1 Introduction

1.1 The purpose of this document is to report the results of the field evaluation of the deposits exposed in the shaft at Silbury Hill; to detail their potential for enhancing our knowledge and understanding of the monument; to assess the risks involved in the realisation of that potential, and to present options for further archaeological recording and investigation.

1.2 This document supersedes an earlier desk-based assessment (McAvoy 2000). The information used to describe the history of Silbury Hill, as hitherto understood, is drawn primarily from a recently published volume by Dr Alistair Whittle (Whittle 1997).

2 General background

2.1 Silbury Hill is a scheduled monument (NM 21707) in the guardianship of English Heritage and forms a key element of the Avebury World Heritage Site. The National Trust had managed the monument on behalf of English Heritage but this arrangement was suspended on 15th August 2000.

2.2 On 29th May 2000 a squarish hole, recorded as approximately 2.25m wide and 10.3m deep, appeared on the top of Silbury Hill. This hole is the opening of a vertical shaft sunk from the top to the base of the mound in 1776-7 on behalf of the Duke of Northumberland. The shaft was reported at the time as being 2.44m (8ft) square and as having been dug by miners from either Cornwall or the Mendips.

2.3 The bottom of the shaft was later encountered in a lateral tunnel dug at the base of the mound in 1849 for the Archaeological Institute. The shaft was noted as having been infilled and was measured at 1.53m by 1.37m (5ft by 4ft 6in).

2.4 On 31st May 2000 a scaffold and corrugated iron structure was erected to create a secure capping over the top of the shaft. This work was carried out with archaeological supervision provided by the National Trust.

2.5 On 12th July 2000 a digital video camera was lowered into the shaft. The images obtained were interpreted as showing lateral adits or galleries and demonstrated that definable stratigraphic sequences were present in the exposed deposits.

2.6 A desk-based assessment of the potential for archaeological recording and investigation was completed on 31st July 2000.

2.7 A field evaluation was carried out on 9th August 2000. The methods and results are detailed below in section 4.

3 Archaeological background

3.1 Silbury Hill is the largest artificial prehistoric mound in Western Europe and is perhaps the most well known example of a type of feature now classified as a 'Monumental Mound'.

3.2 As seen now it is a flat-topped or truncated cone approximately 39m high, 28m wide at the top and 167m wide at the base. The mound lies within the circuit of a broad ditch that has causeways on its south-east and south-west sides.

3.3 Apart from those noted above, antiquarian and archaeological investigations were carried out in 1867, 1886, 1915 and 1922 and resistivity surveys were attempted in 1959 and 1968.

3.4 The most extensive and most recent investigation was undertaken under the supervision of Professor Richard Atkinson in 1968-70. The results of this work are presented in Whittle 1997.

3.5 The major components of the 1968-70 programme were:

1. A tunnel at the base of the mound, driven through to the centre where two further lateral tunnels were excavated.

2. A core drilled from the top of the mound to 3m above the tunnel roof.

3. Four areas opened up on the top and upper slopes of the mound.

4. A section across the southern part of the ditch.

3.6 Whittle, in his consideration of the evidence from the tunnel, has identified eleven structural events in the construction of the mound. These are subsumed here within four broad phases as proposed by Atkinson (1967, 1969, 1971) and set out in the Monument Class Description (Darvill 1989).

I A circle (diameter *c* 20m) was delineated by stakes cut through an old land surface. This area was then filled with a layer of gravel followed by a turf stack. Alternating layers of chalk and soil were added to create a primary mound with a diameter of *c* 36m and a height of *c* 5.5m.

II Chalk from a ditch or quarry and/or the scarping of the adjacent slopes was used to augment the primary mound, increasing the diameter to *c* 73m and the height to *c* 21m.

III Chalk from the encircling ditch and/or the scarping of the adjacent slopes was used to further enlarge the mound and infill the earlier ditch or quarry. This stage of the mound may have been built as a stepped cone using concentric and radial walls of chalk blocks to retain chalk rubble.

IV All but the topmost step was filled in to produce the present smooth profile of the mound.

3.7 Evidence for the chronology of the monument is provided by radiocarbon dates obtained from twigs, vegetation and turves associated with the primary mound (Silbury I) and from antler picks found in the southern external ditch.

3.8 The radiocarbon date obtained from the twigs and vegetation is 2871-2486 cal BC (at 1σ confidence) whilst the radiocarbon dates from the turves range (at 1σ confidence) from 5197-2782 cal BC, although most of the six dates obtained fall within the range 3627-2782 cal BC. Two radiocarbon dates from the antler picks give a range (at 1σ confidence) of 2398-2042 cal BC.

3.9 In his report Whittle casts some doubt upon the reliability of the radiocarbon dates obtained from the primary mound and suggests that the dating for the construction of the whole monument might range between 2800-2000 BC.

3.10 Material to determine the environmental setting of the monument was recovered from deposits in the tunnel; the areas opened up at the top of the mound; and the southern ditch. Analyses were carried out into soil micromorphology, pollen, macroscopic plant remains, insects, molluscs and faunal remains.

3.11 The general conclusion was that the immediate local environment when the primary mound was built was open grazed grassland, which may have had some disturbance, prior to, or as part of mound construction.

3.12 The core drilled through the mound is reported by Whittle as being composed of ‘essentially continuous chalk material’. The core is held with the archive in the Alexander Keiller Museum, Avebury.

4 The field evaluation

4.1 Methodology

4.1.1 The field evaluation took place on 9th August 2000. Graham Daws Associates, specialists in rock mechanics and confined space working, carried out an initial assessment of the stability of the shaft. Staff from English Heritage and its archaeological contractors were then able to inspect the deposits at first hand.

4.1.2 A digital video recording and colour photography provides a further record of the exposed surfaces. Two sediment samples were taken for assessment.

4.1.3 The results of the field evaluation are presented under three sub-headings: the shaft, the recent use of the monument and the archaeology.

4.2 The shaft

4.2.1 The shaft was recorded in a basic dimensional survey (Fig 1) carried out by Graham Daws Associates who also produced a report on the circumstances that resulted in its re-opening (summarised below).

4.2.2 The shaft is a square opening generally 1.8m wide, although broader at the top. The top of the collapsed infill is at a depth of *c*10.3m from the surface and at approximately this depth part of the shaft wall had sheared away to create a cavity (Fig 2). This cavity gave the earlier impression that there were adits or laterals.

