

Opportunistic benthic foraminifera as indicators of eutrophicated environments. Actualistic study and comparison with the Santernian middle Tiber Valley (Central Italy)

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ABSTRACT - The study of extant organisms is the base of the environmental micropaleontology, since the knowledge of natural mechanisms, which regulate their distribution in present environments, is the necessary base for the reconstruction of fossil environments. Since most shallow-water taxa well tolerate a wide range of environmental conditions, the organic flux, which determines trophic levels, appears the most important factor that regulates the distribution of benthic foraminifera. On the contrary, other variables like substrate, temperature and salinity are less important for their occurrence.

Since the end of the 90s, many studies have been performed on recent benthic foraminifera from a small marine basin located along the southern Tuscan shelf, characterized by the sedimentary contribution of the Ombrone River. The geographical features of this basin, named Ombrone River Basin (ORB), are unfavourable to the organic matter dispersion, determining a particularly suitable environment for the study of eutrophicated sea-bottoms. Researches evidenced the correlation between a typical assemblage, dominated by the opportunistic *Valvulineria bradyana* and the organic flux of fluvial origin. Particularly, the statistical multivariate analysis performed on 127 samples from the ORB helped to determine the distribution of such assemblage.

In this work, the quantitative parameters describing the structure of the *V. bradyana* assemblage (species richness, heterogeneity, dominance) are evidenced and discussed, defining an actualistic model for assemblages that could be used to evidence the organic paleo-flux in coastal marine areas influenced by river contributions.

During the Early Pleistocene, the coast of Latium was located in eastern position with respect to the present one. In front to the coast, some structural highs emerged, forming an island lineage parallel to the coast and delimiting a narrow inner basin. In this basin, the Tiber River and other minor rivers built their delta systems. This paleogeographic setting has been evaluated as favourable to the development of eutrophicated environments, and consequently many tens of available samples from the clayey terms of the Chiani-Tevere Formation have been considered for a comparison with the actualistic model. The foraminiferal assemblages from three sites, Civita di Bagnoregio, Orte, and Nazzano, are dominated by *V. bradyana* and show quantitative parameters coinciding with the recent model utilized as marker of the organic flux. These episodes of eutrophication in the inner Tyrrhenian basin may be considered coeval, because all the three successions are ascribed to the Santernian (*Globigerina cariacensis* Zone). Considering the paleogeography of the region, it may be supposed that the Civita di Bagnoregio site was probably influenced by the contribution of a small river which flowed into the Tyrrhenian Sea near this locality. In addition, the Orte and the Nazzano sites corresponded to the Nera and Farfa delta systems, respectively. These preliminary results are encouraging for the development of the research aimed to the reconstruction of the organic paleo-flux along the coast of Latium, with useful implications for a detailed paleogeographic reconstruction of the Santernian middle Tiber Valley. In addition, the good accordance between a paleogeographic reconstruction based on geological evidences and the preliminary results obtained by paleoecological proxies, validate the utility of the actualistic model considered as typical marker of the river organic flux.

RIASSUNTO - [Foraminiferi bentonici opportunisti come indicatori di ambienti eutrofizzati. Studio attualistico e confronto con il Santerniano della media valle del Tevere (Italia centrale)] - Lo studio dei foraminiferi recenti può essere considerato uno strumento essenziale per la micropaleontologia ambientale, poiché la conoscenza dei meccanismi che regolano la loro distribuzione negli ambienti attuali è la base necessaria per la ricostruzione degli ambienti fossili. In aree costiere, generalmente, la disponibilità dei nutrienti non è un fattore limitante per la distribuzione dei foraminiferi bentonici che può essere invece influenzata da altri parametri, quali substrato, temperatura e salinità. Tuttavia, poiché la maggior parte delle specie costiere ben si adatta ad ampie variazioni di queste variabili ambientali, il flusso organico, che determina i livelli trofici, sembra comunque essere il fattore principale che regola la loro distribuzione, a meno che una scarsa ossigenazione non ne limiti l'abbondanza.

Il bacino marino comprendente la foce del fiume Ombrone (ORB), localizzato sulla piattaforma continentale della Toscana Meridionale, è stato ampiamente studiato per quanto riguarda le associazioni a foraminiferi bentonici recenti. Le caratteristiche geografiche di questo bacino favoriscono l'accumulo di materia organica, determinando un ambiente particolarmente adatto allo studio di fondali eutrofizzati. Queste ricerche hanno evidenziato la correlazione tra un'associazione dominata dalla specie opportunistica *Valvulineria bradyana* e il flusso organico di origine fluviale, quindi questa associazione è stata interpretata come indicatrice di un forte accumulo di sostanza organica. L'abbondanza di una specie opportunistica in aree ad elevato accumulo di sostanza organica è dovuta alla sua abilità nel trarre vantaggio dagli elevati livelli trofici collegati ad episodi stagionali di ipossia, che determinano stress ambientale.

In particolare, l'analisi statistica multivariata eseguita su 127 campioni prelevati nell'ORB ha permesso di definire la distribuzione areale di questa associazione, che è presente, a partire dalla foce fluviale, su una fascia parallela alla costa, in direzione nord e sud.

In questo lavoro, sono discussi i parametri quantitativi utili a descrivere la struttura dell'associazione a *V. bradyana* (diversità specifica, eterogeneità e dominanza), al fine di definire un modello attualistico per associazioni fossili correlate al flusso di sostanza organica, in aree marine costiere influenzate da apporti fluviali.

