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VERSITA

Calcareous plankton bio-chronostratigraphy of the Maltese Lower Globigerina Limestone member

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ABSTRACT:

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The planktonic foraminifera and calcareous nannofossil biostratigraphy of the Maltese Lower Globigerina Limestone member has been investigated. The member was dated to early planktonic foraminiferal P22 Zone and nannofossil NP25 Zone (upper Chattian). A climate-stratigraphic approach, based on the quantitative analyses of calcareous nannofossils, was used additionally to achieve a more precise chronology. The species *Coccolithus pelagicus* (diameter ≤11 µm) and the genus *Umbilicosphaera* were selected for the recognition of cold and warm surface waters intervals respectively. The ratio of their percentages enabled the construction of a Climatic Factor (CLF) curve. The CLF values were consistent with a warm climatic phase, which is probably represented by the portion of the oxygen stable isotope curve of Miller *et al.* above the Oi2c event and below the beginning of the cooling trend that culminates in the Mi1 event. Considering these two climatic events and the upper boundary of the NP25 Zone, it can be inferred that the deposition of the Lower Globigerina Limestone member took place between 25.1 and 24.3 Ma.

Key words: Calcareous plankton; Biostratigraphy; Chattian; Lower Globigerina Limestone member; Maltese Archipelago.

INTRODUCTION

The Globigerina Limestone formation (Murray 1890) crops out widely in the Maltese Archipelago, both on Malta and Gozo islands (Text-fig. 1). The type locality and section of the formation was established by Felix (1973) at Il-Qaws (NW of Dingli, on the southwestern coast of Malta Island).

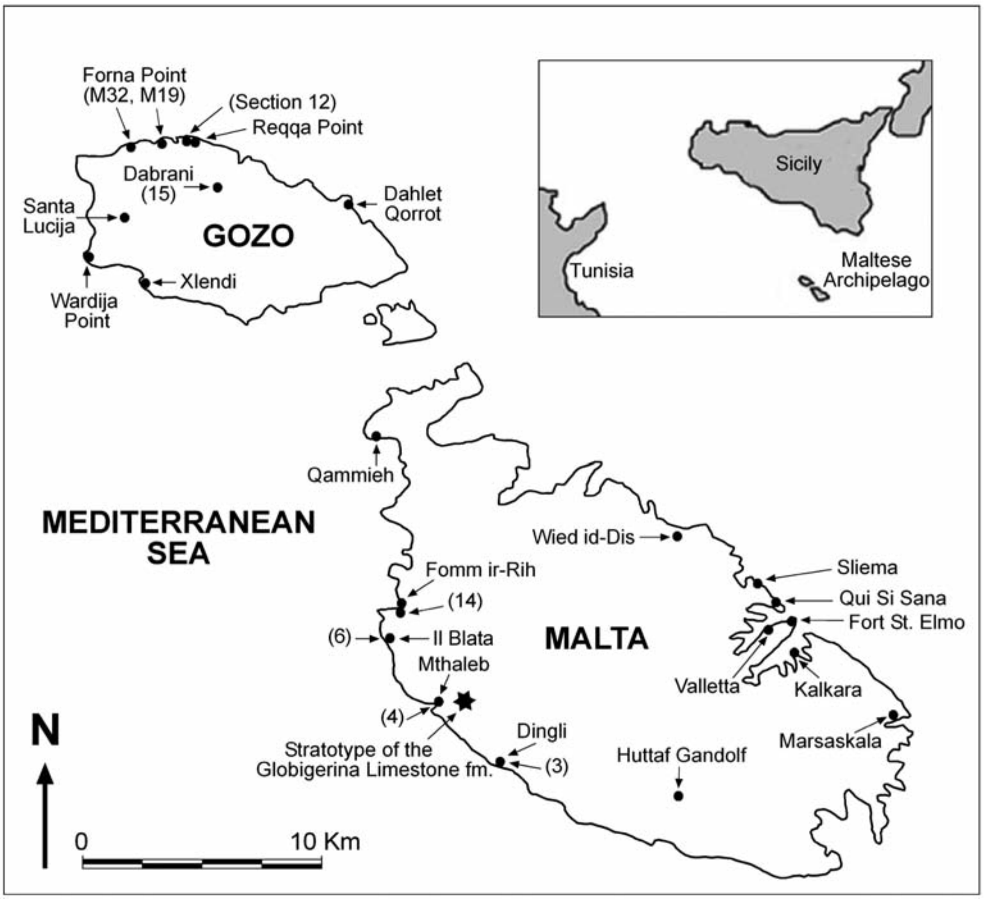
The thickness estimates of the Globigerina Limestone formation vary from c. 20 m to as much as 60 m (Hyde 1955; Felix 1973), 70 m (Bennett 1979; Challis 1979) or even 207 m (House *et al.* 1961; Pedley 1978a, b; Pedley *et al.* 1976). Based on lithological variability and the presence of two distinct phosphatic beds, the formation is commonly subdivided into the Lower, Middle and Upper Globigerina Limestone informal members ("sub-formations" of Rizzo 1932, who introduced the tripartite subdivision of the formation). The phosphatic beds are placed variously at the top of the Lower and Middle Globigerina Limestone members (Pedley *et al.* 1976; Carbone *et al.* 1987; Jacobs *et al.* 1996), at the bases of the Middle and Upper Globigerina Limestone members (Giannelli and Salvatorini 1972, 1975; Bennett 1979; Challis 1979; Rose *et al.* 1992), or at the base and at the top of the Middle Globigerina Limestone member (Kienel *et al.* 1995; Rehfeld and Janssen 1995).

Despite the fact that the first chronostratigraphic data on the Globigerina Limestone formation were published in the late nineteenth century (e.g., Wright 1855); Gregory (1890-91); and Cooke (1896a, b), the first reliable reports date from the 1970s and 1980s century, when Giannelli and Salvatorini (1972) and Mazzei (1980, 1986) recognised the Aquitanian and Burdigalian age of the Middle Globigerina Limestone member and the Langhian age of the Upper Globigerina Limestone member. Moreover, these authors identified sedimentary hiatuses associated with the two phosphatic beds. Their chronostratigraphic conclusions were substantially confirmed by Felix (1973). The researches concerning the Lower Globigerina Limestone member enabled Giannelli and Salvatorini (1972) to suggest a Chattian (Late Oligocene) age for the member, and Felix (1973) to refer it to the Aquitanian (Early Miocene). Subsequently, even though the Chattian age of the member was confirmed by several Sr-isotope analyses (Pratt 1990, unpublished Ph.D. thesis; Rose *et al.* 1992; Jacobs *et al.* 1996; Follmi *et al.* 2008), the attribution of the member to the Aquitanian was quoted in a number of reports (e.g., Rose 1974; Pedley *et al.* 1976; Challis 1979; Menesini 1979a, b; Theodoridis 1984; Pedley 1993; Kienel *et al.* 1995; Rehfeld and Janssen 1995).

The aim of this study is to clarify the age of the Lower Globigerina Limestone member by quantitative and semiquantitative analyses of the planktonic foraminiferal and calcareous nannofossil assemblages. This research was carried out in several sections (including those sampled by Giannelli and Salvatorini 1972), located both on Malta and Gozo islands (Text-fig. 1). The preliminary results were presented by Foresi *et al.* (2007).

LITHOSTRATIGRAPHIC OUTLINE

The Lower Globigerina Limestone member is composed of massive to thick-bedded, yellow-brown biodetrital limestones (biomicrosparites and biomicrites). In the lower part of the member the limestones are coarse-grained, yellow-brown and strongly bioturbated. In the upper part they are fine-grained, marly and pale yellow



Text-fig. 1 Location of the Maltese sections considered in the present work. In brackets are the sections of Giannelli and Salvatorini (1972) and Mazzei (1980, 1986) in colour. Macrofossils are frequent, represented mostly by bryozoans and the echinoid *Scutella* in the lower part, and by pectinid bivalves (mainly *Flabellipecten*) and echinoids (e.g. *Schizaster*) in the upper part. Challis (1979) recognized the *Scutella* biofacies at the base of the unit (the "Scutella bed" in the literature) and the *Schizaster*/*Hemiaster* biofacies in the remaining part.

Pedley (1975, unpublished Ph.D. thesis; and 1989, 1992) reports the maximum thickness of the member as well above 100 m in the Valletta area, with a distinct reduction in thickness near the Comino Straits and on the Rabat Axis (Malta Island), where the member even disappears. In the Malta and Gozo islands, Pedley (1993) reported thicknesses between 0 and 80 m and 5 and 40 m respectively. Bennett (1979), Rose (1985), and Dart *et al.* (1993), reported thicknesses of up to 32 m and up to 20 m respectively.

Previously, the so-called "Scutella bed" or "transitional bed" (a layer with a high concentration of large flat echinoids) was considered the boundary level between the underlying Lower Coralline Limestone formation and the Globigerina Limestone formation. Some authors place the base of the Lower Globigerina Limestone member at the top of the "Scutella bed". Below the "Scutella bed" Carbone *et al.* (1987) defined the "Basal Globigerina Limestone Phosphatic Bed", which is particularly well developed in the northern part of Malta Island and in the western part of the Island of Gozo. This phosphatic bed covers the upper surface of an ubiquitous hardground that Bennett (1979, 1980 unpublished Ph.D. thesis) named "Terminal Lower Coralline Limestone Hardground". Felix (1973), Bennett (1980), Carbone *et al.* (1987) and Rose *et al.* (1992) located the base of the Lower Globigerina Limestone member just above this hardground.

The upper boundary of the Lower Globigerina Limestone member is marked by a prominent hard bed composed of abundant brown phosphatic nodules, glauconite granules, phosphatized (molluscs, echinoids, pteropods, corals, etc.) and non-phosphatized (ostreids, pectinids, *Nautilus*, *Eupatagus*, *Spatangus*, bryozoans, etc.) fossils and shark teeth, in a more or less abundant pale coloured biomicrite matrix. The upper surface of this bed is mainly planar and characterized by a phosphatic polycyclic layer (Pedley and Bennett, 1985) which covers the clasts. The bed was referred to as "C1", or "Lower main conglomerate" (Pedley 1975; see also Pedley *et al.* 1976), "Qammieh bed" (Bennett 1980), or as "Lower Main Phosphorite Conglomerate Bed" (Pedley and Bennett 1985). Subsequently, it was formally referred to as the "Qammieh Conglomerate Bed" by Rose *et al.* (1992). The up to one metre thick Qammieh Conglomerate Bed overlies a phosphatized hardground (the "Terminal Lower Globigerina Limestone Hardground" of Rose *et al.* 1992). The top of the Lower Globigerina Limestone member is defined by some authors at the top of the Qammieh Conglomerate Bed (Giannelli and Salvatorini 1972, 1975; Bennett 1979; Challis 1979; Rose 1985; Rose *et al.* 1992; Pedley 1993; Dart *et al.* 1993; Rehfeld and Janssen 1995; Kienel *et al.* 1995), and by some others at the top of the underlying hardground (Rizzo 1932; Roman and Roger 1939; House *et al.* 1962; Pedley *et al.* 1976; Carbone *et al.* 1987; Jacobs *et al.* 1996).

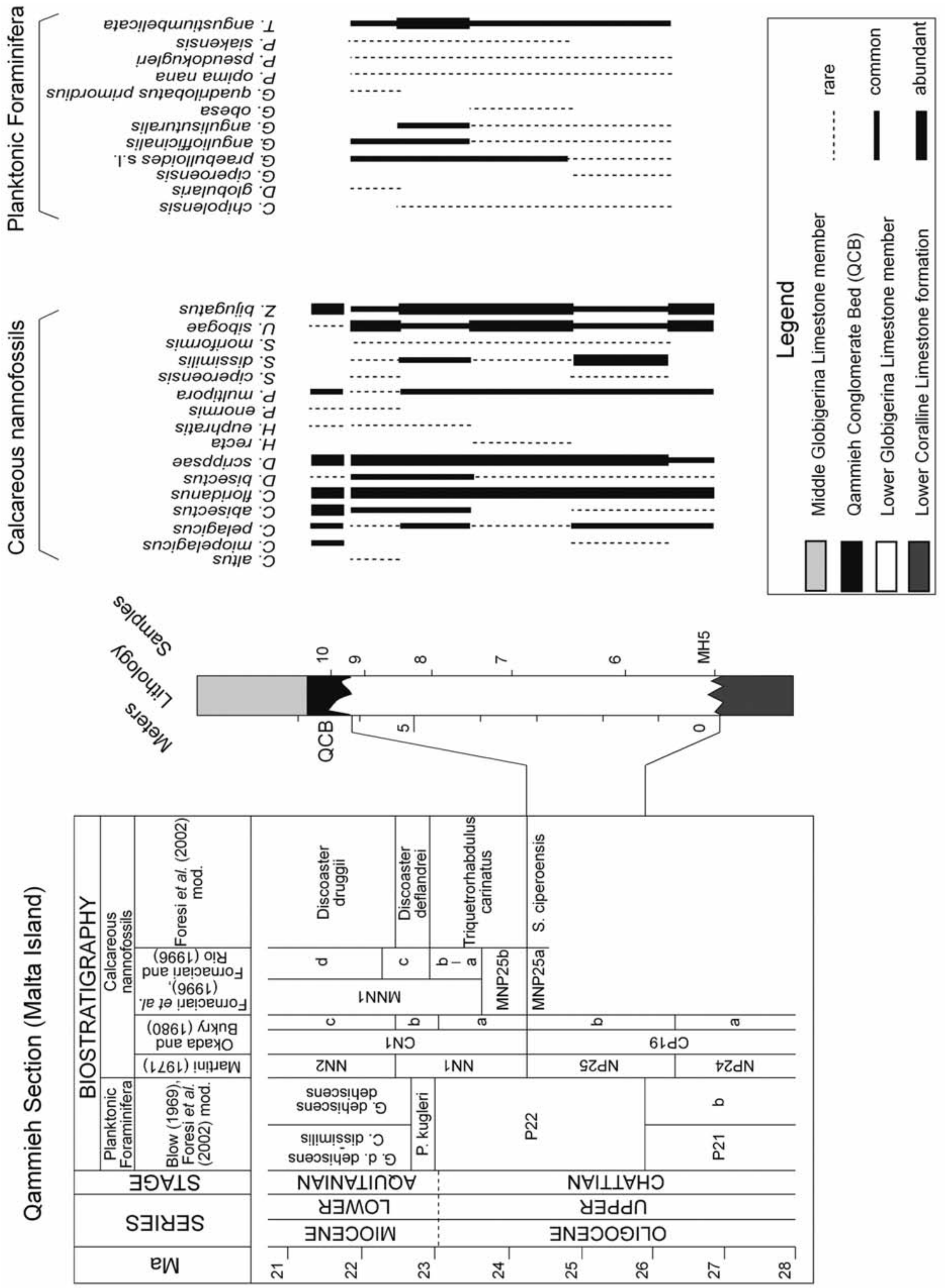
In this study, we consider the upper surfaces of the Terminal Lower Coralline Limestone hardground and Terminal Lower Globigerina Limestone hardground as the base and the top of the Lower Globigerina Limestone member respectively. The arguments for such definitions are the following: (i) the Terminal Lower Coralline Limestone hardground is ubiquitous, readily recognizable, and it marks a discontinuity surface; (ii) all of the several levels rich in *Scutella*, present in the Lower Coralline Limestone formation–Lower Globigerina Limestone member transition lie above the Terminal Lower Coralline Limestone hardground and show lithological characters typical of the Lower Globigerina Limestone member.

