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LATE FLANDRIAN SHORELINE OSCILLATIONS IN THE SEVERN ESTUARY: CHANGE AND RECLAMATION AT ARLINGHAM, GLOUCESTERSHIRE

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Five morphostratigraphic units of estuarine alluvium in an erosively off-lapping relationship underlie the now almost totally reclaimed post-glacial wetland enclosed by the great bend in the upper Severn Estuary at Arlingham. The oldest unit is mud-dominated and includes peats, but the next, probably spanning the Medieval Period, sees the beginning of a substantial influx of sand into the upper estuary. The three youngest units are identifiable with the estuary-wide Rumney, Awre and Northwick Formations, which formed within the past 300 years in response to the repetition of a regional cycle of coastal movement that involved cliff cutting on the salt marshes and then the upbuilding of further mudflats and wetlands. The trend of relative sea level in the area has meanwhile continued upward. Piecemeal wetland reclamation, commencing not later than the Medieval Period, and possibly beginning in Romano-British times, has complicated the development of these morphostratigraphic elements. The reclaimed part of the salt marsh now has the form of an upward and outward flight of geomorphic surfaces that increase in elevation with declining age. Locally, where sea defences have been either abandoned or eroded in response to changes in the pattern of estuarine currents, renewed tidal siltation had led to the burial of soils formed on the reclamations.

1. Introduction

The Severn Estuary, a large and severely macrotidal system on the west coast of Britain, is emerging as a sedimentary environment subject over the past 2000 years or so to a surprisingly large amount of change due to medium- and short-term fluctuations of climate. Reconnaissance work has defined in general terms an estuary-wide, episodic pattern of shoreline movements expressed in the salt marshes by phases of cliff cutting followed by the thick and rapid accretion of mudflats that grow up to marshes at new but lower levels (Allen & Rae 1987). It seems possible that this pattern reflects changes in the trend of windiness in southern Britain. The local trend of relative sea-level, itself partly under climatic control, has meanwhile been upward to the extent of 1–2 m (Allen & Rae 1988). Detailed studies, so far only at Rumney Great Wharf in the lower estuary (Allen 1987*a*, 1990), and at Slimbridge some distance upstream (Allen 1987*b*), point to local sedimentary responses that are somewhat more complicated, due to the variable influence of local factors and human interference. The results of archaeological reconnaissance amply demonstrate that human forces have exerted a powerful effect on the character of the estuarine wetlands since the process of embanking and drainage began in Roman times (Allen & Fulford 1986, 1988, 1990).

This paper briefly describes coastal change, and accompanying human activity and

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Description of plates 2 and 3

Plate 2. Air photographs (December 1946) showing details of strip fields in the Arlingham area. (RAF photographs: Crown copyright reserved.)

Figure 7. Strongly curved, uneven lands in irregular furlongs southwest of Arlingham. Scale bar represents 250 m.

Figure 8. Strongly curved, uneven lands in irregular furlongs south–southeast of Arlingham. Scale bar represents 250 m.

Figure 9. Uniform, straight to slightly curved lands west of Arlingham. KR, Kencroft Rhyne. LM, Leasum Mead. LNL, Long Newbridge Lea. SF, South Field. Note also unploughed alluvium adjoining Long Newbridge Lea and Leasum Mead. Scale bar represents 150 m. See also figure 6.

Figure 10. Comparatively uniform, straight lands north–northwest of Arlingham. Note adjoining unploughed land. Scale bar represents 200 m.

Plate 3. Air photographs (December 1946) showing details of strip fields in the Arlingham area. (RAF photographs: Crown copyright reserved.)

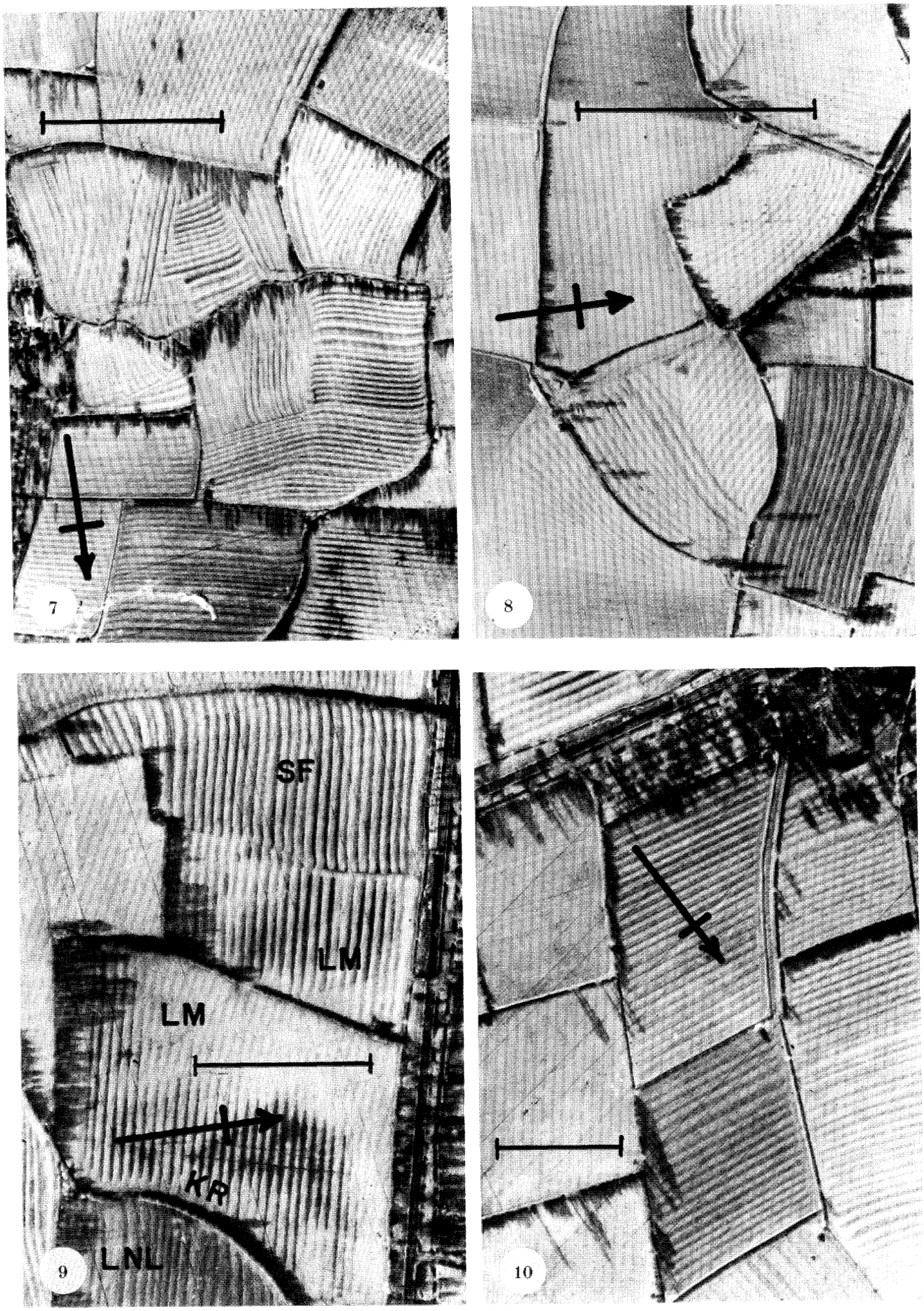
Figure 11. Fields (part of South Field) to the southeast of Passage Pill. Scale bar represents 250 m. Initially long lands evolved separately after a ditch (arrowed) had been cut from the left-hand side to the middle of the large field. The seabank runs across the upper part of the photograph. Note the faint traces of ridge-and-furrow and another seabank on the active marsh riverward of the main defence.

