Site Formation, Preservation and Remedial Measures at Silbury Hill.

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Abstract

The recent internal collapses at Silbury Hill have necessitated a consideration of the impact on environmental remains of the different possible remedial options, as well as providing an opportunity to examine material arising from exploratory interventions. This report brings together the results of these investigations, including material from the recent coring exercise, and from the 1960s excavations. The preservation state of different types of material is discussed, along with evidence for the taphonomic mechanisms that can be deduced from all the available data. Finally, the report attempts to provide a framework for understanding the likely effects of any works carried out.

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Site Formation Background

Silbury Hill is constructed on a spur of chalk protruding from the southern slope of the Kennet valley (Fig. 1). The edge of the valley and toe of the slope where the hill is actually situated, are mantled by undated drift deposit mapped as 'valley gravel' on BGS Sheet 266. There is no memoir for the Sheet 266, but similar map units occur further east at Reading, and descriptions can be found in Blake (1903). The valley gravels usually rest on the chalk, and include banded flint gravels as well as flints in a clayey matrix[1].

North of the hill, the valley floor is composed of a deep deposit of undated alluvial clay. Detailed work by Powell *et al*. (1996) has highlighted the difficulties of correlating alluvium in the area, because of the local nature of the depositional events. However, we assume that it correlates with the post-Beaker or medieval episodes recorded in the uppermost parts of the stratigraphy at various other places in the valley (Evans *et al*., 1993).

By constructing the hill on the spur and then cutting down to the chalk to the west and east, the Silbury builders removed all of the valley gravel in those adjacent areas, and the alluvium now extends around a large part of the circumference. The unusual layout of the alluvial deposits shown on the geological map (Fig. 2) is, therefore, likely to be a product of the sheer scale of the engineering exercise that Silbury represented.

The Current State of Preservation

A view of the overall preservation state of environmental remains at Silbury Hill can only be arrived at by looking at the individual materials recovered from the various interventions. We have three sources of information:-

1) Written evidence from previous excavations (1968 &1970).
2) Evidence from cores taken for the seismic survey (2001& 2003).
3) Evidence from the Evans sample blocks, collected in 1968.

[1] Cornwall *et al.* (1997) use the term 'Clay with flints' to describe the drift underlying Silbury Hill. This name is usually reserved for the interfluve deposits found on the chalk in many areas, so we have chosen to use the term 'valley gravels' as mapped by the BGS, accepting that these gravels may well be partly derived from periglacial action on upslope deposits of clay with flints.

Figure 1. *Aerial view showing geomorphological location of Silbury Hill. (Photo: Bob Croxford)*

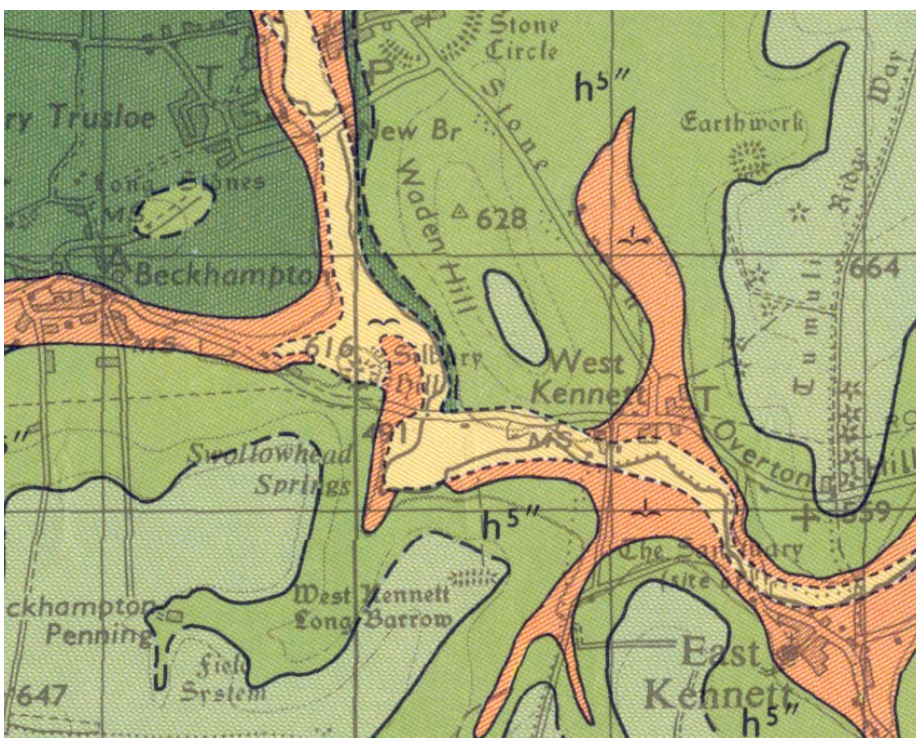


Figure 2. *Geological map of the deposits at Silbury. Green is chalk; orange is valley gravel; yellow is alluvium. (Copyright British Geological Survey)*

Evidence from previous excavations

Site Formation Evidence

Cornwall *et al*. (1997:26) recorded the following typical buried land surface from within the area of the 1968 and 1970 excavations:

0 – 4.5 cm (range 3-10 cm)	Stone-free fine textured soil variously described as fawn, blue or blue grey, but darker under the primary mound. Remains of vegetation were found on its upper surface.
4.5 – 8.3 cm (range of depth 2-4 cm)	Compacted mass of small flints embedded in an iron-stained clay matrix.
8.5 cm and below	Clay with flints (see note [1] on previous page)

It is unclear from this account whether the buried soil was complete or truncated, but it appears to have formed largely on a clay and flint deposit which is presumably a variant of the valley gravel. Iron staining is mentioned, and this often relates closely to buried topsoils. However, since iron-staining and pans are ubiquitous at Silbury, it cannot be taken as evidence of a relict turf line in this case. Well-developed pans are visible in photographs from other parts of the stratigraphy revealed during the Atkinson excavations. Figures 3 and 4 show massive multiple panning overlying some form of cut.

