Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences

Tome 73, No 7, 2020

GEOLOGY
Sedimentology

PETROLOGICAL, MINERALOGICAL AND GEOCHEMICAL CHARACTERISTICS OF THE *GLOBIGERINA* LIMESTONE OUTCROPPING AT FOMM IR-RIĦ, MALTA

Lino Bianco

(*Submitted by Academician T. Nikolov on February 17, 2020*)

Abstract

Fomm ir-Riħ is a scheduled area on the western coast of Malta characterised by an unusual syncline and clay slopes. This article addresses the *Globigerina* Limestone formation, which outcrops at this site of geological interest. The Lower *Globigerina* Limestone, the oldest member of this lithostratigraphic unit, is absent. The matrix to allochems ratio of the Middle *Globigerina* Limestone is significantly different from that of the Upper *Globigerina* Limestone. In both, the matrix is composed of well-preserved micrite, rarely recrystallised to microspar. The petrology and mineralogy of the Middle *Globigerina* Limestone is similar to that of the blue lenticular patches occurring in the Lower *Globigerina* Limestone where it outcrops in other parts of the island, but geochemical data vary. The SiO_2 content of the Middle *Globigerina* Limestone is $< 20\%$, while in the case of the Upper *Globigerina* Limestone, it is $> 20\%$. The SiO_2, Al_2O_3 and Fe_2O_3 content increases gradually from the Middle to the Upper *Globigerina* Limestone member.

Key words: *Globigerina* Limestone, Upper *Globigerina* Limestone, Middle *Globigerina* Limestone, Fomm ir-Riħ, Malta

Introduction. The Maltese archipelago forms part of the Pelagian Block, which extends to eastern Tunisia [1–3]. The focus of this article is the western

This research was undertaken at the University of Leicester and was funded by the Oil Exploration Division, Office of the Prime Minister, Malta.
DOI:10.7546/CRABS.2020.07.12

coast of Malta, specifically Fomm ir-Riħ (Fig. 1a). This area has been designated a Marine Protected Area and a Special Area of Conservation worthy of inclusion in the Natura 2000 network of protected sites (Fig. 1b). Fomm ir-Riħ has a distinctive character: it exhibits the geological succession of the islands, except for the Lower *Globigerina* Limestone (LGL) member, which is absent [4]. This may be either due to the erosion of the floor such that the sediment had no time to be deposited, or due to tectonic reasons. This paper studies the composition of the *Globigerina* members present at this site by means of petrological, mineralogical and geochemical analysis.

Geological setting. Fomm ir-Riħ occurs on the western end of the Great Fault, which runs from the Ras ir-Raħeb headland near Fomm ir-Riħ Bay to Madliena on the northeast of the island. Two sub-formations of the *Globigerina* Limestone formation outcrop at Fomm ir-Riħ: Middle *Globigerina* Limestone (MGL) and Upper *Globigerina* Limestone (UGL), which are Early Miocene (Burdigalian) and Middle Miocene (Langhian) respectively. These members are separated by the upper main phosphorite conglomerate bed [5,6]. Where LGL is present in other parts of the island, its transition to MGL is marked by the lower main phosphorite conglomerate bed; this is not the case from UGL to the overlying Blue Clay. The transition from globigerinid biomicrites to globigerinid marls is short. The non-carbonate content of Blue Clay is $> 70\%$ [7].

The MGL member is a planktonic foraminifera-rich limestone sequence ranging from white soft carbonate mudstone to pale grey marly mudstone. Coccoliths are abundant and thin-shelled pectinid bivalves and echinoids are typically present. The UGL member is a fine-grained planktonic foraminifera-rich limestone sequence [4]. PEDLEY et al. [5] acknowledged that the tripartite nature of this member was first recorded by MORRIS [8]. Stating thickness (t) in feet, Morris [8] distinguished between the lower cream-coloured ($5 \leq t \leq 30$) and the upper pale-cream-coloured ($15 \leq t \leq 30$) wackestones of the UGL, which are separated by pale-grey calcareous marl ($t \leq 50$) which has a lithology identical to the lower part of the Blue Clay [8].

