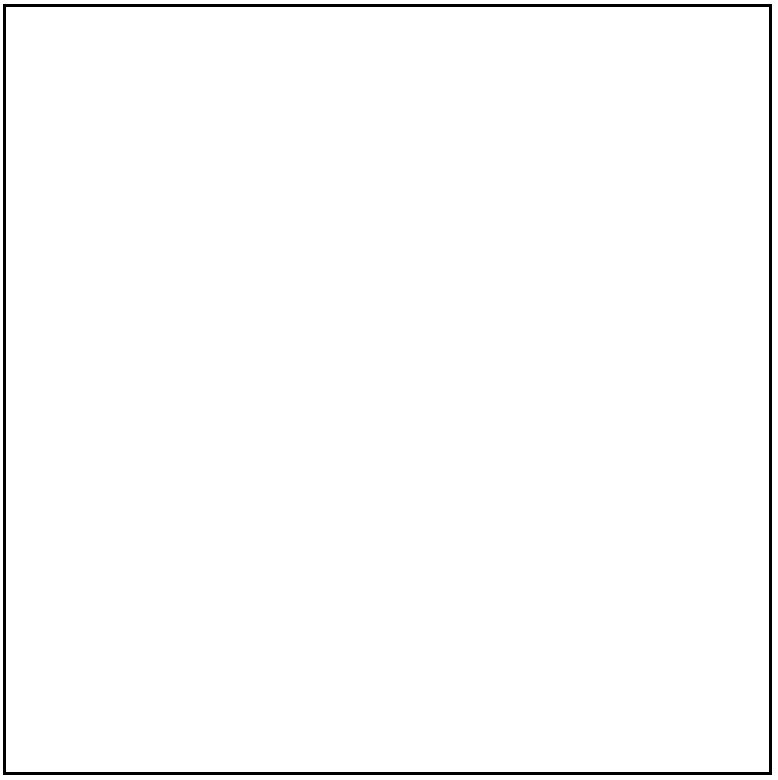
GHAJN TUFFIEHA AREA

- Geology, Geomorphology and Hydrology -



Malta University Services
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1. INTRODUCTION

The GAIA Foundation commissioned the Malta University Services to undertake a survey of the geology, geomorphology and hydrology of Ghajn Tuffieha (Area) to:

(a) expand on the geo-environmental contents of a dissertation by Tracy Micallef, May, 1996, entitled "*The Vegetation of the Blue Clay Slopes of the Maltese Islands*", as well as to Section 4 of "*The Ecological Survey of the Area covered by the Ghajn Tuffieha Emergency Conservation Order*" of January, 1995, carried out by MUS Ltd, by providing a detailed analysis of the present conditions of the Area and by making recommendations for the preservation and rehabilitation of the Area, including the area marked in blue in Figure 1 of the said January 1995 survey, which area is divided into sectors A, B, C and D;

(b) elaborate on Sections 7.5, 7.6 and 7.7 of the January 1996 survey by explaining in detail the basis for the designation of the Sites of Scientific Importance mentioned in the said report and make an attempt to identify any other features within the survey area that qualify as SSI's;

(c) make recommendations regarding the rehabilitation of the makeshift road leading to the beach in order to minimize heavy runoff and erosion;

(d) provide geo-environmental baseline reference for future studies.

To achieve these objectives an extensive bibliographic search of the geology of relevance to the Area was first undertaken. This was followed by a detailed field survey to map, describe and analyse the present geo-environmental conditions. The result of this work is compiled systematically in this report in such a way so as to provide primarily a geo-environmental baseline reference for future studies in the area, and provide, at the same time, answers to the remaining TOR. The main sections of the report are as follows:

Section III treats the geology of the Area, including regional setting, structure and stratigraphy.

Section IV provides a description of the geomorphology of the Area, both in a regional context as well as in terms of the specific features found in the Area.

Section V gives an account of the hydrology of the locality and describes the characteristics of the flow of surface-water over the impervious clay areas as well as the flow groundwater in the

permeable limestones of the aquifers.

Section VI identifies the features of scientific significance that qualify as SSI in terms of the identification and classification criteria outlined in Policies RCO 11 and RCO 12 of the Structure Plan respectively. For each SSI, the study attempted to: (a) Identify the significance of the resource; (b) identify any threat and significant trend in the condition of the resource; and (c) where appropriate, suggest ways of managing better and conserving the resource. For this purpose, conservation profiles are proposed.

2. LOCATION AND DESCRIPTION OF SITE

The site of the survey is located in the northwest of Malta, along the coast from the southern arm of Ir-Ramla Tal-Mixquqa (Golden Bay) to the northern end of Il-Bajja Tal-Gnejna (Gnejna Bay) as outlined in Fig.1. It encroaches inland to include the localities of Tal-Lippija, Ix-Xaghra Tat-Torri and part of Il-Lippija in the south, Il-Hotba L-Bajda, and parst of Ghajn-Tuffieha and It-Tafal in the middle, and an un-named headland lying between Golden Bay and Ghajn Tuffieha Tower in the north, a total superficial area of approximately .8 km^2. The site includes the pronounced promontory of Il-Qarraba and Ir-Ramla Ta' Ghajn Tuffieha (Ghajn Tuffieha Bay) in the west. For the purpose of this survey, the un-named headland is referred to Golden Bay Headland and the site as a whole is referred to as the Ghajn Tuffieha Area.

Morphologically, the area is composed of very distinct units made up of:

(a) a pronounced limestone step culminating at Ix-Xaghra tat-Torri in the south;

(b) a stretch of basin-floor forming Golden Bay headland lying between Ghajn Tuffieha Bay and Golden Bay in the north;

(c) an intervening highly weathered limestone ridge made up of Il-Hotba L-Bajda, Ghajn-Tuffieha and It-Tafal;

(d) steep Blue Clay slopes along the bayhead of Ghajn Tuffieha Bay;

(e) a promontory at Il-Qarraba capped by a small limestone butte;

(f) an isthmus joining the promontory to the mainland;

(g) three stretches of undercliff, one along the coastal edge of Golden Bay headland, one around the Il-Qarraba promontory, and another Ix-Xaghra Tat-Torri facing Gnejna Bay;

(h) three sandy beaches, a large one at Ghajn Tuffieha Bay, a small one on the northern shore of the Il-Qarraba promontory and another small one on the southern shore of the isthmus facing Gnejna Bay.

(i) a wave-cut terrace in the southwest of the area facing Gnejna Bay;

(j) a top-soil cover of very irregular thickness mellowing the morphology of parts of the high-grounds and the headland.

Elevation varies between sea-level along the coast and 100 m ASL at Il-Lippija. The area is characterised by highly variable relief, with surface gradients ranging between the gently inclined tops of the step, butte and headland to moderately undulating weathered top of the ridge, steep clay slopes and near-vertical cliff-walls. This characteristic, together with the pristine state of the site, gives the area a very high aesthetic value which compliments it excellent bathing facilities to render it a very popular recreational area.

Golden Bay headland and parts of Il-Hotba L-Bajda ridge are cultivated, the latter intensely so due to the presence of spring water at Ghajn-Tuffieha and It-Tafal. This water is either extracted from boreholes in the Upper Coralline Limestone at Il-Lippija or collected from a number of gravity springs fringing the limestone step of Ix-Xaghra Tat-Torri. A few farmhouses are found at Il-Lippija and a small sewage treatment plant is found in the very north, overlooking Golden Bay. A dilapidated hotel overlooks Ghajn Tuffieha Bay and a beach-ciosk located on the northern shore of the bay serves refreshments to bathers in the summer months. A sizeable car-park area lies adjacent to the hotel. Two historic towers are located on high grounds, one at the head of the bay and another at Ix Xaghra Tat-Torri overlooking Gnejna Bay. Next to the former tower is a make-shift hut on the very edge of the headland overlooking the bay. A water reservoir and a dilapidated World War II military post are also found at Il-Hotba L-Bajda, the latter overlooking the bay. Apart from these few erections, a number of footpaths and a fringing road in the NE, the site is in a pristine state.

The area is accessible by primary roads from Mgarr, Zebbieh and both sides of Pwales Valley. Concrete steps and a make-shift road leads from the car-park to the main sandy beach at the bayhead. Other minor footpaths crisscross the clay slopes overlooking the bay to lead to the promontory of Il-Qarraba. Another footpath leads from the car-park to Il-Hotba l-Bajda and reaches as far south as Tal-Lippija. The area can also be reached, though less conveniently and with some difficulty, by footpath from Gnejna Bay.

Fig.1 Location of Ghajn Tuffieha Area

3. GEOLOGY

3.1 Regional Structural Setting:

The tectonic framework of the Maltese Islands has a dominant control on the geomorphology of the Area.

Structurally, Malta is divided into two major blocks by the Victoria Lines Fault which downthrows north and runs from the west coast at Fomm Ir-Rih to the east coast at Madliena Tower. The northern block is characterised by a series of normal faults striking ENE which divide the region into horsts, grabens and half grabens. These structural features are reflected topographically in ridges and valleys. In contrast, the southern block is characterised by less pronounced faulting striking NE which does not have a pronounced control on topography as in the north. Here the structures are mainly large scale gentle folds.

This regional structuring is governed by two systems of normal faults of different age and trends. The older generation of Early Miocene faults strikes at about 50° to 70° with fault-planes dipping between 55° and 75°. They are mostly located within a belt approximately 14 km wide defined by two master faults, the Victoria Lines Fault in Malta and the Qala Fault in Gozo. The Ghajn Tuffieha Area lies within this belt (Fig.2) and its faults belong exclusively to this system. They have a pronounced influence on the geomorphology of the area and are responsible for the formation of the ridge, step, basin-floor and associated undercliffs as well as the formation of Ghajn Tuffieha Bay itself. In fact the control of faulting on the geomorphology is seen in the coastline accentuation of the 50° to 70° strike by the bay-to-bay and point-to-point configuration across opposite coasts within the entire belt. The fault-planes are often split into two or more separate sheets, formed by down-dragged lenses of Blue Clay. This is seen is some faults crossing the Area. Vertical throw varies between a few meters to about 100 m, with maximum throw of the master faults about 200 m. Morphological fault scarps are often seen smoothed by denudation and unconformably capped by Pleistocene gravels. Retrogressive erosion has effected headward shifts of some scarps by several hundred meters. By the Early Pleistocene or Pliocene times, all faults of this system became dormant.

The younger generation of faults, some of which are still active, strike at about 120° on Malta and often crosscut the first generation system. These are related to the formation of the extensive rift system running from Pantelleria west of Malta to the Medina Bank in the south. These faults started in the Late Miocene/Early Pliocene and continue in parts up to Present. They are absent at the Ghajn Tuffieha Area and will not be treated further. It is however relevant to point out that the superpositioning of the second generation fault system over the first one was caused by a rotation of the controlling tensional stress regime about 10 m.y. ago when the relative movement of Europe with respect to Africa along the nearby collision front located about 200 km north of Malta, changed direction.

The Ghajn-Tuffieha Area lies in the northern block and consequently it is heavily influenced by normal faulting which subdivides the entire region into units. Structurally, it is made up of the westernmost extremities of two structural units of the northern block, Pwales Valley and Wardija Ridge.
Pwales Valley is a narrow graben defined by two faults, the Golden Bay/Fekruna Fault in the north and Ghajn Tuffieha/St.Paul's Bay Fault in the south. The latter fault throws to the north by approximately 70 m. The intervening graben tilts slightly to the NNE to plunge gently below sea level at St.Paul's Bay. In contrast it forms low cliffs in the west along the coast between Golden Bay and Ghajn Tuffieha Bay.

Wardija Ridge is a horst defined by Ghajn Tuffieha/St.Paul's Bay Fault in the north and Gnejna/Salina Bay Fault in the south. The latter fault throws to the south, the throw varying considerably along its trace. It is about 15 m at Gnejna Bay. The horst is also cut, particularly in the west, by a number of minor faults striking in the same general direction as the bounding major faults. The unit as a whole dips slightly to the NNE.

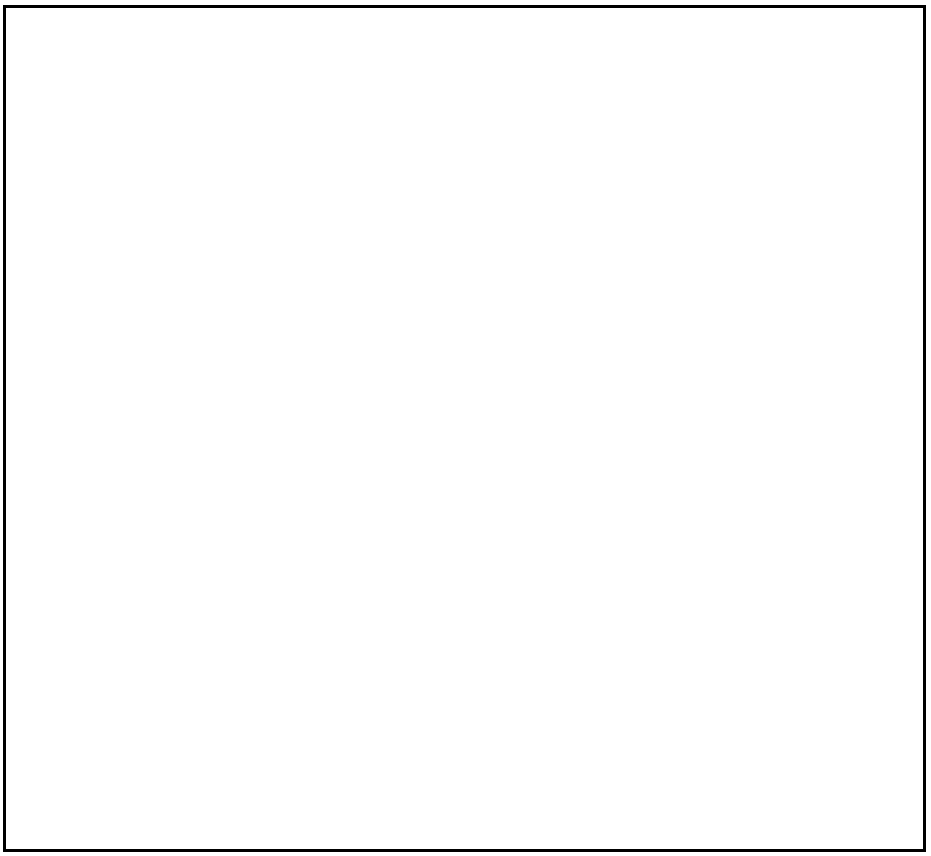

Fig 2 . Ghajn Tuffieha within belt of first generation (Early Miocene) faults striking at 50° to 70° . (after J.H. Illies 1981)

3.2 Structure:

As a whole, the Ghajn Tuffieha Area has a general gentle dip to the NNE. Local deviations from this regional inclination are however observed at a number of places, particularly where the Upper Coralline Limestone is cut by low-cliffs, exposing sharp bedding planes.
Two small synclinal warps, of some hydrological significance, are observed at Ix-Xaghra Tat-Torri (Fig. 3). Another one is found in the limestone basin-floor forming the Golden Bay headland near Ghajn Tuffieha Tower. Very pronounced dips to the NW are also seen in the exposed contact between the Tal-Pitkal and Mtarfa Members making up the butte at Il-Qarraba. Whereas the general dip to the NNE is controlled by the regional dip of Malta, the local deviations are largely influenced by the local tectonism.

Tectonism of the site is defined by four predominant E-W trending normal faults belonging to the first generation of Early Miocene faults. Faults of the second generation are practically absent. These faults, shown in Fig.3, are from north to south:

1. **Ghajn Tuffieha - St.Paul's Bay Fault:**

   This significant normal fault defines the boundary between Pwales Basin in the north and Wardija Ridge in the south. It throws to the north and cuts across the site from near Ghajn Tuffieha Tower in the west to Hal-Ferh in the east. It is by far the most predominant fault in the area with a maximum throw of about 25 m.

2. Ras Il-Gebel Fault:

A well defined step fault runs from Ghajn Tuffieha Tower to Ghajn Astas, north of San Martin. At Ghajn Tuffieha Bay, near the entrance of the footpath lane leading to the bayhead, it is seen throwing to the north by about 6 - 8 m. It is responsible for the vertical low-cliff bounding the limestone basin-floor overlooking Ghajn Tuffieha Bay. This fault formed as a result of drag exerted by the Blue Clay as it was cut by the more pronounced Ghajn Tuffieha - St.Paul's Bay Fault.

3. Il-Qarraba Fault:

This fault runs from the northern shores of Il-Qarraba promontory to Ghajn Tuffieha where it appears to join Tal-Lippija - Wardija Fault. As it cuts exclusively through the Blue Clay it is difficult to trace it properly and ascertain its throw. It is one of several faults which cuts the western extremity of Wardija Ridge in a system of tilted steps, with the main horst lying between this fault and Ras Il-Gebel Fault.

4. Tal-Lippija - Wardija Fault:

Within the Ghajn Tuffieha Area, this fault runs from Tal-Lippija in the west to It-Tafal in the east. It extends further east, changing throw several times before it dies out at Wardija. At Tal-Lippija it throws to the south by about 5 m as it cuts across the wave-cut terrace and the northernmost part of the limestone plateau. A minor fault associated with it is seen feathering out seaward at Tal-Lippija to create a small promontory in the wave-cut terrace.

Fig. 3 Structure and Tectonism of Ghajn Tuffieha Area

3.3 Stratigraphy

Four of the five geological formations of the Maltese Islands outcrop at the Ghajn-Tuffieha Area (Fig.4). They are composed of near-horizontally bedded marine sedimentary rocks of Oligo-Miocene age, unconformably overlain in places by very sporadic thinly developed Quaternary continental and beach deposits. These formations are, from bottom:

Globigerina Limestone Formation
Blue Clay Formation
Greensand Formation
Upper Coralline Limestone Formation

These formations are mainly composed of shallow water cor-algal limestones, blue plastic clays and deep water globigerina limestone. They are best observed along the cliff sections fringing Il-Qarraba and Ix-Xaghra Tat-Torri, and along the steep clay slopes at Ghajn Tuffieha Bay, especially at the isthmus. (Fig. 4). Il-Hotba L-Bajda also provides good exposures of a limestone member not found anywhere else within the Area.

