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The Wenhaston Doom: detail of the centre lower-right compartment depicting St Michael weighing deeds. The painter has conflated in one striking image all Michael's roles: as defender of Heaven (symbolised by his long sword); as herald of the Last Judgement and guider of souls (in his garb as a winged angel); and as an instrument of Judgement (with symbolic scales). The attendant devil, holding a scroll bearing a garbled Latin inscription, may represent Titivillus – in late-medieval drama the best-known devil apart from Satan himself. See 'The Wenhaston Doom: a Biography of a Sixteenth-Century Panel Painting' in this Part. (Photo: Dr Kathleen Whale.)

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THE ANGLO-SAXON LOOM FROM PAKENHAM, SUFFOLK

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I: THE FIND AT GRIMSTONE END

THE 6TH-CENTURY Anglo-Saxon settlement site at Grimstone End, Pakenham was investigated by Basil Brown and others for Ipswich Museum in 1953, with particular attention to the occupation spreads in the vicinity of a large ancient round-barrow and its surrounding ditch, which had been revealed by crop-marks (Brown, Knocker, Smedley and West 1954). A considerable area of occupation was recorded including several clay floors from hut sites, and in two separate locations near to these were found long double rows of clay loomweights of Anglo-Saxon type. The more complete and undisturbed series (Series B) lay in roughly parallel rows about 8ft long, the whole assemblage lying across the mound's ditch at right-angles, and actually within its breadth. Other finds from the site are listed and illustrated by West (1998, 87–89, and Figs. 119–22). Later explorations exposed more of the settlement, and in 1965 a sunken-featured building with combs and spindle-whorls was excavated (Owles and Smedley 1965). This settlement was part of the complex of early Anglo-Saxon occupation sites clustered around the tributaries of the Lark and Little Ouse in north-west Suffolk (West 1998, 267–68).

In the publication of the find Norman Smedley, then Curator of the Ipswich Museum, argued that the rows of weights could not represent collapsed looms, because a shuttle could not be thrown across a loom so broad. Since the weights appeared to have been unfired, he suggested instead that they had been laid out for firing (Brown, Knocker, Smedley and West 1954, 198–99). However, detailed studies of the warp-weighted loom show that bobbins of weft were passed manually, not thrown, across such looms. In a definitive work, Marta Hoffmann described the Pakenham Series B as the remains of one of the largest known looms from north-western Europe, and specifically contradicted Smedley's deduction (Hoffmann 1964, 313–14): others accept her conclusion (Crowfoot 1983, 413; West 1985, 138). This Suffolk discovery was, in fact, one of international significance.

In 1996, in preparation for the new Anglo-Saxon Gallery at Ipswich Borough Council Museum (Plunkett 1997), the writer decided to set up a large warp-weighted loom conformable with the evidences of the Pakenham loomweights, the textiles from early East Anglian contexts, and the findings of Marta Hoffmann from her study of the instrument. The working exhibit (Fig. 69) is now displayed beside the original loom-weight Series B, and to these the present description will supply particulars of the reconstruction, of the thinking behind it, and of the processes involved in making a characteristic textile on it. Excavated East Anglian textiles have had expert interpreters, notably Mrs G.M. and Miss E. Crowfoot, and their work throws much light on how the instrument was used. We were not aware that Ro Bailey (a spinner and tapestry dyer, and attendant at the Southampton City Council's Museums) had experimented successfully in setting up such a loom at God's House Tower Museum (Bailey 1992), but many of our findings agree with hers.

The technology of the warp-weighted loom is very ancient and persistent, having been employed in parts of northern Europe in all centuries since prehistoric times. Hoffmann's study of its construction, distribution and use, published in 1964, could today be enlarged by reference to the many archaeological finds of loom material made in recent years, but remains a definitive text. The principle of the machine is that tensioned (warp) threads are suspended from a horizontal beam and weighted with clay or stone weights. A fundamental feature is that

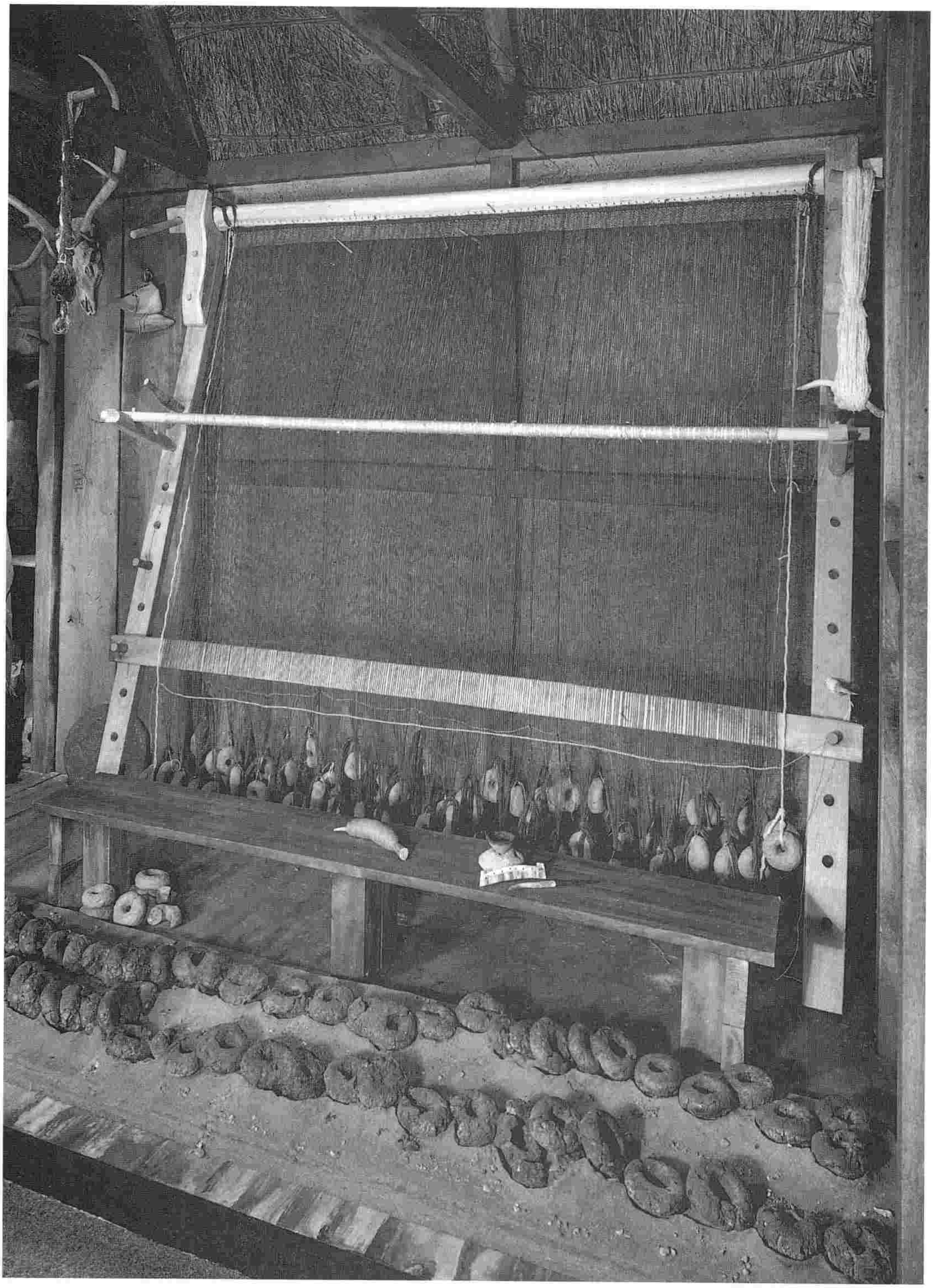

FIG. 69 – The loom reconstruction, together with the original Pakenham loomweights, as displayed in the Anglo-Saxon Gallery at Ipswich Borough Museum, 1996 (*photo: D. Atfield*).

the frame supporting the cross-beam must be leant at an angle, so that while some warp-threads hang vertically (to the rear), alternate strands are hung over a rod (*shed rod*) near the base of the frame, to form the natural *shed* or separation through which the weft can be passed. Each of the vertical threads at the rear is attached by a loop (*leash*) to a horizontal pole (*heddle-bar*) by which they can all be pulled forward at once to form the *counter-shed* or space for the alternate weave.