Figure 12. Field southeast of Arlingham showing evidence (arrowed) of the reorganization of lands, probably related to an intake of unploughed alluvium (towards top). Scale bar represents 100 m.

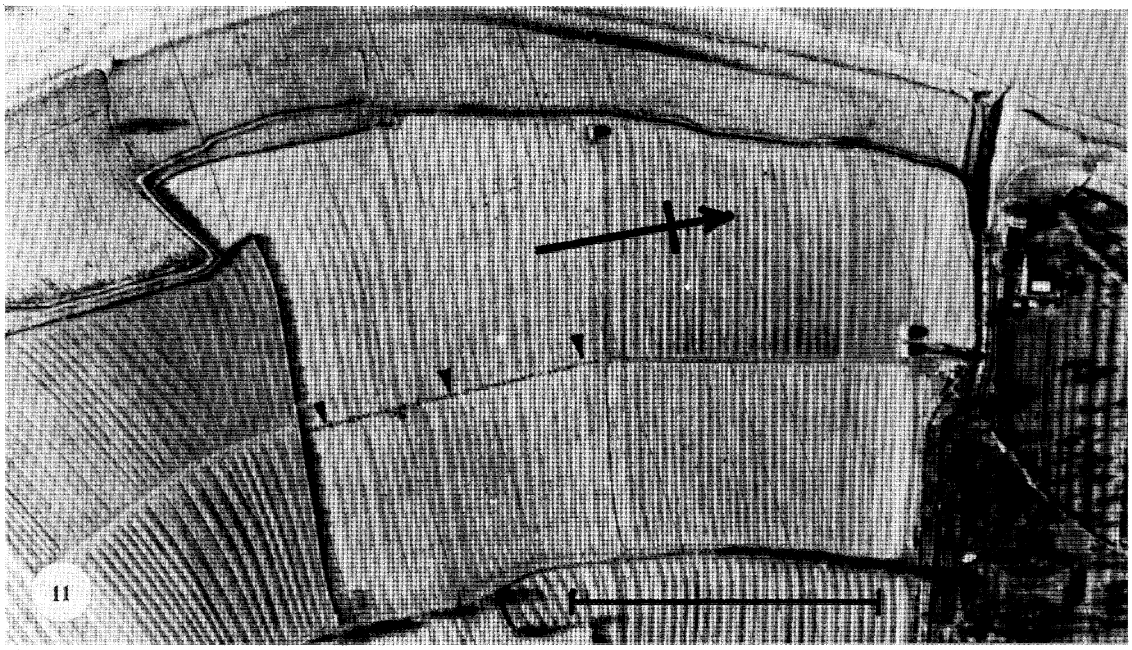
Figure 13. The field called Old Wharf and its sea defences north–northwest of Arlingham. Scale bar represents 200 m.

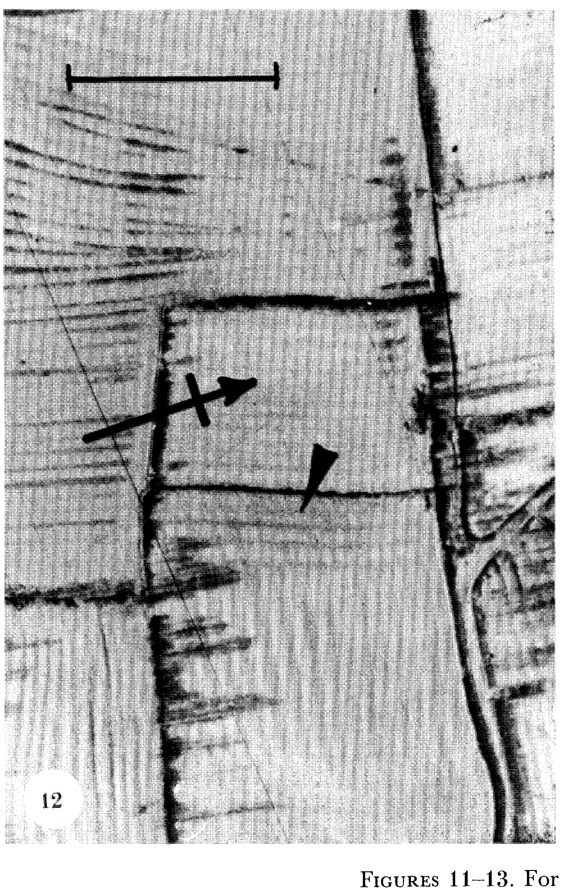
FIGURE 2. Air photograph (June 1969) of the Arlingham peninsula and river bend showing general features of sea defences and field patterns. Scale bar represents 500 m. Note that the light in the photograph is from the bottom and not from the conventional top. (Ordnance Survey photograph: Crown copyright reserved.)

