THE INDUSTRIAL MINERALS OF THE MALTESE ISLANDS: A GENERAL INTRODUCTION

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Oligocene and Miocene shallow water carbonates form the entire Maltese archipelago. The exposed stratigraphic sequence is capped by and resting on shallow water limestone formations. The formations are frequently fissured. Of the various islands of the archipelago, only Malta and Gozo display the whole stratigraphic sequence.

The geological succession of the Maltese Islands is given in Table 1.[1] A general account and discussion of the various formations can be found in Zammit Maempel's book *An Outline of Maltese Geology* (1977). The geological map of the Maltese Islands is given in Figure 1.[2]

UPPER CORALLINE LIMESTONE FORMATION up to 162 m		TORTONIAN	MIOCENE
GREENSAND FORMATION 0 - 12 m		SERRAVALLIAN	
BLUE CLAY FORMATION 0 - 65 m			
GLOBIGERINA LIMESTONE FORMATION 23 - 207 m	UPPER	LANGHIAN	
	UPPER PHOSPHORITE		
	MIDDLE	BURDIGALIAN	
	LOWER PHOSPHORITE		
	LOWER	AQUITANIAN	
LOWER CORALLINE LIMESTONE FORMATION over 140 m		CHATTIAN	OLIGO-CENE

1. Pedley, H.M. House, M.R. and B. Waugh, B., 'The Geology of the Pelagian Block: The Maltese Islands', *The Ocean Basins and Margins*: vol. 4B: The Western Mediterranean, Nairn, A.E.M., Kanes, W.H., and Stehli, G.G., editors, vol. 4B (Plenum Press, 1978), 417133.
2. Pedley, H.M., 'A new lithostratigrophical and paleoenvironmental interpretation for the coralline limestone formations (Miocene) of the Maltese Islands', *Overseas Geology and Mineral Resources, Institute of Geological Studies*, London, vol. 54 (1978).

INDUSTRIAL MINERALS

All the industrial minerals on Malta are sedimentary in origin. They comprise limestone, clays, sandstones and phosphate. It is widely held that the quality of these minerals varies a lot. Although various studies were undertaken on the quality and durability of local limestone, no systematic investigation was ever undertaken. The *Malta Structure Plan* (1991) stated the need for evaluating and assessing the mineral resources of the Islands.

Limestone

This is the main industrial mineral of the Islands. In the last century it used to be exported to a number of Mediterranean countries including Greece, Turkey, and North Africa. [3] Locally, five types of limestones were utilized. These were:

a. First-quality limestone (locally : *żonqor tal-prima*);
b. Second-quality limestone (locally : *żonqor tas-sekonda*);
c. Third-quality limestone (locally : *franka*);
d. Second-class third quality limestone (locally : *soll*);
e. Heat-resistant limestone (locally : *ġebla tal-kwiener*).

First- and Second-quality limestone

The terms *First* and *Second Quality* limestone are used both for the Upper and the Lower Coralline Limestone. Their water absorption after 24 hours immersion is 2 to 3 per cent of their bulk. [4] Frequently both qualities are found in the same quarry. The *second-quality* often occurs above the *first* but sometimes it is intermixed with the *first*.The *first-quality* is brownish yellow to white in colour. Table 2 gives the properties of the first- and second-quality limestone as stated by Colson.

Table 2 : Properties of *First-* and *Second-Quality* building stone

	First-Quality	*Second-Quality*
Geology:	crystallization has taken place.	stone is in its original condition.
Properties :	hard; crystalline; non-porous; weathers very well; easily worked; split straight and smooth; some take polish.	softer than first quality; grains of various sizes; porous; weathers well but not as good as first quality; easily worked.

3. Ellul, M., 'Weathering and Deterioration of Malta Limestone-Causes and Remedies', Paper read at the Second International Symposium on the deterioration of building stones held at Athens; manuscript consulted.
4. Murray, J., 'The Maltese Islands with special reference to their geological structures,' *The Scottish Geographical Magazine*, vol. 6 (1890), 449-88.

