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Wookey Hole Chamber 20 SSSI Audit

Engineering Geology Programme

Commissioned Report

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Wookey Hole Chamber 20 SSSI Audit

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Front cover. Fluting in Wookey Chamber 20. Photo by Gavin Newman.

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Foreword

This report documents an audit of geological features of potential scientific and aesthetic importance in Wookey 20. This audit was created by the British Geological Survey (BGS) under commission by Wookey Hole Caves Ltd as part of the planning conditions for the extension of the show cave from Wookey 9 into Wookey 20.

Acknowledgements

The author of this report wishes to thank Andrew Atkinson, Duncan Price and Naomi Sharp for assistance underground, and to Gavin Newman for use of some of the excellent cave photographs. The owner of Wookey Hole, Daniel Medley is thanked for allowing access to the cave, and for constructive comments on the report. The cave survey used in this report was compiled by Andrew Atkinson, Duncan Price, Gary Jones, Connor Roe and Malcolm Stewart. Thanks to Tony Waltham, Duncan Price and Peter Glanvill for their comments on the report and for information about the underwater fluting.

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1 Introduction

Wookey Hole Caves is a Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981 as amended, and falls within the boundaries of the Mendip Hills Area of Outstanding Natural Beauty. It is notified both for the large-scale development of cave passages and associated limestone scenery which it demonstrates and for the occurrence of two Pleistocene 'bone-caves', containing the fossilised remains of vertebrate animals which lived in the area during the Ice Age. Details of the cave are documented in Hanwell et al. (2010).

A planning application was submitted to Mendip District Council in February 2015 by Wookey Hole Ltd. to extend the show-cave by constructing a tunnel from Wookey Chamber 9 to Chamber 20. The construction of the tunnel would open up part of the cave system previously only accessible to cave divers. The section of cave known as 'Wookey 20' comprises 719 m of passage divided into two distinct elements: the main chamber, which will be open to the public as part of the standard tour; and a passage extending approximately 300 m to the north. This passage is currently not scheduled to be part of the show-cave tour, but it is understood it may be considered for 'Adventure Caving' trips in the future. This part of the cave also includes several minor side passages. The chamber and associated passages are known to contain features, sediments and speleothems (stalagmites, stalactites and flowstone deposits) of both aesthetic and potential scientific importance which may be adversely impacted by the extension of the show-cave and any future 'Adventure Caving' activities.

As part of this application, Natural England provided a statutory consultation response under the provisions of Article 10 of the Town and Country Planning (General Development Procedure) Order 1995, Section 28 of the Wildlife and Countryside Act 1981 (as amended) and Regulation 61 of the Conservation of Habitats and Species Regulations 2010 (as amended). Following this consultation, planning permission for this development was granted by Mendip District Council (application 2015/0328/FUL) on 30th April 2015 subject to certain conditions set out in the Decision Notice. Of these, conditions 10 and 11 are applicable to the geological integrity of the site. These are:

Condition 10. The infrastructure to be installed to facilitate public access to Chamber 20 following completion of the tunnel (including walkways, handrails, power supply and lighting) must not damage cave passage morphology, cave sediments and speleothems. Reason: To protect the cave features for which the site is designated as a statutory nature conservation site of national importance from damage during construction.

Condition 11. As soon as possible after the tunnel is completed, and before any infrastructure is installed and public access commences, the applicant must make arrangements for a cave scientist to record the presence and state of interest features (including sediments and speleothems) found in Chamber 20. The report must be made available to Natural England and placed in the public domain free of charge. Reason: To protect the cave features which are *interest features of the Wookey Hole Site of Special Scientific Interest (SSSI), a statutory nature conservation site of national importance), and a qualifying feature (Caves not open to the public [Chamber 20 in its present state]) of the North Somerset and Mendip Bats Special Area of Conservation (SAC), which is part of the Natura 2000 network of European Sites and a site of international importance.*

In order to fulfil Condition 11, the British Geological Survey was contracted to undertake a geological audit of Wookey Chamber 20 and the passages leading off from it. The tunnel broke through into Wookey 20 on Thursday 16th July 2015, and the geological audit was undertaken on Sunday 19th July 2015 (11 am) by Dr. Andrew Farrant, with the assistance of Andrew Atkinson. Dr. Duncan Price and Naomi Sharp also provided logistical support. On arriving at the site, temporary scaffolding and infrastructure was already being constructed across the floor of the Wookey 20 Chamber. The divers had previously laid conservation tape across the floor of the chamber, delimiting areas of intact sediments and fluted rock formations, and in places in the passage leading off. Further taping was undertaken in the passage leading off the chamber during the audit by the author and Andrew Atkinson.

1.1 LIMITATIONS OF THE REPORT

The minor side passages in Wookey 20 were not examined, nor were any of the underwater passages (sumps) in the cave or inaccessible areas in the roof of Chamber 20. Other parts of the cave, including the existing show cave were not audited. The state of the cave prior to the tunnelling was not assessed in either the show-cave or Wookey 20, and thus a comparison between the cave before and after the tunnelling was not possible except with the aid of photographs. This report does not include an assessment of the bat population or the biodiversity of the cave. The exclusion of any features or deposits from this survey does not imply that these are of no scientific or aesthetic interest. As yet, little or no serious scientific work has been undertaken on the deposits and features within the cave and their scientific value remains unquantified. No geological samples were taken from the cave. The author was not present during the tunnelling operations.

