Micropaleontology

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4. Ages

The biostratigraphy is based on ammonite horizons within the Tenuicostatum and Serpentinus Zones (Venturi, in press) and on provisional horizons within the other zones studied by Venturi and not yet published (personal communication). The ammonite horizons are summarized in Table 1 and ammonite zones have been indicated, for graphic convenience, with age initials followed by a number. Each horizon is reported in metres in Figure 4, 5 and 6, following the Channell et al. (1984) sampling. Recently published data of the Valdorbia Section have been used as well (Cresta et al. 1989, Fig. 37 and 38). Calcareous nannofossil events, reported by Reale (1989), are located on the right side of the four partial sections. The lower part of the Valdorbia section (530 m to 510 m) has been attributed to the Carixian on the base of the first occurrence of Mitrolithus jansae at 499.8 m (Fig. 4) which falls in the upper part of the Davoei Zone (Carixian) according to Reale et al. (1991).

5. Micropaleontology

An important micropaleontological study of the Valdorbia Jurassic microfacies has been carried out by Centamore et al. (1971) in which the Valdorbia section was indicated as "Sezione del Sentino Ovest". A preliminary study of the microfossils occurring in the Valdorbia section both in thin section and in the sample washed residues was illustrated by Cresta et al. (1988), by means of a schematic distribution chart. No distinction between microfacies (observed in thin section) and microfossils (separated from the sediments) was indicated and a further study has allowed a better understanding of the microfaunal distribution and of the microfossil reworking.

In this work the micropaleontological observations concern both the microfaunal content of the microfacies analysed in thin section and the assemblages of the separated microfossils from the washed residues. 160 samples have been collected in stratigraphic order at 1 m interval roughly spanning the period of time from the Carixian to the Early Aalenian. 92 samples, mainly limestones have been processed for microfacies study from the COR, while 68 samples, mainly argillaceous and marly sediments, about 400 gr. each, have been collected mainly from the MS and RAUM units.

5.1 Data presentation

5.1.1 Microfacies

The fossil content is summarised in Figure 20 where the microfacies are arranged in groups with different characteristics.

-   Microfacies 1 (Carixian). The most characteristic fossils are stout calcareous sponge spicules and recrystallized echinoid remains (Pl. 1, Fig. 1, 2 and 3) while other organisms are scattered discontinuously. Radiolarians are associated with gastropods and other microfossils. This microfacies contains Miliolina (Pl. 1, Fig. 8), simple agglutinated foraminifers (Pl. 1, Fig. 5), plurilocular agglutinated foraminifers and Lagenina, both sculptured and smooth (Pl. 1 Fig. 7, Fig. 1, 2, 12, 13 and 14) of which Lenticulina is the dominant taxon.
    Besides Ophthalmidium (Pl. 1, Fig. 11) and Agerina martana (Pl. 1, Fig. 10), there are some tubular, porcellaneous, biloculine forms interpreted here as Planiinvoluta (Pl. 1, Fig. 6 and 9) with a porcellaneous test, according to Koehn Zaninetti (1969). The latter are characteristic but of controversial interpretation be-
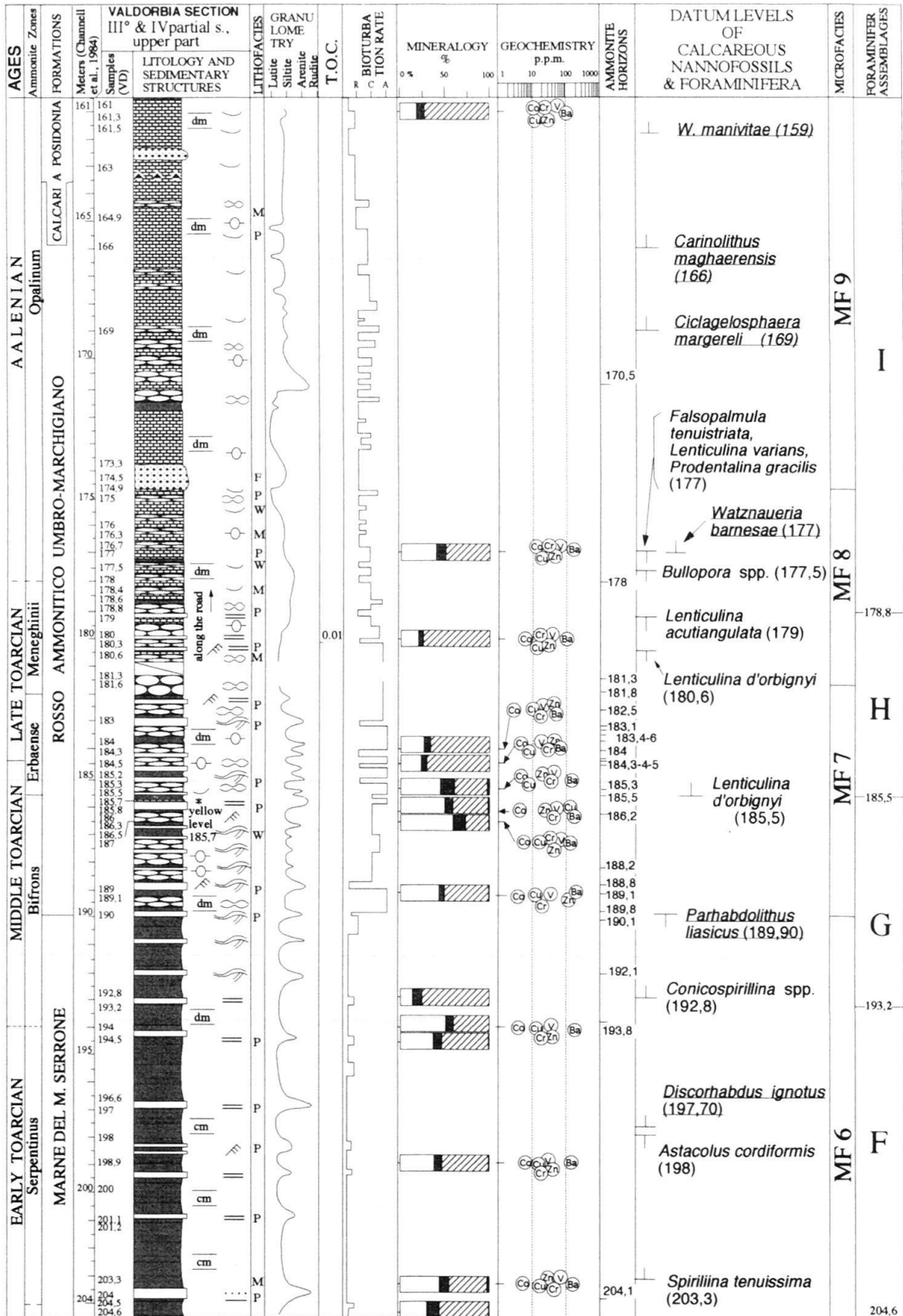
Fig. 6. Partial Sections III and IV, upper parts of the Valdorbia Section.

AGE		Ammonite Zones		Ammonite horizons	VD sections
AAL.	EARLY	AA1	Opalinum	m 170,5 - *Ericites* gr. *fallifax*, *Tmetoceras scissum* m 178 - *Leioceras* sp.	
TOARCIAN	LATE	TO5	Mene ghinii	m 181,3 horizon 14 - *Pleydellia* gr. *ovata* m 181,8 hor. 13 - *Dumortieria meneghinii, Dumortieria* sp.," *Erycites*" *elaphus*	sections III and IV

		TO4	Erbaense	m 182,5 hor. 12b - *Merlaites alticarinatus*
				m 183,1 hor. 12a - *Merlaites alticarinatus, Polyplectus apenninicus*
				m 183,4 hor. 11c - *Peronoceras aculeatum*
				m 183,6 hor. 11b - *Paroniceras sternale*
				m 184 hor. 11a - "*Phymatoceras*" *speciosum, Phymatoceras erbaense,*
				    Chartronia venustula, Praerycites civitellensis
				m 184,3 hor. 10b - "*Phymatoceras*" *speciosum.*
				m 184,4 hor. 10 - *Merlaites clausus*
				m 184,5 hor. 9 - *Merlaites clausus, Merlaites* gr. *gradata*
				m 185,3 hor. 8 - *Collina meneghinii*
				m 185,5 hor. 7 - *Collina gemma, Collina meneghinii, Pseudomercaticeras*
				    gr. *frantzii, Hildoceras* gr. *bifrons.*	

