

COMMON AND RARE LOWER PLIOCENE AGGLUTINATED FORAMINIFERS OF PIEDMONT (NORTHWESTERN ITALY): DISTRIBUTION, TAXONOMY AND PALEOENVIRONMENT

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Abstract. Agglutinated foraminiferal taxa from five stratigraphic sections and eighteen small outcrops of Lower Pliocene deposits were quantitatively analyzed for paleoenvironmental purposes. The studied area is located in Piedmont, northwestern Italy, and includes the northeastern Monferrato, the southern margins of the Turin Hill, the Astigiano, the Albese and part of the Langhe. Studied samples were mainly collected in the marine Argille Azzurre (AA) Formation, and cover a time interval ranging from the MP11 zone to the MP14a subzone in the Pliocene Mediterranean Foraminiferal Zonation. Most of the agglutinated assemblages are dominated, or exclusively made, by calc-agglutinated infaunal species of elongated tapered or subcylindrical shape, mainly represented by *Bigenerina nodosaria* and *Martinottiella communis*. The deep-water infaunal *Cylindroclavulina rudis*, *Eggerella bradyi* and *Martinottiella perparva* characterized the open-sea basinal facies deposited in the central part of the Piedmont region during the earliest Pliocene. These taxa progressively decreased in abundance until to disappear, and were replaced in the upper silty succession by shelf taxa, dominated by *Bannerella gibbosa* and *Textularia aciculata*. In particular, *T. aciculata* showed its highest abundances in infralittoral to shallow circalittoral muddy sediments of probable fluvial origin, widespread in the Astigiano area, and could be suggested as a typical species of shallow marine delta deposits. Among the 42 agglutinated species here determined, *Cyclammina cancellata* and *Reophax scorpiurus* were seldom reported in previous works, *Ammobaculites agglutinans*, *Ammoscalaria* spp., *Cribrostomoides subglobosus subglobosus*, *Haplophragmoides canariensis*, *Psammospaera* spp., and *Psammolingulina papillosa* were not previously found. The occurrence of these rare taxa could be the proxy of particular sea-floor conditions during the MP13 zone, characterized by a locally active bottom circulation and mesotrophic waters.

INTRODUCTION

This work analyzes the agglutinated foraminifers preserved in the Argille Azzurre (AA) and, for a lesser extent, in the Sabbie di Asti (SA) Formations, marine sediments deposited during the Early Pliocene on wide sectors of what is now the Pied-

mont region (northwestern Italy). Agglutinated taxa represent the oldest foraminifers with a mineralized shell, known from the latest Precambrian (Vendian or Ediacarian) (Hemleben et al. 1990; Gaucher & Sprechmann 1999), widespread from the Early Cambrian to all the Phanerozoic (Culver 1991; Kaminski et al. 2008; Pawlowski et al. 2013). They are among the most widely distributed benthic protozoans, thriving in all the marine habitats,

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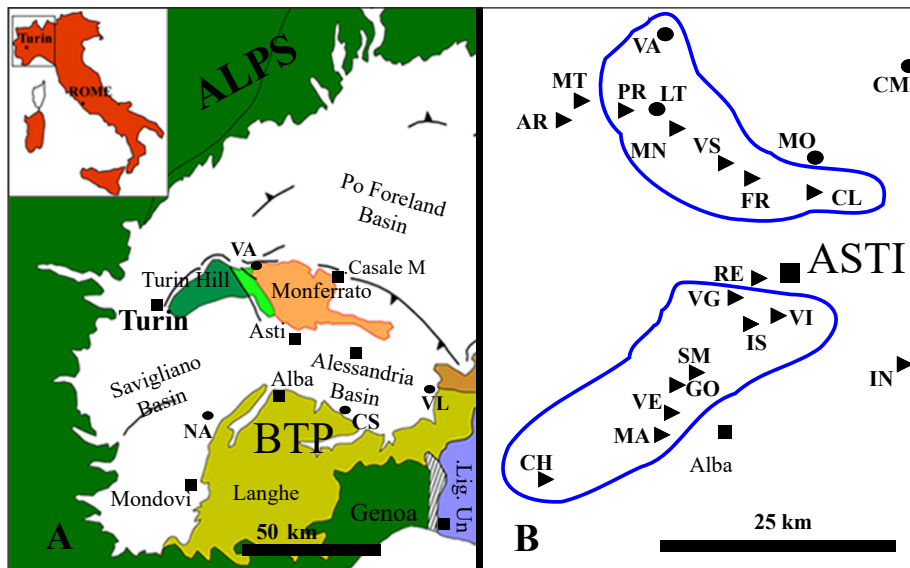


Fig. 1- A) Schematic geological map of the Piedmont region and location of the studied sections. B) detail of location of studied sites.

► Quantitatively studied sections, drillings and small outcrops: AR: Arignano; CH: Cherasco; CL: Calliano; FR: Frinco; GO: Govone S. Sebastiano; IN: Incisa Scapaccino; IS: Isola d'Asti; MA: Monticello d'Alba; MN: Montechiaro; MT: Moncucco Torinese; PR: Primeglio; RE: Revignano; SM: S. Martino Alfieri; VE: Vezza d'Alba; VG: Vaglierano; VI: Vigliano D'Asti; VS: Villa S. Secondo.

● Cited sites: CM: Casale Monferrato; LT: La Torretta; MO: Moncalvo; NA: Narzole; VA: Verrua Savoia; VL: Villalvernia.

Blue lines = Approximate areal of organic-cemented agglutinated taxa occurrence.

from brackish to abyssal depths (Hemleben et al. 1990). They are less or not sensitive to the calcitic dissolution that affects the calcareous forms at great depth (Berger 1972; Sliter et al. 1975), or under extreme conditions (Nardelli et al. 2022). Agglutinated foraminifers exploit different life strategies and microhabitats, with species thriving as infaunal or epifaunal (Murray 2006) and also able to exhibit an epibiotic or epilithic lifestyle (Waskowska & Kaminiski 2019; Lintner et al. 2022).

Agglutinated species are considered a minor component of Northern Italy Pliocene foraminiferal assemblages, and generally they are represented by few long-ranging, calcareous-cemented taxa, such as *Bigenerina nodosaria* d'Orbigny, 1826, *Martinottiella communis* (d'Orbigny, 1826), *Textularia* spp. Previous studies on Northern Italy Pliocene reported the agglutinated taxa only as a part of the total foraminiferal assemblage (Martinis 1954; Sampò et al. 1968; Violanti 2005, with references). Moreover, research specifically devoted to the study of this taxonomic group during Pliocene is very limited, mostly consisting of the old papers on the textularias by Fornasini (1883; 1885; 1887a, 1887b; 1887c; 1887d; 1887e; 1888a; 1888b; 1902-1904a; 1902-1904b) and more recently by Mancin (2001) and Mancin et al. (2012; 2014; 2022).

Few samples, collected in the central Piedmont and dated to the MPI3 foraminiferal zone (Cita 1975; Sprovieri 1992), differed from the exclusively calc-agglutinated assemblages by the occurrence of previously never recorded organic-cemented or ferruginous-cemented agglutinated species.

The studied area encompasses the northeastern Monferrato, the southeastern margins of the Turin Hill, the Astigiano, the Albese, and part of the Langhe (Fig. 1). At the present state of study, the Pliocene marine deposits of the central Piedmont are limited to the Zaccan MPI4a foraminiferal subzone or to a not better determinable MPI4 zone. Younger marine deposits, dated to the Piacenzian MPI5a subzone, based on the occurrence of *Globorotalia bononiensis* Dondi, 1963 and/or *Globorotalia aemiliana* Colalongo & Sartoni, 1967, have been documented only out of the studied area, to the north on the western side of the Turin Hill (Tropeano et al. 2014; Gattiglio et al. 2015), along the northwestern side of the Monferrato at Casale Monferrato (Violanti & Sassone 2008), and to the east at Villalvernia (Pavia et al. 2022).

The sections of Moncucco Torinese, Isola d'Asti, Calliano, Incisa Scapaccino, and Revignano were selected as representative of the different agglutinated assemblages and the corresponding paleoenvironmental settings. The lowermost Pliocene succession (MPI1 and MPI2 zones) is documented in the lower part of the Moncucco section (Trenkwalder et al. 2008; Violanti et al. 2011b), and was recovered also in the Narzole borehole (Violanti et al. 2009). The interval encompassing the MPI3 zone and MPI4a subzone was more widely documented in the whole area. Very often assemblages from silty and sandy lithologies were devoid of planktonic biostratigraphic markers. As a consequence, they were dubiously referred to the Lower Pliocene on stratigraphical basis or on the occurrence of benthic

species, such as *Anomalinoidea helicinus* (Costa, 1857), *Bolivina placentina* Zanmatti, 1957, *Uvigerina rutila* Cushman & Todd, 1941, became extinct at the end of the Zanclean or during the earliest Piacentian (Sprovieri 1986).

Quantitative analyses performed in this study document a strong relation between the specific composition, diversity, and abundance of agglutinated foraminifers and paleoenvironmental setting. Therefore, agglutinated assemblages are suggested to be a useful tool to investigate the Early Pliocene (Zanclean) paleoenvironmental evolution of the Piedmont and northwestern Italy.

MATERIAL AND METHOD

145 samples were collected from natural or artificial sections and from small outcrops along roads or paths across fields and vineyards in the Asti district (PR = Primeglio, MN = Montechiaro, VS = Villa San Secondo, FR1-FR6 = Frinco, VG = Vaglierano, VI = Vigliano d'Asti, SM = S. Martino Alfieri), in the Cuneo district (GO = Govone S. Sebastiano, VE2-VE5 = Vezza d'Alba, MA = Monticello d'Alba), or from drillings for roadworks (CH90 from S272 drilling and CH83, S276 drilling, Cherasco) (Fig. 1). Sediments are gray clays and sandy silts of the AA, in some sites (Calliano, Incisa S. and Revignano) covered by gray to yellow sands and silty sands of the SA, both dated to the Zanclean (Early Pliocene), from the MP11 to the MP14 foraminiferal zones. The biostratigraphic scheme here followed is that of Cita (1975) emended Sprovieri (1992).

For the present study, quantitative data on the Moncucco T. and Isola d'Asti foraminiferal assemblages, presented in Trenkwalder et al. (2008) and Violanti (2012), respectively, were in part recalculated.

Data about the agglutinated taxa in the Moncucco T., Isola d'Asti and Calliano sections are here firstly published, with the exception of those concerning the *Karreriella bradyi* (Cushman, 1911) distribution, figured in Violanti et al. (2011b).

The quantitative study of the Incisa S. and Revignano sections as well as of samples from short outcrops and drillings was carried out for the present research.

For foraminiferal analysis about 200–500 g of dry sediment were disaggregated with water and a small amount of hydrogen peroxide (H_2O_2). Then the material was gently washed, sieved into grain size fractions $>250\ \mu m$, 125–250 μm and 125–63 μm , dried at 50° C and weighed.

Quantitative analyses were carried out on the total $>125\ \mu m$ fraction, split into aliquots containing approximately 300–400 well preserved foraminiferal tests, and observed under the stereomicroscope. Percentages of the identified planktonic and benthic species were calculated on the total of planktonic and benthic specimens, respectively. Percentages of the agglutinated species were calculated on the total benthic taxa. The 125–63 μm residues were not included in the counted fractions, owing to the scarcity or even absence of agglutinated tests.

For the present study, the P/(P+B-ST-SW) ratio was calculated following van der Zwaan et al. (1990) and van Hinsbergen et al. (2005), discarding from the total tests the benthic stress tolerant, opportunistic taxa (ST) (most of *Bulimina* and *Bolivina* species, all *Brizalina*, *Fursenkoina*, *Globobulimina* and most *Uvigerina*) and the infralittoral taxa (SW), transported from shallow depths (*Ammonia*,

Elphidium, *Lobatula*, *Neoconorbina*, *Rosalina*). High numbers of ST and SW specimens affect the relative abundance of planktonic tests, and consequently the estimated paleobathymetry.

The diversity Shannon-Weaver H-Index was calculated using PAST ver. 1.77 (Hammer et al. 2008). The relative abundance of agglutinated (A) specimens on the total benthic (B) assemblage was expressed as the A/B ratio percentage. For each sample, the number of agglutinated genera (AGN) was counted. Percentage variations of the agglutinated species were analyzed. Agglutinated taxa were grouped in the morphological groups proposed by Jones & Charnock (1985), Nagy et al. (1995), Kaminski et al. (1995), Mancin (2001), Kaminski & Gradstein (2005) and Frontalini et al. (2014).

The identification of the foraminiferal species was based on the author's original descriptions and drawings and on Höglund (1947), Colom (1974), Agip (1982), Loeblich & Tappan (1987), Cimmerman & Langer (1991), Sgarrella & Moncharmont Zei (1993), Kaminski & Gradstein (2005), Milker (2010).

The paleoenvironmental interpretations were based on paleoecological affinities of benthic foraminiferal species as reported by Chierici et al. (1962), Blanc-Vernet (1969), Wright (1978), Jorissen (1987), Debenay et al. (1996), Rasmussen & Thomsen (2005), Murray (2006).

The studied material is housed at the Geology and Paleontology Museum of the Turin University under repository numbers MGPT-PU134019 to MGPT-PU134080.

GEOLOGICAL SETTING OF THE STUDIED SECTIONS

The Moncucco T. section (Figs. 1, 2) represents the Pliocene portion of an upper Messinian to Pleistocene succession, extensively described by Trenkwalder et al. (2008). The Zanclean succession consists of about 26 m of bioturbated light gray marly clays. A slightly coarser layer, about 3 decimeters thick, occurred at 18.5 m from the base. Two biocalcarenic beds, each one about 0.50 m thick, are interbedded in the upper part of the section.

The Isola d'Asti section (Figs. 1, 3) is located in the abandoned Merlino brickyard, about 1.5 km NE of Isola d'Asti village. About 24 m of predominantly bioturbated clays, pertaining to the AA, are exposed. Two beds of coarse sands, rich in mollusc shells and fragments, and separated each other's by a 0.2 m thick silty interval, occur between 6.5–7.2 m above the base of the section. Four laminated layers, few centimeters to few decimeters thick, are interbedded with the clays.

The Calliano section (Figs. 1, 4) was sampled in a disused quarry, NE of the Calliano village, along the SS (Strada Statale, National Road) 457. The succession is exposed for about 13 m and consists of a basal layer, about 1 m thick, of blue-gray homogeneous diatomitic clays, overlain by about 4.5 m of yellowish massive clayey silts, passing upward to

about 7.5 m of poorly bedded sandy silts, only in part accessible for sampling.

The Incisa Scapaccino section (Figs. 1, 5) was sampled at about 2 km NW from the center of the Incisa Scapaccino village, during and soon after the digging of the small artificial Valtiverno pond, in the Val Sarmassa Regional Reserve. The succession is about 48 m thick and starts, from the base, with about 4 m of biocalcarenes, now covered by the pond. The biocalcarenes are overlain by about 34 meters of discontinuously exposed yellow to gray clayey silts to silty sands, often extensively bioturbated, interbedded with thin layers of thin to medium-grained sands. After a covered interval, about 5 meters of yellow sands, referable to the SA, are only partly exposed.

The Revignano section (Figs. 1, 6), located in the homonymous hamlet of the Vaglierano municipality, crops out for about 17 m along the Borbore stream, near the railway bridge of the Turin-Asti line. From the base, about 5-6 m of gray silty clays are exposed. Very abundant tubes of the polychaete *Ditrupa arietina* (O. F. Müller, 1776) are directly exposed on the ground. After a covered interval of about 2 meters, the silty clays are followed by about 3 m of gray-yellowish clayey silts, still very rich in *Ditrupa* tubes. The upper part of the succession is extensively covered by vegetation, and only about 3 m of yellow-reddish silty sands are exposed.

RESULTS

The agglutinated foraminiferal distribution in the selected sections

At the Moncucco T. section, a rich planktonic and predominantly calcareous benthic foraminiferal assemblage was collected from 52 samples of the AA at a mean sampling interval of 0.5 m. Biostratigraphic and paleoenvironmental interpretations proposed by Trenkwalder et al. (2008) indicate deposition from the basal Pliocene MP11 zone (*Sphaeroidinellops* spp. acme-zone) to the MP14a subzone (*Globorotalia puncticulata* interval-subzone). The P/(P+B-ST-SW) ratio (Fig. 2) is high to very high (60-80%) in the MP11 and MP12 zones. Upwards, from the coarse level at about 18.5 m from the base, it decreases to values ranging around 60% in almost all samples. The Shannon-Weaner H Index, calculated as a measure of the total benthic di-

versity (calcareous plus agglutinated forms), varies from a minimum value of 1.36 (sample at 23.5 m from the base) to a maximum of 3.70 (sample 22.5 m) (Fig. 2). The abundance of agglutinated specimens (A) on the total benthic (B) foraminiferal assemblage is expressed by the A/B% curve (Fig. 2). Its percentages showed strong variations in adjacent samples, with a general increasing trend in the lowermost part of the Moncucco T. section, with values between 3.5-10.9, and a strong progressive decrease upwards, to values generally between 2-3. The AGN (Agglutinated Genera Number) (Fig. 2) showed low values (1-4) in the basal samples of the MP11 zone, in which only *Karreriella*, *Martinottiella*, *Sigmoilopsis*, *Siphotextularia* or *Textularia* occurred. Then, in the MP11-MP12 interval, the values ranged between 3-7, with the progressive occurrence of *Eggerella*, *Cylindroclavulina* and *Spiroplectinella*. The AGN decreased (<4) in the uppermost layers, dated to the MP14a subzone, in which the epibathyal taxa *Eggerella* and *Cylindroclavulina* are absent. As a whole, 14 agglutinated genera were recognized in the Moncucco T. section. 23 agglutinated species were collected from the total succession, but the number of species for each sample is generally very low, 1 to 5. The most common species are *B. nodosaria*, *Cylindroclavulina rudis* (Costa, 1855), *Eggerella bradyi* (Cushman, 1911), *K. bradyi*, *M. communis* and *Sigmoilopsis schlumbergeri* (Silvestri, 1904), which reach percentages greater than 2% in more than one sample (Fig. 2). Both the first occurrence of *C. rudis* and of *E. bradyi* are registered in the short interval characterized by the presence of mesopelagic *Sphaeroidinellops* spp. (Trenkwalder et al. 2008). The group *Textularia* spp., including *Sahulina conica* (d'Orbigny, 1839) and the genus *Textularia*, here represented by *Textularia aciculata* d'Orbigny, 1826, *Textularia agglutinans* d'Orbigny, 1839, *Textularia candeiana* d'Orbigny, 1839, *Textularia gramen* d'Orbigny, 1846, *Textularia pala* Čížek, 1848 and *Textularia ponderosa* Fornasini, 1887, was absent in many samples or present with values below 2%. *Martinottiella perparva* (Cushman, 1936) (Fig. 2) was recovered in the lower part of the section, with a maximum of 1.15% at 0.4 m from the base, and in the middle part up to 16 m from the base. On the contrary, *Bannerella gibbosa* (d'Orbigny, 1826) and *Spiroplectinella wrighti* (Silvestri, 1903) were found in the upper half of the section, with percentages below 1% and 2%, respectively. Other rare agglutinated species were *Cribragoesella robusta* (Brady,

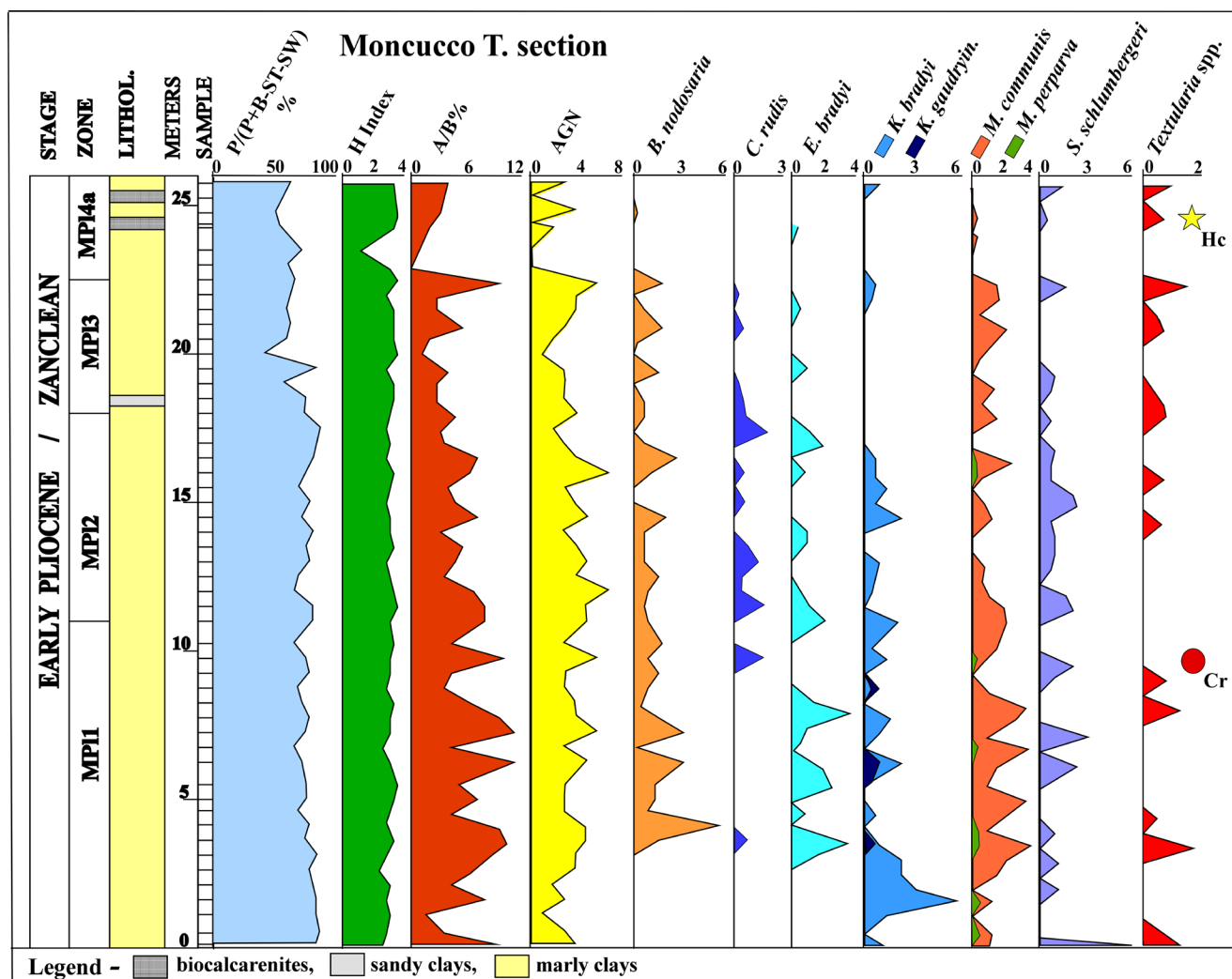


Fig. 2 - Biostratigraphy, lithological column, meters from the section base, sample position, variation of the P/(P+B-ST-SW) ratio percentages, of the H Index, of the A/B ratio percentages, of the AGN value and percentage variations of the agglutinated taxa *B. nodosaria*, *C. rudis*, *E. bradyi*, *K. bradyi*, *K. gaudryi*, *M. communis*, *M. parva*, *S. schlumbergeri*, and *Textularia* spp., Cr = *C. robusta*, Hc = *H. canariensis* occurrence in the Moncucco T. section.

1881), recovered in the sample at 9.7 m with 2.9%, *Haplophragmoides canariensis* (d'Orbigny, 1839) in the sample at 24.20 m, with 0.31%, *Karreriella gaudryioides* (Fornasini, 1885), found in the lower-middle samples, and *Siphotextularia affinis* (Fornasini, 1883), observed in very few samples along the whole section, both with percentages below 1%.

