Review Article

Ghar Dalam Cave: A review of the sediments on the cave floor stratigraphy

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Summary: *The Ghar Dalam cave floor excavations conducted in the late nineteenth and early twentieth centuries have identified a number of stratigraphical divisions containing several fossil animal remains. The original excavation reports are reviewed and correlated to the presently existing floor sample pillar and wall, and the stalagmite structure situated at about 115 feet from the cave entrance. The study confirms the definite presence of eight stratigraphical layers making up four definite faunal stages and a sterile layer. The oldest faunal stages* - Eliomys (Maltamys) *sp.* (=Leithia cartei) *stage and* Pitymys melitensis *stage - have been dated to the Upper Pleistocene by absolute and relative dating techniques specifically to the Riss-Wurm interglacial and the Wurm glacial. The uppermost two faunal stages* - Apodemus sylvaticus *stage and* Rattus rattus *stage - have been assigned to the Holocene period.*

Introduction

The Ghar Dalam cave has yielded an uninterrupted sequence of fossiliferous deposits extending from the Late Pleistocene to Modern times, thus enabling a sequential study of the palaeogeographical state of the Maltese Islands during the Ice Ages. The first serious effort to excavate and study the cave floor was made by J.H. Cooke in the late nineteenth century after A. Issel outlined the importance of the cave in 1865 (Issel, 1866; Cooke, 1893a/b). Subsequent excavations were carried out by the Malta Museum Authorities during the second decade of the twentieth century. These early excavators carefully documented and published their findings in several geological and archaeological journals. The use of varying descriptive terms by the different workers to record the various strata and sub-strata making up the cave floor made stratigraphical correlation difficult.

In 1921, an attempt was made by G. Sinclair to review the stratigraphy of the cave floor basing his study on the sample pillars left in situ by the previous excavators and extending the previous excavations with three trenches (Sinclair, 1924; Keith, 1924). Sinclair's work, after minor modifications, served as the basis for the descriptions of the strata used by subsequent excavators (Caton-Thompson, 1925; Baldacchino, 1934-38; Storch, 1974). Attempts at dating the various Pleistocene deposits have been based on stratigraphical evidence, faunal (microfaunal and macrofaunal) correlations, electron spin resonance and uranium series disequilibria, and chemical and radiometric relative dating using bone F-U-N (Fluoride, Uranium, Nitrogen) content. The Prehistoric deposits have been dated by comparing pottery shards with Carbon 14 dated shards from other prehistoric sites.

Following these studies, the Ghar Dalam cave floor has been described as consisting of a series of stratigraphical divisions reflecting different episodes in the geological history of the Maltese Islands (Zammit-Maempel, 1989). The generally accepted geological and faunistic division of the Ghar Dalam cave floor ignores the various

EXCAVATORS	YEAR	NOTES	REFERENCE
A. Issel	1865	1 trench at about 300 ft from entrance.	Issel, 1866
J.H. Cooke	1892	8 trenches at 20 ft, 30 ft, 50 ft - right & left, 170 ft, 200 ft, 350 ft, fissure at 400 ft from entrance.	Cooke, 1893a/b
N. Tagliferro, G. Despott, C. Rizzo	1912-13	2 trenches at 350 ft - right & left - from entrance.	Ashby & Despott, 1916
T. Ashby, G. Despott, C. Rizzo, R. Castillo	1914	2 trenches at 200 ft - right & left - from entrance.	Ashby & Despott, 1916
G. Despott, C. Rizzo	1916-17	3 trenches at 50 ft, 110 ft, 115ft from entrance.	Despott, 1916/1918
G. Despott	1918-20	3 trenches excavating completely (except for sample pillars/wall) to about 210 ft from entrance.	Despott, 1923
G. Sinclair, G. Despott, G. Flamingo	1921	3 trenches dug from Bone breccia layer to cave floor at 65 ft, 110 ft, and 205 ft from entrance.	Sinclair, 1924; Keith, 1924
G. Caton-Thompson	1922/24	5 trenches at 125 ft, 150 ft, 170 ft (2 trenches), 225 ft from entrance.	Caton-Thompson, 1923/1925
J.G. Baldacchino	1934-37	5 trenches at 20 ft, 42 ft, 120 ft, 138 ft, 170 ft from entrance.	Baldacchino, 1934-38; Trechmann, 1938
G. Storch	1969	1 trench in fissure at about 100 m from entrance.	Stroch, 1970/1974
G. Zammit-Maempel	1996	1 trench at about 240 ft from entrance.	museum display

Table 1. History of excavations in Ghar Dalam
(Illicit excavations recorded in period 1892-1912 and 1914-16 - the latter in the region of 200ft from the entrance)

subdivisions noted by the earlier excavators, particularly the subdivisions of the Red Earth or *Cervus* layer, overall faunistically related to the *Pitymys melitensis* stage by Storch (Storch, 1974). This study attempts to review and correlate the various subdivisions as described by the early twentieth century excavators with the remaining geological features and the presently standing cave floor sample wall and pillar.

