When and Why? The Chronology and Context of Flint Mining at Grime's Graves, Norfolk, England

Frances Healy, Peter Marshall, Alex Bayliss, Gordon Cook, Christopher Bronk Ramsey, Johannes van der Plicht and Elaine Dunbar

Abstract

New radiocarbon dating and chronological modelling have refined understanding of the character and circumstances of flint mining at Grime's Graves through time. The deepest, most complex galleried shafts were worked probably from the 3rd quarter of the 27th century cal BC and are amongst the earliest on the site. Their use ended in the decades around 2400 cal BC, although the use of simple, shallow, pits in the west of the site continued for perhaps another three centuries. The final use of galleried shafts coincides with the first evidence of Beaker pottery and copper metallurgy in Britain. After a gap of around half a millennium, flint mining at Grime's Graves briefly resumed, probably from the middle of the 16th century cal BC to the middle of the 15th. These 'primitive' pits, as they were termed in the inter-war period, were worked using bone tools that can be paralleled in Early Bronze Age copper mines. Finally, the scale and intensity of Middle Bronze Age middening on the site is revealed, as it occurred over a period of probably no more than a few decades in the 14th century cal BC. The possibility of connections between metalworking at Grime's Graves at this time and contemporary deposition of bronzes in the nearby Fens is discussed

Keywords: flint mines, radiocarbon dating, Bayesian modelling, social context of mining, Grime's Graves

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GRIME'S GRAVES

The Grime's Graves flint mines lie in Weeting-with-Broomhill parish, Norfolk, England (52° 28' 50" N, 0° 40' 25" E, NGR TL 81758 89781; Fig. 1). They were among the first flint mines to be excavated in Britain, Canon Greenwell being a notable protagonist. The history of the site's antiquarian recognition and subsequent investigation in the nineteenth and

twentieth centuries is summarized by Mercer (1981, 1–7); Barber *et al.* (1999, 4–16); and Longworth *et al.* (2012, 13–15). It is bound up with that of the Prehistoric Society, whose parent body, the Prehistoric Society of East Anglia, undertook significant excavations in 1914 (Clarke 1915). The inter-war period saw continued excavations, mainly by A.L. (Leslie) Armstrong, published in the Proceedings of the Prehistoric Society of East Anglia (eg Armstrong 1923, 1924, 1927). Work resumed in the 1970s, when a deep shaft and its surrounding surface area were excavated by Roger Mercer for the Department of the Environment in 1971–1972 (Mercer 1981); and a major research project led by Ian Longworth and Gale Sieveking for the British Museum was conducted in 1972–1976, its interim results being published in this journal (Sieveking *et al.* 1973).

Views of the site's chronology varied with the intellectual climate of the times. Canon Greenwell (1870) straightforwardly saw the shaft which he had excavated as a Neolithic flint mine. By the early twentieth century there was a groundswell of opinion to the effect that flint mines at Grime's Graves and elsewhere were Palaeolithic rather than Neolithic, a view voiced forcefully by Reginald Smith (1912), based on the similarity of the primary, 'industrial' stages of flint working at the site to some aspects of Palaeolithic industries. This gathered force, notwithstanding the presence in the already excavated flint mines of the remains of Holocene domesticates, pottery (in Sussex) and a ground stone axehead (in Canon Greenwell's pit at Grime's Graves). Smith maintained this view in his report on the struck flint from the Prehistoric Society of East Anglia's excavations at Grime's Graves (Smith 1915). In the inter-war period, Armstrong developed a sequence in which mining started in Mousterian times and continued into the Neolithic, finishing before a Bronze Age occupation took place. At the start of this scenario were 'primitive' pits: 'These pits, and the tools used in sinking them are of a type not previously recorded and undoubtedly mark an early phase in the evolution of mining. . .. The waste material of both the chipping floors and the pits is rougher and differs in general facies from the familiar Grime's Graves waste' (Armstrong 1927). It was not until the 1930s that Grahame Clark and Stuart Piggott, founder members of the Prehistoric Society, reviewed the dating evidence (artefactual, faunal and stratigraphic) from the British flint mines, concluding '. . . in our view all the evidence points to a Neolithic date for the main flint-mining activity in Britain, no earlier phase having been satisfactorily demonstrated. Its inception seems indeed to be linked with the Windmill Hill culture' (Clark & Piggott 1933).

Topography and Geology

Unlike most of the known English flint mines, which lie on the Chalk downland of Sussex and Hampshire (Barber *et al.* 1999, fig 1.1), Grime's Graves occupies part of the Breckland, a distinctive area of south-west Norfolk and north-west Suffolk, where, while the Chalk lies close to the surface, the gently rolling topography is unlike that of the southern Chalk because of the area's geomorphological history. During the Pleistocene, while the southern English Chalk underwent periglacial, rather than glacial, modification, the East Anglian Chalk was planed-off, at least by the Anglian (OIS 12) ice sheet, if not also by later ones. By the end of the Pleistocene, the East Anglian Chalk, where it was still close to the surface, was covered by diverse sands, gravels, and tills — mainly sands in the Breckland. Ice-sheets stopped short of the region during the cold episodes of the last glaciation (OIS 4 and 2); it may have been at this time that cryoturbation mixed the top of the chalk and the lower part of the sands, forming a chalk-sand deposit which remains below the overlying sand and topsoil. Periglacial activity also gave rise to stripes and other forms of patterned ground.

The Chalks exposed in this part of East Anglia are of the Turonian stage. Within this, the Brandon Flint Series, quarried at Grime's Graves, comprises up to 15 m of relatively massively bedded Chalks with marl seams and widely separated courses of giant (0.2 to over 0.4 m) tabular and nodular flints (Mortimore & Wood 1986; Bristow 1990, 16–29). The flint mined at Grime's Graves in prehistory occurs in three main seams, commonly known by the names given them by the recent gunflint miners of Brandon, Suffolk, which lies 5 km to the south-west. They are effectively described by Saville (1981, 1–2): the topstone, close to the surface of the Chalk, ranges from small pebbles to large nodules, often with convoluted extremities, with a thin grey cortex; the floorstone, which was favoured by the Late Neolithic miners, is semi-tabular, occurring in large, smooth nodules with flat surfaces and convex undersides, covered with a thick, creamy cortex (Fig. 2). The wallstone, stratified between these two, has some of the characteristics of both. Where cortex and nodule form no longer survive, the black flint from all three seams is difficult to distinguish. Flint also occurs in the Chalk between the seams and, in derived form, in superficial deposits.

At the end of a century of excavation, the broad lineaments of the complex could be defined as follows. The highest part of the site forms a slight ovoid spur rising to 29 m OD (Fig. 1). Here, below the zone of cryoturbated sand and chalk, the chalk and its seams of flint are

undisturbed. This is the area of deep, systematically worked, mine shafts sunk through the higher flint seams to the level of the floorstone, which was exploited by means of radiating tunnel-like galleries (Fig. 3). Since the chalk strata locally gently shelve downward from north-west to south-east, the flint seams are deepest in the eastern part of the spur, where shafts can be up to 12 m deep, and shallowest in the west, where they can be as little as 5 m deep. To the north and west of this spur, on lower ground, the flint seams and the upper part of the Chalk are closer to the surface and underwent considerable disruption during the Pleistocene, leading to multifarious mixing and rafting of superficial deposits. These were areas of simpler, unstandardised, quarrying in relatively shallow pits between 1.5 m and 4 m deep, most of them around 2 m (Fig. 4). The most fully investigated of these areas is known as the West Field (Fig. 1). Armstrong's 'primitive' pits (1923, 1924) constitute a separate, distinctive class of features among other less standardized ones in these lower-lying areas. They are not more than 4 m deep, characterised by the use of bone rather than antler picks; by undercuts at the base where they were sunk to the floorstone; and by additional undercuts about half way down, made to extract flint from the glacially contorted deposits that overlay the solid chalk (Fig. 5). Rich, midden-like deposits of Middle Bronze occupation material around the east and south-east of the spur (Fig. 6) were first identified in 1914.