Biological Evidence

The environmental analysis of material from Atkinson's 1968 and 1970 campaigns (Whittle, 1997) was undertaken many years after the actual excavations. In some cases, the analysis was completed but not fully reported (see Table 1). There was a general shortage of documentation associated with the early work (prior to the 1997 volume). For example, Dr. M.C. Speight undertook work on the insects, but no records of processing exist and Robinson (1997) had to deduce the likely method used from the nature of the insect assemblages. Similarly, we know that plant macrofossils were recovered from the turf stack and the old ground surface, but since the results were combined, it is not possible to be certain whether a particular species was recovered from the turf stack, the old ground surface, or both. The author (Williams, 1997) mentions where particular types of remains were found in some cases but not in others, so interpretation remains difficult. As a result it must be stressed that the information derived from the different lines of environmental evidence is analogous rather than directly comparable.

Pollen evidence

The pollen evidence from beneath the mound and into the old ground surface suggests a grazed grassland rich in perennial herbs. Some woodland is indicated, especially by the high values of hazel (*Corylus avellana*). Dimbleby (1997) suggested that these could be derived from hazel thickets or a mosaic of grass clearings interspersed with woodland.

No pollen work was undertaken on samples from the turf stack. One sample taken from tipped chalk rubble at the tail of the primary mound, produced a spectrum dominated by hazel pollen with some grass and grassland plants also represented (Dimbleby, 1997).

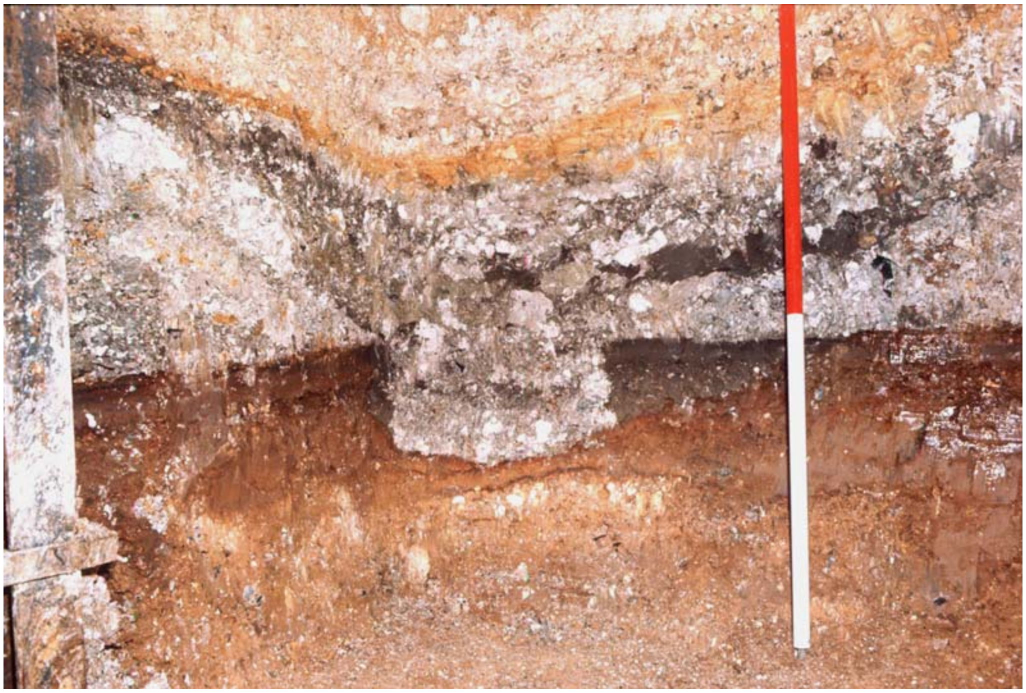


Figure 3. *Panning (red brown bands) exposed in the Atkinson excavations.*

Figure 4. *Panning (red brown bands) exposed in Atkinson excavations.*

Molluscs

The old ground surface was devoid of snails as would be expected of a brown–earth type soil. The stacked turves, however, were derived from chalky parent material and contained molluscs, with many of the shells retaining the periostracum or proteinaceous coat. Open country species were predominant, especially *Vallonia excentrica*, suggesting very dry grassland. There is some indication that the area from which the turves were cut may either have been recently converted from arable to grassland or that the grassland was less heavily grazed a few years before the turves were cut.

Plant macrofossils

The work on macroscopic plant remains is not directly comparable with the pollen evidence, as the samples came from different areas of the mound. Frequently, no record survives of the exact origin of the individual samples, i.e. whether they came from turf stack or the old ground surface.

Williams (1997) states that all the mosses were recovered from the turf stack. The majority are consistent with mature chalk grassland although some species prefer shady, moister conditions. Some pieces of wood were found including twigs up to 20 cm long. Several fragments of burnt and unburnt hazel (*Corylus avellana*) were recovered as well as 3 fragments of nutshell and one kernel. Various other species found include several fragments of hawthorn (*Crataegus monogyna*), and single fragments of pine (*Pinus* sp.), a *Prunus* species (possibly *P. spinosa*, the sloe) and a single yew (*Taxus baccata*) seed (Williams, 1997).

Some seed records from either the turf stack or the old ground surface, e.g. *Urtica dioica* (stinging nettle) and *Montia fontana* ssp. *chondrosperma* (blinks), suggest considerable variation in concentration across the deposits. Due to the poor recording, it is not possible to be very clear about the nature of this heterogeneity. A mature chalkland flora is clearly present, but some species also originate from woodland and disturbed habitats. Weed seeds such as nettle probably represent the soil seed bank, i.e. they once grew on the soil or their seeds were dispersed into it, but they were not necessarily part of the vegetation cover at the time when the turves were cut (Williams, 1997). Differences between the total seed flora of a soil (i.e. viable, dead or decaying seeds) and the vegetation actually found on the surface have been demonstrated at the Overton Down experimental earthwork (Carruthers and Straker, 1996).

