EOCENE LARGER FORAMINIFERAL BIOSTRATIGRAPHY
IN THE SOUTHERNMOST DAUPHINOIS DOMAIN
(MARITIME ALPS, FRANCE-ITALY BORDER)

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Abstract. The Trucco Formation and the Nummulitic Lime-
stone (Dauphinois Domain, Maritime Alps) are characterized by abun-
dant larger foraminifera, specifically nummuloids, orthophragminids
and encrusting foraminifera. In the Maritime Alps, previous studies
suggest a late Lutetian age for the Trucco Formation and a late Lute-
tian-Priabonian age for the Nummulitic Limestone.

Biostratigraphic analysis of the nummuloids, in 11 stratigraphic
sections, allowed us to distinguish 3 biozones:

MALF1 Zone: defined by the presence of Nummulites brong-

darti d’Archiac & Haime, N. puschi d’Archiac, N. perforatus de Mon-
tfort, N. striatus (Bruguère), N. cf. dufrenoyi d’Archiac & Haime, N.

variolusinus/incrassatus and Operculina schwageri Silveri.

MALF2 Zone: defined by the presence of Nummulites perfor-

tatus de Montfort, N. striatus (Bruguère), N. cf. dufrenoyi d’Archiac &

Haime, N. variolusinus/incrassatus and Operculina schwageri Silveri.

MALF3 Zone: defined by the presence of g. Nummulites vari-

olusinus/inrassatus, N. striatus (Bruguère) and Operculina schwageri

Silveri.

According to current larger foraminiferal biozonal schemes, the
age of these local biozones corresponds to the Bartonian p.p.

Moreover, the comparison with biostratigraphic schemes estab-
lished for the Dauphinois Domain and for the Tethyan area evidences
that several typical nummuloid species of the late Bartonian are lacking
in the southern Dauphinois Domain, probably due to a paleogeog-

raphic control.

Introduction

Larger foraminifera and in particular Nummulites
are among the most useful shallow-water paleoecologic
and paleogeographic index fossils, particularly in Alp-

ine-Tethyan areas. Detailed evolutionary lineages of
various groups of Nummulites have been established for
the Tethyan area, especially by Boussac (1911), Hot-
tinger et al. (1964), Blondeau (1972), Herb & Hekel
(1973) and Schaub (1981). Biostratigraphic schemes
based on these lineages have been proposed for the en-
tire Tethyan area (i.e. Schaub 1981; Papazzoni & Sérrti
1995 and Serra-Kiel et al. 1998) and for the Dauphinois
Domain (Boussac 1911; Blondeau et al. 1968; Campre-

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In the last decade, the Dauphinois Domain has been object of detailed sedimentologic and tectonostatigraphic studies in Champvaur area (Gupta 1997, 1999), in Annecy-Entrevaux area (Sinclair 1997; Sinclair et al. 1998) and in the Maritime Alps (Ford et al. 1999; Ford & Lickorish 2004) but the dating of the successions is still based on old data that need careful revision.

This work provides new biostratigraphic data on a stratigraphic interval of great significance to recognize the worldwide demise of large-sized *Nummulites* and the Middle-Upper Eocene boundary.

The individuation of biostratigraphic events, in the southernmost part of the Dauphinois Domain (Maritime Alps), allows us a comparison with other biostratigraphic schemes for the Tethyan area, with general implications related to the stratigraphic distribution of larger foraminifera and to the extinction events occurred in this time span.

The Nummulitic Limestone represents the fully first marine deposit of the Alpine foreland basin; consequently it holds a key role in the understanding of the geodynamic evolution of this domain. For this reason a more precise dating of the Nummulitic Limestone in this sector may provide a strong constrain for tectonostatigraphic models.

**Geological setting**

The studied area is localized in the Maritime Alps, near the French-Italian border, at the southernmost edge of the Dauphinois Domain (Fig. 1a). In this area, the Eocene succession records the initial transgression and the subsidence of the southernmost Alpine foreland basin. This basin-fill succession (Sinclair 1997) rests through an erosional surface upon a Cretaceous substrate that represents the passive-margin wedge developed at the paleoeuropen margin of the Ligurian Tethys Ocean (Ford & Lickorish 2004).

The Eocene succession of the Dauphinois Domain in the Western Alpine foreland basin consists of four main biostratigraphic units (Fig. 2).

