Archaeology & History in Lebanon Issue fifteen : Spring 2002, p. 87-94

Larger Foraminifera of the Jurassic Western Neotethys Ocean

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We dedicate this work to the memory of Dr. Ziad Beydoun, mentor, friend and authority on the geology of the Middle East. His passing away deprives the region of the best tradition of scholarship in field and regional geology.

The biostratigraphical study of the Mesozoic age sediments of the Mediterranean region leads to a better understanding of the palaeogeography and palaeoceanography of the Western Neotethys Ocean and its links with the Eastern Neotethys, and the history of its major structural components. The region is a unique natural laboratory for studying the effects of geological and tectonic processes, and in particular Mesozoic continental terrane movements, orogenesis and continental collisions, and evolution and migration of a wide variety of marine animals and plants. In studying the sedimentology within the framework of an accurate biostratigraphy, the model of the presence of a proto-Mediterranean basin (Western Neothethys), open and connected with the Neotethys s.l. is reinforced. It also helps to document the complex regional evolution between the opening of the North Atlantic and the coming together of the European and African plates. So many conflicting ideas about the complex movements of individual structural elements have diverted the attention of many scientists from the simple story provided by the rocks. There is a tendency for workers to treat each rock sequence as reflecting conditions on a separate microplate, and tectonic complexity certainly obscures the fundamental palaeoceanographical history of the region.

The Mesozoic sedimentary sequences around the Mediterranean are dominated by warm water, shallow marine carbonates of crucial importance as the product and record of climatic/oceanic conditions and interchange in tropical/subtropical inner shelf environments, and as hydrocarbon reservoirs. These deposits are dominantly biogenic in origin, primarily of larger benthic foraminifera and algae, with hermatypic corals. The foraminifera are free-living protozoa which grow an elaborate, solid skeleton. The so-called "larger" ones are all marine, neritic and benthic (bottom-dwelling), and develop complicated endoskeletons, which are reproduced precisely similarly with each successive generation. These internal structures permit the taxa of such microfossils to be accurately identified even when they are randomly thin-sectioned. The larger benthic foraminifera occur today commonly in low latitudes, often associated with coralgal reefs, and had similar distributions in the Mesozoic and Cenozoic. They occurred abundantly in the shelf limestones of the Tethyan Mesozoic and are readily available for study when thin sections of the limestones are prepared for any geological purpose. The larger benthic foraminifera lived in shallow water conditions in association with green algae and occur in various facies, close to or at wave base, in lagoonal settings or in sediments overlying or underlying reef deposits.

The study of the larger foraminifera, in combination with the algae and the planktonic foraminifera, via appearance or disappearance of index taxa during Jurassic-Cretaceous time allows a biostratigraphic correlation of the Jurassic-Cretaceous along the entire Neotethys, and clarifies the effect of regional tectonics in drawing palaeogeographical and palaeoenvironmental maps of that past ocean.

The Lower Jurassic of Western Neotethys has yielded sequences of larger benthic foraminiferal faunas, recognisable in thin sections of marine limestones, which enable broad stratigraphic correlations from Gibraltar[1] and the Balearic Islands[2] in the west to Iraq[5] and Yemen[3] in the east. The biota as a whole is characteristic of inner carbonate platform environments widespread along the rifted western margins of the Early Jurassic Neotethys, notably those recorded from Morocco, Italy and Greece as well as southern Spain. These larger foraminifera are mainly of the family Textulariidae and represent an ecologically homogeneous but polyphyletic group. Their palaeobiogeographical record is established according to general principles of palaeoecology, stratigraphy, population genetics and evolution[4]:

