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Pliocene foraminifera of Piedmont (north-western Italy): a synthesis of recent studies

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Abstract

A synthesis of recent biostratigraphical and palaeoenvironmental studies on foraminifera assemblages of the Piedmont Pliocene (north-eastern Monferrato, Astigiano, Langhe and Monregalese) is discussed. In the region, biozone MPl1 is documented by typical *Sphaeroidinellopsis* assemblages only in its central area. Rich and diversified assemblages of MPl2 biozone, with *Globorotalia margaritae* Bolli & Bermudez*,* and MPl3 biozone, with *G. margaritae* and *G. puncticulata* (Deshayes), are indicative of the upper epibathyal zone, and suggest palaeoenvironmental conditions similar to those of coeval pelagic successions of Sicily and the Tyrrhenian Sea. Already along biozone MPl3, and chiefly biozone MPl4, with *G. puncticulata*, less diversified assemblages become more widespread, indicating shelf palaeoenvironments, subject to heavy transport of displaced foraminifera from more inner neritic zones. In the study area most inner neritic and shallow outer neritic microfaunas are devoid of biostratigraphic markers; only few silty sediments yield *Bulimina basispinosa* Tedeschi & Zanmatti and *Globobulimina ovula* (d'Orbigny), reported from the Middle Pliocene, and can be correlated to the MPl5 biozone.

Key-words: Pliocene, foraminifera, biostratigraphy, palaeoenvironment, Piedmont.

Introduction

This work presents a synthesis of the biostratigraphical and palaeoenvironmental researches carried out by the author on foraminifera assemblages of the Piedmont Pliocene. Further studies are still underway, but the elements collected so far seem to allow for a comprehensive analysis and a comparison with earlier data on the region. The main problems with both biostratigraphical and palaeoenvironmental interpretations of Piedmontese Pliocene successions are usually connected with the lithologies (clays, silts and sands), which are easily and quickly eroded; and with the patchiness and low thickness of outcrops, quite often man-made (roadworks, excavations etc.) and therefore short-lived.

Micropalaeontological analyses were concentrated in three geographical sectors: the north-eastern Monferrato, studied as part of the "Foglio 157 Trino, Carta Geologica d'Italia, scala 1:50.000" (Clari and Polino 2003) project, the Astigiano, and a portion of the south-western Piedmont, between Langhe and Monregalese (Fig. 1). The latter sectors were analysed in various Piedmontese Neogene research projects (MIUR funds), as part of conventions and collaborations with the "Politecnico di Torino". Part of the data were never published before (Astigiano assemblages: Canale, Govone, Baldichieri, Incisa Scapaccino), part were the subject of already published studies or meeting presentations (Trenkwalder and Violanti 2001, 2002, 2004; Boano and Violanti 2002; Ghielmi et al. 2002; Dela Pierre et al. 2003; De Bortoli et al. 2004; Mazzarella and Violanti 2004) or in studies in press at the time of writing (Bove Forgiot et al. in press).

Fig. 1. Sketch map of the most significant sections in the studied sectors of Piedmont. B = Baldichieri; Ca = Canale; Ch = Cherasco; Cl = Calliano; Co = Cortiglione; Cs = Castelcebro; G = Govone; In = Incisa Scapaccino; Is = Isola d'Asti; M = Moncalvo; S = Salmour; V = Verrua Savoia.

Previous studies

Pliocene foraminifera from the Piedmont region have been known since the studies of Dervieux (1892), on the assemblages of Villalvernia. Martinis (1954) presented a far-reaching micro-palaeontological study of the Pliocene succession, analysing it in a number of localities, from Verrua Savoia in the North, to Villalvernia in the South, to the Astigiano and the Morozzo and Cherasco series, and in lithologies pertaining to the Argille di Lugagnano (= Argille Azzurre, Blue Clays) and the Sabbie di Asti (Asti Sands). In particular, Martinis dated the foraminifera from Verrua S. as Middle and Upper Pliocene; instead Zappi (1961) recognized in them assemblages which are indicative of the Lower to Middle-Upper Pliocene. Recent studies attributed most of the sediments in Verrua S. (Silt di Verrua S. and Calcareniti di Castel Verrua, Dela Pierre et al. 2003) to the MPl3 biozone of the Lower Pliocene, based on the co-occurrence of *Globorotalia margaritae* Bolli & Bermudez and *G. puncticulata* (Deshayes) and the top of the Calcareniti to the MPl4a biozone, documented by the presence of *G. puncticulata* alone. Proposed palaeobathymetrical conditions fall in the upper epibathyal-deep outer neritic zone for the basal portion of the Silt di Verrua S., progressively shallowing to the inner neritic-outer neritic zone of the uppermost Calcareniti di Castel Verrua (Trenkwalder and Violanti 2001, 2002; Bove Forgiot et al. in press). Casnedi (1971) presented another regional scale review of Pliocene microfaunas and described rich Lower Pliocene assemblages from the Southern and Western Piedmont Argille Azzurre (in literature also reported as Argille di Lugagnano), with common planktonic specimens (*Globigerina apertura* Cushman*, G. bulloides* d'Orbigny*, Globigerinoides extremus* Bolli & Bermudez*, Globorotalia margaritae, G. puncticulata*) and deep shelf to bathyal benthic species (*Anomalinoides helicinus* (Costa)*, Heterolepa praecincta* (Karrer), *Hoeglundina elegans* (d'Orbigny)*, Planulina ariminensis* d'Orbigny*, Uvigerina peregrina* Cushman*, U. rutila* Cushman & Todd, etc.). Mainly from the surroundings of Asti, Casnedi (1971) reported less diversified assemblages, dominated by shallow water foraminifera (*Ammonia beccarii* (Linnaeus)*, Elphidium crispum* (Linnaeus), sessile forms as *Discorbis* spp. etc.). A number of works concentrated on specific areas instead. In particular, the foraminiferal assemblages of the northernmost Pliocene deposits, in the Biellese area, on the rim of the Western Alps, were described by Barbieri et al. (1974), Aimone and Ferrero Mortara (1983) and referred to Middle-Upper Pliocene, in inner neritic to outer neritic palaeoenvironments. Also in these outcrops, planktonic taxa are scarce and only rare benthic species, as *Buccella granulata* (Di Napoli) and *Ellipsopolymorphina fornasinii* (Galloway) allowed the correlation to the MPl4 biozone; the occurrence of the gastropod *Bufonaria marginata* (Gmelin) restricted the interval to the MPl4a biozone (Basilici et al. 1997). In the Asti area Sampò et al. (1968), Pavia (1970), Ferrero (1971) and Violanti (1996) described the foraminifera from the historical Astian sections to the Villafranchian facies. Within the grey-blue clays (Argille Azzurre), at the bottom of the succession, planktonic tests (*Globigerina bulloides, G. decoraperta* Takajanagi & Saito*, Globigerinoides ruber* (d'Orbigny)*, G. obliquus* Bolli*, G. trilobus* (Reuss)), are rare; benthic foraminifers