Materials and methods. The following three samples were collected from a natural section occurring at Fomm ir-Riħ: FR1 and FR2 are from the UGL-Upper Bed and UGL-Lower Bed, respectively, while FR3 is MGL. All are included in BIANCO [9] but were never published. These results are tabulated parallel to two other samples extracted from the Piccolo Fewda quarry located on the periphery of Mqabba, which were published by BIANCO [10]. Q1 is the best quality building stone, referred to locality as franka; Q3 is an inferior quality stone, known as *sol aħmar* (also written as *soll aħmar*), suitable for dimension stone when used ≥ 60 cm above the damp-proof course. *Sol aħmar* is different from *sol ikħal* (also written as *soll ikħal*), which occurs in the same lithostratigraphical unit, and also different from the blue lenticular patches occurring within the LGL, namely samples B1 and B2, addressed in BIANCO [11,12].

Fig. 1. (a) Site location map plotting the position of the Great Fault (*gf*) shown in red, and (b) aerial photo showing the limits of Fomm ir-Riħ outlined in red (Baseline images: © Google Maps)

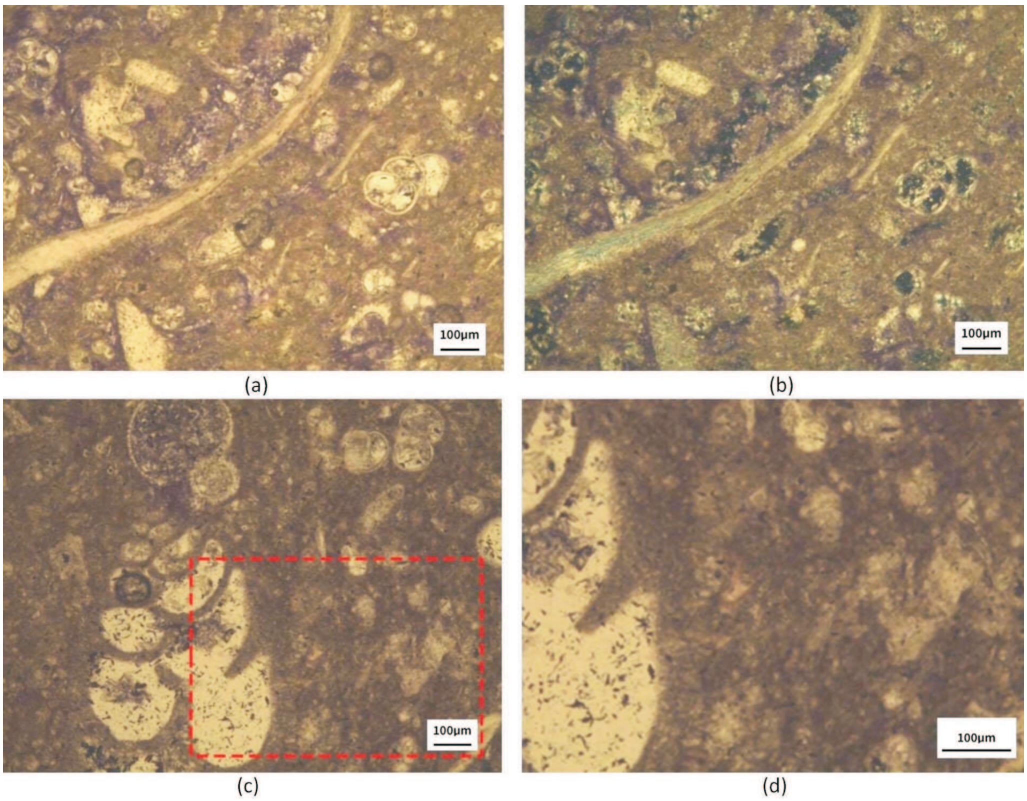

Fig. 2. UGL (Upper Bed): (a) parallel nicols, micrite with planktonic *Globigerina* foraminifera, echinoid bioclasts and part of bivalve shell; (b) crossed nicols, same view as (a), note intraparticle porosity; (c) parallel nicols, micrite with planktonic *Globigerina* foraminifera and benthic foraminifera, and (d) detail from (c) outlined in red