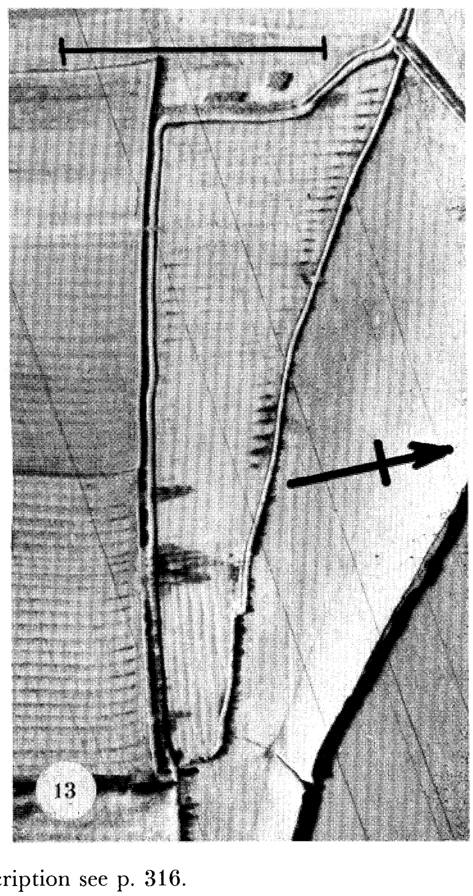
(*Facing p.* 316)



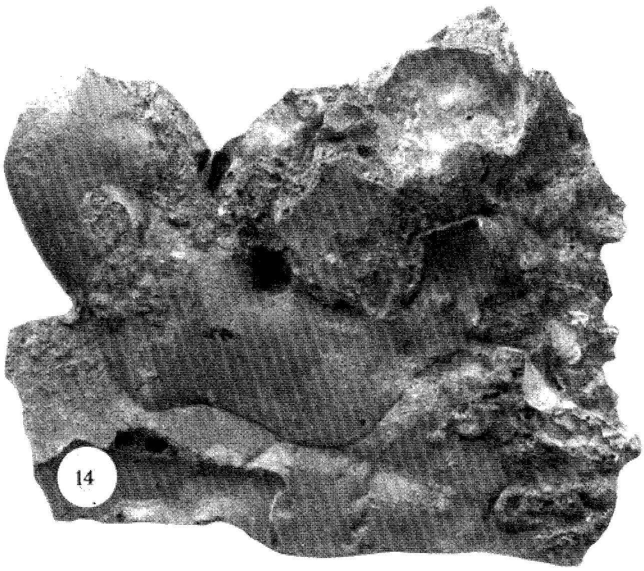
FIGURES 7–10. For description see p. 316.

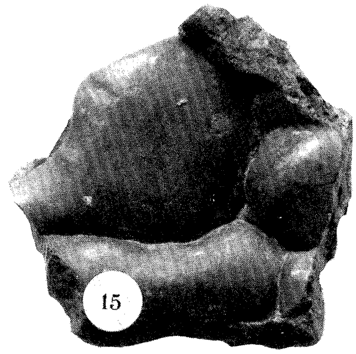


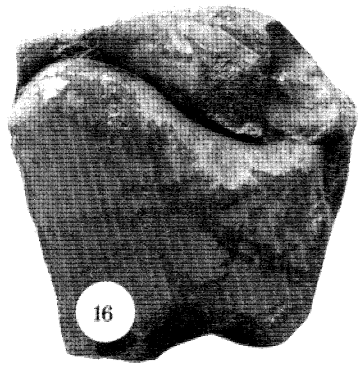




FIGURES 11–13. For description see p. 316.







FIGURES 14–16, 23, 24. For description see opposite.

