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Facies and coralline algae from Oligocene limestones in the Malaguide Complex (SE Spain)

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(With 8 figures, 1 table)

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Abstract

Coralline algae are the main components of the Oligocene (Rupelian–early Chattian?) limestones in Sierra Espuña in SE Spain, one of very few localities with shallow-marine Oligocene deposits in the Iberian Peninsula. Sierra Espuña is part of the Malaguide Complex in the Internal Zones of the Betic Cordillera, which, in the Palaeogene, constituted a terrane in the western Tethys to the east of its present location. Fossil components, lithofacies, and stratigraphic patterns of the Oligocene limestones indicate that they formed on a carbonate ramp that developed on and interfingered with deltaic deposits. The innermost facies belts are packstones to mudstones rich in porcelaneous foraminifers. Seawards of these low-energy environments, a bioclastic belt with corals and coralline algae passed into an area in which flat and branching corals thrived. In a deeper facies belt, rhodoliths and loose-branching and foliose coralline algae were the main sediment producers together with hyaline larger benthic foraminifers. The mastophoroids *Neogoniolithon* and *Spongites* dominate the shallower coralline algal assemblages, whereas melobesioids (*Lithothamnion* and *Mesophyllum* species) and sporolithales (*Sporolithon*) are the most abundant components in the more diverse deeper-water assemblages.

Keywords: Carbonate ramp, Oligocene, larger benthic foraminifers, Corallinales, Rhodophyta, Malaguide Complex, Betic Cordillera, SE Spain

Introduction

References to shallow-water Oligocene carbonates in the Iberian Peninsula are scarce, probably due to the limited extent of the few, scattered outcrops of shallow-marine rocks of this age. Geel (2000) described the facies and foraminiferal assemblages of lower

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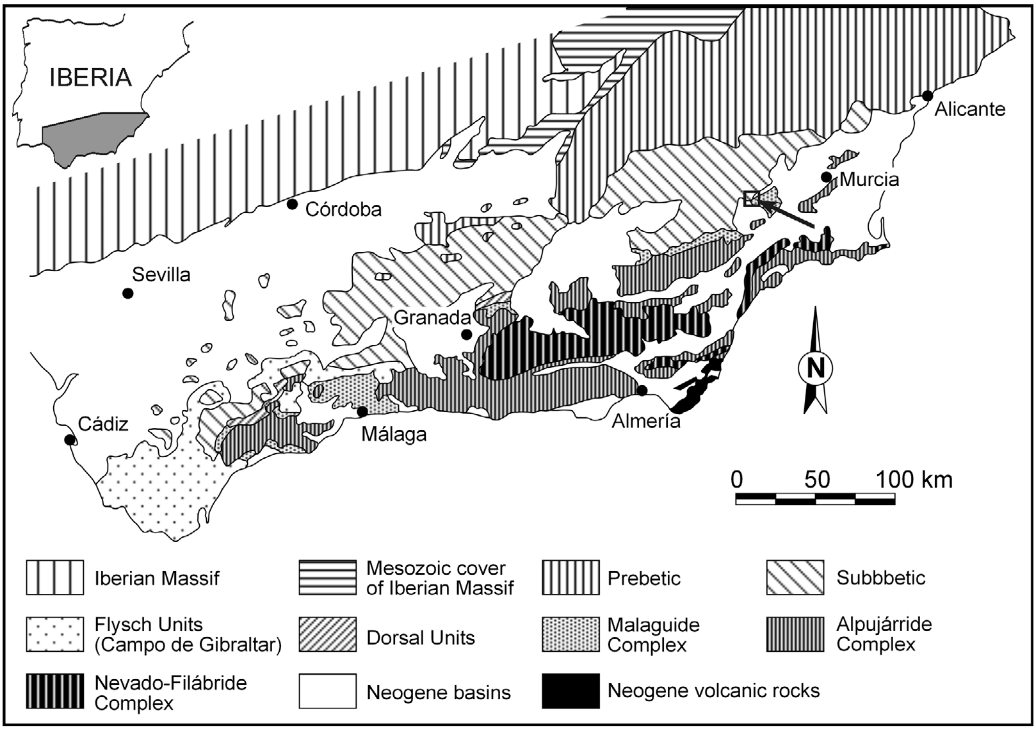

Fig. 1. Geological location of the study area in the Malaguide Complex of the Internal Zones of the Betic Cordillera, SE Spain (modified from Martín-Algarra 1987).

Oligocene limestones belonging to the southern Iberian margin in the eastern Prebetic in Alicante. The occurrence of Oligocene limestones in the Malaguide Complex has been reported in works dealing with regional geology of the Internal Zones of the Betic Cordillera in SE Spain (Paquet 1962, 1969; Lonergan 1993; Martín-Martín 1996). These papers point to the abundance of coralline red algae in the Oligocene limestones, but no further information on coralline algae has ever been published.

We describe here the lithofacies, larger benthic foraminifers and coralline algal assemblages of Oligocene (Rupelian–early Chattian?) carbonates from the Malaguide Complex in Sierra Espuña (Fig. 1). A sedimentary model based on facies and fossil components is proposed, and the distribution pattern of coralline algae within the model is discussed. The coralline algal flora shows a marked similarity with floras known from the Piedmont Basin and other circum-Alpine localities.

Geological setting

The Oligocene limestones of Sierra Espuña belong to the Malaguide Complex, the upper complex of the Internal Zones of the Betic chain, the westernmost European segment