2 Geological Audit

The geological audit confirms the original SSSI designation that "*Wookey Hole is the finest example in Britain of a cave formed by deep phreatic activity and the sequence of fossil and active caves provides evidence of a long and complex geological history*".

2.1 GEOLOGY

Wookey Hole is unusual in that it is developed in both Triassic and Carboniferous strata (Figure 1). Much of the inner part of Wookey Hole (beyond Chamber 9) is developed in the Carboniferous Clifton Down Limestone Formation, which dips at between 30 and 45 degrees to the south (Farrant, 2008). This is overlain by the younger Triassic 'Dolomitic Conglomerate' (more formally termed the 'Mercia Mudstone Marginal Facies'). This is a reddish-brown limestone breccia made up of angular clasts of Carboniferous limestone cemented together, deposited as terrestrial scree or outwash deposits The conglomerate is generally horizontally bedded and overlies the limestone with a marked angular unconformity. Most of the present show cave is developed in the Dolomitic Conglomerate.

The main chamber in Wookey 20 and the passage leading off it are developed in the Clifton Down Limestone Formation at or just below the Triassic unconformity. The unconformity is well exposed in the roof of the Chamber, particularly at the eastern end, in the recently opened access tunnel and in the small chamber at the top end of the passage leading off from the main Chamber.

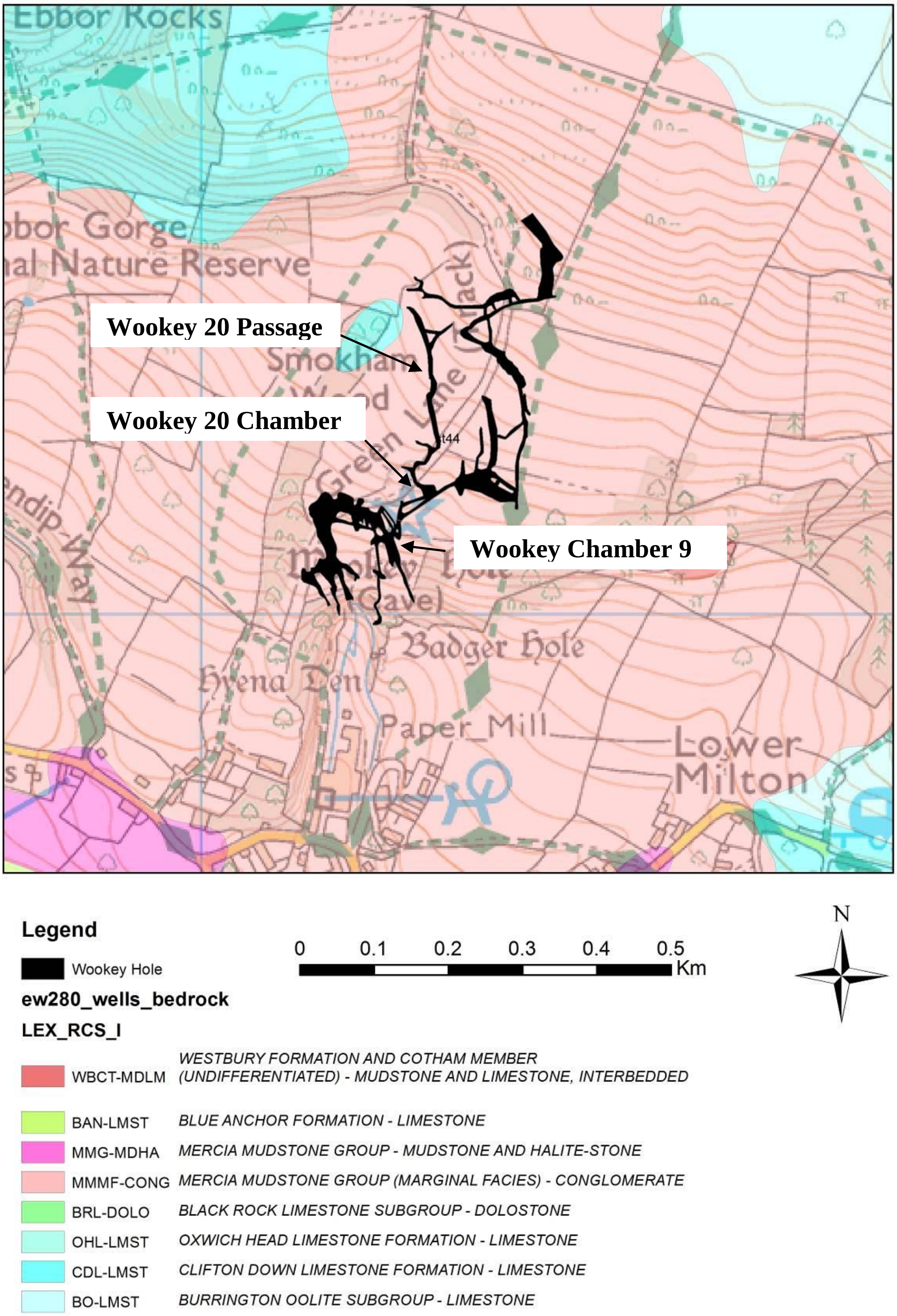

Figure 1. Geological map of Wookey Hole and the surrounding area. DigMapGB 1:50 000 scale data.