Tab. 1. List of sections, samples relative and total number, planktonic and benthic foraminiferal indicative taxa, other taxa (D = Diatoms; R = Radiolarians; S = Siliceous sponges), P/(P+B) ratio, biostratigraphic and palaeoenvironmental interpretations.

are characterized by rare *Uvigerina rutila* and frequent *Ammonia beccarii* and *Nonion scaphum* (Fichtel & Moll). In the yellow sands (Sabbie di Asti) dominant species are *Ammonia beccarii, Brizalina spathulata* (Williamson)*, Bulimina elongata* d'Orbigny*, Cibicides lobatulus* (Walker & Jacob)*, Elphidium* spp., *Florilus boueanum* (d'Orbigny) and *Protelphidium granosum* (d'Orbigny). Buliminids (*B. lappa* Cushman & Parker*, B. minima* Tedeschi & Zanmatti), *Gyroidinoides umbonatus* (Silvestri)*, G. longispira* (Tedeschi & Zanmatti)*, Valvulineria bradyana* (Fornasini) may be more frequent in silty layers, interpreted as outer neritic deposits, whereas *Cribroelphidium decipiens* (Costa) and *Neoconorbina terquemi* (Rzehak) are more common in inner neritic coarse sediments. Rich planktonic and benthic microfaunas of Argille Azzurre, less diversified ones of Sabbie di Asti and of "Facies di Transizione" (transitional facies, silty clays to sandy silts), showing intermediate characteristics compared to the two previous assemblages, were also described by Sechi (1984). Violanti et al. (2000) studied the micro- and macrofossil assemblages of the "Facies di Transizione" of Incisa Scapaccino (Asti), dominated by infaunal and opportunistic foraminifers (*Bulimina elongata, Cassidulina carinata* Silvestri*, Florilus boueanum, Fursenkoina* sp.*, Globobulimina affinis* (d'Orbigny)), most of them reported from disaerobic sediments with high percentages of phytodetritus or organic matter (Jorissen 1987) and suggested a prodelta facies for these lithologies. Similar assemblages have been described in south-western Piedmont: Boni et al. (1987) described a succession, comprised between the Lower Pliocene, testified by the occurrence of *Globorotalia margaritae*, and the Upper Pliocene-Pleistocene, with shallow water taxa (*Elphidium crispum, E. macellum* (Fichtel & Moll), sessile forms), along the T. Pesio (Monregalese). In the Albese area, Sampò (1976) and Montefameglio et al. (1979) attributed clayey marls and sandy clays to the Lower Pliocene MPl3 biozone on the basis of the occurrence of locally common *Globorotalia puncticulata, Anomalinoides helicinus*, *Bulimina minima and Uvigerina rutila*. Pavia et al. (1989), analyzing the macrofossil communities of a coarsening-upward sequence at Breolungi (Mondovì), described also the foraminiferal assemblages, dominated by benthic taxa; the authors pointed out the absence of the Globorotalias and the presence of *Heterolepa dertonensis* (Ruscelli)*, Uvigerina longistriata* Perconig*, U. rutila* and of typical Lower Pliocene taxa such as *Bolivina leonardii* Accordi & Selmi. Violanti and Giraud (1992) studied assemblages from the Monregalese, very poor in planktonic specimens, mainly dating from the Lower-Middle Pliocene based on the occurence of *Bolivina apenninica* Barbieri & Mosna*, B. placentina* Zanmatti*, Bulimina minima, Uvigerina longistriata* and *U. rutila*, but often devoid of any biostratigraphic marker and indicating palaeobathymetries ranging from the deep outer neritic-upper epibathyal to the outer neritic and inner neritic zone. Reworked specimens of Miocene planktonic and benthic taxa have been frequently reported from all the lithologies and geographic areas, in many of the previous mentioned works (Sampò et al. 1968; Zappi 1961; Sechi 1984; Violanti and Girau, 1992; Bove Forgiot et al in press, *inter alias*).

