CENTRO, Vol. 1, No. 3, 1987, pp. 1-14.

The Għar Lapsi limestones: sedimentology of a Miocene intra-shelf graben

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(Received 13th January 1987)

ABSTRACT

The Għar Lapsi succession of west Malta developed during a Late Tortonian – Early Messinian episode of tectonism associated with the Magħlaq Fault Zone. These syntectonic strata, *Porites* coral bioherms bioclastic packstones and wackestones, debris flow deposits and calciturbidites form a prism banked against the southwest-facing fault-line but are absent from the island of Filfla which lies about 4.5km to the west.

Faunal correlation is imprecise; however, the macrofaunas and general foraminiferal microfaunas of the *Porites* bioherm show it to be correlated with the Tal-Pitkal Member (Late Tortonian). The overlying calciturbidites and debris flow deposits are part of the Ġebel Imbark Member (Early Messinian).

These strata are part of a half-graben fill which cuts the Miocene shelf between Filfla and the present Magħlaq cliffs of Malta. The absence of planktonic Foraminifera from the graben fill sequence and low percentages recorded from strata on Filfla island confirm that this structure was intra-shelf in origin rather than a shelf edge feature.

Calciturbidite laminites and debris flow deposits, developed during the Lower Messinian, were deposited during a eustatic fall of Mediterranean sea-level concomitant with the Lower Evaporite Complex of Sicily.

Introduction

The central Mediterranean island of Malta is composed of a sub-horizontal Oligocene and Miocene succession (Felix, 1963; Giannelli and Salvatorini, 1975) terminated by the Upper Coralline Limestone Formation (Pedley, 1978).

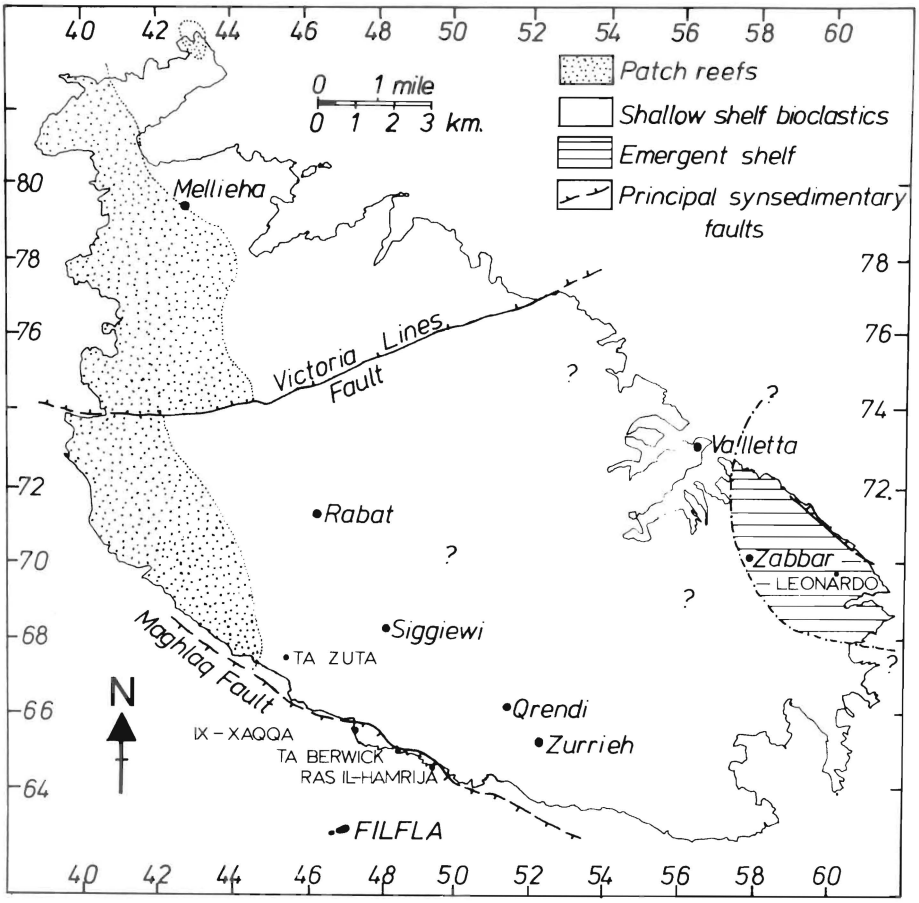

Fig. 1. Map of the island of Malta showing the location of the principal towns, outcrops and faults. The general lithofacies distributions and patch-reef associations are also indicated.

Syndepositional tectonism has exerted a fundamental control upon facies distributions within the islands, but nowhere more so than in the Upper Coralline Limestone Formation. The principal outcrops of Late Tortonian-Early Messinian Upper Coralline Limestone strata lie in the western and northern areas of the island (Pedley, 1983). Additionally, several small outliers of similar aged strata occur in south and central Malta and provide sufficient information to permit a reconstruction of deposits long since removed. These are:

1. Għar Lapsi outlier (Fig. 1, Ix-Xaqqa ta' Ras il-Ħamrija sections)

A 2.3km long coastal outlier, about 0.8km at its widest and bounded on its landward side by the Maghlaq Fault with a calculated throw of about 203m (Pedley *et al.*, 1976). Sediments consist of shallow marine carbonates, including a reefal and thick resediment sequence. Although dislocated by fractures, a full sequence is developed from Blue Clay Formation to top Upper Coralline Limestone Formation.