SECTIONS STUDIED

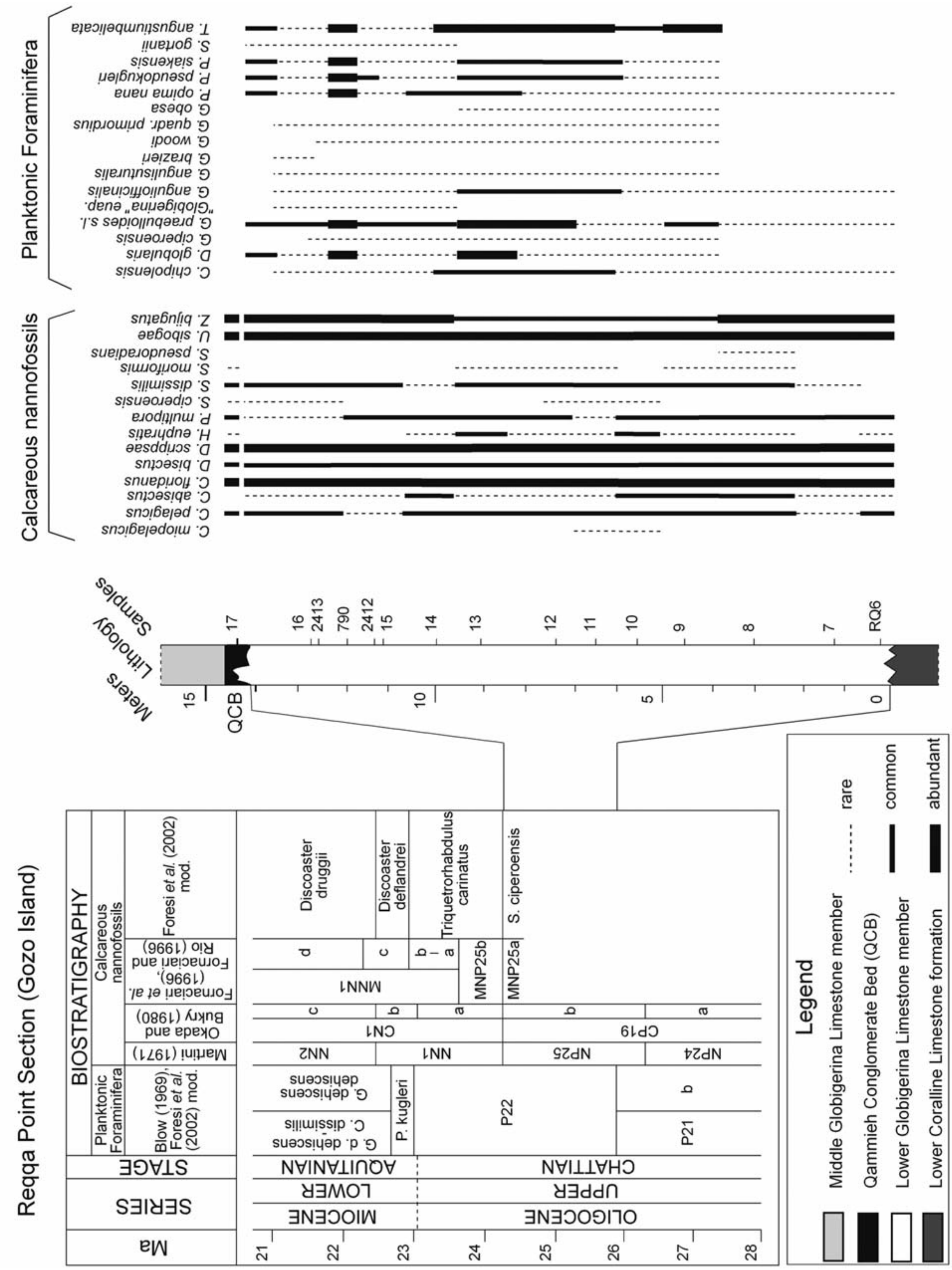
Twenty sections of the Lower Globigerina Limestone member of the Maltese Archipelago (twelve on Malta Island and eight on the Island of Gozo) were studied (Text-fig. 1). Although most of the sections were included in the earlier report by the authors (Foresi *et al.* 2007), all have been subsequently re-sampled. Further details on the sections are summarized in Tables 1 and 2 (in the Appendix).

BIOSTRATIGRAPHY

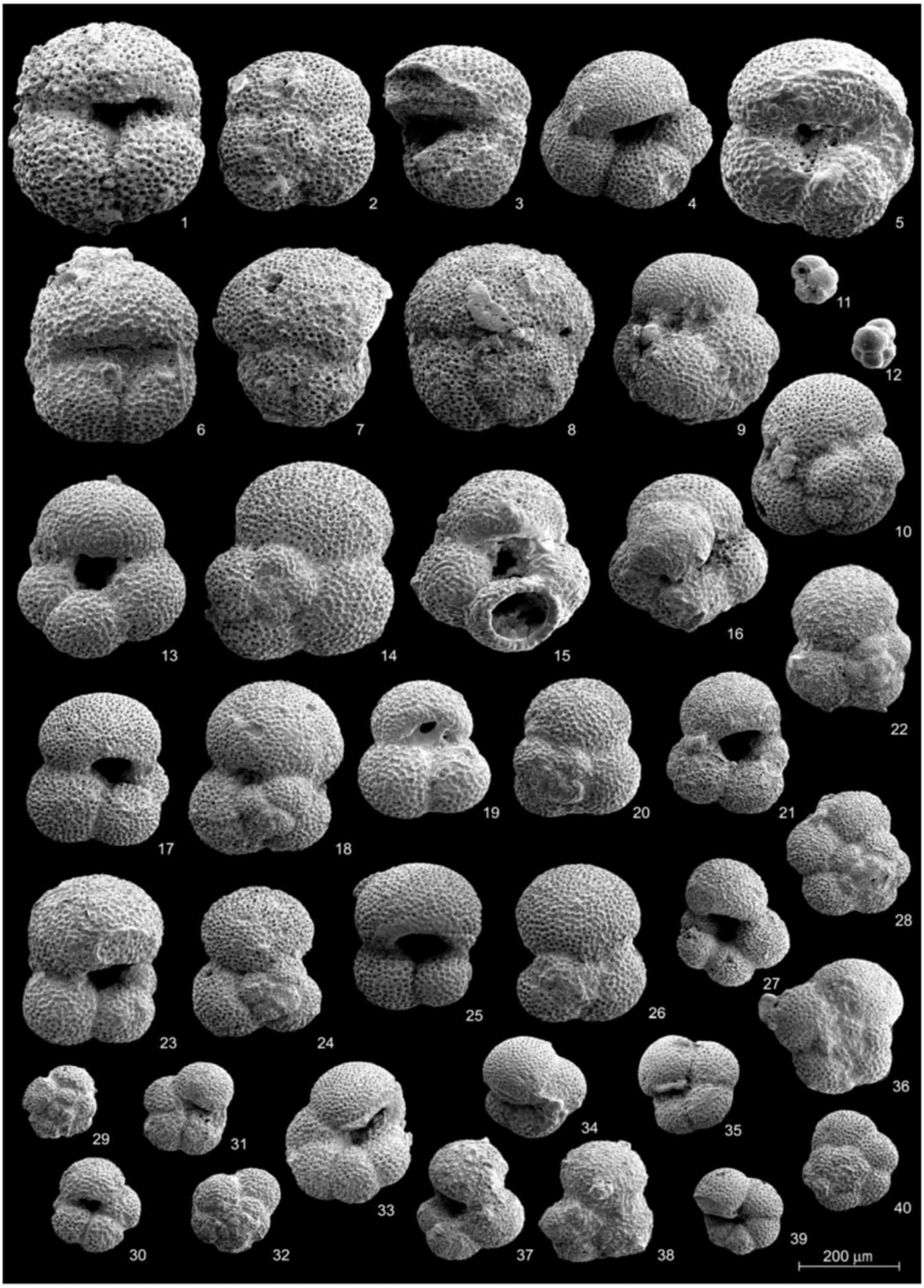
A semi-quantitative analysis was carried out on the planktonic foraminiferal and calcareous nannofossil assemblages (see Tables 3, 4, 5, 6 in the Appendix). Regarding the calcareous nannofossils, a quantitative analysis (a calculation of the percentage of each taxon in relation to a total of 300 specimens) was added for some sections (see Table 7 in the Appendix). The zonal schemes of Blow (1969), Martini (1971), Okada and Bukry (1980), Fornaciari *et al.* (1990), Fornaciari and Rio (1996) and Foresi *et al.* (2002) are compared and used in the biostratigraphic discussion (Text-figs 2, 3, 7).



Text-fig. 2 Semiquantitative calcareous plankton content of the Lower Globigerina Limestone member which crops out in the section of Qammieh (Malta Island). R – rare; C – common; A – abundant



Text-fig. 3 Semiquantitative calcareous plankton content of the Lower Globigerina Limestone member which crops out in the section of Reqqa Point (Gozo Island). R – rare; C – common; A – abundant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Planktonic foraminifera

The assemblages are generally of low diversity and represent a single biostratigraphic unit. All of the taxa identified are listed (genus-level taxonomy follows Iaccarino *et al.* 2005, with some exceptions) and their known stratigraphic ranges are expressed in terms of Blow's (1969) zonal scheme. The ranges of the taxa recognized through quantitative and semiquantitative analyses in the sections of Malta and Gozo islands are shown in Text-figs 2 and 3, and Tables 3 and 4; the critical forms are illustrated in Text-fig. 4.

Cassigerinella chipolensis (Cushman and Ponton, 1932): P17–N14 (N9 in the Mediterranean area, see Foresi *et al.* 2001). Common in many samples, rarely abundant (Text-fig. 4.11, 4.12).

Dentoglobigerina globularis (Bermúdez, 1961): P18–N6 (Last Occurrence (LO) occurring in Chron C6Bn.1r, at 22.8 Ma in Berggren *et al.* 1995). Often common or abundant (Text-fig. 4.13, 4.14).

Globigerina ciperoensis Bolli, 1954: P18–N4. According to ATNTS 2004 (Astronomical Tuned Neogene Time Scale; Gradstein *et al.* 2004a, b) the recalculated age estimate of the LO of *G. ciperoensis* is 22.90 Ma, which is within the earliest chronozone, N4, according to the timescales of both Berggren *et al.* (1995) and Gradstein *et al.* (2004a, b). Present in many samples, but only common in a few (Text-fig. 4.27, 4.28).

Globigerina praebulloides s.l., including the three subspecies *G. praebulloides leroyi* Blow and Banner, 1962 (P15–N8), *G. praebulloides occlusa* Blow and Banner, 1962 (P13–N21) (Text-fig. 4.23, 4.24) and *G. praebulloides praebulloides* Blow, 1959 (P15–N18) (Text-fig. 4.21, 4.22). Ubiquitous, and abundant in many samples.

"Globigerina" euapertura Jenkins, 1960: P15–P22 (N3) (up to N8?). Often common, rarely abundant (Text-fig. 4.2, 4.3).

"Globigerina" sellii Borsetti, 1959. (synonyms: *Globigerina clarae* Bermúdez, 1961; *Globigerina oligocaenica* Blow and Banner, 1962): P19–N6. Present in many samples, but common in only a few (Text-fig. 4.6, 4.7).

"Globigerina" tripartita Koch, 1926: P14–N6. Rare and only present in a few samples from some sections (Text-fig. 4.1).

Globigerinella obesa (Bolli, 1957): P19–Recent. Present, but rare, in many samples (Text-fig. 4.37, 4.38).

Globigerinoides quadrilobatus primordius Blow and Banner, 1962: from the base of P22 (N3) (from P21 in Biolzi 1985; Biolzi *et al.* 1981; Boersma and Premoli Silva 1991; Berggren *et al.* 1995 reported its First Occurrence (FO) in Chron C8r at 26.7 Ma) to N4 (up to N7?). It occurs in most samples, but is never abundant (Text-fig. 4.17, 4.18).

Globoturborotalita anguliofficinalis (Blow, 1969): P16–P22 (N4?). Ubiquitous and often common (Text-fig. 4.31, 4.32).

Globoturborotalita angulisuturalis (Bolli, 1957): base of P21 (N2) (P20 (N1) for Jenkins and Orr 1972)–P22 (N3) (N4?). Less frequent than its immediate predecessor *G. anguliofficinalis* (see Blow 1969) and rarely common (Text-fig. 4.29, 4.30).

