Lower Toarcian organic-rich sediments from the Tuscan Succession (Northern Apennines, Italy): preliminary results

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ABSTRACT: For the first time is here documented the presence of Lower Toarcian black shales in the lower portion of the *Calcari e marne a Posidonia* (Posidonia Marls *auctt.*) belonging to the Tuscan Nappe. It consists of alternations of 30 cm to 5 m thick black laminated marlstone and marly claystone, with TOC values ranging from 0.43% to 2.49%. Based on calcareous nannofossils, the basal portion of the *Calcari e marne a Posidonia* spans the Lotharingius hauffii to Carinolithus superbus zones, and the organic-rich interval lies within the Carinolithus superbus Zone.

INTRODUCTION

Lower Toarcian organic-rich sediments have been recognized in many sections of NW Europe, Tethys area and elsewhere (Jenkyns 1988; Jenkyns *et al.* 2002). In NW Europe the reference sections are located in England, Germany, France and Switzerland (Jenkyns, Clayton 1986, 1997; Jenkyns *et al.* 2002). In SW Europe organic-rich facies have been documented in Italy (see next paragraph) and Spain (Jiménez *et al.* 1996). Similar facies also crop out in the Dinarids, Carpathians, Hellenids and Tunisian Atlas (Jenkyns 1988; Jenkyns *et al.* 2002). Up to present, the dating of the Lower Toarcian anoxic event is still debatable, due to the well-known and documented provincialism of the ammonite fauna (Jenkyns *et al.* 2002). However, the Lower Toarcian organic-rich sediments lying within the Falciferum Zone in NW Europe are located within the uppermost part of the Polymorphum Zone and the lower part of the Serpentinus/Falciferum Zone in the Mediterranean area (Jenkyns *et al.* 2002, and bibliography therein). Actually, the westernmost Tethyan sections (southern Spain), are located in the upper part of the Serpentinus (Falciferum) Zone (Jiménez *et al*. 1996). The aim of this paper is to describe for the first time the Lower Toarcian organic-rich sediments intercalated within the *Calcari e marne a Posidonia* belonging to the Tuscan Nappe. In particular there are presented here preliminary dating based on calcareous nannofossils and the TOC values of these sediments.

In the Northern Apennines, the best studied black shales are intercalated in the Marne del Monte Serrone Fm., widespread in the Umbria-Marche Basin. They were first recognized in the Valdorbia section, where the 9 m thick anoxic facies reaches a maximum TOC value of 2.29% (Jenkyns 1988; Jenkyns and Clayton 1986; Monaco *et al*. 1994). TOC analyses are also available for the Colle d'Orlando and Pozzale sections. In the former section the organic-rich level is 10 m thick and the TOC maximum value ranges from 2.27% to 2.69% (Parisi *et al*. 1998). In the latter section, the TOC value of the 3 m thick black shales ranges from 1 to 2.5% (Mattioli *et al*. 2004). In both sections, as well in the Fonte del Cerro section, the anoxic facies, assigned to the Tenuicostatum Zone, lies between the first appearance (FA) of *Carinolithus superbus* and the FA of *Discorhabdus ignotus* (Reale *et al*. 1992; Bucefalo Palliani and Mattioli 1994). In the condensed (*i.e.* Presale) sections the thickness of organic-rich interval could be reduced to 15 cm (Bartolini *et al*. 1992).

In the Southern Alps, well-exposed Toarcian black shales are located in the Belluno Trough. Between Longarone, Zoldo and the Vajont Gorge, the metre to decimetre thick anoxic facies is intercalated within the Igne Formation (Masetti and Bianchin 1987) and is assigned to the Falciferum Zone (Jenkyns *et al*. 1985). In actual fact, they occur between the Margaritatus and the Falciferum zones (Claps *et al*. 1995). In the Longarone area, where the most complete succession of well-laminated shale and Mn-rich limestone crops out, the TOC value ranges between 1.53% and 3.67% (Claps *et al*. 1995; Jenkyns 1988). In the Lombardy Basin, the anoxic interval has been identified, among others, in the Val Varea and Carpeneda, Monte Brughetto and Val Ceppelline sections (Jenkyns 1988; Cobianchi 1992; Picotti and Cobianchi 1996; Cobianchi and Picotti 2001). In the Val Varrea and Carpeneda sections, it lies on the *Calcare Rosso Nodulare* or the *Rosso Ammonitico Lombardo*, respectively (Cobianchi 1992; Picotti and Cobianchi 1996). In the Val Varrea section, the black shales are 4.5 m thick (Cobianchi