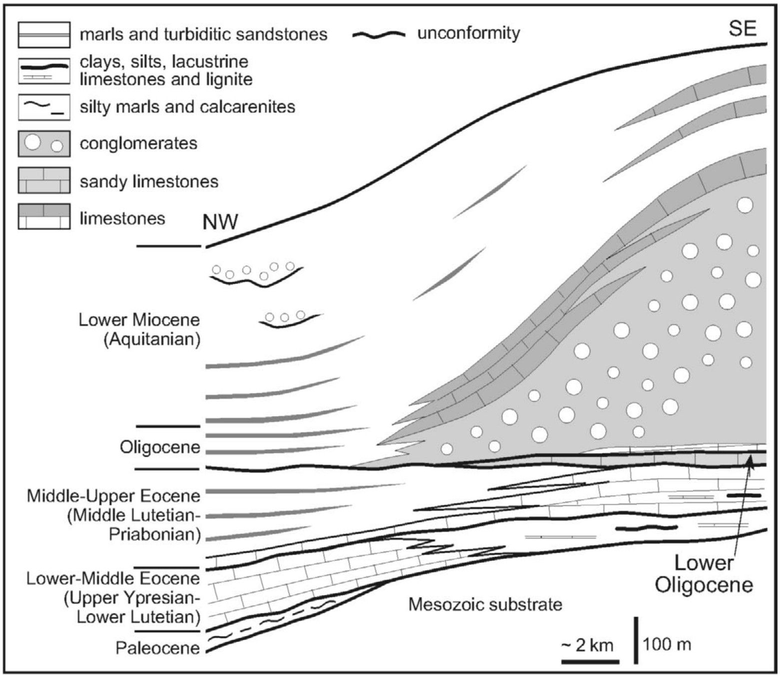

Fig. 2. Paleogene–Lower Miocene sedimentary units in the Malaguide Complex in Sierra Espuña. The Oligocene coralline red algal limestones intercalate with thick conglomerate deposits (modified from Martín-Algarra 1996).

of the Alpine orogenic belt (Fig. 1). The Internal Zones constitute a crustal wedge emplaced against the southern Iberian margin during the early Miocene. Only the Malaguide complex contains well-developed Palaeogene–lower Miocene deposits, which overlie Mesozoic series (Geel 1973). Palaeogeographically, the Malaguide Cenozoic rocks were deposited in the western Tethys to the east of their present-day position (Martín-Algarra 1987; Martín-Martín 1996).

The most complete and best-exposed sections of the Malaguide Palaeogene rocks occur in the Sierra Espuña. Five major sedimentary units separated by unconformities have been distinguished in the area (Martín-Martín 1996; Fig. 2). The lowermost unit, Palaeocene in age, consists of alternating pelagic silty marls and sediment gravity-flow deposits. The lower–middle Eocene (upper Ypresian–lower Lutetian) rocks formed in shallow-marine and transitional environments. They mainly consist of marls and marly limestones rich in gastropods, changing laterally to thick (up to 150 m) inner-platform limestones with imperforate foraminifers (miliolids and alveolinids), which in turn grade into open-platform limestones rich in nummulitids and coralline algae (Martín-Martín 1996). The Middle–Upper Eocene (upper Lutetian–Priabonian) unit includes shallow-water limestones that pass basinwards to marls intercalated with calcarenite beds. The overlying Lower Oligocene sediments consist of backshore marls with gastropods changing

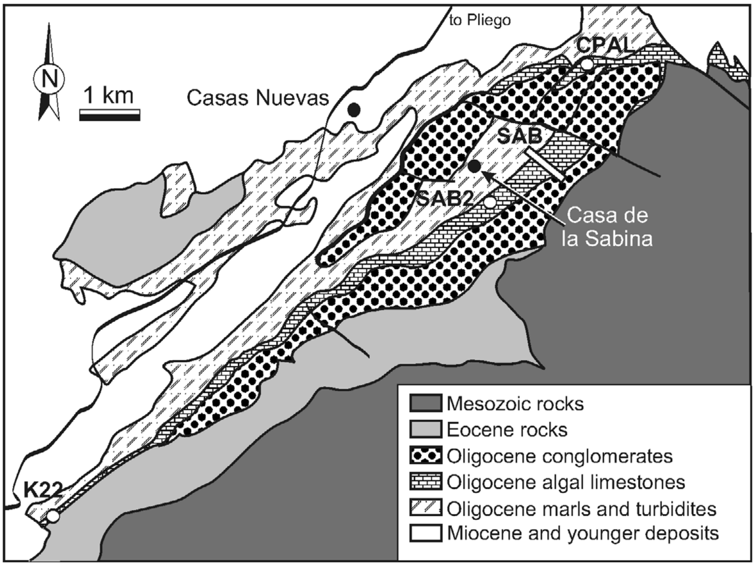

Fig. 3. Geologic map of the study area showing the location of the SAB section near Casa de la Sabina farmhouse and sampled localities (CPAL, SAB2, K22).

laterally to inner-platform calcareous sandstones and conglomerates and then to open-platform limestones with quartz grains and *Lepidocyclina*.

The Oligocene–Aquitanian study unit mainly comprises conglomerates (up to 600 m thick) with calcareous clasts eroded from the Malaguide Mesozoic substrate and underlying Palaeogene units (Fig. 2). The conglomerates intercalate algal limestones with nummulitids and *Lepidocyclina*. The algal limestones and conglomerates change laterally and upwards to marls interbedded with turbiditic calcarenites, sandstones, and conglomerates formed in submarine fans (Fig. 2).

Methods

The algal limestones were logged and sampled at the best-exposed section, east of the farmhouse Casa de la Sabina (UTM 62670–419770, Fig. 3). Additional samples were taken from outcrops at UTM 62665–419885, 62535–419660, and 61825–419160 (Fig. 3). Forty-eight thin sections were cut from the rock samples for facies analysis and foraminifer and coralline algal identification. Isolated specimens of larger benthic foraminifers

Fig. 4. Lithofacies and main fossil components in the SAB section. **A**, packstone with quartz grains and abundant miliolids. **B**, coral floatstone to rudstone with coralline red algae encrusting a coral. **C**, rhodolith packstone to rudstone with foliose and branching coralline thalli. **D**, rhodolith packstone to rudstone with *Nummulites* (N), *Amphistegina* (A) and *Operculina* (O). Scale bar equals 0.5 mm.