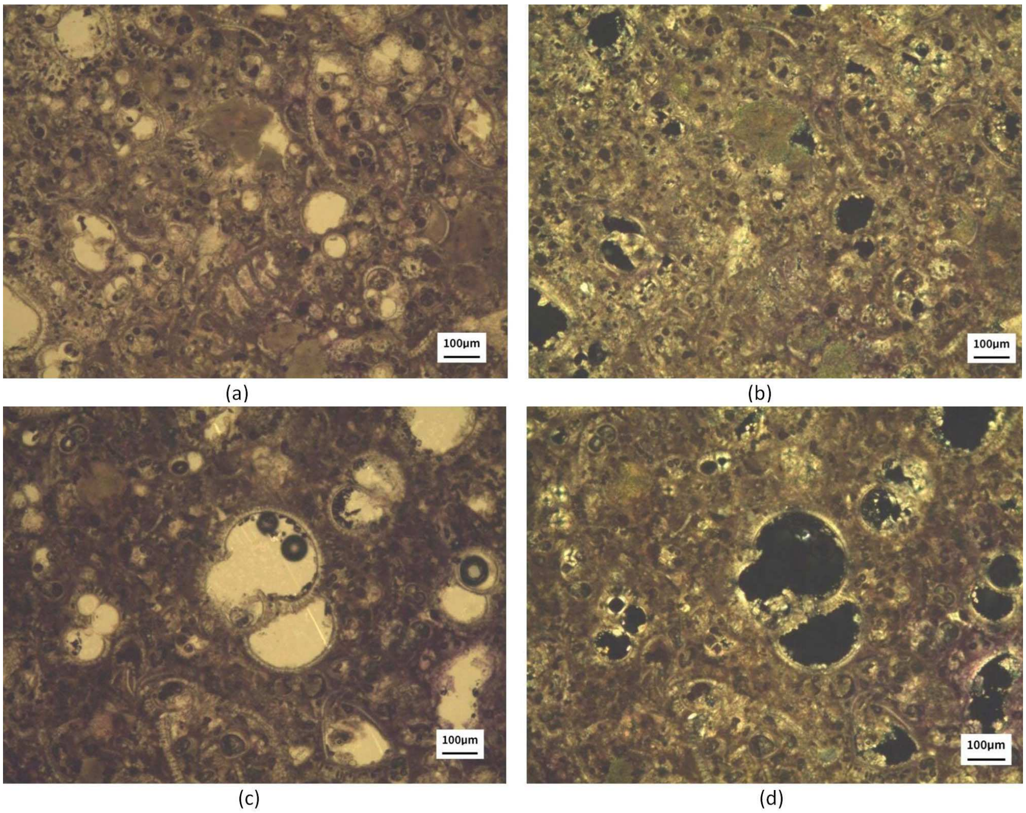

Fig. 3. UGL (Lower Bed): (a) parallel nicols, planktonic foraminifera, benthic foraminifera, glauconite grains, intraparticle porosity; (b) crossed nicols, the same view as (a); (c) parallel nicols, micrite with larger and small planktonic foraminifera, glauconite grains, intraparticle porosity, and (d) crossed nicols, same view as (c)

