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COLONIES OF THE PLANKTONIC GREEN ALGAE *BOTRYOCOCCUS* IN THE CONTINENTAL DEPOSITS OF THE UPPER OLIGOCENE? - AQUITANIAN "SAN PAOLO FORMATION" (Piedmont Tertiary Basin, Langhe Sub-Basin, NW Italy)

ABSTRACT - A lithofacies analysis carried out on the lowermost and uppermost sediments of the "San Paolo Formation" (Upper Oligocene? - Aquitanian) outcropping in the Langhe Sub-Basin (westernmost sector of the Tertiary Piedmont Basin) indicates the development of a sandy-gravelly fluvial depositional system passing upward into shallow marine lithofacies.

Paleoecological data inferred from scanty malacofaunas sampled in topmost record of the "San Paolo Formation" fully agree with the presence of biotopes related to transitional paleoenvironments such us fluvial mouths with low salinity waters and distal or interdistributary zones of a delta complex with normal marine ones.

The microfossils observed in the lower stratigraphic unit, are characterised by the presence of planktonic green algae belonging to the genus *Botryococcus*, indicative of continental freshwater palaeoenvironments.

RIASSUNTO - *Alghe verdi coloniali, planctoniche di* Botryococcus *nei depositi continentali della "Formazione di San Paolo" (Oligocene superiore? – Aquitaniano; Bacino Terziario del Piemonte, Sottobacino delle Langhe, Italia NO).*

La successione sedimentaria dei più antichi depositi ("Formazione di San Paolo" – Oligocene superiore? – Aquitaniano) riferibili alle fasi di progressiva impostazione dell'area bacinale corrispondente all'estremo settore occidentale del Bacino Terziario Piemontese (Sottobacino delle Langhe) è caratterizzata dall'evoluzione di sistemi deposizionali di tipo fluviale verso più recenti sedimenti marini costieri.

Le malacofaune presenti al tetto della "Formazione di San Paolo" ben si accordano con le diversificate condizioni ecologiche caratteristiche dei sistemi deposizionali di transizione.

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Le colonie di *Botryococcus* descritte in questa breve nota sembrano confermare ulteriormente la presenza di un ambiente di sedimentazione continentale alla base della successione.

INTRODUCTION AND GEOLOGICAL BACKGROUND

The Tertiary Piedmont Basin consist of a sedimentary succession, Upper Eocene to Upper Miocene in age, deposited in an episutural setting during the Oligo-Miocene tectonic phases related to the geodynamic evolution of the "Ligurian Knot" (Laubscher, 1991) (fig. 1). In particular, the Langhe Sub-Basin, which represents the western sector of the Tertiary Piedmont Basin, is usually interpreted as a minor tectono-stratigraphic domain bounded by the Valle Erro Fault in the east (Biella *et al.*, 1992; Gelati & Gnaccolini, 1998). Informative papers about the Tertiary Piedmont Basin and Langhe Sub-Basin include those of Pasquarè (1968), Casnedi & Mosna (1970), Forcella (1976), Gelati & Gnaccolini (1980, 1984), Cazzola *et al.* (1981), Capponi & Giammarino (1982), Cazzola & Rigazio (1983), Cazzola & Sgavetti (1984), Giammarino (1984), Gnaccolini (1989), Cazzola & Fornaciari (1990), Miletto & Polino (1992), Falletti *et al.* (1995), Mutti *et al.* (1995), Biella *et al.* (1997), Forcella *et al.* (1999), D'Atri *et al.* (2002).

From east to west, the oldest sediments of the Tertiary Piedmont Basin, resting unconformably on the alpine and apennine related units, can be grouped in two main formations which testify the evolution of its margins from continental to marine palaeoenvironments: the Molare Formation (Lower Oligocene) and the "San Paolo Formation", Upper Oligocene? to Aquitanian in age (Gelati & Gnaccolini, 1996; Pastorino, 1998), as defined by Casnedi (1971).

The "San Paolo Formation" consists of a lower continetal part related to the evolution of a sandy-gravelly fluvial depositional system (Casnedi, 1971; Gelati & Gnaccolini, 1996; Pastorino, 1998) and an uppermost transgressive part reasonably in agreement with the presence of two transitional palaeoenvironments; fluvial mouths, with low salinity waters and distal or interdistributary delta related areas characterised by normal marine waters (Pastorino & Guineri, 2000).

In the lower continetal part of the formation the colonial, planktonic green alga *Botryococcus* occurs.