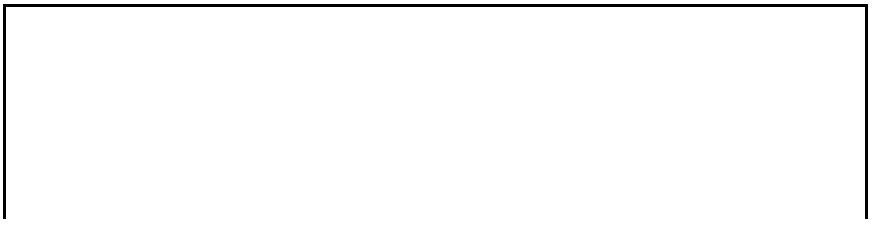

Fig. 4 Schematic Stratigraphic Section

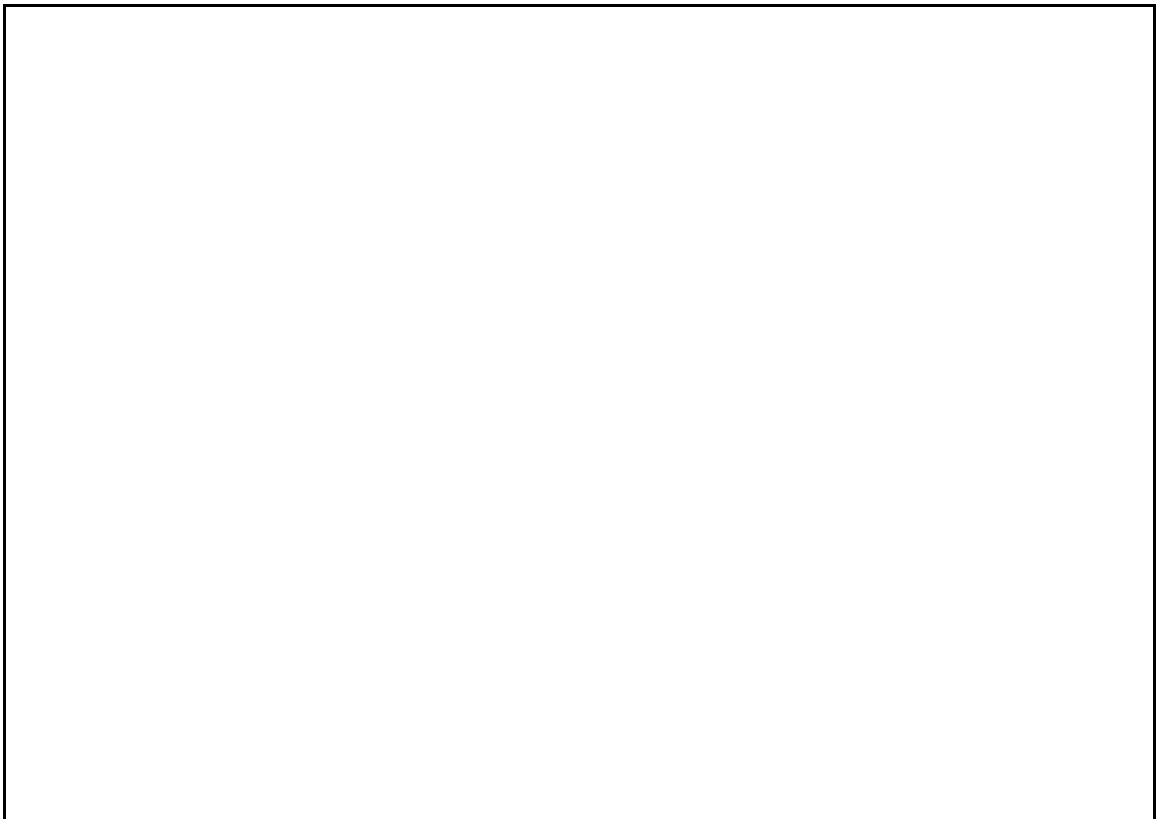

Fig.5 Geological Map

3.3.1 Globigerina Limestone Formation (Mug):

This formation is the least exposed at the Ghajn Tuffieha Area, outcropping only in a very small coastal area that makes up the wave-cut terrace south of the isthmus facing Gnejna Bay (Plate XVI). It represents the topmost bed of the Upper Globigerina Member, the remaining two beds lying below sea-level. This 4 m thick exposure is made up of yellow foraminiferal wackestones with frequent oxidised goethite concretions which impart an orange mottling colour to it. Bedding is absent due to intense Thalassinoidean bioturbation. The exposed surface exhibit honeycomb weathering due to this bioturbation.

Macrofauna is sparse and mainly represented by disarticulated and often fragmented pectinid shells. Among the common are the pteropod *Vaginella*, the gastropod *Epithonium* and the echinoid *Schizaster eurynotus*.
Microfauna is very abundant and often compose the limestone itself. Planktonic globigerinid microfauna is predominant and includes a number of species of *Praeorbulina*, *Globorotalia*, *Globigerinoides*, *Globigerinatella* and *Globigerina*. *Orbulina universa* makes its first local appearance in this unit.

A rich assemblage of ostracofauna is also found in this bed. It includes *Buntonia*, *Ruggieria*, *Cytherella*, *Oblitacythereis*, *Bythoceratina*, *Parakrithe* and *Krithe*, among many others. Some are even restricted to this unit (Russo and Bossio, 1976).

This member is interpreted to have been deposited in water depths ranging from 40 m to 50 m in a mid-Tethyan submarine continental rise (Felix, 1973).

3.3.2 Blue Clay Formation (Mbc):

Exposure of this formation is very common, especially at Ghajn Tuffieha, It-Tafal and the slopes of Ghajn Tuffieha Bay and the isthmus. It is also exposed intermittently between the boulders of the undercliffs of Il-Qarraba promontory and beneath Ghajn Tuffieha Tower and Ix-Xaghra Tat-Torri overlooking Gnejna Bay. Maximum thickness in the area is about 60 m at Tal-Lippija.

This formation represents the only terrigenous sediment of the Maltese rock succession. Its deposition corresponds to the major tectonic phase of the uplifting of the Siculo-Maghrebid chain from where the clay was derived. When exposed, it dries very quickly in the dry summer months to form deep fissures up to 5 cm wide at the surface and extending by about 2 m below the ground. Subsequent wetting in autumn and winter renders this superficial layer unstable and under stagnant conditions mud-slides are produced. Because of the ease with which the Blue Clay is eroded it is only found, with few exceptions, where it is protected by a cap of Upper Coralline Limestone. One of these few exceptions is the Ghajn Tuffieha and It-Tafal area.

It is composed of a bluish grey, colour-banded, plastic kaolinitic marls and clays. The banding derives from the varying concentrations of calcium carbonate in the form of fossil tests of planktonic and benthonic foraminifera. The light coloured layers correspond to a higher calcium carbonate content and lower kaolinite content. The clay content of the dark, almost pure clay bands ranges from 90% to 94% and are best described as marly clays while in the lighter coloured bands it ranges from 80% to 60% and, depending on the exact clay content, can petrographically be described as marly clays, clayey marls or marls. This banding is best observed on the isthmus of Il-Qarraba.

Large selenite crystals exhibiting an octahedral habit are common especially towards the base and top of the formation. Rare sapropel streaks in the form of coaly carbonized plant debris have also been reported. At about 4 m below the top of the formation there is a dark-green 1.5 m thick clayey sand or sand layer rich in glauconite and fossil assemblages. It is best observed at Il-Qarraba.

The Blue Clay contains a rich assemblage of macrofauna represented by molluscs, echinoids, solitary corals, fish remains and marine mammals. Most of the larger fossils have been crushed during consolidation under the weight of the overburden and subsequently pyritised during diagenesis and later altered to limonite and goethite. Macrofauna includes solitary corals such as *Flabellum* and *Stephanophylia*, cuttle bones of *Sepia*, *Aturia*, nuculid bivalves, pectinid bivalves including *Flabellipecten*, *Amussium* and *Clamys*, gastropods, spine-bearing tests of the echinoid *Schizaster eurynontus*, goethite casts of pteropod *Vaginella*. Fish remains are common in the glauconitic sand bed. These include remains of *Isurus*, *Procharcharodon* and *Odontapsis*, vertebrae of *Phoca* and cetaceans, including whales, and teeth of *Carcharodon*, *Isurus* and *Odontapsis*. Microfauna is dominated by planktonic and benthonic foraminifera similar to that found in the underlying Upper Globigerina.

The presence of solitary corals such as *Flabellum*, *Stephanophyllia* within the unit indicates that

despite its terrigenous origin, sedimentation rates were low enough to permit the corals to live. Benthonic and planktonic foraminifers indicate an open marine muddy platform in water about 150 m deep.

The depositional environment is similar to that of the Upper Globigerina (Felix, 1973). Benthonic and planktonic foraminifers suggest an open marine muddy platform in a shallowing water environment. This is suggested by the drastic decrease in the plankton/benthos ratio (Giannelli and Salvatorini, 1975) as well as the presence of *Flabellipecten* and *Amussium* at the base of the overlying Greensand.

The exposure at Ghajn Tuffieha Bay is of significance in stratigraphy and was considered by Felix (1973) as a reference section for the study of this formation in Malta as the type section is in Gozo (re. Section 4.4 for protection rating).

3.3.3 Greensand Formation (Mgs):

This formation is not well developed at the Ghajn Tuffieha Area and is usually less than 0.5 m thick. It is sporadically exposed at the base of the cliffs fringing the coralline areas. It is unconformably overlain by either the Mtarfa or Ghajn Melel member of the Upper Coralline Limestone and is best exposed at Il-Qarraba (Plate I). The contact with the overlying Ghajn Melel Member is sharp and represents an erosional surface. In contrast, where it is overlain by the Mtarfa Member the contact is gradational.

The unit consists of massive, friable, intensely burrowed greyish-green, brown to dark grey marly limestone. The dark colour is imparted by the glauconite which in places appears brown due to oxidation. Petrographically, it is classified as an intensely bioturbated lithoclastic limestone rich in glauconite and gypsum grains. It is rich in *Heterostegina*, *Terebratula*, *Ostrea virleti*, *Schizaster eurinotus*, benthonic micr-foraminifera, sharks teeth, remains of cetaceans, casts of *Conus*, and encrusting briozoans.

The unit is interpreted to have been deposited under very turbulent water conditions in a shelf or platform environment.

Plate I: Sporadic exposure of Greensand Formation lying over Blue Clay at Il-Qarraba

3.3.4 Upper Coralline Limestone:

This formation constitutes the plateaux of Ix-Xaghra Tat-Torri and Golden Bay headland, the hum at Il-Hotba l-Bajda and the butte at Il-Qarraba promontory. It varies in thickness between about 5 m at Il-Hotba L-Bajda to about 10 m at Tal-Lippija. It is best exposed in the cliff sections fringing these structural units, especially at Il-Qarraba and Tal-Lippija where two of its members, Mtarfa and Tal-Pitkal Members are easily observed. A third member, Ghajn Melel, is only exposed at Il-Hotba L-Bajda.

Ghajn Melel Member (Mgm):

This member is only well developed at Il-Hotba L-Bajda (Plate II) where the erosion of the overlying Mtarfa and Tal-Pitkal members provides good exposures of this rather sparse unit. It is only found well developed here as this unit always occurs in conjunction with horsts, forming a sand ridge along their culmination. It is composed of thickly bedded beds of orange-red, friable, bioturbated biocalcarenites containing scattered, derived, rounded lithoclasts, light orange-brown in colour and containing a nucleus of chocolate-brown lithoclastic limestone.

This member has an abundance of macrofauna, especially echinoids *Clypeaster*, and *Echinolampas*, bivalves such as the giant scallop *Chlamys*, and colonies of the bryozoan *Celleporaria*. The giant foraminifer *Heterostegina* is particularly abundant and is found in stacks and rolls at the base of this member.

Its contact with the Greensand Formation underneath is sharp and marked by a well defined erosional surface. Similarly, its contact with the overlying algal rhodolite beds of the Mtarfa Member is also marked by another erosional surface.

The litoclastic composition of this unit, as well as its particular colour, indicate reworking and oxidation of an original sediment during a minor sea-level lowering at the end of the Greensand deposition. Reworking of the original Greensand deposits on

palaeo-horsts in sublittoral shallow water gave rise to sand ridges and banks of Ghajn Melel in relatively calm waters sheltered by the emerged palaeo-horsts.

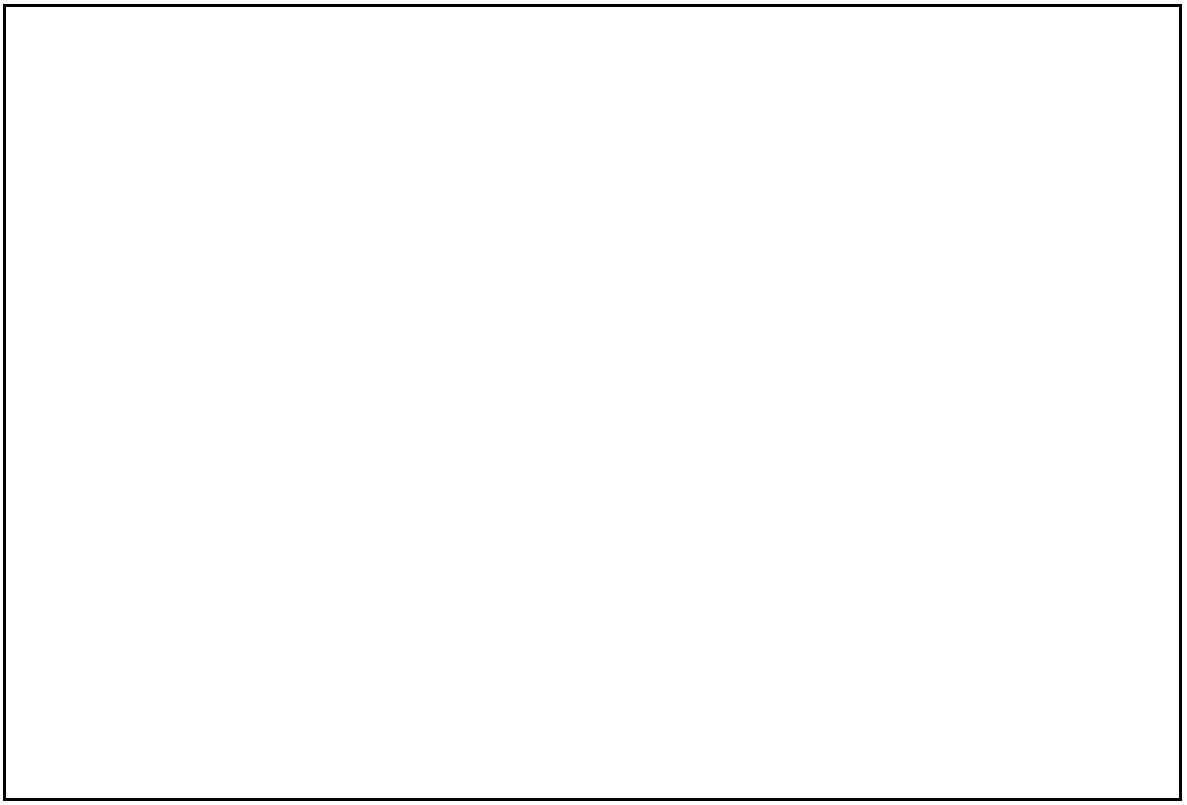

Plate II: Exposure of Ghajn Melel Member at Il-Hotba L-Bajda

Mtarfa Member (Mmt):

Although in Malta this member is subdivided into a number of beds, only the coralline algal biostrome is found at Ghajn Tuffieha Area. It is best exposed near the base of the the butte of Il-Qarraba promontory (Plate III). This bed is also referred to in the literature as a Bioherm but petrographically it is a biostrome as it does not possess the solid framework of bioherms.The strata bear signs of transportation in prograding foreset bedding.

It is approximately 5 m thick made up of alternating cream coloured calcilutites containing coralline algal ovoidal rhodoliths 5 cm to 16 cm in diameter. A thin development of crustose algal marl containing *Terebratula Aphelesia* and algal debris wackestones is found at the base of this member. Within this unit can be seen well exposed NE-SW trending channels and erosion surfaces of high palaeo-reconstruction significance. As a whole, the biostrome is widespread and comprises a number of laterally-linked lenses up to 16 m thick spreading across western Malta and eastern Gozo over a 20 km by 5 km wide corridor broken up by a number of growth faults. A

lens containing a thinly developed reef of *Porites* is also found in the lower third of the member.

A rich macrofauna is found within this bed. This includes echinoids *Schizaster*, *Brissus*, *Cidaris* and *Clypeaster*; molluscs *Clamys* and *Spondylus*; brachiopods *Megathyris*, *Argyrotheca*, *Terebratula* and *Aphelesia*; and bryozoans. The principal constructors of the rhodoliths and the framework of the biostrome are however the coralline algae *Archaeolithothamnium*, *Lithothamnium*, *Mesophyllum* and *Lithophyllum*.

The depositional palaeo-environment of this bed is inferred from the characteristics of the macrofauna. *Lithothamnium* develops under fairly high energy water conditions in water depths ranging from 12 m to 25 m while *Archaeolithothamnium* has an optimal growth at a depth between 12 m and 60 m in restricted, tropical and sub-tropical waters. The development of rhodoliths requires a delicate balance between light conditions and water motion that permits growth on all surfaces to produce a characteristic ovoidal shape.

This bed is the principal source of sand to the sand beaches of the Ghajn Tuffieha Area. It is underlain by the Greensand Formation or Ghajn Melel and is overlain by the Tal-Pitkal Member of the Upper Coralline Limestone.

Tal-Pitkal Member (Mp):

Of the five beds into which this member is subdivided, only the Rabat Plateau bed is found at Ghajn Tuffieha. It forms the upper parts of the cliff sections and the planed tops of Ix-Xaghra Tat-Torri, Il-Qarraba and the basin-floor between Golden Bay and Ghajn Tuffieha Bay. It is the best developed member of the Upper Coralline Limestone in the Area and is well exposed and accessible at Tal-Lippija (Plate IV).

The bed is approximately between 1 m and 8 m thick, made up of pale grey biocalcarenites. At the base the bed shows a rapid change from yellow friable algal biostrome to well cemented bioclastic limestones predominantly composed of algal fragments in massive beds and lenses, highly resistant to weathering.

The lenticular shaped bedding within the bed represents a high energy, very shallow depositional environment in a fore- or inter- patch-reef setting in water depths less than 25 m. The poor sorting of the intraclasts, derived from *Porites* and algal patch-reefs, is also suggestive of close proximity of the source.