The entire structure having been made of wood and set up with wool or linen (all perishable materials), weights are often the only part of the machine to survive under usual archaeological conditions. When not in use weights were stored, and at Upton (Northants.) they had apparently been threaded onto poles for the purpose (Jackson, Harding and Myres 1969, 210). Found singly, or as stored, or discarded as rubbish in pits, their shape, wear patterns, their clay composition, weight, dimension and stamp-marks all offer data for interpretation. Annular weights are characteristic of early Anglo-Saxon machines introduced into Britain after the Roman withdrawal (Hurst 1959). In complexes such as those from West Stow sunken-feature buildings 3, 15 and 47 (West 1985), a larger view is gained through associated contexts and artefacts. The interpretation of buried rows of weights as collapsed loom assemblages can only be made confidently when they really appear to show a 'frozen' arrangement on the lost warp-threads of an unfinished textile set up for weaving, reflecting the use of the machine. This would only appear in excavation if there had been no secondary collapse of the surface onto which the weights had fallen, and if they had remained undisturbed from the moment of the collapse. The abandonment of a valuable set of matching weights, an unfinished textile, and the loom structure itself, all at once, is likely to indicate a sudden accident or deliberate, perhaps hostile immolation. Where, as at Pakenham, there was more than one such assemblage, in separate huts, they may be the witnesses of a more general catastrophe.

II: THE PAKENHAM LOOMWEIGHTS

Photographs of Series B *in situ* as excavated (Fig. 70) show two rows of equal weights, thirty-one in each (with a small supplementary weight near the centre of the straighter row), slumped over a distance of some 8ft (244cm). The rows lay some 8in (20cm) apart at the western end, but they converged towards the east. These weights were raised and removed to Ipswich Museum by arranging them on site in a plaster bed on a wooden frame, preserving approximately their original relative positions, with a residue of the excavated earth laid around them. This was done by Harold E.P. Spencer and Stanley West of Ipswich Museum, assisted by the Curator's son, Derek Smedley (Fig. 71). The weights were displayed for a time, and later lay for many years in the Museum's stores. In connection with the new gallery they were all conserved and consolidated, the old filler removed and fractures refitted. On a strong, new lightweight base the plaster form was recreated in fibre-glass, preserving the spatial relationships between the weights created at the moment when they were raised in 1953. This conservation work is fully described and illustrated in publication (Entwistle and Pearson 1996).

The Grimstone End weights are large (11½cm diam., the hole 4½cm) and quite roughly shaped in annular/intermediate form (Hurst 1959, 23–25), weighing on average about 500g each. As they lay in the ground, they were part-fired and much blackened above (which preserved the forms), but were unfired beneath and had begun to decompose into the underlying soil. Apparently some burning substance had covered the weights after they assumed their last arrangement but before they were covered with earth. If, as Mr Smedley thought, this was a deliberate brushwood firing, the weights perhaps threaded onto poles for the purpose, it was not effective, and the whole collection had been abandoned at the expense of a good deal of work. If, on the other hand, they were attached to a working loom, they were in use in an unfired condition, and were charred by burning materials collapsing onto them when the loom was destroyed by fire. Remnants of wood and charcoal were found to the south of the western (divergent) end of the rows. The West Stow weights were similarly unfired but with burnt debris overlying, and unfired weights are also known from Catholme (Staffs.), Willington (Derb.), Ham (Surrey), Mucking (Essex), and various sites in Lower Saxony (Hamerow 1993, 68).

During the 6th century, East Anglian ceramic technology was adapted to the production of low-fired wares such as the stamped cremation urns, and grass-tempered vessels like those found in the Handford cemetery at Ipswich (see, e.g., Plunkett 1994, 25–27[1]). The harder kiln firings of Ipswich Ware type were developed during the 7th century. Unless very thoroughly dried out before firing, thick clay objects tend to crack when fired. Nonetheless, both well-fired and unfired loomweights are known in working quantities from early Anglo-Saxon contexts – were the fired ones imports? The part-baked weight would be useless, having neither the strength of the full biscuit-firing nor the cohesion of the sun-dried clay. The potter Honor Hussey of Butley was commissioned to produce fired weights for the Ipswich reconstruction (Fig. 72): but in her opinion, unfired weights would perhaps be less prone to flaking and cracking in use than fired ones, provided that the clay were of a good consistency and they were kept dry. They would be less useful for weaving fine linen, where a humid atmosphere is required. It was obviously a great advantage to the 6th-century weaver that good weights could be made in any number without the trouble of firing them, though forethought would

FIG. 70 – The loomweights (Series B) as excavated in 1953 (*photo: N. Smedley*).

still be necessary as one would have to dig the clay, weigh it out, make the weights, and allow quite a long time for them to dry out, before they could be used.

The convergence of the two rows, one of which (north) is straight but the other meandering, and the relative spacing of the weights within each row, are features highly suggestive of a collapsed working loom. In use, the weights hang in two parallel rows a few inches apart. The front row never moves, but the back row swings forward and back as the heddle bars are pulled forwards or released: the threads on which they hang are all linked near the bottom, and the weights move together as a group. When interrupting work, after beating-in the last few rows of weft, it would be natural to leave the heddle in the forward (tensioned) position to hold in the weft, so the rows of weights would be hanging close together when the weavers were absent (the opposite of what is usual with a horizontal loom). The Pakenham distribution suggests the fire severed the warp at the convergent (eastern) end, while the heddle leashes still held the weights forward, but that at the western end the leashes burnt through before the warp, allowing the weights to swing back to their natural position before they fell. The straight, northern row should represent the front or working side of the loom, and the meandering southern row be the back, 'floating' half of the warp.

The point can be continued: because the weights are all of similar mass, they will have hung at equal distances along the bottom of the warp which they tensioned. In case of a fire the

FIG. 71 – Raising the loomweights, 1953. Left to right: Derek Smedley, Stanley E. West, Harold E.P. Spencer (*photo: N. Smedley*).

