Atti Soc. Tosc. Sci. Nat., Mem., Serie A, 88 (1981)
pagg. 243-260, t. 1, tabb. 5.

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A MALTESE PLEISTOCENE SEQUENCE CAPPED BY VOLCANIC TUFA

Riassunto — *Una sequenza pleistocenica ricoperta da tufi nell'isola di Malta.* Viene descritta una sequenza medio-alto pleistocenica presso Mriehel, nella parte centrale di Malta e in particolare viene segnalata, per la prima volta nell'arcipelago, la presenza di una copertura cineritica recente. Vengono riportate le analisi chimiche, mineralogiche e palinologiche e il contenuto in fossili delle formazioni componenti la successione pleistocenica. Rimane tuttavia ancora aperto il problema dell'origine dei prodotti vulcanici e anche per l'età saranno necessarie ulteriori indagini.

Summary — A Middle to Late Pleistocene sequence at Mriehel, central Malta, is described and the presence of a volcanic ash layer capping the Quaternary deposit is recorded for the first time from the Maltese archipelago. The exact age and origin of the volcanic tufa could not be ascertained.

Each of the layers composing the stratigraphic sequence is investigated for its physical, chemical, mineralogical, palynological and other biological contents.

Key-words: — Volcanic tufa, Pleistocene, Malta.

When trenching in 1965 for the foundations of the Girls Grammar School of Mriehel, central Malta (Grid Ref. 507723 and 55 m above sea level), workers cut through a flood-water Middle to Late Pleistocene deposit infilling a large hollow excavated in the Middle Globigerina Limestone bedrock.

STRATIGRAPHY

The complete stratigraphic sequence at this site from top to bottom was as follows:

G. Very pale brown fertile soil (60-105 cms)

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F. Dirty white unstratified, powdery (caked) layer	(60-140 cms)
E. Volcanic ash layer	(30- 45 cms)
D. Very dark red brown loamy soil often with numerous calcareous concretions with cracked surface	(0-180 cms)
C. Brownish loams	(60-180 cms)
B. Greenish or Greenish-brown Clay layer with a Pebble bed (15-30 cms) at its base	(30- 60 cms)
A. Middle Globigerina Limestone bedrock	

The complete sequence was not encountered in all the sections, but solely in the eastern trench (7-8 m), which was the deepest region of the infill. The brown loamy deposit exhibited very marked variation in colour and thickness, but the presence of a pale brown lower deposit overlain by a much darker one was apparent throughout.

The individual layers of the entire sequence were each investigated for their physical, chemical, mineralogical, palynological and biological contents.

B. *The Clay layer* (30-60 cms) was encountered only in the eastern (deepest) parts of the hollow. It consisted of a plastic, pale greenish-yellow (in some section pale greenish-brown) clay in which were embedded abundant remains of *Hippopotamus*. Some of the bones were in a very good state of preservation whilst others were highly rolled or fragmented. At the base of the Clay layer was a *Pebble bed,* consisting of numerous pebbles of various sizes, shape and colour.

Analysis revealed the Clay layer to have a pH of 7.9 and 47% $\pm$ 2% Calcium carbonate. Mineralogical investigations of the granulometric fraction 0.50-0.05 mm did not show any heavy minerals, whilst X-ray diffraction (carried out on the clay fraction $< 2\,\mu$) showed massive presence of a mineral of the Montmorillonite group (probably Beidelite), also small quantities of quartz and several oxides of iron. The mineral was present in all the different layers of the Mriehel deposit.

Palynological investigations of a 180 gms sample yielded only one single pollen grain of *Pinus* with three keels.

The pebbles contained in the Clay layer ranged in size from 2 to 15 cms. in diameter and were limited to the lowermost 15-30 cms. Most were highly rolled with a shiny surface, and in many ways, resembled those now encountered on local beaches. Their colour ranged from dirty white, greyish white, brown to jet black. A limited few, however, were angular and dull-surfaced and could still be identified in colour and consistency as Globigerina Limestone. Some of the shiny, rolled pebbles had embedded in them tiny greenish or brownish nodules, not unlike those encountered in the Globigerina Limestone adjoining the phosphatic beds. Most of the pebbles had eroded patches of encrusted calcite (worn out stalagmitic dripping?) on their surface (Pl. I fig. 7) and a few others parallel calcareous linear encrustations and what looked like the parallel markings of attachment of serpulids, without however, any defenite evidence of a tube (Pl. 1 fig. 6, 8).