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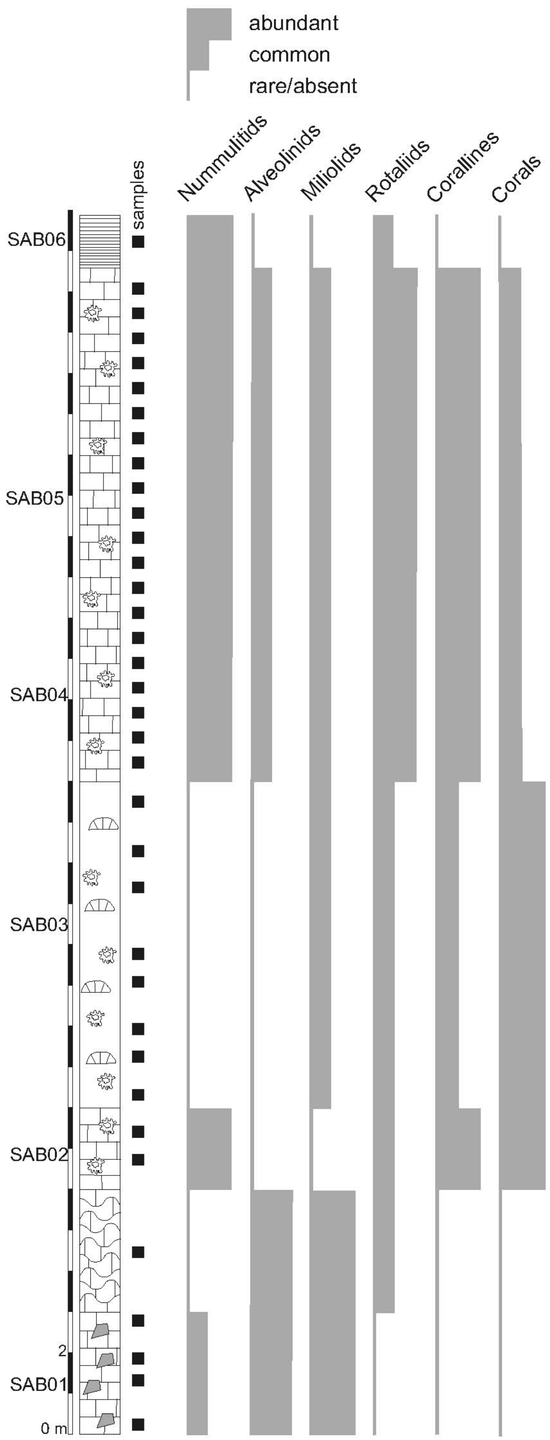
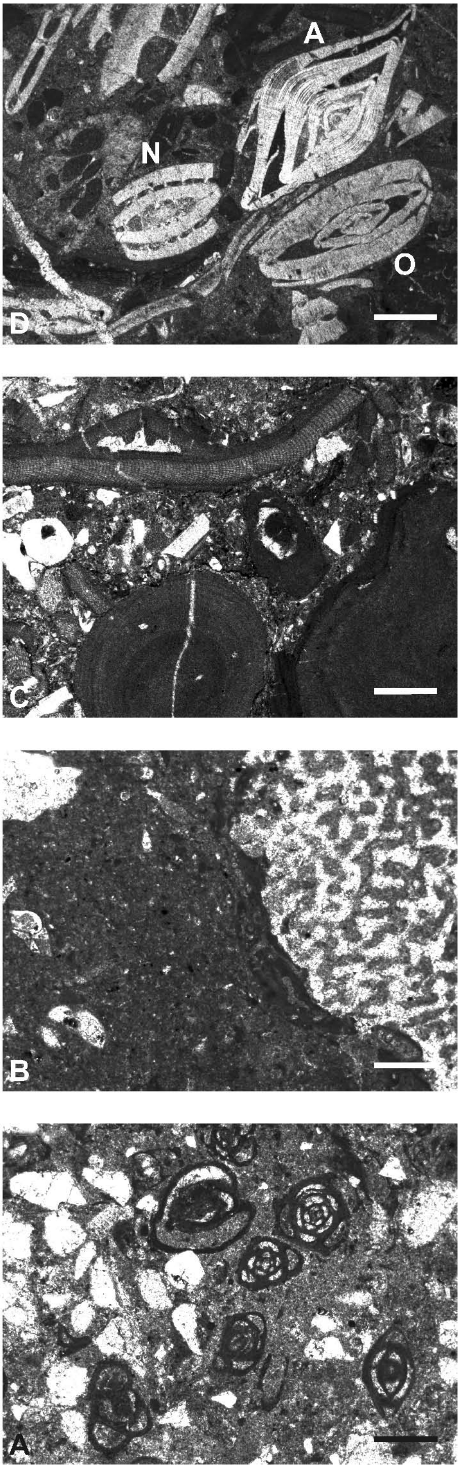

abundant
common
rare/absent
samples
Nummulitids
Alveolinids
Miliolids
Rotaliids
Corallines
Corals
SAB06
SAB05
SAB04
SAB03
SAB02
SAB01
2
0 m


A
N
O
D
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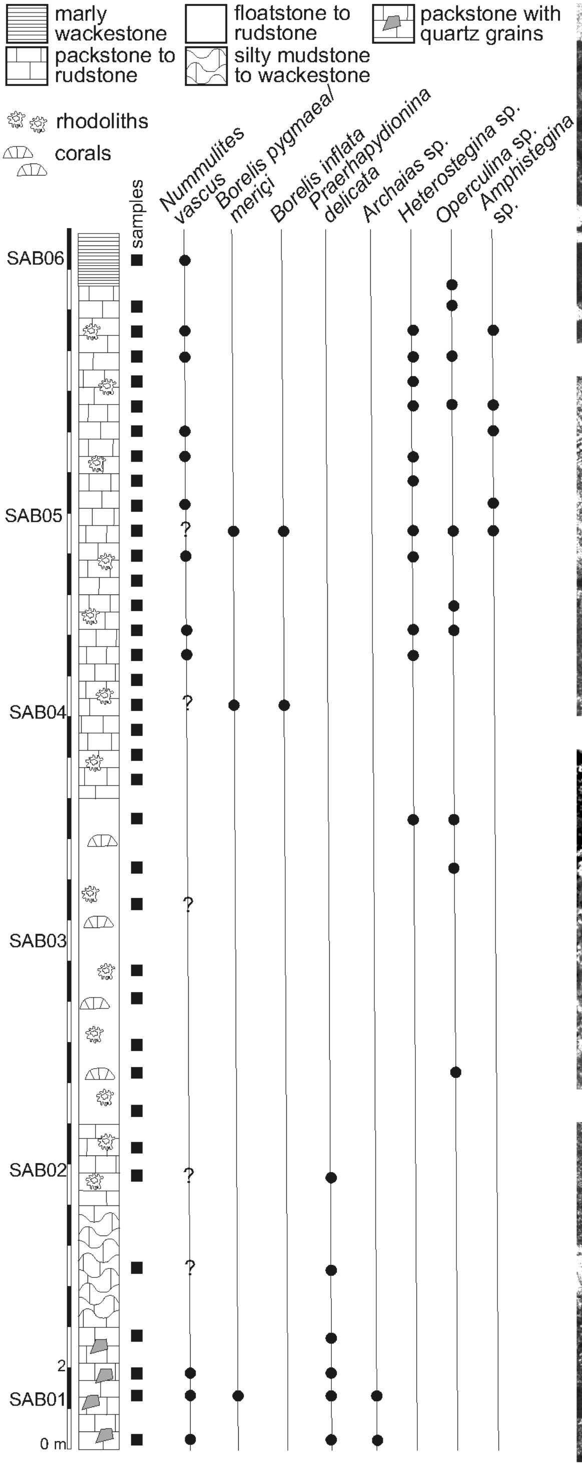
B
A


