Rivista piemontese di Storia naturale, 32, 2010: 3-15 ISSN 1121-1423

PAOLO PASTORINO* - ANDREA BASSO**

Large-scale slump facies in the "Arenarie di Serravalle" fm (Serravallian): the case of Rocca Grimalda (Piedmont Tertiary Basin, Alto Monferrato Sub-Basin, NW Italy)

ABSTRACT - In this paper the geological, palaenvironmental and structural meaning of an arenaceous and sandy sedimentary wedge outcropping near Rocca Grimalda (Alessandria, North-Western Italy) is briefly discussed.

On the basis of the lithostratigraphic setting inferred from field geological mapping and geomorphological evidences, this unit can be probably interpreted, in a three-dimensional view, as a lenticular sedimentary body enclosed in an arenaceous-marly succession.

The lithofacies analysis indicates sedimentary processes related to prevailing mass-flow gravity-driven depositional events.

The subvertical strata observed in two well exposed outcrops are interpreted as the result of large-scale synsedimentary gravity-driven post-depositional deformations rather than tectonic structures strictly related to field regional stresses.

KEY WORDS - Synsedimentary deformations, gravity-driven mass flow processes, Alto Monferrato Sub-Basin, "Arenarie di Serravalle" fm.

RIASSUNTO - *Deformazioni sinsedimentarie alla macroscala nella formazione delle "Arenarie di Serravalle" (Serravalliano): l'esempio di Rocca Grimalda (Bacino Terziario del Piemonte, Sottobacino dell'Alto Monferrato, Italia NW).*

Il Bacino Terziario del Piemonte (BTP) costituisce una successione sedimentaria eo-miocenica individuatasi in corrispondenza dell'attuale Italia nord-occidentale nel contesto dell'evoluzione geodinamica da meso-alpina a tardo-alpina ed appenninica del "Nodo Ligure" (Laubscher, 1991). Assumendo, in relazione alle diverse fasi orogenetiche, il significato di bacino tardo-orogenico, molassico, episuturale e di piggyback il BPT si colloca pertanto in un contesto estremamente diverso rispetto a quello caratteristico dei bacini cratonici o dei margini continentali passivi dove il controllo tettonico sulla sedimentazione è pressoché inesistente.

* Geologo, Libero Professionista, via Villa Superiore 46 - 15060 Silvano d'Orba (AL)
** Geologo, Libero Professionista, Lung'Orba Mazzini 95/2 - 15076 Ovada (AL)

La fase di progressiva bacinalizzazione è rappresentata, a scala regionale, da una successione trasgressiva di tipo fining-up. L’evoluzione deposizionale del BTP esordisce in particolare con sequenze continentali fluviali e marine costiere (Formazione di Molare – Oligocene; “Formazione di San Paolo” Oligocene superiore?-Aquitaniano superiore), alle quali fanno transizione, coerentemente con il continuo approfondimento dell’area bacinale, unità sostanzialmente marnose e rappresentative di una sedimentazione emipelagica distale (Formazione di Rocchetta – Oligocene superiore-Miocene inferiore; Marna di Paroldo – Aquitaniano superiore-Langhiano medio) (Lorenz, 1969; Gnaccolini, 1974; Gnaccolini, 1978; Gnaccolini, 1982; Gelati & Gnaccolini, 1980; Cazzola *et al.*, 1981; Andreoni *et al.*, 1981; Ghibaudo *et al.*, 1985; D’Atri, 1990; D’Atri *et al.*, 1997; Pastorino, 1998).

Importanti fenomeni di risedimentazione torbiditica al limite Oligocene inferiore–Oligocene superiore individuano il coinvolgimento della regione delle Langhe nel contesto dell’evoluzione compressionale appenninica.

In questo lavoro è stato discusso il significato geologico, paleoambientale e strutturale di una successione sabbioso-arenacea riferibile alla formazione delle “Arenarie di Serravalle” (Serravalliano) ed affiorante presso Rocca Grimalda (AL).

Sulla base di un rilievo geologico e di osservazioni geomorfologiche, quest’ultima costituisce verosimilmente un corpo sedimentario a geometria lenticolare interstratificato nell’ambito di una successione essenzialmente marnoso-arenacea (Marne di Cessole - Langhiano).

