The Paleontological monument of Monte Nerone (Umbria Marche Apennines).

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Post-Symposium Field Trip B3
(19-21 September 2002)

THE PALEONTOLOGICAL MONUMENT OF MONTE NERONE (UMBRIA MARCHE APENNINES)

SCIENTIFIC COORDINATOR

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FOREWORD

Monte Nerone area has, since its first geological description, been studied by many geologists from all part of the world. The rich geological heritage of Monte Nerone, has made the area one of the most important areas in Central Apennines for geological teaching and research. This famous marine Mesozoic locality is also a scenic area in the central Apennines. Although the scenery of Monte Nerone is a result of geologic processes, the geology along the road and trails was until few years ago an enigma to most visitors, namedly the non-researcher ones, and to the in-habitants. The Piobbico Civic Museum started in 1997, under the writer direction, a geoconservation programme "Neroniade" both to remedied the situation as to manage the area under the institution of a Regional Geological Monument.

The present guide and the excursion would not have been possible without the joint effort and the enthusiastic work of several young researchers and the generous support of the Piobbico Municipality.

Stefano Cresta

INTRODUCTION

S. CRESTA

The Umbria Marche arcuate fold belt is located in the Northern Apennines in between the front of the Trasimeno-Falterona-Cervarola nappe and the Pliocene Adriatic foredeep. From a lithostratigraphic point of view, it is usually described in terms of three superimposed lithotectonic groups. From bottom to top they include: the basement, the Triassic evaporites, the Mesozoic-Tertiary sedimentary cover. The basement has been drilled in boreholes located at the internal boundary of the Umbria Marche fold belt, but does not outcrop anywhere in the fold belt. The Triassic evaporites do not outcrop either; they were drilled by boreholes, showing that the average thickness in the core of the anticlines is about 2000 metres. The pre-deformation thickness is smaller and it has been estimated as about 1000 metres (LAVECCHIA & PIALLI, 1980). Usually the Triassic evaporites are considered as the major decollement level between the cover and the basement. The sedimentary cover consists in its lower part of neritic and pelagic limestones of Early Jurassic to Palaeogene age (1300-2000 metres) and in its upper part of terrigenous siliciclastic flysch-type deposits of Neogene age (1500-2000 metres). From a structural point of view, the Mesozoic-Palaeogene sedimentary sequence can be regarded as a 1st order litho-structural unit embedded between two incompetent less viscous levels, the floor being the Triassic evaporites and the roof being the Miocene flysch-like deposits. During the Late Miocene-Early Pliocene this sequence underwent an intensive shortening, that gave rise to the Umbria-Marche fold and thrust belt. This belt consists of an alternance of large anticlines, with average wavelenghts of 4-5 km, overturned eastward on adjacent tight asymmetric synclines, with average wavelenghts of 1-2 km. The geometry of the Umbria-marche fold belt is the result of a two-stage deformation. During a first stage (Late Miocene), the Mesozoic-Palaeogene sedimentary sequence, embedded between the Triassic evaporites and the Miocene flysch-like deposits, became largely detached from the basement, was shortened progressively by a combination of buckling and more or less homogeneous strain. During the Early Pliocene the area underwent further shortening and the pre-existing features were transported eastward by the low-angle compressional and transpressional shear planes.

The Jurassic deposits of the Monte Nerone area (Fig 1) record the rifting and the drowning of a part of the vast, Mediterranean Late triassic peritidal carbonate-evaporitic platform (DERCOURT *et alii*, 1993). The post-drowning submarine rift topography comprised basins and fault-bounded swells, *i.e.* the Pelagic Carbonate Platforms (= PCPs). The PCPs are defined as "intrabasinal highs on continental crust, bordered by synsedimentary faults and [...] sites of condensed and discontinuous pelagic carbonate sedimentation over drowned fragments of a former peritidal carbonate platform" (SANTANTONIO, 1994, p. 122). Across the whole Umbria-Marche area a remarkable hiatus, lasting from the early Bajocian to the late early Kimmeridgian, is recorded on the top of PCPs within pelagic cephalopod-rich, nodular limestones of the Bugarone formation. The time-duration of this hiatus spans from about 22 Ma (ODIN, 1994) to about 19 Ma (GRADSTEIN *et alii,* 1994). In the basins, where the sedimentation was continuous, it is possible to observe a drop in the biotic diversity beginning in the early Bajocian and lasting the entire time span of the hiatus (BARTOLINI & CECCA, 1999).

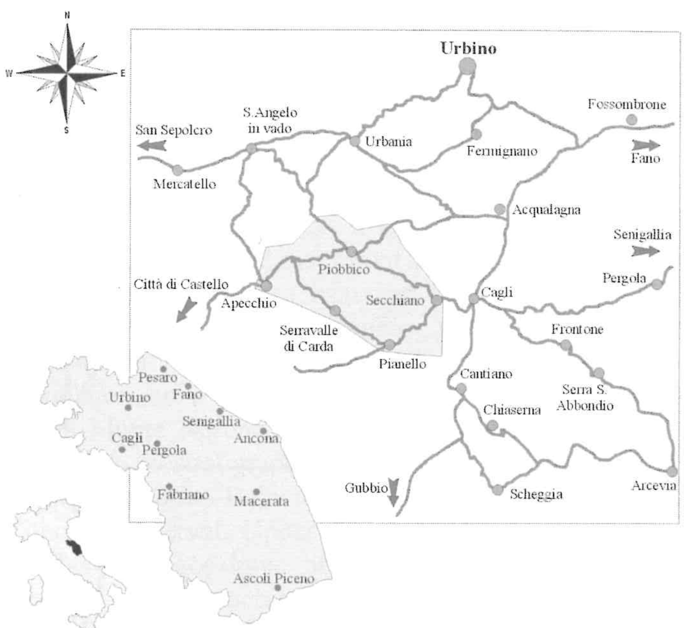


Fig. 1 – Location map of M. Nerone Paleontological Monument.

LITHOSTRATIGRAPHIC SETTING

S. CRESTA

In order to prepare the reader for the sketches and figures contained in the descriptions of the field trips, we present here the descriptions, summarized from the literature, of all the units that make up the Umbria-Marche Jurassic succession. Only the bio and chronostratigraphic features of the sections chosen as examples will be discussed in the field trip notes, while the general characteristics of the lithostratigraphic units will not.

Calcare Massiccio (Hettangian-Sinemurian) – In the Hettangian a carbonate platform with oolitic bar, lagoonal and tidal flat facies developed, above which the poorly stratified, massive carbonate sediments of this unit, consisting of alternating laminated intervals, paleosoils, stromatolitic mats, and oolite bars, were deposited. The

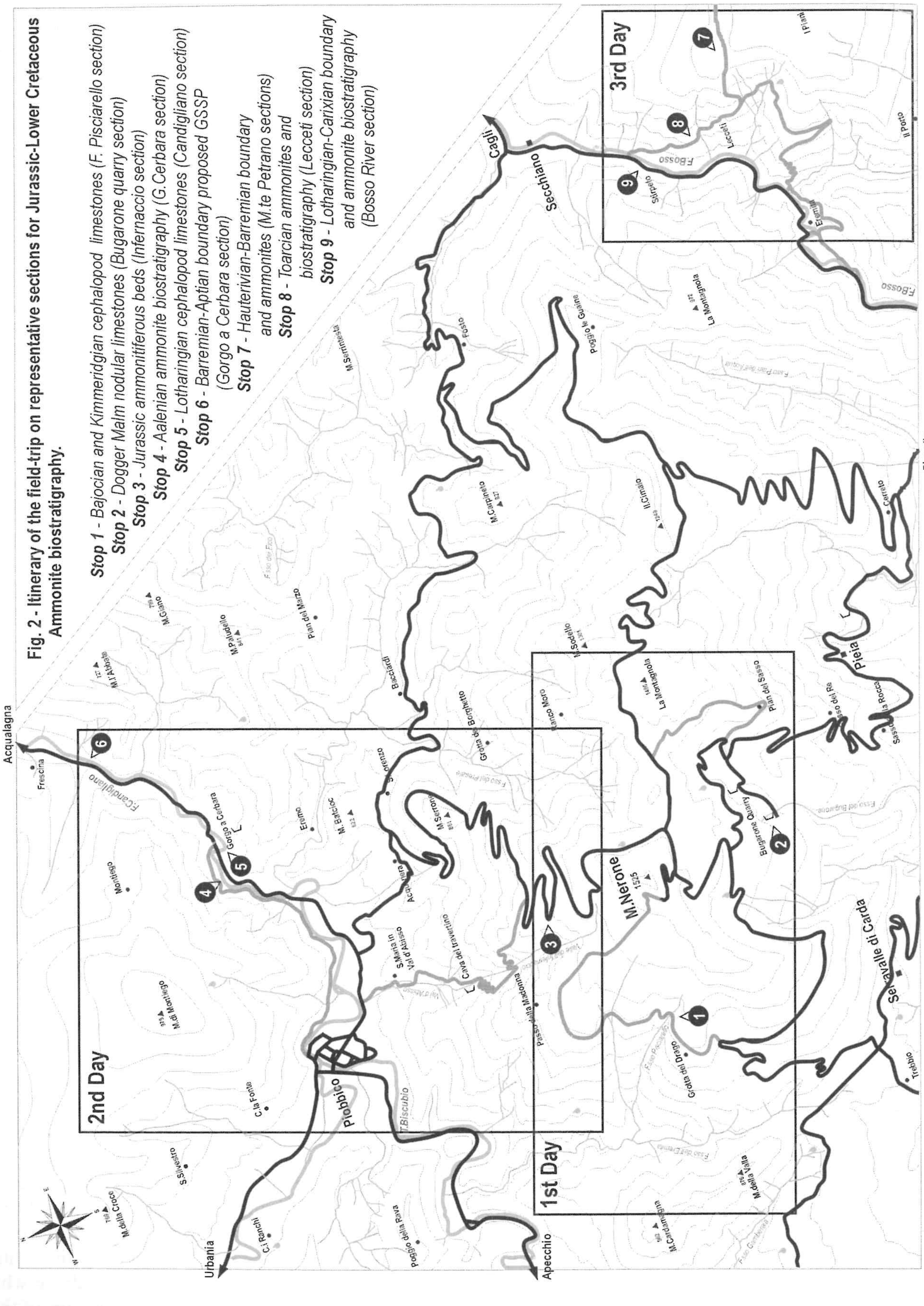


Fig. 2 - Itinerary of the field-trip on representative sections for Jurassic-Lower Cretaceous Ammonite biostratigraphy.

Stop 1 - *Bajocian and Kimmeridgian cephalopod limestones (F. Pisciarello section)*
Stop 2 - *Dogger Malm nodular limestones (Bugarone quarry section)*
Stop 3 - *Jurassic ammonitiferous beds (Infernaccio section)*
Stop 4 - *Aalenian ammonite biostratigraphy (G.Cerbara section)*
Stop 5 - *Lotharingian cephalopod limestones (Candigliano section)*
Stop 6 - *Barremian-Aptian boundary proposed GSSP (Gorgo a Cerbara section)*
Stop 7 - *Hauterivian-Barremian boundary and ammonites (M.te Petrano sections)*
Stop 8 - *Toarcian ammonites and biostratigraphy (Lecceti section)*
Stop 9 - *Lotharingian-Carixian boundary and ammonite biostratigraphy (Bosso River section)*

average thickness of this unit is 500-700 m.

Corniola (Sinemurian-earliest Toarcian) – It typically consists of regularly bedded grey to nutty brown micritic limestones; bed thickness ranges from centimeters to decimeters. Texturally it is generally a mudstone, more rarely a wackstone. Chert is common, and the upper part bears argillaceous interbeds. Since these sediments were deposited in a basin that was still evolving morphologically, turbidites, slumps and slides are common, most notably in the lower part, which can also host megabreccias near basin-margins. The thickness of the unit varies considerably, ranging from ~300 m in basins to 10-20 metres on PCP-tops.

Rosso Ammonitico (early Toarcian *p.p.* – late Toarcian *p.p.*) – It consists of nodular limestones and calcareous marls. The nodules are irregularly shaped, often elongate parallel to the bedding, with dimensions ranging from one to several centimeters, and encased in a clayey-marly matrix. The sediments are greyish-yellowish to red and generally contain rich ammonite assemblages. Graded and laminated turbidites, slumps and pebbly mudstones (often made up of resedimented early diagenetic nodules) can be common in the thicker sections. The thickness of the unit varies from ~50 m to ~7 m on PCP-tops.

Calcari e Marne a Posidonia (late Toarcian *p.p.* - ?Bathonian) – This unit is made of “filaments” rich calcareous mudstones and, more rarely, wackestones. Its lower part is nodular, with interbedded resedimented deposits and slumps. The base has been set just below the point where predominately calcareous sedimentation resumed, following the period of dominantly clayey-marly deposition, while upsection sediments become increasingly chert-rich, gradually changing into the next unit. The thickness of this formation amounts to several tens of metres.

Calcari Diasprigni (?Callovian – late Kimmeridgian) – They consist of radiolarian rich sediments; their skeletons, dissolved during diagenesis, supplied the silica for cherts in lenses, nodules and continuous layers. In the upper part of the unit chert is of the characteristic pinch and swell type, and the calcareous component is virtually null. It is at most some tens of metres thick. This unit sometimes forms intercalations in the Bugarone Formation, in wedges up to 6 m thick. Upsection this unit grades into cherty limestone in thin beds with abundant remains of the crinoid *Saccocoma* and of aptychi, locally forming graded and/or laminated beds, which can be mapped separately (up to ~20 m).

Bugarone (late Toarcian *p.p.* – Tithonian) – This is a typical condensed pelagic platform unit. It consists of bioturbated, more or less dolomitized and locally nodular limestones and marly limestones. It is 16 metres thick in the type section at the Bugarone quarry (Monte Nerone). Based on ammonites, a major stratigraphic gap was identified, rendering its subdivision into two units necessary. The lower one, named *inferiore*, (average thickness 12 meters), falls between the *Dumortieria meneghinii* (late Toarcian) and *Stephanoceras humphriesianum* (early Bajocian) Zones. The upper one, named *superiore* (average thickness 3 metres), falls between the *Crussoliceras divisum* (early Kimmeridgian) and *Simoceras volanense* (early Tithonian) Zones. On pelagic carbonate platforms the *Calcari diasprigni* Fm. can locally occur intercalated between the two units (see above). A *Micritic Cephalopod-rich* lithofacies has been distinguished at Fosso Pisciarello (stop 1.1.) and Gorgo a Cerbara (stop 2.4). The rocks belonging to it are neither nodular nor dolomitized, and contain abundant ammonites, aptychi, belemnites and fossil corals. This lithofacies is generally very thin, because of extreme sedimentary condensation.

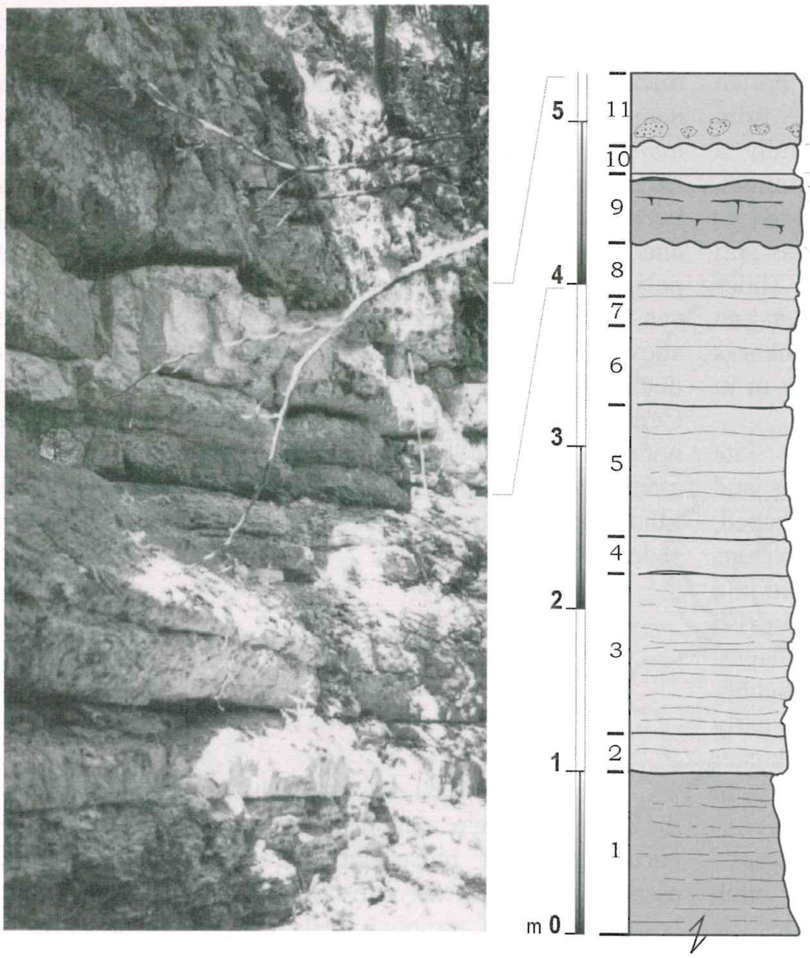
BIOSTRATIGRAPHIC SETTING

S. Cresta

The nearly ideal outcrop of the Jurassic sequence in the Monte Nerone area has over the last twenty years encouraged the biostratigraphic study of ammonite associations. The richly diverse associations favour their correlation on a regional to Tethyan scale, a circle in which Monte Nerone can be considered a Jurassic key-point. The biostratigraphic units identified here define the lower Sinemurian-Bajocian and lower Kimmeridgian *p.p.*-Tithonian interval. Upper Bajocian-lower Kimmeridgian *p.p.* assemblages have never been recorded at Monte Nerone, as well as across the whole Umbria-Marche area.