At Isola d'Asti (Figs. 1, 3) 42 samples were collected at intervals of 5-10 cm within the laminates, of 0.5-1 m in the massive, bioturbated clays. The lower part of the succession was dated by Violanti (2012) to the MPI3 zone, the upper section to the MPI4a subzone, due to the absence of *Globorotalia margaritae* Bolli & Bermudez, 1965 and the occurrence of *Globorotalia puncticulata* (Deshayes, 1832) and *Globorotalia puncticulata padana* Dondi & Papetti, 1968. The P/(P+B-ST-SW) ratio (Fig. 3) shows val-

ues of 40-50% at the base of the section, increases to 80-98% in the samples correlated to the lower MPI3 zone and in the uppermost laminated layer, and ranges between 50-60% in the intervals among the laminates. The H Index (Fig. 3) displays values between 2-3.6 in most of the clays, and decreased to about 1 both in the sandy layers and in the laminates. The agglutinated foraminifera represent a low percentage of the total benthic assemblage in most samples from the clays, with a A/B ratio about 5% (Fig. 3), and are absent or very rare in the laminates and sands. Only in the interval between 5.0-6.7 m from the base, agglutinated tests are common and exceed 20% of the total, ranging between 27.7-37.8%. The AGN (Fig. 3) was high in most of the lower part of the section, reaching a maximum of 10-11 genera in the samples above the sandy inter-

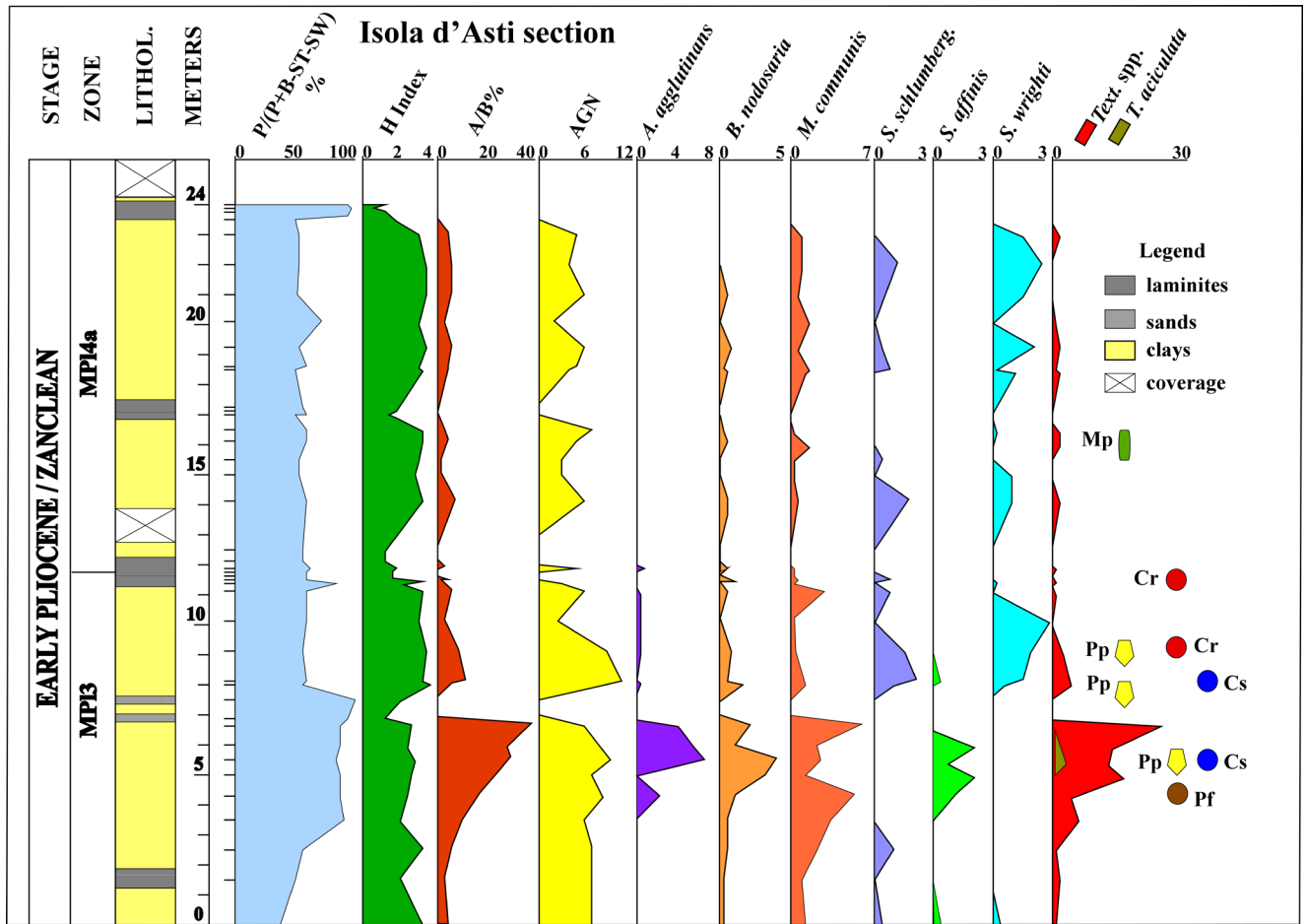


Fig. 3 - Biostratigraphy, lithological column, meters from the section base, sample position, variation of the $P/(P+B-ST-SW)$ ratio percentages, of the H Index, of the A/B ratio percentages, of the AGN and percentage variations of the agglutinated taxa *A. agglutinans*, *B. nodosaria*, *M. communis*, *S. schlumbergeri*, *S. affinis*, *S. wrighti*, *Textularia* spp., and *T. aciculata*, Cr = *C. robusta*, Cs = *C. subglobosus subglobosus*, Mp = *M. perparva*, Pf = *P. fusca*, Pp = *P. papillosa* occurrence in the Isola d'Asti section.

val. Upward, values range between 3-6, influenced by the disappearance of deep circalittoral/epibathyal genera such as *Eggerella*, *Karreriella* and *Martinottiella*. In total, 22 agglutinated species belonging to 14 genera were collected from the clays. The most common taxa, occurring with percentages greater than 2% almost in a single sample (Fig. 3), were *Ammobaculites agglutinans* (d'Orbigny, 1846), *B. nodosaria*, *M. communis*, *S. conica*, *S. schlumbergeri*, *S. affinis*, *S. wrighti*, and *Textularia* spp., here represented by *T. aciculata*, *T. agglutinans*, *T. gramen*, *T. ponderosa*, *Textularia sagittula* Defrance, 1824, and *Textularia soldanii* Fornasini, 1883. In particular, *A. agglutinans* was collected from the lower-middle part of the section, and is common in the interval between 4.30-6.70 m from the base. Species occurring with percentages lower than 2% are *B. gibbosa*, and *K. bradyi*, whereas with values lower than 1% are *E. bradyi*, *K. gaudryinoides*, and *M. perparva* (Fig. 3). *Cribrostomoides subglobosus subglobosus*

(Cushman, 1910), *C. robusta*, *Psammolingulina papillosa* (Neugeboren, 1856), and *Psammospaera fusca* Schulze, 1875 were collected from the clays between 4.3-8.1 m from the base, all with values <1%.

In the Calliano section, 9 samples (CL14 to CL22) were collected with an average sampling interval of about 1-2 m. The scattered occurrence of *G. margaritae* and *G. puncticulata* enable assigning the section to the MPI3 zone (Violanti et al. 2011a). The $P/(P+B-ST-SW)$ ratio (Fig. 4) displays low values, ranging from a maximum of 23% in the basal diatomitic clay to about 11-19% in the clayey silts and to a minimum of 5.84% in the sandy silts. The H Index (Fig. 4) shows rather uniform values, around 3.5 in most samples, and ranges between a minimum of 2.94 in the basal sample to a maximum of 3.71 at 5.5 m from the base. The A/B ratio (Fig. 4) displays a minimum in the basal diatomitic clays (1.37%), it reaches its maximum of about 16% in the lower-

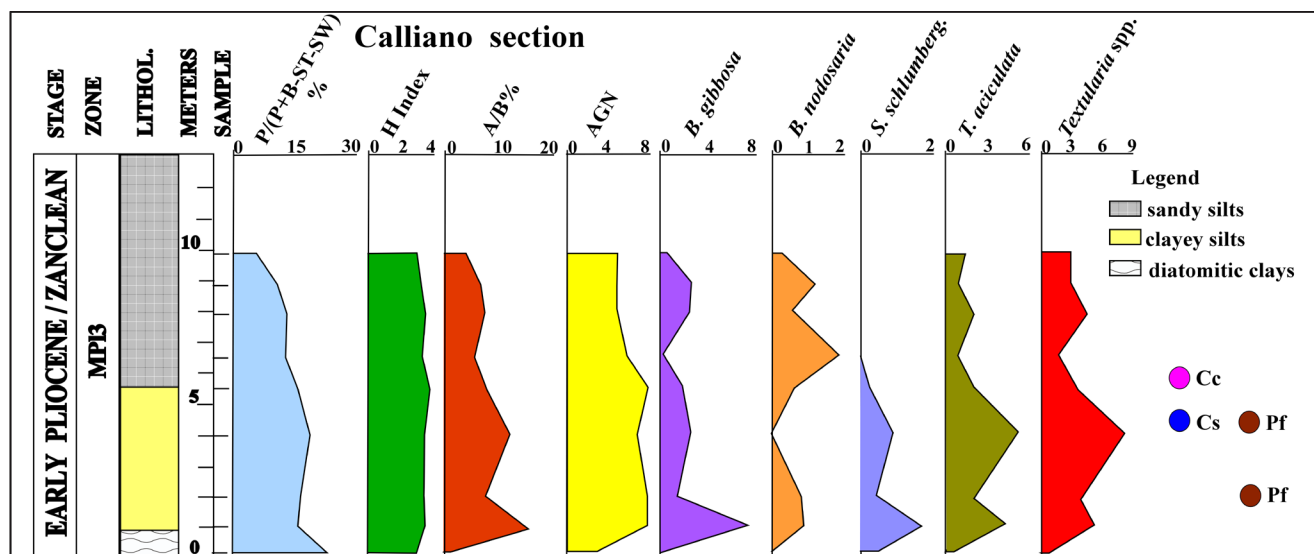


Fig. 4 - Biostratigraphy, lithological column, meters from the section base, sample position, variation of the $P/(P+B-ST-SW)$ ratio percentages, of the H Index, of the A/B ratio percentages, of the AGN and percentage variations of the agglutinated taxa *B. gibbosa*, *B. nodosaria*, *S. schlumbergeri*, *T. aciculata* and *Textularia* spp., Cc = *C. cancellata*, Cs = *C. subglobosus subglobosus*, Pf = *P. fusca* occurrence in the Calliano section.

most clayey silts and shows decreasing percentages upwards. The AGN (Fig. 4) displays a similar pattern, with the lowest value of 3 genera, *Sabulia*, *Spiroplectinella* and *Textularia*, in the diatomitic clays, and the highest numbers of 6-8, yielding also *Bannerella*, *Bigenerina*, *Martinottiella*, *Sigmoilopsis* and *Siphotextularia*, in the clayey silts. A total of 15 agglutinated species belonging to 10 genera were recognized. *B. nodosaria*, *B. gibbosa*, *S. schlumbergeri*, and *Textularia* spp. occur in most samples with percentages often >2% (Fig. 4). *Textularia* spp. is dominated by *T. aciculata* and also represented by *T. agglutinans*, *T. gramen*, *T. ponderosa*, *T. sagittula*, *T. soldanii* and *S. conica*. Very rare specimens of *P. fusca* were found in the samples at 2 m and 4 m, of *C. subglobosus subglobosus* in the sample at 4 m, of *Cyclammina cancellata* Brady, 1879, at 5.5 m. *M. communis*, *S. affinis* and *S. wrighti* are rare, with values less than 1%.

In the Incisa Scapaccino section 20 samples were collected at very variable intervals, ranging from 0.3-1 m up to 7 m, due to the thick coverage and low accessibility of the outcrop (Fig. 5). Foraminifers were absent in the basal mollusc-rich layer and in the overlying biocalcarenes, common but poorly diversified in the clayey silts, and scarce in the upper yellow sands. Tubes of the serpulid *D. arietina* are rather common in the uppermost clayey silts. The $P/(P+B-ST-SW)$ values are very low, below or near 10%, in the lowermost and uppermost samples of the succession, and increase to 20-30% in most

samples from the clayey silt (Fig. 5). The H Index values (Fig. 5) range between 2.69-2.15 in most samples, with a maximum of 3.31 in the yellow sands at 44.6 m and a minimum of 1.8 at 22 m from the base. The agglutinated foraminifers are frequent and the A/B ratio (Fig. 5) is between 15-30% in most of the clayey silts. A strong decrease to about 1-8% is registered in the interval between samples at 22.0-23.8 m, low values are also registered in the upper sands. The AGN (Fig. 5) ranges between 2-4, with a maximum of 5 genera at the top of the clayey silts, given by *Bannerella*, *Bigenerina*, *Siphotextularia*, *Spiroplectammina*, and *Textularia*. A total of 12 agglutinated species was recognized in the succession (Fig. 5). *B. gibbosa*, *B. nodosaria* and *Textularia* spp. are the most common taxa. *T. aciculata* is the more abundant species, and strongly dominates the *Textularia* spp. group, which includes also *T. sagittula*, *T. agglutinans*, *T. candeiana*, *T. gramen*, *T. pala*, and *T. soldanii*, all of them with percentages around or lower than 1%. Very rare (<1%) *S. affinis* and *S. wrighti* were observed.

From the Revignano section, four samples were collected. The three samples from the clayey silts (Fig. 6) yielded very abundant tubes of the opportunistic serpulid *D. arietina* and foraminifers, the overlying sample from the sandy silts was barren. The $P/(P+B-ST-SW)$ ratio shows uniform, extremely low values, below 2%. The H Index is between 1.72 and 2.36. Agglutinated specimens represent about 10% of the assemblages, and the A/B

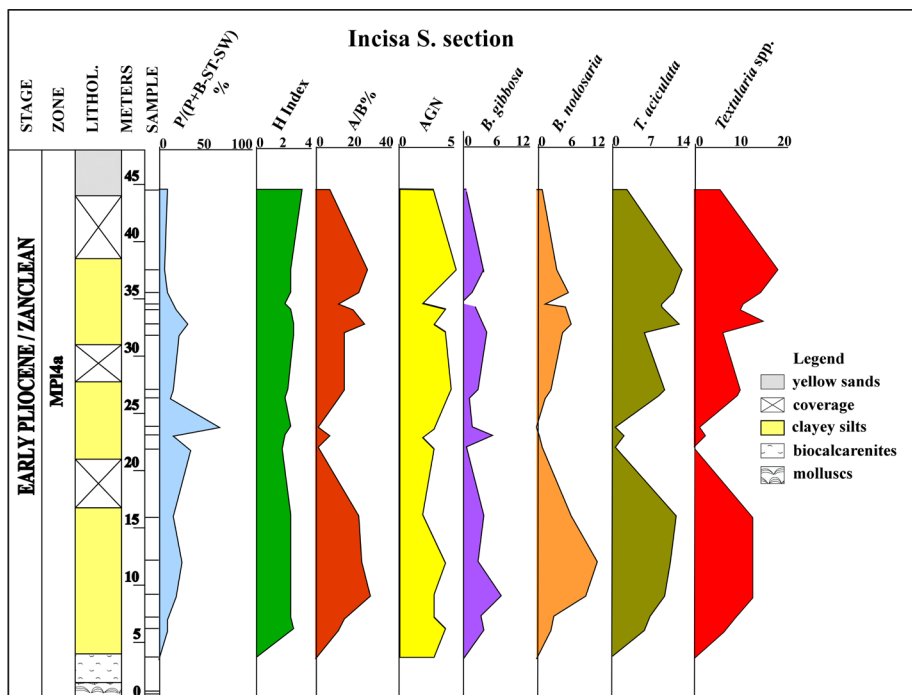


Fig. 5 - Biostratigraphy, lithological column, meters from the section base, sample position, variation of the P/(P+B-ST-SW) ratio percentages, of the H Index, of the A/B ratio percentages, of the AGN and percentage variations of the agglutinated taxa *B. gibbosa*, *B. nodosaria*, *T. aciculata* and *Textularia* spp. in the Incisa S. section.

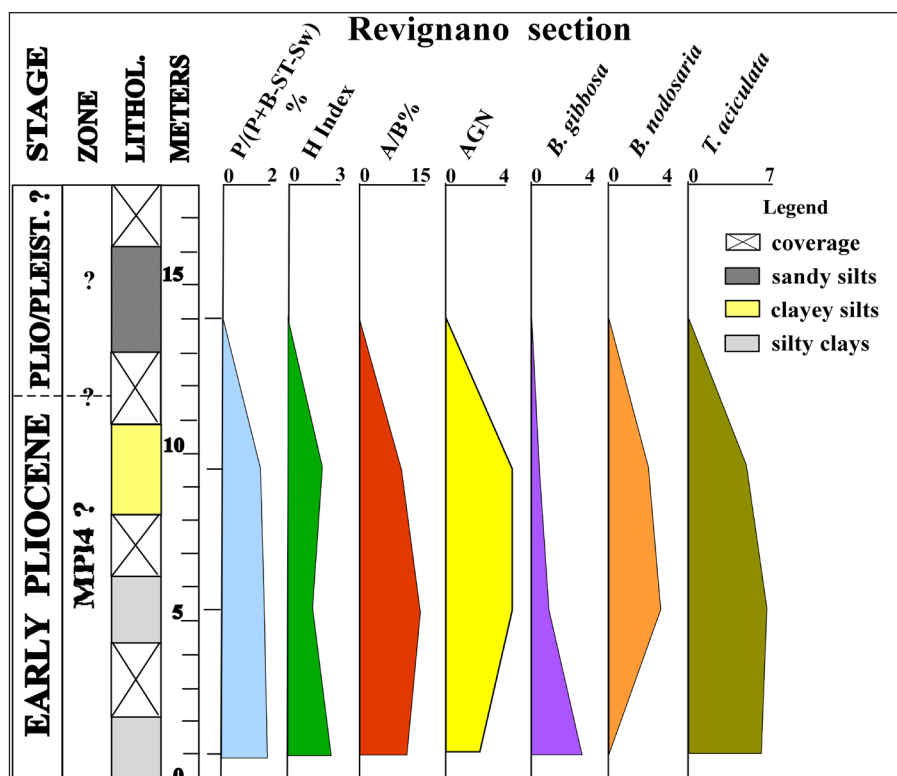
ratio ranges between 9.75-11.54%. Low values are registered for the AGN, ranging between 2-4. Only the genera *Bannerella*, *Bigennerina*, *Sabulia* and *Textularia* were found. Five agglutinated species were collected in the clayey silts: *B. gibbosa*, *B. nodosaria*, *T. aciculata* are rather common, whereas *S. conica* and *T. angularis* display values lower than 1%.

The agglutinated species distribution in the selected small outcrops

The eighteen samples collected from small natural or artificial outcrops, here quantitatively studied, were selected from many others for the occurrence of very rare calcarous-cemented and organic or ferruginous-cemented forms. Sediments consist of clayey or sandy silts, pertaining to the AA, deposited at depth between the circalittoral to the upper epibathyal zones (Dela Pierre et al. 2003; Ghielmi et al. 2019). Some samples yielded frequent to abundant planktonic foraminifers, dominated by *Globigerina bulloides* d'Orbigny, 1826, *Globigerinella obesa* (Bolli, 1957), *Globigerinoides obliquus* Bolli, 1957, *Globoturbotalita* spp. *G. margaritae* and *G. puncticulata* were rather common and sometimes occurred together, allowing the correlation to the MP13 zone (samples PR, GO, SM, VE3) (Fig. 7). In other samples, *G. margaritae* and *G. puncticulata* occurred separately or were missing. In the first case the zone was tentatively indicated, in the second case was not given.

The P/(P+B-ST-SW) ratio is greater than 50% in many samples, it reaches about 70-73% in the samples PR and VE3, respectively (Fig. 7). The lowest values, less of 20%, were observed in the FR1-FR6 samples. The diversity H Index showed values equal or greater than 3.5 in many samples, with a maximum of 4.4 in sample PR (Fig. 7). Samples from the Frinco area (FR1, FR3-FR6) differed in their less diversified benthic assemblages, reflected by the low values of the H Index, ranging from 2.8 to 3.2 (Fig. 7). The A/B ratio percentages (Fig. 7) show large variations, ranging from about 8% to about 26%. The AGN (Fig. 7) ranges from a minimum value of 6 to the maximum of 18 in sample VI, in which most of the rarest agglutinated forms were found. A total of 42 agglutinated species was recognized, but many of them occurred in few samples with percentages lower than 1%. Among the most common species (Fig. 7), *B. gibbosa* is present or frequent in all samples from the Monferrato area, absent or rare in the other samples. *B. nodosaria* occurs in almost all samples. On the contrary, *C. rudis* was only recovered in a few samples of the Albese. *M. communis* is more common in the Astigiano and Albese samples than in those from the Monferrato. *S. schlumbergeri* shows a rather similar pattern, with abundance often below 1%. *Textularia* spp., represented by *S. conica*, *T. aciculata*, *T. angularis*, *T. agglutinans*, *T. candeiana*, *T. communis*, *T. gramen*, *T. pala*, *T. ponderosa*, *T. sagittula* and

Fig. 6 - Biostratigraphy, lithological column, meters from the section base, sample position, variation of the P/(P+B-ST-SW) ratio percentages, of the H Index, of the A/B ratio percentages, of the AGN and percentage variations of the agglutinated species *B. gibbosa*, *B. nodosaria*, and *T. aciculata* in the Revignano section.



T. soldanii, is often common to abundant (Fig. 7). *E. bradyi*, *K. bradyi*, *K. gaudrinoides*, *M. perparva*, *S. affinis*, and *S. wrighti* randomly occur with percentage below or near 1%. Rare specimens of *A. agglutinans*, *Ammoscalaria pseudospiralis* (Williamson, 1858), *Ammoscalaria runiana* (Heron-Allen & Earland, 1916), *Ammoscalaria tenuimargo* (Brady, 1884), *Bigenerina compressissima* Colom, 1946, *C. robusta*, *C. subglobosus subglobosus*, *Crithionina pisum* Goës, 1896, *C. cancellata*, *H. canariensis*, *Lagenammia atlantica* (Cushman, 1944), *P. papillosa*, *P. fusca* Schulze, 1875, *Psammosphaera parva* Flint, 1899, *Recurvoides* sp., *Reophax scorpiurus* de Montfort, 1808, *Rhabdammina* cf. *abyssorum* Sars, 1869, *Siphotextularia* spp., *Spiroplectammia milletti* (Cushman, 1911), and *Spirotextularia fistulosa* (Brady, 1884) were counted in the >125 µm fraction (Fig. 8). Among the very rare species, only *A. agglutinans*, *C. cancellata* and *P. papillosa* are rather common and reach abundances between 2 and 4%.

Morphogroup analysis

In order to improve the paleoenvironmental interpretation of the Piedmont Pliocene succession, the recognized agglutinated species were combined into morphological groups. The morphogroup analysis of agglutinated foraminifers, based on the relation among the test morphology, life position

and trophic habits, proposed by Jones & Charnock (1985), was subsequently modified and successfully applied to fossil and recent assemblages (Nagy et al. 1995; Kaminski et al. 1995; Violanti 2000; Mancin 2001; Kaminski & Gradstein 2005; Kaminski et al. 2011; Murray et al. 2011; Frontalini et al. 2014; Setoyama et al. 2018). In the studied assemblages four broad morphogroups were distinguished (Tab. 1).

Morphogroup A comprises the tubular or branching shapes, thriving as epifaunal, mainly suspension feeders and is here insignificant, being represented by very rare fragments of *R. cf. abyssorum*, recovered only in sample VI (Fig. 10).

Morphogroup B includes epifaunal to shallow infaunal taxa of globular shape such as *C. pisum*, *L. atlantica*, *Psammosphaera* spp., the rounded planispiral and trochospiral forms *C. subglobosus subglobosus*, *C. cancellata*, *H. canariensis*, *Recurvoides* sp. and the elongate keeled with mixed coiling modes *S. milletti* and *Spiroplectinella* spp., included as epifaunal following Kaminski & Gradstein (2005). The morphogroup B is scarce in the studied sections, given almost exclusively by the elongate keeled *S. wrighti* (Fig. 9). Only in samples FR3-FR5, GO, SM, VI, VE3, CH90, and CH83, morphogroup B is rather more represented.

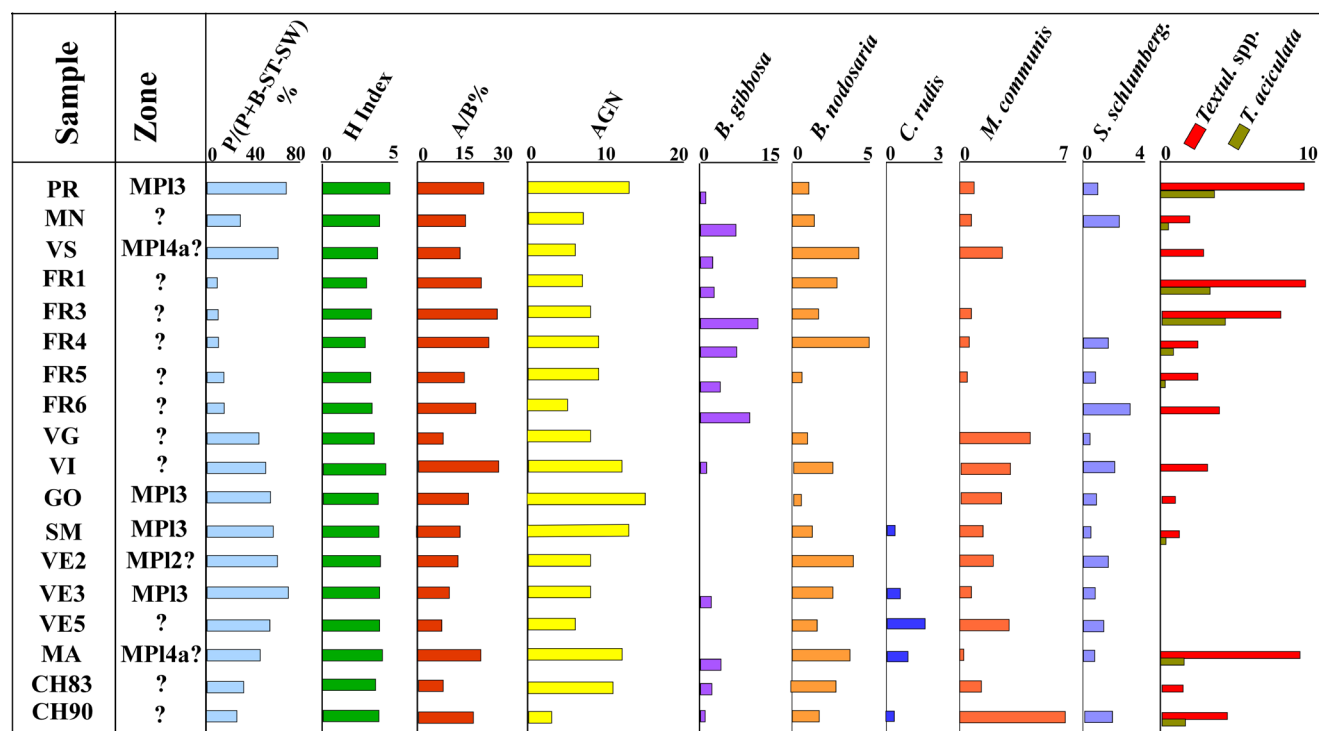


Fig. 7 - Sample abbreviation, foraminiferal zone, P/(P+B-ST-SW) ratio percentages, H Index values, A/B ratio percentages, AGN values and percentages of the agglutinated taxa *B. gibbosa*, *B. nodosaria*, *C. rudis*, *M. communis*, *S. schlumbergeri*, *Textularia* spp., and *T. aciculata* in small outcrops yielding rare agglutinated species. Sample abbreviations: PR = Primeglio, MN = Montechiaro, VS = Villa San Secondo, FR1-FR6 = Frinco, VG = Vaglierano, GO = Govone S. Sebastiano, VI = Vigliano d'Asti, SM = S. Martino Alfieri, VE2-VE5 = Vezza d'Alba, MA = Monticello d'Alba, CH83 and CH90 Cherasco drillings.