Text-fig. 4. Planktonic foraminifera from the Lower Globigerina member of sections on the islands of Malta and Gozo, Maltese Archipelago. **1** – "*Globigerina tripartita*" Koch. Umbilical view; Dingli section, sample 3205; **2-5** – "*Globigerina euapertura*" Jenkins. 2 – spiral view; Forna Point section (M19), sample 3224. 3 – side view, Forna Point section (M19), sample 3219. 4 – umbilical view; Forna Point section (M19), sample 3216. **5** – umbilical view; Sliema Point section, sample 3209; **6-8** – "*Globigerina sellii*" Borsetti. 6 – umbilical view; Sliema Point section, sample 3210. 7 – side view, Marsaskala section, sample 3196. 8 – spiral view, Forna Point section (M32), sample 3200. **9-10, 15-16** – *Subbotina gortanii* (Borsetti). 9 – umbilical-side view; Sliema Point section, sample 3212. 10 – spiral view; Forna Point section (M32), sample 3200. 15 – umbilical view; Dingli section, sample 3203. 16 – umbilical view; Forna Point section (M32), sample 3200; **11-12** – *Cassigerinella chipolensis* (Cushman and Ponton). Sliema Point section. 11 – umbilical view; sample 3212. 12 – spiral view, sample 3211; **13-14** – *Dentoglobigerina globularis* (Bermùdez). Sliema Point section, sample 3209. 13 – umbilical view. 14 – spiral view; **17-18** – *Globigerinoides quadrilobatus primordius* Blow and Banner. Sliema Point section. 17 – umbilical view, sample 3212. 18 – spiral view, sample 3209; **19-20** – *Globoturborotalita woodi* (Jenkins). Sliema Point section, sample 3209. 19 – umbilical view. 20 – spiral view; **21-22** – *Globigerina praebulloides praebulloides* Blow. Reqqa Point section, sample 21 – umbilical view. 22 – spiral view; **23-24** – *Globigerina praebulloides occlusa* Blow. 23 – umbilical view, Sliema Point section, sample 3209. 24 – spiral view; Marsaskala section, sample 3194; **25-26** – *Globoturborotalita brazieri* (Jenkins). Sliema Point section, sample 3209. 25 – umbilical view. 26 – spiral view; **27-28** – *Globigerina ciperoensis* Bolli. 27 – umbilical view; Sliema Point section, sample 3209. 28 – spiral view; Dingli section, sample 3207; **29-30** – *Globoturborotalita angulisuturalis* (Bolli). 29 – spiral view; Reqqa Point section, sample 2410: 30 – umbilical view; Dingli section, sample 3207; **31-32** – *Globoturborotalita anguliofficinalis* (Blow). Sliema Point section, sample 3209. 31 – umbilical view. 32 – spiral view; **33** – *Paragloborotalia siakensis* (LeRoy). Umbilical view; Sliema Point section, sample 3212; **34-36** – *Paragloborotalia opima nana* (Bolli). Sliema Point section. 34 – umbilical view, sample 3210. 35 – umbilical view, sample 3210. 36 – spiral view, sample 3212. **37-38** – *Globigerinella obesa* (Bolli). 37 – umbilical view; Xlendi section, sample MT13. 38 – spiral view; Debrani section, sample 3179; **39-40** – *Paragloborotalia pseudokugleri* (Blow). Sliema Point section, sample 3209. 39 – umbilical view. 40 – spiral view

Globoturborotalita brazieri (Jenkins, 1966): P22 (N3)-N8. Present in several samples, but only common or abundant in a few sections (Text-fig. 4.25, 4.26).

Globoturborotalita woodi (Jenkins, 1960): P18–N23. Present in several samples, but only common in a few (Text-fig. 4.19, 4.20).

Paragloborotalia opima nana (Bolli, 1957): P13–P22 (N3) (up to N12?). Its LO is dated at 21.7 Ma by Miller *et al.* (1985) and at 22.6 Ma by Zhang *et al.* (1993). However, both these ages fall within the N4 chronozone (fide Berggren *et al.* 1995 and Gradstein *et al.* 2004a, b). Ubiquitous, often common or abundant (Text-fig. 4.34–4.36).

Paragloborotalia pseudokugleri (Blow, 1969): FO in the lower half of P22 (N3) (at 25.9 Ma according to Berggren *et al.* 1995; at 26.3 Ma in Pearson and Chaisson 1997); LO in N4 (at 21.6 Ma according to Berggren *et al.* 1995; at 21.31 Ma in Gradstein *et al.* 2004a). Ubiquitous, often common or abundant (Text-fig. 4.39, 4.40).

Paragloborotalia siakensis (LeRoy, 1939): P19–N14. Well represented in many samples (Text-fig. 4.33).

Subbotina gortanii (Borsetti, 1959): P15–N4. Present in many samples, but common in only a few sections (Text-fig. 4.9, 4.10, 4.15, 4.16).

Tenuitellinata angustiumbilicata (Bolli, 1957). Recorded from P16 to the Pleistocene. According to Li *et al.* (1992), who carried out an analysis of tenuitellid stock ranges from oceanic sites, the LO of this species occurred at the top of N5. Ubiquitous and generally abundant.

Tenuitellinata uvula (Ehrenberg, 1861): P21 (N2) – Recent. Very rare and present in only one section.

The planktonic foraminifera allow the studied succession of the Lower Globigerina Limestone member to be assigned to the P22 (N3) Zone. The main arguments are as follows: (i) *Paragloborotalia opima nana*, which occurs in the Lower Globigerina Limestone member, is a direct successor of *P. opima opima* (Bolli), whose LO marks the P21 (N2)/P22 (N3) zonal boundary; and (ii) the FO of *Paragloborotalia kugleri* (Bolli), which marks the P22 (N3)/N4 zonal boundary, as emended by Berggren and Miller (1988; see also Berggren *et al.*1995), is above the top of the Lower Globigerina Limestone member. Only *P. pseudokugleri*, the immediate ancestor of *P. kugleri* (Blow 1969; Spezzaferri *et al.* 1991, among others), is present in the Lower Globigerina Limestone member.

In addition to these arguments, the planktonic foraminifera from the Lower Globigerina Limestone member include elements that substantiate the biostratigraphic assignment of the member to the P22 (N3) Zone. Moreover, they suggest that the member represents rather the lower part of the zone, with its upper part undocumented. The following arguments are of importance: (i) the presence of taxa with their FOs almost at the base (*Globigerinoides quadrilobatus primordius*) or at least in the lowermost part (*Paragloborotalia pseudokugleri*) of the P22 (N3) Zone (*Globoturborotalita obesa, G. woodi, G. brazieri, Tenuitellinata uvula*); (ii) the presence of taxa characterized by their LO at the base of the P22 (N3) Zone (*Globoturborotalita angulioﬃcinalis, Subbotina gortanii gortanii*). The latter species, which also occur in the upper part of the sections, make it possible to restrict the stratigraphic range of the Lower Globigerina Limestone member to the lower part of the zone; (iii) the upper portion of the P22 (N3) Zone is additionally excluded by the occurrence of a low number of *Globigerinoides quadrilobatus primordius* specimens (relatively common only in one level of the Xlendi section and in some samples of the Sliema and Marsaskala sections); in fact, this taxon is recorded as being abundant only in the upper part of this zone.

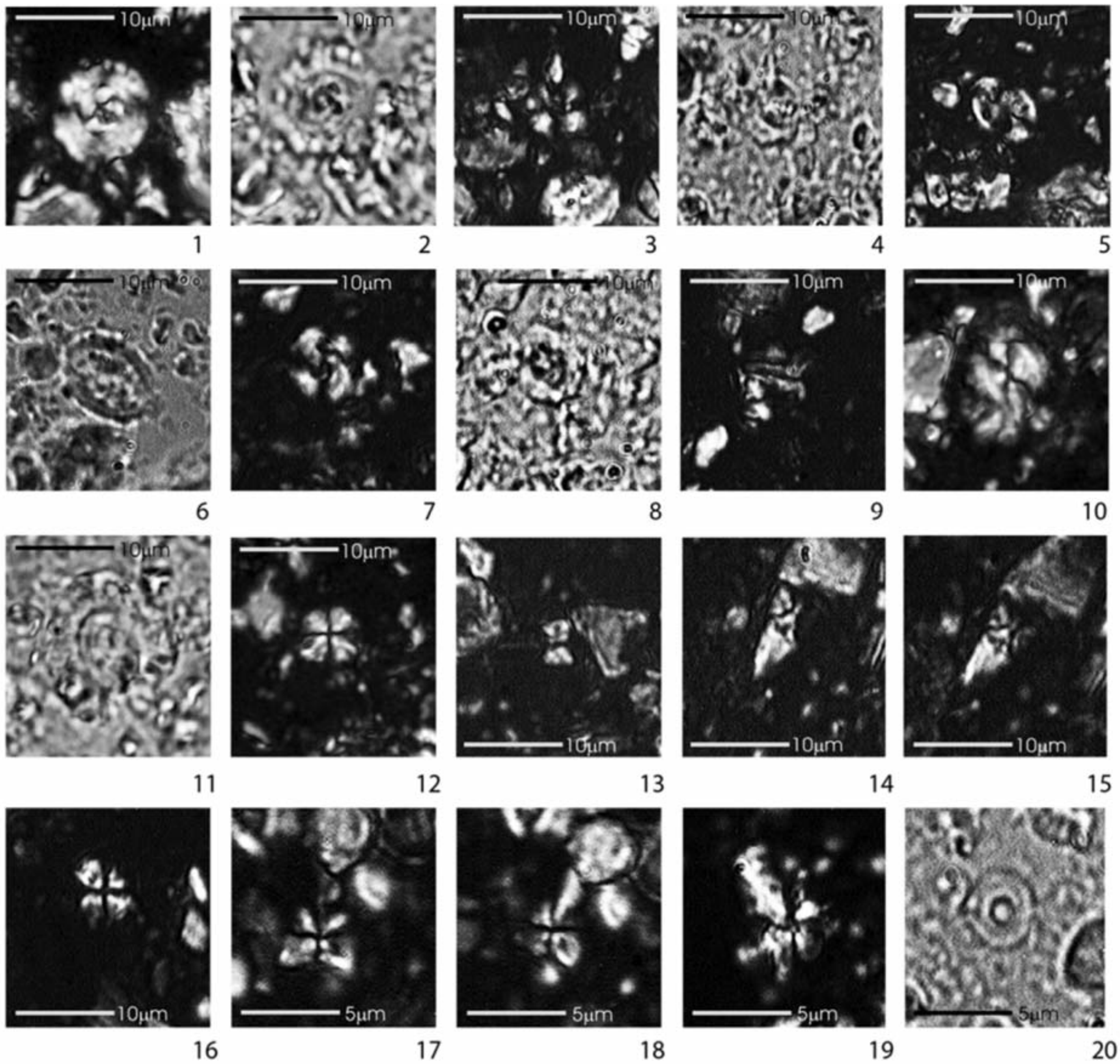
Calcareous nannofossils

Calcareous nannofossils were found in all of the samples studied. The assemblages are rather poor taxonomically and have highly variable states of preservation. The taxa recognised are listed in Text-figs 2 and 3 and in Tables 5, 6 and 7; the critical forms are illustrated in Text-fig. 5.

Coccolithus pelagicus, *Cyclicargolithus floridanus, Dictyococcites scrippsae, Pontosphaera multipora, Sphenolithus dissimilis, Umbilicosphaera sibogae* and *Zygrhablithus bijugatus* are generally common to abundant in almost all of the sections; *Dictyococcites bisectus* and *Helicosphaera euphratis* are rare; *Cyclicargolithus abisectus* and *Helicosphaera obliqua* are present in many samples but with a limited number of specimens; all other taxa are rare, sporadic, or very rare (see Tables 5, 6 and 7 in the Appendix).

Although no significant biostratigraphic events were found within the Lower Globigerina Limestone member, the calcareous nannofossils allow the studied succession to be assigned to the NP25 Zone. The critical arguments are as follows: (i) the co-occurrence of *Cyclicargolithus abisectus*, *Dictyococcites bisectus*, *D. scrippsae*, *Helicosphaera recta* and *Zygrhablithus bi-*

jugatus is commonly indicative of Martini's (1971) NP24–NP25 interval (see Martini 1971; Bukry 1973, 1975, 1978; Martini and Muller 1986; Muller 1976; Bizon and Muller 1979; Perch-Nielsen 1985; Fornaciari *et al.* 1990, among others); (ii) in Martini's (1971) standard zonation, the FO of *Sphenolithus ciperoensis* marks the base of the NP24 Zone, while the LO of the same taxon marks the top of the NP25 Zone. Both the FO and LO of *S. ciperoensis* are also used in the low latitude zonation of Okada and Bukry (1980), to identify the lower and upper boundaries (respectively) of the CP19 Zone. Furthermore, this taxon is well documented in the Mediterranean (e.g., Catalano and Di Stefano 1996; Fornaciari and Rio 1996; among others); (iii) the LO of *Sphenolithus distentus* defines the boundary between the NP24 (CP19a Subzone) and the NP25 (CP19b Subzone) zones; (iv) *S. dissimilis* evolves from *S. moriformis* in the late NP24 Zone and continues up to the middle–late NN2 Zone (Perch-Nielsen 1985); (v) the FO of *Pontosphaera enormis* and *Triquetrorhabdulus carinatus* are



Text-fig. 5. Calcareous nannofossils from the Lower Globigerina Limestone member of sections on the islands of Malta and Gozo, Maltese Archipelago. **1-2** – *Cyclicargolithus abisectus* (Muller), crossed and parallel nicols, sample MH6, Qammieh section; **3-4** – *Cyclicargolithus floridanus* (Bukry), crossed and parallel nicols, sample BL5, Il Blata section. **5-6** – *Pontosphaera multipora* (Kamptner), crossed and parallel nicols, sample BL3, Il Blata section; **7-8** – *Dictyococcites scrippsae* (Bukry and Percival), crossed and parallel nicols, sample MH8, Qammieh section; **9** – *Zygrhablithus bijugatus* (Deflandre), crossed nicols, sample BL5, Il Blata section; **10-11** – *Coccolithus miopelagicus* (Wallich), crossed and parallel nicols, sample BL5, Il Blata section; **12** – *Sphenolithus moriformis* (Bronnimann and Stradner), crossed nicols, sample MH8, Qammieh section; **13-15** – *Sphenolithus ciperoensis* (Bramlette and Wilcoxon), 0°, 20°, 45°, crossed nicols, sample MH6, Qammieh section; **16** – *Sphenolithus dissimilis* (Bukry and Percival), crossed nicols, sample BL5, Il Blata section; **17-19** – *Sphenolithus delphix* (Bukry), 0°-20°-45°, crossed nicols, sample MH6, Qammieh section; **20** – *Umbilicosphaera* sp., parallel nicols, sample BL3, Il Blata section close to the NP24/NP25 boundary (Martini 1981; Perch-Nielsen 1985). According to these authors, the FO of *P. enormis* can also be used to define the base of the NP25 Zone in high latitudes or in areas with poor connections to the open ocean.

Summarising, the constant and abundant presence of *Dictyococcites bisectus*, *D. scrippsae*, *Sphenolithus dissimilis* and *Zygrhablithus bijugatus*, as well as the rare to very limited occurrence of *S. ciperoensis*, *Helicosphaera recta*, *Pontosphaera enormis* and *Triquetrorhabdulus carinatus*, and the absence of *S. distentus*, allow all the sections studied to be assigned to NP25 Zone, excluding, most probably, its uppermost and lowermost parts.

This biostratigraphic result based on calcareous nannofossils agrees well with those obtained from the planktonic foraminifera (see Text-figs 2 and 3).