Material and methods

A literature search was conducted in the various melitensia-holding libraries (the National Library, University and Archaeology Museum Libraries) in Malta to identify the publications relating to the original Ghar Dalam excavations. A total of 34 formal excavations were identified. The larger proportion of these (24 excavations) had been conducted prior to G. Sinclair's publication of 1924 (Table 1). The descriptions in the various published reports were correlated to the presently accepted stratigraphy (Zammit-Maempel, 1989), noting major important sub-strata. Descriptions noting definite evidence of disturbance were not taken into account in the present review. Through the use of Sinclair's review (Sinclair, 1924), these observations were correlated to the geological features and cave floor sample wall/pillar still standing today at Ghar Dalam. The fossils excavated from the various divisions by the various excavators were reviewed. The results of the scientific analyses of the various samples of fossils from different horizons carried out by Prof. K. Oakley at the Museum of Natural History (London) in 1952-1968/69 were also reviewed. The *Hippopotamus* sp. samples submitted to Professor Oakley for scientific study are assumed to have been all obtained from the Bone Breccia *Eliomys (Maltamys)* sp. *(=Leithia cartei)*; while the *Cervus* sp. samples were obtained from the Red Earth Layers dated to the *Pitymys* melitensis faunal stage and the *Equus* sp. sample from the Domestic layer *Apodemus sylvaticus* stage. The mean and standard deviation of the various test results were calculated using a statistical software package [MedCalc for Windows ver.4] to allow comparisons to be made.

Cave floor stratigraphy

G. Sinclair (Sinclair, 1924; Keith, 1924) subdivided the cave floor to four major layers including: (1) the Sterile layers of yellowish-blue clay (~3ft depth) overlaying the cave floor, of which the upper 1 inch of this clay was hardened; (2) a Bone Breccia (~3ft depth) with the multiple hippopotamus and elephant remains, and which included an overlying rounded boulder layer (~1ft thick); (3) the Red Earth Layers (total depth ~7ft) with the principal remains of *Cervus*; and (4) the Surface layer consisting of the superficial boulder layer, cave earth floor and pebble layer under it. The deposits were not evenly distributed in depth, but they apparently thinned out the farther one proceeded into the cave. The Red Earth Layer was described as consisting chiefly of red vegetable soil with alternating layers of "torba" clay in the upper portion. It was subdivided into four sections: (a) the upper three feet consisting of red earth, (b) the middle well-defined bone layer a few inches thick, the principal remains being deer, (c) the lower layer consisting of red earth, and (4) at the bottom another bone layer consisting of deer, elephant and hippopotamus remains.

This description conforms with the descriptions of the previous excavators, notably G. Despott and his co-workers, who in a series of nine extensive excavations repeatedly reported the presence of several subdivisions in the Red Earth Horizon. The first excavation in 1912-13 (Tagliaferro Trench) was dug out at 350 feet (106.7 m) from the entrance, close to a trench dug up and refilled by Cooke in 1892 (Cooke Trench I). No detailed stratification notes are available for this trenchal, though Cooke subdivided this to a total of six layers (Cooke, 1893a, b). The second excavation was made in 1914 (Ashby Rt & Lt Trenches) at 200 feet (61m) from the entrance, again in an area previously disturbed by Cooke (Cooke Trench III). The trench on the right hand side of the cave was described to have no less than 10 layers and was possibly previously disturbed by Cooke's excavations and the subsequent refill. The trench on the left hand side of the cave had definite evidence of previous disturbance (Cooke, 1983a, b; Ashby and Despott, 1916).

In 1916, Despott excavated a trench in a previously undisturbed area (Despott 1916 Trench) around a large stalagmite at about 115 feet (35 m) from the cave entrance. The cave floor was here described as consisting of six layers with a further number of sub-strata separated by stalagmitic plates. Two further

Despott I 50 ft	Despott Outer ~50-80ft	Despott II 110 ft	Despott 1916 115 ft	Despott Middle ~90-123ft	Despott Inner ~128-141ft	Ashby Rt 200 ft	Overall DESCRIPTION
0 [<36"]	0 [<60"]	0	1 [<36"]				boulders
1 [6-12"]	1 [6-24"]					½ [24"]	red soil
2 [12-16"]	2 [12-18"]	1 [12-18"]	2 [12-18"]	1 [12-42"]	1 [12-24"]	3 [12"]	red soil with angular stones
3 [12-18"]	3 [9-18"]	2 [12-18"]	3 [36"]	2 [12-36"]	2/3	4/5/6 [39"]	red earth layers [approx. 3]
4 [<84"]	4 [60-84"]	3 [24"]	4 [26"]	3 [24-48"]	4/5	7/8 [12-30"]	red earth layers [approx. 2]
5 [12"]	5 [>42"]	4 [8"]	5 [8"]	4 [0-36"]	6	absent	flat angular stone breccia
6		5	6	5		9/10	bone breccia