Materials and methods

The samples were collected chiefly from artificial outcrops (active or abandoned quarries, building digs, etc.); in the Astigiano and in south-western Piedmont some also come from core samplings at a depth range of about -30/-190m b.g. Outcrop conditions enabled the sampling of thick exposures only in few localities (Verrua Savoia: about 95 m thick, Calliano: about 17 m, Incisa Scapaccino: about 20 m, Cortiglione: about 40 m, Isola d'Asti: about 26 m) (Tab. 1). Unfortunately, the thickest Verrua S. section is strongly affected by reworking and diagenesis. The study of benthic and planktonic foraminifera was carried out on sieving residues following standard protocols, as described in Trenkwalder and Violanti (2001) and separated into >250 µm, 250-125 µm and 125-63 µm grain fractions; counts were carried out on the whole of the >125 µm fraction. Calcium carbonate percentages, controlled by primary productivity (Olausson 1960) and by dilution by terrigenous material (Hoogakker et al. 2004) in pelagic sediments, have been measured on 1 gr of sediment for most of the samples.

Recent data in stratigraphical order

The data will be discussed in stratigraphical order, from the older assemblages to the younger. In none of the analyzed samples *Sphaeroidinellopsis* specimens have been found, which could be indicative of biozone MPl1 (*Sphaeroidinellopsis* acme zone).

Sphaeroidinellopsis seminulina (Schwager) is instead common in the Argille Azzurre of Moncucco Torinese quarry (Turin Hill), near the contact with the underlying Messinian deposits (Bicchi et al. 2002). Very recently started studies have also recovered *Sphaeroidinellopsis* spp. within the basal Pliocene layers of the Narzole (Langhe) corehole, encompassing the Miocene/Pliocene boundary, and documenting the deposition of deep marine sediments during the MPl1 biozone almost in the central Piedmont basin. These assemblages contain also abundant and large specimens of *Orbulina bilobata* d'Orbigny and *O. universa*, suggesting warm-water conditions (Colombo and Cita 1980; Hemleben et al. 1989); the P/(P+B) ratio was estimed about 60-70%. Epibathyal benthic taxa (*Hoeglundina elegans, Siphonina reticulata* (Czjzek)*, Uvigerina peregrina,* etc.) and species limited to the Lower-Middle Pliocene (*Lenticulina dilecta* (Seguenza)*, L. formosa* (Cushman)*, Planularia cymba* d'Orbigny*, P. discoidalis* Costa*, U. rutila*, *Vaginulinopsis carinata* Silvestri etc.) are common. *Lingulina seminuda* Hantken is also present, never detected in the studied younger Piedmont assemblages. Biozone MPl1 is apparently absent in the stratotype section (Rio et al. 1988) and in other successions on the rim of the Northern Apennine, where a hiatus was postulated at the Miocene/Pliocene limit (Channell et al. 1994).

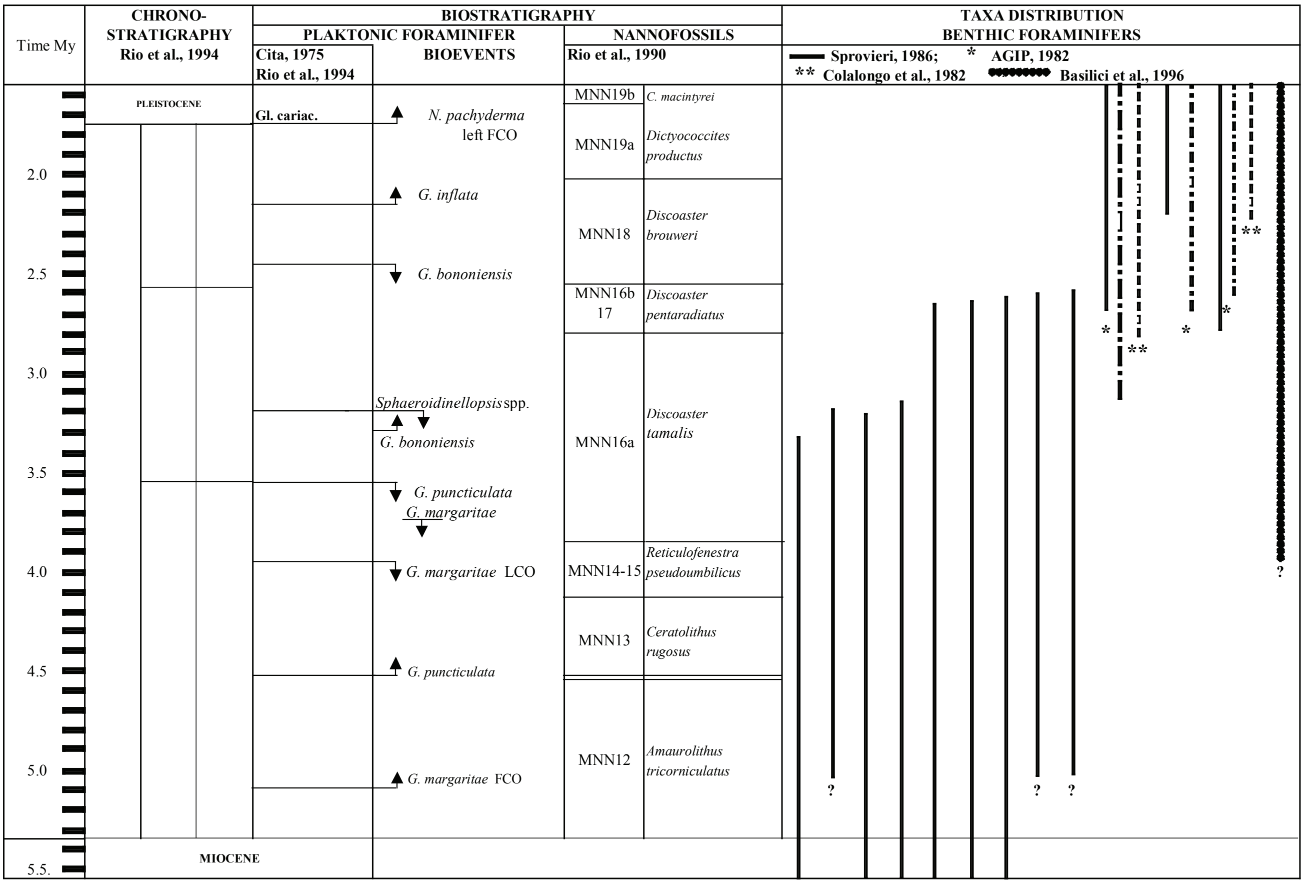
- Biozone MPl2 – Assemblages are documented in few outcrops of the silt-clay member of the Argille Azzurre (Boano and Violanti, 2002), limited to the southernmost portion of the "Foglio Trino" (Cioccaro, Tonco) (Dela Pierre et al. 2003).