Plate III: Exposure of Mtarfa Member at Il-Qarraba

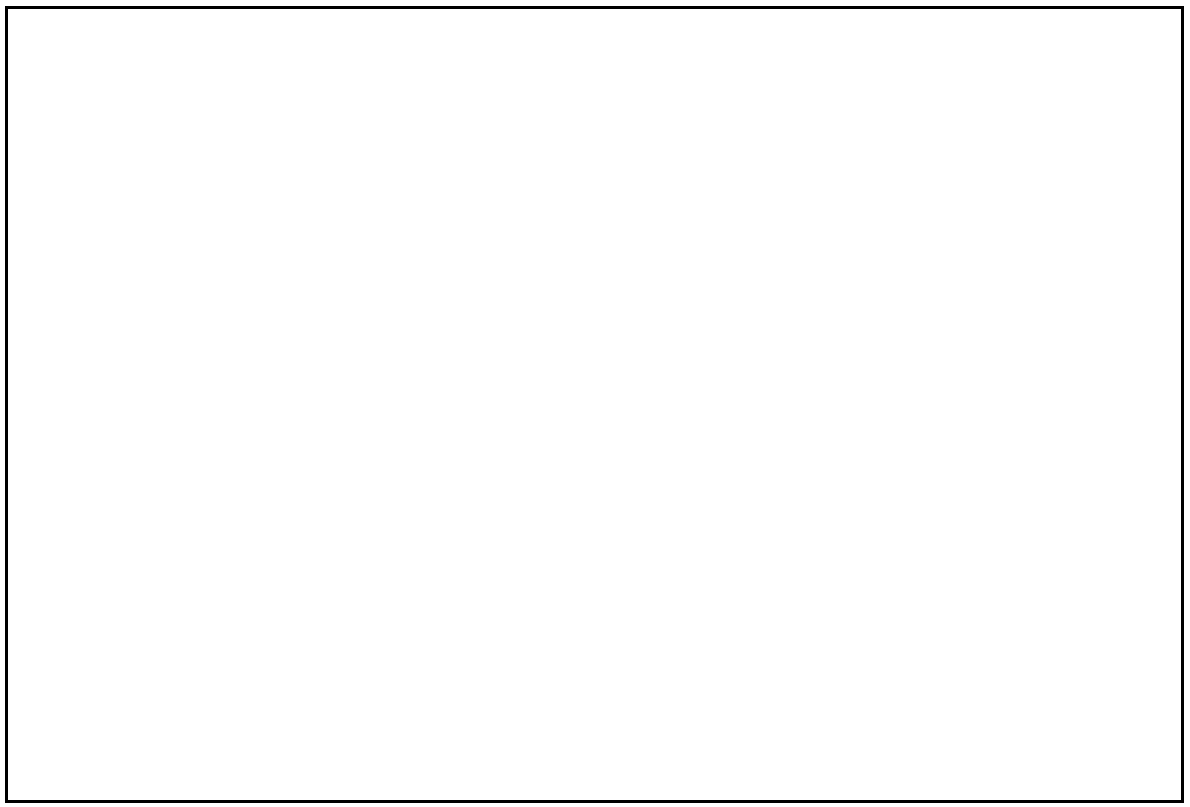

Plate IV: Exposure of Tal-Pitkal Member overlying Mtarfa at Tal-Lippija

3.3.5 Quaternary Deposits (Qv)

The Quaternary deposits of the Maltese Islands lie unconformably on older marine strata of Oligo-Miocene age and are usually easily distinguished by their brick-red colour. They are mostly of continental origin and are important for their fossils of mammalian fauna that migrated from Sicily during the Pleistocene glaciations when the lowered sea level provided land-bridges with the Maltese Islands.

The only significant Quaternary deposits at the Ghajn Tuffieha Area are slope talus deposits resting unconformably on the Blue Clay lining the foot of the low-cliffs, sparse eolian sand deposits forming a shallow terrace on the back-shore of Ghajn Tuffieha Bay, sporadic caliche on the surface of limestone plateaux and fault gouge material (Plate V). The slope talus material is made up of badly sorted gravel cobble and boulders up to several meters thick. The deposits contain numerous gravel-filled channels with imbricated pebbles and calcified roots (rhizoliths) set in a palaeosoil matrix. In addition to the fossil roots, the deposit also contains sparse fragments and whole specimens of land gastropods most of which are still extant today. Sparse fossil fragments of vertebrates are also observed. The eolian sand is made up of weakly cemented, very fine grains of limestone derived from the erosion of the Mtarfa Member like the near-by present-day beach sand.

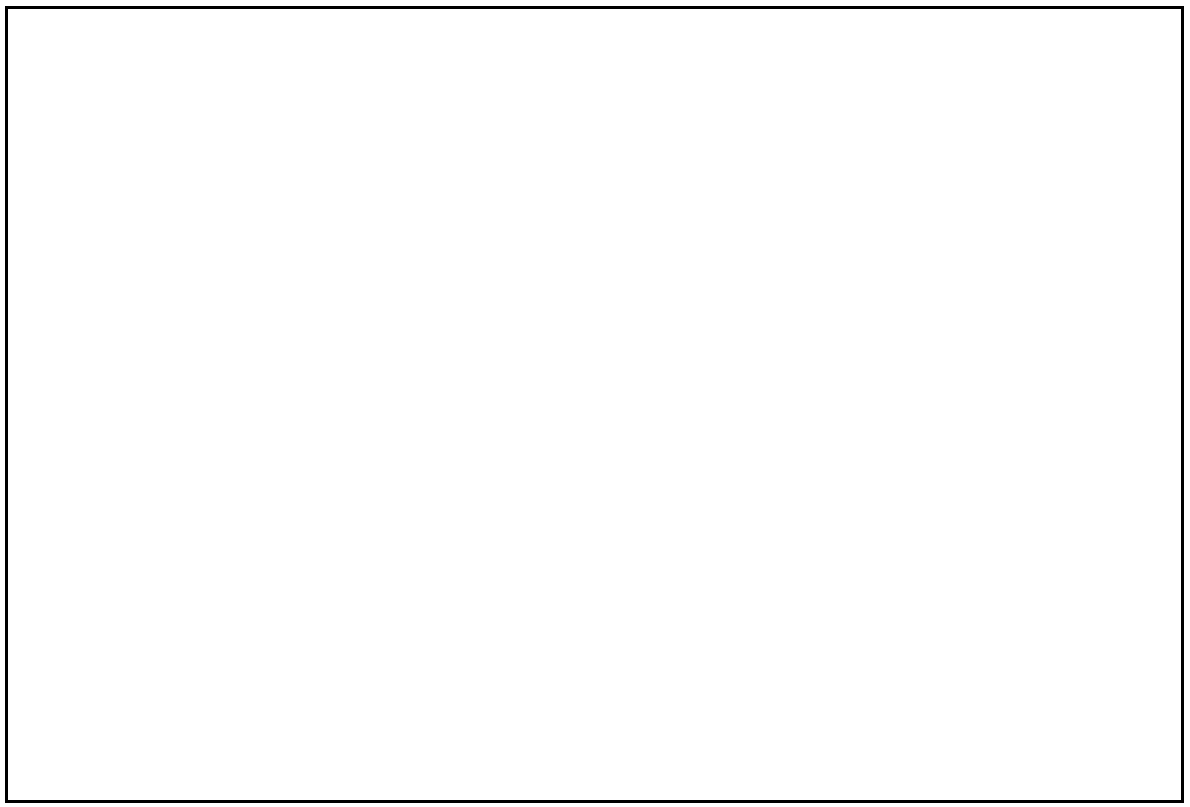

Plate V: Reddish Quaternary caliche and fault gouge material at Tal-Lippija.

4. GEOMORPHOLOGY

The geomorphology of the Ghajn Tuffieha Area is typical of that found in the northern structural block. Here we find morphology controlled primarily by structural endogenetic processes producing an initial landform made up of block faulted horst and graben system, with subsequent drainage, karst and shoreline processes playing a secondary exogenetic role to yield a variety of sequential erosional landforms typical of areas where horizontal weak and resistant strata are found adjacent to each other. In spite of the relatively small size of the Area, several pronounced geomorphological features of this type are found shaping the morphology, producing an aesthetically rich, varied and interesting landform, mellowed in places by a thin soil cover. Noteworthy amongst these features are, from north to south, the following major elements (Fig.6):

(1) A gently tilting basin-floor of Upper Coralline Limestone making up the headland between Golden Bay and Ghajn Tuffieha Bay;

(2) A high eroded Upper Coralline Limestone ridge marked by well defined escarpments making up Il-Hotba L-Bajda, Ghajn Tuffieha and It-Tafal;

(3) A well preserved Upper Coralline Limestone step marked by well defined escarpments making up Tal-Lippija, Ix-Xaghra Tat-Torri and Il-Lippija.

The influence of lithology, doline activity, drainage, weathering and shoreline processes have produced secondary elements which include:

(4) Blue Clay slopes at the back and on the sides of Ghajn Tuffieha Bay;

(5) Undercliffs beneath Ghajn Tuffieha Tower and Il-Qarraba, where the Upper Coralline Limestone lies adjacent to the sea;

(6) A pronounced promontory at Il-Qarraba capped by a fine example of a butte;

(7) A sharp isthmus linking Il-Qarraba promontory to the mainland;

(8) Three sandy beaches;

(9) A wave-cut terrace; and

(10) Soils.

The influence of man has also introduced some terracing in places, particularly at Ghajn Tuffieha and It-Tafal. These elements are described below in order of geomorphological significance.

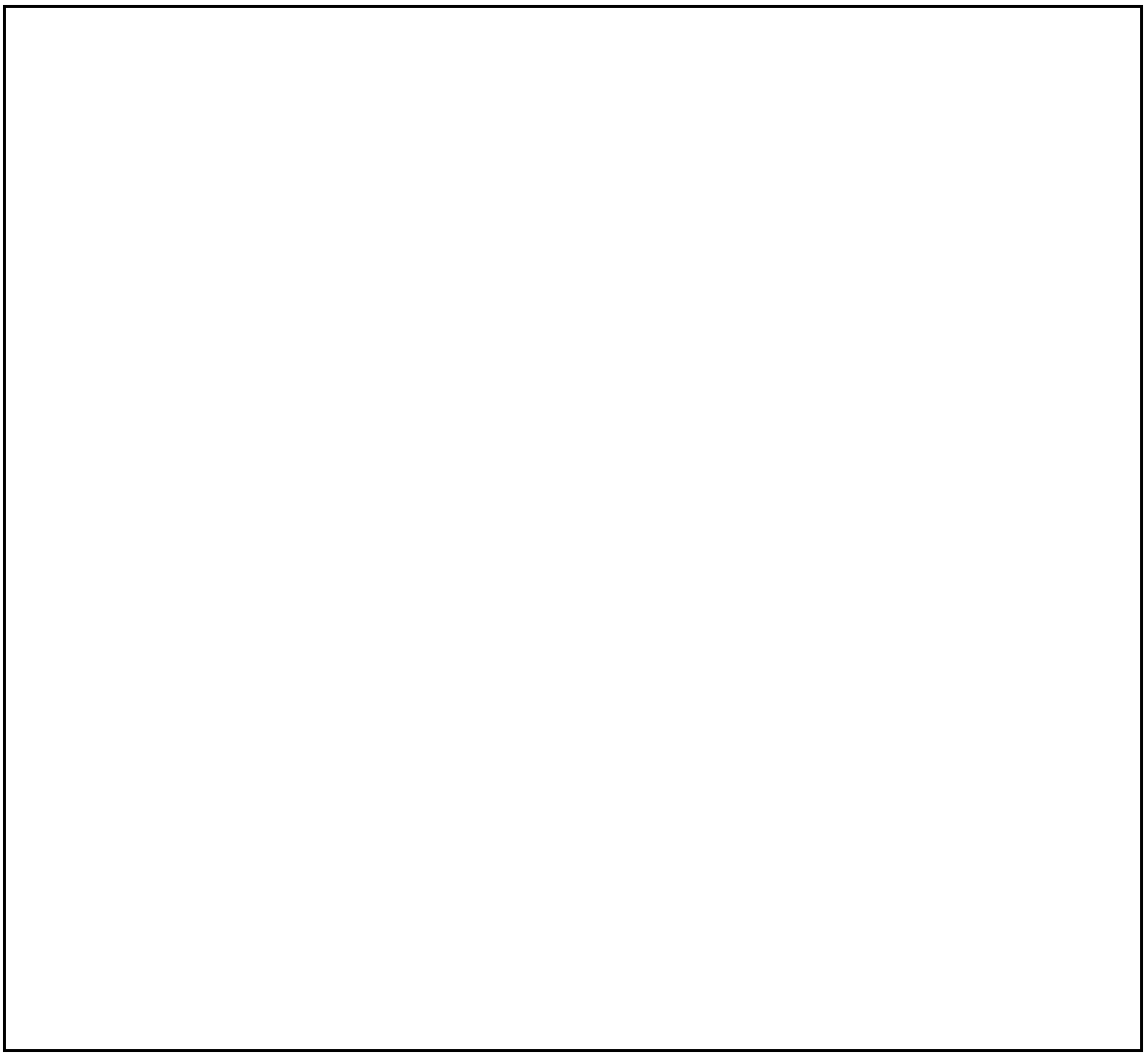

Fig. 6 Geomorphological Units at Ghajn Tuffieha Area

4.1 Il-Hotba L-Bajda Ridge:

Morphologically, the ridge making up Il-Hotba L-Bajda, Ghajn Tuffieha and It-Tafal (Plate VI), is the westernmost extremity of Wardija Ridge. Its general dip to the NNE has exposed the Blue Clay Formation along the western coast in the form of steep slopes, making this formation highly vulnerable to splash and stream channel erosion. The prolonged differential erosion of these slopes gave rise to Ghajn Tuffieha Bay itself.

Within the Area, this ridge has an area of about .11 km^2, with elevation varying between about 40 m ASL in the northeast, near the road leading to Pwales, to about 77 m ASL at Il-Hotba L-Bajda.

Although the ridge is the highest structurally element (horst) in the Area, topographically it is at a lower level than Ix-Xaghra Tat-Torri plateau (step) on account of advanced karst erosion which has almost removed completely the top Upper Coralline Limestone layer to expose the Blue Clay. In fact, Il-Hotba L-Bajda, Ghajn Tuffieha and It-Tafal represent karst topography in an advanced stage of solution activity where the original limestone plateau of the step has been removed by karst weathering, leaving behind an isolated remnant hum at Il-Hotba L-Bajda. This weathering process starts with the formation of deep grooves separating rock fins in the exposed limestone (lapies) which eventually are enlarged by the action of groundwater to form caverns and sinkholes. Further weathering coalesce these doline features to form flat-floored large depressions and ultimately complete removal of the limestone. This exogenetic geomorphological process of erosion is in its initial stage at Ix-Xaghra Tat-Torri and Golden Bay headland where lapies can be seen in the exposed limestone.

The ridge is of particular significance in karst geomorphhology and qualifies for Level 1 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.1. It is also of secondary significance in structural geology on account of Ras Il-Gebel, Il-Qarraba and Tal-Lippija faults (Section 3.2), in stratigraphy on account of the only exposure of Ghajn Melel in the area (Section 3.3.4), and in hydrogeology on account of its karst exogenetic formation (Section 5.1).

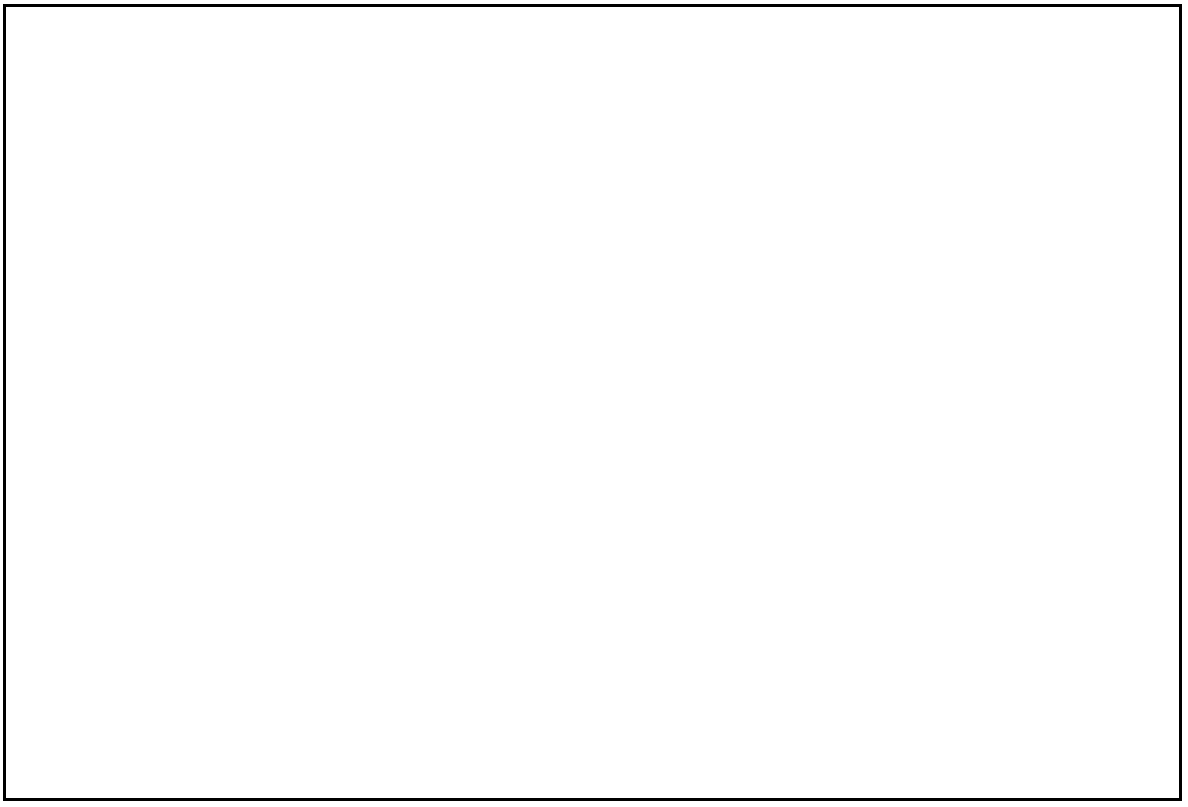

Plate VI: Il-Hotba L-Bajda Ridge

4.2 Golden Bay Headland:

The low-lying limestone plateau forming the headland between Golden Bay and Ghajn Tuffieha Bay (Plate VII) forms part of the floor of a graben which makes up Pwales Basin. It has a quasi-planar surface of approximately .08 km^2 tilting gently in the direction of Pwales. Elevation varies from about 35 m at Ghajn Tuffieha Tower to about 20 m ASL in the north, making it the lowest structural unit in the Area. A thin soil cover of Terra Rossa is cultivated for fodder, vegetable crops and horticultural products using traditional agricultural practise.