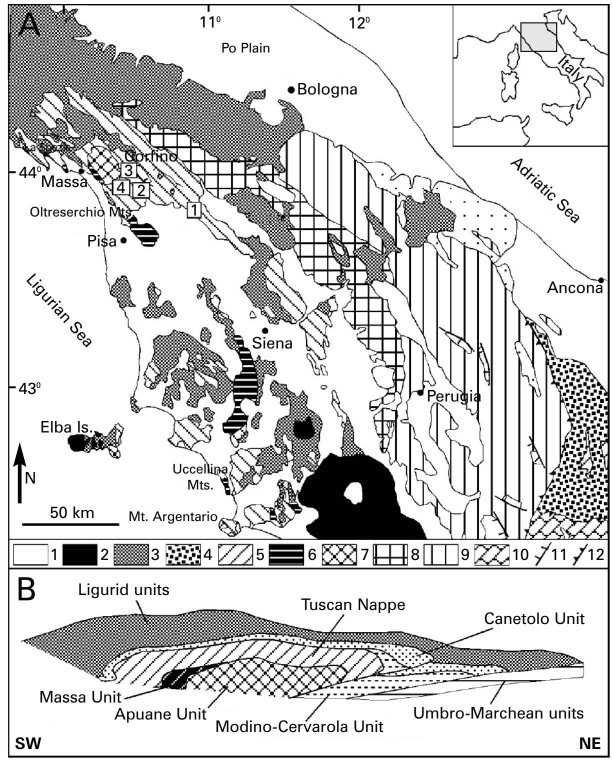

Fig. 1. A – Geological sketch map of the Northern Apennines (Carosi *et al.* 2005). In the squares the location of the study areas: 1 – Montecatini-Monsummano; 2 – Serchio Valley; 3 – Rontano; 4 – Pescaglia. B – Cross section not in scale: 1 – Neogene-Quaternary sediments; 2 – igneous rocks; 3 – Ligurids units; 4 – Tortonian "Molasse", Laga and Pliocene external sediments; 5 – Tuscan Nappe; 6 – Massa unit; 7 – Metamorphic Tuscan units; 8 – Cervarola-Falterona unit; 9 – Umbria-Marchean units; 10 – Lazio-Abruzzi sequences; 11 – main normal faults; 12 – main external thrust.

1992) and the TOC value ranges between 1.12% and 3.69% (Jenkyns 1988). In the Monte Brughetto section, they are 6.5 m thick and the TOC value ranges between 0.53% and 2.61% (Jenkyns 1988). Also in the condensed section of the Lombardy Basin, the thickness of the black shales is reduced to few decimetres. Based on ammonites, the anoxic facies of this area ranges from the uppermost part of the Tenuicostatum Zone to the Falciferum Zone (Jenkyns *et al*. 1985). The calcareous nannofossils recovered by Cobianchi (1992) from the Val Varrea section allowed this author to constrain the black shales between the FAs of *Lotharingius crucicentralis* and *Discorhabdus* aff. *D. striatus* (*i. e. D. ignotus*). At Colle di Sogno black shales lie within the Colle di Sogno Formation, between the FAs of *Lotharingius sigillatus* and *Lotharingius crucicentralis* and the FAs of *Watznaueria fossacincta* and *Discorhabdus striatus* (Erba 2004).

GEOLOGICAL SETTING OF THE STUDY AREAS

The areas studied are located in the Northern Apennines, a polydeformed thrust-and-folded belt, which in Tuscany includes the Apuane and Massa units, the Tuscan Nappe, the Canetolo and the Ligurids units (Fig. 1). Eastwards the nappe pile overlies the Umbria-Marchean units. The succession sampled belongs to the Tuscan Nappe which comprises: 1) Upper Triassic-Lower Jurassic shallow-water platform carbonates, 2) Lower Jurassic-Lower Cretaceous pelagic deepening succession, 3) Lower Cretaceous-Palaeogene basinal to ramp deposits, and 4) Oligo-Miocene foredeep siliciclastic turbidites (Bortolotti *et al.* 1970; Dallan Nardi and Nardi 1972; Fazzuoli *et al.* 1985). Based on thickness and facies variation, several isopic zones have been identified in the Tuscan Nappe (Boccaletti and Sagri 1967; Cerrina Feroni and Patacca 1975).

In the Roggio-Corfino and Monsummano-Montecatini areas a very thick Upper Triassic-Lower Jurassic platform carbonates are overlain by thin and laterally discontinuous Lower Jurassic-Lower Cretaceous pelagic sediments (Boccaletti and Bortolotti 1965; Puccinelli *et al.* 2006a). Between these areas, along the eastern and south-eastern margins of the Apuane Alps, the Tuscan Nappe crops out nicely in the Serchio Valley and Pescaglia area (Puccinelli *et al.* 2006b; Carosi *et al.* 2005). In the most complete and thick successions exposed in both sectors, the thick Upper Triassic-Lower Jurassic shallow-water carbonate showing a variable thickness, grade to very thick Lower Jurassic-Upper Jurassic pelagic successions.