	MIDDLE	TO3	Bifrons	m 186,2 hor. 6b - *Hildoceras angustisiphonatum*
				m 188,2 hor. 6 - *Hildoceras* gr. *semipolitum, Collina* gr. *gemma, Mercaticeras*
				    gr. *mercati, Mercaticeras dilatum*
				m 188,8 hor. 5 - *Hildoceras angustisiphonatum, Hildoceras* gr. *semipolitum,*
				    Mercaticeras thyrrenicum, Mercaticeras gr. *mercati, Pseudomercaticeras* n.
				    sp. (aff. *venzoi), Phymatoceras* gr. *erbaense, Chartronia* gr. *fabale.*
				m 189,1 hor. 4 - *Hildoceras* gr. *lusitanicum, H.* gr. *semipolitum,*
				    Pseudomercaticeras sp.
				m 189,8 hor. 3b - *Hildoceras* gr. *lusitanicum*
				m 190,1 hor. 3a - *Hildoceras lusitanicum, H. tethysi, Mercaticeras thyrrenicum,*
				    Frechiella subcarinata, Rarenodia planulata, Mesodactylites broilii.
				m 192,1 hor. 2b - *Hildoceras sublevisoni*
				m 193,8 hor. 2a - *Hildoceras raricostatum*	

	EARLY	TO2	Serpe ntinus	m 204,1 hor. 1c - *Hildaites* gr. *undicosta, Parahildaites meisteri,* *Praepolyplectus* sp., *Maconiceras ?* sp.	

		TO1	Tenuico statum	m 378,8 hor. 1b - *Dactylioceras* sp., *Praemercaticeras ?* sp.,
				    Meneghiniceras eximium
				m 396,5 hor. 1a - *Dactylioceras (Eodactylites) mirabile, Neolioceratoides* sp.,
				    "*Coeloceras*" sp.
					sect. II

DOMERIAN	L.	DO3	Emac.		
	MIDDLE	DO2	Algovia num	m 490 - *Arieticeras algovianum, Arieticeras retrorsicosta* m 492,90 - *Arieticeras algovianum* m 494 - *Arieticeras* sp.	section I
	EARLY	DO1	Lavinia num	m 496,35 - *Protogrammoceras* gr. *cerebratum* m 497,75 - *Fuciniceras lavinianum*	

Tab. 1. Symbols of the ammonite zones.

cause they have been considered, in general, as shallow water agglutinated foraminifers such as Glomospira and/or Glomospirella. In the Valdorbia Section Glomospira and Glomospirella show, instead, a siliceous test and the microanalysis of the separated specimens exhibits a greater amount of silica cement than agglutinated grains. It is possible, however, that in the Carixian these Ammodiscidae possess a finely agglutinated wall with a calcareous crypto-crystalline cement (Pl. 1, Fig. 5).

In this microfacies Planiinvoluta occurs scattered in the matrix, not included in intraclasts.

– Microfacies 2 (Lower Domerian – Middle Domerian). This microfacies is distinguished from microfacies 1 on account of the decrease in organic content and the almost total disappearance of plurilocular Textularina and Miliolina. Gastropods, thick ostracod valves, Lagenina, some Ammodiscus and Repmanina with siliceous tests, occur together with ammonite nuclei, echinoid fragments, radiolarians and calcispherids (Pl. 1, Fig. 4, 15, 16, 17, 18, 19 and 20). Within microfacies 2, the microfauna does not show clear indications of reworking, with the exception of those at levels 495.2 m and 489 m which are rich in stout calcareous sponge spicules. At 488.95 m – 488 m, corresponding to a slump, the biofacies does not change but is richer in organisms, which suggests that the slumped sediments have a local source in the basin and the sliding process has concentrated the skeletal remains.

– Microfacies 3 (Upper Domerian-LowerToarcian). Microfossils are rare or absent. (Pl. 2, Fig. 1 and 2).

– Microfacies 4 (Lower Toarcian, Tenuicostatum Zone). Strong input of fine detrital materials and pyrite occur at this time. The laminated calcarenite/rudite beds contain reworked oolites, green algae, algal coated grains, large lituolids (Pl. 2, Fig. 3–7 and 9), and Earlandia all derived from a carbonate platform. Miliolina (Pl. 2, Fig. 11–13), almost absent in the marly, autochthonous lithotypes, occur again and are considered as reworked from sediments deposited in an open marine environment immediately after the beginning of the carbonate platform drowning, because they are absent in the "Calcare Massiccio" microfacies. Other rare types of microfacies are mudstones with flat and thin bivalves, absent in the sample washed residue, and some calcified radiolarians (Pl. 2, Fig. 8). Of all the microfacies, number 4 shows the most reworking, as microfauna of different environments and ages are involved. It has to be remarked that in the microfossil distribution chart in Cresta et al. (1988) the vertical distribution of Ophthalmididae and Glomospira and Glomospirella (here interpreted as Planiinvoluta) within the Mirabile Zone has been made on the basis of their occurrence in fine detrital calcisiltite.

– Microfacies 5 (upper part of Tenuicostatum Zone). Calcified radiolarians (Pl. 2, Fig. 10 and 14) are dominant.

– Microfacies 6 and 7 (Serpentinus to Erbaense Zone). These microfacies still indicate an input of fine detrital material into the area but with a minor degree of reworking compared to microfacies 4. However, the occurrence of Planiinvoluta and Earlandia (Pl. 3, Fig. 2, 3 and 4) testify a persistent influence of allochems, such as small porcellaneous foraminifers and pellets. Ophthalmidium and Agerina martana no longer occur above level 190 m. Lagenina are present as well, probably removed from the same environment of deposition. From sample 189 (middle part of Bifrons Zone) upwards the microfacies starts to become enriched with flat bivalve tests (Pl. 3, Fig. 1).

– Microfacies 8 (Meneghinii – Opalinum Zones). This microfacies contains microfossils characteristic of the typical calcareous nodular RAUM such as that of the Pozzale (M. Martani) Section (an "intermediate" section without detrital input, studied by Venturi, in press). The organic content consists of ammonite nuclei and bivalves with shelter porosity, small low-trochospiral gastropods, globochaetes, very tiny heart-shaped brachiopods, biconvex Lenticulina's and a few radiolarians (Pl. 3, Fig. 5–9). These microfossils are also characteristic of the "Dogger" microfacies which is found on the morphostructural highs.

– Microfacies 9 (Aalenian) (Pl. 3, Fig. 10 and 11). In the pebbly mudstone at 174.5 m the intraclasts commonly exhibit the same microfacies as microfacies 8.

5.1.2 Microfossils

The term "microfossils" is used to describe the fossil content which occurs in the washed residue fraction between 63 µm and 2 mm. Microfossils can be rare or absent if only sample fractions greater than 150 µm are used.

The coarse fraction (>2 mm) has been observed, but no qualitative or quantitative analyses have been carried out. Tests or skeletons are mainly calcareous and consist of benthic foraminifers, ostracods, fragments of macroinvertebrates or small whole macroinvertebrates (< 1 cm), represented by microbrachiopods, bivalves, microgastropods, echinoderms,
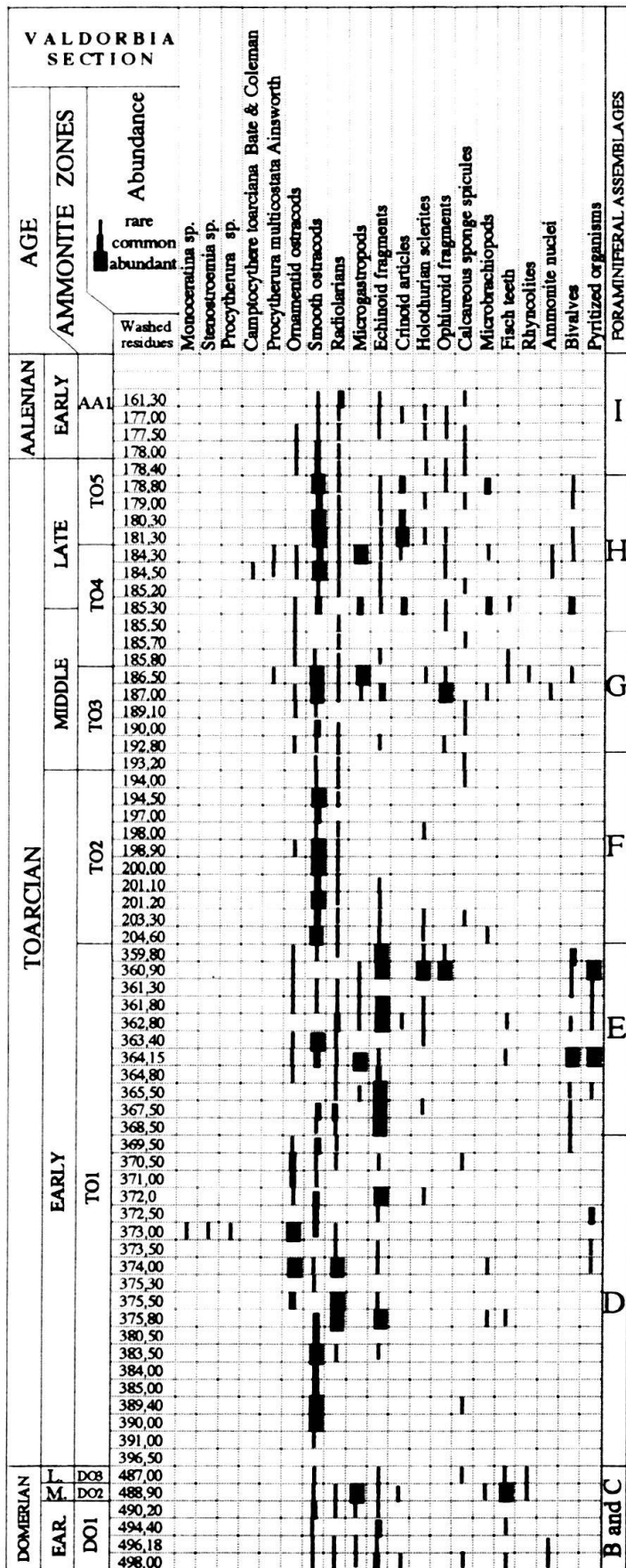
Fig. 7. Microfossil (excluding foraminifers) distribution chart.