Table 2. Despott's excavations at Ghar Dalam
(all excavations failed to breach the bone brecia layer)

trenches were dug out in 1916-17 (Despott I and II Trenches) at 50 feet (15.2 m) and at 110 feet (33.5 m) from the cave entrance. The former cave floor area had been partially disturbed on the right hand side by Cooke in 1892 (Cooke Trench II), the latter site was undisturbed. These excavations have revealed six to seven strata (Despott, 1918). The areas between the trenches at approximately 50-80 feet (15.2-24.4 m), 90-123 feet (27.4-37.5 m), and 128-141 feet (39.0-43.0 m) were subsequently totally excavated during 1918-20 (Despott Outer, Middle and Inner Trenches) to show the presence of several main strata and a number of sub-strata (Despott, 1923). Table 2 correlates the descriptions of the various trench descriptions excavated by G. Despott and his co-workers where these are accurately described.

Before Sinclair's publication of his study in 1924, a series of excavations were conducted by G. Caton-Thompson. Caton-Thompson excavated a series of five trenches. Two of her trenches dug in some 150-210 feet (45.7-64.0 m) from the entrance had been previously excavated and refilled by J.H. Cooke and by T. Ashby & co-workers besides illicit diggers, and a large section of the trench showed evidence of disturbance. Her other three trenches included a trench dug up along the width of the cave at 225 feet (68.6 m) from the entrance, a deepening of that previously dug up (Cooke IV Trench) at 170 feet (51.8 m) from the entrance, and a ledge deposit 125 feet (38.1 m) from the entrance (Caton-Thompson, 1923,1925; Bate, 1923,1925). During the period 1934-38 J.G. Baldacchino conducted a series of five excavations in various regions of the cave floor. In his first two excavations, Baldacchino classified the cave-floor into seven layers, where the third, fourth and fifth layers referred to the Red Earth Layers. In subsequent excavations, Baldacchino subdivided the cave floor into six layers with the third layer referring to the Red Earth Layers and the fourth layer referring to the Pebble Layer (Baldacchino, 1934-38; Trechmann, 1938). More recently, excavations were conducted on a limited scale in 1969 by Dr. Gerhard Storch of the Senckenberg Museum of Frankfurt am Main (Storch, 1970,1974). The most recent excavations reported in a display at the Ghar Dalam Museum were made by Dr. George Zammit-Maempel in 1996 in a recess situated at 75 m (~240 ft) from the entrance.

It would thus appear that all the excavators reported various sub-strata in the Red Earth Horizon. The various sub-strata in the Red Earth Layer are best illustrated by the section of the deposits at Despott 1916 (Figure 1). This trench excavated at 115 feet (35.1 m) from the entrance around a large stalagmite was described to consist of 6 strata. The first layer from the surface included the superficial boulders, while the second layer of about 12-18 inches (30.5-45.7 cm) depth consisted of small stones embedded in fine brick-red earth. The third and fourth layer made up the Red Earth Layer of about 5 feet (1.5 m) depth, while the fifth and sixth layers consisted of the pebble and Bone Breccia layers respectively. The third and fourth layers were characterised by a series of three stalagmitic plates extending from the large stalagmite situated about 10 feet (3.1 m) from the left side of the cave. Evidence of these stalagmitic sheets can still be seen today on the standing outermost stalagmitic column in the cave. At a higher level to the last stalagmitic plate lay a number of detached stalactites on which stalagmitic formations of about 12 inches (30.5 cm) height had developed. This stalagmitic transition is evident on the stalagmitic column as a marked widening of the column (Despott, 1916). The composition of the floor in the region below the bone breccia was demonstrated by G. Sinclair in a trench dug at about 110 feet (33.5 m) from the entrance (Sinclair, 1924).

The Ghar Dalam cave floor sedimentary sequence is presently demonstrated by a Sample Pillar and a Sample Wall situated at about 70 and 85 feet (21.3 and 25.9 m)