2.2 GEOMORPHOLOGY

Wookey 20 can be divided into two distinct sections: the Wookey 20 Chamber; and the section of passage which ascends to the north.

The passage leading north from the main Wookey 20 Chamber forms the descending limb of a 60 m deep phreatic loop, the lowest point of which is the sump pool in the Wookey 20 Chamber. It displays many classic characteristics of a phreatic passage developed in dipping strata and is one of the finest examples of a deep phreatic loop accessible to non-divers the UK. This phreatic loop developed when the water table was at or above c. 125 m OD, and may be associated with the 156 m OD palaeo-water-table level seen in Swildon's Hole (Double Trouble series) (Irwin et al., 2007). It is primarily developed along bedding plane discontinuities, although some joint are visible at various places. The passage trends both along strike and down dip. Strike aligned sections are quasi horizontal and display characteristic elliptical cross sections, whilst dip-aligned sections descend down the dip as more rounded phreatic tubes. Some parts of the conduit descend obliquely down-dip.

The basal part of a deep phreatic loop is the main Wookey 20 Chamber. This is a large strike-orientated section of passage which has been intersected, modified and enlarged by the modern River Axe which enters at the eastern end. It is mostly developed within the limestone, although the Dolomitic Conglomerate is exposed in the roof at the south-eastern end. The ascending limb of the loop is as yet undiscovered, but may ascend off the eastern side of chamber at roof level, rising vertically up joints in the Dolomitic Conglomerate.

The geological features observed within these passages are described below.

2.3 GEOLOGICAL FEATURES

A variety of geological features occur in Wookey 20. Some are of potential scientific interest, whilst others have more aesthetic value. Cave sediments and speleothems are particularly vulnerable to damage and these need particular protection. Bedrock features including scalloping and fluting are more robust and are less prone to damage by casual visitors, but also have aesthetic value when in a clean and pristine state.

The location of individual features in Wookey 20 is shown in Figure 2. The survey used is by Atkinson et al., (2015) and survey is published under the General Public Licence (GPL3+). The source data is available from http://www.cave-registry.org.uk/svn/WookeyCatchment/.

