

Biostratigraphy of the Toarcian foraminifera of the Middle Atlas (Morocco). Correlation with neighbouring regions

Bioestratigrafía de Foraminíferos del Toarciense del Atlas Medio (Marruecos). Correlación con las regiones vecinas

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RESUMEN

Los depósitos del Toarciense del Atlas Medio, generalmente de tipo hemipelágico, presentan características de plataforma y de cuenca. Son depósitos margosos, confinados en los depocentros, y depósitos condensados calcáreo-margosos, en los altos de la cuenca.

Los estudios micropaleontológicos de foraminíferos bentónicos nos permiten seguir la extensión bioestratigráfica de las diferentes especies encontradas. Se han establecido las siguientes cuatro biozonas: biozona con *Lingulina* gr. tenera y *Marginulina* gr. prima; biozona con *Lenticulina obonensis* mg *Planularia*; biozona con *Lenticulina pennensis* mg *Marginulinopsis*, *Ichtyolaria hauffi*, *Dentalina utriculata*, *Citharina longuemari* var. *angusta-gradata* y espectro de *Lenticulina chicheryi*; y biozona con *Lenticulina d'orbigny* mg *Lenticulina*, *Astacolus* y *Planularia*, *Nodosaria pulchra* y *Lenticulina ferruginea* mg *Falsopalmula*.

Palabras clave: Foraminíferos, Biozonación, Toarciense, Atlas Medio, Correlación.

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Introduction

In this study, we present results obtained from foraminifera of Toarcian age from the Middle Atlas in Morocco (Fig. 1a). The structure of this region is dominated by four NE-SW trending anticlines which delineate three synclinal troughs of similar orientation (Fig. 1b).

Toarcian deposits (Fig. 1c) generally lie on Upper Pliensbachian bedded limestones or calcareous marls. At the top of the sequence, these deposits are overlain by Aalenian-Lower Bajocian marls and calcareous marls rich in *Zoophycos*. Toarcian subdivisions can be inferred from ammonoids (Benshili, 1989). The Lower Toarcian is mainly composed by alternating marls and calcareous marls. The Middle Toarcian, represented by various facies, is composed by calcareous marls, limestones and nodular marls, with carbonate units becoming more frequent towards the top. Upper Toarcian sequence is represented by calcareous marls and ferruginous limestones. The Toarcian section, with overall increasing

carbonate content from the base to the top, forms part of a klupfelian-type megasequence (Bejjaji, 2007). Ten sections were studied and 119 species of foraminifera were differentiated from sieved samples.

Biostratigraphy

Foraminiferal assemblages

Benthic foraminifera of the Toarcian deposits are abundant and diverse. The observed foraminiferal taxa are mainly calcareous shell type forms, belonging to the suborders Lagenina, Rotaliina, Miliolina and Spirillinina. Agglutinated forms (*Textulariina* suborder) are secondary components. Biostratigraphic correlations between the different studied sections allow identifying the main characteristic species of any given Toarcian zones (Fig. 2).

Biozones

The vertical distribution of the foraminifera can be used to identify which species are suitable for chronostratigraphic purposes. We use marker species that have been widely

described from Western Europe and Morocco. The selected marker species allow us to establish a regional biozonation comprising four biozones (Fig. 3):

(A) Biozone with *Lingulina* gr. *tenera* and *Marginulina* gr. *prima*: The biozone characterised by the presence of these two marker species is found in the Upper Pliensbachian-Toarcian (Polymorphum zone). This biozone can be divided into four sub-biozones (Boutakiout, 1990): sub-biozone with *Marginulina prima* (lower part of Upper Pliensbachian), sub-biozone with *Bolivina liassica* (middle part of Upper Pliensbachian), sub-biozone with *Lenticulina sublaevis* mg *Saracenaria* and *Lenticulina insignis* mg *Falsopalmula* (uppermost part of Upper Pliensbachian) and, finally, sub-biozone with *Lenticulina bochari* mg *Lenticulina* and *Lenticulina toarcense* mg *Lenticulina* (Lower Toarcian, Polymorphum zone). *Nodosaria obscura*, is also representative of latter sub-biozone.