Assemblages were also found in outcrops in the Alba area (Monticello d'Alba, Piobesi, Vezza d'Alba,) and in core-samples in the Cherasco area (SPD272, roughly -27m b.g.). $CaCO_3$ percentages range between 30-40%. *Globorotalia margaritae* is present, whereas *Globorotalia puncticulata* is not, allowing attribution to the MPl2 biozone of the Lower Pliocene (Cita 1975). Microfaunas are rich, with abundant planktonic foraminifera (P/(P+B) ratio = 70-80%) and can be referred to upper epibathyal sea-bottoms. Benthic foraminifera are well diversified, with frequent specimens of deep outer neritic to bathyal species (*Cibicidoides pseudoungerianus* (Cushman), *Nodosariidae*, *Gyroidinoides neosoldanii* (Brotzen)*, Hoeglundina elegans, Oridorsalis stellatus* (Silvestri)*, Planulina ariminensis, Siphonina reticulata,* etc) (Wright 1978) and common taxa extinct during the Lower-Middle Pliocene (*Anomalinoides helicinus, Bolivina leonardii, Siphonina planoconvexa* (Silvestri)*, Uvigerina longistriata, U. rutila, Vaginulinopsis carinata,* etc.) (AGIP 1982; Sprovieri 1986). *Bolivina gladiiformis* Conato, *B. lucido-punctata* Conato and *B. placentina*, limited to the Lower-Middle Pliocene (Sprovieri 1986), have also been detected (Tab. 2). Some rare individuals of deep benthic species are also present, such as *Parrelloides robertsonianus* (Brady), a typical NADW (North Atlantic Deep Water) form, reported in the Mediterranean starting in biozone MPl2 (Sprovieri and Hasegawa 1990; Barra et al. 1998), and also common in Miocene assemblages indicative of well-oxygenated palaeoenvironment (Kouwenhoven et al. 1999). Shallow water taxa (*Ammonia beccarii, Neoconorbina* spp.) are absent or extremely rare.

- Biozone MPl3 – The stratigraphic interval, documented by the co-occurence of *Globorotalia margaritae* and *Globorotalia puncticulata*, is well represented in the whole study area in clay and silty-clay sediments. Deposition apparently took place at palaeobathymetries varying from the upper epibathyal zone to the outer neritic zone. The most important outcrops are those in Verrua S. (lower and middle portions of the section) and in Calliano (NW Monferrato), the lower part of the Isola d'Asti (Astigiano) section (Violanti et al. 2003; Mazzarella and Violanti 2004; Bove Forgiot et al. in press). $CaCO_3$ percentages are widely variable, ranging between 9-15% within the Isola d'Asti clays and Calliano silts to 30-40% in the Verrua S. silts.

Assemblages from the lower-middle portions of Verrua S. (Silt di Verrua S.) and Isola d'Asti (Argille Azzurre) can be referred to the upper epibathyal zone: planktonic tests are frequent (P/(P+B) = 50-60%), *Globorotalia margaritae* and *Globorotalia puncticulata* are often common.

Benthic assemblages differ from those of biozone MPl2, only for showing more species and individuals from inner neritic/outer neritic taxa (*Bolivina* spp., *Bulimina* spp.*, Cibicidoides ungerianus* (d'Orbigny), *Elphidium* spp.), suggesting a higher input from the shelf and/or a shallower depth compared to older assemblages. The Calliano siltites (Violanti et al. 2003) seem on the other hand to fit a outer neritic zone: plankton foraminifera are scarce (P/(P+B) max 15%), *Globorotalia margaritae* and *Globorotalia punc-ticulata* are very rare, but still allow correlation with the previous successions.



Tab 2. Adopted chrono- and biostratigraphic scheme, distribution of selected benthic taxa, compiled after various sources quoted in the table.