4.2.3 There was no evidence that the shaft had been capped close to the surface. There was, however, evidence of shear features and scoring on the shaft walls to indicate that an upper infill had been present and had fallen.

4.2.4 It is suggested that the formation of a cavity below the upper fill had left this isolated as an unsupported 'plug'. The collapse of this plug may have been triggered by some form of changing water table or water migration as there were signs of water scouring at the 'toe' in section AA.

4.2.5 It is likely that the cavity below the upper fill in the shaft was formed through the collapse of the shaft wall into a lower void. This may have been a result of a progressive upward collapse within the mound, perhaps from a lower adit or from the various tunnels driven through at the base.

4.3 The recent use of the monument

4.3.1 A number of votive objects had been deliberately placed in the cavity between 12th July and 9th August. These were a cloth bull (Fig 3), a small nightlight (Fig 3a, a black crystal and a knotted rope. These objects were left undisturbed.

4.4 The archaeology

4.4.1 Archaeological deposits were exposed in the walls of the shaft and cavity to a maximum depth of 13.5m from the top of the mound. At present these deposits can only be broadly characterised, with varying degrees of detail.

4.4.2 Two distinct phases of construction, each of differing character, can be seen within the upper 13.5m of this part of the mound.

4.4.3 The earlier construction phase (from at least 13.5m to *c* 10.2m depth) is composed of well-modulated bands of chalky soil and chalk (Fig 4). A 0.5kg sample of the uppermost layer in this sequence was processed and provided a few fragments of charcoal of which *Corylus avellana* (hazel) and cf. Pomoideae (hawthorn) could be identified. Mollusc shells were absent but the residue contained possible Greensand grit.

4.4.4 This construction phase appears to have used soil and chalk derived from the stepwise cutting away of the local soil profile. The nature of the deposition sequence can be interpreted as resulting from either systematic mechanisms of excavation and transport or 'structured deposition' during construction. This clearance of the landscape could be related to the scarping of the adjacent slopes and/or the initial excavation of quarries or ditches.

4.4.5 The later construction phase (from *c* 9.8m upwards) is composed primarily of chalk rubble although there are soil lenses and quite thick layers of pale grey ?decayed chalk. No structural remains were noted although it must be emphasised that there was no systematic observation of these deposits. In addition the north side of the shaft was almost completely hidden by clay (Fig 5) which could have been spilt during the original excavation in 1776-7.

4.4.6 This construction phase may have used material derived from the deeper excavation of ditches or quarries.

4.4.7 These two episodes of construction are separated by a dense layer of very white chalk, and above this, a layer containing sarsens and large chalk blocks.

4.4.8 The dense chalk layer represents a major event within the overall construction of the mound. Typically 0.08-0.12m thick and found at a depth of *c* 10.2m from the top of the shaft, this layer was present on all sides of the chamber and was slightly convex at its base. A 0.5kg sample from the layer was processed but no charred plant remains or molluscs were present.

4.4.9 Whilst the dense chalk is essentially a continuous band this is interrupted in two adjacent areas and these interruptions might represent *in situ* features (Fig 6). If man-made, then these could have been small pits or post-holes cut through the chalk or they may be the remains of upstanding features around which the chalk had been laid. Alternatively these features may be a result of trees or bushes rooting on the top of the chalk. There is, however, a possibility that these putative features are merely soil adhering to the exposed surface.

4.4.10 This dense chalk layer can be interpreted as having been deliberately laid down, perhaps to create a bright white capping or possibly a coating for the earlier construction phase. Alternatively the chalk layer could have been a platform or have been associated with construction.

4.4.11 The layer above the dense chalk was fairly thick (*c* 0.4m) and contained frequent sarsens and large angular chalk blocks (Fig 6) that may have been associated with an *in situ* activity prior to the later construction phase. In places this layer was beneath a further thick pale grey layer with small ?flint inclusions.

4.4.12 The results of the evaluation can be compared with our previous understanding of the development of the monument.

4.4.13 The banded soil and chalk of the earlier construction phase visible in the cavity appears to be similar in composition to a deposition sequence recorded at the edge of the primary mound (Whittle, construction step d). The layers in this sequence are described as a laminated heap of chalk and 'Toblerone' (a mixture of brown clay-with-flints and small chalk fragments). Interestingly, this sequence lay directly beneath a steeply sloping layer that is described as trampled chalk.

4.4.14 However the sides of the mound would have had to slope upwards at a minimum angle of *c* 53° from the old land surface for this sequence to be part of the same event as the earlier construction phase exposed in the cavity.

4.4.15 To summarise, the height of the earlier construction phase in the shaft is *c* 6m above the previously projected height of the top of Silbury II. Its composition is, however, more akin to deposits found directly over Silbury I. The later construction phase is more directly comparable to Silbury III.

5 Research aims

5.1 The desk-based assessment identified two principal aims for further work:

Aim 1: To advance our knowledge and understanding of extent and nature of antiquarian investigations at Silbury Hill.

Aim 2: To advance our knowledge and understanding of the construction and use of Silbury Hill.

5.2 The assessment listed a number of questions related to the aims that could be addressed during further work. With regard to Aim 1 these questions were principally related to the lateral openings thought to have been present at the base of the exposed shaft and have been answered by the evaluation.

5.3 The evaluation has raised the possibility, however, that other openings associated with antiquarian investigation may have been present within the mound, perhaps at a lower level. The possibility of detecting these should be borne in mind but this, in itself, would not a reason for undertaking further work.

5.4 Further work would have the potential to answer questions relating to Aim 2, advancing our knowledge and understanding of the archaeology of Silbury Hill. This work would address the following primary goals, programmes and archaeological research priorities identified by English Heritage in Exploring Our Past 1998 (*EOP98*) and set out in the EOP98 Implementation Plan (English Heritage 1999).

Goals and programmes

Primary Goal A: Advancing our understanding of England's archaeology.
Programme 1.7 Assessing and understanding specific landscapes and monuments.

Primary Goal B: Securing the conservation of England's archaeological sites.

Primary Goal D: Promoting public appreciation and enjoyment of archaeology.
Programme 12.2 Avebury World Heritage Site.

Primary Goal E: Supporting the development of professional infrastructure and skills.
Programme 17.2 Development of geo-prospecting methods and techniques.
Programme 17.12 Development of fieldwork recording methods and techniques.