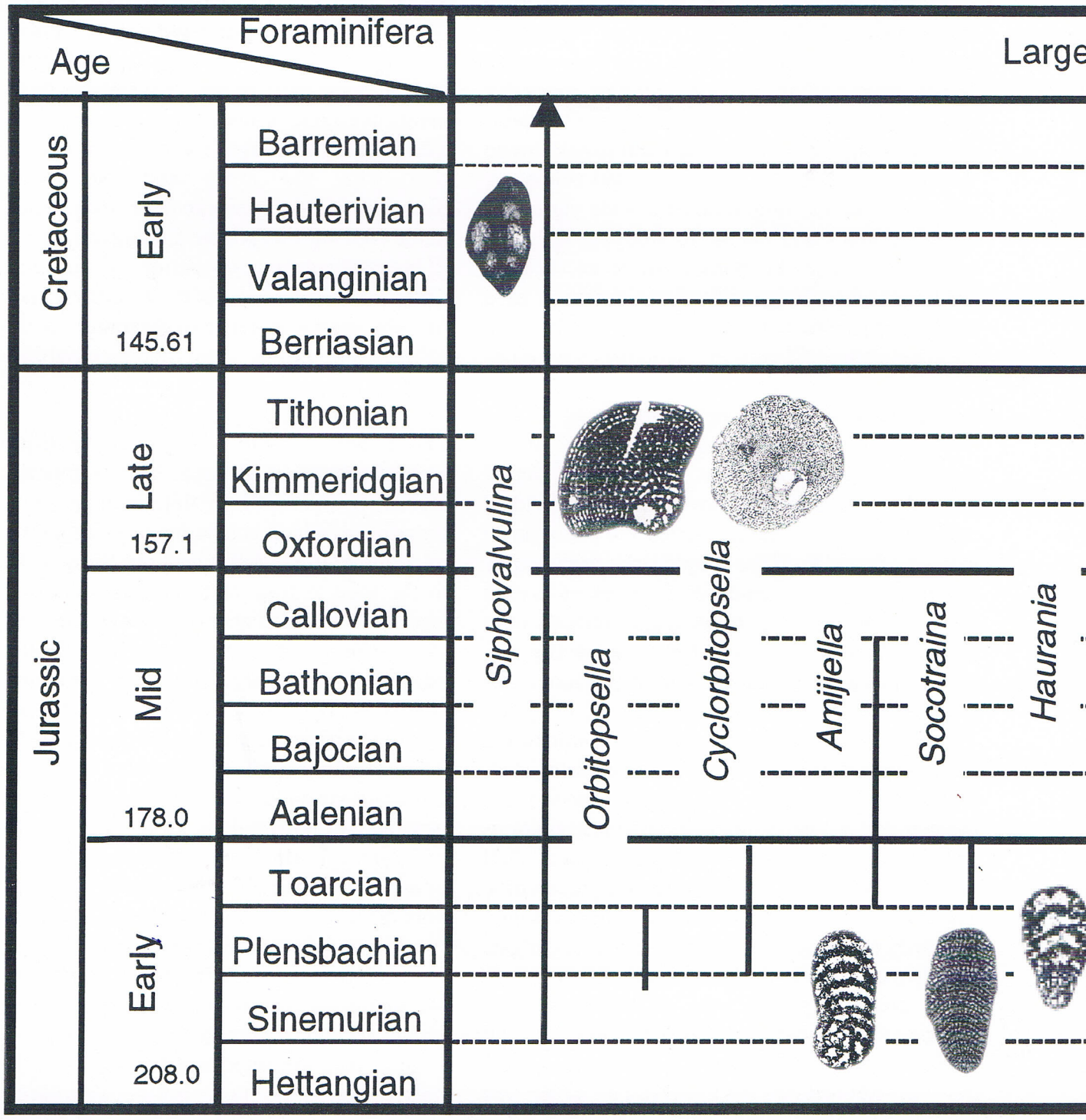
- the textulariids with complex internal structure form a palaeoecological unit, on carbonate platforms, contrasting with other textulariid groups related to open marine environments;
- they are important for reconstructing the palaeogeography and palaeoenvironment of

Neotethys.

In the Eastern Mediterranean, few carbonate sequences of dolostones and limestones from the Lower Jurassic have been systematically sampled. Their preserved foraminiferal assemblages should help locate the earlier stages of the Jurassic within the carbonates. Further sections are important to record sequences in the north of the Lebanon, and would prove useful in correlation with neighbouring Syria. The Upper Jurassic section of central Lebanon[7] has yielded assemblages that have dated the first volcanic emissions in Lebanon as of early Kimmeridgian age. The carbonate sedimentation during the Late Jurassic continued through until the Early Cretaceous and with the advent of Berriasian-Valanginian time a clastic influx invaded the platform.