marly wackestone
packstone to rudstone
floatstone to rudstone
silty mudstone to wackestone
packstone with quartz grains
rhodoliths
corals
samples
Nummulites vascus
Borelis pygmaea/ merici
Borelis inflata
Praerhapydionina delicata
Archaias sp.
Heterostegina sp.
Operculina sp.
Amphistegina sp.
SAB06
SAB05
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SAB03
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2
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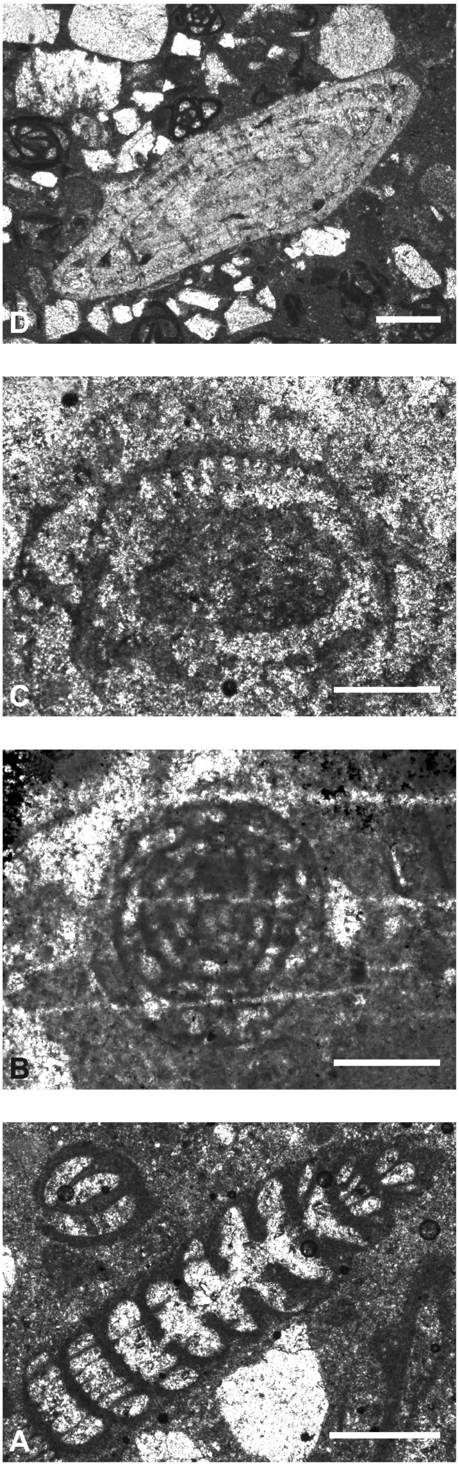
D
C
B
A

were also obtained from marly deposits for precise species identification. The thin sections of the studied limestones are stored in the Departamento de Estratigrafía y Paleontología, Universidad de Granada (Spain).

Results

Algal limestones

The algal limestones and conglomerates in the Oligocene–Lower Miocene unit were included in the El Bosque Formation by Martín-Martín (1996). This formation crops out on the northern slope of Sierra Espuña. The most continuous outcrops extend on a belt from the Cejo de las Palomas at the northeastern limit to the road from Zarzadilla de Totana to Aledo at the south-western end. Rocks in this formation are folded and faulted as the result of Miocene tectonics (Lonergan 1993; Martín-Martín 1996). The best-exposed section of algal limestones occurs east of the farmhouse Casa de la Sabina (UTM 62670–419770, Fig. 3).

Sabina section

The Sabina section is exposed along a small ravine that cuts limestone beds dipping steeply to the northwest. The following units can be distinguished from bottom to top (Fig. 4), overlying conglomerates with clasts from older Palaeogene and Mesozoic rocks:

- Packstone with quartz grains and silty matrix (3 m thick). Abundant miliolids and fragmented small *Nummulites*, alveolinids, soritids (*Archaias*), peneroplids (*Praerhapydionina*), rare rotaliids, and small solitary corals.

- Silty mudstone to wackestone (3 m thick). Rare small *Nummulites*, miliolids, textulariids, bryozoans, and small coralline algal fragments.

- Packstone to rudstone (2 m thick). Broken rhodoliths several centimetres in diameter, with nuclei of coral fragments, coral and mollusc fragments, geniculate corallines, miliolids, rotaliids, and rare *Nummulites*.

- Floatstone to rudstone (8 m thick). Flat coral colonies (20–30 cm wide and up to 8 cm thick) locally encrusted by corallines, in a mudstone to packstone matrix. Branching corals. Echinoid, mollusc, and bryozoan fragments. Miliolids, rare nummulitids, crustose and geniculate coralline algae. Encrusting agglutinated foraminifers (*Haddonia* sp.).

◀ Fig. 5. Occurrences of the biostratigraphic markers and other larger foraminifera in the SAB section. **A**, tangential longitudinal section of *Praerhapydionina delicata* Henson. **B**, subequatorial section of *Borelis inflata* Adams. **C**, tangential oblique section of *Borelis pygmaea* Hanzawa. **D**, tangential oblique subaxial section of *Nummulites vascus* Joly & Leymerie. Scale bars equal 0.5 mm in A and D, and 0.2 mm in B–C.