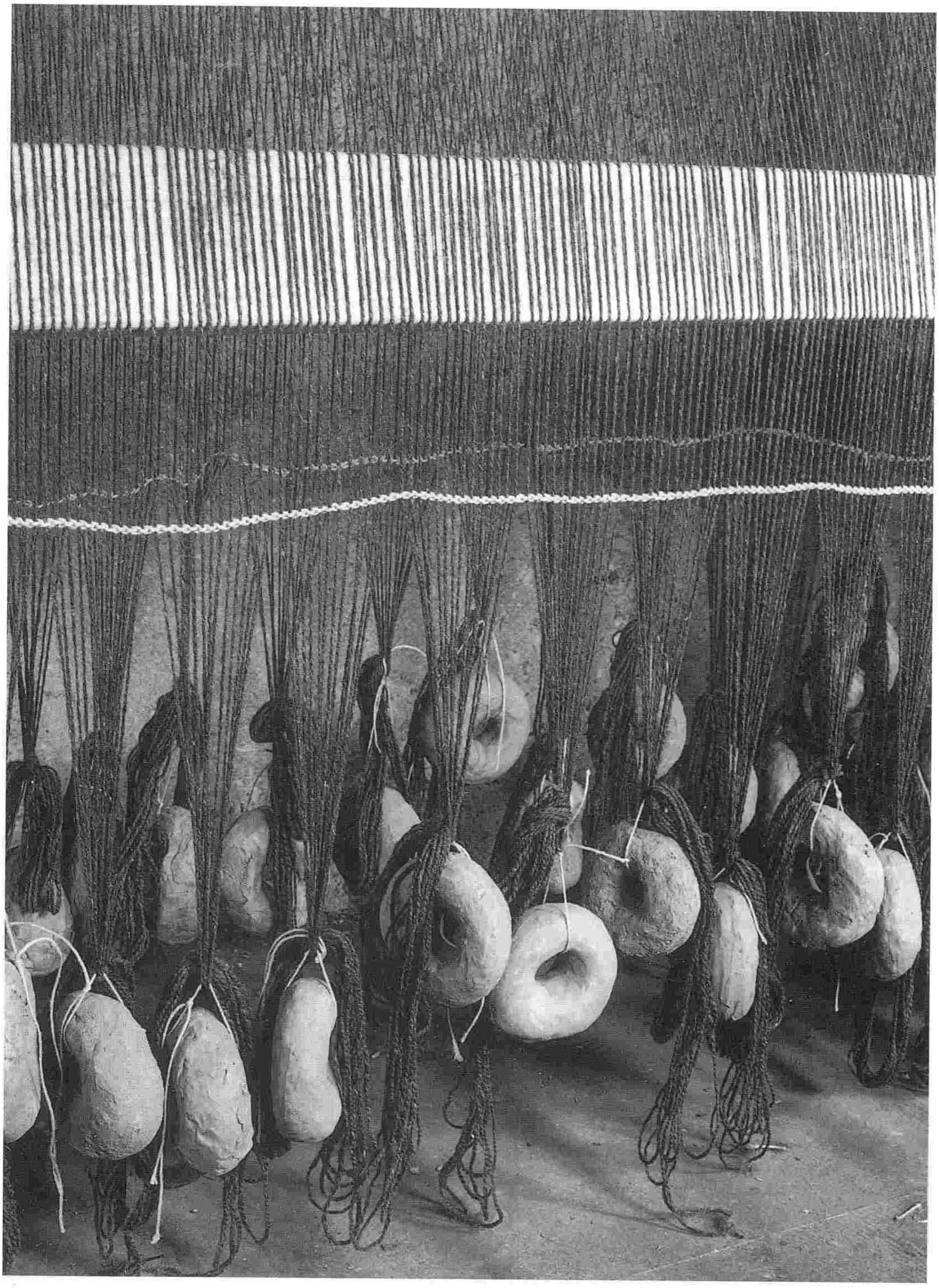

FIG. 72 – Reconstruction: the loomweights suspended. The warp-threads are shown neatly spaced by the chain stitch, where they cross the shed rod. Below, the surplus length of the warp-threads is tied off in bunches before the weights are attached (*photo: D. Atfield*).

woollen threads and linen leashes would burn through before the wooden frame. In their excavated positions, the weights are bunched towards the convergent end, but more spread as they diverge. This variation, seen parallel in the two rows, suggests that the frame of the loom was slipping towards the west as the weights fell. Hence the charcoal found at the south-west corner of the group could represent the collapsed frame, having slumped over to the western side against the north face of a south wall or partition against which it was leaning. The orientation is surprising, since one might expect the doorway to a hut – as in the larger 'halls' – to be in the south wall, to maximise light and minimise draught, and the loom therefore to be set against the north wall opposite the doorway. Any further longitudinal displacement of the weights in the collapse would have been impeded by the spacer-chain which links the warp-threads (see below).

The apparently complete arrangement shows that, over some ninety-five inches, each row contained thirty-one weights, or one every three inches. There were therefore two weights to every three inches of warp, one front and one back, for they were opposed, not alternate. When mounted on the beam (described below) the warp-threads hang in pairs, as loops, and these loops are arranged singly, alternately front and back of the *shed rod*. Thus the weights in each row represent so many bunches of loops or double threads, each occupying three inches across the warp, and each exactly opposed to a weight tensioning the same number of threads in the other row. The divergent (western) ends of the rows show corresponding weights from front and back, neatly opposed, but the terminal of the southerly (?back) row has a pair of weights where the other has only a single. This is clearly visible in photographs taken before the weights were moved. This is best explained as meaning that the last bunch of loops on this row was given two weights, probably to strengthen the selvage and to inhibit the tendency for the textile to taper inwards (*waste*) as it was woven.[2] (A similar expedient was employed in a weaving experiment conducted in 1952–53 (Hoffmann 1964, 135).) It must be supposed that the same applied to the opposite end of the other row, where the collapsed arrangement is less clear. The correct measurement is therefore that there were thirty, not thirty-one, bunches in each row: further deductions from these measurements are given below (Part V).

III: THE LOOM FRAME AND ITS ENVIRONMENT

For reasons to be explained, we took as models for the loom frame the Norwegian looms from Haus, Hord (Hoffmann 1964, nos. 4 and 17), from Fitjar (*ibid.*, figs. 7–18), and a Faeroese instrument (*ibid.*, fig. 64). The frame (Fig. 69) consists of two sturdy upright *posts* of rectangular section, some 8ft (240cm) high, perforated from front to back with large peg-holes, and supporting a *beam* in a bracket near the top of each post. The beam is the main cross-timber from which the warp-threads are suspended: it is cylindrical because a textile longer than the total height of the loom can be woven, in which case the finished work is wound onto the beam by rotation from time to time using a lever at one end. The beam has two longitudinal grooves cut into it forming a ridge, which is perforated all along so that the warp can be sewn on. Our loom was made of oak throughout for strength, because it has to carry a collective weight of at least 32kg. The cylindrical beam is rebated near either end so as to engage closely with the supporting brackets, preventing the risk of lateral slippage, and stabilising the structure. About 18in (45cm) from the floor, a bar (the *shed rod*) is rested or pegged across the uprights, over which the frontal series of warp-threads will hang. A shorter beam and shed rod could be substituted for the longer, using the same posts, for narrower work: the whole machine is adaptable and can be dismantled for storage when not in use.

The height of 8ft for the uprights is a maximum. Because the textile can be wound onto the beam as described above, the height of the loom frame does not limit the vertical length of the textile. The unusual breadth of what was being woven at Pakenham is shown by the length of the rows of weights. The textile intended must have been at least the square of that dimension, because for anything smaller it would be preferable to obtain the length by winding the cloth onto the beam, than to set up so broad a machine. The very long beam implied by the position of the weights, and the sixty-two matching weights themselves, show not the accidental record of some rare or occasional venture into the weaving of a large cloth, but the existence of a machine explicitly designed for the regular production of large textiles. The overall height of the loom is, rather, limited by the ability of an adult, standing on a low bench in front of it, to reach up to the beam where the textile begins. The bench is a valuable part of the assemblage in Norwegian examples, because it raises the weaver to a comfortable height for working the loom, and above the dead space where the weights hang below the shed rod: there is little real evidence to show whether or not Anglo-Saxon weavers stood on benches to work. The advantage of a tall frame is that it provides plenty of working space on the warp for the heddles to operate efficiently and without tangling.