DESCRIPTION OF SITES

Our studies on the continental microfossil assemblages of the "San Paolo Formation" focused on two siliciclastic outcrops few meters thick, respectively, the lower continetal (site 1, fig. 1) and the upper (site 2, fig. 1) shallow marine stratigraphic record of this unit (more detailed stratigrafic correlations are impossible due to the very low regional percentage of exposed sections). The former (site 1, fig. 2) outcrops near Santuario di Vicoforte, where it is characterized by fine-grained and structureless sediments as discussed below. The latter (site 2, fig. 2), exposed near Monastero Vasco, is composed of conglomeratic beds which have been interpreted as mouth bar sediments deposited within shoreface zone depths (Pastorino & Guineri, 2000).

The litostratigraphic setting of each site is more detailed in the following.

Site 1 - Santuario di Vicoforte
(Lat. 44° 21' 30"N, Long. 7° 52' 00"E)

From bottom to top the following units can be recognised:

Level 1 (100 cm thick) – Structureless reddish mudstones and graywackes with carbonaceous flakes.

Level 2 (110 cm thick) – Structureless grey mudstones. Carbonaceous flakes are absent. It is of note the presence of pyrite.

Level 3 (130 cm thick) – From bottom to top grey (50 cm) to ocraceous mudstones. Towards top black and thin (up to 3 cm thick) organic strata can be observed.

Level 4 (200 cm thick) – Structureless sands from black to ocraceous in color toward top.

Site 2 - Monastero Vasco
(Lat. 44° 21' 00"N, Long. 7° 49' 00"E)

Disomogeneous (from poorly to weakly sorted), polygenic and pebble orthoconglomerates (600 cm thick). Pebbles are well rounded and their size varies from 2 to 3 cm. They form structureless (at time a planar fabric can occur) and medium to thick (up to 100 cm) beds bounded by erosional, discontinuous, wavy and non-parallel bedding planes (Campbell, 1967; Bosellini *et al.*, 1989). Scanty valves of *Pycnodonte brongniarti* (Bronn, 1831) and *Ostreinae* sp. can locally occur (Pastorino & Guineri, 2000).

MATERIAL AND METHODS

Eight samples (5 gr) have been processed following standard palynological preparation techniques (their location in each site is visible in fig. 2). All samples were floated using $ZnCl_2$. The residue was rinsed on a 16 µm filter cloth and mounted in glycerine jelly on a microscope slide. One slide from each sample was viewed over the entirety of the 22x22 mm area. *Botryococcus* colonies were measured and photographed using a Polyvar microscope. Their morphologic description follows Burns (1982) while the systematics follows Tappan (1980); Komárková (1991); Batten & Grenfell (1996) and Zippi (1998). The slides are stored at the Dip.Te.Ris., Genova University, Italy.

SYSTEMATIC PALAEONTOLOGY

The genus *Botryococcus* is placed within the family Botryococcaceae by Komárek & Fott (1983), but is assigned to the Dictyophaeraceae by Bourrelly (1966) and Bold & Wynne (1985). The genus was formerly placed in the class Xanthophyta (yellow-green algae), but the presence of chlorophyll *a* and *b* and fine structural evidence mandate its assignment to the class Chlorophyta (Hirose & Ogasawara, 1977). There is now general agreement (Komárková, 1991; Batten & Grenfell, 1996 and Zippi, 1998) that it should be classified as a green alga of the order Chlorococcales, family Botryococcaceae.

The family Botryococcaceae, in agreement with Komárková (1991), is characterized by cells with autosporine reproduction, gathered into the colonies and connected with mucilaginous.

Division Chlorophyta Pascher, 1914
Class Chlorophyceae Kützing, 1843
Order Chlorococcales Marchand, 1895 orth. mut. Pascher, 1915
Family Botryococcaceae Wille, 1909
Genus *Botryococcus* Kützing, 1849
Botryococcus sp.

Description

Viewed by transmitted light microscopy the colonies are yellowish-orange to brownish in colour and rounded to elliptic in outline. At times