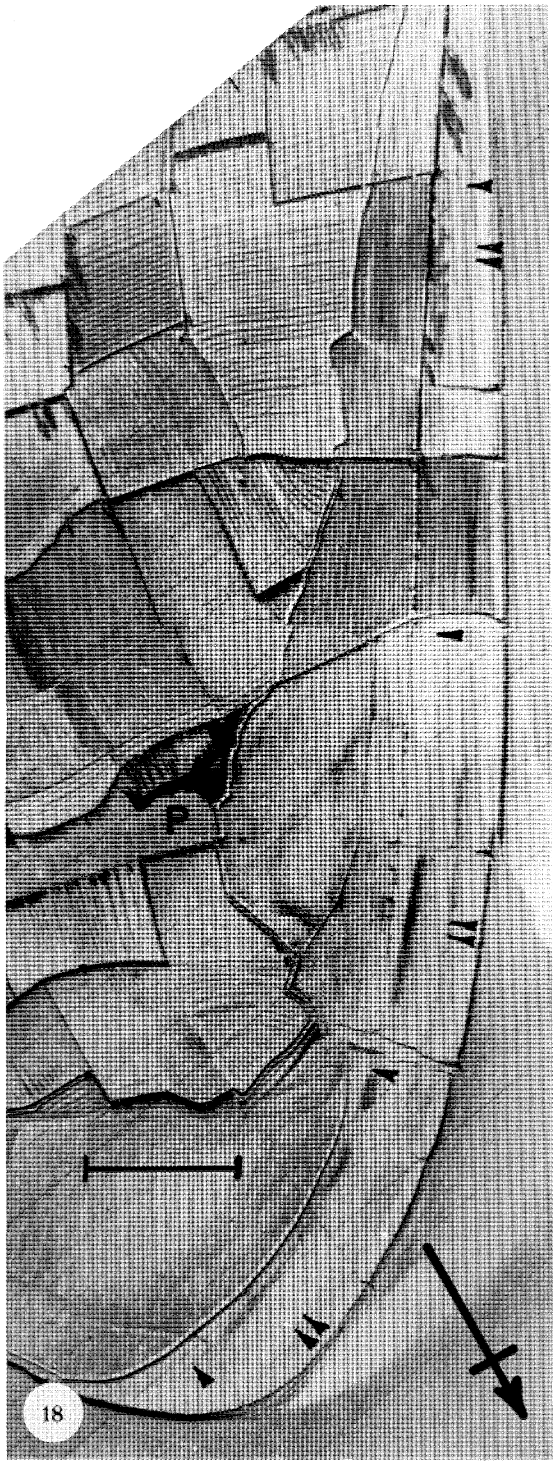
Description of plate 4

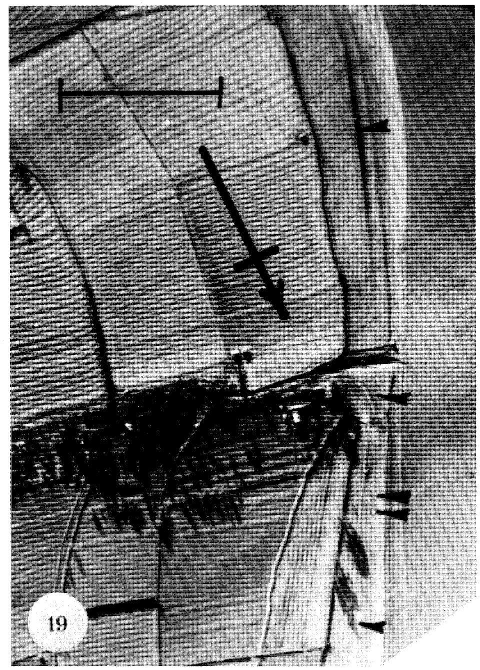
Plate 4. Bloomery slags and geomorphic features from the Arlingham area.

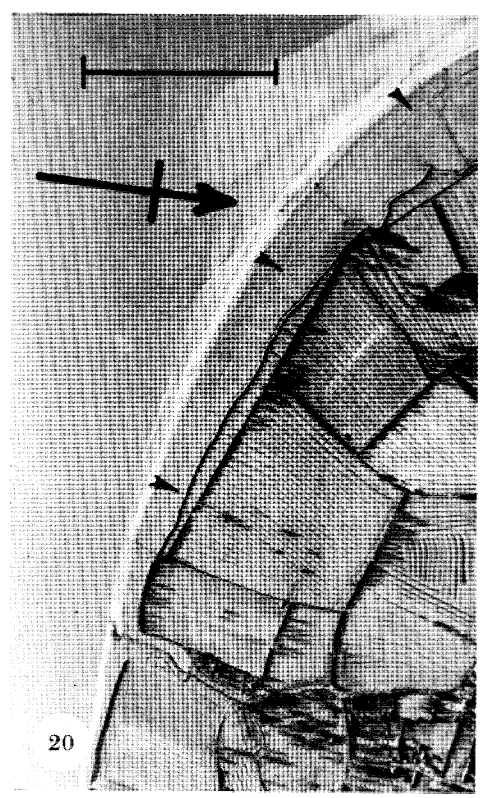
Figures 14–16. Flow-textured upper surface of representative specimens of bloomery slag from the surface strew localized in figure 1*c*. Specimens respectively 78 mm, 42 mm and 37 mm across.

Figure 23. Grassed-over clifflet separating surface 5 (to left) from surface 3 (to right with seabank along hedge) to north–northwest of Hope Pill. Spade for scale.

Figure 24. Partly exposed clifflet separating surface 5 (to left) from surface 3 (to right beyond fence) to south–southwest of Passage Pill (Old Passage Inn visible upper right). Spade for scale.







FIGURES 18–20. For description see opposite.

interference, at Arlingham in the hitherto neglected upper estuary, where the tidal channel follows a series of great bends. Although the intensification of farming in the area, and the need for greater flood protection, mean that little of the evidence originally presented by the salt marshes can now be directly inspected, a general picture of change over the past few thousand years has emerged by combining a field survey of the exposed estuarine alluvium with lithostratigraphic data from commercial boreholes and information from archival sources. A pattern similar to that in other parts of the estuary is evident, but again with significant complications arising from local natural and human factors.

2. General setting

Arlingham lies 15 km southwest of Gloucester, on one of the great incised but now partly silted-up bends of the upper estuary (see figure 1 *a*, *b*, *c* and figure 2, plate 1). The local bedrock, emerging here and there from beneath blanketing estuarine alluvium, is dominated by Triassic marls and by Rhaetic and Liassic shales and limestones. Locally, there are remnants of the Kidderminster and Main Terraces (Wills 1938).

The bend encircling the village is today compound, the tidal channel curving to the right (looking downstream) and to the left at several places in each case (see figure 1 *b*). The two neighbouring outcrops of estuarine alluvium lie close to the levels of the higher tides, at elevations between about 7 and 9.5 m above Ordnance Datum (o.d.). These tracts slope down very gradually both downstream and inward towards the outcropping bedrock. Both areas of alluvium are now largely reclaimed, but a narrow strip of active marsh, drowned by the highest tides (at times augmented by surges and river floods), survives along the channel margin. The inner edges of the tidal sand flats in the channel lie 2.5–5 m below the surface of the active marsh.

