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OLIGOCENE MACROFOSSIL ASSEMBLAGE FROM THE MIDDLE VOBBIA VALLEY, EASTERN TERTIARY PIEDMONT BASIN (NORTHERN APENNINES)

Abstract - In the middle Vobbia Valley, Eastern Tertiary Piedmont Basin, thin sandstones outcrop, intercalated in the Val Borbera Conglomerate of lower Oligocene age. They are characterized by abundant fossil remains. The fossil assemblage mainly consists of corals, bryozoans and molluscs. Rhodophyceans, benthic foraminiferans, and plant macrofossils are also observed. Fossil remains are concentrated in pods and lenses. The autoecological analysis of the colonial organisms suggests environmental conditions characterized by elevated hydrodynamism, high turbidity of waters and mobile substrates. The taphonomic features of the studied deposits and the regional depositional context suggest that the Val Vobbia sandstones can be interpreted as the distal portion of a hyperpycnal flow-induced turbidite system. The environmental conditions suggested by the studied taphocoenosis differ from those revealed by other coral assemblages previously described in the western area of the Tertiary Piedmont Basin. In particular, the coral assemblage recognized in the Val Vobbia sandstones represents the first occurrence of branched colonies in the Tertiary Piedmont Basin.

Key words - Tertiary Piedmont Basin, Val Borbera Conglomerate, Oligocene, Macrofauna, Taphonomy, Northern Apennines.

Riassunto - *Macrofossili oligocenici della media Val Vobbia, settore orientale del Bacino Terziario Piemontese (Appennino Settentrionale).* Nella media Val Vobbia, nel settore orientale del Bacino Terziario Piemontese, all'interno dei Conglomerati della Val Borbera (Oligocene inferiore) sono presenti sottili intercalazioni di arenarie, caratterizzate da numerosi resti fossili. L'associazione fossile è costituita in prevalenza da coralli, briozoi e molluschi e, subordinatamente, da rodoficee, foraminiferi bentonici e resti vegetali. I fossili si rinvengono in lenti caoticamente distribuite nella matrice. L'analisi autoecologica degli organismi coloniali è indicativa di condizioni ambientali caratterizzate da un elevato idrodinamismo, alta torbidità delle acque e substrato mobile. Le caratteristiche tafonomiche del deposito studiato e il contesto deposizionale regionale sembrano indicare che le arenarie fossilifere della Val Vobbia possano rappresentare la porzione distale di un sistema torbiditico indotto da flussi iperpicnali. Le condizioni paleoambientali suggerite dalla tafocenosi studiata differiscono sostanzialmente da quelle derivate da altre associazioni coralline del settore occidentale del Bacino Terziario Piemontese. In particolare, l'associazione fossile osservata nelle arenarie della Val Vobbia rappresenta la prima segnalazione di coralli fossili nel Bacino Terziario Piemontese dominata da forme ramificate.

Parole chiave - Bacino Terziario Piemontese, Conglomerati della Val Borbera, Oligocene, Macrofauna, Tafonomia, Appennino Settentrionale.

INTRODUCTION

The Tertiary Piedmont Basin (TPB) represents a large episutural basin unconformably overlying the tectonic units deformed during the Mesoalpine collisional phase in the linkage area between Western Alps and Northern Apennines (Fig. 1). Based on the nature of the substrate and the subsequent tectono-stratigraphic evolution, the TPB has been subdivided in two areas (Mutti *et al*., 1995). In the Western area, the substrate is made by the Briançonnais units and the Voltri Group both belonging to the Alps. In the Eastern area the substrate is represented by the Antola Unit, the highest unit of the Ligurian stack holding the highest structural position in the Northern Apennines.

The sedimentation of the TPB succession started since the Late Eocene. The stratigraphic evolution records exactly the tectonic phases affecting the underlying substrate; consequently the very complex setting of the TPB succession is consistent with the highly active tectonic evolution of the linkage area between Western Alps and Northern Apennines (e.g. Mutti *et al*., 1995; Forcella *et al*., 1999).

In the Western TPB succession, the lowermost formation is represented by coarse continental deposits (Costa Cravara Breccia). These deposits are followed by the Molare Formation (Lower Oligocene; Gelati *et al*., 1993), which is mainly characterized by alluvial and shallow-marine conglomerates that usually overlay the Alpine substrate. In some limited areas, the trasgression basal surface of the Molare Formation is characterized by the development of coral reefs (Lorenz, 1969; Gnaccolini, 1978; Pfister, 1985; Fravega *et al*., 1987; Vannucci *et al*., 1997).

