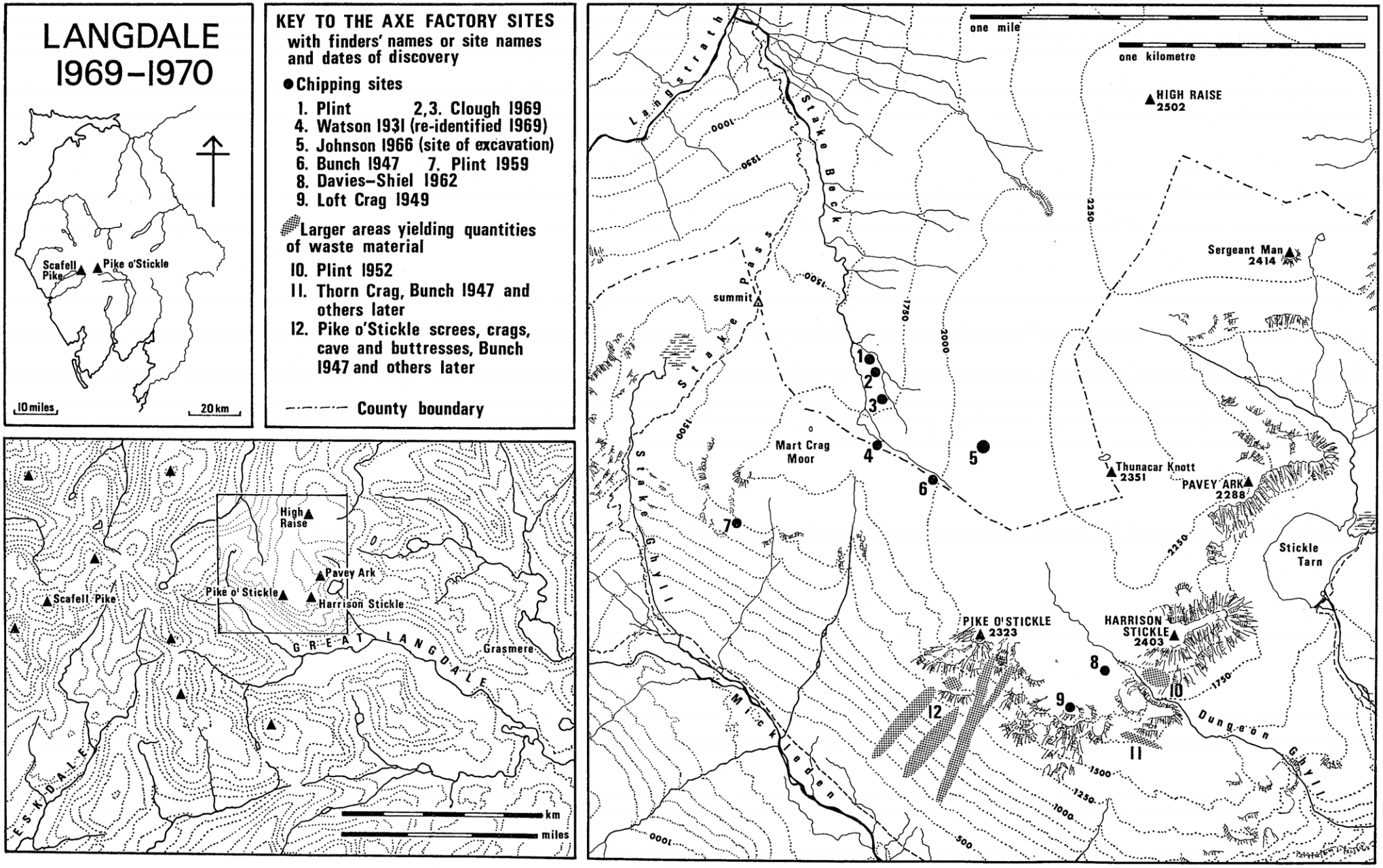

FIG. 1.—Axe factory sites on the Langdale Pikes.
The date for no. 4 should be "before 1921", not "1931".

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facing p. 25.

ART. II.—*Excavations on a Langdale axe chipping site in 1969 and 1970.* By T. H. McK. CLOUGH, M.A., A.M.A.

Read at Durham, September 8th, 1972.

I.

THE existence of chipping sites connected with the manufacture of stone axes in the Great Langdale area of the Lake District has been known for some fifty years. The first recorded discovery is that made before 1921 by Professor D. M. S. Watson when he recognised a chipping site on Mart Crag Moor, between the summit of Stake Pass and Pike o' Stickle. It was after Stake Pass that the industry was then named (Keiller, Piggott & Wallis 1941, 58-68), but following the discovery of more extensive sites on the screes of Pike o' Stickle itself, and the realisation that others were likely to be found, it was seen that such precise terminology was inappropriate. Accordingly, the suggestion made at a timely moment by Miss Clare Fell (Bunch & Fell 1949, 13) that the industry should be named after Great Langdale was adopted (Stone & Wallis 1951, 115). Continuing work in the field in the succeeding years has made it clear that there is indeed a concentration of these chipping sites in the fells at the head of this valley, but it is also emerging that there are many other sites in the high fells surrounding Scafell and Scafell Pike, including Glaramara (Plint 1962).