Morphogroup A	Morphogroup B	Morphogroup C
<i>Rhabdammina</i> cf. <i>abyssorum</i>	<i>Crithionina</i> <i>pisum</i>	<i>Ammobaculites</i> <i>agglutinans</i>
	<i>Lagenammina</i> <i>atlantica</i>	<i>Ammoscalaria</i> spp.
	<i>Psammosphaera</i> spp.	<i>Bannerella</i> <i>gibbosa</i>
	<i>Cribrostomoides</i> <i>subglobosus</i>	<i>Bigenerina</i> spp.
	<i>Cyclammina</i> <i>cancellata</i>	<i>Cribrogoesella</i> <i>robusta</i>
	<i>Haplophragmoides</i> <i>canariensis</i>	<i>Cylindroclavulina</i> <i>rudis</i>
	<i>Recurvoides</i> sp.	<i>Eggerella</i> <i>bradyi</i>
	<i>Spiroplectammina</i> <i>milletti</i>	<i>Karrerella</i> spp.
	<i>Spiroplectinella</i> spp.	<i>Martinottiella</i> spp.
		<i>Psammolingulina</i> <i>papillosa</i>
		<i>Reophax</i> <i>scorpiurus</i>
		<i>Siphotextularia</i> spp.
		<i>Spirotextularia</i> <i>fistulosa</i>
		<i>Textularia</i> spp.
		Milioline shaped
		<i>Sigmoilopsis</i> <i>schlumbergeri</i>

Tab. 1 - Subdivision of the agglutinated foraminifera into 4 morphogroups plus the "Milioline shaped" *S. schlumbergeri*, according to Jones & Charnock (1985), Mancin (2001) and Murray et al. (2011). The Morphogroup D, including planoconvex epiphytal taxa, is absent in the Piedmont Pliocene assemblages.

The morphogroup C is strongly dominant and constitutes the total agglutinated assemblage in most of the studied samples. It comprises the common calc-agglutinated, infaunal forms with elongat-

ed tapered or subcylindrical shape *B. nodosaria*, *E. bradyi*, *K. bradyi*, *M. communis*, and *Textularia* spp. The ovoidal *B. gibbosa* and the stout subcylindrical *C. rudis* were included in this morphogroup.

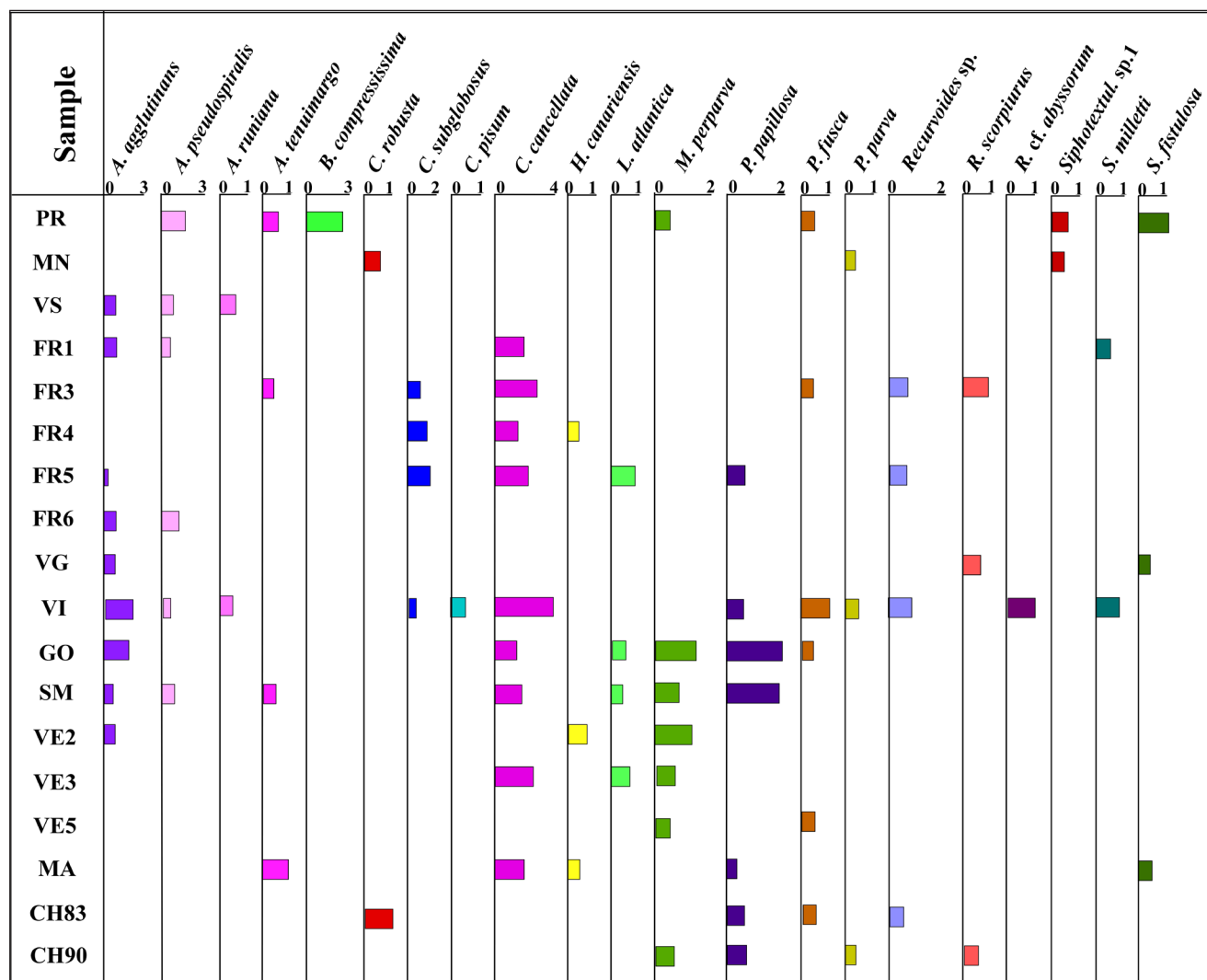


Fig. 8 - Sample abbreviation, percentages of the rare agglutinated species *A. agglutinans*, *A. pseudospiralis*, *A. runiana*, *A. tenuimargo*, *B. compressissima*, *C. robusta*, *C. subglobosus subglobosus*, *C. pisum*, *C. cancellata*, *H. canariensis*, *L. atlantica*, *M. perparva*, *P. papillosa*, *P. fusca*, *P. parva*, *Recurvoides* sp., *R. scorpiurus*, *R. cf. abyssorum*, *Siphotextularia* sp.1, *S. milleti*, and *S. fistulosa* collected in small outcrops from the central Piedmont region. Sample abbreviations, as in Fig. 7.

The milioline shaped morphotype is given by *S. schlumbergeri*, correlated to the morphogroup C both for its flattened-tapered shape and for its inferred infaunal microhabitat (Violanti 2000; Murray et al. 2011). It shows low percentages in the fine sediments, whereas it is absent or insignificant in the inner shelf silty sands and sands. Morphogroup D, including the flattened trochospiral and planispiral epiphytal forms, is totally absent.

DISCUSSION

Quantitative analyses of agglutinated foraminifers were carried out on the sections and small outcrops previously described and selected for their good documentation of the Pliocene succession in

the Piedmont, both from the biostratigraphic and the paleoenvironmental point of view. The agglutinated taxa distribution and inferred paleoenvironmental significance will be discussed following the stratigraphic sequence. Parameters concerning the total foraminiferal assemblages such as the P/(P+B-ST-SW) ratio %, the Diversity H Index, the A/B % and the AGN provide the framework to investigate the paleoenvironmental requirement of the agglutinated species.

Calcareous-cemented species distribution

K. bradyi, *M. communis*, *S. schlumbergeri* and rare *Textularia* spp. are the only agglutinated taxa found at the base of the Pliocene (Fig. 2), among the benthic re-immigrants the Mediterranean Sea after the Messinian Salinity Crisis. They occur in assemblages

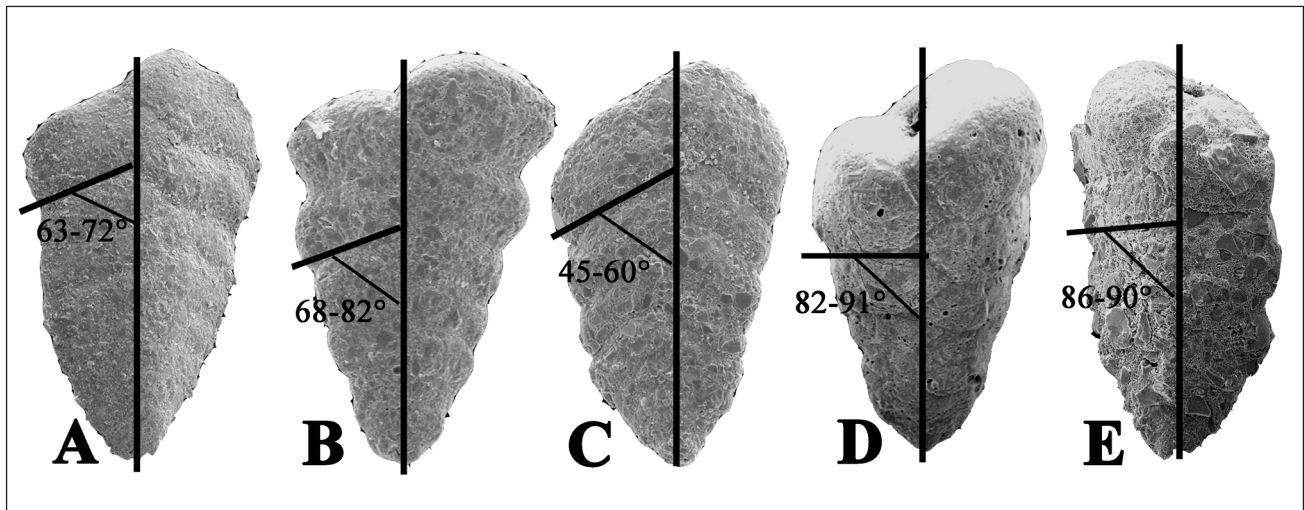


Fig. 9 - Range of the angle values, measured between the chamber upper suture and the median axis in: A = *S. wrighti*, B = *Spiroplectinella* sp., C = *T. aciculata*, D = *T. agglutinans*, E = *T. sagittula*.

strongly dominated by planktonic foraminifers, and with benthic species documenting an upper epibathyal setting and mesotrophic conditions, probably influenced by seasonal productivity (Trenkwalder et al. 2008).

K. bradyi was collected with low percentages in almost all the MPI1 and MPI2 samples and in some of the MPI3 assemblages. This deep circalittoral to epibathyal species (Wright 1978; Murray 2006) is seldom reported in other Pliocene rather deep assemblages of Piedmont (Martinis 1954).

M. communis also occurs in most of the assemblages dated to the MPI1-MPI3 zones (Figs. 2, 3), it is rather common in few small outcrops (Fig. 7), with rather high P/(P+B-ST-SW) ratios and well diversified deep circalittoral/upper epibathyal assemblages. As *K. bradyi*, it is absent in the younger and shallower shelf assemblages of the clayey and sandy silts widespread in the region.

The small *M. perparva* was found in samples dated to the MPI1 zone and in other few deep assemblages of the MPI3 and MPI4a zones (Figs. 2, 3, 8). The taxon, extinct during the MPI5 zone at about 2.4 My (Sprovieri 1986), in the Pliocene Piedmont succession is rare and sporadic, restricted to the deepest assemblages of the area, from marly clays with high to very high P/(P+B-ST-SW) values (60-80%), and rather low A/B%. Rare specimens of the taxon were seldom recorded in Pliocene sediments of the Mediterranean area (Sprovieri 1986; Barra et al. 1998). Therefore, the extinct *M. perparva* seems to have been preferential of deep epibathyal

or mesobathyal depths and its distribution appears more restricted than that of *M. communis*, for probably a more selective ecological requirement.

S. schlumbergeri is the only porcellanaceous species recovered in most of the studied samples, here included in the agglutinated group because of its agglutinated outer coating (Fontanier et al. 2003; Mancin et al. 2015). Only at the base of the Moncucco T. section, MPI1 zone, *S. schlumbergeri* reached a percentage about 5%. It was discontinuously found with abundances less than 3% in the marly clays, clays and clayey silts dated to the MPI2 to MPI3 zones (Figs. 2, 3, 4, 7). *S. schlumbergeri*, a shallow infaunal form (Jorissen & Wittling 1999), positively correlates with high organic matter (Jorissen 1987). The low abundance of *S. schlumbergeri* in the Piedmont, in comparison with those registered in high productivity areas, suggests a rather low availability of food and low surface productivity in the area during most of the Pliocene.

The bathyal *E. bradyi* and *C. rudis*, absent at the base of the Pliocene, occur in the epibathyal assemblages slightly later during the MPI1 zone (Fig. 2) and up to the MPI3 zone (*C. rudis*) or to the MPI4a subzone (*E. bradyi*) with low abundances, <3% and <4%, respectively (Fig. 2). These species re-entered the Mediterranean basin following the influx of the deep-marine calcareous benthic taxa such as *Cibicidoides kullenbergi* (Parker, 1953), *Cibicidoides robertsonianus* (Brady, 1881), and *Siphonina reticulata* (Czjžek, 1848) (Sgarrella et al. 1997), and contributed to the increased benthic diversity and abundance

of agglutinated forms in the lowermost Zanclean. *C. rudis* is recorded from bathyal settings (Sprovieri 1986; Violanti 1987; Sprovieri & Hasegawa 1990). It predominantly selected biogenic grains, most of them foraminiferal fragments or tests, embedded in abundant calcareous cement. Fragments of planktonic foraminifers are abundant on the test surface, and appear to be preferentially picked. Therefore, the distribution of *C. rudis* seems directly related to a sea-floor rich in biogenic debris and abundant planktonic tests. *E. bradyi*, as *C. rudis*, is absent at the base of the Pliocene and occurs slightly later during the MP11 zone (Fig. 2). Its delayed occurrence as well as its early disappearance in comparison with that of *K. bradyi* agree with data of Phleger et al. (1953) and indicate a deeper paleobathymetrical settings for *E. bradyi* than *K. bradyi*.

In comparison with the previous species, *B. nodosaria* was found later in the MP11 zone, in assemblages with slightly decreasing P/(P+B-ST-SW) ratios (Fig. 2). The cosmopolitan *B. nodosaria* is one of the most common agglutinated foraminifers in the studied succession, even if in general with low percentages. The species is reported as a shelf taxon (Blanc-Vernet 1969; Milker & Schmiedl 2012), but was also reported from open-sea, bathyal recent and fossil assemblages (Hasegawa et al. 1990; Frontalini et al. 2014; Symphonia & Senthil 2019). Living specimens of the shallow to intermediate infaunal *B. nodosaria* were reported from mesotrophic upper slope stations (Contreras-Rosales et al. 2012). These data support the hypothesis that in the Piedmont Pliocene epibathyal settings *B. nodosaria* is autochthonous, and not displaced from shallower depths.

Rare *Textularia* spp. are documented from the basal Pliocene (Fig. 2), and are very rare or absent in the deep circalittoral/epibathyal assemblages of the region, with high or middle P/(P+B-ST-SW) ratios and low A/B percentages (Figs. 3, 7, 9). High frequency and diversity of *Textularia* spp. are registered in the silty clays, clayey silts and sandy silts (Figs. 4, 5, 6), as part of assemblages with low to very low P/(P+B-ST-SW) %, common calcareous benthic forms, typical of muddy infralittoral to circalittoral depths such as *Brizalina* spp., *Bulimina* spp., *Cassidulina carinata* Silvestri, 1896, *Nonion boueianum* (d'Orbigny, 1846) (Murray 2006). *T. aciculata* is the dominant species of the group in silty clays or clayey silts rich in *D. arietina*, an opportunistic suspension-feeding polychaete, typical of shallow

circalittoral environments, periodically disturbed by episodes of instability (Peres & Picard 1964; Hartley 2014). *T. aciculata* is common to frequent in the clayey to sandy silts cropping out in the neighbourhood of Asti, overlaying the AA or heteropic between the AA and the SA. These silts show lithologies and fossil assemblages with intermediate characteristics between those of the previous two formations and can be interpreted as circalittoral prodelta deposits, characterized by large amount of clayey-silty sediments, abundant organic matter and moderate dysaerobic conditions. *T. aciculata* is reported from many Pliocene and Pleistocene marine delta successions (Coppa et al. 2001; Di Bella et al. 2002) and from Po Plain Quaternary and Recent sediments (Fiorini & Vaiani 2001; Fiorini 2004). On the basis of this distribution, *T. aciculata* seems to be a rather shallow taxon, preferential of silty-sandy sediments, subjected to periodical supply of mud, and well suited to unstable conditions, such as those influenced by river inflows. Its increasing abundance in the area around the Asti town could be related to the tectonic and regressive phase active during the late Zanclean (Ghielmi et al. 2019), that led to the infilling of the area by prograding and interfingering delta river fronts.

B. gibbosa (Figs. 4, 5, 6) shows a distribution similar to that of *T. aciculata*, and is frequently recorded in the clayey silts and sandy silts dated to MP13-MP14 zones (Martinis 1954; Ghielmi et al. 2019). The taxon is absent in the older bathyal assemblages and rare in the infralittoral sands of the Astian facies (Sampò et al. 1968) and appears to be typical of deep infralittoral and shallow circalittoral depths.

Organic- and ferruginous-cemented species distribution

Specimens of the organic- or ferruginous-cemented taxa found in the Piedmont Pliocene assemblages, such as *Ammoscalaria* spp., *C. pisum*, *C. cancellata*, *H. canariensis*, *L. atlantica*, *P. papillosa*, *Psammospaera* spp., *Recurvoides* sp., *R. cf. abyssorum* and *R. scorpiurus*, are very fragile, easily broken during the study procedures. Therefore, reworking was excluded for their poor preservation potential. For some species, transport or displacement cannot be excluded, suggested by the common broken chambers of *A. agglutinans*, *C. cancellata* and *Recurvoides* sp. Frequencies of the single taxa are often very low

and could be considered as negligible or casual. But the co-occurrence of some or several organic- or ferruginous-cemented taxa in the same sample, as well as their finding in a rather restricted geographic area of the central Piedmont, in a time-interval pertaining to the MPL3 zone, appear significant of peculiar paleoenvironmental conditions.

Sediments yielding these rare forms were sampled at south of Asti, from the hills bordering the Tanaro river valley, and from a northern sector in the Monferrato, south of the Moncalvo town (Fig. 1B). The latter localities are at the southern margin of the “Pliocene Moncalvo gulf” (Sacco 1889), and near to the La Torretta and Calliano outcrops of diatomaceous silts and clays, interpreted as evidences of seasonal rather high productivity episodes during the Zanclean (Violanti et al. 2011a). In the Astigiano, like the other agglutinated taxa, they are absent in the laminated layers, deposited during episodes of sea-floor dysoxia. Therefore, well oxygenated sediments seem to be required for the diffusion of the organic-cemented agglutinated foraminifers.

Data on living assemblages report common to frequent *A. agglutinans*, *C. subglobosus*, *Psammosphaera* spp. and *R. scorpiurus* in mesotrophic environments (Fontanier et al. 2005). *A. pseudospiralis*, *H. canariensis*, *L. atlantica*, *P. fusca*, *R. cf. abyssorum*, *R. scorpiurus*, together with *B. nodosaria* and *T. sagittula*, were reported in rather shallow recent assemblages along the coasts of Turkey, in areas influenced by currents or by deep sea waters (Meriç et al. 2014). All these data document a strong relation among these agglutinated taxa, trophic environment and water circulation, which could explain their finding in the studied sites.

Tests of organic or ferruginous-cemented taxa here recovered could be the “survivors”, fortuitously preserved as part of a more abundant non-fossilising foraminiferal fauna. The occurrence of many fragile species during the MPL3 zone, in sediments deposited on the outer shelf or upper slope, and in assemblages indicating a good sea-floor oxygenation, suggests enhanced circulation and nearly mesotrophic conditions in part of the Asti basin and Monferrato during this time interval. Increasing tectonic activity, leading to the Intra-Zanclean deformation phase and the regressive phase (Ghielmi et al. 2019) as well as seasonality can be at the origin of local condition of strong

currents and water mixing, similar to those now present along canyon or straits slopes and margins (Fontanier et al. 2005; Frontalini et al. 2014).

Morphogroup distribution

The morphogroup methodology was applied for a broad comparison of agglutinated foraminiferal assemblages and paleoenvironments.

The presence of morphogroup A is interpreted as an indicator of a contour current or deeper food-carrying bottom currents (Kaminski et al., 1989; Murray et al. 2011). Despite the low abundance, the presence of the organic- or ferruginous-cemented taxa, included in the morphogroups A (*R. cf. abyssorum*) and B (*C. pisum*, *L. atlantica*, *Psammosphaera* spp., *C. subglobosus subglobosus*, *C. cancellata* and *H. canariensis*) is here interpreted as an evidence of counter currents active in the central Piedmont area during the Zanclean MPL3 zone. The strong dominance of the morphogroup C was interpreted by Jones & Charnock (1985), Kuhnt et al. (1996), Kaminski et al. (1999), Mancin (2001), and Murray et al. (2011) as typical of assemblages from the continental shelf to the upper continental slope, such as those documented in the studied area.

The absence of morphogroup D, including the epiphytal but also interstitial (Jones & Charnock 1985; Violanti 2000) trochamminids, was also observed in the older Epiligurian succession (Mancin 2001) and could be a result of taphonomic processes.

CONCLUSIONS

The general assemblages composition confirms the dominance, or the exclusive presence, of calc-agglutinated infaunal species of elongated tapered or subcylindrical shape, included in the Morphogroup C, and shows significant variations in specific diversity and abundance, strictly related to different paleoenvironmental settings.

The re-flooding of the Mediterranean basin after the MSC and the re-entry from the Atlantic Ocean of foraminifers are evidenced also by agglutinated taxa in the lowermost Pliocene layers, characterized by less diversified assemblages with *K. bradyi*, *Martinottiella* spp., *S. schlumbergeri* and rare *Textularia* spp. The progressive rise of the sea level, registered in the Mediterranean basin during the

MPI1 zone and documented by the influx of deep water calcareous benthic species such as *C. robertsonianus*, *S. reticulata*, and of abundant planktonic taxa, among them the mesopelagic *Sphaeroidinellops* spp., is also registered by the occurrence of *C. rudis*, *C. robusta* and *E. bradyi*. The low frequency of these bathyal species, and the common occurrence of the deep circalittoral to epibathyal *B. nodosaria* and *M. communis*, suggest upper slope depths and open marine conditions during the earliest Pliocene, MPI1 and MPI2 zones, in the central part of the basin. The small, very rare, deep agglutinated *M. perparva* is the first to disappear from the counted fractions. It seems one of the most sensitive agglutinated taxa to the paleoenvironmental changes occurring in the area during the Zanclean. From the MPI3 zone upward, the deepest agglutinated species *C. rudis*, *E. bradyi*, *K. bradyi*, and *M. communis* become progressively rarer or disappear, indicating a reduction in bathymetry and width of the Pliocene marine basin. Diatomitic clays, related to rather high, probably seasonal, productivity episodes, crop out at Calliano and in the nearby Monferrato area. In this time interval, dysaerobic sea-floor conditions are documented by laminated layers at Isola d'Asti. The organic or ferruginous-cemented taxa were found only in sediments deposited after the diatomitic clays or before the laminated layers, suggesting normal or good oxygenation. Among the total of 42 agglutinated species identified in the Lower Pliocene succession of the central Piedmont, many of them were very seldom found, such as *C. cancellata*, *R. scorpiurus* and *R. cf. abyssorum*, or were never reported, such as *A. agglutinans*, *Ammoscalaria* spp., *B. compressissima*, *C. subglobosus subglobosus*, *C. pisum*, *H. canariensis*, *L. atlantica*, *Psammospaera* spp., *P. papillosa*, *S. milletti*, and *S. fistulosa*.

The occurrence of the rare organic-cemented taxa in the central part of the Piedmont basin is here suggested as the only signal of not otherwise registered paleoenvironmental conditions, such as a locally active deep circulation, a rather mesotrophic bottom waters, a complex sea-floor paleomorphology, and seasonality, all influenced by the increasing tectonic activity and by harbingers of the Late Pliocene climatic deterioration.

In the shallower and younger sediments of the MPI4a subzone, agglutinated foraminifers are frequent but poorly diversified. The highest abundance of *Textularia* spp., dominated by *T. aciculata*,

and of *B. gibbosa* is recorded in shallow circalittoral unstable muddy layers, widespread in the Astigiano area, and interpreted as prograding and interfingering fan-delta sediments. *T. aciculata* is suggested as a typical agglutinated species of shallow marine deposits and, when common to frequent, indicative of a deltaic paleoenvironment.

TAXONOMIC NOTES

The taxonomic description of the agglutinated foraminifers recovered in the Pliocene succession of the Piedmont region is here presented. The specific classification was firstly based on the author's taxon original description and drawings and largely follows van Morkhoven et al. (1986), Loeblich & Tappan (1987), Kaminski (2004), Kaminski & Gradstein (2005), Mikhalevich & Kaminski (2007), Mikhalevich (2011; 2013), Hayward et al. (2023) and WoRMS (2023). Data on cement composition are from Hedley (1963), Banner & Pereira (1981), Loeblich & Tappan (1985; 1987; 1989), Bender (1995), Kaminski (2004). Taxa are alphabetically listed.

Ammobaculites agglutinans (d'Orbigny, 1846)

Pl. 1, figs. 1-3

1846 *Spirolina agglutinans* d'Orbigny, p. 137, pl. 7, figs. 10-12.

1920 *Ammobaculites agglutinans* - Cushman, pp. 60-61, pl. 12, fig. 3.

1937 *Ammobaculites agglutinans* - Chapman & Parr, p. 142, pl. 10, fig. 37.

1985 *Ammobaculites agglutinans* - Papp & Schmidt, p. 54, pl. 45, figs. 6-9.

2005 *Ammobaculites agglutinans* - emend. Bartenstein, 1952 - Kaminski & Gradstein, pp. 324-328, pl. 70, figs. 1-8, text-figs. 70.1-3.

2016 *Ammobaculites agglutinans* - Stefanoudis et al., p. 25, pl. 1, figs. 7-8.

Test large, planispiral in the early stage, later uniserial. Planispiral stage involute with 4-5 chambers in the last whorl, fairly depressed umbilicus. Uniserial stage with low, broad chambers, rounded in transverse section. Sutures more depressed in the planispiral stage than in the uniserial portion. Wall coarsely agglutinated, imperforate, with organic cement. Aperture rounded, terminal in the uniserial stage, a basal slit in the planispiral stage.