In the Eastern TPB succession, the basal formation, unconformably overlying the Antola unit, is represented by the Val Borbera Conglomerate of Lower Oligocene age (Cavanna *et al*., 1989; di Biase *et al*., 2002) consisting of more than 2000 m thick fan-delta deposits, characterized by continental to marine lithofacies (Gnaccolini, 1974; Gelati and Gnaccolini, 1978; Mutti *et al.*, 1995; di Biase, 1998). Only in the Costa Merlassino area, older TPB deposits are present. They are represented by the Monte Piano Marl (Late Eocene), sandstone turbidites (Pizzo d'Oca Unit; Late Eocene) and by the Lower Oligocene Rio Trebbio Unit arenitic shelf deposits (Gelati, 1974, 1977; Cavanna *et al*., 1989; Mutti *et al.*, 1995).

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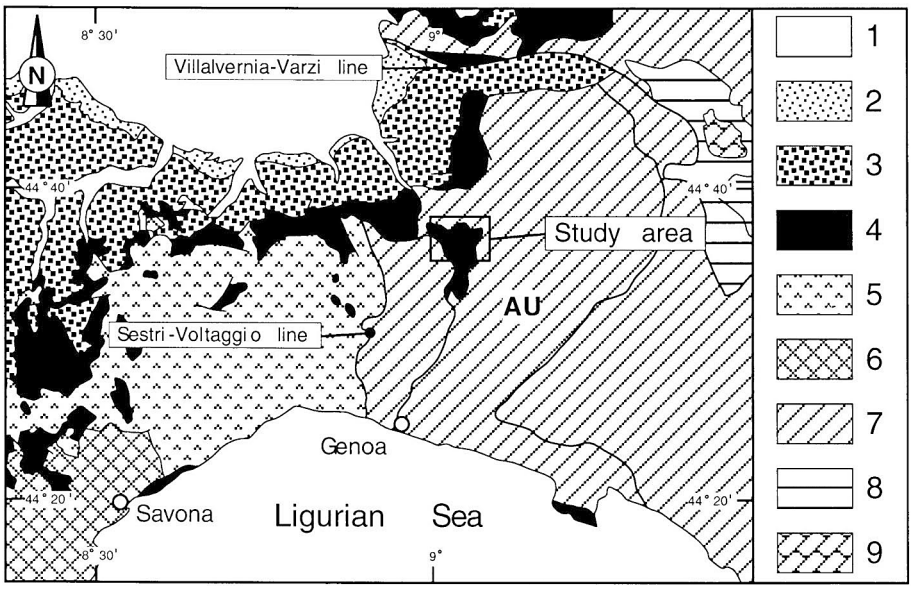

Fig. 1 - Tectonic sketch map of the linkage area between Western Alps and Northern Apennines. 1: Quaternary deposits; 2: Messinian deposits of the Tertiary Piedmont Basins; 3: Miocene sequences of the Tertiary Piedmont and Epiligurian basins; 4: Upper Eocene-Oligocene sequences of the Tertiary Piedmont and Epiligurian basins; 5: Voltri Group and Sestri-Voltaggio zone; 6: Briançonnais crystalline units; 7: Ligurian units of the Northern Apennines, AU: Antola Unit; 8: Subligurian units; 9: Tuscan units.

The paleontological analysis performed in this study provides new data about the possible occurrence of an Oligocene coral reef in the lower part of the Eastern TPB succession.
In particular, the paleoecological indications deriving from the study of the macrofossil assemblage found in the sandstones of the Vobbia Valley can be used as important constraints, supplemental to lithofacies analysis and other fossil indicators, to define the evolution of the depositional context where the TPB succession deposited.

GEOLOGICAL SETTING

The investigated area is located in the middle Vobbia Valley, near the southeastern boundary of the Eastern TPB (Fig. 1). In this area, the Val Borbera Conglomerate directly overlies the Ligurian substrate, represented by the Upper Cretaceous Helminthoid Flysch of the Antola Unit (Fig. 2). In the Vobbia Valley, the contact between the Val Borbera Conglomerate and the Antola Helminthoid Flysch, referred at the regional scale as an unconformity, has never been observed. The strong brittle deformation recognized near the boundary both in the Val Borbera Conglomerate and the Helminthoid Flysch, suggests that it can be interpreted as an unconformity locally tectonized (Fig. 3).
The pebbles of the Val Borbera Conglomerate outcropping in the middle Vobbia Valley mainly originate from carbonatic rocks (marls and limestones) and fine sandstones (Gnaccolini, 1974). Moreover, rare unmetamorphic ophiolitic pebbles have been observed. According to the compositional pattern, proposed by di Biase & Pandolfi (1999) for the Borbera Valley area (north the study area), this composition implies a probable attribution of the conglomerates of the Vobbia Valley to the Borbera depositional unit, representing the middle-lower part of the Val Borbera Conglomerate succession; the Borbera unit has been referred to the lower and middle Rupelian (di Biase *et al.*, 2002).
Along the left side of the Vobbia River, uphill of the medieval Zan Bridge, near the base of the Val Borbera Conglomerate a few meters of fossiliferous sandstones are present. The outcropping sandstones are 10 meters thick and they are arranged in layers, roughly 30 cm thick, characterized by abundant fossil content. Because of fluvial and slide Quaternary deposits, the outcrop is recognizable only for about ten meters, then it is difficult to evaluate the lateral continuity of each layer.
The contact with the underlying Ligurian substrate is hidden by fluvial and slide deposits, and the nearest outcrops of the Antola Flysch are on the opposite side of the river (Fig. 2).
Upward, the transition to the lowermost conglomerate beds is hidden by soils and vegetation. However, the apparent conformity seems indicate a stratigraphic continuity of the sandstones with the Val Borbera Conglomerate (Fig. 4).
The only sedimentary structures recognizable in the sandstones are represented by a thin discontinuous lam-