Colson further distinguished between five varieties of first quality limestone. Table 3 is based on his notes on the various types of this limestone found in Malta. *First-quality* limestone was formerly used for kerbstones, doorsills, stairs, milestones, and monuments. Nowadays they are used as spalls in road construction and as fine and coarse aggregate in the production of concrete and road surfacing. The hard compact variety is still sometimes used as a dimension stone in important buildings and monuments. The soft limestone division within the Upper Coralline formation has been extensively quarried for the manufacture of lime (locally : *ġir*).

The word 'marble' traditionally applied to varieties of the Upper and Lower Coralline Limestone is a misnomer. They are not metamorphic in origin. They are first-quality limestone which take polish. Hyde [5] limits polishable first-quality limestone to the Upper Coralline formation.

Third- and Second-Class Third-quality limestone

These limestone are present in the lowest beds of the Globigerina formation. They are soft, easily quarried, and hewn into any shape. The water absorption of Globigerina limestone after 24 and 72 hours is about 25 per cent [6] and 31 per cent [7] respectively.

Table 3 : Types of *First-Quality* limestone found in Malta

Type	Locality	Diagnostic properties
1	Madliena	colour : light brown; fine-grained; crystalline; clean bright fracture; hard; durable; rings clearly.
2	Madliena	same as type 1 but with larger grains.
3	Madliena	colour : white; no apparent grains; spots and patches of softer stone intermixed; hard; brittle; durable; non-porous.
4	Magħlaq	colour : white; large-grained; hard; durable; somewhat porous; interstices not always filled up.
5	Magħlaq	same as type 4 except for closer grains; non-porous.

5. Hyde, H.P.T., *The Geology of the Maltese Islands* (Malta, 1955)
6. Murray.
7. Hyde.

The third-quality limestone is pale yellow in colour. It was formerly used for roofing slabs and for masonry construction. It is still extensively used as a dimension and ornamental stone. This limestone quality weathers well, becoming harder and light reddish-brown in colour. On weathering, it frequently exhibits honeycomb weathering. A tradition of making sculptures and carvings out of this limestone exists. In Gozo there is actually a small industry concerned with the manufacture of such objects of art.
Second class third-quality limestone is inferior to the third quality limestone. It does not stand exposure and it is used for foundations and in other situations protected from the air. Opinions of stonemasons and quarrymen about what constitutes *soll* differs widely.[8] Frequently it occurs as a bed within the formation and sometimes as blue-coloured patches.

Heat-resistant limestone
Rizzo [9] differentiated between two beds within bed 1 of the Globigerina formation (Table 5). The lower one is heat resistant and hence it was quarried to build ovens and to manufacture small stone stoves (*kwiener*). The best quality of this variety was quarried at Tal-Img˙ajjen in the limits of Xewkija, at Ta' Óamet and in other areas. [10]

Clay
The Blue Clay formation is made of fine particles rich in alumina and water. It has poor cohesion and when mixed with water it makes a thick sticky paste. It can be grey, blue, yellow, or brown in colour. The Clay is responsible for the upper water table and natural springs of the Islands.
The Blue Clay is not used for building purposes. When blended with sand, it was used in the manufacture of local pottery. The civil engineering properties of the Blue Clay were known to the Knights of St John. In the seventeenth century they constructed masonry aqueducts to transfer by gravity water collected from this layer to Valletta, a distance of approximately 13 kilometres. Although of low cohesive properties, the clay was sometimes used as puddle for dams. Other proposed uses of the Clay included the manufacture of alumina and fertilizer. Abstracting aluminium from the high alumina content was thought to be a potential industrial application of the Clay. [11] Such an application is not feasible because the workable quantities are limited and the composition is not stable. [12] Cooke suggested that the crystalline masses of selenite (gypsum) or sulphate of lime present could be utilized as a fertilizer.