3. Morphostratigraphy and dating

(*a*) *A morphostratigraphic model*

The general morphostratigraphy of the estuarine alluvium in the Severn Estuary can be summarized by using a simple model, in which it is only for convenience that the consequences of natural processes and human forces are treated separately.

The high-water shoreline moves horizontally in response to a natural ‘cycle’ in which

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Description of plate 5

Plate 5. Air photographs (December 1946) showing traces of geomorphic surfaces and bordering clifflets along the northwestern and southwestern margins of the Arlingham peninsula (see also figure 1 *c*). (RAF photographs: Crown copyright reserved.)

Figure 18. Coastal strip from Arlingham Warth (bottom) nearly to Passage Pill (top), showing clifflet between surfaces 2 and 3 (single arrow) and between surfaces 3 and 4 (double arrow). The tidal creek cut-off by the construction of the sea defence to form a pond is denoted by P. Scale bar represents 250 m.

Figure 19. Coastal strip centred on Passage Pill, showing (*a*) upstream of the pill the clifflets between surfaces 2 and 3 (single arrows) and between surfaces 3 and 4 (double arrows) and (*b*) downstream of the pill, the clifflet between surfaces 2 and 3 (single arrows). Scale bar represents 250 m.

Figure 20. Coastal strip north–northwest of Hope Pill showing clifflet (arrowed) between surfaces 2 and 3. Scale bar represents 250 m.

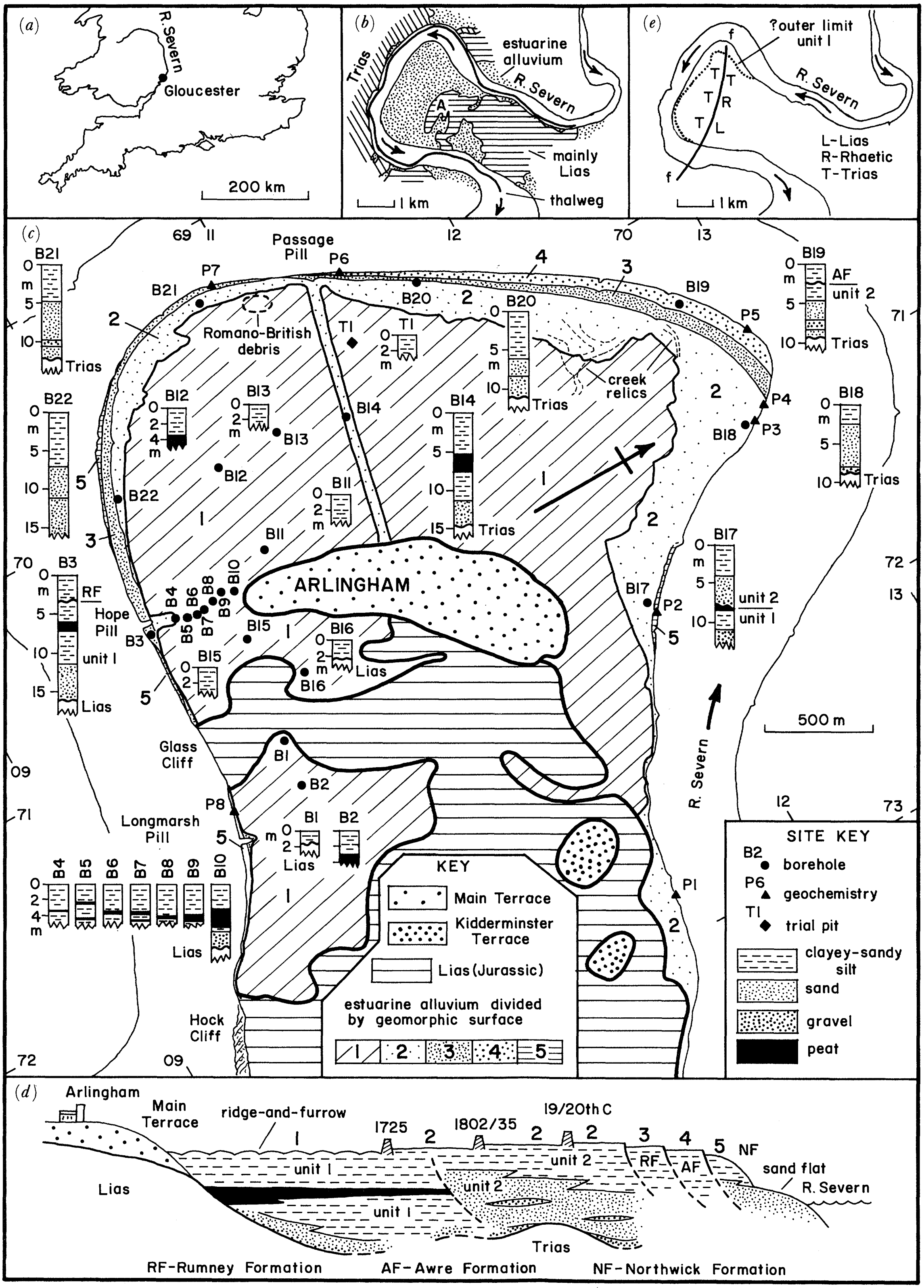

FIGURE 1. Geological and geomorphological features of the Arlingham area. (*a*) Setting. (*b*) Generalized geology and position of the Severn thalweg. A, Arlingham village. (*c*) Details of geology, geomorphic surfaces and stratigraphic profiles (for geochemical profiles see figure 22). (*d*) Schematic morphostratigraphic section (not to scale). (*e*) Conjectured fault and outer limit of unit 1.