The limestone plateau overlies the Blue Clay Formation above sea level to form a perched aquifer which drains in the direction of Pwales. No groundwater is however extracted from within the plateau.

Although karst features such as lapies can be observed in places, particularly in the vicinity of Ghajn Tuffieha Tower, erosion is relatively mild and some of the initial landform relief, of structural origin, is still preserved in the scarp of Ras Il-Gebel Fault in the south.

The headland is of significance in geomorphology particularly when considered in relation with the surrounding area. It qualifies for Level 4 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.4. It also has secondary importance in structural geology on account of the Ghajn Tuffieha fault (Section 3.2) and in hydrogeology on account of the presence of a perched aquifer (Section 5.1).

Plate VII: Headland between Golden Bay and Ghajn Tuffieha Bay

4.3 Ix-Xaghra Tat-Torri Step:

Geographically, this step is made up of Tal-Lippija, Il-Lippija and Ix-Xaghra Tat-Torri (Plate VIII). It is the largest geomorphological unit in the Area, covering some 0.33 km^2, with elevation varying between 70 m and 100 m ASL. Although it constitutes the highest topographical unit in the area, it is a step of Il-Hotba L-Bajda Ridge. Like the ridge, it is composed of a top limestone plateau overlying the Blue Clay Formation. Unlike the ridge however, the limestone is relatively much less karstified and stands at a higher level than the ridge, giving the impression of an opposite structural relationship.

Morphologically, the limestone top is in the form of plateau with a gently undulating top in the form of a NS trending saddle, reaching maximum elevation of 96 m ASL at Ix-Xaghra Tat-Torri. The plateau is surrounded by a near vertical low-cliffs on all sides, except in the extreme east at Il-Lippija where it continues further east. The surface is karstified and practically barren of soil except for sporadic, isolated shallow patches. Rock fins separated by deep grooves developed by the weathering of the exposed limestone are seen in many places. These lapieds represent the initial stage of karst landform. The limestone is probably cavernous in places as doline features are also observed. Further karstification will eventually reduce the platform to a hum, similar to the one found on the Il-Hotba L-Bajda Ridge. Taken as a whole, the surfaces of the step and the adjacent ridge can be said to represent the full process of karst landform development in horizontal strata.

The step is of significant importance in karst geomorphology and qualifies for Level 2 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.2. It is also of importance in structural geology on account of Il-Lippija Fault (Section 3.3), and in hydrogeology on account of the perched aquifer (Section 5.1).

Plate VIII: Ix-Xaghra Tat-Torri Step

4.4 Blue Clay Slopes:

When exposed, the Blue Clay Formation often forms steep smooth slopes of dark grey marls. Such slopes are very well expressed on the sides and at the back of the bayhead of Ghajn Tuffieha Bay, the isthmus to Il-Qarraba promontory and beneath Xaghra Tat-Torri overlooking Gnejna Bay where they reach a maximum height of about 60 m ASL to form the thickest exposures of Blue Clay in the Maltese Islands (Plate IX). Their total area within the Area is approcimately 0.15 km^2. In their natural state, these slopes were initially practically barren of vegetation. In the 60's the slopes at Ghajn Tuffieha Bay were extensively planted.

These exposers are very vulnerable to weathering and erosion, the former by exfoliation and the latter by sheet erosion, stream erosion and splash erosion. Associated with these processes are found various erosional and depositional features such as rills, gullies and slope wash. In fact the slopes are excellent examples of sequential landforms in clay terrain, the product of weathering and erosion.

In exfoliation, the clay breaks apart in shells and plates resembling scales. This process is greatly accelerated by alternating periods of wetting and drying and is most effective during periods of intermittent rainfall. Granular disintegration is not so important and is only limited to the sparse clasts and minerals found in the clay.

Erosion of the slopes is induced by direct rainfall and by running water in the form of sheet or stream flow. Off-track motorcycling and 4-wheel driving during weekends has also contributed to this process in recent years.

Initial sheet flow removes the weathering products of the clay and is responsible for the smooth surface of the slopes, particularly at higher levels. Concentration of sheet flow into streams gives rise to intense runoff, particularly after a dry period. Two such intermittent watercourses run down the slopes from Il-Hotba L-Bajda to the bayhead. Runoff also forms long narrow channels and shoestring rills, the coalescence and deepening of which produced numerous gullies particularly at the base of the slopes at the back of the bayhead.

Splash erosion, the dislodgment and movement of clay particles under the impact of falling raindrops, is significant over the barren slopes of the isthmus of Il-Qarraba promontory. This problem is accentuated by the steep slopes which hasten the washing of this sediment downhill to the shore.

The slopes are of particular significance is geomorphology as they provide an easily accessible site for the study of erosional processes and the Blue Clay Formation and qualify for Level 4 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.4. They are also important in stratigraphy and were considered by Felix (1973) as a reference section for the study of this formation in Malta

as the type section is in Gozo.

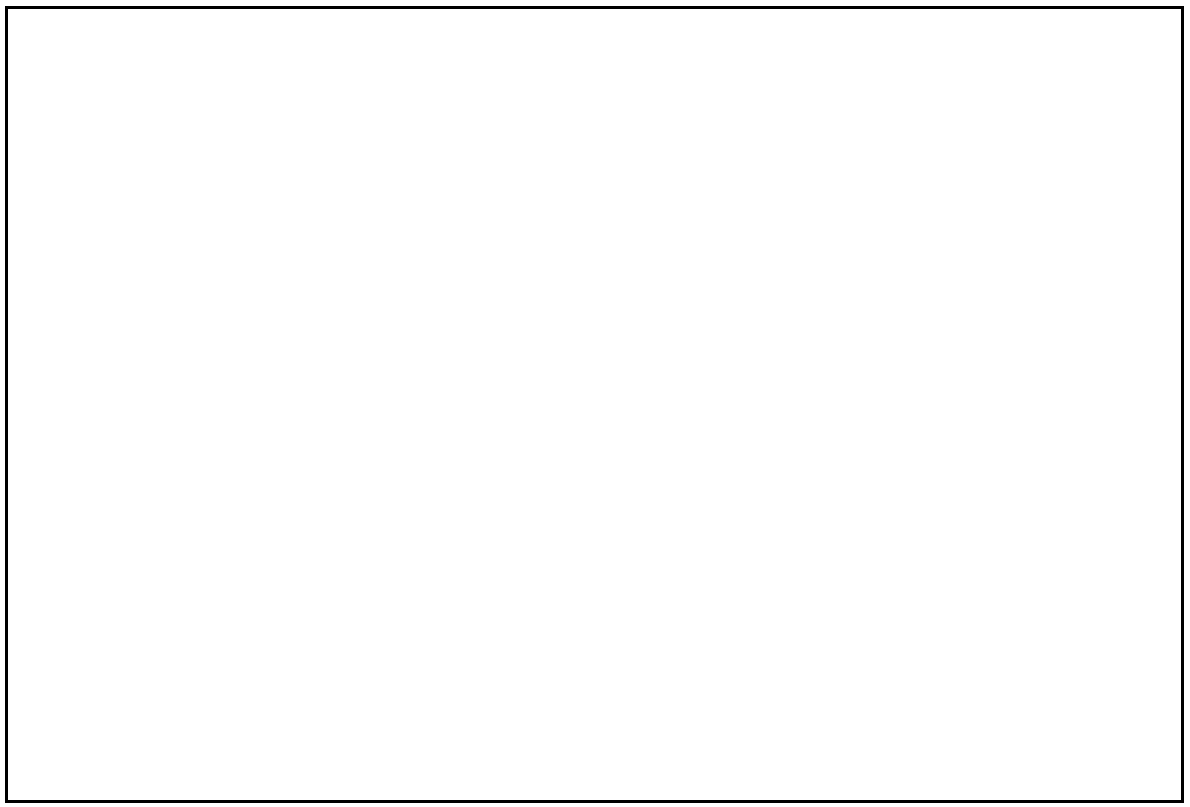

Plate IX: Blue Clay slopes at the back of Ghajn Tuffieha Bay

4.5 Undercliffs:

The coastal low-cliffs at Ghajn Tuffieha Tower and Il-Qarraba promontory (plates X, XI) are characterised by a profile made up of a low vertical drop against the edges of Upper Coralline Limestone plateaux and a steep slope against the Blue Clay underneath. The clay slopes, particularly those at the base of these cliffs, are hardly exposed as they are overlain by a combination of rockslides, slumps and rockfall made up of coralline limestones detached from the edge of the plateaux. The size of these rock fragments ranges from a grain to boulders weighing several tons. Such boulders are common and the talus is often referred to as boulder scree.

The formation of these talus slopes is facilitated by the accelerated weathering and erosion of the Blue Clay which undermines the overlying coralline limestone. The cliffs have recesses which tend to funnel the rock fragments, particularly rockfall, into chute-like exits, causing the formation of minor talus cones. The freshly exposed surfaces of coralline talus is easily weathered as it slides down the clay slopes to reach the shore. The easily weathered Mtarfa Member produces sand grains by this process which are eventually carried away bayward by littoral drift to source the sandy beaches in the area.

These cliffs, termed undercliffs or *rdum*, are of significance in foreshore geomorphology and qualify for Level 4 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.4. They also have some importance in stratigraphy due to the exposures of Upper Coralline Limestone in the cliff section.

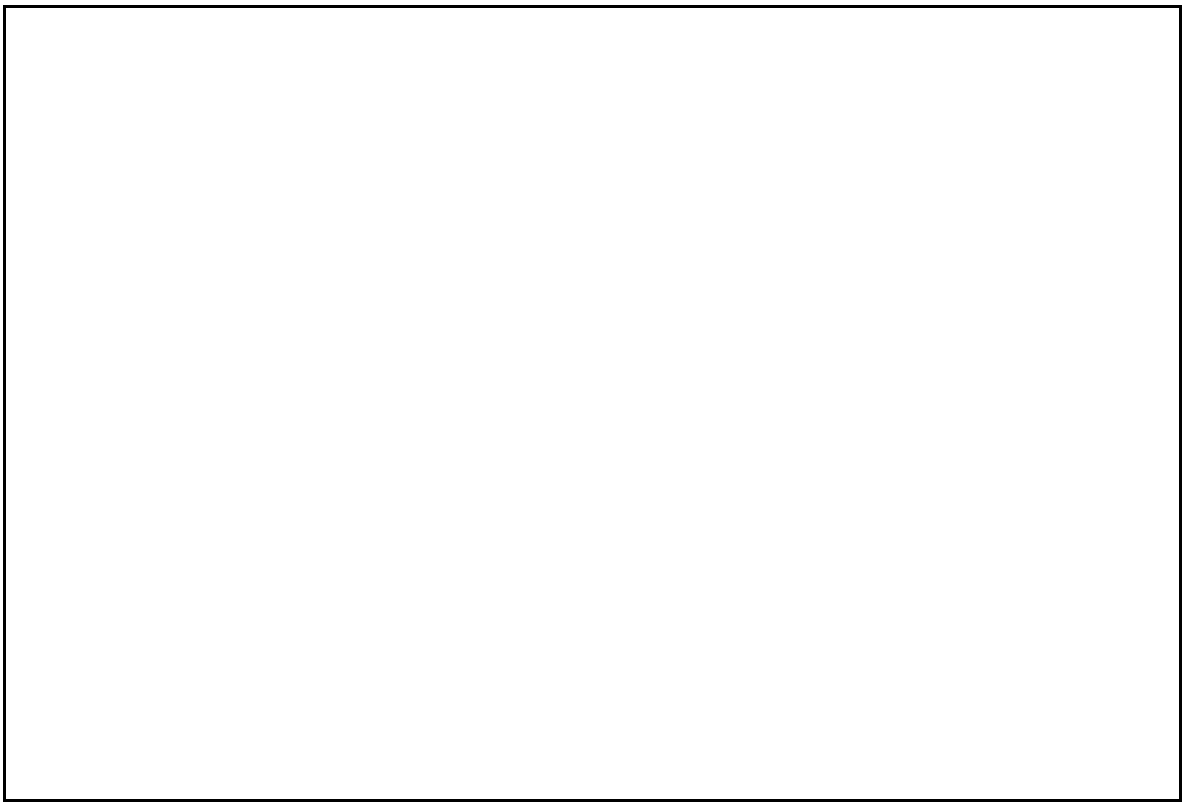

Plate X: Undercliffs at Ghajn Tuffieha Tower

Plate XI: Undercliffs at Il-Qarraba

4.6 Il-Qarraba Promontory:

The pronounced Il-Qarraba promontory, lying between Gnejna Bay and Ghajn Tuffieha Bay, is approximately 450 m long and 300 m wide with an area of approximately 0.09 km^2 (isthmus included). It is made up of a well preserved butte of Upper Coralline Limestone overlying Blue Clay and surrounded by undercliffs (Plate XII). The gently inclined butte is defined by sharp low cliffs on all sides except at the head of the promontory where its highly fractured edge makes its boundary with the undercliffs less distinct to define. Here, strong wave action on the exposed clay tend to subject the butte to accelerated erosion to produce rockslides, slumps and rockfalls which form a well developed undercliff facing the open sea.

Access to the promontory is by footpaths over the Blue Clay slopes of the isthmus. Further out on the promontory, the footpaths wind round boulders and through crevices in the limestone scree. The butte itself may be reached with some difficulty either by climbing a steep low cliff at the landward end of the butte or through crevices in the fractured limestone at the far end.

The promontory is the only one in the Maltese Island preserving a fine example of a butte and qualifies for Level 1 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.1. It is also of significance in stratigraphy on account of the well exposed Upper Coralline Limestone in the cliffs surrounding the butte (Section 3.3.4), and in hydrogeology on account of a small perched aquifer (Section 5.1).

4.7 Il-Qarraba Isthmus:

A very pronounced narrow isthmus, made exclusively of Blue Clay, connects the promontory to the mainland (Plate XII). It is in the form of a narrow, high saddle, approximately 80 m wide and 170 m long and some 23 m ASL at the center of the saddle. The clay is practically barren on top of the

isthmus and is highly susceptible to splash erosion and exfoliation. Sparse vegetation is found on the northern slope while the slope facing Gnejna Bay is barren. Deep horestring rills characterise these steep slopes which wash the run-off and sediments derived from the weathered clay directly into the sea.

The isthmus is the only one made of clay in the Maltese Islands and qualifies for Level 1 protection rating in accordance with Malta Structure Plan Policy RCO 12.1. It is also of significance in stratigraphy on account of the exposed Blue Clay.

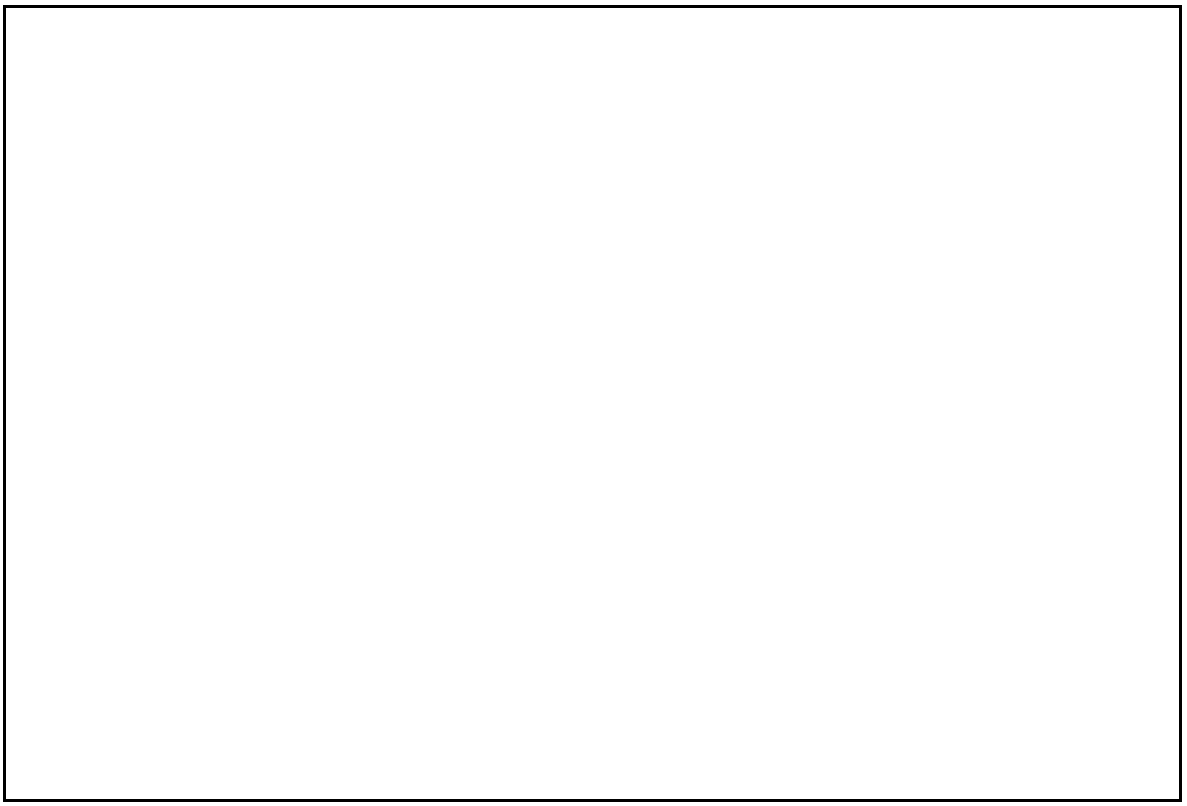

Plate XII: Il-Qarraba Promontory and Blue Clay isthmus

4.8 Sandy Beaches:

Three sandy beaches are found within the Ghajn Tuffieha Area, a significant one at Ghajn Tuffieha

Bay and two small ones, one on the shore of the promontory facing Ghajn Tuffieha Bay and the other on the shore of the isthmus facing Gnejna Bay.