ammonite protoconchs and rhyncholites. The non-calcareous microfossils are fish teeth (very rare) and radiolarians, which occur abundantly in some stratigraphic intervals.

As the benthic foraminifers are the object of this study, quantitative analyses have been carried out only on them and are described in detail below. The other microfossils were processed for semi-quantitative analysis which consists of spreading the washed residue uniformly three times on a standard extraction tray (6 x 10 cm) and establishing numerical classes using the symbols R (rare), defined as less than 10, C (common) between 10 and 50, and A (abundant) for more than 50. With this methodology the distribution chart of microfossils has been constructed (Fig. 7). Ostracods are as abundant or common as benthic foraminifers and these two groups of organisms are the ones most continuously distributed in the sediments. Some sculptured ostracods have been classified by C. Arias (personal communication) and are shown on Figure 7.

Benthic foraminifers are almost always present in the marly lithotypes in variable abundance, according to the different stratigraphic intervals. They are represented by a few Textulariina, Lagenina and Miliolina in the Carixian, by Lagenina and simple agglutinated forms in the Domerian, and mainly by Lagenina in the Toarcian with an increase of Spirillina in the Middle and Upper Toarcian. Faunal analyses were conducted on the benthic foraminifers after all the specimens, occurring in 6 gr. of the washed residue of the sample fraction > 63 μm, have been picked and counted (see Tab. 1 in Bartolini et al., 1992). They were diagnosed in detail and the species distribution and abundance (R < 10%, C = 10–30%, A > 30%) are reported in Figure 8 in order of first occurrence from the bottom to the top of the section. Some of the most indicative species are illustrated in Pl. 4 and 5. Although in the Lagenina etching or other chemical dissolution traces are rare or absent, the tests generally show poor preservation, due to recrystallization or mechanical processes. Thus several forms are left under open nomenclature. The genera are identified in accordance with the classification proposed by Loeblich & Tappan (1988).

Recently several authors (Bernard 1986; Chamney 1976; Morris 1982; Kaiho 1991) have recognized the influence of chemical, physical and trophic parameters of the sea-bottom environment on the general test morphology of benthic foraminifers. There is a general agreement that flat morphology and uncoiled forms of Lagenina are characteristic of a low energy, muddy environment, sometimes poorly ventilated, while strictly coiled and stout specimens occur in ventilated and high energy hydrodynamic environments. For this reason, in Figure 9, the genera have been arranged in morphogroups according the scheme proposed by Bernard (1986) and modified by Bartolini et al. (1992) and reported in this paper in Table 2.

Variations of the foraminiferal dimensions have been noted within the different stratigraphic intervals. Thus the foraminiferal size, as shown in Figure 10, has been subdivided into three classes: small < 200 μm in diameter or length according to the specimen test shape, medium > 200 μm < 500 μm and large > 500 μm.

Percentage values of indicative parameters, such as species diversity, ornate Lagenina, agglutinated foraminifers and Spirillina abundance, have been plotted in Figure 10 as well. The results of the distribution charts and graphics enable us to draw the conclusion that benthic foraminiferal assemblages change with time, thus providing further paleoenvironmental information.
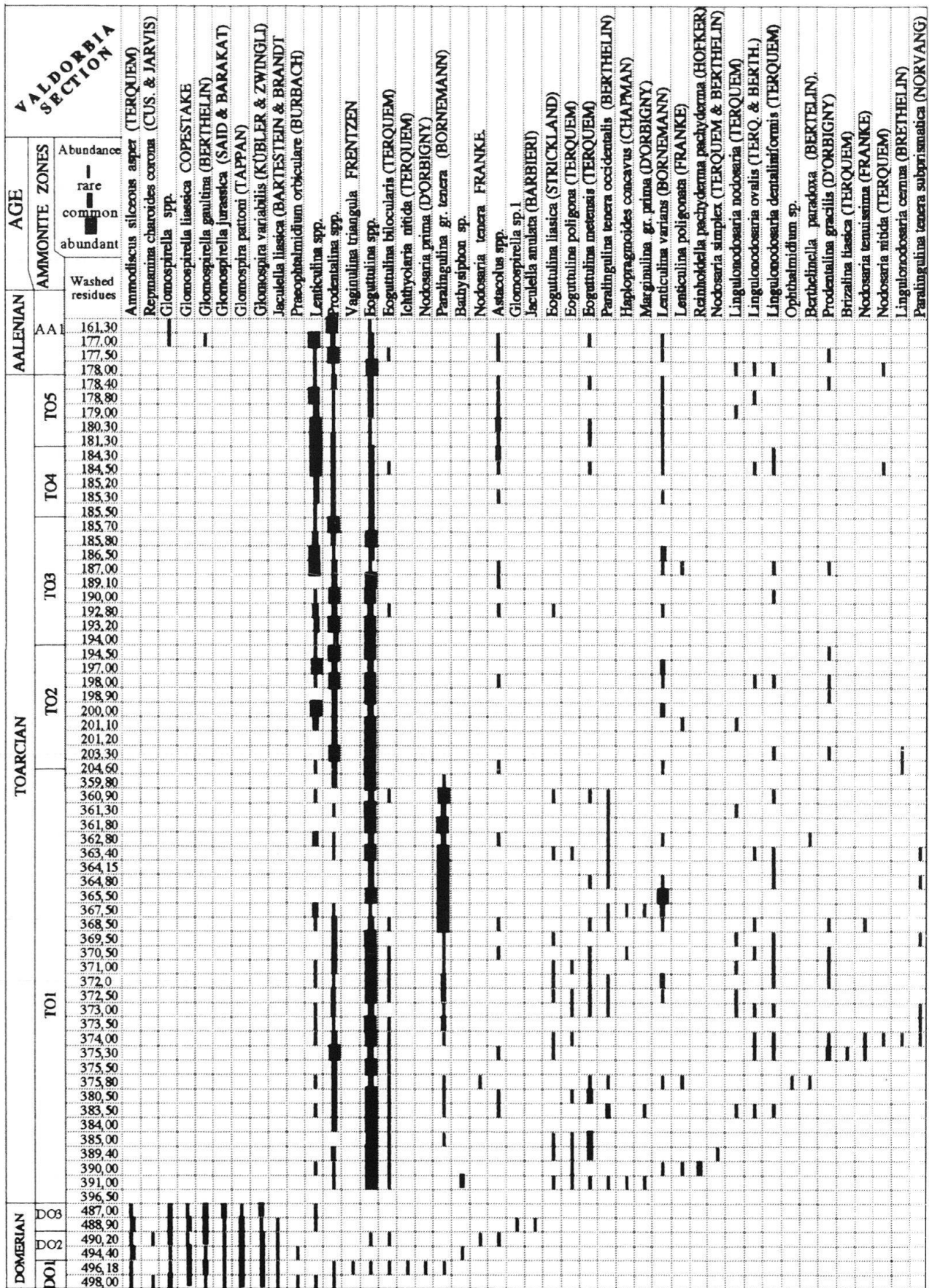
Morphogroup A =	elongated and flat forms: *Lingulonodosaria, Paralingulina, Vaginulina, Citharina.*
Morphogroup B =	elongated and pointed forms: *Eoguttulina.*
Morphogroup C =	cylindrical and elongated forms: *Prodentalina, Pseudolangella, Pseudonodosaria, Nodosaria, Marginulina.*
Morphogroup D =	flattened, planispiral forms: *Astacolus, Falsopalmula, Vaginulinopsis, Lenticulina varians.*
Morphogroup E =	Biconvex, planispiral, strictly coiled forms: biumbelicate Lenticulina as *Lenticulina münsteri.*
Morphogroup F =	planoconvex or conical forms: *Conicospirillina, Turrispirillina, Rehinoldella.*

Tab. 2. Foraminiferal morphogroups.