Remarks. This cosmopolitan species is reported from Late Cretaceous to Recent circalittoral to abyssal depths (Kaminski & Kuhnt 1991; Kaminski & Gradstein 2005; Stefanoudis et al. 2016), and interpreted as an epifaunal/shallow infaunal form

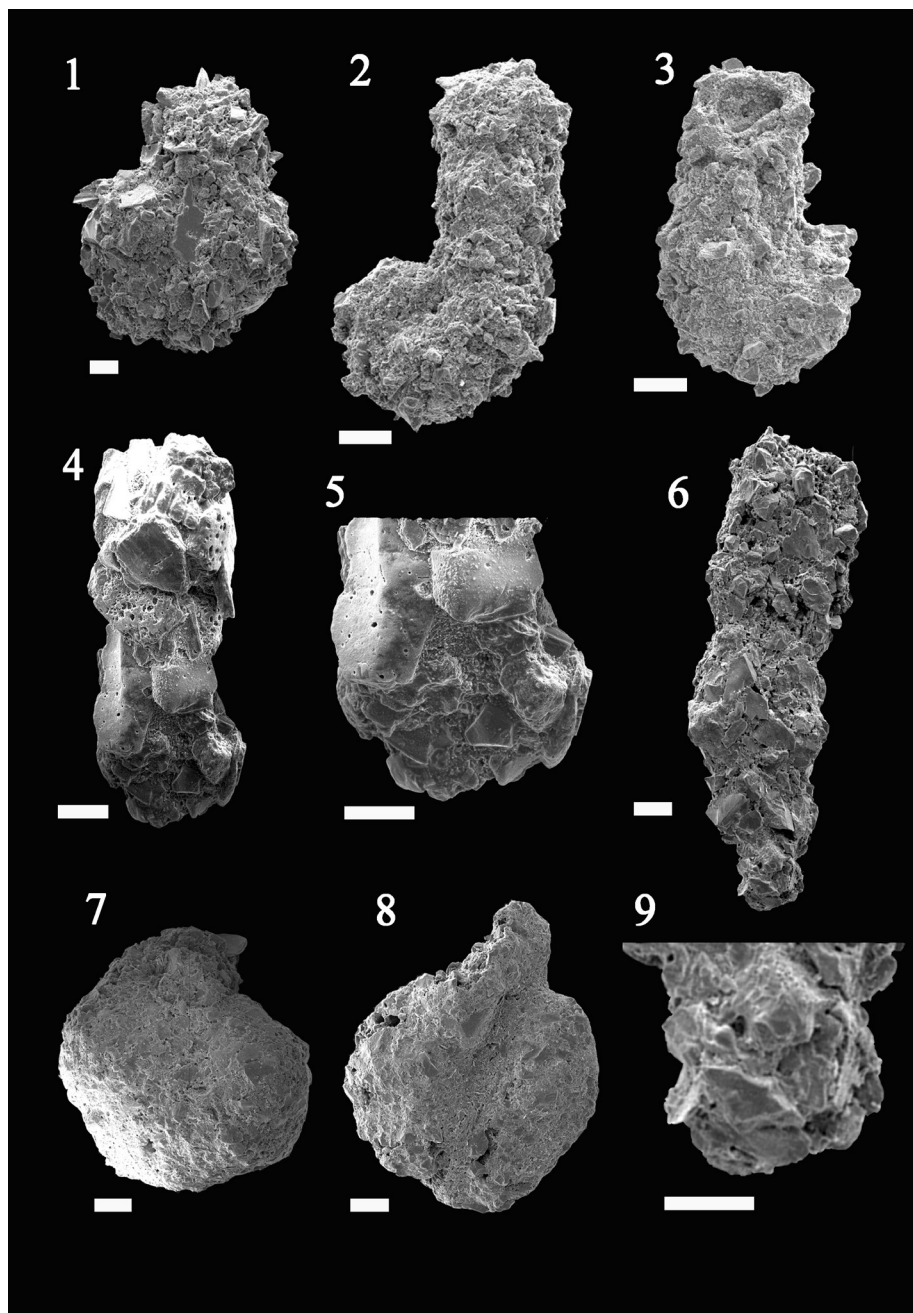


PLATE 1

- Fig. 1 - *Ammobaculites agglutinans* (d'Orbigny, 1846), S. Martino Alfieri, SM, lateral view.
 Fig. 2 - *Ammobaculites agglutinans* (d'Orbigny, 1846), Isola d'Asti, 5.5 m, lateral view.
 Fig. 3 - *Ammobaculites agglutinans* (d'Orbigny, 1846), Isola d'Asti, 5.5 m, lateral view.
 Fig. 4 - *Ammoscalaria pseudospiralis* (Williamson, 1858), Primeglio, PR, lateral view.
 Fig. 5 - *Ammoscalaria pseudospiralis* (Williamson, 1858), Primeglio, PR, enlargement of specimen in Fig. 4.
 Fig. 6 - *Ammoscalaria tenuimargo* (Brady, 1884), Monticello d'Alba, MA, lateral view.
 Fig. 7 - *Ammoscalaria runiana* (Heron-Allen & Earland, 1916), Vigliano d'Asti, VI, lateral view.
 Fig. 8 - *Ammoscalaria runiana* (Heron-Allen & Earland, 1916), S. Martino Alfieri, SM, lateral view.
 Fig. 9 - *Ammoscalaria tenuimargo* (Brady, 1884), Monticello d'Alba, MA, enlargement of specimen in Fig. 6.
 White bar = 100 µm.

(Kuhnt et al. 2000). Sgarrella et al. (1985) found rare specimens in the infralittoral zone of the Gulf of Policastro (Tyrrhenian Sea), only near rivers mouths. It occurs also in recent assemblages from brackish to shallow marine sediments of the Northern Adriatic (Capotondi et al. 2019) as well along the Aegean coasts (Frontalini et al. 2014). Kaminski & Kuhnt (1991) related its variations in size and test morphology to the bathymetry and noted an increase in the number of uniserial chambers in the abyssal forms, in comparison with shelf and bathyal ones.

In the studied Pliocene assemblages, this taxon was found in samples referred to the MP13

foraminiferal zone and to circalittoral or upper epibathyal depths. Many specimens were broken or showed a very short uniserial stage, suggesting transport and a rather shallow paleoenvironment.

Ammoscalaria pseudospiralis (Williamson, 1858)

Pl. 1, figs. 4-5

- 1858 *Proteonina pseudospiralis* Williamson, p. 2, pl. 1, figs. 2-3.
 1930 *Ammobaculites pseudospirale* - Lacroix, pp. 12-13, figs. 15-16.
 1960 *Ammoscalaria pseudospiralis* - Barker, pl. 33, figs. 1-4.
 1980 *Ammoscalaria pseudospiralis* - Boltovskoy et al., p. 54, pl. 35, figs. 4-7.
 1991 *Ammoscalaria pseudospiralis* - Cimerman & Langer, pp. 18-19, pl. 5, figs. 4-6.
 2003 *Ammoscalaria pseudospiralis* - Murray, p. 11, figs. 2-3.

Test elongate, compressed, planispiral in the early stage, then uniserial. Planispiral portion involute, with 1-1.5 whorls, uniserial portion formed by 3-6 nearly rectangular chambers. Sutures very slightly depressed. Aperture terminal, at the end of a neck more or less produced. Wall coarsely agglutinated, imperforate, with organic cement.

Remarks. This cosmopolitan taxon occurs in a wide depth and latitude range (Chapman & Parr 1937; Murray 2006), from more or less sandy deposits between 20 and 50 m in the Gullmar Fjord (Höglund 1947), rare in shallow fjord and shelf and common in deep shelf assemblages (Murray & Alve 2011). In the Mediterranean area it was reported from recent biogenic, detritic sediments of submerged banks (Moncharmont Zei 1962), from muddy shelf (Blanc-Vernet 1969), and upper slope sediments (Sgarrella & Moncharmont Zei 1993; Meriç et al. 2014). It was interpreted as a shallow infaunal form (Barmawidjaja et al. 1992).

In the studied material, rare *A. pseudospiralis* occurs in silty or sandy clays from the Asti area dated to the MP13 zone and in samples PR and FR6 from the Monferrato.

Ammoscalaria runiana (Heron-Allen & Earland, 1916)

Pl. 1, figs. 7-8

- 1916 *Haplophragmium runianum* Heron-Allen & Earland, p. 224, pl. 40, figs. 15-18.
 1947 *Ammoscalaria runiana* - Höglund, pp. 162-163, pl. 9, figs. 23-24, text-fig. 137.
 1971 *Ammoscalaria runiana* - Murray, p. 29, pl. 7, figs. 6-8.
 1991 *Ammoscalaria runiana* - Cimerman & Langer, p. 19, pl. 5, figs. 7-8.
 2011 *Ammoscalaria runiana* - Murray & Alve, p. 25, figs. 15. 2-5.

Test compressed, planispirally coiled, involute, with a terminal uncoiled part. Test with 4-8 chambers in the last whorl, with a subrectangular last uncoiled chamber. Sutures indistinct. Aperture terminal, irregular. Wall coarsely agglutinated, imperforate, with organic cement.

Remarks. The taxon, described by Heron-Allen & Earland (1916), is characterized by a very short uniserial portion, a less compressed text with more abundant cement in comparison to *A. pseudospiralis* and *A. tenuimargo*. It is a shallow water, intertidal-subtidal brackish taxon common in fine to medium sand with <20% mud and low TOC and salinity (Alve & Murray 1999; Murray & Alve 2011).

More commonly described in northern basins, at depths between 5 and 33 m (Höglund 1947; Schönfeld & Numberger 2007). It was also reported in the northern Adriatic, between 0.2 and 1 m depth (Cimerman & Langer 1991; Ćosović et al. 2011).

Rare specimens confidently attributable to this taxon were collected in the circalittoral to upper epibathyal assemblages of samples VI and SM, dated to the MP13 Zone.

Ammoscalaria cf. *tenuimargo* (Brady, 1884)

Pl. 1, figs. 6, 9

- 1884 *Haplophragmium tenuimargo* Brady, p. 303, pl. 33, figs. 13-16.
 1920 *Ammobaculites tenuimargo* - Cushman, pp. 65-66, pl. 13, figs. 3-5.
 1947 *Ammoscalaria tenuimargo* - Höglund, pp. 154-159, pl. 9, figs. 16-22, pl. 31, fig. 2, text-figs. 133-136, 138-139.
 1980 *Ammoscalaria tenuimargo* - Boltovskoy et al., p. 54, pl. 35, figs. 8-11.
 1993 *Ammoscalaria tenuimargo* - Sgarrella & Moncharmont Zei, p. 160, pl. 2, fig. 11.
 2011 *Ammoscalaria tenuimargo* - Murray & Alve, p. 25, figs. 16. 13-15.

Test elongate, much compressed, initially planispiral, then uniserial. Proloculus subspherical, planispiral portion involute, uniserial portion with 4-8 irregularly rectangular chambers, increasing in size as added. Sutures slightly depressed to indistinct. Aperture terminal. Wall very coarsely agglutinated, imperforate, with organic cement.

Remarks. The taxon is cosmopolitan, reported from bathyal depths in the Atlantic (Cushman 1920), it was also found living at depths ranging from 250 to 2668 m (Murray 2006), between 200 and 700 m in the Skagerak (Höglund 1947), occasionally common in shelf deep bottoms (Murray & Alve 2011). Boltovskoy et al. (1980) included *A. pseudospiralis* and *A. tenuimargo*, such as the whole genus *Ammoscalaria*, among the hypoaline forms of the southern Brazil and the Rio de la Plata. In the Mediterranean Sea, rare specimens have been documented from sandy pelitic and pelitic infralittoral and circalittoral sediments of the Gulf of Policastro and the Gulf of Salerno (Sgarrella & Barra 1985; Sgarrella et al. 1985), between 25 and 445 m in the Gulf of Naples (Sgarrella & Moncharmont Zei 1993).

Specimens here determined as *A. cf. tenuimargo* differ from those described by Brady (1884) for a reduced number of chambers and a stouter test. The last chamber, larger than the previous ones and the internal structure, observed in transmitted light, agrees with the characters of the taxon as described by Höglund (1947).

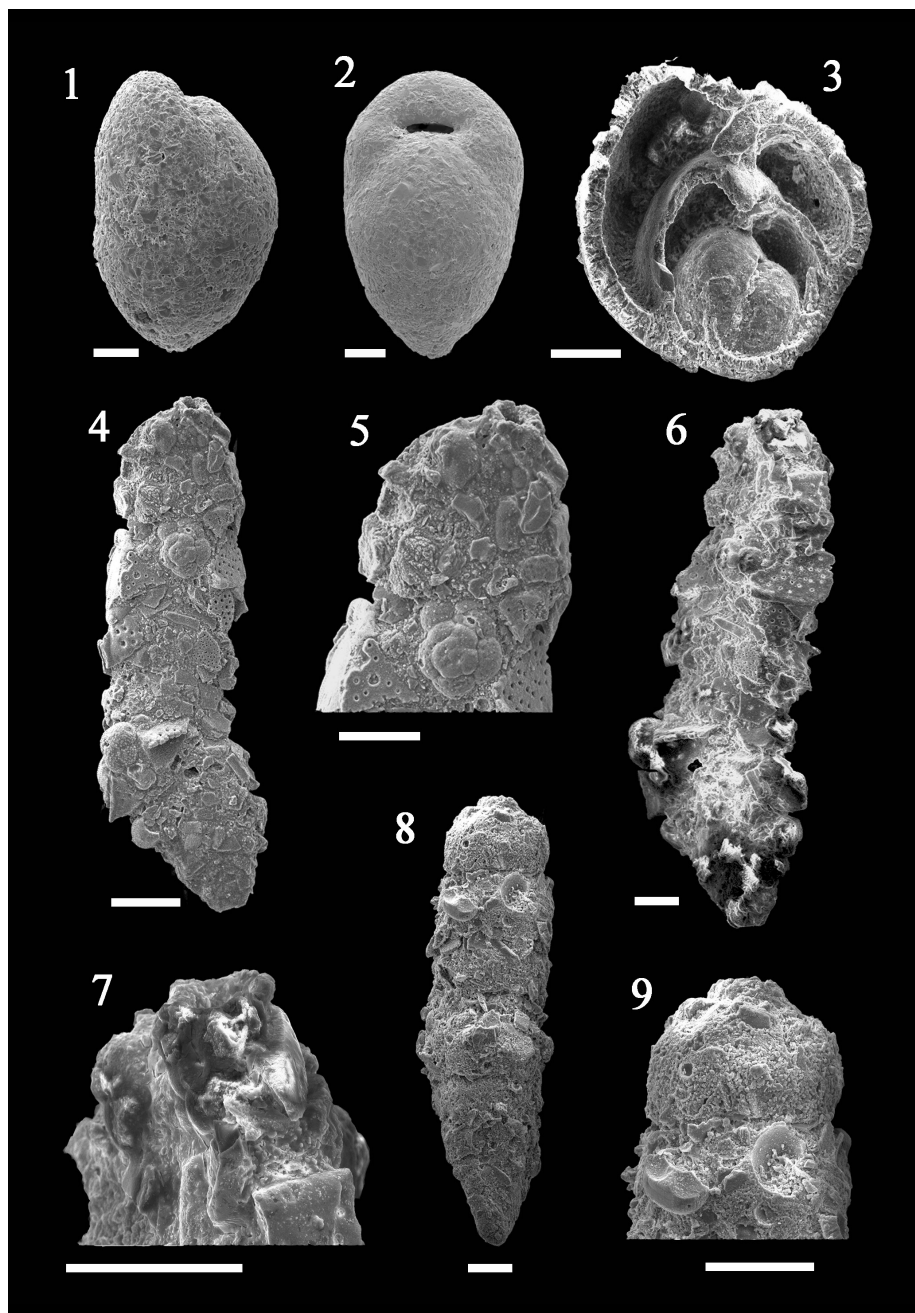


PLATE 2

Fig. 1 - *Bannerella gibbosa* (d'Orbigny, 1826), Incisa S., 9 m, lateral view.

Fig. 2 - *Bannerella gibbosa* (d'Orbigny, 1826), Incisa S., 23 m, edge view.

Fig. 3 - *Bannerella gibbosa* (d'Orbigny, 1826), Primeglio, PR, internal view.

Fig. 4 - *Bigenerina compressissima* Colom, 1946, Primeglio, PR, lateral view.

Fig. 5 - *Bigenerina compressissima* Colom, 1946, Primeglio, PR, enlargement of specimen in Fig. 4.

Fig. 6 - *Bigenerina compressissima* Colom, 1946, Primeglio, PR, lateral-edge view.

Fig. 7 - *Bigenerina compressissima* Colom, 1946, Primeglio, PR, enlargement of specimen in Fig. 6.

Fig. 8 - *Bigenerina nodosaria* d'Orbigny, 1826, Moncucco T., 4 m, lateral view.

Fig. 9 - *Bigenerina nodosaria* d'Orbigny, 1826, Moncucco T., 4 m, enlargement of specimen in Fig. 8.

White bar = 100 µm

It was found in the samples PR, SM and MA, with percentages <1%.

Bannerella gibbosa (d'Orbigny, 1826)

Pl. 2, figs. 1-3

1826 *Textularia gibbosa* d'Orbigny, p. 262, n. 28.

1887b *Textularia gibbosa* - Fornasini, pp. 160-161, pl. 2, fig. 1.

1937 *Dorothia gibbosa* - Cushman, p. 92, pl. 10, figs. 11-13.

1982 *Dorothia gibbosa* - Agip, pl. 4, fig. 6.

1985 *Bannerella gibbosa* - Loeblich & Tappan, p. 201, pl. 13, figs. 1-6.

2005 *Dorothia gibbosa* - Rasmussen, pp. 55-56, pl. 1, figs. 9-10

Test large, ovoidal in the adult, subspherical in juvenile forms, initially trochospirally coiled with

3-5 chambers in the early whorl, very soon growing in biserial stage. Chambers inflated, increasing in size rapidly. Suture very slightly depressed. Aperture a low arch, at the base of the final chamber. Wall thick, outer surface smooth, with calcareous cement.

Remarks. The *B. gibbosa* stratigraphic range is controversial: it is reported from the Oligocene to the Recent by Salvatorini (1968), from the lowermost Pliocene to the Quaternary by Agip (1982). It is also accepted as living by WoRMS (2023). Commonly reported in Pliocene shelf assemblages of the Mediterranean area (Martinis 1954; Sampò et al.

1968; Jonkers 1984; Rio et al. 1988; Di Bella et al. 2002; Rasmussen 2005; Violanti & Sassone 2008), and also recorded in middle Pleistocene assemblages of Southern Italy (Coppa et al. 2001). Blanc-Vernet (1969) considers the species went extinct in the Mediterranean during the Early Quaternary. It was never found in the literature concerning recent benthic foraminifera of the Mediterranean Sea (Cimerman & Langer 1991; Sgarrella & Moncharmont Zei 1993; Alfrević 1998; Banchetti et al. 2008; Milker & Schmiedl 2012; Frontalini et al. 2014; Capotondi et al. 2019).

The species is absent or very rare in the Piedmont lowermost Pliocene upper epibathyal sediments of the MPI1-MPI2 zones. It is common in clayey silts and sandy silts of MPI3-MPI4 zones, from deep infralittoral and shallow circalittoral deposits, widely cropping out in the Asti area.

Bigenerina compressissima Colom, 1946

Pl. 2, figs. 4-7

1946 *Bigenerina compressissima* Colom, p. 130, pl. 4, figs. 37-42.

1987 *Bigenerina compressissima* - Violanti, pp. 262-263, pl. 1, figs. 5-7.

Test elongate, rather small, initially biserial, compressed, consisting of 4-5 pairs of chambers, followed by a longer uniserial stage with 1 to 4-7 very compressed subrectangular chambers, about half high than broad. Straight, slightly depressed sutures. Aperture terminal, subrounded, compressed in the uniserial stage. Wall coarsely agglutinated, rather thin, with little calcareous cement.

Remarks. The species was originally described from the Miocene of Mallorca (Colom 1946). Very rare, well preserved specimens were described in the Lower Pliocene (MPI3 Zone) assemblages of the Rio Torsero (Liguria, Northwestern Italy) (Violanti 1987).

In the studied area *B. compressissima* was found in sample PR, dated to the MPI3 zone.

Bigenerina nodosaria d'Orbigny, 1826

Pl. 2, figs. 8-9

1826 *Bigenerina nodosaria* d'Orbigny, p. 261, pl. 11, figs. 9-11.

1911 *Bigenerina nodosaria* - Cushman, pp. 27-28, figs. 46-48.

1974 *Bigenerina nodosaria* - Colom, p. 87, fig. 6 a-n.

1993 *Bigenerina nodosaria* - Sgarrella & Moncharmont Zei, p. 164, pl. 4, fig. 12.

2012 *Bigenerina nodosaria* - Milker & Schmiedl, p. 38, figs. 10.10-10.12.

2019 *Bigenerina nodosaria* - Symphonia & Senthil, p. 55, fig. 15.17.

Test elongate, initially biserial, compressed, consisting of 5-7 pairs of chambers, followed by a longer uniserial stage with 1 to 4-7 rounded chambers, about as high as broad. Aperture rounded in the uniserial stage, terminal, on a short neck. Wall coarsely agglutinated with calcareous cement and provided with parapores distally branched.

Remarks. The cosmopolitan species is living, reported from the Serravallian (Agip 1982) and is widespread in the Mediterranean circalittoral to upper bathyal assemblages (Blanc Vernet 1969; Colom 1974; Sgarrella & Moncharmont Zei 1993; Alfrević 1998; Milker & Schmiedl 2012; Meriç et al. 2014; Frontalini et al. 2014; 2015).

The species occurs in most of the studied samples. It reaches its highest frequencies in AA silts and sandy silts referred to the circalittoral zone. It is very rare or absent in the infralittoral Asti Sands.

Cribrogoesella robusta (Brady, 1881)

Pl. 3, fig. 1

1881 *Bigenerina robusta* Brady, pp. 53-54, 57-58.

1884 *Bigenerina robusta* - Brady, p. 371, pl. 45, figs. 9-16.

1960 *Cribrogoesella robusta* - Barker, p. 92, pl. 45, figs. 9-16.

1982 *Cribrogoesella robusta* - Agip, pl. 4, fig. 8.

1987 *Cribrogoesella robusta* - Loeblich & Tappan, p. 182, pl. 201, figs. 1-4.

Test elongate, subcylindrical, stout, initially trochospiral with about 3-4 whorls, then followed by a biserial, or streptospiral stage of 2-5 whorls and finally by a uniserial stage. Aperture rounded, interior-marginal in the early stages, cribrate, terminal in the adult uniserial stage. Wall medium to coarsely agglutinated, thick, porous, with calcareous cement.

Remarks. Cushman (1935) erected the genus *Cribrogoesella*, indicating as genotype *Bigenerina robusta* Brady, 1881, illustrated by Brady (1884). The species is reported in the Atlantic from Miocene to Holocene (Loeblich & Tappan 1987). It is very seldom recorded in the Mediterranean area from the Lower Pliocene to about the Middle Pleistocene assemblages (Sampò et al. 1968; Agip 1982; Rasmussen & Thomsen 2005). Blanc-Vernet (1969) reports rare *C. robusta* from Recent and Pleistocene bathyal Mediterranean muds. It was common in the recent Coral Rubble Facies of Santa Maria di Leuca deep-water coral province (Ionian Sea) (Rosso et al. 2010).

In the studied material *C. robusta* very seldom occurs, in sample 9.70 m at Moncucco T., and in samples MN and CH83.

Cribrostomoides subglobosus subglobosus
(Cushman, 1910)

Pl. 3, fig. 2

- 1869 *Lituola subglobosa* Sars, p. 250 (nomen nudum).
1910 *Haplophragmoides subglobosum* - Cushman, pp. 105-106, figs. 162-164.
1930 *Haplophragmoides subglobosum* - Lacroix, p. 11, fig. 13.
1947 *Labrospira subglobosa* - Höglund, pp. 144-145, pl. 11, fig. 2, text-fig. 126.
1974 *Haplophragmoides subglobosum* - Colom, pp. 73, 84, fig. 3, f-j.
2005 *Cribrostomoides subglobosus subglobosus* - Kaminski & Gradstein, pp. 391-395, fig. 92, 1-2, pl. 92, figs. 1-3.
2015 *Cribrostomoides subglobosus* - Kaminski et al., p. 318, fig. 6, J-L.

Test stout, subglobular, involute, initial stage streptospiral, later almost planispiral, 4-6 chambers in the last whorl, gradually increasing in size. Sutures slightly depressed or flush with the surface. Aperture a broad, low slit at the base of the apertural face, bordered by a lip. Multiple openings may occur in larger specimens. Wall thick, finely agglutinated, surface rather smooth, with organic cement, imperforate.

Remarks. A cosmopolitan species (Herb 1971; Murray 2006; Kaminski et al. 2015), known from the Late Cretaceous to Recent (Kaminski & Gradstein 2005). Commonly reported from bathyal to abyssal settings (Höglund 1947; Kuhnt et al. 2000; Kaminski & Gradstein 2005, with references). In the Mediterranean Sea it is recorded from infralittoral sediments (Sgarrella & Moncharmont Zei 1993; Meriç et al. 2014), circalittoral, upper bathyal and bathyal muds (Cimerman & Langer 1991; Fontanier et al. 2008; Frontalini et al. 2014; 2015).

In the studied material very rare specimens occur in the Isola d'Asti section, in samples FR3, FR5 and VI.

***Crithionina pisum* Goës, 1896**

Pl. 3, fig. 3

- 1896 *Crithionina pisum* Goës, p. 24, pl. 2, figs. 1-2.
1899 *Crithionina pisum* - Flint, pp. 266-267, pl. 6, fig. 1.
1947 *Crithionina pisum* - Höglund, pp. 35-36, pl. 2, figs. 1-2; pl. 25, figs. 8-14, 31; text-fig. 7.
1971 *Crithionina pisum* - Herb, pl. 9, fig. 9.
1994 *Crithionina pisum* - Loeblich & Tappan, p. 13, pl. 3, fig. 7.
1995 *Crithionina pisum* - Bender, pp. 32, 43, pl. 9, fig. 6.

Test large, spherical or subspherical, unilocular, wall very thick, loosely agglutinated with elements of different size, giving a rather rough outer surface, more regularly assemblaged on the inner

surface. Wall with organic cement, often porous, occasionally with branched channels.

Remarks. A very rare and seldom reported species, found at about 164 m in the Timor Sea (Loeblich & Tappan 1994) and in deeper stations, exceeding 200 m in depth (Höglund 1947) down to about 3,000 m (Flint 1899). Recorded as living in Antarctic waters (Violanti 1996; 2000).