The first unit is represented by the Trucco Formation (TF) consisting of thin lenticular bodies of continental and estuarine deposits. This as yet informal formation has been proposed by Varrone (2004) to indicate
all the sediments sandwiched between the Upper Cretaceous substratum and the transgressive shallow marine Nummulitic Limestone. This definition has been preferred to the original one of *Microcodium* Formation given by Faure Muret & Fallot (1954), because quite often the upper portion of this unit does not contain *Microcodium* remains but instead brackish mollusæ assemblages characterized by abundant gastropods. These layers were known as Couches à *Cerithium* (Bodelle 1968) and were not included in the original description of the *Microcodium* Formation given by Faure Muret & Fallot (1954). The well-known locality of Trucco (Sturani 1969; Campredon 1977) has been chosen as the type locality, where all the facies recognized in the formation are well exposed. The TF coincides with the "Intra Nummulitic conglomerate" (Ravenne et al. 1987; Apps et al. 2004) and the "Infranummulitic Formation" by Sinclair et al. (1998) defined in Haute Savoie and French Maritime Alps immediately to the west of the studied area. These authors however did not propose any type section.

The TF is characterized, in its lower part, by *Microcodium* and paleosols indicating subaerial conditions followed by continental deposits, while in the upper part estuarine-lagoonal deposits prevail. The age of these deposits has been strongly debated; at present the TF is dubitably referred to the Lutetian (Sturani 1969; Lanteaume 1968).

The following three units (Nummulitic Limestone, *Globigerina* Marls and Ventimiglia Flysch) are known in the Alpine literature as "Priabonian trilogy" (Boussac 1911).

The Nummulitic Limestone (NL) consists of a 30 to 100 m thick time-transgressive succession of shallow-marine limestone that unconformably overlies the TF or directly the Upper Cretaceous substrate. This formation consists of arenaceous limestones, limestones and bioclastic quartzarenites rich in larger foraminifera, deposited on a mixed siliciclastic-carbonate ramp characterized by moderate to high energy (Sinclair et al. 1998; Varrone & Clari 2003). The NL has been usually referred to the upper Lutetian-Bartonian (Campredon 1977; Lanteaume 1990).

The *Globigerina* Marl (GM) consists of bioturbated hemipelagic marls, 10 to 80 m thick deposited in a deep-water setting (Allen et al. 1991). Various bathymetric indicators demonstrate that the top of the GM was deposited at the time of maximum water depth in the Eocene succession (Sinclair et al. 1998). The GM is referred to the Priabonian *l.s.* (Lanteaume 1990; Varrone & d’Atti in press).

The last unit is represented by the Ventimiglia Flysch, a thick unit laterally equivalent to the Annot Sandstone (Stanley 1961; Vanossi 1990) consisting of siliciclastic turbidites supplied by the Maures Esteral Massif (Ravenne et al. 1987). These turbidites are referred to the Priabonian – Oligocene? (Vanossi 1990).

**Methods**

A total of 11 stratigraphic sections were measured (Fig. 1b, Fig. 3) and 226 samples were collected for investigating their larger foraminiferal content.

The samples consist of arenaceous, strongly lithified limestones. After a preliminary examination they were processed for acetate peels (222), thin-sections (32) and cut into random thin-slabs (85 slabs and 95 polishing surfaces). The slabs proved the most successful way to obtain equatorial and axial sections of Nummulitids and to observe the complete fossil assemblages in lithified rocks.

Only 4 less lithified samples were crushed, disaggregated by hydrogen peroxide solution, boiled in a sodium hydroxide solution and then washed through a 65 μm sieve obtaining 56 isolated larger foraminiferal specimens. After observations on external morphology the specimens were polished with increasingly fine grades of carborundum until the required equatorial section was reached.

Of the 226 samples analysed only 97 contain biostratigraphically relevant larger foraminiferal assemblages (Tab. 1).

The biostratigraphic analysis focused on the nummulitids, whereas the orthoquartzamids have been omitted. Previous works (i.e. Campredon 1977; Carbonne et al. 1980) indicate that orthoquartzamids are very abundant in this area, but represented by very few species characterized by a wide biostratigraphic range, unsuitable for biostratigraphic purposes.