Although foraminiferal abundance in the sediments is low, the long interval of time makes changes in the microfossil assemblages easily recognisable. On the basis of micropaleontological examination of several sections of the UMB (Nocchi 1992), a stratigraphic succession of benthic foraminiferal assemblage units has been established. Each assemblage is distinguished from the others by a different ratio of foraminifer genera and morphogroups, by class sizes, species diversity and different accompanying fauna. They are indicated with capital letters in alphabetical order and arranged from the oldest to the youngest. These assemblages, with slight differences, have been recognized in the Valdorbia Section, and are summarized in the scheme of Figure 11. The foraminifer species included in each assemblage can be seen in Figure 8. This scheme is based also on the autochthonous microfacies. The grey-reddish marly stratigraphic interval found above the COR limestones by Nocchi & Bartolini (in press), has been replaced by pebbly mudstones and slumps in the Valdorbia Section. Thus, the cosmopolitan Pliensbachian foraminiferal assemblage BC, characteristic of this interval, is missing.

The following benthic foraminiferal trends can be identified:

a   Decrease and disappearance of Miliolina and plurilocular Textulariina during the Domerian.
b   Disappearance of siliceous biloculine tubular foraminifers in the uppermost Domerian sediments.
c   The average size of foraminifers is between 200 μm and 500 μm (Fig. 10). However in the assemblage E, characteristic of the black shales of the Tenuicostatum Zone, the average foraminiferal size is below 200 μm. An increase in size can be clearly seen after the Serpentinus Zone, in particular at the boundary between the Bifrons and Erbaense Zones (Fig. 10).
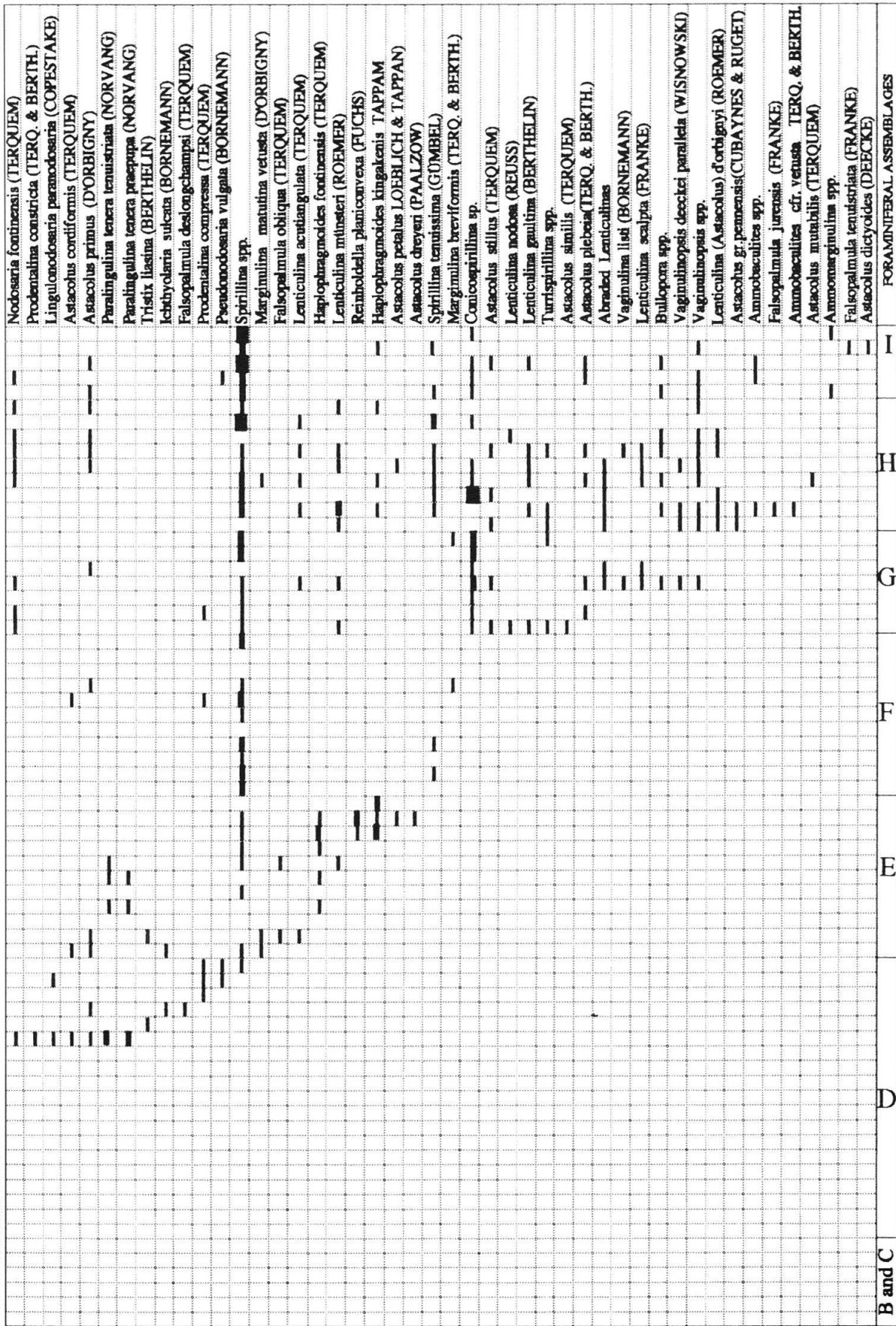
VALDORBIA SECTION

AGE — AMMONITE ZONES

Abundance
| rare
common
abundant

Washed residues

Species columns (left to right):
Ammodiscus siliceous asper (TERQUEM)
Reophanax charoides corona (CUS. & JARVIS)
Glomospirella spp.
Glomospirella liassica COPESTAKE
Glomospirella gaultina (BERTHELIN)
Glomospirella jurassica (SAID & BARAKAT)
Glomospira pattoni (TAPPAN)
Glomospira variabilis (KÜBLER & ZWINGLI)
Isculella liassica (BARTESTEIN & BRANDT)
Praeophtalmidium orbiculare (BURBACH)
Lenticulina spp.
Prodentalina spp.
Vaginulina triangula FRENTZEN
Eoguttulina spp.
Eoguttulina bilocularis (TERQUEM)
Ichthyolaria nitida (TERQUEM)
Nodosaria prima (D'ORBIGNY)
Paralingulina gr. tenera (BORNEMANN)
Bathysiphon sp.
Nodosaria tenera FRANKE
Astacolus spp.
Glomospirella sp.1
Isculella annulata (BARBIERI)
Eoguttulina liassica (STRICKLAND)
Eoguttulina poligona (TERQUEM)
Eoguttulina metensis (TERQUEM)
Paralingulina tenera occidentalis (BERTHELIN)
Haplophragmoides concavus (CHAPMAN)
Marginulina gr. prima (D'ORBIGNY)
Lenticulina varians (BORNEMANN)
Lenticulina poligonata (FRANKE)
Reinholdella pachyderma (HOFKER)
Nodosaria simplex (TERQUEM & BERTHELIN)
Lingulonodosaria nodosaria (TERQUEM)
Lingulonodosaria ovalis (TERQ. & BERTH.)
Lingulonodosaria dentaliniformis (TERQUEM)
Ophthalmidium sp.
Berthelinella paradoxa (BERTHELIN)
Prodentalina gracilis (D'ORBIGNY)
Brizalina liasica (TERQUEM)
Nodosaria tenuissima (FRANKE)
Nodosaria nitida (TERQUEM)
Lingulonodosaria cernua (BRETHELIN)
Paralingulina tenera subprismatica (NORVANG)

AGE / AMMONITE ZONES / Washed residues (depth samples):