Another limiting factor to the height of the loom frame was the height of the walls in the houses or huts in which the looms were to be set up. Weaving equipment of the 6th–7th centuries has been excavated most commonly from the infill or collapse of sunken-featured buildings (*Grubenhäuser*), which can be seen as ancillary to individual 'halls'. Because the loom when in use has to lean at an angle of some seventy degrees against a wall or roof-beam, the walls and environment of the weaving hut are in a sense an extension of the weaving assemblage. The excavation at Pakenham did not, perhaps could not, determine the ground features of the hut in which the weights were lying. At West Stow, the two major loomweight assemblages were in the burnt houses (numbers 3 and 15), and there the weights were found sandwiched between two layers of burnt wooden debris, the lower representing the planked floor which had covered the sunken feature, and the upper representing the walls of the hut. If, therefore, a loom of between six and eight feet in height stood on a suspended planked floor at ground level in a sunken featured building and leant against a wall or interior beam, this supports Stanley West's interpretation, embodied in the West Stow reconstructions, that buildings of this type had tall side walls despite having only a single post-hole at each end of the structure.[3]

It would in theory have been possible to set up a loom actually on the sunken earthen floor of such a hut, if there were no suspended floor: but it is unclear what adequate wall-structure could have existed – which has left no post-hole evidence – to support the leaning loom, and why the contours of the sunken features, for instance at West Stow, are often undisturbed by trampling. The Anglo-Saxon settlement at Mucking (Essex) produced very large numbers of loomweights both fired and unfired, some apparently having been in storage, but none in recognisable loom-collapse patterns. Several buildings contained slots or shallow trenches in their sunken earthen floors which, on the strength of Continental parallels, and by comparison with a feature at Upton, have been interpreted as loom emplacements (Hamerow 1993, 17–18, 66–68; Dixon 1993, 136): but it is not clear that a warp-weighted loom would require such an emplacement, and the shallow trench would make no practical difference to the amount of height occupied by the hanging weights. Furthermore, the supposed Upton 'emplacement' was to accommodate leaning uprights only 76cm apart, a structure so tiny that an emplacement would seem quite superfluous. This theory of emplacements for non-leaning upright looms appears to go back to the interpretations offered by G.C. Dunning (1932, 286–87 and Pls. LIV–LVI), of features in an atypical sunken structure at Bourton-on-the-Water (Glos.), at a time when the character and working methods of the warp-weighted loom were inadequately understood. If modern interpreters mean to infer the existence in East Anglia of another kind of instrument from these evidences, such as the vertical two-beam loom, this could be valid, but it is not strongly supported by textile evidence, and has no bearing on annular loomweight finds.

The frequent association of loom material with sunken featured buildings seems to indicate that some part of the weaving process, or at any rate the storage of weaving equipment, took place in structures of that kind. The requirements for the adequate height, breadth and working space for a loom to produce woollen textiles of useful size imply that those structures had robust walls (and therefore suspended floors), and roof clearance to above head-height,[4] or else that the looms were set up elsewhere when actually in use.

In the Norwegian looms, the peg-holes on the uprights are not only for the fixing of the shed rod, but also to accommodate higher up a pair of moveable *supports* which project forward from the posts. On these bars rests the *heddle-bar*, a pole the full width of the loom onto which some of the warps are knitted with loops of linen yarn, so that the warp-threads which ordinarily hang at the back can all be pulled forwards to effect the *counter-shed* or contrary opening of the weave. The heddle supports are pronged with two or three positions: Ro Bailey suggests they were made from naturally branched pollard wood, but the recurved tholes of the Sutton Hoo ship suggest how the Old English woodworker might have shaped them (Fig. 73).

The ready availability of substantial timbers in early Anglo-Saxon England makes it likely that their loom frames were more similar to the heavy Norwegian examples than either to certain slender North Finland structures (e.g. Hoffmann 1964, Figs 39–47), or to those Icelandic looms in which the heddle-supports are contrived by an arrangement of poles (*ibid*., 116–17, and Figs. 53–54). A brief consideration of Anglo-Saxon technologies assured us that a very well-finished appearance to the wooden frame would have been perfectly achievable in that age, and that a reconstruction suggesting a gnarled or rough-hewn look would be inappropriate and actually misleading. For practical reasons, any roughness is undesirable as the woollen fibres will snag upon it. Moreover, as a piece of equipment which might be used over many years, and which might occupy so large a part of the time, livelihood and available indoor space of an Anglo-Saxon webster, an important loom would probably be constructed with great care, and perhaps painted or carved with ornament. In the 6th century, there may have been residual sacred or ritual connotations in the activity of weaving, from which modern and secular perceptions of the loom as an industrial machine have become dissociated.

The Ipswich reconstruction loom frame was built by Ian Drake of the Museum's Design department in consultation with the author. Materials were obtained in imperial

FIG. 73 – Impression of a 6th-century thole for an oar, from the Sutton Hoo ship, 1939 (*photo: Miss M.K. Lack*).

measurements, and the dimensions of its parts are as follows: upright posts, 8ft high, 1¾ by 3¾in; beam, 8ft long, diam. 4in (slightly less after planing); shed rod, 8ft long, 4 by 1¼in; heddle-bar, 8ft by 1⅛in diam.; elbows for beam rests, 3½in wide by 20in high. The lower edge of the beam rests about 7in below the top of the posts. The upper edge of the shed rod is 2ft 4in above the base of the posts: the peg-holes in the posts are of diameter 1¼in and are centred at a distance of 6in from each other.

IV: MAKING AND MOUNTING THE WARP

The successful operating of a warp-weighted loom to produce textiles of quality depends entirely upon creating uniform and suitable tensions and spacings throughout the web, and further, that these tensions should survive the constant motion of the machine when in use. A key factor here is the correct preparation and mounting of the *warp*; this is the name given to the whole assemblage of hanging, weighted threads which will form the vertical weave of the cloth as it is made. Preserved textiles show that in Anglo-Saxon times the warp was not simply wound onto the beam, but was made separately and then mounted onto the beam by stitching. In principle, a ribbon or braid is woven as *long* as the intended *width* of the textile. As it is woven, long loops of yarn are measured off to one side. The finished ribbon is then fixed horizontally along the beam with the loops hanging from it towards the ground. This provides a woven selvage at the top of the textile and a straight edge against which to weave. The critical advantages are (a) that all the warp-threads are of the same length, (b) the weighted loops, woven continuously from one strand, do not slip against each other under tension, and (c) a uniform header spacing between the vertical strands pro rata per inch is established.

Preserved textiles indicate that in early Anglo-Saxon times it was most usual to weave the header band by tablet weaving, using pierced cards or tablets. In this technique, the longitudinal threads of the ribbon cross and re-cross. A complete prepared warp of this type, never woven into a textile, was found at Tegle (Norway): it is of the 3rd–5th century A.D., and is one of the outstanding survivals in the archaeology of North European textiles (Hoffmann 1964, 153–60, and Fig. 69). In more ancient times, and again during the Viking Age, it was also known for the header-bands to be woven as tabby (where the longitudinal threads remain parallel): the Ipswich reconstruction is currently set up with a tabby-woven header-band, made using the method of Anne Hansen of Manndalen, Kafjård (Troms) in 1955 (Hoffmann 1964, 63–68) – and is therefore not typical of 6th-century English weaving methods.

As the weights show, the Pakenham loom had a header-band about 8ft long. The tabby method is as follows. A number of threads (say, twenty-four) is measured to more than this length and knotted together at each end, and then the two ends knotted together or linked so that the whole forms a loop which can be stretched around two pegs fixed three or four feet apart. The threads are then parted into two groups of twelve, and these in turn into four sets of three. At this point an object resembling a double-toothed comb[5] needs to be introduced between the two groups, and the sets of three threads laid into the teeth alternately above and below the bar of the comb so as to establish a regular spacing and sequence. The warp is woven by drawing a loop from a large ball of yarn (which rests loose on the floor) through the strands, and measuring it off by stretching the loop around two or more pegs at a set distance on the frame. Then the groups of three in the band are crossed over, either by picking them up with a bone point ('thread-picker') or manually, and the next loop is put through and measured off similarly to the first. A useful refinement draws on two separate balls of yarn alternately for the loops, as they are entered into the weave of the ribbon.

