The Sandstone Caves of Nottingham

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Abstract: More than 400 caves are known in the Sherwood Sandstone beneath the city centre of Nottingham. All are man-made. They include caves cut as store-rooms, basements, factories, pub cellars, dwelling houses and air raid shelters, along with a few sand mines; the oldest date back at least 750 years. The caves cause some problems in foundation design for building redevelopment, especially where structural integrity can conflict with conservation interests. Most caves are very shallow, and rock within about three metres of a cave can only safely accept structural loading to less than normal values. Some caves are filled with concrete, though the most interesting and important caves can be conserved by application of appropriate design. The continued protection of the caves depends on a widespread appreciation of their heritage value within the city of Nottingham.

There are no natural caves in Nottingham. The hundreds of caves in the sandstone beneath the city centre are all man-made. Only a few were mines — cut for the purpose of mineral extraction. The rest were cut as cellars, factories, storerooms, dwellings and a variety of other purposes. The term 'cave' is therefore something of a misnomer in the Nottingham situation, but there is no better alternative, and the 'caves' of Nottingham are already so well known that the term is retained in this paper.

The reason that Nottingham has so many caves is simply that the mechanical properties of the bedrock sandstone are ideal for their excavation. All the caves are in the Sherwood Sandstone, which is easily excavated with only hand tools, yet will safely stand as an unsupported arch of low profile. Even back in Saxon times, Nottingham was known for its caves, though the great majority of those which survive today were cut much more recently. Local folklore about the caves has often far outstripped reality; but, even in the cold light of truth, Nottingham still has more man-made caves than anywhere else in Britain.

This paper is only concerned with the caves of Nottingham, but similar man-made caves are also found in the northerly continuation of the Sherwood Sandstone outcrop; caves are recorded at various sites around Arnold, Mansfield, and Worksop, and probably occur elsewhere too. Caves are also known in other similar Lower Triassic sandstones fringing the Midland basins, notably at Stockport, Chester, Hawkstone (near Shrewsbury), Bridgnorth and Kinver; but nowhere matches the cave numbers of Nottingham.

The Geology of Nottingham

The inner city of Nottingham lies on the outcrops of just four rock units (Fig. 1). The oldest is the Lenton Sandstone, which appears to straddle the Permo-Triassic boundary (Charsley, 1989) and forms the lower part of the Sherwood Sandstone; it consists of a red and yellow mottled, fine to medium grained sandstone and is about 30 metres thick. The upper part of the Sherwood Sandstone is the Nottingham Castle Formation, consisting of buff coloured medium to coarse sandstones around 60 metres thick.

Overlying the Sherwood Sandstone to the east is the outcrop of the Mercia Mudstone; this includes the Sneinton Formation with its 40 metres of siltstones and fine sandstones (once known as the Waterstones) directly above the Sherwood Sandstone. The alluvium of the Trent and Leen valleys is mostly sandy clay and is less than 10 metres thick across nearly all the outcrops on figure 1.

The Permo-Triassic rocks dip to the east and southeast at about 1°. Further details of Nottingham's local geology are now available in the various publications from the British Geological Survey's recent programme of mapping the area (notably Charsley *et al.*, 1990; Charsley, 1989; Dean, 1989; Forster, 1989).

The city of Nottingham originated on, and then spread over, the sandstone high ground immediately north of the Trent floodplain (Fig. 1); essentially this is the very gently dipping escarpment of the Sherwood Sandstone, with the Nottingham Castle Sandstone forming most of the outcrop. Westward, the scarp face descends across the Lenton Sandstone outcrop into the Leen Valley. Southward, the fault line scarps which originally truncated the sandstone escarpment have been cut back by lateral expansion of the Trent valley, leaving steep slopes or cliffs along the floodplain margin, most conspicuously at Castle Rock and Sneinton Hermitage. Local relief is only about 70 metres across the whole of the area in figure 1, and Castle Rock reaches to 40 metres above the Trent floodplain. To the east, the sandstone is lost beneath the Mercia Mudstone, and northwards it is much more dissected beyond the Mount Hooton scarp.

The Nottingham Castle Sandstone

This lower Triassic (Scythian) formation consists of poorly sorted, medium to coarse grained, buff coloured sandstones. These exhibit extensive cross bedding, although bedding planes are generally not conspicuous. They contain scattered pebbles, mainly of tough quartzite, which are locally concentrated into conglomerate lenses mainly on scour surfaces (the rock unit was earlier known as the Bunter Pebble Beds). Mudstone flakes are also common on some horizons, and include rafts or lenses more than a metre across. The material originated as flood deposits and sand bars within the distributaries of a major Triassic river system (Charsley, 1989).

The Nottingham Castle Sandstone is a weak, friable

rock, with an unconfined compressive strength generally around 10 MPa (Forster, 1989; Storm, 1988). Its low strength is largely due to its reliance on a weak clay cement, though some localised harder bands have a barite cement. Sherwood Sandstone from deep boreholes in the south of England has widespread cements of calcite, dolomite and anhydrite, but all these minerals are leached from the rock close to the outcrop (Strong and Milodowski, 1987). The leached situation appears to pertain throughout the Nottingham outcrops and within the caves. The clay cement also accounts for the substantial reduction in strength when the sandstone is saturated; this and other mechanical properties of the rock are further considered below, along with their engineering implications.

Though the sandstone is weak, it is also distinguished

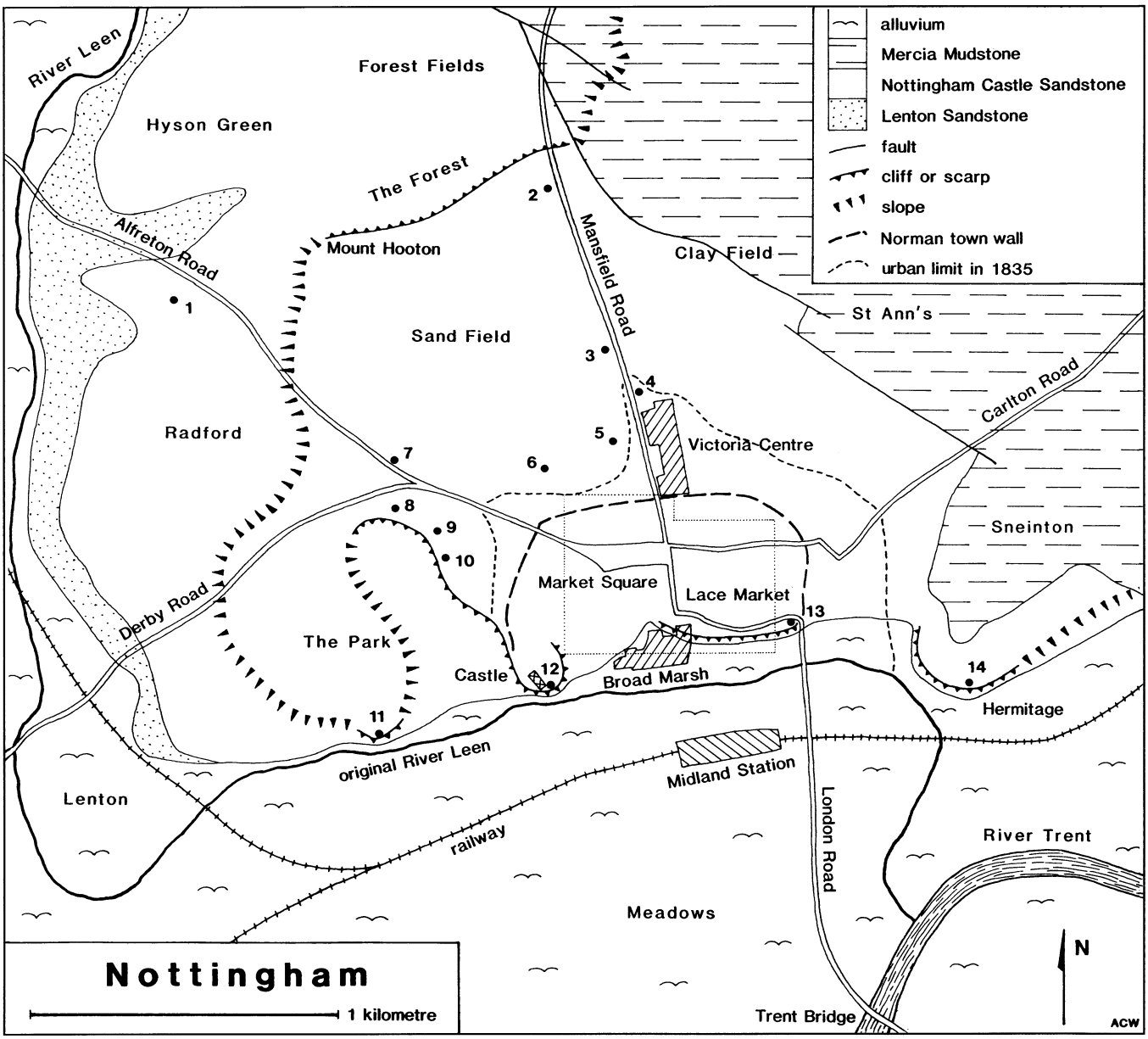


Fig. 1. The main geological and topographical features of the inner part of Nottingham. Selected features of the city's growth are also marked, including just some of the old main roads. The town limit of 1835 is generalised, as there was also some ribbon development along the main roads, and Sneinton, Lenton, Hyson Green and Radford were already established as separate villages. The whole area shown on the map is now urbanised. The River Leen was diverted in 1964 into a culvert from the bend south of Lenton directly into the Trent. There are no surface features remaining of the Norman town wall. The dotted line frames the area shown in figure 2. Numbered spots locate caves referred to in the text and lying outside figure 2 (other outlying caves are not marked):

1 = Player's
2 = Church Cemetery (Fig. 15)
3 = Rouse's mine (Fig. 14)
4 = York House (Fig. 11)
5 = Guildhall (Fig. 16)
6 = Burton's
7 = Running Horse
8 = Newcastle Drive
9 = Park Tunnel
10 = Thomas Herbert's (Fig. 13)
11 = Lenton Hermitage
12 = Castle Rock (Fig. 12)
13 = Hollow Stone
14 = Sneinton Hermitage (Fig. 3).

by its notable lack of fractures. Joint spacing as revealed on the cliff outcrops is generally in excess of 10 metres, and very few joints are encountered within the caves. Along with the scarcity of major bedding planes, this factor is significant in the stability of the cave roof spans. A soft, unfractured rock is ideal for cave excavation.

The Nottingham Castle Sandstone weathers to sand, and site investigations have recorded weathering to depths of 1 to 10 metres (Forster, 1989). However, there is commonly more artificial sand fill than *in situ* weathered material; across much of the city centre outcrop, sound rock is generally encountered at depths of between 2 and 5 metres.

All the city centre caves have been cut in the Nottingham Castle Sandstone (only two outlying caves are in the Lenton Sandstone). Although natural caves in sandstone are not unknown elsewhere in the world, no processes of natural cave formation have been active in the Nottingham outcrops. The story of the caves is the story of man's occupation and industry over a thousand years of the evolution of the city of Nottingham.

The History of the Caves

High ground close to a river crossing is one of the classic sites for primary settlement. Nottingham is of this type, and the oldest part of town lies on the sandstone shoulder now occupied by the Lace Market. In Saxon times a permanent structured settlement covered an area 300 metres by 500 metres, surrounded by a ditch and rampart (Hind, 1943), except along the southern side where the old river bluffs provided a defensive boundary, even in their original form as a mixture of steep slopes and rock cliffs; some of the modern cliffs are the result of more recent artificial modification. This site was known as the village of the Snotingas people; hence the name Snotingaham, though the spelling has since evolved and the s has fortunately been lost. King Alfred's chronicler, a Welsh monk known as Asser, referred to an older British name for the settlement applied in the year 868; this was Tigguacobaucc, which means the place of caves. So maybe even then some residents had found use for sandstone excavations as an alternative to wattle and daub surface structures.

Nottingham grew again with the arrival of the Normans. They built a castle on the hill west of the Saxon town and settled the land between. The Saxon and Norman towns coalesced, and the Norman wall and ditch enclosed the site except along the river cliffs on the south side (Fig. 1). This boundary defined the town for many centuries, and the great majority of the sandstone caves lie within it, as most were cut during this period of urban evolution. Pottery from the period 1250-70 has been found in the caves of Castle Gate and Drury Hill and provides the earliest proven dates for Nottingham's caves (MacCormick, 1990). Clearly the cave excavation must pre-date the pottery; the existence of caves much before that date cannot be proven, though it is almost certain that some of Nottingham's caves do

Pillar Cave in the Drury Hill caves system. A flared pillar supports an unusually wide roof; brickwork has been added to the cave, in the background, but the site is now preserved beneath the Broad Marsh Centre.

date back to pre-Norman times, even if they have since been modified beyond recognition. Though some old caves do exist, the great majority of the caves date from the period 1600-1900. Construction dates and visitor's descriptions are documented for many of the caves. For those undocumented, archaeological excavations have yielded a wealth of 18th century pottery, though there is little from the 15th century (Hind, 1943).

Through the centuries, the population of Nottingham grew, but the size of the town did not keep pace. By 1841, there were 53,000 people crowded into an area little more than that of the Norman town (Hind, 1943).

The map of 1835 shows the contemporary extent of housing and buildings, as shown on figure 1. Generally low quality, crowded housing had stretched beyond the Norman boundary alongside Mansfield Road (to be largely demolished when Victoria Station was built), onto the Broad Marsh and Narrow Marsh areas between the old cliffs and the River Leen (in its original position), and onto the wet floor of the lower St Anne's valley. Any further expansion was prevented by the strict constraints against building on any of the Freemans' fields (effectively commons). These consisted of the Sand Field and Clay Field north of the town

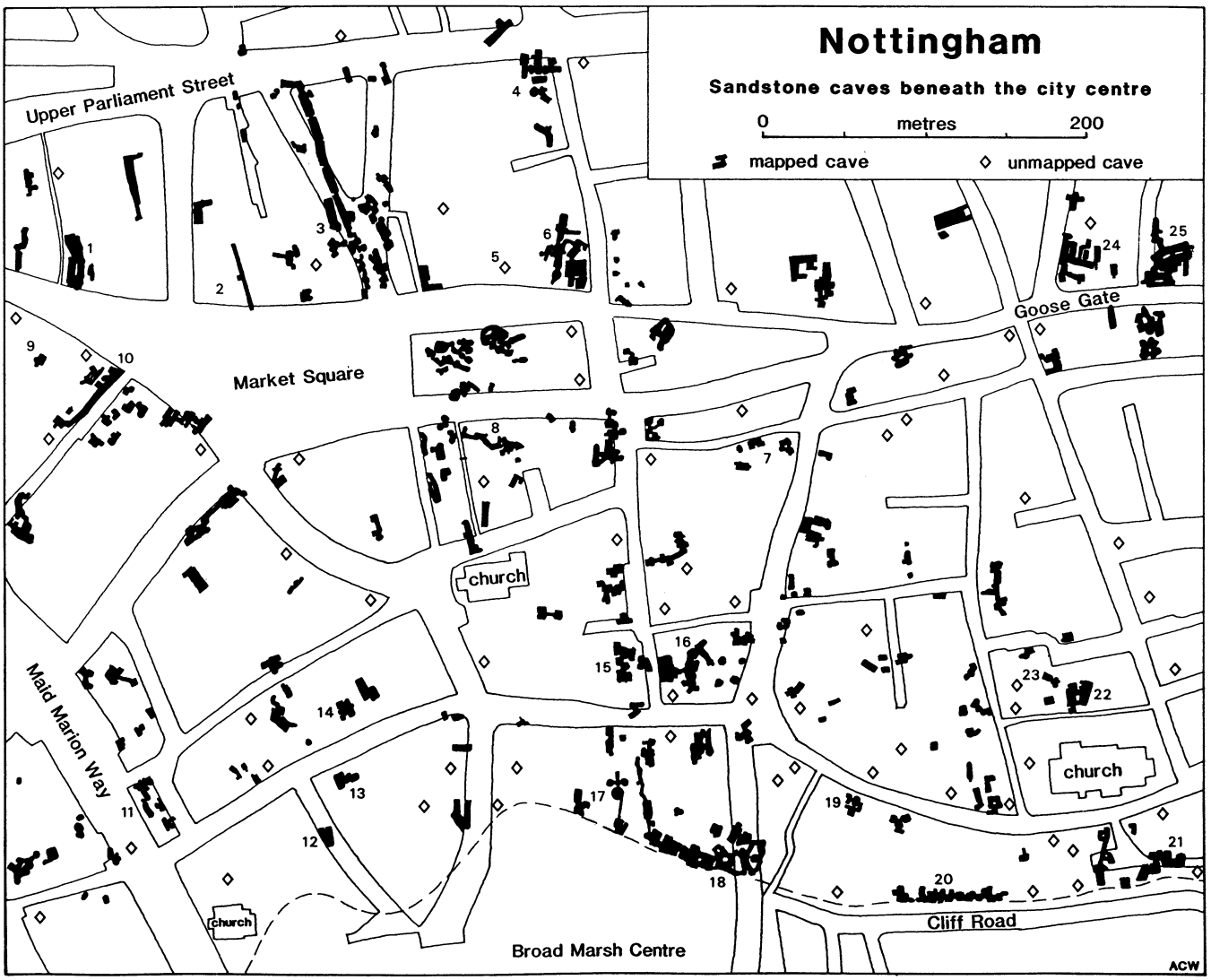


Fig. 2. The caves of central Nottingham as they are known today, superimposed on the modern street pattern. Some of the unmapped caves are only located approximately, and there are certainly many more caves which are concealed, forgotten or unmapped; some of the marked caves have already been destroyed or filled with concrete. Compiled largely from the British Geological Survey register (Owen and Walsby, 1989) with 40 additions of caves recently mapped or discovered. The broken line marks the edge of the alluvial plain and is therefore the southern limit of the caves. Numbers identify caves referred to in the text:

1 = Pearsons (Fig. 8)
2 = Debenham's
3 = Queen Street (Fig. 6)
4 = Corner Pin (Fig. 21)
5 = Black Boy
6 = Lion
7 = Fletcher Gate
8 = Flying Horse
9 = Bromley House
10 = Hickling Laing's (Fig. 10)
11 = Salutation (Fig. 5)
12 = Stanford Street (Fig. 18)
13 = 17 Castle Gate (Fig. 7)
14 = Castle Gate malt kiln
15 = Bridlesmith Gate
16 = Middle Pavement
17 = Willoughby House
18 = Drury Hill (Fig. 9)
19 = Garner's Hill
20 = Shire Hall
21 = Commerce Square
22 = Plumtre House (Fig. 22)
23 = Plumtre House malt kiln (Fig. 4)
24 = Jalland's
25 = Adams

(distinguished by their soils derived from the Sherwood Sandstone and Mercia Mudstone respectively) and the privately owned Park to the west (Fig. 1). These constraints disappeared with the passing of the Enclosure Acts in 1845. Houses and factories rapidly spread northward up the sandstone slope, and eventually saw the demise of the windmills along the Mount Hooton scarp, though much of the Park was not covered with houses until after 1870. The late 19th century saw the cutting of most of the caves outside the Norman town limits, though they were fewer in number and generally larger in size. None lies south of the old town, because there the sandstone is beneath the water table in the Trent Valley.

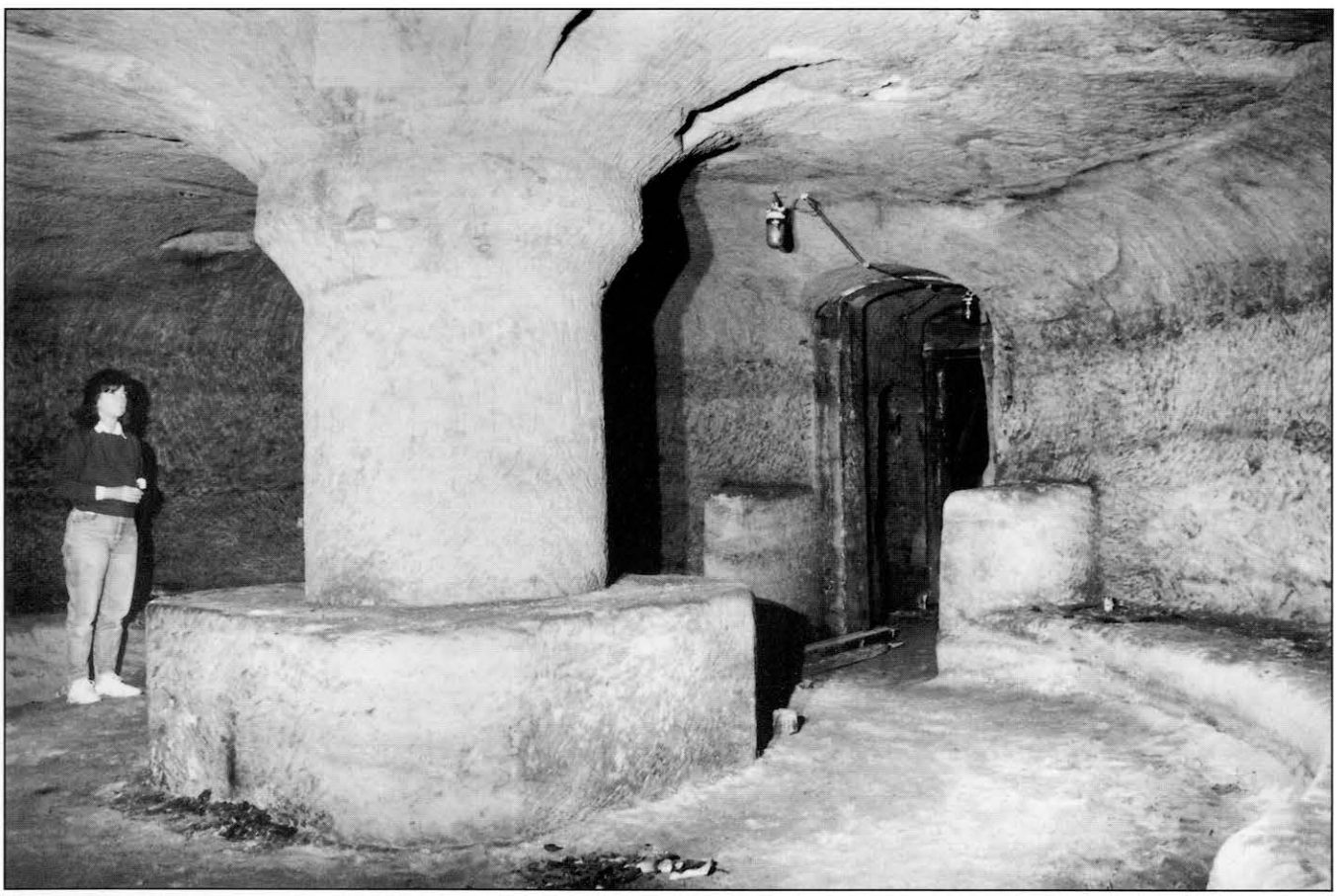
A final phase of cave excavation was for wartime air raid shelters, but by 1900 the pattern of the Nottingham caves was largely complete. Subsequently many caves have been filled, destroyed, lost or forgotten, but figure 2 shows the caves currently known in the city centre area, and it gives a fair picture of their distribution, extent and size.