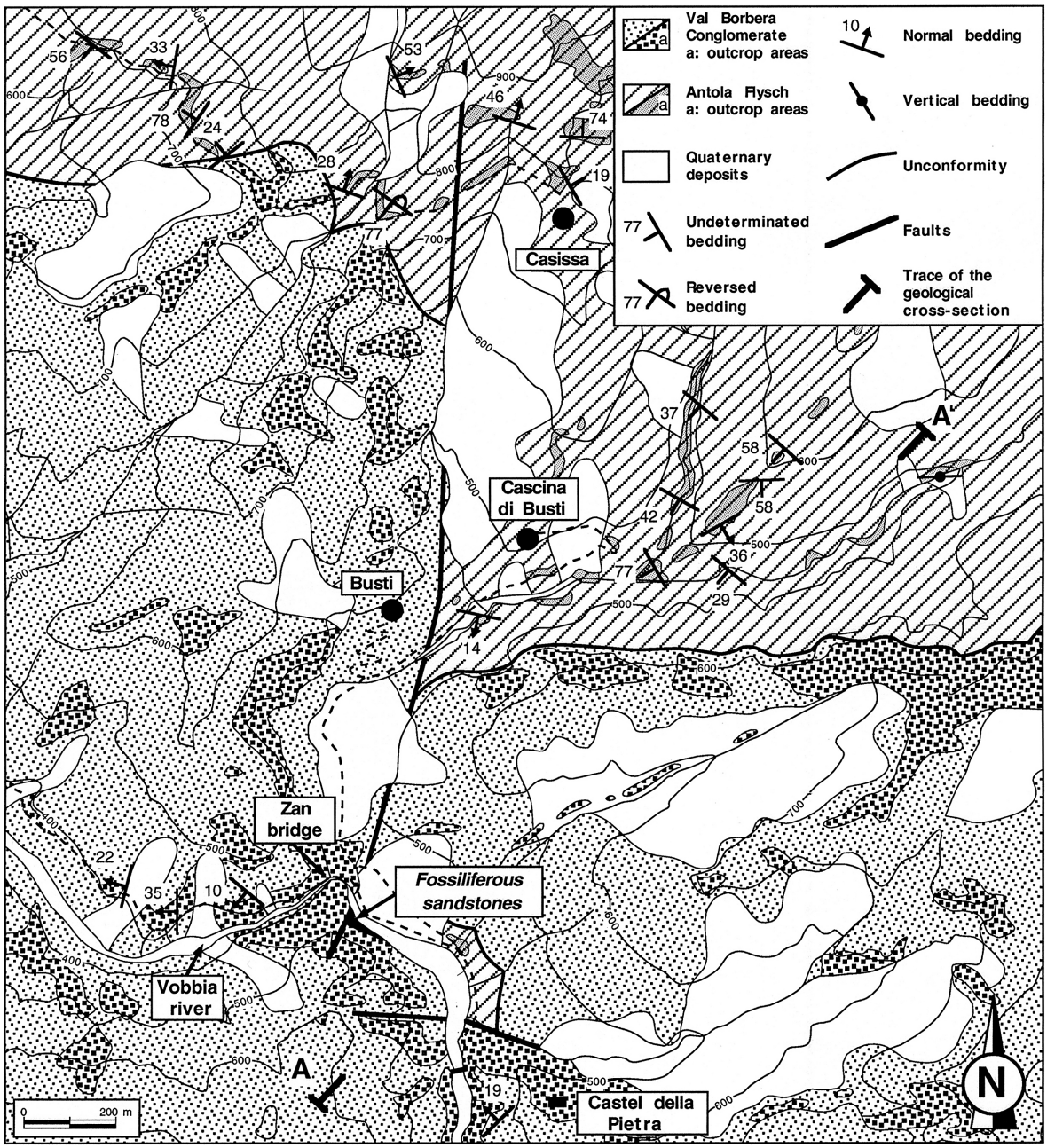

Fig. 2 - Geological map of the investigated area.

ination; an elevated degree of bioturbation can be easily observed. The sandstones are characterized by a matrix-supported texture and, except for fossil remains, by a fine grain size. The sediment mostly consists of extraclasts, represented by micritic and monocrystalline carbonatic grains, together with scarce glauconitic and quarzitic grains. Fossils represent the only recognizable intraclasts (Fig. 5). According to Zuffa (1980), the sandstones can be classified as fine carbonatic extraarenites.