Durante il Pleistocene inferiore, la costa tirrenica del Lazio era localizzata più ad est, rispetto a quella attuale. Di fronte alla costa emergevano alcuni alti strutturali che formavano un allineamento di isole parallelo alla costa, tale da delimitare un bacino marino interno parzialmente isolato. In questo bacino sfociavano il Tevere ed altri fiumi, attualmente suoi affluenti, come il Nera e il Farfa. Questo assetto paleogeografico era adatto allo sviluppo di un ambiente altamente eutrofizzato e quindi sono stati considerati più di 200 campioni, già studiati per altri scopi, provenienti dai termini argillosi della formazione del Chiani-Tevere, per un'applicazione del modello attualistico. Le associazioni a foraminiferi di tre siti (Civita di Bagnoregio, Orte e Nazzano) sono dominate da *V. bradyana* e mostrano parametri quantitativi confrontabili con quelli del modello. Gli episodi di eutrofizzazione riconosciuti nei tre siti possono essere considerati coevi in quanto sono tutti attribuibili al Santerniano (Zona a Globigerina cariacensis). Considerando la ricostruzione paleogeografica basata sullo studio geologico dell'area, si può supporre che il sito di Civita di Bagnoregio fosse influenzato dagli apporti di un piccolo corso d'acqua, non identificabile nell'attuale reticolo idrografico. Si ipotizza, inoltre, che i siti di Orte e Nazzano fossero localizzati nelle immediate vicinanze delle foci del Nera e del Farfa, rispettivamente. Questi risultati preliminari incoraggiano lo sviluppo di una ricerca finalizzata alla ricostruzione del paleo-flusso organico lungo la costa del Lazio, con utili implicazioni per una ricostruzione paleogeografica di dettaglio della media valle del Tevere, durante il Santerniano. Inoltre, la concordanza tra la ricostruzione paleogeografica basata su evidenze geologiche e i risultati preliminari ottenuti tramite la ricostruzione paleoecologica convalida il modello attualistico.

INTRODUCTION

The study of recent benthic foraminifera may be considered an essential tool in the environmental micropaleontology, since the knowledge of natural mechanisms which regulate their distribution in present environments is the base for the reconstruction of fossil environments. In general, the extraordinary potential of foraminifera as paleoecological proxies is due to their wide diffusion in marine environment and to their enormous taxonomic diversification, being the most diverse group of shelled micro-organisms in modern oceans (Sen Gupta, 1999).

In near-shore settings, food availability should not be a limiting factor in foraminiferal distribution and many variables like substrate, temperature, salinity may influence it (Loubere & Fariddudin, 1999). Nevertheless, because benthic foraminifera are not stenotopic to most of the above mentioned environmental variables, the organic flux, which determines trophic levels, appears anyhow the most important factor that

regulates their distribution, unless low oxygen availability does not limit their abundance (Jorissen et al., 1995; Van der Zwaan et al., 1999).

Based on these arguments, the distribution of recent benthic foraminifera in the "Ombrone River Basin" (ORB) has been studied since the end of the 90s. This name is given to the part of Tuscan continental shelf limited North by the Piombino-Isola d'Elba lineage and South by the Argentario-Isola del Giglio lineage (northern Tyrrhenian Sea). This small marine basin is dominated by the Ombrone River delta by sedimentological and morphological viewpoint (Ferretti & Manfredi Frattarelli, 1993) and has been selected, for its semi-enclosed character, to evidence the effects of eutrophication due to fluvial discharge on benthic foraminiferal assemblages (Fig. 1).

Bergamin et al. (1999) evidenced, in correspondence of the Ombrone delta complex, the assemblage dominated by *Valvulineria bradyana* (up to more than 50%), characterised by low specific diversity and heterogeneity, and high faunal abundance. This assemblage was interpreted as marker of the highest organic matter accumulation. The dominance of an opportunistic species is due to its ability to take advantage of high trophic levels, under seasonal episodes of hypoxia which determines environmental stress. The assemblages of the Tiber River delta (central Tyrrhenian Sea) were compared with those of the Ombrone River delta, evidencing that the typical *V. bradyana* assemblage is not a common feature of all Tyrrhenian delta areas, but this assemblage develops only in basins which have the function of nutrient-trap for their semi-enclosed morphology (Carboni et al., 2000). The study of many hundreds of samples all over the ORB permitted to characterise quantitatively the *V. bradyana* assemblage and to evidence its distribution pattern. It was recognised starting from the river mouth and following a belt parallel to the coast, evidencing the trend of the organic flux (Carboni et al., 2004; Frezza, 2004). Finally, Romano et al. (2004) demonstrated the high statistical correlation among *V. bradyana* abundance, organic matter concentration and silty component of sediments, confirming, for this assemblage, the character of marker for eutrophicated environments.

Aim of this paper is to synthesise data collected in many years of study on the recent *V. bradyana*

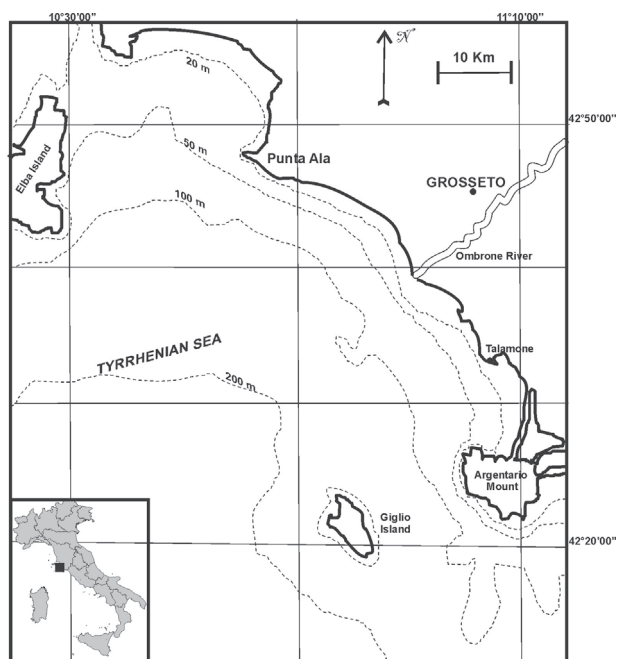


Fig. 1 - Geographical features of the Ombrone River Basin (ORB).