Regionally in Iraq, Iran, Saudi Arabia and Oman the Tithonian is poorly known[8], for it is believed to be represented by fossil-poor dolostones and evaporites that ended Jurassic sedimentation in many areas of the southern Neotethys.

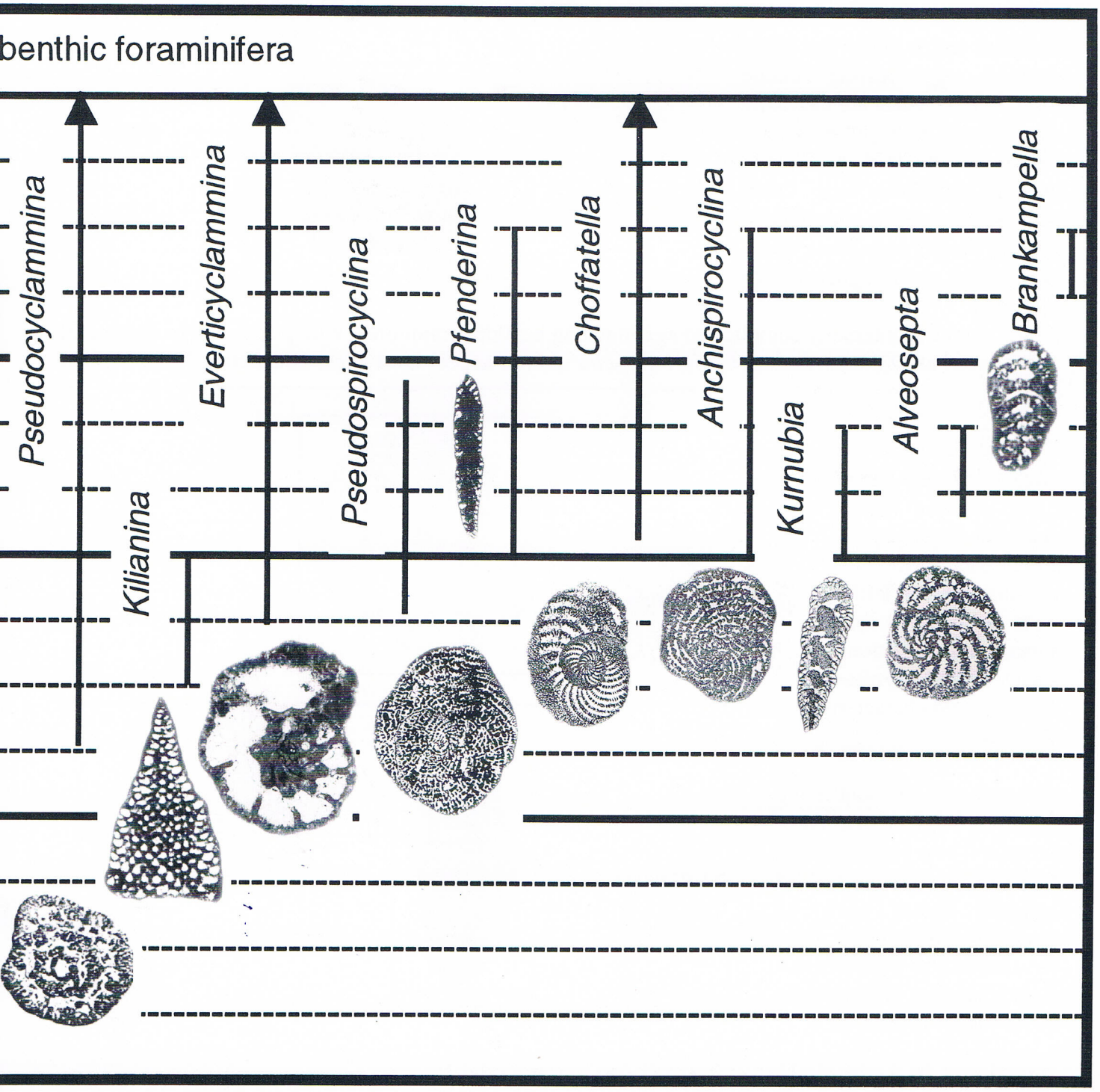
During Berriasian-Valanginian time, the outer unstable platform in central Lebanon[7] (Salima Formation) and the inner stable platform in Iraq (Zangura and Sulaiy formations), and Saudi Arabia (Buwaib Formation) were all subjected to