The deeper mines and their related knapping floors preferentially exploited the floorstone; in the shallower workings, flint of variable character and quality was extracted and worked more indiscriminately, from both *in situ* and derived deposits (Lech 2012). The mining-period industries were generalised, multiproduct ones, producing axeheads, discoidal knives, oblique arrowheads, scrapers and other small flake tools; flint was also removed from the site at earlier stages of the reduction sequence (Saville 1981; Lech 2012). Trace element analysis has correspondingly assigned flakes, scrapers, bifaces and other forms from the surrounding area to Grime's Graves (Craddock *et al.* 2012). The expedient Middle Bronze Age industries were made on flint scavenged from pre-existing spoil heaps (Saville 1981; Herne 1991).

The extent of the mined and quarried area remains unclear. The visible earthworks cover 7.6 ha and consist of 433 pits. Previous excavations have shown that flint was also extracted to the north and west of these, a picture enhanced by geophysical surveys which indicate further pits to the north and west of the visible examples (Favard & Dabas 2007; Linford *et al.* 2009). Some 200–400 m to the south-west of the area shown in Figure 1, test pitting

following tree-felling has revealed probable quarry pits and dense areas of primary knapping debris, suggesting that the kind of extraction and flint working practised on the West Field may have extended this far (Bishop 2012, 223–229).

Previous radiocarbon dating

In the 1960s a small number of antler implements from Grime's Graves and other flint mines was radiocarbon dated by the British Museum Research Laboratory. Within its limitations, the exercise indicated that, while the Sussex sites may have had their origins as early as the turn of the fifth and fourth millennia cal BC, Grime's Graves showed no sign of activity before the turn of the fourth and third millennia (Barker & Mackey 1961; 1963; Barker *et al.* 1969b). The two projects undertaken in the 1970s both generated more numerous radiocarbon measurements, made intermittently over the following decades, and extended the coverage beyond the deep mines. These were collected and reviewed by the late Janet Ambers, of the British Museum's Department of Conservation and Scientific Research, who spelt out the problems of working with them, stemming from questions of the identification, suitability, and contexts of the samples, and of the accuracy and precision of the measurements (Ambers 1996, 100; 1998, 591; 2012, 158). She began to redress these deficiencies by undertaking a selective programme of dating 13 further samples, using only those of high intrinsic and contextual integrity, modern measurement techniques, and high standard of quality control, and applying Bayesian analysis to the results (Ambers 1998; 2012).

By the end of the 20th century, there were 145 radiocarbon measurements from the site. Janet Ambers had shown that it was possible to achieve a high level of accuracy and precision. The overall picture, however, remained much as it was when sketched by Burleigh *et al.* (1979): mining and quarrying began in the mid-third millennium cal BC; the galleried shafts went out of use by the end of the third quarter of that millennium; shallower quarries elsewhere on the site continuing into the early second millennium; and there may have been some intermittent activity on the site between this and the later second millennium Middle Bronze Age occupation.

THE 2008–2014 DATING PROGRAMME

The project

Renewed interest in Grime's Graves, and in the English flint mines in general, grew from a national programme of research into flint mines in England by the former Royal Commission on the Historical Monuments of England (Barber *et al.* 1999). This led to plans by English Heritage to understand the site more fully and present it more effectively. The increasingly frequent and successful application of Bayesian statistical analysis to series of radiocarbon dates on stringently selected samples (Bayliss 2009) offered a means of better defining the chronology of the site, and AMS (Accelerator Mass Spectrometry) provided the means of dating smaller samples of a wider range of specimens than had been feasible during the British Museum's dating programme. This gave rise to a dating programme, funded by English Heritage (now Historic England), the main aims of which included the clarification of the overall timespan of flint mining at the site; of any differences in periods of use between the deeper and shallower workings; of the period of use of the almost undated northern area; and of the relation of the mining and quarrying to the contemporary society.

This was based on existing collections and records, without further fieldwork. One hundred and sixty-two further radiocarbon measurements were obtained in the course of this project, extending the coverage to new features and areas and checking measurements from already-dated contexts. Methods and results, including the structures of the models employed, as well as individual measurements and sample descriptions, are published in detail in an English Heritage Research Report (Healy *et al.* 2014), available at http://research.historicengland.org.uk/. Calibration and Bayesian chronological modelling of radiocarbon dates were undertaken using the program OxCal v4.2 (Bronk Ramsey 2009; Bronk Ramsey *et al.* 2010; Bronk Ramsey & Lee 2013) and the internationally agreed calibration curve for terrestrial samples from the northern hemisphere (IntCal13; Reimer *et al.* 2013). The underlying principles and details of the modelling method are fully explained elsewhere (e.g. Bronk Ramsey 2009; Bayliss 2009; Buck & Juarez 2017).

Pre-existing dates were rigorously assessed to determine how they should be included in the models or whether they should be included at all. It emerged that some measurements on bulk charcoal samples made in the 1970s are more recent than results for antler or for subsequently measured charcoal samples from the same contexts, possibly due to the incomplete removal of humic acid during pre-treatment (Healy *et al.* 2014, 10–11). All these dates are therefore excluded from the models. This does not apply to charcoal samples dated in the 1980s and subsequently. Antler and bone samples dated at this time could also have

suffered incomplete humic acid removal. This seems, however, less probable because, of 11 antler samples dated both in the 1970s and subsequently, 10 yielded measurements statistically consistent with the original ones (Healy *et al.* 2014, table 3). Samples newly selected for dating were predominantly antler or, less frequently, bone, mining tools, which would have been used in the extraction process and which were abundant, especially in the galleried shafts. Antlers, in particular, are ideal samples in that each is one year's growth, since they are shed annually by red deer stags (now in late February/early March — Legge 1981, 100). The large numbers recovered indicate that they were rapidly exhausted and discarded. It is furthermore probable that fresh, springy, resilient antlers would be preferred for digging. Thus, provided that an antler implement was recovered from where it was originally discarded by its user, it should be very close in age to its context. This superficially straightforward choice was sometimes problematic, in that apparently well-stratified antler picks may not always have been contemporary with their contexts. Chalk rubble dislodged when cutting the galleries at the base of the deep mines was generally managed by moving spoil from a gallery currently being excavated into an empty, exhausted one, rather than by the far more laborious process of transporting it to the surface (Longworth & Varndell 1996, fig. 6). Picks discarded during the cutting of a later gallery could thus be incorporated into the rubble filling an earlier one. An additional complication was introduced by the common occurrence of new galleries cutting into those driven from previously excavated pits, already containing rubble and picks that might be displaced into new contexts. Furthermore, since exhausted pits were often deliberately backfilled and the spoil heaps surrounding adjacent pits on the surface were often contiguous or overlapping, there is the possibility that spoil and picks from an older pit could be backfilled into a later one. The most reliable antler samples were thus those found on the bases of pits or galleries, preferably grouped together as if deliberately placed.