Research priorities

Single Monument Classes: 'There is still a strong need to develop our understanding of specific monument types.'

Cognitive landscapes: 'exploring landscapes from perceptions based around belief systems and social ceremonial action.'

5.5 Silbury Hill is one of only four examples of a very rare type of landscape feature classified as 'Monumental Mounds' (Darvill 1989). The other examples are the

Marlborough Mound (where the dating is less secure), the Hatfield Barrow at Marden in Wiltshire and the Great Barrow at Knowlton in Dorset.

5.6 Although their exact purpose is unknown these mounds appear to have been ritual or ceremonial monuments of late Neolithic date, closely related, at least in terms of spatial distribution, to henges and henge-enclosures. One measure of their significance at the time is the huge expenditure of resources spent on construction. Silbury for example has been estimated at 3 million man-hours.

5.7 Further work would provide information that would make a significant contribution to our knowledge of Silbury Hill. This, in turn, would enhance our understanding, firstly of Silbury as a particular type of Neolithic monument and secondly as part of a broader landscape of international significance, witnessed by its designation as a World Heritage Site (WHS).

5.8 The unique survival of a complex of prehistoric monuments that have dominated and influenced the present landscape is the main reason for the designation of the Avebury WHS (Pomeroy 1998). Whilst the WHS is a palimpsest of archaeological features there are a core of major monuments to set alongside Silbury eg Windmill Hill, Avebury and the Long Barrow, Avenue, and palisade enclosures at West Kennet.

5.9 With such a rich diversity of archaeology it is unsurprising that archaeological research is a key activity in the Avebury WHS management plan:

Objective Z: encourage and promote academic research to achieve a deeper understanding of the WHS.

5.10 Although a final version of a research agenda for the WHS is still being compiled, the management plan identifies research themes and those applicable to further work at Silbury Hill are listed below.

- **Ritual and ceremony**: the need for further research in this area dominates the Neolithic and Early Bronze Age.
- **Chronology**: the collection of new dating evidence, both relative and absolute, is a high priority for all periods.
- **Environment**: the area has a high potential for the preservation of environmental evidence.

5.11 The sections above have set out the general research background. The following is a series of specific questions relating to the archaeology of Silbury Hill that further recording and investigation could address:

The lower construction phase (Silbury II?)

Q1 What is the composition of the sequence of banded chalk and soil?

Q2 Where are the sources for these materials?

Q3 What are the mechanisms of extraction, transport and deposition represented in this sequence?

Q4 What are the intervals of time between each event in this sequence?

Q5 What can the biological materials present in this sequence tell us about either activity on the mound or the clearance of the local landscape at the time of construction?

The interval layers

Q6 What is the source of the dense layer of white chalk?

Q7 What is the purpose of the chalk layer? What is its extent and form?

Q8 How long was the surface of the chalk layer exposed for?

Q9 What are the features that appear to be cut through the chalk layer?

Q10 Can biological material be recovered from these features for archaeobotanical analysis?

Q11 What is the composition and source of the layer containing chalk blocks and sarsens?

Q12 What activity on the mound does this layer and its components represent?

The upper construction phase (Silbury III?)

Q13 What is the composition of and source(s) for the chalk and soil?

Q14 What is the angle of rest of stratigraphic deposits?

Q15 Can we determine stages in construction and the presence and disposition of the chalk retaining walls?

Q16 Are archaeological features and/or undocumented investigations present on the top of the mound?

Silbury Hill – all phases

Q17 Are there artefacts or carbonised material derived from *in situ* activities or structures on the mound that will assist with determining the chronology of Silbury Hill?

Q18 What is the relationship between the height of the construction phases in the shaft and the terracing on the sides of the mound?

Q19 Can we establish the extent of the buried ditch or quarry?

Q20 How do the construction phases in the shaft relate to the sequences as previously understood?

5.12 The re-opening of the shaft has raised a new issue related to the conservation of Silbury Hill. The presence of a hitherto unsuspected cavity within the mound, whether naturally or artificially created, has resulted in a serious instability within its structure. Further work directed towards establishing whether other cavities are present would assist with the long-term management and protection of the monument.

6 Health and Safety Issues

6.1 Principal Health and Safety concerns

6.1.1 The principal hazards in carrying out <u>any</u> work on the top of Silbury Hill are:

- the collapse of mound material into the open shaft and cavity.
- falling into the open shaft.
- access and equipment handling, particularly on the steep sides of the mound.

6.1.2 Work carried out that required a physical presence within the shaft and cavity would face additional hazards:

- the further downward movement of the infill that forms the present base of the shaft.
- materials falling down from the surface or from out of the exposed walls.
- working in confined spaces.
- access and egress from the shaft and cavity.

6.2 Health and Safety Legislation, Regulations, Policies, Codes of Practice and Safety Instructions

6.2.1 The Legislation and Regulations in relation to the principal hazards identified above are:

- The Health and Safety at Work Act 1974.
- The Management of Health and Safety at Work Regulations 1992.
- The Construction (Design and Management) Regulations 1994.
- The Construction (Health, Safety and Welfare) Regulations 1996.
- The Manual Handling Operations Regulations 1992.
- The Provision and Use of Work Equipment Regulations 1998.

6.2.2 The Policies, Codes of Practice and Safety Instructions in relation to the principal hazards identified above are to be found in:

- The Health, Safety and Welfare Manual (1999) of English Heritage.
- The Health and Safety in Field Archaeology Manual (1991) of the Standing Conference of Archaeological Unit Managers.
- The Health and Safety Procedures (1995) of the Centre for Archaeology.

6.2.3 The principle requirements under the Statutes, Regulations, Policies, Codes of Practice, and Safety Instructions with regard to the hazards identified above are:

- that the employer must ensure so far as is reasonably practical the health, safety and welfare at work of all employees.

This includes the provision of:

- systems of work that are safe and without risks to health.
- provision of a safe place of work including access and egress.
- a safe work environment.
- risk assessments and procedures to ensure the implementation of an adequate health and safety policy.

'Reasonably practical' does not impose a duty but enables a balance to be made between the risk and the inconvenience of the counter measures to the risk. In the event of an accident, whilst time and expense may be taken into account, the burden lies upon the defence to show that (with hindsight) it was not reasonably practical to have done more than was actually done.