Age-diagnostic larger foraminifers are present in the topmost layers of the TF and are especially abundant in the lower part of the NL (Fig. 3), whereas the upper part of the NL is characterized by scarce fossils content represented by nummulitids, gyspinids and rotilids.

**The Trucco Formation**

The Trucco Formation consists of continental and estuarine deposits filling a paleo-valleys system. The top of this formation usually is characterized by lenticular bodies of quartzarenites with cross bedding and locally hummocky cross stratification. This facies represents submerged discontinuous sand bars embaying a lagoon, while distally inner ramp sediments (NL) were deposited (Varrone & Clari 2003). The depositional environments of the TF and the NL were contiguous and during storm events bioclasts of the inner ramp (especially nummulitids) were transported and deposited in the external part of the lagoon. For this reason the larger foraminifera are confined to the top of the TF and consist of nummulitids, encrusting and attached foraminifera, bivalves and rarely echinoid spines. Lithology and sedimentary structures suggest a high-energy environment and locally the fossil assemblage may consist of both in place and displaced specimens. The displacement and mixing of sediments and faunas, locally, may hamper paleoenvironmental reconstruction but not biostratigraphic analysis because usually the displacement occurs between neighbouring environments.
Fig. 3 - Logs of the 11 stratigraphic sections. Coordinates in latitude-longitude degrees (according to WGS84) of the stratigraphic sections, sample localisation, lithostratigraphy, main stratigraphic surfaces (pre-nummulitic unconformities), ranges of selected species and biozones have been evidenced. Nummulides bronniarti and N. puschi are characterised by the same biostratigraphic range and consequently they are represented with a single symbol (U).
The TF passes with a ravinement surface to the NL, indicating a sea level rise.

The Nummulitic Limestone

The NL consists of mixed carbonate-siliciclastic sediments characterized by lateral changes in thickness (30 to over 100 m) (Fig. 3). Changes in sedimentation indicate a deepening trend, from inner to outer ramp environments.

The NL is characterized, at the base, by a ubiquitous clast-supported polygenic conglomerate, 0.5 to 1 m thick. In this layer the fossil content (within the matrix) consists of nummulitids, orthophragmimids, encrusting foraminifera and fragmented and/or abraded bivalves, gastropods, echinoids, red algae and scaphopods. Abrasion of skeletal remains and sediment texture point to a high environmental energy. This layer has been interpreted as a lag deposit covering the ravinement surface (Varrone & Clari 2003). Lag deposits are usually followed by middle-fine grained allochthonous sandstones and sandy allochthon limestones (sensu Mount 1985) in beds 0.5 to 2 m thick. The fossil content is represented by encrusting foraminifera, nummulitids, orthophragmimids, rotaliids, gastropods, bivalves, solitary corals and echinoids. These sediments have been deposited in an inner ramp environment. In the upper part, the NL consists of alternating (decimetre to centimetre) middle-coarse allochthonous sandstones (sensu Mount 1985) and
silty marls, characterized by an evident thinning and fining upward trend. In the allochemic sandstones the fossil assemblage is rich in orthophragminids, nummulitids, gastropods, bivalves, echinoderms, solitary corals and benthic foraminifera; in contrast, the silty marls are characterized by scarce fossil content consisting mainly in benthic foraminifera (gypsinids and rotaliids), gastropods and rarely nummulitids. The upper part of the NL has been deposited in a middle-outer ramp environment (Varrone & Clari 2003).

**Distribution of larger foraminifera in the Trucoc Formation and in the Nummulitic Limestone**

The larger foraminiferal assemblages recognized in the TF and in the NL are characterized by a low number of species that nevertheless are enough to evidence regional and local biostratigraphic events (Pl. 1).

Three subsequent range biozones have been distinguished (Tab. 2) and indicated with the abbreviation MALF (Maritime Alps Larger Foraminifera).

### MALF1 Zone

The lower zone is characterized by thick, large or small, *Nummulites* species and is defined by the presence of *Nummulites brongniarti* d’Archiac & Haime, *N. puschi* d’Archiac, *N. perforatus* of Montfort, *N. striatus* (Bruguière), *N. cf. dufrenoiy* d’Archiac & Haime, *N. variolarius/incrassatus* and *Operculina schwageri* Silvestri.