Insects

Mark Robinson (1997) analysed insects from samples recovered from the old ground surface and turf stack originally worked on by Dr. Speight. No records survive concerning the details of processing but recovery suggests sieving down to 0.5 mm. Today we would normally sieve to 0.18 or 0.2 mm. It was also not possible to relate samples to tunnel ring number (i.e. specific locations in the tunnel).

The preservation state of the insect remains was variable, suggesting either different conditions within the turf stack, decay of dead insects in the top of the old ground surface, or decay within the turves prior to burial of the mound. What is clear is that insect remains from the turf stack were generally much better preserved than those from the old ground surface.

An interesting aspect of the insect evidence is the lack of wood-dependent taxa. The majority of the insect assemblage is consistent with herb-rich grassland similar to *Festuca ovina/rubra* grassland still found on the chalk of Wiltshire, with some less heavily grazed grassland also present. There were also dung beetles present in proportions that suggest chalk pasture stocking levels similar to today. Although remains of ants were recovered from the samples, the evidence for flying ants remains in doubt. Since dead ants may have been incorporated into the turves it cannot be said that the turves were cut in summer. There were very few aquatic beetles or those associated with wetland habitats (Robinson, 1997).

Animal Bone
Some animal bone was recovered from the mound (exact location not recorded) and from the ditch (Gardner, 1997). Gardner concludes that 'a variety of animals were used, presumably for meat during construction of the mound and ditch' (Gardner, 1997, 49). However, the material from the ditch is from its infilling and must therefore relate to later use of the area.

Summary of evidence from previous excavations
Overall the results from the turf stack show that chalk grassland was already established in the vicinity of Silbury prior to construction of the mound. This is a special habitat resulting from managed grazing and is highly valued for its bio-diversity today. The fact that it was established at Silbury in the Neolithic shows the antiquity of this type of landscape management. Results from sites elsewhere in Britain give a completely different picture suggesting limited clearance of woodland with corridors of open space being created within a largely wooded landscape, or the presence of open woodland with temporary clearings and secondary woodland growth (Robinson, 1997). Nothing comparable has been found in burial mounds. It is simply unique.

Type of Evidence	Old Ground Surface	Turf stack	Capping Layers	Author
Pollen	Present.	Either no pollen work was undertaken or it was not reported on.	Sample from the tail of the primary mound. High hazel may indicate differential preservation.	G. Dimbleby, 1997.
Molluscs	None present.	Present. The periostracum, or proteinaceous coat of many of the shells preserved.		J. Evans, 1972, 1997.
Plant macrofossils	Present.	Present, including mosses.		D. Williams, 1997.
Insects	Present. Overall not as well preserved as those from the turf stack.	Present, but preservation variable.		M. Robinson, 1997.
Bone			Present but location not recorded.	N. Gardner, 1997.

Table 1. *Summary of the biological evidence obtained from the 1968-70 tunnel excavations.*

Evidence from the cores taken for the seismic survey

Five cores were taken around the periphery of the summit (Cores 1-5) in August 2001 and a further two were taken in the middle (Core 6 and 7) in March 2003. Their locations are shown on Figure 5. None of the peripheral ones (Core 1 -5) went through significant turf stack deposits, but they did penetrate primary mound material (capping layers). Cores 6 and 7 both went through the turf stack.