6.2.4 The policy of English Heritage is to comply fully with the Health and Safety at Work Act 1974, Regulations and Approved Codes of Practice. It is also the policy of English Heritage to adopt best industry standards. With regard to work within the shaft and cavity these state that:

- all excavations more than 1.2m deep must have their sides properly supported.
- no one may enter such an excavation unless it is adequately supported.

[Construction (Health and Safety Regulations) 1996; British Standards BS6031: 1981 Earthworks; Safety Instruction No 10.5 English Heritage, CfA Safety Procedures].

The shaft and cavity constitute an excavation, although of a form not often encountered. The shaft does not constitute a mine under the definition in the Mines Regulations 1993.

6.3 Risk Assessment 1

6.3.1 This is the formal risk assessment required under the Management of Health and Safety at Work Regulations 1992, and applies to:

- work that might be undertaken that requires a physical presence within the shaft and cavity.
- the specific hazard of the collapse of material into the shaft or cavity.

6.3.2 The following chart is a non-numerical technique for estimating the level of risk, taken from Safety Instruction 4.2 of the English Heritage Health, Safety and Welfare Manual 1999. The chart is itself taken from British Standard BS 8800 Occupational Health and Safety Management.

In the chart, descriptions of the likelihood of risk are matched against descriptions of the possible severity of an incident to determine levels of risk. The following terms are used to assess severity:

Slightly harmful eg superficial injuries, minor cuts and bruises.
Harmful eg lacerations, burns, concussion, serious sprains, minor fractures.
Extremely Harmful eg amputations, major fractures, multiple and fatal injuries.

'Tolerable' in this instance means that the risk has been reduced to the lowest level that is reasonably practical.

	Slightly harmful	**Harmful**	**Extremely harmful**
Highly unlikely	TRIVIAL	TOLERABLE	MODERATE RISK
Unlikely	TOLERABLE	MODERATE RISK	SUBSTANTIAL
Likely	MODERATE RISK	SUBSTANTIAL RISK	INTOLERABLE

6.3.3 The first issue is to determine the severity of the harm that would be caused to people working within the shaft and cavity through the collapse of mound material, if no preventative measures to be put in place ie in the current situation.

The effect of such an occurrence is judged as being **extremely harmful**, with very serious or fatal injuries as an inevitable consequence, particularly given the absence of a means of extraction in the event of an emergency.

If more than one person were present within the shaft and cavity when a collapse occurred then this would be classified as a **disaster**.

6.3.4 The next issue is to determine the likelihood of such a collapse occurring, if no preventative measures are taken. Whilst the uppermost walls of the shaft itself have stood since 1777 they have been supported, to a greater or lesser extent, by the infill and this is of course no longer the case. The walls are more structurally coherent than if the shaft had just been excavated and it could be argued that the content of the mound around the shaft walls has reached a degree of stability. This 'stability' is, however, seriously compromised by the lower cavity that has removed support from beneath the shaft walls.

The current physical situation mirrors the circumstances that are thought to have resulted in previous collapses, with the most recent episode being only 5 months ago. In lieu of, and probably even after, a structural survey, it is impossible to determine what effect forces such as water migration and pressure are having on the stability of the shaft and cavity walls.

This is particularly relevant given the amount of rainfall that has occurred since the collapse of the upper fill and the uneven distribution of water caused by the present decking platform. Also the risk of collapse must become greater as time passes due to the possible freezing and melting of water held within the mound during cold weather.

The introduction of people into the shaft and cavity may in itself further increase the risk of a collapse occurring through inadvertent or deliberate actions, such as cleaning the exposed surfaces.

In these circumstances it is judged that the collapse of the mound material into the shaft and/or cavity is an event that is **certain** to happen without preventative measures. This leads to the conclusion that the hazard posed by the collapse of the mound material is an **Intolerable Risk** to people who might be working within the shaft and cavity, were no further preventative measures to be taken.

6.3.5 It may be suggested that this level of risk can be reduced through limiting the time that people are exposed to the hazard of collapse. Whilst recognising that collapse is inevitable in the present circumstances, the premise is that such a collapse may not occur during the limited period that people would be exposed to the danger.

If it was felt that the collapse and the presence of people within the shaft and cavity was an unlikely coincidence of events then the hazard would still represent a **Substantial Risk**, were no further preventative measures to be taken.

If it were felt that the collapse and the presence of people within the shaft and cavity were a very unlikely coincidence of events then the hazard would still represent a **Moderate Risk,** were no further preventative measures to be taken.

6.3.6 To summarise, a physical presence within the shaft under the present circumstances therefore represents, in the worst case, an **Intolerable** level of risk. If a degree of optimism about the outcome is applied then the risk levels become either **Substantial** or **Moderate**. Such optimism is, however, not a good basis for planning for work to be carried out and a prosecution under the Health and Safety at Work Act 1974 can take place even if no accident occurs.

6.3.7 The next step in the risk assessment process is the compilation of a Risk Action Plan. This is based on the following table (reproduced from the English Heritage Safety Instruction 4.2).

RISK LEVEL	ACTIONS REQUIRED
Trivial	No action is required and no documentary records need to be kept
Tolerable	No additional controls are required. Consideration may be given to a more cost effective solution or improvement that imposes no additional cost burden. Monitoring is required to ensure that controls remain in place.
Moderate	Efforts should be made to reduce the risk, but the costs of prevention should be carefully measured and limited. Where the moderate risk is associated with extremely harmful consequences, further assessment may be necessary to establish more precisely the likelihood of harm as a basis for determining the need for improved control measures.
Substantial	Work should not be started until the risk has been reduced. Considerable resources may have to be allocated to reduce the risk.
Intolerable	Work should not be started until the risk has been reduced. If it is not possible to reduce the risk even with unlimited resources, work has to remain prohibited.

The level of risk identified above associated with a physical presence within the shaft and cavity in the present circumstances is such that are sufficiently such that work **must not** be undertaken until the level of risk can be reduced.

6.3.8 At the time of writing there is no practical scheme that will:

- fully exploit the potential provided by the deposits. This can only be achieved through a physical presence in the shaft and cavity.

- reduce the risk level resulting from this presence.