In the studied material, it was found in sample VI.

***Cyclammina cancellata* Brady, 1879**

Pl. 3, figs. 4-5

- 1879 *Cyclammina cancellata* Brady, p. 62.
1884 *Cyclammina cancellata* - Brady, p. 351, pl. 37, figs. 8-15.
1974 *Cyclammina cancellata* - Colom, p. 84, fig. 4 d-e.
1995 *Cyclammina cancellata* - Bender, p. 43, pl. 5, fig. 6.
2005 *Cyclammina cancellata* - Kaminski & Gradstein, pp. 476-480, fig. 118-1, pl. 118a, figs. 1-4, pl. 118b, figs. 1-6.
2009 *Cyclammina cancellata* - Kender et al., p. 505, pl. 9, figs. 5-6.

Test large, planispiral, involute, biconvex. Perypheral margin rounded to subacute. Umbilical area depressed. Chambers numerous, about 9-12 in the last whorl, gradually increasing in size. Sutures slightly depressed, curved to sigmoid. Wall finely agglutinated, often containing coarse mineral grains, with an inner alveolar layer and an outer imperforate thin layer. Organic cement, imperforate.

Remarks. A cosmopolitan species, known from the Late Eocene to Recent, reported as bathyal to abyssal (Hermelin 1989; Kaminski & Gradstein 2005; Kaminski et al. 2008). In the recent assemblages of the Mediterranean Sea it was known from bathyal muds (Blanc-Vernet 1969), from 500 m depth downward (Colom 1974), rare in the deep-water coral province of Santa Maria di Leuca (Rosso et al. 2010). In the Gulf of Naples it was found in a depth range of 250-410 m (Scorziello 1979). Martinis (1954) reported rare *Cyclammina* sp. from the Pliocene sandy clays of Piedmont.

In the studied material, *C. cancellata* was recognized in samples from the Astigiano and Monferrato areas, dated to the MPI3 zone or of undetermined Pliocene age.

***Cylindroclavulina rudis* (Costa, 1855)**

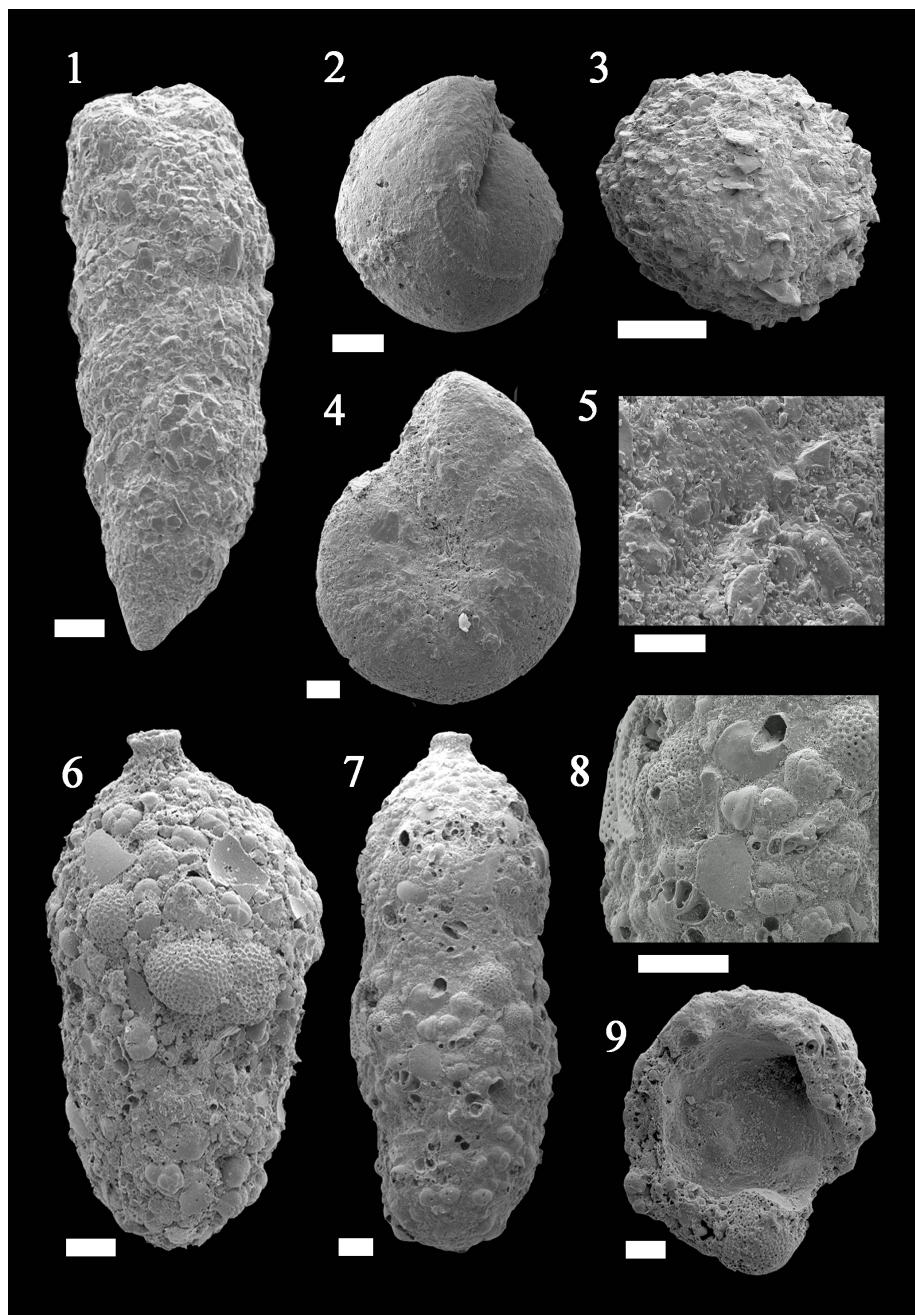
Pl. 3, figs. 6-9

- 1855 *Glandulina rudis* Costa, p. 142, pl. 1, figs. 12-13.
1884 *Clavulina cylindrica* - Brady, p. 396, pl. 48, figs. 32-38.
1894 *Clavulina rudis* - Fornasini, p. 23, pl. 19, fig. Z.

PLATE 3

- Fig. 1 - *Cribrrogoesella robusta* (Brady, 1881), Moncucco T., 9.7 m, lateral view.
 Fig. 2 - *Cribrrostomoides subglobosus subglobosus* (Cushman, 1910), Frinco, FR5, lateral view.
 Fig. 3 - *Crithionina pisum* Goës, 1896, Vigliano d'Asti, VI, lateral view.
 Fig. 4 - *Cyclammina cancellata* Brady, 1879, Frinco, FR3, lateral view.
 Fig. 5 - *Cyclammina cancellata* Brady, 1879, Frinco, FR3, enlargement of specimen in Fig. 4.
 Fig. 6 - *Cylindroclavulina rudis* (Costa, 1855), S. Martino Alfieri, SM, lateral view.
 Fig. 7 - *Cylindroclavulina rudis* (Costa, 1855), Primeglio, PR, lateral view.
 Fig. 8 - *Cylindroclavulina rudis* (Costa, 1855), Primeglio, PR, enlargement of specimen in Fig. 7.
 Fig. 9 - *Cylindroclavulina rudis* (Costa, 1855), Frinco, FR5, internal view of a broken last chamber.

White bar = 100 µm.



- 1937 *Liebusella rudis* - Cushman, pp. 168-169, pl. 20, figs. 17-21.
 1960 *Cylindroclavulina bradyi* - Barker, pl. 48, figs. 32-38.
 1982 *Cylindroclavulina rudis* - Agip, pl. 4, fig. 1.
 1990 *Cylindroclavulina rudis* - Sprovieri & Hasegawa, p. 431, pl. 1, figs. 3-5.
 1994 *Cylindroclavulina bradyi* - Loeblich & Tappan, p. 34, pl. 48, figs. 7-19.

Test very large, stout, subcylindrical in the adult specimens, globular in the juveniles. Early stage indistinctly triserial, followed by a short biserial stage and by a longer uniserial stage with 3-4 low chambers. Sutures indistinct, aperture a narrow slit produced on a thin, short neck. Wall thick, agglutinating biogenic debris (bryozoans, molluscs, small plank-

tonic and benthic foraminiferal tests), arranged to give a slightly rough outer surface. Inner surface smooth. Abundant calcareous cement.

Remarks. A probable synonymy between *C. rudis* and *C. bradyi* can be inferred. The original descriptions and drawings of *C. rudis* Costa, 1855 and of *C. bradyi* Cushman, 1911 do not show substantial differences. None of the two authors evidenced in their descriptions and figures the nature of the agglutinated material, almost totally biogenic, and mainly given by foraminiferal tests. This appears to indicate an active selection of clasts by the foraminifer, giving the test a very characteristic and di-

agnostic appearance, evidenced in the drawings of Brady (1884) of *Clavulina cylindrica*, then referred to *Cylindroclavulina bradyi* by Barker (1960). In literature by Italian researchers, only *C. rudis* is reported from the Upper Oligocene (Agip 1982). The taxon disappeared from the Mediterranean during the Pleistocene, around 1.8 My (Sprovieri 1986).

It occurs with abundances near 2% in the upper MP11 and MP12 zones samples of the Moncucco section and in sample VE5.

Eggerella bradyi (Cushman, 1911)

Pl. 4, figs. 1-3

- 1911 *Verneuilina bradyi* Cushman, pp. 54-55, fig. 87.
 1960 *Eggerella bradyi* - Barker, p. 96, pl. 47, figs. 4-7.
 1989 *Eggerella bradyi* - Hermelin, pp. 32-33, pl. 2, figs. 1-2.
 1990 *Eggerella bradyi* - Sprovieri & Hasegawa, pl. 1, figs. 7-8.
 1995 *Eggerella bradyi* - Bender, p. 44, pl. 6, fig. 10.
 2002 *Eggerella bradyi* - Holbourn & Henderson, p. 8, figs. 1.12-13.

Test small, conical, initially trochospiral, with 4½ or 5 inflated chambers in the first whorl, later triserially arranged. Sutures depressed. Wall finely agglutinated, canaliculate, with abundant calcareous cement. Aperture a slit, bordered by a thin lip, at the inner margin of the last chamber.

Remarks. A cosmopolitan living species, known from the Oligocene (Agip 1982), reported as deep infaunal (Kuhnt et al. 2000). It is very seldom reported from deep-water Pliocene assemblages (Martinis 1954). Wright (1978) and Sprovieri & Hasegawa (1990) pointed out the easy confusion with *Karrieriella bradyi* immature specimens and the possibility that these two species might be often lumped together.

In the studied area, *E. bradyi* specimens are rare, reaching abundances of about 2-4% only in the epibathyal clays from part of the MP11 and MP12 zones, absent in shelf deposits.

Haplophragmoides canariensis (d'Orbigny, 1839)

Pl. 4, fig. 4

- 1839 *Nonionina canariensis* d'Orbigny, p. 128, pl. 2, figs. 33-34.
 1930 *Haplophragmoides canariensis* - Lacroix, p. 10, fig. 11.
 1945 *Haplophragmoides canariensis* - Cushman, p. 285, fig. 8.
 1967 *Haplophragmoides canariensis* - Towe, text-fig. 1.
 1991 *Haplophragmoides canariensis* - Cimerman & Langer, p. 18, pl. 4, figs. 7-9.
 2014 *Haplophragmoides canariensis* - Meriç et al., p. 214, pl. 1, figs. 22-23.

Test rather small, planispirally enrolled, involute, with 5½-6 inflated chambers in the last whorl,

rapidly increasing in size, peripheral margin lobulate. Sutures straight and depressed. Umbilical area depressed. Aperture is a small interio-marginal arch, at the base of the last chamber. Wall thin, medium to coarsely agglutinated, outer surface rather smoothly finished, with organic and ferruginous cement, imperforate.

Remarks. A cosmopolitan living species, epifaunal to shallow infaunal (Murray 2006), reported from brackish to shelf and bathyal depths (Brady 1884; Lacroix 1930; Blanc-Vernet 1969; Colom 1974; Cimerman & Langer 1991; Murray 2006; Frontalini et al. 2014; Dong et al. 2019).

Very rare specimens were found in samples FR1, VE2 and MA.

Karrieriella bradyi (Cushman, 1911)

Pl. 4, figs. 5-6, 8-9

- 1911 *Gaudryina bradyi* Cushman, pp. 67-68, fig. 107.
 1978 *Karrieriella bradyi* - Wright, p. 713, pl. 5, fig. 18.
 1994 *Karrieriella bradyi* - Loeblich & Tappan, pp. 25-26, pl. 30, figs. 8-16.
 1995 *Karrieriella bradyi* - Bender, p. 46, pl. 6, fig. 11.
 2002 *Karrieriella bradyi* - Holbourn & Henderson, pp. 11-12, figs. 2, 4-5.
 2015 *Karrieriella bradyi* - Mancin et al., pl. 1, figs. 2-2a, pl. 5, figs. 1-2.

Test rather small, conical, initially trochospiral, with 3½ or 4 chambers in the first whorl, rapidly reducing to biserial. Chamber subrounded in transverse section, regularly and slowly increasing in size. Suture depressed, often encrusted by thin deposits. Wall very finely agglutinated, with abundant calcareous cement, canaliculate. Aperture is oval, elongate, surrounded by a prominent lip, near the inner margin of the last chamber.

Remarks. It is a cosmopolitan living species, known from the middle Eocene (Agip 1982), rather commonly reported as rare from recent and Pleistocene marine sediments (Brady 1884; Herb 1971; Murray 1971; 2006; Mancin et al. 2015) as well as from Pliocene deep circalittoral and bathyal assemblages (Martinis 1954; D'Onofrio 1981; Jonkers 1984; Barra et al. 1998; Rasmussen 2005). In the Mediterranean bathyal deposits, it is frequently associated with the triserial *Eggerella bradyi* (Wright 1978; Sprovieri & Hasegawa 1990). Phleger et al. (1953) report a shallower upper depth limit for *K. bradyi* (about 155 m) than that of *E. bradyi* (about 600 m) in the North Atlantic. Also in the Piedmont assemblages, *K. bradyi* showed a rather different dis-

PLATE 4

Fig. 1 - *Eggerella bradyi* (Cushman, 1911), Moncucco T., 7.7 m, lateral view.

Fig. 2 - *Eggerella bradyi* (Cushman, 1911), Moncucco T., 7.7 m, enlargement of the apertural area, specimen of Fig. 1.

Fig. 3 - *Eggerella bradyi* (Cushman, 1911), Moncucco T., 7.7 m, enlargement of the lateral wall, specimen of Fig. 1, showing calcareous nannofossils agglutinated in the wall.

Fig. 4 - *Haplophragmoides canariensis* (d'Orbigny, 1839), Frinco, FR1, lateral view.

Fig. 5 - *Karrieriella bradyi* (Cushman, 1911), Moncucco T., 1.5 m, lateral view.

Fig. 6 - *Karrieriella bradyi* (Cushman, 1911), Primeglio, PR, side view.

Fig. 7 - *Karrieriella gaudryinoides* (Fornasini, 1885), Moncucco T., 3.5 m, side view.

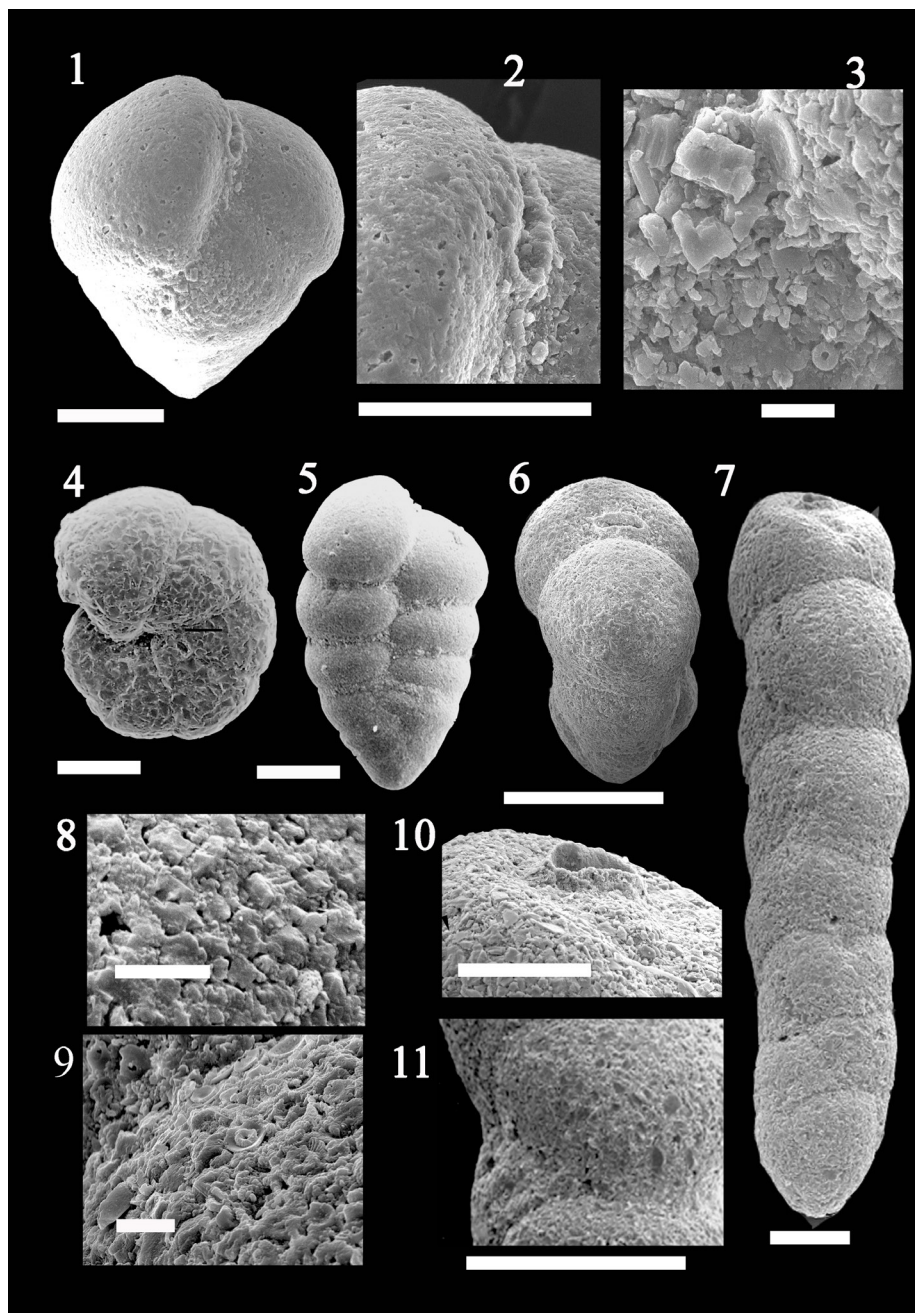
Fig. 8 - *Karrieriella bradyi* (Cushman, 1911), Moncucco T., 1.5 m, enlargement of the outer surface, specimen in Fig. 5.

Fig. 9 - *Karrieriella bradyi* (Cushman, 1911), Primeglio, PR, enlargement of the outer surface of specimen in Fig. 6, showing calcareous nannofossils agglutinated in the wall.

Fig. 10 - *Karrieriella gaudryinoides* (Fornasini, 1885), Moncucco T., 3.5 m, enlargement of the apertural area, specimen of Fig. 7.

Fig. 11 - *Karrieriella gaudryinoides* (Fornasini, 1885), Moncucco T., 3.5 m, enlargement of specimen in Fig. 7.

White bar = 100 μ m, Figs. 1-2, 4-7, 10-11; 10 μ m, Figs. 3, 8-9.



tribution than *E. bradyi*, suggesting a shallower bathymetrical range for the first taxon.

In the studied area, *K. bradyi* occurs in the MPI1 and MPI2 zones epibathyal assemblages. It is scarce in the deep circalittoral/upper epibathyal assemblages of the MPI3 zone.

Karrieriella gaudryinoides (Fornasini, 1885)

Pl. 4, figs. 7, 10-11

1885 *Clavulina gaudryinoides* Fornasini, p. 8, pl. 6, figs. 3-9.

1937 *Karrieriella gaudryinoides* - Cushman, p. 131, pl. 15, figs. 16-17.

1954 *Karrieriella gaudryinoides* - Ferasin, p. 22, pl. 2, figs. 6-8.

1982 *Karrieriella gaudryinoides* - Agip, pl. 5, fig. 3.

Test stout, subcylindrical, initial stage trochospiral and conical, with 3-4 whorls of chambers, then triserial (about 1 whorl) and rapidly reducing to biserial. The biserial portion represents more than 2/3 of adult specimens, chambers are inflated, subcircular and irregularly disposed along the axis. The last chambers tend to become uniserial. Wall rather coarse agglutinated, with abundant calcareous cement and parapores. Aperture rounded in the uniserial stage, surrounded by a prominent lip, areal, near the inner margin of the last chamber.

Remarks. The species is known from the lower Miocene (Ferasin 1954; Agip 1982) to the low-

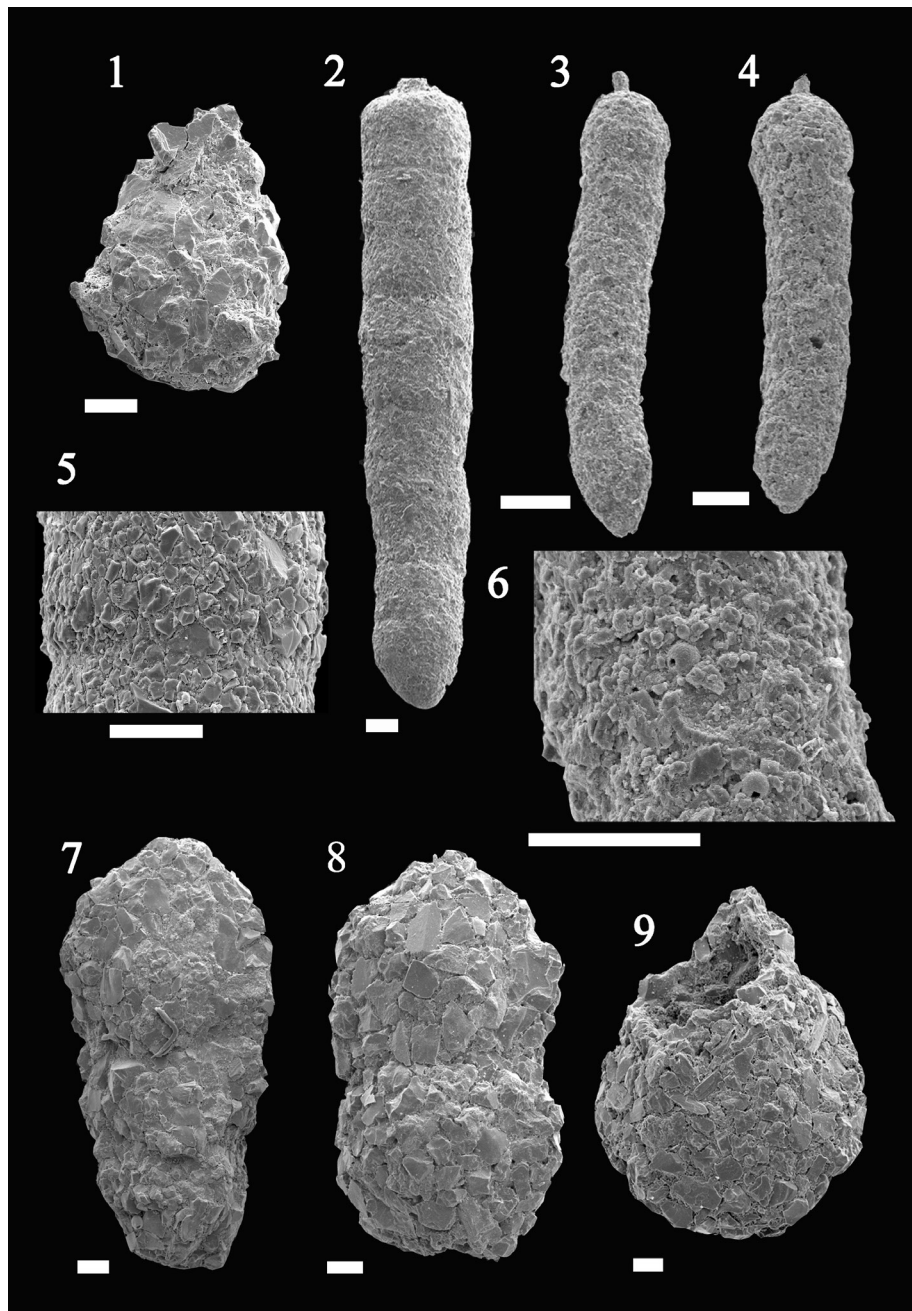


PLATE 5

- Fig. 1 - *Lagenammina atlantica* (Cushman, 1944), S. Martino Alfieri, SM, lateral view.
 Fig. 2 - *Martinottiella communis* (d'Orbigny, 1826), Isola d'Asti, 6.7 m, lateral view.
 Fig. 3 - *Martinottiella perparva* (Cushman, 1936), Moncucco T., 0.40 m, lateral view.
 Fig. 4 - *Martinottiella perparva* (Cushman, 1936), Moncucco T., 1.5 m, lateral view.
 Fig. 5 - *Martinottiella communis* (d'Orbigny, 1826), Isola d'Asti, 6.7 m, enlargement of specimen in Fig. 2.
 Fig. 6 - *Martinottiella perparva* (Cushman, 1936), Moncucco T., 0.40 m, enlargement of specimen in Fig. 3.
 Fig. 7 - *Psammolingulina papillosa* (Neugeboren, 1856), Isola d'Asti, 1.5 m, microspheric form, lateral view.
 Fig. 8 - *Psammolingulina papillosa* (Neugeboren, 1856), Monticello d'Alba, MA, macrospheric form, lateral view.
 Fig. 9 - *Psammolingulina papillosa* (Neugeboren, 1856), Isola d'Asti, 1.5 m, lateral view of a broken initial chamber
- White bar = 100 µm.

er MPI5 zone (Late Pliocene) (Sprovieri & Hasegawa 1990). It is rare in the Pliocene assemblages of Italy (Martinis 1954; D'Onofrio 1981; Di Bella et al. 2002; Violanti et al. 2009).

In the studied material it occurs in few samples from the lower-middle part of the Moncucco and Isola d'Asti sections, in samples VG, VI, SM and CH90, with percentages below 1%.