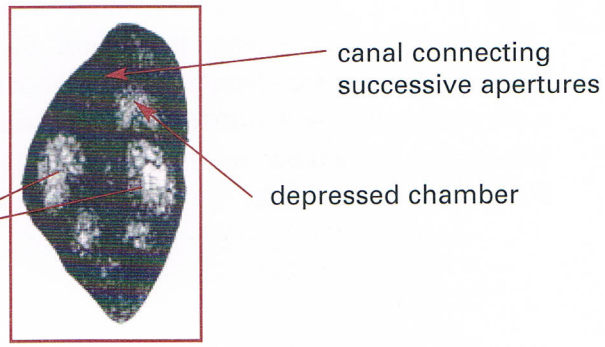
shallow marine and evaporite sedimentation. However, during Valanginian-Hauterivian time, the outer unstable shelf in Lebanon was subjected to an influx of fluvio-deltaic deposits whereas the inner stable shelf of Iraq, Iran, Gulf States and Saudi Arabia remained exposed to carbonate/evaporite sedimentation. Normal marine carbonate sedimentation resumed over both areas during Barremian-Aptian time.

Jurassic Larger Benthic Foraminifera

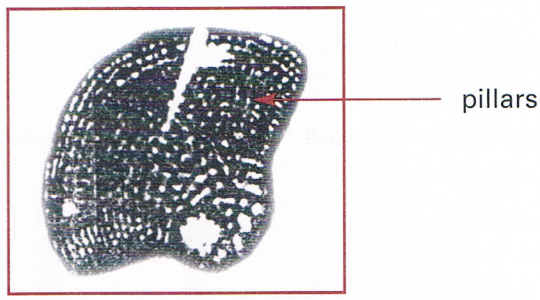
The Early Jurassic (Sinemurian) larger benthic foraminifera from the Gibraltar Limestone Formation of the Rock of Gibraltar[1], Italy, Spain, Lebanon, Syria[5] and Morocco[4] are mostly textulariids. The textulariids are elongate, with a biserial test, at least in in the early stage, in some later reduced to uniserial. The biota as a whole is characteristic of inner carbonate platform environments widespread along the rifted western margins of the Early Jurassic Neotethys. They are more primitive than species well-known from the later Early Jurassic (Pliensbachian) of the Mediterranean region, especially Morocco[4] and



Italy [6]. These earliest Jurassic assemblages include distinctive smaller foraminifera such as *Siphovalvulina* with depressed chambers which ranges from the Sinemurian to the Upper Cretaceous.
The dasyclad alga *Palaeodasycladus* is abundant and well-preserved, consistent with deposition in shallow marine, inner platform conditions.

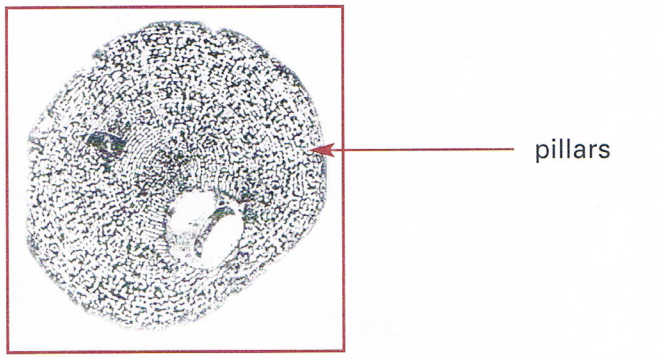


Despite a seemingly favourable depositional palaeoenvironment, the Gibraltar Limestone lacks the more diverse foraminiferal assemblages, and foraminiferal species with more complex test structures, reported from higher in the Lower Jurassic of the Western Neotethyan realm. It therefore seems likely that large, complex, agglutinating benthic foraminifera, which are internally complicated with pillars and/or intramural alveoli did not appear until Pliensbachian time. Other foraminifera with complicated internal morphology occur stratigraphically even higher in the Mesozoic.