Due to their relationships with the overlying conglomerates, the sandstones of the Vobbia Valley represent arenitic intercalations in the Val Borbera Conglomerate; the attribution of the studied sandstones to the Borbera depositional unit allows to refer these deposits to a probable Rupelian age.

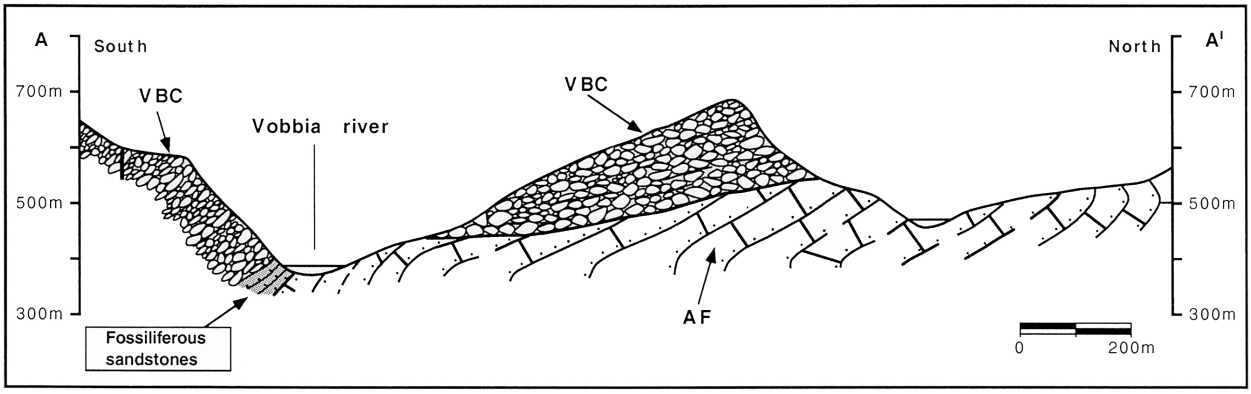

Fig. 3 - Schematic geological cross-section of the investigated area. The boundaries of the section are reported in the geological map.

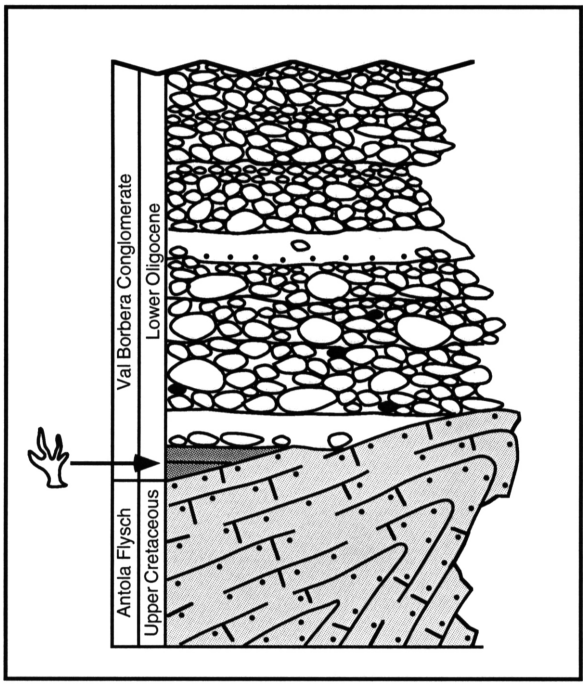

Fig. 4 - Stratigraphic column of the investigated area.

Tab. 1 - Faunal list of middle Vobbia Valley identified fossils.

Cnidaria
Actinacis rollei Reuss, 1864
Astraeopora sp.
Goniopora ramosa (Catullo, 1856)

Bryozoa
Meniscopora syringopora (Reuss, 1848)
Smittina sp.

Mollusca
Turritella sp.
Chlamys sp.
Cardiidae ind.

PALEONTOLOGICAL ANALYSES

In the studied sandstones of the middle Vobbia Valley, the fossils are stochastically distributed within the matrix; however, at the outcrop scale, fossil concentrations can be recognized in thin pods and lenses showing about 2 m of lateral extension.
The observed tanatocoenosis mainly consists of corals, bryozoans, molluscs, and rodophycean fragments. Small benthic foraminifera and carbonaceous plant remains are also present. Although fragmented, corals and bryozoans are often well preserved, whereas molluscs are represented mainly as internal casts (Fig. 6).
In particular, three taxa of hermatypic corals, two of cheilostomatous bryozoans, and three of molluscs, have been recovered (Tab. 1; Figs. 6, 7, 8). In addition, a number of heavily fragmented coral and bryozoan specimens have been also collected. These specimens probably belong to additional taxa, but the state of fragmentation does not allow a taxonomic diagnosis. Thus, the original paleobiodiversity was probably elevated.
Rodophycean fragments are of difficult taxonomic interpretation.
Colonial organisms are fragmented but poorly eroded, and bivalve molluscs are often observed with joined valves (Cardiidae ind.).
Among the corals, *Astraeopora* sp. is the most abundant taxon (Fig. 7), followed by *Goniopora ramosa*, and successively by *Actinacis rollei*. The coral biota is totally constituted of branched colonies. All the specimens consist of small fragments characterized by a good degree of preservation. The morphology of corallites and the structure of coenosteum are sometimes well recognizable and then, the identification of corals is rather easy.
The bryozoan tanatocoenosis is exclusively composed of zoarial habit of the erect rigid type, mainly adeoniforms (*Meniscopora syringopora*) (Fig. 8), and subordinately eschariforms (*Smittina* sp.).
Based on the paleontological content, the age of the studied deposits cannot be exactly determinate. The