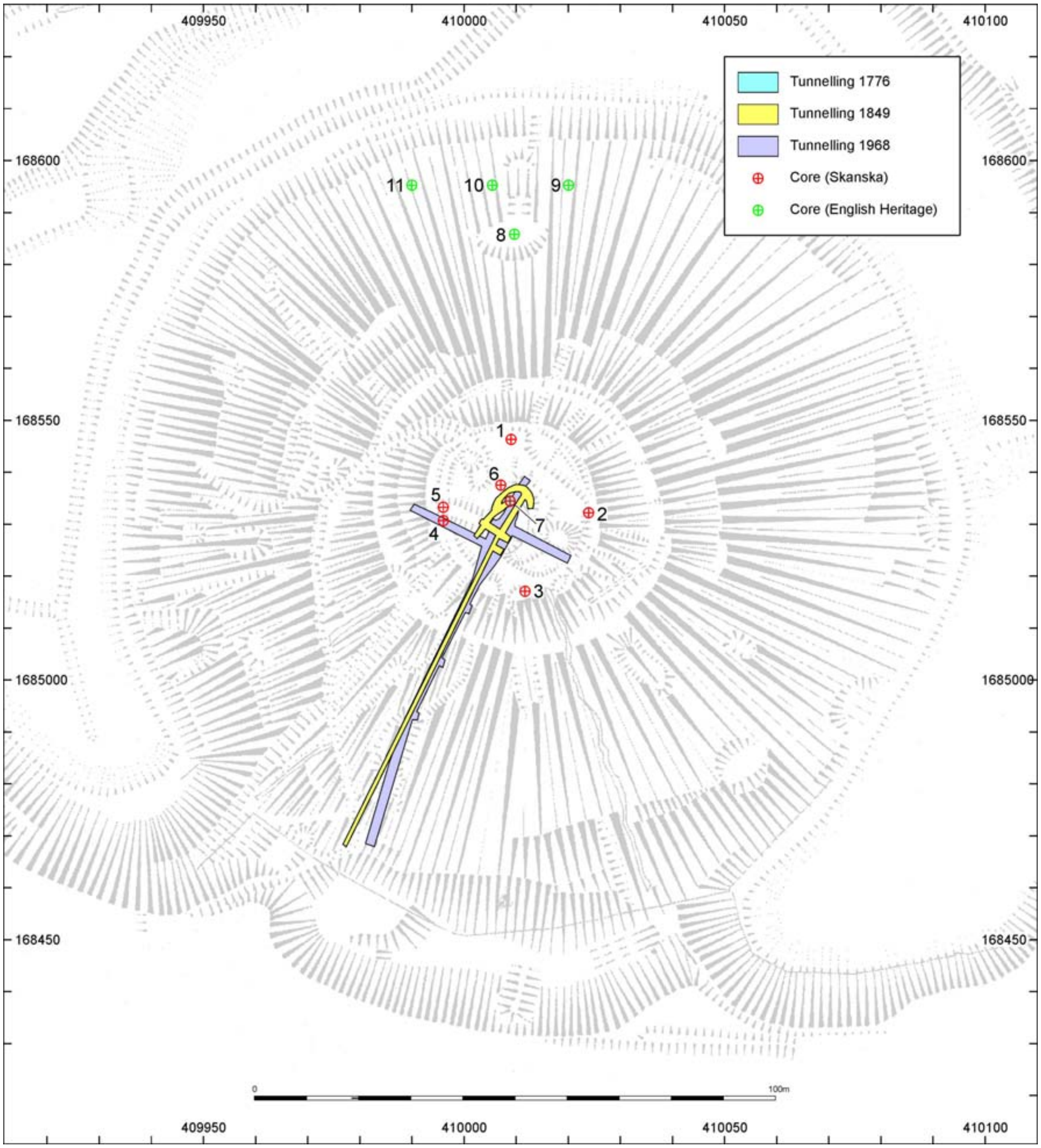


Figure 5. *Plan of Silbury Hill showing locations of the cores.*

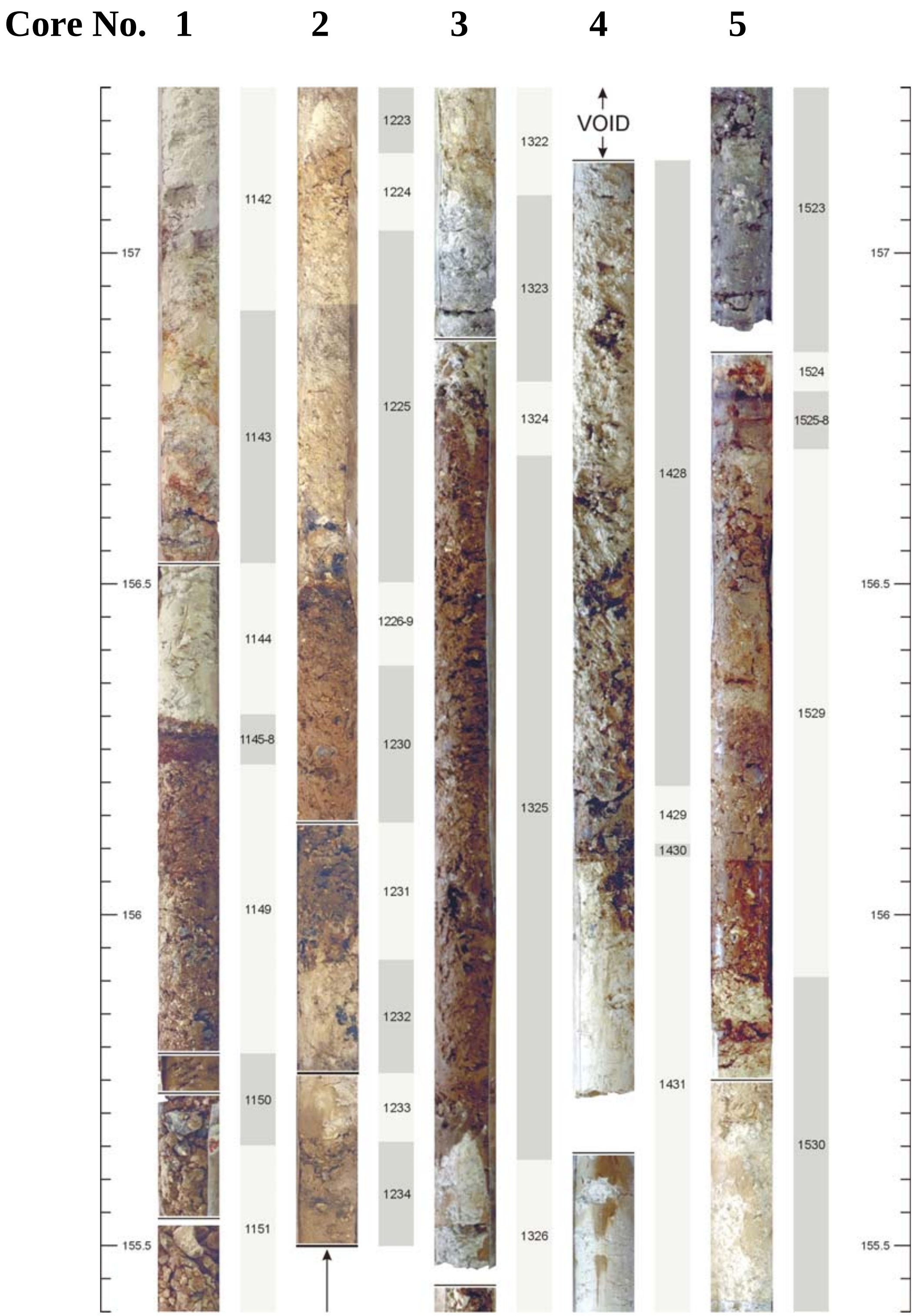


Figure 6. *Old ground surfaces as exposed in Cores 1 – 5. Some colour differences are due to variation between the individual photographs.*

Site Formation Evidence

The cores are largely composed of 30+ metres white chalk rubble with small lengths of around 1 – 2 m of brown or black deposits towards the base. The general area of these dark basal deposits for Cores 1-5 is shown on Fig. 6. They consist of the buried land surface materials and valley gravel subsoils, and in turn usually overlie a few metres of solid chalk. It is uncertain exactly what type of soil profile would have occupied the land surface before construction. The nearest exposure of a soil developed on valley gravel is about 100 m east of Silbury Hill (see Figure 2), and this has 10-15 cm of relatively dark humic topsoil overlying a further 10 cm or so of lighter brown soil (Figure 7). Assuming this represents a typical valley gravel soil, then Cores 1, 2, 4 and 5 do not appear to contain complete buried profiles. Core 3 contains a deep clay and flint deposit over the geology, which could be a full profile assuming considerable variability in the valley gravel make-up, and that the organic matter had been oxidised away. However, the preservation of dark organic materials elsewhere in the cores suggests that this latter process would be unlikely to have occurred. Aside from some uncertainty about Core 3, then, the general state of the old ground surfaces in the cores is consistent with there having been a phase of de-turfing for the building of the stack. The truncated surfaces thus do not have in-situ topsoils, but are marked in some cases by dark organic bands, or by red iron staining (Fig. 6, Core 1, 1145-8; Core 5, 1525-8), both of which could result from trampling.