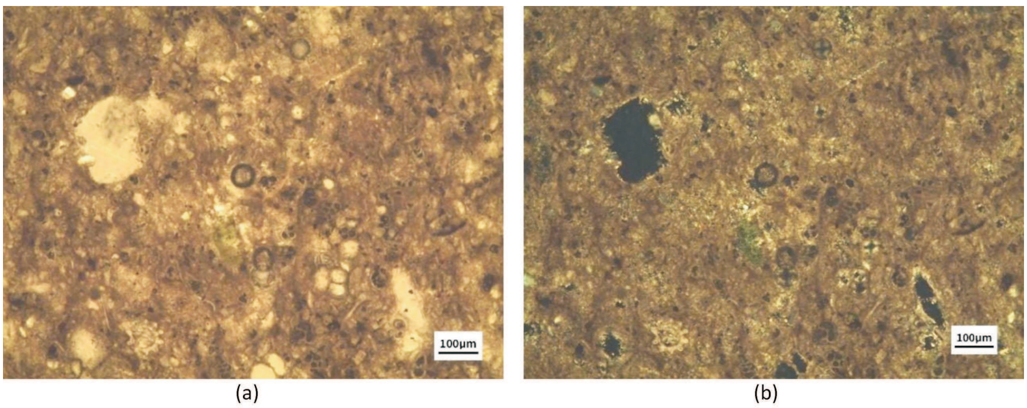

Fig. 4. MGL: Similar to ferruginised *Globigerina* mudstone reproduced in [12]: (a) parallel nicols, micrite with planktonic *Globigerina* foraminifera, benthic foraminifera, and a glauconite grain; (b) crossed nicols, the same view as (a), intraparticle porosity is present

Thin sections were analysed under a Zeiss Axioskop 40 transmitted light-microscope. An ARL 8420+ X-ray fluorescence spectrometer and a Philips PW1729 X-ray generator were also used. An oriented mount technique was applied for the preparation of the clay mineral analysis, since it enhances the d001 peaks [13].

The petrographical analysis and microphotographs were carried out by Professor Elena Koleva-Rekalova. The classification of the limestone proposed by Dunham [14] was used to describe the texture of the carbonate samples.

Results and discussion. The petrographical characteristics of the *Globigerina* limestone samples under study are given in Table 1.

In FR1, the micrite is well preserved and rarely recrystallised to microspar (Fig. 2). There are single dolomite rhombs in the matrix. Small planktonic *Globigerina* foraminifera predominate; generally their chambers represent pores. Single benthic foraminifera also occur. The echinoid and bivalve bioclasts are scarce; the sizes of echinoderm fragments are less than 0.5 mm and bivalve fragments not larger than 1.0 mm. Sporadic glauconite grains sized predominantly < 0.15 mm are visible. The LGL samples are *Globigerina* wackestones with scarce clastic grains [10]. In Q1, the micrite is recrystallised to microspar and pseudospar. Pores are present too. Small planktonic *Globigerina* foraminifera occur; single and strongly altered benthic foraminifera are also present. Bioclasts of echinoids and bivalves are rare, altered and difficult to discern. Some glauconite grains are visible. In Q3, the micrite is recrystallised to microspar; it is preserved only in places that resemble micrite intraclasts. Planktonic *Globigerina* foraminifera occur; bioclasts and single benthic foraminifera are also present. Only one bivalve fragment has a size of 1.2×0.03 mm. Glauconite grains are scarce.

Petrologically, the micrite matrix in FR2 varies from 45% (wackestone) to 55%; the texture turns into packstone in some places where the allochems exceed 50% (Fig. 3). The matrix is composed of relatively well-preserved micrite; it is occasionally brown in colour due to the presence of Fe-oxides. The micrite is rarely recrystallised to brighter microspar. The allochems are mainly large planktonic foraminifera; small planktonic *Globigerina* foraminifera are present but in lesser quantities. Single benthic foraminifera are also present. Most of the chambers of the larger foraminifera are empty and the porosity is higher. Some chambers of the small foraminifera also represent pores. When the material filling the chambers is preserved, it can be noted that it is composed of micrite, commonly recrystallised to microspar and spar. Some chambers of the larger foraminifera are filled with phosphate, glauconite or dark brown Fe-oxides. There are echinoid and bivalve bioclasts, most of them with sizes less than 1.0 mm, rarely reaching 1.9×0.6 (bivalve); 1.5×0.6 (echinoid); 1.7×0.4 (bivalve); 1.4×0.15 (bivalve) mm. Sporadic small bioclasts are silicified. Glauconite grains of varying sizes (0.15×0.09; 0.15×0.15; 0.23×0.15; 0.45×0.15 mm) and shapes (rounded, ellipsoidal and irregular) are relatively common. The terrigenous components are

Table 1

Petrographical characteristics of limestone samples

Composition	Fomm ir-Riħ			Mqabba [10]		Msida [12]	
	MGL	UGL		LGL		LGL	
	FR3	FR2	FR1	Q1	Q3	B1	B2
Matrix	90%	55–45%	60%	80%	65%	70%	90%
Allochems	10%	45–55%	40%	20%	35%	30%	10%
Terrigenous components	single; sizes < 0.10 mm	single; sizes < 0.10 mm	single; sizes < 0.15 mm	rare	rare	single; sizes < 0.15 mm	single; sizes < 0.10 mm
Classification	*Globigerina* mudstone	*Globigerina* wackestone to packstone	Ferrugenised *Globigerina* wackestone	*Globigerina* wackestone	*Globigerina* wackestone	*Globigerina*-bioclastic wackestone	*Globigerina* mudstone