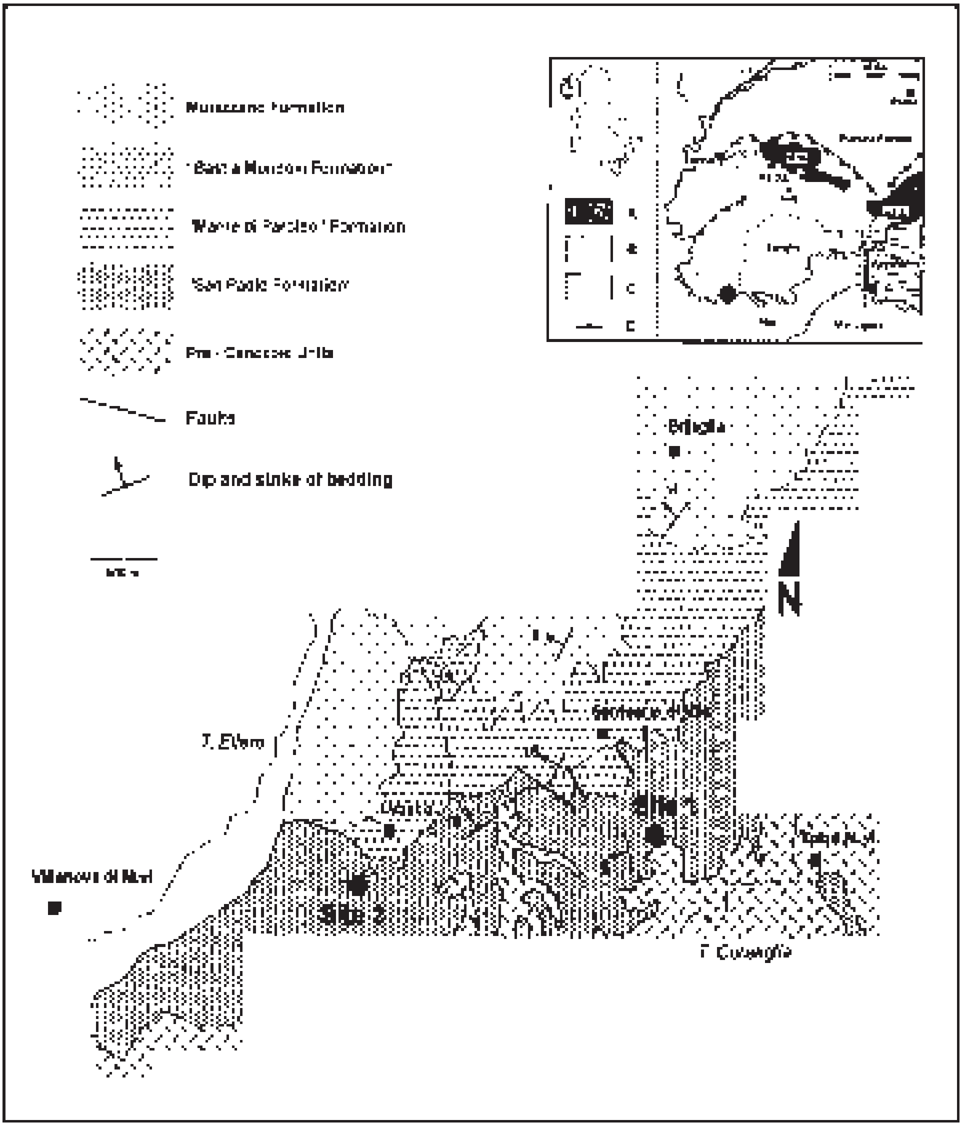

Fig. 1 - Geological map of the studied area with the site (black circle) where *Botryococcus* colonies were collected. **A** = Apennine-related basins; **B** = Alpine-related basins; **C** = Plio-Quaternary basins; **D** = buried thrusts; **L.I.** = Insubric Line; **L.V.V.** = Villarvernia-Varzi Line; **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).

colonies are virtually amorphous masses showing only few traces of the original form. When the preservation is relatively good, colonies show numerous radially arranged cells (autospores, *sensu* Batten & Grenfell, 1996) of ellipsoidal to cylindrical shape (fig. 3). The size of the colonies ranges from to 25 to 105 µm. Individual cells are 2.5 to 4 µm wide and 5 to 10 µm long.

Remarks

The microfossil colonies recovered in the "San Paolo Formation" are quite similar to *Botryococcus* cf. *braunii* found in the Miocene of the Woodlark Basin (illustrated by Testa *et al.*, 2002) and *Botryococcus* sp. cf. *braunii* described by Batten & Grenfell (1996) (pl. 1, figs. 8, 9 and 12). Specimens of *Botryococcus* are more abundant in samples collected from site 1 than those from site 2.

ECOLOGICAL REQUIREMENTS OF *BOTRYOCOCCUS*

The planktonic, colonial green algae *Botryococcus* has a long geological history, from the Late Precambrian to the present day (Konzalova, 1973; Tappan, 1980; Batten & Grenfell, 1996; Guy-Ohlson, 1998). This microalga has no biostratigraphical significance but is important from a palaeoenvironmental perspective (Guy-Ohlson, 1992; Batten & Grenfell, 1996; Zippi, 1998; Roiron *et al.,*1999; Flores, 2002).

Modern *Botryococcus* is a fresh to brackish water planktonic green alga that generally lives in bogs, temporary pools, ponds, lakes and saline lagoons (Emberger, 1968; De Deckker, 1988; Guy-Ohlson, 1992; Hudson *et al.*, 1995; Batten & Grenfell, 1996; Lee, 1999). Vazquez-Duhalt & Arredondo-Vega (1991) noticed that *Botryococcus braunii* is unable to reproduce in normal marine conditions. Some authors reported that the environments in which *Botryococcus* competes most successfully are generally characterised by shallow water and relatively low rainfall.