(a) Ghajn Tuffieha Bay Sandy Beach:

Ghajn Tuffieha is popular mostly for its sandy beach which occupies half the bayhead in the form of a wedge-shaped belt, approximately 150 m long and 25 m wide, tapering gradually towards the south (Plate XIII) where it turns into a narrow, 100 m long sand/cobble beach. The wider berm in the north is attributed to longshore drift. The north-westerly waves entering the bay change course as they strike the promontory of Il-Qarraba to surf obliquely on the shore of the bayhead to produce this drift.

Like all other sandy embayments in Malta, the trend in evolution of Ghajn Tuffieha Bay is the progressive erosion of the promontories on the sides and the widening of the bayhead by a widening beach as littoral drift brings in the product of erosion in the form of sand. The sand is largely produced by the erosion of the Upper Coralline Limestone of the promontories, particularly the Mtarfa Member. This member is marly and easily broken down to fine sand by weathering as the scree slides down the clay slopes under the action of gravity. This process is facilitated by the accelerated erosion of Blue Clay which undermines the limestone, causing it to beak to produce boulders.

The contribution of the erosion of the Ghajn Melel Member and Greensand Formation to the supply of sand is secondary to that of the Mtarfa Member. Although these two units are the principal sources of the ginger coloured sand at Ramla (Gozo) they are barely developed at Ghajn Tuffieha to produce an abundant supply of sand. Furthermore, the sand at Ghajn Tuffieha has the same yellowish-orange colour as the Mtarfa Member rather than the deeper colour of sand sourced by Ghajn Melel or the greyish sand sourced by Greensand.

The active surf lens appears to be in equilibrium, with a surf-base at a depth of about 10 m. Seasonal adjustments of the lens, as well as adjustments accompanying periods of storm waves and calm sea, are normal and do not appear to cause long-term changes in the lens profile itself. The determination of trend in the condition of the beach however requires a long period of monitoring before one can ascertain whether the sandy beach is static, expanding or contracting. Some preliminary conclusions can however be drawn on two important observations. The absence of sand ridges on the beach would exclude progradation (causing enlargement of the sandy beach) taking place. The narrow berm of the beach contrasts sharply with the abundant supply of source rock within the bay, suggesting that retrogradation is most likely taking place and that shrinkage is likely to have reached its maximum level. This is also supported by the absence of aeolian dunes in the bay.

Easy access, as well as the parking facilities near the dilapidated hotel, contribute to the popularity of the beach with bathers. Conrete steps build over the clay slopes lead directly to the beach and a footpath, cut in the clay, provides equally easy access.

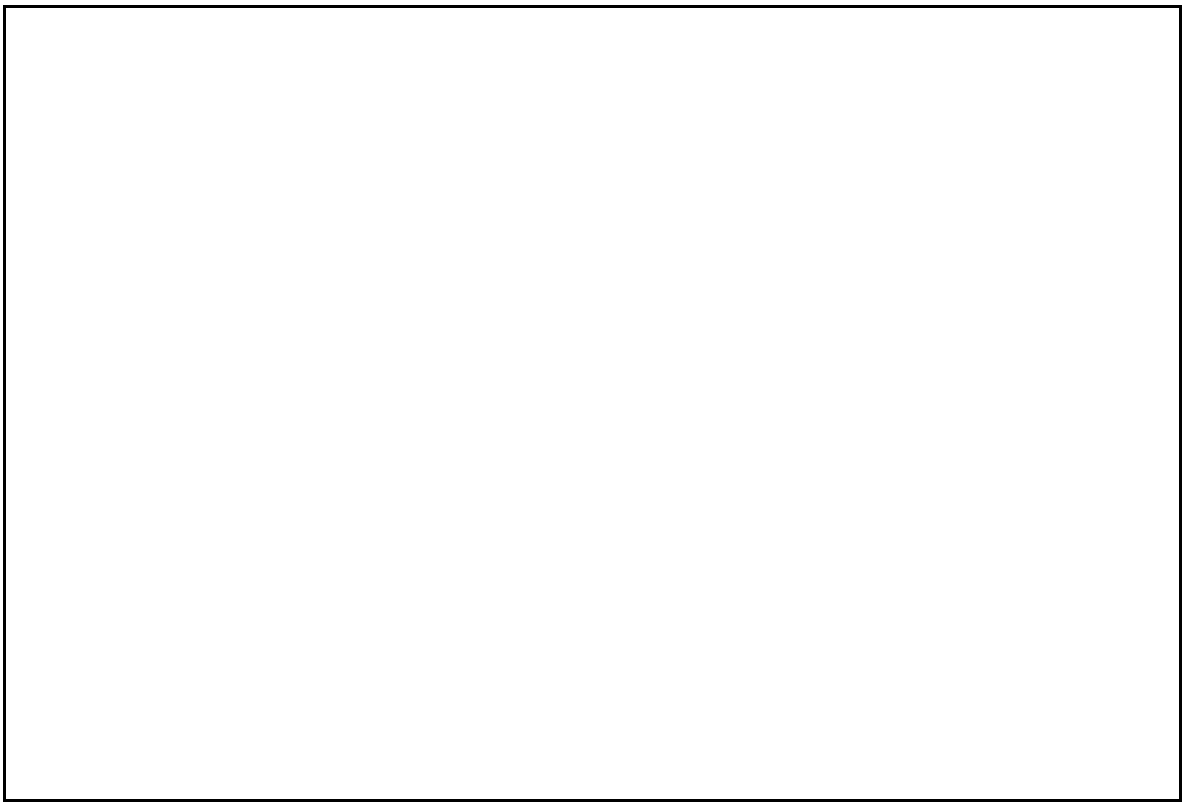

Plate XIII: Sandy beach at Ghajn Tuffieha Bay

(b) Isthmus Sandy Beach:

The small sandy beach on the southern shore of the isthmus (Plate XIV) is very similar to that of Ghajn Tuffieha Bay except in size which is only about 90 m long and 8 m wide. The source of sand is the weathering of Mtarfa Member detached from the limestone butte of the promontory in the form of rock-fall and boulder scree. A limited supply of sand may also reach the beach as littoral drift from the direction of Gnejna Bay. In contrast to the larger sand beach, this one has no apparent longshore drift as wave action, of a predominant reflective nature, reaches the beach perpendicularly. The sand at the back of the berm has an admixture of material derived from the erosion of the adjacent steep Blue Clay slopes. The berm crest is practically non-existent, suggesting a very small active lens and weak wave action.

Access to the beach by land is very difficult. From Ghajn Tuffieha it can be reached by sliding down the dangerously steep clay slopes or by a torturous route around the promontory. The approach from Gnejna Bay is less difficult but equally torturous.

(c) Sandy Beach at Il-Qarraba:

Some bouders from the undercliff of Il-Qarraba promontory protrude out into Ghajn Tuffieha Bay to trap sand as it drifts bayward to form a small sandy beach, about 50 m long, on the northern shore of the promontory (plate XV). The berm of this beach is curved and only about

5 m wide. The sand lens probably forms part of that of the main beach.

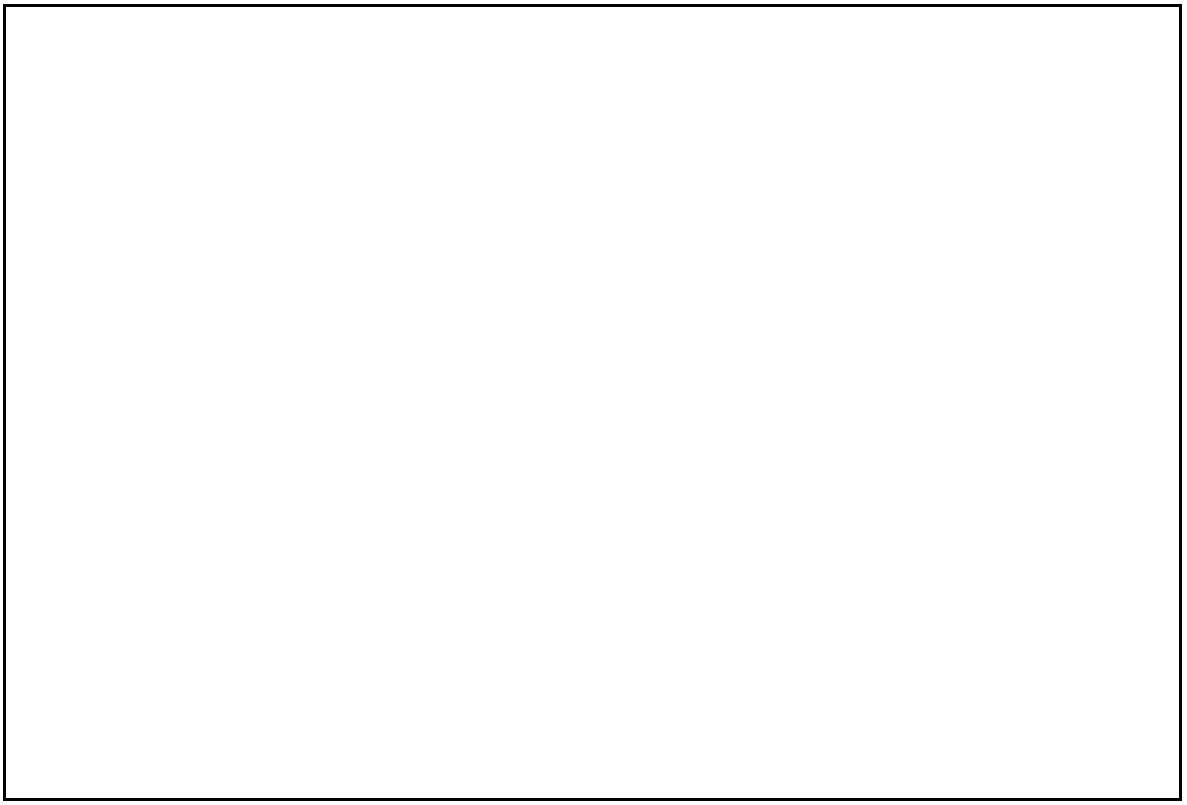

Plate XIV: Small sandy beach on the southern shore of the isthmus

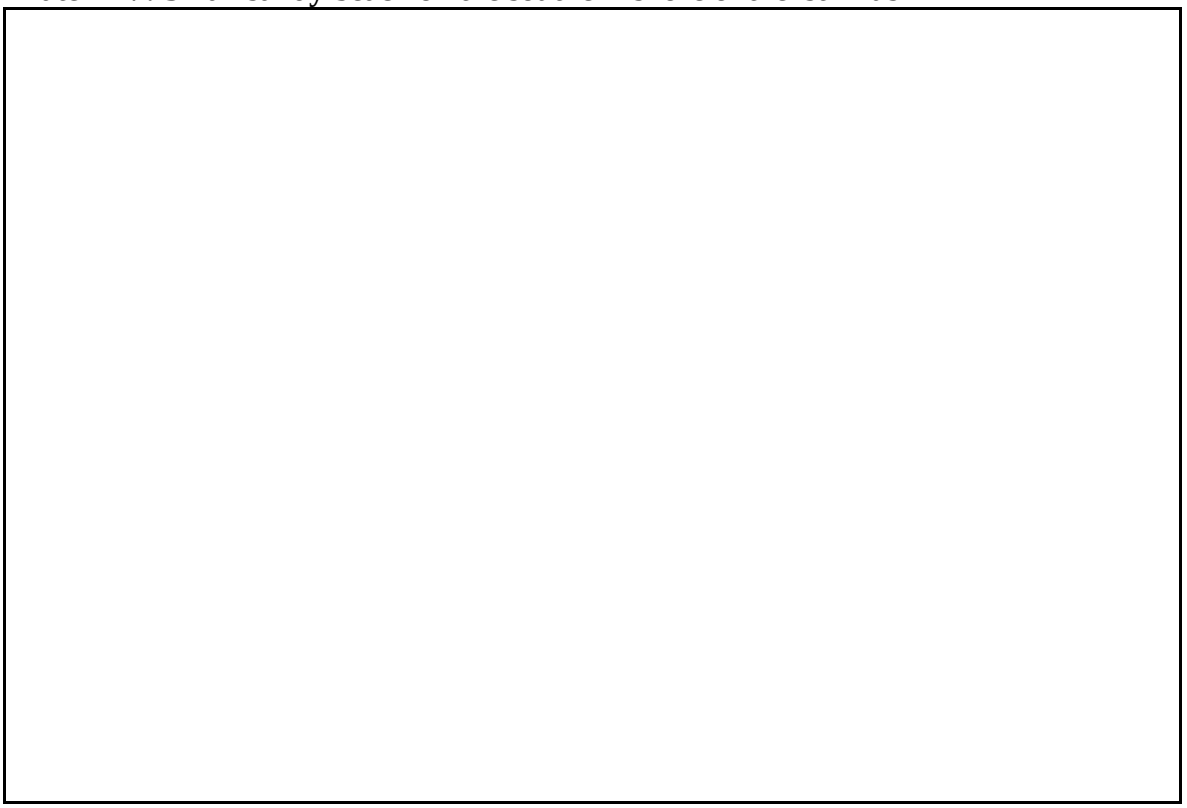

Plate XV: Sandy beach on the northern shore of Il-Qarraba promontory

Each of the three beaches described above is of significant geomorphological importance and qualifies for Level 1 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.1.

4.9 Wave-cut Terrace at Gnejna Bay:

A small but pronounced wave-cut terrace is found in the very south of the area, on the coast facing Gnejna Bay (Plate XVI). It consists of a stretch of flat coastal exposure of Upper Globigerina raised above sea-level by a few tens of centimetres and formed by the marine erosion of the overlying soft Blue Clay. The terrace is therefore the contact between the Upper Globigerina Member and Blue Clay Formation. The erosion of the clay by wave action extends to the steep slopes at the back of the terrace where a notch cut in the base of slopes is seen in places. Unlike classical wave-cut terraces, this terrace is therefore unrelated to drops in sea-level and is purely the result of differential erosion. The influence of Tal-Lappija Fault has produced a striking projection of the terrace out into the bay.

Although not easily accessible, the terrace is popular with bathers in the summer months on account of its flat surface and sharp ledges which drop vertically into relatively deep water, an ideal platform for divers and sunbathers alike.

The terrace is of significant geomorphological interest and qualifies for Level 2 Protection Rating in accordance with Malta Structure Plan Policy RCO 12.2.

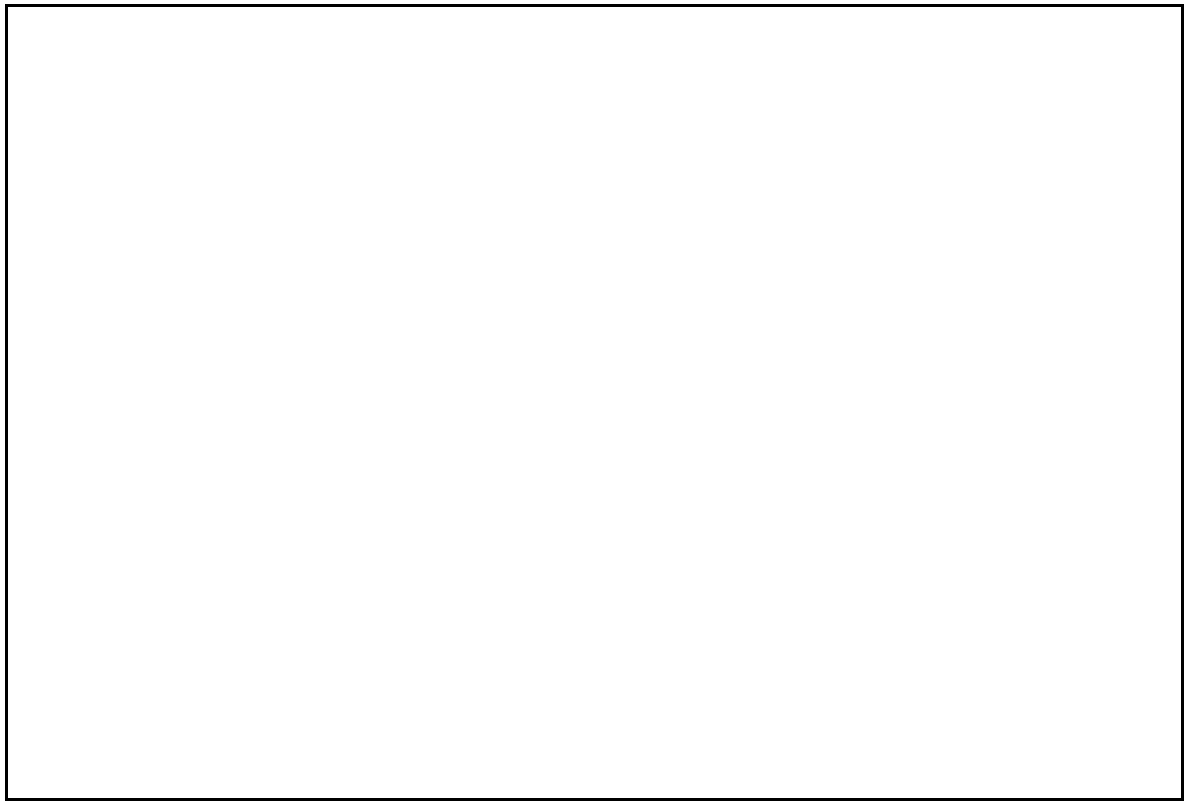

Plate XVI: Wave-cut Terrace of Upper Globigerina facing Gnejna Bay

4.10 Soils:

Of the three classes of soils, three soil complexes and one soil sequence of the soil classification of the Maltese Islands (D.M.Lang, 1961), three classes represented by the Tas-Sigra Series and Xaghra Series of the Terra Rossa Class and the Fiddien Series of the Carbonate Raw Soil Class, one complex represented by L'Inglin Complex, and the Rdum Sequence are found at Ghajn Tuffieha Area. No significant disturbed areas containing soil derived from outside the area is observed. The distribution of these lithogenic soils is shown in Fig. 7. None of them is of particular scientific importance to merit protection.

Tas-Sigra Series:

At Ghajn Tuffieha Area, this soil is confined to parts of Golden Bay headland. It is shallow to moderately deep, reddish brown, heavy textured soil with a strong granular or subangular blocky surface horizon. It is strongly decalcified, with a humus enriched surface layer and an organic content of about 3.0 % and a pH of about 8.5. Its parent material is the decalcified residue of the weathering of the Upper Coralline Limestone with subsequent movement and deposition. In areas where this soil has been concentrated by gravity-wash and retention rubble walls, as in the northern half of the headland, the depth can reach about one metre. Here, the soil is cultivated, mostly for vegetable crops in the wet season.