Table 2

XRF analysis of limestone samples

Oxides	Fomm ir-Riħ			Mqabba [9]		Msida [11]	
	MGL	UGL		LGL		LGL	
	FR3	FR2	FR1	Q1	Q3	B1	B2
SiO_2	18.41	24.16	26.85	03.28	06.38	17.83	15.20
MgO	01.52	01.98	01.07	00.84	00.91	01.18	01.07
Al_2O_3	02.21	04.41	07.36	00.97	01.57	02.99	02.84
Fe_2O_3	01.22	02.97	03.03	00.36	00.91	01.55	01.34
MnO	00.04	00.04	00.04	00.00	00.00	00.04	00.04
TiO_2	00.21	00.33	00.47	00.09	00.18	00.40	00.33
CaO	44.86	41.02	39.57	52.86	50.14	42.93	42.43
Na_2O	00.18	00.22	03.47	< LOD	00.01	00.12	04.01
K_2O	00.91	01.30	01.06	00.29	00.53	00.87	00.74
P_2O_5	00.73	00.95	01.17	00.12	00.29	00.23	00.22

LOD: limits of detection

subrounded to subangular with quartz grains being recognizable.

FR3 is a *Globigerina* mudstone similar to sample B2, extracted from blue lenticular patches within the LGL [12] (Fig. 4). The micrite matrix is well preserved and locally recrystallised to microspar where the porosity is slightly increased. The green-brown colour is probably due to clay minerals. Small planktonic *Globigerina* foraminifera are present; benthic foraminifera and bioclasts are rare. In some places the micrite is recrystallised to microspar.

The geochemical composition of the FR samples is tabulated along with LG samples (Table 2). The SiO_2, Al_2O_3 and Fe_2O_3 content of FR samples increases gradually towards the upper end of the *Globigerina* formation. The percentage of the other non-carbonate content of sample FR3 is similar to sample B1 [12]. The X-ray diffraction analysis recorded the presence of calcite and quartz in the rock samples. Other non-carbonate minerals noted in the insoluble residue include zeolite and augite in FR3, and K-feldspar and muscovite mica in FR1 and FR2. Gypsum and illite are also present in FR1 and FR2 respectively. The illite has less potassium and more silica than muscovite [15]. It can form during diagenesis through the alteration of other clay minerals, or due to postdepositional weathering of silicates (notably K-feldspar and muscovite). Similar to smectite, illite is structurally related to micas.

Conclusion. A section was studied in [16] to clarify the age of the LGL through quantitative analyses of calcareous nannofossils included Fomm ir-Riħ. As per the official designation of this area, the site falls just within the limits where only the Middle *Globigerina* Limestone and Upper *Globigerina* Limestone members outcrop. The following conclusions were noted:

1. The matrix to allochems ratio of the Middle *Globigerina* Limestone is significantly different from that of the Upper *Globigerina* Limestone; the former is more similar to the blue lenticular patches occurring in the Lower *Globigerina* Limestone.
2. The matrix of both divisions of the Upper *Globigerina* Limestone is composed of well-preserved micrite that is rarely recrystallised to microspar. Glauconite grains are present.
3. Small planktonic *Globigerina* foraminifera predominate in the upper division of the Upper *Globigerina* Limestone but are less profuse than in the lower division of Upper *Globigerina* Limestone, which is predominantly composed of large planktonic foraminifera. Echinoid and bivalve bioclasts, present in the lower unit of Upper *Globigerina* Limestone, are rare in the upper unit of Upper *Globigerina* Limestone.
4. The SiO_2, Al_2O_3 and Fe_2O_3 content increases gradually from the Lower *Globigerina* Limestone member towards the upper end of the *Globigerina* formation, the Upper *Globigerina* Limestone member.
5. Although differing in geochemical composition, the Middle *Globigerina* Limestone, a *Globigerina* mudstone, is similar to the blue lenticular patches oc-

curring in the Lower *Globigerina* Limestone with respect to petrography and qualitative mineralogy.

