jenkyns, 1976; Arthur *et al.*, 1987 and Kuffman, 1988). Whereas, these environmental perturbations could have caused the late phases of the Cenomanian rudistid's extinction. Correlations from the Caribbean to interior North America based on eustatic curves and planktonic foraminifera suggest that the Cenomanian rudistid's extinction event occurred prior to the *Rotalipora cushmani* – *R. greenbomensis* Zones, and thus prior to the global interval of chemically perturb bed oceans. The Late Cenomanian rudistid extinction plotted within these foraminifera zones, whereas the extinction of the Rotaliporids occurred later, during the earliest phases of the stepwise mollusca extinction (Kauffman, 1988). These biostratigraphic correlations, as well as the comparison of timing of Caribbean extinction to the data of Raup and Sepkoski (1984, 1986), suggest that the rudistid extinctions were the first step (Kauffman, 1988) in the Cenomanian – Turonian mass extinction interval (91ma). Although there is a cluster of meteorite impact craters around (95 – 100) ma (Grieve, 1982 and Alvares and Muller, 1984) there is, to date, no clear evidence linking these events to marine extinction process (Johnson and Kauffman, 1990).

In the Mediterranean Province, chronostratigraphy of the Cenomanian – Turonian boundary in the carbonate platform areas is well established, and the rudist or large foraminifera can be integrated with ammonite or planktonic biozones (Bilotte, 1978; Philip, 1978; Polšák *et al.*, 1982 and Bethou, 1984). Two main results were inferred from these data: First, during the Late Cenomanian, the platforms were extensive; during the Early Turonian they became drastically reduced. Second, accurate correlations are possible between carbonate platform and oceanic biozonations (Philip *et al.*, 1989 a and b).

Caprinidaecoen zones fit with the *Rotalipora cushmani* and lower *Archaeocretacea* planktonic foraminifera's biozones. The first appearance datum of the *Hippuritidae* family is coeval with the upper part of the *Archaeo cretacea* biozone. The major demise's stage of carbonate platforms and the decrease in the diversity of benthic carbonate platform association (rudists and foraminifera) occurred during the upper *Archaeo cretacea* and *Helvetica* biozones (Philip and Crumiere, 1991). These data strongly support the fact that the onset of the demise of the carbonate platforms was related to the global oceanic anoxic event (OAE2) dated from the *Archaeo cretacea* Zone (Schlanger *et al.*, 1987).

The second stage demise of the Rudists recorded at the top of the Mishrif Formation by the disappearance of Radiolitidae species: *Durania araudi* (Fig.3.1, 3.2, 3.3, 3.4), *Sauvagesia sharpie* (Bayle) (Fig.3.5), *Praeradiolite sechennesis* (Figs.3.8 and Fig.9.1 and 9.2), *Praeradiolite sarladensis* Taucas (Fig.3.6 and 3.7), and benthic foraminifera, especially Miliolids, with abundance of planktonic foraminifera of the Khasib Formation. The demise of radiolitidae might be resulted from the sea level rise; consequently, destroyed the carbonate platform of the rudist.

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