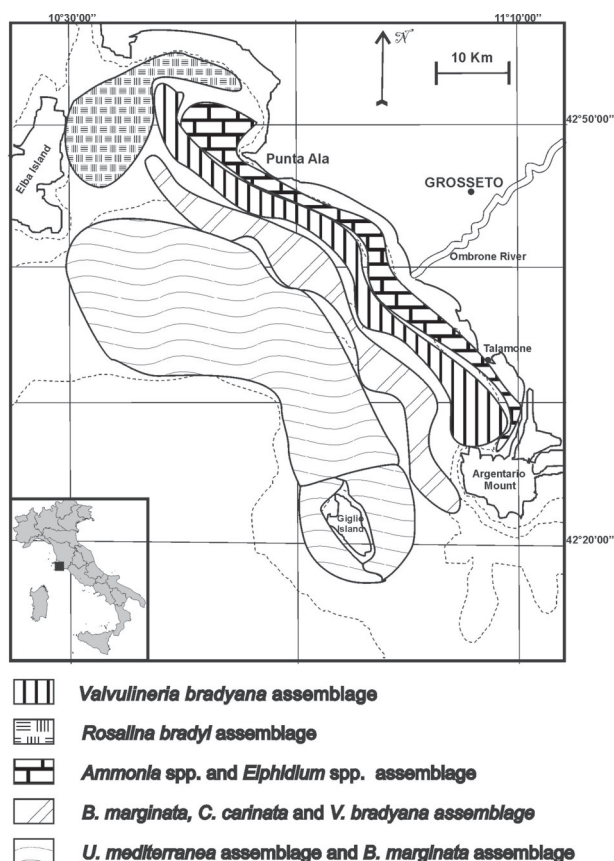


Fig. 2 - Distribution of benthic foraminiferal assemblages in the ORB (after Frezza, 2004).

assemblage. The quantitative parameters describing the structure of the assemblage (species richness, heterogeneity, dominance) are evidenced and discussed, defining a conceptual actualistic model valid for the paleoenvironmental reconstruction of the organic flux in coastal marine areas influenced by riverine contributions. Such a model is compared to fossil foraminiferal assemblages from the Middle Tiber Valley (MTV) which has been widely studied in its geological (see Mancini et al., 2004 for a review), biostratigraphical and paleoecological aspects (Carboni & Di Bella, 1996a, b; Di Bella, 1997; Borzi et al., 1998; Di Bella et al., 2002). From this comparison, preliminary results on the possibility to reconstruct the organic paleo-flux of riverine origin are expected.

THE *VALVULINERIA BRADYANA* ASSEMBLAGE FROM RECENT SEDIMENTS

The quantitative data supporting the actualistic model are obtained from 127 samples, collected between 15 and 184 m water depth, on the continental shelf and the upper slope of the ORB and analysed by Frezza (2004). A total of 256 benthic foraminiferal species was classified from the fraction $>125 \mu\text{m}$. The data set, containing the relative abundance of 48 common species ($>5\%$), was used to perform the multivariate statistical analyses (Hierarchical Cluster Analysis - HCA - and Principal Component Analysis - PCA). The output of Q-mode HCA recognised six foraminiferal assemblages, corresponding to six distinct biofacies, according to Scott et al. (2001): infralittoral assemblage with *Ammonia* spp. and *Elphidium* spp., on silty sandy clayey bottom (24 samples); infralittoral epiphytic assemblage (*Posidonia oceanica* prairies) with *Rosalina bradyi*, on sandy clayey sediments with vegetation cover (12 samples); infralittoral/upper circalittoral assemblage with *V. bradyana* on silty clayey or clayey silty bottom (43 samples); upper circalittoral assemblage with *Bulimina marginata*, *Cassidulina carinata* and *V. bradyana*, on clayey sediments (16 samples); lower circalittoral assemblage with *B. marginata*, on clayey bottom (24 samples); lower circalittoral assemblage with *Uvigerina mediterranea* on clayey sediments (8 samples) (Fig. 2). For each assemblage, the species richness is measured by the most frequently used index for foraminiferal assemblages, the α -index of Fisher et al. (1943). The heterogeneity, which takes into account both number of species and distribution of individuals among species, is given by the Shannon-index, a function that is commonly used as an index of diversity (Murray, 1991). In addition, in order to evidence the rule of the opportunistic taxa, the Percentage Dominance (PD) is also calculated (Walton, 1964). All the data are reported in Tab. 1.

Among these assemblages, the *V. bradyana* assemblage is considered in this work (Fig. 3). This assemblage is comparable with the *Valvulineria complanata* assemblage of Murray (1991) that was found in areas influenced by the contribution of Rhône and Po rivers (Kruit, 1955; Jorissen, 1988). It was found between 30 and 94 m water depth, along a belt parallel to the coast, starting from the Ombrone River mouth to the gulf of Follonica toward North and to the

Assemblage	samples number	water depth (m)	environment	α -index			Shannon-index			PD (% Dominance)		
				range	average	st. dev.	range	average	st. dev.	range	average	st. dev.
<i>Ammonia</i> spp. and <i>Elphidium</i> spp.	24	15-39	infralittoral	9.01-21.98	15.28	3.60	2.91-3.76	3.22	0.22	6.3-18.9	13.4	3.10
<i>Rosalina bradyi</i>	12	24-78.5	infralittoral	5.45-19.16	14.07	3.96	2.21-3.38	3.07	0.35	10.8-37.5	18.7	8.40
<i>Valvulineria bradyana</i>	43	31-94	infralittoral-upper circalittoral	6.76-29.30	12.52	4.14	2.22-3.59	2.83	0.30	8.7-43.0	25.3	7.50
<i>Bulimina marginata</i> , <i>Cassidulina carinata</i> and <i>Valvulineria bradyana</i>	16	69-109	upper circalittoral	11.37-17.53	14.97	2.08	2.74-3.44	3.03	0.19	11.6-23.8	17.9	4.20
<i>Bulimina marginata</i>	24	95-177	lower circalittoral	11.83-20.16	15.89	2.30	3.00-3.41	3.20	0.09	9.5-23.4	15.9	3.20
<i>Uvigerina mediterranea</i>	8	104-184	lower circalittoral	12.31-20.23	15.39	2.86	2.81-3.44	3.07	0.22	14.6-31.7	21.5	5.50

Tab. 1 - Range, average and standard deviation values of α -index, Shannon-index, PD of the six assemblages recognised in the ORB.