AALENIAN — AA1
161,30
177,00
177,50
178,00

TOARCIAN
TO5
178,40
178,80
179,00
180,30
181,30

TO4
184,30
184,50
185,20
185,30
185,50
185,70
185,80

TO3
186,50
187,00
189,10
190,00
192,80
193,20
194,00

TO2
194,50
197,00
198,00
198,90
200,00
201,10
201,20
203,30
204,60

TO1
359,80
360,90
361,30
361,80
362,80
363,40
364,15
364,80
365,50
367,50
368,50
369,50
370,50
371,00
372,0
372,50
373,00
373,50
374,00
375,30
375,50
375,80
380,50
383,50
384,00
385,00
389,40
390,00
391,00
396,50

DOMERIAN
DO3
487,00
488,90
DO2
490,20
494,40
DO1
496,18
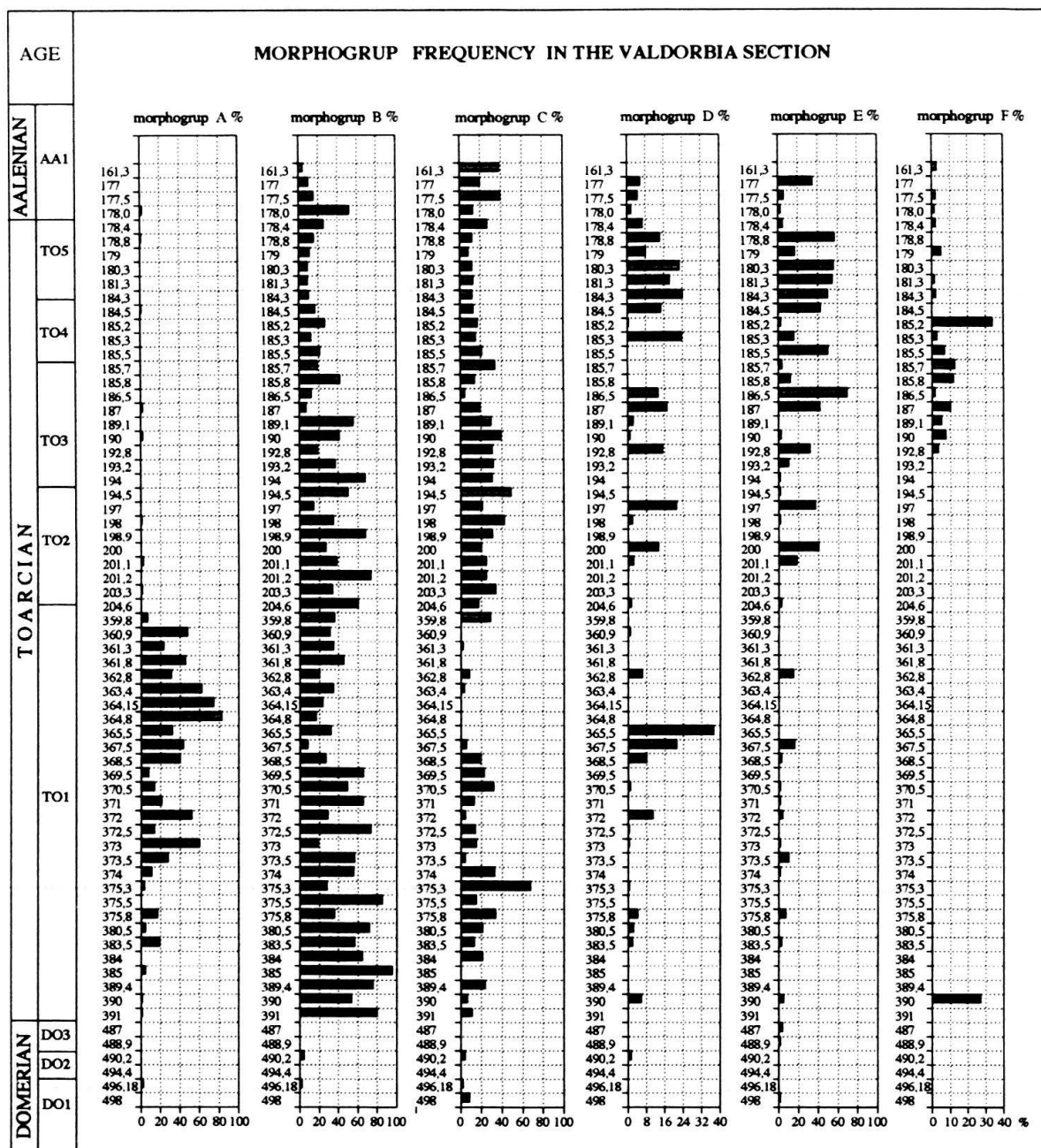498,00

Fig. 8. Foraminifer species distribution chart.

Fig. 9. Morphogroup percentages.

d Increasing in Spirillina, biconvex Lenticulina (morphogroup E) (Fig. 9) and Coni-
   cospirillina (Pl. 5, Fig. 4–6) and the occurrence of abraded and "cigar-shaped"
   Lenticulina's (Fig. 13, Pl. 4, Fig. 1 and 4) from the Bifrons Zone upwards.
e Decrease in the foraminiferal content in the Lower Aalenian as shown in Fig. 8.

In the UMB benthic foraminifers show a low density in the sediments, so that the species
distribution depends upon the quantity of sample collected. Furthermore they are clearly
related to ecological factors affecting the sea-bottom so that they can be time-transgres-
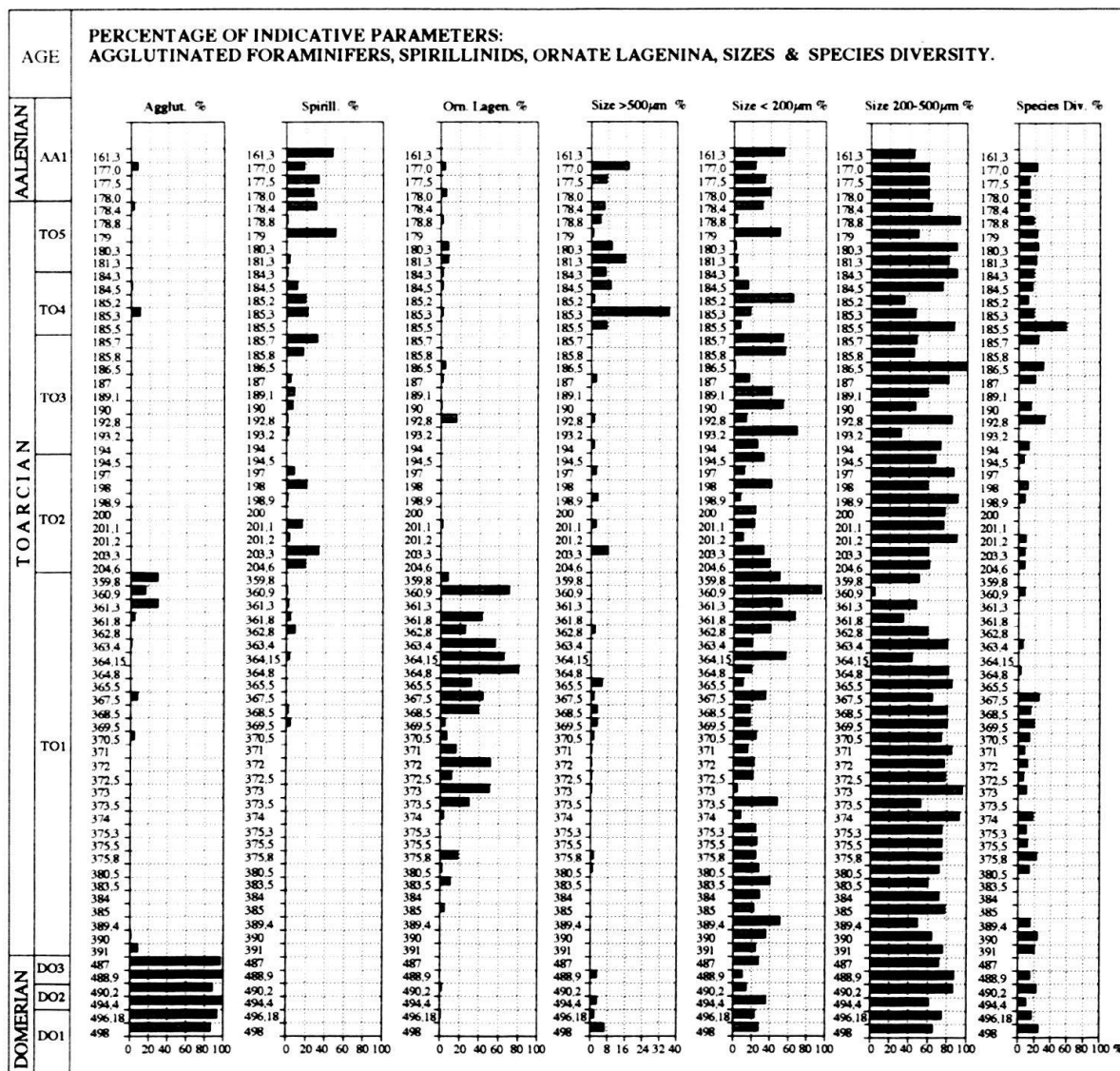
Fig. 10. Percentage of indicative parameters.

sive. However a few forms that have been calibrated by ammonite and nannofossil biostratigraphy in other UMB sections, have been found here and can be considered as good index species. These are shown in Figure 12. The disappearance of Glomospira-Glomospirella is variable between the Emaciatum and Tenuicostatum Zones. Conicospirillina first occurrence (FO) is at the boundary between Serpentinus/Bifrons Zones approximately. Lenticulina d'orbignyi (Pl. 5, Fig. 10) FO falls always within the Erbaense Zone or at the boundary between Bifrons/Erbaense while the last occurrence (LO) falls within the Meneghinii Zone.