2. Filfla Islet outlier (Fig. 1)

An Upper Coralline Limestone stack lying 4.5km offshore to the southwest of Malta, consisting of shallow shelf wackestones and packstones succession lying over about 15m of Blue Clay Formation.

3. San Leonardo outlier, east of Żabbar (Fig. 1)

A peritidal sequence of uncertain Late Miocene age containing charophytes and hydrobid gastropods (Pedley and Waugh, 1976). It lies unconformably on *Globigerina* Limestone Formation (Lr. Miocene).

Past studies of these outliers are few. Trechmann (1938), gave some account of the Quaternary geology around Għar Lapsi and the lithostratigraphies of each were outlined in Pedley *et al.* (1976); Pedley (1978). Consideration was given to regional structural aspects including the Magħlaq Fault by Illies (1981); Reuther (1984a, 1984b).

The unique lithostratigraphy of the Għar Lapsi outlier is the subject of this paper. The outlier, though small, is the only part of an extensive Central Mediterranean Pantelleria rift system currently to be exposed. As such it provides an insight into syntectonic depositional processes associated with the rift development. Furthermore, the youngest parts of the deposit record a Late Miocene emergence better than that seen in any other Maltese locality.

General Regional Lithostratigraphy

Before embarking on a consideration of local stratigraphies, it is important to make reference to the Upper Coralline Limestone shelf succession common to the Maltese Islands. This is provided in the Ta' Żuta cliffs, which lie about 3.4km west of Siġġiewi (Figs. 1 and 2), at the south end of the Rabat Plateau.

1. Ta' Żuta, Rabat Plateau (Fig. 1 and 2)

a) *Mtarfa Member:* The oldest Upper Coralline Limestone unit is the Mtarfa Member (16m) which contains, at its base, a thin laminar micrite bed unique to the locality (The Fawwara Fish Bed, Pedley, 1978). The glauconitic Greensand Formation lies at the base of the fish bed.

The main body of the member comprises a lower cream coloured wackestone and packstone shelf sequence with a full marine fauna including scattered planktonic foraminiferids (Ġebel Mtarfa Beds), and an overlying white wackestone and packstone sequence containing fewer fossils and no planktonics (Rdum il-Ħmar Beds of Pedley, 1978). Both beds are massive and, other than ubiquitous bioturbation, generally lack sedimentary structures. Ripple lamination occurs in the upper part of the Rdum il-Ħmar Beds.

b) *Tal-Pitkal Member:* The Tal-Pitkal Member conformably overlies the Mtarfa Member. This shallow shelf sequence developed progressively upwards into coarse grained bioclastic packstone with an abundant marine fauna and coralline algae content. At Ta' Żuta (a typical example of the eastern facies) reefs are absent, however, in more northwesterly outcrops *Porites* patch-reefs are common in the upper part of the Member.