Results (Figs 7, 9, 10, Table 1)

The results summarised here are from the preferred model for the galleried shafts (Healy *et al.* 2014, 21–40, figs 15–41; alternatives are explored in the original report) and from separate models for other aspects of the site (Healy *et al.* 2014, 42–53, figs 45, 47, 49–51, 57–59).

According to the preferred model, the galleried shafts began to be worked in the second half of the 27th century cal BC and were abandoned in the late 25th or early 24th century cal BC,

having been worked for between two and two and a half centuries (Table 1; Figs 7 and 9: *start galleried shafts*, *end galleried shafts*; Fig. 10: *work galleried shafts*). The most recent estimate for an individual shaft is a *terminus post quem* for the sinking of an unexcavated shaft, pit Y, provided by the estimated end date of *2465–2385 cal BC* (*95% probability*), probably *2455–2405 cal BC* (*68% probability*; Fig. 78: *tpq pit Y*) for a long-lived, dense and extensive knapping floor which was overlain by the spoil upcast from this shaft (Longworth *et al.* 1991, figs 3–4; Longworth *et al.* 2012, 86–89, pls 5–6). It must be remembered, however, that only a small proportion of the more than 430 shafts still visible as earthworks has been excavated, let alone dated, and that these investigated features are unevenly distributed (Fig. 1). The dated examples may thus not be entirely representative.

There may be a hint of later mining in one of five galleries driven from the base of an unexcavated shaft, pit 15 D, which were explored by the Prehistoric Flintmines Working Group of the Dutch Geological Society, Limburg Section (Longworth & Varndell 1996, figs 43–44). Three antlers were *in situ*, arranged compactly and symmetrically against a wall of gallery 15D1, in undisturbed fill (Felder 1976, fig. V-V-II-10: antlers 108, 109, 110). Two of these were dated in the 1970s: statistically consistent replicate measurements on one have a weighted mean of 2290–2150 cal BC (2σ; BM-1056a 3838±42 BP, BM-1056b 3740±48 BP), the date for the other is 2270–2030 cal BC (2σ; BM-980 3736±58 BP). The measurements for both antlers are in turn statistically consistent (T'=0.8; T'(5%)=3.8; ν=1; Ward & Wilson 1978). Their tight grouping in the gallery and the consistency of the measurements indicate that they were not accidental intrusions. Their 23rd to 21st century cal BC dates are, however, so much later than the 100-odd other dates from the galleried shafts, including 26th to 24th century cal BC dates from galleries 15D2 and 15D4 attributed to the same pit (Healy *et al.* 2014, fig. 37: *BM-978*, *-1011*, *-1057*, *-1260*), that they throw the model into poor overall agreement if included in it. Either these dates are inaccurately recent, or pit 15 D seems to have been re-opened and gallery 15D1 worked towards the end of the third millennium cal BC. This is plausible on two counts: the pit, at less than 6 m deep, is one of the shallower galleried shafts and hence relatively accessible; and simple pits were still being worked in the west of the site at this time. Pit 15 D was certainly reopened and further worked in the mid second millennium cal BC, as described below.

Individual start and end dates were calculated for 14 features which had yielded four or more dates other than those excluded from the model. These features were sometimes entire shafts,

sometimes single galleries or groups of galleries when these are the only investigated parts of a particular shaft. Among these, the earliest were some of the deepest, with deeper and shallower pits worked throughout the period (Figs 1, 8). There is no hint of any simple progression across the area. Instead, several locations were returned to after extended intervals. For example, while Greenwell's original pit and the adjacent Greenwell's pit E were among the first galleried pits to be opened, nearby Greenwell's pits A and C were among the last, pits of various depths having been sunk in various parts of the field in the interim (Fig. 8). A possible interpretation is that each part of the field was worked by a different social group, who periodically returned to it. This finds some support in the record of pits 11 A to 11 H, a cluster of relatively shallow pits linked by galleries (Longworth & Varndell 1996, 45–49), all worked within the timespan of the galleried pits, although there were insufficient measurements to made estimates for individual pits (Healy *et al.* 2014, fig. 28). A number of antlers from these pits have common features which suggest that they had been shed by a single stag over a number of years (Clutton-Brock 1984, 38–9). It is not clear from this account precisely which antlers all of these were, or from which pits they all came, but the markings legible in a photograph of three of them (*ibid.* pl. 6) show that the smallest came pit 11 A and two larger ones from pit 11 D. It is as if a single group of people, gathering antler from a single herd, returned in successive years to the same small area of the mines.

Far fewer suitable samples were available from simple extraction pits on the West Field (Table 1) and date estimates are consequently less precise. They began to be worked in the later 27th or the 26th century cal BC and continued to be exploited until the 22nd or 21st century cal BC (Fig. 9: *start simple pits on West Field*, *end simple pits on West Field*). Despite the imprecision of the estimated start date, it is *88% probable* that these pits began to be worked after the galleried shafts, the interval between *start galleried shafts* and *start simple pits on West Field* being *−40 to +140 years* (*95% probability*), probably *15 to 115 yea*rs (68% probability; Fig. 10: *start galleried/start simple*). Their exploitation, however, outlasted that of the galleried shafts by 2 to 4 centuries (Fig. 10: *end galleried/end simple*), with a total span of as much as five centuries (Fig. 10: *work simple pits on West Field*). Even if galleried pit 15 D saw limited fresh working in the late third millennium cal BC, as noted above, the interval would be *−10 to +290* years (*95% probability*), probably *55 to 205 years* (*68% probability*; *dig 15D1/end West Field*, distribution not shown).

There is only a handful of reliable dates for episodes of knapping, transient occupation and other activity on the West Field which are not demonstrably linked to extraction. This aspect of the site has been particularly affected by the exclusion, on the grounds of possible inaccuracy, of pre-existing dates measured on bulk charcoal samples, as noted above. Those for antler samples are shown, with their contexts, in Figure 12. They indicate that antler implements were used — whether to scavenge flint from pre-existing spoil heaps or to work freshly-dug pits — and flint was worked on the West Field into the 20th and 19th centuries, possibly into the 18th century, cal BC, beyond the estimated abandonment of simple pits there. The West Field clearly continued in use; it remains to be seen whether so far undated or unexcavated pits were sunk and quarried in the same centuries. They quite possibly were. It must be remembered that the simple pits on the West Field are much less extensively and thoroughly dated than the galleried shafts, principally because there were far fewer suitable samples (Table 1). The present state of uncertainty is summed up by an antler pick, the subject of an 19th to 18th century cal BC radiocarbon date (Figure 12: *BM-812*), lying at the edge of a knapping floor close to two unexcavated pits infilled with chalk rubble (Sieveking *et al.* 1973, 200, 207, fig. 12:b, pl. XXII).

The 'primitive' pits were dated by means of the bone picks which characterize them (Fig. 13). These implements, some of them described by Legge (1992, 69–71) and Boyd (1996), were generally made on cattle longbones, predominantly radii or tibiae, with the midshaft cut obliquely to form a point and the remaining articulation retained. They were indubitably mining tools: some had chalk rammed into their hollow distal ends; others had split longitudinally under pressure. Twelve such implements from five 'primitive' pits all dated to the mid third millennium cal BC, as did a further two bone picks from gallery 15D3 in the pit 15 complex. On this basis, mining with bone picks was carried out between the 17th and 15th centuries cal BC (Fig. 9: *start 'primitive' pits and gallery 15D3, end 'primitive' pits and gallery 15D3*), over a period of *5–160 years* (*95% probability*), probably *35–120 years* (*68% probability*; Fig. 10: *work 'primitive' pits and gallery 15D3*). This episode of mining would have taken place at least seven and a half centuries, probably more, after the abandonment of the galleried shafts (Fig. 10: *end galleried/start 'primitive'*) and at least four centuries, probably more, after the dated simple pits on the West Field had ceased to be worked (Fig. 10: *end simple/start 'primitive'*).