As the work progresses, the bunch of threads forming the band is constantly slipped around the pegs to keep the working point near the weaver. At the same time the long measured loops are counted off in equal groups: the odd and even loops are counted off separately, and when a certain number have been measured (say, twenty) each series is twisted together and rolled into balls to keep the measuring pegs free and the threads untangled. (It would be quite possible to run each counted bunch through a loomweight and tie off, though this would not form the working attachment of the weight.) This process is continued until the full *breadth* of the intended cloth is represented by the *length* of the band. Anne Hansen was able to manoeuvre the band and to measure out the loops of the warp to a regular length, without moving from her working position seated on the floor.

Making the warp is an essential part of the weaving process, and an important and time-consuming activity. The system described above, using a frame to measure off the warp loops, is widespread and traditional, and essential if a person is working alone: but in a communal environment it might have been managed more simply. If two posts were firmly fixed at one end of a hut with the header-band threads stretched between them, one person could work the band and enter the loops, and a second person could measure out (O.E., *metan*) the loop by carrying it along the hut to a peg or fixed position. The alternate loops could be separated out as they were measured. If weights were stored at the far end of the hut, it would be possible to attach them provisionally to the bundles of loops as work progressed. If that is conjecture, the fact that warp-making was carried on efficiently, systematically, and at all times when textiles were made, is not; and the precise method of measuring the loops is not known. The obscure loomweight and post-hole complexes found in sunken-featured buildings may in many cases be warping assemblages, however they measured the warp. If weaving was carried on as an organized industrial activity, warp production was intensive, and some division of labour in the various phases of textile manufacture may well have existed.

The finished ribbon is sewn onto the beam with the loops hanging down: with the shed rod in place (fairly high up the frame), the alternate loops of the warp can then be disposed, as already gathered and rolled, one loop falling vertically from the beam and the next lying forwards over the shed rod. Great care is needed: an error in the alternation of the loops at this stage will produce a serious flaw in the weave all through the fabric. The loops should not be cut open.

V: ATTACHING THE WEIGHTS AND SPACER CHAINS

The loops of warp-threads being longer than the height of the loom, they were tied off in simple slip-knots which fell below the level of the shed rod and a few inches above the floor. They were assembled in bunches of equal numbers of threads, front and back, corresponding to the proportion to be weighted by each loomweight. Since we have already calculated that there was one weight front and back over every 3in of the Pakenham rows, it was only necessary to note that, using a rug-yarn, twelve loops of warp (= twenty-four warp-threads) issued from the header-band over that distance, or eight threads to the inch. Each weight therefore tensioned six alternate loops (= twelve threads) using this warp, and the opposed pairs of weights carried twenty-four threads between them. Compared with most excavated textiles from early East Anglian contexts, this is an extremely coarse warping, suitable only for a rug or blanket: some show counts of thirty threads per inch. The count established in the header-band is in ratio to the gauge of the yarn, and therefore the same loomweight will give similar tension to a small number of coarse threads or to many finer ones over a given distance. We cannot determine the thread-count of the destroyed Pakenham textile from the size and distribution of the weights.

Following the method of Anne Hansen, the weights were first attached all along the bunches of the straight-hanging threads at the rear. A loose ring of cord (a *thrum*) passes through the hole in the weight and directly through the bunch of warps above the knot: the weight helps the knot to tighten and prevent slippage. The method of weaving the header-band does not allow the weights to hang directly in the natural loops of the warp. The wear-marks of threads sometimes seen on excavated loomweights are caused by the motion of the weight swinging from side to side on the thrum as the heddle is moved. Each bunch now hangs with the threads converging on the weight, forming pendant triangular configurations.

The convergence of the warp-threads would, if uncorrected, create serious unevenness in the textile. An equal spacing has to be established between all the warp-threads at the bottom, so that they are held parallel. This is effected by running a chain of linen yarn across from one side to the other – one for the back row of warp-threads, and another for the front – each loop of the stitch picking up a single thread all along. It is worked at middle height, to ensure the correct order is maintained, and then drawn down the warp-threads so that it lies a short distance above the weights, and below the shed rod. All the strands now lie tight and parallel right down to the spacer chain, and the weights collectively bear evenly upon the warp from end to end, transmitting any movement through the whole web. Any slack noticed in the warp-threads below the spacer chain and above the knots is corrected by untying and retying the knots. The back spacer-chain needs to be put on before the front one, otherwise it is impossible to get at the rear warps from the front. The loose ends of the spacer chain on the front part of the warp may be tied off firmly against the posts to position it and to pull out any lateral slackness, but the back warp must float freely. The spacing of the threads will be affected by the gauge of yarn used for the chain.

VI: CREATING THE HEDDLES

At this stage in our reconstruction the warp-threads were hanging taut in their looped pairs, two front, two back, etc., with a clear *shed* or space between them formed by the difference of angle between those hanging vertically at the back and those brought forwards over the shed rod (Fig. 74). It was now necessary to knit the heddle of loops (leashes) by which the rear threads would be brought forward to make the counter-shed for the opposite weave.

The next step depends on the nature and pattern of the textile to be woven. If it will be a plain tabby (one thread forward, one thread back), one must split up the pairs in the warp by crossing over the second and third thread in every two pairs, and knitting the heddle accordingly. When the first row of weft is put in, the alternating sequence is established permanently. This 'crossover' can be seen in preserved Neolithic textile fragments, and shows that the method of making the warp with blind loops is very ancient, and even for a tabby weave does not require the loops of the warp to be cut open (Collingwood 1960). However, as will be explained below, the majority of preserved 6th–7th-century English loom-made textiles show patterns (four-shed twills) in which the loops of the warp were left in pairs (not crossed over), and which were constructed using three heddles knitted in different sequences, in addition to the natural shed. Thus on the natural shed the warps are woven in pairs (two forward, two back), and the second of the three heddles produces the counter-shed or opposite weave. The first and third heddles are knitted in other sequences, in which selected warps from both front and back of the natural shed are leashed: as these sequences are, like the second and fourth, the inverse of each other, they may be knitted at the same time. The patterns are varied not only according to the knitting of the heddles themselves but also by the sequence in which each heddle is used.

Of all the parts of the loom, perhaps the most critical measurement is the length of the leashes on the heddle in relation to the various fixed positions in which the heddle-bar can be placed on the supports. The length must be such that when the natural shed is in place, with the heddle-bar resting back against the frame, there is sufficient space between the front and back of the warp for the bobbin to be passed through easily; but that when moved to the front

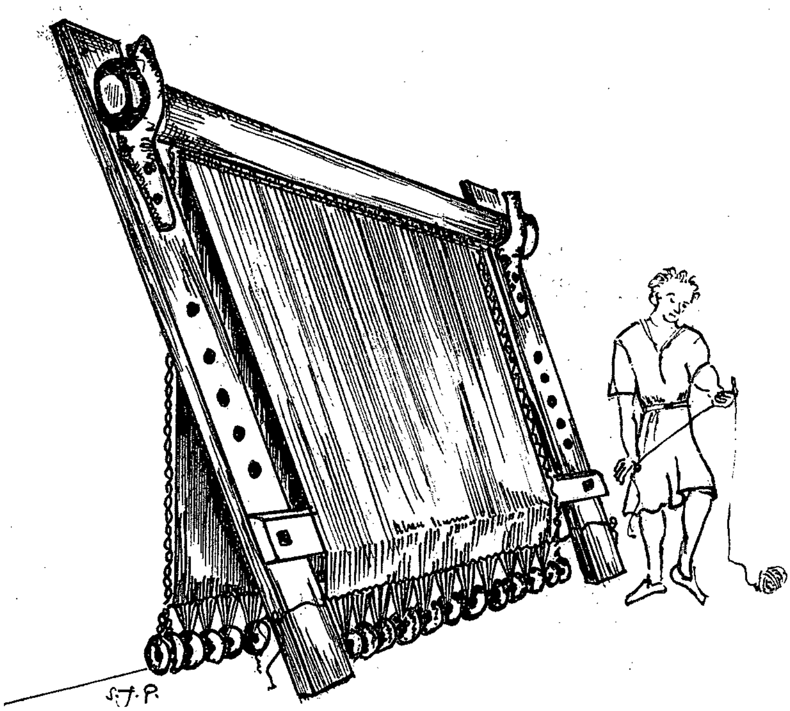

FIG. 74 – The loom showing the front and back warp assembled, before the heddle is knitted (*drawing: S.J. Plunkett*).