While detailed studies on ammonite biostratigraphy have been carried out in many Jurassic outcrops in the Umbria-Marche region, the Monte Nerone area is the only one where all the ammonite zones recognisable in the Sinemurian-Tithonian interval occur over an area less than ten square km’s wide. This is the reason why it has been suggested as a key locality for biostratigraphy within the Mediterranean Province.

The paleogeographic framework arranges the Jurassic sections to be examined into pelagic carbonate platform (PCP) and basin sequences; the ammonite biostratigraphy of the middle Pliensbachian-Aalenian interval, represented in both paleoenvironments, shows the same bioevent sequence. The Sinemurian of the PCP sequences is in a shallow water facies (*Calcare Massiccio*) generally with no ammonites, with the notable exceptions of the Pieia and Gorgo a Cerbara outcrops (Cecca *et alii*, 1987), in which, however, the Liassic depositional geometry is peculiar. The upper Aalenian-lower Bajocian and Kimmeridgian-Tithonian sequence bears ammonites only in the PCP areas.



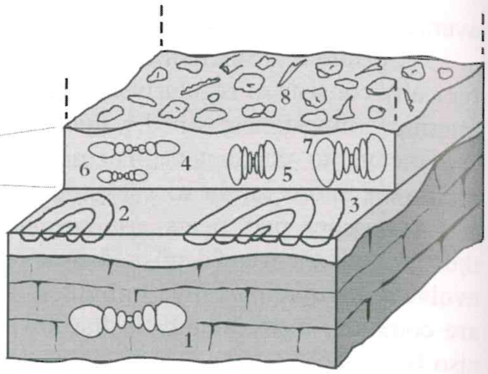


Fig. 3 – Schematic representation of the Toarcian – Kimmeridgian interval in the Fosso Pisciarello section. The following biostratigraphic interpretation is given:
Bed 1, *Geczyceras speciosum* Zone;
Bed 2, *Dumortieria meneghinii* Zone;
Bed 3, *Leioceras opalinum* Zone;
Beds 4-6, barren;
Beds 7-8, *Otoites sauzei* Zone;
Bed 9a, *Otoites sauzei* Zone;
Bed 9b, *Stephanoceras humprhiesianum* Zone with reworked ammonites from *O. sauzei* Zone (*E. greppinii* MAUBEUGE,*E. contrahens* BUCKMAN, *Skirroceras* sp.);
Bed 10, reworking level with *O. sauzei* and *S. humphriesianum* Zone ammonites reelaborated shells (*Emileia* spp., *Lokuticeras tenuicostatum* (HOCHSTETTER), *Stephanoceras pyritosum* (QUENSTEDT), *Skirroceras* n. sp. aff. *Dolichoechus* BUCKMAN, *Stemmatoceras frechi* RENZ);
Bed 11, Kimmeridgian condensed cephalopod limestone (for details see text).

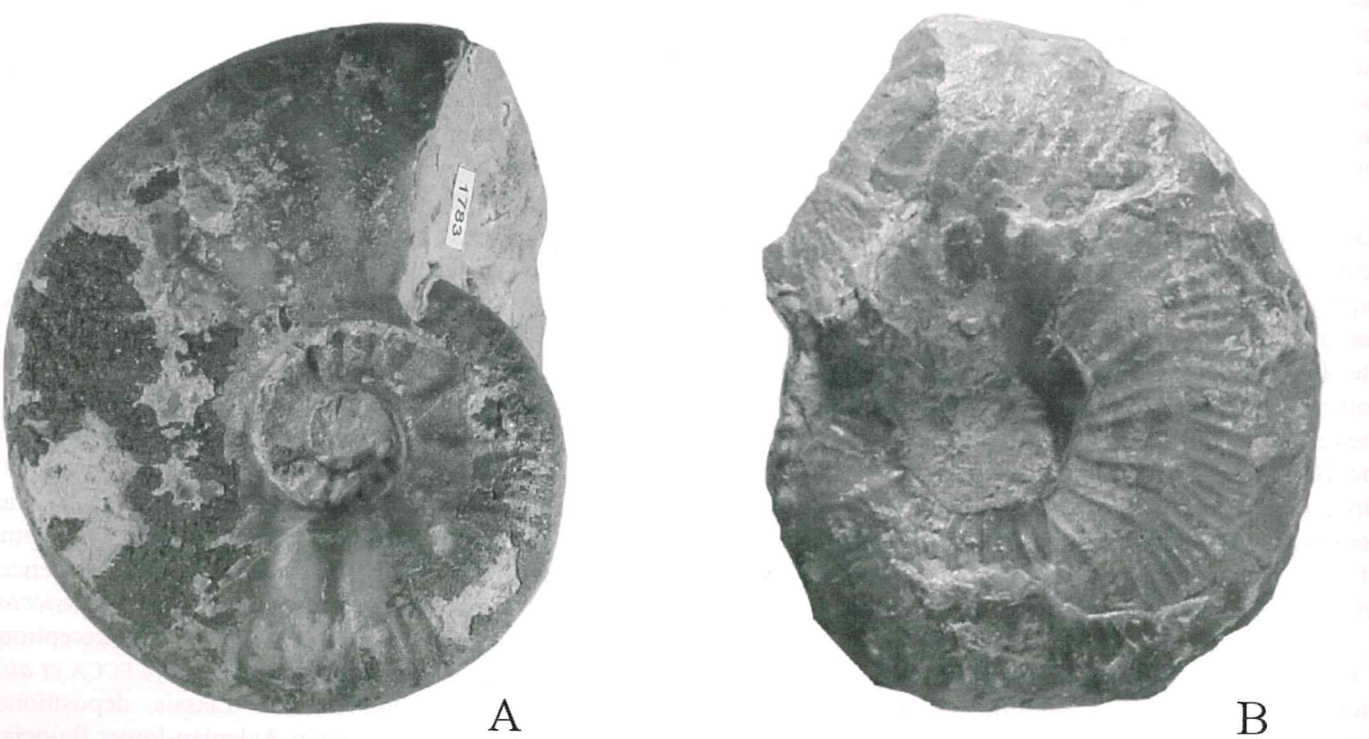


Fig. 4 – Kimmeridgian ammonites from Bed 11 of Fosso Pisciarello section: A, *Taramelliceras (Metahaploceras) strombecki* (OPPEL), x 0,8; B, *Taramelliceras trachinotum* (OPPEL), x 0,8.

The biostratigraphic study is based upon the sections sampled in the Bosso zone (basin), Pieia-quarry (slope), Bugarone quarry (PCP), Pian del Sasso (PCP), Ranchetti quarry (PCP), Collungo (PCP), Pisciarello stream (PCP-margin), Campo al Bello (PCP), Ranchi (PCP-upper slope), Infernaccio (PCP-upper slope), Presale-stream (PCP), Gorgo a Cerbara (basin). The reference area for the lower and middle-upper Lias (*Arietites bucklandi* - *Hildaites levisoni* Zones) is the basin sequence exposed in the Bosso River valley (River, Stirpeto, Eremita, Lecceti); for the upper Lias and lower Dogger (*Hildoceras bifrons* - *Stephanoceras humphriesianum* Zones) it is the upper slope sequence between Monte Nerone (PCP) and Gorgo a Cerbara (basin); for the Malm (*Crussoliceras divisum* - *Durangites* Zones) it is the Monte Nerone PCP sequence. The biostratigraphic considerations will however take into account all the outcrops of the intervals considered, mentioned in the text as auxiliary sections.

The Standard Ammonite Zonation adopted as reference is the one proposed by the Groupe Français d'étude du Jurassique (1997) because it updates the Tethyan framework and at the same time also gives an account of the surveyed peculiarities in the different paleogeographic dominions.

STOP 1 – BAJOCIAN AND KIMMERIDGIAN CEPHALOPOD MICRITIC LIMESTONES (FOSSO PISCIARELLO SECTION)

(see also CECCA *et alii*, 1990, p.106)

D. DI PIETRO & D. MARINUCCI

In this section the sampled levels show the smallest thicknesses caused by the high sedimentary and stratigraphic condensation.

Above the lower Bajocian limestones (Fig. 3) we find a first layer (30-40 cm thick), divided in two by a discontinuity surface.

In the lower part the following species have been recognized: *Taramelliceras (T.) trachinotum* (OPPEL), *T. (Metahaploceras)* gr. *strombecki* (OPPEL), *Orthaspidoceras* gr. *uhlandi* (OPPEL), *O. Garibaldi* (GEMMELLARO), *Lithacosphinctes* aff. *evolutum* (QUENSTEDT), *Nebrodites (Mesosimoceras) benianus* (CATULLO in CANAVARI). This assemblage can be referred to the Divisum Zone for the presence of *O. uhlandi* and *T. trachinotum,* even if the presence of numerous *T. (M.) strombecki* specimens (Fig. 4), hardly ever so plentiful in the Apennines, could mean that in the first level there is a condensation of the *Taramelliceras (Metahaploceras) strombecki* and *Crussoliceras divisum* Zones.

In the upper part the following species have been recognized: *Taramelliceras (T.)* gr. *compsum* (OPPEL), *T. (T.) pugiloides* (CANAVARI), *Hemihaploceras (Zitteliceras) piccininii* (ZITTEL), *Aspidoceras acanthicum* (OPPEL), *Aspidoceras longispinum* (SOWERBY), *Orthaspidoceras ziegleri* CHECA, *Pseudowaagenia acanthomphala* (ZITTEL), *Nebrodites (N.) peltoideus* (GEMMELLARO), *Hybonoticeras beckeri* (NEUMAYR), and *H. pressulum* (NEUMAYR).

The assemblage as a whole is ascribable to the upper Kimmeridgian, *Hybonoticeras beckeri* Zone, even if the presence of *N. peltoideus* suggests that the *Taramelliceras compsum* Zone is condensed in this layer.

The second layer (from 30 to 50 cm), in which a remarkable sedimentary and stratigraphic condensation is detected, contains ammonites belonging to the lower Tithonian, *Hybonoticeras hybonotum, Semiformiceras darwini, Semiformiceras semiforme* and *Semiformiceras fallauxi* Zones. We point out the presence of *Glochiceras (Paralingulaticeras) lithographicum* (OPPEL), *Taramelliceras (Fontannesiella) valentinum* (FONTANNES), *Semiformiceras darwini* (NEUMAYR), *S. semiforme* (OPPEL) *Pseudolissoceras rasile* (ZITTEL), *P. bavaricum* BARTHEL, *Aspidoceras rafaeli* (OPPEL), *Virgatosimoceras* gr. *albertinum* (CATULLO), *V.* gr. *micrum* OLORIZ, *Simoceras aesinense* MENEGHINI, *S. biruncinatum* (QUENSTEDT), *S. admirandum* ZITTEL, *Pseudodiscosphinctes geron* (ZITTEL), *P. rhodaniforme* OLORIZ, *P.* aff. *chalmasi* (KILIAN).

The next bed is characterized by an extremely irregular thickness (20-40 cm) and by many discontinuity surfaces, crossing each other and thus isolating lenses differing in fossiliferous content and degree of dolomitization. The ammonites are abundant, sometimes forming "lumachella" deposits, and indicate the upper Tithonian and the lowermost Berriasian. Because of severe condensation, the chronostratigraphic signal had to be cross-checked through the study of Calpionellids assemblages. At 10 cm from the base of the layer, assemblages referable to *Calpionella* Zone (*sensu* ALLEMANN *et alii*, 1971), *Calpionella alpina* Subzone (*sensu* REMANE *et alii*, 1986) were found, indicating the lowermost Berriasian.

Afterwards, the stratification becomes ill-defined, while the dolomitization is more and more intense. From this point, the sampling went only one metre on. The boundary between the *Remaniella* and *Calpionella elliptica* Subzones can be placed at about 50 cm from the base of this last part of the section, while the boundary between the *Calpionella* and *Calpionellopsis* Zones is at about 80 cm from the base. In correspondence of this boundary we found the following ammonites species:

Jabronella aff. *paquieri* (SIMIONESCU), *Jabronella* sp., *Spiticeras* sp.

STOP 2 – LIAS-DOGGER NODULAR LIMESTONES (BUGARONE QUARRY SECTION)

S. CRESTA, D. DI PIETRO & A. GRIPPO

LITHOLOGY

The Bugarone Formation is a condensed, ammonite-bearing sequence which is found on pelagic platforms throughout the Umbria-Marche Apennines. In the field, it shows a striking rhythmicity, with evident hierarchical bedding patterns in the namesake quarry walls of Monte Nerone (Fig. 5).

The limestones in this sequence are biomicrites of pinkish-brownish color, separated by planar partitions of bluish-gray clay, but more massive and more brownish strata peppered with dolomite rhombs also occur. The stratigraphic sketch given here bears only limited resemblance to the rhythmic patterns exposed on the quarry wall. Sawed surfaces on quarried slabs stacked in the quarry show an incipient nodularity, with creamy, more calcareous nodules in a matrix slightly more marly, greenish to buff, and seemingly bioturbated. The faunal content includes "filaments" representing cross-sections of bivalves of the *Bositra* and *Lentilla* types, early globigerinacean foraminifera and ammonites.

AMMONITE BIOSTRATIGRAPHY

Through the analysis of the identified species in the sampled sections it has been possible to recognise, mainly among the Hammatoceratids, some bioevents that allowed the definition of local biozones correlated to the standard scale (*P. planinsigne, E. sutneri, E. fallifax, E. intermedius, P. klimakomphalum, R. longalvum, E. amplectens* Biozones, CRESTA, 1996). We must add that it has not been possible, up to now, to define with certainty to which extent the Standard Zones, including their subzones and biohorizons, are actually represented in the Apenninic Aalenian. Due to these uncertainties we conservatively chose to make use of the classical Stage subdivisions (*Leioceras opalinum, Ludwigia murchisonae, Graphoceras concavum* Zones).

Dumortieria meneghinii Zone - To this Unit we refer 9 beds, 57 cm thick, with 2 fossiliferous levels (beds

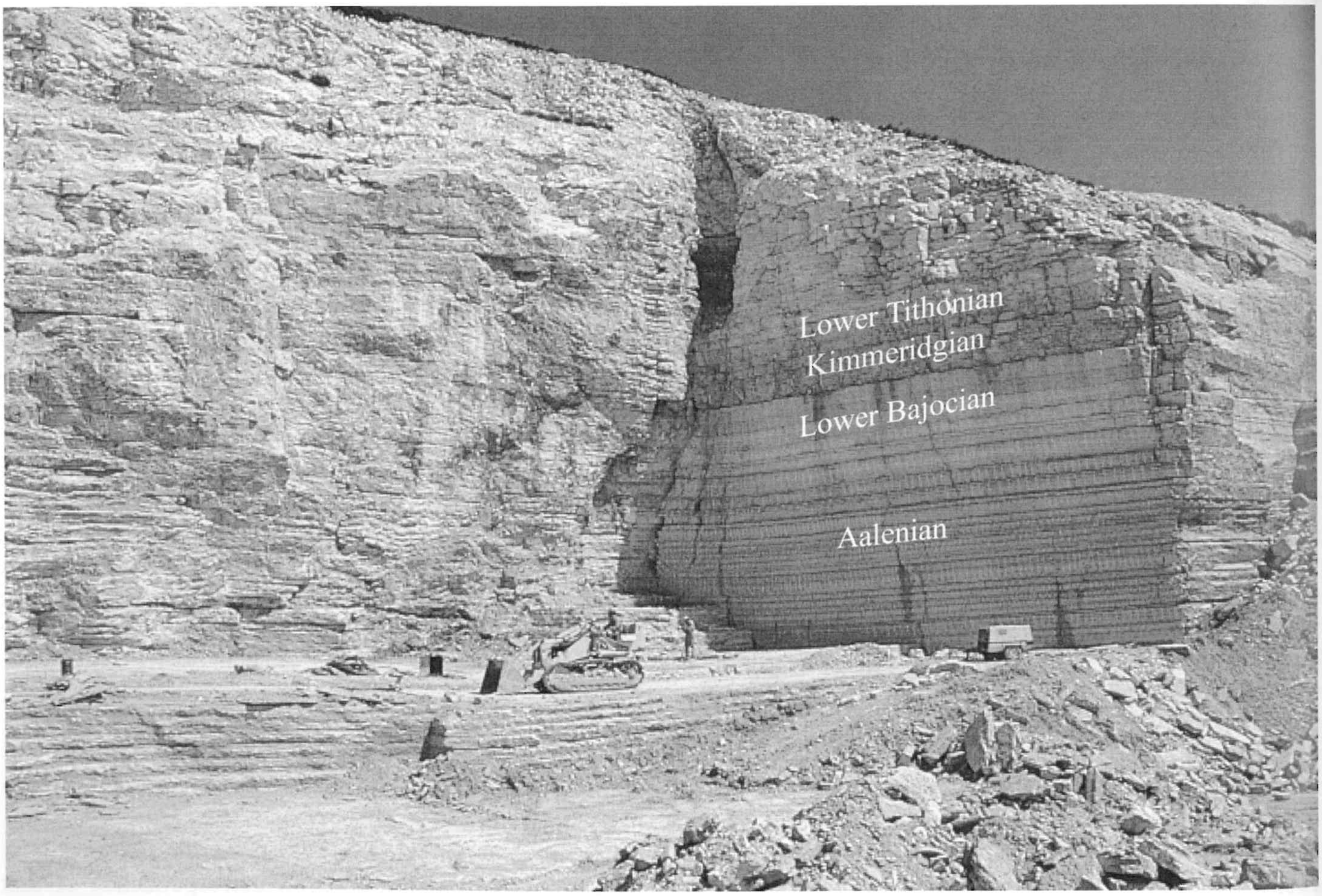


Fig. 5 – Middle- Upper Jurassic beds of the Bugarone Quarry section.