There has always been some uncertainty about the exact location of Professor Watson's site. While the excavations described below were in progress in 1969, I took the opportunity of searching the area myself. It is now clear that a site, very similar to the one being

excavated, which I found then and which was at first thought to be a new discovery, is in fact Watson's original site. Its location agrees exactly with the description cited by Bunch & Fell (1949, 3 & pl. II), which is written on a broken roughout now in Manchester Museum (no. 02603) and reads "Found with others and chips in a small manufacturing site 10 feet sq. ½ mile S.E. of summit of Stake Pass, Lake District." The site is not in the spot indicated by Bunch and Fell on their map, since it lies a little further to the south-east. The accompanying map of the area (Fig. 1) shows its position in relation to the smaller one found by Mr B. Bunch in 1947, another (no. 1) found by Mr R. G. Plint which was once thought likely to be Watson's site but is really his own discovery, and others found by myself in 1969. It also shows the site found by Mr Peter Johnson in 1966 which is the subject of this report.

The site in question lies about half a mile north of Pike o' Stickle at an estimated height of 2,050 feet above O.D. (National Grid reference NY 27400814). It is on open ground on the western flank of Thunacar Knott, which slopes on the whole quite gently down towards Mart Crag Moor and Stake Beck. It is just within the Cumberland county boundary, although Pike o' Stickle itself is in Westmorland. From the site there is an extensive view westwards ranging from Pike o' Blisco to the south through Crinkle Crags, Bowfell, Great End, Great Gable and Glaramara to Skiddaw which is visible in the distance beyond Sergeant's Crag to the north. The valley of Langdale cannot be seen at all but Stake Pass, leading from Mickleden to Langstrath and Borrowdale, can clearly be seen; so also can the pass from the top of Rossett Ghyll towards Esk Hause which leads to Eskdale or to Sty Head and Wasdale, and which provides an easy high-level route from the Langdale Pikes towards

the west Cumberland coast. Curiously, the summit of Pike o' Stickle is out of sight although it is possible to see the upper half of anyone standing there.

The chipping site is in a shallow scoop in the fellside where a saucer of peat which once formed over the archaeological material is now eroding and spilling downhill to expose at its base an extensive bed of chippings. Johnson's exploration of the site following its discovery produced not only a considerable quantity of waste material and broken roughouts but also a small amount of charcoal. This was accepted by the British Museum Research Laboratory for radiocarbon analysis and yielded a date of 4680 ± 135 B.P. (2730 ± 135 B.C.) (BM 281). However, no adequate records had been made and it was felt that a more detailed investigation of the site should be carried out before this date could be properly evaluated. In 1968 Dr Winifred Pennington (Mrs T. G. Tutin) was able to take a series of samples for pollen analysis; her report on these is presented as a valuable supplement to this paper. In 1969 and 1970, at the instigation of Miss Clare Fell, two brief seasons of excavation, amounting to about two weeks in all, took place. Variable weather hindered the work; and those camping on the site in 1970 also survived an earth tremor.

II.

The excavation.

It still remains uncertain exactly how much of the site had been disturbed since its discovery in 1966. The processes of natural recovery and erosion had largely concealed the limits of irregular shallow trenches in the space of two or three years. However, it was clear before the excavation began in 1969 from the quantities of flakes and rock fragments lying

around, and from the discovery of broken axe roughouts amongst the disturbed material, that the site was of some importance. Since little time was available, it was decided to examine the disturbed area in front of the collapsing peat-hag so as to record anything that might survive there, before extending the excavation into untouched parts of the site. In the event it proved possible to do little more than encompass the disturbance and to extend the excavated area up to the still-standing peat on the eastern (uphill) side.

A thin layer of disintegrated peat, representing old spoil-heaps, covered most of the area. Below this in some places, but absent from an irregular area of disturbance in the centre of the excavation, there still survived a layer of recent vegetation. Beneath this were the remains of the eroded hag, varying in depth from about 10-25 cm. Below this peat was the chipping-floor itself, with its layer of flakes and broken roughouts; this in turn lay directly above the natural inorganic or mineral soil which presented a grey stony surface everywhere on the site. Thus the archaeological deposits presented few complications.

Numbers of large stones were lying on this natural soil. When they first appeared in 1969 it seemed possible that in part they represented the tumbled remains of some flimsy windbreak originally supported on dry-stone footings. However, further work in 1970 indicated that many of them had been thrown aside from the recently disturbed area, so that their appearance was deceptive. Other large stones were still partly embedded in the natural soil. Similarly, it became clear that a number of the roughouts which were found had already been moved. The plan of the site as excavated (Fig. 2) therefore shows only those finds which probably remained untouched.

The only features suggestive of occupation on the site apart from the axe-making débris described below