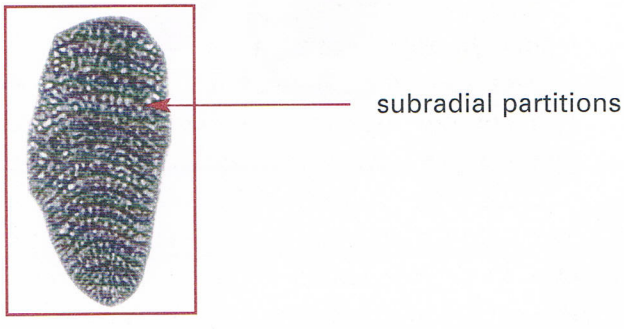


Large, complex, internally complicated agglutinating benthic foraminifera with pillars and/or intramural alveoli such as *Orbitopsella* and *Cyclorbitopsella* did not appear until latest Sinemurian-Pliensbachian time.

Cyclorbitopsella ranged into the latest Early Jurassic (Toarcian) but *Orbitopsella*, a Plensbachian form, is missing and new forms with solid walls but subradial partitions such as *Socotraina* appeared and characterised the Toarcian.



Although the Toarcian is the youngest stage of the Early Jurassic it also yields the earliest species of typically Mid Jurassic forms such as *Amijiella* which range from the Toarcian to the Bajocian-Bathonian and *Haurania* in the Bajocian-Bathonian.



The later part of the Mid Jurassic (Bathonian-Callovian) is also characterised by *Kilianina* in which the walls of the septa were thickened in a broad central zone.

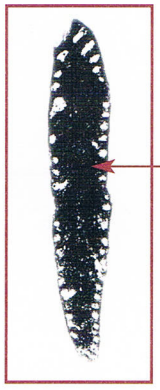
Pfenderina with secondary infillings and internal partitions appeared in the Late Jurassic (Oxfordian) and ranged into the Early Cretaceous (Valanginian) of southern Europe, but not in the Middle East where it survived until the Late Cretaceous.

The Late Jurassic age Bhanness Complex Formation is a distinctive unit of carbonates and associated volcanics in central Lebanon[7]. Detailed descriptions and figures of larger foraminifera collected from six sites of its carbonate sequence allowed the distinction of two different assemblages of Early Kimmeridgian age[7]. These two assemblages led for the first time to a regional biostratigraphic correlation of the Upper Jurassic strata of the coastal Levant including the Lebanon outcrops and also clarified the effect of regional tectonics on the preservation of index taxa of Oxfordian/Kimmeridgian age. Locally in central Lebanon it has also become possible to date the contemporaneous volcanics of the Bhanness Complex as early Kimmeridgian.

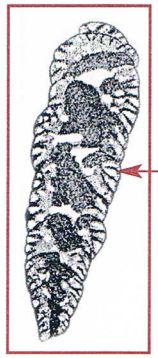
Amijiella sp.

Kilianina sp.

Pfenderina sp.



Kurnubia sp.

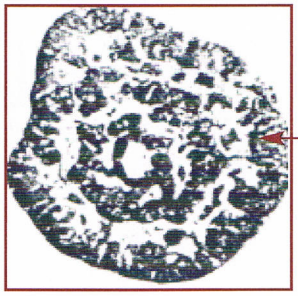


The Late Jurassic and Early Cretaceous assemblages of Western Neotethys[9] compare closely with those described from Israel, Lebanon, Iraq, the United Arab Emirates and Saudi Arabia[8]. In the Oxfordian *Kurnubia* with reticulate hypodermis evolved and persisted until the late Kimmeridgian.