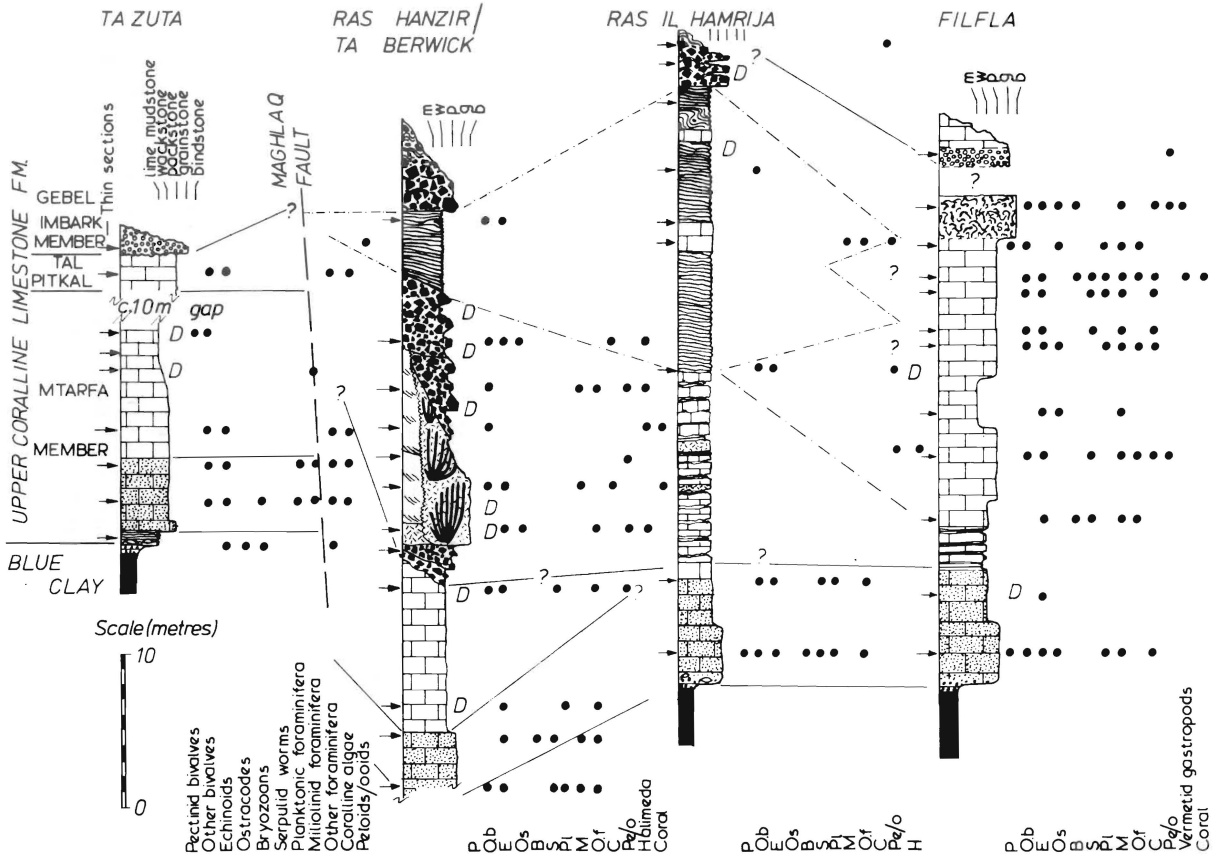

Fig. 2. Bar columns taken from each of the main outcrops of the Upper Coralline Limestone Formation (See Fig. 1 for localities). Solid lines indicate correlation of members listed on the left hand side of the figure. Heavy broken line is the principal fracture of the Magħlaq Fault. Chains of dots and dashes show internal correlation of the Għar Lapsi succession. D indicates dolomitization (usually microdolomite). Small arrows (left side of columns) are sample points with generalized thin-section data plotted opposite on the right side of the column. Note the presence of miliolinid Foraminifera throughout all columns and presence of planktonic forams, generally in the base of the Mtarfa Member only, except in the Filfla section.

c) *Ġebel Imbark Member:* The top of the Tal-Pitkal beds is truncated by an intra-formational erosion surface, and ooidal grainstones of the Ġebel Imbark Member overlie the hiatus directly. About 3m of these are preserved locally. Slightly younger micritic strata of restricted shallow water aspect overlie the oolites in northern Malta but not in the Rabat Plateau area.

Lithostratigraphy of Other Outliers

The following two outliers show contemporaneous strata developed SW of the Magħlaq Fault.

1. Filfla Islet (Fig. 1 and 2)

The Ġebel Mtarfa Beds (about 7m thick and with a glauconitic base) are similar to those in the Ta' Żuta section and consist of massive bedded cream wackestones (stippled lower part to Mtarfa Member in Fig. 2). The overlying Rdum il-Ħmar Beds (about 11m thick) are massive bedded white non-ferroan wackestones and mudstones containing an abundant lucinid and cardiid bivalve fauna (moulds and casts).

The Tal-Pitkal Member conformably overlies the Mtarfa Member. It is represented by about 11m of pale grey packstones and is terminated by about 3m of serpulid biostrome. The latter probably correlates with patch-reefs in the Tal-Pitkal member of the Rabat Plateau (see Pedley, 1979, 1983).

The Ġebel Imbark Member (only seen in fallen blocks) appears to be represented by about 2m of typical, white ooidal grainstone lying with sharp contact close above the serpulid biostrome. Other elements of the member were not accessible for sampling. The similarity between the Filfla and Ta' Żuta successions, therefore, is strong.

2. Għar Lapsi Outlier

Carbonates in this outlier, in contrast, become highly variable above the recognisable Mtarfa Member. The beds are best considered by locality as many are hitherto undescribed and their relative ages are not always clear.

(a) *Ras il-Ħamrija* (Fig. 1): This most southeasterly outcrop gives the following succession: The Mtarfa Member (15m) is of standard type. The lowest beds (Ġebel Mtarfa Beds) consist of massive bedded, cream to yellow wackestones and packstones. At their base is a glauconitic streak and a transitional contact with the underlying Blue Clay Formation. The member contains pectinids, small bryozoan colonies and *Terebratula* at its base *(Terebratula-Aphelesia* Bed of Pedley, 1976) but macrofaunas become sparse higher in the member. The transitionally overlying Rdum il-Ħmar Beds are atypical. Their lowermost massive bedded nature gives way higher in the sequence to thinner beds of pale grey carbonate mudstones and wackestones, finally grading upwards into laminated mudstones. These have previously been described as the Għar Lapsi beds (Pedley, 1978) and to avoid confusion with previous discussions they will hereafter be addressed as 'mudstone laminites'. Although faunas are sparse, *Halimeda* plates abound at a few levels towards the top.