CONCLUSIONS

The macrofossil content in the "marine" upper portion of the "San Paolo Formation" is composed of rare but useful malacofaunas (Pastorino & Guineri, 2000), while the lower continental stratigraphic record is un-

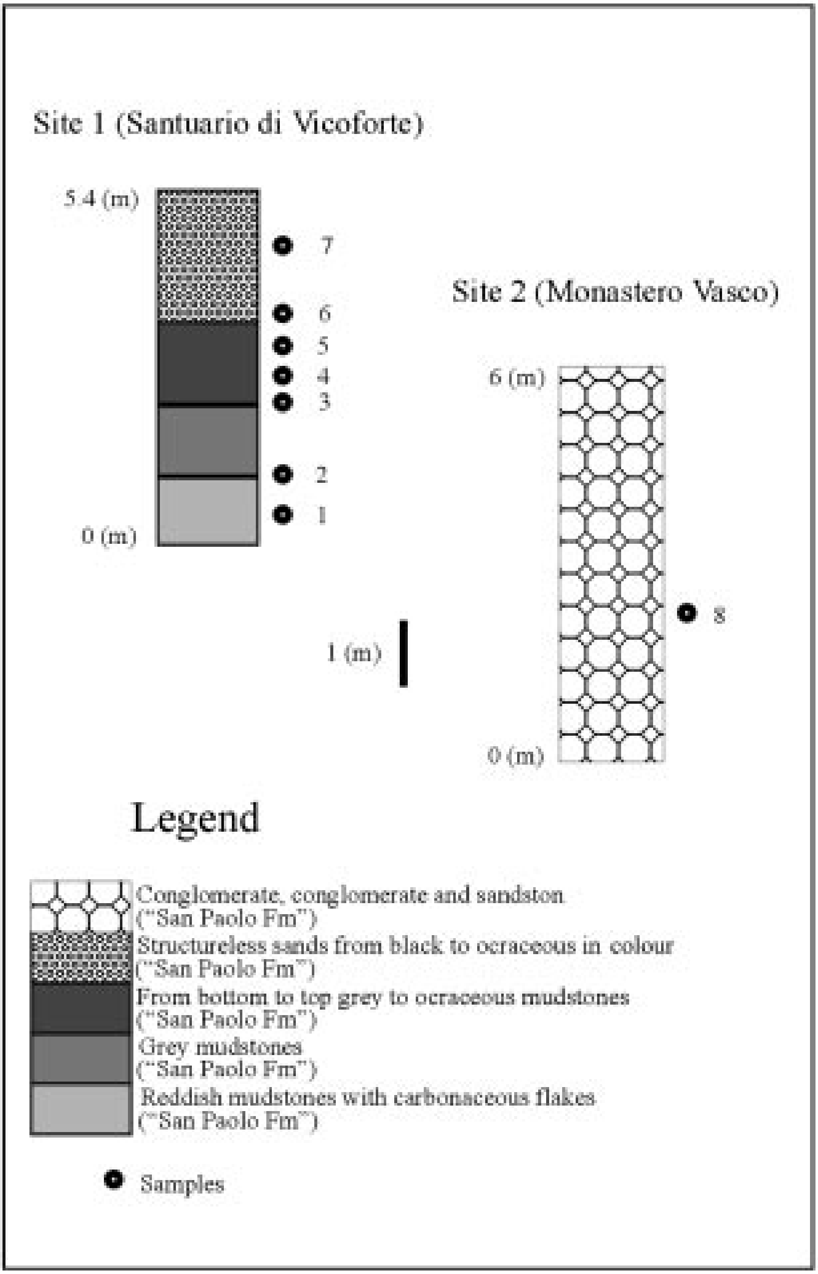

Fig. 2 - Lithostratigraphy and samples location of the studied outcrops.

fossiliferous. Nevertheless, the occurrence, in such strata, of continental microfossil assemblages characterised by the presence of *Botryococcus,* allows us to confirm the fluvial origin of the basal units of the formation.

Fig. 3 - *Botryococcus* sp. colony showing various cells. Scale bar = 10µm.

In particular, our preliminary results, showing the decrease in *Botryococcus* abundance from lower to upper units of the "San Paolo Formation", are reasonably in agreement with the evolution of the basin margins from fluvial to transitional palaeoenvironments. The ecological requirements of modern *Botryococcus* suggest that the lower structureless fine-grained units of the "San Paolo Formation" could have been deposited in calm freshwater conditions in small continental basins such as ponds or lakes. The few, badly preserved *Botryococcus'* colonies found in site 2 have probably been degraded by being transported from a continental source to the marine environment, indicated by the malacofauna (Pastorino & Guineri, 2000).

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