3 and 7). In this Unit the ammonite fauna is characterized by the presence of *Dumortieria meneghinii* (HAUG in ZITTEL) and *D. taramellii* FUCINI; among the Hammatoceratids, besides the persistence of *Geczyceras personatum* (MERLA), *Neronia elaphus* (MERLA), the first representative of Erycitids, appears.

Pleydellia aalensis Zone - To this Unit we refer 14 beds, 133 cm thick, with 4 fossiliferous levels (beds 10, 11, 14, 19). The ammonite fauna is dominated by platycones belonging to the genera *Pleydellia* and *Cottewoldia*, in the lower and middle parts of the unit (*Pleydellia mactra* and *Pleydellia aalensis* Subzones). In the upper part (*Pleydellia buckmani* Subzone) the fauna is generally very scarce and is dominated by serpenticones of the genus *Catulloceras* GEMMELLARO along with Phylloceratina.

Leioceras opalinum Zone - To this Unit we refer 26 beds, 217 cm thick, with 5 fossiliferous levels (beds 24, 28, 33, 41, 44). In the association, whose characteristic element is *Tmetoceras scissum* (BENECKE), we identified *Leioceras (Cypholioceras) lineatum* (BUCKMAN), *Leioceras opalinum* (REINECKE), *Leioceras comptum* (REINECKE), *Planammatoceras* gr. *planinsigne* (VACEK), *Erycites sutneri* GEMMELLARO, and *E. fallifax* ARKELL.

Ludwigia murchisonae Zone - To this Unit we refer 35 beds, 337 cm thick, with 9 fossiliferous levels (beds 48, 50, 51, 55, 61, 62b, 62c, 62e, 63). The levels indicated by the old Authors under the name of *Erycites fallax beds* were referred to this Unit. The Zone in its lower part (*Ludwigia haugi* and *Ludwigia murchisonae* Subzones) is characterized by *Erycites intermedius* (HANTKEN in Prinz), *Abbasitoides modestus* (VACEK), *T. scissum* (BENECKE), *T. regleyi* (DUMORTIER), *Planammatoceras tenuinsigne* (VACEK), *Csernyeiceras subaspidoides* (VACEK), *Alocolytoceras ophioneum* (BENECKE), *Ancolioceras opalinoides* (MAYER), *Ludwigia haugi* DOUVILLE, and the bloom of *E. fallifax* ARKELL. In the upper part (*Bradfordia bradfordensis* Subzone) the association becomes poor and its definition is based upon the presence of *Pseudaptetoceras klimakomphalum* (VACEK) and of the earliest Haplocerataceae (*Praestrigites* sp.).

Graphoceras concavum Zone - To this Unit we refer 11 beds, 213 cm thick, with 3 fossiliferous levels (beds 73, 82, 83). The Zone is recognizable through the appearance of *Riccardiceras longalvum* (VACEK) and *Abbasites* sp. to which, in the upper levels, *Euaptetoceras amplectens* BUCKMAN, *E. amaltheiforme* (VACEK), *Riccardiceras telegdirothi* (GECZY), *Haplopleuroceras subspinatum* BUCKMAN, *Euhoploceras modestum* BUCKMAN, *Graphoceras limitatum* (BUCKMAN), *G.* gr. *decorum* BUCKMAN, *Bradfordia inclusa* BUCKMAN, *Praestrigites deltotus* BUCKMAN are associated. The same association characterises, in the Bajocian GSSP of Cabo Mondego, the terminal part of the *Graphoceras concavum* Zone (*Graphoceras limitatum* Subzone; *Euaptetoceras amplectens* Horizon).

BEDDING

Our attention was attracted by the hierarchical bedding patterns in the sequence (Fig. 6). Major beds, 24-35 cm thick, are generally separated by one or two beds a few cm thick. We have numbered these "major bedding units" up to number 26. The top of unit 25 lies 7.1 m above the base; above the top of unit 26 the bedding patterns become less regular, and were not included in our study.

A number of units deviate from this pattern: Unit 9, 10 and 11 show no thin interbeds and are separated only by faint bedding planes; Unit 12 is an "ugly duckling" thicker than most interbeds yet only half as thick as the other major bedding units, and bounded by clayey layers in which traces of very thin interbeds are visible. Units 18 and 19 were assigned to a completely homogenized unit of twice average thickness. Units 20 and 21 lack a central major bed, each consisting of 4-5 "interbeds". Complete amalgamations of various units have prevented us from carrying our analysis beyond unit 26.

Such bedding patterns are not uncommon in the deep-water marls of the Cretaceous, where they occur in stratigraphic segments showing MILANKOVITCH rhythmicity. There one can follow gradations: low-carbonate/high-carbonate precession couplets are generally grouped in sets of five into eccentricity bundles, in which the lowest and highest are thinnest and the middle ones thicker.

In the more calcareous Barremian Maiolica Limestone and the Cenomanian Scaglia Bianca limestone the shaly parts become reduced to bedding planes, and the middle beds in the bundle commonly become amalgamated by bioturbation. By analogy, it would seem: that units 20 and 21 of this section represent such eccentricity bundles of precessional couplets; that in most units the central couplets have been lost by bioturbation; that in units 9-10 all precessional traces have been lost and the eccentricity cycles have become nearly amalgamated; and that in units 18-19 such amalgamation has occurred at the eccentricity level as well.

A first analysis of these rhythms allowed to estimate the duration of the section in ~3.3 million years for a time span that extends from the late Toarcian to the late Aalenian.

A second, more complete image analysis study (GRIPPO *et alii,* in prep.) allowed a cyclostratigraphic reconstruction of the lower part of the section, thus bracketing the lower and middle Aalenian.

Computer-processed scans of outcrop photographs (for the methodology, see GRIPPO and FISCHER. in prep.) quantified the rhythms, and frequency analysis of the treated data provided consistent power spectra, showing

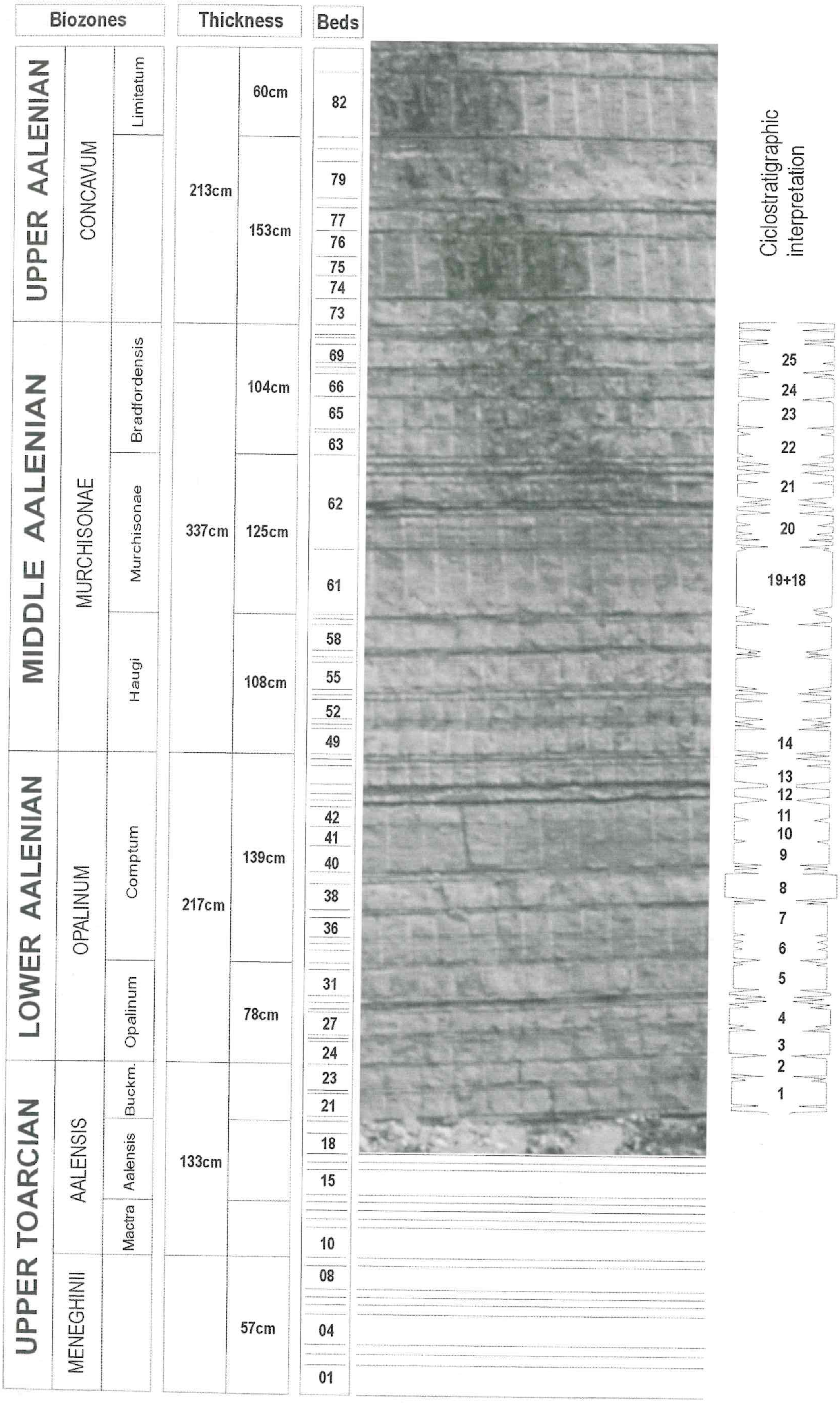


Fig. 6 – Upper Toarcian-Aalenian schematic log of Bugarone Quarry wall.

the full hierarchy of Milankovitch frequencies.

In particular, a tentative identification of the main bedding cycle with the ca. 100 ka eccentricity period yielded spectra in which all of the consistent peaks correspond to orbital periods as expected for the Jurassic, i.e. with obliquity and precession shorter than present values.

Owing to the scarcity of radiometrically datable strata, the Jurassic stages have long been assigned pragmatic values that assumed essentially equal zonal duration. With this approach, it is possible to estimate the mean accumulation rate of this sequence in 2.9 Bubnoff, a reasonable figure for such a condensed section. Counting eccentricity cycles, it is possible to obtain a zonal duration of about 2,200 ka for the lower and middle Aalenian, while planned further analysis would eventually make it possible to estimate the duration of the whole Aalenian stage.

STOP 3 – JURASSIC AMMONITIFEROUS BEDS IN THE INFERNACCIO SECTION

S. CRESTA, D. DI PIETRO & D. MARINUCCI

The section is exposed on the right side of the Infernaccio valley, on the northern slope of Monte Nerone, at an altitude of 1148 m, and can be reached by car along the road taking to the mount top from the north.

The Jurassic sequence is about 30 metres thick; for a detailed description see CECCA *et alii* (1990); figure 7 shows the sampled lower Bajocian beds, 5 metres thick, also sketched in figure 8. In order to compare the description by CRESTA *et alii* (1995), the progressive numbering of the levels given by the Authors was maintained; our new excavation, on the other hand, stressed further subdivisions to be made within some of these levels, making an integration of the numbering necessary.

Early Bajocian

The sequence has rather uniform lithology, ranging from limestone to severely bioturbated dolomitized limestone. Dolomitization mainly affects the matrix, more rarely the filling of the fossils and burrows, and its intensity generally decreases from the top to the bottom of the sequence.

The ammonites are preserved again as inner moulds (Fig. 9); in some layers (53a-g) they are sometimes deformed by sliding along their horizontal axes and their position is always parallel or subparallel to the bedding. The collected specimens have variable size (4 to 30 cm) and the association in each individual layer does not show any evident signs of re-elaboration (inverse geopetal structures, moulds with eroded or striped-by-dragging surfaces). Most of the specimens have a body chamber and in many of them the peristome is preserved (Stephanoceratidae and Otoitidae).

The faunal content of each level is summarized as follows:

Level 38 (10 cm) - *Docidoceras* sp. (2), *Eudmetoceras* cf. *eudmetum* BUCKMAN (1), *Euaptetoceras amaltheiforme* (VACEK) (2).

Level 39 (15 cm) - *Euaptetoceras amaltheiforme* (VACEK) (1), *Phylloceras* sp (1)

Level 40 (20 cm) - *Docidoceras* gr. *limatum* POMPECKJ (3), *Docidoceras telegdirothi* (GÉCZY)(1), *Euaptetoceras amaltheiforme* (VACEK) (8), *Haplopleuroceras subspinatum* BUCKMAN (1), (?) *Hyperlioceras* sp. (1), *Praestrigites deltotus* BUCKMAN (3), *Euhoploceras acanthodes* BUCKMAN (1), *Holcophylloceras* sp. (2), *Phylloceras* sp. (1), *Lytoceras* sp. (1).

Level 41 (a10, b15, c10 cm) - From bed **b**: *Docidoceras zemistephanoides* GÉCZY (1), *Strigoceras* sp. (1).

Level 42 (a5, b20 cm) - From bed **b**: *Bradfordia inclusa* BUCKMAN (1), *Docidoceras* gr. *limatum* POMPECKJ (1), *Holcophylloceras* sp (1).

Level 43 (a10, b10, c10, d10, e15 cm) - From bed **c**: *Shirbuirnia stephani* BUCKMAN (1), *Shirbuirnia* sp. (1), *Strigoceras* sp. (1); from bed **e**: *Fissilobiceras* sp. (2).

Level 44 (a30, b15, c10 cm) - From bed **b**: *Fissilobiceras fissilobatum* (WAAGEN) (1), *Mollistephanus* sp. (1).

Level 45 (a10, b5, c15 cm) - From bed **a**: *Papilliceras arenatum* BUCKMAN (2), *Phylloceras* sp. (1), *Calliphylloceras* sp.(1), *Holcophylloceras* sp.(1).

Level 46 (a10, b5 cm) – No ammonites found.

Level 47 (20 cm) - *Kumatostephanus paucicostae* FALLOT et BLANCHET (1), *Kumatostephanus* sp. (2), *Skirroceras baylei* (OPPEL) (1), *Skirroceras* sp. (1), *Strigoceras* sp. (1), *Hebetoxyites incongruens* BUCKMAN (1), *Emileia* gr. *contrahens* BUCKMAN (3), *Emileia bulligera* BUCKMAN (1), *Emileia* sp. (2), *Otoites delicatus* BUCKMAN (1), *Otoites contractus* (SOWERBY) (4), Sonninidae gen. ind, sp. ind. (2), *Phylloceras* sp. (3), *Holcophylloceras* sp. (6), *Partschiceras* sp. (1), *Megalytoceras* sp. (2).

Level 48 (a15, b5, c10 cm) - From bed **a**: *Skirroceras baylei* (OPPEL) (11), *Kumatostephanus* sp. (1), *Emileia contrahens* BUCKMAN (2), *Otoites* sp. (1), (?) *Witchellia* sp. (1), *Phylloceras* sp. (6), *Calliphylloceras* sp. (1), *Holcophylloceras* sp. (12), *Lytoceras* sp. (3), Nautiloidea ind. (1).

Level 49 (a10, b10, c10 cm) - No ammonites found.

Level 50 (a5, b5, c10, d5 cm) - No ammonites found.