Primary mound material in the cores is variable. In the turf stack deposits of Core 6, very dark (10 YR 2/1) material is preserved over about 20 cm, but the more general case is mixtures of trampled chalky topsoil, valley gravel materials and pure chalk.

The interface of the primary mound material and the long cores of chalk rubble representing the upper part of the hill are, in most cases, not marked by iron staining. Solid iron pans are not present at all in the cores, but some micro-panning is visible in one part of Core 5 (157.7-157.65 m OD). This exposure is similar to the excavation photographs (Figures 3 and 4) and at a microscopic level, it is possible to find manganese deposition forming small near-dendritic patches (Figure 8) associated with the pans. These are typical products of fluctuating redox conditions, with iron and manganese entering solution where conditions are reducing, then crystallising out where conditions are oxidising.

The formation of multiple pans is relatively common in soils and sediments, but is not well understood. There is evidence in the literature for reduced iron in solution oxidising out preferentially on areas where it has been deposited before, and this may lead automatically to the formation of multiple pans under some circumstances. From the point of view of preservation, however, the multiple or single nature of the pans probably affects the redox (oxidising and reducing) conditions less than the continuity of the pans around the turf stack. If we had a well-developed pan continuously surrounding the stack, then we would justified in suspecting that the turf materials were strongly deoxygenated along the lines of the Scandinavian examples (see discussion below). This is not the case, but that does not mean that there are no areas of reducing conditions present at all. The single core (Core 6) which actually went through the turf stack shows anoxic preservation conditions around 157-158 m OD. Gaseous exchange must therefore have been hampered in these layers by some form of seal. The fine silt and clay in the soil of the turf stack itself may have been sufficient. Rather than there being a single thin layer of cementation, preservation appears to have been achieved by the cumulative effect of the low-permeability layers around the outside of the stack hindering gaseous exchange with the interior.

An obvious second possibility for explaining the areas of good preservation is that acidic conditions have developed in the stack. Since the chalk and chalk-rich layers of the hill will be alkaline, pH tests were initially carried out along the darkest and most organic areas of Core 6, to determine the lowest pH that could be expected in the stack. The results were:-

Depth (m)	Depth m OD	Sample	pH
27.43 – 27.45	159.22 - 159.20	Mainly chalk slurry	8.1
27.68 – 27.70	158.97 - 158.95	Mainly chalk slurry	8.1
27.68 – 27.70	158.97 - 158.95	Iron-stained chalk and topsoil mixture	7.9
28.13 – 28.15	158.52 - 158.50	Iron-stained chalk and topsoil mixture	7.9
28.34 – 28.36	158.31 - 158.29	Iron-stained chalk and topsoil mixture	7.9
29.28 – 29.30	157.37 - 157.35	Iron-stained chalk and topsoil mixture	7.7
29.67 – 29.69	156.98 - 156.96	Black humic layer	7.9
29.88 – 29.90	156.77 - 156.75	Dark brown homogenous zone	7.7
30.05 – 30.07	156.60 - 156.58	Valley gravels - type sandy clay	7.6

Although there are considerable amounts of organic matter present in the dark black and brown layers, acidity has not built up, probably because of a continuous wash of $CaCO_3$ - rich water coming from above. Clearly, therefore, low pH is not a preservation mechanism at Silbury.

Biological Evidence

Core 5

The 80 cm of Core 5 encompassing the dark layer, buried surface and the subsoil (contexts 1522-1529) was assessed for pollen, macroscopic plant remains and insects. For the pollen, 1 cm slices were taken every 4 cm respecting the interfaces. 16 samples were then selected and prepared using standard methods. Pollen concentration was low and preservation was generally poor except at the junction of the old ground surface with the trampled dumped soil (top of 1525 and bottom of 1524) where preservation was better with sufficient pollen surviving to produce meaningful results (D. Robinson, 2003). The results from the pollen assessment are similar to those obtained by Dimbleby (1997) from outside the turf stack and show high values for hazel (D. Robinson, 2003)

Samples for plant macrofossils, insects and molluscs were taken at 2 cm intervals from the subsoil (contexts 1528-1526), old ground surface (context 1525) and dumped deposits (contexts 1524-1523a) and at 4 cm intervals from the valley gravel (context 1529), the less organic dumped soil (context 1523), and the chalk rubble (context 1522) respecting the interfaces. The samples were processed by careful wet-sieving, separating the organic fraction from the inorganic fraction using a simple wash-over technique. The organic fraction was kept in distilled water, and the inorganic fraction was dried onto a 0.5 mm mesh (M. Robinson, 2003).

The condition of biological remains was variable. However, in samples from the old ground surface (1525) and the capping deposits (contexts 1523a and 1524) preservation was good with fragments of insects, molluscs, moss and other plant macroscopic remains being recovered (M. Robinson, 2003). This clearly demonstrates that biological material survives not only in the turf stack but also in the layers immediately sealing it.

The remains provide similar evidence to that obtained from the earlier work, with grassland and disturbed ground indicated (M. Robinson, 2003). The disturbed ground element appears to be slightly better represented than in the earlier work, probably reflecting the source of these capping layers.