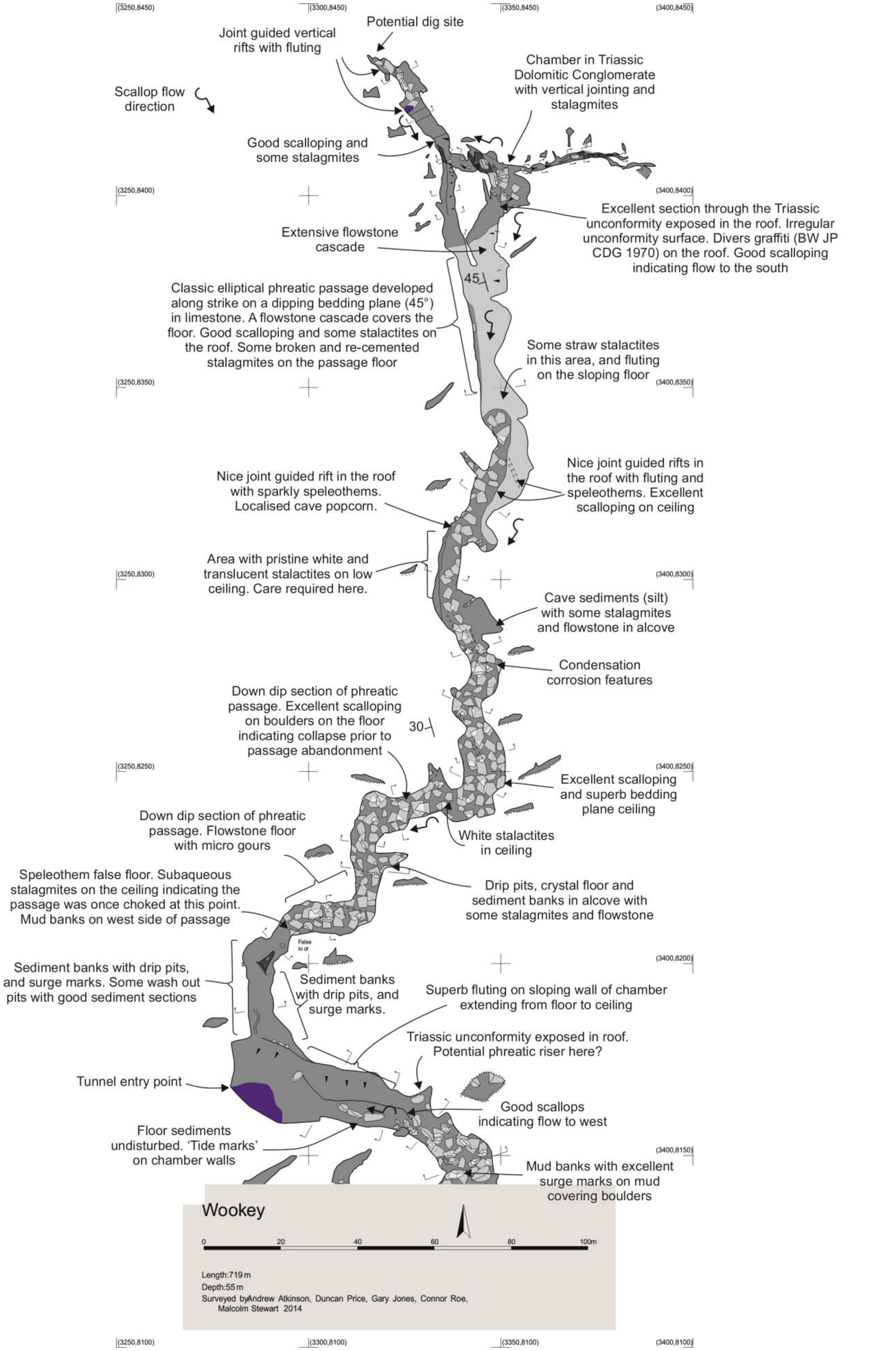

Figure 2. Location of geological features in Wookey 20. Cave survey by Atkinson et al. 2015.

2.3.1 Triassic unconformity

The unconformity between the Triassic Dolomitic Conglomerate and the Carboniferous limestone is well exposed at several points in Wookey 20. It is best exposed close to the top end of the passage leading north from the chamber. Here a small chamber is developed within the conglomerate, and the unconformity is clearly seen just above the inscriptions left by the cave divers Brian Woodward and John Parker who first found this passage in 1970 (BW JP CDG 1970). The unconformity is also well exposed in the roof of the main chamber, between the tunnel entry point and sump at the east end of the chamber (Figure 3). The blasting of the access tunnel has also revealed an excellent new exposure of the unconformity, which should be clearly visible to visitors. The same unconformity is also observed in the Wookey 12-13 complex.

Figure 3. Section through the Triassic unconformity in the roof of Chamber 20.

The large limestone clasts within the conglomerate can be clearly seen. The muddy slope in the lower part of the photograph (Figure 3) is on Carboniferous Limestone.

2.3.2 Scalloping

Parts of Wookey 20 display excellent phreatic scalloping, particularly in the upper parts of the passage leading off main chamber (Figure 4). These are scientifically important as the size of the scallops can be used to quantify flow velocity and direction when the passage was last active. From this, estimates of palaeo-discharge can be obtained. Scallop morphology clearly indicates flow to the south, confirming the passage formed the descending limb of a deep phreatic loop. In some places, boulders on the floor are also scalloped, indicating passage breakdown whilst the conduit was still active. Scallops are robust features and are unlikely to be damaged by caver traffic, although their aesthetic value may be compromised if covered in mud.

Figure 4. Well defined phreatic scalloping exposed in the upper part of Wookey 20.

The scallops in this image are on bedrock and indicate phreatic flow downwards (south) into the continuation of the passage in the background. The hand is 20 cm long.

2.3.3 Condensation corrosion

As well as phreatic scallops, bedrock dissolution features associated with condensation corrosion are locally common. These typically occur as small 0.1-2 cm dissolutional dimples on the passage walls and roof, which look superficially similar to scallops (Figure 5). They are formed when warm humid air condenses on the colder rock walls of the cave passage. Water condensing on the cave walls quickly attains equilibrium with the carbon dioxide in the surrounding air, and consequently dissolves limestone. When diurnal or seasonal variations of the air temperature are active as is the case close to cave entrances, condensation rates can become quite significant. The occurrence of condensation corrosion features suggests that there may be a route for warm surface air to enter this part of the cave, either at the top end of the passage or in the roof of the main Wookey 20 Chamber.

Figure 5. Possible bedrock condensation corrosion features in the upper part of Wookey 20 passage.

2.3.4 Fluting

The most impressive feature of Wookey 20 is the spectacular fluting on the wall of the main Chamber opposite the breakthrough point (Figure 6). These are the most spectacular examples of these features in the UK and are unusual in their extent and size. They are similar to surface features known as 'rillenkarren' which are produced by rainfall on limestone outcrops. Similar fluting also occurs, albeit on a smaller scale at the top end of the Wookey 20 passage, close to the terminal choke, particularly on the vertical sides of joint guided avens. These flutes are thought to have been formed by a combination of dissolution by water draining down the rock slope from bedding plane fissures at the top of the slope and by condensation corrosion. The latter occurs when warm humid air condensing on cold rock surfaces to generate acidic water which then runs down the wall to produce the fluting. Some additional water may be derived from water dripping down out from fissures in the roof above the fluting. Although these features are relatively robust, care should be taken to preserve them as they are the most spectacular geomorphological feature in the cave.