erosion, creating a bold cliff at the edge of the salt marsh and a sloping platform below (see figure 3*a*, *b*, *d*), alternates with the accretion of tidally introduced mineral matter, leading to the upbuilding eventually of a new marsh but at a lower level than the prior wetland (see figure 3*c*, *d*). Repetition of the cycle may lead to a broad salt marsh composed of outwardly descending terrace-like geomorphic elements, each underlain by an erosively based lithostratigraphic unit of estuarine silt (thicknesses up to 5–10 m are recorded). These terraces and silt units form an off-lapping sequence of morphostratigraphic elements (see figure 3*e*). As the regional trend of relative sea level is upward (Allen & Rae 1988), each terrace remains within the reach of the tide (unless subject to reclamation), and so continues to accrete. As on open coasts (see, for example, Pethick 1980, 1981), the lowest (youngest) marsh accretes the fastest, because it is (i) drowned annually by the largest number of tides, and (ii) wetted for longest by each tide. Theoretically, the terraces remain distinct in altitude, but experience in the turbid Severn Estuary shows that after 200–250 years the elevation difference between two adjoining features is reduced to a few centimetres or so, making the two marshes in practice difficult if not impossible to separate.

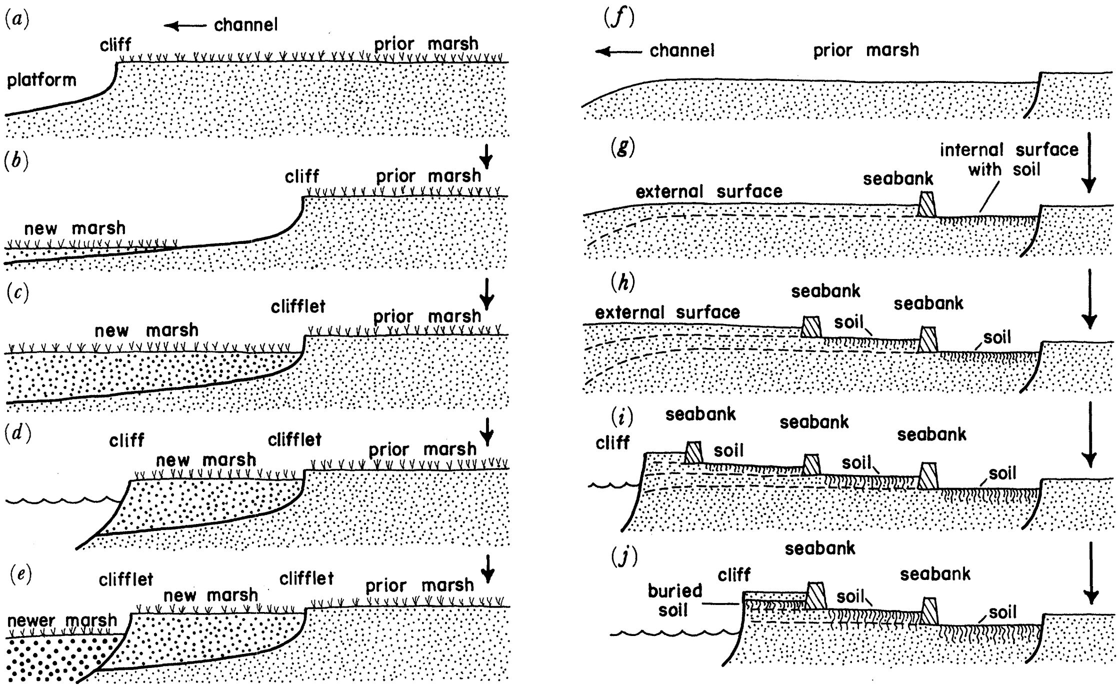

FIGURE 3. A model for the morphostratigraphic development of post-glacial estuarine alluvium in the Severn Estuary, under the influence of a rising relative sea level, repeated depositional offlap after erosion (*a*–*e*), and progressive human reclamation (*f*–*j*).

Two geomorphic surfaces arise where a sea defence is constructed so as to enclose part of an active salt marsh under a régime of upward-trending relative sea level (see figure 3*f*, *g*). The internal surface, denied further tidal silt, becomes fossilized (soil formation) and through sediment consolidation may sink slightly. However, the external surface, still exposed to the tide, continues to accrete. Further reclamation creates an outwardly ascending flight of terrace-like geomorphic surfaces (see figure 3*h*, *i*). Outward through this sequence, the silt unit associated with the prior marsh becomes progressively less abbreviated. The neglect or erosion (renewed cliff cutting) of the outermost seabank leads to the resumption of tidal siltation on an internal surface and to the burial, with the creation of a diastem, of the soil that horizonated beneath it (see figure 3*j*).

(*b*) *Dating morphostratigraphic elements*

An eclectic approach is essential. The more useful and widely applicable dating methods available in the Severn Estuary exploit (i) the relative horizontal and vertical position of the element, (ii) the presence of archaeological materials (e.g. structures, pottery, industrial residues), (iii) material evidence for past agricultural practices, (iv) archival sources (historical maps, air photographs), and (v) the pollution geochemistry of the mud-flat and salt-marsh deposits.

The Arlingham area yields little archaeological material but affords widespread evidence of early agricultural practices. These can be dated on general grounds and partly by using local archival sources.

The archival and related evidence (see Appendix A) includes a sequence of maps dating from 1725. All but the oldest are of high planimetric accuracy but, having been made for a wide variety of purposes, differ greatly in the extent to which features which must have been present on the ground achieved representation. The maps are therefore used cautiously and comparatively. There is helpful air photography from 1946 (Royal Air Force) and 1969 (Ordnance Survey).