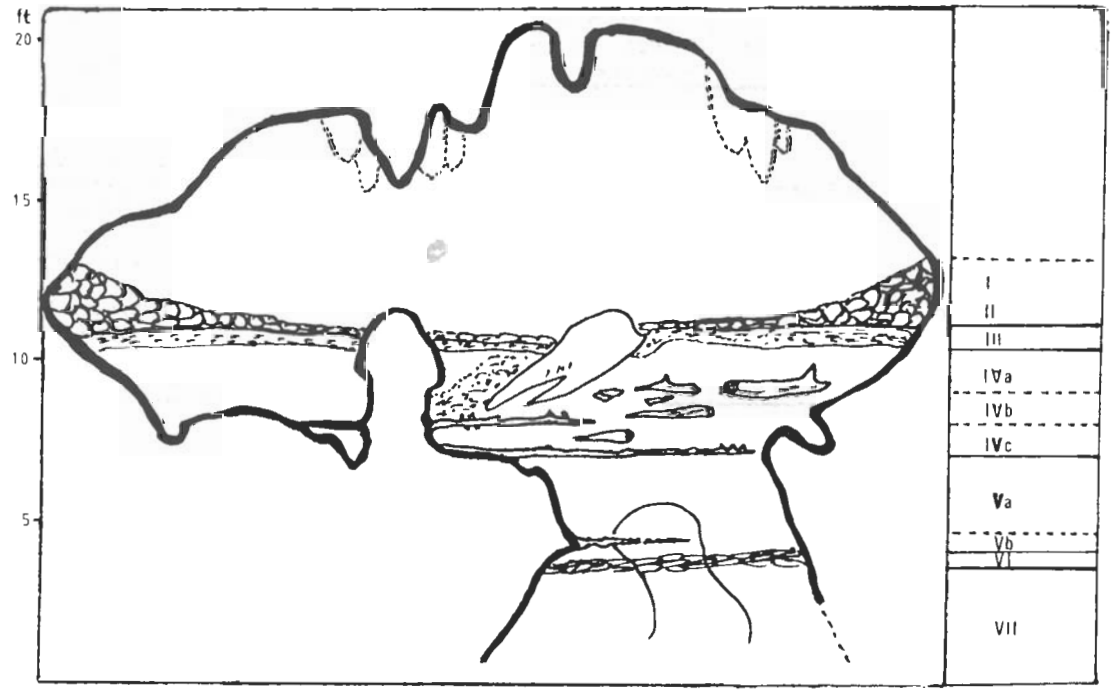

Fig. 1. Section of the deposits at Despott 1916

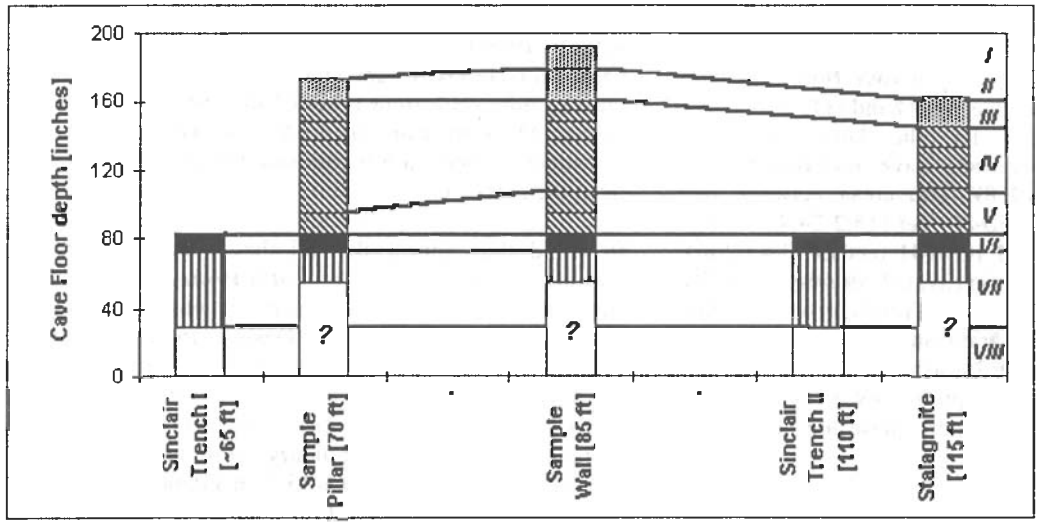

Fig. 2. Ghar Dalam stratigraphy. The correlation between the Sample pillar and wall, and the stalagmitic sheets of the Despott 1916 trench. (Superficial boulder layer (1) now not evident in sample sites)

respectively from the entrance. These have been accurately documented by G. Sinclair (Sinclair, 1924). The Sample Pillar is made up of seven layers consisting of an uppermost cave earth layer, four layers making up the Red Earth horizon, and the boulder/small stone layer overlying the bone breccia. The Red Earth horizon layers include an uppermost red soil, followed by a torba layer, a thick red earth layer and a fossiliferous layer containing red earth. The Sample Wall appears to be composed of eight layers. The superficial layers are made up of a cave earth layer overlying a pebble containing earth. These layers are separated from the underlying Red Earth Horizon by a thin stalagmitic cap composed of red soil. The Red Earth horizon is made up of six layers including a red soil, a torba layer, a fossiliferous layer, a red soil layer, a fossiliferous layer and another red soil layer. This overlies the boulder/small stones layer and the Bone Breccia. At both sites the bone Breccia has not been completely excavated, thus the lowermost detrital clay layer has not been exposed. The composition of the lowermost cave floor layers was demonstrated by the first trench dug by Sinclair at about 65 feet from the entrance (Sinclair, 1924). The correlation between the Sample pillar and wall, and the stalagmitic sheets of the Despott 1916 trench is shown in Figure 2.

Based on the above descriptions, it appears that the cave floor stratification at Ghar Dalam can be summarised as consisting of eight main strata (Table 3). During their deposition, the Red Earth Layers dried out periodically for a period sufficient for the stalagmite and the surrounding floor deposits to acquire a stalagmitic extension. This process occurred at least on three, possibly four occasions.