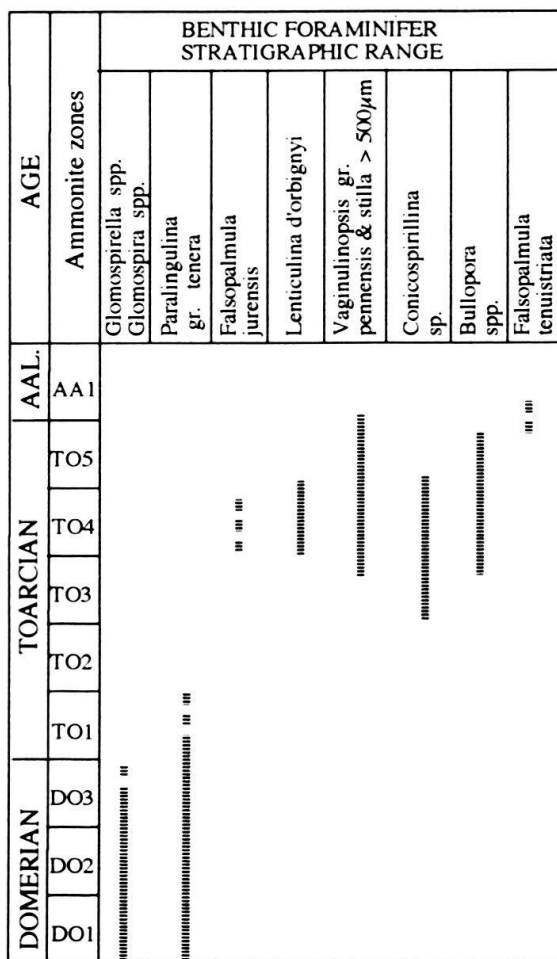| AGE	STRATIGRAPHIC INTERVALS AND UNITS	ASSEMBL. UNITS	ANALYSIS METHODS	BENTHIC MICROFORAMINIFERAL ASSEMBLAGES	OTHER ORGANISMS
Late Toarcian - E. Aalenian (TO5 - AA1)	178,8-160 (RAUM - CP)	I	washed residue and thin section	DECREASING FORAMINIFERS. SPIRILLINA UNIT. Rare agglutinants. *Glomospira*'s and *Glomospirella*'s appear again. *Lenticulina*'s, *Eoguttulina*'s and *Prodentalina*'s and *Conicospirillina*'s. Microfacies **8** and **9.**	Flat and smooth bivalve accumulations and abundant echinoderm debris. Common radiolarians. Small brachiopods, microgastropods and ammonite nuclei in thin section
Late Toarcian (TO4- TO5)	185,5 - 178,8 (RAUM)	H	washed residue and thin section	LARGE AND ABUNDANT LAGENINA UNIT: ASTACOLUS AND VAGINULINOPSIS >1mm AND LARGE, PARTIALLY ABRADED LENTICULINA: *Lenticulina d'orbignyi* and *Lenticulina munsteri* . *Prodentalina*'s and decreasing *Eoguttulina*'s. *Spirillina*'s and *Conicospirillina*'s. *Bullopora*'s. Characteristic assemblages of nodular calcareous marly RAUM. Microfacies **7** and **8.**	Rare, large sculptured ostracods. Microgastropods posidoniids, crinoids large echinoid spines. Holothurian sclerites. Common microbrachiopods and ammonite nuclei
Middle Toarcian (TO3)	193,2-185,5 (MS -RAUM)	G	washed residue	LENTICULINA, PRODENTALINA AND EOGUTTULINA UNIT. Abundant foraminifers, increasing *Lenticulina*'s and *Lenticulina münsteri* . Common *Spirillina*'s. Abraded *Lenticulina*'s, *Turrispirillina*'s, *Conicospirillina*'s, *Bullopora*'s appear.	Rare sculptured ostracods. Crinoids. Echinoderms. Posidoniid lumachellas. Microbrachiopods. Holothurian sclerites.
Early - Middle Toarcian (TO2-TO3)	204,6-193,2 (MS)	F	washed residue	PRODENTALINA AND EOGUTTULINA UNIT. Size increasing polymorphinids which become common and abundant in sample fraction>150μm. Common *Lenticulina*'s, mainly represented by *Lenticulina varians*, *Spirillina*'s.	Smooth ostracods. rare echinoderms debris, holothurian sclerites and posidoniids. Common radiolarians
Early Toarcian (TO1)	369,5-359,2 (MS)	E	washed residue	SMALL PARALINGULINA GR. TENERA. UNIT. Rare or common Lagenina mainly in the sample fraction <150μm. Abundant *Eoguttulina*'s. *Prodentalina*'s, *Astacolus* and rare *Lenticulina*'s such as *Lenticulina varians*.	A.radiolarians. Small ornated ostracods, pyritized microgasteropods and bivalve prodissoconchs. Thin and transparent echinoid spines
Early Toarcian (TO1)	400-369,5 (MS)	D	washed residue	EOGUTTULINA UNIT. Rare or common Lagenina, mainly *Eoguttulina*'s and *Prodentalina*'s in the sample fraction <150μm. Small *Astacolus* and *Lenticulina gr. varians*. Small Lagenina showing a Pliensbachian affinity. Rare or common *Paralingulina* gr. *tenera* . *Bathysiphon* horizon in the lowerst part.	Common or abundant radiolarians. Small smooth ostracods. Very rare other organisms.
Dom.	498,6-487 (COR)	C and	washed residue	GLOMOSPIRELLA AND GLOMOSPIRA UNIT. *Glomospira,Glomospirella, Ammodiscus, Bathysiphon, Jaculella*	Radiolarians and rare macroinvertebrate debris
Dom. Carix.	487- 500 (COR)	B	thin section	SMOOTH AND ORNATE LAGENINA . Rare siliceous agglutinants. Microfacies **2**	Radiolarians, gastropods, echinod., thick ostracods
Carixian	530-510 (COR)	?A	thin section	SCULPTURED LAGENINA AND MILIOLINA UNIT. Rare plurilocular agglutinants. Microfacies **1**	Gastropods, ehinoids, crinoids., large calcar. spicule sponge

AGE	Ammonite zones	BENTHIC FORAMINIFER STRATIGRAPHIC RANGE							
		Glomospirella spp. Glomospira spp.	Paralingulina gr. tenera	Falsopalmula jurensis	Lenticulina d'orbignyi	Vaginulinopsis gr. pennensis & suilla > 500μm	Conicospirillina sp.	Bullopora spp.	Falsopalmula tenuistriata
AAL.	AA1								▮ ▮
TOARCIAN	TO5					▮		▮	
	TO4			▮ ▮ ▮	▮	▮	▮	▮	
	TO3					▮	▮		
	TO2								
	TO1		▮ ▮						
DOMERIAN	DO3	▮							
	DO2	▮							
	DO1	▮	▮						

Fig. 12. Biostratigraphic value of the most indicative benthic foraminifers.