L’analisi di facies condotta su tale unità è coerente con lo sviluppo di prevalenti processi sedimentari di tipo gravitativo sia sin- che post-deposizionali, mentre gli strati arenacei subverticali ben esposti in due affioramenti dislocati presso il concentrico sono stati interpretati come il prodotto di deformazioni gravitative sinsedimentarie piuttosto che la conseguenza di stress tettonici regionali.

INTRODUCTION AND GEOLOGICAL BACKGROUND

The Tertiary Piedmont Basin (TPB) is a sedimentary succession, Upper Eocene to Upper Miocene in age, deposited during the Oligo-Miocene tectonic phases related to the geodynamic evolution of the “Ligurian Knot” (Laubscher, 1991) (fig. 1). In this way, the TPB is usually be considered as a piggyback basin developed on the alpine chain (Ori & Friends, 1984, Miletto & Polino, 1992) that evolved in episutural setting resting on the Europe-Adria suture (Gelati & Gnaccolini, 1998). Particularly, the Alto Monferrato Sub-Basin represents a minor tectono-stratigraphic domain of it bounded by the Valle Erro Fault toward west and by the Scrivia Fault in the east (Biella *et al.*, 1992).

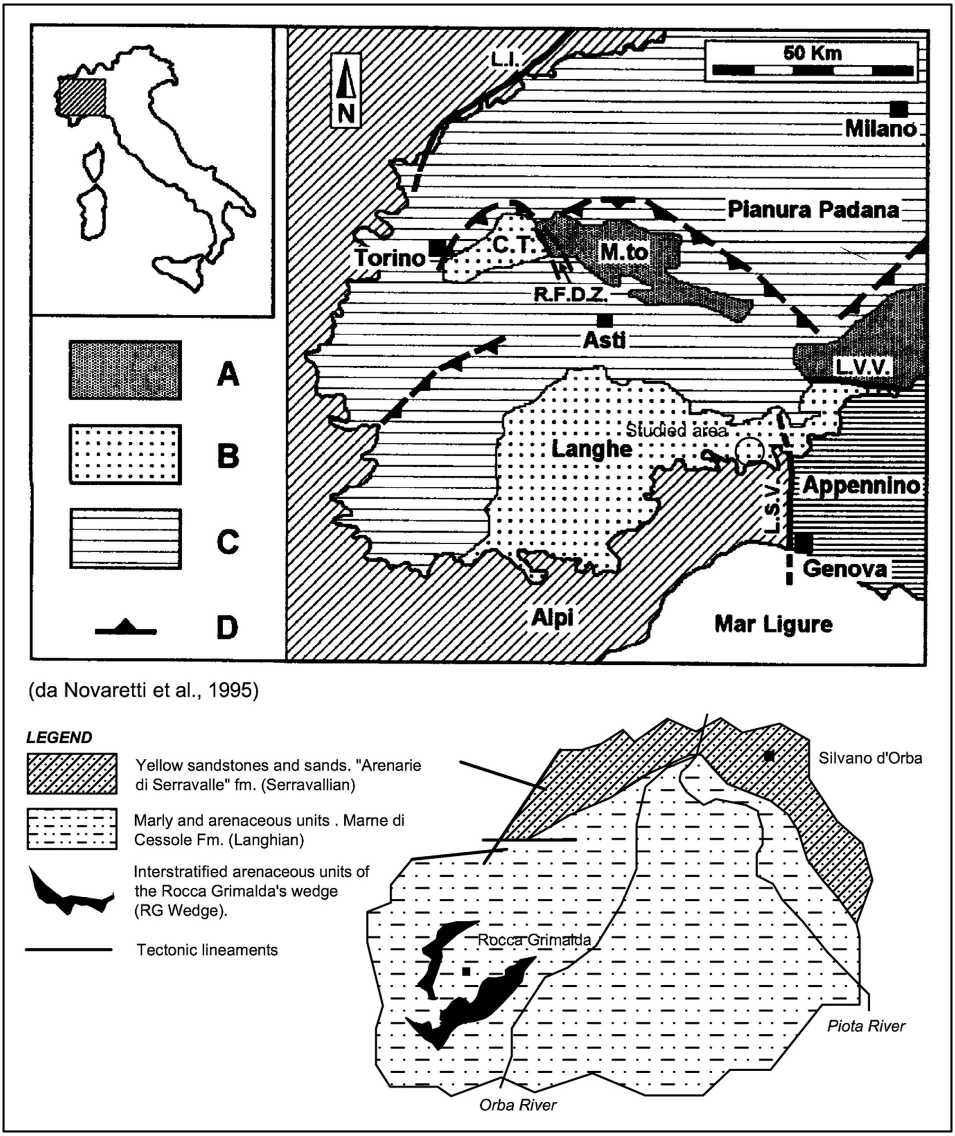


Fig. 1 - Geological sketch map of the investigated area - scale 1:50.000. **A** = Apennine-related basins; **B** = alpine-related basins; **C** = plio-quaternary basins; **D** = buried thrusts; **L.I.** = Insubric Line; **L.V.V.** = Villarvernia-Varzi Line; **L.S.V.** = Sestri-Voltaggio Line; **R.F.D.Z.** = Rio Freddo Deformation Zone; **C.T.** = Torino Hill; M.to = Monferrato (modified from Novaretti *et al.*, 1995).

The oldest fining-up sediments record the evolution of its margins from continental and shallow marine paleoenvironments (Molare Formation - Oligocene) towards emipelagic depositional settings (Marna di Paroldo fm. - Aquitaniano superiore-Langhiano medio).