Dark underground holes are fertile breeding sites for myths and rumours. Fanciful stories about Nottingham's caves far outdistance the reality. Druidical remains have been spoken of and have appeared on some old maps — but such a religious connection has no supporting evidence. Caves 2000 years old, with underground forests and farms are pure fairy tale. The most widespread myths are of long tunnels beneath the city. Anecdotes are often told concerning long underground journeys, but always rely on "a friend of my grandfather" or "someone who lived here before" as their source. Most popular are stories of a cave from Mansfield Road to the Castle, perhaps because both sites do have quite extensive caves, but the link does not exist. Even wilder are the stories of a cave from the Castle to Wollaton Hall — which would have offered a very wet journey beneath the water table of the Leen Valley. There are not, and never were, any such long tunnels under Nottingham. Figure 2 shows the isolated nature of the caves. Each cave or cave system was excavated beneath the land or property of its owner; most underlie just a single building, though some do reach a little further.

The reality of Nottingham's caves is that they were cut because the rock is easily excavated. A roof span of 3, 4 or perhaps 5 metres is normally stable where there is around 2 metres of good rock above it. Once cut, the thermal stability of the ground ensures that the caves have a constant temperature of 14°C (or 57°F); and above the water table they are dry, unless there is some drainage problem with the ground above. The caves were therefore very useful building extensions, ideal for storage, but also usable as factories, workshops or even dwellings.

Cave dwellings and rock houses

Caves, whether natural or man-made, could provide acceptable and convenient sites for dwellings in years gone by, but were readily abandoned when brick and



Fine rock carving in the largest of the three circular wine cellars beneath the garden of Willoughby House.

cut timber made conventional houses so much more comfortable. Such was the case in Nottingham, though few of the caves predate the advent of normal housing. Some caves can be dated back to 1250. The Saxon chronicles of Asser record caves in the Town 400 years earlier, but there is no archaeological proof of any particular site. It is certainly very reasonable to assume that cave houses did exist in Nottingham at the earlier Saxon date, but the particular caves have very likely been subsequently destroyed or modified beyond recognition.

A feature of all the known cave houses is that they were entered horizontally in steep slopes or cliffs of the sandstone, in contrast to the greater numbers of cave store-rooms etc mostly cut at later dates and entered down flights of steps from level ground. There are travellers' tales from 1610 and 1639 of many or most of the people of Nottingham living underground (Stapleton, 1903); but the town contained only a limited number of sites where horizontal entry was possible, and these early reports are probably greatly exaggerated.

Among the older cave dwellings is Lenton Hermitage, in the low cliff now on the southern edge of the Park (Fig. 1). This included the chapel of St Mary de la Roche, and was the property of Lenton Priory (founded soon after 1100); two monks were recorded living in the cave hermitage in 1244 (Stapleton, 1904). The site was sacked by Roundhead soldiers in 1651, but five caves survived, each opening onto the foot of the cliff. One was in use as an office until 1962, but all are now almost obscured behind the garages on Castle Boulevard.

The largest group of rock houses was at Sneinton Hermitage, east of the old town (Fig. 1). Over 300 metres of sandstone cliff faced onto the floodplain, with the River Leen originally very close to its western end (Fig. 3). Cave houses were cut into the cliff along its entire length, but nearly all were lost when the cliff line was cut back a century ago. Records of the rock houses reach back to 1518, and some were inhabited at least as late as 1867. The few surviving rock houses (Fig. 3) are probably typical of most. Each room is no more than 3 metres across, and reaches back less than 10 metres from the cliff face. Shelves and cupboards are cut into the rock, and, where caves lead through from one to another, carefully sited openings ensure daylight reaches the inner recesses.

Some of the Sneinton Hermitage caves were larger. They were two levels high behind the public houses and included a dance hall at the back of the Earl Manvers before it was destroyed by a rockfall in 1829. The great cave nearer the eastern end of the cliff was 11 metres across, roughly circular, and 6 metres high with 6 rock columns supporting the sandstone roof (Best, 1985). Sadly the Hermitage caves did not survive the onslaught of the railways. The middle of the cliff was destroyed in 1888 when the railway reached in to a yard built on a terrace cut in the rock of Lees Hill directly behind the Hermitage (Fig. 3). Worse was to

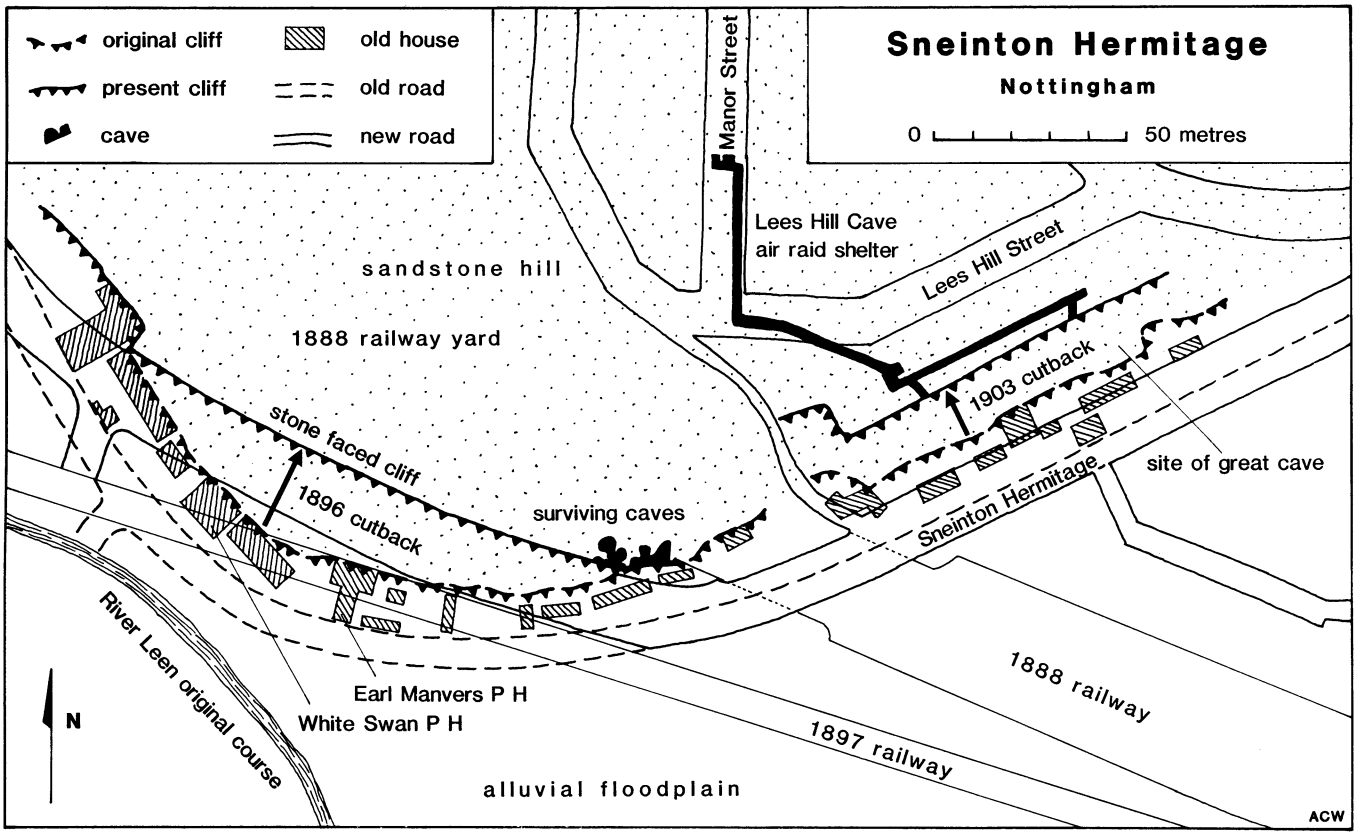
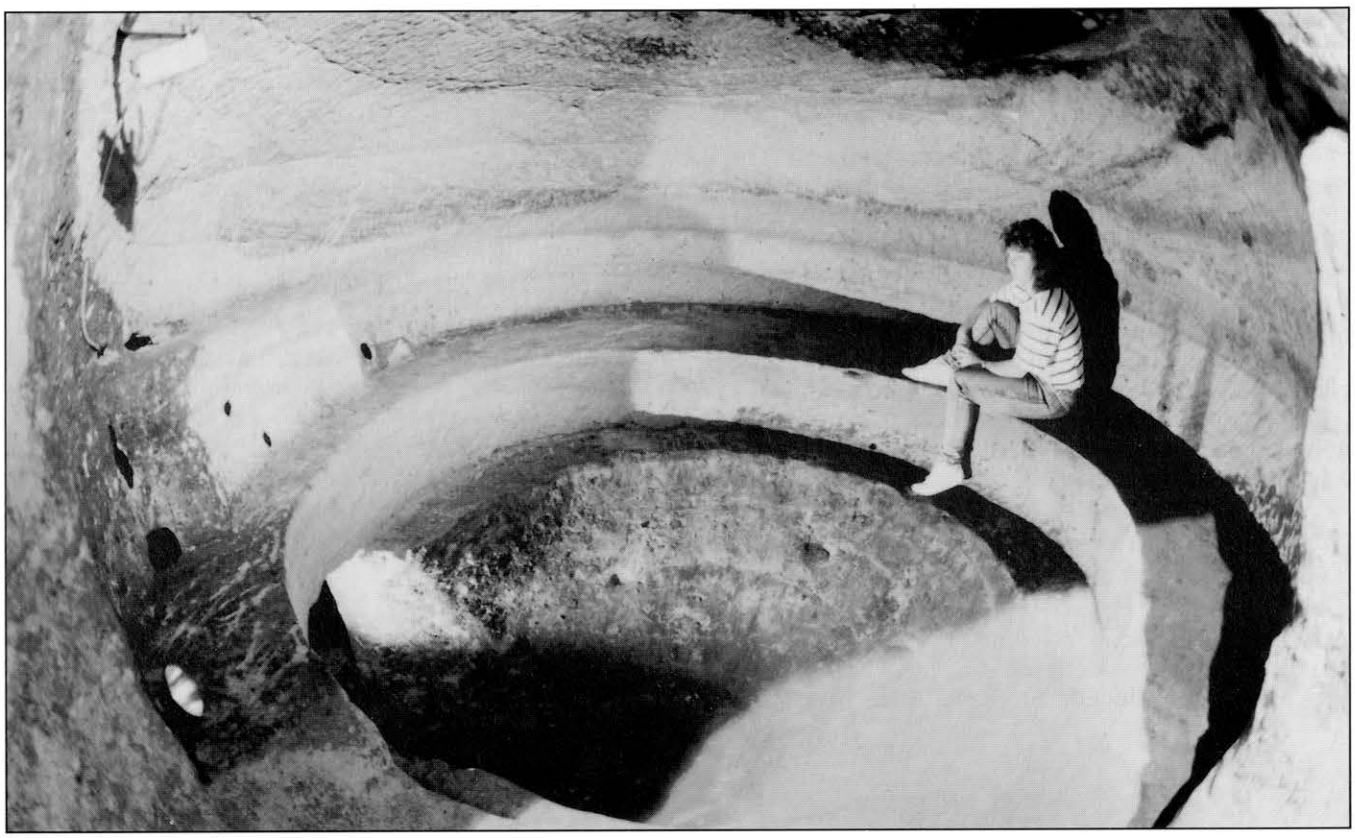


Fig. 3. Past and present features of Sneinton Hermitage, just east of Nottingham. Caves were cut into the whole length of the original cliff shown on this map; they were nearly all destroyed in three phases of railway construction and road widening. Modern houses are not marked and the site of the great cave is only known approximately. (Compiled from Ordnance Survey maps of 1884 and 1915, with cave surveys by Tony and Jan Waltham and by Nottingham City Council.)



The splendidly preserved malt kiln cave on Castle Gate; the stoke hole to the central fire pit is just visible.

follow; all the western caves were destroyed in 1896 when the cliff was cut back to accommodate the new road displaced by another railway at a lower level. Then the eastern caves were all destroyed in 1903 when that part of the cliff was cut back to allow new houses alongside a widened road. The air raid shelter cave was cut even later and has no relation to what was a splendid group of rock houses. And today, even the railways are no longer there.

At various times, rock houses were cut into the foot of the cliffs round much of Castle Rock; the main group is still visible with their entrances bricked up along Castle Road (Fig. 12). The caves include those now at the back of the Trip to Jerusalem Inn; an upper cave over the inn has a uniquely surviving window frame set in the rock, though this was probably a late addition to a much older cave (MacCormick, 1990).

The fourth bluff along the floodplain margin, that below the Lace Market, also has its caves, and some now surviving along Cliff Road may have been dwellings, though the records are not definitive. In the same cliff, the caves of Shire Hall include slightly different "residential" caves, in that some were used as punishment cells. More dungeons lay beneath the old Town Hall at Weekday Cross (MacCormick, 1990), but were destroyed by the railway's arrival in 1894. Both sets of caves were recorded in penal use over 200 years ago.

Paupers lived in various caves alongside the main roads out of Nottingham. Mansfield Road (up to the top of the Forest), Derby Road (up to Canning Circus) and Hollow Stone (eastwards out of the Lace Market) all originally lay in depressions with sandstone scars alongside them; some rock faces survive along Hollow Stone, but are lost behind buildings and raised road levels along most of the other two. Records describe people living in caves alongside all three roads at various times between the fourteenth and nineteenth centuries. The town records of 1335 and 1595 refer to "todeholes" which may have been leper colonies in the caves along Mansfield Road (Silkstone, 1978), and some of these old dwelling caves may partly survive in the rooms immediately north of the mine entrance in what later became Rouse's sand mine (Fig. 14). Any cave houses along Derby Road would have been destroyed in 1740 when the old hollow way (sunken road) was filled in by degrading the slopes and rocks along its sides (Blackner, 1815).

Hollow Stone was originally the main route into town from the south, as it turned up from the road across the Trent and Leen bridges. It occupied a narrow ravine between sandstone scars which long had caves cut in them. One cave on the south side was used as a guard house in 1538, and also had internal steps up to the cliff top above (Blackner, 1815). Squatters were ejected from the caves in 1607 before the entrances were sealed up (Hamilton, undated), though some caves in the same road were rented to the poor in 1611 (MacCormick, 1990). But many or all of these caves must have been destroyed when Hollow Stone was widened in 1740 (Blackner, 1815), and it is a new generation of caves which were bricked up to discourage vagrants in 1975. However, to this day, some of the caves on Hollow Stone and Garner's Hill (and probably others) are used by the city tramps for occasional sleeping and heavy

drinking — though this can barely be called "living" in the caves.

Malt kiln caves

Distinctive among the older of Nottingham's caves are the small systems which included malt kilns. Entirely cut in the sandstone, the kiln was a circular room 3-4 metres across, with a ledge around a central pit. One entry into the bottom of the pit was the stoke hole for a charcoal fire; the second upper entry gave access to the grain which was roasted on a platform resting on the ledge above the fire. The adjacent caves usually contained various pits and ledges (for storage), and in most cases also a well; a larger adjacent room, used for germination of the grain, typically had a central column left in the rock (Hamilton, undated; MacCormick, 1990). A flight of steps commonly led straight to daylight.

All these features are seen in the splendid malt kiln caves beneath the site of the old Plumtre House (Fig. 4). Eighteen malt kiln caves have been found in Nottingham, but all have been damaged to some extent. Later brickwork has been placed through the kilns of both the Plumtre House site and the Bromley House site on Angel Row (Hoskins, 1991); fortunately the kiln of the Castle Gate site is still intact, but concrete columns now breach the adjacent room. The Castle Gate caves also contain a privy and cess pit, cut in the rock distressingly close to the well; ale produced at this site was probably rather stronger than intended.

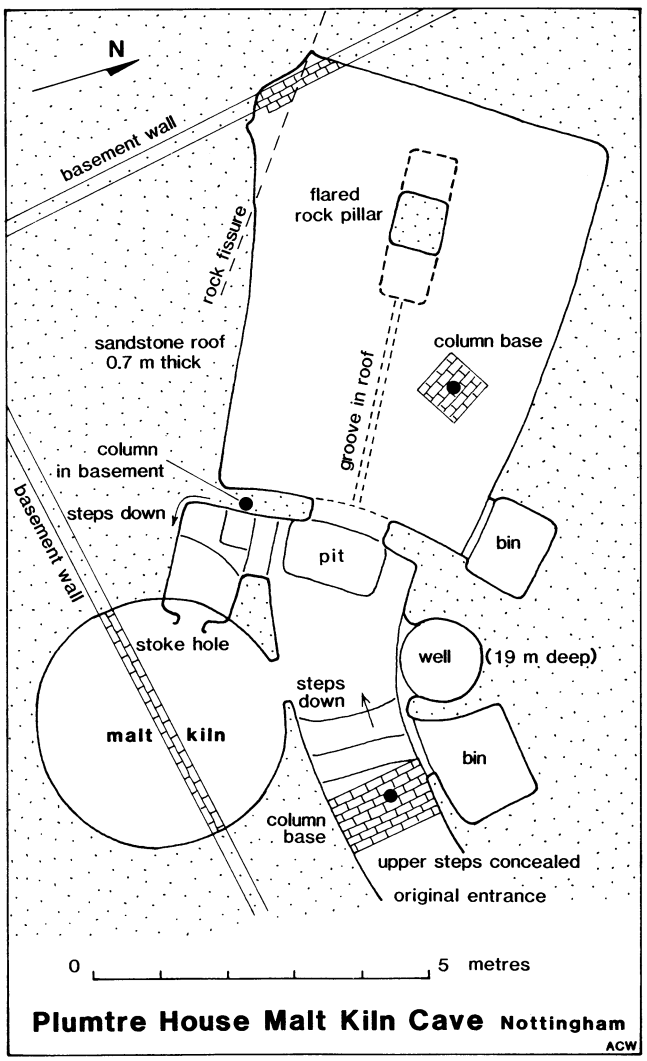


Fig. 4. The malt kiln cave found beneath the site of Plumtre House late in 1991. Neither the kiln nor the well had yet been excavated; the depth to the water table is about 17 metres. The room between the well and the kiln was unroofed, and the roof of the main room was thinned from its original thickness, both during construction of the Victorian factory basement (survey by Tony Waltham).

The malt kiln caves at Castle Gate and under the old Drury Hill (Fig. 9) have both yielded thirteenth century pottery (MacCormick, 1990). But it appears that most or even all of the cave kilns were abandoned soon after 1600. The kiln in the large cave system under the north side of Goose Gate (Fig. 2) had a later cave cut right through its floor so that now only the roof and part of the perimeter ledge survive.

Public house cellar caves

Constant temperature in the sandstone caves made them ideal for the storage of ale, and many were cut beneath inns and public houses. Indeed, beer cellars are almost essential for an inn, and the shallow rockhead across much of Nottingham generally made it easier to dig cave cellars than to construct more conventional basements. Some of the inn caves were also used for drinking, and long ago many of them were used for brewing. Here again the constant temperatures were important, and many of the city taverns brewed their own ale below ground, after buying in the malt from those who had the cave kilns.

The pub cellar caves have a characteristic form. Most are 3-4 metres wide and perhaps twice as long, commonly with one rounded end. They are mostly just deep enough to leave about two metres of solid rock over their roofs, though some are deeper for no known reason; the caves beneath the Lion Hotel on Clumber Street have 5.2 metres of rock over them, and could not be any deeper as their floor level is just about at the water table. The cellar caves are distinguished by their perimeter thralls; these are low ledges cut in the rock, though commonly rebuilt in brick where the rock was too much abraded after years of use. The thralls kept the barrels up off the floor, so that the ale could easily be drawn; they were not for sleeping on, nor were they seating around any central pit for cock fighting — two of the more fanciful myths associated with Nottingham's caves. Many cellar caves also have a barrel hoist cut through their rock roof.

The Salutation Inn, now on Maid Marion Way, has an unusually large set of beer caves beneath it (Fig. 5). These show four separate stages of excavation, recognisable where the thralls are cut through. The oldest caves are the group of three small rooms across the north end of the site, at the foot of the entrance steps. A second stage of this upper level added one longer room off to the south. Both these stages of the caves pre-date the existing building whose foundations blocked the original steps and necessitated a new flight of entrance steps directly above the second stage cave.