The macro & microfauna in the various cave floor layers

The faunal correlations as described during the excavations suggest a number of definite faunal stages

LAYER	STRATA	DESCRIPTION	FAUNAL STAGE
I	Superficial Stone/Boulder Layer	Layer of rounded boulders, particularly thick near the sides of the cave.	
II	Cave Earth Layer	Dark reddish clayey cave earth	*Rattus rattus* Stage
III	Small stones/pebbles Layer	Darkish grey cave earth thickly strewn with subangular stones and pebbles.	*Apodemus sylvaticus* Stage
IV a	Upper Red Earth Layers	A deep vegetable soil with a number of brownish-red and whitish alternating layers. This deep deposit was subdivided into at least five divisions by stalagmitic plates, calcite incustrations or torba floors.	*[?] Apodemus sylvaticus* Stage [lower level]
IV b IV c			*Pitymys melitensis* Stage [Upper level] or *Cervus* stage
V a V b	Lower Red Earth Layers		*Pitymys melitensis* Stage [Lower level] or Carnivora Stage
VI	Pebble Layer	A deposit consisting of rolled small boulders and pebbles embedded quite loosely in a clayey red earth.	
VII	Bone Breccia Layer	A clayey deposit containing markedly rolled fossil bone remains. Light green in colour becoming brownish in the inner regions of the cave. Markedly consolidated in the outer regions of the cave.	*Maltamys sp.* stage or Gliridae stage
VIII	Detrital Clay Layer	A plastic laminated clay, yellowish blue in colour.	Sterile Layer

Table 3. Stratification of Ghar Dalam cave floor.

represented by various layers. The Holocene deposits are represented from below upwards by the approximate upper fifth of the Red Earth layers, the pebble layer, the cave earth layer, and the superficial large stones/boulder layer (Table 3: layers I-III/IVa). These layers were characterised by the presence of domestic animals remains. These four layers have been subdivided into two faunal stages by G. Storch on the basis of their rodent fauna: an upper *Rattus rattus* Stage (level I-II) and a lower *Apodemus sylvaticus* Stage (level III/IVa) (Storch, 1974). The fauna of the Domestic Animals Layers was investigated by Storch and by Boessneck and Kuver in 1970. The micro mammalian fauna included the species *Crocidura russula, Rhinolophus hipposideros, Rhinolophus euryale, Myotis oxygnathus, Apodemus sylvaticus, Rattus rattus* and *Mus musculus*. The domesticated mammal species included *Bos taurus, Capra hicus, Ovis aries, Sus scrofa domesticus*, and *Felis catus*. In addition, the skeletal remains included the avian species *Gallus gallus domestica, Columba livia* and *Coccothraustes coccothraustes*; and the herpetofauna remains of *Testudo* sp., *Chalcides ocellatus tiligugu* and *Discoglossus pictus* (Storch, 1970; Boessneck & Kuver, 1970). These studies confirmed the findings of previous excavators who also reported the species *Equus* sp., *Cervus* sp., *Oryctolagus cuniculus, Branta bernicla* and *Bufo viridis* (Despott, 1916; Despott, 1923; Caton-Thompson, 1923; Bate, 1935). It is noteworthy that the lower levels, including those designated Prehistoric by pottery associations were characterised by the presence of *Cervus* remains. The presence of *Cervus* until comparatively late prehistoric times was noted by J.G. Baldacchino in 1935 (Baldacchino, 1934-38). The animal remains, including *Cervus*, from these upper layers were approximately identical to those excavated from the Neolithic tombs at Xemxija (Pike, 1971). Excluding the *Cervus* sp., *Rhinolophus euryale* and *Bufo* sp. remains, the wild fauna identified in the upper layers is similar to mammals presently occurring on the Maltese Islands, and suggest ecological conditions similar to those of the present day. The *Testudo* (? *graeca*) may have been imported by man for food or may have persisted from the Late Pleistocene period (Savona-Ventura, 1984).

The subsequent faunal stage includes the Red Earth layers below the first stalagmitic transition (Table 3: layers IVb-c/Va-b) which have been designated by G. Zammit-Maempel as the Deer or *Cervus* Layer and by G. Storch as the *Pitymys melitensis* Stage (Zammit-Maempel, 1989; Storch, 1974). This layer is characterised by a number of present day living European mammalian, reptilian and amphibian species which are now extinct in the Maltese Islands. The mammalian microfauna investigated by Storch included the species *Pitymys melitensis, Crocidura* sp., *Rhinolophus hipposideros, Rhinolophus euryale, Rhinolophus mehelyi, Rhinolophus blasii*, and *Miniopterus schreibersi*. The avian fauna included the species *Turdus* sp., *Scolopax ghardalamensis, Corvus* cf. *frugilegus*, passerine birds and an unidentified Estrildidae. The herpetofauna remains included the species *Bufo bufo* and *Emys orbicularis* (Storch, 1974; Caton-Thompson, 1925; Fischer & Stephan, 1974; Despott, 1923; Savona-Ventura, 1984). The macro-mammalian species are represented by a significant number of remains of *Cervus* sp., which have been shown to exhibit a graduated sequence of sizes of deer bones suggestive of a local progressive stunting event (Zammit-Maempel, 1989). Another herbivore excavated from these remains included the *Bos* sp. excavated from the middle third of the third layer of Baldacchino Trench IV (Baldacchino, 1934-38).