The coloured pebbles had a higher relative density and a lower absorbtion value than the raw Globigerina Limestone pebbles. Relative density of the pebbles investigated ranged from 2.35 in a white, worn specimen with greenish specks and a water absorbtion value of 5.3% (Author's Coll. ZM/4), to 2.90 in a highly rolled, reddish brown pebble with a 0.8% water absorbtion (ZM/6). Water absorbtion values ranged from nil% in a light brown pebble having R.D.2.56 (ZM/3), to 6.2% in a yellowish white rolled pebble of Globigerina Limestone having R.D.2.45 and lacking any lustre on its surface (ZM/1).

A thin section of the reddish brown pebble referred to above (ZM/6) revealed a calcareous micrite with rich microfauna of planctonic foraminifera (Globigerinoides, *Orbulina, Globurotalia*) and abundant fragments of echinoderms. Its age was set as Post Lower Miocene. A jet black pebble (ZM/7) showed on section a fine grain calcareous material characterised by sub-parallel porous bands impregnated with oxides of iron and stromatolits. Micritic matrix showed occasioinal planctonic (Globigerinoids s.l.) and benthonic foraminifera. Its age was assessed as Tertiary.

The black limestone lost its colour on heating strongly to become white. It was soluble in HCl. dil. except for a black residue which seems to be finely divided amorphous carbon. No manganese present. Though there is no evidence to show that the pebbles are of foreign origin, it was not possible to establish with any certainty the local nature of some of them.