Xaghra Series:

This shallow soil is confined to Ix-Xaghra Tat-Torri, Il-Hotba L-Bajda ridge, and the butte of Il-Qarraba promontory. It is invariably associated with karst landscape as it represents the residue left behind by the leaching of limestone, as in Tas-Sigra soil but without subsequent movement. It is a very shallow soil, red, heavy textured, decalcified soil with a strong subangular or angular block structure occurring intermittently among the limestone outcrops of the karstified Upper Coralline Limestone along solution channels and fissures. Elsewhere, particularly on the exposed high plateaux, it is only found in scattered patches and is only of importance to the local wild flora. Total CaCO3 varies between 25% and 60%, humus content is relatively high, 3% or more, and pH is about 8.1 to 8.4

Fiddien Series:

This soil, belonging to the Carbonate Raw Soil Class, is found at the back of Il-Hotba L-Bajda Ridge, at Ghajn Tuffieha and It-Tafa. It is of the Light Textured Type, typically found on the flat lower valleys of the Blue Clay lying above the Globigerina Limestone. It is formed on locally transported colluvial, leached erosion product of Blue Clay and has undergone in the process a preferential loss of the very fine particles. It probably has an admixture of some overwash of Xaghra soil derived from upslope. It is light olive brown to grey brown in colour, moderately heavy textured clay loam, granular, normally containing about 50% $CaCO_3$ and extremely low in humus, with a pH of about 8.0. It is very slowly permeable. It is moderately deep, particularly in the lowlying parts of Ghajn Tuffieha and It-Tafal where it is cultivated in the wet season for cereal, fodder and some traditional vegetable crops.

L'Inglin Complex:

This man-made soil complex is found in the terraced fields on the north-eastern slopes of Ix-Xaghra Tat-Torri step. It is a pale brown to red, shallow to moderately deep, light to heavy textured soil resembling Xaghra soil from which it was largely derived to form terraced fields. Local variations in colour and texture from Xaghra soil is attributed to admixture of unweathered, slightly weathered and decalcified materials used in terracing. It has a relatively high organic matter content of about 3.5% and is intensely cultivated under irrigation from local springs.

Rdum Sequence:

This soil is found on the Blue Clay slopes and in the undercliff areas. It is a very shallow to moderately deep uncultivated soil. Its parent material is derived from the weathering products of the Upper Coralline and Greensand at the foot of the cliffs, spreading out over the slumping Blue Clay. Elsewhere in Malta it is often found overlying the whole sequence of Upper Coralline, Greensand, Blue Clay, Globigerina and Lower Coralline bedrock. At Ghajn Tuffieha Area it only overlies part of this sequence, ie the Greensand, Blue Clay. Local variations in the soil are due to variations in the contribution of parent material from the various members of the lithosequence as well as on the slope.

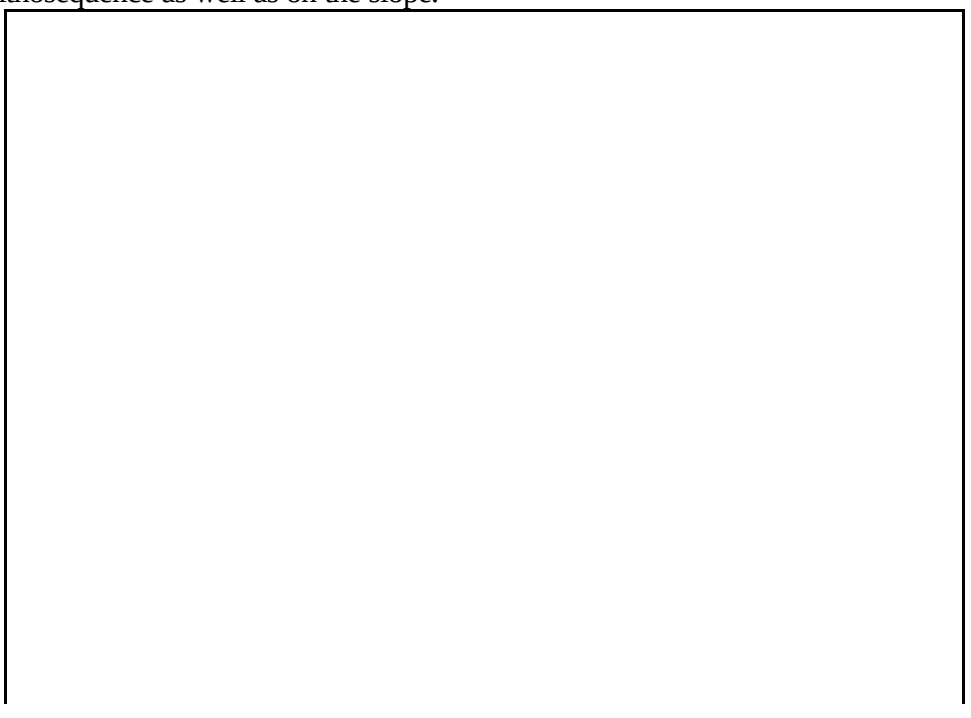

Fig.7 Soil Map of Ghajn Tuffieha Area

5. HYDROLOGY

The hydrology of the Ghajn Tuffieha Area is characterized by the two extreme surface permeability conditions of the karst landform of the Upper Coralline Limestone and the impervious steep slopes of the Blue Clay. In the former case water, flow is essentially subterranean and is almost independent of the temporal distribution of rainfall whereas the later is superficial and heavily dependent on the rainfall distribution.

5.1 Hydrology of the Limestone Exposures:

Surface water on the Upper Coralline Limestone is practically non-existent as subterranean flow, facilitated by the highly porous and permeable nature of the limestone, is overwhelmingly predominant. Here, the layered combination of Upper Coralline Limestone and Blue Clay provides strongly contrasting zones of permeability lying one above the other to form ideal conditions for the infiltration of rainwater and its storage in three perched aquifers, two sizable ones at Ix-Xaghra Tat-Torri and Golden Bay headland, and a small one at Il-Qarraba promontory (Fig.8). The high porosity and permeability of the Upper Coralline Limestone constitutes excellent aquifer characteristics whereas the Blue Clay underneath provides the aquiclude. The base of the aquifer is also synclinal at a number of places, providing limited storage. The limestone hum at Il-Hotba L-Bajda is too thin to constitute a significant perched aquifer. Although it provides some initial groundwater percolation, saturation is reached relatively very quickly and the excess water is shed over the adjacent clay exposures. It is however not unreasonable to assume that some of its groundwater is fed to Pwales Basin across Ras Il-Gebel fault.

The presence of a small area of permeable Upper Globigerina at sea level in the south also gives rise to a small mean sea level aquifer which is restricted to lateral recharge by the overlying Blue Clay.

(a) Perched Aquifer at Ix-Xaghra Tat-Torri:

The aquifer at Ix-Xaghra Tat-Torri has a catchment area of about 325,000 m^2, making it the largest of the three. no recharge figures for this aquifer have ever been calculated. It is however expected that recharge is significantly higher than the average figure of about 25% for the Maltese Islands on account of the garigue nature of the ground which renders evapotranspiration losses low, as well as its karst nature which renders surface run-off losses to insignificant levels. The average yearly recharge potential of 40,625 m^3 of this aquifer, based on the national 25% figure, is therefore very conservative.

Groundwater flow within the aquifer is controlled by two synclinal warps and the local dip to the north. Part of the recharge water is eventually lost as discharge at a number of gravity springs fringing the "xaghra", particularly at Ghajn Tuffieha (outside the Area) from where the name of the locality is derived. The rest is largely extracted at a number of private wells for irrigation purpose in the east. This extraction is facilitated by a synclinal warp at the base of the aquifer which directs the flow of groundwater to the east were the wells are located.

(b) Perched Aquifer at Golden Bay Headland:

The aquifer at Golden Bay headland is part of a much larger combination aquifer which occupies the entire Pwales Basin. In the Area, it is the second largest, with a catchment area of 75,000 m^2 and a conservative annual recharge potential of 9,160 m^3 based on the yearly recharge average of the Maltese Islands. The aquifer is slightly synclinal near Ghajn Tuffieha Tower and its base dips gently to the east. Although the aquifer is not exploited within the Area, its groundwater flows further inland in the direction of Pwales valley where it is practically fully extracted at several private wells to irrigate the fertile valley.

(c) Perched Aquifer at Il-Qarraba:

The perched aquifer at Il-Qarraba is very small and disturbed by several open fissures particularly in the west. It is only of importance to the wild flora and fauna of the promontory. Its catchment area is approximately 8,000 m^2 giving it a yearly average recharge potential of about 1,000 m^3. Its base overlying the aquiclude is quasi-planar inclined gently to the NW where most of its water is discharged at minor gravity seeps.

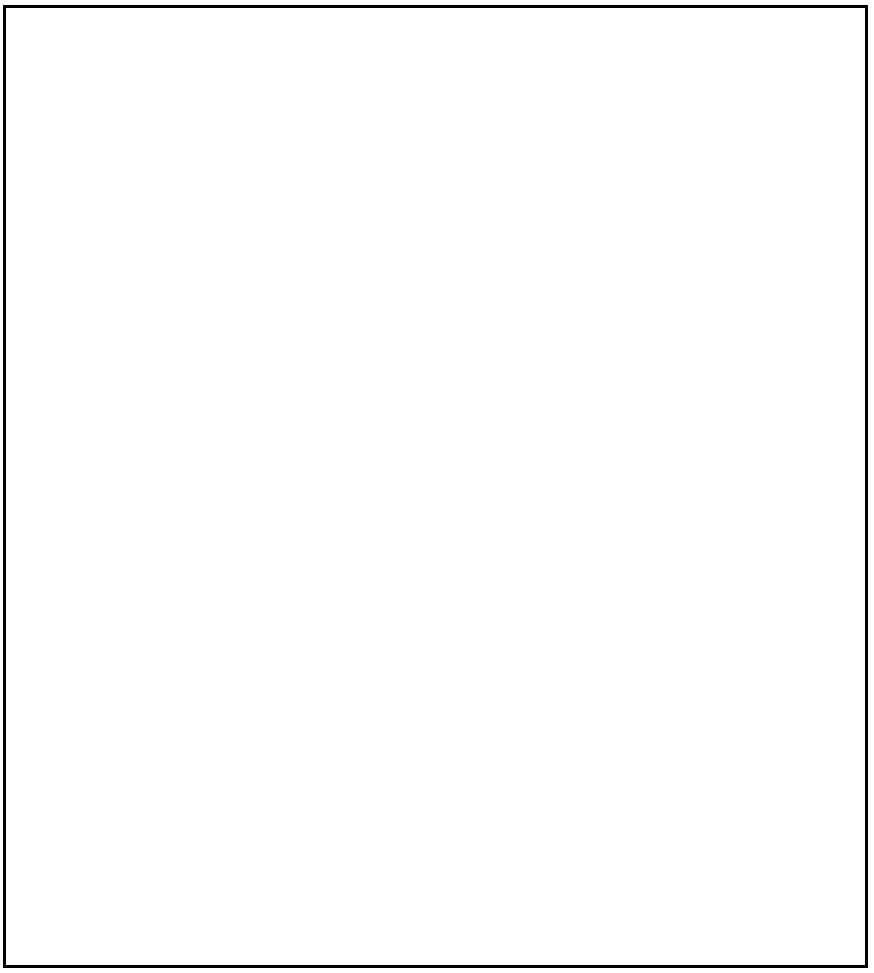

Fig.8 Hydrology of the Ghajn Tuffieha Area

5.2 Hydrology of the Blue Clay Exposures:

Whereas the hydrology of the limestone areas is characterised by a predominant subterranean flow of water, that over the Blue Clay exposures is exclusively characterised by a surface flow. Rainfall over the clay exposures at Ghajn Tuffieha, It-Tafal and the slopes of Ghajn Tuffieha Bay is initially absorbed in the highly porous clay until saturation of the top couple of meters is reached when

surface flow takes over. Saturation of this superficial layer is reached very quickly on account of the low permeability of the clay and surface flow is therefore frequent, especially during periods of prolonged rainfall or heavy downpours. The temporal distribution and intensity of rainfall therefore control the extent of water absorbtion and the extent of surface flow. The amount of yearly precipitation is not a determining factor to this balance between retention and run-off.

As the nature of the surface flow depends very much on the surface characteristics of the ground, the flow at Ghajn Tuffieha and It-Tafal is significantly different from that over the steep Blue Clay slopes of Ghajn Tuffieha Bay. The surface of the former is pitted while that of the slopes is in places smooth and barren.

(a) Surface Flow over the Blue Clay slopes:

When surface flow occurs over the slopes of Ghajn Tuffieha Bay, it starts as overland flow in the form of sheet flow over the barren smooth clay surface and, where the clay surface is pitted, in the form of rivulets overflowing from one rill and gully to the next. Where such pitting is found, there is a degree of surface detention which

together with the initial absorbtion, helps to reduce the surface water loss. Sheet flow and rivulets over these steep slopes quickly discharge into a number of small first-order stream channels which lead directly to shore. Here, the steep gradients of the slopes amplify the flow velocity to give rise to turbulent flow, strong enough to erode the clay and

carry the sediments to the beach.

Two processes of clay erosion are recognised over the steep clay slopes, stream channel erosion and splash erosion.

Stream erosion is caused both by hydraulic action and mechanical wear or abrasion. The former is the effect of pressure and shear force of flowing water exerted upon the clay particles. Abrasion occurs through the impact of rock particles carried in the water against the exposed bedrock of the stream channel. The eroded material is carried as suspension load and as bed load. Where the proportion of water to solid clay matter is large, particularly in the stream channels at high elevation, mudflow may result after heavy rainfall.

Splash erosion, the dislodgment and movement of clay particles under the impact of falling raindrops, is significant over the barren slopes of the Isthmus to Il-Qarraba. This problem is accentuated by the steep slopes which hasten the washing of this sediment downhill to the shore. Openings in the clay surface tend to become clogged by splash erosion, causing a reduction of infiltration and absorbtion capacity.

As the Blue Clay slopes plunge down directly on the shore, most of the sediment carried down the stream channels does not settle onshore but is discharges into the sea. Some slope wash and bed load does however manage to settle on the back beach, in the form of small fans. Most of this material is however washed away by seawater during heavy seas. The sediment discharged in the sea gives rise to a plume of suspended clay particles which, during periods of heavy rainfall, reaches far out at sea beyond the entrance of Ghajn Tuffieha Bay.

(b) Surface Flow at Ghajn Tuffieha and It-Tafal:

In contrast, there is practically no sheet flow at Ghajn Tuffieha and It-Tafal on account of the pitted nature of the clay which in many places is also covered by soil derived from the weathering of the clay itself. Rivulets and minor stream channels are not permanent features of the surface as most of the soil cover is tilled. The slopes here are also gentle and less prone to stream erosion. Erosion is also reduced by the tilling of the soil which improves the water retention capacity of the surface. Vegetation is also more abundant, rendering splash erosion insignificant as the vegetative cover breaks the force of falling raindrops and absorbs the energy of overland flow.

There is no evidence of soil creep or superficial creep, probably because of the shallow nature of the soil and the gentler slopes.

5.3 Mean Sea Level Aquifer:

The presence of porous and permeable Upper Globigerina Limestone at sea level in the southern parts of Ghajn Tuffieha Area gives rise to a very restricted mean sea level aquifer of no practical local use. This aquifer is limited by two factors; it is overlain by impermeable Blue Clay which limits its recharge to lateral infiltration from the east and south, and it is located at considerable depth, beyond the possibilities of the traditional exploitation methods of farmers. The aquifer is therefore not exploited within the Area. It is in lateral continuity with the principal Mean Sea Level Aquifer and is therefore influenced by the hydrogeological conditions of the latter. This continuity also provides the necessary recharge. The closest extraction point of this aquifer is located at Gnejna.

6. SITES OF SCIENTIFIC IMPORTANCE:

6.1 Sites of Scientific Importance:

In the course of the 1995 survey, 3 sites of scientific importance were recognized within the survey area, the Undercliffs (*rdum*), the Blue Clay Slopes, and Il-Qarraba Promontory. Since then, the area was increased to include the adjacent localities of Il-Lippija, Tal-Lippija, It-Tafal, Ghajn Tuffieha, Il-Hotba L-Bajda and Golden Bay headland. Another 3 SSIs are recognised within this new area, Il-Hotba L-Bajda Ridge, Golden Bay Headland, and Ix-Xaghra Tat-Torri Step. The isthmus, the group of sandy beaches and the wave-cut terrace, assimilated with the 3 sites recognized in the 1995 survey, are designated as seperate SSIs in this report. All these 9 sites satisfy one of the criteria of Policy RCO 11 of the Structure Plan and are of significance for their geological and geomorphologic significance. The protection level 4 assigned to the Blue Clay Slopes in the 1995 survey was also regraded to 2. The location of these sites coincides with the geomorphologic units shown reproduced in Fig.9. Two of these sites are under immediate threat and three are under minor or potential threat.

Fig.9 Location of Sites of Scientific Importance within Ghajn Tuffieha Area.

SSI	GEOLOGICAL SIGNIFICANCE	PROTECTION RATING	VALUE		
	Policy RCO 11	Policy RCO 12	EDUCATIONAL	RESEARCH	AESTHETIC
Il-Hotba L-Bajda Step	Geomorphology Structural Geology Hydrogeology Stratigraphy	Level 1	High	High	High
Golden Bay Headland	Geomorphology Structural Geology Hydrogeology	Level 4	Medium	Medium	High
Ix-Xaghra Tat-Torri Step	Geomorphology Structural Geology Hydrogeology	Level 2	High	High	High
Blue Clay Slopes	Geomorphology Stratigraphy	Level 2	High	High	High
Undercliffs	Geomorphology Stratigraphy	Level 4	High	High	High

Il-Qarraba Promontory	Geomorphology Stratigraphy	Level 1	High	High	High
Il-Qarraba Isthmus	Geomorphology Stratigraphy	Level 1	High	Medium	High
Sandy Beaches	Geomorphology	Level 1	Medium	Medium	Medium to High
Wave-cut Terrace at Gnejna	Geomorphology	Level 2	Medium	Medium	High

TABLE I: Sites of Scientific (Geological/Geomorphological) Importance

6.2 Conservation Profiles:

As the objective of designating protection levels to sites of scientific importance is to enable their proper conservation, it is useful to propose a conservation profile for each site even if the whole of Ghajn Tuffieha Area is designated as one SSI. These profiles highlight the conservation practice to be adopted for each site. In implementing these profiles, the following approach could be adopted.