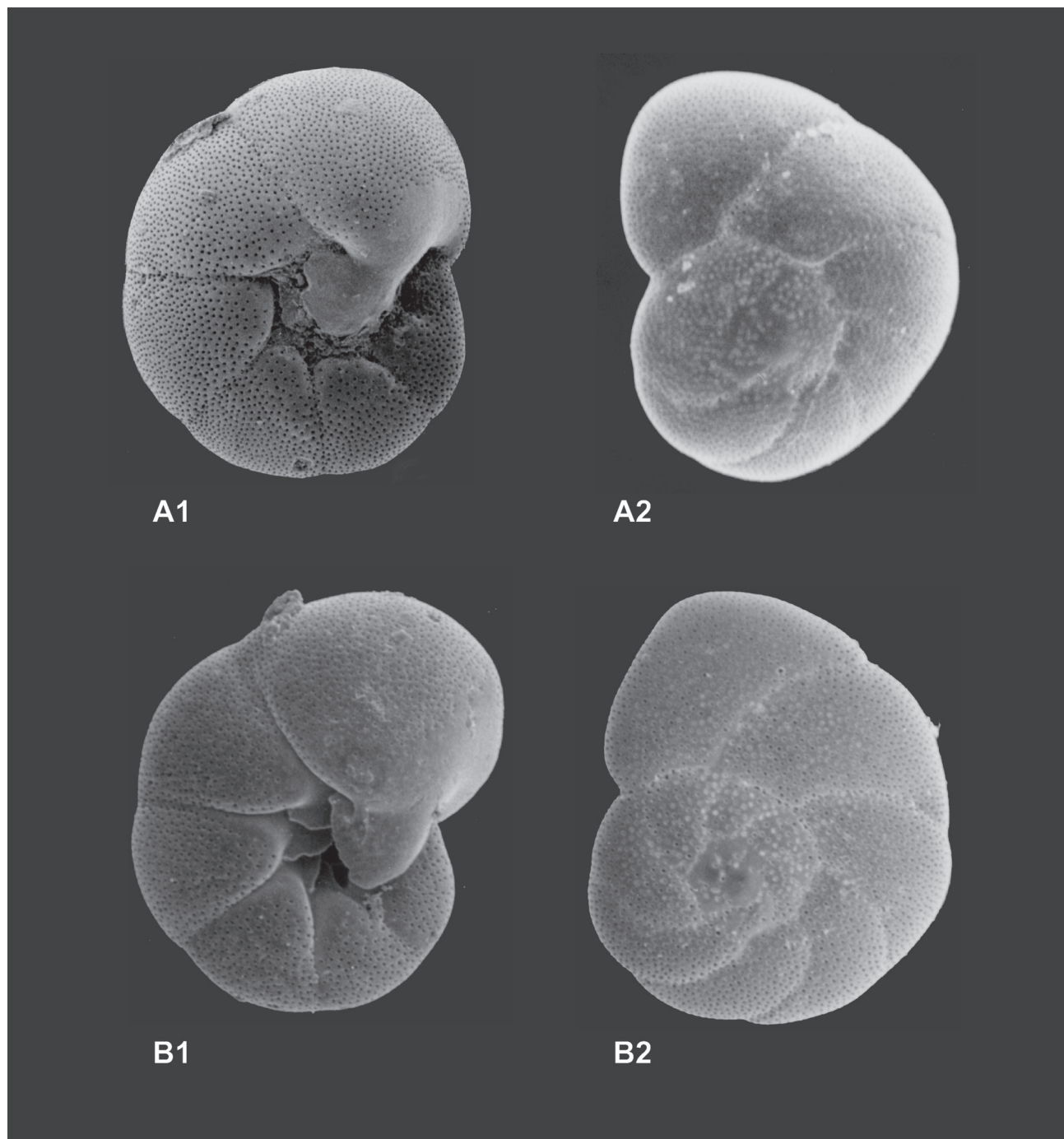


Fig. 3 - *Valvulineria bradyana* (Fornasini), x 150. A) Specimen from the ORB: A1) ventral side; A2) dorsal side. B) Specimen from the Orte Borehole: B1) ventral side; B2) dorsal side.

Argentario promontory toward South (Fig. 2). In addition to *V. bradyana*, this assemblage comprises also *B. marginata*, *Rectuvigerina phlegeri*, *Ammonia inflata*, *A. beccarii*, *Elphidium crispum*, and miliolids. The average values of Fisher and Shannon indexes are low, 12.5 and 2.83 respectively, while the average PD (25.3%) is clearly higher than that showed by the other assemblages. The wide range of the three parameters, which partly overlaps those of the neighbouring assemblages, is attributable to the high number of samples pertaining to the *V. bradyana* assemblage. The lowest limit for diversity and heterogeneity and the

highest limit for dominance are showed by samples characterised by the highest organic input, located near the river mouth, while the highest diversity and heterogeneity and the lowest dominance are showed by of samples at the limit of the distribution area. These features well reflect the scheme proposed by Verhallen (1991), which indicates the highest dominance of opportunistic species with increasing trophic levels, before the disappearing of foraminifera in anoxic environment.