The fossil assemblage also comprises *Fabiana cassis* (Oppenheim), *Gyroidinella cf. magna* (Le Calvez), *Orbulites sp.* and *Sphaerogypsina globulus* (Reuss).

Locally, the assemblage at the base of MALF1 is represented exclusively by large and flat forms of the *N. brongniarti-puschi* group, probably indicating an ecological control.

This zone has been recognized in 8 stratigraphic sections in the upper part of the Trucoc Formation (where present) and the lower part of the NL (Fig. 3) and seems to be restricted to the southern part of the studied area.

### MALF2 Zone

MALF2 is defined by the presence of *Nummulites perforatus* of Montfort, *N. striatus* (Bruguière), *N. cf. dufrenoiy* d’Archiac & Haime, *N. variolarius/incrassatus* and *Operculina schwageri* Silvestri (Tab. 2 and Fig. 3). The fossil assemblage also comprises *Gyroidinella cf. magna* (Le Calvez) and *Sphaerogypsina globulus* (Reuss).

The lower boundary coincides with the last occurrence of *Nummulites brongniarti* d’Archiac & *N. puschi* d’Archiac.

MALF2 has been recognized in 7 stratigraphic sections (Fig. 3) in the lower-middle part of the NL.

### MALF3 Zone

The upper zone is characterized by the dominance of small *Nummulites* species and is defined by the presence of gr. *Nummulites variolarius/incrassatus*, *N. striatus* (Bruguière) and *Operculina schwageri* Silvestri.

The lower boundary coincides with the last occurrence of *Nummulites perforatus* of Montfort.

This zone has been recognized in 3 stratigraphic sections (Fig. 3) in the upper part of the NL.

### Discussion

The three biozones identified (MALF1, MALF2 and MALF3) have been compared with biostratigraphic schemes established for the Dauphinois Domain and for the Tethyan area, with the aim to individuate common biostratigraphic events suitable for correlations (Tab. 3).

### Dauphinois Domain

The more significant biostratigraphic schemes of the Dauphinois Domain are the ones established by Blondeau et al. (1968) and Sztrákós & du Fornel (2003).

The biostratigraphic events utilized to distinguish MALF1, MALF2 and MALF3 (Tab. 3) well correspond with those of Blondeau et al. (1968) and Sztrákós & du Fornel (2003), nevertheless an important incongruence has been evidenced in their schemes.

The incongruence concerns the occurrence/absence of *Nummulites millecaput*. In fact, on the base of the occurrence of *N. millecaput*, the authors individuate a late Lutetian (?)-early Bartonian biozone (biozone A of Blondeau et al. 1968 and biozone 1 p.p. of Sztrákós & du Fornel 2003) (Tab. 3). This biozone is defined by the presence of *N. millecaput* (a Lutetian species) associated with typical Bartonian species (*N. perforatus, N. brongniarti, N. striatus*). Detailed stratigraphic analyses (Varrone & Clari 2003) exclude reworking processes that should be invoked to explain this unusual assemblage.
In our opinion, the specimens characterized by very large test and spiral-doubling indicated as *N. millecaput* are referable to *Nummulites cf. defrenoyi* (a late Lutetian-early Bartonian species). In comparison to *N. millecaput*, *N. cf. defrenoyi* shows a minor thickness of the test, the absence of a bulging in the central part, a more irregular coiling and septa that are long, thin and undulated.

Considering these observations, biozone A of Blondeau et al. (1968) and biozone 1 *p.p.* of Sztrákos & du Fornel (2003) can be included in the MALF1 zone of the present work, early Bartonian *p.p.* in age.

**Tethyan area**

The more significant biostratigraphic schemes of the Tethyan area are the ones established by Schaub (1981), Papazzoni & Sirotti (1995) and Serra-Kiel et al. (1998) (Tab. 3).

The MALF1, MALF2 and MALF3 zones are all included in the *N. brongniarti* Zone of Schaub (1981) known in literature as Biarritzien (*sensu* Hottinger & Schaub 1960) (Tab. 3).