The regional, compressional, tectonic stresses due to the evolution of the Apennine belt since Early Oligocene - Late Oligocene boundary induced conspicuous reworking events (Faletti *et al.*, 1995). The sedimentary succession of the TPB records the widespread occurrence of resedimented bodies deposited from submarine gravity-driven processes as described by many authors (Gelati & Gnaccolini, 1980; Cazzola *et al.*, 1981; Cazzola & Rigazio, 1983; Cazzola & Sgavetti, 1984; Cazzola & Fornaciari, 1990; Pastorino, 1998). Other informative papers about the Tertiary Piedmont Basin include those of Pasquarè (1968), Forcella (1976), Capponi & Giammarino (1982), Giammarino (1984), Gnaccolini (1989), Miletto & Polino (1992), Falletti *et al.* (1995), Mutti *et al.* (1995), Biella *et al.* (1997), Forcella *et al.* (1999), D’Atri *et al.* (2002).

Particularly, this paper focuses on the geological, paleoenvironmental and structural meaning of an areanaceous and sandy lenticular sedimentary body ascribed to the “Arenarie di Serravalle” fm. (*Serravallian*) as reported on the official geological map (Sheet 70 “Alessandria”, Geological Map of Italy, 1:100.000, Boni & Casnedi, 1970).

GEOLOGICAL AND STRUCTURAL SETTING

The sedimentary succession of the TPB outcropping in the studied area is topped unconformably by the oldest pleistocene fluvial lithofacies of the Orba River.

On the basis of both field mapping and geomorphological observations (because of high vegetation cover) the geological sketch map of fig. 1 has been outlined. The “Arenarie di Serravalle” fm. is relatively well exposed near Silvano d’Orba: the left loop of the Piota River before its confluence in the Orba River could be interpreted as due to the transition from marly units (Marne di Cessole fm. - *Langhian*) towards more competent sandstones. Although more detailed large-scale lithostratigraphic correlations can be at time unclear because transitional boundaries between these formations, we believe that the sandstones outcropping near Rocca Grimalda could be better interpreted as a lenticular body, approximately 90 m thick, interstrafied within a prevalent marly-arenaceous succession (Rocca Grimalda’s Wedge - RG-Wedge). The more gentle topographic relief on the left side of the Orba Valley between Rocca Grimalda and Silvano d'Orba could be related to the subsurface presence of prevailing marly units (fig. 2).