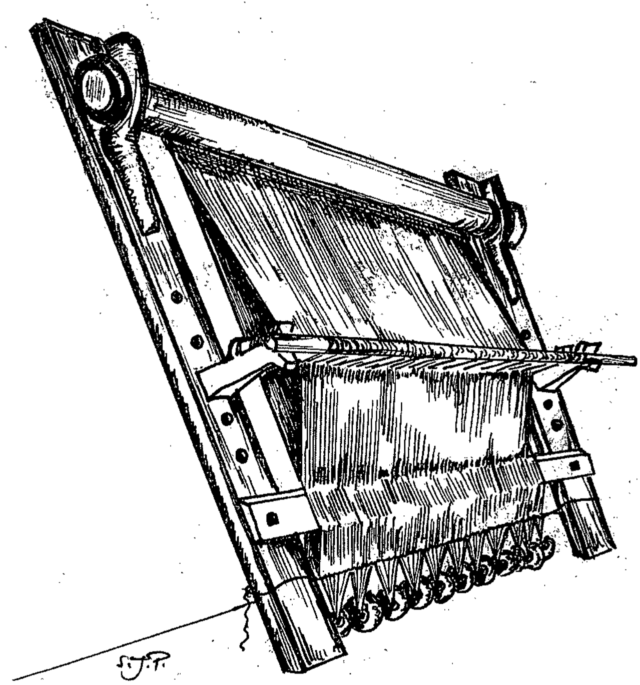

FIG. 75 – The loom with one heddle, and heddle-supports in place, on the counter-shed (*drawing: S.J. Plunkett*).

position to open the counter-shed, there is similarly a space for the bobbin to work through. These essential measurements can be established in various ways. On the heddle-bar supports, between the forward stop and the frame, we placed a second, intermediate stop exactly halfway, and rested the bar in this middle position. A long rod was then brought in from one side, in front of the front warp, to pick up the sequence of warp-threads to be knitted to the bar, and when it had been drawn across the full width of the loom it rested in place against the front of the frame. The heddle leashes were then knitted around each of the selected strands onto the heddle-bar, at a distance to allow an equal opening of the shed forwards and back, and then the rod was removed and the warps hung back in the leashes.

The leashes are formed of linen yarn which is tied to the heddle-bar, looped around the warp to the length established as described, and then brought back to the bar and tied off. If the ties group too closely on the bar, causing the warps to bunch, further twists can be added around the bar between leashes. The leashes are traditionally formed by carrying a ball of linen yarn around each of the selected warp-threads manually, and tying them off tightly against the bar. The same might be achieved by carrying the leading end of a ball of yarn behind all the selected warp-threads, tying the end off upon the bar, and then drawing a succession of loops from it forward onto the heddle-bar and linking them as a chain: this method would be quick and rhythmical, and could be disassembled very simply to conserve the yarn, but might lead to slippage of one leash against the other under tension.

When the heddle-bar is released to the back position on its rests, the rear warp swings back to its natural position: the shed can be reopened by bringing the heddle-bar forward again. The frame must be leant well back, or else as the weights bring the fulcrum of balance forward, there is a real possibility of the entire loom falling forward onto the weaver. Hoffmann found it a universal practice in Iceland, Western Norway, the Faroes, and among the Lapps, to move the heddle-bar one end at a time, and not to lift it from the centre (Hoffmann 1964, 110). With a single heddle our loom was first set up to produce a plain tabby weave (Fig. 75).

VII: OPERATING THE LOOM

For most patterns a single bobbin of weft is worked across the loom in each shed. The weaver, standing on the low bench which is now placed in front of the machine, passes three times in front of the loom for each row that is entered. First the shed is opened (one end of the heddle at a time) and the weaver goes along with a pin-beater – a small, smooth pointed rod, usually of bone – putting the hand through the front warp and running the beater between the front and back warp-threads at the top, to ensure that they are all fully separated. At the next transit the bobbin of weft (wound onto itself, or on a small spindle) is carried through the shed, putting the hands through the threads of the nearer part of the warp and passing the bobbin from hand to hand, unwinding it all the while (Fig. 76). Then the weaver crosses a third time, pushing the weft thread up towards the weaving edge with the back of the hand and pulling out any slack or surplus length, which would produce small 'worms' in the textile. (If a temple is being used to prevent the textile from wasting (see note 2), it is fixed on the cloth a short way above the weaving edge.) Finally the weft is doubled around the last warp thread to strengthen the selvage, the shed is changed, and the process begins again.

After several rows, the counter-shed is opened to hold in the last line of weft, and an object shaped like a sword,[6] usually of metal or wood, is put in from the front and used to beat tightly together all that has been woven (Fig. 77). The small combs often found associated with weaving evidences are not suitable as pronged beaters for this process, because they distort the warp spacing, the 'diminuendo' effect on their outer teeth means they cannot be engaged properly with the warp, and they also weaken and fray the warps by friction (Ling Roth 1950, 129–34).

FIG. 76 – Reconstruction: weaving on the counter-shed. The heddle-bar is in the forward position, the linen heddle pulls the rear warp-threads through to the front under tension, and the bobbin is passed through the shed manually (*photo: D. Atfield*).

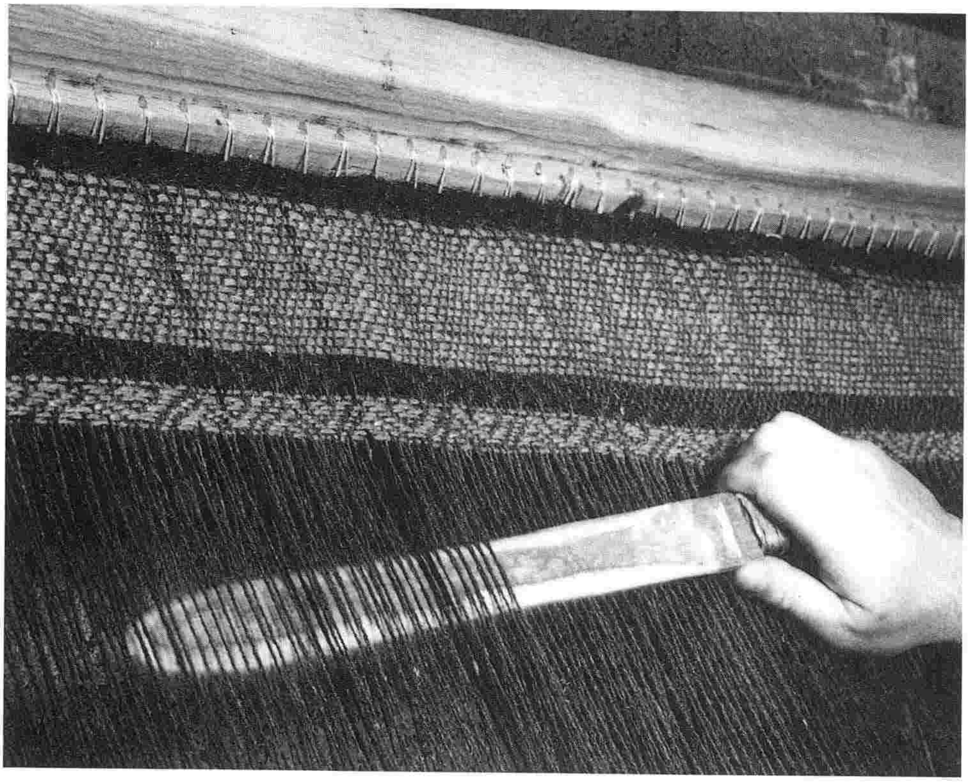

FIG. 77 – Reconstruction: beating the rows in. After several rows have been woven, they are beaten up with the weaving sword. The dark strip at the top of the cloth is the header-band. (*photo: D. Atfield*).