To clarify the biostratigraphic attribution, it was decided to highlight the calcareous plankton content (for calcareous nannofossils it is considered very rare to rare if it is <3%; common, between 3% and 10%; and abundant if it is >10%) of two sections (one located in Malta and one in Gozo) where the Lower Globigerina Limestone member is relatively thick and its base and top can be observed (Text-figs 2 and 3).

CHRONOSTRATIGRAPHY

The dating of the Maltese sections to the lower part of the foraminiferal P22 (N3) Zone and to the nannofossil NP25 Zone (probably with the exception of its upper and lowermost parts) definitely establishes the Chattian age of the Lower Globigerina Limestone member (Text-figs 2 and 3). This historically shared correspondence between the P22 (N3) (almost all) and NP25 zones and the Chattian age has recently been referred by the International Union of Geological Sciences (IUGS), through the acceptance of the Global Stratotype Section and Point (GSSP) for the base of the Neogene Period (that is the Oligocene/Miocene, as well as the Chattian/Aquitanian boundary) proposed by Steininger *et al.* (1997). The GSSP of the Paleogene/Neogene Period-System boundary was placed 35 m from the top of the Lemme-Carrosio Section in the Pedimont Basin (northern Italy), close to the base of Subchron C6Cn.2n, dated at 23.80 Ma (according to the Time Scale of Berggren *et al.* 1995). Billups *et al.* (2004) subsequently proposed a revised age of 23.03 Ma for this boundary and it was also reported in the Astronomically Tuned Neogene Time Scale (ATNTS) (Gradstein *et al.* 2004a, b). From a biostratigraphic viewpoint (see also Aubry and Villa 1996; Iaccarino *et al.* 1996; Steininger *et al.* 1996, 1997) the Oligocene/Miocene boundary is located in the uppermost part of the P22 (N3) Zone (2 m below the FO of *Paragloborotalia kugleri* s.s.) and in the NN1 Zone (MNN1b Subzone of Fornaciari and Rio 1996), close to the FO of *Sphenolithus capricornutus* and below the LO of *Sphenolithus delphix*.

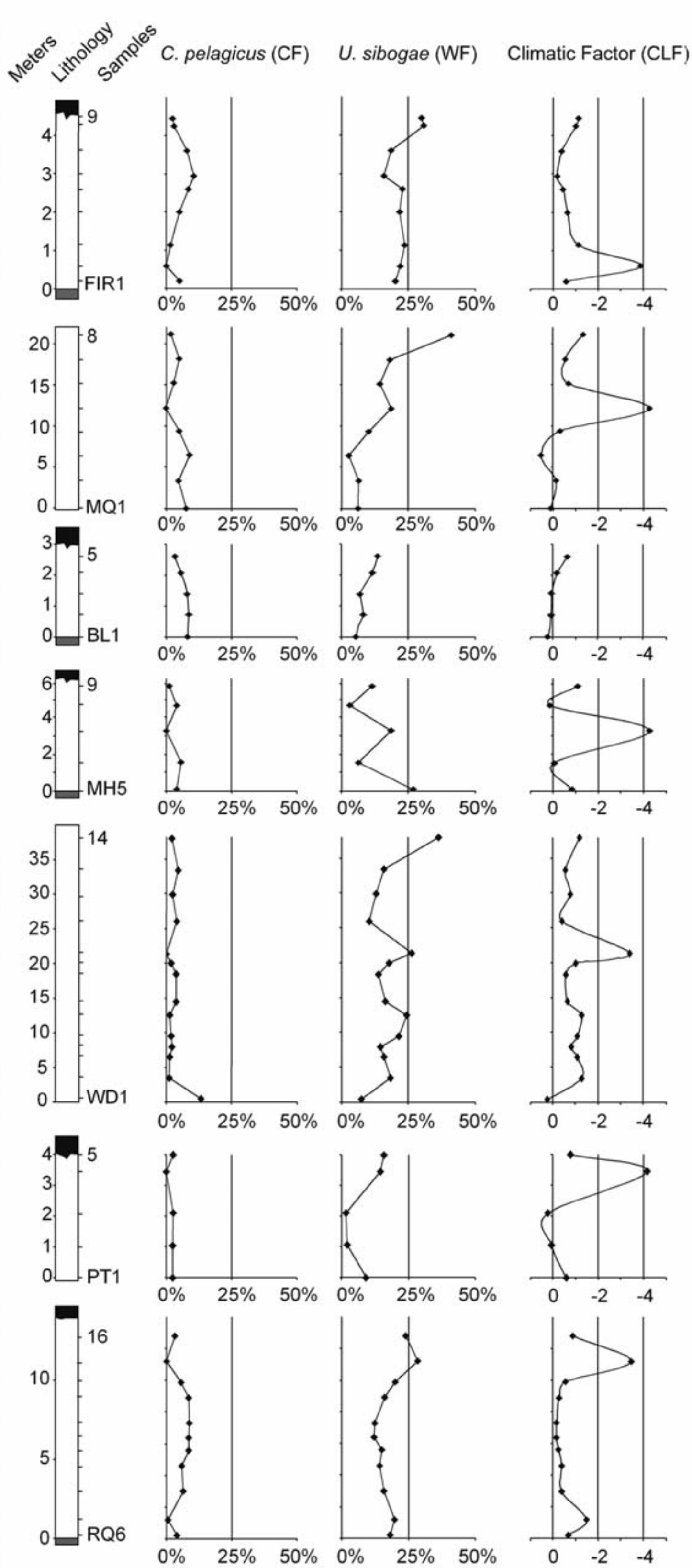
CLIMATE-STRATIGRAPHIC APPROACH

The quantitative analysis of the nannofossil assemblages (see Table 7 in the Appendix), carried out on selected sections (Island of Gozo: Reqqa Point and Wardija Point; Malta Island: Qammieh, Fomm Ir-Rih, Wied id Dis, Huttaf Gandolf and Il Blata), was the basis for a climate-stratigraphic approach.

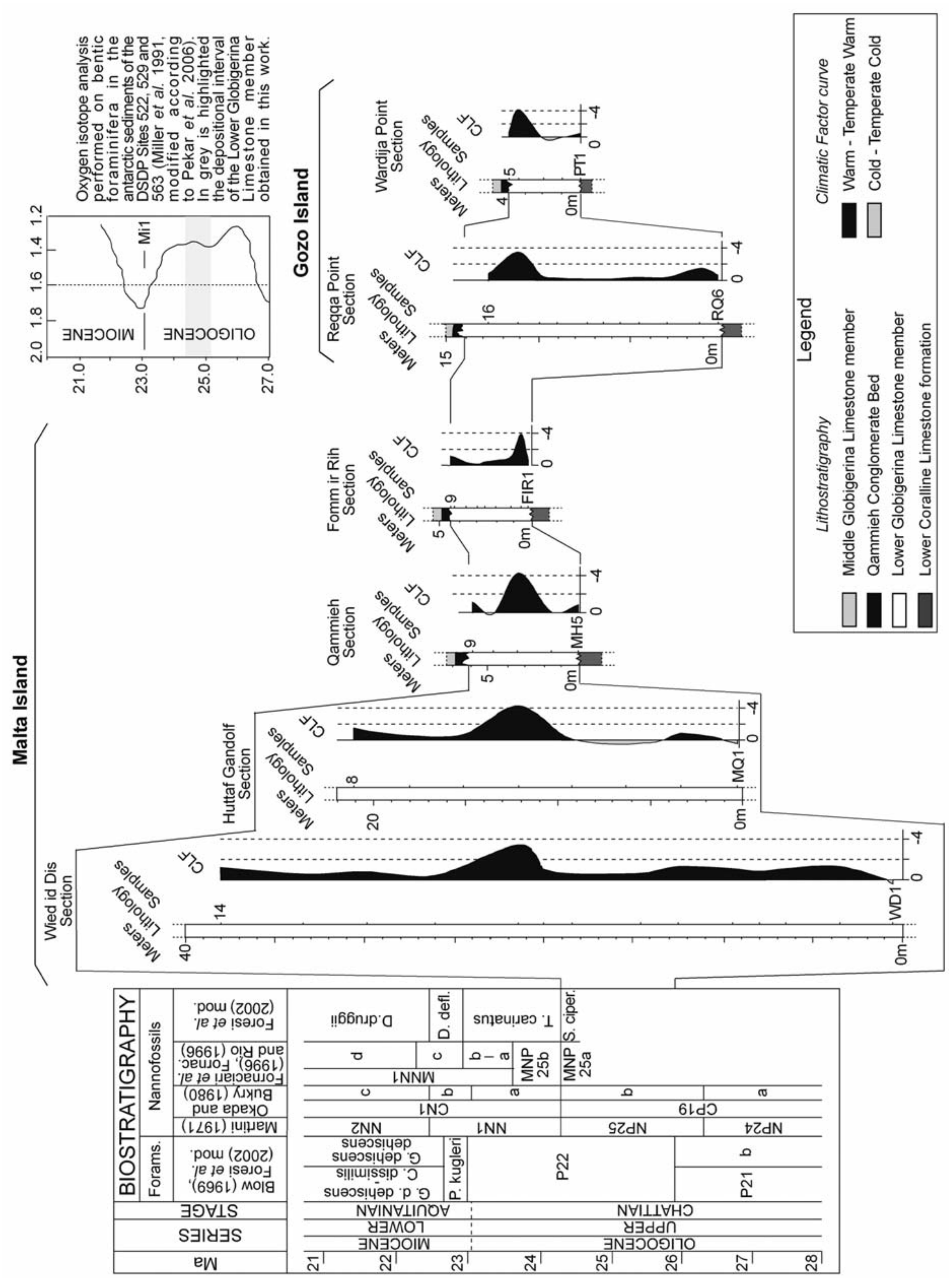
Of the nannofossil taxa recognised in the sections studied, two extant forms were selected: the species *Coccolithus pelagicus* (<11 µm) and the genus *Umbilicosphaera*. Both show very strict surface water temperatures preferences (Hasle 1960; Black 1965; McIntyre and Bè, 1967; McIntyre *et al.* 1970; Bartolini *et al.* 1970; Okada and Honjo 1973; Roth and Berger 1974; Geitzenauer *et al.* 1976; Haq and Lohmann 1976; Braarud 1979; Okada and McIntyre 1979; Haq 1980; Roth and Coulbourn 1982; Zhang and Siesser 1986; Kleijne *et al.* 1989; Honjo 1990; Sambleten and Schroeder 1992; Brand 1994; Winter *et al.* 1994; Baumann 1995; Wells and Okada 1996; Andruleit 1997; Flores *et al.* 1997, 1999; Findlay and Flores 2000; Geisen *et al.* 2002, 2004; Saez *et al.*, 2003; Sato *et al.* 2004; Hagino and Okada 2006; Marino *et al.* 2008; Bonnet *et al.* 2010). *Coccolithus pelagicus* (between 6 and 11 µm in dimensions, which Geisen *et al.* 2002, 2004 defined as *C. pelagicus* subsp. *pelagicus* and Saez *et al.* 2003 raised to the rank of species) characterizes the living assemblages of the Transitional and Subarctic floral zones; its optimum temperature is between 8° and 10°C (McIntyre and Bè 1967; McIntyre *et al.* 1970) in the Atlantic Ocean, and between 9° and 12°C (Roth and Berger 1974) in the Pacific Ocean. The genus *Umbilicosphaera* characterizes oceanic areas of Tropical and Subtropical zones where the sea surface temperature ranges between 24° and 28°C.

Based on temperature preferences of its modern counterparts *Coccolithus pelagicus* (<11 µm) and the genus *Umbilicosphaera* were selected as key species for the recognition of cold and warm surface waters respectively. Consequently, their relative abundance in relation to the total assemblages was used to construct Cold Factor (CF) and Warm Factor (WF) curves. An opposing trend of the two factors is generally evident (Text-fig. 6), thus proving the validity of the choice of these two

Samples	*C. pelagicus* (CF)	*U. sibogae* (WF)	CLIMATIC FACTOR
	Fomm ir-Rih		
FIR1	5.40%	20.03%	-0.6
FIR2	0.00%	21.89%	-3.86
FIR3	1.69%	23.54%	-1.14
FIR4	4.98%	21.76%	-0.64
FIR5	8.48%	22.80%	-0.43
FIR6	10.40%	15.86%	-0.19
FIR7	7.81%	18.48%	-0.37
FIR8	2.99%	30.76%	-1.01
FIR9	2.26%	29.86%	-1.12
	Huttaf Gandolf		
MQ1	7.60%	5.97%	0.10
MQ2	4.68%	6.25%	-0.13
MQ3	8.86%	2.53%	0.54
MQ4	5.00%	10.00%	-0.30
MQ5	0.00%	18.51%	-4.27
MQ6	2.85%	14.28%	-0.70
MQ7	5.04%	18.06%	-0.55
MQ8	1.95%	41.02%	-1.32
	Il Blata		
BL1	8.33%	5.20%	0.20
BL2	8.20%	6.90%	0.07
BL3	7.87%	6.79%	0.06
BL4	6.50%	12.65%	-0.29
BL5	3.26%	13.40%	-0.61
	Qammieh		
BL1	3.92%	26.62%	-0.83
BL2	5.55%	6.34%	-0.06
BL3	0.00%	18.49%	-4.27
BL4	4.08%	3.06%	0.12
BL5	0.94%	11.37%	-1.08
	Wied id Dis		
WD1	13.27%	7.40%	0.25
WD2	0.94%	18.23%	-1.29
WD3	1.33%	16.00%	-1.08
WD4	2.24%	14.60%	-0.81
WD5	1.77%	21.35%	-1.08
WD6	1.24%	24.29%	-1.29
WD7	3.70%	16.40%	-0.65
WD8	3.61%	13.67%	-0.58
WD9	1.72%	17.73%	-1.01
WD10	0.00%	26.08%	-3.42
WD11	4.07%	10.29%	-0.40
WD12	2.25%	13.00%	-0.76
WD13	4.51%	15.78%	-0.54
WD14	2.12%	32.62%	-1.19
	Wardija Point		
WD1	2.50%	9.10%	-0.56
WD2	2.40%	2.00%	0.08
WD3	2.70%	1.60%	0.23
WD4	0.00%	14.60%	-4.16
WD5	2.70%	15.70%	-0.76
	Reqqa Point		
RQ6	3.84%	18.26%	-0.68
RQ7	0.62%	19.62%	-1.50
RQ8	6.35%	15.71%	-0.39
RQ9	5.70%	14.25%	-0.40
RQ10	8.29%	14.97%	-0.26
RQ11	8.29%	12.22%	-0.17
RQ12	8.59%	12.50%	-0.16
RQ13	8.35%	16.07%	-0.28
RQ14	5.56%	20.04%	-0.56
RQ15	0.00%	28.44%	-3.45
RQ16	3.24%	24.05%	-0.87



Text-fig. 6 Climate-stratigraphic framework of Lower Globigerina Limestone member



Text-fig. 7 Reconstruction of the Cold Factor (CF), Warm Factor (WF) and Climatic Factor (CLF) curves relative to the chosen sections. In figure, the Lower Coralline Limestone formation is indicated in light grey colour, the Lower Globigerina Limestone member in white and the Qammieh Conglomerate Bed in black colour taxa as climate indicators. The ratio between the percentages of CF and WF (represented in logarithmic form in order to highlight the negative values) was considered indicative of the Climatic Factor (CLF): high and low CLF values represent evidence of "cooling" and "warming" conditions respectively (Text-fig. 6).