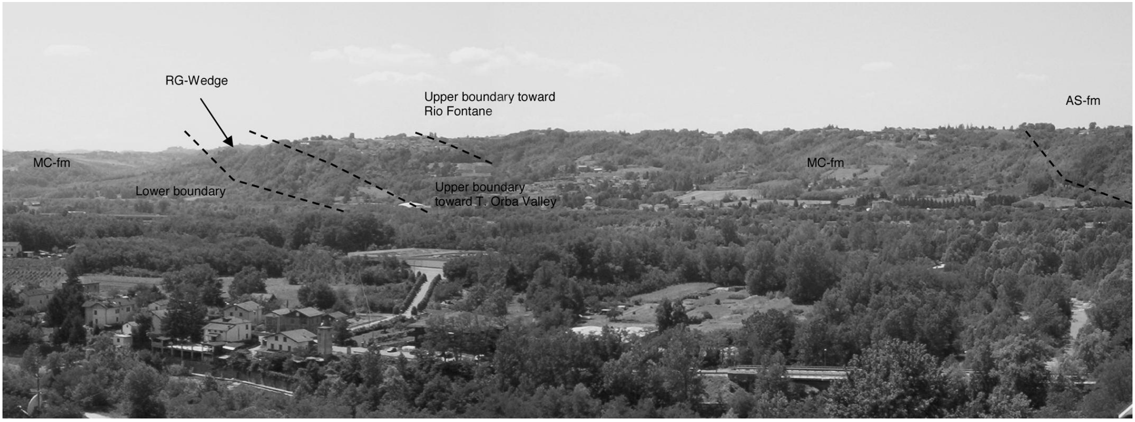


Fig. 2 - Panoramic view of the Rocca Grimalda's area (left side of the Orba River). The main litostratigraphic boundaries are indicated. **MC-fm** (Marne di Cessole fm.); **AS-fm** ("Arenarie di Serravalle" fm.); **RG-Wedge** (Rocca Grimalda's Wedge).

As showed in fig. 3, even if the attitude of bedding planes both in the Marne di Cessole fm. and "Arenarie di Serravalle" fm. is at time randomly distributed, the structural setting of the miocene formations in the area of Rocca Grimalda, characterized by an average dip direction toward N-NW, fully agree with the large scale regional one.

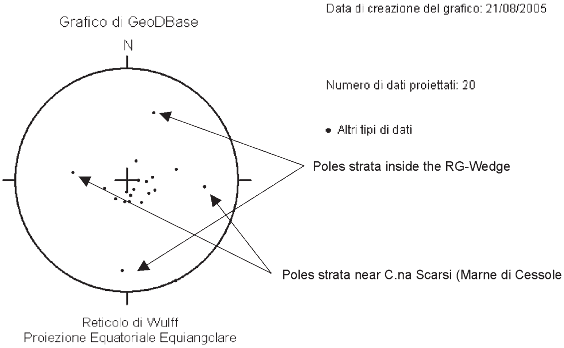


Fig. 3 - Stereographic plot of bedding planes (Marne di Cessole fm. and "Arenarie di Serravalle" fm.)

LITHOFACIES ANALYSIS

The large-scale structural setting of the RG-Wedge as well as the textural features of sedimentary strata appears extremely chaotic and disorganized.

In the RG-Wedge three main lithofacies can be described; particularly, in this paper the Shanmugam's (1996) terminology for submarine gravity-driven mass-flow processes has been followed. Refer to Bosellini *et al.* (1994) and Campbell (1967) for the classification of strata's thickness and textural features.

More detailed lithofacies analysis are difficult in field because high vegetation cover as well as for the inaccessibility of the main outcrops.

Lithofacies S1

Description

Structurelles yellow medium and coarse-grained sandstones organized in very thick beds (1÷1,5 m) bounded by erosional, wavy and parallel bedding planes (fig. 4a). At time, a parallel lamination can occur towards top as well as a faint normal grading. Flute casts, rip-up clasts and load-structures can be locally observed. Some strata show the presence of medium thick cross-lamine (fig. 4b).