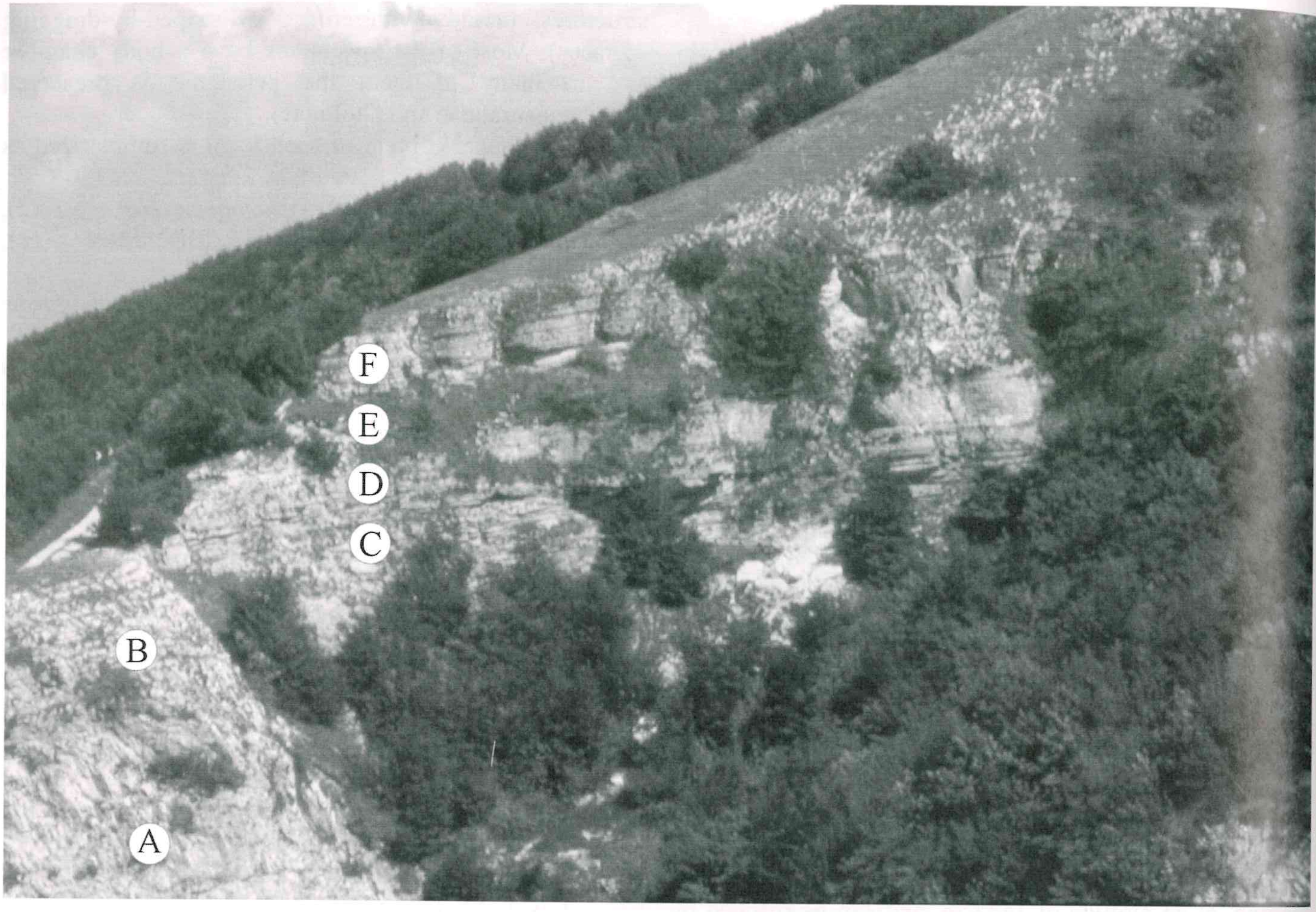


Fig. 7 – Jurassic beds of the Infernaccio section: A) *Calcare massiccio* Fm.; B) *Corniola* Fm.; C) *Lower Bugarone* Fm. (Upper Toarcian-Aalenian beds); D) *Lower Bugarone* Fm. (Lower Bajocian beds); E) *Calcari diasprigni* Fm.; F) *Upper Bugarone* Fm. (Kimmeridgian-Lower Tithonian beds).

Level 51 (15 cm) - *Labyrinthoceras meniscum* (WAAGEN) (2).

Level 52 (a10, b15 cm) - No ammonites found.

Level 53 (a5, b5, c8, d8, e5, f10, g5, h5 cm) - From bed **c**: *Stephanoceras tenuicostatum* HOCHSTETTER (3), *Skirroceras macrum* (QUENSTEDT) (1), *Skirroceras dolichoechus* (BUCKMAN) (1), *Phylloceras* sp. (1). From bed **d**: *Stephanoceras scalare* WEISERT (1), *Stephanoceras tenuicostatum* HOCHSTETTER (1), *Stephanoceras pyritosum* (QUENSTEDT) (1), *Stephanoceras* sp. (9), *Skirroceras* sp. (4); From bed **h**: *Stephanoceras* sp. (3), *Stemmatoceras frechi* RENZ (4), *Lytoceras* sp (1), *Phylloceras* sp. (2), *Holcophylloceras* sp. (2).

Level 54 (a15, b10, c5 cm) - From bed **b**: *Phylloceras* sp. (3).

Level 55 (a15, b5 cm) - From bed **a**: *Phylloceras* sp. (1).

Kimmeridgian-lower Tithonian

Above a level about 4 metres thick of radiolarian-rich limestones rests a non-fossiliferous calcareous bed (20 cm), followed in turn by a 1 m thick bed referred to the upper Kimmeridgian, *Hybonoticeras beckeri* Zone, for the presence of *Pseudowaagenia acanthomphala* (ZITTEL) and *Lithacoceras (Virgalithacoceras)* aff. *fruticans* (SCHNEID). The lower Tithonian is represented by 8 beds (fig. 10) in which the following species were sampled (CECCA *et alii*, 1990, p. 110) (Fig. 11):

Bed 3 (30 cm, *Hybonoticeras hybonotum* Zone) – *Protetragonites quadrisulcatus* (D'ORBIGNY), *Hybonoticeras hybonotum* (OPPEL), *Glochiceras (Paralingulaticeras) lithographicum* (OPPEL).

Bed 4 (20 cm, *Semiformiceras darwini* Zone) – *Protetragonites quadrisulcatus* (D'ORBIGNY), *Phylloceras serum* (OPPEL), *Ptychophylloceras ptychoicum* (QUENSTEDT), *Lytoceras sutile* (OPPEL), *Haploceras (H.) carachteis* s.l. (M/m)(ZEUSCHNER), *Pseudolissoceras rasile* (ZITTEL), *Semiformiceras darwini* (NEUMAYR), *S. darwini* morf. *beticum* OLORIZ, *Schaireria neoburgensis* (OPPEL), *Virgatosimoceras* gr. *albertinum* (CATULLO), *V. micrum* OLORIZ, *Simoceras praecursor* SANTANTONIO, *Lithacoceras* gr. *lemenci* (PILLET & FROMENTEL), *"Subplanitoides" pseudocontiguus* DONZE & ENAY, *Dorsoplanitoides* sp.

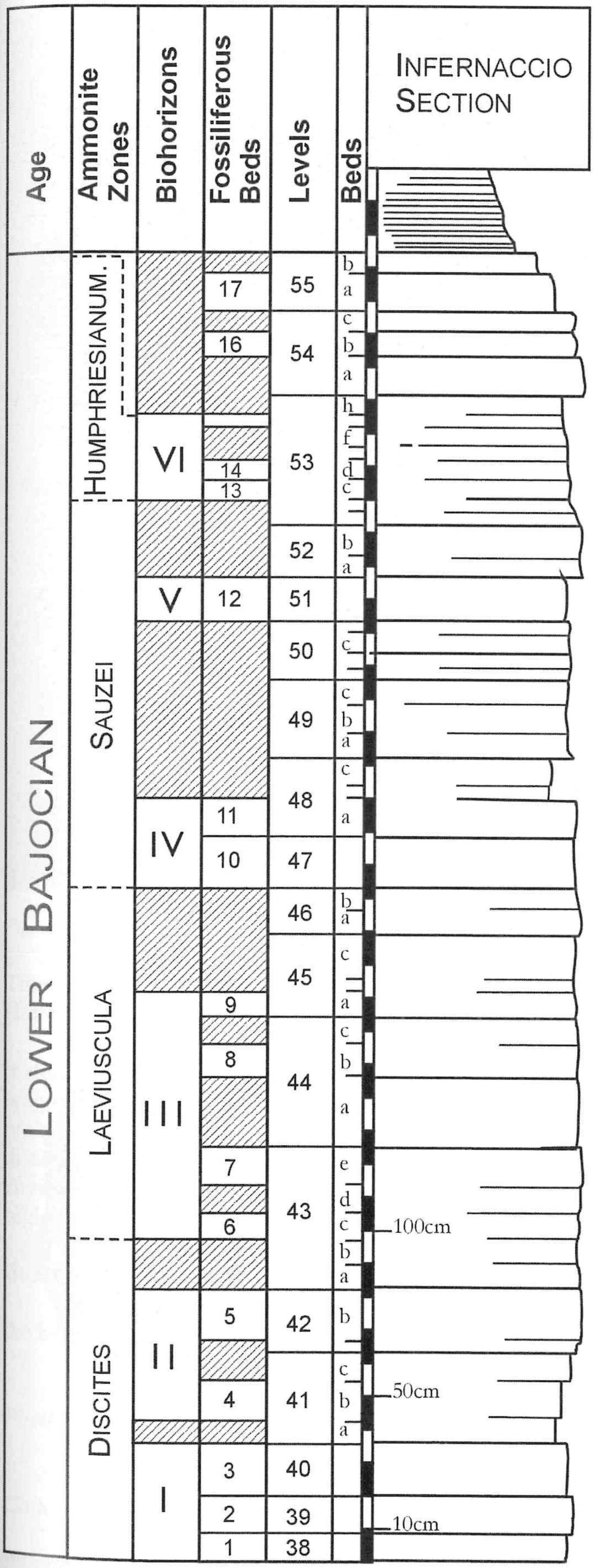


Fig. 8 – Lower Bajocian schematic log of the Infernaccio section.

Bed 5-7 (50 cm, *Semiformiceras semiforme* Zone) – *Lytoceras* sp., *Ptychophylloceras ptychoicum* (QUENSTEDT), *Haploceras verruciferum* (OPPEL), *H. (H.) carachteis* s.l. (M/m) (ZEUSCHNER), *Semiformiceras semiforme* (OPPEL), *Simoceras aesinense* Meneghini, *Pseudodiscosphinctes geron* (Zittel).

Bed 8 (30 cm, *Semiformiceras fallauxi* Zone) – *Semiformiceras fallauxi* (OPPEL).

STOP 4 – AALENIAN AMMONITE BIOSTRATIGRAPHY IN THE GORGO A CERBARA SECTION

S. CRESTA & S. URETA

The biostratigraphic study of the Toarcian-Aalenian boundary in the Gorgo a Cerbara section started in the eighties (KALIN & URETA, 1987; CRESTA, 1988) and has been continuous through the years (CECCA *et alii*, 1990; CRESTA *et alii*, 1995).

The ammonite assemblages of the Lias-Dogger boundary, sampled in the Gorgo a Cerbara section, are typical of the Apenninic region, within the Mediterranean province. Moreover, unlike coeval Mediterranean outcrops (San Vigilio and Monte Erice), built up by few decimetrical highly condensed levels, this 8 m thick succession provides a somewhat "expanded" picture of lower-middle Aalenian biostratigraphy. For systematic study, 336 specimens typical of the *Dumortieria meneghinii* (upper Toarcian)-*Ludwigia murchisonae* (middle Aalenian) interval were identifed. 167 of them belong to the suborder Ammonitina, 116 to Phylloceratina, and 53 to Lytoceratina. For palaeontological and biostratigraphical details, see KALIN & URETA (1988), CRESTA *et alii*, (1995). To summarize, the association is made up by 336 specimens distributed in 30 fossiliferous levels, within a 58-layer succession (Fig. 12), subdivided as follows:

- *layers 1-13* (1,35 m) upper Toarcian, *Dumortieria meneghinii* Zone, 3 fossiliferous levels, 8 collected specimens (Phylloceratina 2, Grammoceratinae 6);
- *layers 14-19* (1,30 m) upper Toarcian, *Pleydellia aalensis* Zone, 4 fossiliferous levels, 24 collected specimens (Phylloceratina 9, Lytoceratina 4, Grammoceratinae 11, Erycitidae 1);
- *layers 20-33* (2,50 m), lower Aalenian, *Leioceras opalinum* Zone, 11 fossiliferous levels, 118 collected specimens (Phylloceratina 46, Lytoceratina 8, Grammoceratinae 3, Tmetoceratinae 19, Graphoceratidae 6, Erycitinae 34, Hammatoceratinae 2);
- *layers 34-46* (2,10 m), middle Aalenian, *Ludwigia murchisonae* Zone, 12 fossiliferous levels, 186 collected specimens (Phylloceratina 60, Lytoceratina 41,

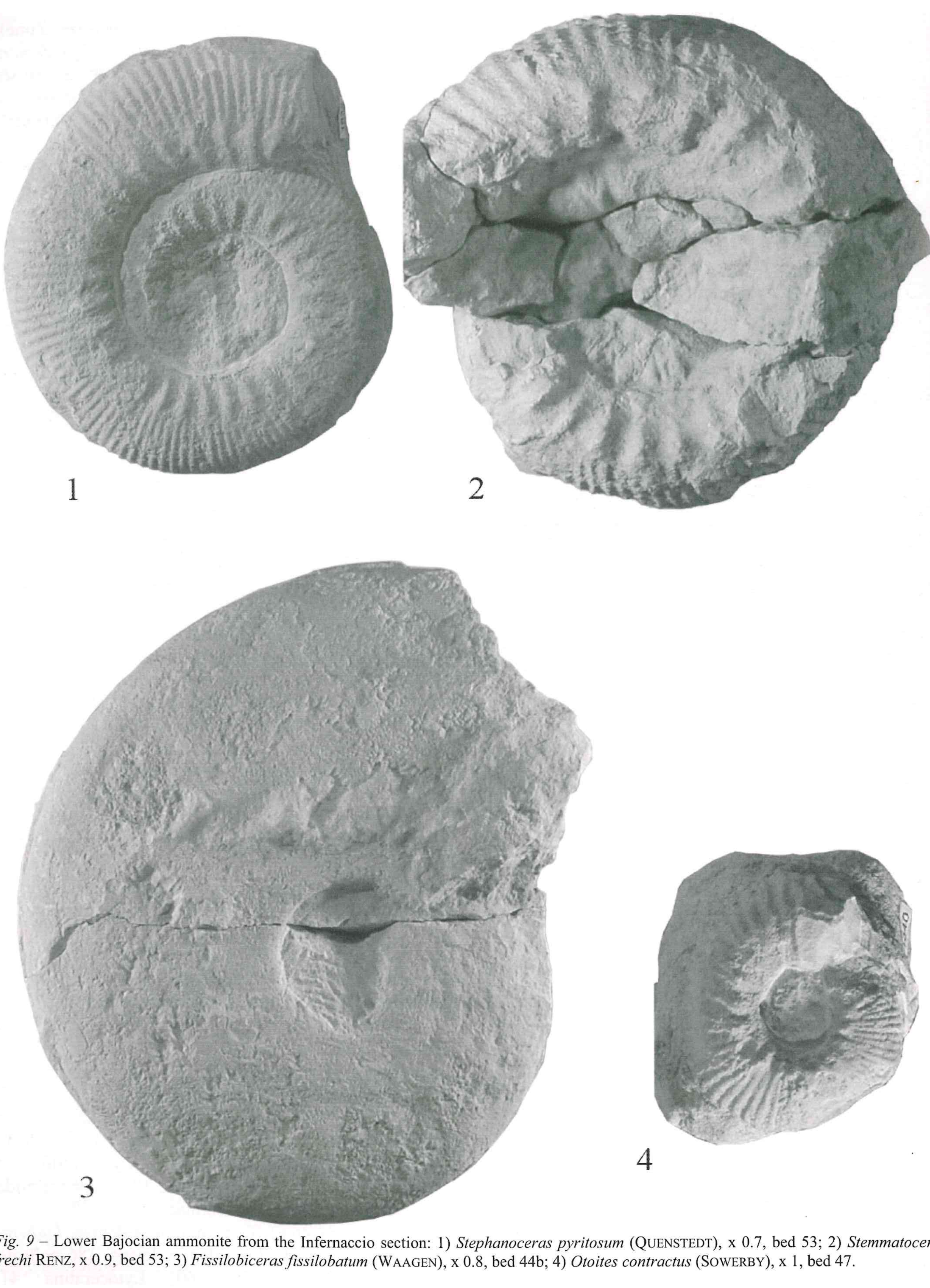


Fig. 9 – Lower Bajocian ammonite from the Infernaccio section: 1) *Stephanoceras pyritosum* (QUENSTEDT), x 0.7, bed 53; 2) *Stemmatoceras frechi* RENZ, x 0.9, bed 53; 3) *Fissilobiceras fissilobatum* (WAAGEN), x 0.8, bed 44b; 4) *Otoites contractus* (SOWERBY), x 1, bed 47.

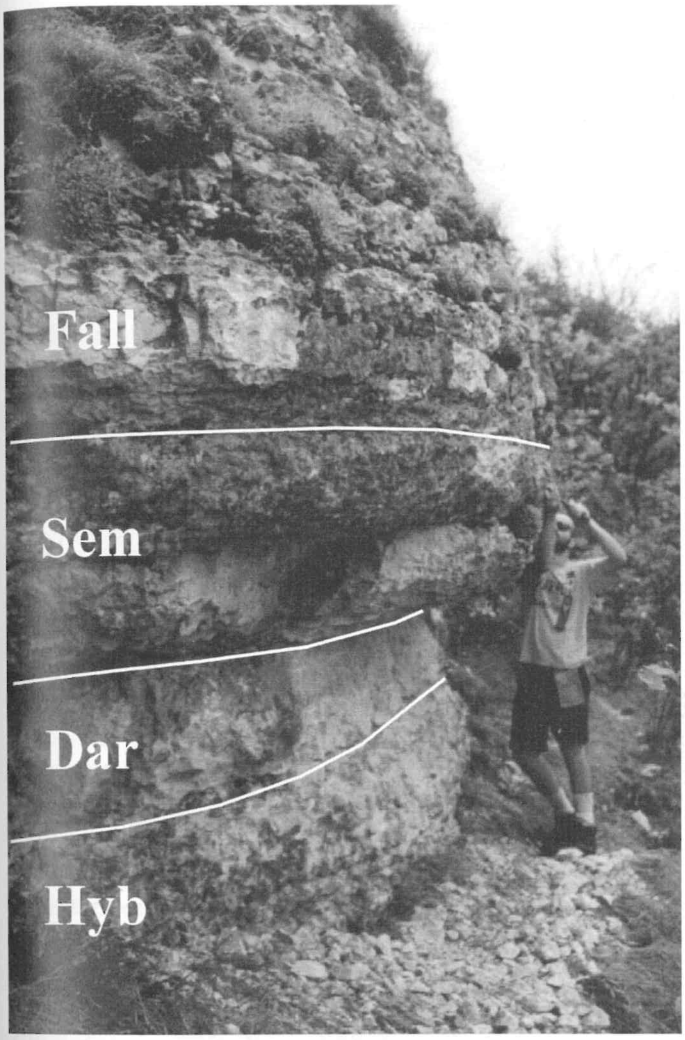


Fig. 10 – Lower Tithonian fossiliferous beds of Infernaccio section.