Although the sampling performed is not adequate to define a climatic curve, it seems important to remember that all the CLF values are consistently negative and show no significant increase in any direction; consequently, the Lower Globigerina Limestone member can only have been deposited in the warm climatic phase of the oxygen isotope curve of Miller *et al.* (1987, 1989, 1991a, b, 2005) which follows the Oi2c event (according to Pekar *et al.* 2006 this $\delta^{18}O$ event can be dated at about 25.1 Ma) and precedes the beginning of the cooling trend that culminates in the Mi1 event (Raffi *et al.* 2006, based on the calibration of the oxygen isotope curves of Zachos *et al.* 2001 and Billups *et al.* 2004 with the Astronomical Tuned Neogene Time Scale of Lourens *et al.* 2004, date this beginning at about 23.4 Ma).

By combining the obtained biostratigraphic data (lower part of the P22 (N3) Zone, the CLF curve and the reference isotope curve of Miller *et al.* (1991b modified according to Pekar *et al.* 2006), it is possible to define more accurately the time interval for the deposition of the member (Text-fig. 7). This deposition should start after 25.1 Ma (see above) and end well before 24.3 Ma (age estimated by Raffi *et al.* 2006 for the upper boundary of the NP25 Zone).

The obtained CLF curves were further applied to an attempt at fine-stratigraphic inter-correlation of particular sections (Text-fig. 7). In Text-fig. 7, it is shown that, although the sections are biostatigraphically referred to the same zone, their chronostratigraphic range within this zone varies. This is also supported by precise comparison of quantitative data from planktonic foraminifera and calcareous nannofossils (see Tables 3, 4, 5, 6 and 7 in the Appendix).

CONCLUSIONS

The planktonic foraminiferal and calcareous nannofossil assemblages of the Lower Globigerina Limestone member of the Maltese Archipelago have confirmed that the member belongs to the lower part of the planktonic foraminiferal P22 (N3) Zone of Blow (1969) and to the nannofossil NP25 Zone of Martini (1971) (with the exception of its uppermost and lowermost parts). Consequently, the member is of late Chattian age.

A climate-stratigraphic approach based on quantitative analyses of calcareous nannofossil assemblages was applied to two sections on Gozo Island (Reqqa Point and Wardija Point) and five sections on Malta Island (Qammieh, Fomm Ir-Rih, Il Blata, Wied id Dis and Huttaf Gandolf). The species *Coccolithus pelagicus* (with diameter <11 µm) and the genus *Umbilicosphaera* were selected as key forms for the recognition of cold and warm surface waters respectively. The ratio of the percentages of these taxa enabled the construction of the Climatic Factor (CLF) curve.

All samples in the Lower Globigerina Limestone member provided CLF values consistent with a warm climatic phase which should be related to the Chattian heating documented by the oxygen isotope curve of Miller *et al.* (1987, 1989, 1991a, 1991b, 2005). In particular, our CLF curve matches well the portion of the Miller *et al*. curve above the Oi2c event ($\delta^{18}O$ event highlighted by Pekar and Miller 1996; Sugarman *et al.* 1997; Shackleton *et al.* 1999; Pekar *et al.* 2002, 2006 and Miller *et al.* 2005) and below the beginning of the cooling trend that culminates in the Mi1 event. Based on the studies of Pekar *et al.* (2006) and Raffi *et al.* (2006), it is possible to date the two climatic events at about 25.1 Ma and 23.4 Ma respectively. Consequently, this is the time assumed for the deposition of the Lower Globigerina Limestone member.

Further clarification of the timing of the end of deposition of the Lower Globigerina Limestone member is implicitly provided by the biostratigraphic attribution based on the nannofossil assemblages; in fact, the recognition of the NP25 Zone (with the exception of its uppermost and lowermost parts) enables this sedimentary event to be dated well before 24.3 Ma (age estimated by Raffi *et al.* 2006 for the upper boundary of the NP25 Zone). Indirect confirmation in this sense comes from the study of Föllmi *et al.* (2008), which provides an age ranging from 23.5 to 22.0 Ma for the overlying "Lower Main Phosphate Bed" (the "Qammieh Conglomerate Bed" of Rose *et al.* 1992). It is also worth recalling the age of 24.54 ± 0.8 Ma provided by Jacobs *et al.* (1996) for the Qammieh Conglomerate Bed.

The obtained CLF curve also appeared a very useful tool in a refined chronostratigraphic inter-correlation of particular sections. Based on the characteristics of the CLF curve (supported partly by quantitative micropalaeontological data), it can be inferred that particular sections of the Lower Globigerina Limestone member, although referable to a single biostratigraphic zone, represents various actual ranges. This suggests distinct sedimentary environments during the deposition of the Lower Globigerina Limestone member throughout the entire archipelago.

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APPENDIX

GOZO ISLAND

SECTIONS	LOCATION	THICKNESS OF LGLm	SAMPLES	REMARKS
Reqqa Point (Section 12 in Giannelli and Salvatorini 1972 and in Foresi *et al*. 2007)	Western side of Reqqa Point, along the northern coast of Gozo Island, 2 km WNW of Marsalforn	14 m	25 .	The succession composed of (from bottom to top): **(a)** upper part of the LCLf (including the "ScutellaBed")up to the TLCLHg; **(b)** the LGLm (with its phosphatized base) up to the TLGLHg; **(c)** the QCB, 30-50 cm thick. In its lower part (7 m thick), the LGLm is brown-yellow in colour, medium-size grained, very rich in bioturbation and with abundant *Scutella* in the first 1.50 m. Its upper half is light yellow in colour, friable, marly and with abundant *Flabellipecten* (concentrated in a medium level) and echinoids. The hardground at the top (less than 1 m thick) is hardly phosphatized
Forna Point (M19 and M32 sections of Foresi *et al.* 2007)	Along the northern coast of Gozo Island	14 m	36 ..	The succession composed of (from bottom to top): **(a)** the upper part of the LCLf up to the TLCLHg; **(b)** the LGLm (with its phosphatized base) up to the TLGLHg; **(c)** the QCB, 30-50 cm thick. The LGLm crops out with thickness and lithological features very similar to those of the Reqqa Point section
Santa Lucija	4 km NW of Santa Lucija, by the side of the road climbing from Wied Ilma up to in the Ghajn Abdul hill	14 m	8	The succession composed of (from bottom to top): **(a)** the upper part of the LGLm; the member is well diagenized, finely grained, yellowish in colour and characterized by bioturbations and bivalves. **(b)** A not well evident in outcrop TLGLHg; **(c)** the QCB, 20-40 cm thick.
Dabrani (Section 15 in Giannelli and Salvatorini 1972 and in Foresi *et al*. 2007)	Along the Marsalforn Valley, on the South-eastern flank of Dabrani hill	16 m	6	The succession composed of the LGLm. The unit starts above the phosphatized base for about 16 m; the "Scutella Bed" crops out in the lowermost part. At present, the LGLm sediments are widely covered with detritus and vegetation. Giannelli and Salvatorini (1972) report that the succession of the member is alike the foregoing sections
Wardija Point	North-western coast of Gozo Island, WNW of Xlendi Bay and just South of Wardija Point	4 m	5	The succession composed of the upper part of the LGLm up to the TLGLHg; the QCB crops out for 30-40 cm
Xlendi (Section 17 in Foresi *et al*. 2007)	South-western coast of Gozo Island, just South of Xlendi Bay	22 m	10 ...	The succession composed of (from bottom to top): **(a)** upper part (7-8 m above sea level) of the LCLf with abundant, large-size *Lepidociclina*, common pectinids, and rare *Scutella*; **(b)** the LGLm up to the TLGLHg; **(c)** the QCB, 30-50 cm thick. The LGLm shows a lowermost part (50 cm thick) composed of a yellow-ocre, coarse-grained limestone, rich in *Scutella* and bryozoans. Also present are others bivalves, echinoids, gasteropods and bioturbations. The 14 m of overlying hard sediments are medium-coarse grained, brown in colour, with abundant *Flabellipecten* particularly at the top. Above, for 7.5 m, the member is more friable and marly, yellowish, with rarer bioturbations and rich in echinoids and pectinids. At the top, the TLGLHg is 40-50 cm thick, with numerous *Thalassinoides* burrows, (filled with phosphatic elements in light matrix)
Dahlet Qorrot	Along the North-eastern coast of Gozo, just South of the homonymous locality	5m	4	The succession composed of the upper part of the LGLm up to the TLGLHg; the LGLm is well cemented, with medium-fine grained deposits, yellowish in colour, rich in *Flabelli-pecten* and echinoids in the upper part. The TLGLHg is 70 cm thick. The QCB, up to 60 cm thick, characterized by phosphatic elements up to 20-30 cm in diameter
Ras-il-Hobz	Just West of Ras-il-Hobz, on the southern coast of Gozo and East of Mgarr Ix-Xini	9 m	5	The succession composed of (from bottom to top): **(a)** the LGLm (with the exception of itslowermost deposits) with many bioturbations and, in the lower part, common *Scutella* (6 m thick). In the upper part, about 2 meters thick, Fla*bellipecten* and echinoids occur up to the TLGLHg (70-80 cm thick); **(b)** the QCB is about 20-30 cm thick

. 14 samples for foraminifera. + 11 samples for calcareous nannofossils
.. 17 samples for foraminifera + 19 samples for calcareous nannofossils
... 10 samples for foraminifera + 7 samples for calcareous nannofossils

Table 1. Location, thickness of Lower Globigerina Limestone member, number of collected samples and main lithostratigraphic features of the studied sections on Gozo

MALTA ISLAND				
SECTIONS	**LOCATION**	**THICKNESS OF LGLm**	**SAMPLES**	**REMARKS**
Qammieh	Along the north-western coast of Malta Island, at Rdum il-Qammieh	9.50 m	5	The succession composed of (from bottom to top): **(a)** the upper part (3.50 m thick) of LCLf (very rich in large *Lepidociclina*); 3 hardgrounds (10 cm, 15-30 cm and 20-30 cm thick respectively, with the highest one representing the TLCLHg, with common *Scutella*, *Flabellipecten*, other bivalves and bryozoans; **(b)** the LGLm (with phosphatized base) up to TLGLHg; **(c)** the QCB 40-50 cm thick. LGLm (6 m thick) with lower part characterized by many bio-turbations and abundant bryozoans, pectinids and common *Scutella* (in lowermost 3 m of the unit), and an upper part with abundant pectinids and echinoids. Upwards (at 2/3 from the base) the member becomes light yellow, poorly bioturbated and more friable. Higher up there is a hardground, with phosphatic elements and pectinids. Other discontinuty surfaces are present at the top of TLGLHg
Fomm-ir-Rih (Section M14 in Foresi *et al*. 2007)	Most internal part of Fomm-ir-Rih Bay, almost at the mouth of Wied Gerzuma, just near the "Victoria lines Fault"	4.50 m	16 .	The succession composed of (from bottom to top): **(a)** the uppermost part of LCLf (very rich in foraminifera, bryozoans and echinoids) up to the TLCLHg (with planar phosphatized upper surface); **(b)** the LGLm up to TLGLHg; **(c)** QCB 20-35 cm thick. LGLm characterized by bioturbations and abundant bryozoans, pectinids and echinoids
Il-Blata (Section 6 in Giannelli and Salvatorini 1972 and in Foresi *et al.* 2007)	Along the western coast of Malta Island, about 1 Km SW of Fomm-ir-Rih Section	3.40 m	8 ..	The succession composed of (from bottom to top): **(a)** the uppermost part of LCLf up to the TLCLHg; **(b)** the LGLm (with phosphatized base) up to the TLGLHg; **(c)** the QCB 20-100 cm thick. The LGLm characterized by abundant bryozoans and and numerous bioturbations, echinoids and pectinids; the latter concentrated in the lower and upper part. *Scutella* is abundant in the lowermost part
Mthaleb (Section 4 in Giannelli and Salvatorini 1972 and in Foresi *et al.* 2007)	Mthaleb area, just North of Il-Qaws (NW of Dingli, Malta Island)	1.30 m	1 ...	The succession composed of (from bottom to top): **(a)** the LGLm up to TLGLHg ; **(b)** the QCB 30-40 cm thick. LGLm characterized by numerous biotur-bations (upper part), bryozoans, pectinids, and echinoids. Rare *Scutella* occur in the basal coarse-grained yellowish biodetritic limestone (30 cm thick)
Dingli (Section 3 in Giannelli and Salvatorini 1972 and in Foresi *et al.* 2007)	South-western part of Malta Island, at the cliffs of Dingli, just 1Km South of the homonymous village	1.40 m	5	The succession composed of (from bottom to top): **(a)** the LGLm up to the TLGLHg; **(b)** the QCB which is about 15-25 cm thick. The LGLm is represented by whitish marly limestones (60-100 cm thick); the macrofossils are rare
Wied-id-Dis	Eastern part of Malta Island, along the way up to Gharghur, about 4Km NW of Sliema	40 m	14	The succession composed of LGLm (yellowish limestones and light yellow marly limestones) characterized by rare pectinids
Sliema Point-Qui Si Sana (Sliema Section in Foresi *et al.* 2007)	Composite section: lower part c. 200 m NW of the Sliema Point Tower; upper part at Qui-Si-Sana, c. 500 m SSE of the Sliema Point Tower	7 m	8	The succession composed of (from bottom to top): **(a)** the LGLm up to the TLGLHg (the base of the unit crops out along the coast of Balluta Bay, there, at the top of LCLf, there is a hardground, with seaweeds and *Scutella*; **(b)** the QCB 15-30 cm thick. The LGLm characterized by common pectinids (*Flabelli-pecten*), echinoids, and numerous bioturbations
Fort St Elmo (St.Elmo Section in Foresi *et al.* 2007)	North side of the Grand Harbour (Valletta), along the coast next to Fort St. Elmo	15 m	6	The succession composed of the lower part of the LGLm, which is especially rich in echinoids and bioturbations
Valletta	Along the Triq L-Assedju L-Kbir, that borders the Marsamxett Harbour, and SSW of St. Michael's Bastion	33 m	6 :	The succession composed of the middle-upper part of LGLm (yellowish, fine calcarenite with scattered echinoids) up to TLGLHg; the QCB (5-15 cm thick) crops out along the Triq Marsamxett, next to St. Paul's Cathedral)