Interpretation

These strata was probably emplaced by cohesionless and unchanellized mass-flow gravity-driven events, in which frictional freezing processes (Lowe, 1979) occurred during deposition. The presence, in some beds, of parallel laminations towards top and of a normal grading texture, can be explained with a decreasing of the flow density during deposition inside the main event. Turbolent flow conditions could be deduced by the presence of flute casts and rip-up clasts. In this view, the main, primary, sedimentary processes were probably related to the development of mixed sandy debris-flows and turbidity currents emplaced in the form of depositional lobes. These lithofacies could be compared to the lobe deposits described by Cazzola *et al.* (1981).

Also the occurrence of cross-lamine inside some strata fully agree with sedimentary processes related to low-density mass-flow events. This lithofacies can be compared with the Facies B described in his turbiditic depositional model by Ricci Lucchi (1980). In this way, a bottom meso-topography characterized by the presence of tractional bed-forms, such as dunes (H = 1,0÷1,2 m), can be supposed. A "dune" horizon is described by

Gnaccolini (1989) in the Bastia Mondovì body. Their origin as reworked textures related to deep-marine bottom-currents, evenly associated to grain by grain depositional processes, seems unlikely.

Lithofacies CS1

Description

Folded, structureless, chaotic and unstratified yellow medium and coarse-grained sandstones (fig. 4c).

Interpretation

This one is probably the most diffuse lithofacies, being the large-scale sedimentary feature of the RG-Wedge characterized by chaotic and folded strata. According to literature (Pickering *et al.*, 1986), these structures have been here interpreted as the product of submarine post-depositional slumping processes on plastic sediments. Small-scale folded beds also probably occur in the Marne di Cessole fm. near C.na Scarsi, although their origin is uncertain. Sinsedimentary sliding events are described in the Cortemilia Fm. by Gnaccolini (1968) and in the "Bastia Mondovì Fm." by Pastorino (1998).

Lithofacies CS2

Description

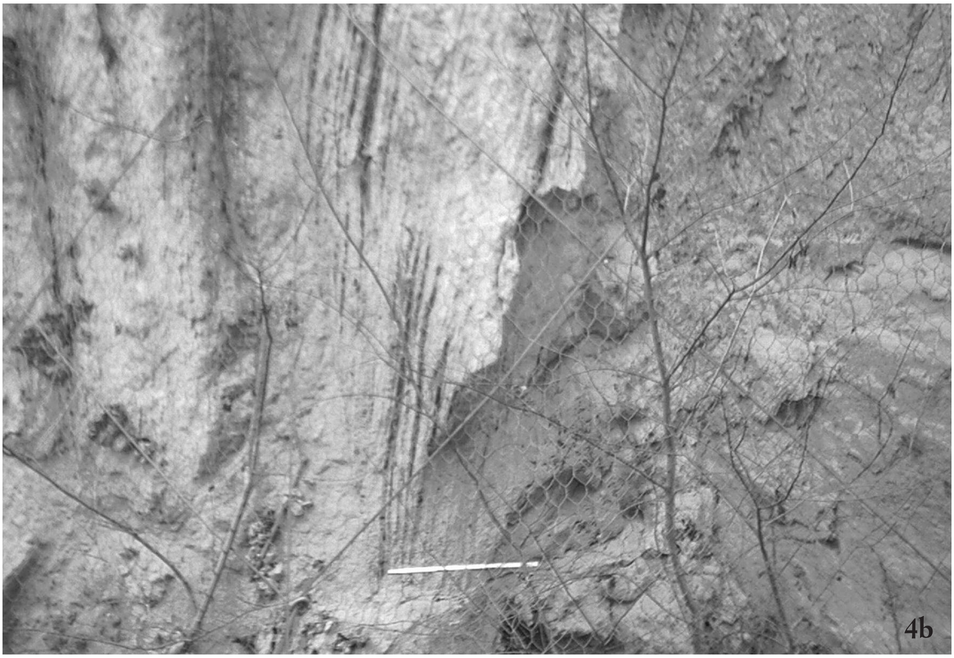
Fine-grained marl, organized in thick strata (0,6÷1,0 m) with nodular and "strained" texture due to sharp, wavy and non-parallel discontinuities.

Interpretation

This lithofacies has been here interpreted as the product of post-depositional internal strains produced during sliding. Particularly, the sedimentary processes was probably related to slow sedimentary creeps inside decollement ooze strata during their downslope movements (Stow, 1994).