8. Dr. A. Torpiano, personal communication.
9. Rizzo, C., *Report on the Geology of the Maltese Islands* (Malta, 1932).
10. Hyde
11. Rizzo.
12. Hyde.

Glauconite deposits

Glauconite deposits make the entire Greensand formation. It is made up of sand like glauconite grains cemented by silica, lime, clay, and oxides of iron. It is highly porous and since it is overlying the clay, it forms a natural underground reservoir for the surface water percolating from the surface, joints and fissures of the Upper Coralline formation. [13]

The Greensand has no practical use in the building industry. Although a sand of low grade can be obtained, it is not suitable for mortar or concrete making. Also, recovery of such sands is very expensive because outcrops are not easily accessible.

Phosphorite

Phosphorite beds have been developed within the Globigerina formation. The thickness of these beds varies from a few centimetres to over a metre. Spratt, [14] Cooke, [15] and Rizzo [16] agree that these nodules enhance the fertility of local soil. All authors had therefore suggested the exploitation of these beds for local use as a fertilizer. Spratt [17] and Cooke [18] had also suggested the exploitation of these beds on a commercial scale. Although deposits are of inferior quality, the latter suggested the Italian market as a potential export destination. Rizzo [19] gave a number of reasons why this proposition was not feasible.

To contemporary standards, commercial low grade phosphorite-bearing strata are present in Gozo. About 1492.5 cubic metres of such strata are contained within the Xlendi and Qawra subsidence structure.[20] When weighted against the environmental implications involved with an extractive operation, these deposits are not worth exploiting.

Tables 4, 5, 6, and 7 are based on Colson's remarks on the Lower Coralline, Globigerina, Greensand, and Upper Coralline Formations respectively. [21]

13. Ibid.
14. Spratt, T.A.b. and Forbe E., 'On the Geology of the Maltese Islands', *Proceedings of the Geological Society,* vol 4. (1843), 225-9.
15. Cooke, J.H., Notes on the Globigerina Limestone of the Maltese Islands, *Geological Magazine,* vol. 33 (1896), 502-11
16. Rizzo.
17. Spratt.
18. Cooke
19. Rizzo
20. Padley H.M. and S.M. Benett, 'Phosphorites, Hardgrounds, and Sundepositional Solution Deposition: A peleoenvironmental model from the Miocene of the Maltese Islands', *Sedimentary Geology,* vol 45, 1-34.
21. Murray.

Table 4 : Classification of the Lower Coralline Limestone

Bed	*Diagnostic properties*	*Uses*
3	very durable; crystalline; hard; non-porous; high crushing value; uniform in colour.	building stone.
2	nodule seam.	no use in building.
1	transition (Scutella) bed; soft; often mixed and merging into the calcareous sands of the overlying stratum; fine-grained; not durable; Echini project outwards when stone decays away.	not much used in building.

Table 5 : Classification of the Globigerina Limestone

Bed	*Diagnostic properties*	*Uses*
9_2	darker stone; does not withstand exposure.	foundations and other cases where protection from air is present.
9_1	pale yellow limestone but turns to light reddish brown colour after some time; composed of minute fossils; easily split into thin slabs; hardens when exposed to air; weathers very well; no fossils are present except for remains of saurians etc., and a few shells;	building stone; paving stone; thin slabs for roofing over beams; exported to Turkeyand other countries of the Mediterranean.
8	thin layer of nodules (often missing).	no use for building purposes.
7	white, yellow fine-grained rock; building stone small nodules or chert (or hard substances resembling chert) scattered about in it.	building stone.
6	pale red, yellow or bluish rock; stands well when not exposed to the air; to the air; fossils are scarce.	foundations and rough walls or inside thick massesof buildings.
5	band of green nodules often partially embedded in the overlying layer - colour seems to be only on the surface.	not indicated.
4	nodule seam similar to bed 2 but thicker; contains plenty of sharks' teeth.	not indicated
3	thin layer of soft stone containing small nodules of selenite, manganese, etc.	not indicated.
2	top nodule seam; consists of conglomerate of shells, casts of shells in a peculiar dark brown polished material, corals, etc., in a brown matrix which varies from soft to hard.	no use in building.
1	dark bluish grey when freshly cut; rapidly dries to pale grey when exposed; quite soft; weathers badly; scaling off in successive flakes when exposed to weather.	used in roughest kinds of building.