C. *Brown loamy deposits* (60-180 cms). The colour of this de-

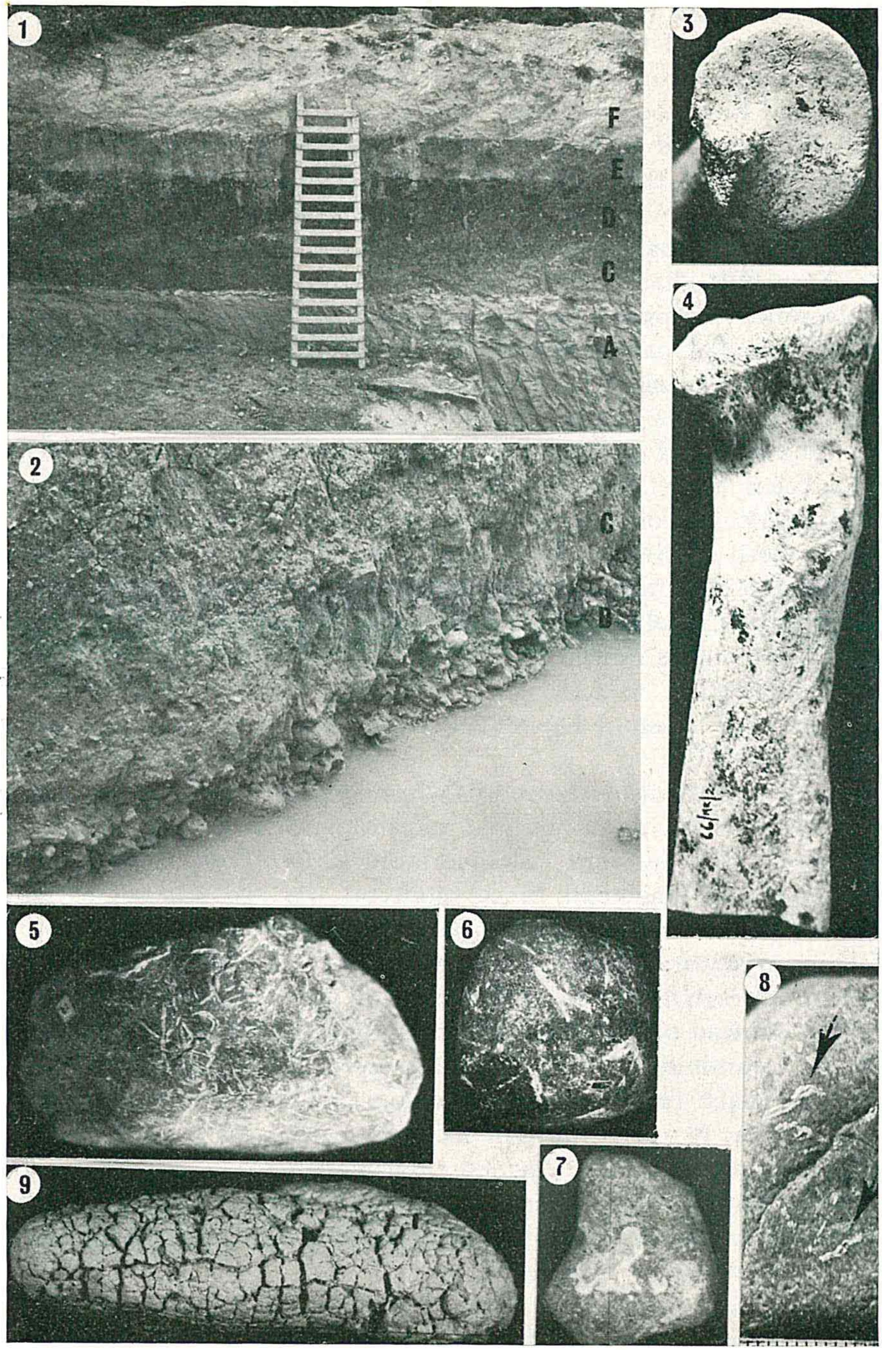

PLATE I

posit is pale greyish/greenish brown in the lowermost 60 cms but becomes progressively darker brown in the upper regions.

A number of carbonised roots were noted growing perpendicularly downwards and extending up to a depth of 5-6 m below ground level.

The lowermost pale deposit had a pH 7.80 and a $CaCO_3$ content of 38% ± 2%. X-ray diffraction carried out on the clay fraction $< 2\mu$ revealed the massive presence of a mineral of the montmorillonite group (probably Beidelite), some quartz and small quantities of various oxides of iron.

A 100 gms sample yielded 180 grains of heavy minerals. These were distribuited in the following proportions: Amphiboles 49%, Pyroxene monoclinic 15%, Zircon 13%, Garnet 6%, Rutile 3%, Disthene 3%, Tourmalin 2%, Sphenol 2%, Anastase 0.5%, Staurotide 0.5%.

No pollen grains were recorred from a 180 gms sample. The lowermost regions of this deposit (in a section lacking Clay layer), yielded elephants' tusks and a well preserved antler of *Cervus elaphus* L.

The uppermost darker brown deposit of this layer had a pH 7.90 and a $CaCO_3$ content of 42% ± 2%. No pollen grains were

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PLATE I

Fig. 1 - West Trench, Mriehel, Malta. Exposed sequence: Middle Globigerina Limestone (A), Brownish loams (C), Dark red brown loam (D), Volcanic ash layer (E), Dirty white layer, upper surface disturbed (F).

Fig. 2 - East Trench, Mriehel, Malta. Exposed sequence: Clay layer with large-pebble bed at its base (B), Brownish loams (C).

Fig. 3 - Right postero-lateral view of right radius (proximal 125 mm) of *Ursus* recovered brom upper region of Brownish loams. Note characteristic rotation of proximal articular surface with respect to shaft. Shaft max. AP diam. 28.4 mm, max. lat. diam. 21.1 mm (over tubercle). (Author's Coll. 66/MR.2).

Fig. 4 - Proximal articular surface of right radius of *Ursus* (ZM/66/MR.2). Medial edge eroded. Max. diam. 47 mm, Max. width ant. fossa 33.5 mm, post. fossa 28.6 mm, AP. diam. neck 28.6 mm, lat. diam. neck 29.2 mm. Index of proximal articular surface 71.28.

Fig. 5-8 - Coloured pebbes from the large-pebble bed at base of the Clay layer, East Trench, Mriehel, Malta.

Fig. 5 - Brown pebble (88 × 60 × 35 mm) with deep etchings.

Fig. 6 - Dark grey pebble with linear and tube-like calcareous encrustations (30 × 20 × 15 mm).

Fig. 7 - Brown pebble (50 × 50 × 10 mm) with enbedded greenish small nodules and calcitic sheet-like encrustations in recessed areas.

Fig. 8 - Grey pebble (30 × 25 × 15 mm) with tube-like calcareous encrustations Scale in mm.

Fig. 9 - Calcareous concretion (65 mm × 20 mm) from Dark red brown loam showing deeply cracked surface.

recorded in a sample of 180 gms. As in all the other layers, x-ray diffraction carried out on the clay fraction $< 2\,\mu$ revealed the presence of a member of the Montmorillonite group, probably Beidelite. Some quartz and small quantities of various oxides of iron were also noted. Mineralogical investigation revealed no heavy minerals in the residual fraction.

The transition from the brown deposits to the overlying deep reddish brown loam was very gradual and imperceptible, but in some sections it was marked by the presence of two pebble beds with an intervening layer of fragmented, tightly packed *Cervus* remains. The whole complex measured about 30 cms in thickness and was generally found at the top of the brown deposits. (At some sites however, it was located at the base of the overying deep red brown loam).

The upper pebble bed was composed of cobbles (diam. c. 15 cms), flattened, angular fragments of decaying Globigerina Limestone from the bedrock and flattened, angular, coloured pebbles 2-6 cms long. The flat surface of the latter was aligned horizontally and indicated strong water action. Most pebbles were smudged with a black, carbonaceous material and some bore also black dendritic impressions.