Tmetoceratinae 20, Graphoceratidae 14, Erycitinae 36, Hammatoceratinae 15);

layers 47-58 (2 m), non fossiliferous. From the middle Aalenian onwards, the remains of organisms with aragonitic shell disappear from the stratigraphic record, probably as a consequence of the increased effects of dissolution in the depositional and diagenetical environments. This could be related to subsidence and regional bathymetric evolution (KALIN & URETA, 1988).

BIOSTRATIGRAPHY

The recorded ammonoidea sequence (Fig. 13), from the base to the top, is the following:

bed 4 .- *Calliphylloceras* sp.

bed 5.- *Dumortieria taramelli* FUCINI (4) *Phylloceras* sp.

bed 11.- *Dumortieria moorei* (LYCETT) (2)

bed 14.- *Pleydellia mactra* (DUMORTIER) (3), *Cotteswoldia* cf. *costulata* (ZIETEN)

bed 15.- *Catulloceras dumortieri* (THIOLLIÈRE) (2), *Pleydellia aalensis* (ZIETEN), *Phylloceras* sp. (2), *Calliphylloceras* sp., *Alocolytoceras* sp.

bed 16.- *Pleydellia aalensis* (ZIETEN), *Catulloceras dumortieri* (THIOLLIÈRE), *Erycites* sp., *Calliphylloceras* cf. *altisulcatum* (PRINZ), *Calliphylloceras* cf. *nillsoni* (HEBERT), *Phylloceras* sp. (2), *Lytoceras* sp. (2)

bed 17.- *Catulloceras dumortieri* (THIOLLIÈRE) (2), *Phylloceras* sp.; *Alocolytoceras* sp.

bed 18.- *Catulloceras dumortieri* (THIOLLIÈRE), *Phylloceras* sp.

bed 20.- *Leioceras opalinum* (REINECKE), *Tmetoceras scissum* (BENECKE) (2), *Calliphylloceras altisulcatum* (PRINZ), *Calliphylloceras* sp. (2), *Holcophylloceras ultramontanum* (ZITTEL) (2)

bed 21.- *Leioceras opalinum* (REINECKE), *Holcophylloceras ultramontanum* (ZITTEL), *Phylloceras* sp.

bed 22.- *Tmetoceras scissum* (BENECKE), *Phylloceras* sp. (2), *Lytoceras* sp.

bed 23.- *Catulloceras dumortieri* (THIOLLIÈRE), *Calliphylloceras* sp., *Phylloceras* sp.

bed 24.- *Leioceras opalinum* (REINECKE), *Catulloceras dumortieri* (THIOLLIÈRE) (2), *Planammatoceras planinsigne* (VACEK), *Planamatoceras* sp. (2), *Tmetoceras scissum* (BENECKE), *Alocolytoceras* sp., *Phylloceras* sp. (3), *Calliphylloceras* sp.

bed 26.- *Erycites fallifax* ARKELL (2), *Tmetoceras scissum* (BENECKE), *Lytoceras* sp.

bed 27.- *Leioceras* sp., *Tmetoceras scissum* (BENECKE) (4)

bed 29.- *Tmetoceras scissum* (BENECKE) (5), *Alocolytoceras* cf. *ophioneum* (BENECKE), *Phylloceras* cf. *perplanum* PRINZ

bed 30.- *Leioceras* sp., *Erycites fallifax* ARKELL (6), *Planammatoceras* sp., *Phylloceras* sp. (4), *Calliphylloceras* sp. (4)

bed 32.- *Erycites fallifax* ARKELL (11), *Tmetoceras scissum* (BENECKE), *Calliphylloceras nillssoni* (HEBERT), *Calliphylloceras* cf. *nillsoni* (HEBERT), *Phylloceras* sp. (4), *Lytoceras* sp.

bed 33.- *Leioceras* sp., *Erycites fallifax* ARKELL (10), *Erycites* sp. (3), *Tmetoceras scissum* (BENECKE) (5), *Holcophylloceras ultramontanum* (ZITTEL) (3); *H,* cf. *ultramontanum* (ZITTEL), *Holcophylloceras* sp. (2) *Calliphylloceras* cf. *altisulcatum* (PRINZ), *Calliphylloceras* sp. (2), *Phylloceras* sp. (8), *Lytoceras* sp. (2)

bed 34.- *Ludwigia haugi* DOUVILLE, *Ancolioceras opalinoides* (MAYER) (2), *Erycites fallifax* ARKELL (5), *Erycites intermedius* HANTKEN in PRINZ, *Tmetoceras scissum* (BENECKE) (2), *Spinammatoceras pugnax* (VACEK), *Planammatoceras* sp., *Abbasitoides modestus* (VACEK) (2), *Alocolytoceras* cf. *ophioneum* (BENECKE), *Phylloceras* sp., *Calliphylloceras* sp., *Lytoceras* sp., *Holcophylloceras* sp. (3)

bed 35.- *Tmetoceras scissum* (BENECKE) (5), *Tmetoceras regleyi* (DUMORTIER) (2), *Phylloceras* sp.

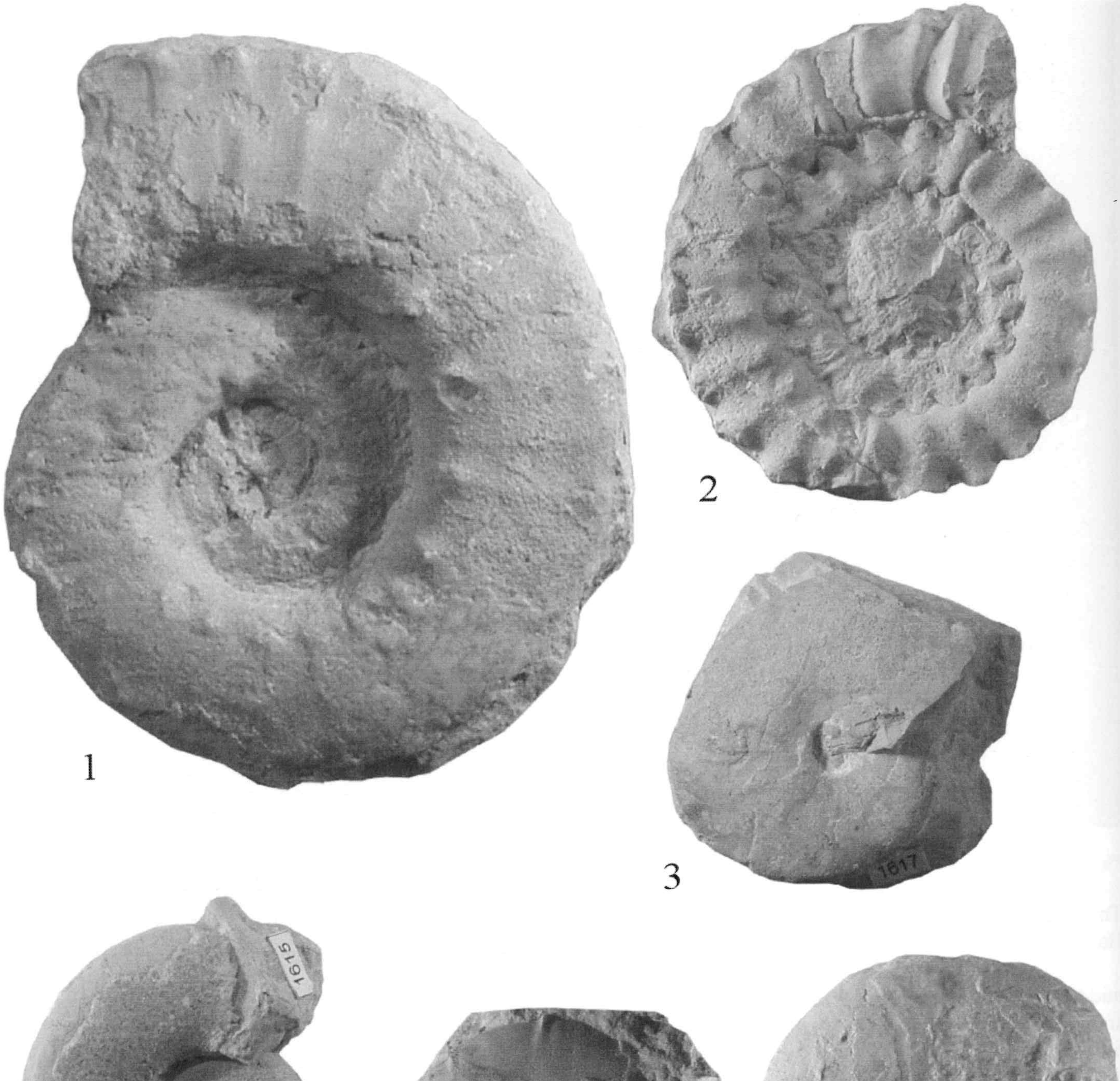


Fig. 11 – Lower Tithonian ammonites from the Infernaccio section: 1) *Hybonoticeras hybonotum* (OPPEL), x 0.8, bed 3; 2) *Simoceras aesinense* MENEGHINI, x 0.8, bed 6; 3) *Semiformiceras semiforme* (OPPEL), x 0.9, bed 5; 4) *Haploceras verruciferum* (OPPEL), x 0.9, bed 5; 5) *Ptychophylloceras ptychoicum* (QUENSTEDT), x 0.9, bed 4; 6) *Semiformiceras darwini* (NEUMAYR), x 0.9, bed 4.

(11), *Alocolytoceras ophioneum* (BENECKE) (4), *Malladaites ?* sp. (2), *Abbasitoides modestus* (VACEK) (4), *Lytoceras vaceki* GECZY (2), *Erycites intermedius* HANTKEN in PRINZ (2), *Erycites fallifax* ARKELL (4), *Ancolioceras opalinoides* (MAYER) (3), *Calliphylloceras* sp. (7), *Alocolytoceras* sp., *Holcophylloceras* sp. (4), *Spinammatoceras* sp., *Planammatoceras* sp.

bed 36.- *Ancolioceras opalinoides* (MAYER) (2), *Erycites intermedius* HANTKEN in PRINZ , *Planammatoceras planinsigne* (VACEK), *Tmetoceras scissum* (BENECKE) (3), *Tmetoceras regleyi* (DUMORTIER) (3), *Tmetoceras* sp., *Calliphylloceras nilssoni* (HEBERT), *Lytoceras* cf. *rasile* (VACEK), *Holcophylloceras* sp. (2), *Phylloceras* sp.

bed 37.- *Calliphylloceras nilssoni* (HEBERT), *Phylloceras* sp. (2)

bed 38.- *Accardia* cf. *procerinsigne* (VACEK), *Planammatoceras* sp., *Ancolioceras opalinoides* (MAYER)

bed 40.- *Ancolioceras opalinoides* (MAYER), *Abbasitoides modestus* (VACEK) (6), *Tmetoceras scissum* (BENECKE) (2), *Erycites* sp. (3), *Phylloceras* sp. (2), *Lytoceras vaceki* GECZY (2), *Erycites intermedius* HANKEN in PRINZ (2), *Alocolytoceras ophioneum* (BENECKE) (3), *Calliphylloceras* sp. (2), *Holcophylloceras* sp.

bed 41.- *Abbasitoides modestus* (VACEK), *Erycites* cf. *intermedius* HANKEN in PRINZ (3), *Holcophylloceras ultramontanum* (ZITTEL), *Alocolytoceras ophioneum* (BENECKE) (2), *Alocolytoceras* cf. *ophioneum* (BENECKE), *Alocolytoceras* sp. (3), *Lytoceras* sp. (4), *Phylloceras* sp. (7), *Holcophylloceras* sp. (2), *Ancolioceras* sp. (2), *Lytoceras amplum* (OPPEL), *Lytoceras vaceki* GECZY, *Calliphylloceras* sp., *Planammatoceras* sp., *Tmetoceras* sp., *Erycites* cf. *fallifax* ARKELL (2)

bed 42.- *Ancolioceras opalinoides* (MAYER), *Erycites* cf. *fallifax* ARKELL, *Accardia* cf. *lorteti* (DUMORTIER), *Pseudaptetoceras* cf. *klimakomphalum* (VACEK), *Ancolioceras* sp., *Planammatoceras* sp. (2), *Holcophylloceras* cf. *ultramontanum* (ZITTEL), *Calliphylloceras* cf. *connectens* (ZITTEL), *Alocolytoceras* cf. *ophioneum* (BENECKE), *Lytoceras* cf. *rasile* VACEK, *Lytoceras* sp. (2), *Holcophylloceras* sp., *Phylloceras* sp. (2)

bed 43.- *Ludwigia murchisonae* (SOWERBY), *Eudmetoceras* sp., *Calliphylloceras* cf. *nilssoni* (HEBERT), *Phylloceras* cf. *perplanum* PRINZ, *Lytoceras* cf. *vaceki* GECZY, *Lytoceras* sp., (3), *Calliphylloceras* sp. (2)

bed 45.- *Erycites fallifax* ARKELL, *Phylloceras* sp., *Lytoceras* sp.

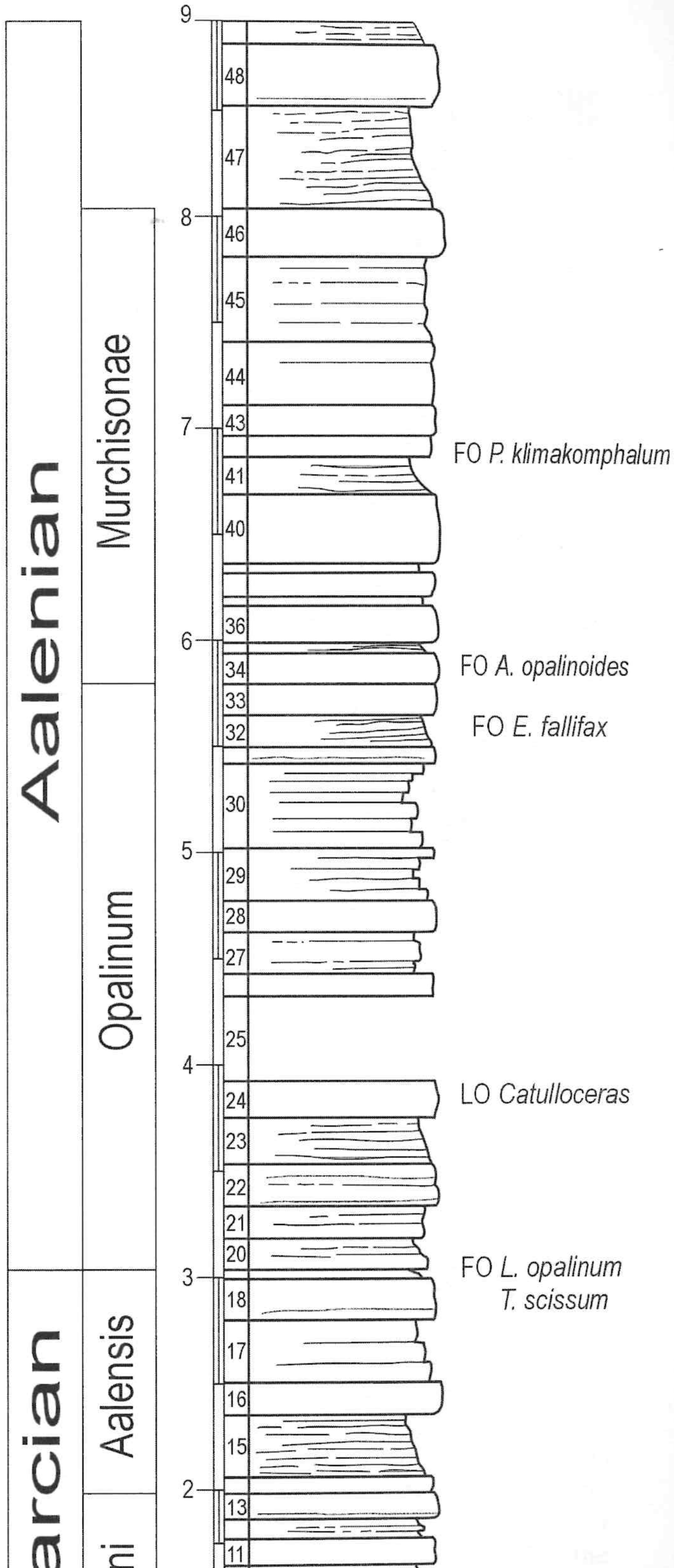


Fig. 12 – Upper Toarcian – Lower Aalenian schematic log of the Gorgo a Cerbara section.