The comparison with the Shallow Benthic Zones (SBZ) of Serra-Kiel et al. (1998) is more articulated. MALF1 and MALF2 zones are both referable to SBZ17, early Bartonian in age (Tab. 3). The disappearance of *N. brongniarti* and *N. puschi* that represents the biostratigraphic event separating MALF1 to MALF2 is not considered as a regional event in the scheme of Serra-Kiel et al. (1998). Consequently, we suppose that this biostratigraphic event, recognized in the entire

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<td>C Zone</td>
<td>N. boulelli N. incrassatus N. striatus N. ptukhiani N. chavannesi</td>
<td>N. aff. fabianii N. striatus</td>
<td>N. biliated N. cyrenaicus N. vicari N. boulangieri</td>
<td>N. biliated N. cyrenaicus N. vicari N. boulangieri</td>
<td>N. biliated N. cyrenaicus N. vicari N. boulangieri</td>
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<td>B Zone</td>
<td>N. brongniarti N. chavannesi N. perforatus N. striatus N. ptukhiani</td>
<td>N. brongniarti N. perforatus N. ptukhiani N. imperforatus</td>
<td>N. biliated N. cyrenaicus N. vicari N. boulangieri</td>
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<td>A Zone</td>
<td>N. millecaput N. imperforatus N. brongniarti</td>
<td>N. millecaput N. striatus N. imperforatus N. imperforatus</td>
<td>N. biliated N. cyrenaicus N. vicari N. boulangieri</td>
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<td>MALF2</td>
<td>N. brongniarti N. defrenoyi N. perforatus N. striatus N. variolarius-N. incassatus Op. schwageri</td>
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<td>MALF1</td>
<td>N. brongniarti N. defrenoyi N. perforatus N. imperforatus N. imperforatus N. imperforatus N. variolarius-N. incassatus Op. schwageri</td>
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<td>SBZ16</td>
<td>N. herbi N. aturicus N. carpenteri A. gigantea</td>
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Tab. 3 - Comparison between Maritime Alps Larger Foraminiferal biozones (MALF) and different biostratigraphic schemes established for the Dauphinois Domain and for the Tethyan area. A late Bartonian age is tentatively (?) inferred for MALF3 zone.
southern Dauphinois Domain (Sztáros & du Fornel 2003) can probably due to a paleoecological control.

MALF3 zone is dubitatively correlated to the SBZ18 of Serra-Kiel et al. (1998), late Bartonian in age. This correlation, based on the disappearance of Nummulites perforatus and N. cf. dufrenoiy, is uncertain because in the Maritime Alps the species characterizing SBZ18 are completely lacking. In fact, the early Bartonian assemblage (MALF1 and MALF2 coinciding with SBZ17) is followed by a biozone (MALF3) containing a low-diversity larger foraminifera fauna with few stratigraphically significant species.

The difference between the Maritime Alps and the Tethyan area associations is limited to this interval (MALF3 – SBZ18 zones). In fact, in the westernmost sectors (Arc de Nice, Campredon 1977) associations comparable to those of MALF3 zone are followed by typical Priabonian assemblages referable to SBZ19 of Serra-Kiel et al. (1998) (Tab. 3: Blondeau et al. 1968 and Sztáros & du Fornel 2003).

The comparison with the scheme of Papazzoni & Sirotti (1995) evidences that MALF1 and MALF2 correspond both to the Nummulites lyelli Zone, early Bartonian in age (cf. SBZ17 of Serra-Kiel et al. 1998). Instead, MALF3 should partially correspond to the N. variolarium/incurvatus Zone (late Bartonian p.p.). In the southern Dauphinois Domain, the N. biedai Zone of Papazzoni & Sirotti (1995), late Bartonian p.p. in age (corresponding to the lower part of SBZ18 of Serra-Kiel et al. 1998), is lacking and the entire late Bartonian interval is represented by a larger foraminiferal assemblage dominated by N. variolarium/incurvatus and N. striatus (Tab. 3).

Moreover, according to Papazzoni & Sirotti (1995), the range of N. striatus is more extended than that indicated by Serra-Kiel et al. (1998).

The reason of the absence, in the southern Dauphinois Domain, of the more typical species of the late Bartonian is unclear. Detailed stratigraphic analyses (Varrone & Clari 2003) allow us to exclude the existence of a stratigraphic gap. Therefore, this fact can be explained supposing that a paleogeographic control has isolated during a short interval (late Bartonian) the southern Dauphinois Domain to the other Tethyan areas.