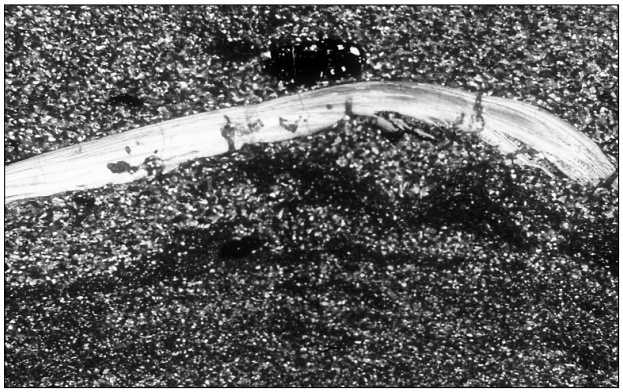

Fig. 5 - Thin section of the sediment showing a bivalve shell and a carbonaceous plant remain.

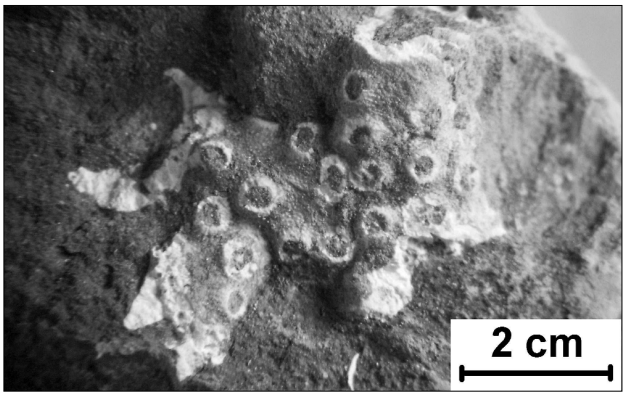

Fig. 7 - *Astraeopora* sp.

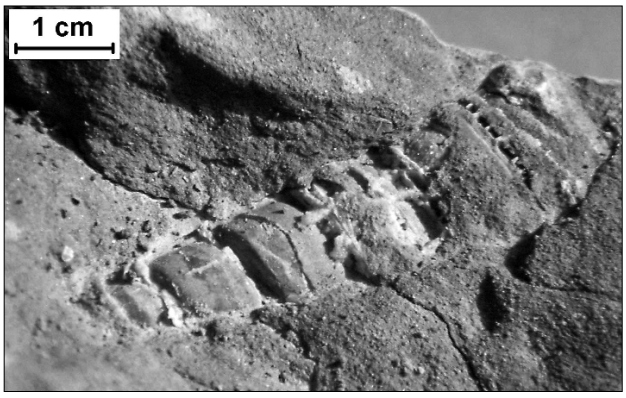

Fig. 6 - Internal casts of turritellid grastropods.

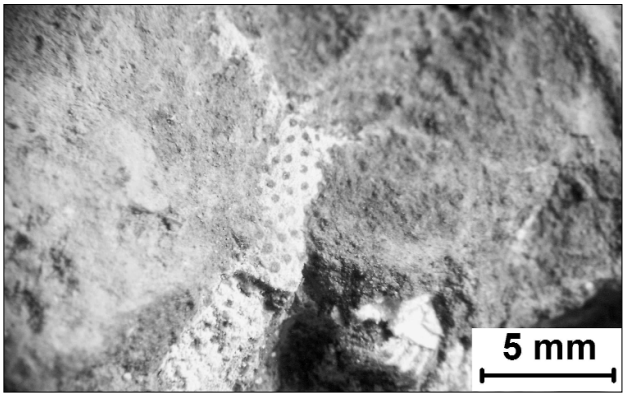

Fig. 8 - *Meniscopora syringopora* (Reuss, 1848).

analysis of the calcareous nannofossils has revealed a generic reworking of Cretaceous and Paleogene taxa. The macrofossil content has a poor resolution from a biostratigraphical point of view. Among the corals, *Actinacis rollei* ranges from Priabonian to Chattian (Bosellini & Russo, 1995). A similar stratigraphic distribution is also indicated by *Meniscopora syringopora* among bryozoans (Braga & Barbin, 1988; Bizzarini & Braga, 1999). However, although rather approximate, the biostratigraphical information provided by the macrofauna is in agreement with the data furnished by the calcareous nannofossil biostratigraphy, which attributes the stratigraphically corresponding deposits to the Rupelian (di Biase *et al*., 2002).