According to the literature, the Tuscan Nappe shows many similarities with the Umbro-Marchean succession, particularly for the Lower Jurassic to Lower Cretaceous sedimentary record (Kalin *et al.* 1979). Both were deposited on a the block-faulted subsiding southern continental margin of Tethys, which broke up the carbonate platform into several half-graben systems, affected by prolonged subsidence and increasing water depth (Bernoullii *et al.* 1979; Winterer and Bosellini 1981). Based on sharp lateral variation of thickness and facies of the Tuscan Nappe, the pelagic Jurassic deposits of the Serchio Valley and Pescaglia area were probably deposited in a subsiding paleotrough, located between the Roggio-Corfino and the Monsummano-Montecatini paleohighs (Fazzuoli *et al.* 1985 and bibliography therein).

LITHOSTRATIGRAPHY AND LOCATION OF THE SAMPLED SUCCESSIONS

Due to the discontinuous exposures and the incomplete lithostratigraphic record of the Tuscan Nappe, particularly more intense in the case of the clay and marly formations, the presence of black shales within the dominantly marly *Calcari e marne a Posidonia* has only recently been identified based on refined mapping. Recognized in a number of places, the organic-rich interval is nicely exposed in the Rontano, Passo Lucese, Bolognana and Ma-

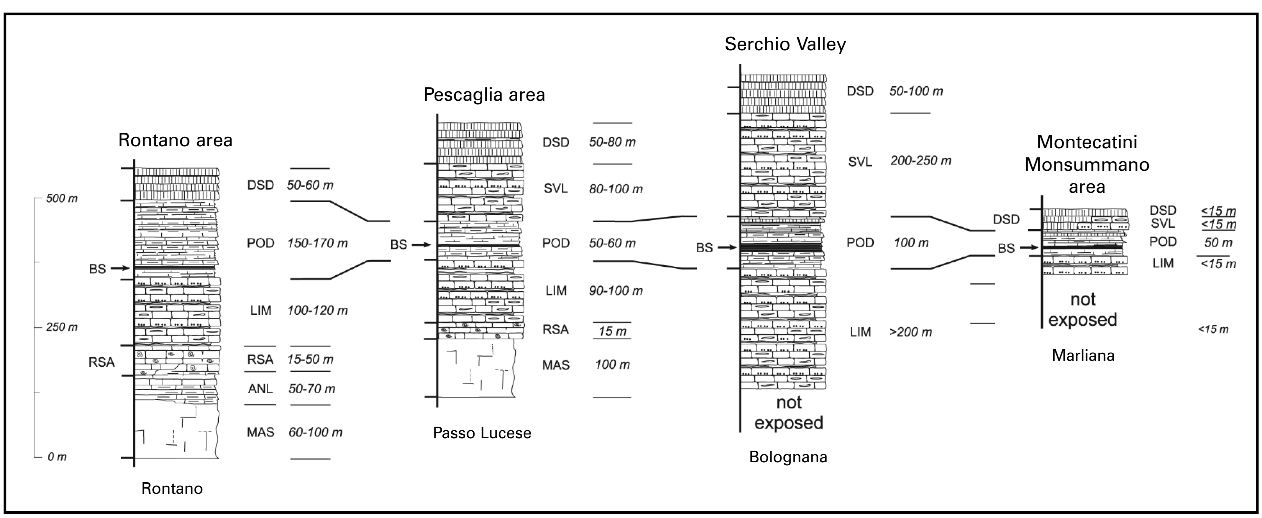

Fig. 2. Lithostratigraphy of the Jurassic deep-marine succession overlying the Lower Jurassic shallow-water carbonates (MAS), in the investigated sections: Rontano, Passo Lucese (Pescaglia area), Bolognana (Serchio Valley) and Marliana (Montecatini-Monsummano area). BS – organic-rich interval; MAS – *Calcare Massiccio*; ANL– *Calcari ad Angulati*; RSA – *Rosso Ammonitico*; LIM – *Calcare selcifero di Limano*; POD – *Calcari e marne a Posidonia*; SVL – *Calcare selcifero della Val di Lima*; DSD – *Diaspri*.