The weavers stand on the bench to be at a comfortable height for working close to the beam, because in that position the shedding action is most effective. As the fabric grows, the supports for the heddle-bar are pulled from their holes and reset lower down the frame, to keep the space within the shed large enough for the bobbin to be passed through easily. If on the natural shed there be a tendency for the rear warps to drift forwards, the whole frame can be reset at a greater angle of lean: then the warps hang well back in the leashes. When a length of the textile is completed, some of the finished cloth is wound onto the beam, by rotating it, to bring the working edge back towards the top of the frame. The knots at the bottom of the warp-threads can then be untied and retied lower down, or released to their full length, and the thrums can be repositioned accordingly. The spacer chain is released, pushed down the threads to the position below the shed rod, and reattached to the sides of the frame. The heddle is not affected, but the bar supports can be repositioned higher in the posts. By this process, a cloth considerably longer than the full height of the loom can be woven.

In the weaving observed at Fitjar, the two weavers had a bobbin each, and they worked simultaneously from either end, exchanging at the centre, and therefore entered a double row of weft in each shed. This was not a typical Anglo-Saxon weave,[7] but a loom of the Pakenham size may well have been worked by two or three people at once for speed and efficiency.

VIII: PATTERNS AND TENSIONS

Studies of preserved textiles suggest that early Anglo-Saxon weavers were skilled in the use of looms working three heddles at a time. Diagonally-patterned twills form a high proportion of excavated textiles from contexts of this date in East Anglia (Crowfoot and Jones 1984, 17–18; Crowfoot 1985; Crowfoot *et al.* 1987). The four-shed twill (using three heddles and the natural shed) produces a fine diagonal herringbone effect which can be developed into lozenges or chevrons by introducing returns into the pattern. The broken lozenge twill (Fig. 78), a variant of this technique, was a particularly widely-used pattern for loom-woven fabrics found in high-status contexts (see, e.g., Crowfoot 1983; Hoffmann 1964, 239–57).[8] Four-shed textiles of the kind and quality illustrated by Crowfoot and Hoffmann may have formed the standard product of early Anglo-Saxon looms, and will form the subject of a future experiment on the Ipswich Museum reconstruction.

The sequence of the leashes and the effect of the broken lozenge pattern are indicated in Fig. 78. They are very easy to memorise, and once learnt would require no written or spoken mnemonic. The second heddle is the counter-shed and is leashed to produce the opposite of the alternate pairs of the natural shed. The first and third heddles are also opposites of one another, and begin on the second thread of a natural pair: they are leashed for two pairs alternately forward and back (xx oo xx oo), and the fifth pair picked and dropped as singles (x o), which introduces the vertical shift in the pattern. The horizontal shift in the pattern, and the reverse of the chevron to produce the lower part of the lozenge, is managed by the sequence of using the heddles. One works 1, 2, 3, 4 (natural), and 2 (counter-shed – to produce the shift): then, reversing the natural and counter-shed, 1, 4, 3, 2, and 4 (natural shed – to shift again). Then the process begins again.

The four-shed twills perhaps derive from loom technology of Syria and the near East, but it seems clear the examples found in Norway and England were local productions. The sequential grouping and separation of pairs of warp-threads from row to row in twill patterns has the very practical value that it helps to eliminate a tendency for the warp-threads to bunch, and this is presumably why these patterns were favoured. An even tabby weave is, by comparison, difficult to achieve, and produces a less dense textile. The East Anglian weavers, knowing the technology of multiple heddles, could produce decorative textiles by varying the colours of the warp and weft. The few examples of three-shed twills from early Anglo-Saxon contexts (absent from Norway at this date) are thought not to have been made on warp-weighted looms because the asymmetrical weave would be distorted by the method of weighting. If not all imports, these textiles might indicate the survival of a Roman two-beamed loom into the Anglo-Saxon period (Crowfoot and Jones 1984, 18).

The warp-weighted loom is primarily an instrument for mechanical cloth production, using the heddles. For tapestry work, high tensions are wanted and a fixed frame is more suitable. It is possible to imagine a hybrid technique in which the whole warp lies in a single plane, but is tensioned with weights. This would have the special potential that, if a symmetrical pattern with horizontal axials were woven, the shed of each row picked up manually could be reserved by a rod which is pushed down towards the bottom of the warp and later drawn up in sequence to complete the pattern. Using weights, the length of the warp could be taken up in this way without affecting the tension: also different patterns could be built up in various parts of the same textile.[8] However, the evidence for this is not forthcoming from actual textile remains.

IX: WEAVING VOCABULARY

The vocabulary of the loom has Old English sources (see, e.g., Clark Hall, 1931). The *warp* and *weft* signify the motions of the threads. *Weorp* is that which is thrown or cast (down), from O.E. *weorpan*, so that warp refers to the whole of the hanging threads set out and weighted before the weaving begins, and (more figuratively) is that which is established or set forth. *Weft*, the thread which has been woven, is derived from an oblique part of the O.E. verb *wefan* (or *weofan*) meaning to weave, with connotations of contriving or arranging: it is one of a group of

1	x x o o	x o x x	o o x x	o o x o	x x o o	
2	o x x o	o x x o	o x x o	o x x o	o x x o	(Counter-shed)
3	o o x x	o x o o	x x o o	x x o x	o o x x	
3	x o o x	x o o x	x o o x	x o o x	x o o x	(Natural Shed)

Sequence: 1, 4, 3, 2, (4), 1, 2, 3, 4, (2): &c.

Heddle 1	:	o x x o o	x x o o x	o x x o o	x x o o x
Shed rod (4)	:	x x o o x	x o o x x	o o x x o	o x x o o
Heddle 3	:	x o o x x	o o x x o	x o o x x	o o x x o
Heddle 2	:	o o x x o	o x x o o	x x o o x	x o o x x
Shed rod (4)	:	x x o o x	x o o x x	o o x x o	o x x o o
Heddle 1	:	o x x o o	x x o o x	o x x o o	x x o o x
Heddle 2	:	o o x x o	o x x o o	x x o o x	x o o x x
Heddle 3	:	x o o x x	o o x x o	x o o x x	o o x x o
Shed rod (4)	:	x x o o x	x o o x x	o o x x o	o x x o o
Heddle 2	:	o o x x o	o x x o o	x x o o x	x o o x x