MALTA ISLAND				
SECTIONS	**LOCATION**	**THICKNESS OF LGLm**	**SAMPLES**	**REMARKS**
Kalkara	Along the rock walls around the Grand Harbour below Kalkara (lower part) and to the side of the road facing the Kalkara Creek (upper part)	8 m	3	The succession composed of a portion of the LGLm, developed as fine-grained, marly and bioturbated yellowish sediment, with abundant echinoids
Huttaf Gandolf	Next to Huttaf Gandolf locality (South of Luqa Airport), in a quarry on the side of the road Luqa-Mqabba	22 m	18 ::	The succession composed of the LGLm (yellowish fine-grained limestones). Macrofossils are rare
Marsaskala (Marsaskala Section in Foresi *et al.* 2007)	North coast of Marsaskala Bay (South eastern part of Malta Island)	13 m	8	The succession composed of (from bottom to top): **(a)** uppermost part of the LCLf (with *Lepidociclina* and *Scutella*) up to the TLCLHg; **(b)** the LGLm up to the TLGLHg; **(c)** the QCB, 20-35 cm thick (along the coastal road and in Zonqor Point). The LGLm characterized by common bioturbations, bryozoans, pectinids and echinoids in the lower part; rare pectinids in the upper part

. 7 samples for foraminifera + 9 samples for calcareous nannofossils
.. 3 samples for foraminifera + 5 samples for calcareous nannofossils
... 1 sample for foraminifera
: 6 samples for foraminifera and 5 samples for calcareous nannofossils
:: 18 samples for foraminifera and 8 samples for calcareous nannofossils

Table 2. Location, thickness, member, number of collected samples and main lithostratigraphic features of the studied sections on Malta

Malta Island	*Cassigerinella chipolensis*	*Dentoglobigerina globularis*	*Globigerina ciperoensis*	*Globigerina praebulloides* s.l.	*"Globigerina" euapertura*	*"Globoquadrina" sellii*	*"Globigerina" tripartita*	*Globigerinella obesa*	*Globigerinoides quadr. primordius*	*Globoturborotalita anguliofficinalis*	*Globoturborotalita angulisuturalis*	*Globoturborotalita brazierii*	*Globoturborotalita woodi*	*Paragloborotalia opima nana*	*Paragloborotalia pseudokugleri*	*Paragloborotalia siakensis*	*Subbotina gortani*	*Tenuitellinata angustiumbilic.*	*Tenuitellinata uvula*
Qammieh Section																			
MH5	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MH6	R	/	R	R	/	/	/	/	/	R	R	/	/	R	R	/	/	C	/
MH7	R	/	/	C	/	/	/	R	/	R	/	/	/	R	R	R	/	C	/
MH8	R	/	/	C	/	/	/	/	/	C	C	/	/	R	R	R	/	A	/
MH9	/	R	/	C	/	/	/	/	R	C	/	/	/	R	R	R	/	C	/
Fomm Ir-Rih Section																			
FIR5	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/	/	/	R	/
A	/	/	/	/	/	/	/	R	/	/	/	/	/	/	R	/	/	R	/
FIR6	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
FIR7	R	/	/	C	/	/	/	/	/	/	/	/	/	/	/	R	/	R	/
FIR8	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
B	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
FIR9	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Il Blata Section																			
709	R	R	R	R	R	/	/	R	R	R	/	/	R	/	R	/	R	R	/
MT10	/	/	R	/	/	/	/	/	/	/	/	/	/	R	/	/	/	R	/
0	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/	/	/	R	/
Sliema Point-Qui Si Sana Section																			
3208	R	C	R	A	R	/	/	R	R	C	R	C	C	A	A	/	R	A	R
3209	R	A	C	A	C	C	/	R	C	A	C	R	C	A	C	R	R	A	/
3210	R	A	R	A	C	C	R	/	C	R	R	A	C	C	A	/	R	A	/
3211	R	C	R	A	R	C	/	R	/	R	R	/	R	C	C	/	/	A	/
3212	R	A	C	A	C	/	R	R	R	R	/	/	R	A	R	R	R	C	/
3213	C	C	/	/	C	/	/	R	C	R	/	/	/	C	R	/	R	A	/
QS1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3214	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Fort St. Elmo Section																			
3165	R	C	/	R	C	/	/	/	R	/	/	/	/	C	C	C	/	R	/
Kalkara Section																			
VT1	R	C	/	A	C	R	R	R	R	C	/	/	/	A	A	C	C	A	/
VT2	R	C	R	R	R	R	/	/	R	R	/	/	/	C	C	R	C	A	/
VT3	R	R	/	R	R	/	/	/	/	R	/	/	/	R	R	/	R	R	/
Marsaskala Section																			
MK4	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MK5	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3194	C	C	R	A	R	/	/	R	R	R	/	/	R	C	C	/	R	A	/
3195	C	C	C	A	R	/	/	C	C	R	/	/	R	C	R	/	/	A	/
3196	C	C	C	A	R	R	R	R	C	R	/	/	/	A	C	/	R	A	/
3197	C	A	R	A	R	/	/	R	R	R	/	/	/	A	C	/	R	A	/
Wied id-Dis Section																			
WD1	A	R	/	A	/	R	/	/	R	R	R	/	/	C	R	C	R	A	/
WD2	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
WD3	C	R	/	C	C	R	/	/	R	R	/	/	R	/	R	C	/	C	/
WD4	C	A	R	A	C	R	/	C	R	A	R	/	/	C	C	C	R	A	R
WD5	R	R	/	R	R	/	/	/	/	R	/	/	/	/	C	R	R	R	/
WD6	R	/	/	R	/	/	/	/	/	/	/	/	/	R	R	R	/	C	/
WD7	R	/	/	R	/	/	/	/	/	/	/	/	/	R	R	R	/	R	/
WD8	R	/	/	R	R	/	/	/	R	/	/	/	/	R	R	R	/	R	/
WD9	C	/	/	R	/	/	/	/	R	/	/	/	/	R	R	R	/	C	/
WD10	/	/	/	/	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/
WD11	R	/	/	C	/	/	/	/	R	/	/	/	/	R	R	R	/	C	/
WD12	R	R	/	R	/	/	/	/	/	/	/	/	/	R	R	R	/	R	/
WD13	/	C	/	/	/	/	/	/	/	/	/	/	/	/	/	/	R	/	/
WD14	R	/	/	C	R	R	/	/	/	/	/	/	/	R	R	/	/	R	/

Malta Island	*Cassigerinella chipolensis*	*Dentoglobigerina globularis*	*Globigerina ciperoensis*	*Globigerina praebulloides* s.l.	*“Globigerina” euapertura*	*“Globoquadrina” sellii*	*“Globigerina” tripartita*	*Globigerinella obesa*	*Globigerinoides quadr. primordius*	*Globoturborotalita anguliofficinalis*	*Globoturborotalita angulisuturalis*	*Globoturborotalita brazierii*	*Globoturborotalita woodi*	*Paragloborotalia opima nana*	*Paragloborotalia pseudokugleri*	*Paragloborotalia siakensis*	*Subbotina gortani*	*Tenuitellinata angustiumbilic.*	*Tenuitellinata uvula*
Dingli Section																			
3203	R	A	R	A	C	R	R	R	R	R	R	/	/	C	R	R	C	C	/
3204	/	R	R	R	R	/	/	/	R	R	/	/	R	C	/	/	R	C	/
3205	R	C	R	A	R	R	R	R	R	C	/	/	/	A	/	C	R	A	/
3206	R	A	R	A	C	/	R	/	R	C	C	/	R	A	C	R	C	A	/
3207	/	A	R	A	A	/	/	R	R	C	R	/	C	A	C	C	C	A	/
Huttaf Gandolf Section																			
MQ1	R	R	/	C	R	/	/	/	/	R	/	/	/	C	/	C	/	C	/
3180	R	A	R	A	C	R	R	R	R	C	R	/	/	C	R	R	R	A	R
MQ2	/	R	/	C	R	/	/	/	/	R	/	/	/	R	R	R	/	C	/
3181	R	C	R	A	R	/	R	R	/	R	R	R	/	C	C	R	R	A	/
3182	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MQ3	/	/	/	C	/	/	/	/	/	R	/	/	/	R	R	/	/	R	/
3183	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MQ4	R	/	/	R	/	/	/	R	/	R	/	/	/	/	R	/	/	R	/
3184	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3185	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MQ5	/	/	/	R	/	/	/	/	/	R	/	/	/	R	R	/	/	R	/
3186	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MQ6	R	R	/	R	/	/	/	/	/	/	/	/	/	/	R	/	/	R	/
3187	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3188	R	R	/	C	/	/	/	/	/	R	/	/	/	R	R	R	/	R	/
MQ7	R	R	/	R	/	/	/	/	/	R	/	/	/	/	R	/	/	R	/
3189	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
MQ8	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Mtahleb Section																			
643	/	C	R	A	R	/	/	R	R	R	/	/	R	R	/	/	C	A	/

Table 3. Semiquantitative foraminiferal content of the analyzed sections of Lower Globigerina Limestone member on Malta

Gozo Island	*Cassigerinella chipolensis*	*Dentoglobigerina globularis*	*Globigerina ciperoensis*	*Globigerina praebulloides* s.l.	*"Globigerina" euapertura*	*"Globoquadrina" sellii*	*"Globigerina" tripartita*	*Globigerinella obesa*	*Globigerinoides quadr. primordius*	*Globoturborotalita angulioffincinalis*	*Globoturborotalita angulisuturalis*	*Globoturborotalita brazieri*	*Globoturborotalita woodi*	*Paragloborotalia opima nana*	*Paragloborotalia pseudokugleri*	*Paragloborotalia siakensis*	*Subbotina gortani*	*Tenuitellinata angustiumbilic.*	*Tenuitellinata uvula*
Reqqa Point Section																			
12C	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
12D	R	/	/	R	/	/	/	/	/	R	/	/	/	R	/	/	/	R	/
12E	R	/	/	R	/	/	/	/	/	R	/	/	/	R	/	/	/	R	/
788	R	R	R	C	/	/	/	R	R	R	R	/	R	R	R	R	/	A	/
2408	/	R	/	R	/	/	/	/	/	R	/	/	/	R	/	/	/	R	/
2409	C	R	R	A	/	/	/	R	/	C	R	/	R	R	C	C	/	A	/
789	C	A	R	A	R	R	/	R	R	C	R	/	R	C	C	C	R	A	/
2411	R	R	/	C	/	/	/	/	/	R	/	/	/	C	R	R	/	R	/
2412	/	R	R	C	/	/	/	/	/	R	/	/	/	R	C	R	/	A	/
790	R	A	R	A	R	R	/	/	R	R	R	/	R	A	A	A	/	A	/
2413	R	R	/	C	R	/	/	/	R	R	R	R	/	R	R	R	R	R	/
2414	/	C	R	C	/	R	/	/	/	/	/	/	/	C	C	C	R	C	/
Forna Point Section																			
3216	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3217	R	R	/	A	/	/	/	/	R	R	/	R	/	/	R	C	/	C	/
3218	/	R	R	C	/	/	/	/	/	R	/	/	/	R	R	/	/	R	/
3219	R	C	R	C	R	R	/	/	R	R	R	/	R	C	C	C	R	C	/
3220	R	R	/	C	R	/	/	/	/	C	/	/	/	/	R	R	/	R	/
3221	/	R	R	C	R	/	/	/	/	C	R	/	/	/	R	R	R	C	/
3222	C	C	R	C	R	/	/	/	/	C	R	/	R	R	R	R	/	R	/
3223	R	C	R	C	/	/	/	/	/	C	R	/	/	R	R	C	/	R	/
3224	C	C	R	A	R	/	/	R	R	C	R	/	/	C	R	C	R	C	/
3199	C	C	R	C	R	/	/	R	R	C	R	/	/	R	C	C	/	C	/
3225	R	R	/	R	R	/	/	/	/	R	R	/	/	/	R	R	/	R	/
3226	R	R	/	R	R	/	/	/	R	R	/	/	/	/	R	/	/	R	/
3200	R	A	R	A	C	C	/	R	/	R	/	/	/	C	C	A	R	C	/
3227	/	R	/	C	R	R	/	/	/	/	/	R	R	/	R	C	/	A	/
3201	R	C	R	A	R	/	/	R	/	R	/	/	R	C	R	R	R	C	/
3228	/	A	R	A	R	/	/	/	R	R	R	/	/	C	C	/	R	A	/
3229	/	C	R	C	R	R	/	/	/	R	R	/	/	C	C	/	R	A	/
Dahlet Qorrot Section																			
DQ1	R	/	/	R	/	/	/	/	/	R	R	/	/	R	R	R	/	R	/
DQ2	R	/	/	R	/	R	/	R	/	C	R	/	/	R	R	R	/	R	/
DQ3	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
DQ4	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Wardija Point Section																			
PT1	C	C	R	A	C	/	R	R	R	R	R	/	R	C	/	A	R	A	/
PT2	R	R	R	R	R	R	/	/	R	C	/	/	R	C	R	C	R	A	/
PT3	R	R	R	A	R	/	/	R	R	R	R	/	R	C	R	C	R	A	/
PT4	R	A	/	A	C	/	R	/	R	R	/	/	R	C	R	C	/	R	/
PT5	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Xlendi Section																			
MT10	R	/	/	C	/	/	/	/	/	/	/	/	R	R	R	/	/	C	/
MT11	R	R	R	A	R	/	/	/	/	C	/	/	R	C	R	/	/	C	/
MT12	R	R	/	C	R	/	/	/	/	/	/	/	R	R	R	/	/	A	/
MT12bis	R	C	R	A	/	C	R	/	/	R	R	/	R	A	R	C	/	C	/
MT12ter	/	R	R	C	/	/	R	/	/	R	R	R	R	C	R	/	/	C	/
3191	R	A	R	A	C	R	/	R	R	R	R	R	R	C	C	A	R	A	/
MT13	C	C	C	R	R	R	/	R	R	C	R	/	R	A	R	R	R	C	/
MT14	/	R	R	A	R	R	/	R	/	R	R	/	/	A	R	R	R	A	/
3192	/	A	R	A	C	R	/	R	C	R	R	R	R	A	C	A	R	A	/
3193	R	/	R	C	R	/	/	R	/	R	R	R	R	C	C	R	R	A	/