***Lagenammina atlantica* (Cushman, 1944)**

Pl. 5, fig. 1

1944 *Protonina atlantica* Cushman, p. 5, pl. 1, fig. 4.

1991 *Lagenammina atlantica* - Cimerman & Langer, p. 15, pl. 1, figs. 1-3.

1996 *Lagenammina atlantica* - Violanti, p. 36, pl. 2, figs. 3-4.

1998 *Reophax atlantica* - Alfirević, p. 37, pl. 1, fig. 3.

2019 *Lagenammina atlantica* - Capotondi et al., p. 31, fig. 2.6.

Test unilocular, irregularly ovoidal. Wall coarsely agglutinated with organic cement. Aperture small, subrounded. The form of the test is strongly influenced by the dimension of the agglutinated grains.

Remarks. The taxon is cosmopolitan (Murray 2006), rare in the Mediterranean, where it is reported from circalittoral to bathyal depths (Sgarrella & Barra 1985; Sgarrella et al. 1985; Sgarrella & Moncharmont Zei 1993; Alfirević 1998; Frontalini

et al. 2014; Capotondi et al. 2019; Di Bella et al. 2019).

Extremely rare in the studied assemblages, it was found in samples FR5, GO, SM and VE3.

***Martinottiella communis* (d'Orbigny, 1826)**

Pl. 5, figs. 2, 5

- 1826 *Clavulina communis* d'Orbigny, p. 102, n. 4.
 1933 *Martinottiella communis* - Cushman, p. 37, pl. 4, figs. 6-8.
 1960 *Martinottiella communis* - Barker, p. 98, pl. 48, figs. 3-4, 6-8.
 1984 *Martinottiella communis* - Jonkers, p. 131, pl. 1, fig. 6.
 1989 *Martinottiella communis* - Hermelin, p. 34, pl. 2, figs. 5-6.
 1990 *Martinottiella communis* - Sprovieri & Hasegawa, pl. 1, fig. 5.
 2015 *Martinottiella communis* - Mancin et al., pl. 2, fig. 1.

Test initially triserial, with about 3-5 little evident whorls, followed by a long uniserial part with short cylindrical chambers. Suture depressed. Aperture a small arch at the end of a very short neck. Wall rather thick, agglutinating small to medium size clasts, with calcareous cement, canaliculate.

Remarks. The cosmopolitan species was known from the lower Eocene (Agip 1982), frequently reported from Mediterranean Miocene and Pliocene assemblages (Ferasin 1954; Martinis 1954; Jonkers 1984; Rio et al. 1988). It is common to abundant in the modern deep sea from high latitudes (Chapman & Parr 1937; Herb 1971), and in the upper Quaternary bathyal sediments of the SW Pacific (Mancin et al. 2015).

In the studied samples it occurs in most of the AA sediments indicative of epibathyal settings.

***Martinottiella perparva* (Cushman, 1936)**

Pl. 5, Figs. 3-4, 6

- 1936 *Listerella communis* (d'Orbigny) var. *perparva* Cushman, p. 40, pl. 6, figs. 5a-b.
 1982 *Martinottiella perparva* - Agip, pl. 5, fig. 7.
 1990 *Martinottiella perparva* - Sprovieri & Hasegawa, pl. 1, fig. 8.

It differs from *Martinottiella communis* for its smaller dimensions, the more coarsely agglutinated wall, indistinct sutures, and a very thin but robust neck, often well preserved.

Remarks. In the Mediterranean area, the species is generally rare and seldom reported in deep assemblages from the Langhian to the Pliocene (Agip 1982; Sprovieri & Hasegawa 1990), up to the MPI5 zone (Sprovieri 1986).

The species was recovered in the AA epibathyal assemblages of the Moncucco T. section

and of the Narzole borehole (Violanti et al. 2009), referred to the MPI1 and MPI2 biozones, and in one samples from the Isola d'Asti section, MPI4a sub-zone.

***Psammolingulina papillosa* (Neugeboren, 1856)**

Pl. 5, figs. 7-9

- 1856 *Lingulina papillosa* Neugeboren, pp. 97-98, pl. 5, fig. 6a-b.
 1982 *Reophax papillosus* - Agip, pl. 1, fig. 1.
 1997 *Psammolingulina papillosa* - Foresi et al., pl. 3, fig. 1.
 1999 *Psammolingulina papillosa* - Popescu, p. 416, pl. 7, fig. 5.

Test stout, large, uniserial, composed by 2-3 compressed, subcircular chambers of nearly equal size. The first lenticular chamber may be more ovate in outline than the following ones. Peripheral margin acute. Sutures slightly depressed, straight. Wall thick, with coarse grains, mainly of quartz, firmly agglutinated, traversed by meandering pores and with organic cement. Aperture a small terminal slit.

Remarks. Common in Middle Miocene assemblages from the Central-Eastern Europe (Popescu 1999; Filipescu 2001). In the Northern Italy Pliocene the taxon is rare (Lualdi 1981; Agip 1982; Rio et al. 1988).

Very few specimens occur in AA deep circalittoral/upper epibathyal clays and silty clays, dated to the MPI3 biozone (Isola d'Asti section), in the samples GO, VI, SM, MA, CH83 and CH90.

***Psammosphaera fusca* Schulze, 1875**

Pl. 6, fig. 1

- 1875 *Psammosphaera fusca* Schulze, p. 113, pl. 2, fig. 8.
 1932 *Psammosphaera fusca* - Heron-Allen & Earland, pp. 327-328, pl. 8, figs. 1-4, pl. 17, figs. 4-6.
 1947 *Psammosphaera fusca* - Höglund, pp. 46-49, pl. 4, figs. 9-14.
 1996 *Psammosphaera fusca* - Violanti, p. 36, pl. 2, fig. 1.
 2005 *Psammosphaera fusca* Schultze emend. Heron-Allen & Earland, 1913 - Kaminski & Gradstein, pp. 125-127; pl. 8, figs. 1-9; fig. 8.
 2012 *Psammosphaera fusca* - Milker & Schmiedl, p. 26, fig. 9.2-3.

Test large, spherical, unilocular. Wall thick, composed by coarse grains, dominantly of quartz, some calcitic clasts may be included, cement organic, imperforate. Most specimens are devoid of an evident aperture, as noted in the original description and by Höglund (1947).

Remarks. *Psammosphaera fusca* Schulze (not Schultze), 1875 is worldwide recorded, from Cretaceous to Recent (Höglund 1947; Kaminski & Gradstein 2005). It is reported from the Western

Mediterranean shelf (Milker & Schmiedl 2012) to the coasts of Turkey (Meriç et al. 2014), and from bathyal depths (Cita & Zocchi 1978). It is present also in modern circalittoral assemblages (Sgarrella & Barra 1985; Frontalini et al. 2014). It is often associated with an opportunistic fauna in areas affected by deep-sea currents or by dysaerobic conditions, related to seasonal upwelling (Kaminski & Gradstein 2005).

Rare specimens were found in the lower part of the Isola d'Asti and Calliano sections, in samples PR, FR3, GO, VI, VE5 and CH83.

***Psammosphaera parva* Flint, 1899**

Pl. 6, fig. 2

- 1899 *Psammosphaera parva* Flint, p. 268, pl. 9, fig. 1.
 1910 *Psammosphaera parva* - Cushman, pp. 36-37, figs. 29-30.
 1962 *Psammosphaera parva* - McKnight, p. 99, pl. 9, fig. 4.
 1996 *Psammosphaera parva* - Violanti, p. 36, pl. 2, figs. 2, 5.

Test small, spherical, unilocular, without an evident aperture. Wall thin, composed by rather fine grains, mainly given by quartz and rock fragments, firmly agglutinated, cement organic, imperforate.

Remarks. The taxon differs from *P. fusca* for its small diameter and the smaller, more uniform clasts included in the wall. Flint (1899, p. 268) described the species with “test often built around a long sponge spicule, which tranfixes the test”. The very rare Piedmont specimens, collected from samples MN, VI and CH90, do not yield the sponge spicule, described as often present, (therefore not always), but for the other characteristics, such as the small test, and uniform clasts dimensions seem to correspond to the Flint's species.

***Recurvoides* sp.**

Pl. 6, fig. 3

Test large, trochospirally enrolled, plano-convex, with 4-4.5 chambers in the last whorl. The last chamber increases in dimensions more rapidly than the previous ones. The umbilicus is moderately depressed. Sutures straight and very slightly depressed. Wall thick, with abundant coarse mineral grains and less frequent smaller grains, loosely cemented. Cement organic. Aperture not evident, infilled by sediment.

Remarks. Very rare specimens and fragments, here tentatively assigned to the genus *Re-*

curvoides, occur in samples FR3, FR5, GO, VI and CH83.

***Reophax scorpiurus* de Montfort, 1808**

Pl. 6, fig. 4

- 1808 *Reophax scorpiurus* de Montfort, p. 331, fig. 130.
 1884 *Reophax scorpiurus* - Brady, pl. 30, figs. 12, 14-17.
 1930 *Reophax scorpiurus* - Lacroix, pp. 547-549, fig. 1 a-c.
 1947 *Reophax scorpiurus* - Höglund, p. 81, pl. 9, figs. 9-10, pl. 26, figs. 52-55, p. 89, text figs. 51-52.
 1991 *Reophax scorpiurus* - Cimerman & Langer, p. 17, pl. 4, figs. 1-4.
 2018 *Reophax scorpiurus* - Capotondi et al., pl. 1, fig. 10.

Test elongated, with 4-6 subglobular to subcylindrical chambers, uniserially arranged along a straight or slightly curved axis. Wall coarsely agglutinated, with poorly sorted terrigenous grains. Cement organic. Aperture terminal, rounded, at the end of a short neck.

Remarks. The taxon is worldwide known, from very wide latitudinal and depth ranges (Brady 1884; Boltovskoy et al. 1980; Culver & Buzas 1986; Alve et al. 2011). Epifaunal, favouring areas of high organic flux (Kuhnt et al. 2000), but showing infaunal maxima in living foraminiferal fauna (Fontanier et al. 2005). In the Mediterranean it is reported from recent circalittoral to epibathyal assemblages (Blanc-Vernet 1969; Sgarrella & Moncharmont Zei 1993; Di Bella et al. 2019).

In the Piedmont Pliocene it was recorded by Sampò et al. (1968) in the “Astian” assemblages around Asti. Very rare specimens were found in samples FR3, VG and CH90.

***Rhabdammina cf. abyssorum* Sars, 1869**

Pl. 6, fig. 5

- 1869 *Rhabdammina abyssorum* Sars, p. 248 (nomen nudum).
 1884 *Rhabdammina abyssorum* - Brady, p. 266, pl. 21, figs. 1-13.
 1990 *Rhabdammina abyssorum* - Charnock & Jones, p. 152, pl. 1, figs. 23-24; pl. 2, fig. 9; pl. 13, fig. 22.
 1995 *Rhabdammina abyssorum* - Bender, p. 49, pl. 1, fig. 10.
 2014 *Rhabdammina abyssorum* - Meriç et al., p. 213, pl. 1, figs. 1-3.

Test free, large, with 3-5 long cylindrical arms of rather uniform diameter, radiating from a central subglobular chamber. Wall thick, coarsely agglutinated, firmly cemented, embedding large quartz and rock grains. Organic cement, brown-reddish in color for iron oxides. Aperture at the end of the tubular arms.

Remarks. A living cosmopolitan taxon, recorded from the Turonian (Charnock & Jones

PLATE 6

Fig. 1 - *Psammospaera fusca* Schulze, 1875, Isola d'Asti, 4.3 m, lateral view.

Fig. 2 - *Psammospaera parva* Flint, 1899, Vigliano d'Asti, VI, lateral view.

Fig. 3 - *Recurvoides* sp., Vigliano d'Asti, VI, lateral view.

Fig. 4 - *Reophax scoriurus* de Montfort, 1808, Vagliano, VG, lateral view.

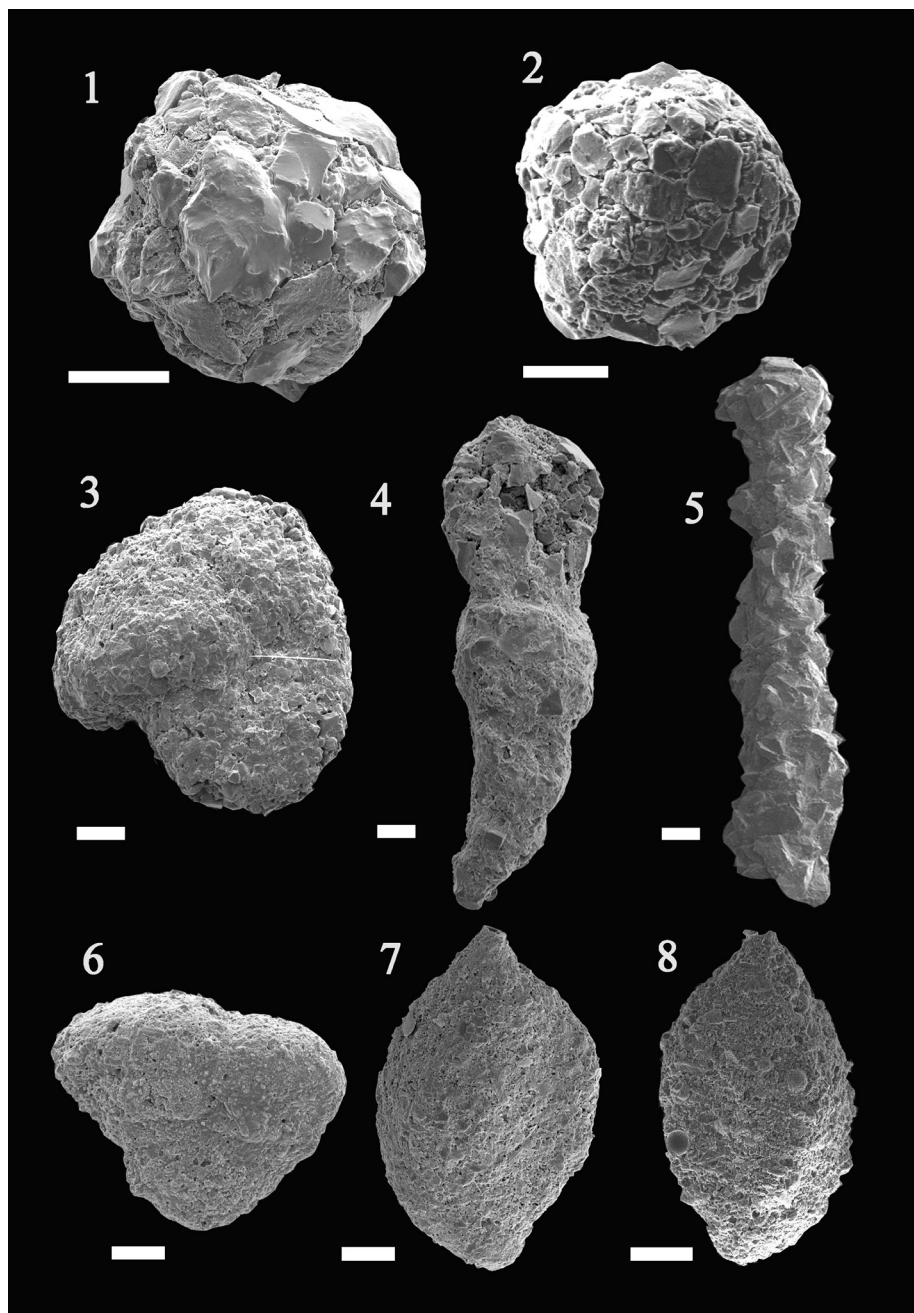
Fig. 5 - *Rhabdammina* cf. *abyssorum* Sars, 1869, Vigliano d'Asti, VI, lateral view.

Fig. 6 - *Sabulia conica* (d'Orbigny, 1839), Isola d'Asti, 1.5 m, lateral view.

Fig. 7 - *Sigmoilopsis schlumbergeri* (Silvestri, 1904), Moncucco T., 0.10 m, lateral view.

Fig. 8 - *Sigmoilopsis schlumbergeri* (Silvestri, 1904), Primeglio, PR, lateral view.

White bar = 100 µm



1990). It is abundant in bathyal muds (Jones & Charnock 1985), but also found in shallower assemblages (Brady 1884; Chapman & Parr 1937; Sgarrella & Moncharmont Zei 1993). It is an epibenthic suspension-feeder (Kuhnt et al. 2000; Kaminski & Wetzel 2004). Assemblages of living rhabdamminids are abundant in continental slope areas influenced by deep currents (Kuhnt & Collins 1995). In the Mediterranean Sea *Rhabdammina abyssorum* and *Rhabdammina* sp. were reported from deep shelf and upper epibathyal depths (Sgarrella et al. 1985; Frontalini et al. 2014).

Rare fragments of *Rhabdammina* sp. were reported in Piedmont Pliocene "Astian" assemblages by Sampò et al. (1968). Rare tubular fragments were found in sample VI.

Sabulia conica (d'Orbigny, 1839)

Pl. 6, fig. 6

1839 *Textularia conica* d'Orbigny, p. 143, pl. 1, figs. 19-20.

1884 *Textularia conica* - Brady, p. 48, pl. 43, figs. 13-14.

1977 *Textularia conica* - Le Calvez, pp. 18-19, figs. 1-2.

1991 *Textularia conica* - Cimerman & Langer, p. 22, pl. 10, figs. 7-9.

1993 *Textularia conica* - Sgarrella & Moncharmont Zei, p. 166, pl. 3, figs. 4-5.

- 1998 *Textularia conica* - Alfirević, p. 39, pl. 3, fig. 2.
 2004 *Sabulia conica* - Diz et al., p. 271, pl. 1, fig. 10.

Test short, small, biserial throughout, with few pairs (4-5) of subtriangular chambers, wider than high, rapidly increasing in size. Sutures straight or fairly curved, slightly depressed. Wall coarse to medium size grained with calcareous cement, canaliculate. Aperture a low arch at the inner margin of the last chamber.

Remarks. A very frequently recorded taxon, but probably, as observed by Lacroix (1932), many reports had included under this name juvenile specimens of other textulariids. In the Mediterranean, it occurs in the infralittoral and circalittoral zones (Koukousioura et al. 2011), down to 671 meters in the Eastern Mediterranean (Parker 1958), and from 15 to about 300 m (Frontalini et al. 2014) in the Aegean Sea. Also reported from Pliocene and Pleistocene assemblages of the Mediterranean area (Coppa et al. 2001; Di Bella et al. 2002).

In the Piedmont succession, it is rather common in the lower part of the Isola d'Asti clays, very rare in the silty-sandy sediments.

Sigmoilopsis schlumbergeri (Silvestri, 1904)

Pl. 6, figs. 7-8

- 1904 *Sigmoilina schlumbergeri* Silvestri, p. 267, pl. 7, figs. 12-14, text figs. 6-7.
 1960 *Sigmoilopsis schlumbergeri* - Barker, pl. 8, fig. 1.
 1991 *Sigmoilopsis schlumbergeri* - Cimerman & Langer, p. 48, pl. 46, figs. 10-14.
 1994 *Sigmoilopsis schlumbergeri* - Loeblich & Tappan, p. 59, pl. 103, figs. 9-12.
 2015 *Sigmoilopsis schlumbergeri* - Mancin et al., pl. 2, fig. 6; pl. 3, fig. 4.

Test free, ovate, with initially sigmoidally, finally planispirally arranged chambers, 4-5 chambers scarcely evident on the surface. Wall porcellaneous, with a rather rough agglutinated coating, often obscuring the very slightly depressed sutures. Aperture rounded, at the end of the last chamber, with a small tooth, often missing in the fossil specimens. The agglutinated material, mainly inorganic, can be more or less coarse.

Remarks. A living cosmopolitan species, in the Mediterranean Sea sediments reported from the upper Miocene to Quaternary (Agip 1982) and from a depth-range of about 30-1000 m (Sgarrella & Moncharmont Zei 1993; Alfirević 1998).

In the Piedmont succession, it occurs with low percentages in the circalittoral/upper epibathy-

al clays and marly clays dated to the MP11-MP14a zones.

Siphotextularia affinis (Fornasini, 1883)

Pl. 7, figs. 1-4

- 1883 *Sagrina affinis* Fornasini, p. 189, pl. 2, fig. 10 a-c.
 1888a *Sagrina affinis* - Fornasini, pp. 44-45, pl. 3, fig. 1.
 1968 *Siphotextularia affinis* - Salvatorini, p. 301, pl. 3, fig. 12.
 1982 *Siphotextularia affinis* - Agip, pl. 4, fig. 9.
 1984 *Karrerella affinis* - Jonkers, p. 131, pl. 1, fig. 3.

Test elongate, biserial throughout, with 4-7 pairs of inflated, subrounded chambers regularly increasing in size. Sutures oblique, depressed, median area slightly depressed. Wall very finely agglutinated, very often yielding a large amount of calcareous nanofossils, with calcareous cement, canaliculate. Aperture areal, near the internal margin of the last chamber, subrounded, produced on a short neck and surrounded by a thin lip.

Remarks. The stratigraphic range of this taxon is known from the Tortonian to the Quaternary (Salvatorini 1968). It is reported from Pliocene circalittoral and upper epibathyal assemblages (D'Onofrio 1981; Jonkers 1984; Violanti 1987) of the Mediterranean area.

In the studied material *S. affinis* is rather common in the lower clays of the Isola d'Asti section (MP13 zone).

Siphotextularia sp. 1

Pl. 7, figs. 5-7

Very rare specimens, recovered only in the PR (Primeglio) and MN (Montechiaro) samples, were ascribed to this form. They differ from *S. affinis* from their very large and stout tubular neck, and a rather more subangular chambers. They could be a different species as well as an aberrant form of *S. affinis*.

Spiroplectammina milletti (Cushman, 1911)

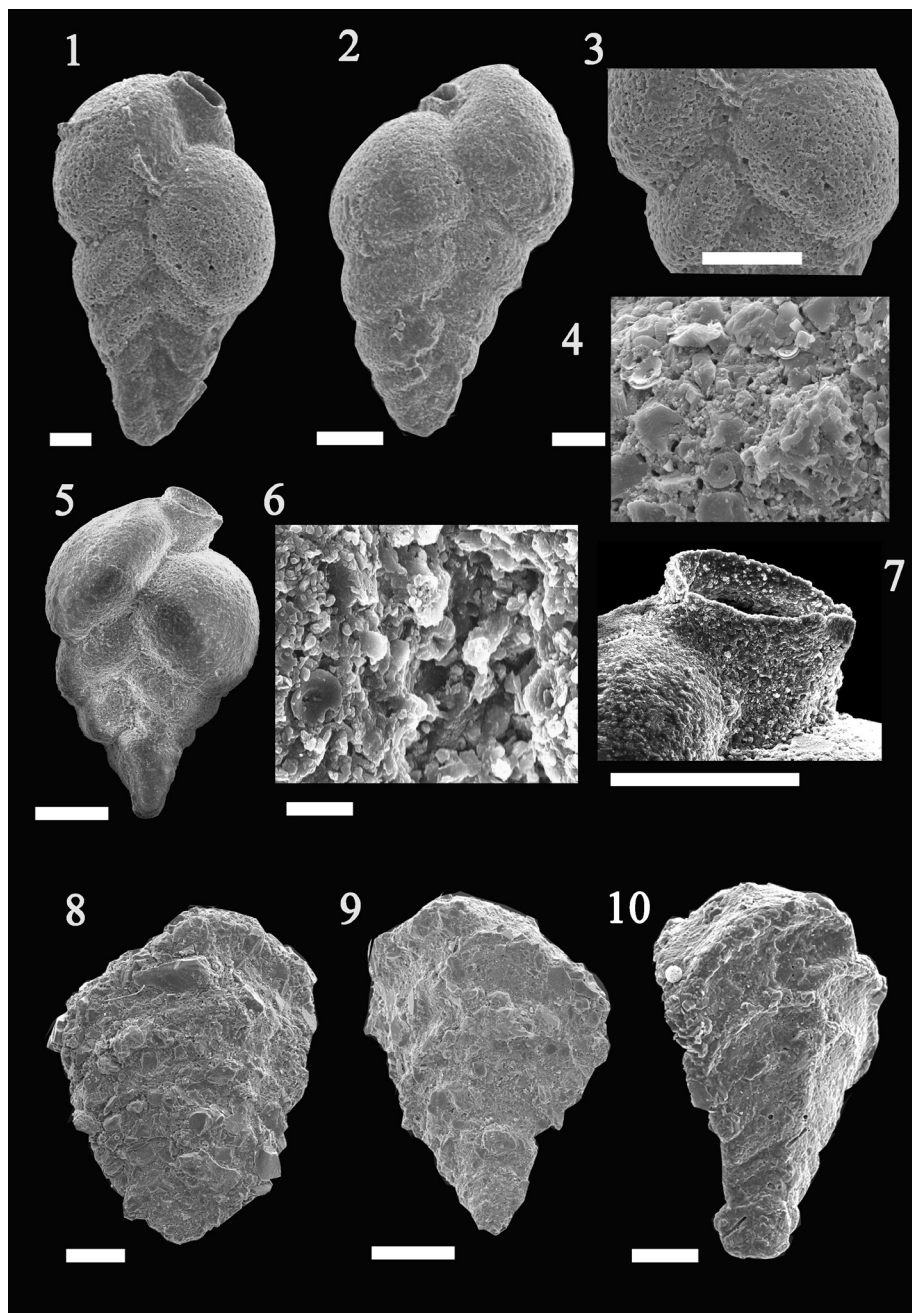
Pl. 7, figs. 8-10

- 1911 *Textularia milletti* Cushman, p. 133, figs. 18-19.
 1932 *Spiroplectammina milletti* - Cushman, p. 7, pl. 1, figs. 5a,b.
 1987 *Textularia milletti* - Loeblich & Tappan, p. 173, pl. 192, figs. 17-19.
 1994 *Textularia milletti* - Loeblich & Tappan, pp. 28-29, pl. 35, figs. 5-7.