Similar features have been observed in the sumps up to Wookey 22 (Duncan Price pers. comm.) and also in the Lake in Wookey 20 - though the latter are now partially obscured by rubble. They have been observed to continue down to -6.3 m below the current water level. As these features are subaerial in origin, this might suggest that the possibility of the water-level in Wookey may have been lower in the past, either due to a rock-fall/scree damming up the entrance, or the leakage to Glencott Spring being blocked. The current sluice gate raises the water level by c. 1.5 m. However, similar features, known as "pseudokarren", have been observed in underwater caves in Yorkshire (Murphy and Cordingley, 1999). These are thought to be abrasional features, formed by the repetitive circulation of sand grains under phreatic conditions. In this scenario, sand grains forced upwards by water flow under pressure then settles out and descends down the grooves under the influence of gravity before being recirculated under high water conditions.

Figure 6. Close up of the superb fluting exposed in Chamber 20. See also the frontispiece.

2.3.5 Cave sediments

Cave sediments occur locally throughout Wookey 20, but are concentrated mostly in the lower part of the passage nearest the river. The sediments are mostly fine grained silts and clay. The best sediment sections occur in a small washed out gulley in the short section of horizontal passage close to the initial climb out of the Chamber (Figure 7). Here approximately 80 cm of sediment are exposed forming a fining-up slack-water deposit. The base of the section is relatively coarse-grained sand with small well-rounded limestone granules, limonite and mud flakes. This passes up into finer-grained sands, and capped by silt. The sediments record the gradual abandonment of the conduit as the river adjusted to the development of the present river passage.

Some of the cave sediment banks exhibit nice examples of surge marks and drip pits, particularly at the lower end of the passage exiting off Chamber 20. These are some of the best preserved examples on Mendip. The former are produced by the swash and backwash of pulsed floodwaters (Bull, 1978), whilst the latter are created by water dripping onto the mud banks from above. Ripple marks or other sedimentological features indicative of flow were not observed, although they may have once existed in the chamber floor prior to its discovery. There is evidence of former higher water levels from sediment 'tide marks' preserved on the walls around Wookey Chamber 20. These indicate water levels were once a few metres higher.

The floor of the main chamber is underlain by sand. Much of the chamber floor had been walked over by cave divers prior to the tunnelling, but several areas were still pristine, especially close to the wall. It is not known how thick the sediments are.

Cave sediments are particularly vulnerable to disturbance, and every effort should be made to make sure key sediment sections are taped off and protected. Many of the most vulnerable sediment banks and speleothems had been taped off prior to the construction of the tunnel, and ongoing conservation work will enhance this. Small sections of the pristine sediment floor in the Wookey 20 Chamber were damaged during the construction of the scaffolding, despite them being taped off (Figure 13). Below the top few centimetres, the underlying deposit is still largely intact.

Figure 7. Cave sediments close to the main Wookey 20 Chamber.

Here drip waters have washed out some of the sediments, creating a good section through them. Coarse pebble sand with mud-flakes, ironstone and limestone clasts at the base pass up into finer grained sand and silt.

2.3.6 Speleothems

Speleothem deposits are relatively uncommon in Wookey 20, and there are few outstanding flowstone deposits. Clean white stalactites up to 10-20 cm long occur sporadically in parts of the passage leading north. These are probably of Holocene age. Some of these occur in low sections of passage and are very vulnerable to damage. Taping will be required to protect these. Towards the upper end of the Wookey 20 passage, the passage is locally obstructed by a large flowstone cascade with micro gours. Whilst this is a more robust deposit than the stalactites, taping will help preserve it in a pristine state.

Approximately half way along the passage there is evidence of an earlier phase of speleothem deposition. A series of flowstone gours on the passage floor can be traced downslope into a section of false floor (Figure 8). Here the flowstone has been undermined and collapsed by settlement of the underlying boulder floor. Naturally broken speleothem fragments occur on the passage floor. Traces of sub-aqueous speleothem on the roof at this point indicate that the passage here was once totally blocked and a series of gour pools had developed prior to subsidence.

Calcified drip pockets are present in some of the mud banks. In some places, particularly near the area of the false floor, these calcite drip pockets have been washed out of the mud, and occur scattered on the floor.

Figure 8. The speleothem false floor exposed in the passage leading off the Wookey 20 chamber.

The stalagmite here was originally deposited over boulders and sediment which have since subsided or washed out, leaving it suspended. Fragments of broken speleothem litter the passage floor.

2.4 IMPACT OF THE TUNNELLING ON THE CAVE.

This section highlights the impact of the tunnelling on the state of 'interest features' in the cave. Overall, the tunnel appears to have been well constructed and has had little long-term impact on the scientific integrity of the SSSI which is based largely on the phreatic morphology of the cave as a whole. The key features of scientific importance are still intact and have not been significantly damaged by the tunnelling operations. The tunnel has also revealed a new exposure of the Triassic unconformity. The show-cave owner is working with the caving community to put in range of conservation measures in Wookey 20 to protect features of both scientific and aesthetic importance. It should be noted that the constructive working partnership between the show-cave owner and the caving community is excellent, and has significantly reduced the impact of the tunnelling on the cave.