5.2 Data discussion

5.2.1 Paleoecological inferences

Paleoecological studies concerning Jurassic benthic microforaminifers are rather scarce and controversial due to the difference between such assemblages and more recent ones. Stam (1986) discusses the two major interpretations concerning small benthic Jurassic foraminifers.

a   Jurassic Spirillinina, Lagenina and simple representatives of Textulariina have been believed to be characteristic of Jurassic shelf to marginal marine deposits in the European and North African epicontinental seas (Gordon 1970; Johnson 1976; Copestake 1989; Nicolin & Ruget 1988; Stam 1986; Nagy et al. 1990; Nagy & Johansen 1991; Cubaynes et al. 1991, etc.). The two main foraminiferal components belong to the suborders Textulariina and Lagenina and occur in highly varying proportions while other groups are seldom dominant in the various marine shelf environments affected by sea-level fluctuations.

b   According to Luterbacher (1972), Kuznetsova (1974), Bartenstein (1974), Kuznetsova & Seibold (1978), Sliter (1980), Basov & Krasheninnikov (1983), Gradstein (1983)

Fig. 11. Foraminiferal assemblage scheme.

and Riegraf et al. (1984), Lagenina, Spirillinina and Glomospirella-Glomospira assemblages characterize bathyal and abyssal deposits in the DSDP Sites of North Atlantic and Indian Oceans during Late Jurassic – Early Cretaceous. Most of these authors discuss the possibility of faunal reworking but they give the Jurassic UMB as an example of a deep water environment. In fact, Kimmeridgian Lagenina and Spirillinidae were found by Farinacci (1965) in the Monti Martani area and were considered by the author as deep water benthic foraminifers. After several field investigations, however, Farinacci found out that the foraminiferal assemblage described in 1965 was contained in a mass flow originating from a shallow water morpho-structural high into a depressed area that was characterized by siliceous and calcareous deposits known as the "Calcari diasprigni" stratigraphic unit (A. Farinacci, personal communication).

In 1981, having collected a large amount of new paleontological and sedimentological data, Farinacci and her group revised Farinacci's original interpretations of the M. Martani Ridge, in "The Ammonitico Rosso Symposium" (Farinacci and Elmi [Eds.] 1981). They considered the M. Martani area as a shallow water area of deposition, directly affected by eustatic sea level changes during the Jurassic.

In this paper the information given by the first group of authors has been useful in interpreting the sea-bottom features of the Valdorbia area in the early Jurassic and is considered here to fit the UMB for the following reasons:

1 The assemblage variations, the recognizable trends in the microfauna related to sedimentological and geochemical changes, and the agglutinated foraminiferal turnover near the Domerian/Toarcian boundary are difficult to explain in a bathyal or abyssal environment.

2 Macroinvertebrates, although in stunted forms, occur throughout all the section exhibiting a decrease in size from Domerian to Lower Toarcian and an increase in the Middle and Upper Toarcian. On the basis of the microfacies analysis they cannot be considered as reworked fauna from a shallow water carbonate platform. Their distribution would be rather unusual in a bathyal environment.

3 In bathyal environments in the North Atlantic Ocean, during the late Jurassic the agglutinated foraminifers are always abundant and the macroinvertebrates rare or absent. In the Valdorbia area the faunal distribution is completely different.

4 Thin and small bivalves (posidoniids) have been demonstrated to be benthic organisms by Kauffman (1981), Conti & Cresta (1982) and Conti & Monari (1992). In the Valdorbia Section they are associated with common microbrachiopods and microgastropods. A trend of increasing numbers of bivalves and brachiopods, and a decrease in benthic foraminifers in a sedimentary sequence, such as has been noted in the upper part of the Valdorbia Section, is not easily explanable in a deep environment.

5 The investigated Jurassic foraminiferal assemblages have been compared with those occurring in the bathyal "Scisti a Fucoidi" Fm. of the Lower Cretaceous in the UMB, which Coccioni has been studying (R. Coccioni, personal communication). The Toarcian and the Early Cretaceous Lagenina are somewhat similar but in the Early Cretaceous the macroinvertebrates are almost absent, the ostracods rare and the Textulariina more abundant and diversified than in the Early Jurassic.

It is well known that small benthic foraminifers have adapted to a great range of environments during geological history. Lagenina, Spirillina and Glomospira-Glomospirella could have adapted to different ecological factors affecting the sea-bottom in the Early Cretaceous after the deepening of the relatively shallow-water sea-floor which persisted in a small area of the Umbria-Marche basin (topographic highs) during the Late Jurassic.

In this paper the bathymetric terminology has been taken from van Morkoven & Berggren (1986): 0–30 m inner shelf; 30–100 m middle shelf; 100–200 m outer shelf; and 200–600 m upper bathyal. These environmental interpretations have been drawn from foraminiferal studies of the Jurassic European epicontinental shelves but use of this bathymetric terminology does not imply that the Valdorbia area was an epicontinental sea during the Early Jurassic. In fact the Jurassic UMB was not near or related to a continent, because the sediments do not show any coarse terrigenous input. The micropaleontological assemblages, however, permit an acknowledgement of sea-level fluctuations in Toarcian deposits, which are poorly differentiated in lithology, as in the Western European shelves (Cubaynes et al. 1990).

– Assemblage **A**. This assemblage has been considered by Nocchi (1992) to characterize an environment of deposition corresponding to a middle shelf. In the Valdorbia Section, however, it is uncertain whether the organisms were local or have been displaced from elevated surrounding areas, although the microfacies 1 does not show clear indications of reworking. In the morphostructural highs, in fact, the isochronous lower part of COR is rich in microfossils (Nocchi 1992) some of which (Miliolina) occur in the Valdorbia section as well, while others (Involutina liassica, Trocholina etc) are rare or absent.
– Assemblages **B** and **C**. The two assemblages alternate through the whole Domerian section. Consideration of each one separately would result in an interpretation of repetitive and abrupt fluctuations in the sea-bottom depth. Assemblage B, containing mainly Lagenina associated with ammonites, echinoids and radiolarians seems to indicate open marine, distal shelves with normal salinity and oxygenation (Johnson 1976; Cubaynes et al. 1989); whereas, assemblage C (Pl. 4, Fig. 1–7) (simple Textulariina, including Glomospira and Glomospirella, associated with Verneulinoides, Haplophragmoides), is interpreted as indicative of a shallow water, restricted marginal environment, with reduced salinity and terrestrial influx, or of a lowstand of sea-level (Løfoldli & Thusu 1979; Nagy & Johansen 1991; Cubaynes et al. 1989). It is more appropriate to consider both these assemblages together in order to interpret the marine environment of deposition. The problematic assemblage C has already been discussed by Nocchi & Bartolini (in press). One of the few papers dealing with Glomospira-Glomospirella paleoecology is that of Chamney (1976). He interprets the Glomospira-Glomospirella assemblages as a response to the siliceous content in the marine waters and to the high level of current energy of the marine environment. Furthermore Chamney (1976), together with Gradstein & Berggren (1981), suggest that factors controlling agglutinated foraminiferal assemblages can be the availability of $CaCO_3$, post-depositional dissolution of calcareous-hyaline foraminifers, low salinity and/or low temperature, lack of oxygen and pH fluctuations. These factors can affect both marginal brackish waters and the deepest part of the oceans.

Following the paper of Nocchi & Bartolini (in press), further investigations have been carried out both in the UMB and in the pelagic Jurassic internal Ionic Zone of Greece. These investigations have shown that the Upper Domerian interval, consisting of thin marls interstratified with limestones and particularly rich in Glomospira-Glomospirella (assemblage C), extends to other south Tethyan areas, such as Greece. Assemblage C, therefore seems indicative of more extensive environmental conditions in the Domerian than those suggested by Nocchi & Bartolini who considered the possibility that the concentration of siliceous benthic foraminifers were due to pressure dissolution of calcium carbonate.

In the Valdorbia area the Corniola depositional environment was, probably, affected by changes of physical and chemical conditions in the water mass. These factors could have been a decrease in sea-floor temperature, an increase in silica, as indicated by radiolarian content, during a relative deepening, and an oceanic opening during the deposition of assemblage A. These water mass features could also have eliminated Miliolina and Involutinina, enhanced simple siliceous Textulariina and left unaffected the Lagenina, which inhabit deeper shelf areas as well. Other factors could be considered to be low calcareous productivity over a short period, the slow sedimentation rate causing an increase in the relative clay content, without excluding diagenetic processes and pH fluctuations.

- Assemblage **D**. This assemblage is characterized mainly by small Eoguttulina (predominantly Eoguttulina metensis) associated with Prodentalina, and by a scarcity of macroinvertebrates. Among the agglutinated foraminifers, Bathysiphon and Hyperammina are abundant and the only fauna occurring at the bottom of this stratigraphic interval. Finely agglutinated Bathysiphon can be found to a depth below 200 m (Chamney 1976; Boltvoskoy & Wright 1976). Stam (1986) suggests, moreover, that Eoguttulina's and Prodentalina's prefer relatively deep water, between 150–200 m or more. Ruget (1980) attributes a restricted environment to assemblages dominated by polymorphinids.