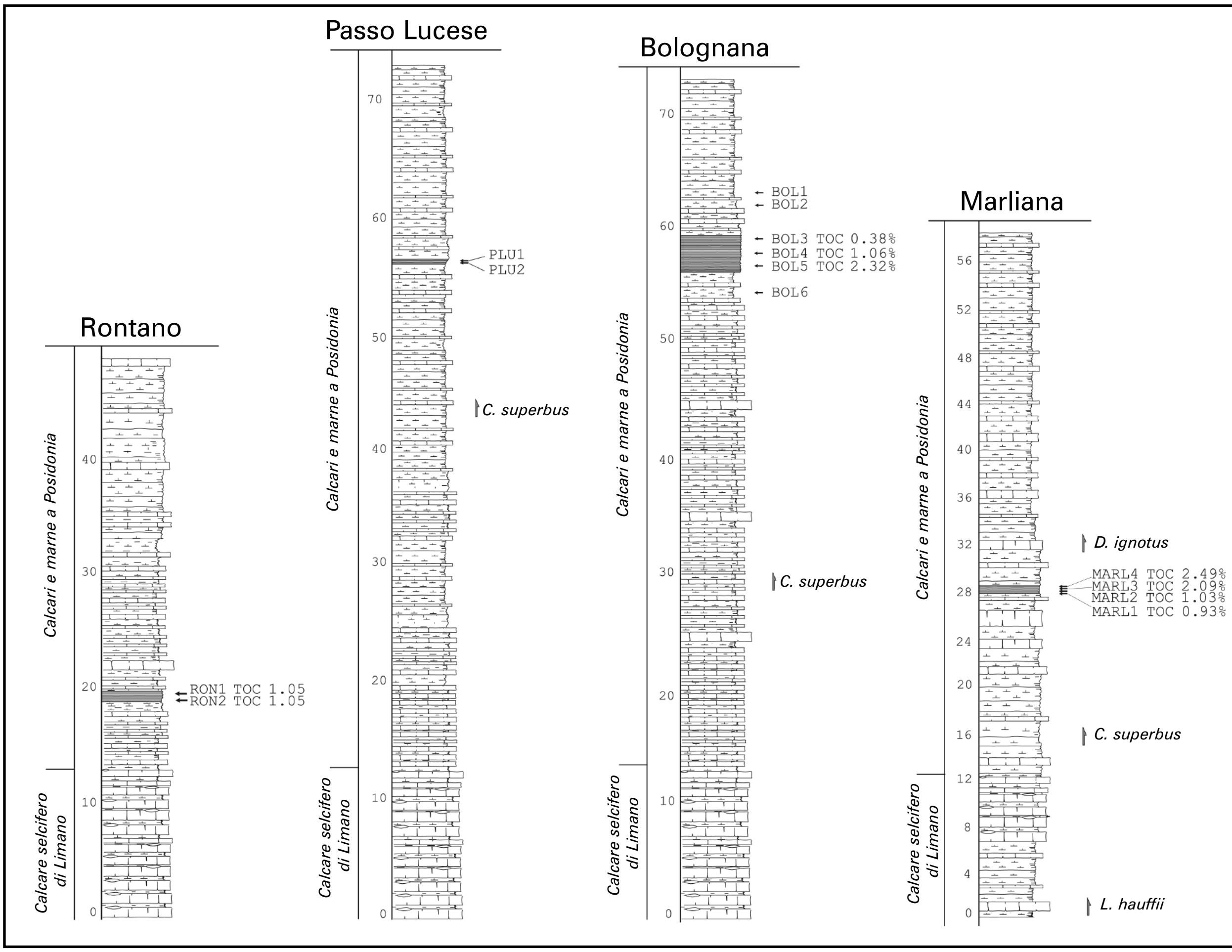

Fig. 3. Lithostratigraphy and thickness in metres of the sampled portions, stratigraphic position of the organic-rich interval in the Rontano, Passo Lucese (Pescaglia area), Bolognana (Serchio Valley) and Marliana (Montecatini-Monsummano area) sections, TOC values and calcareous nannofossil events.

rliana sections (Fig. 2). Showing a variable thickness, it occupies different stratigraphic positions with respect to the *Calcare selcifero di Limano/Calcari e marne a Posidonia* boundary (Fig. 3).

In the Monsummano-Montecatini area, the Jurassic pelagic succession comprises the *Calcare selcifero di Limano*, the *Calcari e marne a Posidonia*, the *Calcare selcifero della Val di Lima* and/or in places the *Diaspri* (Dallan *et al*. 1981). In the Marliana section, the 65 m thick *Calcari e marne a Posidonia* is represented by a calcareous (in the lowermost portion) to marly calcareous (dominant) lithofacies. Along the Torbido Creek (NE of Marliana), the 1 m thick organic-rich interval lies 16 m above the *Calcare selcifero di Limano/Calcari e marne a Posidonia* boundary. It consists of thin to very thin laminated brownish to black marls and marly claystones, sometimes siliceous, with TOC value ranging from 0.91% to 2.49%.