The Tal-Pitkal Member cannot specifically be identified here. In its place the mudstone laminites (about 20m thick) are developed above the Mtarfa Member. Individual laminae range from 30mm to 10mm in thickness and often comprise 1m thick laminaset units. Contorted beds occur on the north side of Ras il-Ħamrija and

Fig. 3. View looking SE from near Għar Lapsi, of the Ta' Berwick cliff section, with the Ras il-Ħamrija peninsula in the distance. See Fig. 4 for explanation of lithologies present.

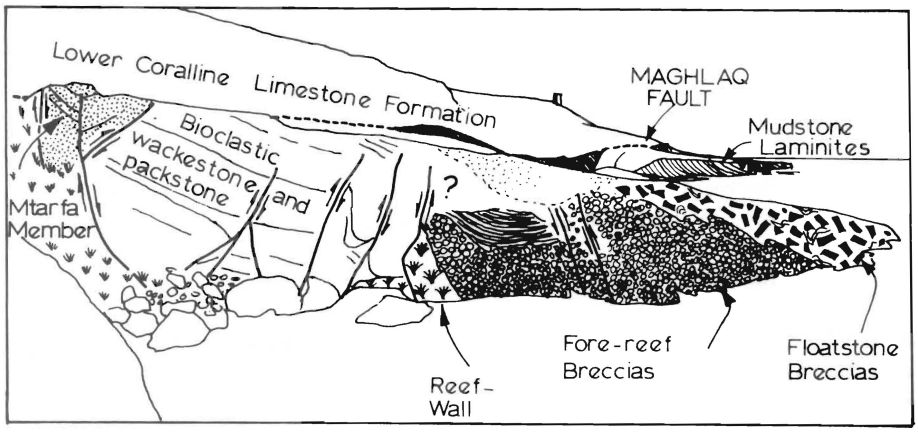

Fig. 4. Detail of the view in Fig. 3 illustrating the distribution of named units and local faulting within the succession. Note the dominance of fore-reef talus versus *in situ* reef and the rapid lateral facies changes in the section. Height of Ta' Berwick cliffs about 18m.

small ripples with northwest orientated crests occur on mudstone laminite bedding planes. Other bedding surfaces carry disarticulated lucinid bivalves with convex-up orientations. No other macrofaunas occur.

Lithoclast floatstone breccias (about 3m preserved) occur above a sharp truncation surface terminating the mudstones. The floating clasts are principally of dolomitized laminated mudstone supported in a bioclast-rich, undolomitized matrix. Other clasts show soft sediment deformation and deformed laminae are common. Thin micritic levels occur towards the preserved top of the breccias. Pedley (1978) records porcellanous micrites and birds-eye textures from this level.

(b) *Ta' Berwick, Ras Ħanżir and Għar Lapsi* (Fig. 1): Collectively, these centrally located localities, though tectonically disturbed, preserve a readily identifiable Mtarfa Member (about 15m thick). This consists of a lower, cream coloured wackestones and packstones sequence, ascribable to the Ġebel Mtarfa Beds, and overlying pale-grey, chalky but massive bedded Rdum il-Ħmar Beds. An arbitrary upper limit to the Mtarfa Member is provided by a step-faulted surface near Għar Lapsi above which occur *Halimeda* gravels and a reefal succession. At Għar Lapsi a considerable thickness of reef breccias appears to underlie an *in situ Porites* reef. The Ta' Berwick sequence is representative of this part of the outlier (see Figs. 2 and 3).

A *Porites* reef, developed directly on the Rdum il-Ħmar Beds (Mtarfa Member), is restricted in occurrence to these localities. It consists of *in situ* and part rotated blocks of pale-grey, tough wackestone, containing *Porites* coral growths (organ-pipe growth-form, cf. Grasso and Pedley, in press). The unit is up to 10m in thickness. The coral rods are 1.5-2m long and 30-50mm diameter. A maximum visible development of about 5m of standing reef wall is present, though smaller *in situ Porites* patch-reefs are developed higher in the reef breccias west of Għar Lapsi.

On the north side of this coral reef-wall occurs a well bedded to cross-stratified bioclastic and ooidal wackestone and packstone (rarely grainstone) sequence (here about 10m thick). This sequence abuts the north side of the reef wall, with vertical contact immediately east of Għar Lapsi (see Figs. 2 and 3). On the south side of the reef wall occur poorly bedded *Porites* reef breccias which dip crudely towards the south. The thickness of the breccias varies according to locality and at outcrop are distributed lateral to the observable reef-wall (Ta' Berwick), below and above it (Għar Lapsi) and at times only above it (Ras Ħanżir). A thin development of mudstone laminites (about 4m thick) is seen above the breccias at Ta' Berwick.

Lithoclast floatstone breccias cap the sequence with sharp underlying contact. Over 6m are preserved and are identical to those at Ras il-Ħamrija. A tough micritic capping level near Għar Lapsi contains both calcrete and rhizocretion fabrics (see later).