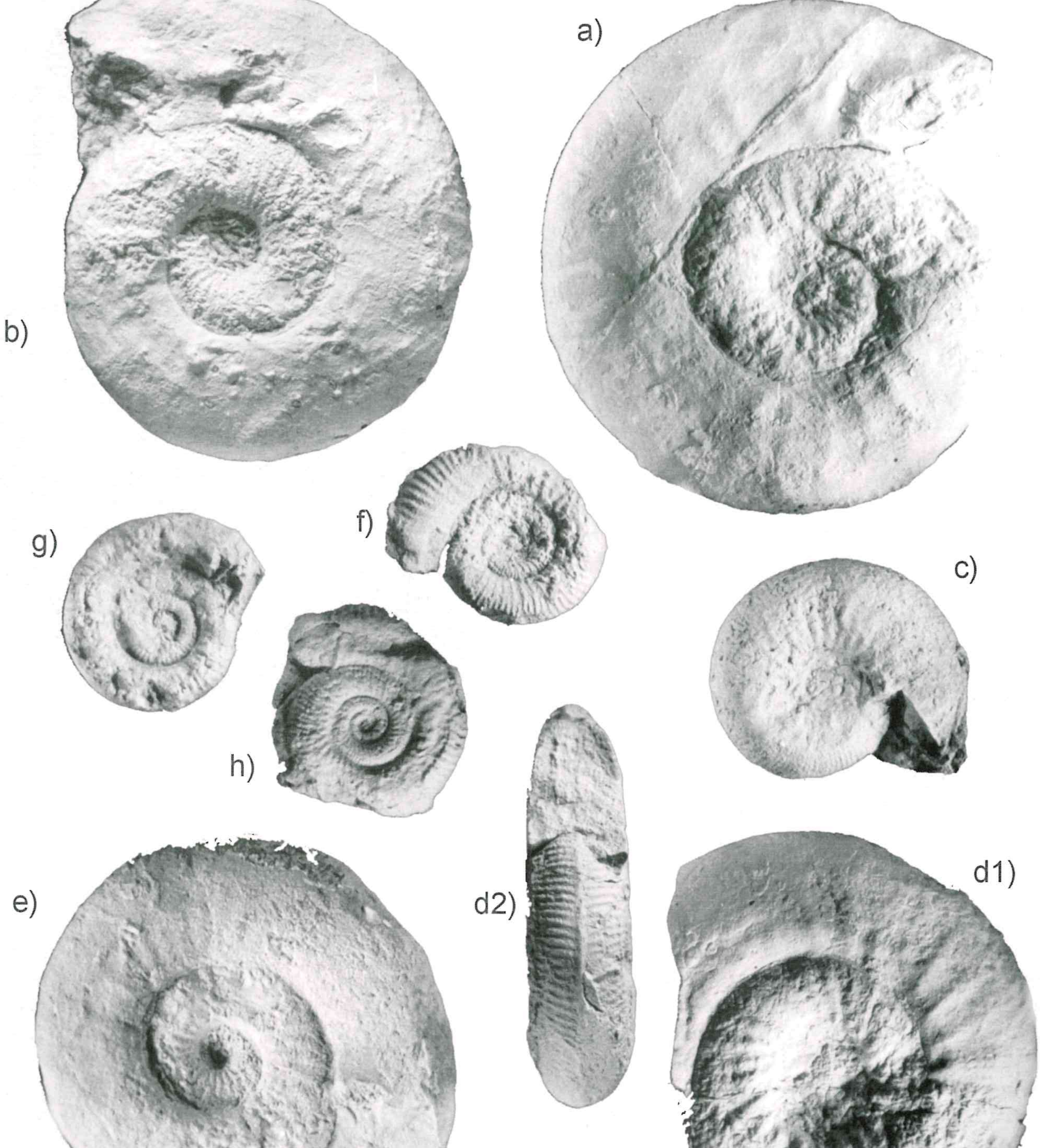


Fig. 13 – Aalenian Erycitids from the Gorgo a Cerbara section (all specimens x 0.9): a) *Erycites fallifax* ARKELL, bed 36, mature specimen with peristome, *Ludwigia haugi* Subzone; b) *E. fallifax* ARKELL, bed 32, mature specimen with peristome, upper part of the *Leioceras opalinum* Zone; c) *E. fallifax* ARKELL, bed 32, phragmocone, upper part of the *L. opalinum* Zone; d) *E. fallifax* ARKELL, bed 32, mature specimen, upper part of the *L. opalinum* Zone: d1) lateral view; d2) ventral view, showing a rudimental keel; e) *E. fallifax* ARKELL, bed 32, mature specimen, upper part of the *L. opalinum* Zone; f) *Abbasitoides modestus* (VACEK), bed 40, immature specimen, upper part of the *L. opalinum* Zone; g) *A. modestus* (VACEK), bed 41, mature specimen, *Ludwigia haugi* Subzone; h) *A. modestus* (VACEK), mature specimen, *L. haugi* Subzone.

STOP 5 – THE PROPOSED GLOBAL BOUNDARY STRATOTYPE SECTION AND POINT (GSSP) FOR THE BARREMIAN-APTIAN BOUNDARY AT GORGO A CERBARA

R. COCCIONI

The studied section is located 4 km east of the town of Piobbico in the bed of the Candigliano River and east of Monte Nerone. The lithological boundary between the Marne a Fucoidi and the Maiolica Formations is gradational and it has been placed above the uppermost occurrence of black chert in the Maiolica limestones according to COCCIONI *et alii* (1987).

Following the discussions at and after the Second International Symposium on Cretaceous Stage Boundaries (Brussels, 1995), the majority of the Aptian Working Group (AWG) selected the base of magnetic chron M0 as the event for defining the base of the Aptian stage (figure 14). After accepting the base of magnetic chron M0 as the base of the Aptian stage, the AWG identified the Gorgo a Cerbara section (Umbria-Marche Basin, Central Italy) as possible GSSP for the base of the Aptian Stage (ERBA *et alii*, 1996). This section represents an excellent exposure of uppermost Valanginian to lower Aptian pelagic carbonates (Fig. 15), and offers a wide range of available stratigraphies including litho-chronostratigraphy (BRALOWER, 1987; COCCIONI *et alii*, 1992; JUD, 1994; CECCA *et alii*, 1994), magnetostratigraphy (LOWRIE & ALVAREZ, 1984; CHANNELL *et alii*, 1995, 2000), calcareous nannofossil (BRALOWER, 1987; COCCIONI *et alii*, 1992; ERBA, 1994; CHANNELL *et alii*, 1995, 2000) and planktonic foraminiferal biostratigraphy (COCCIONI *et alii*, 1992; CECCA *et alii*, 1994), radiolarian biostratigraphy (JUD, 1994; DUMITRICA and DUMITRICA, 1994; ERBACHER, 1994; ERBACHER *et alii*, 1996; ERBACHER & THUROW, 1997), dinoflagellate biostratigraphy (COCCIONI *et alii*, 1993), chemostratigraphy ($\delta^{13}C$, $\delta^{18}O$) (HADJI, 1991; ERBACHER, 1994; ERBACHER *et alii*, 1996; ERBACHER & THUROW, 1997) and cyclostratigraphy (HERBERT, 1992; FIET, 2000; FIET & GORIN, 2000).

Moreover, the Oceanic Anoxic Event 1a (OAE1a) is represented by the black shales of the Selli Level (COCCIONI *et alii*, 1989, 1997). The uppermost Hauterivian Faraoni Level also occurs.

Magnetostratigraphy was originally performed by LOWRIE & ALVAREZ (1984), but the section was resampled in great detail across magnetic chron M0 to increase the stratigraphic resolution of the boundaries (ERBA *et alii*, 1996; CHANNELL *et alii*, 2000). The Barremian-Aptian boundary has been designated to coincide with the base of polarity chron M0 at 893.20 m of LOWRIE & ALVAREZ (1984) which originally documented the magnetic stratigraphy at Gorgo a Cerbara (see also, ERBA *et alii*, 1996; CHANNELL *et alii*, 2000). However, a detailed field survey across the Barremian-Aptian transition has revealed that the original meter levels painted by LOWRIE & ALVAREZ (1984) on the rocks, and still preserved there, are largely irregularly spaced and do not correspond to the meter unit measure. Following ERBA *et alii*, (1996) and further, more accurate field investigations (COCCIONI & GALEOTTI with collaborators, in press), the irregularly spaced meter levels of LOWRIE & ALVAREZ (1984) have been re-arranged by calibrating them to the lithological log of COCCIONI *et alii* (1992). The relative position of the events included in the interval surveyed by COCCIONI *et alii* (1992) was modified accordingly. The base of magnetic chron M0 results, therefore, to fall at 35.40 m of COCCIONI *et alii* (1992).

Formal ratification of the proposed Barremian-Aptian boundary stratotype section at Gorgo at Cerbara should take place in the near future.

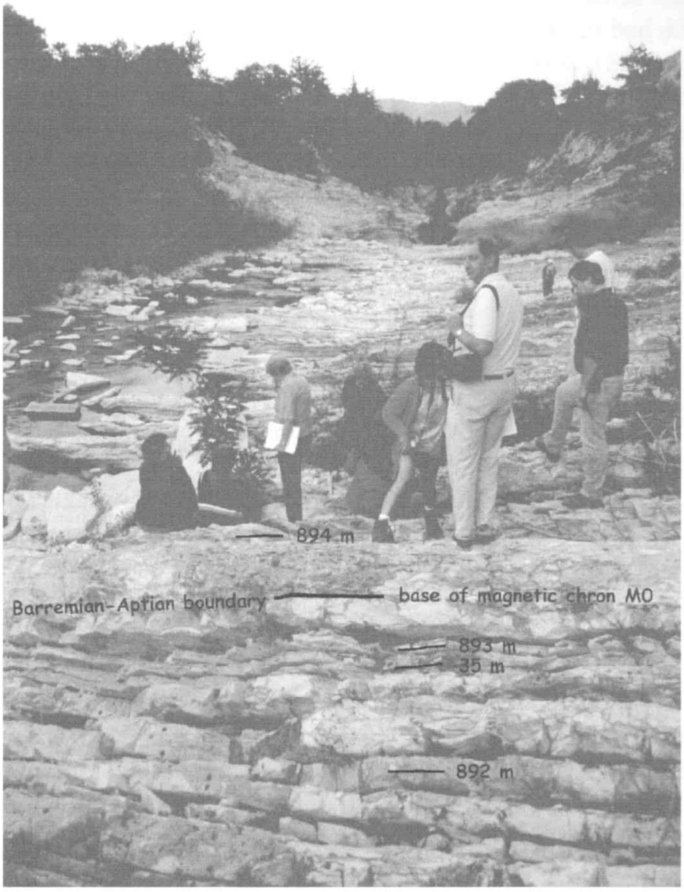


Fig. 14 – Meter levels 892, 893 and 894 of LOWRIE & ALVAREZ (1984) and meter level 35 of COCCIONI *et alii* (1992) are here recognizable. The base of magnetic chron M0 which has been selected as the event for the definition of the Barremian-Aptian boundary falls at 893.20 m of LOWRIE & ALVAREZ (1984) that is at 35.40 m of COCCIONI *et alii* (1992).

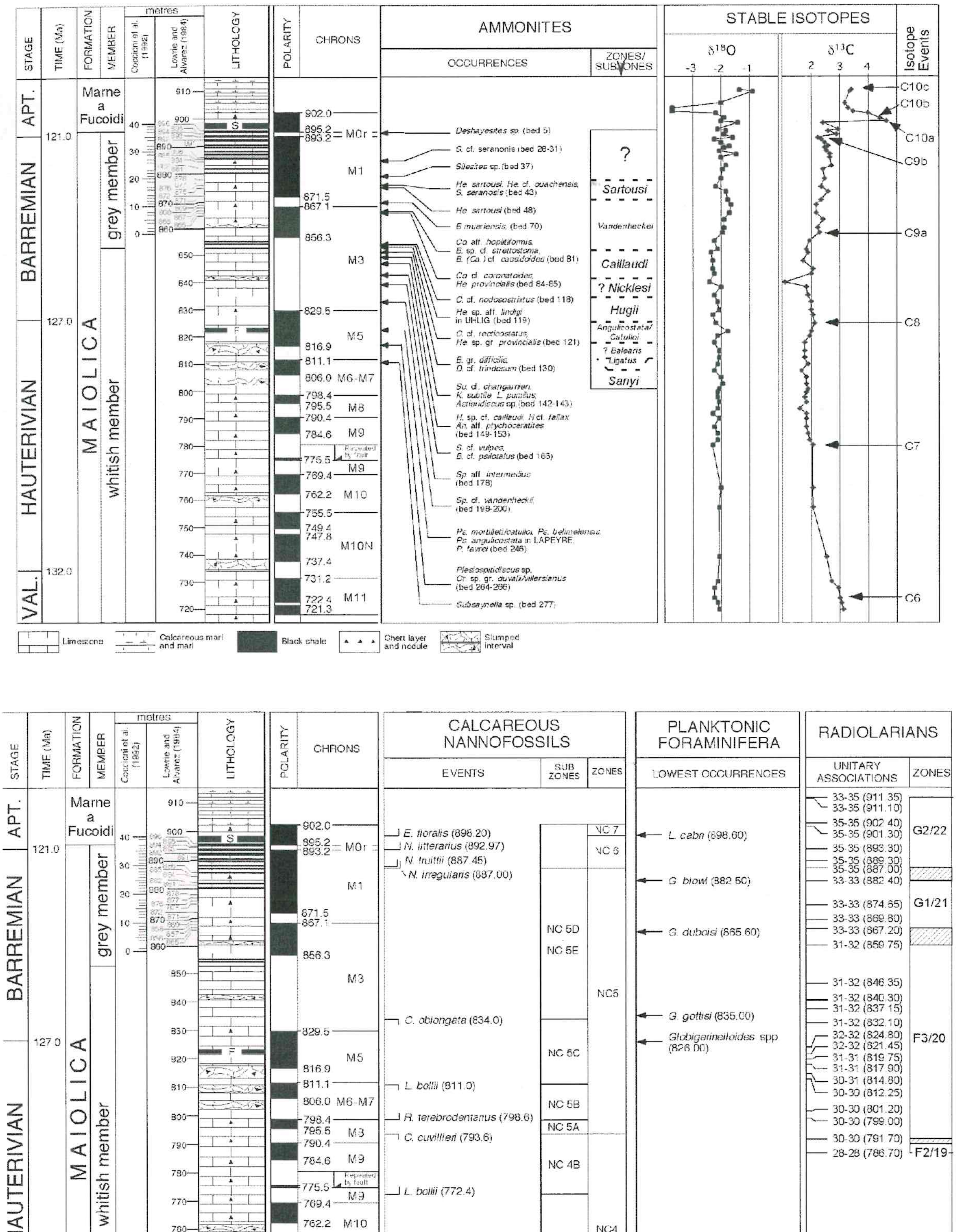


Fig. 15 – Uppermost Valanginian-lower Aptian integrated stratigraphy at Gorgo a Cerbara (after COCCIONI, GALEOTTI *et alii*, in prep.). Abbreviation: F=Faraoni Level; S=Selli Level. The Nannoconid crisis (see ERBA, 1994) was identified by CHANNEL *et alii* (2000) at meter level 896 of LOWRIE & ALVAREZ (1984) that is at 37.52 m of COCCIONI *et alii* (1992). Polarity chronozones and time scale after HARDENBOL *et alii* (1998).

AMMONITE BIOSTRATIGRAPHY (from CECCA *et alii,* 1995a, p. 192)

The record of ammonites from the uppermost Hauterivian-Barremian is not continuous; however, a few diagnostic layers have been detected and described as follows.

Hauterivian-Barremian boundary – The oldest ammonite was found in bed 277: it has been identified as *Subsaynella* sp.. In the beds 264-266 at 817.5 m, *Crioceratites* sp. gr. *duvalii* LÉVEILLÉ / *villiersianus* (D'ORBIGNY) and *Plesiospitidiscus* sp. indicate a late Hauterivian age, earlier than the *P. angulicostata* Auct. Zone and this level can be ascribed to the *B. balearis* or to the *P. ligatus* Zones. The *P. angulicostata* Zone, and particularly the *P. catulloi* Subzone, is very well represented in bed 246 which corresponds to the guide-bed of the Faraoni Level (CECCA *et alii*, 1994a). The Hauterivian-Barremian boundary falls surely above bed 246, which contains latest Hauterivian faunas, and below beds 198-200 where we collected a typical Barremian *Spitidiscus*, *i.e.* an interval between meters 822 and 833 of LOWRIE & ALVAREZ (1984). In the absence of faunas in the latter interval, the boundary is drawn betwen metres 824 and 828 on the basis of data from other sections (Mount Petrano). Then this Stage boundary falls in chron CM4.

Lower Barremian – Typical Barremian *Spitidiscus* occur between beds 200-178 but this does not correspond to the actual FO of *Spitidiscus*. This interval is assigned to the *S. hugii* Zone, although no other significant Ammonitina have been found. At beds 151-153 specimens of the genus *Holcodiscus* occur, including the zonal index *H. caillaudi* (D'ORBIGNY). The fauna of beds 142-143 is also placed in the *H. caillaudi* Zone because of the presence of *Subpulchella* cf. *changarnieri* (SAYN), which is limited to the early Barremian (VERMEULEN, 1980). No significant faunas have been found in the interval between beds 177 and 154. The sediments inbetween could belong partly to the *S. hugi* and *H. caillaudi* Zones and partly to the *S. nicklesi* Zone. The lower Barremian sediments of the Gorgo a Cerbara section are included in chron CM3.