6.3.9 The archaeological deposits that have the most recognised potential lie in the faces of the cavity and the possibility of supporting the shaft walls prior to carrying out archaeological work within the cavity has been considered. This is technically possible and a detailed scheme exists. However the new lateral pressures that shoring, for example, would impose on the shaft walls may increase rather than reduce the likelihood of the collapse of the cavity.

6.3.10 The full exploitation of the potential of the deposits also requires the removal of sediments for geoarchaeological and archaeobotanical study. A detailed sampling scheme exists but its implementation would certainly increase the likelihood of a collapse occurring.

Coring from the top of the mound has been considered as an alternative means of retrieving samples from sediments that would be comparable to those exposed in the shaft. However, at a depth of 10m or more, coring is unlikely to be laterally accurate and provides no view of the context being sampled. These two factors together would hamper interpretation to such an extent that coring is not recommended as a feasible technique.

6.3.11 It is possible to support the shaft walls after the cavity has been infilled and a detailed scheme exists for this work. The benefits to be gained are, however, outweighed by the additional exposure to the risk of collapse whilst this work is being carried out.

6.3.12 The conclusions of this risk assessment are that:

- the introduction of people into the shaft and cavity should not take place unless the risk level can be reduced.
- there is no practical way that this can occur.
- the introduction of people into the shaft and cavity would be in contravention of the English Heritage policy to comply with Approved Codes of Practice and best industry standards.

6.4 Risk assessment 2

6.4.1 This is the formal risk assessment required under the Management of Health and Safety at Work Regulations 1992 and applies to:

- work that might be undertaken from the top of the mound involving remote access to the shaft and cavity.
- the specific hazard of the collapse of material into the shaft or cavity.

6.4.2 The severity of the effect of collapse and the likelihood of collapse occurring are the same here as in risk assessment 1. The difference is that it is possible to reduce the risk level through ensuring that the decking platform at the top of the mound would retain its structural integrity in the event of the collapse of mound material into the shaft and cavity. This will involve an assessment of the existing platform by a competent person and its reconfiguration as necessary.

6.4.3 The conclusions of this risk assessment are that:

- remote access to the shaft and cavity is possible provided that the risk level is reduced.
- the risk level can be reduced through a reconfiguration, if necessary, of the decking platform.
- measures will need to be put in place, and separately assessed, to create a safe system of working whilst any reconfiguration of the decking platform is taking place.

7 Options for further work

7.1 Option 1: remote access to the shaft, infilling, and archaeological survey afterwards on and around the mound.

7.1.1 This option is based on the premise that remote access will take place from a decking platform at the top of the mound, and that such a platform will withstand the collapse of material into the shaft.

7.1.2 Work carried out under this option will make the deposits within the shaft accessible through the provision of a measured, visual and graphic record. The work will directly address questions 7, 14-16 and 18-20 set out in section 5.11 and the management aim set out in section 5.12.

7.1.3 The fieldwork components of the programme will consist of:

- introducing survey control.
- reconfiguring the decking platform.
- carrying out three-dimensional laser scanning within the shaft and cavity.
- carrying out radar survey within the shaft.
- infilling the shaft and cavity and dismantling the decking platform.
- carrying out geophysical survey on and around the mound.

7.1.4 The following particular arrangements will be made with regard to Health and Safety:

- at least one mobile phone will be available at all times whilst people are working on Silbury Hill.
- First aid facilities will be available at the top of Silbury Hill with an Accident Book and English Heritage Accident Report Forms.
- all personnel on the decking platform will wear a full body harness, anchored to secure ground fixings.
- work will not be carried out in conditions that are wet, excessively windy or when lightning is felt to be possibility.

7.1.5 A Global Positioning System (GPS) will be used to place temporary survey control points on the top of the mound. This control will be used to reference the laser scanning and internal radar survey and to put in ground control that will be used in the external geophysical surveys.

This will be an opportunity to create two permanent intervisible survey stations at ground level. These stations would be located in areas that are not thought to be archaeologically sensitive, and would be designed to create minimum ground disturbance, be visually unobtrusive and present no Health and Safety risks.

7.1.6 The present decking platform may have to be reconfigured so that it will retain its structural integrity in the event of a collapse of mound material into the shaft and cavity. This reconfiguration would include the provision of guardrails around the access to the shaft and the provision of shelter for personnel and equipment.

If the decking platform has to be reconfigured then the design for this will require an archaeological assessment. Any ground disturbance during this work will take place under archaeological supervision.

7.1.7 Three-dimensional laser scanning will be deployed within the shaft and cavity to provide:

- a measured, visual and graphic record of the exposed deposits.

The equipment used will be a Callidus 3-D laser scanner mounted, with lighting, on an extending mast fixed to the decking platform. The laser will be operated through a PC controller and a generator on the top of the mound. The Callidus system uses a Class 1 laser and is eye-friendly. The measuring head contains the laser scanner, a software-controlled black and white CCD camera (600 dpi) and an electronic compass. In the measurement process the laser scanner is turned by 360° along the horizontal plane and the laser beam disperses by means of a rotating mirror to cover 180°+ in the vertical plane. The CCD camera is integrated into the system to provide summary and close-up images.

The measuring head will be lowered to *c* 10m from the surface of the mound ie just above the top of the collapsed infill. At this depth it will be able to gather 3-dimensional data on all the deposits in the cavity, although there will be an increase in the obliqueness of the angle of measurement as the depth of the deposits increases in relation to the measuring head. The head will then be raised and measurement will be repeated at suitable intervals within the shaft to provide overlapping coverage.

It must be noted that application of this technique to the deposits in the shaft presents technical difficulties. A system will have to be devised that will allow the measuring head to be stable at a depth of 10m. At the time of writing this is still being developed but is felt to be achievable.

The scanning will provide a point cloud of three-dimensional information and this will allow the shape and orientation of the walls of the shaft and cavity to be modelled. The points gathered in the data cloud have, however, to be translated into meaningful archaeological information eg to distinguish one layer from another or to identify individual sarsens. Ideally a web of registration points should be placed on the walls of the shaft and cavity prior to the laser scanning. This would involve 1 person descending in to the shaft for a period of approximately 2 hours but the risk exposure is unacceptable. In the present circumstances the registration points will be provided by ropes or rods clearly marked at measured intervals lowered vertically down each face of the shaft prior to the scanning.

These measurement devices will be captured by the laser scanning and the CCD camera and will provide a basis for interpreting the data cloud. The images provided by the CCD camera will be augmented by replacing the measuring head with a high resolution digital camera.