DISCUSSION AND CONCLUSIONS

The fossil assemblage recognized in the sandstones collected in the Vobbia Valley is indicative of a frankly marine depositional environment, probably characterized by an elevated biodiversity. The evident fragmentation and the scanty degree of erosion together with the occurrence of molluscs with joined valves are indicative of a rapid burial process. The thin lamination, the fine grain size and the matrix-supported texture indicate a depositional environment located below the wave-base.

The taphonomic and stratigraphic features of the described deposits well fit with those described in distal storm deposits developed in a shallow-marine shelf (Fürsich & Oschmann, 1993). However, as discussed by Mutti *et al.* (1996), the sedimentological and stratigraphic features of the shelfal sandstone lobes of hyperpycnal induced turbidite deposits, can be easily confused with storm-dominated deposits.

Taking into account the stratigraphic context of the studied deposits, which represent an intercalation in the fan-delta deposits of the Val Borbera Conglomerate succession, the sandstones of the Vobbia Valley can be better explained as the distal portion of shelfal sandstone lobes, consisting in turbidite deposits, which were

triggered by hyperpycnal flows. These deposits originate in flood-dominated fan-deltas characterized by small fluvial systems, with a high gradient in the transfer zone placed close to marine basins (Mutti *et al.*, 1996). In these systems, the genesis of the turbidite flows is mainly related to the presence of instable sediments (Zeng *et al.*, 1991). The hyperpycnal flows induces the development of turbidity currents, which are able to erode the substrate, involving part of the benthic fauna (Mutti *et al.*, 1996). In this setting, the conglomeratic facies represents the proximal portion of the entire system.

Similar deposits to those of the Vobbia Valley, occurring in the Val Borbera Conglomerate succession in zones adjacent the Vobbia Valley (Borbera Valley area), have been already interpreted in the same way by di Biase (1998).

Some further paleoecological observations can be done despite the evident reworking of the fossils. Fossil assemblages who are included in turbidite deposits can be considered as census communities (*sensu* Kidwell, 1998), which are communities reflecting zero or minimal time averaging of individuals. The information provided by these assemblages has a low degree of trustworthiness with respect to the spatial fidelity of the specimens. By contrast, these assemblages show a high level of trustworthiness concerning structural composition and temporal resolution (Behrensmeyer *et al.*, 2000). The exclusive occurrence of branched morphs among corals and erect rigid zoarial habit among bryozoans is indicative of environments characterized by elevated hydrodynamism, high turbidity of waters and mobile substrates (Schopf, 1969; Roy & Smith, 1971; Hubbard & Pocock, 1972; Pfister, 1985; Bosellini & Stemann, 1996). Corals probably were located on mobile substrates that allowed the development of the branched growth forms only. The zoaria of *Meniscopora syringopora* and *Smittina* sp. grew on the corals because a rigid substrate is necessary for the growth of the bryozoans with erect rigid zoarial habit (Lagaaij & Gautier, 1965; Moissette & Saint-Martin, 1995).

The arenitic sediments, which now incorporate the fossil remains, probably were the mobile substrate on which part of the communities grew. Thus, the mobile substrate was affected by successive turbidite events that caused the rapid transport and the definitive burial of the organisms. These catastrophic events were followed by a progressive re-colonization of the substrate by communities of similar taxonomic composition that were destroyed by the successive events. Hyperpycnal flows remobilized non-cohesive sediments transforming them into self-sustained high density and viscous fluids, generating fossil-rich, disorganized sediments, which were displaced in the distal part of the shelf or in deeper basins. The concentration of fossils in pods was probably intensified by bioturbation activity (Fürsich & Oschmann, 1986).

From a biogeographical point of view, the coral fauna recognized in the TPB of the Vobbia Valley shows close relationships with other Oligocene associations of the western Tethys area, such as those described from the Veneto (?Eo-Oligocene) region (e.g. D'Achiardi, 1866; Reuss, 1869; Frost, 1981), and from Salento, Apulia (Bosellini & Russo, 1992; Bosellini & Perrin, 1994).

Fossil assemblages of similar taxonomic composition have been recognized in Oligocene deposits from the western part of the TPB (Lorenz, 1969; Gnaccolini, 1978; Pfister, 1980; 1985; Fravega *et al.*, 1987; 1988; 1994; Vannucci *et al.*, 1997). In all these cases the coral colonies are prevalently of massive type, directly growing on the local Alpine substrate, mainly represented by the Voltri Group. The development of the coral colonies has been referred to a progressive transgression toward the South (Fravega *et al.*, 1987). Despite the similar taxonomic composition, the assemblage here presented differs from the others described in the TPB succession for its paleoecological features. In fact, massive colonies clearly dominate the coral assemblages of the Western TPB, while in the Eastern TPB only branched colonies have been recognized. This difference can be explained with the presence of different substrates and hydrodynamic conditions, which probably reflect the different tectono-sedimentary evolution in the two areas of the TPB.