**Conclusion**

The present work, focused on the larger foraminiferal biostratigraphy of the Trucco Formation (TF) and the Nummulitic Limestone (NL), in the south-easternmost edge of the Dauphinois Domain (Maritime Alps), has evidenced:

1) The top of the Trucco Formation is early Bartonian p.p. in age, while in previous works this stratigraphic interval was usually considered upper Lutetian (Lanteaume 1968).


3) The larger foraminiferal assemblages recognized in the TF and in the NL allow us to distinguish three biozones (MALF, Maritime Alps Larger Foraminifera):

**PLATE 1**

- Fabiana cardia: axial section (10x) (SP14b).
- Orbitadiscus sp. (10x) (SP14b).
- Nummulites puschi, B form: sub-equatorial section (2.5x) (PZ6).
- Nummulites puschi, B form: equatorial section (2.5x) (PZ2).
- Nummulites puschi, A form: axial section (2.5x) (PZ3).
- Nummulites puschi, A form: axial section (5x) (PZ6).
- Nummulites perforatus, B form: equatorial section (2.5x) (BO28).
- Nummulites perforatus, A form: equatorial section (7.5x) (BO28).
- Nummulites perforatus, B form: axial section (2.5x) (BO31).
- Nummulites perforatus, A form: axial section (10x) (MR10).
- Nummulites perforatus, A form: sub-equatorial section (10x) (RTO2).
- Nummulites perforatus, A form: sub-equatorial section (10x) (RTO2).
- Nummulites cf. dufrenoiy, B form: sub-axial section (2.5x) (GR3).
- Nummulites cf. dufrenoiy, B form: sub-axial section (2.5x) (GR3).
- Nummulites brongniariti, B form: sub-axial section (2.5x) (PZ2).
- Nummulites brongniariti, B form: equatorial section (10x) (MR6).
- Nummulites variolarium/incurvatus, equatorial section (25x) (BO77).
- Nummulites variolarium/incurvatus, detail of the assemblage (10x) (RTO23).
- Nummulites variolarium/incurvatus, sub-equatorial section (25x) (MC6).
- Nummulites variolarium/incurvatus, sub-equatorial section (25x) (MC7).
- Nummulites variolarium/incurvatus, sub-equatorial section (25x) (SP21).
- Nummulites variolarium/incurvatus, external view (25x) (RT16).
- Operculina schaegneri, external view (15x) (BO29).
- Nummulites striatus, A form: sub-equatorial section (5x) (MC8).
- Nummulites striatus, A form: sub-equatorial section (5x) (MR11).
- Nummulites striatus, B form: equatorial section (7.5x) (GR8).
MALF1 Zone: defined by the presence of Nummulites bronniarti d’Archiac & Haimé, N. puschi d’Archiac, N. perforatus de Montfort, N. striatus (Bruugiére), N. cf. dusrenoiy d’Archiac & Haimé, N. variolarius/incrassatus and Operculina schwageri Silvestri.

MALF2 Zone: defined by the presence of Nummulites perforatus de Montfort, N. striatus (Bruugiére), N. cf. dusrenoiy d’Archiac & Haimé, N. variolarius/incrassatus and Operculina schwageri Silvestri. The lower boundary of MALF2 corresponds to the last occurrence of Nummulites bronniarti d’Archiac & Haimé and N. puschi d’Archiac.

MALF 3 Zone: defined by the presence of gr. Nummulites variolarius/incrassatus, N. striatus (Bruugiére) and Operculina schwageri Silvestri. The lower boundary of MALF2 corresponds with the last occurrence of Nummulites perforatus de Montfort and N. cf. dusrenoiy d’Archiac & Haimé.

4) The first two biozones (MALF1 and MALF2), both early Bartonian p.p. in age, have a local significance. In fact, the biostratigraphic event separating MALF1 and MALF2 (disappearance of N. bronniarti and N. puschi) is not recorded in other Tethyan areas.

5) In the southern Dauphinois Domain, the more typical nummulitid species of the late Bartonian are lacking, probably due to a paleogeographic control which affected the area until the Priabonian. Only a low-diversity larger foraminiferal assemblage is present. This assemblage has been assigned to a third biozone (MALF3), late Bartonian p.p. (?), in age, whose lower boundary is defined by the disappearance of N. perforatus and N. cf. dusrenoiy (biostratigraphic events recognized in the entire Tethyan area).

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