It should be noted that the precise interpretation of the points in the data cloud will present considerable difficulties at the present time.

7.1.8 A Ground Penetrating Radar (GPR) survey will then be carried out within the shaft to try to detect:

- structural features such as chalk walls within the later construction phase.

The equipment used will be a Pulse Ekko 1000 GPR console and 225/450 MHz centre frequency shielded antennae. The GPR console, power supply and PC controller will be stationed on the surface and a means would have to be devised to attach the antennae to the mast used in the laser survey.

At least one, and preferably more, radar transects will be collected down the vertical faces of the shaft. The station intervals will be 0.1m between traces with a suitable sample window to allow penetration to a depth of ~5m.

It must be noted, however, that there are considerable technical difficulties that should temper the expectation of successful results.

7.1.9 On completion of the laser scanning and radar survey the shaft can be infilled and the decking platform removed. As part of this process a non-metallic pipe, at least 0.20m in diameter, should be placed vertically within the shaft. This will provide access for instrumentation that may be required in a future geophysical survey.

7.1.10 Geophysical survey will then take place to try to detect and provide information on:

- the presence of any further cavities within the mound.
- the presence and disposition of archaeological features, and other undocumented interventions, in the upper levels of the mound.
- the overall character and form of the mound and its internal structure.
- the outer ditch and the buried ditch or quarry.

The techniques used would be conventional magnetic and area resistance surveys on the summit of the mound and Ground Penetrating Radar (GPR) across the mound. In the future this work could be augmented by resistivity pseudosectioning or seismic survey.

One radar profile will be collected across the entire monument with additional profiles as warranted. The equipment used in the radar survey will be a Pulse Ekko 100 GPR console together with a low frequency antenna (50MHz) to allow penetration to a depth of >30m. Manually triggered traces will be collected at 1m intervals over the steep slopes of the mound and elevation data will be recorded to allow for topographic correction.

Whilst the dense chalk layer itself represents a poor geophysical target, the change in density of material above and below this interface, and the presence of sarsens, should provide a suitable dielectric contrast to reflect incident EM waves from the GPR.

However, the presence of chicken wire, placed on the top of the mound to stabilise the turf, will reduce the possibility of achieving successful outcomes with these techniques, particularly with magnetometry. Resistivity survey might not be as affected if there has been some soil development and the chicken wire has corroded.

7.1.11 As the decking platform will be designed to withstand the possibility of collapse, archaeological fieldwork under this option will pose low risks with regard to Health and Safety, given the controls that are expressed above. The risk of sprains and minor injuries due to the handling and use of equipment on steep slopes, particularly in wet conditions, would be addressed through wearing suitable footwear and the provision of adequate handling capacity.

A separate risk assessment will be needed for activities associated with any reconfiguration of the decking platform.

7.1.12 Dr Colin Shell of the University of Cambridge has carried out a detailed aerial photogrammetric survey of the mound and it is hoped that this will be made available to the project.

7.1.13 An assessment will be made of the existing core through the mound.

7.1.14 The results of the field evaluation, the laser scanning, the topographic and geophysical surveys, the core assessment and previous investigations will be assimilated to create a three-dimensional computer-generated model of Silbury Hill.

7.1.15 The project team for the archaeological components of this option will be:

Fachtna McAvoy	Project manager (archaeology)	Centre for Archaeology
Grant Little et al	Laser scanning Survey control	Survey Associates
Arthur McCallum	Engineering	Conservation Engineering
Andrew David et al	Geophysical surveys	Centre for Archaeology
Miles Hitchen	Computing	Centre for Archaeology
Adrian Brown	Records/archiving	Centre for Archaeology
John Vallender	Graphics	Centre for Archaeology
David Webb	Logistics	Centre for Archaeology

7.1.16 The fieldwork programme for this option will be:

Day 1	Decking reconfiguration and laser set up Survey control
Day 2	Laser survey
Day 3	Laser survey and GPR survey (internal)
Day 4	Geophysics survey (external)
Day 5	Geophysics survey (external)

7.1.17 The programme set out above will be translated into a fully costed and timetabled project design once decisions have been taken on the archaeological option to be adopted and the means and methods for infilling the shaft. The means of transporting infill material to the top of the mound could perhaps be utilised for the movement of the equipment that may be needed to reconfigure the decking platform and for the laser survey.

7.2 Option 2: infilling the shaft with archaeological survey afterwards on and around the mound.

7.2.1 This option is based on the premise that the current decking platform is not able to withstand the effects of collapse and that platform could not be reconfigured to do so because this is either not practical, not safe or would involve an acceptable disruption of archaeological deposits.

7.2.2 This option will only directly address questions 18-20 and the management aim stated in section 5.12. The record of the deposits in the shaft will be that produced prior to, and during the evaluation.

7.2.3 The fieldwork programme will consist of:

- infilling the shaft and cavity and dismantling the decking platform.
- introducing survey control.
- carrying out geophysical survey on and around the mound.

7.2.4 A non-metallic pipe, at least 0.20m in diameter, should be placed vertically in the shaft prior to infilling. This will provide access for instrumentation in any future geophysical survey. The shaft can then be infilled and the decking platform can be dismantled.

7.2.5 Two temporary survey control points will be brought on to the top of the mound using local Ordnance Survey triangulation points and a total station theodolite. This control will be used to provide spatial referencing for the top of the shaft and the geophysical survey.

This will be an opportunity to create two permanent intervisible survey stations at ground level as set out above in section 7.1.5.

7.2.6 Geophysical survey will take place as set out above in section 7.1.10

7.2.7 <u>Archaeological</u> work under this option would involve a low risk with regard to Health and Safety. The risk of sprains and minor injuries due to the handling and use of equipment on steep slopes, particularly in wet conditions, would be addressed through wearing suitable footwear and the provision of adequate handling capacity.

Work related to the infilling of the shaft would require a separate risk assessment.

7.2.8 The procurement of a topographic survey and the assessment of the existing core are the same as set out above in sections 7.1.12 and 7.1.13.

7.2.9 The results of the field evaluation, the topographic and geophysical surveys, the core assessment and previous investigations will be assimilated to create a three-dimensional computer-generated model of Silbury Hill.