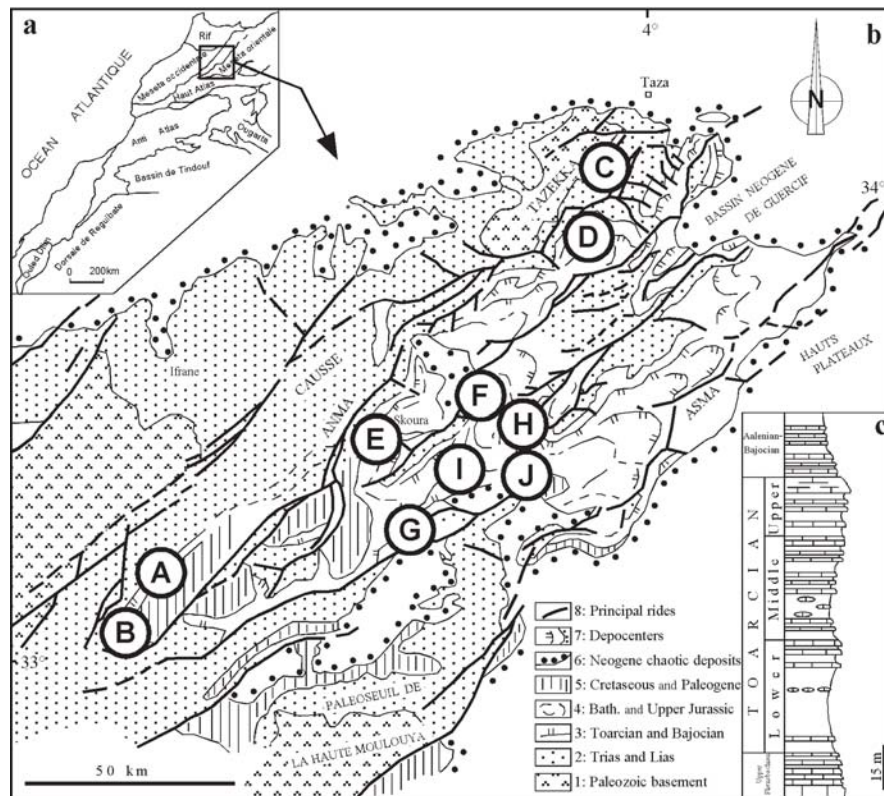


Fig. 1.- Geographical and geological sketch. a: Location of the Middle Atlas; b: Geological map of the Middle Atlas and sections studied (A: Ain Kahla; B: Fellat; C: Ain n'Tislit; D: Tazarine; E: Ait Albegal; F: Tizi Issoulietène; G: Aijil Ikhartarn; H: Issouka; I: Tagnamas; J: Saïd Arrahim); c: Synthetic lithostratigraphic column of Toarcian deposits.

Fig. 1.- Localización geográfica y geológica. a: Localización del Atlas Medio; b: Mapa geológico del Atlas Medio y localización de los perfiles estudiados (A: Ain Kahla; B: Fellat; C: Ain n'Tislit; D: Tazarine; E: Ait Albegal; F: Tizi Issoulietène; G: Aijil Ikhartarn; H: Issouka; I: Tagnamas; J: Saïd Arrahim); c: Columna estratigráfica sintética de los depósitos Toarcienses.

- (B) Biozone with *Lenticulina obonensis* mg *Planularia*: This biozone is defined by the distribution of this species and coincides with the Serpentinus zone.
- (C) Biozone with *Lenticulina pennensis* mg *Marginulinopsis*, *Ichtyolaria hauffi*, *Dentalina utriculata*, *Citharina longuemari angusta*, *Citharina longuemari gradata* and spectre *Lenticulina chicheryi*: This biozone is characterised by the disappearance of *Lenticulina obonensis* mg *P.* and the appearance of the cited species (Middle Toarcian). *Lenticulina pennensis* mg *Marginulinopsis*, *Ichtyolaria hauffi* are restricted to the Middle Toarcian.
- (D) Biozone with *Lenticulina d'orbignyi* mg *Lenticulina*, *Astacolus* and *Planularia*, *Nodosaria pulchra* and *Lenticulina ferruginea* mg *Falsopalmula*: This biozone corresponds to the

appearance of these two marker species. *Lenticulina pennensis* mg *M.* and *Ichtyolaria hauffi* disappear during the Upper Toarcian-Aalenian.

Correlation with neighbouring regions

The distribution of foraminifera is discussed and compared with previous studies from Morocco and Western Europe.

The Upper Pliensbachian-Toarcian

In this horizon, the distribution of foraminifera is very similar to that proposed for neighbouring regions (Morocco, Spain, France and Portugal).

The Pliensbachian-Toarcian boundary is characterised by the total extinction of *Lenticulina sublaevis* mg *Saracenaria* and *Bolivina liassica*. Both have been previously considered as Upper Pliensbachian indicators in various locations. The Pliensbachian-Toarcian

boundary is coincident with the appearance of several Toarcian species (e.g. *Lenticulina toarcense* mg *L.*, *Lenticulina bochari* mg *L.* and *Nodosaria obscura*).