The lower pebble bed consisted of small angular stones, mostly white in colour and lacked lustre.

D. *Very dark red brown loam* (0-180 cms).

Thickness of deposit varied considerably; It occured usually as a horizontal layer but was encountered also as horizontal lenses or as irregular large patches.

The loamy deposit was characterised by its very deep red brown colour and by the presence of numerous calcareous concretions. These ranged in size from 3-5 cms in length with a width of about 2 cms. Shape ' too ' varied considerably, but colour was of a biscuit hue. They almost all had their external surface cracked with a marked tendency of the fissures to form a rectangular pattern (Pl. 1 fig. 9). Broken specimens revealed the tendency to a « kernel and crust » formation, often with the crust completely detached. The presence of these concretions gave the deep red brown loam a characteristic mottled appearance.

Deposit had a pH 7.50 and a $CaCO_3$ content of $51\% \pm 2\%$. No pollen grains were recorded from a 180 gms sample. X-ray diffraction revealed the massive presence of a member of the Montmorillonite group (probably Beidelite), some quartz and small quantities of various salts of iron.

Mineralogical investigations: 100 gms yielded only 120 grains of heavy minerals and these included Titanomagnetite (intact hexagonal crystals) and seven types of minerals with predominance of pyroxene monoclinic (76%), amphiboles (green hornblende) (15%), and augite (acicular), tourmalin (4%), sphene (2%), garnet and staurotide (each 0.5%). The hornblendes and the rare glaucophanes are in the form of large sized grains. All above grains show little, if any, attrition.

E. *Volcanic ash layer* (30-45 cms).

The brown loamy soils are capped by a cinnamon coloured, loosely packed, loess-like deposit (30-45 cms thick), which on section reveals numerous air spaces (1-3 mm diam.). In the absence of any evidence of their being animal burrows, they were assumed to be an indication of the aeolian nature of the deposit. Mineralogical analysis subsequently confirmed the deposit to be a volcanic ash fall.

On exposure the cut surface acquired a much lighter hue and on handling it crumbled very easily into a fine powder slightly coarser than talc. The layer contained many black grains clearly visible to the naked eye, as well as numerous micaceous flakes that glittered in the sun. The deposit was not in the form of multiple layers but constituted one discrete bed that showed no sign of subsidiary bedding and appeared to be a single homogeneous mass. No pebbles or organic remains were detected in the limited surface of the exposed sections.

Deposit had a pH 7, $CaCO_3$ content of 23% $\pm$ 2%. No pollen grains. Mineralogical studies on the 0.50-0.05 mm fraction revealed 77% monoclinic pyroxene and 23% amphibole. The presence of very fragile grains of titanomagnetite was also noted. X-ray diffraction tests on the clay fraction $< 2\mu$ showed the constant presence of a mineral of the montmorillonite series (probably Beidelite), and traces of quartz and various oxides of iron (present in all the layers of the Mriehel Pleistocene deposit. Microscopical examination of the powder by J. Keller confirmed once more the volcanic nature of the material. Its constituents were found to be brown glass shards of a refractive index $1.55 > n > 1.53$, various feldspars, volcanic augite and euhedral magnetite.

F. *Dirty white layer* (60-140 cms). An unstratified layer made up of small hard irregular lumps of caked powder which crumbled easily when subjected to finger pressure. Occasionally, small fragments of decomposing Globigerina Limestone present. No pebbles, organic remains or artefacts were seen, but only recent roots extending from the overlying layer of vegetative soil (60-105 cms) were detected in the various sections. The deposit yielded no pollen grains.

When mixed with water, the dirty white layer formed a thick whitewash, which when it dripped over the trench wall, stained the surface of the underlying deposits (Pl. 1 fig. 1).

Upper and lower surfaces of the dirty white layer were both perfectly horizontally aligned. (In Pl. 1 fig. 1 the upper surface was disturbed during bulldozing operations).

The loamy soil had a pH 7.70 and contained 34% ± 2% $CaCO_3$. X-ray diffraction of the clay fraction $< 2\mu$ revealed the constant presence of massive amounts of a mineral of the montmorillonite group (probably Beidelite), quartz and small quantities of various oxides of iron. Titanomagnetite was also detected.

Mineralogical investigation of the granulometric fraction 0.50-0.05 mm revealed only 24 grains of heavy minerals in a 100 gm sample. These are expressed in the following percentages: Pyroxine monoclinic 50%, amphiboles 30%, Sphene 8%, Tourmalin 4%, Epidote 4%. On account of the very small number of grains counted (24), the percentages quoted would have doubtful, if any, statistical value.