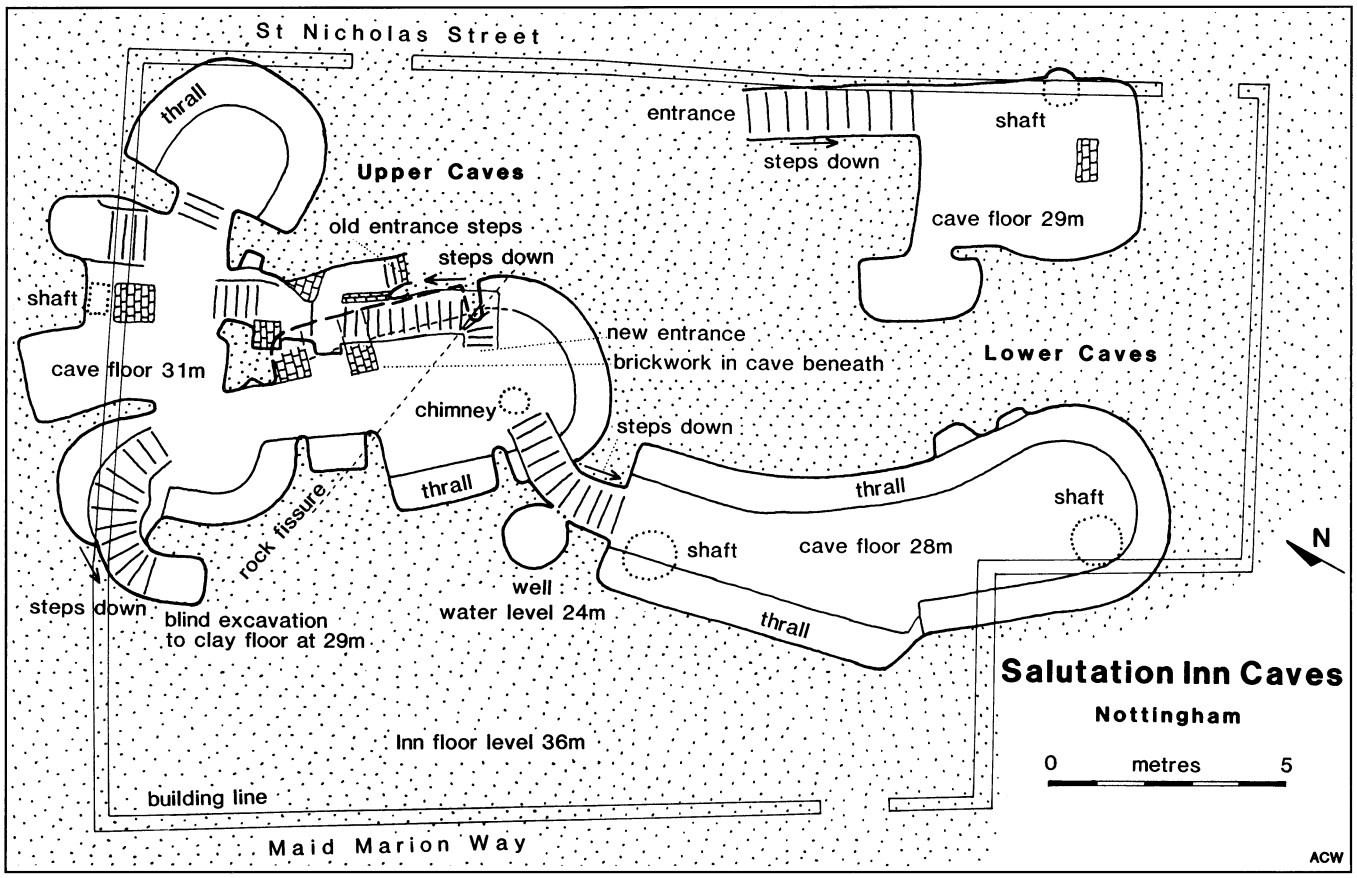


Fig. 5. Plan of the caves under the Salutation Inn on Maid Marion Way. The different levels are indicated by the approximate floor altitudes. There is believed to be another cave, currently inaccessible, beneath the frontage on St Nicholas Street between the two mapped caves. (Survey by Tony Waltham and Richard Storm).

Steps down to a blind end in the northwest corner may have been abandoned before reaching a new lower level, or may have just gone down to a cold air trap used for storing ice or supplies. A third stage lower level was reached further to the south, and this appears to have had a fourth stage extension which introduced the bend in the lower cave, probably to keep it largely beneath the site boundary. In contrast to the Salutation, many of the city pubs had only one or two cave cellars each, such as beneath the old Roebuck and Yorker Inns on Mansfield Road (Fig. 11).

Most of the pub cellar caves are probably post-medieval, but their consistency of style makes them difficult to date. Some may be much older. The caves behind the Trip to Jerusalem Inn, below Castle Rock (Fig. 12), have many claims to antiquity thrust upon them, but both the Inn and the caves date only from the early part of the seventeenth century. Older caves could have existed in the foot of Castle Rock but would have been totally destroyed around 1600 when the cliff was cut back to enlarge the yard and building site to its present dimensions. Around 1875 the last of Nottingham's pub caves were cut in the St Ann's area.

In the centre of Nottingham, the number of pub cellar caves almost matches the number of pubs, including those that no longer survive. There used to be pubs in profusion — one for every 17 houses in the city in 1740 (Hind, 1943). Small taverns were particularly thick on the ground in the notorious slums of the nineteenth century between Long Row and Parliament Street. Most of this zone has long been redeveloped, but the distribution of the caves follows the line of the old alleyways which led north from the Market Square; this is best seen in the Queen Street area (Fig. 6) though the caves are now full of concrete. The sand and rock rubble dug from these many caves appears to have been easily swallowed up by early road repairs and landfill.

Older storage caves and undercrofts

Most of Nottingham's caves were cut to provide dry, safe and convenient storage rooms beneath buildings in the crowded old town where space was at a premium; and many were for storing products other than ale. The older storage caves are largely within the site of the old town (Fig. 1), and consist of either single caves or small groups of caves reached by staircases cut in the rock from the buildings above.

Many caves were just beneath private houses. The splendid Georgian house at 17 Castle Gate was built in 1740-50 with two cave cellars (Fig. 7) which were probably designed as wine stores; the larger cave partly under number 19 appears to be a later addition, perhaps from when that house was built in 1775. Much larger are the two caves which were cut beneath Plumtre House when it was built next to St Mary's Church in 1724. There are two caves, at differing levels, each one 5 metres wide with a flat arched roof 2.6 metres high; one is 8 metres long, the other is 11 metres long

(Fig. 22). They were splendid cellar caves, but they were lost when the House was demolished and Birkin's factory was built over them in 1855. The new foundations cut through the entrance to the caves, and new stairs were probably cut into each cave at that time, but these two were subsequently blocked and forgotten. The caves were found again during redevelopment in 1988.

Finest of all the private cellar caves is the group beneath the garden of Willoughby House on Low Pavement. Cut when the house was built in 1738-41, there are three circular caves, of which the largest is 7.6 metres in diameter (Fig. 9). Each has an elegant central column with a table cut in the rock; the largest cave has a perimeter thrall, and the smaller have brick wine bins.

Away from the private houses, various materials were stored in the caves. Wool was kept in some of the caves beneath the old Vault Hall (on Drury Hill) and perhaps also beneath Shire Hall, before it was shipped out on the Trent barges (Hind, 1943). Some caves were even used as bank vaults. Others appear to have been ice houses, use for making ice from packed snow which

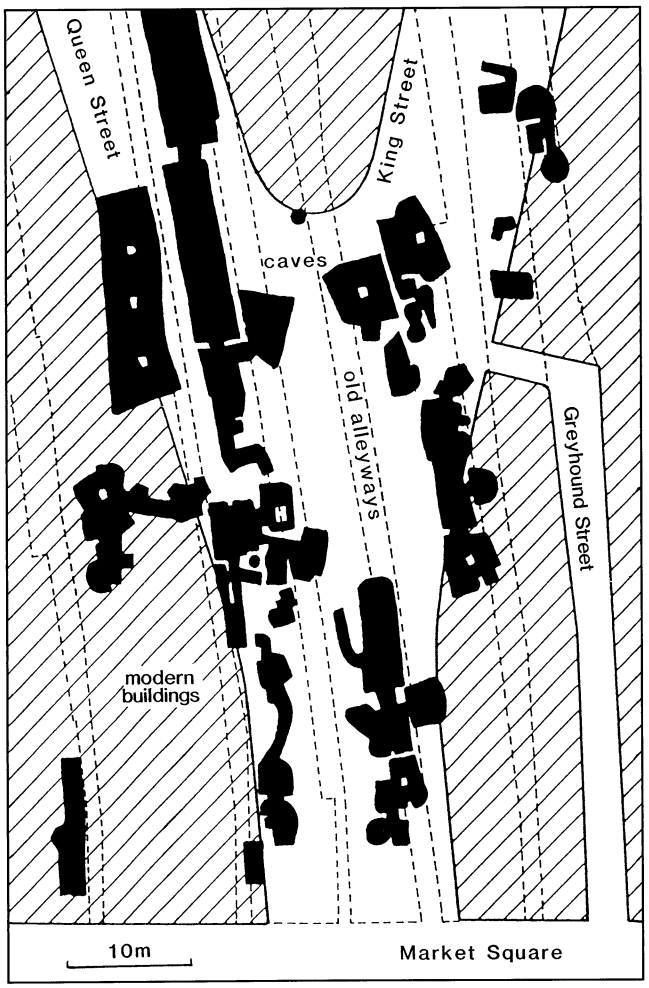


Fig. 6. Some of the caves beneath the north side of the Market Square, with their pattern clearly related to the old closely spaced alleyways of which just part of Greyhound Street survives today. The caves were all filled during redevelopment just before 1900. (Compiled from Nottingham City Council records and 1884 Ordnance Survey map.)

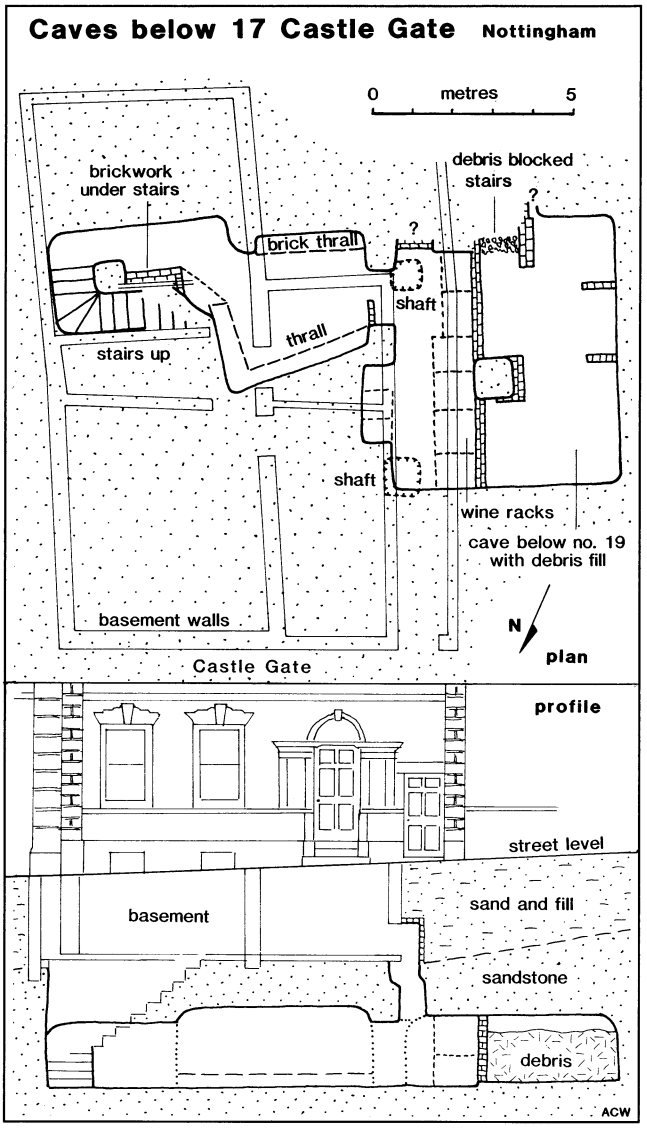


Fig. 7. Plan and profile of the caves beneath 17 Castle Gate. (Cave survey by Tony Waltham and Ian Spibey).

created its own microclimate in the cold air trap provided by a deep cave.

The larger medieval caves, or undercrofts, were probably used for storing a variety of merchandise. Perhaps the finest that survives is under the site of the old Pearsons department store on Long Row (Fig. 8). A single cave 18 metres by 8 metres has six flared rock columns of various sizes from which the rock roof is sprung in a series of broad three-dimensional arches. The original entrance is at the south end, nearest the sloping ground surface and closer to Long Row, but is obscured by brickwork probably of Tudor age (MacCormick, 1990). The south end has also been damaged by eighteenth century basements set into the rock but with a built roof. Beneath these another cave lies close to the Long Row frontage. It lacks the elegant roof arching, and is probably younger than its medieval neighbour on the higher level; it was filled with concrete in 1990.

Besides storage, some caves were suitable for manufacturing, especially where fluids had to be kept

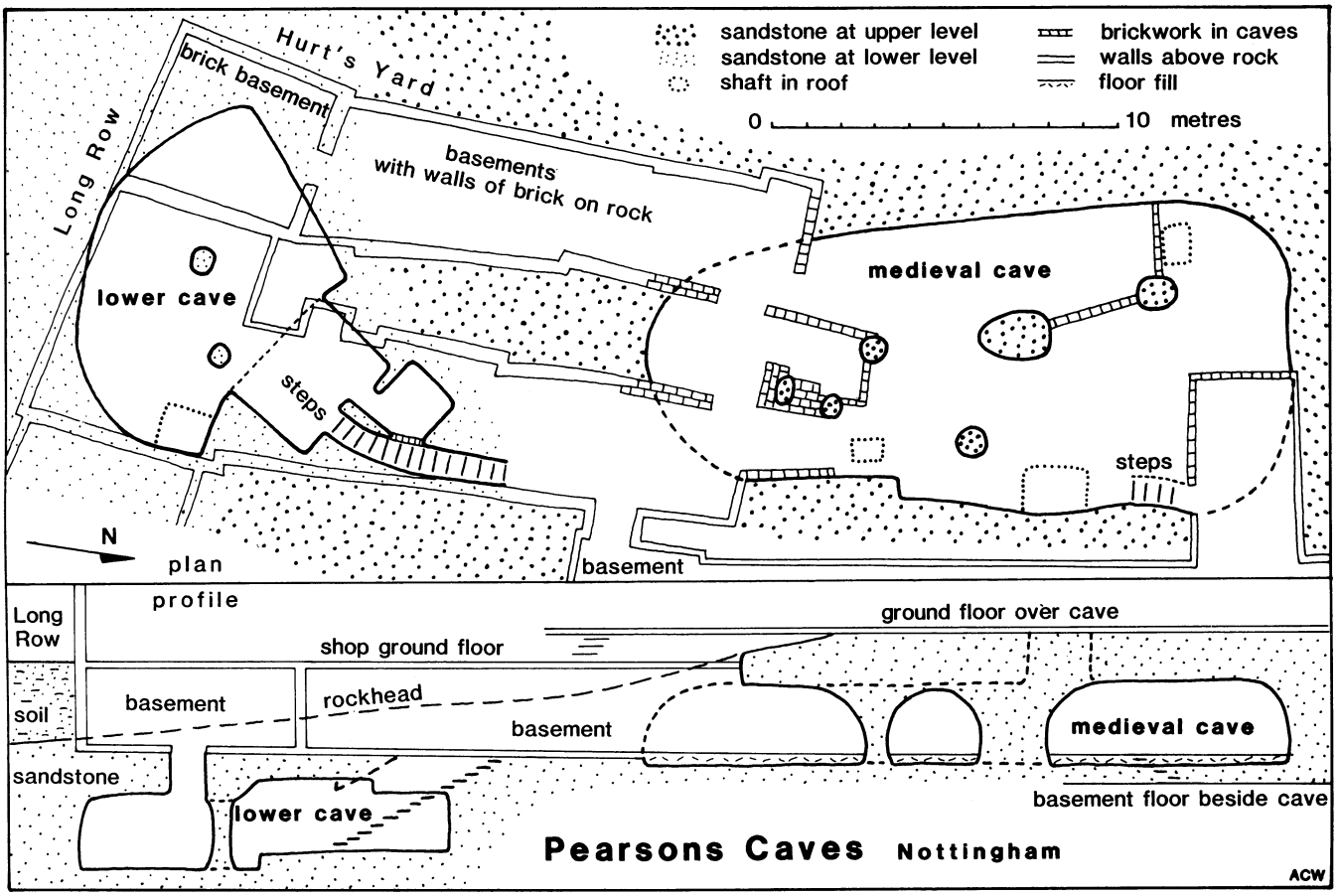


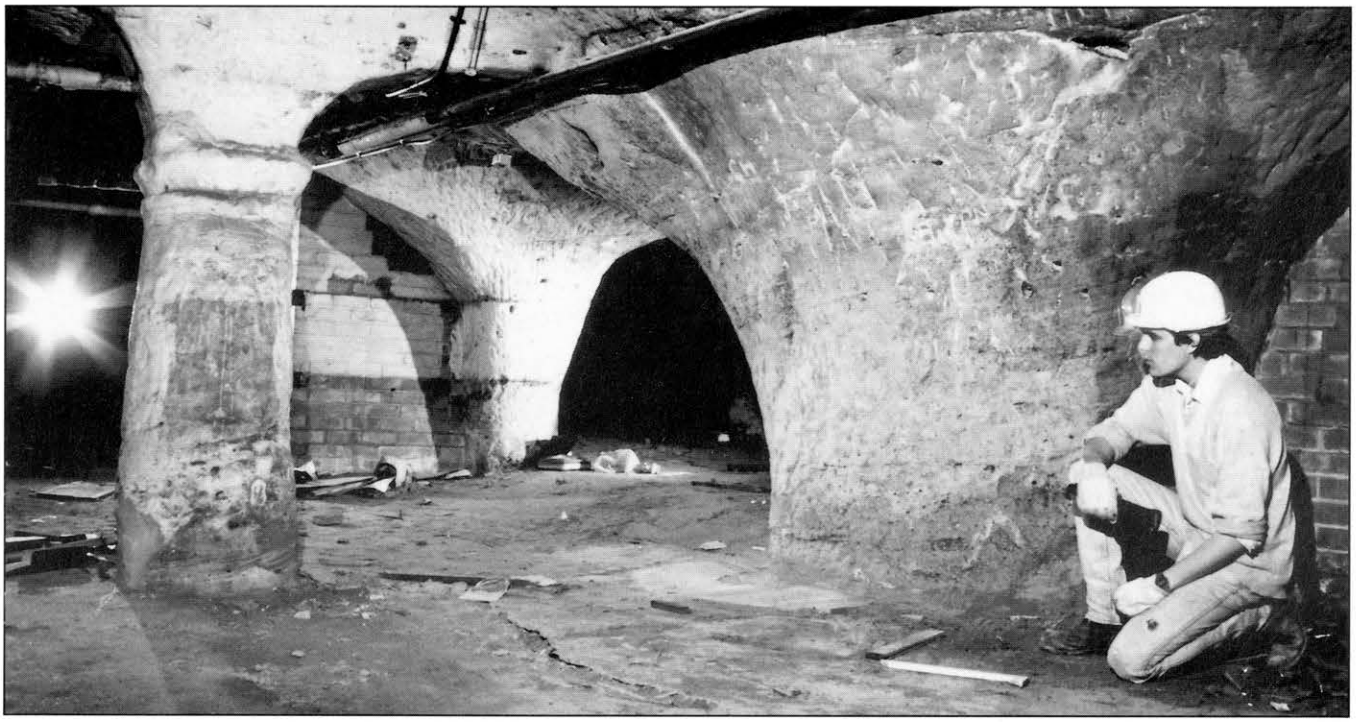
Fig. 8. Plan and profile of the caves beneath the now-demolished Pearsons department store on Long Row. Some brickwork has been omitted for clarity; the lower cave is now full of concrete but the upper level still survives. (Cave surveys by Joynes, Pike and Associates and by Tony Waltham and Jenny Walsby).

at constant temperature (as in the case of the brewing). The tannery in the Drury Hill caves, now beneath the Broad Marsh Centre (Fig. 9) was the only underground tannery in Britain. Over 5 metres wide and twice as long it has a series of vats cut in the rock floor to hold the different solutions required for tanning animal skins. It was in use at least as early as the fifteenth century up until 1639 (MacCormick, 1990), and was one of dozens of tanneries in the Narrow Marsh area; together they created an environment so foul that supposedly even the rats kept away — with the benefit that it stayed clear of the plague. Next to the Tannery Cave, the Pillar Cave is of similar size, but with a fine single central pillar and no rock vats in its floor. It has yielded pottery dated to 1270-1300 from a cess pit in its floor (MacCormick, 1990). Both these caves originally opened to daylight at the foot of the sandstone cliff bordering the marsh, but they were modified through the centuries, and the entrance room of the Pillar Cave had collapsed before about 1400.

Featured in many caves are the wells which reach down through them or from them. The sandstone is a good aquifier; the water table slopes gently down to the floodplain, so that it is just below the cave floors in the Drury Hill area but is at much greater depth further north in the town. Some wells were needed where water was required in the caves, while others passed through the caves to yield supplies for the houses above. Most have niches in their walls to provide foot and hand holds or to hold timbers which allowed the well-diggers to climb up and down, but there is no sound evidence that any of these vertical shafts were for access to the caves.

The caves below Wollaton Hall, west of Nottingham, were cut mainly for the storage of wine, ale and perhaps water; some date back to when the Hall was built in 1588. They lie across the boundary of the Nottingham Castle and Lenton sandstones. One cave room now has standing water in it, and is known as the Admiral's Bath; it originally had a horizontal entrance from the slope in front (north) of the Hall, but this was blocked and buried by landscaping long ago. Probably only since then has water been ponded in the cave, partly supported there by the lower permeability of its Lenton Sandstone floor or perhaps by some artificial clay puddling. Closer to the Hall, there is sometimes a very small water flow from the sandstone in the caves, but it is unlikely that the cave was ever a significant water supply for the Hall. The Admiral's Bath cave may have originated as a garden folly, with the brick-lined cellars only linking it to the cave beneath the Hall at a later date.

Some of the city centre caves, in the Broad Marsh area, also have standing water in them — because they now reach below the water table. As the cave floors must have been dry originally, the water table appears to have risen by about one metre, probably in response to landfill raising the ground levels of the adjacent part



The fine columns and roof arches in the medieval undercroft cave beneath the old Pearsons department store.