In the first place it is important to establish that all the sites selected for conservation are **conservable**. Non-conservable sites are those sites where conflicting interests favour their exploitation which deprives them of their natural characteristics. All the sites at Ghajn Tuffieha Area are conservable.

Secondly, it is useful to establish the ease with which the conversation of each site can be done as this varies from site to site, and to establish a **conservation plan** for each site based on the conservation profiles. Although most of the sites at Ghajn Tuffieha Area are in a pristine state, they need continuous monitoring and management and a few require some intervention. The latter category includes the Blue Clay slopes, one sandy beach and those sites where agricultural activity is carried out. The appropriate route to counteract threats to these sites is to undertake practical

measures at the site and to enforce conservation proposals through legislation and the Planning Authority. It is also important to keep in mind that practical measures do not always mean conventional engineering practice in protection and conservation as novel applications of traditional structures are often more effective. This is particularly important where the sites are in a natural state as at Ghajn Tuffieha Area and the introduction of engineering measures could contrast sharply with the natural state of the sites.

The **enhancement** of sites is also a fundamental issue in conservation. At Ghajn Tuffieha Area, this is best achieved through research and educational use of the sites rather than by actual interventions such as landscaping and other means which alter their natural state. Site information boards that include a conservation element are effective in informing the public who visits the area. Explanation of geological and geomorphological features at roadside and footpath viewpoints is particularly effective if done in simple language and is accompanied by schematic diagrams. Ideal locations for notice boards are at the car-park next to the entrance to Ghajn Tuffieha Bay, at the top of the footpath leading to Il-Hotba L-Bajda, at the end of the footpath leading to the isthmus, and of course at the back of the main sandy beach.

It is also important to **monitor** the state of each site in order to be able to give warnings of degradation or other threat, to draw attention to any need of intervention and to evaluate the effectiveness of any conservation measure that may have been carried out.

Finally, the establishment of a computerised site **database** on a scale of 1:25,000 is essential to all stages of conservation. This database should not only include details of the physiographyical (topography, footpaths, etc..) and geo-environmental (stratigraphy, structure, etc..) baseline characteristics of the sites, but also their use, management, owners, state of conversation, access and safety measures to visitors.

To reach the above objectives it is useful to draw on the experience of the English "Nature Conservancy Council" and use a conservation model adopted from its "Earth Conservation Strategy". In this model, sites of geological and geomorphological importance are classified in two groups, "EXPOSURE" sites and "INTEGRITY" sites (Table II). The conservation of these groups is then approached differently as indicated in the table.

SITE CATEGORY	TYPE	CONSERVATION STRATEGY
INTEGRITY	Active Geomorphological Site	Minimise changes and preserve integrity of site.
	Cave and Karst Site	
	Static Geomorphological Site	
	Unique Mineral or Fossil Site	
	Depleted Mineral Resource*	
	Inland Outcrop or Stream	

EXPOSURE	Section	
	Exposure in Disused Quarry	
	Stratigraphic Type Section	
	Foreshore Exposure	
	Exposure in Active Quarry	
	Shafts, Tunnels and Galleries	
	Aquifer Discharge*	Preserve exposure, judging changes on their merit in terms of exposure, and, where required enhance sites.

Table II: Classification of Sites of Scientific (Geological/Geomorphological) Importance and applicable Conservation Strategy. (Adopted from NCC's ECS with the inclusion of new types marked *)

The sub-classification of "Exposure" and "Integrity" sites is shown in Tables III and IV respectively together with an outline of the typical operations and potential for damage to each type. These outlines are drawn from ECS of NCC with some adaptation to local conditions. They constitute the basis for the conservation profile of each site designated in this report. They provide an overview of the means by which the conservation of the sites can be effected. They are a practical guide to solving the problems threatening the conservation of these sites.

The following are the **conservation profiles** of the SSIs designated in this report (Pages 46 - 54).

	POTENTIAL FOR DAMAGE		
TYPE of SITE	**Highly Damaging**	**Can be Damaging if work is not sensitively planned & executed**	**Damaging in exceptional circumstances**
Static Geomorphological Site	Major excavation/levelling Dumping and infilling Major afforestation First time ploughing Coastal reclamation Industrial developments Housing development	Pits or trenches Small plantations Fencing	Sites generally vulnerable and no specific operation is indicated
Active Geomorphological Site	As for static geom. sites Stream management Sand fencing Slope stabilisation	Minor examples of operations to left may avoid damage	Sites generally vulnerable and no specific operation is indicated

	Dredging in coastal areas Introduction of vegetation		
Caves and Karst	Effluent disposal Dumping Quarrying Entrance closure Collecting	Changes in agricultural practice Water extraction from boreholes Entrance control Recreational caving	Minor developments above cave passages
Unique Mineral and Fossil Site	Industrial development Housing development Waste disposal & infilling Removal of material Collection	Research and small scale collection Stabilisation of faces	Sites generally vulnerable and no specific operation is indicated
Site Built of Depleted Mineral Resource	Demolition Major restoration Collection	Minor restoration	Sites generally vulnerable and no specific operation is indicated

Table III: Sub-classification of Integrity Sites and potential for damage from typical operations.

	POTENTIAL FOR DAMAGE		
TYPE of SITE	**Highly Damaging**	**Can be Damaging if work is not sensitively planned & executed**	**Damaging in exceptional circumstances**
Disused Quarries, pits and cuttings	Major excavation/levelling Dumping and infilling Major afforestation First time ploughing Coastal reclamation Industrial developments Housing development	Pits or trenches Small plantations Fencing	Sites generally vulnerable and no specific operation is indicated
Active Quarries and pits	As for static geom. sites	Minor examples of operations to	Sites generally vulnerable and no

	Stream management Sand fencing Slope stabilisation Dredging in coastal areas Introduction of vegetation	left may avoid damage	specific operation is indicated
Stratigraphic type section, coastal and river cliffs	Effluent disposal Dumping Quarrying Entrance closure Collecting	Changes in agricultural practice Water extraction from boreholes Entrance control Recreational caving	Minor developments above cave passages
Foreshore exposures	Industrial development Housing development Waste disposal & infilling Removal of material Collection	Research and small scale collection Stabilisation of faces	Sites generally vulnerable and no specific operation is indicated
Inland outcrops and stream sections	Demolition Major restoration Collection	Minor restoration	Sites generally vulnerable and no specific operation is indicated
Shafts, tunnels and galleries	Infilling Surface subsidence Effluent or waste disposal	Show tunnel/gallery developments	Demolition above shaft etc Normal agricultural practice
Aquifer discharge	Infilling Effluent or waste disposal Excavations	Groundwater extraction exceeding safe limit	Demolition or restoration of erection above discharge

Table IV: Sub-classification of Exposure Sites and potential for damage from typical operations.

SITE:	Il-Hotba L-Bajda Ridge
Type:	SSI(7) (Static Geomorphological Site) (+ Karst, Inland Outcrop)
Category:	Geology/Geomorphology (Integrity Site)
Protection Rating (Quality):	Level 1
Report Reference:	SS 7640 /4.1

Conservation Principles:

Recreational	Small developments are only compatible where activities developments
Major excavations	Excavations in general, including quarrying, are highly incompatible with site conservation.
Road works	Road works are highly incompatible and damaging to the site.
Services	Limited minor trenching for laying services is only compatible with siteconservation if excavations are limited to the periphery of the site adjacent to roads.
Dumping	Dumping, effluent disposal and backfilling are highly damaging on any scale.
Housing & developments	Erection of houses, as well as industrial plants, including fish-industrialfarı
Agricultural	Use of greenhouses and cloches reduces the aesthetic value of practiceth

SITE:	Golden Bay Headland
Type:	SSI(7) (Static Geomorphological Site) (+ Foreshore Exposure, Karst)
Category:	Geology/Geomorphology (Integrity Site)
Protection Rating (Quality):	Level 4
Report Reference:	SS 7640 /4.2

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the site.
Recreational &	Small developments are only compatible where activities commercial
Major excavations	Excavations in general, including quarrying, are highly incompatible with site conservation.
Road works	Road works are highly incompatible and damaging to the site.
Services	Limited minor trenching for laying services is only compatible with conservation if excavations are limited to the peripheral road.
Dumping	Dumping, effluent disposal and backfilling are highly damaging on any scale.
Housing & developments	Erection of houses and industrial plants, including fish-farms, industrialar
Agricultural	Use of greenhouses and cloches reduces the aesthetic value of practiceth increases the aesthetic value of the site.

SITE:	Ix-Xaghra Tat-Torri Step
Type:	SSI(7) (Static Geomorphological Site) (+ Inland Outcrop, Karst)
Category:	Geology/Geomorphology (Integrity Site)
Protection Rating (Quality):	Level 2
Report Reference:	SS 7640, SS 7540 / 4.3

Conservation Principles:

Recreational	Small developments are only compatible where activities developments
Major excavations	Excavations in general, including quarrying, are highly incompatible with site conservation.
Road works	Road works are highly incompatible and damaging to the site.
Services	Limited minor trenching for laying services is only compatible with conservation if excavations are located away from the rim of the structure.
Dumping	Dumping, effluent disposal and backfilling are highly damaging on any scale.
Housing & developments	Erection of houses, as well as industrial plants, including fish-industrialfar
Agricultural	Use of greenhouses and cloches reduces the aesthetic value of practiceth the gravity springs fringing the step plateau.

SITE: Blue Clay Slopes

Type: SSI(8) (Foreshore Exposure)
(+ Active Geomorphological Site)
(+ Stratigraphic Section)

Category: Geology/Geomorphology (Exposure Site)

Protection Rating (Quality): Level 2

Report Reference: SS 7640 / 4.4

Conservation Principles:

Recreational Recreational activity is only compatible if it does not cause activitiesaltera use of vehicles is highly damaging. Horse riding is compatible if restricted to footpaths.

Excavations Excavations of any sort, including quarrying, are highly incompatible with site conservation. Past quarrying activity has already caused some repairable damage to the slopes.

Road works Road works are highly incompatible and damaging to the site.

Services Trenching for laying services is highly incompatible with conservation as excavations destroy the stability of the slopes.

Dumping Dumping, effluent disposal and backfilling are highly damaging on any scale.

Plantations Large scale tree plantation is incompatible with conservation, but limited plantation of indigenous trees would enhance the site and reduce the erosion of the slopes.

Hydrological Erection of hydrological structures could be damaging and structuresshou

Agricultural Grazing is highly damaging as it weakens the resistance of the practicecla

SITE:	Undercliffs
Type:	SSI(8) (Foreshore Exposure)
Category:	Geology/Geomorphology (Exposure Site)
Protection Rating (Quality):	Level 4
Report Reference:	SS 7640 /4.5

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the 'rdum'.
Recreational	Recreational activity is only compatible if it does not cause activitiesaltera
Excavations	Excavations in general are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Services	Limited trenching could be compatible if the disturbed surface is properly reclaimed.
Plantations	Tree plantation on the slopes is incompatible with conservation as it covers the clay slopes, the principal characteristic of interest of the isthmus.
Landfill	Landfill is incompatible with conservation.
Excavations	Excavations in general are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Hydrological	Erection of hydrological structures could be damaging and structuresshou

SITE:	Il-Qarraba Promontory
Type:	SSI(8) (Foreshore Exposure) (+ Static Geomorphological Site)
Category:	Geology/Geomorphology (Exposure Site)
Protection Rating (Quality):	Level 1
Report Reference:	SS 7640 /4.6

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the 'rdum'.
Recreational	Recreational activity is only compatible if it does not cause activitiesaltera
Excavations	Excavations in general are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Services	Limited trenching could be compatible if the disturbed surface is properly reclaimed.
Plantations	Tree plantation on the slopes is incompatible with conservation as it covers the clay slopes, the principal characteristic of interest of the isthmus.
Landfill	Landfill is incompatible with conservation.
Excavations	Excavations in general are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Hydrological	Erection of hydrological structures could be damaging and structuresshou

SITE: Il-Qarraba Isthmus

Type: SSI(8) (Foreshore Exposure)
(+ Static Geomorphological Site)

Category: Geology/Geomorphology (Exposure Site)

Protection Rating (Quality): Level 1

Report Reference: SS 7640 / 4.7

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the isthmus.
Recreational	Recreational activity is only compatible if it does not cause activitiesaltera vehicles is highly damaging. Horse riding is compatible if restricted to footpaths.
Excavations	Excavations in general are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Services	Trenching is highly damaging as it destroys the stability of the clay slopes.
Plantations	Tree plantation on the slopes is incompatible with conservation as it covers the clay slopes, the principal characteristic of interest of the isthmus.
Landfill	Landfill is incompatible with conservation.
Hydrological	Erection of hydrological structures to reduce erosion of clay structuresco

SITE:	Sandy Beaches
Type:	SSI(7) (Active Geomorphological Sites)
Category:	Geology/Geomorphology (Integrity Sites)
Protection Rating (Quality):	Level 1
Report Reference:	SS 7640 / 4.8

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the beaches. Sand reclamation by natural means can however be beneficial to the enhancement of these beaches.
Recreational &	Small developments are only compatible at Ghajn Tuffieha Bay commerc
Excavations	Excavations and removal of sand are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.
Plantations	Large scale tree plantation in the valleys is incompatible with conservation, but limited plantation of indigenous trees would enhance the site.

SITE: Wave-cut Terrace at Gnejna Bay

Type: SSI(7) (Active Geomorphological Site)
(+ Foreshore Exposure)

Category: Geology/Geomorphology (Integrity Site)

Protection Rating (Quality): Level 2

Report Reference: SS 7640 / 4.9

Conservation Principles:

Marinas	Marinas and other coastal engineering schemes are highly incompatible with effective site conservation.
Coastal reclamation	Coastal reclamation is incompatible with site conservation as it destroys the natural characteristics of the terrace.
Recreational developments	Developments, on any scale, are incompatible with site conservation.
Excavations	Excavations, including minor ones, are incompatible with conservation.
Dumping	Dumping, effluent disposal and backfilling are highly damaging even on a small scale.

6.3 Major Threats & Conflicting Interests:

Although the natural state of Ghajn Tuffieha Area as a whole is almost pristine, some sites are threatened by recreational, tourist and agricultural activities.

(a) Recreational Activities:

The most serious threat is attributed to the use of motor vehicles on the Blue Clay slopes. In recent years, bathers developed the habit of driving down to the sandy beach of Ghajn Tuffieha rather than using the footpath or steps. This has seriously degraded the poor resistance of the clay to weathering and erosion and has greatly accelerated its erosion. The clay slopes at the back of the beach have been levelled and used as parking and camping areas (Plate XII), destroying Quaternary beach deposits. Vehicles are also seen venturing further inland on the slopes during the picnic season. Another very harmful activity is attributed to off-track motocycling on the clay slopes. Although there seems to have been some control to this activity recently, serious damage to the clay slopes has already been made. Apart from the mechanical erosion induced by wheels on the soft clay, the clay is clogged in the process, rendering it more vulnerable to erosion.

Another threat to the clay slopes which apparently has greatly diminished in recent years, but which nevertheless remains a potential danger, is the removal of large volumes of soft clay for use in the production of pottery. Although fresh cuttings in the clay slopes are not seen nowadays, deep cuttings made several years ago when the importation of better quality clay was not practised, can still be seen. The reclamation of these sites by plantation of trees would embellish the slopes.

Clearly, the above threats to the slopes and the principal sandy beach are attributed to an easy access to the bay (Plate XVIII). The permanent blocking of the entrance of the main footpath near the car-park is indispensable to the protection of the slopes. To render it further inaccessible to all vehicles, it should also be stepped. This could be achieved by the use of thick logs laid across the path at frequent intervals and levelling the path between the logs. Improving the safety of the concrete steps would also encourage its use in favour of the footpath. This could be achieved by installing suitable handrails. Picnics on the clay slopes could also be limited to a selection of sites. A few footpaths, particularly those near the isthmus, could also be reclaimed to restore more natural value. Unfortunately, little can be done to reclaim the Quaternary beach deposits which are now overlain by clay.

The future fate of a disused military post located on the edge of the cliff overlooking the bay near Ghajn Tuffieha Tower (Plate XIX) should be given serious consideration as its current use as a make-shift weekend retreat downgrades the area, particularly the aesthetic value of the nearby historic tower. The reclamation of the derelict military erection at Il-Hotba L-Bajda, presently used irresponsibly by picnickers and hunters, should be given some consideration as it has some historic value.

(b) Agricultural Activity:

Land reclamation for agricultural purpose in the vicinity of the Ghajn Tuffieha Area has been taking place for several years. This reclamation normally takes place on the barren 'xaghra' surfaces of the Upper Coralline Limestone and can be seen at several places such as the slopes of Pwales valley and east of Ix-Xaghra Tat-Torri. The barren surface of the latter site makes it highly vulnerable to this reclamation practise, particularly that farming activity is already present in the east of the 'xaghra'. Such reclamation is highly damaging to the natural landscape.

The use of cloches and glasshouses in areas of natural beauty do not blend well with the aesthetic value of the landscape. This agricultural practise, although of economic importance, has damaged the natural state of several beauty spots in Malta and Gozo, Pwales valley being an example. It is also being practised at Ghajn Tuffieha Area particularly on the headland between Golden Bay and Ghajn Tuffieha Bay and at It-Tafal. Some control is needed to restrict its use particularly in areas exposed to wide panoramic views from several directions.

The extraction of groundwater from wells at Ix-Xaghra Tat-Torri step could pose a threat to the natural habitat of the area. Extraction from wells cause the water level of the perched aquifer to drop very quickly, particularly that it is a relatively small aquifer. This lowering of the water table affects the performance of gravity springs, causing them to dry sooner. A remedial measure to this problem is to ensure that the permitted extraction rates of the wells are not exceeded.

(c) Tourist Developments:

Activities related to the tourist industry also pose some threat to the Area, particularly to the sandy beach of Ghajn Tuffieha Bay. The kiosk (Plate XX) on the north side of the beach contrasts very sharply with the natural state of the surrounding environment and could be improved to make it blend better. Removal of the derelict terraces of the Riviera Martinique is also needed to embellish the general view of the bay. Erection of further structures, including new tourist developments of any magnitude, should be disallowed in the area. The potential impact of a possible future development of the Riviera Martinique should be given serious consideration.

The above threats, conflicting interests and remedial measures are tabulated in Table V for each of the threatened SSI.