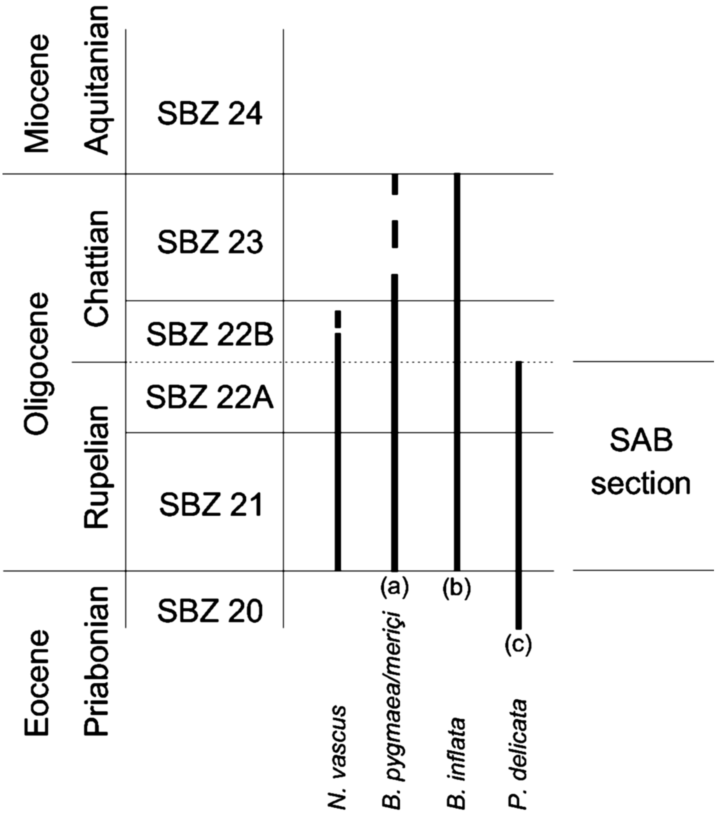

Fig. 6. Biostratigraphical setting of the Oligocene coralline red algal limestones in the SAB section. Shallow Benthic Zones (SBZ) and stratigraphic distribution of the most important biostratigraphic markers after Cahuzac & Poignant (1997). (a) after Hottinger (1974), Cahuzac & Poignant (1997), Sirel (2003); (b) after Hottinger (1974), Sirel (2003); (c) after Hottinger (2007).

- Packstone to rudstone (13 m thick). Rhodoliths a few centimetres in size and loose branching and foliose coralline algae variously fragmented. Abundant nummulitids (*Heterostegina*, *Nummulites*), rotaliids (*Amphistegina*, *Asterigerina*), acervulinids (*Sphaerogypsina*), alveolinids (*Borelis*), miliolids, solitary corals, bryozoans, echinoids, molluscs, and peyssonneliacean red algae (*Polystrata alba* (Pfender) Denizot).
- Marly wackestone (at least 2 m thick). Abundant *Nummulites*.

The section is overlain by poorly exposed silty marls rich in planktonic foraminifers. Laterally, south of the Sabina section, the larger benthic foraminifer *Lepidocyclina* occurs as a relatively rare component of the packstones/rudstones rich in coralline algae.

Age of the Sabina section

The Oligocene–Miocene zonal scheme for shallow-water deposits includes six biozones (SBZs) defined on the basis of different groups of larger benthic foraminifers (Cahuzac &

Poignant 1997). The biostratigraphic markers within this scheme identified in the Sabina section are *Nummulites vascus* Joly & Leymerie, *Borelis pygmaea* Hanzawa/*B. meriçi* Sirel, *B. inflata* Adams, and *Praerhapydionina delicata* Henson (Fig. 5). According to Cahuzac & Poignant (1997) and Sirel (2003), the range of *Nummulites vascus* is SBZ 21–22B, corresponding to a Rupelian–early Chattian age (Fig. 6), although its possible persistence into SBZ 23 cannot be excluded (Schaub 1981; Drooger & Laagland 1986; Bassi et al. 2007). *Praerhapydionina delicata* disappears at the end of the SBZ 22A (late Rupelian) according to Hottinger (2007), whereas other markers present, such as *Borelis pygmaea* and *B. inflata*, may span the entire Oligocene (SBZ 21–23). Based on the known chronostratigraphic range of these species, the Sabina section is probably Rupelian in age, although the upper part of the section, with no records of *P. delicata*, can extend to the early Chattian.

Facies interpretation and sedimentary model

Based on lithofacies, fossil components, and vertical relationships of the units in the section, the following interpretation is proposed for the facies and sedimentary model (Fig. 7). The limestones of the El Bosque formation probably formed on a carbonate ramp that developed on delta conglomerates at the northern margin of an emergent relief composed of Mesozoic to pre-Oligocene rocks of the Malaguide Complex. Packstones rich in miliolids were deposited in the innermost areas of the ramp. Terrigenous influence is recorded by the occurrence of quartz grains, and a certain degree of turbulence is reflected by the fragmentation of *Nummulites* tests. Seawards of the most proximal facies belt, there was a low-energy area where fine-grained carbonate with a few bioclasts (mainly miliolids) was deposited. Miliolids are common components in shallow-water, low-energy environments in many modern and ancient examples of carbonate platforms (Reiss & Hottinger 1984; Piller 1994; Haunold et al. 1997). In Oligocene deposits in the Western Tethys, small-miliolid facies have been reported from shallow subtidal facies (Pedley 1998) and inner- to proximal-middle-ramp settings (Nebelsick et al. 2000, 2005; Beavington-Penney & Racey 2004; Brandano et al. 2009a). Recent peneroplids and soritids mainly thrive in shallow-water, low-energy areas (Hottinger 1977, 2001; Hohenegger 2000). Oligocene soritids (*Archaias*) have been reported from proximal inner-ramp settings on the northern margin of the Western Tethys (Bassi & Nebelsick 2010) and from Malta (Brandano et al. 2009a, b). The occurrence of miliolids, peneroplids, and soritids may also indicate the presence of seagrass patches (Hottinger 1997; Haunold et al. 1997). These muddy facies changed laterally to more turbulent and open environments in which bioclastic sediments with coral, mollusc and foraminifer fragments accumulated together with algal nodules and coralline fragments.