In the Serchio Valley and Pescaglia area, the Jurassic pelagic succession is very thick, but the sedimentary record is incomplete. However, in these areas, the *Calcari e marne a Posidonia* is usually interposed between the *Calcare selcifero di Limano* and the *Calcare selcifero della Val di Lima*. In the Bolognana section, the 100 m thick *Calcari e marne a Posidonia* consists of calcareous and marly calcareous lithofacies, which becomes progressively marly upwards. Well-exposed along the Rio Forcone Creek (NW of Bolognana), the 5 m thick organic-rich level is made up of laminated, thin to medium thick black marls and marly claystones with a TOC value ranging from 1.06% to 2.32%. This thick interval, lying 45-50 m above the *Calcare selcifero di Limano/Calcari e marne a Posidonia* boundary, is also exposed in a few other nearby localities. In the Passo Lucese section (SW of Pescaglia), the 30 cm thick black

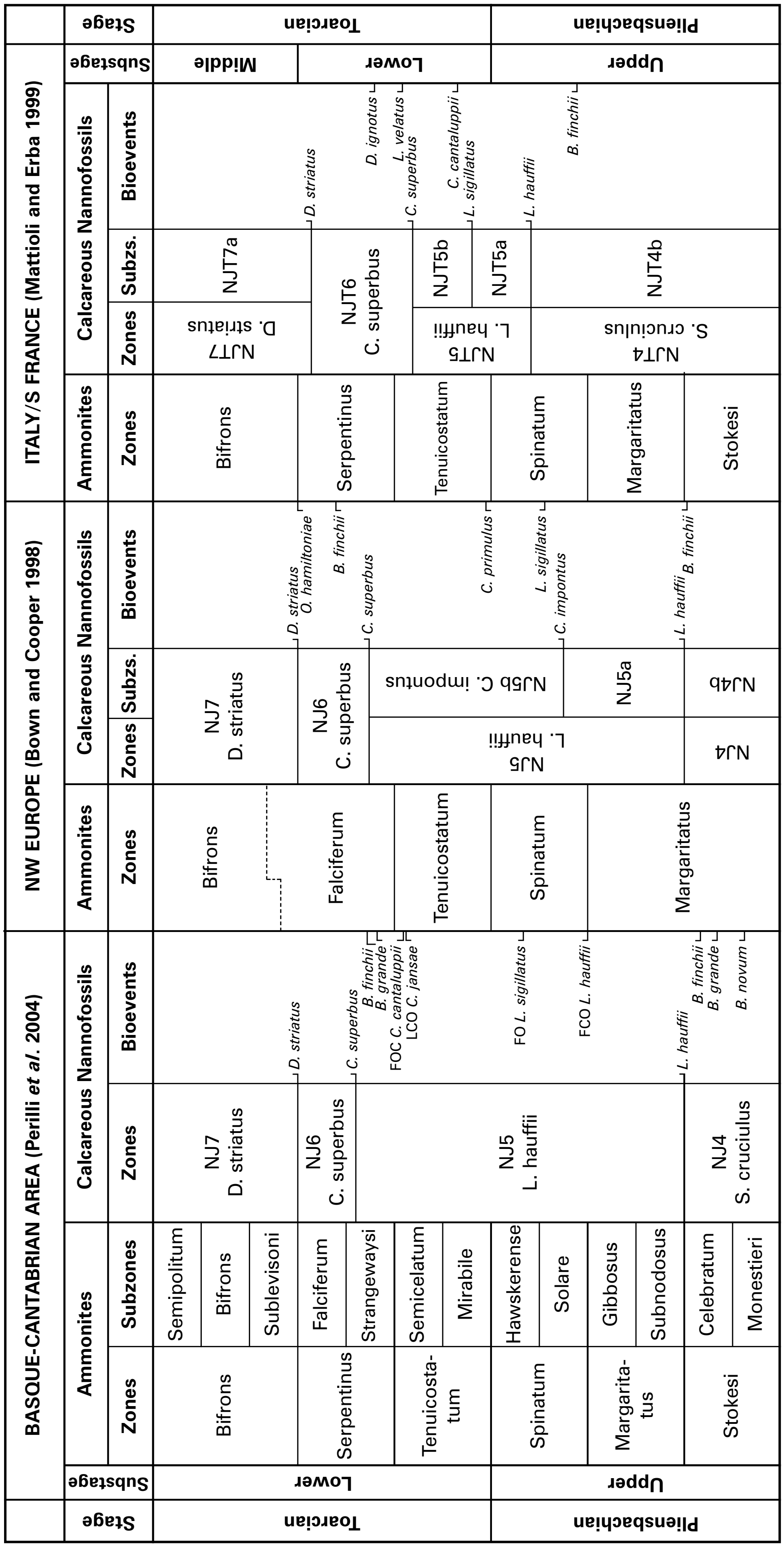

Fig. 4. Calcareous nannofossil zones and nannohorizons recognized in NW Europe and Italy/S France, and both zones and events recognized in the Basque-Cantabrian area.

shales lie a few decametres above the base of the *Calcari e marne a Posidonia*. In the Pescaglia area, the organic-rich level has been recognized also in a few other localities, always in the lower portion of the *Calcari e marne a Posidonia* that in this area is mainly represented by marly lithofacies and ranges in thickness from 50-60 to 80-120 m.