An important question here is whether the 'primitive' pits were first sunk in the mid second millennium. The answer is 'yes'. Seven of the dated bone picks came from niches at the bases of the pits, and two more were from at or near the bases. Five antler implements with third millennium cal BC dates from two of these pits are all from upper fills and seem to have been backfilled into the features from pre-existing spoil. In the case of pit 15D, there is no question of initiation in the second millennium, since antler picks from galleries 15D2 and 15D4, all apparently *in situ*, are of mid third millennium cal BC date, and the dated examples are only four among many (Longworth & Varndell 1996, fig. 44). The dated bone picks are two out of at least six recovered from the pit, five of them from galleries 15D1, 15D3 and 15D5. Their distribution is consistent with the reopening of the shaft a millennium after its original excavation, followed by at least partial exploration of its galleries. In these circumstances, marks in gallery 15D2, interpreted as those made by a polished flint or stone axe (Longworth & Varndell 1996, 59) may have been made by bone picks. As with the late second millennium cal BC antlers in gallery 15D1, the pit's depth of 5–6m would have made its reopening less of a challenge than that of the 12m deep pits at the other side of the field.

Activity contemporary with the working of these pits is almost certainly represented by the small tally of Early Bronze Age pottery from the site. This is concentrated on the West Field (Fig. 1), most of it in the same excavated area as F105, one of the dated 'primitive' pits (Longworth *et al.* 1988, 23–24; 2012, 184). Conspicuous here is F108, a shallow depression containing most of the pottery, with struck flint and other occupation material (Longworth *et al.* 2012, 78–79). A slighter Early Bronze Age presence, this time entailing scavenging, is evidenced in the east of the site by a compact deposit of knapping debris including a sherd probably of Food Vessel or Collared Urn (Longworth 1981, 39) in a pit-like depression in the top of the infilled 1971 pit, a deep galleried shaft worked in the second quarter of the third millennium cal BC (Mercer 1981, 19–20; Saville 1981, 13–15).

An interval of around a century (Fig 10: *end 'primitive'/start middens*), probably elapsed before Middle Bronze midden material began to build up on the site. There is no hint that mining continued during this phase. On the evidence of two massive assemblages — 490 kg of struck flint from midden contexts in the 1972 pit and 606 kg from midden contexts in pit X— the Middle Bronze Age users of the site scavenged already-mined flint from earlier spoil heaps and knapping floors, without engaging in mining (Saville 1981, 2, 18; Herne 1991, 23,

29–30). The midden deposits are occupation debris by any standards. The quantity of Middle Bronze Age pottery from the site, over 8000 sherds in total in contrast to approximately 500 sherds from all periods of the Neolithic and Early Bronze Age, expresses the difference between this episode and previous activity (Longworth 1981; Longworth *et al.* 1988 12–25; Longworth *et al.* 2012, 184). The flint and pottery were accompanied by correspondingly large quantities of animal bone and burnt or calcined flint, as well as by bone, antler and bronze tools, and the debris of bronze-working, typically in a dark, often almost black, organic matrix. There are other comparable accumulations in addition to the shaft-tops from which samples have been dated (Peake 1915, 115–8; Smith 1915, 212–3; Longworth *et al.* 1988, 36, fig. 14). They are strongly concentrated in an arc around the east and south-east of the visible pits (Fig. 1).

Suitable samples, most of them carbonised residues on the interior surfaces of Middle Bronze Age pots, the remainder articulating animal bone, were identified from three locations, the Black Hole (Armstrong 1924, 192–193; 1927, 107–109; Longworth *et al.* 1988, 27–31, 51–64, 105–109; 1991, 94–95, 108–121, 176), the top of the 1972 pit (Mercer 1981, 36–38) and the top of shaft X (Longworth *et al.* 1988, 31–35; 1991, 13–20). Measurements for all eleven newly dated samples are statistically consistent (T'=13.8; T'(5%)=18.3; ν=10), irrespective of location and of their stratigraphic position in the 1972 pit and pit X sequences. This accords with the homogeneity of the pottery assemblages and with evidence for effectively single-episode deposition in the dispersal of sherds of the same vessel through the depth of the Black Hole and the even distribution of morphological traits through the deposits in pit X (Ellison 1988). The material would have been deposited between the later 15th and the earlier 13th century cal BC (Fig. 9: *start middens*, *end middens*) over a period of at most a century and a half, probably much less (Fig 10: *generate middens*).

DISCUSSION

The 27th to 24th centuries cal BC

There is no evidence for any chronological progression from shallow pits sunk to relatively accessible flint to deeper pits sunk with considerable skill and difficulty to far less accessible material. Not only did the galleried pits begin to be worked before the shallower pits on the West Field (Fig. 10: *start galleried/start simple*), but, among those galleried pits, the earliest were some of the deepest (Fig. 8). It is as if those who worked the first galleried pits were

already skilled and experienced. If so, this raises the question of where those skills and experience were gained. The minutiae of the methods by which the deep shafts were worked (Longworth & Varndell 1996) matched those practiced on the South Downs (Barber *et al*. 1999, 38–40), over a thousand years before, and, before that, in adjacent parts of the continent (Whittle *et al.* 2011, 255–256, 789, fig. 14.129). It is difficult to see how these standardised methods and skills could have been preserved and passed on over the intervening centuries. Barber (2005) concludes that, while there is ample evidence for activity at the Sussex mines in the third and early second millennia cal BC, when large quantities of mined flint were used for knapping and for monument building, there is as yet no conclusive evidence that fresh pits or shafts were dug in this period, although others have argued the case (e.g. Russell 2001, 246–248). One possible exception is the undated mines at Stoke Down. Here, on the basis of a fairly brief inspection (Healy 2011), the debitage is of quite different character to much of that of the other Sussex flint mines, and could suggest a Late Neolithic date. The pits excavated at Stoke Down, however, were no more than 5 m deep, with slight undercuts in a couple of cases, but no galleries (Wade 1924; Barber & Dyer 2005). Even if they are Late Neolithic they do not perpetuate the mining technology of the deep, galleried, fourth millennium shafts. The same is true of simple, relatively shallow pits sunk into secondary flint deposits in Aberdeenshire, probably around the turn of the fourth and third millennia cal BC (Saville 2008). Did one or a few skilled miners come from the continent? The mines at Spiennes in Belgium, for example, continued to be worked into the early third millennium cal BC (Collet 2014, 17–19).

Contrasts between the galleried shafts and the West Field go beyond depth, skill, methods, and the flint seams exploited. Lech (2012, 119–121) sees the deep mines and extensive knapping floors like that excavated in 1972–74 as worked by highly skilled specialists who were meshed into a long-distance exchange system in which symbolic significance attached to the mines and their floorstone products, while the simpler, more superficial workings served to meet local needs. Carved chalk objects were more frequent in the galleried shafts than in the simple pits. Mercer (1981, 60–64) and Varndell (1991) record chalk artefacts, including balls, ‘cups’ and a phallus, from several definitely third millennium cal BC contexts in and among the galleried shafts. There were furthermore *in situ* chalk carvings on the walls of one (Peake 1915, 73–75, figs 5–6, 8, pls XII–XIII; Barber *et al.* 1999, 65, fig. 5.10). Yet the only such object from an indubitably third millennium cal BC context on the

West Field is a single chalk ball from the lowest layer of a dated simple pit (Varndell 1991, 100, 115: C156).