Upper Barremian – The lower/upper Barremian boundary has been tentatively drawn around bed 130. Above the faunas of the *H. caillaudi* Zone no ammonites unambiguously typical of the *A. vandenheckii* Zone have been found. Typical late Barremian ammonites occur in beds 121-119: *Heinzia* gr. *provincialis* (D'ORBIGNY), *H.* aff. *lindigi* (KARSTEN in UHLIG) and *Costidiscus* sp. cf. *recticostatus* (D'ORBIGNY). *Coronites* aff. *coronatoides* (SAYN) occurs in beds 84-85, and in bed 81 we have found *Barremites (Cassidoiceras)* cf. *cassidoides* (UHLIG), *H.* gr. *provincialis*, *C.* aff. *hoplitiformis* (SAYN). The faunas of the beds between beds 130 and 81 are then included in the *A. vandenheckei* Zone. The occurrence of *H. sartousi* (D'ORBIGNY) in bed 48 clearly indicates the *H. sartousi* zone; this species is rather abundant in bed 43 where it is associated with *H.* cf. *ouachensis* (SAYN). Above bed 43, ammonites become extremely rare and mainly represented by the *Silesites seranonis* (D'ORBIGNY) group, which is poorly significant for biostratigraphic purposes. Above bed 28, *i.e.* above metre 882, the beds are barren or do not contain biostratigraphically significant fossils. A single specimen, identified as ?*Prodeshayesites* sp. was found in bed 5, indicating the lower Aptian.

STOP 6 – AMMONITE BIOSTRATIGRAPHY OF THE HAUTERIVIAN-BARREMIAN BOUNDARY IN THE MONTE PETRANO SECTIONS

(see also CECCA *et alii*, 1995, p. 199)

A. MARINI

The sections are exposed along the road which leads from the town of Cagli up to the top of Monte Petrano. Numerous outcrops of the Maiolica formation are found along road-cuts. They are isolated from each other because of faulting. The complete succession is exposed on the northern flank of the mountain (outcrops **M** and **N**). Outcrop **A** exposes some beds with *Holcodiscus caillaudi* (D'ORBIGNY) and *Nicklesia pulchella* (D'ORBIGNY) *sensu* KILIAN (1888) [probably belonging to *Subpulchellia compressissima* (D'ORBIGNY)]. This has been confirmed by COMPANY *et alii* (1993), and this level can be ascribed to the *caillaudi* horizon of their *S. compressissima* Zone, which corresponds to the lower part of the *H. caillaudi* Zone *sensu* HOEDEMAKER & COMPANY.

One of the best sections of the Faraoni Level as well as the Hauterivian-Barremian boundary is exposed at outcrop **B** (Fig. 16) where this boundary can be traced based on the FO of a characteristic heteromorph ammonite ["*Paraspinoceras*" *evolutum* (FALLOT & TERMIER)]. Several specimens were collected in this bed, allowing to define its intraspecific variability. Two morphotypes are distinguished: one is characterized by simple ribs, while the other has buckled ribs in the young stage and simple ribs in the adult.

The bed B32 is the Guide bed of the Faraoni Level. Specimens of *Pseudothurmannia* have been found also in the overlying calcareous beds 33 and 34, along with some gastropod specimens. These gastropods, which are characterised by very long, fine, hook-shaped spines, show some morphologic affinities with the genus *Harpagodes*. They are quite common in the studied outcrops from Gorgo a Cerbara (stop 2.9) to Monte Tenetra.

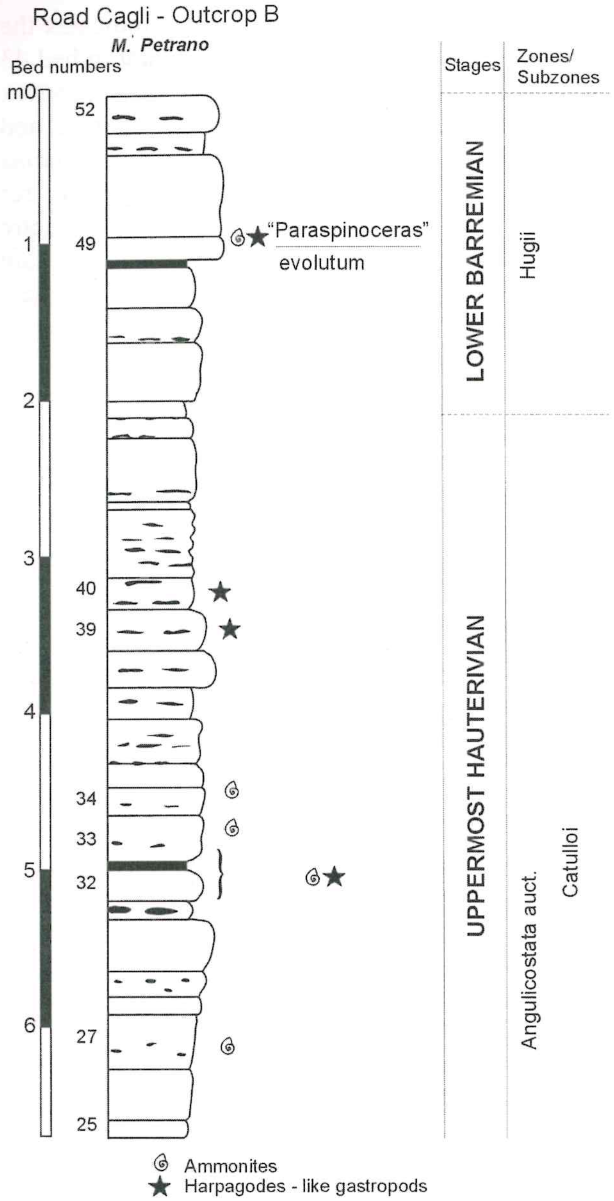


Fig. 16 – Schematic log of Hauterivian – Barremian boundary of M. Petrano section B.

In bed 49 we have found a fauna only composed by specimens belonging to "*Paraspinoceras*" *evolutum* (FALLOT & TERMIER). They occur above the *Pseudothurmannia* beds and according to VERMEULEN (1972) this species indicates the base of the Barremian.

STOP 7 - DOMERIAN-TOARCIAN BOUNDARY IN THE LECCETI SECTION

(see also FARAONI *et alii*, 1994)

A. DILIGENTI & F. DURONIO

The reference window for the lower Toarcian outcrops along the left side of the Bosso River, locality "I Lecceti", and it can be reached by a suspended gangway some hundreds of metres SW of Secchiano. FARAONI *et alii* (1994) sampled an interval 6.5 metres thick in which they recognised 13 fossiliferous levels (Fig. 17).

Polimorphum Zone – This is a 5-layer unit, 1.5 metres thick, with 5 fossiliferous levels. The zone is characterised in its lower part by *Dactylioceras (Eodactylites)*, and by the persistence of the species association of Domerian affinity (Hildoceratids and Phylloceratids). It includes two associations, the lower of which is characterised by *D. (Eodactylites) mirabile* (FUCINI), *D. (E.) polimorphum* (FUCINI), *D. (E.) simplex* (FUCINI), *D. (E.) pseudocommune* (FUCINI) (*faunula* 1 by CRESTA *et alii*, 1995), and the upper one by Dactylioceratids close to *Orthodactylites (Secchianoceras* VENTURI), by the last differentiation of *Neolioceratoides* (incl. *Petranoceras* VENTURI) and by a Toarcian acme of *Protogrammoceras bassanii* (FUCINI). This association has not yet been found in the PCP areas, where the zone is probably condensed in a hard-ground level. As previously mentioned, several species of Domerian affinity, belonging to *Fontanelliceras, Distefania, Canavaria, Geyeroceras, Meneghiniceras, Calaiceras* and *Harpophylloceras*, are present in association here and in the other outcrops.

A similar association was described by KALIN & URETA (1988) at Gorgo a Cerbara, including the following species: *D. (Eodactylites) mirabile* (FUCINI), *D. (E.)* cf. *polymorphum* (FUCINI), *D. (E.) pseudocommune* (FUCINI), *Neolioceratoides schopeni* (FUCINI) and *N. hoffmani* (GEMMELLARO).

Levisoni Zone – In this unit, 5 metres thick, recognised within a marly sequence with isolated nodular episodes only in the Bosso-Lecceti section, 8 fossiliferous levels were identified. The Zone is characterised in the lower part by *Rakusites tuberculatus* Guex, *Taffertia taffertensis* Guex, *Nodicoeloceras* gr. *merlai* (PINNA) and by small forms with harpoceratoid morphology belonging to the genus *Hildaites* (*H. exilis, H. striatus* GUEX). For this association, coinciding with the *faunula* 2 by CRESTA *et alii* (1995, Presale section), FARAONI *et alii* (1994) propose the use of the *Hildaites striatus* Subzone.

In the upper part of the unit the striated morphologies are replaced by species with strong, sinuous, occasional ribs, separated by intercostal spaces as large as the ribs themselves (*H. eremitensis* VENTURI, *H. pseudolevisoni* VENTURI, *H. undicosta* MERLA).

Fig. 17 – Biostratigraphic distribution of Lower Toarcian recognized ammonite species of Bosso-Lecceti section.

Orthildaites douvillei (DUMORTIER) and *Praemercaticeras* sp. can be found along with these, as well as several species of Dactylioceratids still requiring better palaeontological classification. For this association, coinciding with the *faunula* 3 by CRESTA *et alii* (1995), FARAONI *et alii* (1994) propose the name of *Hildaites pseudolevisoni* Subzone.

STOP 8 – CARIXIAN AMMONITE BIOSTRATIGRAPHY IN THE BOSSO RIVER VALLEY

(from FARAONI *et alii*, 1996, p.81)

Jamesoni Zone - The reference window for this interval outcrops along the Bosso River below the Cagli-Pianello road, about 1.5 km SW of the village of Secchiano. Recent studies by FARAONI *et alii* (1994, 1996) added to the original biostratigraphic framework extabilished by FERRETTI (1975) and DOMMERGUES *et alii* (1983). The window opens onto 39 metres of sequence, divided into 89 layers, 21 of which are fossiliferous. The recognised species are summarised in fig. 18; for further details, see FARAONI *et alii* (1996). For the biostratigraphic description of the interval, these authors proposed the adoption of the following biozones:

Tetraspidoceras quadrarmatum biozone (layers 39-81, thickness 19 metres, 9 fossiliferous levels). This unit, proposed as an Oppel-zone, is characterised by the presence of *Tetraspidoceras qudrarmatum* (DUMORTIER); its lower limit does not coincide with the appearance of the marker, which is restricted to the upper part of the biozone, but with a *Galaticeras* sp. and *Radstockiceras gemmellaroi* biohorizon overlain by an assemblage with *Radstockiceras.* aff. *numismale* (OPPEL), *Catriceras catriense* VENTURI, *"Catriceras"* sp., *Aegolytoceras varicosum* VENTURI, *Partschiceras striatocostatum* (MENEGHINI) and *Polymorphites calensis* FARAONI *et alii*.

Miltoceras sellae biozone (layers 82-125, 20 metres thick, 12 fossiliferous levels). This unit, proposed as a taxon range zone, is characterised by the replacement of the deroceratid species with two rows of spines (*T. quadrarmatum* (DUMORTIER), *"Epideroceras"* gr. *ancyrense* BREMER) by others with one row of spines like *Miltoceras sellae* (GEMMELLARO). Three bioevents [(*Farinaccites clavatus* FARAONI *et alii*, *Polymorphites apenninicus* FARAONI *et alii*, *Tropidoceras* gr, *flandrini* (DUMORTIER)] are recognisable in this biozone.

Ibex and *Davoei* Zones - This interval reference window outcrops along the left side of the Bosso River above the Cagli-Pianello road, at a short distance from the previous one. Also in this case the recent studies by FARAONI *et alii* (1994, 1996) enhanced the biostratigraphic framework set by FERRETTI (1975) and DOMMERGUES *et alii* (1983), leading to the proposal of the biostratigraphic units adopted here. The window opens onto 26 metres of sequence, divided into 75 layers 43 of which are fossiliferous. The recognised species are summarised in fig. 19; for further details see FARAONI *et alii* (1996). For the biostratigraphic description of the interval, these authors proposed use of the following biozones:

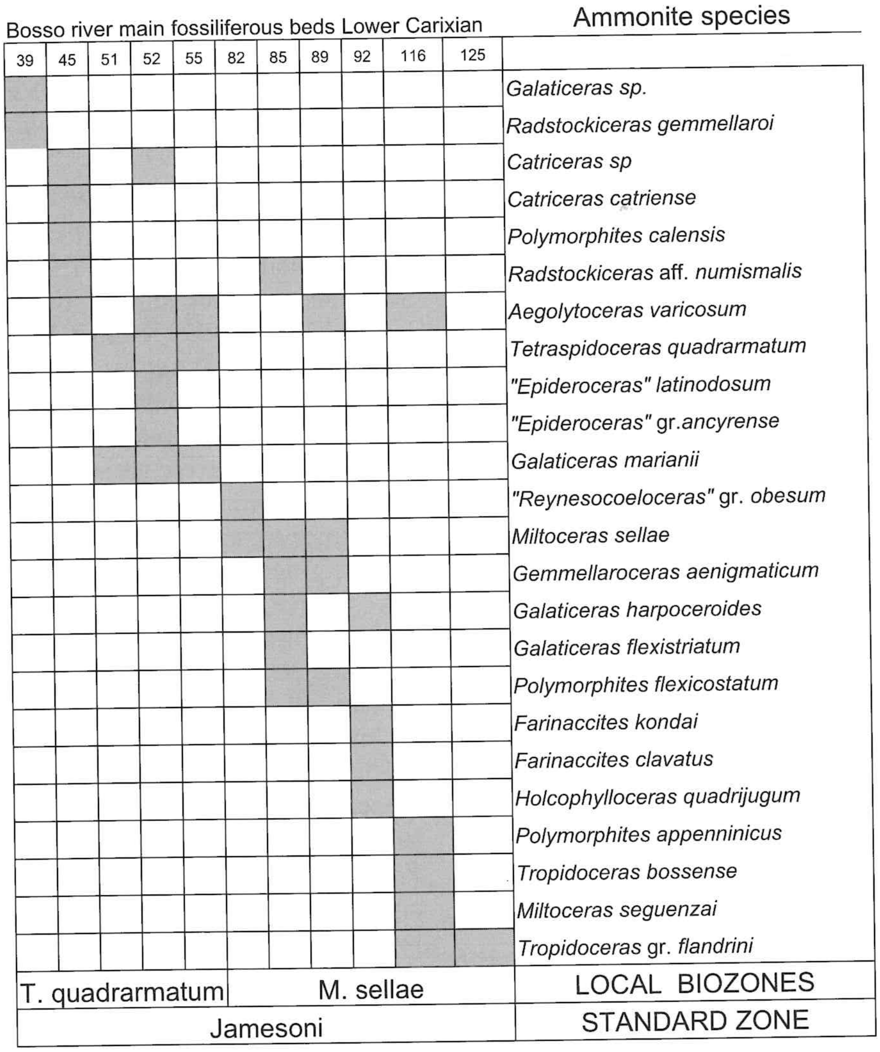


Fig. 18 – Biostratigraphic distribution of Lower carixian recognized ammonite species of Bosso-River section.

Metaderoceras gemmellaroi biozone (layers 141-179, thickness 14.5 metres, 29 fossiliferous levels). Apart from the distribution of *Metaderoceras gemmellaroi* (LEVI), appearing about two metres from its lower boundary, this unit is characterised by a basal biohorizon with *Dubariceras dubari* DOMMERGUES, MOUTERDE & RIVAS and a diverse fauna with *Tropidoceras* (*T. demonense* GEMMELLARO, *T. mediterraneum* GEMMELLARO, *T. calliplocum* GEMMELLARO) and the first representative of *Protogrammoceras*, mainly bisulcate forms of the *P. hungaricum* GÉCZY group. Three bioevents (*Tropidoceras mediterraneum* GEMMELLARO, *Dayiceras* sp. aff. *D. Dayiceroide* MOUTERDE and *Metaderoceras beirense* MOUTERDE) are recognisable in this biozone, which corresponds to the *Tragophylloceras ibex* Zone.

Protogrammoceras dilectum biozone (layers 180-216, 10.5 metres, 14 fossiliferous levels). This unit, partly corresponding to the *P. dilectum* horizon by FERRETTI (1975) proposed by BRAGA *et alii* (1982), is adopted by FARAONI *et alii* (1996) in virtue of the good correspondence between the Apennine and Betic associations (Spain). In this section the lower part of the biozone is characterised by *Reynesocoeloceras simulans* (FUCINI), *Liparoceras (Becheiceras) bechei* (SOWERBY) and *Gemmellaroceras aenigmaticum* (GEMMELLARO), and the upper one by *Protogrammoceras dilectum* (FUCINI) and *Fuciniceras costicillatum* (FUCINI). This biozone is correlated with the *Prodactylioceras davoei* Zone.