(c) *Ix-Xaqqa* (Fig. 1): At the extreme west end of the outlier occurs a thick (>25m) bioclastic development arranged in wedging sets of planar-bedded units, each 0.5-4m thick. The base of the sequence is not seen and the cliff line exposures are mainly inaccessible. Samples from the top of the outcrop suggest the entire succession to be composed of wackestones and packstones, sometimes *Halimeda*-rich or with abundant ooids and peloids. Offshore observation indicates that the wedging sets become more complex and total unit thickness becomes greater towards the Magħlaq fault-line.

Petrogaphic Interpretation of the Għar Lapsi Outlier Lithologies

1. *Mtarfa Member*

The Ta' Berwick and Ras il-Ħamrija sequences are closely comparable to the Ta' Żuta succession with an abundance of bivalve moulds, echinoid plates, bryozoan debris and foraminiferids. Pectinid debris and planktonic Foraminifera are restricted to the basal cream coloured wackestones and packstones (Ġebel Mtarfa Beds) which, at Ras il-Ħamrija, carry detrital glauconite and *Terebratula* sp. immediately above their contact with the Blue Clay Formation. The pale-grey upper beds (equivalent to the

Rdum il-Ħmar beds at Ta' Żuta) are typically wackestones with fewer and smaller bioclasts. These are now moulds. The entire member is composed of non-ferroan calcite.

The Filfla developments are also similar but differ in that planktonic Foraminifera generally occur throughout the member, albeit rather sparsely.

2. ***Porites reef***

The rock consists principally of micrite providing an interstitial fill, but scattered mollusc moulds and *Halimeda* plates are common. *Porites* colonies (now moulds) are the only observable framework. Around Għar Lapsi the reef grades laterally northwards into *Halimeda* packstones. Most of the reefoid strata is now non-ferroan dolomite. The fabric is very comparable to that of patch-reefs within the Tal-Pitkal Member of north Malta described by Pedley (1979).

3. ***Porites reef breccias***

These are petrologically identical to the *Porites* wall strata. Clast sizes vary from sub-millimetre up to 0.3m. Interstitial matrix is minimal but bioclastic packstone may be present. Most of the reef material is now dolomicrospar.

4. *Bioclastic packstones and grainstones*

These strata comprise the majority of the poorly accessible Ix-Xaqqa sections and the cross-stratified strata north of the *Porites* reef-wall. Bioclastic debris is often well rounded and ooidal levels are common. *Halimeda* packstones are interspersed throughout the sequence. Non-ferroan carbonates appear to dominate.

5. *Mudstone laminites*

The laminated mudstones often show normal grading of micro debris set in a micrite matrix. Frequently, sub-centimetre thick individual laminae show sharp basal contacts especially from the Ras il-Ħamrija sections. Clasts are usually silt sized and indeterminate, however, occasional bivalve and benthonic Foraminifera occur and rare quartz is recorded. Typically, the rocks are non-ferroan carbonate mudstones and wackestones. Dolomicrospar and gypsum micro-veining are present at Ras il-Ħamrija.

6. *Lithoclast floatstone breccias*

The non-ferroan wackestone and packstone matrix of these rocks contains much indeterminate bioclastic debris and occasional benthonic Foraminifera. The randomly orientated clasts are principally angular to sub-rounded fragments of mudstone laminate. Clast sizes range from cobbles down to millimetre long fragments, many apparently having been dolomitized prior to incorporation.

The highest preserved stratum in this unit contains fewer and smaller lithoclasts, and is often dominated by micrite with peloidal or clotted texture. Both rhizocretion and vadoid fabrics are present in these micrites in the Għar Lapsi and Ras il-Ħamrija localities.

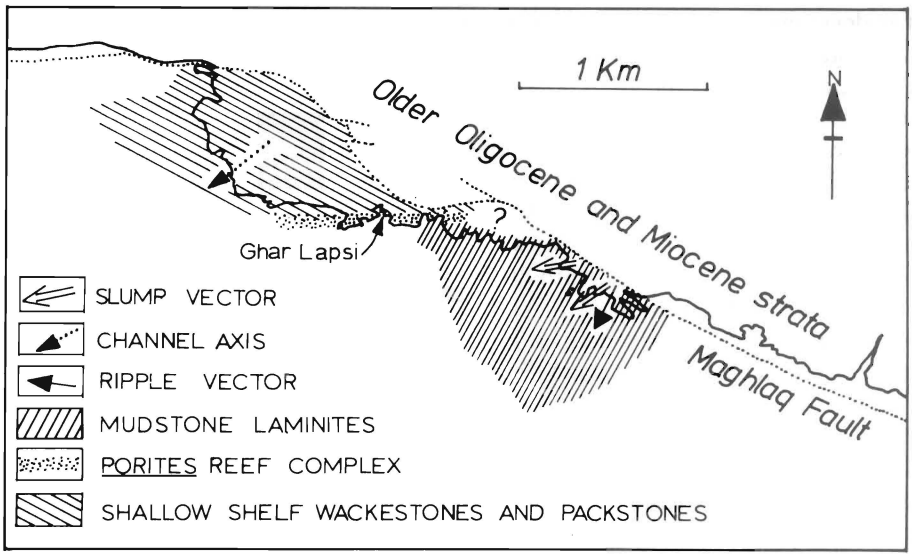

Fig. 5. Plan view of the Għar Lapsi area showing the distribution of the major lithological units. The reef-wall occurs immediately to the south of an E-W branch fault from the Maghlaq fracture. Various current vector data obtained from surface outcrops are also indicated.