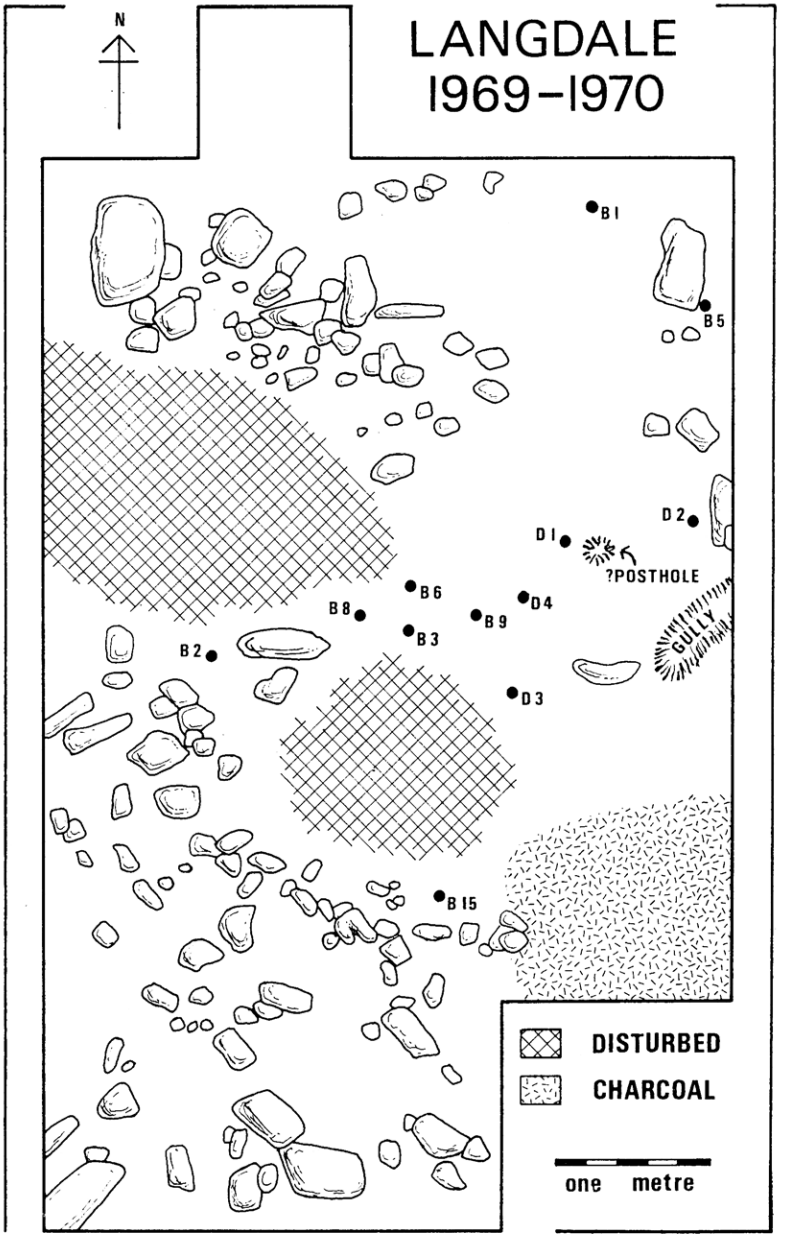

FIG. 2.—Langdale 1969-1970: plan of the Thunacar Knott excavation.

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were the end of a narrow shallow gully and a rather doubtful post-hole nearby, both found in 1970. In the few days available it was not possible to investigate these features any further, and it may be that remains of huts or other light structures will be found on these sites when further organised work takes place.

The lack of definite structural features was disappointing, but the project was rewarded in 1970 by the discovery of a thinly scattered layer of small charcoal fragments. These occurred in the same layer as the axe chippings in the south-east corner of the excavation and were clearly associated with them. It was possible to collect enough of this charcoal to submit the sample, weighing a little less than 20 grams when dry, for radiocarbon analysis. The date obtained by the British Museum Research Laboratory is 4474 ± 52 B.P. (2524 ± 52 B.C.) (BM 676).

The pollen samples on which Dr Pennington reports below, taken in 1968, are from the standing peat beside the main excavation. A duplicate series was taken during the excavation in 1969. The analyses begin in the mineral soil and pass upwards through the layer of chippings into the peat. Minute pieces of charcoal, much too small to collect for radiocarbon dating, were present in these samples.

In 1969 a small trench, only 3 sq. m. in size, was laid out on another peat-hag where there had also been some recent disturbance, about 10 metres north-west of the main excavation and downhill from it. There was little to be gained from sampling the very wet peat at this point since the nature of the deposits made it likely that they had formed in comparatively recent times. The most interesting feature of this trench was the nature of the waste material. Many thousands of small trimming flakes were found piled over several rocks below the peat. It was noticeable that there were no roughouts and very few chippings more than 50 mm.

long amongst the considerable mass of flakes present here. The quantity of large flakes and broken or discarded roughouts found in the main trench, whether disturbed or not, suggests that the preliminary flaking of lumps of raw material took place there; while in contrast this heap of small trimming flakes represents the work of an experienced craftsman, skilled enough to bring the roughouts into a state in which they were ready for polishing.

III.

The finds.

The archaeological material from the site consists almost entirely of flakes and roughouts. There were also one or two possible hammerstones. The finds are grouped according to the circumstances in which they were discovered. Any specimen which had obviously been thrown aside previously, or about which there was any doubt, has been treated as unstratified; nevertheless, it is virtually certain that they all came from the layer of chippings in the main trench described above.

Three samples from the 1969 season (A.1, B.5, B.15) were submitted to Professor F. W. Shotton, who very kindly examined them and confirmed that all three were of absolutely typical Group VI rock. All the other roughouts and flakes except one are almost certainly of the same material. During the 1970 season two finds, a roughout fragment (B.21) and a possible hammerstone (B.22) were recognised to be of a rock other than the fine-grained Group VI tuff, showing that other material was occasionally used. They were examined by Dr F. S. Wallis and Mr E. D. Evens, and also by Professor Shotton and Dr W. A. Cummins, but could not be assigned to any group.

It has also been possible to record three of the roughouts previously found on the site through the kindness of Mr Peter Johnson; they are described below (C.1—C.3). Miss Clare Fell has enabled me to see drawings of two other broken roughouts from the site (C.4, C.5 below).

The finds from the excavations of 1969/70 have been deposited together at the Brathay Hall Field Studies Centre, Ambleside. The five petrological thin sections have been given to the Department of Geology in the University of Birmingham.

The stratified material is as follows:

B.1, B.2 Roughout in two pieces, broken by transverse fracture. Length 206 mm. Fig. 3.

B.3 Cutting edge of roughout, broken along natural cleavage lines. L. 175 mm.

B.5 Part of narrow roughout, broken at each end; Group VI rock (Prof. F. W. Shotton). L. 122 mm. Fig. 3.