Fig. 4 - Main lithofacies of the RG-Wedge. **4a**) Lithofacies S1: structureless yellow medium and coarse-grained sandstones organized in very thick beds (1÷1,5 m) bounded by erosional, wavy and parallel bedding planes (scale bar 40 cm). **4b**) Lithofacies S1: medium thick cross lamine (scale bar 60 cm). **4c**) Lithofacies CS1: structureless, chaotic and unstratified yellow medium and coarse-grained sandstones. On the upper side of the outcrop a small-scale slump fold is visible. **4d**) Panoramic view of the subvertical strata outcropping near Rocca Grimalda. These ones have been interpreted as large-scale post-depositional slump facies. ➡


4a


4b


4c


4d

CONCLUSIONS

As previously outlined, the sedimentary oligo-miocene evolution of the TPB often records the regional occurrence of resedimented units at time emplaced in large-scale sedimentary wedges (Gelati & Gnaccolini, 1980; Cazzola *et al.*, 1981; Cazzola & Rigazio, 1983; Cazzola & Sgavetti, 1984; Cazzola & Fornaciari, 1990; Pastorino, 1998). Field analysis on a thick arenaceous succession outcropping near Rocca Grimalda allow us the following conclusions.

1. On the basis of both geological mapping and geomorphological observations, the sedimentary succession on which Rocca Grimalda developed can be interpreted as an arenaceous coarse-grained sedimentary three dimensional lenticular body interstratified in a mixed marly-arenaceous succession (Marne di Cessole fm.).

2. Lithofacies analysis carried out on sandstones are in agreement with prevailing sedimentary processes related to mass-flow gravity-driven events. Particularly, in this view two main depositional mechanisms has been described: mixed sandy debris-flows and turbidity corrents occured as well developed very thick beds (lithofacies S1) and massive, chaotic sedimentary events probably related to more dense and important post-depositional submarine slumping processes (lithofacies CS1 and CS2). These lithofacies, although can occur at any location, tend to be dominant in slope environments (Shanmugam *et al.,* 1995). As depicted for other tectono-stratigraphic domains of the TPB (Pastorino, 1998), the sandstones of the RG-Wedge probably deposited in slope apron submarine paleoenvironments. The large-scale depositional features of the RG-Wedge appear chaotic and “structureless”, being probably related to mass-flow post-depositional processes. In this way, correlations between lithofacies S1, CS1 and CS2 with respect the lithostratigraphic setting of the sedimentary wedge in terms of depositional processes are unclear.

3. It is of note the presence of subvertical beds well exposed in two outcrops near the village of Rocca Grimalda (fig. 4d). The lack of structural correlations between these units and the regional setting indicates that these stepply dipping layers are enclosed in the sedimentary wedge. In this way, according to their lithostratigraphic and depositional features, we believe that these ones could be better interpreted as large-scale post-depositional slump facies, such as slump folds or contorted beds, rather than tectonic structures strictly related to field regional stresses.

ACKNOWLEDGMENTS

The authors are particularly grateful to the anonymous referee for its critical reading of the manuscript.

REFERENCES

Andreoni G., Galbiati B., Maccabruni A., Vercesi P.L., 1981 – Stratigrafia e paleogeografia dei depositi oligocenici sup. e miocenici inf. nell'estremità orientale del bacino ligure-piemontese. Riv. Ital. Paleont.,87: 245-282.

Biella G.C., Clari P., De Franco R., Gelati R., Ghibaudo G., Gnaccolini M., Lanza R., Polino R., Ricci B. & Rossi P.M., 1992 – Geometrie crostali al nodo Alpi/Appennino: conseguenze sull'evoluzione cinematica dei bacini neogenici: Riassunti 76a Riunione estiva Soc. Geol. It., Firenze: 192-195.

Biella G.c., Polino R., De Franco R., Rossi P.M., Clari P., Corsi A., Gelati R., 1997 – The crustal structure of the western Po Plain: reconstruction from integrated geological and seismic data. Terra Nova, 9 (1): 28-31.