Notation 9_1 and 9_2 was used to differentiate between varieties of the same bed. Owing to the presence of chert nodules in bed 7, this bed is harder and more difficult to work than bed 9. The cost of working this bed was one-third more expensive than bed 9.
Applying Rizzo's classification. [22] the Lower Globigerina limestone corresponds to bed 9 while the Middle and Upper Globigerina limestone corresponds to beds 5 to 7 and 1 to 3 respectively.

Table 6 : Classification of the Greensand Formation

Bed	*Diagnostic properties*	*Uses*
3_2	same materials as bed 31 but harder; vast amounts of large flat used in rough sea urchins; weathers badly - harder fossils in high relief.	no use in building; work.
3_1	yellowish colour; contains more clay than bed 2; requently morecompact and harder than bed 2; contains black grains from the bed above.	no use in building.
2	black and yellow sands with red patches in some places; breaks up building stone; easily; contains a lot of clay and calcareous matter.	not suitable for not suitable for mortar except when washed (economically unfeasible).
1	sandy rock hardened at the top; hard to soft; white and yellow not red contains black grains.	not indicated.

Notation 3_1 and 3_2 was used to differentiate between varieties of the same bed. Bed 3_2 has been used in Fort Chambray and the perimeter walls of the old cemetery.

Table 7 : Classification of the Upper Coralline Limestone

Bed	*Diagnostic properties*	*Uses*
3_2	hard and close texture; crystalline structure; semi-translucent in appearance; few cavities; casts of small shells harder than those present in beds 1 and 2; durable and weathers well; hard and close texture.	building stone.
3_1	soft; full of cavities and fissures containing soft white powders; weathers very badly.	not indicated.
2	identical in composition to bed 1; differs from bed 1 in that casts are smaller and the cementing material is granular in appearance.	building stone.
1	very loose in structure; very porous; easily broken; weathers into holes very easily.	rubble wall construction; not suitable as building stone.

22. Rizzo.

Notation 3_1 and 3_2 was used to differentiate between varieties of the same bed.

QUARRYING

Two types of quarries are present in Malta : hardstone and softstone. Hardstone quarries work the first and second class quality limestone while the softstone quarries work the third- and second-class third-quality limestone. Limestone from both quarry types is extracted by open-pit methods.

Hardstone quarries are worked by drilling and blasting throughout the depth of the quarry. The material is then crushed, grounded, and screened. Large blocks are lifted from the quarry by cranes and transported to factories working this limestone as dimension stone. New systems for hardstone quarrying using hydraulic hammers are being introduced. [23]

Limestone from the softstone quarries is obtained by sawing blocks with tungsten carbide tipped circular saws directly from the rock bed in the sizes used for building. These saws generate a lot of fine dust. By controlling this dust both the health of the quarrymen and the environment will benefit. Some of this fine dust is used in making mortar. It may be possible to sell this fine dust for non-construction purposes.

In 1990 there were 70 softstone and 26 hardstone licensed quarries.[24] The variation in number of hardstone and softstone quarries for 1970-1986 is given in Figure 2. Volume extracted over the same period is given in Figure 3. Both figures are based on data published in the Malta Structure Plan Technical Report No. 5.3 (1991).

23. New Systems for Hard Stone Quarrying, *The Architect*, April 1993.
24. *Malta Structure Plan Technical Report* No. 5.3: Report of Survey : Quarries (Malta, 1991)

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