Grooved Ware pottery is also rare on the West Field (Fig. 1): there are just four sherds from two contexts, in which they were probably redeposited because Early Bronze Age pottery was also present (Longworth *et al.* 2012, 57, 78, 184). From the galleried shafts and a knapping floor related to them, however, there are almost 600 sherds, including at least six semi-complete pots (Longworth 1981, 39, figs 22–23; Longworth *et al.* 1988, 13–14, figs 4–6). All the pots are bowls, a form present in other Grooved Ware assemblages but always as a minority element beside more frequent jars. Five of the semi-complete bowls were found in galleries or on or close to pit bases. They show every sign of deliberate placement. It would, indeed, be difficult to think of a practical reason for taking a semi-complete pot down a flint mine. This is particularly clear at the base of the 1971 pit, where, on the surface of a platform built of large flint blocks, there were a small area of charcoal and two larger areas of dark, apparently organic, material, one containing small flint fragments from the breaking-up of nodules, the other substantial parts of two elaborately decorated Grooved Ware bowls (Mercer 1981, 23, figs 11, 13). Other formal placements are detailed by Varndell *et al.* (forthcoming), not least the large quantities of antler implements often purposefully grouped in galleries and on shaft bases (e.g. Peake 1915, figs 3, 8; Mercer 1981, fig. 13; Longworth & Varndell 1996, figs 5, 17, 18, 44). These groupings echo the placement of antlers in the ditches of Late Neolithic monuments on the Wessex Chalk, notably that of a pile of 57 antler picks on the floor of a terminal flanking the south-eastern entrance of Durrington Walls in Wiltshire (Wainwright and Longworth 1971, 22). The much scarcer antler implements from shallower pits tend to have been incorporated in infilling (this is one reason why the shallower pits have proved more difficult to date). Formal placements of all kinds are confined to the deeper mines; and those where they are most marked, the 1971 pit and the pits of the Greenwell complex, are among the deepest excavated so far.

The extra-functional aspects of mining and quarrying have been well rehearsed (eg Barber *et al.* 1999, 61–7, 73; Topping 1997; 2004; 2005; 2010; Topping and Lynott 2005; Edmonds 1995, 59–66). A mid-third millennium emphasis on fine flint and stone artefacts (Edmonds 1995, 100–114), and a weak local tradition of constructing large communal monuments, seen in the successive scarcity of causewayed enclosures and henges, may together have contributed to the development of a consciously archaising, symbolically-charged practice,

conducted by skilled specialists. In some ways, the site could even have been an equivalent to the great Late Neolithic monuments of some other regions, in the sense of forming a focus where people would gather and meet, away from their usual contacts and localities, engaging in activities peculiar to the place, in the distinctive, developing man-made setting of old mineshafts and masses of chalk and flint (Bishop 2012, 330–331).

The 'monumental' aspects of the site seem to have diminished when the galleried pits ceased to be worked. This was the end of formal placements and the end of the exercise of standardised, highly developed, mining skills. In Lech's terms, the work of highly skilled specialists linked to long-distance exchange networks ended, while simpler, less skilled extraction for local needs continued. It may be pertinent that this took place around the turn of the 25th and 24th centuries cal BC (Fig. 9). In other words, it coincides with the introduction to Britain of Beaker pottery, in *2460–2330 cal BC* (*95% probability*), probably *2410–2345 cal BC* (*68% probability*; Parker Pearson *et al.* (forthcoming): *start_start_beakers*). It is, indeed, impossible to estimate which was the earlier, the interval between them being *–70 to +80 years* (*95% probability*), probably *–20 to +55 years* (*68% probability*; Fig. 10: *end galleried/start Beakers*). Beaker pottery is virtually absent from the site, despite the working of simple pits to the end of the 3rd millennium cal BC. The total is two rusticated sherds, both from superficial contexts (Longworth *et al.* 1988, 15–16, fig 3: N12, N13), and one further possibly Beaker sherd (Longworth *et al.* 2012, 78). One interpretation of this extreme scarcity lies in the association of the ceramic with the introduction to Britain of metallurgy and a gamut of other new practices and beliefs, apparently by an incoming population (Olalde *et al.* 2018). The end of the galleried pits could reflect the transformation of indigenous networks of exchange, communication, and influence.

There is also continuity. The working of simple pits on the West Field up to the turn of the third and second millennia cal BC remained within the insular Late Neolithic tradition. Lech (2012, 116–118) concludes that, despite differences in raw material quality and knapping skill, a sample from a knapping floor where floorstone from the surrounding galleried shafts was worked and a knapping deposit from the West Field show the same approach to flint working, with similar multiple products. Across the West Field, although no other deposits have been analysed in detail, the production of discoidal knives and axeheads was widespread, as it was across the site as a whole (Lech 2012, 121–141), and forms often associated with Beaker pottery, such as barbed and tanged arrowheads, are universally rare

(Lech 2012, 143–44), although frequent in the surrounding area (Green 1980, fig 47), as is Beaker pottery itself (Cleal 1984, figs 9.6–9.7; Garrow 2006, fig 3.7; Healy *et al.* 2014, 60–61, 67). Those who continued to work simple pits on the West Field at Grime's Graves to the end of the third millennium cal BC may have been a population who asserted traditional ways and values, including the manufacture of fine objects in flint rather than in metal, in the face of innovations that may have been unwelcome and threatening.

Lech's (2012, 119–121) view of the simpler, more superficial workings at Grime's Graves serving to meet local needs meshes with Bishop's (2012, 325) characterisation of Grime's Graves as one end of a spectrum of extraction, collection and knapping in a wider Breckland flint procurement zone. The West Field pits and the mixed raw material, mixed skill level, and 'industrial' character of the knapping there correspond to what Bishop to what Bishop (2012, ch. 9) has documented in the surrounding area, especially to the south and south-west. Looking farther afield, the shallow, haphazard working of largely non-floorstone flint on the West Field, merging into the overall character of flint exploitation in the Breckland, conforms to a recurrent pattern of later Neolithic flint procurement. This tended to take the form of an 'industrial' facies to occupation in the areas of more readily accessible flint deposits, with or without shallow quarries, whether on Suffolk and Cambridgeshire Chalk (Bishop 2012, 154–168), the Clay-with-Flints of Cranborne Chase or the South Downs (Gardiner 1991; 1990; 2008), the dry valleys of Salisbury Plain (Richards 1990, 158–71), or the tills of Flamborough Head (Durden 1995). This also accords with wider developments. Gauvry (2008, 146, 150) makes the point that, in the later third millennium cal BC in northern Europe, 'modest, opencast and shallow pit-mining was common', with some exploitation sites linked to the production of fine, highly crafted non-functional artefacts. In this period, the galleried shafts are exceptional on a European as well as on a British scale. The summed radiocarbon probability densities of Kerig *et al.* (2015, figs 2–3) and the radiocarbon dates assembled by them similarly indicate the exceptional lateness of Grime's Graves.

The later third and early second millennia cal BC

The last centuries during which the simple pits on the West Field were worked coincided not only with the earlier part of the currency of Beaker pottery, but with the start of upsurge in settlement on the margin of the Fenland some 15 km to the west. Here, a slightly lowered watertable, the end of marine conditions in the centre of the basin, and the renewed growth of freshwater peat (Waller 1994, 153–154) seem to have combined to make the south-eastern

fen margin more attractive than it had been in the earlier part of the third millennium. Occupation sites in this zone are characteristically preserved on natural hillocks subsequently covered by peat. The pottery from them is predominantly Beaker and Early Bronze Age (Food Vessel Urn, Collared Urn, Biconical Urn), the majority of the Beaker being stylistically late, with features of Needham's (2005; 2012) Long-Necked group.