Boni A., Casnedi R., 1970 – Note illustrative fogli 69-70 (Asti e Alessandria) della Carta Geologica d'Italia. Soc. Geol. It., 64 pp., Roma.

Bosellini, A., Mutti, E., Ricci Lucchi, F., 1994 – Rocce e successioni sedimentarie. Scienze della Terra, Utet, Torino, 395 pp.

Campbell C.V., 1967 – Lamina, laminaset, bed and bedset, Sedimentology, 8, 7-26.

Capponi G., Giammarino S., 1982 – L'affioramento oligocenico del Rio Siria (Bacino di Santa Giustina, provincia di Savona), nel quadro dei movimenti tardivi della falda di Montenotte. Atti Soc. Tosc. Sc. Nat., A, 89: 101-113.

Cazzola C., Fonnesu F., Mutti E., Rampone G., Sonnino M., Vigna B., 1981 – Geometry and facies of small, fault-controlled deep-sea fan system in a transgressive depositional setting (Tertiary Piedmont Basin, North-Western Italy). 2nd I.A.S. European Regional Meeting, Bologna, Libro guida delle escursioni: 8-53.

Cazzola C., Fornaciari M., 1990 – Geometria e facies dei sistemi torbiditici di Budroni e Noceto (Bacino Terziario Piemontese): Atti Tic. Sc. Terra, 33: 177-190.

Cazzola C., Rigazio G.P., 1983 – Caratteri sedimentologici dei corpi torbiditici di Valla e Mioglia, Formazione di Rocchetta (Oligocene-Miocene), del Bacino Terziario Piemontese: Giornale di Geologia, 45 (2): 87-100.

Cazzola C., Sgavetti M., 1984 – Geometria dei depositi torbiditici delle Formazioni di Rocchetta e Monesiglio (Oligocene superiore-Miocene inferiore) nell'area compresa tra Spigno e Ceva: Giornale di Geologia, 45: 227-240.

D'Atri A., 1990 – Analisi sedimentologica, biostratigrafia e sequenziale della successione del Miocene inferiore tra le valli Lemme e Bormida di Spigno (margine sudorientale del Bacino terziario ligure-piemontese). Università degli Studi di Torino, Tesi di Dottorato, 1990.

D'Atri A., Dela Pierre F., Festa A., Gelati R., Gnaccolini M., Piana F., Clari P., Polino R., 2002 – Tettonica e sedimentazione nel "retroforeland alpino". 81° Riunione estiva S.G.I., Torino, Guida all'escursione post-congresso, Litografia Geda, 114 pp.