In conclusion, the assemblage described in this paper is the first record of a fossil coral reef in the eastern part of the TPB, and probably it represents the earliest occurrence in the entire basin.

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REFERENCES

Behrensmeyer A.K., Kidwell S.M., Gastaldo, R.A., 2000. Taphonomy and Paleobiology. In: Erwin D.H., Wing S.L. (eds.), Deep Time - Paleobiology's Perspective. *Paleobiology* 26 (Suppl. n. 4): 103-147.

Bizzarini F., Braga G., 1999. I Briozoi Priaboniani dei Dintorni di Crosara (Vicenza - Italia). *Ann. Mus. Civ. Rovereto* 13: 91-126.

Bosellini F.R., Perrin C., 1994. The coral fauna of Vitigliano: qualitative and quantitative analysis in a back reef environment (Castro Limestone, Late Oligocene, Salento Peninsula, Southern Italy). *Boll. Soc. Paleont. It.* 33 (2): 171-181.

Bosellini F.R., Russo A., 1992. The Castro Limestone: stratigraphy and facies of an Oligocene fringing reef (Salento Peninsula, Southern Italy). *Facies* 26: 145-166.

Bosellini F.R., Russo A., 1995. The scleractinian genus *Actinacis*. Systematic revision and stratigraphic record of the Tertiary species with special regard to Italian occurrences. *Riv. It. Paleont. Strat.* 101 (2): 215-230.

Bosellini F.R., Stemann T.A., 1996. Autecological significance of growth form in the scleractinian *Actinacis rollei* Reuss (Oligocene, Lessini Mountains, Northern Italy). In Cherchi A. (ed.): Autecology of selected fossil organisms: Achievements and problems. *Boll. Soc. Paleont. Ital.*, Spec. Vol. 3: 31-43.

Braga G., Barbin V., 1988. Les Bryozoaires du Priabonien Stratitypique (Province Vicenza, Italie). *Revue de Paléobiol.* 7 (2): 495-556.

Cavanna F., Di Giulio A., Galbiati B., Pieri M., 1989. Carta geologica dell'estremità Orientale del Bacino Terziario Ligure-Piemontese. *Atti Tic. Sc. Terra* 32.

D'Achiardi A., 1866. Corallari fossili del terreno nummulitico delle Alpi Venete. *Mem. Soc. Ital. Sci. Nat.* 2/4: 1-53.

di Biase D., 1998. Stratigrafia fisica, facies e significato dei Conglomerati della Val Borbera. PhD thesis, Parma University, 90 pp.

di Biase D., Pandolfi L., 1999. L'evoluzione composizionale dei Conglomerati della Val Borbera (Bacino Terziario Piemontese): evidenze e vincoli per l'esumazione di unità a metamorfismo HP/LT nelle Alpi occidentali. GEOITALIA, 2° Forum FIST, Bellaria, 20-23 settembre 1999, Riassunti 1: 286-288.

di Biase D., Pandolfi L., Catanzariti R., 2002. The sedimentary record of the mesoalpine orogenic wedge exhumation in the lower oligocene deposits of the Borbera Valley (Eastern sector of the Tertiary Piedmont Basin). 81ª Riunione estiva della Società Geologica Italiana «Cinematiche collisionali: tra esumazione e sedimentazione», Torino, 10-12 settembre 2002, Riassunti: 133-134.

Forcella F., Gelati R., Gnaccolini M., Rossi P.M., Bersezio R., 1999. Il Bacino Terziario Ligure-Piemontese tra il monregalese e la Valle del T. Lemme: stato delle ricerche e prospettive future. In G. Orombelli (Ed.) Studi geografici e geologici in onore di Severino Belloni: 339-365.

Fravega P., Giammarino S., Piazza M., Russo A., Vannucci G., 1987. Significato paleoecologico degli episodi coralgali a nord di Sassello. Nuovi dati per una ricostruzione paleogeografico-evolutiva del margine meridionale del Bacino Terziario del Piemonte. *Atti Soc. Tosc. Sci. Nat., Mem., Ser. A* 94: 19-76.

Fravega P., Giammarino S., Traverso G., Vannucci G., 1988. Insediamenti coralgali e loro significato nell'evoluzione delle conoidi oligoceniche della Val Lemme (Bacino Terziario del Piemonte). In E. Robba (Ed.) Atti IV Simposio Ecologia e Paleoecologia delle Comunità Bentoniche. *Mus. Reg. Sci. Nat. Torino*: 199-221.

Fravega P., Piazza M., Stockar R., Vannucci G., 1994. Oligocene coral and algal reef and related facies of Valzemola (Savona, NW Italy). *Riv. Ital. Paleont. Strat.* 100: 423-456.