The dating of this period on the south-east fen edge is poor, an accident of the timing and manner of the excavation of the sites. A proxy for its earlier part is provided by Beaker-associated burnt mounds in the zone, which are dated to the last quarter of the third millennium cal BC (Bates & Wiltshire 2000; Bayliss *et al.* 2004). The chronology of the Early Bronze Age aspect of the occupation depends almost entirely on *termini post quos* measured on bulk charcoal samples and the resulting tentative estimates are very imprecise (Healy *et al.* 2014, 61). National chronologies would place the English currencies of Food Vessel and Food Vessel Urn in the 22nd to 19th centuries cal BC (Wilkin 2014, 39–41, 70, 388–389). On the southern edge of the Fenland basin, Bayesian modelling of dates almost all measured on calcined bone from Collared Urns in a single barrow cemetery at Over, Cambridgeshire, places their local funerary use in the 20th to 18th centuries cal BC (Garrow *et al.* 2014, fig. 230). Biconical Urn, sometimes present in substantial quantities on the south-eastern fen edge settlement sites, as at Mildenhall Fen (Clark 1936, figs 5–8) and some locations in Hockwold-cum-Wilton (Healy 1996, figs 73–76, 82–87) is very poorly dated. It is tentatively placed towards the end of the Early Bronze Age by its associations, such as gold foil-covered beads accompanying a cremation deposit at Great Bircham, Norfolk (Tomalin 1986; Lukis 1843) or faience beads accompanying another at Semer, Suffolk (Smedley & Owles 1964, 192–193). The best-dated assemblage comes from a pit at Yarnton, Oxfordshire, which would have been filled in the second quarter of the second millennium cal BC (Hey *et al.* 2016, 107, 290–293, 652). Middle Bronze Age pottery is absent from the zone, where occupation seems to have ceased by the mid second millennium cal BC, as conditions became progressively wetter (Waller 1994, 154–155), while already ongoing deposition of metalwork in the basin increased (Healy 1996, figs 23–5).

The flint assemblages from these sites are almost entirely from formerly peat-covered palaeosols, which can and do contain material of various ages, so that associations are broad ones. While most flint brought to the fen edge from the Breckland in the late third and the second millennium cal BC was from heterogeneous, often superficial, sources on the chalk,

such as was worked within the Breckland itself, a minority has the macroscopic characteristics of Grime's Graves floorstone and *might* have come from there, especially when it retains a characteristic thick, creamy cortex (Healy 1998). It occurs primarily as debitage, less frequently in a variety of flake tools, especially scrapers (Healy 1991, 126). Macroscopic identification, however tentative, of flint from other seams at Grime's Graves is not possible, so that larger quantities from the West Field may have been dispersed from the site. Despite the apparently 'indigenous' character of artefact production on the West Field at Grime's Graves, it is possible that raw material that left the site as, for example, cores or blanks was further worked by its (culturally distinct?) consumers.

Alongside this 'everyday' use, there is also the possibility of more specialised products, manufactured away from the site and perhaps distributed well beyond it. One artefact type of the early part of this period which calls for large blanks of high quality flint is the flint dagger, quintessentially associated with the Beaker pottery which is practically absent from Grime's Graves (Frieman 2014, 47–50). British examples were generally made on flakes (Frieman 2014, 42), which would have had to be large, since some finished daggers reach 190 mm in length (*ibid.*, supplementary material). They were made from various materials from various sources (*ibid*., 41–42), but the need for large flakes of high quality flint, combined with a concentration of finished daggers in East Anglia, especially the area around Grime's Graves (*ibid.*, fig. 1), could point to a Breckland source, if not to the site itself. Frieman's description of several examples as of black or blackish flint (*ibid.*, supplementary material) would be compatible with their manufacture from Grime's Graves flint. The notion of raw material from a quarry site, whether mined or not, being used for fine, perhaps specialist-made, objects at a time of specialist craftsmanship in metal is appealing. Indeed, it could reflect similar concepts to the selection of a particular facies of the Great Langdale tuff for bracer manufacture in the late third millennium cal BC (Woodward *et al.* 2011, 29, 86–87). Here the selection of particular outcrops, with distinctive working properties and visual qualities (*ibid.* 29, 119), could suggest extraction at source.

As well as everyday items, a minority of the flake tools possibly of Grime's Graves flint from the fen edge settlement sites include barbed and tanged arrowheads and plano-convex and other scale-flaked knives. These are among the most recent finely-worked flint artefacts in Britain. Barbed and tanged arrowheads are found in both Beaker and Early Bronze Age associations (Green 1980, 129–130, 243–252; Longworth 1984, 69–70). They continued to

be made during the working of the 'primitive' pits, as exemplified by two rough examples from a pit at Wootton, Northampton, two short-life charcoal samples from which yielded statistically consistent radiocarbon dates in the 16th to 15th centuries cal BC (Chapman & Carlyle 2012). A few may have been produced in the Middle Bronze Age, like a burnt example from a cremation deposit in a truncated Middle Bronze Age urn excavated the Camp Ground, Colne Fen, Earith, Cambridgeshire (Evans 2013, 73–77, 79 figs 3.12:1, 6.1:2). The Food Vessel and Collared Urn associations of some plano-convex and related knives are long established (Saville 1985, 129–130; Longworth 1984, 66–68).

Some of the settlements on the fen edge yield fragments of flint saddle querns, sometimes reworked as knapping material. Such querns are a peculiarity of a region poor in suitably large slabs of abrasive stone, and are made by dressing the surface of a slab of flint with a hammerstone, as in a Biconical Urn-associated assemblage from Mildenhall Fen, Suffolk (Clark 1936, 44–5). Complete examples tend to occur as stray finds (Healy 1996, 62, 74, fig 43). Where fragments occur in surface or excavated collections, these tend to be of predominantly Bronze Age rather than Beaker technology (Healy 1991, 124). The form and size of floorstone nodules would be ideal for quern manufacture.

The 16th to 15th centuries cal BC

Given that scavenging or superficial working on the West Field helped fill the general need for flint raw material on the fen edge to the west through the early centuries of the second millennium cal BC, it is surprising that deeper mining should have resumed, with new, standardised practices, in the 16th century cal BC. This last demonstrable episode of mining at Grime's Graves is clearly distinguished by its methods and bone tools, a distinctiveness already expressed in Armstrong's description of his 'primitive' pits. These features have so far been identified in the north and west of the site (Fig. 1). Why this form of flint mining emerged is a fascinating question. This episode falls towards the end of dense Early Bronze Age occupation on the fen edge to the west and towards the end of the manufacture of the last finely made flint implements like those noted above.

Armstrong's identification of a pick from pit 3 (Fig.12: A98) as made on a human femur (1923, 121) has been confirmed by Legge (1992, 69). Other implements from pit 3A, tentatively also identified as human by Boyd (1996, 94), proved not to be so in the course of

examination prior to sample selection for this project (Sharon Clough pers. comm.). Even a single implement of human bone, however, brings a symbolic dimension to this phase of mining. It suggests a link to the wider Early Bronze working, use and wearing of human bone, exemplified by a pointed tool with some polish on the tip made on a human tibia which accompanied a burial in a barrow on Garton Slack, Yorkshire (Mortimer 1905, 213; Woodward & Hunter 2015, 126, fig. 4.12.2: ID 639). The same study of Early Bronze Age grave goods identified six further objects certainly or possibly of human bone comprising three belt hooks, two pendants and a tube (Woodward & Hunter 2015, 114, 128–129, 195 555–557, table 13.1).