Bathymetric distribution of the *V. bradyana* assemblage coincides in large part with that of the *B.*

marginata, *C. carinata* and *V. bradyana* assemblage. This overlap occurs in the upper circalittoral zone, between 69 and 94 m water depth, where the main factor determining the assemblage composition and structure appears to be the trophic level and/or bottom oxygenation. The first assemblage prevails in areas of high organic matter accumulation, like in front to the Ombrone River delta and in the Talamone Bay.

The R-mode PCA, performed by Frezza (2004) evidenced that the *V. bradyana* assemblage has a strong correlation with the silty sediment fraction. As silt is normally related with high percentages of organic matter (Piérard et al., 1996), it seems logical suppose that *V. bradyana*, silt and organic matter are closely correlated (Cicero et al., 2002, 2003). This relationship was clearly demonstrated by the statistical analysis performed by Romano et al. (2004), just in the study area.

THE SANTERNIAN FROM THE MIDDLE TIBER VALLEY

The extant MTV corresponds to the Paglia-Tevere graben, an extensional basin which developed since the Early Pliocene, during the post-collisional phase of the Tyrrhenian Apennine margin (Fig. 4). This tectonic depression was filled by Plio-Pleistocene marine sediments and, partly, by transitional and continental deposits, mainly in its marginal areas. Two sedimentary cycles have been recognised in the succession, the oldest one entirely attributable to the Pliocene and the youngest one that deposited mainly during Early Pleistocene. The Chiani-Tevere Formation, which forms the second cycle, consists of blue-grey sandy clays, sandy silts and silty sands, evidencing a regressive trend from inner shelf to shoreface environment (Girotti & Mancini, 2003; Mancini et al., 2004). The foraminiferal assemblages of this formation were widely studied by stratigraphical and paleoecological viewpoint. In particular, the clayey terms of this formation, attributed to the Santernian (*Globigerina cariacensis* Zone), bearing assemblages with prevailing *C. carinata*, Buliminidae, and Boliviniidae, are interpreted as low-oxygen bottom markers. Locally, strong enrichment of *V. bradyana*, which becomes the dominant species, is recorded in these successions, particularly in the sites of Civita di Bagnoregio, Orte, and Nazzano (Di Bella, 1995; Carboni & Di Bella, 1996a; Di Bella et al., 2002).

During the Piacentian-Santernian time interval, the Tyrrhenian coastline was located East with respect to the present one. It bordered the ridge of Monte Peglia, Monti Amerini, Monti di Narni, Sabini, and Lucretili. In front to this coast, some structural highs (Ferento, Monte Razzano, Monte Soratte, Monti Cornicolani) emerged, forming an island lineage parallel to the coast with a narrow inner basin, partially isolated from the outer one (Fig. 5). In this basin, the Tiber and other rivers that presently are contributors of the Tiber, like Nera and Farfa, built their delta systems (Mancini et al., 2004). This paleogeographic setting was favourable to the development of a nutrient-trap in which the maximum organic flux was concentrated in a belt parallel to the coast and marked by a typical

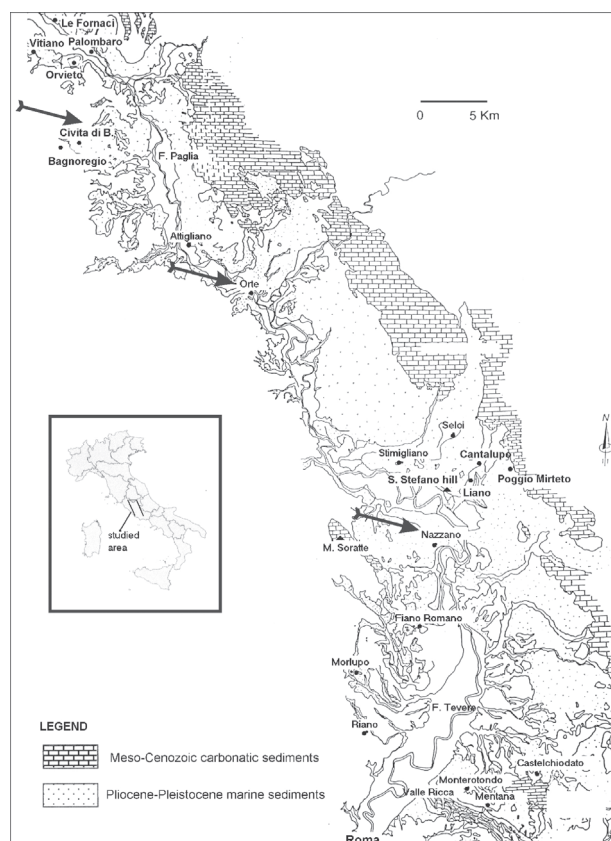


Fig. 4 - Geological sketch of the middle and lower Tiber Valley with the sites studied by Di Bella (1995). The sites analysed in this paper are indicated by black arrows.

foraminiferal assemblage as described in the actualistic model.

COMPARISON BETWEEN FOSSIL AND RECENT ASSEMBLAGES

Di Bella (1995) analysed 234 samples from the area delimited East by Sabini Mountains and West by Soratte-Cornicolani Mountains, extending, from North to South, from Orvieto to Valle Ricca (Fig. 4). She performed a bio-stratigraphical study and carried out quantitative analyses on benthic foraminiferal assemblages for palaeoecological purpose. These results have been processed in order to obtain data comparable with those of the actualistic model from the ORB. Consequently, the α -index, the Shannon-index and the PD have been calculated. From the available data, the assemblages from three sites are recognised as corresponding to the recent model utilized as marker of the organic flux (Tab. 2).