Discussion of Facies Trends

The Upper Coralline Limestone of the Għar Lapsi outlier is of greater thickness than the local standard succession. Above a recognisable Mtarfa Member, the sediments show few similarities with either the Ta' Żuta or Filfla sections. The facies interrelationships within the Għar Lapsi outlier are made more complex by faulting. Nevertheless, the descernible facies trends appear to be related to an early fault controlled topography.

Virtually all contemporaneous strata northeast of the Maghlaq Fault Zone (east Malta) has been lost by erosion; however, the preservation of the Għar Lapsi outlier facies argues for the existence of a shallow water depositional area in southern Malta during the Late Miocene from which much of the sediment was derived (see current vectors in Fig. 5). Peritidal sediments at San Leonardo near Żabbar (Fig. 1) confirm the former existence of more extensive carbonate deposits in this area. The Għar Lapsi carbonates can be grouped into two genetic associations:

1. *The reef wall complex*

The *Porites* reef wall provides the key for interpretation of the Għar Lapsi succession. This narrow E-W trending biohermal build-up extends from Ta' Berwick to Għar Lapsi and then out to sea. It is the only development within the islands of a typical Late Miocene 'Type B' reef (cf. Esteban, 1979) though other comparable reefs are common in W Sicily (Catalano, 1979., Esteban and Catalano, 1982) and in SE Spain (Esteban *et al.*, 1977). These atypical, monospecific coral reefs with their rod-like, aberrant growths are thought to have developed during the Late Miocene close to basin facing breaks of slope. The rod-like growth-form of *Porites* is considered by Esteban (1979) to develop as a rapid growth response to an increased sedimentation rate. However, a study of central Sicilian reefs (Grasso and Pedley, in press) suggests

that it developed as a growth response, for maintaining optimum colony position in areas prone to tectonic or eustatic change. The Għar Lapsi outlier reef-wall faces south (Fig. 5) and is located immediately to the south of a similar trending fault-line (marked by a monoclinal flexure in Pedley and Waugh, 1976 Fig. 5). This fault is thought to have undergone Late Miocene synsedimentary movement and provided a submarine break of slope upon which the reef-wall developed. The reef wall is badly fractured in all outcrops, and portions of it may have collapsed during development at Għar Lapsi to produce the rotated reef wall blocks seen in sea cave sections.

The *Porites* reef breccias lie south of the reef wall in the Ta' Berwick sections (Fig. 3 and 4). The close association of these friable, unsorted, monomict breccias with the reef-wall, and their crudely defined off-reef dips, readily identifies the breccias as proximal fore-reef talus deposits. Volumetrically, they are much more important than the reef-wall.

The thick succession of bioclastic wackestones and packstones (rarely grainstones) of Ix-Xaqqa are only found to the north of the reef-wall. Their fair to well sorted nature, cross-stratification and absence of planktonic elements indicate that they are part of a turbulent water succession. Unfortunately the one contact between the two units, at Ta' Berwick, has suffered (? syndepositional) faulting which may have brought the reef-wall up into a juxtaposed position with respect to the packstones and grainstones. In other areas NW of Għar Lapsi the packstones and grainstones appear to be slightly younger than the reef-wall. They correspond probably to the 'calcareous lagoon' deposits in a general Miocene reef model proposed by Esteban (1979).

The expanded thickness of these bioclastic strata in the vicinity of the Magħlaq Fault at Ix-Xaqqa suggest fault movement during deposition. Some planar surfaces now dip towards the fault and are succeeded by further wedges of sediments which have restored horizontality. The sediment yield appears to have been locally derived possibly from areas to the east of the Magħlaq Fault. The presence of *Halimeda* plate levels abundant Miliolacea and ooidal beds in the sequence relates them closely to the top of the Tal-Pitkal Member and possibly also to the Ġebel Imbark Member of the standard Maltese succession (Pedley, 1978, 1983).

2. *Younger sediments*

Present day coastal erosion to the south of the reef-wall deposits has removed laterally penecontemporaneous beds, however, a thin development of the mudstone laminites typical of those developed at Ras il-Ħamrija lies directly on reefal talus at Ta' Berwick (bedded lens beneath question mark in Fig. 4) and demonstrates the laminites to be younger. Collectively, the laminar nature, occasional normal grading of units, basal erosion surfaces and ripple bed-forms typical of these lime mudstones indicates that they are likely to be the product of deposition from low-viscosity density flows. The absence of channelling and large lithoclasts argues against a point source fan deposit, but is compatible with a scarp or shelf edge sheet (cf. Crevello *et al.*, 1985). Current vectors (Fig. 5) indicate that the flows (calciturbidites) emanated from the NE, down a gentle palaeoslope. The subsequent preservation of bedforms points to tranquil conditions between events.