The bone implements themselves (e.g. Fig. 12: A96, A97) find their readiest and most frequent parallels among those used in the rare second millennium cal BC copper mines where bone survives, notably Great Orme, Gwynnedd (Dutton & Fasham 1994, 275–279, figs 12–13) and Ecton Hill, Staffordshire (Timberlake 2014, fig. 16), and where antler implements were also used. Great Orme was worked from the start of the second millennium cal BC (Timberlake 2014, fig. 25: *start_great_orme*). At Ecton Hill, where most dates were measured on bone implements, one mine was modelled as having been worked from *1840–1695 cal BC* to *1760–1650 cal BC* (*95% probability*; Timberlake 2014, fig. 20: *start_the_Lumb*, *end_the_Lumb*); and another from *1920–1740 cal BC* to *1870–1635 cal BC* (*95% probability*; Timberlake 2014, fig. 20: *start_SQM*, *end_SQM*). These relatively late dates form part of a progression in the start of early copper mining from the last quarter of the third millennium cal BC in mid-Wales, subsequently spreading to north Wales and then to north-west England, probably springing from the earlier introduction of copper mining to south-west Ireland (Timberlake & Marshall 2013).

The 16th to 15th century cal BC estimate for the working of the 'primitive' pits at Grime's Graves is later than the Ecton Hill estimates and falls towards the end of the estimated span of early copper mining in Wales and north-west England (Timberlake 2014, fig. 25). It may be that, paradoxically, copper mining in the west and north-west may have lent fresh significance to the extraction of materials from the ground and hence prompted a renewal of systematic flint extraction at long-significant site in the east, adopting the toolkit of already established copper miners.

One possible product of this period is the flint saddle quern, noted above. These continued to be made and used into the Middle Bronze Age, as evidenced by fragments among the

massive industry from the top of shaft X at Grime's Graves (Herne 1991, fig. 31). It is difficult to find other instances of mid second millennium cal BC flint or stone quarrying in Britain or in neighbouring countries, although it may yet prove to have taken place at the Sussex mines. Second, even first millennium, cal BC flint mining took place in the Czech Republic, where the products seem to have been mainly utilitarian (Oliva 2011), and in Poland (Lech & Lech 1995, 475–479; Herbich & Lech 1995, 502–504; Lech *et al.* 2011), where finely worked bifacial forms were produced, some of them on mined flint, into the later second millennium (Migal 2004).

The 15th and 14th centuries cal BC

The source of the Middle Bronze Age material tipped into the shaft-tops would have been immediately local. *In situ* contemporary features were found cut into pre-existing knapping floors in the same areas as the middens, among them floors 15, 16, 79 and 85 (Longworth *et al.* 1988, 25–27). Soil layers interleaved with the black, midden-like layers tend to be almost equally rich in cultural material, suggesting that this was present on the surrounding surfaces. In the case of the 1972 pit, a skin of dark occupation material occupied part of the surface between it and the 1971 pit (Mercer 1981, 12–3, figs 2, 4). This may have been a vestige of the actual occupation; alternatively it may indicate that the middens were originally more extensive, surviving only where protected by the hollows in the tops of infilled shafts. It may be significant that neither the Black Hole, the 1972 pit nor pit X retained its surrounding ring of chalk upcast at the time of excavation, all having been discovered during the investigation of apparently level areas. This suggests that the spoil was removed in the course of the Middle Bronze Age activity.

The Middle Bronze Age occupation at Grime's Graves has several exceptional aspects, notably its area, the kind of metalwork produced there, and, above all, the midden-like deposits themselves. It was extensive: the excavated Middle Bronze Age occupation material which forms an arc around the east and south-east of the site extends over more than 1 ha (Fig. 1). The results of test pit excavation at various locations in this area in the 1970s (Longworth *et al.* 1988, 6, fig. 9) suggest that it would be exceptional *not* to find Middle Bronze Age pottery when breaking the ground here. One might envisage settlement and other activity on the surface between and beyond the midden-filled shaft-tops. If the occupation was spatially continuous then the total accumulation was massive. It should be noted that the

two finds shown in the west of the site in Figure 1 consist of only 29 and 22 sherds respectively (Longworth *et al.* 1988, 27; 2012, 184), in contrast to the thousands of sherds from the south and south-east. The stylistic homogeneity of the Middle Bronze Age pottery assemblages and the statistical consistency of the recently obtained radiocarbon determinations from three locations suggest that all derive from a single episode of activity. The contemporary vegetation is unknown, since the wooded environment indicated by mollusca from the upper fills of the 1971 pit (Evans & Jones 1981) is now dated to the first quarter of the first millennium cal BC (Healy *et al.* 2014, 53, fig. 62). The area could have been quite open in the late second millennium.

The actual metalwork from the Grime's Graves deposits is characterised by largely fragmentary ornaments, personal implements, tools and casting debris, such as occur on other contemporary settlements. The quantity, however, is high: 42 items in contrast to a maximum of nine from any of the other dry-land settlement contexts listed by Needham (1991a). Truly exceptional is the presence of clay mould fragments from the casting of at least three channel-bladed, basal-looped spearheads. Their size, with minimum blade lengths of 30 cm, excluding the sockets, puts them among 'ceremonial' or 'parade' weapons. There are examples of these among the mass of metalwork recovered from the fens to the east (Needham 1991b, 158; cf Evans 1881, figs 406, 409; Pendleton 1999, map 38, fig. 57: 256, fig. 63: 257, 259). This strongly suggests a link between the Grime's Graves occupation and deposition in the fen.

The midden deposits themselves remain in some ways unique. The numerous middens that have been investigated in southern Britain the 40 years since the excavation of pit X (e.g. Waddington 2008, fig 11.1) are predominantly of Late Bronze/Early Iron Age, rather than Middle Bronze Age, date (Waddington 2009, ch. 4). It is increasingly, if belatedly, clear that Middle Bronze Age settlements in Norfolk and Suffolk tend to consist of enclosures, field systems and houses, like those in other regions. Such features have been convincingly dated on the east Norfolk coast (Gilmour *et al.* 2014), and similar cropmarks have been identified in the valleys linking the Breckland and the Fens, although most excavated examples have so far proved to be Late rather than Middle Bronze Age (Yates 2007, 98–100), like Game Farm, Brandon, Suffolk, 4 km downstream from Grime's Graves (Gibson *et al.* 2004, 36–41, 49–51), although some may have earlier origins. This is a still-emerging picture, but, in its present shape, it aligns the character of mid and late second millennium cal BC occupation in

the region with that of the rest of lowland England and makes the Grime's Graves middens look even more unusual.