In the Early Jurassic a transition from simple Textulariina and Lagenina assemblages to Lagenina-only assemblages is indicative of a deepening towards deep and distal shelf areas (Johnson 1976; Cubaynes & Ruget 1987). Simple siliceous Textulariina seem to prefer a shallower habitat than Lagenina. As a whole assemblage D is believed to indicate the deepest environment of deposition within the Valdorbia Section. Within the stratigraphic interval represented by assemblage D, Pliensbachian Lagenina, such as Marginulina gr. prima, Berthelinella paradoxa, Ichthyolaria sulcata, Pseudonodosaria vulgata, are at first small and rare and then disappear altogether. In the Valdorbia section, however, the turnover of the cosmopolitan shelf benthic foraminifers within the Tenuicostatum Zone is not obvious as in other sections of the UMB (Nocchi & Bartolini in press) due to lack of the stratigraphic interval with the assemblage BC. The earlier disappearance of Glomospirella compared to Lagenina, is odd, since factors which are favorable to their growth, such as clay and organic silica, increase. Such a disappearance could be explained by the deepening of the sea-floor (Boltovskoy & Wright 1976).

- Assemblage **E**. This assemblage characterizes the black shale lithofacies, of the middle-upper part of the Tenuicostatum Zone, and has already been discussed by Bartolini et al. (1992). It corresponds to disaerobic-anaerobic conditions on the sea-floor

which are favorable to a bloom of small and flat forms of morphogroup A (Pl. 4, Fig. 10 and 17) such as Paralingulina gr. tenera and Eoguttulina. These are considered opportunistic taxa which thrive best in poorly ventilated environments as they are infaunal organisms and already adapted to poorly oxygenated sediments. In the Valdorbia section Spirillina and Haplophragmoides (Pl. 5, Fig. 8) also occur in this stratigraphic interval while in other sections, such as Pozzale (Bartolini et al. 1992) they are almost absent. The species diversity (Fig. 10) is variable indicating that the depositional environment was probably occasionally oxygenated. Among the other organisms small pyritized ostracods belonging to Procytherura are common together with other forms (Pl. 6, Fig. 10 and 15). The other organisms (juvenile forms) characteristic of the black shales (Bartolini et al. 1992) are indicative of starved conditions unfavorable to their growth.

– Assemblage **F**. In this assemblage smooth Lagenina are almost the only group recovering from the benthic crisis of the Tenuicostatum Zone and are characterized by an irregular increase of Lenticulina. According to Cubaynes et al. (1989), Cubaynes & Ruget (1987), Bielecka & Posaryska (1954), assemblages dominated by Lagenina are indicative of distal, outer shelves or deeper shelf areas with accumulation of marly argillaceous sediments.

– Assemblages **G** and **H**. The two assemblages are considered together because they share some features which are believed to have paleoecological significance. The increase in both abundance and in size of strictly coiled lenticulinids of morphogroup E (Fig. 9 and 10) (see also Fig. 5 in Bartolini et al. 1992), the relative decrease in the Eoguttulina and Prodentalina specimens and the occurrence of abraded, stout , biconvex Lenticulina are indicative of a change in water depth and in the hydrodynamic regime. According to several authors (Lipina 1961; Chamney 1976; Cubaynes et al. 1991) large, robust forms developing an involute, reinforced test, thick walls and closely packed chamber arrangements, indicate less favorable marine conditions due
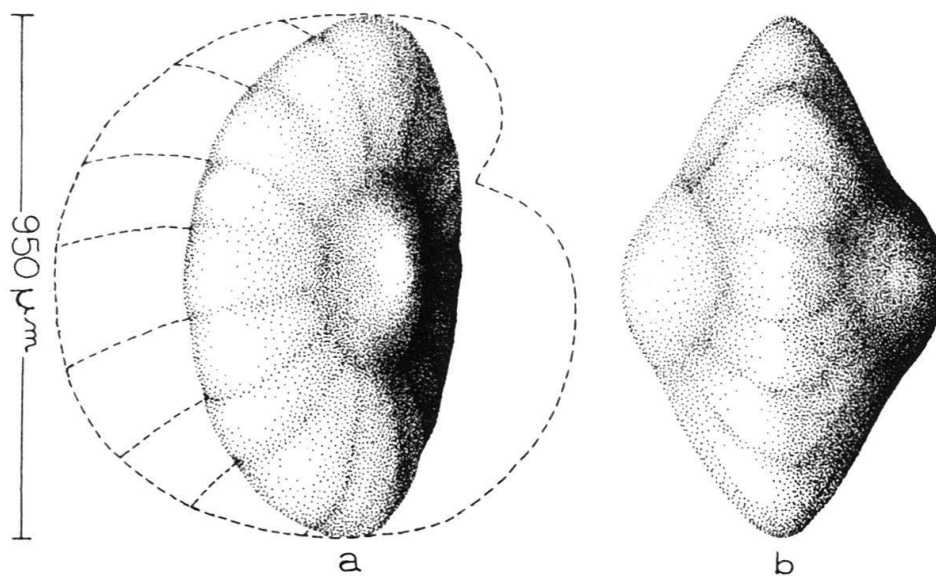

Fig. 13. Schematic drawing of a "cigar shape" Lenticulina münsteri (same specimen in Pl. 6, Fig. 1 and 2) **a** side view; **b** axial view.

to high energy level created by the action of wave base or currents. Cubaynes et al. (1990) report that lowstand sea-level benthic foraminiferal assemblages are represented almost exclusively by the morphogenus Lenticulina s.s. Moreover assemblages dominated by Spirillina and Lenticulina gr. münsteri seem characteristic of shallow marine environments (Morris 1982) while Stam (1976) suggests a depth value of 50 m – 100 m for Spirillina and Lenticulina. According to him the two groups show a significant positive correlation with a shallowing trend in the sequence. Abraded forms (Pl. 6, Fig. 1–4) can indicate areas under the influence of modest currents and waves (Murray 1984). Here the term "cigar-shaped" is attributed to stout biconvex Lenticulina's with umbilical plugs that reinforce the axial central area so that the marginal areas are more easily eroded with the rolling axis perpendicular to the coiling one (Fig. 13). This particular shape is probably due to a rolling action with a mechanical stress perpendicular to the axial area due to current or storm wave action upon epifaunal or primary weed fauna, without affecting benthic forms living inside the sediments.

The major difference between assemblages G and H consists of an abrupt increase in size within the Erbaense Zone both in tightly coiled forms, such as Lenticulina gr. munsteri, and also in well-preserved, large uncoiled forms, such as Astacolus and Vaginulinopsis (Pl. 5, Fig. 12, 13, 14 and 15) which are believed to have been dominant in distal shelves during highstand deposits (Cubaynes et al. 1989). Within assemblage H, benthic foraminifers indicative of a calm environment are mixed with foraminifers indicative of moderately agitated sea-floor conditions. An explanation may be that the remains of epifaunal organisms, such as biconvex Lenticulina, may be moved horizontally along the sea-floor and broken specimens concentrated locally while infauna specimens, such as Astacolus and Vaginulinopsis are more likely to remain undamaged and undisturbed.

As a whole the environment of deposition of the assemblages G and H, which lack Miliolina, is not a very shallow environment, such as an inner shelf, but corresponds, probably, to a transitional environment from a distal to a middle shelf with mixed fauna indicative of differentiated energy conditions on the sea-floor.

At the boundary between assemblages G and H (Erbaense Zone) the abrupt increase in Astacolus and Vaginulinopsis could indicate a sudden junction of the thermocline with the sea-floor and a consequent increase in oxygen, temperature and trophic conditions, such as the availability of grass flooring the sea-bottom. Large, flat and uncoiled foraminifers are believed to have a phytal habitat and to have thrive in an environment with increasing trophic factors which could be supported by the occurrence of microgastropods. The abraded "cigar-shaped" Lenticulina's can be related to an oscillatory flow regime near the sea-bottom at the major storm wave base as well.

The occurrence of Procytherura (Pl. 6, Fig. 7) among the ostracods is also probably indicative of a relative shallow-water environment. Procytherura multicostata is a common Toarcian species in the South West Germany (Arias 1991).

Assemblage I (mainly Lower Aalenian). A new crisis seems to affect the benthic foraminifers which decrease in size, abundance and species diversity, several species disappearing altogether (Fig. 8). The appearance again of Glomospira-Glomospirella could be interpreted as reflecting an increase in the silica content in the water and/or a return of shallower conditions than those in the underlying stratigraphic interval, which is borne out by the richness of macroinvertebrate organisms in the biofacies.