In conclusion, it would appear that the depositional setting developed in response to syndepositional downfaulting of the block to the south of the reef-wall. This created a local deeper water area which acted as a trap for shallow shelf derived resediment.

The lithoclast floatstone breccias show evidence of having moved by viscous flow.

The planar, erosional basal contact of the breccias is closely associated with soft sediment drag folds in the underlying mudstone laminites. Large volumes of mudstone laminite material have been ripped up in both lithified and unlithified states and have been included in the deposit.

The floatstones matrix, however, with its miliolid foraminifers, echinoids and bivalve debris of embayment or lagoonal aspect is not recognised elsewhere at outcrop and appears to represent soft sediment stripped from carbonate shelf areas once lying immediately to the NE of the Magħlaq Fault. Above the basal metre, several thinner (5-10cm) debris flow units alternate with cms-thick, normally graded couplets. Collectively, these probably represent Bouma-type Tab turbidite cycles, deposited close to source and demonstrate that the lower levels of the gravity flow deposit are of subaqueous origin. These sediments are closely comparable with descriptions of debris flow deposits in the literature (e.g. Middleton and Hampton, 1973; Fisher, 1971; Carter, 1975; Lowe, 1976). They do not, however, appear to show reverse grading at outcrop though Quaternary diagenesis has obscured primary textures in most sections.

Massive bedded micritic levels occurring at the top of the preserved succession between Għar Lapsi and Ras il-Ħamrija show diagenetic growth of vadoids (up to 20mm diameter), and laminar calcrete. Parts of the micrite deposit show autobrecciation associated with rhizocretion fabrics (principally alveolar texture), Although it cannot be stated unequivocably that these youngest strata are contemporaneous with the floatstone breccias, their pale grey colour (cf. reddened colour and friable nature of all local Quaternary palaeosol phenomena) suggests that they are Late Miocene in age. It has also been observed in this study that other rhizoid fabrics have penetrated the reef-wall outcrops at Ta' Berwick and the ooidal levels (Ġebel Imbark Member) of the Rabat Plateau near Ta' Żuta. In all cases, the absence of haematitic staining abnormal for Quaternary fabrics on Malta suggests an earlier Miocene subaerial episode connected with the latter part of the floatstone breccia deposition.

Palaeoenvironmental Model

Gravity flow deposits are an unusual aspect of Maltese Miocene sedimentation (for exceptions see Pedley, 1980; Pedley and Bennett, 1985). It is, therefore, necessary to fit the Għar Lapsi occurrence into a regional context.

The simplest interpretation is that the Magħlaq Fault together with the *Porites* reef-wall, lying on the shoulder of a splay fault from the Magħlaq Fault, lay at the edge of the carbonate shelf. Sediment prisms, developed in deeper water against the faulted shelf margins, were derived from SE Malta.

This interpretation is unsatisfactory. Firstly, a total absence of planktonic microfossils but abundance of Miliolacea in the Għar Lapsi succession (only minor percentages of planktonics present in the Filfla succession) suggests deposition on shelf rather than in basin. Secondly, the presence of subaerial features in the uppermost floatstone breccia deposits is incompatible with a basinal setting. Finally, the absence of reef material in both the floatstone breccias and mudstone laminite deposits argues against a typical platform margin reef-wall development along a submarine fault scarp.

Nevertheless, contemporaneous faulting is also well documented in other parts of the Pelagian Block such as in SE Sicily (Ghisetti and Vezzani, 1980) and Lampedusa (Grasso *et al.*, 1985) and is related to plate collision far to the north.

The depositional setting of the Għar Lapsi carbonates is speculative, however, the