Basinwards of the bioclastic deposits, the seafloor was colonized by flat and fine-branched coral colonies encrusted by crustose coralline algae. Packstones to floatstones with rhodoliths and corals have been described in distal inner-ramp facies of the Chattian limestones in Malta (Brandano et al. 2009a, b). In deeper locations, rhodoliths and loose coralline algae were the main sediment producers. Larger benthic foraminifers, mainly

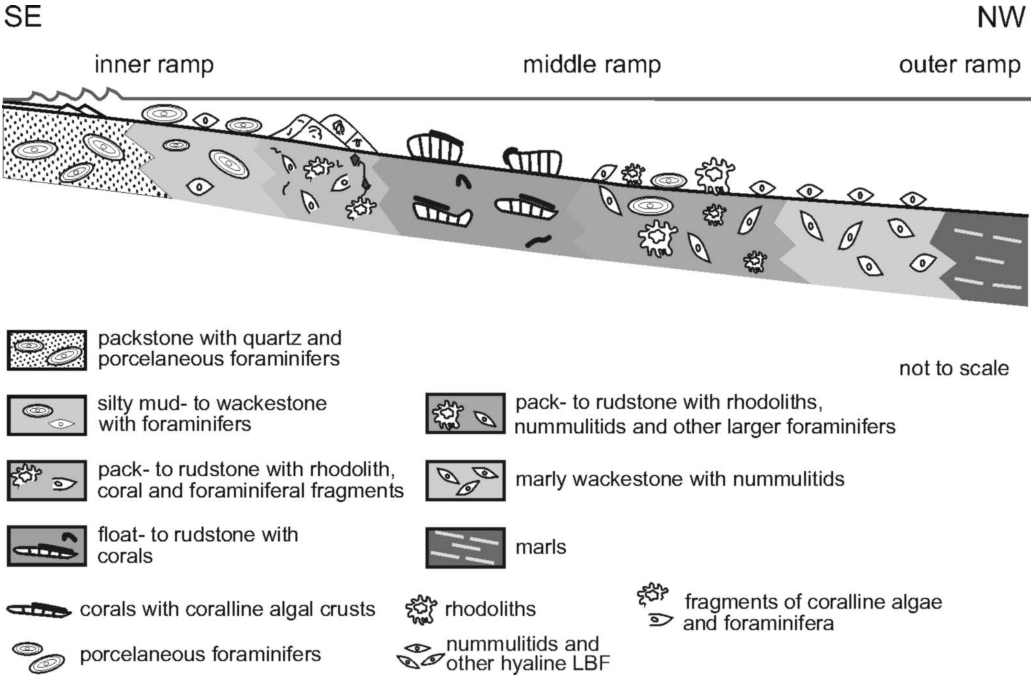

Fig. 7. Sedimentary model proposed for the Oligocene limestones in Sierra Espuña. The carbonate ramp developed on and laterally interfingered with deltaic conglomerates not shown in the scheme.

Nummulites and *Amphistegina*, were also abundant and diversified. The Oligocene small-*Nummulites* facies consists of *Nummulites*, *Operculina*, *Heterostegina*, and *Spiroclypeus* in middle-ramp deposits of the circum-Alpine area, northern Slovenia, and Malta (Pedley 1998; Nebelsick et al. 2005). Calcareous red algae and larger benthic foraminifers (*Amphistegina*, *Asterigerina*, *Heterostegina*) are the main components in the deeper-ramp facies described in the Chattian of Malta by Brandano et al. (2009a, b). *Nummulites* remained as the main component in the muddy and silty environments in the outer facies belt of the ramp in the transition to the slope/basin environments in which pelagic marls and sediment gravity flow deposits formed.

This facies interpretation implies a transgressive pattern of rock stacking, which has already been reported in the Oligocene–Lower Miocene sediments of the Malaguide Complex (Martin-Martín 1996).

Coralline algal assemblages

No identifiable coralline algae have been recorded in the innermost facies belts characterized by abundant miliolids. In the rest of the facies, three algal assemblages can be recognized (see Tab. 1 for separation of taxa mentioned below):

1) *Spongites personatus* (Airoldi) Vannucci, Quaranta & Basso, 2008 (Figs 8C–D) is the most common alga in the packstone/rudstone with rhodoliths. Thick warty crusts of this species cover coral nuclei, together with minor thin thalli of *Karpathia*. Fragments of unidentified melobesioids and scattered fragments of geniculate corallines occur in the matrix.

2) *Neogoniolithon contii* (Mastrorilli) Quaranta, Vanucci & Basso, 2007, and *Neogoniolithon raripunctatum* Mastrorilli, 1968 (Figs 8A–B) are the most common coralline species in the coral floatstone. Branched and contorted foliose plants of the former taxon seem to have grown directly on fine-grained sediment, as reported in the type locality of the species and other sections in the Piedmont Basin (Quaranta et al. 2007). The fruticose plants of *N. raripunctatum* encrust coral skeletons or, more frequently, appear as branch fragments in the matrix, together with *Subterraniphyllum* and geniculate corallines. Encrusting and warty plants of *Lithothamnion peleense* Lemoine, 1918 (Fig. 8E) and *Karpathia* occur on corals.

3) The most diversified coralline algal assemblage is the packstone/rudstone with rhodoliths and coralline branches and fragments. *N. contii* and *N. raripunctatum* occur in this assemblage, but their relative abundance is lower in relation to the coral-rich facies. *Spongites personatus*, *Spongites* sp. A, *Spongites* sp. B, *Spongites* sp. C, *Spongites* sp. D, *Karpathia*, and *Lithoporella* occur as other mastophoroids in the assemblage. Melobesioid species such as *Lt. peleense*, *Lithothamnion bourcartii* Lemoine, 1924, *Lithothamnion roveretoi* Airoldi, 1932, Melobesioideae sp. A, Melobesioideae sp. B, *Mesophyllum obsitum* Airoldi, 1932, and Melobesioideae sp. indet. are the most abundant components together with the sporolithales *Sporolithon lugeonii* Pfender, 1926, *Sporolithon* sp. A, *Sporolithon* sp. B (Fig. 8F). The peyssonneliacean *Polystrata* and geniculate corallines are locally common. Plants of all these taxa occur in rhodoliths of several growth phases, some with nuclei of coral fragments. *N. contii* and *Mesophyllum* appear as foliose branching plants that grew on the fine-grained sediment. Fragments of branching and foliose plants are common in the matrix.