Benthic foraminifera are dominated by infaunal forms, typical of pelite-rich sea-bottoms (*Bulimina minima* Tedeschi & Zanmatti, *Cassidulina carinata* Sivestri, *Val-vulineria bradyana* (Fornasini)) or sandy-silty sea-bottoms (*Dorothia gibbosa* (d'Orbigny), *Florilus boueanum* (d'Orbigny)) of the shelf. Epiphyte taxa are common (*Neoconorbina terquemi* (Rzehak), *Rosalina globularis* d'Orbigny). In Calliano, as in silts from the Canale area, siliceous sponge spicules, radiolarians and diatoms are also present. Siliceous microfossils, which are proxies of a good productivity, are also abundant in the silts from Castelcebro (NW Monferrato), with oligotypic foraminiferal assemblages (*Brizalina* spp., *Fursenkoina* spp.). The silts have been dated through nannofossils to the MNN14-15 biozone (Lozar, oral comm.), corresponding to the interval between the top of MPl3 and the base of MPl4 (Channell et al. 1994).

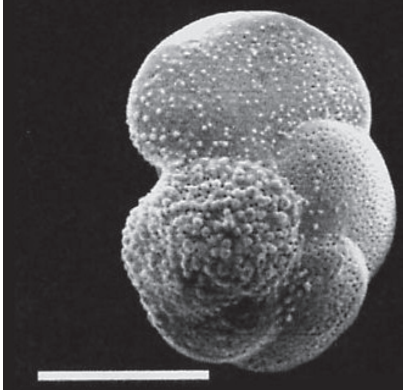
- Biozone MPl4a - Assemblages from this biozone are also widely represented in the whole area, in lithologies either akin to the Argille Azzurre (clay member and silty-clay member) (Boano and Violanti 2002; Ghielmi et al. 2002) or belonging to the Sabbie di Asti (or similar to the latter, such as the topmost sands in the Calcareniti di Verrua S. (Dela Pierre et al. 2003; Bove Forgiot et al. in press). The biozone was also recognized in core-samples in the Baldichieri-Tigliole area (corehole A20, -80m b.g.). The most representative sections are the top portion of the Isola d'Asti and Verrua S. sections, the Moncalvo section (Trenkwalder and Violanti 2004) and the Vezza d'Alba section. $CaCO_3$ percentages are generally similar to those of sediments correlated to the MPl3 biozone and range between 10-30%; they reach 50-80% only in the coarse biogenic Calcareniti di Verrua S. Assemblages vary greatly along with lithologies: in clay-rich sediments they appear to be richer in species fitting the deep outer neritic zone, with common specimens of *Globorotalia puncticulata* and *Globorotalia puncticulata padana* Dondi & Papetti and P/(P+B) ratio ranging about 30-50-%. In coarser sediments, assemblages typical of outer neritic to inner neritic palaeoenvironments are found, with few planktonic individuals (P/(P+B) <5-10%) and a percentage increase in shallow forms. Benthic infaunal taxa that go extinct during biozone MPl5 or at its top (*Bolivina lucido–punctata, Bolivina placentina*, *Bulimina minima*) are usually present to common. In the bioturbated clays of Isola d'Asti laminated layers are preserved with abundant planktonic foraminifera and benthic faunas typical of disaerobic sea-bottoms (*Bolivina* spp., *Brizalina* spp.). The study of this succession is currently under way, to verify whether these same levels can be correlated with Pliocene sapropels present in various Northern Appennine areas (Capozzi and Picotti 2003). In various sites (Asti-Govone area, Baldichieri, Cortiglione, Moncalvo, Montaldo Scarampi, Valleandona, Monregalese) the frequent biocalcarenite levels are indicative of intense input from the inner shelf.

- Biozone MPl5 – Silts and sandy silts referable to this biozone have been recovered in very few outcrops of the Southwestern Piedmont, near Cherasco and Canale. The presence of common to rare, empty and well preserved tests of *Bulimina basispinosa* Tedeschi & Zanmatti and *Globobulimina ovula* (d'Orbigny), which appeared in the Middle Pliocene (AGIP 1982) MPl5 biozone (Sprovieri 1986), supports this biostratigraphic interpretation. $CaCO_3$ percentages are lower than 5%. Assemblages can be referred to the shallow outer neritic zone: planktonic specimens are scarce (P/(P+B) = 5-10%) and zonal markers as *Globorotalia aemiliana* Colalongo & Sartoni and *G. bononiensis* Dondi are missing. Dominant benthic species are *Brizalina spathulata* (Williamson)*, Bulimina elongata, Florilus boueanum, Dorothia gibbosa* (d'Orbigny)*, Spiroplectinella wrightii* (Silvestri), also common in older silty layers. *Buccella granulata* (Di Napoli) seldom occurs. Very rare tests of *G. puncticulata*, infilled by sediment and with a different preservation, have been interpreted as reworked. None of these assemblages yield *Bulimina marginata* d'Orbigny, reported from the upper Middle Pliocene (Dondi and D'Andrea 1986; Verhallen 1991). The recovered co-occurrence of *Bulimina basispinosa* and *Globobulimina ovula* as well the absence of *Bulimina marginata* is in agreement with data from the Northern Italy (AGIP 1982; Colalongo et al. 1982) (Tab. 2), where *Bulimina marginata* occurs after the two previous taxa and could suggests a correlation to the MPl5a biozone. The biostratigraphic distribution of these species reported from the Southern Italy is instead different (Sprovieri 1986) and could suggest a palaeo-environmental control.