Legge (1981, 96) made the point that the quantities of chalk brought to the surface during mining would have distinguished Grime's Graves from the rest of the Breckland, making the area attractive by enriching its sandy soils and hence providing improved pasture for the largely dairy-based economy reflected in the slaughter pattern of the cattle (Legge 1981, 86–89; 1992, 25–31). He also found that the slaughter pattern of the sheep reflected year-round occupation (1981, 84–6; 1992, 28, 33–4). The lack of an immediate water source would have been mitigated by closeness to the Little Ouse, less than 2 km away. Bishop (2012, 333–337), less prosaically, makes the point that, in the late second millennium cal BC, the spoil heaps and part-filled shafts at Grime's Graves would been far more visible and impressive than they are now, and that, apart from their practical use as improved pasture, would have carried powerful connotations of past populations and past ways at a time when more and more of the wider landscape was becoming divided and bounded. Such an old, well-known landmark might have become a focus where members of neighbouring farming communities could meet at significant times. Whether or not there was a permanent population, aggregation would provide a context for the slaughter and consumption of animals from what were primarily dairy herds, for ceremony, and for the manufacture of large, conspicuous spearheads which could have been cast into the fens some 10 km to the west. Grime's Graves would again have filled some of the functions of a monument.

CONCLUSIONS

At any period, the Grime's Graves flint mines were, like all flint mines, unnecessary, since local industries were predominantly made from surface flint of the surrounding Breckland (Healy 1998). This is exemplified at Kilverstone, 6 km to the south-east, where raw material was consistently local and superficial, regardless of whether it was from Early, Middle or Late Neolithic or Beaker contexts or from undated ones (Garrow *et al.* 2006, 54, 85, 89, 91, 91). The impetus for various episodes of activity at the site would from the first have transcended practical need. The expertise needed to work deep, galleried shafts seems to have already been fully developed when deployed at the site. Its introduction there in the 27th century cal BC may have meshed with the wider development of the Breckland as an important flint source to which people may have travelled from other areas; with an increased

emphasis on the production of fine, skilfully made artefacts from selected materials; as well as with the development of new forms of monumentality in other regions. All of these could impart value to the extracted material itself, a value enhanced as the site developed as a focus for aggregation and ceremony. It may be significant that the abandonment of the galleried shafts with their monumental characteristics and placed deposits more-or-less coincided with the introduction to Britain of the suite of new practices and beliefs associated with Beaker pottery. The continued significance of Grime's Graves and its flint, perhaps bound up with a persistence and preservation of old ways, would have developed from its history and monumentality. Perceptions and uses of the site would have grown with the times. It is tempting to see an episode of mining in the 16th to 15th centuries cal BC as a reaction to copper mining in the west and north.

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AUTHORS' ADDRESSES

Frances Healy, 20 The Green, Charlbury, Oxon OX7 3QA. HealyFM@cardiff.ac.uk

Alex Bayliss and Peter Marshall, Scientific Dating Team, Historic England, 1 Waterhouse Square, 138–42 Holborn, London EC1N 2ST. Tel 020 7973 3299, 020 7973 3287. Alex.Bayliss@HistoricEngland.org.uk, Peter.Marshall@ HistoricEngland.org.uk

Christopher Bronk Ramsey, Oxford Radiocarbon Accelerator Unit, Research Laboratory for Archaeology, Dyson Perrins Building, South Parks Road, Oxford OX1 3QY. christopher.ramsey@rlaha.ox.ac.uk

Gordon Cook and Elaine Dunbar, Scottish Universities Environmental Research Centre Radiocarbon Laboratory, Scottish Enterprise Technology Park, Rankine Avenue, East Kilbride G75 1QF. gordon.cook@glasgow.ac.uk, elaine.dunbar@glasgow.ac.uk

Johannes van der Plicht, Centrum voor Isotopen Onderzoek, Rijkuniversiteit Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands. j.van.der.plicht@rug.nl

Figure 1. Plan of Grime's Graves showing features mentioned in the text, 'primitive' pits, middens, and the distribution of major pottery styles. Based on Longworth *et al* 2012, fig 1. © Trustees of the British Museum

Figure 2. Floorstone *in situ* in pit 1. Photo: Hallam Ashley. © Historic England Archive

Figure 3. A shaft with galleries radiating from the base at the level of the floorstone: E.T. Lingwood's published section of pit 2 (Peake 1915, fig. 7)

Figure 4. A simple pit on the West Field (F6 in cutting 950/820; Longworth *et al*. 2012, fig 33). © Trustees of the British Museum

Figure 5. Profiles of 'primitive' pits 3 and 3A, showing two tiers of niches, the first bottoming on the surface of the *in situ* chalk, the second at floorstone level (Longworth & Varndell 1996, fig 32 (part)). © Trustees of the British Museum

Figure 6. The top of the 1972 pit, showing intercalated dark midden deposits and soil layers. © Roger Mercer

Figure 7. Estimates for the start and end of the working of galleried shafts and for the initial working of those galleried shafts for which individual estimates have been made and of the 1972–1974 knapping floor which was overlain by upcast from pit Y

Figure 8. Start estimates for the galleried shafts shown in Figure 7, in approximate chronological order from bottom to top, together with their approximate depths. The estimated depth for pit Y is that for Greenwell's pit nearby.

Figure 9. Schematic diagram showing the periods of use of the main episodes at Grime's Graves, together with the currency of Beaker pottery in Britain(Parker Pearson *et al*. forthcoming, fig. 2.1). The date estimates for Grime's Graves are listed in Table 1.

Figure 10. Durations and intervals (Table 1).

Figure 11. Posterior density estimates for dates for antler samples from surface knapping areas and the post-mining infilling of pits on the West Field, exported from models in Healy *et al.* (2014)

Figure 12. Bone picks from ‘primitive’ pit 3 (Legge 1992, fig 33). The example on the right (A98) is made from a human femur shaft. The other two are made from the distal ends of cattle tibiae. The upper example (A 96) is dated to 1530–1430 cal BC (2σ; 3220±28 BP; OxA-22528). © Trustees of the British Museum

Table 1. Selected highest posterior density intervals.

Effective likelihoods are dates, or weighted means of dates, which are not excluded from the models.

Parameter	*Highest posterior density interval* (*95%*)	*Highest posterior density interval* (*68%*)	Features	Effective likelihoods
start galleried shafts	*2665–2605 cal BC*	*2650–2620 cal BC*	31	146
end galleried shafts	*2435–2360 cal BC*	*2420–2385 cal BC*		
start simple pits on West Field	*2670–2500 cal BC*	*2615–2520 cal BC*	14	32
end simple pits on West Field	*2185–1995 cal BC*	*2155–2050 cal BC*		
start 'primitive' pits and gallery 15D3	*1625–1500 cal BC*	*1580–1515 cal BC*	5	19
end 'primitive' pits and gallery 15D3	*1510–1405 cal BC*	*1495–1435 cal BC*		
start middens	*1450–1370* (*72%*), *1370–1320* (*23%*) *cal BC*	*1425–1380* (*59%*) *1340–1330* (*9%*) *cal BC*	3	11
end middens	*1395–1260 cal BC*	*1385–1345* (*37%*) *1335–1300* (*31%*) *cal BC*		
work galleried shafts	*180–290 years*	*200–255 years*	31	146
work simple pits on West Field	*330–570 years*	*370–500 years*	14	32
work 'primitive' pits and gallery 15D3	*0–160 years*	*30–120 years*	5	19
generate middens	*0–160 years*	*0–70 years*	3	11
start galleried/start simple	*−40* to *+140 years*	*15* to *115 years*	-	-
end galleried/end simple	*200* to *415 years*	*240* to *350 years*	-	-
end simple/start 'primitive'	*415* to *650 years*	*485* to *610 years*	-	-
end 'primitive'/start middens	*−10* to *+165 years*	*20* to *110 years*	-	-
end galleried/start Beakers	*−70* to *+80 years*	*−20* to *+55 years*	-	-
start Beakers/end simple	*180–415*	*220–345*	-	-