B.6 Part of roughout, broken after irregular flaking. L. 143 mm. Fig. 3.

B.8 Narrow roughout, spoilt by plunging flakes. L. 155 mm.

B.9 Butt of roughout. L. 88 mm. Fig. 3.

B.15 Fragment of flawed roughout; Group VI rock (Prof. F. W. Shotton), noticeably banded. L. 58 mm. Fig. 4.

D.1 Butt of roughout, broken by transverse fracture. L. 113 mm.

D.2 Another, similarly broken. L. 99 mm.

D.3 Another, similarly broken. L. 58 mm.

D.4 Part of coarsely flaked roughout; flawed rock. L. 90 mm.

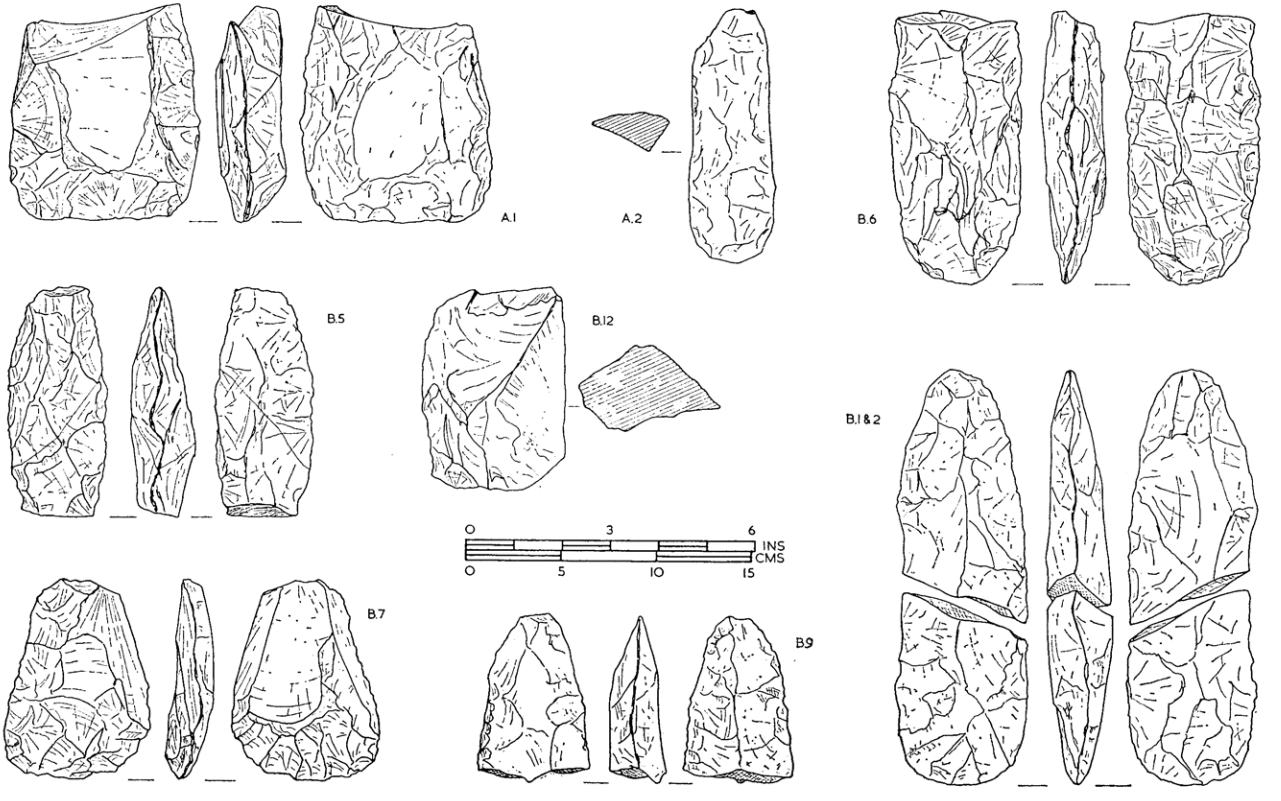

FIG. 3.—Roughouts from the Thunacar Knott excavation. Scale : ¼.

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The unstratified material is as follows:

A.1 Cutting edge of roughout, broken by transverse fracture; Group VI rock (Prof. F. W. Shotton). L. 113 mm. Fig. 3.

A.2 Part of small roughout, broken along lines of natural cleavage. L. 133 mm. Fig. 3.

A.3 Trimming flake, ?recently broken. L. 74 mm.

B.4 Butt of roughout, broken after irregular flaking. L. 145 mm. Fig. 4.

B.7 Small roughout, spoilt by plunging flake detached from butt. L. 105 mm. Fig. 3.

B.10 Large flake, ?from early trimming stage. L. 123 mm.

B.11 Block of raw material, spoilt by misdirected blows. L. 141 mm. Fig. 4.

B.12 Another, spoilt by irregular flaking. L. 108 mm. Fig. 3.

B.13 Another, spoilt by irregular flaking and natural cleavage. L. 131 mm.

B.14 Large flake with smaller flakes detached. L. 111 mm.

B.15 Large block of raw material with some initial flaking, broken by transverse fracture. L. 180 mm.

B.17 Part of roughout, broken by transverse fracture. L. 86 mm.

B.18 Another, similarly broken. L. 110 mm.

B.19 Another, poorly flaked, similarly broken. L. 55 mm.

B.20 Part of coarsely flaked roughout, similarly broken. L. 145 mm.

B.21 Butt of roughout; an ungrouped tuff (Dr F. S. Wallis). L. 38 mm. Fig. 4.