Inevitably on a project of this nature, some issues did arise during the operations, particularly at each end of the tunnel which have had a detrimental impact on the cave. The preliminary geotechnical report (Gould, 2015) submitted during the planning application highlighted the potential impacts tunnelling operations could have on the cave (sections 3 – 4.1.2 and 3 – 4.2.5.).

3 – 4.1.2 *"The tunnelling operations will also generate noise, dust vibrations and have the potential to contaminate the groundwater. These will need to be carefully considered and appropriate measures taken to protect the cave system and the wider environment."*

3 – 4.2.5. *"Blasting operations will cause vibration of the ground in the vicinity of the tunnel heading, although if the blast is designed correctly any damaging vibrations should attenuate rapidly from the blast site. The effects of blast vibrations on the show cave ornamentation (stalactites and stalagmites) should be assessed by the tunnel design engineer. It is possible that vibrations from the blasting operations might also potentially disturb loose rocks in the submerged natural cave connecting Chamber 9 and Chamber 20."*

The show cave management made a considerable effort to put in place measures to mitigate the impact of the tunnelling. The Method Statement provided for the planning application by the tunnelling contractor (Tunnel Contractors Method Statement, 2014) states that "*The first couple of blasts within chamber 9 will be carried out with lighter blasts to prevent disturbance of existing rock formations within the chamber*." A separate Method Statement for the tunnel blasting operations (Blasting Engineers Method Statement, May 2015) is more explicit regarding the protection of cave features. The section on 'Blast Protection' states:

"On completion of charging the holes the tunnel mouth [in Chamber 9] *would be covered with suitable protective covering as deemed necessary by the shot-firer in consultation with the Drilling Contractor & Tunnellers. These may include Steel Trench sheet piles, sleeper-mat and rubber conveyor belt matting, sandbags etc."* In Wookey 9, blast curtains made from straw bales, car tyres and railway sleepers were put in place. The tunnel contractors state that dust suppression, waste water collection and bio-oils were used during the tunnelling and strictly adhered to throughout the contract. A sump tank was installed in Chamber 9 to catch any waste water.

A separate section in the Method Statement for the tunnel blasting operations discusses the breakout into Wookey 20.

"Merging of Tunnel into Cavern 20.

At present, the cave divers have not given us an accurate length or direction of the proposed tunnel drive. It is therefore essential that as we near what we may later learn to be a good close proximity to Chamber 20 when the data is obtained, that considerable advance "Probe Drilling" is brought in. We intend that this shall be in "Line Ahead" and leftwards, rightwards, above and below the tunnel line, as it is essential that as we near the "Breakthrough Point" blasting methods will be seriously curtailed and maybe even be concluded, leaving the final breakthrough *to be effected with Jiggers or similar equipment, in order to maximise* (sic?) *the ecological effect on the walls of Chamber 20, and to afford maximum protection to the speleotherms* (sic), *sediments, sump pool and rock strata that may possibly lie in the path of this operation. We recognise this as a major requirement of both Natural Englands' concerns and our own desire as cave conservationists with a history dating back to 1970. We also note the requirement of Mendip District Council's planning consent.*

Tool Box talks regarding construction techniques, specifically linked to the tunnel exiting into any cavern or chamber we may yet meet along the tunnel drive as well as good conservation housekeeping will be given to all staff engaged in this operation by the Directors of both [the tunnel engineers], *Wookey Hole Caves Ltd and* [the blasting engineer].

We are advised by the Cave Divers at this stage that no "taping" of any formation exists in Chamber 20, though this may not necessarily indicate any reason why we should not proceed to merge the Tunnel and Chamber 20 with extreme caution."

The Wookey Hole management also engaged Bristol University "*to install seismometers in couple of locations to monitor vibrations throughout the cave system and picked up on an early blast a reading of peak particle velocity of 0.2mm/sec which they thought was very good and not damaging to the rest of the cave system or the bats."* (D. Medley pers. comm.).

From visual inspection of Chamber 20 after the tunnel broke through, and from verbal reports following the tunnelling operations, the blasting of the tunnel has had some detrimental impacts on the cave, both in Wookey 9 and Wookey 20. Most of these are aesthetic, and do not impact on the scientific integrity of the SSSI. Despite the blast curtains, it is understood that a stalactite curtain in the roof of Chamber 9 above the 9:2 sump pool was dislodged during the initial tunnelling operations. This may have been avoided using a more considerate blasting methodology. A safety net was subsequently installed in the roof of Chamber 9 to protect against any further rock-fall. The railings in the existing show-cave in Chamber 9 were significantly damaged by the initial blast, mainly because the rubber conveyor matting they were covered with acted to absorb some of the blast wave. This may have protected other features from potential damage. The lower walls of the chamber are presently coated by rock dust, which probably can be washed off. There is no evidence of any other damage attributable to the tunnelling within Chamber 9 or in the associated high level passage (D. Price, pers. comm.). However, a full 'before and after' audit of Chamber 9 was not undertaken.