Frost S.H., 1981. Oligocene reef coral biofacies of the Vicentin, Northeast Italy. *S.E.P.M.*, Spec. Publ. 30: 483-539.

Fürsich F.T., Oschmann W., 1986. Storm shell beds of *Nanogyra virgula* in the upper Jurassic of France. *N. Jb. Geol. Paläont. Abh.* 172: 141-161.

Fürsich F.T., Oschmann W., 1993. Shell beds as tools in basin analysis: the Jurassic of Kachchh, western India. *J. Geol. Soc. London* 150: 169-185.

Gelati R., 1977. La successione Eo-Oligocenica di Garbagna (Alessandria) al margine orientale del Bacino Terziario ligure-piemontese. *Riv. It. Paleont.* 83: 103-136.

Gelati R., Gnaccolini M., 1978. I Conglomerati della Val Borbera, al margine orientale del Bacino Terziario Ligure-Piemontese. *Riv. Ital. Paleont. Strat*. 84: 701-728.

Gelati R., Gnaccolini M., Falletti P., Catrullo D., 1993. Startigrafia sequanziale della successione oligo-miocenica delle Langhe, Bacino Terziario Ligure-Piemontese. *Riv. Ital. Paleont. Strat*., 98: 425-452.

Gnaccolini M., 1974. Osservazioni sedimentologiche sui conglomerati oligocenici del settore meridionale del Bacino Terziario Ligure-Piemontese. *Riv. Ital. Paleont. Strat.* 80: 85-100.

Gnaccolini M., 1978. Osservazioni su una piccola scogliera organogena oligocenica affiorante presso Cairo Montenotte (Savona). *Riv. It. Paleont. Strat*. 84: 403-410.

Gnaccolini M., 1982. Oligocene fan-delta deposits in Northern Italy: a summary. *Riv. Ital. Paleont*. 87: 627-636.

Hubbard J.A.E.B., Pocock Y.P., 1972. Sediment rejection by recent scleractinian corals: a key to palaeo-environmental reconstruction. *Sonder. Geol. Rundschau* 61: 598-626.

Kidwell S.M., 1998. Time-averaging in the marine fossil record: overview of strategies and uncertainties. *Geobios* 30: 977-995.

Lagaaij R., Gautier Y.V., 1965. Bryozoan assemblages from marine sediments of the Rhône delta, France. *Micropaleontology* 11: 39-58.

Lorenz C., 1969. Contribution a l'étude stratigraphique de l'Oligocene et du Miocene inferieur des confins liguro-piemontais (Italie). *Atti Ist. Geol. Univ. Genova* 6: 253-888.

Moissette P., Saint-Martin J.-P., 1995. Bryozoaires des milieux récifaux miocènes du sillon sud-rifain au Maroc. *Lethaia* 28: 271-283.

Mutti E., Papani L., di Biase D., Davoli G., Mora S., Segadelli S., Tinterri R., 1995. Il Bacino Terziario Epimesoalpino e le sue implicazioni sui rapporti tra Alpi ed Appennino. *Mem. Sci. Geol.* 47: 217-244.

Mutti E., Davoli G., Tinterri R., Zavala C., 1996. The Importance of Ancient Fluvio-Deltaic Systems Dominated by Catastrophic Flooding in Tectonically Active Basins. *Mem. Sci. Geol*. 48: 233-291.

Pfister T., 1980. Palaookologie des oligozanen Korallenvorkommens von Cascine sudlich Aqui (Piedmont, Norditalien). *Jb. Naturhist. Mus. Bern* 7: 247-262.

Pfister T., 1985. Coral Fauna and Facies of the Oligocene Fringing Reef near Cairo Montenotte (Liguria, Northern Italy). *Facies* 13: 175-226.

Reuss A., 1869. Paläontologische Studien über die älteren Tertiärschichten der Alpen. 2. Abtheilung. Die fossilen Anthozoen und Bryozoen der Schichtengruppe von Crosara. *Denkschr. Akad. Wiss. Wien, math.-natw. Kl*. 29: 215-298.

Roy K.J., Smith S.V., 1971. Sedimentation and Coral Reef Development in Turbid Water: Fanning Lagoon. *Pac. Sci*. 25: 234-248.

Schopf T.J.M., 1969. Paleoecology of Ectoprocts (Bryozoans). *J. Paleont.* 43 (2): 234-244.

Vannucci G., Piazza M., Pastorino P., Fravega P., 1997. Le facies a coralli coloniali e rodoficee calcaree di alcune sezioni basali della formazione di Molare (Oligocene del bacino terziario del Piemonte, Italia nord-occidentale). *Atti Soc. Tosc. Sci. Nat., Mem., Ser. A* 104: 13-40.

Zeng J., Lowe D.R., Wiseman W.J., Bornhold B.D., 1991. Flow properties of turbidity currents in Bute Inlet, British Columbia. *Sedimentology* 38: 975-996.

Zuffa G., 1980. Hybrid arenites: their composition and classification. *Journ. Sed. Pet.* 50: 21-29.

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