B.22 ? Hammerstone; rock as B.21 (Dr F. S. Wallis). Width about 80 mm.

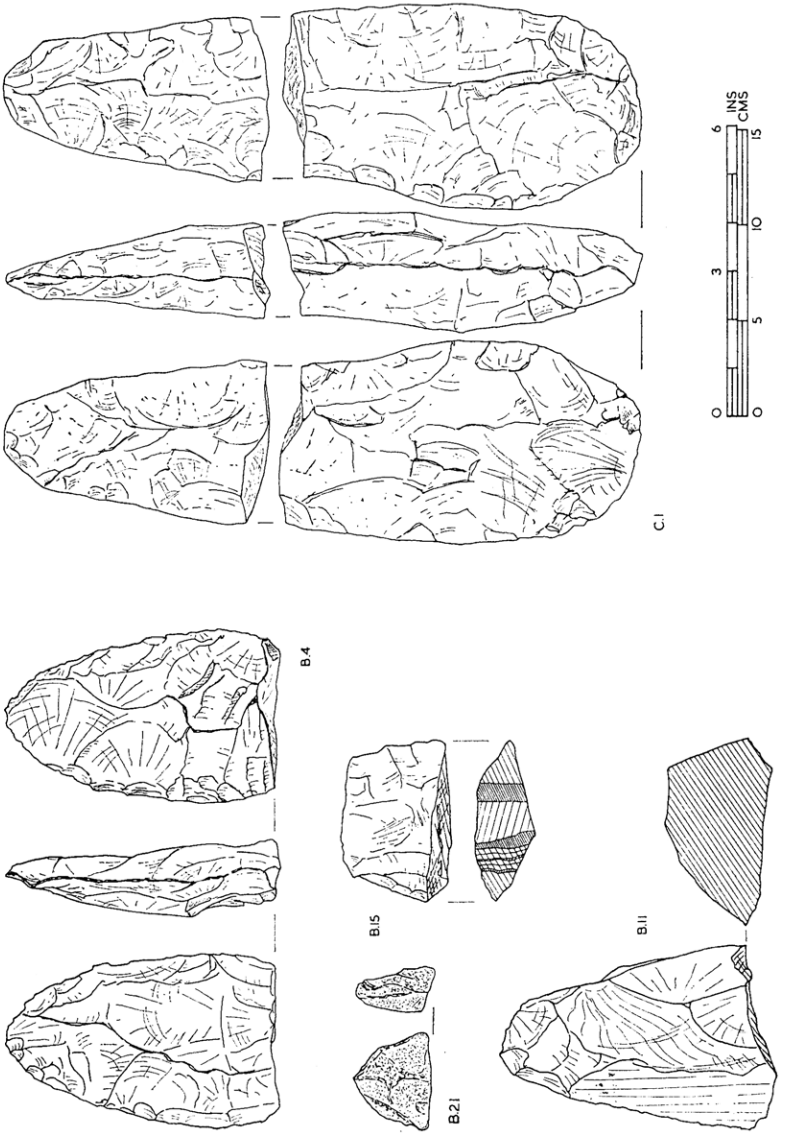

FIG. 4.—Roughouts from the Thunacar Knott excavation. Scale : ¼.

Earlier finds from the site include the following:

C.1 Very large roughout in two pieces; differential weathering on one part (yellowish-brown on one side, shades of grey with brown staining on the other) indicates that it probably comes from the junction of peat and natural soil. L. 315 mm. Fig. 4.

C.2 Narrow poorly-flaked roughout. L. 200 mm.

C.3 Roughout broken during early flaking. L. 165 mm.

C.4 Butt of roughout, broken by transverse fracture. L. about 125 mm.

C.5 Another, similarly broken. L. about 120 mm.

IV.

The evidence recorded during these excavations is not such that one can propose anything very categorical about the site. It is one of a number of similar sites which lie on easy ground to the north and west of Pike o' Stickle, many but not all of them now or formerly covered with peat. The exact source of the rock which was used on each site is not known, since there is no immediately visible outcrop in the vicinity. One would not expect the heavy raw material to be carried very far, although the practice of removing blocks of rock to a more or less distant settlement site is proposed by Houlder (1961, 126) for Mynydd Rhiw and cited for Graig Lwyd; such a practice would seem to be uneconomic in both time and labour, and the considerable output from the Langdale factories as well as the wide distribution of their chipping sites suggests that different working methods were used. Many of the sites have remained hidden beneath the peat, and this covering may also conceal the answer to the problem. The alternative to carrying the raw material is to work it where it occurs and this certainly

took place on the crags of Harrison Stickle, Loft Crag and Pike o' Stickle (Fell 1954, Plint 1962) where the now increasingly dangerous screes are littered with waste flakes. It is possible that each of these apparently random chipping sites represents the utilisation of scattered blocks of the fine-grained Group VI tuff. Although the axe-makers were highly selective in their choice of material, and experiment has shown that freshly exposed rock is easier to work and to polish than weathered rock (information from Mr G. Taylor), they will have taken advantage of such stray blocks to save the effort of quarrying where possible.