Civita di Bagnoregio section

One of these sites is a section located in the northern sector of the study area, South of Civita di Bagnoregio, very close to the village (Fig. 4). The section, which has an altitude spanning between 310 and 360.5 m asl, is constituted by sandy clays, with a sandy level

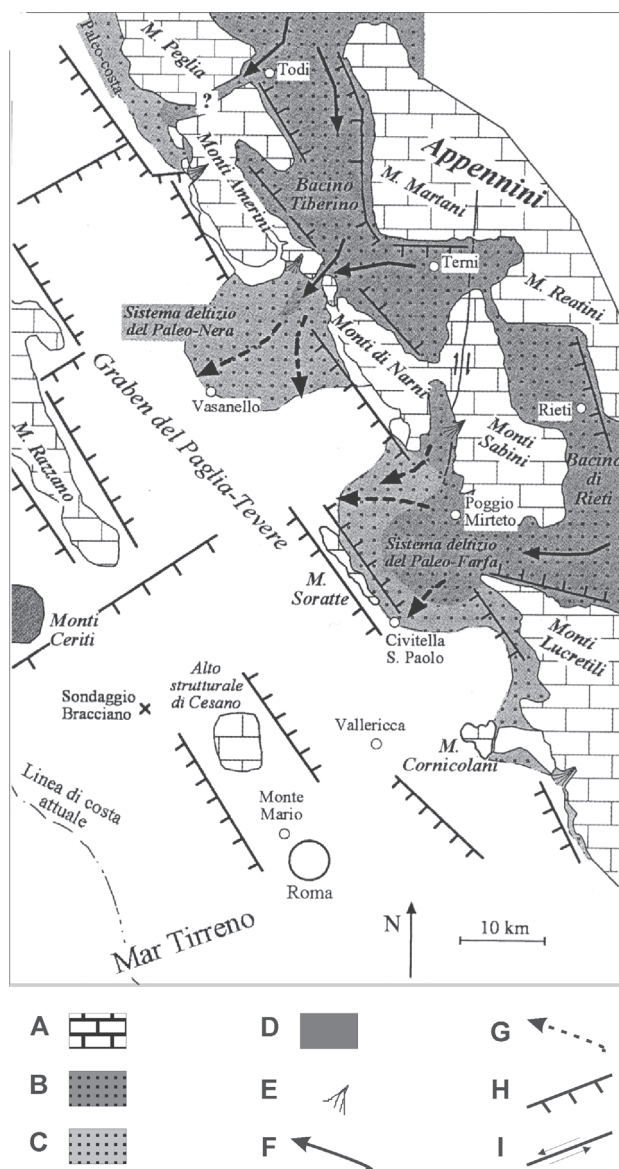


Fig. 5 - Paleogeography of Latium coast during the Santernian. Legend: a) Mesozoic-Cenozoic substratum; b) alluvial and lacustrine, intermontane deposits; c) deltaic and coastal, siliciclastic deposits; d) volcanites; e) fan delta; f) fluvial palaeocurrent direction; g) direction of delta progradation; h) normal fault; i) transcurrent fault. (after Mancini et al., 2004, modified).

containing pectinids at about 315 m asl, and a volcanic cover at the top (Fig. 6). For three (CB3, BA6 and CB13) of the 14 samples, results of quantitative analysis are not available. Samples CB11 (352 m asl) and CB14 (358.5 m asl) are dominated by *V. bradyana* (24.7 and 19.8%, respectively) and show a strong similarity with the actualistic model because values α -index, Shannon-index and PD are very close to the average values of recent samples (Tab. 2). In spite of the significant dominance of the opportunistic species, the relatively high values of species diversity and heterogeneity may suggest an eutrophicated environment, with moderate stress due to hypoxia. This could indicate a site rather far from the source of the organic flux. The intermediate sample CB12 may not be compared with the recent *V. bradyana* assemblage because the prevailing species is *B. marginata*. It is interesting to evidence that this assemblage is very similar to the *B. marginata*, *C. carinata*, and *V. bradyana* assemblage that in the ORB is spread in the area adjacent to that dominated by *V. bradyana*.

Orte borehole

The studied borehole was drilled in the Tacconi quarry, near Orte town, at 92 m asl (Fig. 4). It is 90.5 m deep, constituted by alternance of clays and sandy clays, with increasing sandy content in the upper metres (Fig. 7). On the whole, 54 samples were collected, among which 4 samples collected from clayey sediments, between -44 and -39 m (OR27-OR30) are comparable with the actualistic model. They are dominated by *V. bradyana*, with PD very similar to that of the actualistic model, while indexes of diversity and, secondly, heterogeneity are considerably lower (Tab. 2). Particularly, the α -index of all samples is under the lower limit of the range showed by the recent assemblage. Samples collected directly in front to the Ombrone River mouth, 3-4 km far from the coast (Bergamin et al., 1999) show a similar species diversity (α -index: 4-5), but lower heterogeneity (Shannon-index: 1.8) and much higher dominance (PD: 53%). This apparent discrepancy could be at least partly explained by the selective loss of fragile or small species, which may have occurred in the fossil assemblage due to taphonomic processes. Considering the relatively high values of PD, we may suppose a

Valvulineria bradyana assemblage										
locality	age	α -index			Shannon-index			PD (% Dominance)		
		range	average	st. dev.	range	average	st. dev.	range	average	st. dev.
Ombrone River	Recent	6.76-29.30	12.52	4.14	2.22-3.59	2.83	0.30	8.7-43.0	25.3	7.50
Nazzano	Santernian		6.17			2.28			27.7	
Orte		3.53-5.93	4.92	0.23	1.90-2.47	2.29	0.29	21.6-33.3	27.1	4.60
Civita di Bagnoregio		13.09-14.11	13.60	0.12	2.77-3.00	2.88	0.51	19.8-24.7	22.2	2.45

Tab. 2 - Range, average and standard deviation values of α -index, Shannon-index, PD: comparison between recent *V. bradyana* assemblage and fossil assemblages.