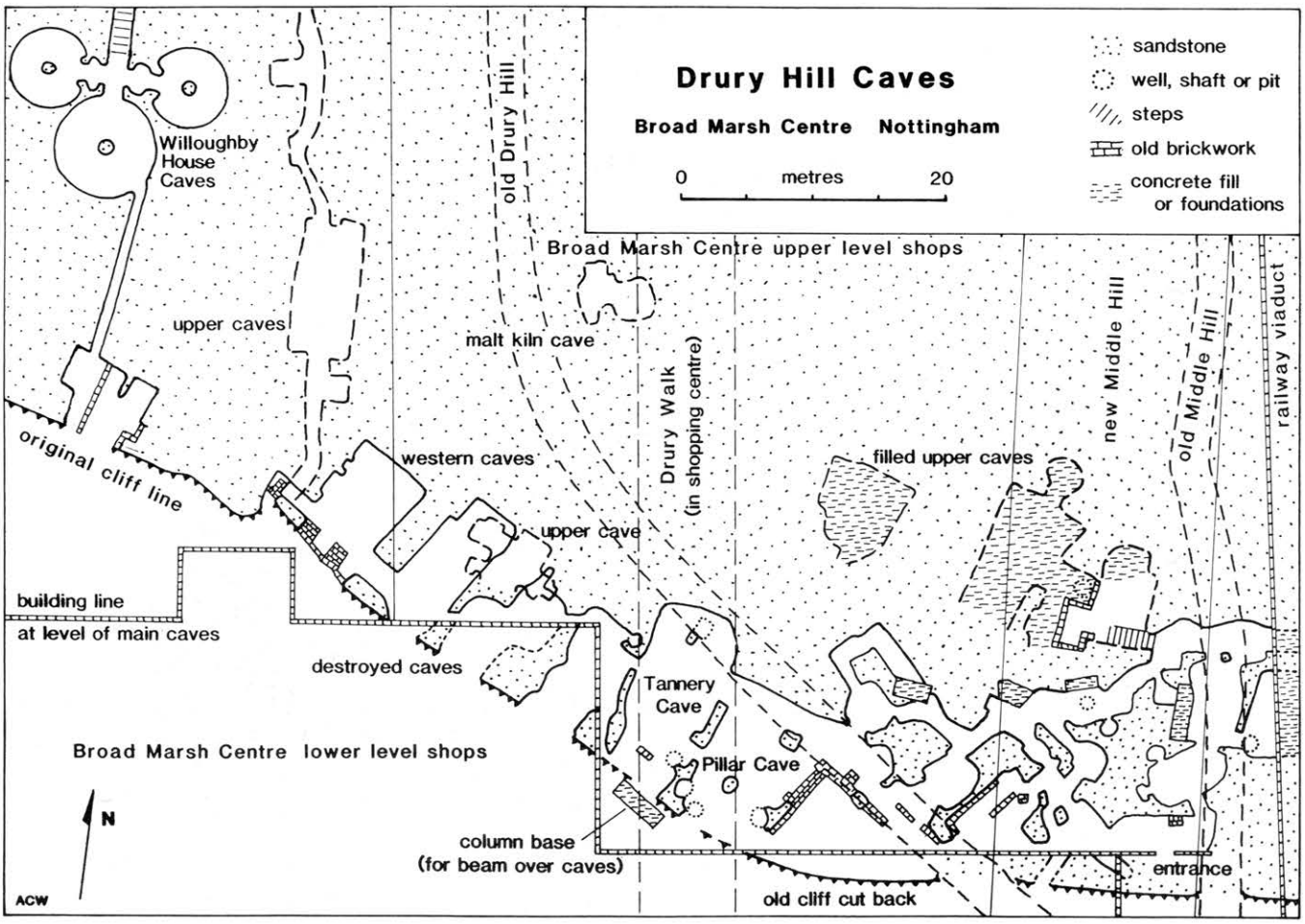


Fig. 9. Plan of the main group of caves cut into the sandstone cliff where the old Drury Hill climbed from the flood plain into the old town. Most of the caves are now preserved beneath the Broad Marsh Shopping Centre. (Compiled from various cave surveys by Ron Sheldon and the Royal Institution of Chartered Surveyors, Tony Waltham and Angus Tillotson, and Nottingham City Council.)

of the floodplain. (This is independent of the short term decline of the water table due to over-abstraction and its recent rise in response to the reduction of pumping.)

Later storage caves and vaults

The development of Nottingham and the growth of its industries were matched by the needs for greater storage capacity. The later caves tend to be larger, often characterised by systems of parallel rooms; they have more squarely cut corners, and lack the elegant flared pillars of some of the older caves. In 1791 the Adams Brewery cut its system of caves beneath the north side of Goose Gate (Fig. 2), and some of these spacious rooms were later used by a nineteenth century butcher, though probably after they were unroofed and incorporated as shop basements. In the Victorian era redevelopment of the buildings above was often made easier by unroofing the caves and cutting back their rock sides to accommodate load-bearing walls for the new, larger buildings; some of the Drury Hill caves were modified in this way (Fig. 9).

A variation in style was presented by the Hickling Liang wine vault caves alongside St James Street (Fig. 10), cut just before 1800. The front building in Angel Row already had some small old caves beneath it, so the wine vaults went in even lower, with their floor 8 metres below street level. A large shaft drops the full depth, beside access steps which twist down through the older caves, and the main cave below has barrel rails close to the foot of the shaft and brick wine racks everywhere else. Another large series of caves housed Jalland's wine vaults beneath the north side of Goose Gate.

Nottingham's rapid expansion following the 1845 Enclosure Act led to a small number of larger caves being cut beyond and north of the old town limits (Fig. 1). Skinner and Rook's wine vaults now lie behind the Guildhall; they were cut in 1860, enlarged a decade later, but then heavily modified for the 1939 war (Fig. 16). Around the same time the Nottingham Brewery cut extensive caves beneath its site on Mansfield Road, now under York House (Fig. 11). These were cut in various stages, and even broke through into the old cellars beneath the Yorker Inn. An important addition was the tunnel which reached out into the old Victoria Station built in 1894; this allowed the beer to be taken direct from the brewery cellars to rail wagons on its own siding in the station. Circular marks from the barrels can still be seen on the cave walls, though this exit is now sealed behind a later retaining wall in the railway cutting. Also in the same area, Burton's gas refrigerated cold store was cut in 1885 as two levels of large caves close to Talbot Street (Fig. 1).

The sandstone reaches north into the Basford area, and a number of caves survive there. The largest were cut in 1852-1880 beneath Shipstone's brewery on

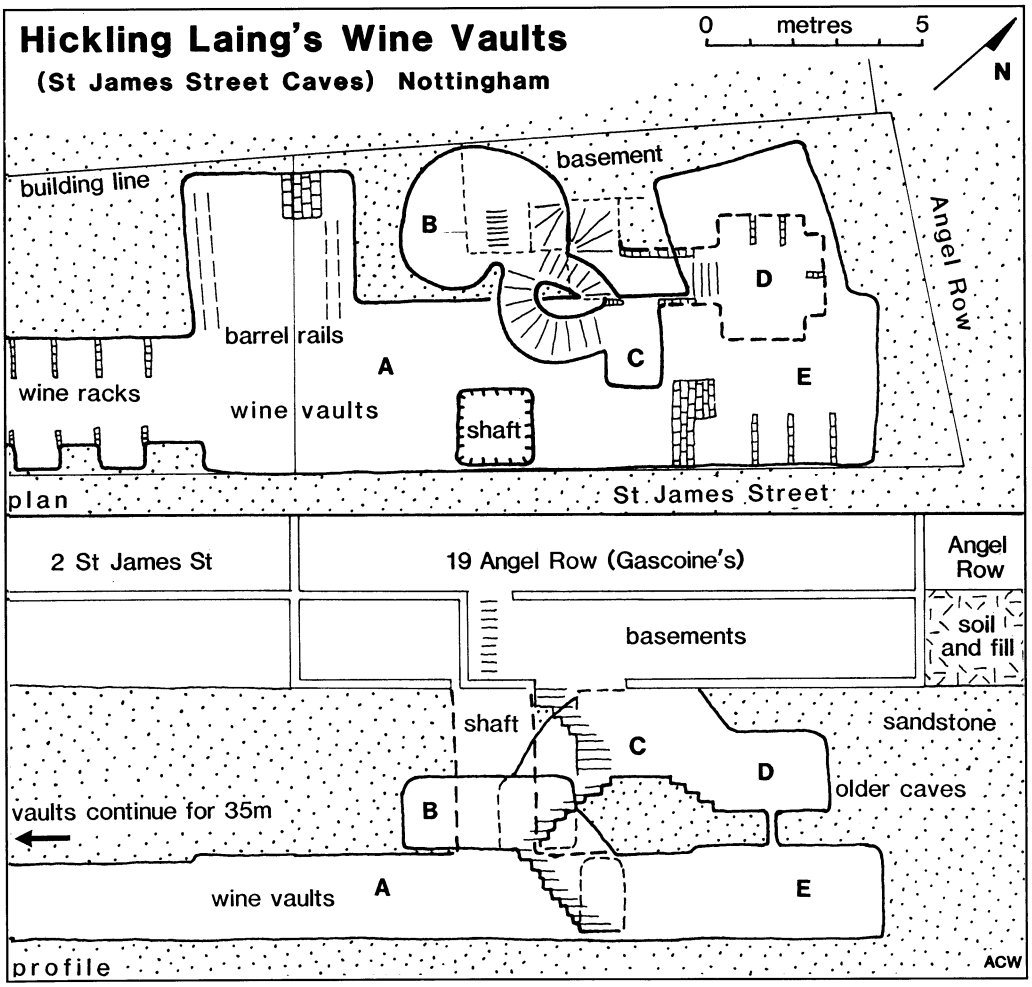


Fig. 10. The caves which now lie beneath Gascoines estate agency at the western end of the Market Square. The lettering of the various rooms is purely to facilitate correlation between plan and profile. The main wine vaults, about 200 years old, are just the lower level, A and E, and the upper caves, B, C and D, were much older storage rooms. They are now all connected by stairs cut in the sandstone, and a shaft drops from street level into the deeper wine vaults. (Survey by Tony Waltham).

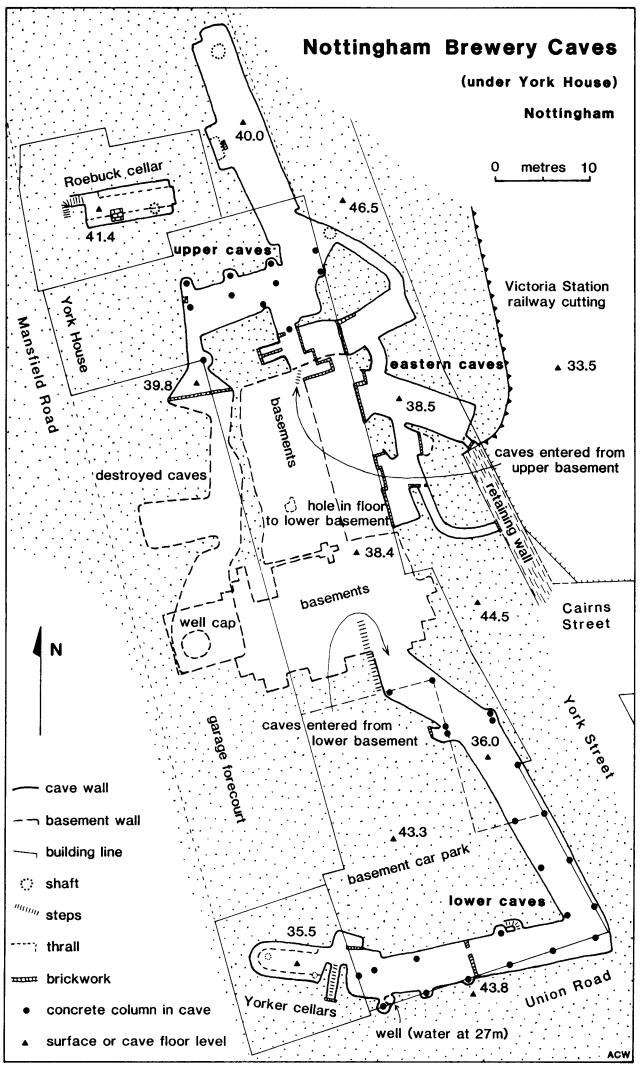


Fig. 11. The caves beneath York House and adjacent sites along Mansfield Road, which were originally the beer cellars of the Nottingham Brewery and two older public houses, and also included some older caves now destroyed. (Compiled from various cave surveys by Tony Waltham and Pete Walker, Lyndon Clarke and David Waldram, Martin Davies and Richard Thompson, and Nottingham City Council.)

Radford Road (north of Fig. 1). Nine caves each 50 metres long and 5 metres wide form an orderly parallel system with various short cross links — in marked contrast to the irregular little rooms of the medieval caves beneath the old town.

Cave tunnels

The myths concerning long cave tunnels beneath Nottingham far outweigh the reality, but a number of caves in Castle Rock do have dimensions and proportions which mean that their prime purpose was underground access (Fig. 12). Certainly some of the Castle caves are medieval, and the oldest is probably Mortimer's Hole which may be dated to 1194 and links the top of the Rock with Brewhouse Yard at the foot. With no easy surface route off the south end of the Rock, the cave created convenient access, with steps for the 35 metre descent to the yard where ale was brewed and corn was milled to supply the Castle. The connection with the royal paramour Roger Mortimer only dates from his arrest at the Castle in 1330, and may have involved one of the other caves. Davey Scot's Hole provides a cave route out of the Castle to the northwest, and there may be another lost cave leading out to the north. The link from the Western Passage into the Rock Chambers (the Castle cellar caves) was only cut in 1956 to create the circular route of the modern cave tours.

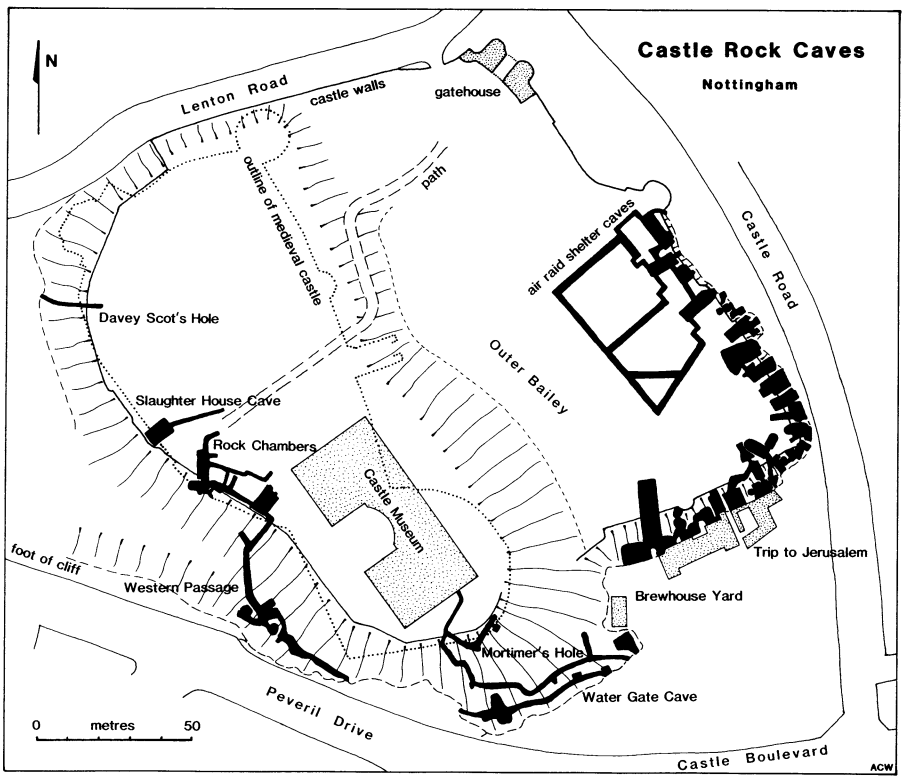


Fig. 12. The various caves under Nottingham Castle Rock. Mortimer's Hole descends from top to foot of the cliff, as does Western Passage with its recent link into the Rock Chambers. The Brewhouse Yard caves include very old brewing chambers, and also the pub cellars of the Trip to Jerusalem and the Gate Hangs Well (which was just east of the Trip). The smaller caves along Castle Road post-date the medieval walls, and the air raid shelter caves were cut in the Second World War. The medieval castle on the higher part of the rock was finally demolished around 1651, and the Castle Museum occupies the house/"castle" rebuilt in 1878. The old Outer Bailey occupies a lower terrace. (Compiled from surveys by Nottingham City Council and Kimberley Brewery.)

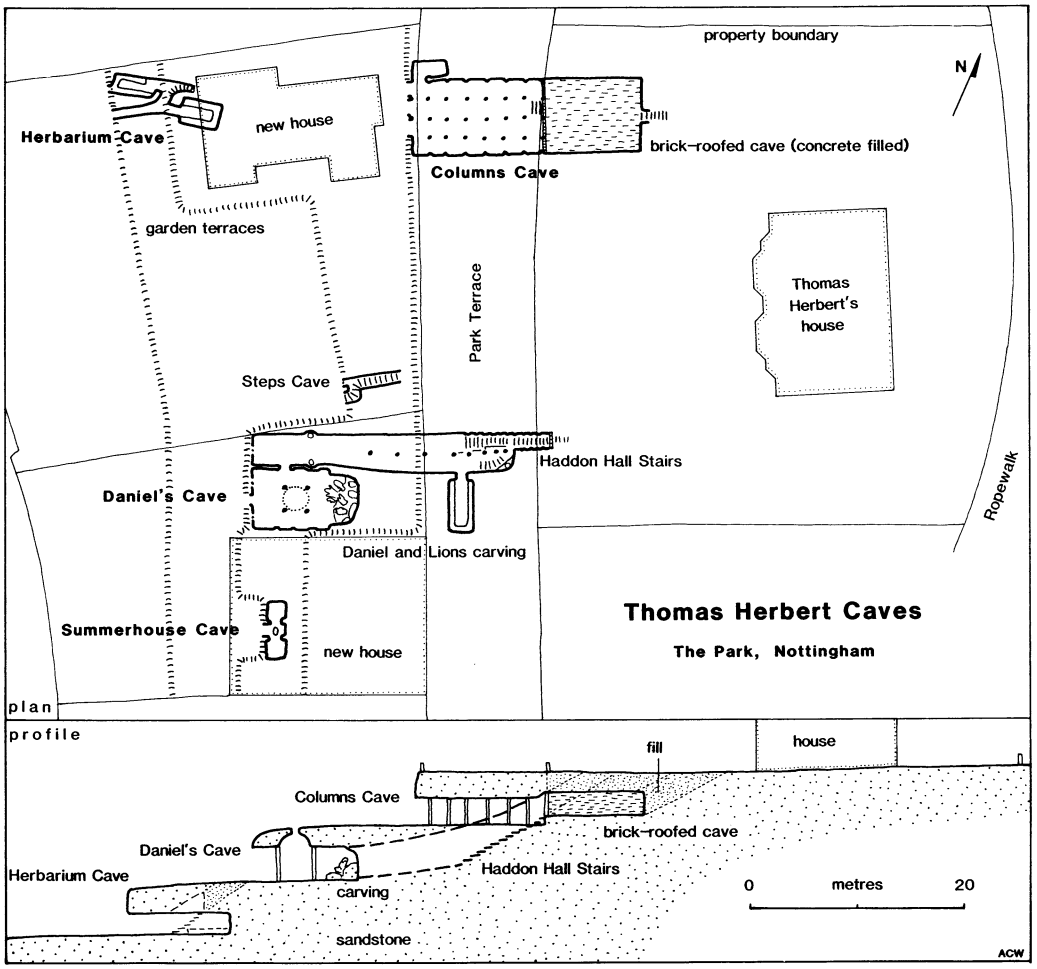


Fig. 13. The Park caves which originally lay in Thomas Herbert's garden. Each cave is open at the front where it was cut back from a garden terrace, but each also has a back entrance down a flight of steps from the terrace above. All the staircases have now been filled or capped. The profile omits some caves for purposes of clarity and does not show the new houses below Park Terrace. (Compiled from rough surveys by Tony and Jan Waltham).

Very different from the man-sized tunnels of the Castle caves, the Park Tunnel is a massive 8 metres high and wide. Dead straight for its 75 metre length, it was opened in 1855 to provide direct access from the Park to Derby Road (Fig. 1). Designed to permit coach-and-fours to pass inside, it was sadly made redundant before its completion by the construction of easier roads elsewhere into the Park. It is now tucked almost out of sight behind walls and buildings, and is nearly blocked at the Derby Road end, but it is still open as a footpath, perhaps best reached by the spectacular descent down the steps from Upper College Street.