The tunnelling operations inadvertently entered the side of Wookey 10 (given uncertainties in underwater cave survey data, this was always a possibility), causing some rock debris to fall into the lake in Wookey 10. To avoid the ingress of additional debris during blasting, a steel protection plate was constructed around it to protect it from loose spoil and gas fumes and reduced blasts were undertaken until they were a safe distance away from it (D. Medley, pers. comm.). During subsequent operations to enlarge this opening to give a better view into the chamber, some additional material fell in. A survey by the cave divers indicates the debris is in the form of a cone 5 m in diameter and around 2 m high (D. Price, pers. comm.). This could be removed at a later date. There is currently a lot of silt in the sumps between Wookey 3 and the slot beyond Wookey 9, and the lower 'Loop' route from Wookey 9:1 to 9:2 is presently blocked. Some of this silting occurred before the tunnel was constructed (D. Price, pers. comm.), so may be natural. Visibility along the Deep Route down to the Slot is now good, although the formerly gravel slop between 15 and the Slot is now covered in silt. Much of this will probably be flushed through during winter floods. A few shards of rock have fallen down in the sump beyond Wookey 10.

The entry of the tunnel into Chamber 20 has had some detrimental impacts on the chamber (Figure 9 and Figure 10). The contractors state that "*the breakthrough into Chamber 20 was carried out as gently as reasonably practicable and covered by on site signed briefings. A small 2' 6" diameter hole was blown in the bottom left hand corner to gain access*". Based on probing, "*the blast design was adjusted accordingly*" and was "*all agreed with on-site discussions*". The rest of the rock face was shaped out with air jiggers.

However, the blasting associated with the breakout into Chamber 20 showered part of the chamber with rubble, and much of the floor beneath the breakthrough point was covered in blast debris or material subsequently dislodged from the ceiling. Flying debris created visible impact marks on the opposite wall of the chamber, including on part of the fluting, over 10 m from the entry point and several metres above the sediment floor (Figure 11). A quantity of rubble fell in the lake in Wookey 20. In addition, the rock around the exit point was heavily shattered, and required concreting. The section of wall that the tunnel entered into Chamber 20 was very unstable and had to be barred down and significantly trimmed with jackhammers to ensure the safety of all persons within the area. Inevitably, some of the debris fell on to the sediment floor and into the sump. Some minor damage also occurred during the construction of the scaffolded walkway despite the sediments being taped off.

It is clear the majority of the damage in Chamber 20 was caused by the use of explosives during the final phase of blasting to achieve the break-through. As outlined in the blasting Method Statement, this damage could have been avoided by the use of simple alternative rock-removal methods such as a jackhammer or hydraulic breaker to remove the last half-metre of rock, particularly as the distance to breakthrough was well known in advance from probe holes. Furthermore, more considerate excavation methods would have resulted in less shattered rock, reducing the potential for roof failure. Despite what was written in the Method Statement for the tunnel blasting operations, no measures were put in place in Chamber 20 to prevent the sediments or cave features being impacted from falling debris or fly-rock. Given the cave is a Site of Special Scientific Interest and a bat hibernaculum, it is clear the effects of the break out into Chamber 20 on the show cave ornamentation, on the cave sediments and rock sculpturing in the chamber were not fully assessed by those involved with the blasting. Nor were sufficient appropriate measures put in place to protect the chamber from the detrimental impacts of the final phase of blasting. A more precautionary approach (as highlighted in the Method Statement) should have been taken, especially given the scientific importance of the sediments and features in Wookey 20 had yet to be fully assessed. Fortunately, the effects of the blasting missed the most vulnerable parts of the chamber, although this is probably more through luck than judgement, and the integrity of the SSSI was not compromised. Most of the detrimental effects are superficial and aesthetic in nature and may be remedied by the removal of blast debris. It is understood that much of this has now been done or is underway.

The rest of Chamber 20 away from the tunnel breakthrough point and the scaffolded walkway is still in a relatively pristine state. Here, no detrimental effects from the tunnelling have been observed; any damage here occurred prior to tunnel breakthrough. The conservation measures already put in place in the passage off the main chamber by the show-cave management in collaboration with the caving community, together with the recommendations outlined in this report should be sufficient to keep it this way. However, continued vigilance and regular inspections will be required in future to prevent long-term deterioration. This audit and a photographic base-line record should assist with this.

Figure 9. Wookey 20 just prior to the breakthrough of the tunnel.

The probe hole can be seen in the top middle of the photo. Image by Gavin Newman.

Figure 10. Wookey 20 just after the breakthrough of the tunnel.

The debris from the final blast can be seen on the floor. Significant spalling of the limestone roof has also occurred, which was brought down after the blasting. Image by Gavin Newman.

Figure 11. Fluted wall opposite the breakthrough point, about 10 m from the blast site.

White areas are impact marks caused by flying debris (fly rock). The sheer face at the base of the photo is about 1.5 m high.

Figure 12. Fly rock debris on the floor of Chamber 20, at the base of the fluted wall.