Discussion

The coralline algal assemblages in the Oligocene deposits of Sierra Espuña vary in response to palaeodepth. Assemblages in the shallowest facies, according to the proposed facies model, are dominated by mastophoroid species belonging to *Spongites*, *Neogoniolithon*, and *Karpathia*, with minor melobesioid corallines (*Lithothamnion*). In deeper facies, melobesioids (several *Lithothamnion* species and *Mesophyllum*) and sporolithales (three *Sporolithon* species) are the most important components of the more diverse coralline assemblages. The number of mastophoroid species is higher in the deeper assemblages than in those in the shallower bioclastic and zooxanthellate-coral facies, but the relative abundance of the group decreases with depth. This depth-related change of coralline assemblages is similar to the trend observed in present-day tropical settings (Adey & Macintyre

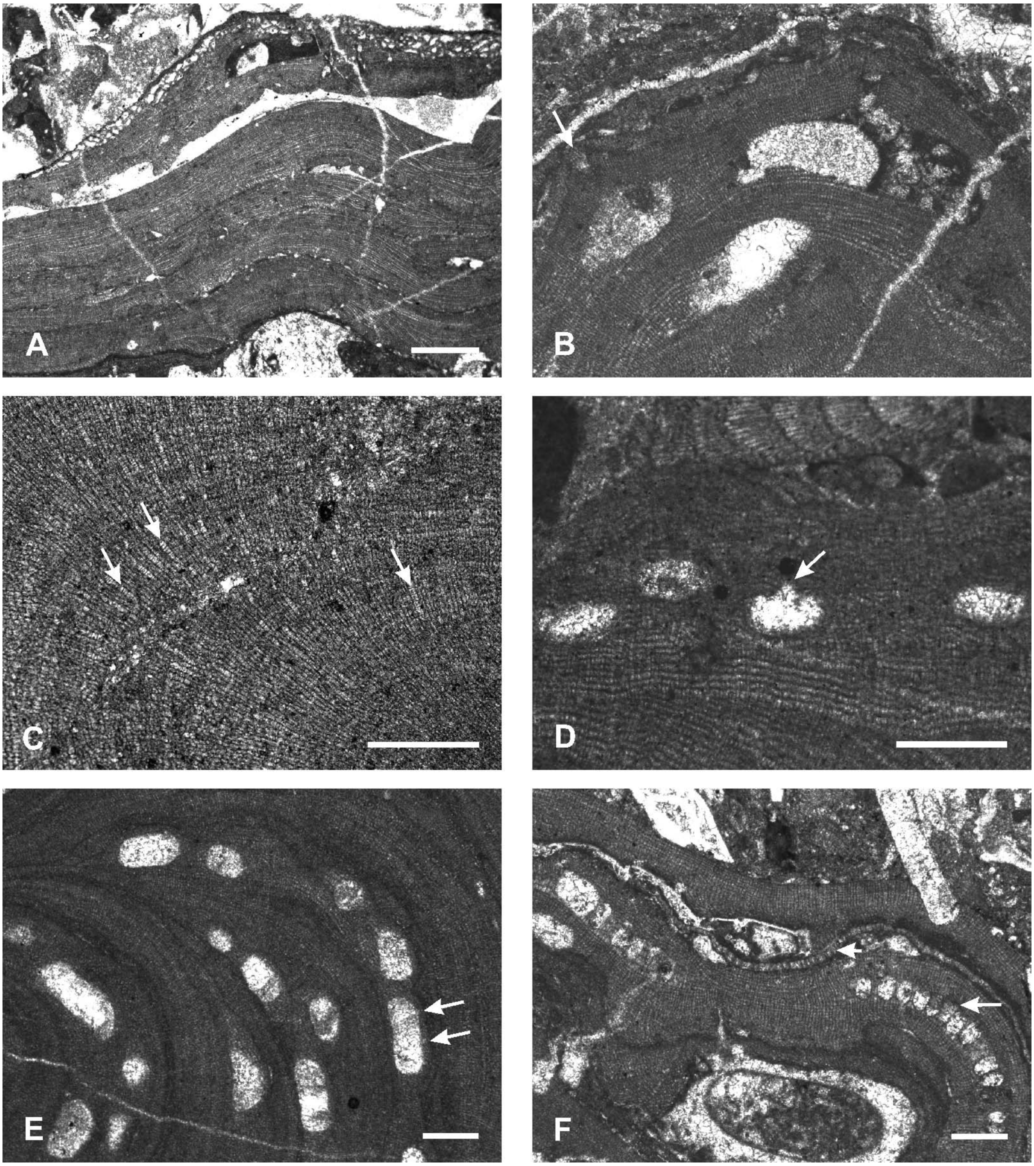

Fig. 8. Coralline algae from the Oligocene deposits of the Malaguide Complex, Sierra Espuña, SE Spain. **A–B**, *Spongites personatus* (Airoldi, 1932) Vannucci, Quaranta & Basso, 2008; A, superimposed encrusting thalli; B, longitudinal sections of very large uniporate conceptacles showing a long pore canal (arrow); **C–D**, *Neogoniolithon raripunctatum* Mastrorilli 1968. C, section of a protuberance showing fan-like cell filaments and trichocytes aligned in vertical rows (arrows); D, longitudinal sections of uniporate conceptacles with a conical pore canal (arrow). **E**, *Lithothamnion peleense* Lemoine, 1918; longitudinal oblique section of a zoned protuberance showing several small multiporate conceptacles, arrows point to pore canals; **F**, *Sporolithon* sp. B, superimposed encrusting thalli with longitudinal sections of sporangial compartments grouped in sori (arrow); a unistratose thallus of *Lithoporella* is also present (arrow-head). Scale bars equal 0.2 mm in B–F, and 0.5 mm in A.