Discussion and comments

Heavy minerals. In an attempt to trace the source of the Mriehel deposits, comparative analysis was made of local Tertiary rocks. Maltese rocks are of sedimentary origin and listed in the order of their deposition are: Lower Coralline Limestone, Globigerina Limestone, Clays, Greensand and Upper Coralline Limestone. Mineralogical investigations of each of these formations was carried out by Murray (1890) and by Formaggio (1972). Murray's study included also the marine deposits around Malta. Their respective findings are tabulated hereunder for comparison with the findings recorded from the present study of the Quaternary deposit at Mriehel. Attention is drawn to the record by both Murray and Formaggio of calcite, quartz, feldspars (plagioclase) and clay minerals in each of the five local formations.

Working on Fomm ir-Rih section, FORMAGGIO (1972) reported calcite as being present in the region of 98.6% with Mg, Fe and Sr as impurities. He also noted that montmorillonite and « another mineral » were present in all the local Tertiary formations, kaolinite in some and clinoptilolite only in the Globigerina Limestone. As the latter mineral is said to form through the alteration of volcanic ash in subaerial environment, it is indicative of volcanic activity and of shallow waters during Globigerina Limestone deposition.

Mineralogical investigations of the Mriehel Quaternary deposits reveal that they are only partly derived from local Tertiary sedimentary rocks, for they contain a high proportion of minerals derived from metamorphic and volcanic rocks. As most of these minerals show little (if any) evidence of attribution, it is probable that they were derived from nearby volcanic activity or at most, from the erosion of metamorphic and volcanic rocks in nearby land masses once connected with Malta but now submerged.

TAB. 1 - Analysis of Maltese Tertiary rocks and of marine deposits round Malta (Table based on Murray, 1890).

	Calcium carbonate	Phosphoric acid	Clayey matter	Iron oxide	Quartz	Feldspars	Augite	Zircon	Tourmalin	Glauconite	Hornblend	Magnetite	$CaSO_4$	Iron pyrite	Rutile
Upper Coralline Limestone	82.9— —91.9%	+	+	+	+	+	+	+	+	+					
Greensand	28.6— —89.6%	+			+	+	+	+	+	+	+	+			
Clays	2.56— —30%				+	+	+	+	+	+	+		++	++	
Globigerina Limestone	63— —94%	+		+	+	+	+	+	+	+	+				+
Lower Coralline Limestone	95.6— —98.6%	±	+	+	+	+	+		+	+					
Marine deposits round Malta	73-- —81%		+		+	+	+	+	+	+		+			

TAB. 2 - Analysis of Maltese Tertiary rocks (Fomm ir-Rih) (Table based on Formaggio, 1972).

	$CaCO_3$	Impurities (Mg, Fe, Sr)	Quartz	Feldspars (Plagioclase)	Phosphates	Clay minerals	Clinoptilolite
Upper Coralline Limestone	98.6%	+	+++	+	—	++	—
Clays	98.6%	+	+++	+	—	++	—
Globigerina Limestone	98.6%	+	+/++	+/—	+/++	+/++	+/+++
Lower Coralline Limestone	98.6%	+	+/++	+	+	++	—

Palynological investigations. These were carried out with the aim of determining the flora of the Central Mediterranean region throughout the whole sequence (Middle Pleistocene to Recent) and of comparing it with that recorded from deposits at Cueva del Toll near Barcellona (Spain) in the West and at Mount Carmel (Palestine) in the East.

The project failed completely as palynological investigations revealed the Mriehel deposits to be practically sterile, with only one single pollen grain of «*Pinus* with three keels» being recorded from a 180 gms sample of the Middle Pleistocene Clay layer. The fertile soil layer, however, yielded pollen grains of sub recent *Pinus* as well as numerous spores of fungi.

The absence of pollen grains in the Maltese Pleistocene sequence does in no way indicate absence of any local vegetation throughout the period. It merely shows that highly calcareous soils are highly inimical to the preservation of the euxine or outer cover of the pollen grain.

Animal remains. The most important organic finds recorded from this site consisted of a fragment of a jaw of a baby *Hippopotamus* with the first incisor just protruding from the mandible, tusks of dwarf elephants, an almost complete antler of *Cervus elaphus* L. and the proximal end of the radius of a small (adult)

TAB. 3 - Analysis of the Mriehel Quaternary sediments carried out for the author (1967) at the Laboratory of Quaternary Research, C.N.R.S., Bellevue, France.