The macromammals of the Red Earth deposits of the deeper layers (Table 3: layers Va-b), are further characterised by the presence of carnivores in the form of *Canis lupus, Vulpes vulpes* and *Ursus arctos* (Cooke, 1893a; Ashby & Despott, 1916; Despott, 1923; Baldacchino, 1934-38). The lower Red Earth deposits were also described by a number of excavators to contain hippopotamus and elephant remains generally attributed to the species *Hippopotamus pentlandi* and *Palaeoloxodon mnaidrensis* (Cooke, 1893a/b; Despott, 1918; Despott, 1923; Caton Thompson, 1923). The carnivores and larger herbivores are conspicuously absent in the Upper Red Earth deposit (Table 3: layers IVb-c), and the only hippopotamus fossil recorded in the Upper Red Earth layer was a series of leg bones found in a moderately deep fissure in the Despott Middle trench which probably dated to an earlier period (Despott, 1923). The presence of these hippopotamus and elephant remains in the Red Earth layers has been attributed to these fossils being displaced from the lower Breccia deposits by the violence of the flooding, or by these fossils being by some coincidence caught up or lodged on ledges and fissures (Sinclair, 1924; Caton-Thompson, 1925). The difference in mineralization and the unrolled state of these Red Earth Layer fossils contrast with those found in the lower Bone Breccia deposits. Furthermore many of these deposits were distributed evenly thoughout the deposit, and it is possible that these animals lived contemporary with the *Cervus* during the time of deposition of the Lower Red Earth Deposit (Cooke, 1893a; Despott, 1918; Despott, 1923; Baldacchino, 1934-38).

Hippopotamus pentlandi and *Palaeoloxodon mnaidrensis* are specific names referring to the pigmy forms of hippopotamus and elephant excavated from various Pleistocene sites in Malta. The remains of hippopotamus and elephant from the Lower Red Earth layer may however have referred to animal species having modern proportions. The recently excavated hippopotamus remains from Ghar Dalam appear to belong to an animal having proportions which match modern hippopotamus species (Ghar Dalam Museum exhibit). In 1914, the excavation of a hippopotamus skull was described. The skull measured 2ft 3in (68.58 cm) from tip of snout to the occipital bones. In contrast the modern rare pigmy hippopotamus (*Choeropsis liberiensis*) with a total length of about 1.5-1.7 m (4.9-5.7 ft), has a head length which approximates 37-43 cm. This species lives along streams and in wet forests of West Africa. The modern hippopotamus (*Hippopotamus amphibius*) may reach a length of 2.9-4.9 m (9.5-16 feet), with an approximate head length of 72-122 cm (Ashby & Despott, 1916). The excavation of elephant remains of normal dimensions attributed to the species *Palaeoloxodon antiquus* was excavated in 1908 by N. Tagliaferro from a Pleistocene

fissure deposit at Zebbug. The excavation of large sized elephant remains was previously reported by A.L. Adams and T. Spratt in the 19th century. The elephant tusks excavated from the Red Earth layer by J.G. Baldacchino in 1936 (Baldacchino Trench 4) were reported to be of large dimensions, measuring 86-165 cm along the outer curve (Tagliaferro, 1915; Adams, 1866; Spratt, 1867; Baldacchino, 1934-38). Both *Cervus* and *Palaeoloxodon* appear to have lived contemporaneously with the giant land tortoise *Geochelone robusta* (Tagliaferro, 1913).

The third faunal stage (Table 3: layers VI-VII) is characterised by a large amount of rolled bones belonging to *Hippopotamus pentlandi*, *H. melitensis*, *H. minor*, *Palaeoloxodon mnaidriensis*, *P. melitensis*, and *P. flaconeri* represented in the Pebbles and the Bone Breccia Layers. This stage has been referred to as the Hippopotamus Layer corresponding to the *Leithia cartei* Stage of Storch (1974) and Zammit-Maempel (1989). The identification of the *Leithia cartei* micromammal by Storch (1974) has recently been questioned, and G. Storch now prefers to refer the micromammal to the *Eliomys (Maltamys)* sp. (Stroch, personal communication in lit. dated 24 March 1998). In view of this, the present authors prefer to refer to this stage as the Gliridae stage. The *Cervus* remains described from this stage were generally found in the uppermost parts of these deposits (Despott, 1918; Despott, 1923). This faunal stage would appear to require larger fresh water areas, forests with high trees and open areas (Storch, 1974). This stage is characterised by the absence of large carnivore species, accounting for the tendency towards dwarfism of the herbivores and towards gigantism of the lower mammals. The only record of an *Ursus arctos* remain from this horizon was a third upper incisor tooth obtained from the second trench dug by J.G. Baldacchino (sixth layer). This was a thin 9-12 inches deposit and the specimen may have belonged to the upper deposit, particularly since the excavation site had been previously disturbed by Cooke and Caton-Thompson (Baldacchino, 1934-38). Only one carnivore has been definitely associated with this faunal stage - *Nesolutra euxena* - a mustelid found in the Tal-Gnien fissure at Mqabba, Malta (Bate, 1935). The micromammal fauna included the rodent species Eliomys (Maltamys) ? gollcheri; the shrew *Crocidura* cf. *russula*; and the chirpoteran species *Rhinolophus hipposideros*, *Rhinolophus mehelyi birzebbugensis*, *Rhinolophus blasii*, *Myotis exilis*, *Myotis bechsteini robustus*, *Myotis ghardalamensis*, *Myotis capaccini*, *Eptesicus praeglacialis*, *Pipistrellus pipistrellus*, and *Miniopterus schreibersi*. The avian fauna was represented by *Anas acuta* (?), *Coturnix coturnix*, *Alectoris graeca* (?), Scolopax ghardalamensis, Tyto alba, Otus scops, *Hirundo* sp., *Turdus* sp., *Carduelis chloris*, *Coccothraustes coccothraustes*, and *Sturnus vulgaris* (Fischer & Stephan, 1974).