The two sections have been correlated to produce the species range chart shown in Fig. 19. Our data indicate that some modifications must be made to the schemes by GÉCZY (1976) and BRAGA *et alii* (1982). Our proposal includes the following points:

- to subdivide the lower Carixian into the *Tetraspidoceras quadrarmatum* Oppel Zone (Bosso River section, beds 39 to 81, thickness 19 meters - below) and the *Miltoceras sellae* taxon range zone (Bosso River section, beds 82 to 125, thickness 20 meters - above);

Bosso-Stirpeto main fossiliferous beds Middle-Upper Carixian																				Ammonite species
141	142	147	163	166	167	168	170	172	174	180	181	182	183	185	187	188	190	195	216	
X	X	X		X					X		X								X	*Juraphyllites libertus*
	X								X											*Juraphyllites diopsis*
X																				*Dubariceras dubari*
	X																			*Tropidoceras mediterraneum*
	X																			*Tropidoceras demonense*
	X																			*Tropidoceras calliplocum*
	X																			*Protogrammoceras* cf. *hungaricum*
		X	X	X		X	X	X	X											*Metaderoceras gemmellaroi*
		X	X	X	X	X	X	X	X											*"Acanthopleuroceras" sp.*
			X		X	X	X													*Dayiceras sp.*
				X				X												*Dayiceras* aff. *dayiceroide*
				X																*Diaphorites vetulonius*
								X												*Galaticeras aegoceroide*
								X						X	X					*Fieldingiceras sp*
									X											*Metaderoceras beirense*
									X		X	X	X	X	X	X				*Protogrammoceras sp*
									X											*Juraphyllites planispira*
											X	X			X		X			*Liparoceras (Becheiceras) bechei*
											X									*Gemmellaroceras aenigmaticum*
										X	X	X		X	X				X	*Reynesocoeloceras sp.*
													X	X						*Reynesocoeloceras simulans*
															X					*Phrycodoceras* sp. aff. *P. taylori*
																X		X		*Protogrammoceras dilectum*
																			X	*Fuciniceras costicillatum*
																			X	*Fieldingiceras fieldingii*
Metaderoceras gemmellaroi										Protogrammoceras dilectum										LOCAL BIOZONES
Ibex										Davoei										STANDARD ZONES

Fig. 19 – Biostratigraphic distribution of Middle and Upper Carixian recognized ammonite species of Bosso-Stirpeto section.

- to use the *Metaderoceras gemmellaroi* Oppel zone (Stirpeto section, beds 141 to 179, thickness 14,5 meters) for the middle Carixian;

- to use the *Protogrammoceras dilectum* taxon range zone (*sensu* BRAGA *et alii*, 1982) for the upper Carixian (Stirpeto section, beds 180 to 216, thickness 10,5 meters).

REFERENCES

ALLEMAN G., CATALANO R., FARES F. & REMANE J. (1971) - *Standard Calpionellid zonation (Upper Tithonian-Valanginian) of the Western Mediterranean Province.* Proc. IInd Planktonic Conference, Roma 1970, **2**, 1337-1340.

BARTOLINI A.C. & CECCA F. (1999) – *20 My hiatus in the Jurassic of Umbria-Marche Apennines (Italy): carbonate crisis due to eutrophication.* C.R. Acad. Sci. Paris, **329**, 587-595.

BRAGA J. C., COMAS RENGIFO M. J., GOY A. & RIVAS P. (1982) - *Comparaciones faunisticas y correlaciones en el Pliensbachiense de la Zona Subbetica y Cordillera Iberica.* Boll. R. Soc. Esp. Hist. Nat. (Geol.), **80**, 221-244.

BRALOWER, T.J. (1987) - *Valanginian to Aptian Calcareous Nannofossil Stratigraphy and correlation with the upper M-Sequence magnetic anomalies.* Marine Micropaleontology, **11**, 293-310.

CECCA F., CRESTA S., PALLINI G., SANTANTONIO M. (1987) - *Le Lotharingien-Carixien de Gorgo a Cerbara (Monte Nerone, Apennins des Marches): un exemple de passage d'un milieu de plate-forme carbonatée à un milieu pélagique.* 2ème Colloque sur le Lias, Cahier Inst. Catholique Lyon, serie Science, **1**, 57-66

CECCA F., CRESTA S., PALLINI G, SANTANTONIO M. (1990) - *Il Giurassico di Monte Nerone (Appennino marchigiano, Italia centrale): biostratigrafia, litostratigrafia ed evoluzione paleogeografica.* Atti 2° Conv. Int. "Fossili, Evoluzione, Ambiente", 63-139

CECCA F., FARAONI P., MARINI A. & PALLINI G. (1995) –

Field-trip across the representative sections for the Upper Hauterivian-Barremian ammonite biostratigraphy in the Maiolica exposed at Monte Nerone, Monte Petrano and Monte Catria (Umbria-Marche Apennines). Memorie descrittive Carta Geologica d'Italia, **51**, 187-211.

CECCA, F., PALLINI, G., ERBA, E., PREMOLI SILVA, I., & COCCIONI, R. (1994) - *Hauterivian-Barremian chronostratigraphy based on ammonites, nannofossils, planktonic foraminifera and magnetic chrons from Mediterranean Domain.* Cretaceous Research, **15**, 457-467.

CECCA F., & VASICEK Z. (2000) - *Early Aptian ammonites from the top of maiolica and the anoxic "Selli Level" (lombardy, Southern Alps).* Bollettino Società Paleontologica Italiana, **39**(1), 29-45.

CHANNELL, J.E.T., CECCA, F., & ERBA, E. 1995. *Correlations of Hauterivian and Barremian (Early Cretaceous) stage boundaries to polarity-chrons.* Earth and Planetary Science Letters, **134**, 125-140.

CHANNELL, J.E.T., ERBA, E., MUTTONI, G., & TREMOLADA, F. (2000) - *Early Cretaceous magnetic stratigraphy in the APTICORE drill core ans adjacent outcrop at Cismon (Southern Alps, Italy), and correlation to the proposed Barremian-Aptian boundary stratotype.* GSA Bulletin, **112**(9), 1430-1443.

COCCIONI, R., ERBA, E., & PREMOLI SILVA, I. (1992) - *Barremian-Aptian calcareous plankton biostratigraphy from the Gorgo a Cerbara section (Marche, central italy) and implications for plankton evolution.* Cretaceous Research, **13**, 517-537.

COCCIONI, R., GALEOTTI, S., & SANTARELLI, A. (1993) - *Preliminary palynological analysis of the Maiolica-Scisti a Fucoidi transition (Barremian-Aptian) in the Gorgo a Cerbara section (central Italy).* Paleopelagos, **3**, 199-205.

COCCIONI, R. & GALEOTTI, S. with collaborators (in press) - *Cretaceous key sections.* In: Coccioni, R. and Parisi, G. (eds.) - Jurassic to Miocene stratigraphy and palaeontology of pelagic Carbonates: The classic sequence of the Umbria-Marche Basin (Italy). Developments in Palaeontology and Stratigraphy, Elsevier.

COCCIONI, R., NESCI, O., TRAMONTANA, M., WEZEL, F.C. & MORETTI, E. (1987) - *Descrizione di un livello-guida "radiolaritico-bituminoso-ittiolitico" alla base delle Marne a Fucoidi nell'Appennino umbro-marchigiano.* Boll. Soc. Geol. It., **106**(1), 183-192.

COCCIONI, R., FRANCHI, R., NESCI, O., WEZEL, F.C., BATTISTINI, F., & PALLECCHI, P. (1989) - *Stratigraphy and mineralogy of the Selli Level (Early Aptian) at the base of the Marne a Fucoidi in the Umbro-Marchean Apennines, Italy.* In: Wiedmann, J. (ed.), Cretaceous of the Western Tethys. Proceedings 3rd International Cretaceous Symposium,Tübingen 1987, 563-584. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

COMPANY M., SANDOVAL J. & TAVERA J.M. (1993) - *Ammonite biostratigraphy of the Lower Barremian in the Subbetic Domain (Betic Cordillera, Southern Spain).* !st Gen. Meet. IGCP Project 362: Tethyan and Boreal Cretaceous Abstracts, 8-10.

CRESTA S. (1988) - *Association d'ammonites et biostratigraphie de l'Aalénien et du Bajocien inférieur des Apennins d'Ombrie-Marches (Italie Centrale).* Proceedings 2nd Int. Symp. on Jurassic Stratigraphy: 209-224.

CRESTA S., BASILICI G., BUSSOLETTI A., COMAS M.J., ELMI S., FERNANDEZ-LOPEZ S. R., FERRETTI A., GOY A., HENRIQUES M. H., KALIN O., JIMENEZ A., MARTINEZ G., SANDOVAL J., URETA S. & VENTURI F. (1995) - *Relazione sul Workshop "Paleontologia e biostratigrafia dei sedimenti ammonitiferi toarciano-Bajociani in successioni di alto morfostrutturale dell'Appennino umbro-marchigiano: l'area di Monte Nerone. Correlazioni con altre regioni della Tetide occidentale" (Piobbico, agosto 1993).* Boll. Serv. Geol. Ital., **112**, 129-139.

CRESTA S. (1996) - *Aalenian Ammonite biostratigraphy in Northern Apennines (Italy).* In A.C. Riccardi (Ed.): Proceedings 4th Int. Symp. on Jurassic stratigraphy, Georesearch Forum, **1-2**, 135-137.

CRESTA S. (in press) – *Jurassic Ammonite biostratigraphy in the Monte Nerone area.* In Coccioni R. & Parisi G. (eds.) – Jurassic to Miocene stratigraphy and palaeontology of pelagic carbonates: the classic sequence of the Umbria-Marche basin (Italy). *Developments in Paleontology and Stratigraphy*, Elsevier.

DERCOURT J., RICOU L. E. & VRIELYNCK B. (1993) - *Atlas Tethys Palaeonvironmental maps.* Gauthier-Villars, Paris, 307 p.

DOMMERGUES J.L., FERRETTI A., GECZY B., & MOUTERDE R. (1983)- *Elements de correlation entre faunes d'ammonites mésogéennes (Hongrie, Italie) et subboréales (France, Portugal) au Carixien et au Domérien inférieur. Précision sur la limite Carixien-Domerien Mésogée.* Geobios, **16**(4), 471-499.

DOMMERGUES J.L., FERRETTI A., & MEISTER CH. (1994) - *Les faunes d'ammonites du Sinémurien e l'Apenin central (Marche et Toscane, Italie).* Bollettino Società Paleontologica Italiana, **33**,

DUMITRICA D. & DUMITRICA JUD, R. (1995) - Aurisaturnalis carinatus *(Foreman), an example of phyletic gradualism among Saturlanid-type radiolarians.* Revue de Micropaléontologie, **38**(3), 195-216.

ERBA E., 1994. *Nannofossils and superplumes: the Early Aptian "nannoconid crisis".* Paleoceanography, **9**(3), 483-501.

ERBA E., AGUADO R., AVRAM E., BARABOSCHKIN E.J., BERGEN J.A., BRALOWER T.J., CECCA F., CHANNELL J.E.T., COCCIONI R., COMPANY M., DELANOY G., ERBACHER J., HERBERT T.D., HOEDEMAEKER P., KAKABADZE M., LEEREVELD H., LINI A., MIKHAILOVA I.A., MUTTERLOSE J., OGG J.G., PREMOLI SILVA I., RAWSON P.F., VON SALIS K., & WEISSERT H. (1996) - *The Aptian Stage.* In: Rawson, P.F., Dhondt, A.V., Hancock, J.M., and Kennedy, W.J. (eds.), Proceedings "Second International Symposium on Cretaceous Stage Boundaries", Brussels 8-16 September 1995. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre, **66**-Supp., 31-43.

ERBACHER J. (1994) - *Entwicklung und Paläoozeanographie mittelkretazischer Radiolarien der westlichen Tethys (Italien) und des Nordtlantiks.* Ph.D. Thesis, Univ. Tübingen, 119 p.

ERBACHER J. & THUROW J. (1997) - *Influence of oceanic anoxic events on the evolution of mid-Cretaceous radiolaria in the North Atlantic and western Tethys.* Marine Micropaleontology, **30**, 139-158.

ERBACHER J., THUROW J. & LITTKE R. (1997) - *Evolution patterns of radiolaria and organic matter variations: A new approach to identify sea-level changes in mid-Cretaceous pelagic environments.* Geology, **24**(6), 499-502.

FARAONI P., MARINI A. & PALLINI G. (1994) - *Biostratigrafia ad ammoniti della Corniola carixiana della valle del F. Bosso (Appennino marchigiano).* Paleopelagos **4**: 275-288.

FARAONI P., MARINI A., PALLINI G. & VENTURI F. (1994) - *Nuove faune ad ammoniti delle zone ad E. mirabilis ed H. serpentinus nella valle del F. Bosso (PS) e loro riflessi sulla biostratigrafia del limite Domeriano-Toarciano in Appennino.* Studi Geologici Camerti, vol. spec. "Biostratigrafia dell'Italia centrale", 247-297.

FARAONI P., MARINI A., PALLINI G. & VENTURI F. (1996) - *New Carixian ammonite assemblages of Central Apenines (Italy), and their impact on Mediterranean Jurassic biostratigraphy.* Paleopelagos, **6**, 75-122.

FERRETTI A. (1975) - *Ricerche biostratigrafiche sul Sinemuriano-Pliensbachiano nella gola del F. Bosso (Appennino marchigiano).* Rivista Italiana di Paleontologia e Stratigrafia, **81**(2), 161-194.

FIET N. (2000) - *Calibrage temporel de l'Aptien et des Sous-étages associés par un approche cyclostrtaigraphique appliquée à la série pélagique de Marches-Ombrie (Italie Centrale).* Bull. Soc. géol. France, **171**, 103-113.

FIET, N. & GORIN, G. (2000) - *Lithological expression of Milankovitch cyclicity in crabonate-dominated, pelagic, Barremian deposits in central Italy.* Cretaceous Research, **21**, 457-467.

GECZY B. (1976) - *Les ammonitines du carixien de la Montagne de Bakony.* Akademiai Kiado, 1-223.

GRADSTEIN F.M., AGTERBERG F.P., OGG J.G., HARDENBOL J., VAN VEEN P., THIERRY J. & HUANG Z. (1994) – *A Mesozoic Time Scale.* J. Geophys. Res., **99**(B12), 24051-24074.

GRIPPO, A., FISCHER, A.G., & CRESTA, S. (in prep.). *Milankovitch cyclicity in a Jurassic sequence: chronology and other implications.*

GRIPPO, A., & FISCHER, A.G. (in prep.). *The photolog-gray scale log approach to cyclostratigraphy.*

GROUPE FRANÇAIS D'ETUDE DU JURASSIQUE (1977) - *Biostratigraphie du Jurassique Ouest-européen et méditerranéen: zonations parallèles et distribution des invertébrés et microfossiles.* Cariou E., Hantzpergue P. (Coord.): Bull. Centre Rech. Elf Explor. Prod. Mem **17**: 1-440.

HADJI S. (1991) - *Stratigraphie isotopique des carbonates pelagiques (Jurassique supérieur-Crétacé inférieur) du Bassin d'Ombrie-Marches (Italie).* Ph.D. Thesis, Univ. Pierre et Marie Curie, Paris, 118 pp.

HARDENBOL J., THIERRY J., FARLEY M.B., JACQUIN T., DE GRACIANSKY, P.-C. & VAIL P.R. (1998) - *Mesozoic and Cenozoic Sequence Chronostratigraphic Framework of European basins.* In: de Graciansky, P.-C., Hardenbol, J., Jacquin, T., & Vail, P.R., eds, Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. SEPM Special Publ., Tulsa

HERBERT T. D. (1992) - *Paleomagnetic calibration of Milankovitch cyclicity in Lower Cretaceous sediments.* Earth and Planetary Science Letters, **112**, 15-28.

KALIN & URETA (1988) – *El Lias superior y el Dogger inferior en Gorgo a Cerbara (Apenino Central): Aspectos bioestratigraficos y sedimentologicos.* Estudios Geol., **43**, 489-511.

JUD R. (1994) - *Biochronology and Systematics of Early Cretaceous Radiolaria of the Western Tethys.* Mémoires de Géologie, Lausanne, **19**, 147.

LAVECCHIA G. & PIALLI G. (1980) – *Appunti per uno schema strutturale dell'Appennino umbro-marchigiano. 2 La copertura.* Studi geologici camerti, **6**, 23-30.

LOWRIE W. & ALVAREZ W. (1984) - *Lower Cretaceous magnetic stratigraphy in Umbrian pelagic limestone section.* Earth and Planetary Science Letters, **71**, 315-328.

ODIN G.M. (1994) – *Geological Time Scale.* C.R. Acad. Sci. Paris, **318**, ser.II, 59-71.

REMANE J., BORZA K., NAGY I., BAKALOVA-IVANOVA D., KNAUER J., POP G. & TARDI-FILACZ E. (1986) - *Agreement on the subdivision of the standard calpionellid zones defined at the IInd Planktonik Conference, Roma 1970.* Acta Geologica Hungarica, **29**, 15-26.

SANTANTONIO M. (1994) *Pelagic carbonate platforms in the geologic record: their classification and sedimentary and paleotectonic evolution.* AAPG Bulletin, **78**(1), 122-141.

VERMEULEN (1972) - *Considerations sur la* Psilotissotia malladae *(Nickles) et l'origine du genre* Nicklesia *Hyatt.* C. R. Somm. Soc. Geol. France, **7**, 23.

VERMEULEN (1980) - *Etude de la famille des Pulchelliidae.* Thèse de L'Université de Nice, 1-92.