In the Rontano area, the entire 150-170 m thickness of the *Calcari e marne a Posidonia* is represented almost completely by marly lithofacies. In this area, which represents a link sector between the Serchio Valley (paleotrough) and the Roggio-Corfino (paleohigh), the *Calcari e marne a Posidonia* is interposed (towards the Serchio Valley) between the *Calcare selcifero di Limano* and the *Calcare selcifero della Val di Lima*, and between the *Rosso Ammonitico* or the *Calcari ad Angulati* and the *Diaspri* or *Scaglia toscana* (towards the Roggio-Corfino area). In the Rontano section, the 50 cm thick organic-rich interval is exposed 7 metres above the *Calcare selcifero di Limano*/*Calcari e marne a Posidonia* boundary. It consists of brownish to black laminated marlstones and marly claystones. On the left side of the Fosso Trava (E to SE of the Rontano), this level is exposed in the section sampled and in some other localities, where it lies 5 to 7 metres above the base of the *Calcari e marne a Posidonia*.

AGE OF THE ORGANIC-RICH LEVEL

Up to present, the age assigned to the lower portion of the *Calcari e marne a Posidonia* is based on a few scattered fossil remains collected within this formation and from the underlying *Calcare selcifero di Limano* (Perilli *et al*. 2008). The ammonites recovered from the *Calcare selcifero di Limano*, belonging to the Margaritatus and Spinatum zones, allow the assignment of this formation to the Upper Pliensbachian. The overlying lower portion of the *Calcari e marne a Posidonia* can be referred to the Lower to Middle Toarcian based on the few and scattered specimens of *Hildoceras levisoni*, *H. bifrons* and *H. semipolitum*, among others. Unfortunately, the ammonites, collected within these formations are often fragmented and frequently with doubtful geographic and/or stratigraphic position. To improve the dating of the organic-rich interval, closely-spaced samples have been collected from the lower portion of the *Calcari e marne a Posidonia* and the underlying uppermost part of *Calcare selcifero di Limano*. The sections sampled are Marliana, Bolognana, Passo Lucese and Rontano (Fig. 3). More than 300 samples have been collected and simple smear slides prepared in order to investigate the calcareous nannofossils. The analyses have been performed with a Light Microscope at 1250 X magnification. References for citated taxa can be found in Bown and Cooper (1998), whereas in Perilli *et al*. (2008) are reported the range charts of the calcareous nannofossil assemblages quoted below.

The most significant set of samples are those collected in the Marliana section where the assemblages are characterized by the presence of *Lotharingius hauffii, Calcivascularis jansae, Biscutum novum* and *Calyculus* spp. along with a few specimens of *Crepidolithus crassus*, *Biscutum grande* and *Biscutum finchii*. Consequently, the co-occurrence of *Lotharingius hauffii*, *Carinolithus superbus* and *Calcivascularis jansae* from the bottom of the section allows the recognition of the Lotharingius hauffii and Carinolithus superbus zones (Fig. 4). Furthermore the organic-rich level lies between the FA of *Carinolithus superbus* and the FA of *Discorhabdus ignotus*. This latter marker has been identified few metres above the organic-rich level. In the nearby Monsummano section the *Calcare selcifero di Limano/Calcari e marne a Posidonia* boundary lies within the Lotharingius hauffii Zone, and the overlying lower portion of the latter formation spans from the Lotharingius hauffii Zone to the Carinolithus superbus Zone.

In the Serchio Valley, between the Turrite Cava and the Turrite Secca creeks, fossiliferous samples are very few, and are usually characterized by a small number of specimens belonging to the species *Lotharingius hauffii, Biscutum novum, Crepidolithus crassus* and *Calyculus* spp. However in some sections (Solco Calaverno, Fosso Miglianello and Fosso Busdragno), the occurrence of *Carinolithus superbus* in the lower portion of the *Calcari e marne a Posidonia*, allows the recognition of the Lotharingius hauffii and the Carinolithus superbus zones. In the Bolognana section, *Carinolithus superbus* has been identified some metres below the thick organic-rich level.

Likewise in the Pescaglia area, fossiliferous assemblages recovered from the lowermost portion of the *Calcari e marne a Posidonia* are few and are characterized by a low number of specimens. Nevertheless, the Lotharingius hauffii and Carinolithus superbus zones have been documented in two sections (Trebbio and Torre) located a few kilometres NE of the Passo Lucese section. In two samples located below the organic-rich level exposed in the Passo Lucese section, the presence of both the *Lotharingius hauffii* and *Carinolithus superbus* allows the recognition of the Carinolithus superbus Zone.