Test of medium to small size, stout, compressed. Planispirally coiled juvenile chambers, well developed in the megalospheric forms. Adult chambers biserially arranged, rapidly increasing in width,

PLATE 7

- Fig. 1 - *Siphotextularia affinis* (Fornasini, 1883), Calliano, 5.5 m, lateral view.
- Fig. 2 - *Siphotextularia affinis* (Fornasini, 1883), Isola d'Asti, 5.0 m, lateral view.
- Fig. 3 - *Siphotextularia affinis* (Fornasini, 1883), Calliano, 5.5 m, enlargement of specimen in Fig. 1.
- Fig. 4 - *Siphotextularia affinis* (Fornasini, 1883), Calliano, 5.5 m, wall enlargement of specimen in Fig. 1.
- Fig. 5 - *Siphotextularia* sp. 1, Primeglio, PR, lateral view.
- Fig. 6 - *Siphotextularia* sp. 1, Primeglio, PR, wall enlargement of specimen in Fig. 5.
- Fig. 7 - *Siphotextularia* sp. 1, Primeglio, PR, apertural neck of specimen in Fig. 5.
- Fig. 8 - *Spiroplectammina milletti* (Cushman, 1911), Isola d'Asti, 1.5 m, lateral view, microspheric form.
- Fig. 9 - *Spiroplectammina milletti* (Cushman, 1911), Isola d'Asti, 1.5 m, lateral view, microspheric form.
- Fig. 10 - *Spiroplectammina milletti* (Cushman, 1911), Isola d'Asti, 1.5 m, lateral view, macrospheric form.
- White bar = 100 μ m, Figs. 1-3, 5, 7-10; 10 μ m, Figs. 4, 6.



larger than high, with thick, rough upper margins and depressed lower margins. Peripheral margin acute. Sutures often indistinct. Wall coarsely agglutinated, including dominant inorganic fragments and few biogenic debris, with calcareous cement. Parapores evident on the outer surface. Aperture a narrow arch at the inner margin of the last chamber.

Remarks. A very rare and seldom recorded taxon, known from deep Quaternary and Recent assemblages of the Pacific, Indian and Antarctic Oceans (Cushman 1911; 1932; Heron-Allen & Earland 1922), Timor Sea (Loeblich & Tappan 1994) and Arabian Sea (Almogi-Labin et al. 2000).

Very rare specimens were found in samples FR1 and VI.

Spiroplectinella wrighti (Silvestri, 1903)

Pl. 8, figs. 1-4

- 1903 *Spiroplecta wrighti* Silvestri, p. 60, figs. 1-6.
- 1981 *Spirorutilus wrighti* - Banner & Pereira, p. 104, pl. 6, figs. 7-8, 10; pl. 7, figs. 1-2, 5.
- 1987 *Spiroplectinella wrighti* - Loeblich & Tappan, p. 112, pl. 120, figs. 1-16.
- 1993 *Spiroplectinella wrighti* - Sgarrella & Moncharmont Zei, p. 161, pl. 3, fig. 13.
- 2010 *Spiroplectinella wrighti* - Di Bella, pl. 3, fig. 1.

Test elongated, compressed, initial stage planispiral, adult stage biserial, rapidly and regularly increasing in breadth. Peripheral margin acute, with a marginal keel sometimes in part preserved in the fossil specimens. Sutures straight, slightly depressed or poorly evident in the first adult chambers, the angle formed by the chamber upper suture with the median axis is comprised between 63-72° (Fig. 9). In some specimens, the upper margin of the last 1-3 chambers may be curved and thickened. Wall finely agglutinated, with calcareous cement. Aperture a low arch at the inner margin of the last chamber.

Remarks. Frequently reported in the Mediterranean area from circalittoral to upper epibathyal Tortonian to Recent assemblages (Martinis 1954; Sampò et al. 1968; D'Onofrio 1981; Agip 1982; Rio et al. 1988; Coppa et al. 2001; Frontalini et al. 2014), but, as observed by Sgarrella & Moncharmont Zei (1993), frequently confused with *Textularia sagittula*. This latter taxon, on the basis of the original description, differs from *S. wrighti* for the lacking of a real planispiral stage and for the sutures nearly orthogonal to the median axis (Fig. 9).

In the Piedmont Pliocene assemblages *S. wrighti* rather commonly occurs, but reaches abundances around 3% only in the Isola d'Asti deep circalittoral-upper epibathyal clays (MPI3-MPI4a zones).

Spiroplectinella sp.

Pl. 8, figs. 5-7.

Test elongate, compressed, with a planispiral stage both in microspheric and macrospheric forms. About 7-8 pairs of sub-rectangular chambers, slowly increasing in breadth in the biserial adult stage. Sutures distinct, slightly depressed, the chamber upper suture forming an angle with the median axis ranging between 68-82° (Fig. 9). Peripheral margin acute, lobate. Wall smooth, including small regularly arranged inorganic debris, abundant calcareous cement, with parapores. Aperture a low arch at the inner margin of the last chamber, bordered by a thin lip.

Remarks. Few specimens were collected from the circalittoral clayey silts of Incisa S. and in the AA silty clays of the northern Monferrato (Arignano, Verrua S.), all dated to the MPI4a subzone.

Spirotextularia fistulosa (Brady, 1884)

Pl. 8, figs. 8-9

1884 *Textularia sagittula* DeFrance var. *fistulosa* Brady, p. 362, pl. 42, figs. 19-22.

1960 *Textularia sagittula* DeFrance var. *fistulosa* - Barker, p. 86, pl. 42, figs. 19-22.

1987 *Spirotextularia fistulosa* - Loeblich & Tappan, p. 113, pl. 121, figs. 7-12.

2005 *Textularia sagittula fistulosa* - Rasmussen, p. 58, pl. 2, figs. 4-5.

2013 *Spirotextularia* cf. *fistulosa* - Peryt, fig. 4 C.

2016 *Spirotextularia fistulosa* - Saelan, p. 23, pl. 1, fig. 8 a-b.

Test lanceolate, compressed. Initial stage planispiral with 4 chambers, later biserially arranged, with 7 pairs of chambers. Chambers rapidly increasing in size, lateral edges of the chambers with tubular projections. Sutures straight to slightly curved, fairly depressed. Wall finely agglutinated, with calcareous cement.

Remarks. The taxon was known from the Miocene (Peryt 2013) and Pliocene (Rasmussen 2005; Makled et al. 2017), mainly recorded from subtropical and tropical mid sublittoral to uppermost bathyal sediments of the Pacific and Indian Oceans (Brady 1884; Loeblich & Tappan 1994; Ujié & Hatta 1995; Saelan 2016; Twarog et al. 2021).

Rare tests were recognized in samples MA, MN, PR, VG.

Textularia aciculata d'Orbigny, 1826

Pl. 9, figs. 1-6

1826 *Textularia aciculata* d'Orbigny, p. 263, pl. 11, figs. 1-4.

1880 *Textularia aciculata* - Terrigi, p. 191, pl. 2, figs. 24-27.

1898 *Textularia aciculata* - Fornasini, p. 208, pl. 1, figs. 4-5.

1985 *Textularia aciculata* - Sgarrella & Barra, p. 27, pl. 2, fig. 7.

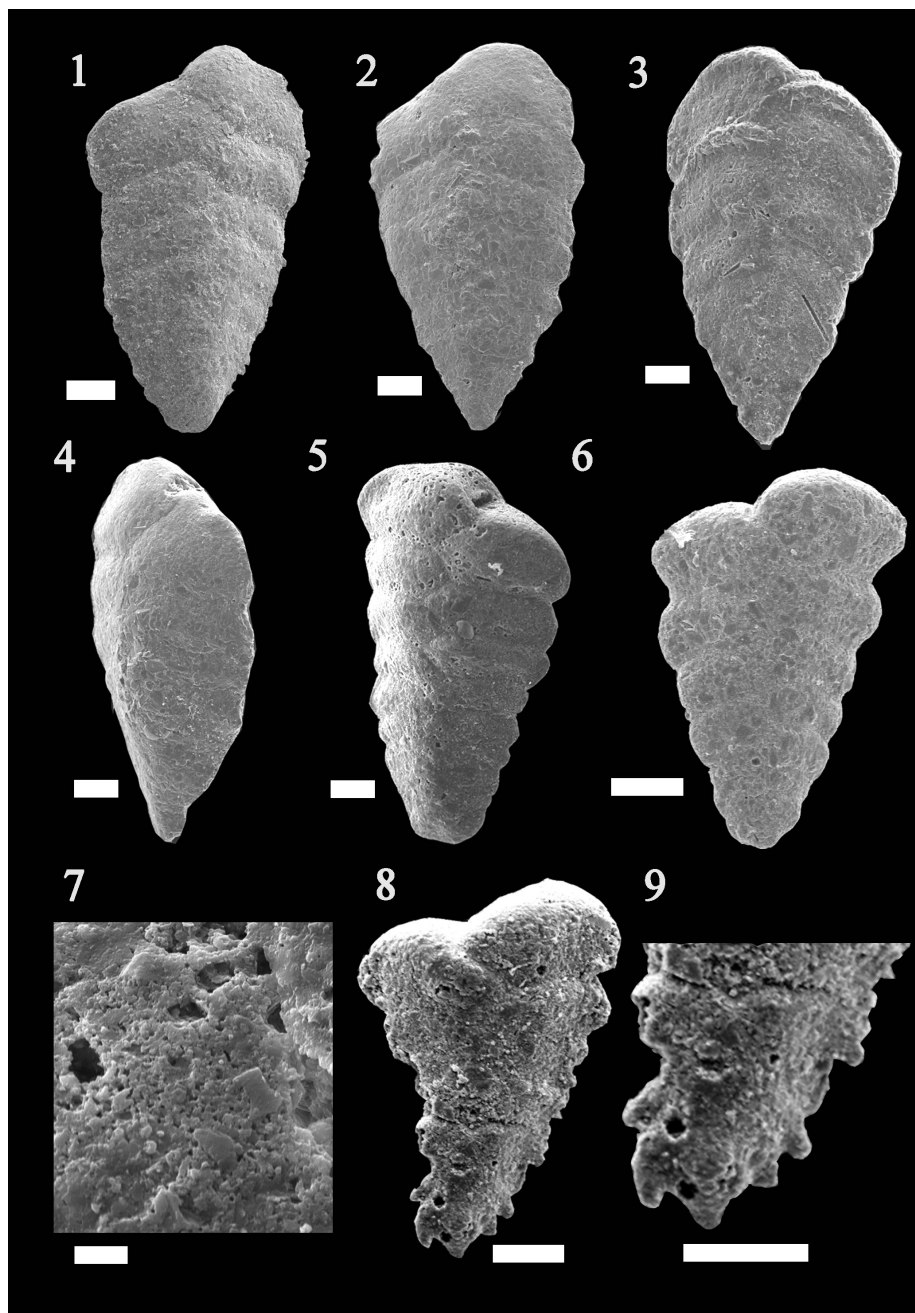
2001 *Textularia aciculata* - Coppa et al., pl. 3, fig. 2.

2001 *Textularia aciculata* - Fiorini & Vaiani, p. 367, pl. 1, fig. 9.

Test elongate, tapering, biserial throughout. Aboral part acutely pointed in the microspheric generation, more rounded in the megalospheric one. 6 to 8 pairs of compressed chambers, gradually increasing in size. Sutures straight and oblique, slightly depressed, not or poorly evident in the early chambers, the upper suture forming an angle ranging between 45-60° with the median axis (Fig. 9). Peripheral margin acute to subrounded. Wall thin, fine to medium size grained, including small biogenic debris (molluscs, sponge spicules, foraminifers, calcareous nanofossils), with calcareous cement, canaliculate, outer surface rather smooth. Aperture a medium arch at the inner margin of the last chamber.

PLATE 8

- Fig. 1 - *Spiroplectinella wrighti* (Silvestri, 1903), Isola d'Asti, 8.1 m, lateral view.
 Fig. 2 - *Spiroplectinella wrighti* (Silvestri, 1903), Isola d'Asti, 10.1 m, lateral view.
 Fig. 3 - *Spiroplectinella wrighti* (Silvestri, 1903), Isola d'Asti, 10.1 m, lateral view.
 Fig. 4 - *Spiroplectinella wrighti* (Silvestri, 1903), Calliano, 2 m, latero-peripheral view.
 Fig. 5 - *Spiroplectinella* sp., Arignano, AR1, lateral view.
 Fig. 6 - *Spiroplectinella* sp., Incisa S., 6 m, lateral view.
 Fig. 7 - *Spiroplectinella* sp., Arignano, AR1, wall enlargement of specimen in Fig. 5.
 Fig. 8 - *Spirotectularia fistulosa* (Brady, 1884), Primeglio, PR, lateral view.
 Fig. 9 - *Spirotectularia fistulosa* (Brady, 1884), Primeglio, PR, enlargement of specimen in Fig. 8.
 White bar = 100 μ m, Figs. 1-6, 8-9; 10 μ m, Fig. 7.



Remarks. *T. aciculata* is often reported from Italian Pliocene (Terrigi 1880; Fornasini 1887d; 1888b; Martinis 1954; Sampò et al. 1968; Rio et al. 1988; Di Bella et al. 2002), Pleistocene (Coppa et al. 2001; Fiorini & Vaiani 2001) and Recent assemblages (Sgarrella & Barra 1985; Aiello et al. 2021). In the cited literature, it is generally recorded from circalittoral silty to clayey deposits. The species is accepted, as fossil and recent, by WoRMS (2023). On the contrary, Poignant (1998), in her review of some d'Orbigny species, invalidated *T. aciculata*, as a junior synonym of *Textularia angularis* d'Orbigny, 1826. At a first sight, *T. aciculata* may be confused with *S. wrighti*, for their apparent similar morphol-

ogy. *T. aciculata* can be differentiated from *S. wrighti* on the basis of: 1) The absence in *T. aciculata* of any planispiral juvenil stage, occurring in *S. wrighti*, verified by the observation of some hundred specimens in transmitted light under a transparency agent (lavander or thuja oil). 2) The angle formed by the upper suture with the median axis ranging between 45-60° in *T. aciculata*, between 63-72° in *S. wrighti* (Fig. 9). 3) The coarser and of less uniform size grains agglutinated in the wall of *T. aciculata* than in *S. wrighti*.

In the studied area, the species is very rare or absent in the oldest epibathyal assemblages of the MP11-MP12 zones, whereas it is common to fre-

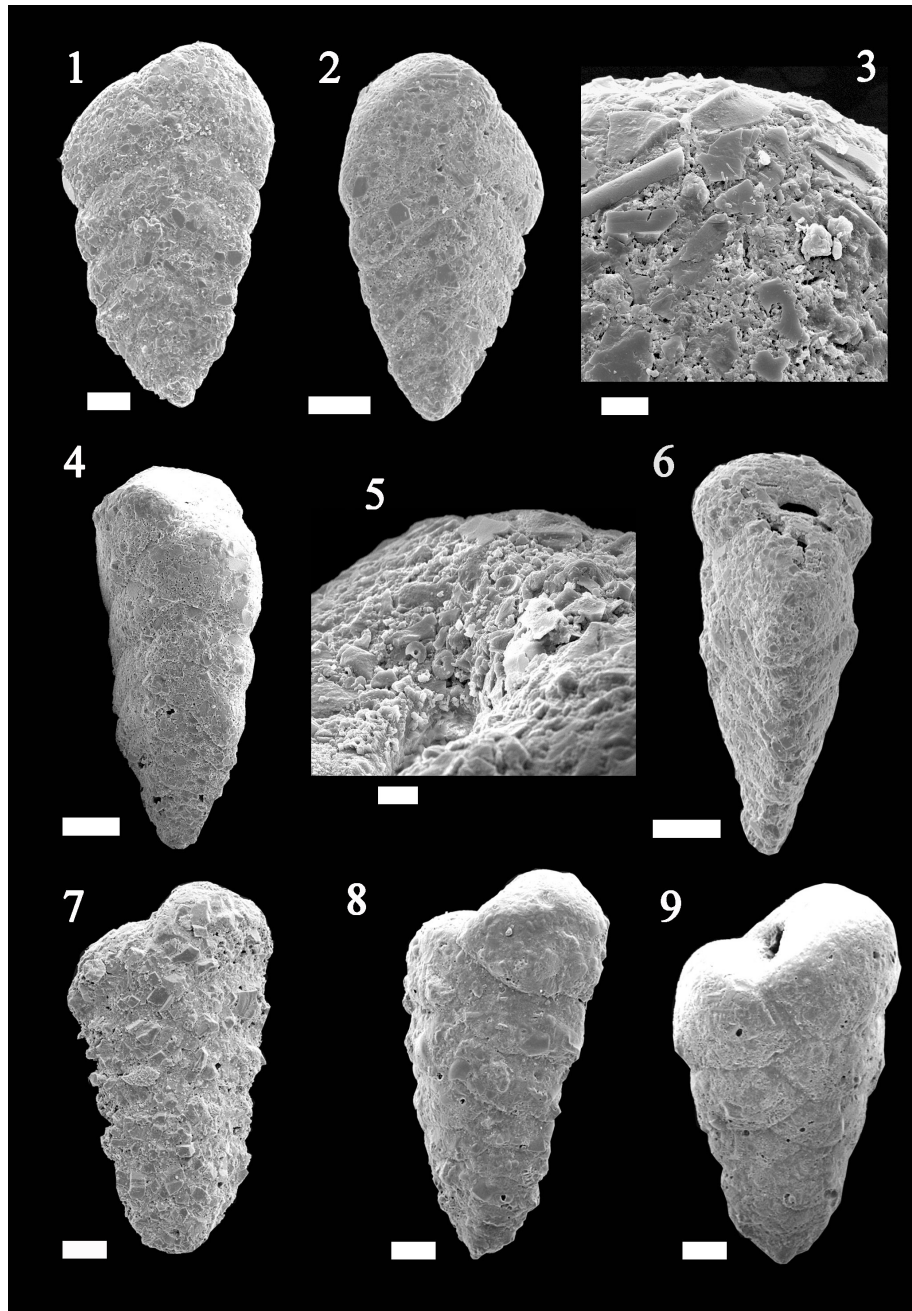


PLATE 9

Fig. 1 - *Textularia aciculata* d'Orbigny, 1826, Incisa S., 16 m, lateral view.

Fig. 2 - *Textularia aciculata* d'Orbigny, 1826, Calliano, 5.5 m, lateral view.

Fig. 3 - *Textularia aciculata* d'Orbigny, 1826, Calliano, 5.5 m, wall enlargement of specimen in Fig. 2.

Fig. 4 - *Textularia aciculata* d'Orbigny, 1826, Incisa S., 34.2 m, latero-peripheral view.

Fig. 5 - *Textularia aciculata* d'Orbigny, 1826, Incisa S., 34.2 m, wall enlargement of specimen in Fig. 4.

Fig. 6 - *Textularia aciculata* d'Orbigny, 1826, Revignano, REV2, side view.

Fig. 7 - *Textularia agglutinans* d'Orbigny, 1839, Isola d'Asti, 1.5 m, lateral view.

Fig. 8 - *Textularia agglutinans* d'Orbigny, 1839, Frinco, FR5, lateral view.

Fig. 9 - *Textularia agglutinans* d'Orbigny, 1839, Calliano, 2 m, lateral view.

White bar = 100 μm, Figs. 1-2, 4, 6-9.; 10 μm, Figs. 3, 5.

quent in the deep infralittoral/shallow circalittoral silts and clayey silts, dated to the MPI3-MPI4a zones, and interpreted as shallow marine delta deposits.

Textularia agglutinans d'Orbigny, 1839

Pl. 9, figs. 7-9

1839 *Textularia agglutinans* d'Orbigny, p. 144, pl. 1, figs. 17-18, 32-34.

1884 *Textularia agglutinans* - Brady, pl. 45, figs. 1-3.

1980 *Textularia agglutinans* - Boltovskoy et al., p. 51, pl. 32, figs. 5-7.

1981 *Textularia agglutinans* - Banner & Pereira, p. 93, pl. 1, figs. 6-7.

2001 *Textularia agglutinans* - Fiorini & Vaiani, p. 367, pl. 1, figs. 1-4.

2010 *Textularia agglutinans* - Milker, p. 91, pl. 1, fig. 10.

Test elongate, biserial, with 7-10 pairs of regularly increasing chambers. Last chambers sub-rounded. Sutures straight, slightly depressed, often obscured by the coarse grains, the chamber upper suture forming an angle with the median axis ranging between 82-91° (Fig. 9). Peripheral margin sub-rounded. Wall thick, from rather finely to coarsely agglutinated, with variable amounts of calcareous cement, canaliculate. Aperture a short arch at the inner margin of the last chamber.

Remarks. A cosmopolitan living species, known from the Oligocene (Cushman 1922; Gal-

loway & Heminway 1941). In the Mediterranean area it was reported mainly from shallow sandy or detrital shelf sediments (Blanc-Vernet 1969; Garcia-Sanz et al. 2018), down to 330 m in the Gulf of Naples (Sgarrella & Moncharmont Zei 1993). Mercado et al. (2015) documented its epiphytic life mode on vegetated rocky substrates along the Israeli Mediterranean coasts.

The species is rare in most of the studied samples, common only in the lower part of the Isola d'Asti section. The clast granulometry and cement amount can strongly differ, in relation to the more or less sandy sediment, and a range from very coarse (Pl. 9, fig. 7) to a rather smooth wall (Pl. 9, fig. 9) occurred.

Textularia articulata d'Orbigny, 1846

Pl. 10, fig. 1

- 1846 *Textularia articulata* d'Orbigny, p. 250, pl. 15, figs. 16-18.
 1941 *Textularia articulata* - Galloway & Heminway, p. 329, pl. 8, fig. 1a-b.
 1965 *Textularia articulata* - Cicha & Zapletalová, p. 121, fig. 15.
 1974 *Textularia articulata* - Colom, p. 88, fig. 8a-c.
 1997 *Textularia articulata* - Foresi et al., pl. 3, fig. 4.

Test elongate, biserial, compressed, with 5-8 pairs of chambers gradually increasing in size. Sutures depressed, straight or faintly curved, less distinct in the initial chambers. Peripheral margin subangular to carinate, often weakly lobate. Wall fine to medium size grained, smoothly finished, with abundant calcareous cement. Aperture a low arch at the inner margin of the last chamber.

Remarks. The species is known from the Miocene of Europe, North America and Caribbean area (Galloway & Heminway 1941; Cicha & Zapletalová 1965; Foresi et al. 1997). In WoRMS (2023) it is considered as synonym of *Textularia mariae* d'Orbigny, 1846, following the opinion of Papp & Schmid (1985). The specimen figured by these last authors to support their opinion (p. 89, pl. 82, figs. 2-3) appears very different from the d'Orbigny drawings, for the test general morphology, sutures inclination and chambers growing ratio. *T. articulata* is here retained as a valid species.

In the Piedmont assemblages, it is very rare, found in silty clays pertaining to the MPI3 zone (Calliano, Isola d'Asti and Verrua S. sections, sample CH83).

Textularia candeiana d'Orbigny, 1839

Pl. 10, fig. 2

- 1839 *Textularia candeiana* d'Orbigny, p. 143, pl. 1, figs. 25-27.
 1911 *Textularia candeiana* - Cushman, p. 12, figs. 14-17.
 1932 *Textularia candeiana* - Cushman, p. 9, pl. 2, fig. 4a-b.
 1932 *Textularia candeiana* - Lacroix, pp. 17-18, figs. 15-17.
 1980 *Textularia candeiana* - Boltovskoy et al., p. 51, pl. 32, figs. 8-11.
 1992 *Textularia candeiana* - Bender, pl. 1, figs. 2-5, pl. 4, figs. 3-7.

Test elongate, biserial throughout, with 10-12 pairs of chambers rapidly increasing in size. Initial stage acute, lanceolate, adult stage inflated, producing a subrounded transverse section. Sutures nearly straight, indistinct to slightly depressed in the last chambers. Wall medium to coarse grained, with abundant calcareous cement. Aperture a low arch at the base of the apertural face.

Remarks. Described from Recent sands of Cuba, living in nearshore Indian Ocean waters off Kenya (Bender 1992), the species is documented from the Oligocene and Miocene (Snyder et al. 1988), and from Mediterranean infralittoral to circalittoral Pliocene, Pleistocene and Recent assemblages (Lacroix 1932; Moncharmont Zei 1962; Sgarrella et al. 1985; Moncharmont Zei et al. 1984; Coppa et al. 2001; Fiorini & Vaiani 2001; Violanti & Sassone 2008).

Very rare specimens randomly occur in Piedmont silty-sandy sediments correlated to the MPI3-MPI4a zones and shelf paleoenvironments.