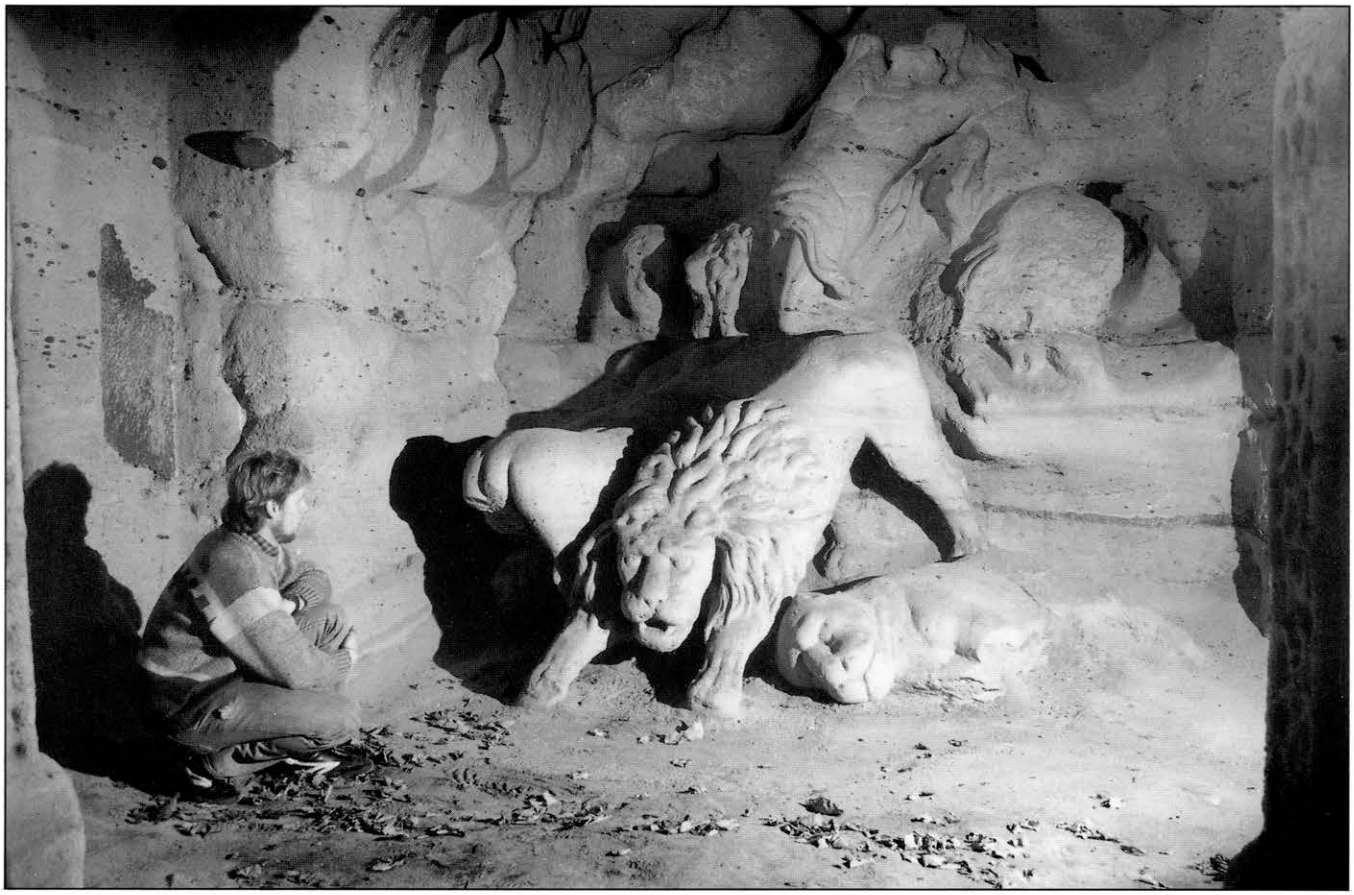
Carved and ornamental caves

Decorative carving of the sandstone adorns a number of the medieval caves in Nottingham. Bas-relief heads, some on shields, are depicted on many old drawings of the caves, and one survives carved near the top of a column in a cave under a shop on Long Row. Sadly most of the others have been lost or destroyed. Carved crosses also survive on the walls of the Goose Gate caves. Some of the sandstone columns within the larger cave rooms are also carved with ribs and shoulders; one column in the older Pearson's cave is round with a carved square capital, and the carving of the pillars in the Willoughby House caves is even more ornate.

A group of caves in the Park contain ornamentation and carvings on a scale far surpassing any other in Nottingham. Alderman Thomas Herbert was an affluent Victorian lace manufacturer who had a large house on the Ropewalk (since extended and converted into offices). His back garden fell away down the steep slope into the Park Valley, and beneath its terraces he had cut a fantastic series of caves (Fig. 13). Their decorative nature places them as follies, in the grandest of Victorian traditions, and they were reputedly cut to relieve local unemployment.

Each main cave originally had a staircase entry at the rear, and then opened out horizontally onto the next terrace down the garden. Columns Cave is at the highest level, with a single room 13 metres long and 7 metres wide. Its roof was supported by 18 columns each square cut, with ornate capitals and etched panels; half pillars are carved in the walls with bas-relief figures and crucifixes cut in the rock between. A rear extension of the cave had brick columns and brick roof arches when it was filled with concrete in 1976 to stabilise the carpark above. Fortunately, the main sandstone cave survives beneath Park Terrace with 17 rock columns and just one brick replacement.

One terrace below, Daniel's Cave is the most spectacular of all. A cave 10 metres by 6 metres, open to daylight, has four central columns around a carved and ribbed roof dome rising to a skylight. Carved into the sandstone forming its rear wall is the spectacular image of Daniel in the Lion's Den. Close to life size, Daniel and six lions are carved with three-dimensional



The statue of Daniel in the Lions' Den carved in 1856 in the bedrock sandstone of the magnificent cave in Thomas Herbert's garden. This photograph was taken in 1991, after some of the Lion's limbs and part of Daniel's head had been lost to vandals.

detail entirely in the bedrock sandstone without any added masonry. The whole scene, about three metres high and four metres wide, is a work of art destined never to be moved. In the same cave, the date 1856 and the initials T H were carved on the rock wall (Nix, 1984), but are no longer readable. From the side of Daniel's Cave, a spacious passageway leads back into the rock and then up a pillared staircase with balustrades carved in the sandstone to exactly copy a staircase in Haddon Hall. Niches and columns contain statues and a wealth of detail, all executed in the bedrock.

Adjacent to Daniel's Cave, the Summerhouse Cave is smaller and bears a date carving of 1872. It has a central font, animals carved in bas-relief and full relief on the walls and columns, and its wall recesses are adorned with blocks of tufa, probably imported from the Peak District; the whole effect verges on the grotesque. The lowest cave again has entrances on two levels, and its two small rooms have perimeter ledges which suggest it may once have been used as some form of herbarium. Many of the window openings, in all the caves, were originally fitted with frames and stained glass, but little of these survive. Being open to the elements, the cave walls have been severely weathered over a century of exposure; many of the carvings and statues have lost their details, though notably less in the upper recesses of the Haddon Hall staircase. The Daniel carvings have also weathered and are still decaying, and also suffered badly from vandalism when the caves were unprotected on wild land; Daniel and one lion have lost their heads, and a few legs are missing too. Fortunately the caves are now gated and protected in the gardens of new houses along Park Terrace, which cuts right through the Alderman's original garden, though their open entrances still leave them prone to weathering decay.

The sand mines

Mostly too weak to yield decent building stone, some of the Nottingham Castle Sandstone is so friable that it is easily excavated to produce loose sand. In historical times this was in demand, as building sand, and also for spreading on the floors of houses and public buildings to absorb the dirt, long before carpets were in use. Cleaner sand could be obtained underground where the best beds could be followed without problems of land ownership, and two groups of mines were established up the Mansfield Road; there were also more small mines along the south side of Derby Road (Blackner, 1815).

James Rouse worked a sand mine on the west side of Mansfield Road (Fig. 1) for at least 30 years at the end of the eighteenth century (Blackner, 1815). This was a typical hand-worked pillar-and-stall mine with unsystematic working achieving up to 80% extraction in some parts (Fig. 14). Pillars are mostly rounded, and stalls are generally 2-3 metres wide, but enlarging to

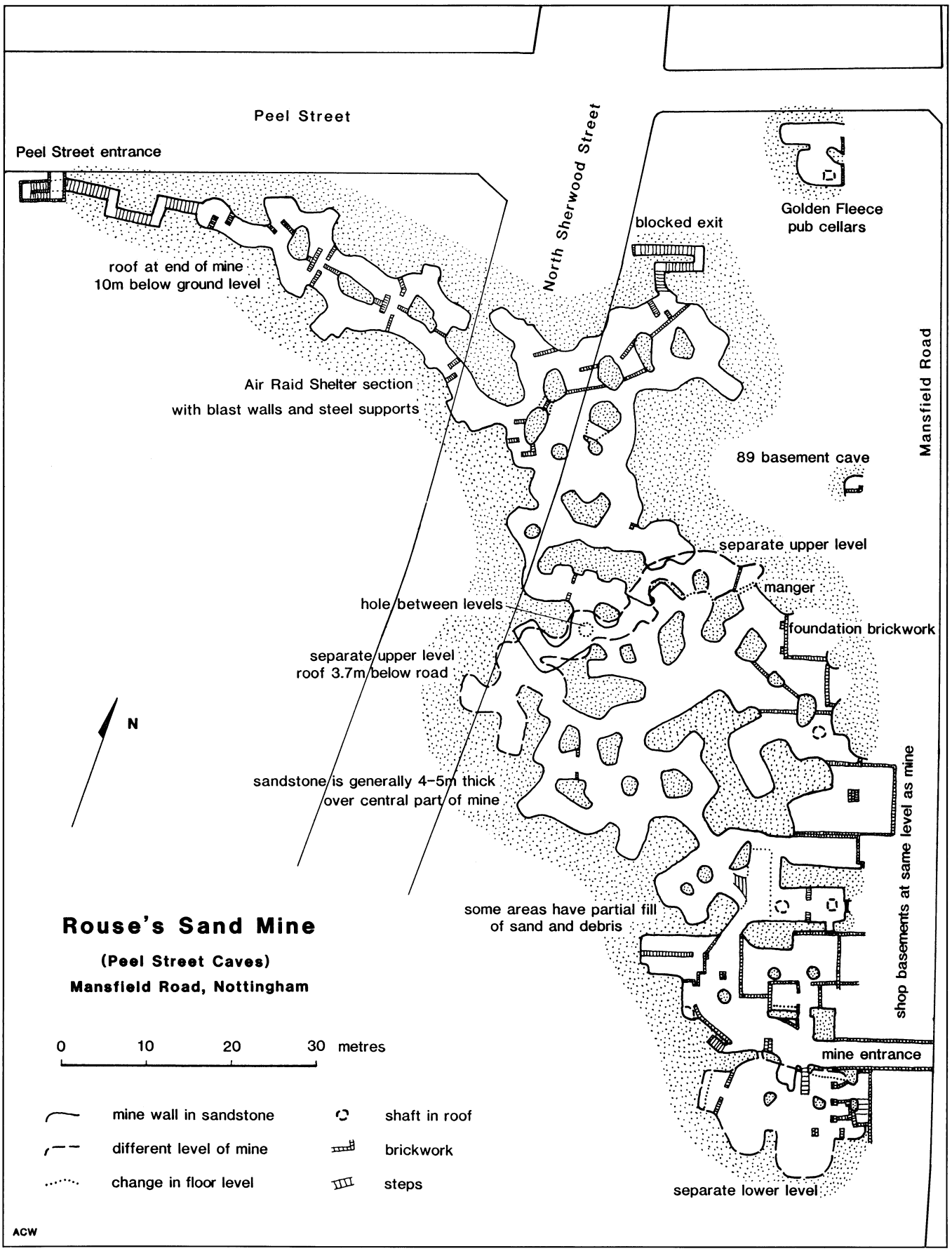


Fig. 14. Outline survey of Rouse's sand mine extending between Mansfield Road and Peel Street. (Drawn largely after Nottingham City Council survey, with additions and corrections by Tony Waltham.)

5 metres in a few rooms. The working followed the bedding of the sandstone, almost horizontally, but incorporated two levels each about 2 metres high. In a few places these are separate and superimposed (marked on figure 14), but mostly they were coalesced to form higher galleries which had been worked in two stages.

The mine yielded over 10,000 tons of sand. It was entered direct from Mansfield Road, and the easy drift access allowed the use of donkeys for hauling underground; a trough cut in the rock may have been a manger for their feeding. Parts of the mine alongside Mansfield Road may predate Rouse's involvement. The mine also worked through some much older caves, originally pub cellars and perhaps cave dwellings; remains of these are recognisable in some of the rooms close to the entrance. The location of the mine was dictated by the quality of sand available close to the old town. It extended beneath the Sand Field (Fig. 1), which was Freeman's land — effectively a common — where surface quarrying would not have been permitted.

After the mine ceased working, its entrance was lost until it was rediscovered in 1837. Soon after that, foundations for the new houses along Mansfield Road were cut into the mine to reach solid rock below, and may have destroyed a number of other original entrances. Sealed again behind the new brickwork, the mine was a tourist site in 1892, advertised as Robin Hood's Mammoth Cave with thousands of coloured lamps illuminating the 2000 year old passages (Ilife and Baguley, 1971)! Other fables of an ancient troglodyte fortress (Silkstone, 1978) were equally distant from reality. Parts of the mine were subsequently used as an air raid shelter in the Second World War. For this purpose, two new entrances were cut with flights of steps in the rock into the north end of the mines, and that on Peel Street is now the only one open.

Further up the Mansfield Road, there were more sand mines around Gallow's Hill where it crosses the Mount Hooten scarp (Fig. 1). These were associated with sand quarries which lay in the eighteenth century waste land on both sides of the Mansfield Road (Fig. 15). Because this area was waste land, these were uncontrolled public sand pits, where people dug for their own sand.

The early workings were therefore rather chaotic, and only some remain, with modifications from the nineteenth century. There were three original quarries, in a line, each working southwards into the steep slope. There must then have been either some restrictions on land take or some variation in the sandstone, because two of the quarries extended southwards into mines. These were both drift-entered, pillar-and-stall workings, very similar to Rouse's except that they were not so extensive. They successfully exploited a zone of the sandstone much weaker and more friable than the rock forming the walls of most of the other caves in Nottingham.

East of the Mansfield Road, three sections of old mine survive behind the old quarry wall (referred to as the Mine Caves on Fig. 15), though the whole site is rather

One of the larger galleries in Rouse's sand mine west of Mansfield Road; the pillar-and-stall plan and the two levels of working are visible.

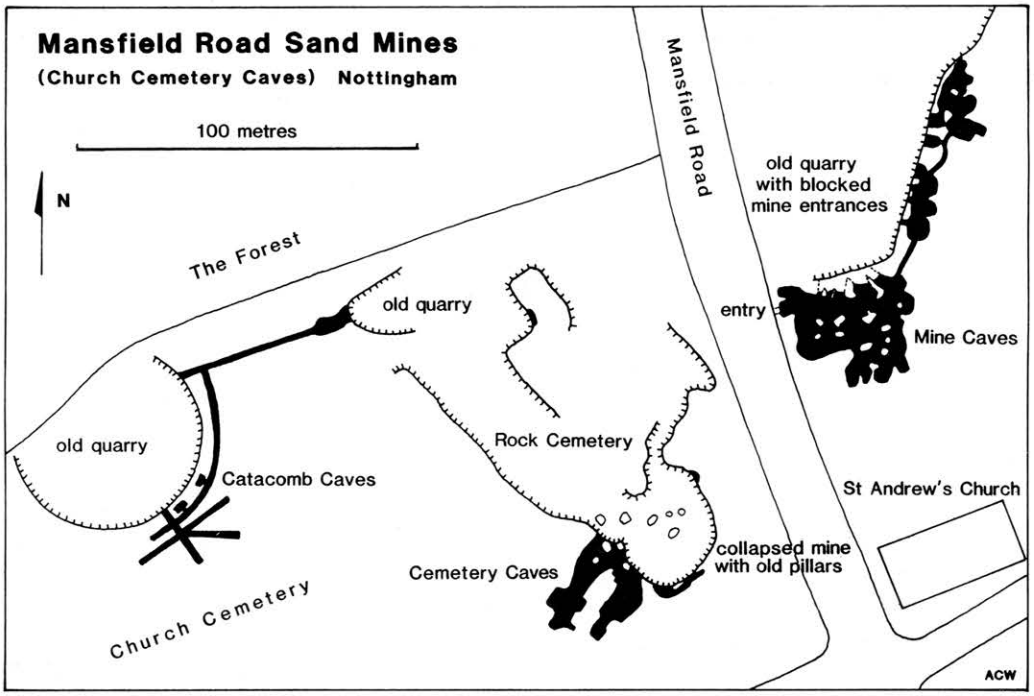


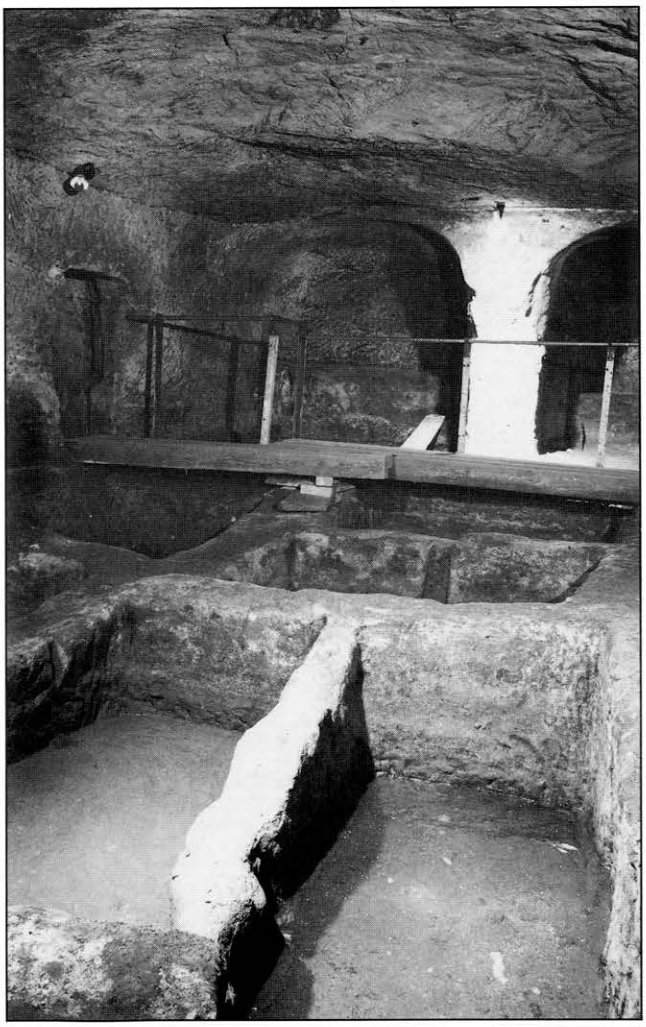
Fig. 15. The various old quarries, sand mines, collapsed mines and catacombs in and around the Church Cemetery on Mansfield Road. Originally an area of sloping waste land, the site was peppered with quarries and mines during the eighteenth century; the remains of these now provide a dramatic rock setting for the cemetery. (Compiled from various surveys by Tony Waltham, Richard Storm, Ian Spibey and Pete Walker, and by Nottingham City Council).

obscured by Victorian houses. West of the road, a similar quarry and mine lay on the site now forming the Rock Cemetery. The quarry was north of the mine, as dictated by the ground slope, but the position of the original edge of the mine is uncertain. There appears to have been some system or order in the mine, as it had an underground tramway, but the extraction was a little excessive leaving rock pillars which were too thin or too widely spaced. In 1806 a miner was killed in a rockfall, and in 1811 the Corporation broke down the mine roof (Blackner, 1815); this was probably in the interest of safety, but would also have yielded a good tonnage of new sand. Then in 1850, a ropewalk occupied the site (Hind, 1943). Today, the Cemetery Caves (Fig. 15) are the surviving remnant of the old mines; the collapsed section of the mine, with the stumps of its pillars still recognisable, now forms the magnificent setting of the Rock Cemetery.

The western quarry had no associated mines and was subsequently landscaped into the circular amphitheatre which exists today. This was probably done around 1859-63 when the Catacomb Caves were cut from a tunnel linking the two quarries (Fig. 15). This project was an attempt at providing underground burial chambers, but it remained unfinished when the contractor went bankrupt. Popular ideas of Druid origins of the caves and of passages beneath the Mansfield Road are totally unfounded. Adaptation of the Mine Caves as a wartime air raid shelter gave them the new entrance direct from Mansfield Road and also the two short tunnels linking the three groups of old mine workings.

The Caves in Modern Times

The legacy of perhaps 1000 years of cave excavation in Nottingham is a scatter of caves beneath much of the city. There is at least the possibility of a cave being known or found under almost any building,



Vats cut into the sandstone floor of the Tannery Cave which originally opened into the cliff face at the edge of Broad Marsh. The walkway in the background is for the cave tours now run through the Drury Hill Caves.

construction site or road in the old part of the town bounded by the Norman wall and the alluvial floodplain (Fig. 1). Open caves with thin rock roofs provide a special hazard for civil engineering works (see below). The almost continuous process of city centre redevelopment is constantly modifying the known data on the caves, and figure 2 can only be regarded as an interim map of the cave distribution. Building demolition frequently reveals previously unrecorded caves, to add to the map, while new foundation works may destroy other caves — and many marked on figure 2 are already full of concrete.

Caves have been lost through Nottingham's redevelopment for more than a hundred years. Back in 1892-95 slum housing north of the Market Square was demolished and replaced by the office blocks on Queen Street and King Street. All the caves there were filled with concrete (Fig. 6), including a number of pub cellars and one great cave room 20 metres long by 5 metres wide with central columns (Stapleton, 1904). At least these caves were mapped and recorded before filling — and the same has happened in other cases; the caves under Stanford Street (Fig. 18) and the old Corner Pin public house (Fig. 21) are now also concrete filled. Unfortunately many other caves were not documented. Not surprisingly an extensive series of caves lay beneath the Black Boy Hotel on Long Row, but these were filled with concrete when the Littlewood's store replaced the hotel (Fig. 2) and no map or description survives. In other cases of redevelopment, caves were destroyed when new basements or foundations were excavated to reach solid, non-cavernous rock. More than 100 years ago, a number of caves were excavated and destroyed to build the department store which is now Debenham's; only two caves survive under this large site (Fig. 2). More caves were destroyed for the basements of the Pearsons store east of the surviving medieval cave and only fragments of their entrance stairways were left in the rock. Victorian brickwork is a feature in so many caves, including Rouse's sand mine (Fig. 14) and the Drury Hill caves (Fig. 9), and is an indication of how much history has been lost.