DISCUSSION

Based on data reported in the papers focusing on Lower Toarcian black shales cropping out in Italian sections, in the Northern Apennines and Southern Alps, the TOC values range from 1% to 5% (Jenkyns *et al*. 2002). In both areas, the thickness of the organic-rich interval ranges from decametres to a few decimetres in expanded and condensed sections, respectively. Comparable TOC values and thicknesses of the black laminated marlstone and claystone alternations have been documented for the Tuscan Nappe. Based on ammonites, the anoxic event is located within the Tenuicostatum Zone in the Umbria-Marchean Basin and in the overlying Falciferum or Serpentinus Zone in the Belluno Trough and Lombardy Basin (Jenkyns *et al*. 2002 and bibliography therein). Unfortunately, in both the Northern Apennines and Southern Alps, condensed sections and hiatuses are documented, and the ammonite records are discontinuous. In addition, the placement of the boundary between the Tenuicostatum and Serpentinus (or Levisoni) zones in the Umbria-Marchean Basin or between the Tenuicostatum and the Serpentinus (or Falciferum) zones in the Belluno Trough and Lombardy Basin, is not based on the zonal marker species.

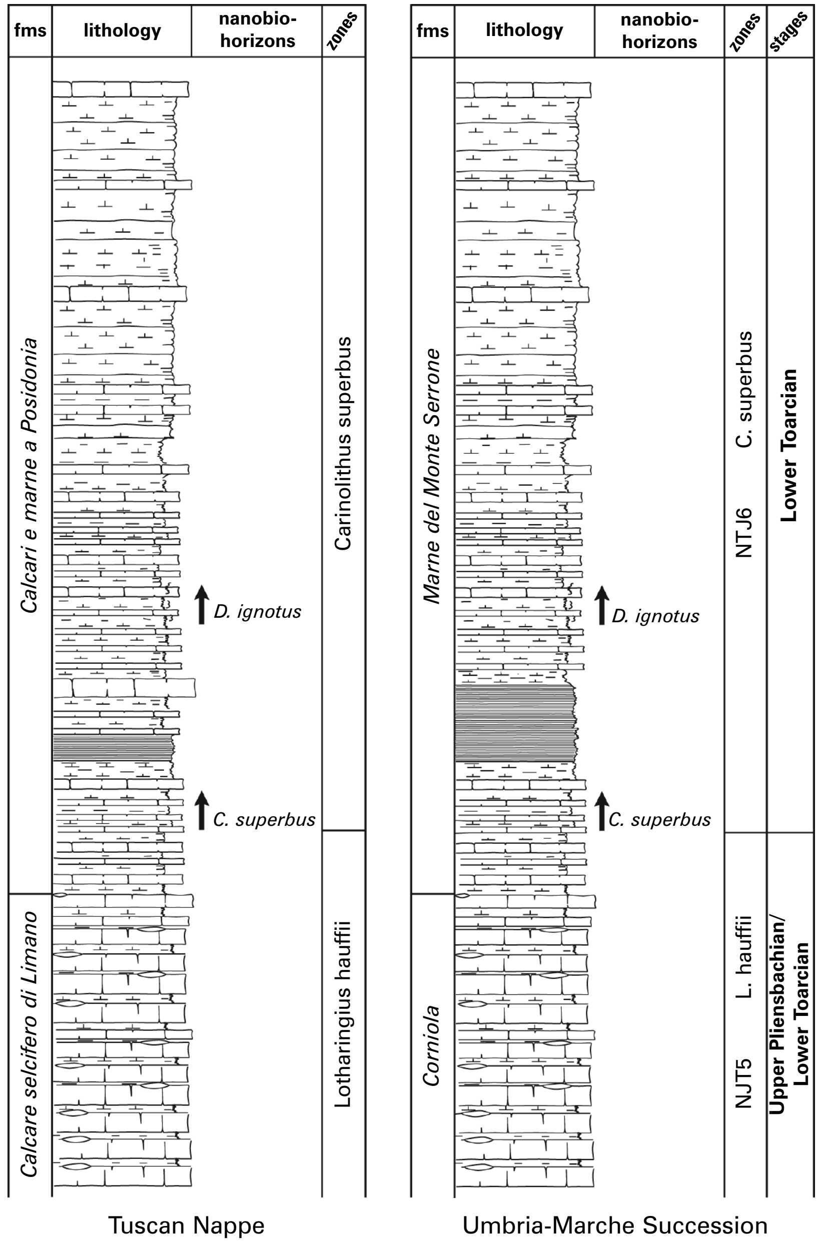

Fig. 5. Age and stratigraphic position of nannobiohorizons and black shales in the Tuscan Nappe and Umbria-Marche succession.