Relative dating of fossil remains

A variety of scientific tests utilising nitrogen, fluorine, iron, phosphate and uranium oxide, established as useful in determining relative dating of fossil remains, were performed on various animal bone samples excavated from Ghar Dalam by Prof. K. Oakley of the Museum of Natural History (London). These bones belonged to the *Hippopotamus* sp., *Cervus* sp., *Sus* sp., and *Equus* sp. excavated from various depths of the cave floor. The results of these tests are available in the form of original readings in the "Green Book" at the Museum (Brit. Mus., n.d.). These results were first fully published in 1997 (Brit. Mus., n.d.; Mifsud & Mifsud, 1997) (Table 4).

The assessment of the nitrogen, fluorine, phosphate and uranium content is a useful method of assessing whether several bones found in association in the same stratigraphic deposit are in fact of the same relative age.

SPECIES	SAMPLE	Fluorine	Uranium	Nitrogen	Phosphate	Iron
Hippopotamus	*Ma.4*	0.1 0.1	N/A	0	34	0
	Ma.21	N/A	4	0.23	N/A	N/A
	Ma.22	N/A	9	0.31	N/A	N/A
	Ma.33	N/A	N/A	0.4	N/A	N/A
	Ma.34	N/A	N/A	0.4	N/A	N/A
	mean+sd *(n)*	0.1+0.0 (2)	6.50+3.54 (2)	0.27+0.17 (5)	34 (1)	0 (1)
Cervus	*Ma.3*	0.25 0.3	N/A	0.13	33.5	<0.2
	Ma.23	N/A	12	0.23	N/A	N/A
	Ma.24	N/A	7	0 0.41	N/A	N/A
	Ma.25	N/A	4	0 0.48	N/A	N/A
	mean+sd *(n)*	0.28+0.04 (2)	7.67+4.04 (3)	0.21+0.24 (6)	33.5 (1)	<0.2 (1)
Sus	*Ma.32*	N/A	8	0.88	N/A	N/A
	mean+sd *(n)*	N/A	8 (1)	0.88 (1)	N/A	N/A
Equus	*Ma.30*	N/A	0	1.01	N/A	N/A
	Ma.31	N/A	0	2.64	N/A	N/A
	mean+sd *(n)*	N/A	0+0.0 (2)	1.83+1.15 (2)	N/A	N/A

Table 4. Chemical assay results *(N/A: not assessed)*.

In the deposit, the bone's protein, mainly collagen, content is very gradually reduced by the process of chemical decay. Thus the most useful index for the amount of protein present is the bone's nitrogen content, which for a modern bone is around 4%. With increasing age, the nitrogen content progressively decreases. The rate at which the level of nitrogen declines depends on the temperature, the water, chemical and bacteriological content of the environment in which the bone is buried. The phosphate content similarly decreases with time. At the same time, percolating ground water has significant effects on the composition of bone. Elements present in solution in the ground water - fluorine, uranium and iron - are absorbed gradually by the bone. Thus, the content of fluorine, uranium and iron in buried bone gradually increases. The rate of increase in fluorine, uranium and iron depend on the local concentrations of the elements in the percolating water and the rate of water flow. Modern bone has only traces of these elements, with the level of uranium oxide being practically nil, fluorine being less than 0.1%, while iron amounts to about 0.007%. Nitrogen estimation alone can be misleading since the rate of chemical decay is a markedly complicated process dependant upon a number of chemical and biological variables. In addition, the assays available (Weiler & Strauss: unwashed and Government Laboratory using Kjeldahl) are not always reproducible and give a wide range of results for the same sample. In contrast, the uptake of fluorine and uranium by buried organic remains is related to chemical factors alone resulting in more accurate and reliable assays. In view of the variables, the chemical tests cannot be used for the basis of absolute dating tests, but on an individual site chemical dating can distinguish bones of different age found in apparent stratigraphical association. The interpretations of a series of results must thus be considered in the light of the limitations of the technique (Renfrew & Bahn, 1994; Mifsud & Mifsud, 1997).