The remaining part of Core 5 consisted of around 29 m of chalk rubble from the rest of the mound, and this was also assessed for the presence of biological remains. Samples were taken at 25 cm intervals respecting interfaces, and floated using a 0.25 mm mesh for the flot and a 0.5 mm mesh for the residue. Tiny fragments of charcoal were present at intervals throughout the depth of the mound. This material could have blown in from nearby fires or been transported on the builders' feet. Occasional molluscs were also found within this part of Core 5, but too few to merit further analysis.

Core 6

Since Core 5 did not penetrate the turf stack, limited investigations were carried out on Core 6 (which did), so as to get an idea of preservation within the turf stack and whether any deterioration of biological remains had occurred since the 1968-70 excavations.

The boundary between the turf stack proper and the overlying capping deposit is rather indistinct. However, three samples were collected as follows:-

> A 20 g sample from a black humic layer believed to represent an actual turf at 29.67-29.69 m (pH 7.9). The sample contained some very well preserved remains including seeds of *Ranunculus* Sugenus Ranunculus (buttercup) with their surface layer of cells still surviving. Molluscs also showed exceptional preservation but the Coleoptera (beetle) remains were fragmented and the surface condition of some of them was poor.
>
> A 20 g sample was taken from a mid-brown layer containing very little chalk, (probably topsoil material) within the turf stack proper 29.51-29.53. The material from the mid-brown layer was fairly well preserved but showed some degradation.
>
> A 45 g sample was taken from the iron stained chalk and topsoil mixture at the top of the turf stack (29.28-29.30 m). This sample contained many fragments of chalk, perhaps representing subsoil material (pH 7.7). The insects from this sample were fragmented but their surface condition was good. Macroscopic plant remains were absent but there were numerous weathered mollusc shells suggesting that this material was derived from the base of the soil profile just below the worm-sorted horizon (M. Robinson, 2004).
>
> In addition two pollen smears were taken at 29.60 m and 29.8 m. No pollen was observed in either sample.

The results indicate that the patchy preservation within the turf stack is dependent on the nature of the construction material. Thus, the humic layers of the turves contain well preserved remains, while the topsoil contains degraded material and the bottom of the turves (subsoil) contains fragmentary remains of molluscs, and insects which may have fallen down the soils cracks not long after the turf was cut (M. Robinson, 2004).

Evidence from the Evans samples

Site Formation Evidence

Three irregular blocks of turf stack stratigraphy were received by John Evans from the 1968 excavations. One of these (TS1) seems to be a compressed chalk soil profile with a strongly

Figure 7. *Modern valley gravel soil profile to the east of Silbury Hill.*

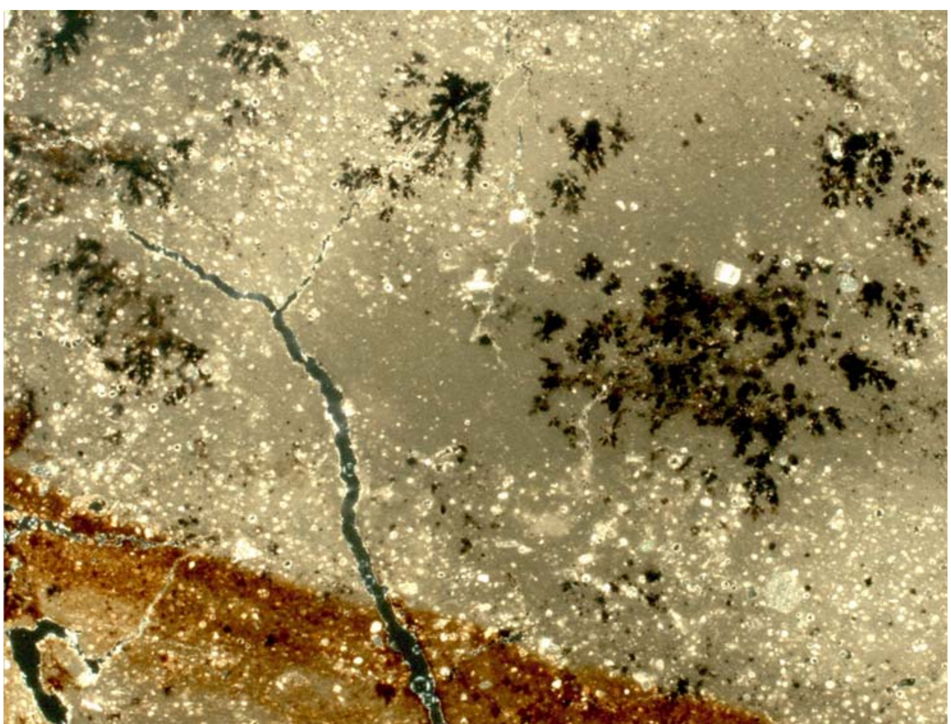


Figure 8. *Manganese crystallisation (black growths) above the iron pan (red band) in Core 5. (* x *13, in crossed polarised light).*

Figure 9. *TS2* **-** *Sample made up of a series of turfs from a valley gravel soil.*