However, several Pliensbachian species persist through to the early Toarcian. As described from the South Rifian corridor (Boutakiout, 1990; Boutakiout *et al.*, 1995; El Youssfi, 2000), northeast Morocco (Boudchiche, 1994), High Atlas (El-Kamar, 1997; Amhoud, 1999) and Western Europe (Copestake and Johnson, 1984; Ruget, 1988, 1990; Qajoun, 1994), the base of the Toarcian corresponds to an important renewal of foraminifera. This renewal is coincident with the global anoxic event (Jenkyns, 1988; Bassoullet and Baudin, 1994) and with important phase of transgression started in the Early Toarcian. Throughout the Middle Atlas, however, the disappearance of Pliensbachian species seems to be relatively late and occurs at the top of Polymorphum zone, or even in Serpentinus zone.

The range of the majority of species is correlated with those in Morocco, with the exception of *Lingulina* gr. *tenera*, which survived into the Serpentinus zone whilst they generally disappeared in the Polymorphum zone (South Rifian corridor, northeast Morocco, High Atlas and Western Europe).

The Lower Toarcian

The Lower Toarcian is characterised by *Haurania (Platyhaurania) subcompressa*. This species is found exclusively in the Lower Toarcian.

Despite some local appearances at the base of Lower Toarcian, we consider that *Lenticulina obonensis* mg *P.* is characteristic species of Serpentinus zone. In Western Europe, this species is restricted to the Polymorphum zone (Ruget, 1988) but can be found up to the base of the Serpentinus zone in northeast Morocco (Boudchiche, 1994). In the South Rifian corridor, *Lenticulina obonensis* mg *P.* is confined to the Serpentinus zone, at the top of Lower Toarcian deposits (Boutakiout *et al.*, 1995; El Youssfi, 2000). In the High Atlas, this species is absent (El-Kamar, 1997; Amhoud, 1999).

The Middle Toarcian

Several Toarcian species appear and flourish during the Middle Toarcian. This period corresponds to the biozone with *Lenticulina pennensis* mg *M.* and