1973; Adey 1979, 1986; Adey et al. 1982; Bosence 1983, 1991; Rasser & Piller 1997) and Neogene examples (Braga & Martín 1988; Perrin et al. 1995; Braga & Aguirre 2001; Brandano et al. 2005; Bassi et al. 2006; Braga et al. 2010). Brandano et al. (2009a, b) record the occurrence of mastophoroids only in the shallower coralline algal assemblages of the inner ramp in the Maltese Chattian deposits, whereas the deeper assemblages in the middle ramp are made up of melobesioids, sporolithales, and peyssonneliaceans. In contrast, other distribution models of assemblage components along palaeoenvironmental gradients in Oligocene deposits do not show a dominance of mastophoroids in shallower facies. *Lithothamnion* species dominate coarser-grained settings, whereas *Mesophyllum* is most abundant in deeper and finer-grained substrates (Bassi & Nebelsick 2000; Nebelsick & Bassi 2000; Nebelsick et al. 2000).

Neogoniolithon raripunctatum Mastrorilli, first described in the Oligocene of NW Italy (Mastrorilli 1968), seems to be the oldest record of a thick mastophoroid species with profuse development of heterocysts, which are characteristic of shallow-water coralline assemblages in present-day coral reefs (Adey 1979, 1986).

Most coralline species identified were first described or reported in the Oligocene deposits of the Piedmont Basin in NW Italy (Airoldi 1932; Conti 1950; Mastrorilli 1968; Giammarino et al. 1970; Fravega & Vannucci 1980a, b; Fravega et al. 1987, 1993; Vannucci et al. 1993, 1997, 2008). It seems that there is a coralline flora characteristic of the Oligocene reef-related environments in the western Mediterranean despite the nomenclatural problems due to the uncertain circumscription of many taxa names described from Oligocene deposits in the region. The lack of information and the uneven taxonomic approaches with which the reported coralline assemblages from the different basins have been treated prevent any definition of the temporal and spatial limits of this "Piemonte coralline flora". The most remarkable feature of the coralline algal assemblages in the Oligocene limestones of the Malaguide Complex is the absence of members of the subfamily Lithophylloideae Setchell (1943). The subfamily is confidently recorded since the Late Cretaceous in Georgia (Maslov 1956; Braga et al. 2005) and the eastern Alps (Moussavian 1989; see Aguirre et al. 2010) and, therefore, its absence in the study deposits is probably due to biogeographical causes. The occurrence of members of this subfamily in other Oligocene deposits of the western Mediterranean is arguable as many of the references to *Lithophyllum* species in the literature (Airoldi 1932; Conti 1950; Mastrorilli 1968; Giammarino et al. 1970; Fravega & Vannucci 1980a, b; Fravega et al. 1987, 1993; Vannucci et al. 1993, 1997, 2008) might correspond to species of mastophoroid genera (Braga et al. 1993). If the absence of lithophylloids is confirmed, this can be an outstanding palaeobiogeographic trait of the Oligocene coralline algal flora in the western Mediterranean. With the current state of knowledge of Oligocene coralline algae, however, no differentiation of palaeobiogeographical regions seems feasible despite the widespread geographical distribution of localities with algal records (Braga et al. 2010).

1. calcified compartments, sori	**SPOROLITHALES**
1. conceptacles	**CORALLINALES**
SPOROLITHALES, SPOROLITHACEAE	
1. A few sporangial compartments per sori	*Sporolithon* sp. A
1. Numerous sporangial compartments per sori	2
2. Sporangial compartments rectangular in section and narrow, 30–40 µm in ID x 90–100 µm in IH	*Sporolithon lugeonii*
2. Sporangial compartments eliptical in section, 50–60 µm in ID x 90–100 µm in IH	*Sporolithon* sp. B
CORALLINALES	
1. Sporangial conceptacles uniporate	**CORALLINACEAE**
1. Sporangial conceptacles multiporate	**HAPALIDIACEAE**
CORALLINACEAE, Mastophoroideae (Cell fusions as predominant interfilamental cell connections)	
1. Thallus dimerous	2
1. Thallus monomerous	3
2. Thallus with a conspicuous ventral layer of palisade-cell filaments	*Lithoporella* sp.
2. Thallus with a ventral layer of large, irregular cells	*Karpathia* sp.
3. Coaxial ventral core through most of the thallus	4
3. Non-coaxial ventral core	5
4. Vertical files of heterocysts (larger cells), conceptacles	*Neogoniolithon raripunctatum* Mastrorilli, 1968
4. Vertical files of heterocysts absent,	*Neogoniolithon contii* (Mastrorilli) Quaranta, Vannucci & Basso
5. Sporangial conceptacles > 600 µm in ID	*Spongites personatus* (Airoldi) Vannucci, Quaranta & Basso
5. Sporangial conceptacles < 600 µm in ID	6
6. Fruticose plants, branches slender	*Spongites* sp. A
6. Non-fruticose plants, encrusting to warty	7
7. Relatively thick (~ 100 µm) plumose ventral core	*Spongites* sp. B
7. Thin plumose ventral core	8
8. Conceptacles flask shaped (~ 250 µm in ID x 150 µm in IH)	*Spongites* sp. C
8. Conceptacles flat conical (~ 300 µm in ID x 120 µm in IH)	*Spongites* sp. D
HAPALIDIACEAE, Melobesiodeae	
1. Ventral core coaxial through most of the thallus	*Mesophyllum obsitum* Airoldi, 1932
1. Ventral core non-coaxial	2
2. Epithallial cells flattened and flared ?	3
2. Epithallial cells unknown	4
3. Conceptacles < 300 µm in ID	*Lithothamnion peleense* Lemoine, 1918
3. Conceptacles > 300 µm in ID	5
5. Ventral core plumose and thick	*Lithothamnion bourcartii* Lemoine, 1924
5. Ventral core plumose and thin	*Lithothamnion roveretoi* Airoldi, 1932
4. Thin encrusting plants, conceptacles protruding, 400–500 µm in ID	*Melobesioideae* sp. A
4. Plants encrusting, thin and flat, sporangial conceptacles small < 200 µm	*Melobesioideae* sp. B

◀ Table 1. Identification key with characters separating the coralline algal genera and species recognised in the Oligocene of Sierra Espuña. Note that these separating characters are not by themselves alone diagnostic of the taxa included in the key. ID, internal diameter; IH, internal height.

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