Fortunately, many caves do survive, and some are still in use. Those in use are dominated by the pub cellars, as they are still excellent for the storage of beer barrels. Others tend to be used as little more than rubbish dumps, as urban space is always at a premium, and many caves are too damp for storage of many materials. Heavy duty electricity cables have been laid through some of the caves beneath York House. Yet more of the caves had their entrances bricked up, and have then been forgotten; these tend to cause the most

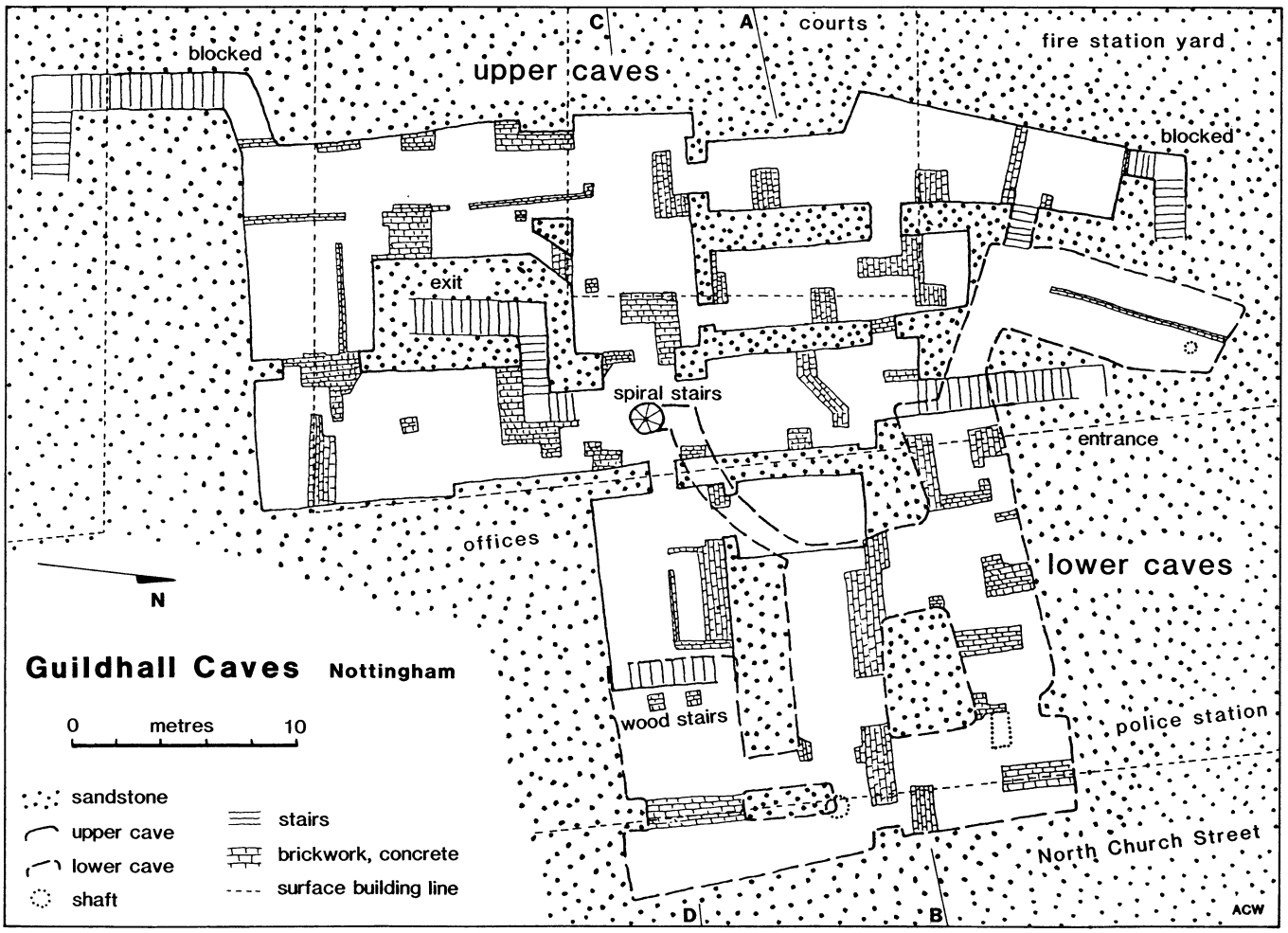


Fig. 16. The caves beneath the police station, courts and yards behind the Guildhall. Originally cut as wine cellars they were modified and heavily reinforced during the 1939-45 war. (Compiled from outline survey by Nottingham City Council, with detail added by Tony Waltham).

problems in engineering redevelopment.

Within the twentieth century, the story has mainly been of the destruction of the caves, but there have been some new additions. Garages for private cars were cut in the sandstone directly off Newcastle Drive in the Park (Fig. 2) in 1965. The most important phase of new cave excavation was for air raid shelters in the Second World War.

Air raid shelter caves

A deeply buried cave with a thick roof of solid sandstone, and an overlying cushion of earth and buildings, seemed to offer the best protection against most types of bombs likely to descend on Nottingham during the 1939-45 war. Consequently the early years of the war saw a burst of activity with the excavation of some new caves and the modification of others, while a few schemes for more massive new caves were shelved and forgotten.

The new purpose-built air raid shelter caves are distinguished by their extended linear form, with straight tunnels mostly only three metres wide at much greater depth than most other caves, and always with at least two entrances. To achieve more easily the depth, and roof cover, they are mainly in sloping ground. The Lees Hill air raid shelter cave was cut into the modified cliff at Sneinton Hermitage (Fig. 3), and another system was cut into the lower levels of Castle Rock (Fig. 12). There are just a few more purpose-built air raid shelter caves in the Radford area, including the largest, cut under the Player's factory (Fig. 1) and capable of sheltering some thousands of people.

Existing caves were also utilised or modified in anticipation of the air raid threat, and a city council register dating from February 1941 had 77 caves available as public shelters. Most of the larger caves which were easily accessible at the time appear on this register, and many had some modifications to improve their safety. A second entrance was obligatory; in some this meant that new flights of stairs were cut through the rock — as in both the old sand mines (Figs. 14 and 15); elsewhere this was just a shaft with a vertical ladder, or, in a few cases, a narrow spiral staircase. Some caves had blast walls installed near their entrances; these were basically massive off-set brick buttresses to act as baffles and reflect some of the shock wave energy (as can be seen on figures 14 and 16). Steel roof supports were installed in a few caves, though this was rather a case of over-design, and most had some form of electric lighting fitted. Short lengths of new tunnel were cut to link some adjacent caves and thereby improve access; these include the tunnels linking the three surviving sections of old sand mine east of the Mansfield Road (Fig. 15), and also some of the connections in the Drury Hill caves (Fig. 9).

Two caves are worthy of special note. The old wine vaults beneath the buildings behind the Guildhall were fitted out for emergency use as the local Civil Defence headquarters. These extensive and spacious caves (Fig. 16) were ideal for the purpose, particularly when modified and strengthened by a plethora of blast walls, extra roof supports, concrete reinforcement, room dividers and a final total of five entrances. The strengthening was largely justified by the rock cover of only 3-5 metres (Fig. 17). Rather different was one of the caves under Castle Rock which was used for the wartime storage of radium; ideal protection for such a sensitive material, it was finally cleaned out — very, very thoroughly — in 1953.

Engineering and Construction Over the Caves

Unrecorded caves with their entrances hidden behind brickwork or rubble provide an obvious engineering hazard where bedrock sandstone may normally be regarded as suitable for most foundations. The situation in Nottingham is about as difficult as it can be, with the large numbers and erratic distribution of caves under the town centre.

There appears to be just one recorded case of a building falling into a Nottingham cave. During the last century, the pillar of a building frontage on Albert Street (now occupied by the Marks and Spencer store) was inadvertently built over the crown of a cave, and subsequently collapsed through into it (Stapleton, 1904). The collapse of Stanford Street in 1990 (Fig. 18) was also due to the failure of the sandstone forming a cave roof. Two other recent road collapses — one in Glasshouse Street in 1978 and another in Forman Street — may also have been cave roof failures but details are not available.

A second failure mechanism associated with the caves is where a structural cap, a debris layer or a debris plug fails over an unsealed shaft or staircase. This happened on a building site on Long Row in 1991. A vibrating roller was being used to compact a granular base for a floor slab; either the vibration or the previous night's rain must have loosened the debris below the placed fill, as a hole a metre in diameter suddenly opened in the fill. This was a shaft 10 metres deep, brick-lined for its upper half, which subsequently proved to link into the caves beneath the Lion Hotel. The shaft was

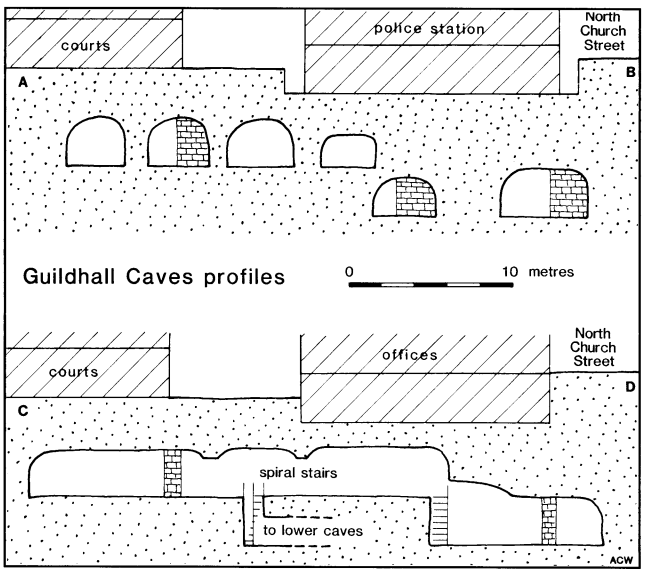


Fig. 17. Profiles through the Guildhall caves along lines AB and CD marked on Figure 16.

later capped, and the reinforced floor slab now safely spans it. A similar mechanism could have been responsible for the Glasshouse Street and Forman Street failures.

This is a very short list of failures, and there have almost certainly been more which have passed undocumented; most would have occurred on redevelopment sites and would have been rapidly remedied or filled in by the contractors at work. There have also been many cases where the ground has dropped into caves during the removal of an old floor or the excavation and lowering of bedrock to achieve a new foundation level.

Slightly different is the disintegration of cave walls which are exposed to the atmosphere, instead of being protected behind doors beneath a building. Exposure leads to repeated changes of moisture content, and, even more significantly, to frost action; under these conditions the sandstone weathers rapidly by granular loosening. In Thomas Herbert's Park caves (Fig. 13), the sandstone matrix has weathered back, leaving included quartzite pebbles projecting from the wall and indicating the approximate original profile. The weathering has taken 10-20 mm off the walls in about 130 years, and the loose sand forms a scree at the foot of each wall; it is noticeable how much the weathering decreases away from the entrance and up the Haddon Hall staircase (Fig. 13) where statues and wall detail are much better preserved. The walls of some other exposed caves, notably those along Hollow Stone, are rotten and softened due to the same weathering. This process was probably a significant factor behind the collapses of the sandstone cliffs with caves cut in them. 1829 was a remarkably bad year with two collapses at Sneinton Hermitage (Best, 1985) destroying some caves and parts of the two public houses (Fig. 3); in the same year, a rockfall destroyed five houses along Narrow Marsh, where Cliff Road now lies (Fig. 2). With the caves already cut into the face, and the rock steadily weathering away, there was no simple remedy; at both sites, the cliffs were cut back and many caves were destroyed — especially along the eastern part of the Hermitage (Fig. 3).

Sandstone strength and cave roof failure

The Nottingham Castle Sandstone varies in unconfined compressive strength within the range of 1-30 MPa (Forster, 1988; Storm, 1988), with a mean value of less than 10 MPa. Samples recently tested from within various caves have all yielded strength values in the lower end of this range, and even lower values have been obtained on weathered material. The sandstone's mean dry density of only 1.7 Mg/m^3 (Forster, 1989), equivalent to a saturated moisture content of 17%, indicates the high porosity and hence the very low degree of grain contact within the rock; this is a characteristic of sandstones of low strength (Dobereiner and de Freitas, 1986).

As is typical of weak sandstones, the strength of the Nottingham Castle Sandstone declines significantly when saturated. The saturated strength of samples taken from various caves has been found to decline to between 20% and 65% of the dry strength. This broadly matches the halving of strength on saturation recorded for the sandstone by Walsby *et al.* (1990), though these values were generally higher, for both dry and saturated strength, than the cave sandstones. The decline to only 20% of dry strength was recorded for the particularly friable sandstone exploited in the Mansfield Road sand mines, which had a dry unconfined compressive strength of close to 1 MPa for the fallen blocks which were sampled in a weathered state. The tested sandstones recovered their strengths fully when dried after a period of saturation. These parameters suggest that clay minerals are the dominant cement in the sandstone, and the high porosity probably reflects solutional loss of calcite through weathering.

Clay cement permits plastic deformation of the sandstone before failure by fracturing. Wherever cave roofs are seen to be failing, the sandstone clearly displays closely spaced bedding planes which are not visible in adjacent undeformed wall exposures. The rock separates into beds 10-40 mm thick, which sag under their own weight and then fail as beams. In some cases, these

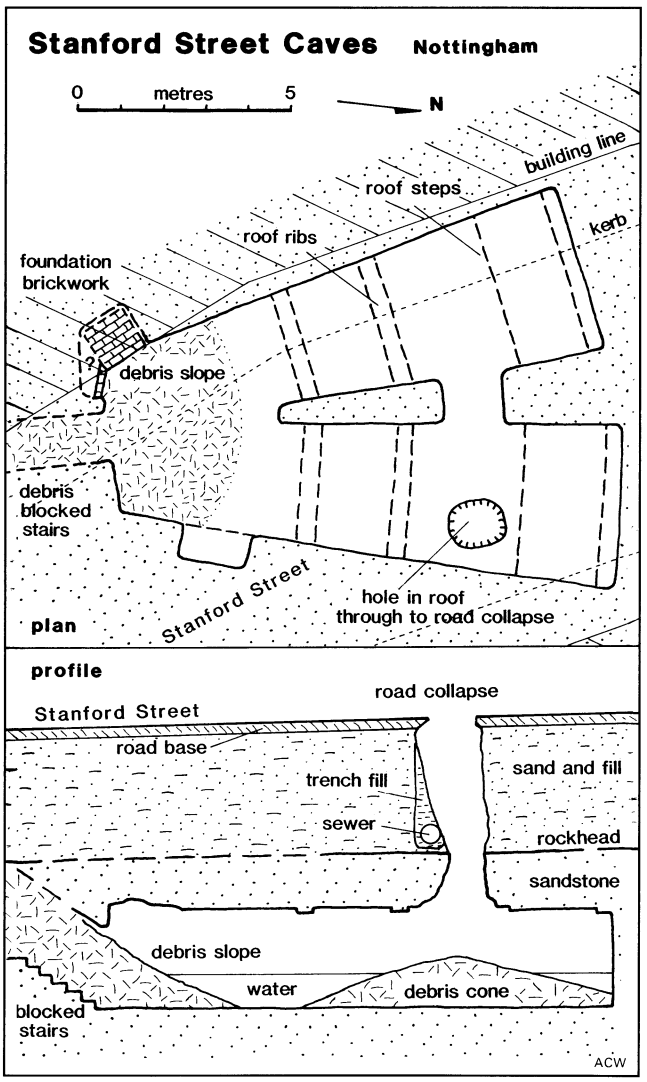
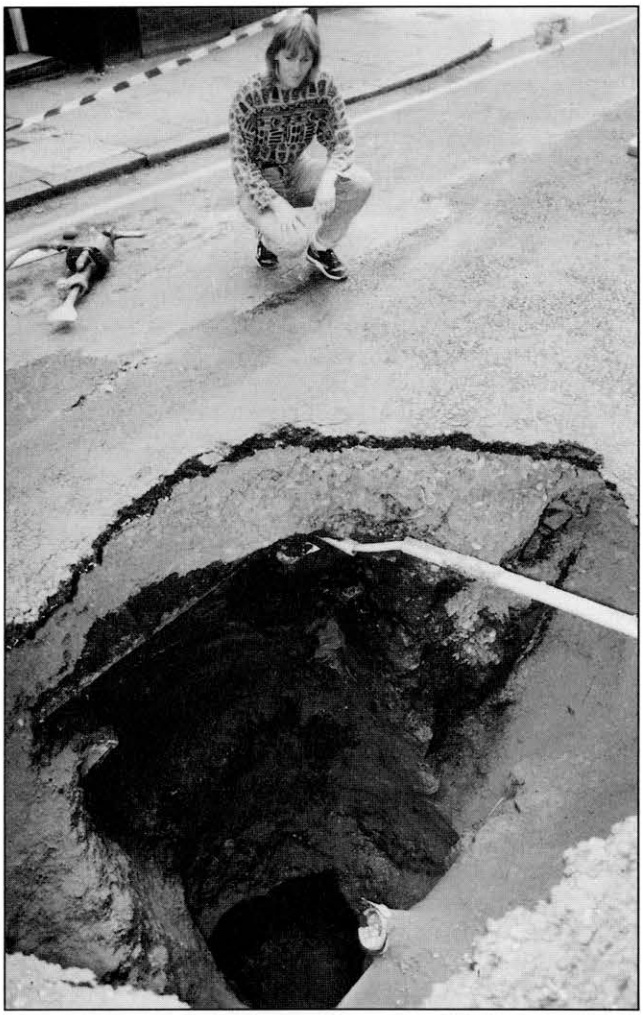


Fig. 18. The caves beneath Stanford Street revealed by the collapse of the road in 1990 and before filling with concrete. (Survey by Tony Waltham, Ian Spibey and Jenny Walsby).

separating roof beds can be pushed up by hand, and on release settle back to their sagged position. No complete failure cycle has been monitored, but spot observations suggest that a time scale of years may be involved from when the rock is first saturated.

The loss of strength on saturation of the sandstone could have implications with respect to caves now flooded by rises in the water table beneath Nottingham in response to the landfill on the alluvial plain. Rock pillars within the caves would be threatened most. No sign of deterioration is yet apparent in the cave pillars under Drury Hill and Castle Gate which now stand intermittently or permanently in water. Perhaps fortunately, these pillars are cut in some of the stronger horizons of sandstone, and have also been destressed by recent removal of structural loads.

Critical to any cave roof failure is, not only the rock strength, but also the roof dimensions in terms of thickness, span and arch profile. Over most caves in Nottingham, the thickness of sound rock is generally only 1-3 metres, discounting any rock weathered to a dense *in situ* sand. Roofs much thinner than a metre would generally fail during the disturbance of cave excavation. Thicker roofs do occur, over part of Rouse's sand mine (Fig. 14) and over some beer cellars in public houses. The Golden Fleece cellars (Fig. 14) have 5 metres of rock cover, probably because they were excavated in the softer sandstone bed exploited by the nearby mine. The Lion Hotel caves (Fig. 2) have 5.2 metres of rock cover for no apparent reason; the caves could not be any deeper as the floors are at the water table. Under the Running Horse, on Alfreton Road (Fig. 1), the cave cellars are 11 metres down, but this is largely because the pub is built on a terrace of made ground, and there is only the usual two metres of solid rock over the caves.



The collapse of Stanford Street very soon after it happened; most of the open hole is in soil and fill, but rock is just visible around the dark hole breaching the cave roof.

A maximum span for the cave roofs is about 5 metres, as in the Plumtre House caves (Fig. 22). Any caves wider than this, and many that are narrower, have rock pillars in them. Many pillars are less than 0.5 metres wide and probably have more ornamental benefit than structural use, though other more substantial pillars were clearly left to provide roof support (Figs 7, 8 and 21). In most cases the roof has been cut as a very gentle arch, though it is more nearly flat in many of the younger caves. There are variations; the Stanford Street caves were given semi-circular profiles, with ornamental ribs, and the medieval cave under Pearsons (Fig. 8) has a roof which is a spectacular complex of three-dimensional arches between its splendid flared pillars.

Small scale roof failure is a widespread feature in the Nottingham caves. Some sign of failure, either currently active or historical and subsequently stabilised, has been observed in 20% of the caves visited by the author. Of a list of more than 20 recorded roof failures, about half have occurred or have still been active within the last ten years. In nearly all cases the failure exposes bedding planes within the sandstone, and progressive development nearly always creates an arched profile which is stronger and more stable. In some cases a single fairly deep failure breaks up to an existing weak bedding plane; this is commonly along a pebble bed horizon consisting of poorly sorted sediment including grains, particles, flakes and rafts of mud (now mudstone). In other cases, there is no single geological control, and the roof breaks into uniform beds 10-40 mm thick before falling away, either singly or in multiples. Most fallen roof disintegrates into sand when it hits the cave floor; some blocks or very thin beds survive the impact, but most are still too weak to be picked up by hand.

The one documented roof span failure which broke through to cause a surface collapse occurred under Stanford Street in the summer of 1990 (Fig. 18). The cave entrance had been blocked many years previously, so the early stages of failure were not observed. Progressive roof failure, at an unknown rate, eventually caused sandstone 1.3 metres thick to fall away, exposing rockhead within the cavity. Subsequent ravelling (falling into the void) of the soil would have been more rapid, until a cavity was created bridged only by the unreinforced road base and blacktop. This then failed under the wheel of a slow-moving lorry, as a typical crown hole collapse. The hole, more than 5 metres deep, was unstable with vertical and overhanging sides. A hundred tons of sand was then tipped into the hole, to form a shaft fill sitting on a stable cone within the cave below. The shaft was then re-excavated, and shored and stabilised in the process, so that the cave was again

open and could be safely entered. The process of upward failure of the cave roof was then apparent, even though the fallen debris remained buried under the tipped sand, and another site of initial roof failure was found at the south end of the cave. Premature plans to cap the hole with a concrete slab resting on rockhead were abandoned, and the whole cave was filled with concrete up to rockhead level. The poured concrete now sits on the unconsolidated sand and debris which covered the cave floor, but the potential compaction of this is very low.

The basic cause of the Stanford Street failure was a leaking water main, from which water losses had been known for some length of time. Water had drained down to rockhead and had then percolated through the sandstone into the cave. The loss of strength in the saturated sandstone had then allowed progressive failure to develop upwards. Without doubt, the major cause of cave roof failure in Nottingham is saturation of the sandstone by stray water input, though other factors contributory in specific cases include tree-root action, surface weathering and overstressing. There is therefore a need to keep the roof rock of the caves dry, and the normal situation with buildings or paved areas above effectively does this. The medieval cave under Pearsons (Fig. 8) had part of its roof rock exposed in 1990 when demolition of the department store left only a timber floor between direct rainfall and the rock. One small collapse did subsequently occur, and since then a waterproof bitumen seal has been placed over the rock to protect the cave until a new building covers it.