At a time when more and more Langdale products are being identified all over Britain it is disappointing that little can be deduced from the small sample of material from this site. One can indeed postulate the presence of a craftsman, working amidst a litter of tiny flakes on the final trimming which preceded polishing, but the roughouts found vary so greatly in size and shape, from what might have been a small trimming axe or adze like B.7 (Fig. 3) to the large felling axe suggested by C.1 (Fig. 4), that one cannot distinguish a concentration on any particular type of implement. The evidence from this site is not sufficient to allow a detailed study of the manufacturing methods employed, or of the influence which the rock used may have had upon the implement types made. However, it may be remarked that the shape of a number of Group VI products, with broad cutting edge and narrow butt, with the sides often slightly asymmetrical (whether or not they are faceted), and the greatest thickness towards the cutting edge, may be a result of using heavy flakes as roughouts, as in the case of B.7. It remains to be seen whether further work will point to any degree of specialisation, and this will entail both detailed investigation of more chipping sites and careful study of the finished products and

their distribution. It is a problem to which Manby (1965) has made a contribution in an earlier volume of these *Transactions*, pointing out but perhaps laying undue emphasis upon the difficulties of assessing the significance of many of the smaller implements which may (or may not) have been altered by re-use and resharpening.

Clearly the importance of the site lies not so much in the finds as in the radiocarbon dates of 2730 ± 135 B.C. (BM 281) and 2524 ± 52 B.C. (BM 676) which have been obtained from it. Although Langdale (Group VI) axes have been found in dated contexts elsewhere in Britain, they appear on those sites as a result of trade. Even Ehenside Tarn, Cumberland, where numbers of Langdale axes were found, some incompletely polished, is one step removed from their genesis; and discrepant dates from that site leave much in doubt. The dates published here are the first to come from one of the factory sites where the trade began, and it is therefore essential to see whether they agree with what is already known. These dates, together with the Blea Tarn evidence (Pennington 1970 and below), suggest that at least this site, one of many involved in axe production in the area, was operating in the second quarter of the third millennium B.C. It may be noted that the combined standard error of the two dates (i.e. one standard deviation on each date) is almost the same as the difference between them.

At Windmill Hill, Wiltshire, charcoal from the primary silt of the Outer and Middle Ditches produced a date of 2580 ± 150 B.C. (BM 74), and two flakes probably from a single Group VI axe were found in primary silt in the Inner Ditch. Another Group VI flake was found in Pit 3 there, possibly also in a primary context, but products of Group VII (Graig Lwyd, Caernarvonshire) seem to have been late arrivals here (Smith 1965, II and III). Implements

of Groups VI and VII have, however, occurred together on other sites, including the henge at Cairnpapple, West Lothian, the North Deighton barrow, Yorkshire, and the West Kennet Avenue, Wiltshire (Evens *et al.*, 1962, 234). Group VII implements have themselves been closely dated on occasion, like that from the peat at Shapwick Heath, Somerset, for which there is a date of 2590 ± 130 B.C. (Q 430); a Peterborough sherd from Meare Heath occurred in a similar position in the peat. Another Group VII axe, from Swaffham Engine Drain, Swaffham Prior, Cambridgeshire, has been dated according to its position in the peat to about 2500 B.C. (Dewer & Godwin 1963, 23 ff. and 43). These examples also draw in other sites such as Hurst Fen and Peacock's Farm, Shippea Hill or Swale's Tumulus, Worlington (Clark 1960, 242 f.).

Also relevant are the dates from the single entrance Henge A at Llandegai: 2790 ± 150 B.C. (NPL 220) from a primary fire-pit, 2530 ± 145 B.C. (NPL 224) from a cremation circle outside the entrance, and 2470 ± 140 B.C. (NPL 221) from the end of the primary silting. C. H. Houlder, to whom I am indebted for this information, interprets these dates as indicating use of the henge for ceremonial and burial purposes from about 2650 B.C., possibly for a couple of centuries. Axe material of Groups VI and VIII (probably S.W. Wales) was found here.

This network of dates and associations, slender though it may be, holds together quite firmly. It indicates that the main *floruit* of the Langdale industry was in the region of 2750-2500 B.C., and within those limits perhaps nearer to 2500. This agrees with the dates from the recently investigated chipping site. The working hypothesis put forward by Piggott (Evens *et al.* 1962, 234) was that "a middle to late third millennium date would accord with the other evidence for the exploitation of Group VI rock". This has been

followed by Keen and Radley (1971, 27) in their recent treatment of the Yorkshire material. However, Miss Fell (1964, 41) has already taken the date of 3014 ± 300 B.C. (C 462) from Ehenside Tarn as a possible pointer to the early use of these rock sources, and it now seems increasingly likely that this was so; the balance of the evidence from many pollen diagrams relating to sites in the Langdale area, which reflect the sequence of forest clearance, also supports this case (Pennington 1970, 71). Further work is now necessary in order to provide a greater range of dates for this extensive group of working sites in the centre of the Lake District.

On the other hand, there are various later dates and associations to suggest a long-continuing trade in, or at least use of Group VI implements. Even in the Neolithic sites mentioned above, the Langdale products are often broken or show attempts at re-use. Among the later examples, there is a re-used axe fragment from a Bell Beaker context at Chew Park, Somerset (Evens *et al.* 1962, 234); other fragments were found with domestic Beaker material at Hockwold, Norfolk (Clough and Green 1972). A single flake from a Langdale axe was found lying on the natural surface near disturbed human remains possibly associated with a Developed Southern British Beaker in the Bee Low round cairn, Youlgreave, Derbyshire (Marsden 1970, 193 and 206). The relationship between Beakers and the Langdale industry is by no means clear. Possibly the Langdale sites were no longer operating by the time Beaker settlers came to the area; possibly their arrival was the final contributor in a sequence of events leading to the demise of the axe factories. The later dates of 2101 ± 115 B.C. and 2175 ± 115 B.C. (Q 303) from Ehenside Tarn are probably relevant here and may reflect this last phase of the factories' existence. It is perhaps worth making the point, often

overlooked, that the technique of working Langdale stone is somewhat different from that of working flint (just as implements of these two materials have to be drawn in different ways), and the unsuccessful attempts at re-use mentioned above probably reflect the failures of various flint-workers to cope with an unfamiliar medium. Only rarely is re-flaking successful (Clough and Green 1972, 140).