Note the taping put in place to protect the sediment floor prior to breakthrough (replaced after blasting). Subsequent verbal reports suggest much of the debris has now been removed.

Figure 13. The taped mud floor in Wookey Chamber 20.

This sediment floor was slightly damaged during installation of the scaffolding by contractors unware of the reason for the taping. Note the ‘tide marks’ on the wall.

3 Recommendations

The opening up of any new cave system requires certain steps to be taken in order to protect and preserve features of potential scientific and aesthetic importance.

3.1 CAVE CONSERVATION MEASURES.

Additional conservation measures are required in order to protect delicate and or sensitive features before the Chamber and the passage is opened up for general access. Many of these have already been completed by the show cave owner in collaboration with the caving community, are in progress, or are being planned.

- Any delicate and or sensitive sites identified in this audit should be taped off, ideally with a buffer zone of 0.5-1 m where practicable to prevent further deterioration of the site (in progress).
- A full photographic audit of both the chamber and the passage should be undertaken, using fixed location photography or laser scanning (planned). This should be repeated at certain

time intervals to assess any deterioration in the integrity of the site and the rate of deterioration (if any).

- Any cavers visiting to the cave should abide by the Cave Conservation Code as outlined by the British Caving Association (see http://british-caving.org.uk).
- Lighting should be subdued and not permanent to prevent growth of algae and lampenflora on sediment banks and rocks.
- Consideration should be given to the use of netting to prevent rubbish and or stones being thrown into the lake in Wookey 10. Signage should also be put up to remind visitors not to drop rubbish or stones into the lakes.
- Any digging or excavations for exploration purposes should be done sensitively with due respect for the cave environment, and with the minimum of disturbance to the existing passage, under principles set out in the BCA Cave Conservation Code.
- The wooden railway sleepers used to support the temporary scaffolding should be removed at the earliest opportunity to prevent mould growth.
- Some form of access arrangement should be put in place to ensure reasonable access to the caving community whilst preserving the cave environment.

3.2 FUTURE IN-CAVE ENGINEERING OR TUNNELLING WORKS

Whilst significant conservation measures were put in place during this project, additional recommendations to enhance existing cave conservation procedures during any future engineering or tunnelling works in the cave (including the installation of walkways, lighting etc) are listed below.

- There should be clear line of management responsibility for cave conservation.
- All site contractors should be briefed on cave conservation by a responsible and experienced person, and refrain from crossing onto any taped areas, or damaging rock, mud or calcite formations unless strictly necessary.
- Any work should have clear method statements that are approved by Natural England and fully adhered to by the contractor(s). This is particularly important when working in areas of natural parts of the cave. These should include measures to reduce any damage to the cave features including bats and biodiversity.
- Contractors should be adequately supervised during operations, particularly in sensitive parts of the cave.
- Geotextiles should be use to cover any vulnerable sediments if they are likely to be damaged during the installation of any infrastructure, to prevent or reduce damage by falling debris, foot-fall, construction materials and equipment etc.
- Consideration should be given to the use of geotextiles to form a protective barrier beneath any infrastructure constructed on sediments. Organic materials such as wood likely to generate mould, fumes or leachates should be avoided.
- Where operations are likely to impact on the cave, 'before and after surveys' of cave features (including bats and biodiversity) should be undertaken to assess any impact on the cave where possible.

3.3 ADVENTURE CAVING

It has been stated that Wookey 20 may opened up for 'Adventure Caving' trips if deemed commercially viable. Unlike Gough's Cave in Cheddar, which has been open for over a century, the passages in Wookey 20 are in a relatively pristine state with many areas as yet not disturbed by humans. Consequently, from a cave conservation standpoint, Wookey 20 is not suitable for mass groups of Adventure Cavers as at Cheddar. However, it may be suitable for more limited or 'exclusive' groups led by a suitably qualified and trained guide.

Prior to any Adventure Caving operation, it is recommended that:

- Any speleothems, mud formations and other sensitive or delicate features are taped off with a buffer zone of 0.5-1 m where practicable and a fixed point photographic record of the cave established.
- Where possible without significantly impacting on the cave, a route should be identified through the passage such that visitors are able to stick to a single pathway through the cave. This may involve taping, moving small rocks to create an easier route, or creating unobtrusive barriers to avoid novice cavers stumbling into or walking over sensitive areas.
- Paths over sediments are particularly problematic. Consideration should be given to using some form of geotextile or other long term protective covering to avoid creating deep ruts in the sediment, particularly on the section of passage closest to the chamber.
- The limit of any Adventure Caving route should be the large stalagmite bank just prior to the climb up into the conglomerate chamber at the end of the passage. This is for both conservation and practical (safety) purposes.
- Any Adventure Caving instructors should be fully briefed on the scientific importance of the site, and be conversant with cave conservation best practice. Adventure Caving groups should also be briefed on the importance of cave conservation before each trip.
- Party size should be restricted to 6 maximum including the guide, and wear suitable caving equipment.

References

The documents relating to the planning application are available on the Mendip District Council planning website at http://publicaccess.mendip.gov.uk/online-applications.

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