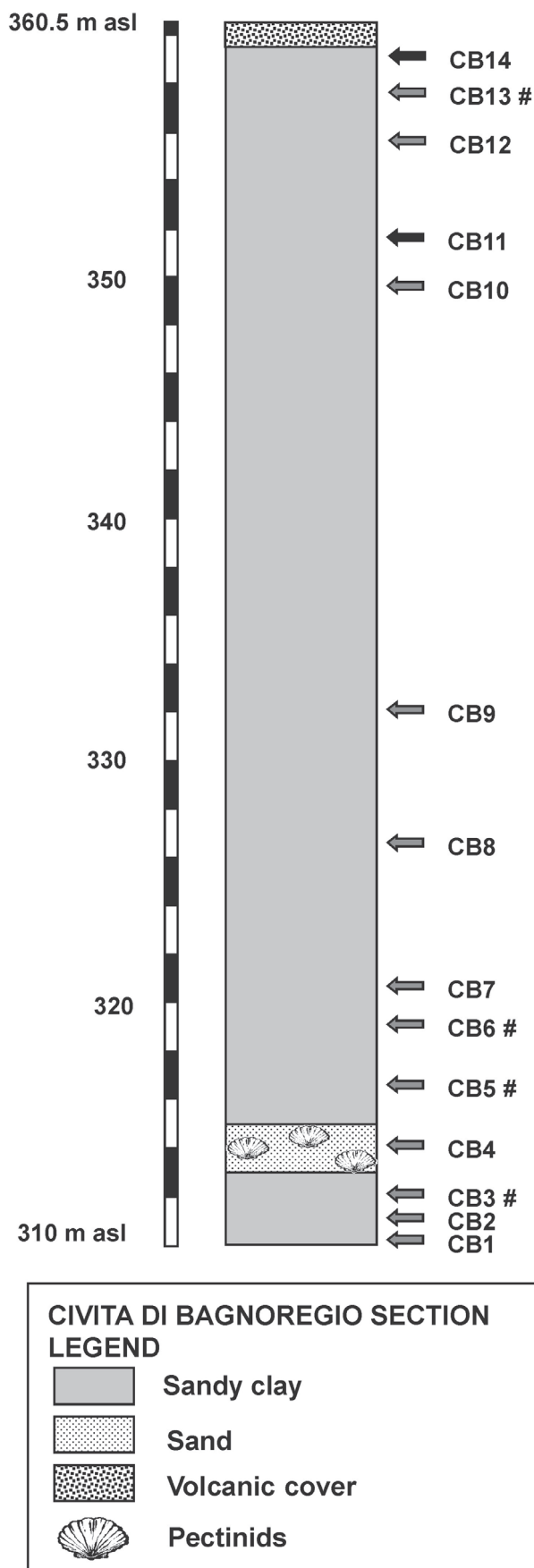


Fig. 6 - Civita di Bagnoregio section with samples studied by Di Bella (1995). The black arrows evidence samples with the *V. bradyana* assemblage. # indicates quantitative data not available.

significant degree of environmental stress due to considerable input of organic matter from a neighbour river mouth. The comparison of this index with those of samples from the Ombrone River delta body and the neighbouring area (Bergamin et al., 1999), could indicate that the site was located on the marginal sector of a delta complex.

Nazzano section

The third site of our study is a section about 43 m thick, with the bottom at 100 m asl, located at the 31th km of the Tiberina Road. It is comprised in an old, disused quarry, near Nazzano town (Fig. 4), now utilised as communal rubbish dump. The lithology consists of sandy clays with rare sandy levels in the upper part (Fig. 8). On the whole, 14 samples were collected, among which only sample NA6 (129 m asl) showed the dominance of the opportunistic *V. bradyana* (Tab. 2). As regards the α -index, Shannon-index and PD, there is a similarity with the Orte borehole and, consequently, the same influence of taphonomic processes may be supposed. A paleoenvironment rather similar to that supposed for Orte is recognised in this site. In fact, in spite of the small size of Farfa River, probably its load discharge was dispersed with difficulty because of the proximity of the Soratte ridge, in front of the river mouth (Fig. 5).

CONCLUSIONS

The data on benthic foraminiferal assemblages collected by Di Bella (1995) from more than 30 sites along the MTV have been considered, in order to give preliminary data concerning the reconstruction the organic paleo-flux of riverine origin along the Tyrrhenian coast, during the Santernian. The paleoecological interpretation is supported by the comparison of fossil assemblages with the actualistic model, elaborated by a detailed study of the recent foraminifera assemblages related to the organic flux from the Ombrone River (Frezza, 2004). The comparison is possible due to the nutrient-trap feature showed both by the recent ORB and by the Santernian coastal marine basin.

The assemblage found at Civita di Bagnoregio site indicates the presence of a small river mouth located in the neighbourhood, which probably lasted long time. During this time-span the direction of the organic flux was subjected to changes in direction. The source of the organic flux may have been a small river, not easily referable to the present hydrographic network, which during part of the Santernian flowed in the Tyrrhenian Sea many kilometres North to this site. The Orte site, differently, appears located in the marginal area of a delta body, which may correspond to the Nera delta system. It probably was a well-developed delta, characterised by high organic input. A similar paleogeographic setting may be supposed for the Nazzano site, where the Farfa River built its delta during a brief episode of the Santernian.