Further dates are required from other sites to determine their place in the sequence and to indicate for how long the Langdale industry as a whole was active. At present, such dates as there are from sites where Langdale (Group VI) axes were received as imports strongly suggest that the greatest activity took place between about 2750-2500 B.C. However, future work may substantiate an impression that the Langdale axe factories were by no means short-lived but rather were operating for the greater part of a millennium. In this connection it is particularly important that these chipping sites should remain intact and undisturbed until a sufficient opportunity arises for their more detailed and fully recorded examination. Until such a detailed survey incorporating a full geological and petrological investigation has been achieved, the place of the hundreds of known Group VI and related products in the wider context of Neolithic Britain will not be fully understood.

Acknowledgements.

I am glad to record my thanks to all those who have contributed in many ways to the project, in particular to Miss Clare Fell and Dr Winifred Pennington (Mrs T. G. Tutin); also to Mr C. H. D. Acland and the National Trust for permission to excavate; to Mr J. C. Barringer and the Cambridge University

Board of Extra-Mural Studies for organisation; to Mr R. Burleigh and the British Museum Research Laboratory for radiocarbon dating; to Mr C. H. Houlder and Mr R. G. Plint; to Mr E. D. Evens, Dr F. S. Wallis, Professor F. W. Shotton and Dr W. A. Cummins for petrological work; to Mr and Mrs A. B. Ware and the staff of the Brathay Hall Field Studies Centre, Ambleside, for equipment, accommodation, supplies and transport.

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APPENDIX.

Pollen analysis at the Langdale axe chipping site.

By WINIFRED PENNINGTON (Mrs T. G. Tutin).

The series of samples analysed was taken in July 1968 during a visit with Mr Peter Johnson. It is by no means certain that the face from which these samples were collected was the identical one from which Mr Johnson collected, in 1966, the charcoal sample which gave the date 2730 B.C. ± 135 (BM 281), and no charcoal was visible in 1968. The two exposed sections were, however, very similar, on Mr Johnson's evidence, and it would be expected that natural peat erosion would have destroyed (in the intervening two years) the actual face from which sample BM 281 was collected, together with any remaining pieces of charcoal. Samples prepared for pollen analysis showed that microscopic pieces of charcoal were present in both the stony mineral soil at the base of the section and in the lowest sample in which pollen was preserved.

The pollen content of this sample and of five overlying samples (Fig. 5) when compared with dated pollen diagrams from Blea Tarn (Fig. 6) and Angle Tarn nearby, indicates an age very close to the two radiocarbon dates, BM 281 and 676, from pieces of charcoal. That is, the pollen spectra from this site show that the basal peaty soil containing microscopic pieces of charcoal is of the same age as the sediment in Blea Tarn and Angle Tarn which lies *c.* 20 cm. above the Elm Decline, and is therefore dated to the "second quarter of the third millennium B.C." — p. 38. This correlation is made on the presence in the peat samples of the pollen of the ribwort plaintain (*Plantago lanceolata*) which is not found in the profiles from Blea Tarn and Angle Tarn before 3000 B.C. (see Fig. 6 and Tutin (1969) for Angle Tarn): also on reduced percentages of elm (*Ulmus* sp.) pointing to a date after 3000 B.C., and on the disappearance of pine (*Pinus* sp.) from the peat samples about 10 cm. above the base of the section, which is correlated with the great reduction in the proportion of pine pollen in the sediments of Angle Tarn at a horizon dated to *c.* 2500 B.C.

Interpretation of these changes in the pollen spectra suggests the following sequence. A widespread disturbance of virgin forest is indicated by the Elm Decline at 3200-3000 B.C. (^{14}C age). A few centuries after this there was, round Blea Tarn, sufficient actual clearing of oak-birch-hazel forest to produce patches of grassland, with bracken (*Pteridium*) and tormentil (*Potentilla*), and herbs which included that characteristic plant of human

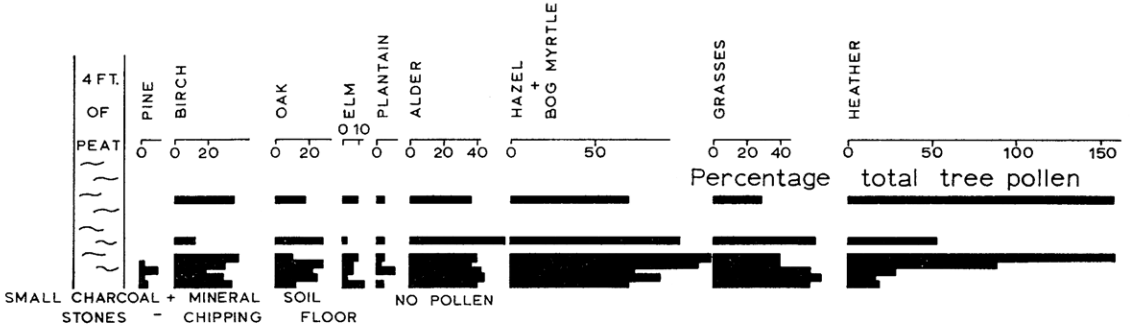

FIG. 5.—Pollen diagram from Thunacar Knott, at a site close to that from which sample BM 281 was collected. It shows how peat accumulated above the chipping floor with charcoal, and how within the peat is recorded the change from upland forest, with pine, to heather moor.