Non-Indicative Assemblages – in the whole area foraminiferal assemblages were also observed without any planktonic marker, which can only be attributed to the Pliocene on the basis of benthic taxa. The absence of meso-pelagic planktonic forms, such as the genera *Sphaeroidinellopsis* and *Globorotalia*, seems to be caused by palaeo-environmental factors. Significantly, we can notice:

a) Rich and diversified assemblages, which can be compared with those in biozone MPl2, referring to epibathial/deep outer neritic palaeoenvironments: the P/(P+B) ratio is in the 50-70% range, most benthic taxa have a distribution ranging between Miocene and Lower-Middle Pliocene (*Anomalinoides* spp*., Heterolepa dertonensis* (Ruscelli)*, Lingulina seminuda, Uvigerina rutila*, etc.), and are common also in pelagic Neogene assemblages of the Mediterranean area (Wright 1978; Barra et al. 1998; Kouwenhoven et al. 1999). Benthic forms going extint within or starting with the Pliocene, such as respectively *Bolivina leonardii* or *Bolivina gladiiformis and B. placentina* (AGIP 1982; Sprovieri 1986) are extremely rare. They have been observed in sediments close or in continuity with Miocene deposits (Messinian or older), for NE Monferrato, in the Primeglio, Piea and Moncalvo areas, in the Astigiano (Govone) and in the southernmost sector of the Monregalese, south of Mondovì (Carrù, Fiammenga, Pianfei). On samples coming from the latter, biostratigraphical analyses of nannofossils were carried out, which turned out to be non-conclusive (Amore, pers. comm.)

b) outer neritic to inner/outer neritic assemblages, with a low P/(P+B) ratio, without *Uvigerina rutila*, but with *Bolivina apenninica* Barbieri & Mosna*, Bolivina placentina, Bulimina minima*, extinct during biozone MPl5 (Sprovieri, 1986). In silty-clay to sandy silts deposits (Cortiglione, Incisa Scapaccino) the assemblages are dominated by opportunistic infaunal forms (*Brizalina* spp.. *Bolivina* spp., *Cassidulina carinata, Florilus boueanum, Fursenkoina* spp*.*). *Spiro-plectinella wrighti*, probably mud-dweller with preference for a low clay input (Jorissen 1987) is often common. In sandy levels assemblages are very poor and *Ammonia beccarii, Cribroelphidium decipiens, Elphidium* spp., *Protelphidium granosum* (d'Orbigny) and sessile forms (*Cibicides lobatulus, Neoconorbina terquemi*) are the most common taxa. *Buccella granulata* is seldom present in the Sabbie



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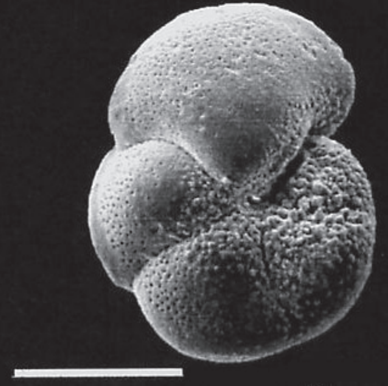

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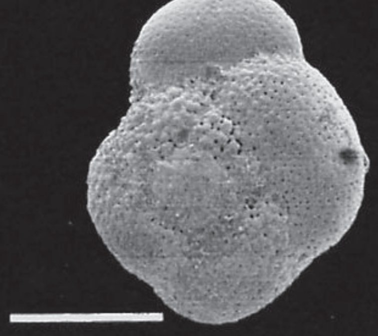

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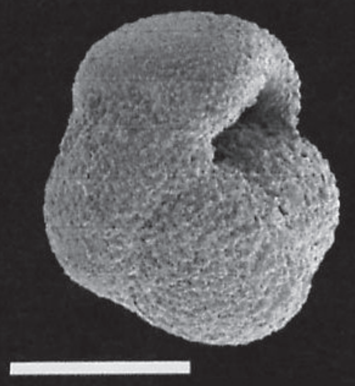

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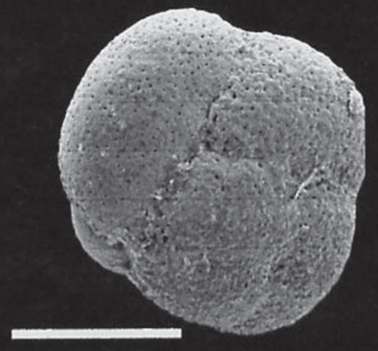

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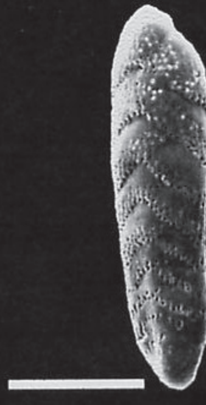

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di Asti at Cortiglione, within the Baldichieri cores, Cherasco area cores SPD286, S2810 and Monteu R. core and is identified also in samples from the Moncalvo outcrop, referred to the biozone MPl4a, for the very rare presence of *Globorotalia puncticulata* (Trenkwalder and Violanti 2004).

Reliability of depth estimates

As it can be inferred from the previous discussion, data concerning the P/(P+B) ratio and the benthic taxa composition are often conflicting, compared with those of Mediterranean pelagic successions in many studied assemblages, chiefly those correlated to the MPl3 and MPl4 biozone, and to epibathyal to outer neritic zones. With the exception of those samples referable to MPl1 and MPl2 biozones, displaced shallow water benthic specimens (*Ammonia beccarii, Elphidium crispum, E. macellum, Rosalina globularis,* etc.) are usually common to abundant, even when deeper taxa (*Hoeglundina elegans, Planulina ariminensis, Uvigerina peregrina, U. rutila,* etc.) are frequent.