It is generally presumed that at Ghar Dalam, the *Hippopotamus* predated the *Cervus* layers, although the stratigraphic evidence in fact suggests that these animals may have overlapped. The scientific results suggest that the *Hippopotamus* and *Cervus* samples submitted may have been contemporary or possibly that the *Cervus* specimens were in fact older than the *Hippopotamus* ones. The nitrogen and phosphate mean levels did not appear to show any differences, while the mean fluorine and uranium values appeared overall higher in the *Cervus* specimens. These observations could be interpreted as evidence that the *Hippopotamus* and the *Cervus* samples are contemporaneous. The observed results may, however, have resulted from the stalagmitic impregnation of the *Hippopotamus* bones in the Bone Breccia. The stalagmitic impregnation would have prevented further percolation into the bones by water carrying fluorine and uranium, thus maintaining stable values of these elements in the bones.

The *Equus* specimens assayed suggested that these were definitely younger than both the *Cervus* and *Hippopotamus* specimens on the basis of higher nitrogen values and markedly lower uranium values. The *Sus* specimen assayed appeared to be contemporary with the *Cervus* on the basis of the uranium level, and possibly younger on the basis of the nitrogen value. The specimen was however definitely older than the *Equus* remains.

It would thus appear that the F-U-N tests performed on the Ghar Dalam bone remains confirm three definite stratigraphical horizons. The lowest horizon yielded the *Hippopotamus* and *Cervus* remains. This may in fact represent two divisions, with the lowest stalagmitic hardened division yielding the *Hippopotamus* and the upper Red Earth division the *Cervus* remains. The middle horizon yielded the *Sus* remains, while the upper horizon yielded the *Equus* remains.

Conclusions

It would appear that the Ghar Dalam cave floor stratification reflects a number of geological events with changes in the local fauna in each period. The lowermost layer consists of a detrital clay formed in a closed cave system with no influence from the external environment. The overlying *Hippopotamus* Bone Breccia has been dated by electron spin resonance and uranium series disequilibria to 130,000-110,000 BP and has been assigned faunistically to the *Leithia cartei* [Gliridae Stage] faunal stage (Bouchez et al, 1988; Storch, 1974) placing this in the Upper Pleistocene (Riss-Wurm interglacial or Early Wurm glacial). This is followed by the rounded boulder/small stones layer which, while faunistically poor, seems overall similar to the preceding one. The Red Earth horizon represents the deposits of the Wurm fourth glacial. This horizon appears to be faunistically composed of two main stages, the earlier [Carnivora Stage] being characterised by the macromammalian species *Hippopotamus* sp., *Palaeoloxodon* sp., *Vulpes vulpes*, Canis lupus, and *Ursus* cf *arctos* besides the Cervus sp.; while the younger stage [*Cervus* Stage] being characterised by *Cervus* sp. and *Bos* sp. and a marked absence of carnivores and the larger herbivores. The date c. 125,000 BP has been adopted as the beginning of the last interglacial transgression and the beginning of the Wurm glacial (Phillips, 1980). The Maltese Islands were apparently connected with Sicily, Tunisia, Libya and Sardinia during the Riss glacial of the Middle Pliestocene (c.780,000-125,000 BP); and with Sicily during the Wurm glacial (Upper Pleistocene - c.125,000-10,000 BP). The Wurm glacial has been subdivided into three main subdivisions with a number of interstadials. The Late Wurm glacial started at c.23,000 years BP and was characterised by two short interstadials. This last connection with Sicily accounts for the present prevalence of a Sicilian-type fauna on the Maltese Islands (Phillips, 1980; Pasa, 1953; Corti & Lanza, 1973). The Islands area during the Ice Ages was, like the rest of the Mediterranean, not directly influenced by glaciation, but by Pluvial periods. These Pluvial periods were subdivided into three sub-phases. The first phase or the Pseudo-Pluvial Period was characterised by a summer which was cooler than today and a warmer winter. Rain precipitation was less restricted in spring and autumn. These climatic conditions resulted in the extension of the central European forest into the Mediterranean region. The unsettled weather further aggravated in the second phase or true Pluvial Period when the summer became more unsettled with much rain and rapid intense temperature changes while the winters were cooler. The Pluvial Phase was followed by a rapid return to present day type Mediterranean climate with a decline in total rain precipitation. The Mediterranean

region may in fact have been rather arid during the glacials, increasing in humidity during the interglacial periods (Attenborough, 1987; Hunt, 1997; Savona-Ventura, 1985). The Holocene period dated to c.<10,000 years BP is apparently represented by the uppermost layer of the Red Earth horizon, accounting for about one-fifth of the thickness of this horizon, together with the layers assigned as the *Apodemus sylvaticus* stage (dated 7,200-2,700 years BP) and the *Rattus rattus* stage (dated <2700 years BP). These are characterised by the presence of domesticated animals.

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