6. The SiO_2 content of the Middle *Globigerina* Limestone is higher than that of the blue patches occurring in the Lower *Globigerina* Limestone (the SiO_2 content of the blue patches and *sol ikħal* is $> 10\%$ and $< 10\%$, respectively [11]).
7. The SiO_2 content of the Upper *Globigerina* Limestone is $> 20\%$, increasing to the top of this lithostratigraphic unit; in the case of the Middle *Globigerina* Limestone it is $< 20\%$.

Acknowledgements. The author would like to thank Professor Elena Koleva-Rekalova from the Geological Institute of the Bulgarian Academy of Sciences, Sofia, for the microphotographs and her advice on the petrographical interpretations.

REFERENCES

[1] Burollet P. F. (1969) Petroleum Geology of the Western Mediterranean Basin, Joint Conf. Inst. Petrol. and Amer. Assoc. Petrol. Geol., Brighton.

[2] Burollet P. F. (1973) Importance des facteurs salifères dans la tectonique tunisienne, In: Livre Jubilaire de M. Solignac, Ann. Mines Géol., Tunis, **26**, 111–120.

[3] Burollet P. F., J. M. Mugniot, P. Sweeney (1978) The Geology of the Pelagian Block: The Margins and Basins off Southern Tunisia and Tripolitania, In: The Ocean Basins and Margins, (Eds Nairn A. E. M., W. H. Kanes, F. G. Stehli), Springer, Boston, MA.

[4] Oil Exploration Directorate (1993) Geological Map of the Maltese Islands, Malta, Office of the Prime Minister.

[5] Pedley H. M., M. R. House, B. Waugh (1976) The Geology of Malta and Gozo, Proceedings of the Geologists' Association, **87**, 325–341.

[6] Pedley H. M., S. M. Bennett (1985) Phosphorites, hardgrounds and syndepositional solution subsidence: A palaeoenvironmental model from the Miocene of the Maltese Islands, Sedimentary Geology, **45**, 1–34.

[7] Murray J. (1890) The Maltese Islands with special reference to their geological structure, Scottish Geographical Magazine, **6**, 449–488.

[8] Morris T. O. (1952) The Water Supply Resources of Malta, Malta, Government Printing Office.

[9] Bianco L. (1993) Some Factors Controlling the Quality of Lower *Globigerina* Building Stone of Malta, Unpublished M.Sc. dissertation, University of Leicester.

[10] Bianco L. (2017a) Limestone replacement in restoration: The case of the church of Santa Maria (Birkirkara, Malta), International Journal of Conservation Science, **8**(2), 167–176.

[11] Bianco L. (2017b) Mineralogy and geochemistry of blue patches occurring in the *Globigerina* Limestone Formation used in the architecture of the Maltese Islands, C. R. Acad. Bulg. Sci., **70**(4), 537–544.

[12] Bianco L. (2018) Petrological characteristics of blue lenticular patches occurring in the Lower *Globigerina* building limestone of Malta, Romanian Journal of Materials, **48**(1), 115–120.
[13] Drever J. I. (1973) The preparation of oriented clay minerals specimens for x-ray diffraction analysis by a filter-membrane peel technique, American Mineralogist, **58**, 553–554.
[14] Dunham R. J. (1962) Classification of carbonate rocks according to depositional texture, Classification of carbonate rocks (Ed. W. E. Ham), American Association of Petroleum Geologists, Memoir 1, 108–121.
[15] Leeder M. R. (1982) Sedimentology: Process and Product, London, Chapman & Hall.
[16] Baldassini N., R. Mazzei, L. M. Foresi, F. Riforgiato, G. Salvatorini (2012) Calcareous plankton bio-chronostratigraphy of the Maltese Lower *Globigerina* Limestone member, Acta Geologica Polonica, **63**(1), 105–135.

Faculty for the Built Environment
University of Malta
Msida MSD 2080, Malta
e-mail: lino.bianco@um.edu.mt