Structural loading of rock over the caves

The Sherwood Sandstone around Nottingham is generally credited with a safe bearing pressure of 1 MPa for general foundation design, though Forster (1989) cites values of 400-1600 kPa based on standard penetration testing of weathered material. A critical concern is the effect that any caves should have on the normal value, which is applicable to sound rock in a confined situation.

To gain some understanding of the factors involved, a series of tests, involving the loading to destruction of scale models of caves, has been undertaken at Nottingham Polytechnic (Waltham and Chorlton, 1990; Holland, 1991). A loaded foundation pad over a cave ultimately causes a plug failure within the rock (Fig. 19). A plug of rock, close to the size of the loaded pad, is pushed into the cave; the rock mainly fails in shear with a small amount of tensile fracture in the lower, flared section of the plug. Tests have shown that the plug shape and its failure load are almost independent of cave width; however, thin roofs over caves more than 5 metres wide could perhaps fail as beams. Loads which are offset from the caves produce complex curved plugs (Fig. 19).

The model tests have shown that the presence of a cave is irrelevant where its roof is thicker than about 3-4 metres, in the worst case of loading on a one square metre foundation pad centrally over the cave. With thicker roofs, loading causes crushing of the rock before any failure of the cave. Cave roofs less than 3 metres thick do fail, under loads which are close to those theoretically calculable from the plug surface area and the rock shear strength. A cave roof about 2 metres thick will fail at roughly half the load that will cause failure of solid rock, and the failure load is roughly halved again over a cave roof just one metre thick (Waltham and Chorlton, 1990). The influence of the cave declines where it is not directly below the loaded foundation. With a roof 1.5 metres thick, failure is into a cave up to 1.5 metres away from the foundation (measured as the distance from the foundation centre to the nearest cave wall); this influence decreases until a cave with a roof 2.5 metres thick is only relevant if at least its wall is directly beneath the foundation centre line (Holland, 1991). Further studies are in progress to evaluate the influence of cave shape, the presence of cave pillars, foundation shape and size, rock fractures and strength variation, and the presence of soil cover, together with combinations of the various parameters.

In the light of this empirical test data, it is appropriate to reassess some of the existing structures overlying the Nottingham caves. The Victorian warehouse over the Plumtre House caves had its foundations taken down though the shallow staircase entrance cave (Fig. 22), but rightly ignored the main caves, safe beneath 3.4 metres of rock. However, the footings of 17 Castle Gate rest on only a metre of rock spanning a 3 metre wide cave (Fig. 7), and a stanchion inside the Pearsons department store stood directly over the centre of the lower cave beneath just 1.25 metres of rock. The wall of a lace warehouse on Broadway was found to stand on just 0.7 metres of rock over an unsuspected cave — where supportive brickwork was hastily placed (Stapleton, 1904), and minimally loaded brickwork rests on barely half a metre of rock over the front of the Pillar Cave now beneath the Broad Marsh Centre. Although

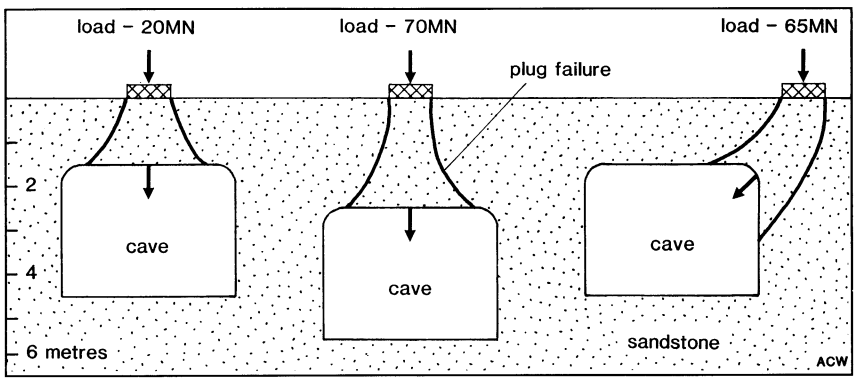


Fig. 19. Three examples of rock failure caused by the structural loading of the sandstone over caves. In each case, the load is applied on a foundation pad 1 metre square. The loads over each cave are those required to form the plug failure, and the contrasts in their values demonstrate the influence of both rock roof thickness and loading away from the cave axis. Drawn from model tests by Holland (1991); the absolute loading values suffer from problems with scale factors from the models, but, on the same models, rock with no cave usually crushes at loads around 70 MN; the relative values are significant.

modern regulations may preclude situations like these, their structural integrity is ensured both because the loadings in all cases are nowhere near the maximum permitted, and also because the guideline safe bearing pressures do incorporate large safety factors to account for rock variability.

Site investigation with respect to the caves

With so many caves already known in the Nottingham sandstone, good site investigation practice has to be designed so that any potentially hazardous voids in the rock are found and evaluated before the commencement of construction work. Inside the Norman town wall and north of the floodplain (Fig. 1) caves are likely to be found on almost any site and searches must therefore be thorough. Outside this area, the rest of the Nottingham Castle Sandstone outcrop may contain caves, but the chances are greatly reduced, and there is more likelihood of any caves being documented, as these are mainly the newer ones; consequently, conventional site investigation practice is generally adequate, unless a site — for example that of an old public house — is particularly suspected to have caves.

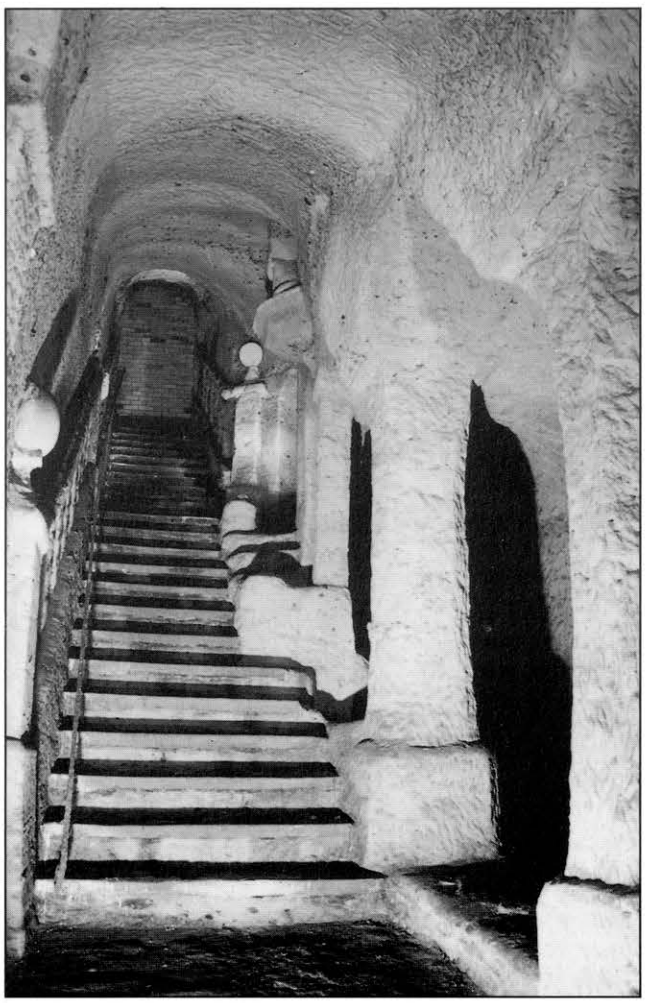
Checking the available data is the first stage of any site investigation. The records and maps of the Nottingham caves were notoriously scattered, and almost impossible to assess, until the British Geological Survey conducted an extensive search and compiled a single register (Owen and Walsby, 1989). This documents more than 400 caves or cave systems, including their locations, size and depth, plans and descriptions where available, and state of filling or access if known. It was up to date in February 1989, and since then more than 50 additions, either new caves or new data, have been added. The computerised B.G.S. files are regularly updated (currently by Jenny Walsby) and a supplement is being prepared for publication. This database can never claim to be complete, as so many caves are inaccessible and forgotten (figure 2 identifies just some of the lacking data). An inherent disadvantage is that many caves are only found during site redevelopment; consequently, the lack of data, in the form of unknown caves, is greatest on sites not recently redeveloped and therefore most subject to new construction. This situation, and the value of the database, will improve over time.

Site clearance and demolition frequently reveals unsuspected caves. Access can then be gained and they can be accurately and quickly surveyed. Many have entrances bricked up, and some have walls inside them underneath old property boundaries; judicious removal of brickwork is always the cheapest way to reach and assess any caves, as was the case at the south end of the caves found when building York House (Fig. 11).

If all the caves on a site have still not been found and mapped, rock drilling is then necessary. In recent times most of this has been carried out by John Prior, a Nottingham contractor. He uses a hand-held pneumatic drill with extension steels and air flushing; a cave is instantly recognised, even if it is filled with debris, by an increase in penetration rate accompanied by loss of flush return.

There are currently no formalised regulations for test drilling the Nottingham sandstone in the search for caves. A hundred years ago rock was test drilled for 1.8 metres (Stapleton, 1904), but general practice applied within the city has evolved since then. Now, each column base on a site is drilled to prove 3 metres of sound rock, where a loading up to about 250 kN is envisaged. Sound rock must be proven for 5 metres for design loadings in excess of either 500 or 1000 kN. Inclined holes may also be required to provide the same length of sound rock at either 30° or 45° from the vertical. These rather variable guidelines, applied by the Nottingham City Council Department of Building Control, certainly prevent any building failures due to the presence of caves, but appear to represent a case of over-design.

In the light of the model test data outlined above, a more appropriate guideline for site investigation would be as follows: beneath a foundation site, prove solid rock for 3.5 metres in a vertical borehole, and, for design loadings greater than 200 kPa also prove solid rock for 3.5 metres in three holes inclined at 30° from the vertical in directions at 120° to each other. This would be the most economical way of finding potentially hazardous caves (Fig. 20), though some of the caves thus



The grand staircase cut into the sandstone, as a direct replica of a staircase in Haddon Hall, to provide the original main entrance to Daniel's Cave in Thomas Herbert's Victorian garden.

intersected may represent no threat to a foundation. It effectively establishes solid rock within a critical zone (as recognised by Holland, 1991), outside of which caves are irrelevant to foundation integrity. Boreholes through 5 metres of solid rock are normally unnecessary. Boreholes radially offset by 1.5 metres could be an alternative to the inclined holes, if site access permitted, but bores at 45° inclination could miss significant caves (Fig. 20). A grid of bores 3 metres deep would be adequate for the site of a normal raft foundation. These site investigation guidelines would also appear to offer appropriate defence against the occurrence of destructive crown holes. Though less is known about the extent of roof failure in saturated sandstone under Nottingham, crown holes are not recorded, and appear to be unlikely to develop, through rock cover of even just two metres.

When a cave with no other entrance is found by a borehole, it is usually necessary to excavate a hole through the rock to reach it and survey its extent. Mapping caves by serial boreholes is rarely effective or economical at such shallow depths.

The construction alternatives

Where caves are found to exist beneath a construction site, the three basic alternative courses of action are to fill the cave, to add support inside the cave, or to design the structure to bridge the cave. The procedure which is appropriate on any individual site depends on the balance between the cost of the engineering works and

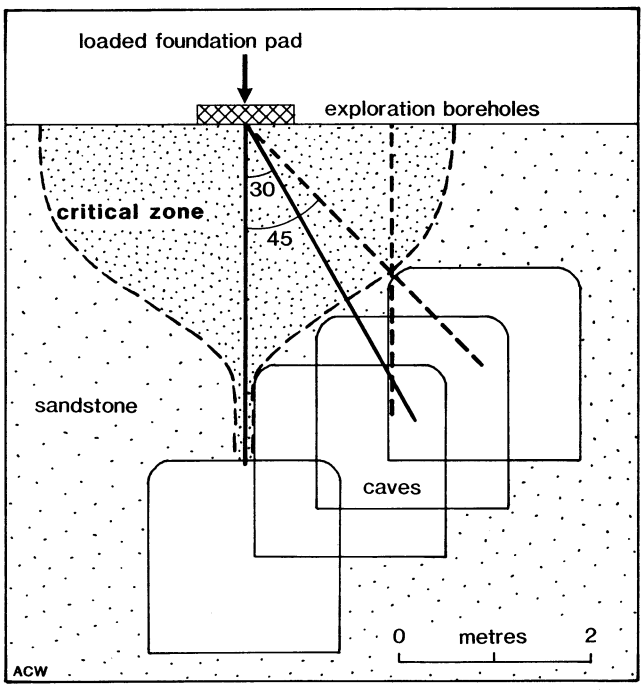


Fig. 20. The placing of site investigation boreholes beneath a planned foundation to prove solid rock within the critical zone, inside which any cave may affect the foundation integrity. Caves in any of the four overlapping positions marked would not normally affect the foundation, but all would be located by 3.5 m long boreholes vertically and at 30° from the vertical. Alternative borehole positions shown by broken lines have some disadvantages (see text).

the historical value, and hence the need for conservation, of the cave. Recent clearance of a site for redevelopment on Fletcher Gate revealed four caves; three were small old pub cellars, modified by Victorian brickwork, and once mapped could simply be filled with concrete; the fourth was a small group of cave rooms with thralls, roof shafts and one rock column, and these will be preserved beneath foundations which will span them. It is normally only necessary to fill the caves or place support inside them for the construction of heavy structures. Light building extensions on a concrete slab can be placed over most caves, and strip foundations loaded to 100 kPa would normally be safe over just a metre of sound, dry rock. In these cases, variations in shape of both the foundations and the caves require individual assessment of each site, but reinforcing of strip and raft foundations can permit the spanning of voids, and 3 metres of rock cover may not be required.

Filling the caves

Filling a cave with concrete does re-establish solid ground for any engineering works, but is terminally destructive of any potential historical value. It is usually appropriate for small isolated square-cut caves of no great vintage, of which so many in Nottingham are rather unremarkable, but it would be an environmental tragedy to fill any of the larger, more unusual caves in the city. Even filling involves the cost of concrete, and in many cases the caves first need clearing of debris so that the concrete bears on a solid rock floor. Filling is often regarded as the simple remedy, but each cave should be viewed on its merits.

The Stanford Street caves were filled in 1990, and this was appropriate, even though a fine cave was lost (Fig. 18). The filling operation cost many thousands of pounds, but the cave had two zones of active roof failure, there was no access except through the collapse, and structural work to carry the road safely over the cave would have been very much more expensive.

The caves under the Corner Pin public house were initially only partially filled in zones under the line of the load-bearing exterior walls (Fig. 21). Mass concrete was poured behind breeze block walls which were built in the cave (and provided with temporary bracing until the concrete was solid). This was a successful compromise which conserved at least some of the caves, though these too were subsequently, and rather unnecessarily, filled after a change of site management. Another cave on the same site had a line of bored piles taken right down through it to support a structural wall, before it also was completely filled.

Just as destructive as filling is bulk excavation and replacement by basements. The Victorian department store for Griffin and Spalding on Long Row (now Debenhams; Fig. 2) had more basements than was originally planned, when multiple levels of caves beneath the sloping site were all cleared and destroyed to reach sound rock for the foundations (Stapleton, 1904).

Structural support within the caves

The most obvious compromise between engineering

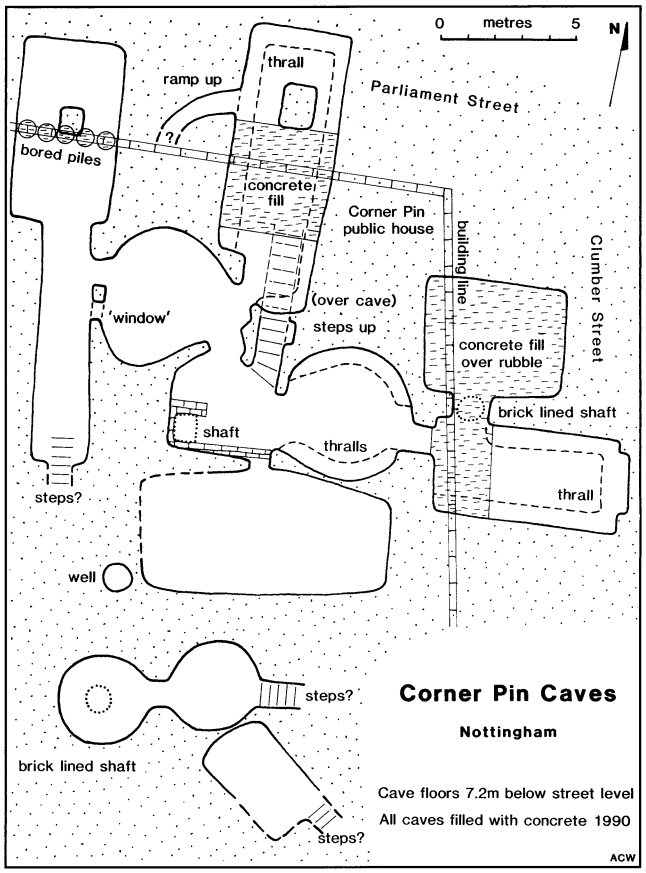


Fig. 21. Caves found during the redevelopment of the Corner Pin public house on Clumber Street. An initial stage of partial concrete filling is shown, though all the caves were later filled. The three southern sets of steps (all marked with ?) and parts of the cave walls (marked by broken lines) were not completely excavated or recorded before being filled with concrete. (Compiled from surveys by Tony Waltham and Ian Spibey, using some outline data by John Burrows Partners.)

safety and conservation is the placing of solid support within the caves directly beneath the lines or points of structural loading. Simplest is the construction of brick walls or columns at the relevant points in the caves, and there are numerous examples under Nottingham. Many sections of complete or partial walls have been placed in the Guildhall caves beneath load-bearing exterior walls of the buildings, and are clearly recognisable on figures 16 and 17 (beside the brick walls placed purely for blast deflection). A free standing brick column underlies an exterior wall of the Salutation Inn (Fig. 5), and spur walls of brickwork have been added in the Plumtre House and Hickling Laing caves (Figs 22 and 10). The Victorian architect T. C. Hine hastily constructed support walls of brick inside a cave which he found beneath less than a metre of rock on which a new warehouse wall had just been built. There is great scope for brickwork strengthening and the Drury Hill caves contain a plethora of added columns, walls and arches mostly too small to appear on figure 9.

Alternative to isolated supports within the caves are column bases carried down through the caves to bear on solid rock below floor level. These remove any structural reliance on the sandstone over the caves, but do come at increased cost. The Plumtre House caves have a modern concrete column base just breaching the upper cave, as well as Victorian brick footings extending down through the entrance stairway (Fig. 22). A number of concrete column bases are also visible in the walls of the Drury Hill caves (Fig. 9) and each lies beneath a main structural feature within the Broad Marsh Centre (Waltham, 1989).

In modern construction, end-bearing piles can be placed through a cave, where they effectively become columns not supporting but passing right through the roof rock. A large diameter bore passes through the cave roof, and can then be extended into the cave floor, or a normal column base can be cut out of the floor rock. Cast concrete piles were used for the foundations of York House, on Mansfield Road, and many of them pass through the old brewery caves, while others stand in niches cut into the cave walls (Fig. 11). The cylindrical piles were cast in Sonatubes — lightweight fibreboard tubes 520 mm in diameter, which could be lowered down the bored holes and into the caves; a reinforcement cage was lowered into each tube before pouring the concrete, and there was no need to build temporary shuttering inside the caves. An alternative is to use a steel H-section pile which forms a stanchion within the cave bearing on a concrete base within the cave floor — as was used for one column on the Plumtre House site (Fig. 22).

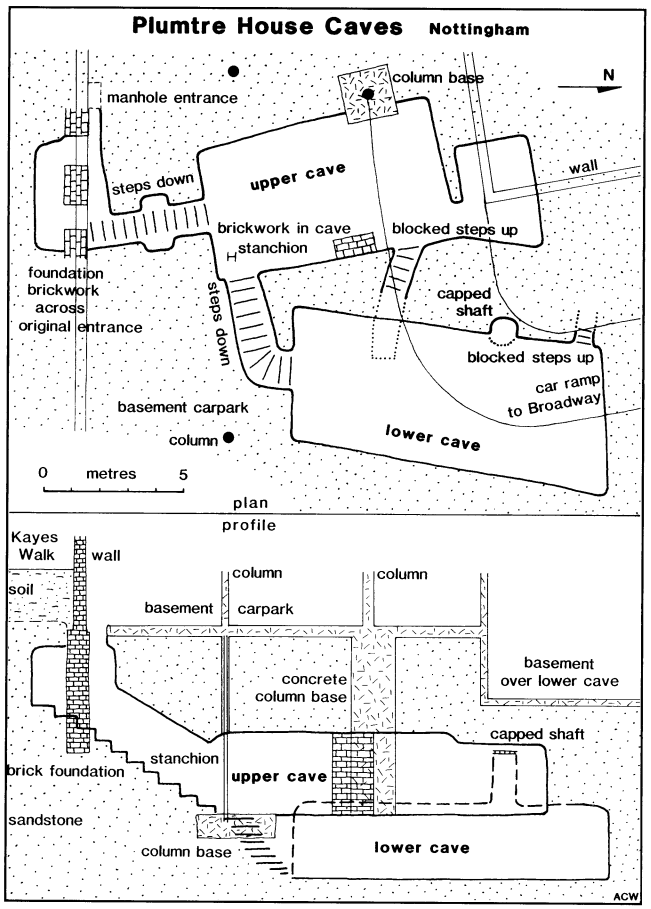


Fig. 22. The caves that once lay beneath Plumtre House, with the foundation works of brick, concrete and steel for the redeveloped Victorian factory which now occupies the Lace Market site. (Survey by Tony Waltham, Jenny Walsby and Angus Tillotson).