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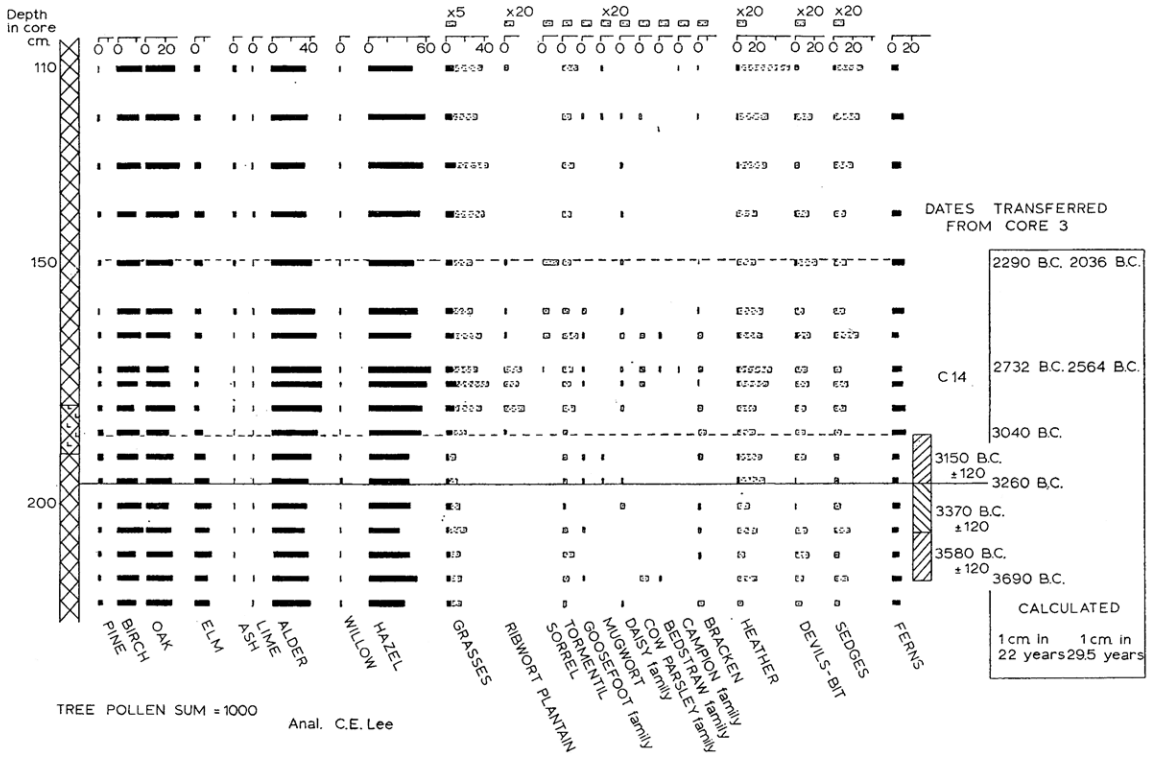

FIG. 6.—Pollen diagram from a sediment core from Blea Tarn, Langdale, analysed by Mrs Christine Lee. Horizontal broken lines show the section of the core which records temporary clearances in the woods round Blea Tarn. Immediately below this, three radiocarbon dates (C.14 —K 957, 958 and 959) — give the rate of accumulation of sediment. Using (i) this rate, and (ii) an alternative rate based on mean accumulation rate to the present, limiting dates for the beginning and end of the clearance phase have been calculated (right hand column). Both charcoal dates (BM 281 and BM 676) fall within this period of pollen evidence for human settlement.

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settlement the ribwort plaintain, as well as docks, cow parsley and fat hen. Round Blea Tarn this episode was only temporary, lasting from about 2700 until 2300 B.C. on the time-scale provided by three radiocarbon dates (Fig. 6) — after this the forest closed in again. On the higher fells round Angle Tarn and the site on Thunacar Knott the changes in the upland forests during this period were more permanent, and included the final disappearance of native pines from the Lake District fells. At the site on Thunacar Knott a great increase in proportion of heather (*Calluna*) pollen accompanies the disappearance of the pine (Fig. 5) and shows that heather moor replaced forest over considerable areas at this time. The increase in heather pollen appears also in the pollen diagram from Angle Tarn (Tutin 1969).

The blanket of peat which now covers much of this part of Thunacar Knott and adjacent fells (cf. p. 36) probably began to form soon after the disappearance of the upland forest, as a result of natural soil changes on these wet uplands, though the existing sections cannot tell us with certainty what time elapsed between the last use of the chipping floors and the date when true peat began to grow over and cover them. We may suppose from the biological evidence that the men who worked the axe factories found extensive upland forests when they came to the Lake District, and since the implements they made were designed to cut down trees, it seems reasonable to attribute to their activities both the temporary disturbance of valley woods (Blea Tarn) and the more permanent destruction of upland forests round their factory sites, since radiocarbon dating has shown that the changes in the pollen rain took place at the same time as that at which charcoal was being formed among the chipping floors. As yet it is not clear whether the charcoal is confined to the hearths of camping sites near the workings, or represents a widespread destruction of standing trees or felled timber as part of deliberate forest clearance on the uplands. A fuller discussion of vegetation history in north-west England at this time is given in Pennington (1970).

Pennington, W. 1970. "Vegetation history in the north-west of England: a regional synthesis." In *Studies in the vegetational history of the British Isles* (eds. D. Walker and R. G. West) (Cambridge), 41-80.

Tutin, W. 1969. "The usefulness of pollen analysis in interpretation of stratigraphic horizons, both late-glacial and post-glacial", *Mitt. Internat. Verein. Limnol.* 17, 154-164.