D’ATRI A., PIANA F., TALLONE S., BODRATO G., ROZ GASTALDI M., 1997 – Tettonica oligo-miocenica nell’Alto Monferrato (Bacino Terziario Piemontese) e nel settore nord-occidentale del Gruppo di Voltri (Acqui Terme – Cassinelle, AL). Atti Tic. Sc. Terra, 5: 85-100.
FALLETTI P., GELATI R., ROGLEDI S., 1995 – Oligo-Miocene evolution of Monferrato e Langhe, related to deep structure. In Atti del Convegno rapporti Alpi-Appennino e guida alle escursioni, Peveragno (CN), 31 Maggio-1 Giugno 1994: 1-19.
FORCELLA F., 1976 - Avanzamento delle ricerche sull’assetto strutturale ed interpretazione geodinamica del Gruppo di Voltri. Ofioliti, 11 (3): 221-234.
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, Brigati Genova: 339-365.
GELATI R., GNACCOLINI M., 1980 – Significato dei corpi arenacei di conoide sottomarina (Oligocene-Miocene inf.) nell’evoluzione tettonico sedimentaria del Bacino Terziario Ligure Piemontese. Riv. Ital. Paleont. Strat., 86: 167-186.
GELATI R., GNACCOLINI M. with contributions of PETRIZZO, M.R., 1998 – Synsedimentary tectonics and sedimentation in the Tertiary Piedmont Basin, northwestern Italy. Riv. It. Paleont. Strat., 104 (2): 193-214.
GHIBAUDO G., CLARI P., PERELLO M., 1985 – Litostratigrafia, sedimentologia ed evoluzione tettonico-sedimentaria dei depositi miocenici del margine sud-orientale del Bacino terziario ligure-piemontese (Valli Borbera, Scrivia e Lemme). Boll. Soc. Geol. It., 104: 349-397.
GIAMMARINO S., 1984 – Evoluzione delle Alpi Marittime Liguri e sue relazioni con il Bacino Terziario del Piemonte ed il Mar Ligure. Atti Soc. Tosc. Sc. Nat., Mem., A, 91: 155-179.
GNACCOLINI M., 1968 – Il Bacino delle Langhe (Piemonte) durante il Miocene. Riv. Ital. Paleont. Strat., 74 (1): 133-142.
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 – L’“Unità di San Rocco” nella Formazione di Molare tra le valli del T. Stura e del T. Lemme. Riv. Ital. Paleont. Strat., 84: 411-442.
GNACCOLINI M., 1982 – Oligocene fan-delta deposits in Northern Italy: a summary: Riv. Ital. Paleont. Strat., 87: 627-636.
GNACCOLINI M., 1989 – Il Langhiano-Serravalliano tra le Valli del Tanaro e del Belbo. Confronti con i dintorni di Gavi e di Finale Ligure. Riv. Ital. Paleont. Strat., 95 (1): 55-74.
LAUBSCHER H.P., 1991 – The arc of the western Alps today. Eclogae Geol. Helv., 84 (3): 631-659.
LORENZ C., 1969 – Contribution à l’ètude stratigraphique de l’Olicocène infèrieur des confines Liguro-Pièmontais (Italie). Atti Ist. Geol. Univ. Genova, 6: 253-888.
LOWE D.R., 1979 – Sediment gravity flows: their classification and some problems of application to natural flows and depositis. S.E.P.M., Sp. Publ., 27: 75-82.
MILETTO M. & POLINO R., 1992 – A gravity model of the crust beneath the Tertiary Piemonte Basin (northwestern Italy). Tectonophysics, 212: 243-256.

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.

Novaretti A., Bicchi E., Condello A., Ferrero E., Maia F., Tonon M., Torta D., 1995 – La successione oligo-miocenica del Monferrato: sintesi di dati biostratigrafici. In Atti del Convegno Rapporti Alpi-Appennini e guida alle escursioni, Peveragno (CN) , 31 Maggio-1 Giugno 1994: 39-59.

Ori G.G., Friend P.F., 1984 – Sedimentary basins formed and carried piggyback on active thrust sheets. Geology, 15, 475-478.

Pasquarè G., 1968 – La serie di Montenotte: un elemento alloctono sovrapposto al Bacino Oligocenico di Santa Giustina (Alpi Liguri). Riv. It. Paleont. Strat., 74 (4): 1257-1273.

Pastorino P., 1998 – Il bacino delle Langhe (Bacino Terziario del Piemonte, Italia nord-Occidentale) ad ovest di San Michele di Mondovì: evoluzione deposizionale, paleogeografica e tettonica dall'Oligocene Superiore? al Miocene Medio. Università degli Studi di Genova, Dipartimento di Scienze della Terra, Tesi di Dottorato, 1998.

Pickering K, Stow D., Watson M., Hiscott R., 1986 – Deep-water facies, processes and models: a review and classification scheme for modern and ancient sediments. Earth Sc. Reviews, 23: 75-174, Amsterdam.

Ricci Lucchi F., 1980 – Sedimentologia. Parte III Ambienti sedimentary e facies. CLUEB, 545 pp., Bologna.

Shanmugam G., Bloch R.B., Mitchell S.M., Beamishmn G.W.J., Hodgkinson R.J., Damuth J.E., Straume T., Syvertsen S.E., Shields K.E. 1995 – Basin-floor fans in the North Sea: sequence stratigraphic models vs. Sedimentary facies. AAPG Bullettin, 79, 4: 477-512.

Shanmugam G., 1996 – High-density turbidity currents: are they sandy debris flows? Journal of sedimentary research, 66, 1.

Stow D.A.V., 1994 – Deep sea processes of sediment transport and deposit. In Sediment transport and depositional processes. Kennet Pye (Ed.), Blackwell Scientific Pubblications, 257-291.