Environmental conditions and the tectonic evolution could be the factors explaining these microfossils associations. Data concerning the Lower Pliocene climate in the North Mediterranean document warmer and more humid conditions than present ones, respectively annual temperature 1-4°C higher and annual precipitation 400-700 mm higher than today (Fauquette et al. 1999a). Moreover, the strong tectonic activity documented in the Northwestern Italy (Piana and Polino 1995) as in the Mediterranean area (Boccaletti et al. 1990) during the Neogene led to the uplift of the Alps and to the reduction of the marin Piedmont basin. Palaeoaltitude estimates, based on pollen records, suggest great altitude for the Southern Alps at the Lowermost Pliocene, about 2000 m for the Mercantour Massif (Fauquette et al. 1999b), nowadays about 2800 m high. As a consequence, fast erosion of emerged lands and intense input of terrigenous material affected the marine bottoms, transporting shallow water deposits and microfaunas along the shelf and the slope.

Discussion and conclusions

The biostratigraphical and palaeoenvironmental analysis of the foraminifera assemblages from the Piedmont Pliocene allows us to underline some general elements:

1) The MPl1 biozone of the lowermost Pliocene occurs only in the central part of the Piedmont basin, where common specimens of *Sphaero-idinellopsis*, a deep mesopelagic planktonic genus, suggest a palaeodepth about or greater than 600-800 m. Along the basin margins or in less deep bottoms sedimentation probably occurred in the same time-interval, but palaeobathymetrical conditions prevented the diffusion of the zonal marker. This hypothesis is supported by some non-indicative assemblages from outcrops near Mondovì, very similar to those of the Moncucco quarry and Narzole core MPl1 biozone and in particular characterized by benthic taxa never recovered in younger microfaunas, as *Lingulina seminuda, Planularia discoidalis, P. cymba*.

2) The foraminiferal assemblages, which can be dated to the MPl2 biozone based on the presence of *Gt. margaritae*, have a composition very similar to coeval microfaunas found in pelagic sediments from Sicily (Vismara Schilling and Stradner 1977; Rio et al. 1984, Violanti 1989; Sgarrella et al. 1999) on the basis of the high P/(P+B) ratio and the presence of bathyal benthic taxa, *P. robertsonianus* among them.

3) Compared to deep sea sediments from the Mediterranean area (Rio et al. 1991), Piedmont

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Plate 1

Fig. 1. *Globorotalia margaritae* Bolli & Bermudez, spiral view, sample PA14 (Govone).
Fig. 2. *Globorotalia margaritae* Bolli & Bermudez, umbilical view, sample PA14 (Govone).
Fig. 3. *Globorotalia puncticulata* (Deshayes), spiral view, sample A23 (Verrua Savoia).
Fig. 4. *Globorotalia puncticulata* (Deshayes), umbilical view, sample A23 (Verrua Savoia).
Fig. 5. *Globorotalia puncticulata padana* Dondi & Papetti, spiral view, sample M4 (Monticello d'Alba).
Fig. 6. *Bolivina lucido-punctata* Conato, side view, sample MA18 (Isola d'Asti).
Fig. 7. *Bulimina minima* Tedeschi & Zanmatti, side view, sample I7 (Incisa Scapaccino).
Fig. 8. *Uvigerina longistriata* Perconig, side view, sample A9 (Verrua Savoia).
Fig. 9. *Uvigerina rutila* Cushman & Todd, side view, sample A11 (Verrua Savoia).
Scale bars = 200 µm

assemblages, and especially those pertaining to biozones MPl3 and MPl4, show lower values in the $CaCO_3$ content as well in the P/(P+B) ratio, even when outer neritic to epibathyal taxa are frequent. Terrigenous material is always abundant, derived by high supply of sediments from the surrounding coasts and intense transport, and calcareous particles are diluted within the silicoclastic ones. Planktonic tests result diluted between the common inner neritic and outer neritic benthic specimens. As a consequence, the values of the P/(P+B) ratio proposed for the Mediterranean (Wright 1978) and successfully applied to palaeobathymetrical interpretations of pelagic Pliocene and Pleistocene successions, cannot be directly extrapolated to the Piedmont deposits, strongly influenced by transport from shallower depths and high contents in siliciclastic matter.

4) Palaeogeographical conditions of the Piedmont area are more diversified in the intervals which can be correlated with biozones MPl3 and MPL4a. The evolution of the deposits is easily compared with what was previously outlined for the Cuneo sector (Bottino et al. 1994; Cavalli and Vigna 1995). Deeper deposits, from an upper epibathyal environment and referred to the MPl3 biozone, show microfaunas whose traits are similar to those in the earlier MPl2 zone; but they show a difference in the increasing percentage of displaced benthic individuals, suggesting enhancing erosion and transport from the shelf. Shallower, outer neritic silty-clay deposits, are found starting in same biozone MPl3. In the following MPl4a biozone, assemblages from an upper epibathyal palaeoenvironment, with *Gt. puncticulata* and *Gt. puncticulata padana*, are still documented in the clays of Isola d'Asti and of Vezza d'Alba. In the study area, on the other hand, silty-sandy and sandy sediments, often of a turbiditic nature, become widespread, showing calcarenitic levels and microfaunas ranging from the shallow outer neritic to the inner neritic. Some levels (Cortiglione, Moncalvo), while devoid of any planktonic marker, are likely to be referred to zones MPl4-MPl5, based on the presence of *Buccella granulata* and the absence of younger species. The recovering of *Bulimina basispinosa* and *Globobulimina ovula* documents the Middle Pliocene MPl5 biozone, probably MPl5a biozone on the absence of *B. marginata*. These data confirm the deposition of marine sediments during the Middle Pliocene in the Southwestern Piedmont as reported in literature, mainly on lithostratigraphic bases.