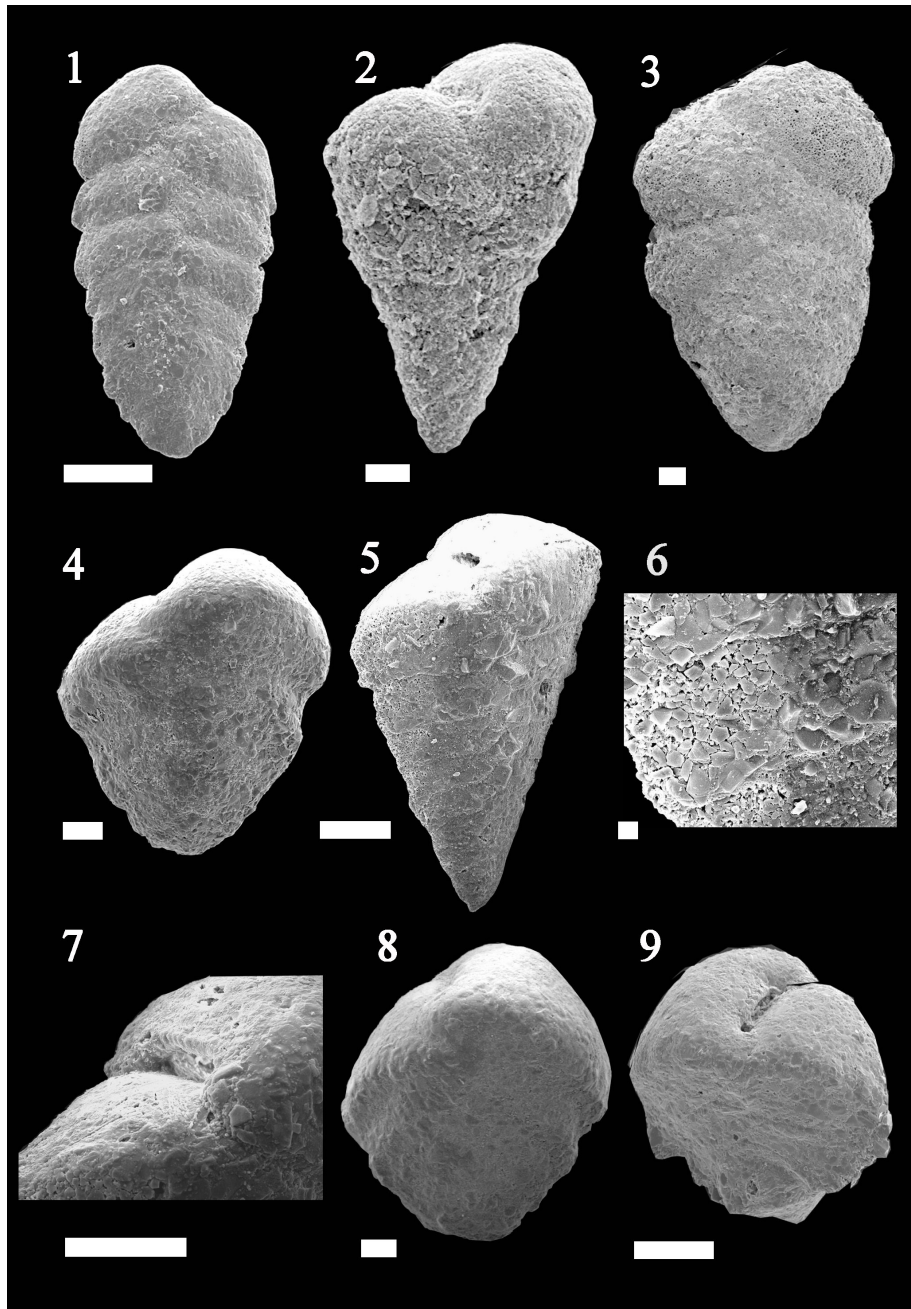
Textularia gramen d'Orbigny, 1846

Pl. 10, figs. 3-4

- 1846 *Textularia gramen* d'Orbigny, p. 248, pl. 15, figs. 4-6.
 1846 *Textularia abbreviata* d'Orbigny, p. 249, pl. 15, figs. 7-12.
 1887b *Textularia gramen* - Fornasini, pp. 388-389, pl. 11, fig. 4.
 1887c *Textularia abbreviata* - Fornasini, pp. 399-400, pl. 11, figs. 1, 3.
 1937 *Textularia pseudogramen* - Chapman & Parr, pp. 153-154.
 1948 *Textularia abbreviata* - Renz, p. 168, pl. 1, figs. 10-11.
 1962 *Textularia pseudogramen* - Barker, pl. 43, figs. 9-10.
 2005 *Textularia gramen* - Rasmussen, pp. 56-57, pl. 1, figs. 16-17.

Test of medium to large size, biserial, and of variable morphology, ranging between two end shapes, a rather lanceolate form with up to 6-8 pairs of chambers (Pl. 10, fig. 3) and a shorter, stout, more inflated form, subrhomboidal in transverse section, with 4-5 pairs of chambers, rapidly increasing in size, corresponding to *Textularia abbreviata* d'Orbigny, 1846 (Pl. 10, fig. 4). Peripheral margin acute. Sutures more or less distinct, slightly curved

PLATE 10



- Fig. 1 - *Textularia articulata* d'Orbigny, 1846, Isola d'Asti, 1.5 m, lateral view.
 Fig. 2 - *Textularia candeiana* d'Orbigny, 1839, Isola d'Asti, 1.5 m, lateral view.
 Fig. 3 - *Textularia gramen* d'Orbigny, 1846, Frinco, FR5, lateral view.
 Fig. 4 - *Textularia gramen* d'Orbigny, 1846, form "*abbreviata*", d'Orbigny, 1846", Isola d'Asti, 8.1 m, lateral view.
 Fig. 5 - *Textularia pala* Čížek, 1848, Primeglio, PR, lateral view.
 Fig. 6 - *Textularia pala* Čížek, 1848, Primeglio, PR, wall enlargement of specimen in Fig. 5.
 Fig. 7 - *Textularia pala* Čížek, 1848, Primeglio, PR, apertural area of specimen in Fig. 5.
 Fig. 8 - *Textularia ponderosa* Fornasini, 1887, Moncalvo, 20.45 m, lateral view.
 Fig. 9 - *Textularia ponderosa* Fornasini, 1887, Isola d'Asti, 5.5 m, lateral view.
 White bar = 100 μ m, Figs. 1-5, 7-9; 10 μ m, Fig. 6

and depressed. Wall fine to medium size grained, with abundant calcareous cement. Aperture a small arch at the base of the last chamber.

Remarks. Fornasini (1887b) pointed out the difficulty to separate *T. abbreviata* from *T. gramen* and from short ("abbreviate") forms of other *Textularia* species (*Textularia subangulata* d'Orbigny, 1846, *Textularia haueri* d'Orbigny, 1846). Rasmussen (2005) regarded *T. pseudogramen*, separated by Chapman & Parr (1937) on the basis of its higher number of chamber than *T. gramen*, as conspecific of the latter species. Following the opinion of Papp & Schmidt (1985) and of WoRMS (2023), *T. abbreviata* is here retained as synonym of *T. gramen*. In the Mediterra-

nean area it frequently occurs in sandy circalittoral sediments, recorded down to 345 meter depth in the Gulf of Naples (Sgarrella & Moncharmont Zei 1993). In the Northern Italy and Switzerland Pliocene it is recorded in the form *T. abbreviata* (Ferasin 1954; Martinis 1954; Violanti & Sassone 2008).

Rare specimens occur in the silty marls and silts of the MPI3-MPI4a zones from Isola d'Asti, Calliano, and Frinco.

***Textularia pala* Čížek, 1848**

Pl. 10, figs. 5-7

1848 *Textularia pala* Čížek, p. 148, pl. 13, figs. 25-27.

- 1974 *Textularia pala* - Colom, p. 89, fig. 6 q.
 1993 *Textularia pala* - Sgarrella & Moncharmont Zei, p. 166, pl. 3, fig. 8.
 2012 *Textularia pala* - Milker & Schmiedl, p. 40, figs. 10.21-22.
 2014 *Textularia* cf. *pala* - Merić et al., p. 215, pl. 5, fig. 14.
 2015 *Textularia pala* - Frontalini et al., fig. 4.1.

Test of medium size, triangular, biserial throughout, with 10-12 pairs of compressed chambers regularly increasing in size. Sutures distinct, horizontal to slightly curved. Wall very fine grained, with large amount of calcareous cement. Aperture a short slit at the base of the apertural face.

Remarks. A living species (Aiello et al. 2021), reported from the Miocene (Čížek 1948), rare in Pliocene and Pleistocene assemblages (Ferasin 1954; Moncharmont et al. 1984; Violanti & Sassone, 2008). In Recent Mediterranean assemblages, it occurs in a depth-range between 18 and 450 meters in the Gulf of Naples (Sgarrella & Moncharmont Zei 1993), in shallow sandy sediments (Colom 1974), down to about 100 m in the northern Aegean Sea (Frontalini et al. 2014).

In the studied succession rare specimens occur in the silts and silty sands of the MPL3-MPL4a zones.

Textularia ponderosa Fornasini, 1887

Pl. 10, figs. 8-9

- 1887e *Textularia ponderosa* Fornasini, p. 400, pl. 11, figs. 5-6.
 1982 *Textularia ponderosa* - Agip, pl. 2, fig. 8.
 1987 *Textularia ponderosa* - Violanti, p. 261, pl. 1, fig. 1.

Test stout, short, with 4-6 pairs of chambers biserially arranged, more large than high, triangular in transverse section and rapidly increasing in size, prominent in their upper portion. Sutures curved, often indistinct. Peripheral margin acute. Wall thick, coarsely agglutinated, with calcareous cement. Aperture a low arch at the inner margin of the last chamber.

Remarks. Fornasini (1887e) figured and gave a very brief description of the taxon, distinguishing *T. ponderosa* on the basis of its curved and prominent chambers. The species is limited to the Lower Pliocene (Agip 1982), it is generally rare and recorded from silty and sandy sediments (Sampò et al. 1968; D'Onofrio 1981; Violanti 1987).

In the Pliocene Piedmont succession it is very rare and randomly occurs in silty-sandy deposits.

Textularia sagittula Defrance, 1824

Pl. 11, figs. 1-3

- 1824 *Textularia sagittula* Defrance, p. 177, pl. 13, fig. 5.
 1888a *Textularia sagittula* - Fornasini, p. 46, pl. 3, figs. 2-4.
 1974 *Textularia sagittula* - Le Calvez, pp. 82-84, pl. 21, figs. 1-4.
 1987 *Textularia sagittula* - Loeblich & Tappan, pp. 173-174, pl. 193, figs. 1-2.
 2005 *Textularia sagittula* - Rasmussen, pp. 57-58, pl. 2, fig. 3.
 2010 *Spiroplectinella sagittula* s.l. - Milker, pp. 92-93, pl. 1, fig. 16.
 2015 *Spiroplectinella sagittula* - Frontalini et al., fig. 4.4.

Test lanceolate, compressed, biserial. Chambers rapidly increasing in size in the first 3-4 pairs, then gradually increasing in size. Peripheral margins acute to subrounded, nearly parallel in the adult stage. Sutures straight or slightly curved, indistinct to slightly depressed, the chamber upper suture forming an angle with the median axis near to 90° (Fig. 9). Wall medium to coarse agglutinated, with dominant inorganic debris and abundant calcareous cement, canaliculate. Aperture a short arch at the base of the last chamber.

Remarks. A controversial species, accepted in WoRMS (2023) as *T. sagittula*, but attributed in literature both to the genus *Textularia* or to *Spiroplectinella*. *T. sagittula* is the type species of the genus *Textularia*, the “adventitious third chamber against the first pair of chambers in the microspheric generation” (Loeblich & Tappan 1987), could be interpreted as an initial planispiral stage, typical of the genus *Spiroplectinella*. Parker (1958) placed in synonymy the two species as *T. sagittula* and reports the taxon highest frequencies shoaler than 201 m in the Eastern Mediterranean. Frontalini et al. (2014) reported the taxon, as *S. sagittula*, frequent to abundant in the upper 100 m, but also present down to about 600 m in the northern Aegean Sea. Blanc Vernet (1969) reported *T. sagittula* from infralittoral vegetated sea-floor down to upper bathyal muds.

In the studied succession it is rare, rather common in silty-sandy intervals.

Textularia sagittula Defrance var. *calaritana*

Fornasini, 1887

Pl. 11, figs. 4-5

- 1887a *Textularia sagittula* Defrance var. *calaritana* Fornasini, p. 30 nomen nudum.
 1887b *Textularia luculenta* Brady var. *calaritana* Fornasini, pp. 394-395, pl. 10, fig. 3 a-b.
 1991 *Spiroplectinella wrighti* - Cimerman & Langer, pl. 6, figs. 2-4.
 2012 *Spiroplectinella sagittula* - Milker & Schmiedl, pl. 9, fig. 20.

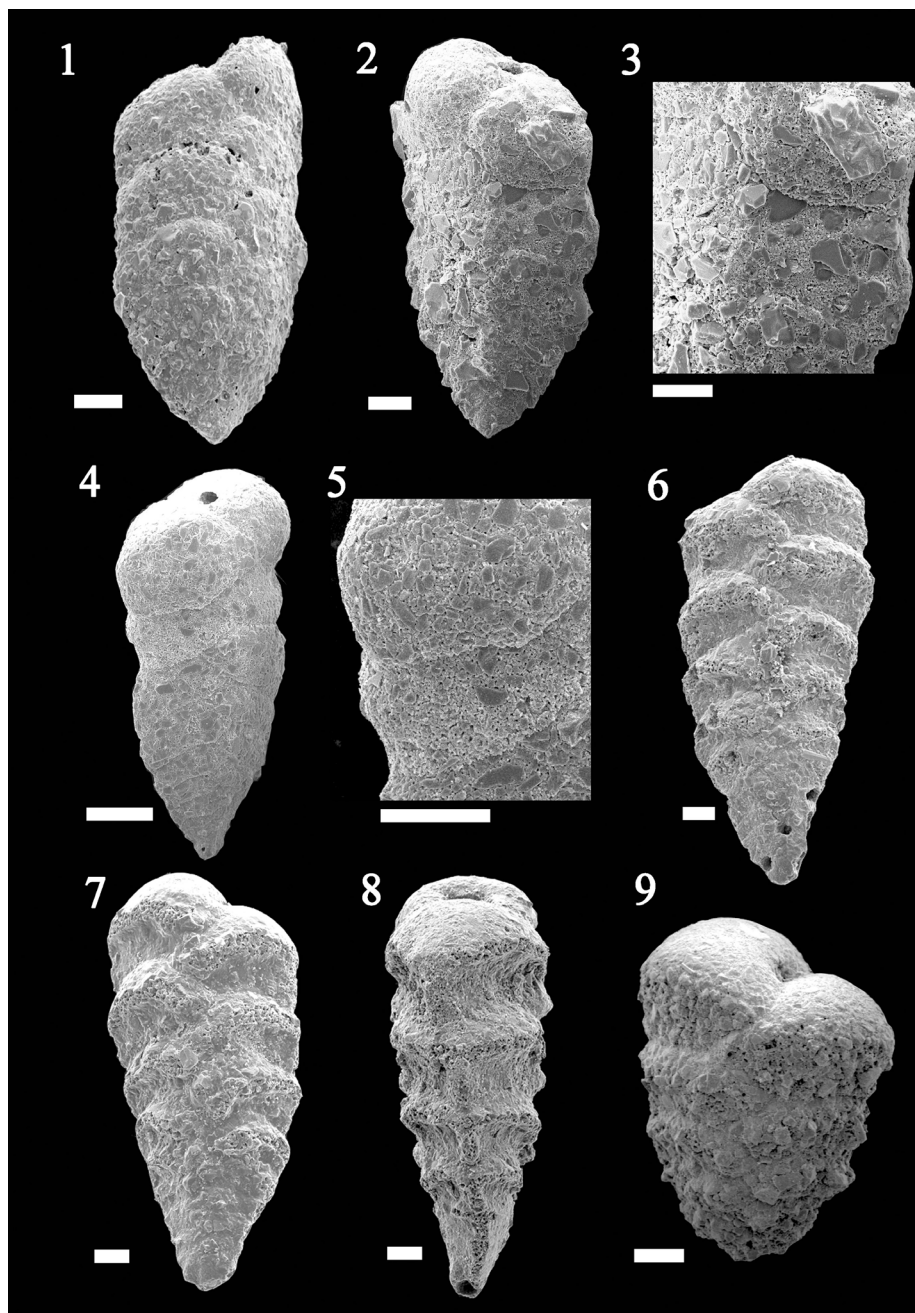


PLATE 11

Fig. 1 - *Textularia sagittula* Defrance, 1824, Primeglio, PR, lateral view.

Fig. 2 - *Textularia sagittula* Defrance, 1824, Calliano, 6.5 m, lateral view.

Fig. 3 - *Textularia sagittula* Defrance, 1824, Calliano, 6.5 m, wall enlargement of specimen in Fig. 2.

Fig. 4 - *Textularia sagittula* Defrance, 1824, var. *calaritana* Fornasini, 1887, Primeglio, PR, lateral view.

Fig. 5 - *Textularia sagittula* Defrance, 1824, var. *calaritana* Fornasini, 1887, Primeglio, PR, wall enlargement of specimen in Fig. 4.

Fig. 6 - *Textularia soldanii* Fornasini, 1883, Incisa S., 9 m, lateral view.

Fig. 7 - *Textularia soldanii* Fornasini, 1883, Calliano, 7.9 m, lateral view.

Fig. 8 - *Textularia soldanii* Fornasini, 1883, Isola d'Asti, 6.0 m, side view.

Fig. 9 - *Textularia soldanii* Fornasini, 1883, Isola d'Asti, 6.0 m, juvenile specimen, lateral view.

White bar = 100 µm

The form differs from the typical *T. sagittula* only in the last 2-4 pairs of chambers, more inflated in their central part and with more depressed and distinct sutures. The peripheral margin, nearly continuous in the approximately first half of the test, is lobate in the uppermost 1 or 2 pairs of chambers.

Remarks. Fornasini (1887a) named this taxon as *Textularia sagittula* Defrance var. *calaritana* on one specimen collected from Miocene sediments in the surroundings of Cagliari (Sardinia). In the subsequent paper on the Italian textularias (Fornasini 1887b), he figured the specimen, but referred the variety to the species *T. luculenta* Brady, 1884. It is accepted

in WoRMS (2023) at the species level. Tests showing the lobate last pairs of chambers, characteristic of “*calaritana*”, were figured in recent assemblages among typical *S. wrighti* or *S. sagittula* (Cimernan & Langer 1991; Milker & Schmiedl 2012). Here it is preferred to maintain the form at the rank of a variety of *T. sagittula*, if not a morphotype.

Rare specimens were randomly observed, but not separated from the typical *T. sagittula* during the countings.

Textularia soldanii Fornasini, 1883

Pl. 11, figs. 6-9

PLATE 12

Fig. 1 - *Textularia truncata*, Höglund, 1947, Moncalvo, 2 m, lateral view.

Fig. 2 - *Textularia truncata*, Höglund, 1947, Moncalvo, 2 m, enlargement of specimen in Fig. 1.

Fig. 3 - *Textularia tuberosa* d'Orbigny, 1826, Frinco, FR1, lateral view.

Fig. 4 - *Textularia tuberosa* d'Orbigny, 1826, Frinco, FR1, apertural area of specimen in Fig. 3.

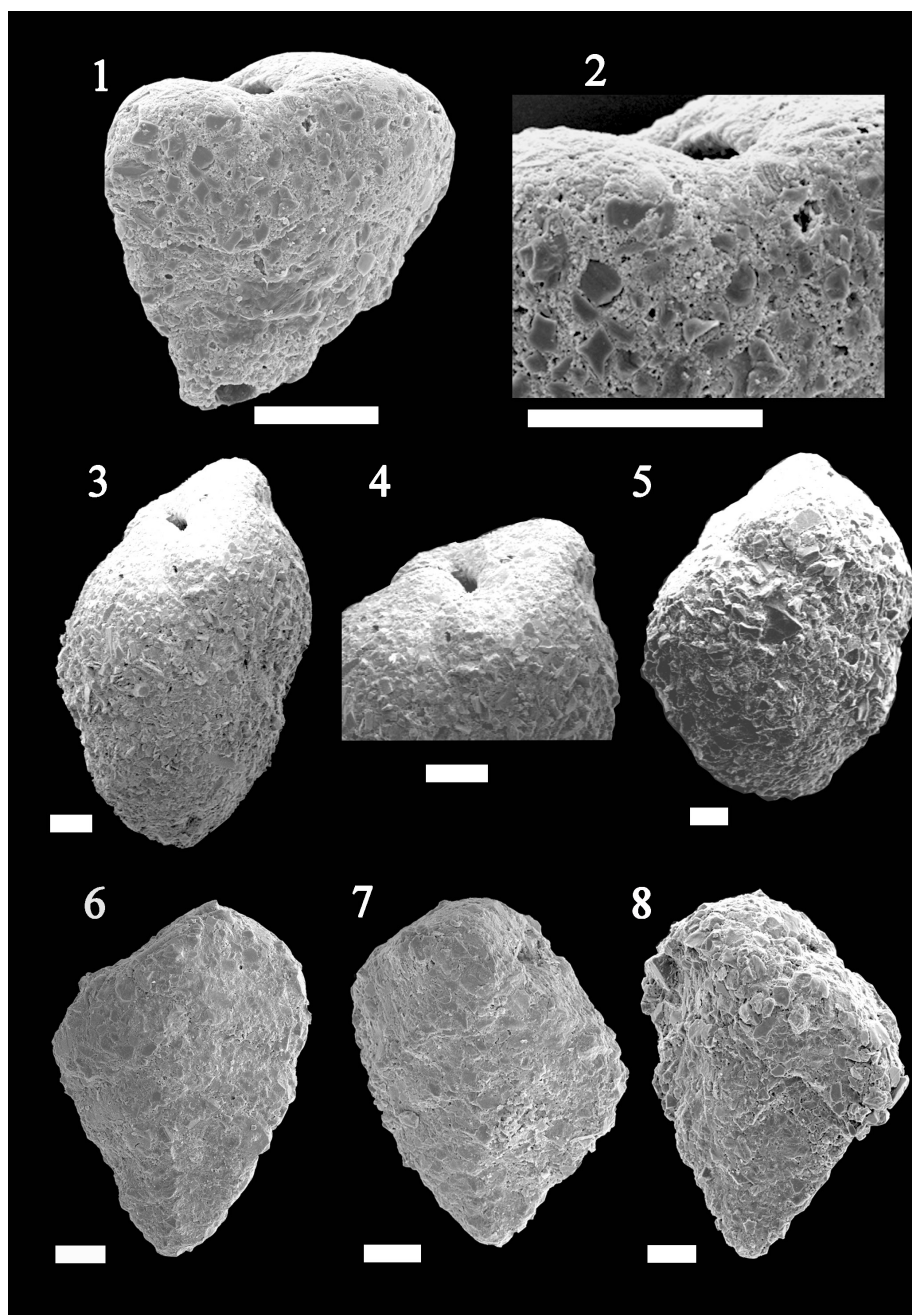
Fig. 5 - *Textularia tuberosa* d'Orbigny, 1826, Isola d'Asti, 6.7 m, juvenile specimen, lateral view.

Fig. 6 - *Textularia* sp. 1, Primeglio, PR, lateral view.

Fig. 7 - *Textularia* sp. 1, Revignano, REV2, lateral view.

Fig. 8 - *Textularia* sp. 1, Primeglio, PR, oblique-lateral view.

White bar = 100 µm



1791 *Polymorpha sagittulae* Soldani, pl. 133, fig. Q.

1883 *Textularia sagittula* DeFrance var. *soldanii* Fornasini, p. 183, pl. 2, fig. 2.

1887c *Textularia soldanii* - Fornasini, p. 377, pl. 9, figs. 3-4.

1888b *Textularia soldanii* - Fornasini, p. 318, pl. 11, fig. 1.

1982 *Textularia soldanii* - Agip, pl. 2, fig. 10.

1987 *Textularia soldanii* - Violanti, p. 262, pl. 1, fig. 2.

Test elongate, large, biserial through, aboral part acute, 6-11 pairs of chambers, in the adult stage rapidly increasing in size and provided by a thick, protruding edge or an irregular thorny crest. Sutures fairly curved to straight. Peripheral margin acute. Wall thick, coarsely agglutinated, with calcareous cement, canaliculate. Aperture a low basal slit at the inner margin of the last chamber.

Remarks. The species, described by Fornasini (1883) from the Pliocene of Ponticello di Savena (Bologna, Northern Italy), was previously figured, but not described, by Soldani (1791). *T. soldanii* is common in many shelf to upper slope assemblages from Miocene (Tortonian) to Pleistocene (Agip 1982; Rio et al. 1988). Reported as fossil in WoRMS (2023), it is included in the list of the extant Mediterranean species (Banchetti et al. 2008), without reference source.

Rare specimens occur in clayey-silty sediments, from the upper part of the AA formation of Isola d'Asti, Calliano, Incisa S. sections, and of samples MN, FR3, CH90.

***Textularia truncata* Höglund, 1947**

Pl. 12, figs. 1-2

- 1947 *Textularia truncata* Höglund, pp. 175-176, pl. 12, figs. 8-9, text-figs. 147-149.
 1958 *Textularia truncata* - Le Calvez, p. 149, pl. 1, fig. 5.
 1991 *Textularia truncata* - Cimerman & Langer, p. 22, pl. 12, figs. 1-3.
 1994 *Textularia truncata* - Loeblich & Tappan, p. 30, pl. 35, figs. 8-13.
 2003 *Textularia truncata* - Murray, p. 15, figs. 3. 17-18.

Test biserial, short, of medium size, triangular in lateral view, oral end truncate, chambers wider than high, rapidly increasing in size. Peripheral edge subrounded. Sutures distinct, horizontal or slightly oblique. Wall medium size grained with abundant calcareous cement, rather smoothly finished, traversed by parapores. Aperture a low arch at the inner margin of the last chamber.

Remarks. A rare living species, described by Höglund (1947) from depths ranging between 15-73 m and worldwide recorded (Le Calvez 1958; Murray 2003).

Very rare specimens were collected from the AA clays and silty clays of the Isola d'Asti, Incisa S. and Verrua S. sections and from the SA silty sands at Moncalvo.

***Textularia tuberosa* d'Orbigny, 1826**

Pl. 12, figs. 3-5

- 1780 *Nautilus amphorarius* Soldani, p. 108, pl. 7, fig. 46 E.
 1798 *Polymorphum janiforme* Soldani, p. 39, pl. 14, fig. h.
 1826 *Textularia tuberosa* d'Orbigny, p. 263, n°. 26.
 1887b *Textularia tuberosa* - Fornasini, pp. 161-162, pl. 2, fig. 2a-b.
 1902-1904a *Textularia tuberosa* - Fornasini, p. 6, fig. 2.
 1902-1904b *Textularia tuberosa* - Fornasini, pl. O, fig. 2.

Test rather large, ovoidal, biserial, with a low number of convex, inflated chambers. Sutures oblique, poorly depressed to indistinct. Peripheral margin rounded. Wall coarsely agglutinated, mainly including inorganic clasts, with abundant calcareous cement, canaliculate. Aperture a rather large arch at the inner margin of the last chamber.

Remarks. D'Orbigny (1826) named *T. tuberosa* giving as reference *N. amphorarius* Soldani, 1780 = *Polymorphum janiforme* Soldani, 1798. Fornasini (1887b; 1887d) reported *T. tuberosa* from the Miocene, Pliocene and Pleistocene of Italy. Accepted as an extant species in WoRMS (2023). Reported in the list of the extant Mediterranean species (Banchetti et al. 2008), without references source.

Very rare specimens were collected in the AA assemblages of the Isola d'Asti and Verrua S. sections and in sample FR1.

***Textularia* sp. 1**

Pl. 12, figs. 6-8

Test of lozenge shape, biserial, with 5-8 pairs of chambers, fastly increasing in width. Peripheral margin acute, a keel may be present in the adult stage. The median part of the test, along the axis, is slightly inflated, giving a distinct median ridge. Sutures oblique, fairly depressed to indistinct. Wall rather thick, medium to coarse agglutinated, almost exclusively made by inorganic clasts, with abundant calcareous cement, and parapores. Aperture a very small arch at the inner margin of the last chamber.

Remarks. *Textularia* sp. 1 differs from *T. aciculata* for the more rhomboidal shape of the test, the acute peripheral margin, the evident median ridge and the irregularly agglutinated wall. In the studied area, rare specimens occur in the circalittoral silts and sandy silts assemblages.

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