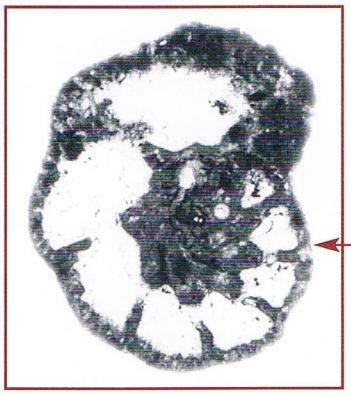
It was joined by more complicated planispiral forms, spirally enrolled in their early stages but which may uncoil; lituolids with intramural alveoli such as *Pseudocyclammina* (Bajocian-Aptian),

Everticyclammina (Late Bathonian-Early Albian), *Pseudospirocyclina* (Callovian-Tithonian), *Anchispirocyclina* (Oxfordian-Valanginian) and *Alveosepta* (Late Oxfordian-Kimmeridgian).

Pseudocyclammina sp.

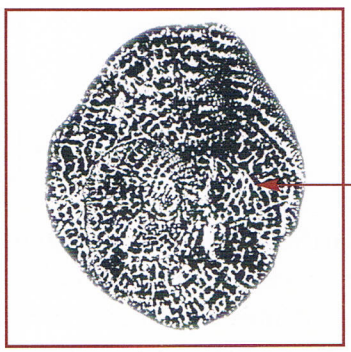


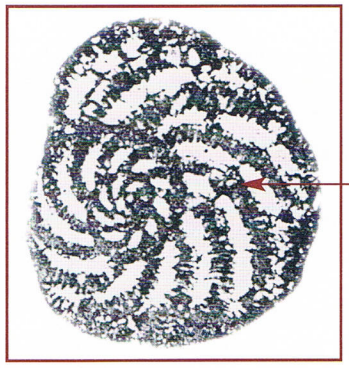
Everticyclammina sp.



Pseudospirocyclina sp.

Anchispirocyclina sp.





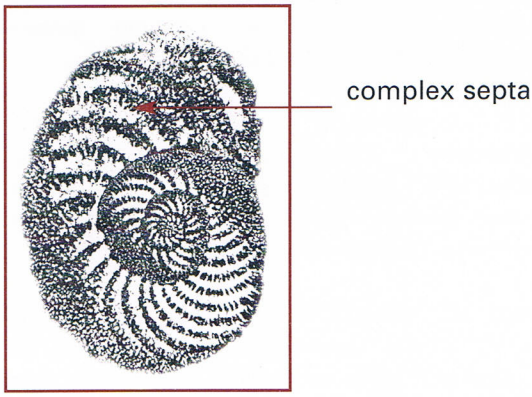
Alveosepia sp.

Forms with narrow alveoles and a regularly labyrinthic hypodermis (e.g. *Alveosepta*) occurred from Portugal through North Africa and southern Europe to the Middle East, ranged from the Late Oxfordian to Kimmeridgian and occupied a deeper water palaeoenvironment than the contemporaneous forms with larger alveoles and irregularly labyrinthic hypodermis (e.g. *Everticyclammina*).

Bramkampella sp.

A very few forms from the Jurassic survived into the Early Cretaceous, e.g. *Everticyclamimina*, *Pseudocyclammina*. In contrast, many new forms with hypodermal alveoles such as *Bramkampella* (Valanginian) dominate the Early Cretaceous assemblages, and forms with complex septa such as *Choffatella*, which were rare in the Late Jurassic (just one species), become abundant in the Cretaceous (Oxfordian-Santonian).

The time distribution of these foraminifera is shown in Fig. 1.



Choffatella sp.

Conclusion

The commonality of the Mediterranean Jurassic assemblages with those recorded from Southern Turkey, Iran, Saudi Arabia, Iraq and the Gulf States along with Syrian and Israeli assemblages, is remarkable[7]. This commonality is indeed surprising given the presence in the Neotethys of palaeohighs, and vertical tectonics affecting differentially subsided and uplifted platform blocks. The study of the distribution and phylogenetic evolution of these assemblages, and the test structure of their major components help us to understand the events which prevailed during Mesozoic times and which influenced the palaeogeography of the Neotethys. This in turn elucidates the complex evolution of the orogenic belts and the more stable masses between them during the opening of the North Atlantic and the coming together of the European and African plates.

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