7.2.10 The project team for the archaeological components of this option will be:

Fachtna McAvoy	Project manager (archaeology)	Centre for Archaeology
Tom Cromwell	Survey	Centre for Archaeology
Andrew David et al	Geophysical surveys	Centre for Archaeology
Miles Hitchen	Computing	Centre for Archaeology
Adrian Brown	Records/archiving	Centre for Archaeology
John Vallender	Graphics	Centre for Archaeology
David Webb	Logistics	Centre for Archaeology

7.2.11 The fieldwork programme for this option will be:

Day 1	Survey control, geophysics survey
Day 2	Geophysics survey

7.2.12 Work under this option is designed to take place after the infilling of the shaft. The programme set out above will be translated into a full project design once a decision on the archaeological option to be adopted has been taken and the date for infilling the shaft has been established.

8 Dissemination

8.1 The archive resulting from any further work will be deposited in the Alexander Keiller Museum in Avebury (registered with the Museums and Galleries Commission) and summaries will be provided for the local SMR and NAR.

8.2 At present it is envisaged that dissemination of the academic results will be through articles in Antiquity and the Proceedings of the Prehistoric Society.

9 Statutory designations and approvals

9.1 Scheduled monument consent will have to be obtained if intrusive work is to be carried out. This consent would be issued by the Inspector of Ancient Monuments under Class 6 of the Ancient Monuments and Archaeological Areas Act 1979.

9.2 A license for geophysical survey under section 42 of the 1979 Act is not required in this instance as the Archaeometry branch of English Heritage is carrying out the survey work.

9.3 Silbury Hill is a Site of Special Scientific Interest (SSSI) under the Wildlife and Countryside Act 1981. English Nature will be notified of the intended programme and will be provided with a copy of the project design.

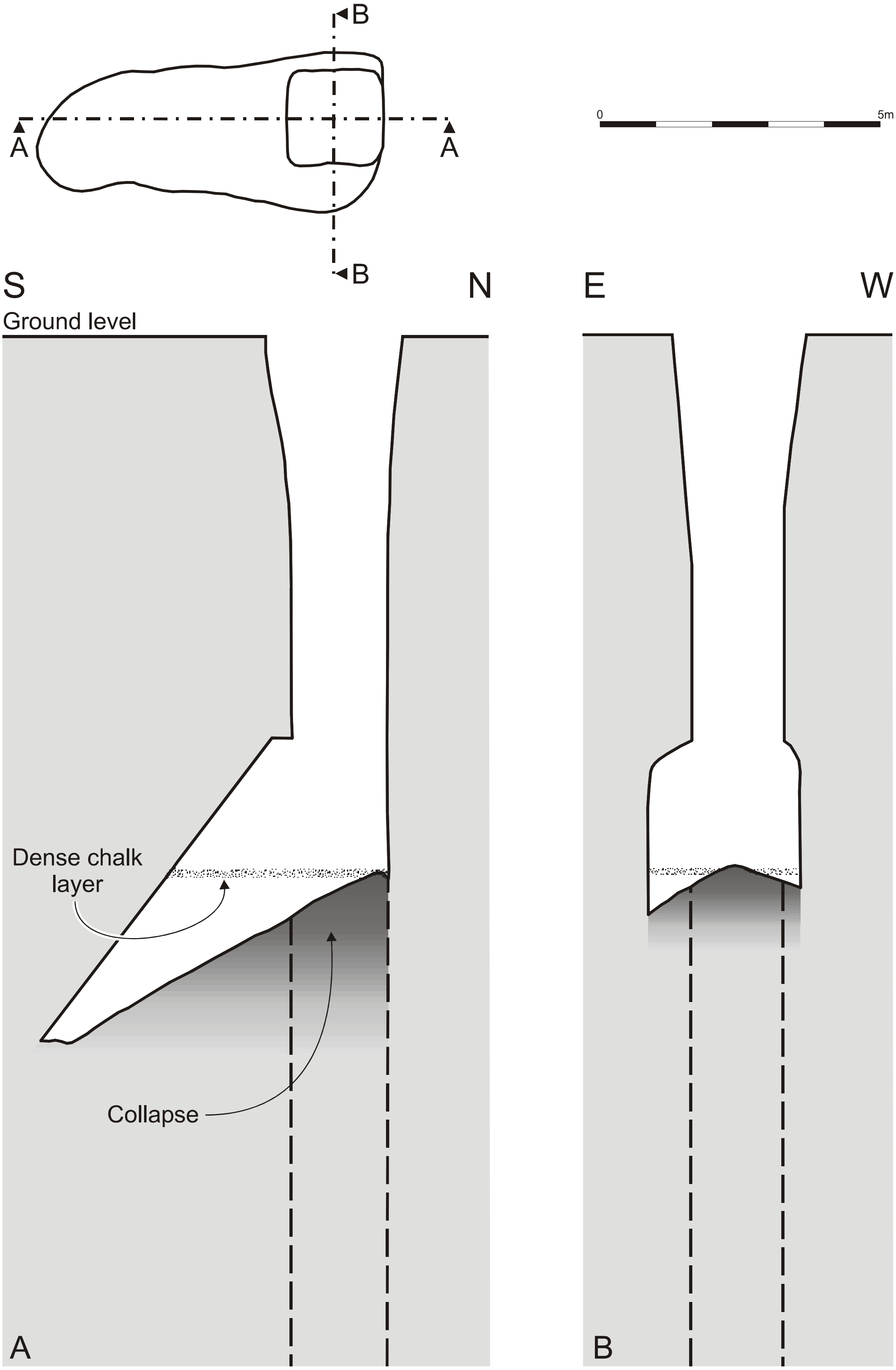

Figure 1: simple dimensional survey of the shaft and cavity (after G Daws ass)