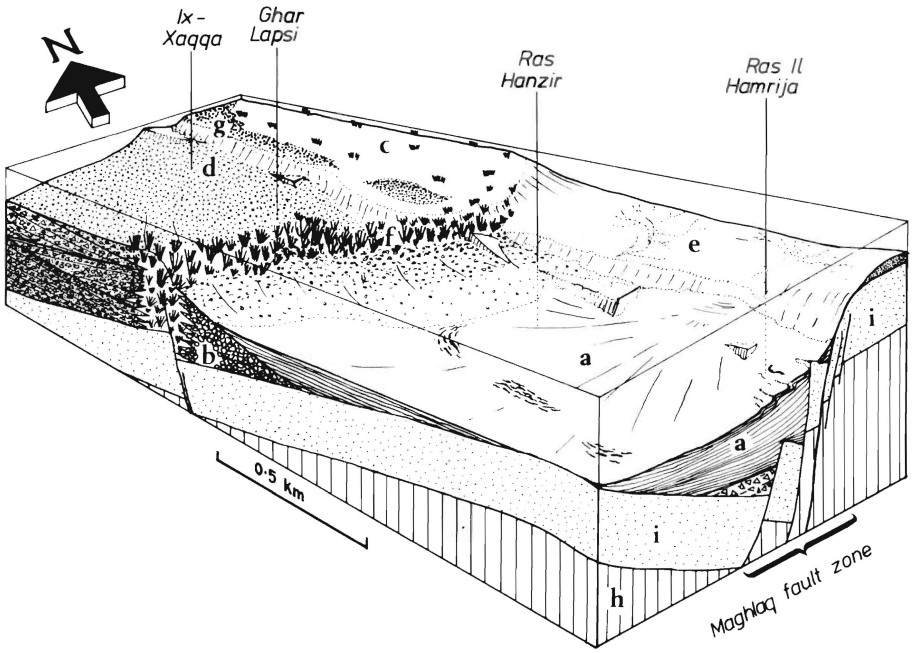

Fig. 6. Block model to illustrate the hypothetical interrelationships between faults and sedimentary packages. The model depicts a time immediately prior to the terminal floatstone breccia episode. (a) lime mudstone laminites; (b) reef talus; (c) inner shelf of standard sequence carbonates with scattered patch-reefs and miliolid-rich shelf sediments; (d) back-reef bioclastic and ooidal packstones derived in part from the stable shelf are to the northeast of the Magħlaq Fault zone; (e) Eastern Malta shelf area which sourced the laminite and debris flow deposits, (strata younger than *Globigerina* Limestone (Serravallian), not now preserved in this area except at San Leonardo near Żabbar); (f) *Porites* reef-wall with fringing fore-reef tallus.; (g) ooidal shoal waters contributing sediments to area (d); (h) Blue Clay Formation with glauconitic remains capping (Greensand); (i) shallow marine wackestones and packstones of the Mtarfa Member.

absence of gravity flow deposits in the Filfla section argues for an intra-shelf graben or half-graben setting. By implication this suggests that the Magħlaq Fault is not a master fault of the Malta Graben but is of secondary status.

There can be little doubt that the *Porites* reef complex developed as an accretionary prism against a fault (c.f. Speksnider, 1985) but this was a local branch fault of the larger Magħlaq system. Shelf sedimentation and subsidence kept pace with each other for a time. Figure 6 demonstrates the hypothetical relationships between the evolving Għar Lapsi succession and adjacent Maltese areas.

The arrival of calciturbidite deposits above the reef complex is the first proof of a significant step along the Magħlaq scarp but the sudden arrival of these gravity flow deposits may well indicate the intervention of eustatic events which were ultimately to lead to subaerial emergence of the entire shelf.

Eustatic sea level fall: Palaeosol fabrics associated with the floatstone breccias also affect other Upper Coralline Limestone units in the vicinity of Ta' Żuta and Għar Lapsi during a period when regional tectonic trends suggest continuing subsidence of the outlier (Reuther, 1984). The emergent fabrics of Ta' Żuta occur at the top of a regressive sequence and as such are predictable; these contemporaneous Għar Lapsi

outlier features however mark a sudden change from deeper marine to subaerial deposition and are interpreted as recording a sudden eustatic sea level fall.

A Late Miocene desiccation of the Mediterranean Sea is well documented in the literature (e.g. Ruggieri and Sprovieri, 1976) and resulted from isolation of the sea from the World oceans followed by partial evaporation of contained waters. The earliest effects of this in the Maltese area are seen to be associated with the Late Tortonian Tal-Pitkal Member (Pedley, 1983). These correlate well with emergent events in SE Sicily generally associated with reef tops in the Carlentini Formation (Grasso *et al.*, 1982). The youngest marine Miocene strata of the region appears, on lithostratigraphical grounds, to be Early Messinian in age. Marine Pliocene is unrecorded from the Maltese Islands and the Ragusa Platform of SE Sicily, both areas of which apparently became subaerial simultaneously and only received a patchy marine Quaternary cover.

It is concluded that the floatstone breccias of the Għar Lapsi outlier are the only onshore Maltese representatives of a thick resediment succession reflecting emergence and stripping off of unconsolidated, latest Miocene lower Messinian strata from the south Malta area during the initial stages of Mediterranean desiccation.

Conclusions

The Għar Lapsi succession is a syntectonic sediment accumulation recording subtle Late Tortonian and Early Messinian movements of the Magħlaq Fault zone. The general absence of planktonic microfaunas in the outlier and low percentages in the Filfla section argues for deposition of the fault-bounded sediments in an intra-shelf graben and, therefore, reduces the status of the Magħlaq Fault. Hitherto, this fault was considered a master fault of the Malta Graben; here it assumes secondary status.

The Għar Lapsi carbonates are mainly a resediment sequence eroded from south eastern Malta. The petrographic details of these re-sediments provide a unique record of sediment types no longer preserved.

Syndepositional changes from submarine to subaerial conditions are the result of a principal drawndown event associated with the desiccation of the Mediterranean Sea. The event was basin wide and permits direct correlation with the base of the Lower Evaporite Complex (lower Messinian) of Sicily.

It is to be mentioned that the last statement-hypothesis is a controversial subject. A final confirmation of its validity depends upon a comprehensive knowledge of mercury biogeochemistry in the Mediterranean Sea.

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