Gozo Island	*Cassigerinella chipolensis*	*Dentoglobigerina globularis*	*Globigerina ciperoensis*	*Globigerina praebulloides* s.l.	*"Globigerina" euapertura*	*"Globoquadrina" sellii*	*"Globigerina" tripartita*	*Globigerinella obesa*	*Globigerinoides quadr. primordius*	*Globoturborotalita anguliofficinalis*	*Globoturborotalita angulisuturalis*	*Globoturborotalita brazierii*	*Globoturborotalita woodi*	*Paragloborotalia opima nana*	*Paragloborotalia pseudokugleri*	*Paragloborotalia siakensis*	*Subbotina gortani*	*Tenuitellinata angustiumbilic.*	*Tenuitellinata uvula*
Dabrani Section																			
3174	R	/	/	R	/	/	/	/	/	/	/	/	/	/	R	R	/	R	/
3175	/	/	/	R	/	/	/	/	/	R	/	/	/	R	R	R	/	R	/
3176	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
3177	/	R	R	C	R	/	/	R	/	C	R	/	/	C	C	R	/	A	/
3178	R	R	/	C	R	R	/	/	/	R	R	/	R	C	C	R	/	A	/
3179	/	C	R	A	C	R	/	R	R	R	/	R	/	C	C	C	R	A	/
Ras Il-Hobz Section																			
HO1	R	R	/	C	/	/	/	/	/	R	R	/	/	R	R	R	/	R	R
HO2	R	R	/	A	R	/	/	R	/	C	R	/	/	C	C	/	/	C	/
HO3	R	R	/	R	/	/	/	/	/	R	/	/	/	R	R	/	/	R	/
HO4	R	C	/	A	R	R	/	R	R	C	/	/	/	C	C	/	R	A	/
HO5	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Santa Lucija Section																			
SL1	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
SL2	R	R	/	R	/	/	/	/	/	R	/	/	/	R	R	R	/	R	/
SL3	R	R	/	R	/	/	/	/	/	R	/	/	/	/	R	/	/	R	/
SL4	/	C	R	A	C	C	/	/	R	C	R	/	/	R	A	R	R	C	/
SL5	A	C	R	A	R	/	/	R	R	/	/	/	/	R	R	R	R	R	/
SL6	R	C	/	C	C	/	R	/	R	R	/	/	/	C	R	R	R	A	/
SL7	R	C	R	A	C	/	/	R	R	R	/	/	/	C	R	C	R	A	/
SL8	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

Table 4. Semiquantitative foraminiferal content of the analyzed sections of Lower Globigerina Limestone member on Gozo

Malta Island	*Braarudosphaera bigelowii*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Discoaster deflandrei*	*Helicosphaera euphratis*	*Helicosphaera obliqua*	*Helicosphaera intermedia*	*Helicosphaera recta*	*Pontosphaera enormis*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus compactus*	*Sphenolithus delphix*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Qammieh Section																					
MH5	/	/	C	R	A	R	C	/	/	/	/	/	/	C	/	/	/	/	/	A	A
MH6	/	R	C	R	A	R	A	/	/	/	/	/	/	C	R	/	/	A	R	C	A
MH7	/	/	/	/	A	R	A	/	/	/	/	R	/	C	/	/	/	R	R	A	A
MH8	/	/	C	C	A	C	A	/	R	/	/	/	/	C	/	/	/	C	R	C	A
MH9	/	/	R	C	A	C	A	/	R	/	/	/	R	R	R	/	/	R	R	A	C
Fomm ir-Rih Section																					
FIR1	/	/	C	/	A	C	A	/	/	/	/	/	/	R	/	/	/	C	R	A	A
FIR2	/	/	A	/	A	C	A	/	/	/	/	/	/	C	/	/	/	R	R	A	A
FIR3	/	/	R	R	A	R	A	/	/	/	/	/	/	C	/	/	/	R	R	A	A
FIR4	/	/	C	R	A	/	A	/	R	R	/	/	/	R	/	/	/	C	C	A	A
FIR5	/	/	C	R	A	R	A	/	R	/	/	/	/	C	R	/	/	R	R	A	A
FIR6	/	/	A	R	A	R	A	/	R	R	/	R	/	C	/	/	/	C	R	A	A
FIR7	/	/	C	R	A	C	A	/	/	R	/	R	/	R	/	/	/	C	R	A	A
FIR8	/	/	R	/	A	/	A	/	/	/	/	/	/	C	/	/	/	R	/	A	A
FIR9	/	/	R	/	A	/	A	/	/	/	/	/	/	C	/	/	/	R	/	A	A
Il Blata Section																					
BL1	/	R	C	C	A	/	A	/	/	/	/	/	/	/	R	/	/	C	/	C	A
BL2	/	R	C	C	A	R	A	/	/	/	/	/	/	/	R	/	/	C	R	C	C
BL3	/	/	C	C	A	R	A	/	/	/	/	/	/	/	R	/	R	C	R	C	C
BL4	/	R	C	C	A	R	A	/	/	/	/	/	/	/	R	/	/	C	/	A	A
BL5	/	/	R	C	A	R	A	/	/	/	/	/	/	/	R	/	R	C	R	A	A
Sliema Point-Qui Si Sana Section																					
3208	/	/	C	R	A	R	A	/	C	/	/	R	R	R	/	R	/	C	R	A	R
3209	/	R	R	R	A	R	A	R	C	/	R	/	R	R	/	/	/	C	R	A	R
3210	/	/	R	R	A	R	C	/	R	/	/	/	R	R	R	R	/	C	R	C	R
3211	R	R	C	R	A	R	A	/	C	/	/	R	R	R	/	/	/	C	C	A	R
3212	/	R	A	C	C	R	C	R	C	/	R	R	/	C	R	/	/	C	R	A	R
3213	/	/	R	R	C	R	A	/	C	R	/	/	/	R	/	/	/	A	R	A	C
QS1	/	/	R	/	R	R	C	/	R	/	/	/	/	/	/	/	/	R	/	C	R
3214	/	/	C	R	A	R	C	/	R	/	/	/	/	R	/	/	/	C	R	A	C
Fort St. Elmo Section																					
MT2	/	/	/	/	R	/	/	/	/	/	/	/	/	/	/	/	/	R	/	R	R
MT3	/	/	R	/	R	/	/	/	R	/	/	/	/	R	/	/	/	/	/	R	R
Kalkara Section																					
VT1	/	C	C	R	A	R	A	/	R	/	R	R	/	R	R	/	R	C	C	C	R
VT2	/	R	R	/	A	/	A	/	/	/	/	/	/	R	/	/	/	R	R	C	R
VT3	/	/	C	R	A	R	A	/	R	/	/	/	/	R	/	/	/	R	R	C	R
Wied id-Dis Section																					
WD1	/	/	A	R	A	C	A	/	C	/	/	/	/	C	R	/	/	C	R	C	R
WD2	/	/	R	R	A	C	A	/	R	/	/	/	/	C	/	/	/	R	R	A	C
WD3	/	/	R	R	A	C	A	/	R	/	/	/	/	C	/	/	/	R	R	A	C
WD4	/	/	R	R	A	C	A	/	R	R	/	/	/	R	/	/	/	R	R	A	R
WD5	/	/	R	R	A	C	A	/	C	/	/	/	/	C	R	/	/	R	/	A	C
WD6	/	/	R	R	A	C	A	/	R	/	/	/	/	R	R	/	/	C	/	A	C
WD7	/	/	C	R	A	C	A	/	C	/	/	/	/	C	R	/	/	C	/	A	C
WD8	/	/	C	/	A	C	A	/	C	/	/	/	/	R	R	/	/	C	R	A	C
WD9	/	/	R	/	A	C	A	/	R	/	/	/	/	C	R	/	/	R	R	A	A
WD10	/	/	/	/	A	R	A	/	R	/	/	/	/	R	/	/	/	C	R	A	A
WD11	/	/	C	/	A	C	A	/	R	/	/	/	/	R	R	/	/	R	/	A	C
WD12	/	/	R	/	A	C	A	/	R	/	/	/	/	R	/	/	/	R	/	A	C
WD13	/	/	C	/	A	C	A	/	R	/	/	/	/	C	/	/	/	/	/	A	A
WD14	/	/	R	/	A	/	C	/	/	/	/	/	/	R	/	/	/	/	/	A	A

Malta Island	*Braarudosphaera bigelowii*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Discoaster deflandrei*	*Helicosphaera euphratis*	*Helicosphaera obliqua*	*Helicosphaera intermedia*	*Helicosphaera recta*	*Pontosphaera enormis*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus compactus*	*Sphenolithus delphix*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Huttaf Gandolf Section																					
MQ1	/	/	C	C	A	A	A	/	R	R	/	/	/	R	R	/	/	C	R	C	R
MQ2	/	/	C	/	A	C	A	/	R	/	/	/	/	/	/	/	/	C	/	C	C
MQ3	/	/	C	/	A	C	A	/	/	/	/	/	/	/	R	/	/	C	/	R	A
MQ4	/	/	C	R	A	R	A	/	R	R	/	/	/	/	R	/	/	C	/	A	A
MQ5	/	/	/	/	A	A	A	/	R	/	/	/	/	/	/	/	/	/	/	A	A
MQ6	/	/	R	R	A	C	A	/	/	R	/	/	R	C	R	/	/	C	/	A	A
MQ7	/	/	C	R	A	C	A	/	/	R	/	/	R	C	R	/	/	C	/	A	A
MQ8	/	/	R	/	C	/	R	/	/	/	/	/	R	A	R	/	R	R	/	A	A
Marsaskala Section																					
MK3	/	/	R	R	C	R	A	/	R	/	/	R	/	R	R	/	/	C	R	C	R
MK4	/	/	C	C	A	C	A	/	/	/	/	/	/	/	/	/	/	C	/	A	C
MK5	/	R	C	R	A	C	C	/	R	/	/	/	R	R	/	/	/	R	/	A	R
MK7	/	R	R	R	C	R	C	/	R	/	/	/	/	/	/	/	/	R	R	C	R
Valletta Section																					
VT4	/	/	/	/	R	/	R	/	/	/	/	/	/	C	/	/	/	C	R	A	A
VT5	/	/	C	/	R	/	R	/	/	/	/	/	/	C	/	/	/	C	/	A	A
VT6	/	/	R	/	C	/	R	/	/	/	/	/	/	R	/	/	/	C	/	A	A
VT7	/	/	R	/	C	/	C	/	/	/	/	/	/	C	/	/	/	C	R	A	A
VT8	/	/	R	/	R	/	R	/	/	/	/	/	/	C	/	/	/	C	R	A	A

Table 5. Semiquantitative calcareous nannofossil content of the analyzed sections of Lower Globigerina Limestone member on Malta

Gozo Island	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Helicosphaera euphratis*	*Helicosphaera obliqua*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus conicus*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Sphenolithus pseudoradians*	*Triquetrorhabdulus carinatus*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Reqqa Point Section																	
RQ6	/	C	R	A	C	A	R	/	C	/	/	/	/	/	/	A	A
RQ7	/	R	R	A	C	A	/	/	C	/	/	R	/	/	/	A	A
RQ8	/	C	C	A	C	A	R	/	C	/	/	C	R	R	/	A	A
RQ9	/	C	C	A	C	A	R	/	C	/	/	C	R	/	/	A	C
RQ10	R	C	R	A	C	A	C	/	C	R	/	C	/	/	/	A	C
RQ11	R	C	R	A	C	A	R	/	R	R	/	C	R	/	/	A	C
RQ12	/	C	R	A	C	A	R	/	C	R	/	C	R	/	/	A	C
RQ13	/	C	R	A	C	A	C	/	C	/	/	C	R	/	/	A	C
RQ14	/	C	C	A	C	A	R	/	C	/	/	R	/	/	/	A	A
RQ15	/	R	R	A	C	A	/	/	C	/	/	C	/	/	/	A	A
RQ16	/	C	R	A	C	A	/	/	R	R	/	R	/	/	/	A	A
Forna Point Section																	
DB1	/	R	R	A	R	C	R	/	R	/	/	R	/	/	/	A	A
DB2	/	C	R	A	R	A	/	/	C	/	/	/	/	R	/	A	A
DB3	/	C	R	A	C	A	R	/	R	R	/	R	R	/	/	A	C
DB4	/	C	C	A	C	A	C	/	R	R	/	C	R	/	/	A	C
DB5	R	C	C	C	C	C	R	/	R	/	/	C	R	/	/	A	C
DB6	/	R	R	C	R	A	R	/	C	/	/	R	/	/	/	A	R
DB7	R	C	R	A	C	C	R	/	R	/	/	C	/	/	/	A	A
DB8	R	C	R	C	C	A	C	R	C	R	/	C	/	/	/	A	A
DB9	/	R	C	C	C	A	C	/	R	/	R	C	R	/	/	A	A
DB10	/	C	R	A	R	A	R	/	R	R	/	C	R	/	/	A	A
DB11	/	R	R	C	R	C	R	/	R	/	/	R	/	/	/	A	C
DB12	R	C	R	A	C	A	/	/	C	/	/	C	R	/	/	A	C
DB13	/	R	R	A	R	C	/	/	C	/	/	R	/	/	/	A	C
DB14	R	C	C	A	R	A	C	/	C	R	R	C	/	/	/	A	A
DB15	R	C	R	A	R	A	C	/	C	/	/	C	R	/	/	A	R
DB16	/	R	C	A	C	A	R	/	R	/	/	C	R	/	/	A	C
DB17	/	C	R	C	R	C	C	/	R	/	/	C	/	/	/	A	C
DB18	R	R	R	A	R	C	C	/	C	R	/	R	/	/	/	A	C
DB19	/	C	R	A	R	A	R	/	R	/	/	C	R	/	/	A	C
Wardija Point Section																	
PT1	/	R	/	A	C	A	/	/	/	/	/	C	/	/	/	C	A
PT2	/	R	/	A	R	A	/	C	/	/	/	C	R	/	/	R	A
PT3	/	R	C	A	R	A	R	R	R	R	/	C	R	/	/	R	C
PT4	/	/	/	A	/	A	/	/	/	/	/	C	R	/	/	A	A
PT5	/	R	C	A	R	A	/	/	R	R	R	C	/	/	/	A	C
Xlendi Section																	
MT10	/	R	R	A	R	C	R	/	R	R	/	/	R	/	/	A	C
MT11	/	R	R	C	R	C	R	/	R	/	/	C	R	/	/	C	R
MT12	/	R	R	C	/	C	/	/	R	/	/	R	/	/	/	C	R
MT12bis	/	R	R	C	R	C	R	/	R	/	/	R	/	/	/	A	R
MT12ter	/	R	R	C	R	C	R	/	R	/	/	C	/	/	/	C	C
MT13	/	R	R	C	R	C	R	/	R	/	/	C	/	/	/	A	R
MT14	/	C	R	C	R	C	C	R	R	/	/	C	C	/	/	A	R
Dahlet Qorrot Section																	
DQ1	/	C	/	A	R	A	R	/	C	/	/	C	R	/	/	A	A
DQ2	/	C	R	A	C	A	/	/	C	/	/	C	/	/	/	A	C
DQ3	/	C	/	A	/	A	R	/	C	/	/	R	/	/	/	A	A
DQ4	/	C	/	A	C	A	/	/	C	R	/	R	R	/	/	A	A