On the contrary, the continuous nannofossil assemblage records recovered from the Umbria-Marchean succession and from the Tuscan Nappe (this paper) allow the location of the organic-rich interval between the FA of *Carinolithus superbus* and the FA of *Discorhabdus ignotus*. Hence it lies within the Carinolithus superbus Zone, which spans from the FA of *Carinolithus superbus* to the FA of *Discorhabdus striatus* (Fig. 5). In both Boreal and Tethyan sections the FA of *Discorhabdus striatus* roughly coincides with the boundary between the Serpentinus/Falciferum/Levisoni and Bifrons zones. The FA of *Carinolithus superbus* is located within the Serpentinus Zone or the Falciferum Zone of NW Europe, Switzerland and

Morocco (Bown, Cooper 1998; de Kaenel *et al.* 1996). In Italy/S France the FA of *Carinolithus superbus* has been recognized within the Tenuicostatum Zone (Mattioli and Erba 1999). Recently, the appearance of *Carinolithus superbus* has been placed within the Levisoni Zone in Central Portugal (Perilli and Duarte 2006) and within the Serpentinus Zone in Northern and Central Spain (Perilli 1999, 2000). Moreover, in Portugal and Spain the appearance of the genus *Carinolithus* has been documented across the Tenuicostatum/Falciferum or the Polymorphum/Levisoni Zone boundaries, respectively. Consequently it approaches the boundary between the Tenuicostatum/Polymorphum and Serpentinus/Falciferum/Levisoni zones.

According to the literature (Goy 1981; Bown 1987), the genus *Carinolithus* evolved from the genus *Calyculus* and this transition took place within the Early Toarcian. Mattioli (1996) locates this evolutionary step in the Tenuicostatum Zone. Based on morphometric analyses (Perilli, *in progress*), in Spain the appearance of the genus *Carinolithus* approaches the Semicelatum/Strangewaysi Subzone boundary (*i. e.* Tenuicostatum/Serpentinus Zone boundary). In Portugal, the transition from *Calyculus* to *Carinolithus* lies across the Polymorphum/Levisoni (Tenuicostatum/Serpentinus) Zone boundary (see Elmi *et al.* 1989). In summary all the mentioned authors document a sharp transition from the genus *Calyculus* to the genus *Carinolithus,* which shows the same morphological variation in NW Europe as well in Italy, Spain and Portugal. Consequently this could be considered a reliable event that in Italy lies slightly below the Lower Toarcian anoxic event.

CONCLUSIONS

For the first time the Lower Toarcian anoxic event has been recognized also in the Tuscan Nappe, based on refined mapping of the pelagic Lower Jurassic Tuscan succession, and lithostratigraphic analyses of the Pliensbachian/Toarcian transition, exposed in several sections of the Tuscan Apennine. In the sections investigated, the well-bedded siliceous calcilutites of the *Calcare selcifero di Limano* grade to the bivalve-bearing, marly calcareous to marly lithofacies of the lower part of the *Calcari e marne a Posidonia*. The boundary between these formations coincides with the sharp increase in marly levels, and lies within the Lotharingius hauffii Zone. The lower part of the *Calcari e marne a Posidonia* shows a thin to very thin laminated brownish to black marlstone and claystone alternance, with TOC value comprised between 0.43% and 2.49%. Ranging in thickness from 30 cm to 5 m, it lies within the Carinolithus superbus Zone.

Consequently, the sampled lower part of the *Calcari e marne a Posidonia* (Posidonia Marls) is correlated with the *Marne del Monte Serrone* of the Umbria-Marche succession characterized by the presence of the Lower Toarcian black shales, lying between the appearances of *Carinolithus superbus* and *Discorhabdus ignotus*. Hence, along a large area of the sunken southern margin of Tethys, during the latest Pliensbachian-earliest Toarcian time interval (Lotharingius hauffii Zone), siliceous-bearing limestone periplatform sedimentation (*Calcare selcifero di Limano* and *Corniola*) gave way to a predominantly Early Toarcian (from Lotharingius hauffii to Carinolithus superbus zones) marly deposition (*Calcari e marne a Posidonia*, *Marne del Monte Serrone*). At that time (Carinolithus superbus Zone), in the Umbria-Marchean and Tuscan domains, sedimentation recorded the Early Toarcian anoxic event, which coincides with the maximum flooding surface documented in both Tethyan and Boreal sections.

QUOTED CALCAREOUS NANNOFOSSIL TAXA

Biscutum finchii (Crux, 1979) Bown, 1987
Biscutum grande Bown, 1987
Biscutum novum (Goy, 1979) Bown, 1987
Calyculus spp. indet.
Carinolithus superbus (Deflandre, 1954) Prins in Grün *et al.*, 1974
Calcivascularis jansae (Wiegand, 1984) Bown & Young in Young *et al.,*1986
Crepidolithus crassus (Deflandre, 1954) Noël, 1965
Discorhabdus ignotus (Górka, 1957) Perch-Nielsen, 1968
Discorhabdus striatus Moshkovitz et Ehrlich, 1976
Lotharingius crucicentralis (Medd, 1971) Grün et Zweili, 1980
Lotharingius hauffii Wind et Cepe, 1974
Lotharingius sigillatus (Stradner, 1961) Prins in Grün *et al.,* 1974
Watznaueria fossacincta (Black, 1971) Bown et Cooper, 1989

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