5) Most shallow water assemblages of sandy sediments, lithologically referencing the Sabbie di Asti or "Villafranchian" facies, include only long distribution taxa (*Ammonia beccarii, Elphidium* spp., *Florilus boueanum,* etc.). On the other hand, many of them seem to be coeval to or slightly younger than the previous ones: assemblages composition is as a whole similar, and occasionally taxa that go extinct during biozone MPl5 or at its top (*Bolivina lucido–punctata, Bulimina minima*) are found. while species appearing in the middle or at the top of MPl5 (*B. marginata*) are absent. Based on the data collected so far, in the study area (north-eastern Monferrato, Astigiano, Langhe-Monregalese) marine sediment deposition comes to an end during biozone MPl5.

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Riassunto

[I foraminiferi Pliocenici del Piemonte (Italia nord-occidentale): una sintesi degli studi recenti]

Viene qui presentata una sintesi delle recenti ricerche biostratigrafiche e paleoambientali condotte sulle associazioni a foraminiferi del Pliocene piemontese (Monferrato nord-orientale, Astigiano, Langhe e Monregalese).

Associazioni a *Sphaeroidinellopsis*, che documentano sicuramente la biozona MPl1 sono state rinvenute solo nella zona centrale del Piemonte, in materiali il cui studio è iniziato durante la stesura del presente lavoro (Pozzo Narzole, Langhe) e sono state segnalate in precedenza a Moncucco Torinese (Collina di Torino); nelle aree specificamente esaminate per il presente lavoro non è invece documentata. Alcune associazioni prive di markers planctonici del Monregalese potrebbero essersi deposte nnella stessa biozona, in base alla composizione faunistica simile e alla presenza di taxa bentonici (*Lingulina seminuda, Planularia discoidalis*) non più rinvenute nelle microfaune più giovani.

Le associazioni di ambiente epibatiale, databili alla biozona MPl2 in base alla presenza di *Gt. margaritae*, risultano ben confrontabili con le coeve microfaune dei sedimenti pelagici della Sicilia in base all'elevato rapporto P/(P+B) e alla presenza di taxa bentonici batiali, tra cui *P. robertsonianus*, forma tipica della NADW (North Atlantic Deep Water), segnalato in Mediterraneo a partire dalla biozona MPl2.

In confronto ai sedimenti pliocenici profondi dell'area mediterranea (Rio et al., 1991), le associazioni piemontesi delle biozone MPl3 e MPl4, mostrano valori inferiori del rapporto P/(P+B), anche in presenza di comuni taxa diffusi dal circalitorale profondo al batiale (*Hoeglundina elegans, Oridorsalis stellatus, Siphonina reticulata, Uvigerina rutila* ecc.). Il comune trasporto di materiale da fondali meno profondi ne sembra la causa ed è documentato anche dall'elevato quantititativo di materiale silicoclastico nei residui esaminati. I depositi più profondi, di ambiente epibatiale e riferibili alla biozona MPl3, presentano microfaune con caratteri simili a quelli della precedente biozona MPl2; si differenziano tuttavia per l'aumento percentuale di esemplari bentonici trasportati dalla piattaforma. Depositi siltoso-argillosi meno profondi, circalitorali, si individuano a partire dalla stessa biozona MPl3. Nella successiva biozona MPl4a associazioni di ambiente epibatiale superiore, con *Gt. puncticulata* e *Gt. puncticulata padana*, sono documentate nelle argille di Isola d'Asti e di Vezza d'Alba. Nell'area esaminata diventano però prevalenti i sedimenti siltoso-sabbiosi e sabbiosi, frequentemente torbiditici, con livelli calcarenitici e con microfaune indicative di fondali dal circalitorale poco profondo all'infralitorale. Il ritrovamento di *Bulimina*

basispinosa e *Globobulimina ovula* documenta la biozona MPl5 del Pliocene Medio, probabilmente la biozona MPl5a in base all'assenza di *B. marginata*. Le associazioni di acque basse dei sedimenti sabbiosi, riferibili come litologie alle Sabbie di Asti o a facies "Villafranchiane" contengono solo taxa a lunga distribuzione (*Ammonia beccarii, Elphidium* spp., *Florilus boueanum* ecc.). Tuttavia sembrano essere coeve o di poco successive a quelle precedenti: la composizione delle associazioni è complessivamente simile, sono presenti taxa che si estinguono durante la biozona MPl5 o alla sua sommità (*Bolivina lucido–punctata, Bulimina minima*), mentre sono assenti specie che compaiono nella parte media o alta della MPl5, quali *Bulimina marginata*. In base ai dati finora raccolti, la deposizione di sedimenti marini nell'area esaminata (Monferrato nord-orientale, Astigiano, Langhe-Monregalese) sembra chiudersi durante la biozona MPl5.

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