MRIEHEL sequence	Code letter	Collection site (Trench)	Number of grains of heavy minerals in sample (180 gms unless otherwise stated)	$CaCO_3$% ± 2%	Iron oxide	Quartz	Mineral (Montmorillonite series)) ? Beidelite	Augite	Zircon	Tourmalin	Hornblend	Magnetite	Rutile	Garnet	Anatase	Sphene	Staurotide	Disthene	Chloritoide	Epidote	Amphibole	Pyroxene monoclinic	Glauc. camp.
Dirty white layer	F	W2	24 (100 gms)	34%	+	+	+			4		+				8		4		4	30	50	—
Volcanic ash layer	E	W1	very rich in minerals	23	+	+	+					+									23	77	
Very dark red brown layer with calcareous concretions	D	W1	very rich in minerals	18	+	+	+		13	10			8	4	+	3	1	2		14	37	8	
Brown layer (upper region)	C_2	W2	120	51	+	+	+	+		4	15			0.5		2						76	2
Brown layer (lowermost region)	C_1	W1	180	38	+	+	+	+	13	2		+	3	6	0.5	2	0.5	3	0.5	6	49	15	
Clay layer containing Pebble bed	B	W2	nil	47	+	+	+																

Ursus arctos L. (Pl. 1 fig. 3, 4). *Hippopotamus* remains were abundantly present in the Clay layer and some were found also in the overlying light greysh brown deposits. Their preservation varied, some being in a perfect state of preservation whilst others were fragmented and rolled. *Cervus* remains were highly fragmented and compactly packed to form a 15-30 cms band just above the horizontal Globigerina Limestone-pebble bed separating the pale brown loams from the overlying darker brown soils.

The find of a long bone (proximal end of a right radius) of a small (adult) *Ursus arctos* L. (Pl. 1 fig. 3, 4) is worth recording with a comment in view of the rarity of such animal remains in local Pleistocene deposits. Remains of carnivora are rare in the Pleistocene deposits of all the Mediterranean islands. In Maltese deposits, the record is limited to isolated teeth or fragments of jaws with teeth (COOKE 1893, BALDACCHINO 1936) and isolated digital bones and claws (ASHBY & DESPOTT 1916, DESPOTT 1929, BALDACCHINO 1936, 1937). In addition to these records the present author recovered a molar of *Ursus arctos* from a Pleistocene fissure at Wied Incita, l/o Attard, Malta, where it was associated with avain, reptilian and micromammalian remains.

Biochemical investigations. Analytical dating (N% and eU_{308} ppm) of animal remains from Mriehel and two other contemporary Pleistocene sites (Ghar Dalam and Fleur de Lys) were carried out for the author by Dr. K.P. Oakley, then of the sub Department of Anthropology, British Museum (Natural History).

The results obtained from these assays (particularly the eU_{308} values) show marked 'apparent' discrepancies, superficially suggesting that such analytical dating is particularly ineffective when applied to Malta. As the investigations were carried out in two different batches, it is possible that this may account for some of the variations obtained. The assays of the Mriehel Middle Pleistocene animals (Elephant and *Hippopotamus*) yielded figures ranging from 0.2-0.3% Nitrogen. Ghar Dalam remains yielded exactly similar values, but a Fleur de Lys *Hippopotamus* long bone showed a content of 0.9%N.

Percentage Nitrogen multiplied by 2.5 yields roughly the Collagenous Carbon percentage.

The Nitrogen percentage content of Upper Pleistocene animals

(*Cervus* and *Ursus*) from Mriehel and Fleur de Lys was 0.2% but Ghar Dalam animals contained 0.2-0.48% N. This might represent the range of fluctuation of Nitrogen in a single age group.

It is interesting to note here that an antler from the Neolithic of Tarxien yielded 0.5%N and a human vertebra from a body buried in the Pleistocene deposit at Fleur de Lys had a 2.58%N content revealing its recent origin.

Marked variations and 'apparent' discrepancies were noted particularly in the assays of Uranium 308 carried out on animal remains from Ghar Dalam and Mriehel deposits.

Middle Pleistocene remains from Mriehel yielded figures ranging from 8 to 31 parts per million Uranium 308, whilst those from Ghar Dalam yielded 4-9 ppm U_{308}.

Upper Pleistocene animals from Mriehel contained 18-41 ppm, whilst those from Ghar Dalam yielded 4-14 ppm.

The higher values yielded by the Mriehel animals have been interpreted as reflecting the « exposed », open burial environment, whilst the lower values given by the contemporary fauna from Ghar Dalam reflect the « sheltered » environment. The Mriehel (Tab. 4) and Ghar Dalam (Tab. 5) results are tabulated hereunder.

TAB. 4 - Nitrogen content and radiometric assay of Pleistocene animal remains found at Mriehel.