These preliminary results are encouraging for the development of the research aimed to the reconstruction of the organic flux along the paleo-coast of Latium,

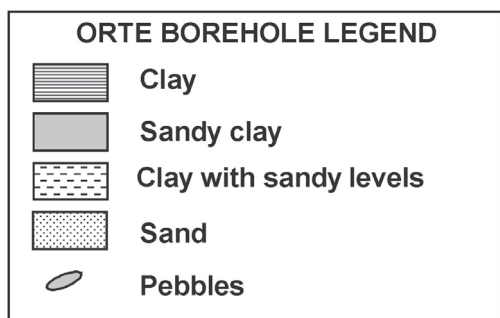
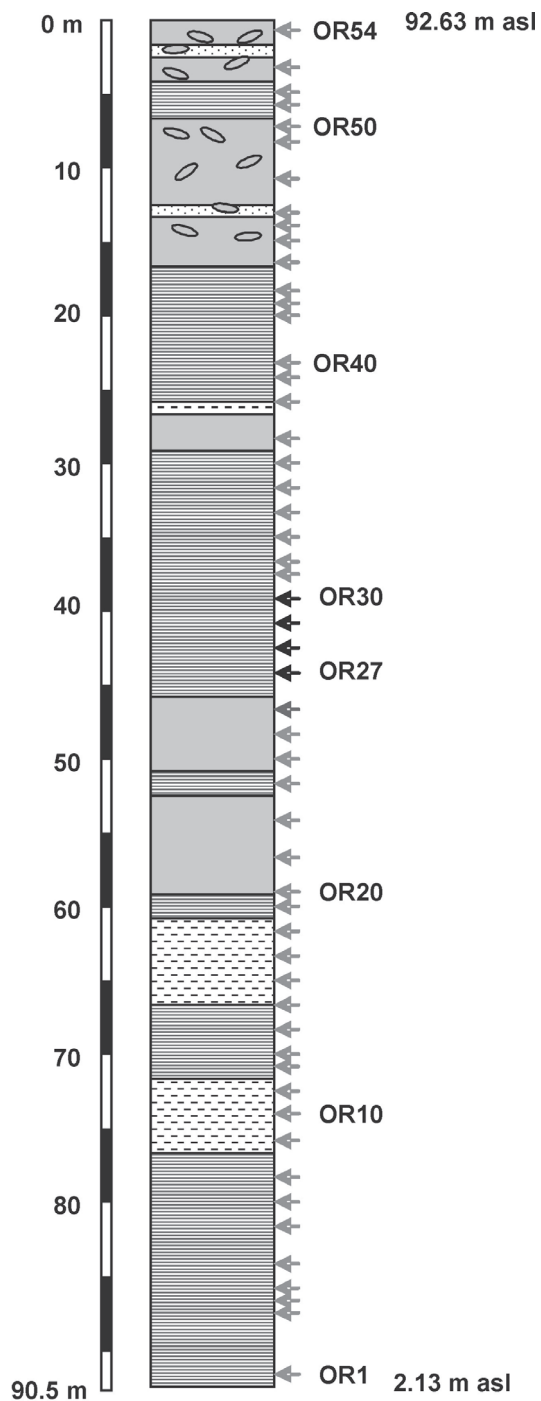


Fig. 7 - Orte borehole with samples studied by Di Bella (1995). The black arrows evidence samples with the *V. bradyana* assemblage.

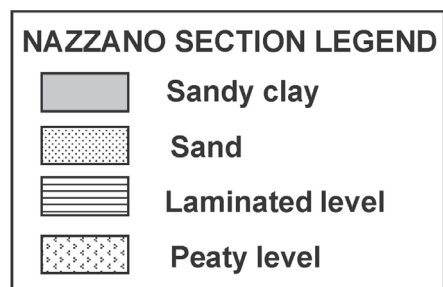
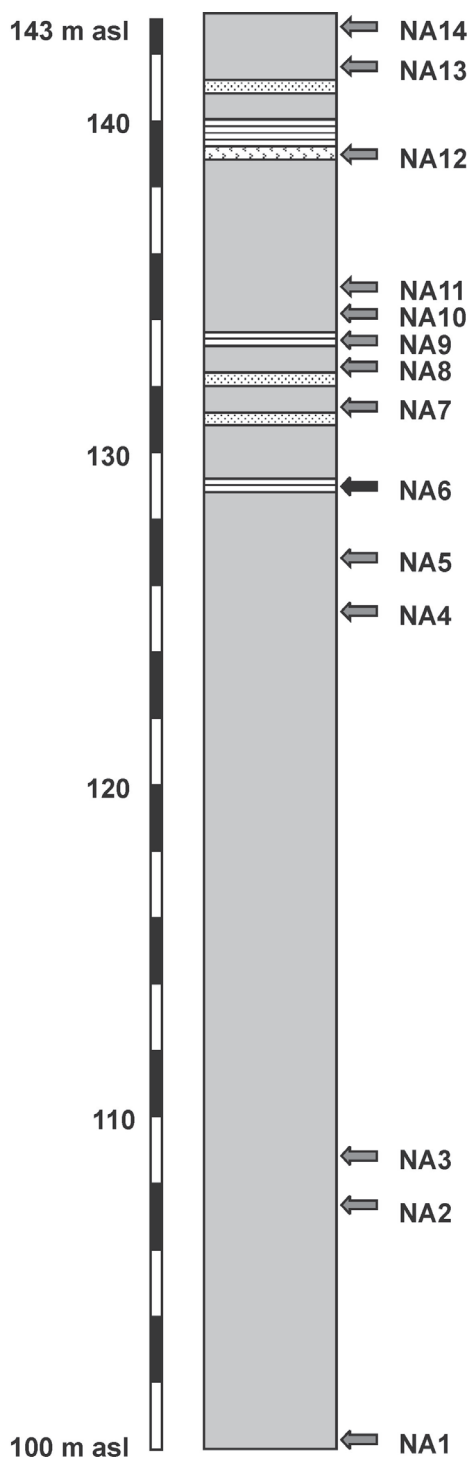


Fig. 8 - Nazzano section with samples studied by Di Bella (1995). The black arrows evidence samples with the *V. bradyana* assemblage.

with useful implications for a more detailed paleogeographic reconstruction of the Sanernian MTV. In addition, the good accordance between the paleogeographic reconstruction based on geological evidences performed by Mancini et al. (2004) and the preliminary results obtained by paleoecological proxies, validate the utility of the actualistic model considered as typical marker of the riverine organic flux.

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