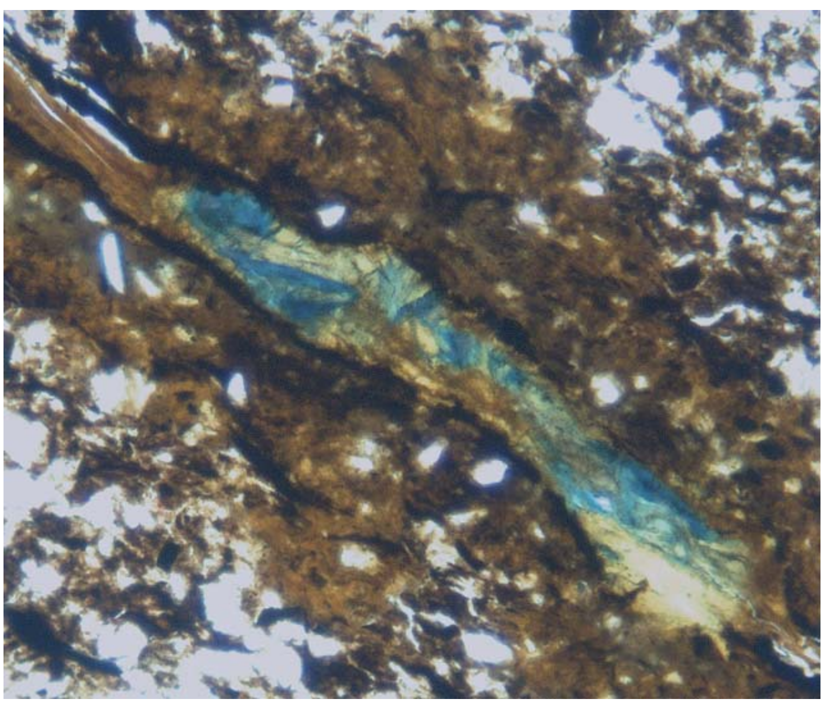


Figure 10. *Vivianite growth from a turf/turf junction in sample TS2 (x 93, in plane polarised light).*

organic surface layer, possibly trampled and still rich in chalk and other calcareous remains. The two others (TS2 and 3) appear to be thin turves from a decalcified valley gravel soil profile (see Fig. 9). Between each turf layer, there was moss still in its growing position; a sample of this moss is being used to produce a radiocarbon date. In thin section it can also be seen that many of the turf/turf junctions in TS2 have growths of vivianite in them suggesting biologically rich (phosphate) and wet (reducing) conditions (Fig. 10). Again, these conditions cannot be thought of as ubiquitous throughout the hill, and must represent localised areas of wetness and reduction.

All three lumps were presumably made up of materials cut from the spur on which the hill is situated, so it seems likely that different superficial soils were present at the start of construction. These would probably consist of the decalcified valley gravel soils on the main body of the spur, and a shallow chalk profile further south (closer to chalk slope).

Biological evidence

28 pollen samples were taken from TS1, TS2 and TS3 and prepared using the standard methods. The concentration of pollen and spores was extremely low and most were so degraded as to make further identification impossible (D. Robinson, 2002). Those that could be identified were robust types such as Poaceae (grasses), Asteraceae (dandelion family), *Alnus* (alder) and Filicales/ *Polypodium* (fern) spores indicating the differential preservation of pollen in these deposits (D. Robinson, 2002).

Preservation Summary

The discovery of iron pans combined with the anecdotal evidence for extremely good preservation (e.g. that the buried grass layer was 'still green') at Silbury prompted comparisons with the South Scandinavian barrows. These are mainly early Bronze Age constructions, some of which contained very well-preserved organic remains. Their interiors were often almost completely encased by iron pan, maintaining extreme reduction and wetness (Holst *et al*., 2001). Experimental work by Breuning-Madsen and Holst (1998) and Breuning-Madsen *et al*. (2000:2001) has shown clearly that excellent preservation is possible under these circumstances with plant matter and buried meat kept in pristine condition for the duration of a three year experiment.

Although this level of preservation was not found in any of the Silbury Hill materials recently studied, reduction has clearly played the major role. As the turves were piled up, the living organisms in them continued using up oxygen, but photosynthesis ceased. The degree of anoxia that developed locally would be controlled by the rate of gaseous exchange between the mound and the outside air. This must be roughly the same in chalk barrows generally, but with Silbury achieving a lower rate (as measured from the centre to the outside) by virtue of its size and the extra compression of the construction materials caused by 'the enormous weight of the mound' (Evans 1972:267). Additionally, however, there is an unknown degree iron pan formation, which must both respond to, and alter the small-scale pattern of oxygen and CO_2 gradients, resulting in a palimpsest of different localised conditions.

An interesting parallel may be found at the Motte of Werken in West Flanders. This is a mound about 6 m high, made up of successive construction and occupation layers derived from polder and coversand soils. Redox conditions are extremely variable, and organic artefacts from the occupation layers are well preserved in some parts of the mound but completely oxidised in others. In some places, wood is preserved in a highly reducing zone, but can be traced through into another more oxidising zone, where all that remains is a stain the soil. The variations in oxidation and reduction are marked by migration and accumulation of iron, manganese and phosphatic compounds (Gebhardt and Langohr, 1999).

A summary of the biological material preserved within the primary mound at Silbury is given in Table 2. The preservation of insects, plant remains and molluscs within the turf stack represents the remains of a Neolithic chalk landscape. This landscape was established before the construction of the mound, remarkably early given that it results from managed grazing, and that much of the rest of Britain was largely wooded at this time. The remains are unique and of international importance. Our recent investigations have shown that macroscopic remains are preserved not only within the turf stack but also in the dumped soil layers immediately sealing it. Furthermore, the examination of Core 6 would suggest that no deterioration of macroscopic material has occurred in the turf stack away from the tunnels since the 1968-70 excavations. By contrast, pollen preservation within the turf stack and dumped soil layers is poor to non-existent. It is only in the old ground surface that conditions are sufficiently acidic to preserve pollen in reasonable quantities. Here, insects and plant macroscopic remains are also generally well-preserved, but land snails are absent. Conversely, the high pH levels in the turf stack have led to the destruction of pollen and fern spores but have ensured the survival of mollusc shell.