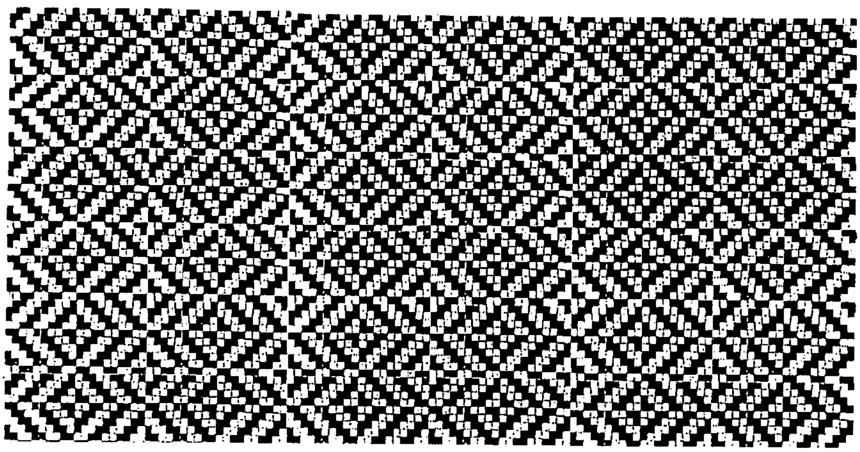

FIG. 78 – System for weaving a broken lozenge twill: (a) method of leashing the heddles, and sequence in which they are woven; (b) encoded module for a single unit of the pattern. (O and X signify that the weft thread passes respectively over or behind the warp strands in sequence); (c) schematic representation of 36 units: appearance of the textile.

nouns similarly formed, signifying the result of motions or actions, such as *rift* (rive, riven), *cleft* (cleave, cloven), *gift* (give, given) or *theft* (thieve). The shed, or opening of the alternate warp-threads, relates to the verb *sceadan* meaning to divide or part, used both transitively and intransitively, with figurative overtones of discrimination, calculation and system.

The *webb* or *webb-geweorc* is the woven work, the *webba* the male weaver, and the *webbestre* the female weaver. The *web-beam* is the cross-beam of the loom, while the *web-gerethru* (web-oarings) surely refer to the heddles, for the heddle-bars are moved (one end at a time) as if a rower were working his oar, and rest in seatings which function like tholes: here the nautical meaning of the word is applied figuratively to the loom. A *web-gerod* (loom-rod) and *web-teag* (loom-tie) are less certain, and the *web-tawa* refers to the weaving apparatus generally. Related to *webb* are *webbian*, to contrive, and *webbung*, conspiracy.

Another late vocabulary for textile equipment is given in the Old English text of *Gerefa*, where it is stated (Liebermann 1898–1916, I, 455) that a large estate should own '*fela towtola: flexlinan, spinl, reol, gearnwindan, stodlan, lorgas, presse, pihten, timplean, wifte, wefle, wulcambe, cip, amb, crancstaef, sceathele, seamsticcan, scearra, naedle, slic*' ('. . . many textile-tools: flax-lines, spindle, reel, yarnwinder, slays, poles, presses, (*pihten*), temples, wefts, weaving-threads, wool-combs, beam, reed, cranking stave, shuttle, seam-sticks, shears, needle, beater'). Of these, *sceathele* seems to carry the meaning 'shed-cover', i.e. that which covers or marks the division of the warp, so that the apparent onomatopoeia of the word 'shuttle' may be no more than a late accretion to its original meaning. Gale Owen-Crocker (1986, 177) conjectures that the absence of loomweights from this list means that by the 11th century a two-beam loom, or a horizontal treadle-loom, may have displaced the warp-weighted loom (see note 8). These evidences post-date the Pakenham loom by over four centuries.

CONCLUSION

Our reconstruction, on open display at Ipswich Museum[9] beside the original weights of which it is an interpretation, shows how they can represent a collapsed loom. It enables us to reconstruct the progress of a 6th-century catastrophe, and to differentiate these weights from other excavated rows which may represent storage or warping. The bone needles, points and combs often associated with weight finds probably relate more to ancillary weaving activities than to the mechanical operation of the loom.

Combs and needles are found as women's grave-goods, and various sources suggest that the pre-urban weavers were often women, working in organised, social, and collective ways (Hamerow 1993, 17). The processes of warping and weaving offer opportunities for division of labour. The scale and potentialities of the Pakenham machines – of which there were at least two – indicate organised production workshops making large textiles of standardised character and quality, probably for commercial as well as domestic purposes. An iron bell from the site (West 1998, 88, and Fig. 120.15) may be a relic of the sheep-farming which supported that industry. Sheep-farming and textile production have been characteristic parts of Suffolk's economy from earliest English times.

In the absence of any surviving 6th-century English loom, our reconstruction is no more than a conjecture, built upon Hoffmann's observation of Scandinavian looms some two hundred years old. However, the evidence of the weights and from textiles reveal the basic principles. There is much to recommend the conclusion that the Pakenham loom was a tall, substantial and carefully designed structure, operated by skilled weavers capable of controlling complex tensions and systems through the large instrument; and that by processes closely similar to those described above, they produced textiles of quality and perhaps of beauty and intricacy.

ACKNOWLEDGEMENTS

Ian Drake of Ipswich Borough Museums made the loom frame, Honor Hussey of Butley made the new weights, and Peter Collingwood of Stoke-by-Nayland gave valued advice at the start of the project. Miss Elisabeth Crowfoot has advised me about the textiles. Dr Stanley West discussed the original find and recovery, and also S.F.B.s and wear-patterns on combs. Bob Entwistle and Jeanette Pearson of Ipswich Borough Museums, Conservators, carried out the difficult task of conserving the original weights and renovating their display mounting with great care, expertise, resourcefulness and success. I also wish to thank Hilary Underwood, John Fairclough and Douglas Atfield. The responsibility for the opinions expressed rests with the author.

NOTES

1 The largest urn shown in the Plate referred to is 170mm high, not 70mm as printed in the caption.

2 The wasting of the cloth was in later times prevented by using a *temple,* a long hinged piece of wood with nails as hooks at either end, which stretches the cloth from edge to edge as it is woven. This is apparently meant by the word *timplean* in the list of textile equipment given in the 11th-century old English text *Gerefa* (Liebermann 1898–1916, I, 455). The suggested double-weighting of the selvages at Pakenham does not enable us to know whether a temple was in use on this loom or not, but it may represent an earlier solution to the problem of wasting.

3 The Skolt-Lapps of Finland have looms which are leant not against a wall, but against the ridge-beam of the roof of a hut, and worked from underneath (Hoffmann 1964, 81ff.). The advantage is that the loom can be put in a building with low walls, but the working method is laborious. This appears to have been a localised modification, and not the isolated survival of a once-widespread method.

4 Looms for hemp and linen, where high humidity was required, were worked under cover in excavated pits in Germany, in the time of Pliny (Hamerow 1993, 17), and in Hungary during the 7th–8th centuries (Endrei 1961). Percy Beales described how in later times linen looms were sometimes fixed into the ground in earth-floored cellars, sprinkled with water, for similar reasons (Baines 1989, 91). Among the type-series of Middle Saxon Ipswich Ware pottery at Ipswich Museum is a closed and pierced bottle-like vessel resembling a water-sprinkler, one function of which may have been for dampening linen threads in weaving.

5 A very small number of fixed heddles have been recovered from Roman contexts, including one from South Shields (de la Edoyere 1989, 63 and Fig. 37a). If the Anglo-Saxons possessed them, all examples have perished: but the superlative quality of Anglo-Saxon braids makes it certain that some device was used to establish spacing in the longitudinal threads, and to provide the initial shed. Possibly the ordinary antler comb was used for the equivalent purpose.

6 The sword-beater was often made of iron, and may sometimes have been an actual weapon re-used. An example was found in Hall 17 at West Stow (Crowfoot 1985).

7 A very ancient piece of preserved textile from Trindhøj (Denmark) shows three wefts operating at once, which is most likely to mean three weavers weaving simultaneously: see Broholm and Hald 1935, 242 and Fig. 31; and Barber 1991, 178 and Fig. 6.6.

8 I am grateful to Hilary Underwood for suggestions.

9 The reconstruction is featured in the Video Presentation 'Talking Saxon' produced by English Heritage in association with Suffolk Films (1997).

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