Gozo Island	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Helicosphaera euphratis*	*Helicosphaera obliqua*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus conicus*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Sphenolithus pseudoradians*	*Triquetrorhabdulus carinatus*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Ras Il-Hobz Section																	
HO1	R	C	C	A	R	A	/	/	R	/	/	/	R	/	/	C	R
HO2	/	R	C	A	R	A	/	/	R	/	/	R	C	/	/	C	C
HO3	R	R	C	A	/	A	R	/	R	/	/	R	R	/	/	C	C
HO4	R	R	C	A	R	A	R	/	R	/	/	R	/	/	/	A	C
HO5	R	C	R	A	/	A	/	/	R	/	/	C	R	/	/	A	C
Santa Lucija Section																	
SL1	/	C	C	A	/	A	/	/	R	/	/	C	C	/	/	C	A
SL2	R	A	R	A	R	A	R	/	/	/	/	C	/	/	/	C	C
SL3	/	C	/	A	/	A	R	/	R	/	/	R	R	/	/	C	A
SL4	R	C	/	A	R	A	R	/	/	/	/	R	R	/	/	A	C
SL5	/	R	C	A	R	A	/	/	R	/	/	R	R	/	/	A	C
SL6	R	C	C	A	C	A	R	/	/	/	/	C	C	/	/	C	C
SL7	/	C	C	A	R	A	/	/	/	/	/	R	R	/	/	A	C
SL8	/	C	R	A	R	A	/	/	R	/	/	C	C	/	/	C	A

Table 6. Semiquantitative calcareous nannofossil content of the analyzed sections of Lower Globigerina Limestone member on Gozo

	Braarudosphaera bigelowii	*Chiasmolithus altus*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Helicosphaera euphratis*	*Helicosphaeraobliqua*	*Helicosphaera recta*	*Pontosphaera enormis*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus delphix*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Qammieh Section																			
MH5	0.00	0.00	0.00	3.92	1.85	10.18	1.85	8.33	0.00	0.00	0.00	0.00	9.25	0.00	0.00	0.00	0.00	26.62	37.96
MH6	0.00	0.00	1.58	5.55	1.58	33.33	2.38	23.8	0.00	0.00	0.00	0.00	4.76	1.19	0.00	12.30	1.58	6.34	5.55
MH7	0.00	0.00	0.00	0.00	0.00	28.36	2.83	22.69	0.00	0.00	0.70	0.00	5.67	0.00	0.00	1.41	2.83	18.49	17.02
MH8	0.00	0.00	0.00	4.08	3.57	35.71	8.16	20.40	0.51	0.00	0.00	0.00	4.08	0.00	0.00	3.06	2.04	3.06	15.30
MH9	0.47	0.47	0.47	0.94	3.79	34.19	3.31	27.48	1.89	0.00	0.00	1.42	1.89	0.94	0.00	2.84	0.94	11.37	8.53
Fomm ir-Rih Section																			
FIR1	0.00	0.00	0.00	5.04	0.00	23.26	4.95	16.78	0.00	0.00	0.00	0.00	2.33	0.00	0.00	4.45	2.43	20.03	20.69
FIR2	0.00	0.00	0.00	0.00	0.00	30.84	5.40	13.18	0.00	0.00	0.00	0.00	6.78	0.00	0.00	2.67	1.10	21.89	18.10
FIR3	0.00	0.00	0.00	1.69	1.21	24.84	0.48	21.60	0.00	0.00	0.00	0.00	3.88	0.00	0.00	2.66	1.85	23.54	18.20
FIR4	0.00	0.00	0.00	8.48	1.36	25.99	0.00	17.91	1.58	1.81	0.00	0.00	2.04	0.00	0.00	3.40	3.26	21.76	15.87
FIR5	0.00	0.00	0.00	8.48	1.71	31.29	0.76	13.74	1.92	0.00	0.00	0.00	3.81	0.38	0.00	2.29	1.55	22.80	11.25
FIR6	0.00	0.00	0.00	10.1	2.94	27.89	2.31	16.06	1.89	1.47	1.05	0.00	3.59	0.00	0.00	3.15	0.68	15.96	12.60
FIR7	0.00	0.00	0.00	7.81	2.60	22.17	4.50	13.27	0.00	2.13	2.92	0.00	3.75	0.00	0.00	4.97	2.65	18.48	14.69
FIR8	0.00	0.00	0.00	2.99	0.00	22.65	0.00	12.82	0.00	0.00	0.00	0.00	6.41	0.00	0.00	1.68	0.00	30.76	22.64
FIR9	0.00	0.00	0.00	2.26	0.00	26.24	0.00	11.76	0.00	0.00	0.00	0.00	7.69	0.00	0.00	1.80	0.00	29.86	20.36
Il Blata Section																			
BL1	0.00	0.00	1.04	8.33	4.16	32.81	0.00	30.20	0.00	0.00	0.00	0.00	0.00	1.56	0.00	6.24	0.00	5.20	10.41
BL2	0.00	0.00	0.85	8.20	3.50	31.25	1.40	30.00	0.00	0.00	0.00	0.00	0.00	1.35	0.54	7.06	0.96	6.79	8.15
BL3	0.00	0.00	0.00	7.87	3.08	27.61	1.63	34.90	0.00	0.00	0.00	0.00	0.00	1.35	0.54	7.06	0.96	6.79	8.15
BL4	0.00	0.00	0.40	6.50	3.30	24.75	1.55	27.95	0.00	0.00	0.00	0.00	0.00	1.10	0.00	7.25	0.00	12.65	14.55
BL5	0.00	0.00	0.00	3.26	4.71	22.82	0.72	23.55	0.00	0.00	0.00	0.00	0.00	1.44	0.36	9.42	1.45	13.40	18.84
Huttaf Gandolf Section																			
MQ1	0.00	0.00	0.00	7.60	3.80	32.60	10.86	26.08	0.54	1.08	0.00	0.00	0.54	1.63	0.00	6.52	1.63	5.97	1.08
MQ2	0.00	0.00	0.00	4.68	0.00	35.43	4.16	34.37	2.08	0.00	0.00	0.00	0.00	0.00	0.00	6.25	0.00	6.25	6.77
MQ3	0.00	0.00	0.00	8.86	0.00	26.58	5.06	30.14	0.00	0.00	0.00	0.00	0.00	1.26	0.00	7.59	0.00	2.53	17.98
MQ4	0.00	0.00	0.00	5.00	0.83	30.00	2.50	21.66	0.83	0.83	0.00	0.00	0.00	1.66	0.00	5.00	0.00	18.51	34.25
MQ5	0.00	0.00	0.00	0.00	0.00	22.22	10.18	12.03	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.51	34.25
MQ6	0.00	0.00	0.00	2.85	0.95	30.00	8.09	18.09	0.00	1.90	0.00	1.42	3.80	0.95	0.00	3.33	0.00	14.28	13.33
MQ7	0.00	0.00	0.00	5.04	2.36	26.82	4.20	21.21	0.00	0.84	0.00	2.52	3.04	1.68	0.00	4.04	0.00	18.06	10.10
MQ8	0.00	0.00	0.00	1.95	0.00	5.12	0.00	2.56	0.00	0.00	0.00	2.12	11.82	2.84	0.00	2.56	0.00	41.02	28.64
Wied id-Dis Section																			
WD1	0.00	0.00	0.00	13.27	2.16	21.60	9.41	27.20	6.63	0.00	0.00	0.00	3.54	0.77	0.00	4.16	1.54	7.40	2.31
WD2	0.00	0.00	0.00	0.94	1.03	25.78	7.54	31.13	2.83	0.00	0.00	0.00	3.77	0.00	0.00	1.88	1.14	18.23	5.66
WD3	0.00	0.00	0.00	1.33	1.33	32.00	9.00	26.33	1.66	0.00	0.00	0.00	3.33	0.00	0.00	2.00	0.66	16.00	6.33
WD4	0.00	0.00	0.00	2.24	0.93	31.46	6.17	32.20	1.49	0.74	0.00	0.00	1.31	0.00	0.00	2.62	0.56	14.60	2.62
WD5	0.00	0.00	0.00	1.77	1.06	23.84	6.40	27.75	3.20	0.00	0.00	0.00	5.33	1.06	0.00	2.13	0.00	21.35	6.04
WD6	0.00	0.00	0.00	1.24	0.31	25.23	3.11	28.03	1.55	0.00	0.00	0.00	2.80	0.31	0.00	3.12	0.00	24.29	9.34
WD7	0.00	0.00	0.00	3.70	0.52	33.86	6.34	22.75	3.17	0.00	0.00	0.00	3.17	0.79	0.00	4.76	0.79	16.40	3.70
WD8	0.00	0.00	0.00	3.61	0.00	32.54	4.71	26.10	2.98	0.00	0.00	0.00	1.57	0.78	0.00	5.18	1.25	13.67	7.54
WD9	0.00	0.00	0.00	1.72	0.00	26.60	4.18	27.17	1.92	0.00	0.00	0.00	3.20	0.49	0.00	2.21	0.49	17.73	14.28
WD10	0.00	0.00	0.00	0.00	0.00	28.57	1.86	19.25	0.00	0.00	0.00	0.00	2.48	0.00	0.00	3.72	1.86	26.08	16.14
WD11	0.00	0.00	0.00	4.07	0.00	29.51	6.99	33.59	2.52	0.00	0.00	0.00	1.94	0.77	0.00	2.71	0.00	10.29	7.57
WD12	0.00	0.00	0.00	2.25	0.00	39.00	4.00	30.00	1.00	0.00	0.00	0.00	1.50	0.00	0.00	1.76	0.00	13.00	7.50
WD13	0.00	0.00	0.00	4.51	0.00	27.06	6.76	28.57	2.63	0.00	0.00	0.00	3.38	0.00	0.00	0.00	0.00	15.78	11.27
WD14	0.00	0.00	0.00	2.12	0.00	19.14	0.00	19.14	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	36.17	32.62
Reqqa Point Section																			
RQ6	0.00	0.00	0.00	3.84	1.44	28.84	4.32	21.15	0.96	0.00	0.00	0.00	6.73	0.00	0.00	0.00	0.00	18.26	14.42
RQ7	0.00	0.00	0.00	0.62	1.86	28.34	3.73	28.03	0.00	0.00	0.00	0.00	3.11	0.00	0.00	2.80	0.00	19.62	11.83
RQ8	0.00	0.00	0.00	6.35	3.34	30.10	5.01	16.38	2.00	0.00	0.00	0.00	4.01	0.00	0.00	3.01	1.33	15.71	11.70
RQ9	0.00	0.00	0.00	5.70	3.08	28.74	4.03	21.37	0.95	0.00	0.00	0.00	7.36	0.00	0.00	4.98	0.71	14.25	8.78
RQ10	0.00	0.00	1.84	8.29	2.99	29.03	5.52	18.20	3.45	0.00	0.00	0.00	5.06	0.69	0.00	3.22	0.00	14.97	6.68
RQ11	0.00	0.00	2.18	8.29	2.18	28.82	6.76	19.86	1.74	0.00	0.00	0.00	2.83	0.65	0.00	5.67	1.09	12.22	7.64
RQ12	0.00	0.00	0.00	8.59	1.95	25.19	6.44	22.65	2.53	0.00	0.00	0.00	4.68	0.78	0.00	6.05	0.58	12.50	8.00
RQ13	0.00	0.00	0.00	8.35	1.87	29.01	6.05	21.50	3.54	0.00	0.00	0.00	3.54	0.00	0.00	3.54	0.20	16.07	6.26
RQ14	0.00	0.00	0.00	5.56	3.34	29.62	5.79	16.48	2.22	0.00	0.00	0.00	4.00	0.00	0.00	2.89	0.00	20.04	10.02
RQ15	0.00	0.00	0.00	0.00	1.72	24.97	4.31	16.37	0.00	0.00	0.00	0.00	3.44	0.00	0.00	3.87	0.00	28.44	16.81
RQ16	0.00	0.00	0.00	3.24	1.35	28.64	5.94	18.10	0.00	0.00	0.00	0.00	2.16	1.08	0.00	2.97	0.00	24.05	12.43

	Braarudosphaera bigelowii	*Chiasmolithus altus*	*Coccolithus miopelagicus*	*Coccolithus pelagicus*	*Cyclicargolithus abisectus*	*Cyclicargolithus floridanus*	*Dictyococcites bisectus*	*Dictyococcites scrippsae*	*Helicosphaera euphratis*	*Helicosphaeraobliqua*	*Helicosphaera recta*	*Pontosphaera enormis*	*Pontosphaera multipora*	*Sphenolithus ciperoensis*	*Sphenolithus delphix*	*Sphenolithus dissimilis*	*Sphenolithus moriformis*	*Umbilicosphaera sibogae*	*Zygrablithus bijugatus*
Wardija Point Section																			
PT1	0.00	0.00	0.00	2.50	0.00	25.00	5.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	9.20	25.60
PT2	0.00	0.00	0.00	2.40	0.00	44.00	2.40	17.00	0.01	4.00	0.00	0.00	0.00	0.00	0.00	9.00	2.80	2.00	16.40
PT3	0.00	0.00	0.00	2.70	6.00	36.00	0.90	32.70	0.90	0.90	0.00	0.00	0.90	0.90	0.00	9.01	1.15	1.60	6.05
PT4	0.00	0.00	0.00	0.00	0.00	14.30	0.00	15.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50	3.10	14.60	43.50
PT5	0.00	0.00	0.00	2.70	3.70	22.70	1.80	24.60	0.00	0.00	0.00	0.00	0.90	0.90	0.90	9.20	0.00	15.70	5.80

Table 7. Quantitative calcareous nannofossil content (percentages) of Lower Globigerina Limestone member in selected sections of the Maltese Archipelago