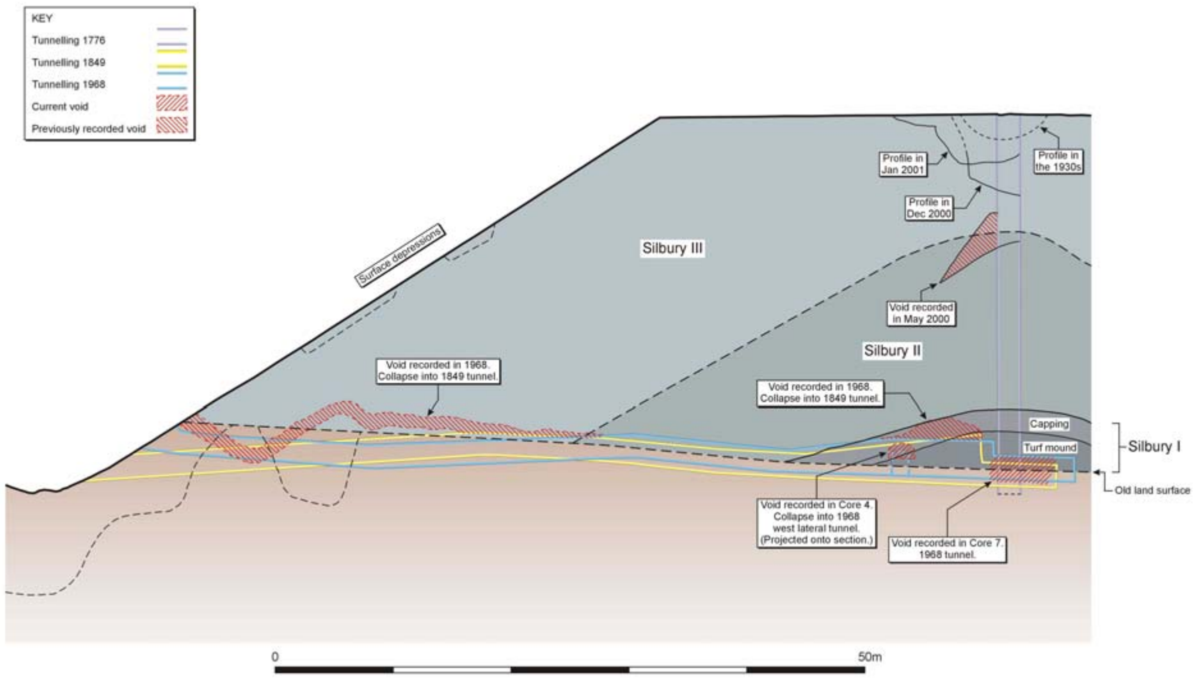
An important factor in the overall preservation state is that these deposits are unlikely ever to have dried out completely due to the protection afforded by the mound. In addition, temperature fluctuations, which may play a part in decay, will have been negligible.

Type of evidence	Old ground surface	Turf stack	Capping layers
Pollen	Pollen reasonably abundant, mainly well preserved.	Pollen very sparse and degraded. Only a few robust types identifiable.	Pollen sparse and degraded. Only robust types present.
Molluscs	None present.	Present. The periostracum, or proteinaceous coat of many of the shells preserved in the humic layer. Degraded in the chalky soil and only robust fragments in the subsoil materials.	Molluscs present.
Plant macrofossils	Good preservation.	Good preservation in the dark humic layer (actual turf). In the general matrix less so, and absent from the subsoil materials	Good preservation but material fragmentary.
Insects	Good preservation.	Good preservation in the dark humic layer (actual turf) but some surface damage. Less abundant in other parts of this deposit but good surface condition in the subsoil materials.	Good preservation but material fragmentary.
Bone	None found.	Some burnt bone.	None found.

Table 2. *Preservation of biological remains within Silbury Hill based on investigation carried out on the cores and Evans samples.*

Preservation and Remedial Options

Remedial works at Silbury consist of a number of engineering possibilities which could be applied in various ways. From a preservational point of view, the different approaches divide simply along the lines of the two main void types.



Schematic partial section through Silbury Hill showing: tunnelling and previously recorded voids (largely after Whittle 1997), and recently recorded collapses and voids.

Figure 11. *Existing voids in Silbury Hill.*

Recent collapse crater and boreholes.

The crater and boreholes can all be filled using chalk or chalk products and water according engineering needs. The void in the turf stack can be filled with a chalk and water mix via the existing borehole, as the relatively high pH values in Core 6 imply little change attendant on introduction of chalk. There is no reason to use sand.

Lateral voids

The main options for the lateral voids in Silbury Hill consist either of no intervention, filling them via new boreholes, or emptying out the tunnels and shoring them up. These options all have implications for the preservation conditions inside the hill, in as far as we have been able to understand them. The existing known voids are shown in two dimensions on Figure 11. Imagining these in three dimensions, it seems unlikely that they take up more than 10% of the primary mound.

Minimum Intervention

If the minimum intervention option is chosen, then the existing voids will undergo slow or sudden collapses internally over a period of many years, and gradually work their way up towards the surface. We do not know the extent of the lateral expansion that would occur as they ripple upward, but it seems reasonable to assume that they would emerge at least 3 times the starting width if they were able to ripple all the way to the summit.

The primary mound material would collapse into these voids. This would not cause it to undergo further significant gaseous exchange with the outside (over and above that undergone in the 1960s), but the environmental deposits would be mechanically damaged and stratigraphically compromised. Based on Figure 11, therefore, and allowing for some void expansion on collapse, we would be unlikely to lose more than about a further 5% in total of the primary mound deposits. The collapsed material would probably be less compressed than the original mound material, so gaseous exchange with the outside air might be hastened, but we cannot quantify that effect.

Locate voids and fill with chalk and water mix via new boreholes.
This option cannot be supported from a preservational point of view because the additional penetration of the primary mound must imply new opportunities for gaseous exchange and decay in areas that are currently well sealed.

Emptying and shoring
If the emptying and shoring option is chosen, air will have to be allowed in for the duration of the works, and this will have some effect on the existing anoxia. It would probably alter the preservation state of material within about 10 cm of the tunnel walls. Since these have already had a period of exposure to the air in the past, it is probably not a very significant loss. The shoring up process would, however, require some re-profiling of the void walls, and the main loss of environmental material would be incurred by this activity. Depending on engineering options, it would probably be of the order of a 20-100 cm ‘rind’ around the tunnel or void. We would thus lose a small percentage (probably again less than 5%) of the environmental deposits.

The emptying and shoring option should be accompanied by a significant recording exercise, which will act as ‘preservation by record’ against the slow long term decay of the turf stack materials. There must also be a plan for sealing the tunnel walls from gaseous exchange with the outside air. This could be by refilling with a dense powder, or by applying impermeable cladding behind the supports.

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