SSI	THREATS	CONFLICTING INTERESTS	RESTORATION
Blue Clay Slopes	Erosion of blue clay slopes by vehicles and picnickers; Minor excavations for clay; Derelict terraces of Riviera Martinique contrasts with landform.	Recreational activity.	Prohibit entry of vehicles; Improve conditions of steps; Limit picnic sites; Reclaim minor excavations in face of slopes; Reclaim some footpaths; Plant tress/shrubs at selected sites; Remove derelict terraces of Riviera Martinique.
Sandy Beach at Ghajn Tuffieha Bay	Levelling of clay over Quaternary beach deposits; Beach kiosk contrasts sharply with landform.	Recreational activity & tourist development.	Prohibit picnics, camping and parking of vehicles on the back-beach; Improve aesthetic condition of the beach kiosk; Stop further development.
Ix-Xaghra Tat-Torri Step	Potential reclamation of 'xaghra' for agricultural use; Groundwater over-extraction from private wells.	Agricultural activity.	Control agricultural activities including the extraction of groundwater from private wells.
Golden Bay Headland	Use of cloches contrasts with landform; Potential development of Riviera Martinique.	Agricultural activity & tourist developments.	Control use of cloches & glasshouses; Remove make-shift hut neat Ghajn Tuffieha Tower; Stop further developments.
Il-Hotba L-Bajda Ridge	Use of cloches at It-Tafal & Ghajn Tuffieha; Use of derelict military post at Il-Hotba L-Bajda by picnickers and hunters.	Recreational & hunting activities	Restoration and better use of abandoned military post; some control on use of cloches & glasshouses.

TABLE V: SSIs Under Threat

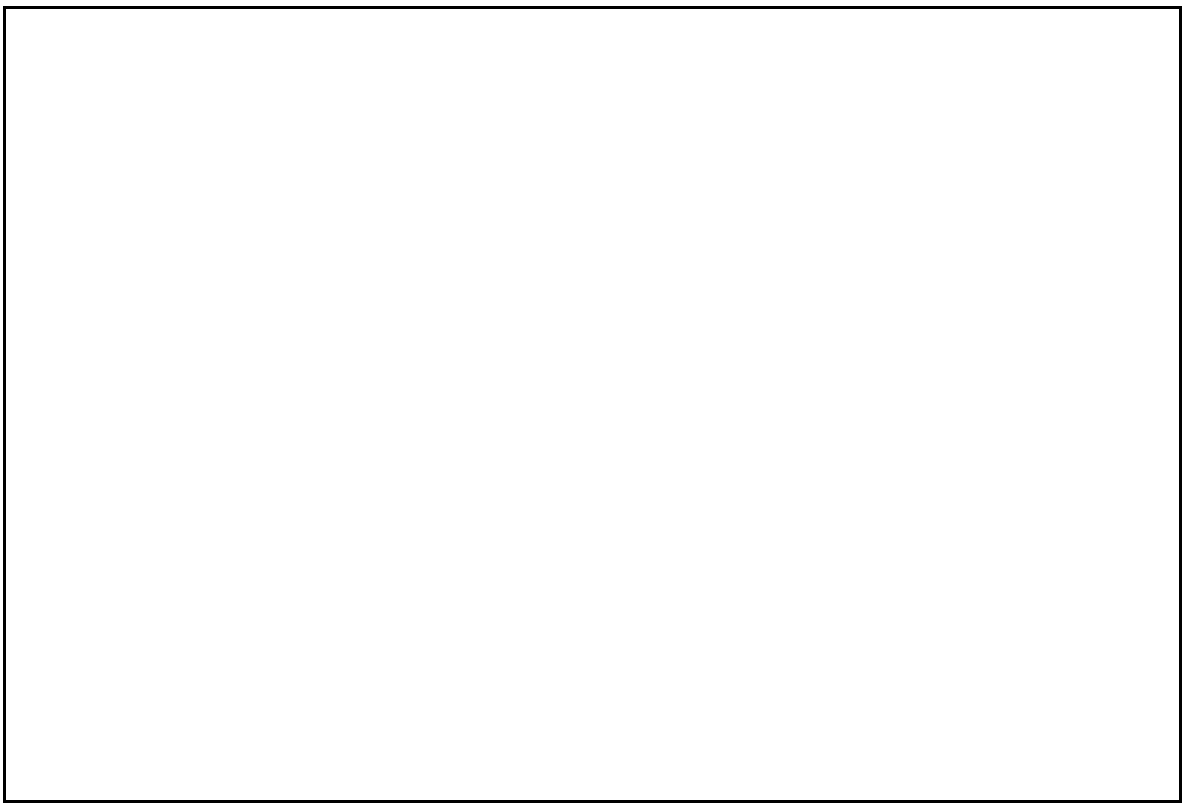

PLATE XVII: Main footpath leading to Ghajn Tuffieha Bay provides easy access to vehicles.

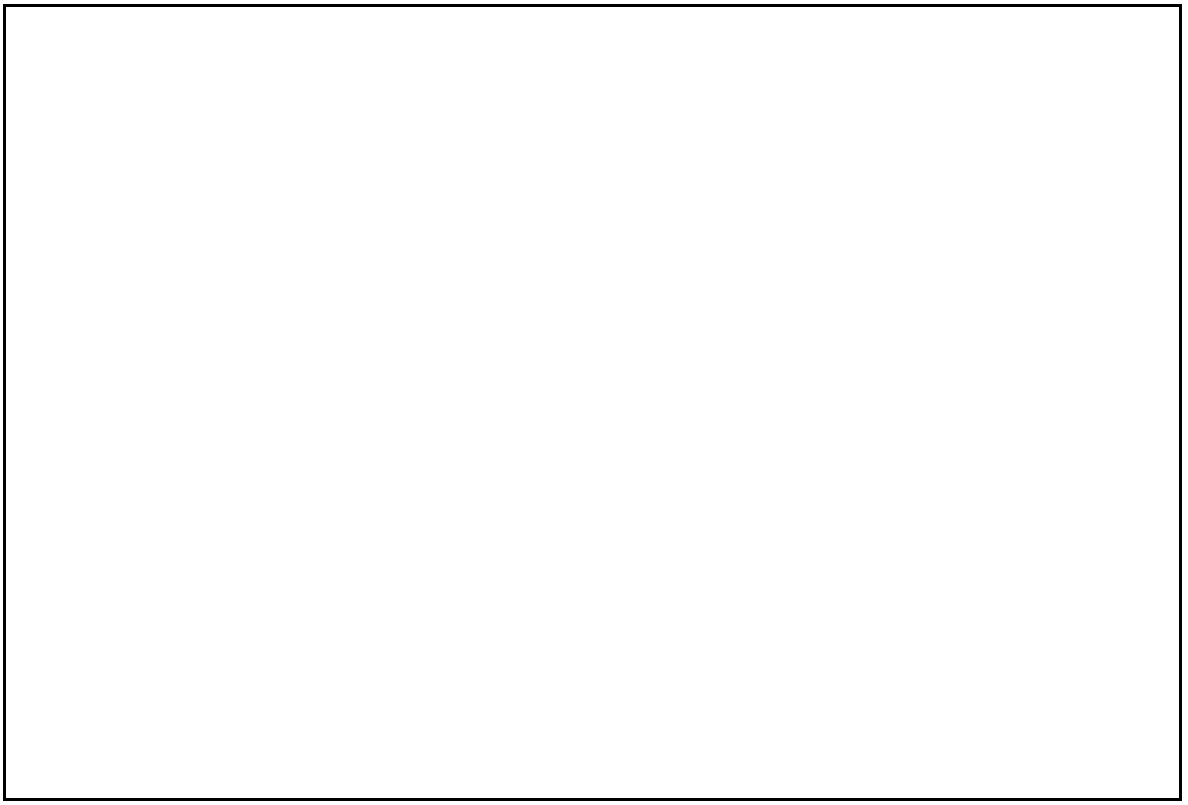

PLATE XVIII: Irresponsible use of the Blue Clay slopes by campers.

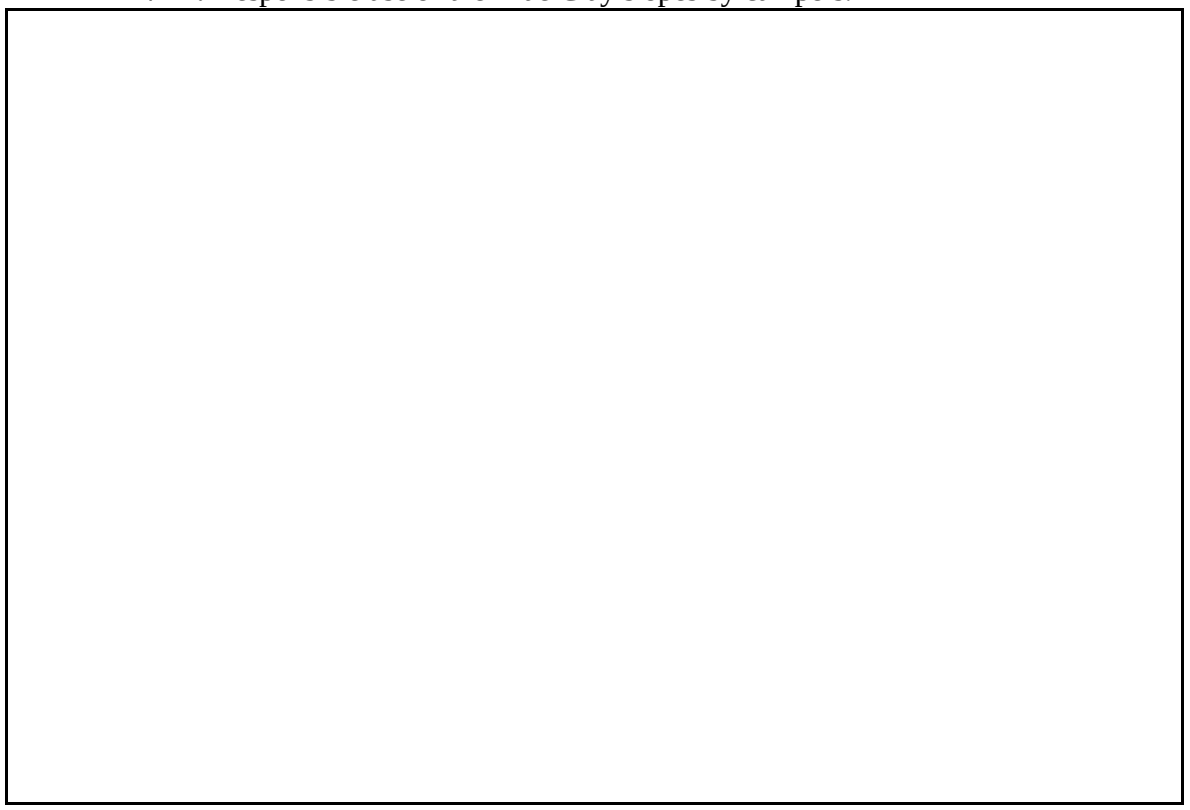

PLATE XIX: Make-shift weekend retreat near Ghajn Tuffieha Tower downgrades the aesthetic value of the site.

PLATE XX: Beach kiosk at Ghajn Tuffieha Bay contrasts sharply with the sandy beach and clay slopes.

7. SUMMARY

1. The Ghajn-Tuffieha Area lies in the northern structural block of Malta. Structurally, it is made up of the westernmost extremities of two structural units of the this northern block, the Pwales Valley and the Wardija Ridge.

2. Tectonism of the Area is defined by four predominant E-W trending normal faults of Early Miocene age. These faults are Ghajn Tuffieha - St.Paul's Bay Fault, Ras Il-Gebel Fault, Il-Qarraba Fault and Tal-Lippija - Wardija Fault.

3. Four of the five geological formations of the Maltese islands outcrop at the Ghajn Tuffieha Area. They are composed of near-horizontally bedded marine sedimentary rocks of Oligo-Miocene age, uncomfortably overlain in places by very sporadic thinly developed Quaternary continental and beach deposits. These formations are, from bottom, Globigerina Limestone Formation, Blue Clay Formation, Greensand Formation and Upper Coralline Limestone Formation.

5. The geomorphology of the Area is typical of that found in the northern structural block where morphology is controlled primarily by structural endogenetic processes producing an initial landform made up of block faulted horst and graben system, with subsequent drainage, karst and shoreline processes playing a secondary exogenetic role to yield a variety of sequential erosional landforms.

6. Several pronounced geomorphological units are found shaping the morphology of the Area to produce an aesthetically rich, varied and interesting landform. These units are, Il-Hotba L-Bajda Ridge, Golden Bay Headland, Ix-Xaghra Tat-Torri Step, Undercliffs, Blue Clay Slopes, Il-Qarraba Promontory, Il-Qarraba Isthmus, 3 Sandy Beaches, and a Wave-cut Terrace.

7. Five types of soils are found within the Area. These are Tas-Sigra Series, Xaghra Series, Fiddien Series,. L'Inglin Complex, and the Rdum Sequence.

8. The hydrology of the Ghajn Tuffieha Area is characterized by the two extreme surface permeability conditions of the karst landform of the Upper Coralline Limestone and the impervious steep slopes of the Blue Clay. In the former case, water-flow is essentially subterranean, giving rise to three perched aquifers at Ix-Xaghra Tat-Torri Step, Golden Bay Headland and Il-Qarraba Promontory. The

presence of a small area of permeable Upper Globigerina at sea level in the south also gives rise to a small mean sea level aquifer.

9. In the course of the 1995 survey, 3 sites of scientific importance were recognized within the survey area, the Undercliffs, the Blue Clay Slopes, and Il-Qarraba Promontory. In the course of this survey, another 3 SSIs are recognised within the new area. These sites coincide with the geomorphological units of Il-Hotba L-Bajda Ridge, Golden Bay Headland and Ix-Xaghra Tat-Torri Step. The isthmus, the 3 sandy beaches and the wave-cut terrace, assimilated in the SSIs of the 1995 survey, are also designated seperate SSIs in this survey.

10. All of these 9 sites satisfy one of the criteria of Policy RCO 11 of the Structure Plan and are of significance for their geological, hydrological and/or geomorphologic significance. A protection rating varying between 1 and 4 is assigned to each of these sites.

11. The protection level 4 assigned to the Blue Clay Slopes in the 1995 survey was also regraded to 2.

12. The Blue Clay Slopes and the sandy beach at Ghajn Tuffieha Bay are under immediate threat while Ix-Xaghra Tat-Torri, Golden Bay Headland and Il-Hotba L-Bajda Ridge are under potential threat.

13. The most serious threats are attributed to the use of motor vehicles on the Blue Clay slopes and the levelling of clay on the back-beach of Ghajn Tuffieha Bay. The former has seriously degraded the already poor resistance of the clay to weathering and erosion and has greatly accelerated its erosion. The latter has destroyed Quaternary beach deposits.

14. Another threat to the clay slopes which apparently has greatly diminished in recent years, but which nevertheless remains a potential danger, is the removal of large volumes of soft clay for use in the production of pottery. The reclamation of these sites by plantation of trees would embellish the slopes.

15. The permanent blocking of the entrance of the main footpath leading to the bay near the car-park is indispensable to the protection of the slopes. To render it further inaccessible to all vehicles, it should also be stepped. This could be achieved by the use of thick logs laid across the path at frequent intervals and levelling the path between the logs.

16. The future fate of a disused military post located on the edge of the cliff overlooking the bay near Ghajn Tuffieha Tower should be given serious consideration as its current use as a make-shift weekend retreat downgrades the area, particularly the aesthetic value of the nearby historic tower.

17. The reclamation of the derelict military erection at Il-Hotba L-Bajda, presently used irresponsibly by picnickers and hunters, should be given some consideration as it has some historic value.

18. Land reclamation for agricultural purpose in the vicinity of the Ghajn Tuffieha Area has been taking place for several years. The barren surface of the Xaghra Tat-Torri Step makes this site highly

vulnerable to reclamation, particularly that farming activity is already present to the east of the 'xaghra'. Such reclamation is highly damaging to the natural landscape.

19. The use of cloches and glasshouses in areas of natural beauty do not blend well with the aesthetic value of the landscape. This agricultural practise, although of economic importance, has damaged the natural state of several beauty spots in Malta and Gozo, and is also being practised at Ghajn Tuffieha Area particularly at Golden Bay Headland and at It-Tafal. Some control is needed to restrict its use particularly in areas exposed to wide panoramic views from several directions.

20. The extraction of groundwater from wells at Ix-Xaghra Tat-Torri step could pose a threat to the natural habitat of the area. Extraction from wells cause the water level of the perched aquifer to drop very quickly, particularly that it is a relatively small aquifer. This lowering of the water table affects the performance of gravity springs, causing them to dry prematurely. A remedial measure to this problem is to ensure that the permitted extraction rates of the wells are not exceeded.

21. Activities related to the tourist industry also pose some threat to the Area, particularly to the sandy beach of Ghajn Tuffieha Bay. The kiosk on the north side of the beach contrasts very sharply with the natural state of the surrounding environment and could be improved to make it blend better. Removal of the derelict terraces of the Riviera Martinique is also needed to embellish the natural view of the bay.

22. Erection of further structures, including new tourist developments of any magnitude, should be disallowed in the area. The potential impact of a possible future development of the Riviera Martinique should be given serious consideration.

23. The appropriate route to counteract threats to these sites is to undertake practical measures at the site and to enforce conservation proposals through legislation and the Planning Authority.

24. The introduction of engineering protective measures such as the construction of dams and retention walls could contrast sharply with the natural state of the sites and should be avoided.

25. The enhancement of sites is a fundamental issue in conservation. With the exception of the Blue Clay Slopes, this is best achieved through research and educational use of sites rather than actual interventions.

26. Site information boards that include a conservation element are effective in informing the public who visits the area. Explanation of geological and geomorphological features at roadside and footpath viewpoints is particularly effective if done in simple language and is accompanied by schematic diagrams.

27. Ideal locations for notice boards are at the car-park next to the entrance to Ghajn Tuffieha Bay, at the top of the footpath leading to Il-Hotba L-Bajda, at the end of the footpath leading to the isthmus, and at the back of the main sandy beach.

28. It is important to monitor the state of each site in order to be able to give warnings of degradation or other threat, to draw attention to any need of intervention and to evaluate the effectiveness of any conservation measure that may have been carried out.

29. The establishment of a computerised site database on a scale of 1:25,000 is essential to the future conservation of the sites. This database should not only include details of the physiographyical (topography, footpaths, etc..) and geo-environmental (stratigraphy, structure, etc..) baseline characteristics of the sites, but also their use, management, owners, state of conversation, access and safety measures to visitors.

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