MRIEHEL	BMNH/Anthrop. Dept. Ref. No.	N%	eU_{308} ppm
Elephant tusk	Ma. 14	0.3	8
Hippopotamus			
molar	Ma. 15	0.3	31
canine	Ma. 16	0.2	11
radius	Ma. 17	0.2	24
Cervus			
antler	Ma. 18	0.2	23
metatarsal	Ma. 19	0.2	41
Ursus			
radius	Ma. 20 [=ZM/66/MR.2]	0.2	18

TAB. 5 - Nitrogen content and radiometric assay of Pleistocene animal remains found at Ghar Dalam.

GHAR DALAM	BMNH/Anthrop. Dept. Ref. No.	N%	$eU_{3}O_{8}$ ppm
Hippopotamus			
molar	Ma. 21	0.23	4
molar	Ma. 22	0.31	9
Cervus			
antler	Ma. 24	0.41	7
metatarsal	Ma. 23	0.23	12
Sus			
tooth	Ma. 32	not det.	8
Equus			
tooth (? cultural layer)	Ma. 31	not det.	nil

Conclusions

The dirty white layer seems to be identical with that exposed in « Sda S. Giuseppe, Hamrun » during trenching operations for the laying of water pipes about seventy five years ago. COOKE (1896, p. 204) described that layer as « a whitish, highly calcareous layer, very homogenous and apparently structureless; plastic and tenacious when wet, but incoherent when dry. Il contains a few small fragments of decomposing Globigerina Limestone and numerous landshells in a good state of preservation. Two feet in thickness ».

The Hamrun site is at about the same height above sea level as the Mriehel deposit and almost 1.5 km to the east of it. The composition and physical characters of the two layers is very similar and both contained fragments of decaying Globigerina Limestone, but no land shells were detected in the Mriehel deposit. At one particular site in Hamrun, the white layer was found just underlying the soil as at Mriehel, whilst at another site, the vegetable soil was underlain by « an orange coloured loam » (probably the ash layer detected at Mriehel) and there was no trace of the white deposit.

It is possible that this layer represents the product of flood waters. The perfectly horizontal upper and lower limits of this layer may be significant.

Some of the pebbles in the Clay layer are defenitely of local origin (Globigerina Limestone), but it was not possible to establish categorically the local origin of the coloured pebbles as these were markedly altered. Micropalaeontological investigations could establish only that they were defenitely of Tertiary origin, and in some, merely that they were of Post-Lower Miocene age.

Many of the pebbles carry stalagmitic encrustations that are thicker in recessed areas but eroded at the edges to conform to the shape of the pebble. This indicates that pebble formation succeded the stage of stalagmitic dripping on them (Pl. I fig. 7). Deep linear etchings (? root etchings) (Pl. I fig. 5) and enigmatic calcareous linear encrustations, often forming parallel rows resembling the attachments of serpulid worms, form a prominent feature of the pebbles (Pl. I fig. 6, 8). However, unlike the elephant molars recorded by BERDAR (1974) from about the same level (45-60 m above sea level) in a Pleistocene deposit at Messina, Sicily, none of the Mriehel pebbles carried any marine biodonts attached.

The *Cliona* - riddled Globigerina Limestone pebble recovered by the author from the brown layers (1968 p. 9) is considered to be an accidental introduction by flood waters.

This is the first record of a volcanic ash layer from the Maltese archipelago. On account of the vegetable soil cover and the crops in the adjoining fields, it was not possible to establish its lateral extent. It was probably represented by the 45 cms thick « orange coloured loam, unstratified and containing an abundance of land shells » recorded by COOKE (1896) from the pipe line trenches and many other excavations at Hamrun. Cooke's sites lie about 1.5 kms to the east of Mriehel Girls Grammar School where the ash layer was located, and at about the same height above sea level. Unfortunately, none of Cooke's samples and specimens are now available.

At the Mriehel building site, the ash layer was clearly exposed only on the wall of the Western trenches where the fertile soil still formed part of the local stratigraphic sequence (see ZAMMIT-MAEMPEL, 1968, fig. 7). In accordance with local legislation to safeguard the preservation of local fertile soil (Act 29/1973, *Malta Government Gazette* Supplement No. 12879, 6th Nov., 1973), the vegetable soil (and with it possibly also the ash layer) had been bulldozed away from the entire building site. No attempt was made by the Government to recover the palaeosols.

The numerous air spaces in this tuff layer, as well as its loosely bound nature, suggested that it was an ash fall deposited directly at the site rather than transported and accumulated there through the agency of flood waters as in the other layers.