The fine sediments of the Severn Estuary have become increasingly polluted with heavy metals (zinc, copper, lead) and particulate industrial wastes (coal dust, fly ash) since the mid-nineteenth century, owing to urbanization and industrialization in the hinterland. After adjusting for grain size, the abundance of these components can be used approximately to date the younger estuarine silts, both relatively and, because a radiometric calibration is available (Clifton & Hamilton 1979), also absolutely (Allen & Rae 1986, 1987; Allen 1987*c*, 1988*a*). Some caution in interpretation is necessary, however, as site-specific factors appear to have some influence on the levels of the heavy metals surviving in the sediments. The data are best assessed with some emphasis on the scale and shape of stratigraphic profiles of the grain-size corrected metal abundances (metal index values). The full pattern involves three chemozones. Chemozone I ranges up to *ca.* A.D. 1845, and is typified by essentially steady metal values. In chemozone II, extending from *ca.* 1845 to *ca.* 1945, the metals increase in abundance by a factor of several times. Chemozone III above sees a modest decline in the levels.

(*c*) *Summary of morphostratigraphy at Arlingham*

The available evidence permits five main geomorphic surfaces and five sedimentary units to be recognized in the post-glacial estuarine alluvium (see figure 1*c*, *d*). The youngest three surfaces and units correspond exactly. The geomorphic surfaces presumed to have been linked to units 1 and 2 are no longer separable on the ground and consequently are treated as one.

4. The character and age of surface 1

This is the lowest-lying of the geomorphic surfaces and lies within the innermost of the seabanks depicted (sketchily) on the map of 1725 (GRO D2998/1) (see figure 4). The outer defence survives locally as a bank (e.g. British National Grid Reference SO 698 116 to SO 701 119) but today is mainly evident as a ramp, having been grubbed out and graded during land improvements. Originally, as is evident from ramps in the fields, the defences ran back from the mouth of Passage Pill to the high ground at Arlingham village, but by the time the map was made a sluice (Brick Kiln Sluice) had been built nearer the river. Northwest of Arlingham (SO 704 121), the seabank was built as a dam across a large funnel-shaped hollow, now a pond (see figure 1*c*), thought to have been a tidal creek that reached back into the alluvium (see also RAF 1946, OS 1969). In the fields riverward of the pond there are subtle traces of an extension of the tidal creek. The outer and better-drained part of the enclosed alluvium in 1725 was laid out as great open fields ploughed in strips (see figure 5*a*). Judging from the field names (mead, lea), and referring to the air photographs (RAF 1946, OS 1969), the inner part was unploughed grassland and arable converted to grassland.

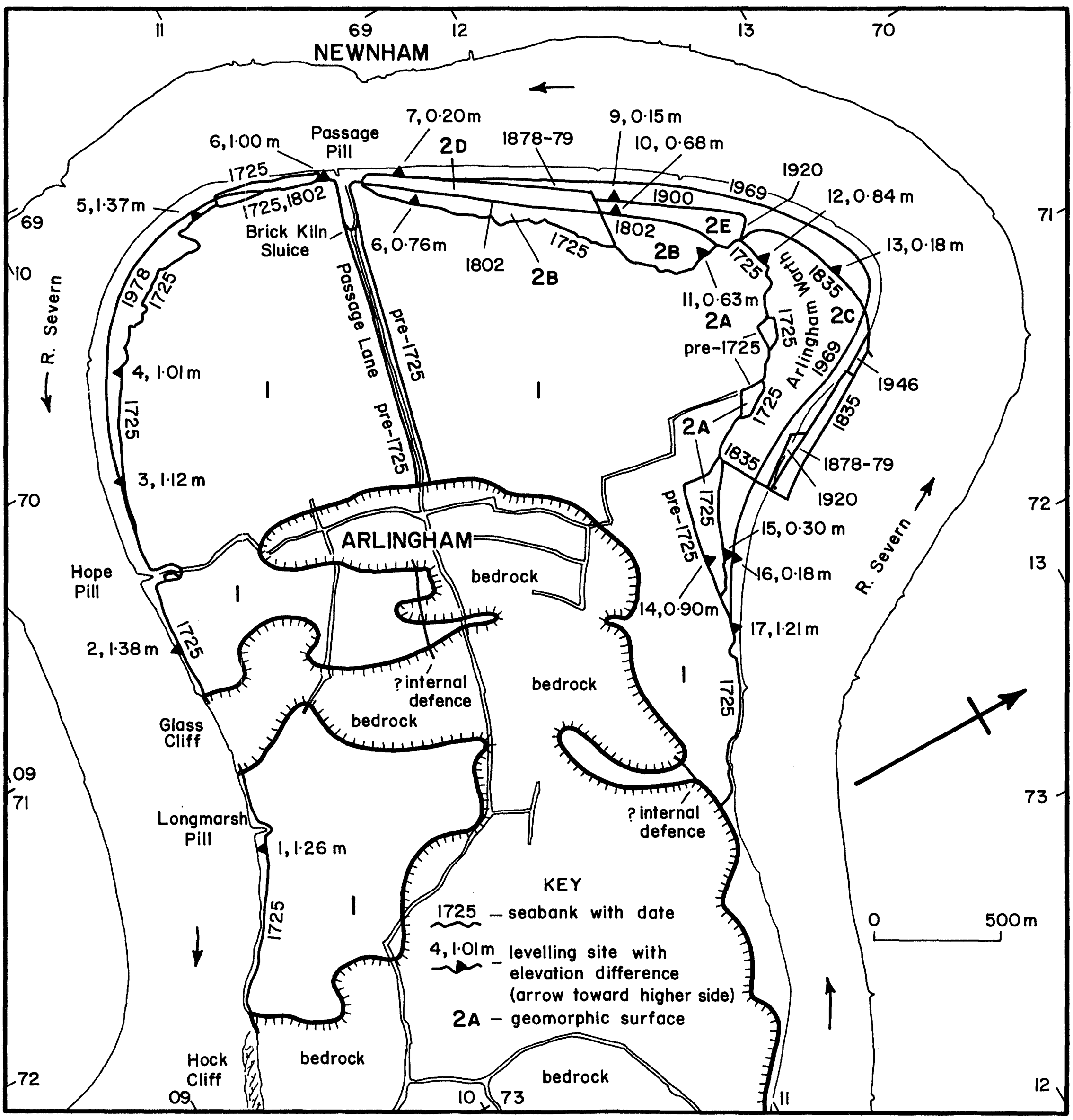

Figure 4. Sea defences in the Arlingham area, together with the dates at which they first appear on maps and air photographs, and elevation differences measured across them. See Appendix A for summary of sources.