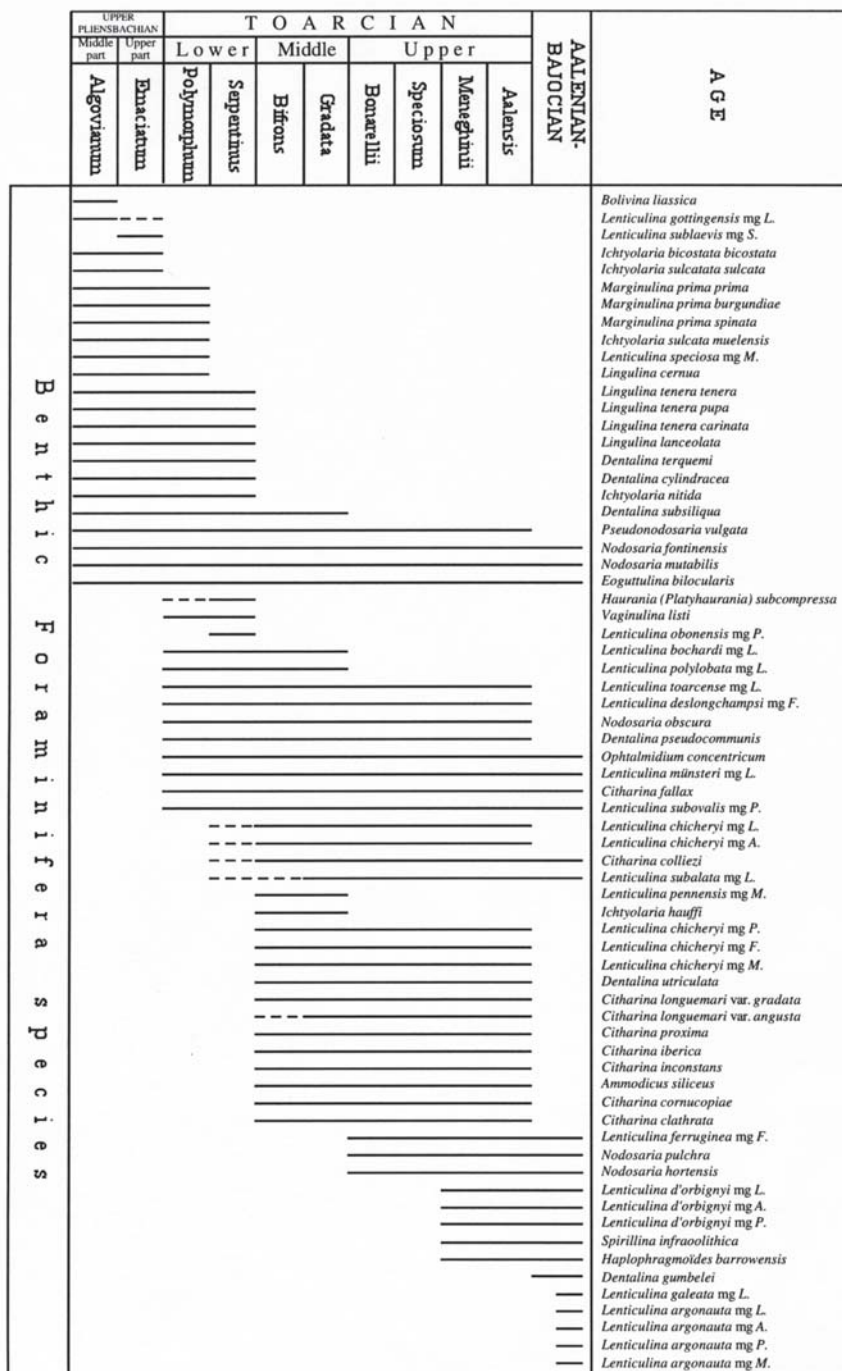


Fig. 2.- Distribution of main Toarcian foraminifera of the Middle Atlas.

Fig. 2.- Distribución de los principales foraminíferos del Toarciense del Atlas Medio.

chicheryi at the Lower-Middle Toarcian boundary is similar in all neighbouring regions.

The Upper Toarcian-Aalenian

The appearance of *Lenticulina d'orbigny* mg L., A. and P., as well as *Nodosaria pulchra* and *Lenticulina ferruginea* mg F. is a sensitive marker of Upper Toarcian-Aalenian. In the South Rifian corridor, the first two species define a distinct biozone during this period (Boutakiout, 1990). The record of *Lenticulina d'orbigny* mg L., A. and P. is very early in Europe. This species therefore exhibits a diachronous occurrence from North to South. *Nodosaria pulchra* has also been described in several locations in Europe, where it is essentially restricted to the Upper Toarcian-Aalenian.

Conclusion

The distribution of Toarcian benthic foraminifera from the Middle Atlas and their correlation with neighbouring regions of Morocco and Western Europe (Spain, France and Portugal), shows quite well-defined biostratigraphical extensions, which allow four biozones to be established. They can give precision to dating at sub-stage level or at ammonoid zone level.

Comparisons with studies from other regions exhibit similarities which demonstrate that stratigraphical subdivisions of the microfauna may be an useful tool when ammonoids are absent.

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Ichtyolaria hauffi, found in association with *Dentalina utriculata* and spectre *Lenticulina chicheryi*. In the Middle Toarcian, the bloom of *Citharina* represents an important event, especially in the northeast of the studied area. This event is congruent with other regions where *Citharina longuemari angusta* and *Citharina longuemari gradata* can also be commonly found.

Lenticulina pennensis mg M. has been described in the Middle Toarcian of

various Moroccan and western European locations. In northeast Morocco, this species is associated with *Ichtyolaria hauffi* (Boudchiche, 1994) whereas in Western Europe it is found with *Dentalina utriculata* (Ruget, 1988).

First record of *Lenticulina chicheryi* is in the Serpentinus zone but its main development, with various morphogenera, occurs only during the Middle Toarcian, where the spectre is complete. The appearance of *Lenticulina*

AGE		BIOZONATION	
AALENIAN			
T O A R C I A N	Upper	Aalensis	<i>Lenticulina d'orbignyi</i> mg L., A., P., <i>Nodosaria pulchra</i> , <i>Lenticulina ferruginea</i> mg F.
		Meneghinii	
		Speciosum	
	Middle	Bonarellii	<i>Dentalina utriculata</i> , <i>Citharina longuemari angusta</i> , <i>Citharina longuemari gradata</i> , spectre <i>Lenticulina chicheryi</i>
		Gradata	
	Lower	Bifrons	<i>Lenticulina pennensis</i> mg M., <i>Ichtyolaria hauffi</i>
		Serpentinus	
Polymorphum			
Upper Pliensbachian	Upper part	Emaciatum	<i>Lenticulina obonensis</i> mg P. <i>Lenticulina toarcense</i> mg L., <i>Lenticulina</i> <i>Bochari</i> mg L., <i>Nodosaria obscura</i>
	Middle part	Algovianum	<i>Lingulina</i> gr. <i>tenera</i> , <i>Marginulina</i> gr. <i>prima</i> <i>Lenticulina sublaevis</i> mg S. <i>Bolivina liassica</i>

Fig. 3.- Main Toarcian biozonation of the Middle Atlas.

Fig. 3.- Principales biozonas del Toarciense del Atlas Medio.

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