In such a case, an ash layer 30-45 cms thick, would represent a volcanic activity of considerable intensity which must necessarily have had considerable effect on the flora and some of the fauna of the Maltese Islands at the time. In these limited exposures, however, no organic remains were detected at this level.

The absence of an ash layer from the well-preserved and well-documented stratigraphic sequence at Ghar Dalam 10.5 km to the southeast of Mriehel, could be attributed to the shielding effect of the Cave's roof. This would have prevented the ash fall from capping the Late Pleistocene deposit in that Cave. The Ghar Dalam sequence includes a bone free clay layer of Pliocene or early Pleistocene age, a Middle Pleistocene bone breccia layer with *Hippopotamus* and elephant remains, a Late Pleistocene brown soil layer with *Cervus* remains and a holocene Cultural or Pottery layer containing artefacts dating from the earliest Maltese Neolithic times (c. 5, 200BC) to Modern times.

It has not yet been possible to determine the precise source of the Mriehel tuff, but a Mediterranean origin (Sicily or the Strait of Sicily) is most likely. Nearby possible sources would be Etna (210 km E. of N. of Malta), Pantelleria (240 kms W.N.W. of Malta) and Linosa (140 kms W. of the Island) all of which are along the directions of frequent strong winds blowing over Malta.

Etna has been an active volcanic centre since at least the Early Pleistocene and at one stage suffered a cataclysmic eruption which produced the Val del Bove. The dates at which activity commenced at Pantelleria and Linosa are not known. Pantelleria is still of mild sulphataric activity. Linosa, like Etna, suffered a cataclysmic « blow out » at one stage followed by eruptions from several minor centres. The Cavas (Scogli di Tramontana) look as fresh as though they were formed « only yesterday ».

It should be noted that the range over which ash material is distributed depends on several factors, including the volume of the material ejected, height of ejection, particle size and wind speed (KENNETH and THUNELL, 1975). In this connection it is interesting to note also that some of the volcanic ashes of the Mediterranean deep sea cores (Nincovich and Hayes, 1969; Rapp et al., 1973) and the volcanic ash deeply embedded in the Franchiti deposits on S.W. Greece (Rapp, 1978) have been found to have originated about 25,000 years B.P. from the distant island of Ischia, off the Bay of Naples, so that distant sources cannot be excluded.

Recent volcanism in the strait of Sicily was lately reviewed also by Zarudski (1977). A search in literature for comparable records at this particular time in Sicily and other Mediterranean Islands yielded no positive results. The Alkalic series products which occur in the Greek territory are of an age older than the Pliocene (Pers. Comm. Dr. N. Apostalides).

The age of the volcanic tuff, too, could not be established (Prof. Vincent, Dr. Keller, pers. comm.). It is too young for the Rubidium-Strontium or the Uranium-Thorium-Lead methods. Its age seems to fall precisely into that embarassing gap (from the point of view of geologists, archaeologists and historians) between the sorts of ages one can determine by the Potassium-Argon method and by the Carbon 14 method.

It can be stated however, that as the ash layer overlies the Late Pleistocene *Cervus* deposit, it must necessarily be younger than it and as no heavy ash fall has been reported over the Maltese Islands during historical times, it is probably older than the earliest known local records.

Acknowledgements

Through the kindness of Prof. Henriette Alimen, Director, Laboratory of Quaternary Research, C.N.R.S., Bellevue, France, and the co-operation of her staff, the following investigations were carried out on samples from the entire stratigraphic sequence: Pollen analysis (Mle F. Beucher), Heavy minerals (Mme Dubois-Page) and Sedimentological tests, pH, Calcimetry and X-ray diffraction (M Lucien Casta);

The physical and chemical nature of the pebbles in the Clay layer were investigated by Mr M. Atherton (Malta College of Arts, Science and Technology) and their micropalaeontology by Dott. Giannelli and Dott. G. Salvatorini (Istituto di Geologia e Paleontologia, Università, Pisa, Italia);

Dr K.P. Oakley (formerly of the sub-Department of Anthropology British Museum, Nat. Hist.) carried out bio-chemical tests (N% and Uranium estimations) on the organic remains; Dr. Keller (Heidelberg) and Prof. Vincent (Oxford) studied the volcanic tuff.

Dr. N. Apostolides, Director General, Institute of Geology and Mineral Exploration, Athens, contributed useful information on the volcanic ashes of the Greek territory;

Dr. T.O. Morris (Malta), who read the early version of this paper and Prof. Federici (Pisa), the final draft, both contributed valuable suggestions.

Their help is gratefully acknowledged.

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(*ms. pres. il 31 dicembre 1981; ult. bozze il 30 aprile 1982*)