Figure 2: the cavity at the base of the shaft

Figure 3: votive bull

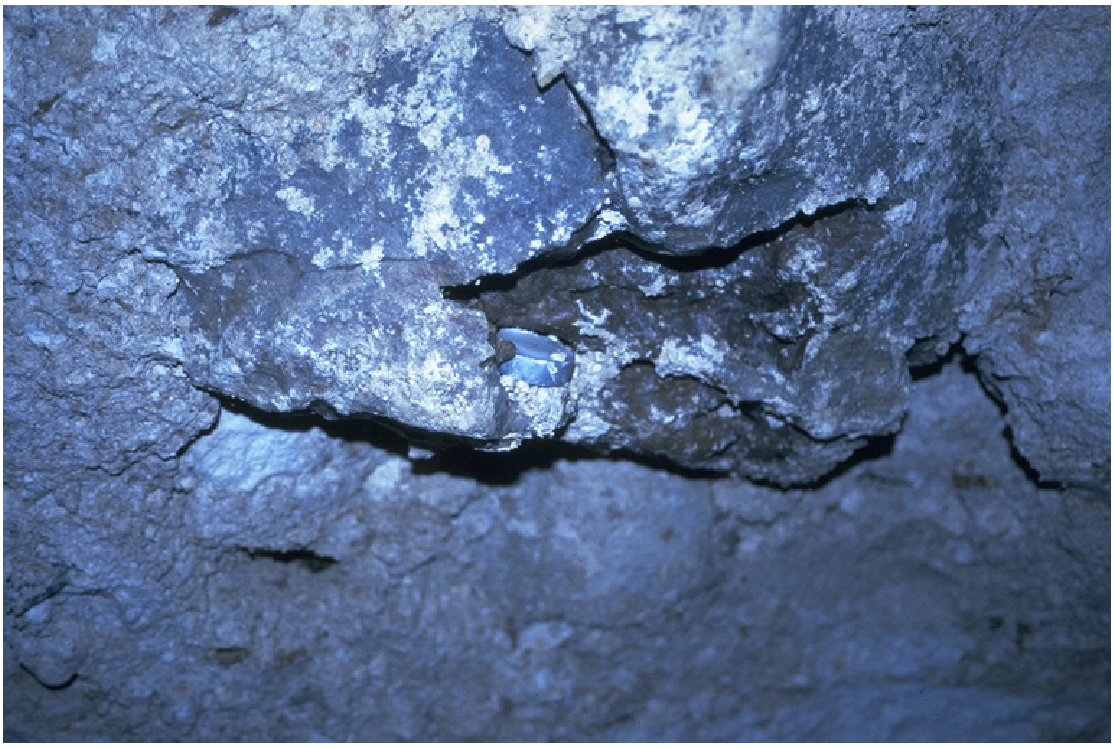

Figure 3a: candle lying within sarsen

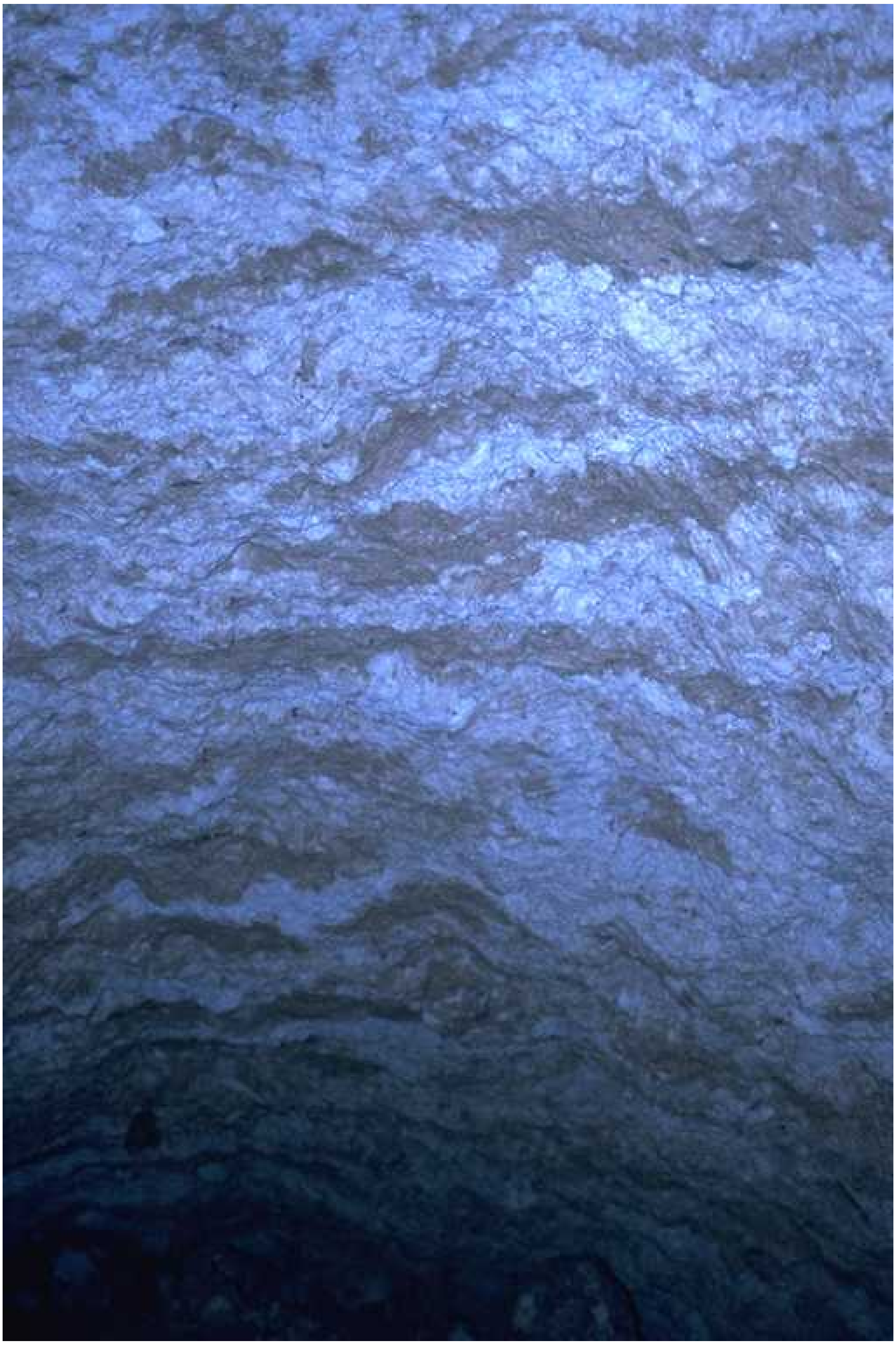

Figure 4: chalk and soil bands

Figure 5: chalk rubble and clay spillage layer in the shaft wall

Figure 6: dense chalk layer with sarsen

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The risk assessments are the responsibility of the author.

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