Bridging over the caves

Foundations designed to span the caves beneath may be the most elaborate alternative but are perfectly feasible on many sites and have the benefit of complete cave conservation. Many reinforced floor slabs stand safely over caves, including the malt kiln caves beneath the Broad Marsh Centre (Fig. 9) and a debris filled cave beneath a car park just west of the Plumtre House caves; both are now accessible through manholes. Back in 1880, a steel H-beam was installed to carry a new internal wall safely above the caves below when an old chapel on Fletcher Gate was converted to smaller units. 400 years earlier, extra footings were incorporated under the Severns building (on its original site on Middle Pavement) to reduce the point loading over the caves (Hamilton, undated). Within foundation design, there are many possibilities, using spread footings, and reinforced strips and slabs, of reducing to acceptable levels the loadings imposed on rock with caves below.

The scope for bridging over caves is well demonstrated by the Broad Marsh Centre which was built over the conserved Drury Hill caves (Fig. 9). The caves are so shallow that the foundations could not bear on the roof rock, and one column with a design loading of 6 MN would have stood in the northern corner of the Pillar Cave close to the Tannery Cave (Waltham, 1989). This was not acceptable, so a deep concrete beam spans the caves from solid rock on the north side to a column in front of the Tannery Cave (Fig. 23). The beam is 20 metres long, spanning 12 metres of cave; the rock was used for the formwork to cast it, but the beam now takes the load of the column bearing close to its mid-point. Similar ground beams and a reinforced raft could have supported the new offices built in 1966 over the malt kiln caves on Castle Gate, and so have avoided placement of the concrete columns within the caves; this cave complex is only a maximum of 11 metres long, but there would have been difficulties in establishing footings without encroaching on adjacent properties.

The Future of the Caves

The list of Nottingham's caves is changing every year. Destruction and losses have been going on since Victorian times, with concrete filling, less permanent rubble filling, sealing of entrances, damaging brickwork modifications, and even brick interior walls under property boundaries. On the positive side are the new discoveries. In each of the past few years the best of these have been found during building demolition prior to redevelopment: in 1988, the Plumtre House caves, with their two large rooms; in 1989, the Corner Pin caves, already filled with concrete; in 1990, the separate lower cave under the Salutation Inn, with its contents of artefacts; and in 1991, the malt kiln caves at both the Plumtre House site and south of Low Pavement, which bring the city total to 18 underground malt kilns.

Some losses are inevitable when urban development is driven by economic forces. Damage can be minimised, but concrete filling, or total excavation, is permanent. There is therefore a clear need to fully record any caves before filling, so that they can take their place in the historical profile of the city. Large cave systems were totally destroyed on the sites where the Debenhams and Littlewoods stores now stand on Long Row, and any plans or records have been lost and can never be replaced.

Much more recently, the Corner Pin caves were prematurely filled under a site engineer who was distressingly proud of his lack of historical interest. The record that was compiled (Fig. 21) was gained partly under a more sensitive predecessor, and subsequently largely by good luck. The site was potentially important, next to a gateway in the old town wall, yet the unusual window between two of the caves was never fully revealed and the site drawings of the southern caves were hopelessly inadequate. There was no real need to fill the caves; the old building had stood for many years (with the caves hidden by a brick wall across the top of the steps down from the basement), and planning restrictions prevented the new one from going any higher.

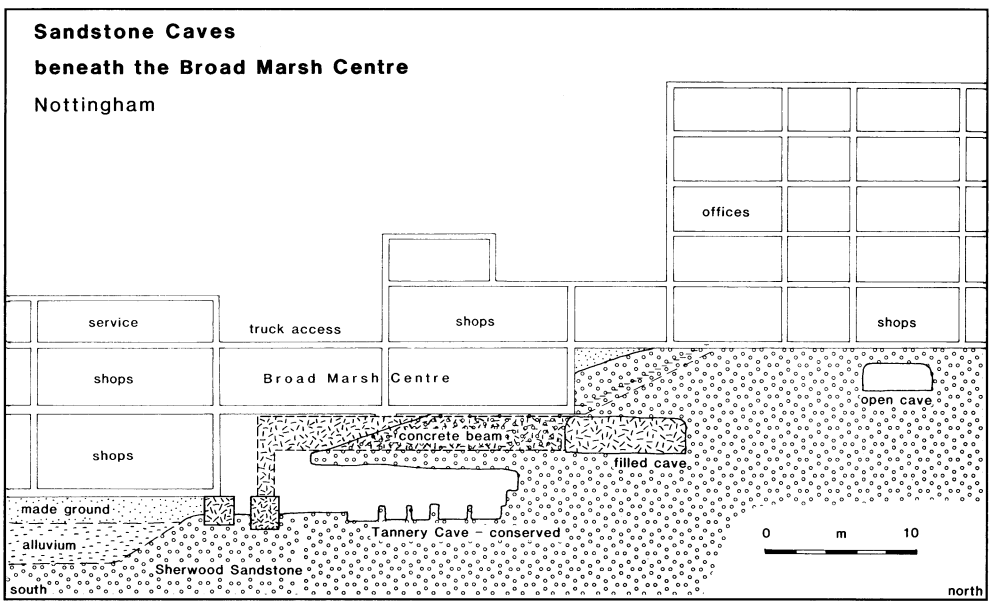


Fig. 23. Projected section through the Broad Marsh Shopping Centre showing the massive concrete foundation beam which spans the caves. The beam lies almost over the narrow rib of sandstone left between the Pillar and Tannery Caves (see Fig. 9); the caves directly beneath the beam do not extend as far north as the projected outline of the Tannery Cave.

Losses of historical data, such as at the Corner Pin, should be avoidable. Timing is critical where a cave does have to be filled, as construction projects can be expensive to stop or delay, but even a brief visit by a surveyor and an archaeologist can be valuable (MacCormick, 1990). Sadly, some developers, site engineers and contractors lack any sensitivity for the heritage value of the caves. Fortunately, there is a growing proportion who do value the environment, but regulations are still needed as a line of defence against the ravages of the former.

Conservation and protection of the caves

At present, six of Nottingham's medieval caves are scheduled Ancient Monuments. These are the Castle Rock caves, Lenton Hermitage, the Middle Pavement complex (Fig. 2), the Broad Marsh or Drury Hill caves, and the malt kiln caves of both Drury Hill and Castle Gate. There is scope and justification for increasing the list of protected sites, and perhaps the Salutation Inn, Pearsons, Rouse's mine, Willoughby House, Goose Gate, and Thomas Herbert's Park caves would be the prime contenders to double the list. Without further national protection, the state of all the other Nottingham caves lies in the hands of the City Council. It needs a strong commitment to preserve, investigate, record and increase public awareness, or the city's stock of caves will decline in both number and quality (MacCormick, 1990). The caves were mentioned in the 1980 Statement of Planning Policy for Nottingham, but this lacked enthusiasm and strength of purpose. Alan MacCormick, archaeologist in the city's Human History Department, was concise and positive (1990): "What is needed is a clear understanding of this city's cave heritage on which could be based a policy for selective preservation and interpretation". Management of some caves as tourist attractions could be included, and could provide some financial return. The situation has improved within the last few years, but only slowly.

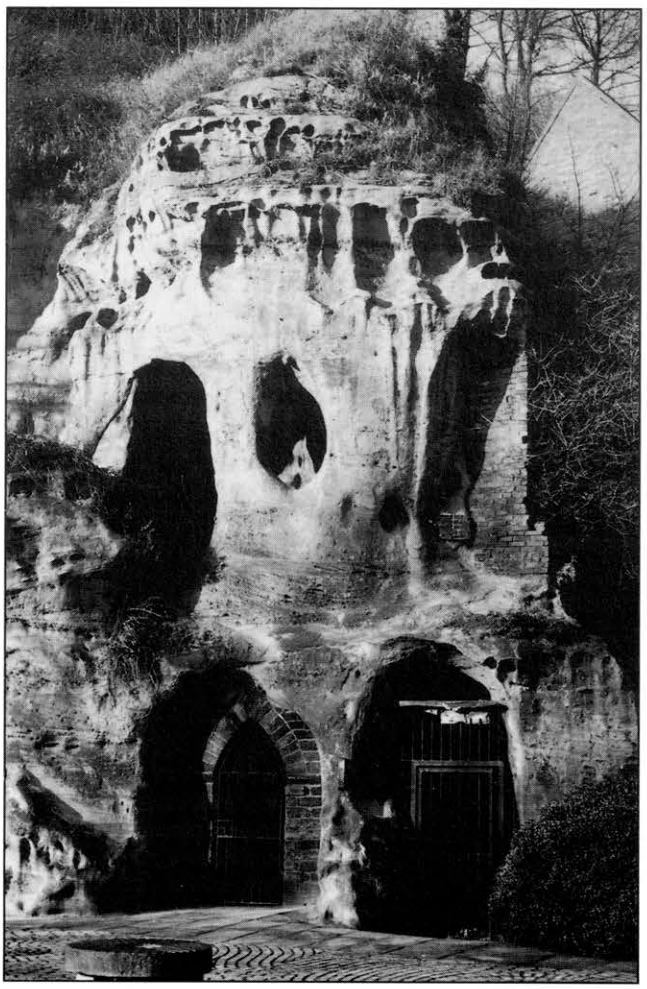
At the time of writing, the city planning department has no formalised policy on cave protection. The main threat to the caves comes from building redevelopment, but the city council's only control is applied along informal principles. There is no systematic control and no legislative power, and protection of the caves relies on individuals' interpretation of policy. The key stage is in the planning permissions, and approvals are now normally, but not automatically, subject to two clauses relating to caves.

The first clause considers any known caves and may demand that they are safeguarded in a particular manner. However, the department of building control is necessarily a major influence within the planning permission process, and their objective is to ensure the structural integrity of the buildings — perhaps at the expense of caves which could affect the foundations. Sympathy for the caves, and cooperation with the archaeologists, is improving over time, but building regulations which may be over-conservative could unnecessarily damage the caves. The need for the column bases inside the Plumtre House cave (Fig. 22) could be questioned when 3.4 metres of rock overlies the void; spread footings would have offered a less destructive alternative, and there is clear need for further research in this field.

A second clause in the planning permission requires that the city's archaeologist is given access to any previously unknown caves that are exposed by the site works. This relies on the contractors advising the council of any discoveries, and, because of potential consequent delays, there is some incentive for irresponsible site operators to quickly conceal or fill any caves. Even where the regulations are known to have been ignored, the council has little or no power or scope for remedial action.

Until 1990, these clauses were only appended to planning permissions where caves were known or suspected. Since then they have been applied as normal practice on sites within the city centre. This welcome change of policy grew from increasing awareness and publicity over the caves' heritage value and tourism potential, but the clause concerning unknown caves should be absolutely automatic and legally enforceable, at least on sites inside the line of the Norman town wall.

There is also a need to restrict drilling into known caves. When a rock drill breaks through a cave roof from above, it breaks off a flat cone of rock up to a metre



The lower entrance to Mortimer's Hole and other caves at the foot of Castle Rock, gated for protection but now a venue for many of Nottingham's visitors and tourists.

across. Yet the only purpose is to gain data on the cave location and roof thickness which can be obtained perfectly easily by competent surveying in accessible caves. The fine medieval cave under Pearsons (Fig. 8) was damaged in this way only a few years ago, and such unnecessary drilling should be restricted within the planning process.

Protection of the caves should be increased by refinement of Nottingham's planning policy, and also by more sympathetic, research-based foundation design. The conservation measures beneath the Broad Marsh Centre (Fig. 23) show what is possible in the latter sphere; often all that is needed is the right concept and an appreciation of the value of environment and heritage. An imaginative approach was recently applied in the Plumtre House caves. For the site redevelopment, a tower crane was installed with its base partly over the lower cave, where temporary supports of timber beams and acro screw jacks were installed as an added precaution; they were very adequate and left the cave undamaged.

A special case is provided by the need to protect some caves from the effects of water and weathering. The exposed rock over the medieval cave under the old Pearsons site (Fig. 8) was given a waterproof seal in June 1991, and at the same time the cave entrances were closed to reduce frost action through the winter; the costs amounted to less than a quarter of a percent of the site demolition costs, but should effectively protect the cave. There is no roof leakage in Thomas Herbert's magnificent ornamental caves in the Park (Fig. 13), but the rock carvings are weathering through the action of atmospheric moisture and frost. Replacement of doors and windows would achieve a reduction in their rate of deterioration, without which some chemical or physical protection of the sandstone will soon be necessary.

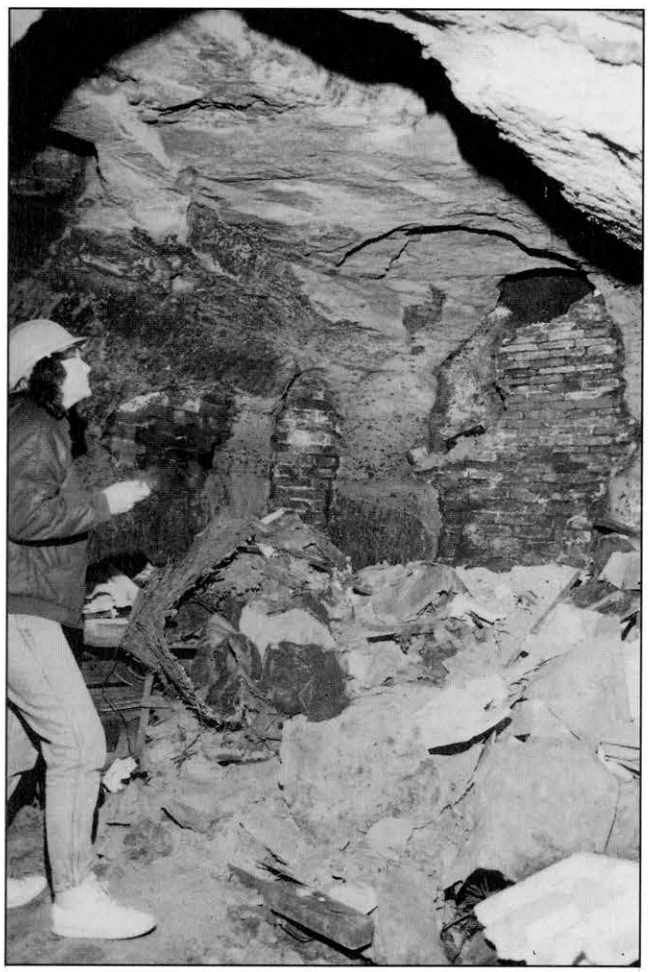
The caves as a resource

The benefits of utilising the caves include the protection that is then afforded them because of the interest or value that they gain. Caves which are ignored or forgotten are more readily damaged or destroyed in future years.

At least a dozen public houses in Nottingham still use their rock caves as beer cellars. In many ways they are still ideal, though some can be damp through lack of ventilation, and the health authorities are sometimes over-zealous with regulations. The Trip to Jerusalem and the Hand and Heart inns both have some of their bars within caves, and there have been plans for the surviving Pearsons cave to be used as a cafe or restaurant. The splendid cellar caves under the Salutation Inn are no longer used for beer storage or as bars, but are readily accessible to customers at most times.

Tourist or visitor access to most of the caves is made difficult by conflicts of interest where the caves are only entered through buildings serving a totally different purpose. The historical value of a cave is preserved where it is only accessible through a manhole in the floor of a private office, but its tourist value is impossible to realise. Currently there are regular guided tours of Mortimer's Hole beneath the Castle and the caves under Wollaton Hall, as well as access to the cave in the Brewhouse Yard museum (Fig. 12). Tours are also organised by volunteer groups, on a less frequent, more irregular basis, to the caves of Drury Hill (Fig. 9), Shire Hall, Bridlesmith Gate (Fig. 2) and Sneinton Hermitage (Fig. 3). To this list of visitable caves may be added the three pub caves noted above, and some of the pub beer cellar caves which are accessible by appointment for special interest groups. The Goose Gate caves (Fig. 2) may also be accessible in the not too distant future, and the Park Tunnel is on a public footpath at the end of Tunnel Road.

Speculative plans for cave tours by the city council include two interesting opportunities. Tours through the Drury Hill caves could be extended with a minimum of new engineering works, to provide a route through the western caves, then out through the original cliff and along to the Willoughby House caves (Fig. 9). This would make a splendid tour, including some of the most interesting caves in the city, and could constitute a significant Nottingham tourist attraction. However, it will require some form of negotiation with the Willoughby House owners, and also an entrance approach more acceptable than the concrete wasteland

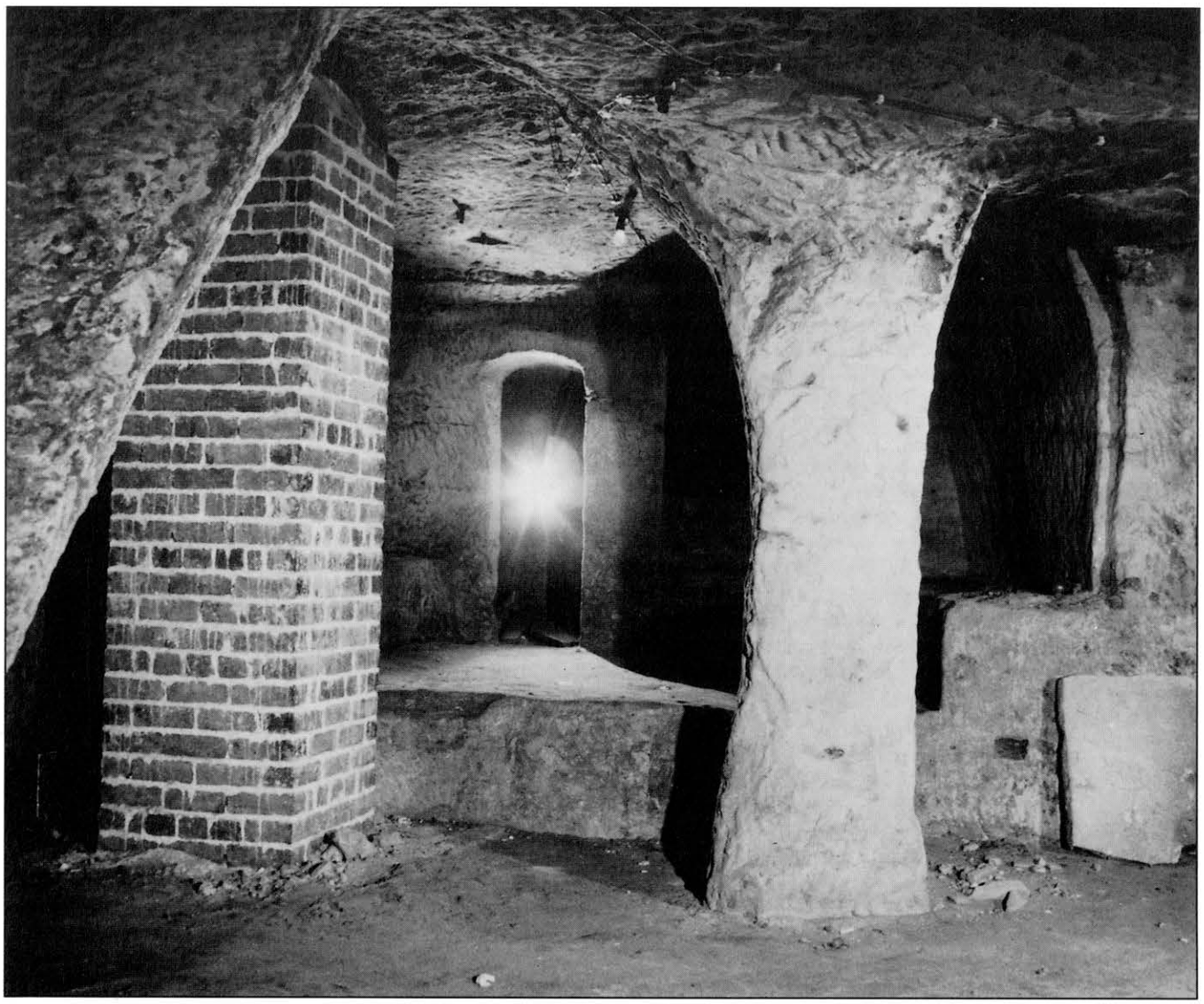


One of the caves recently exposed along Fletcher Gate in a rather dismal state: there is much added brickwork in the walls, the roof is breaking away and the floor is covered with rubbish.

behind the shopping centre. Rouse's old sand mine is the most extensive cave in Nottingham (Fig. 14) and it too has potential for an unusual underground tourist facility. The city council already owns the Peel Street entrance, but any serious development of the site will have to be through the main entrance on Mansfield Road; this is through the shops/offices/factory block currently up for sale in a rather derelict state, and will therefore depend on the cooperation and interest shown by a new owner.

Beyond the pub cellars and tourist sites, the scope for utilising Nottingham's caves is rather restricted. A cave on Castle Road houses a rifle range, there is the garage on Newcastle Drive, and the Guildhall caves are used for fireman training. Others are used for storage, but often end up more as dumping grounds. Plans have been announced to install a night club in the old Burton's cold store caves (Fig. 1), and also a sauna complex in the caves beneath the new Commerce Square residential development (Fig. 2).

For the many other caves, where commercial development is not possible, the value lies in their historical record and role in the environmental heritage of Nottingham. Today this is appreciated, and selective conservation is therefore warranted. In some cases, legal agreements between private landlords and the city council would be appropriate, and grant aid to pay for protective measures and access provision may not be unreasonable. These concepts require recognition and coordination within council policy, but they should eventually ensure that the caves remain as a part of Nottingham's urban structure.



The lower level cave below the old Pearsons department store with two original pillars left in the sandstone (the flared pillar on the left is only half seen in profile). A brick column was later addded to provide extra structural support for the building above, and the whole cave has since been filled with concrete.

Access to the Caves and Cave Data

Nearly all the caves referred to in this paper are private property, and either have gated entrances or are only reached through private buildings. With the exception of the few caves described as open for tourists, visitors and pub customers, access is generally not available and requests for casual visits are not encouraged.

The cave maps in the text figures of this paper have been prepared to illustrate the morphology and features of the caves, and are therefore only based on surveys of appropriate accuracy; they are not surveys of engineering grade. The British Geological Survey publications do not contain cave maps. Many caves have never been accurately mapped, but available cave maps may be obtainable through the Survey subject to normal charges. The more obscure publications cited below are mostly available in the Local Studies section of the Nottingham County Library.

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Photographs

All photographs by Tony Waltham.

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