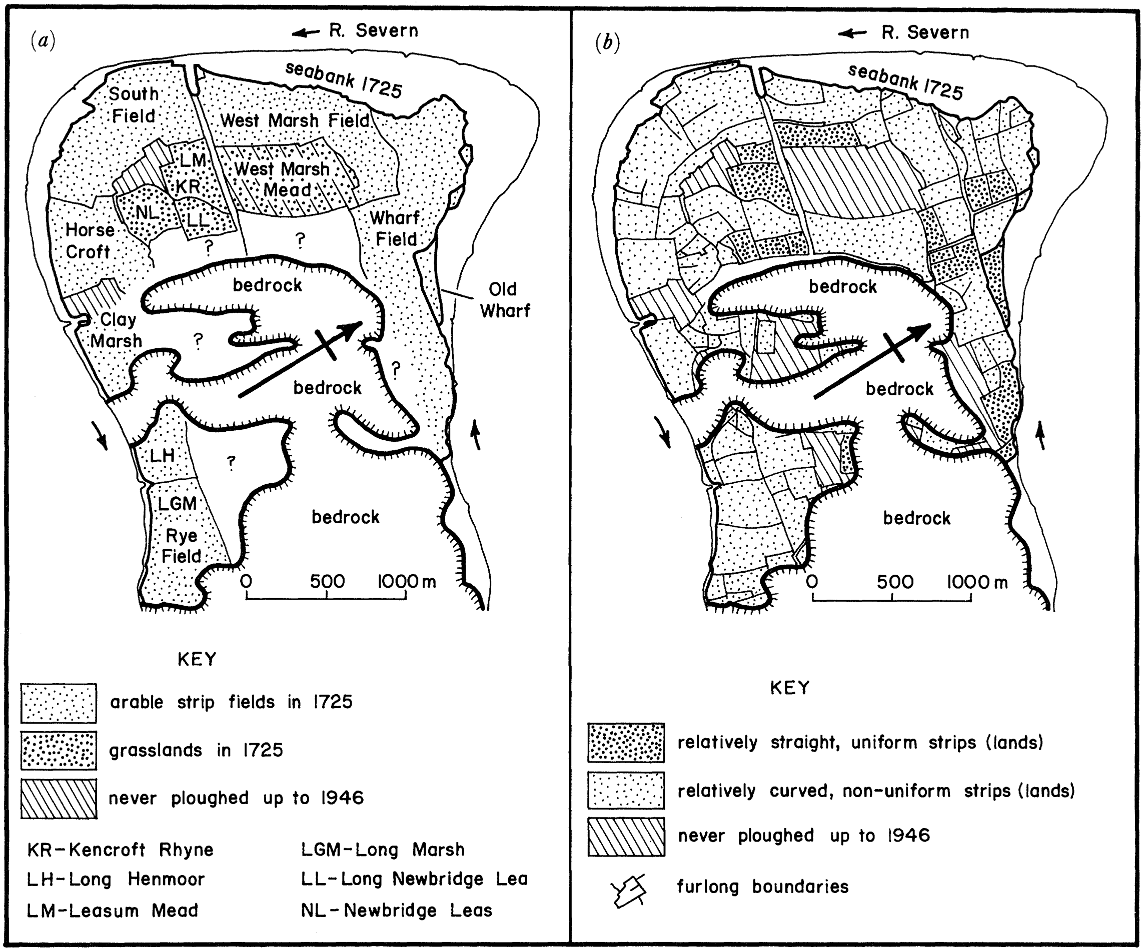

FIGURE 5. Early fields on the estuarine alluvium of the Arlingham area. (*a*) Land use deduced from early maps and from air photographs. (*b*) Distribution of unploughed ground and of types of strip field.

Figures 2 and 6 reveal details of these important and widespread strip fields. The strips, or lands (Hall 1982), vary from about 5 to 15 m in width and in places are up to 300 m long. They form roughly parallel sets, called furlongs (Hall 1982), which range in plan from irregular to approximately rectangular. The furlongs are of two, continuously intergrading types (see figure 5*b*). The first sort, normally irregular in plan, consists of lands of various widths but bold relief that are relatively strongly curved, many having a pronounced reversed-S plan (see figures 7 and 8, plate 2). The second kind of furlong, typically rectangular, consists of almost straight low-relief lands of much the same width (see figures 9 and 10, plate 2), and seems either to fill gaps between clusters of furlongs of the first sort or to border unploughed grassland (see figure 5).

The air photography (RAF 1946) unmistakably reveals changes in the extent and lay-out of the open fields. One field (see figure 11, plate 3) was first laid out as a set of exceptionally long lands. Later, perhaps in response to worsening drainage, it was partly divided from the south by a large ditch, so that the strips in the separated portions began to evolve differently under further cultivation. Figure 12, plate 3, represents several cases in which relatively wide, curved and variable lands (in this instance commencing on high ground) were overlain by a newer furlong (in this case ranging on to a lower-lying and presumably virgin area).

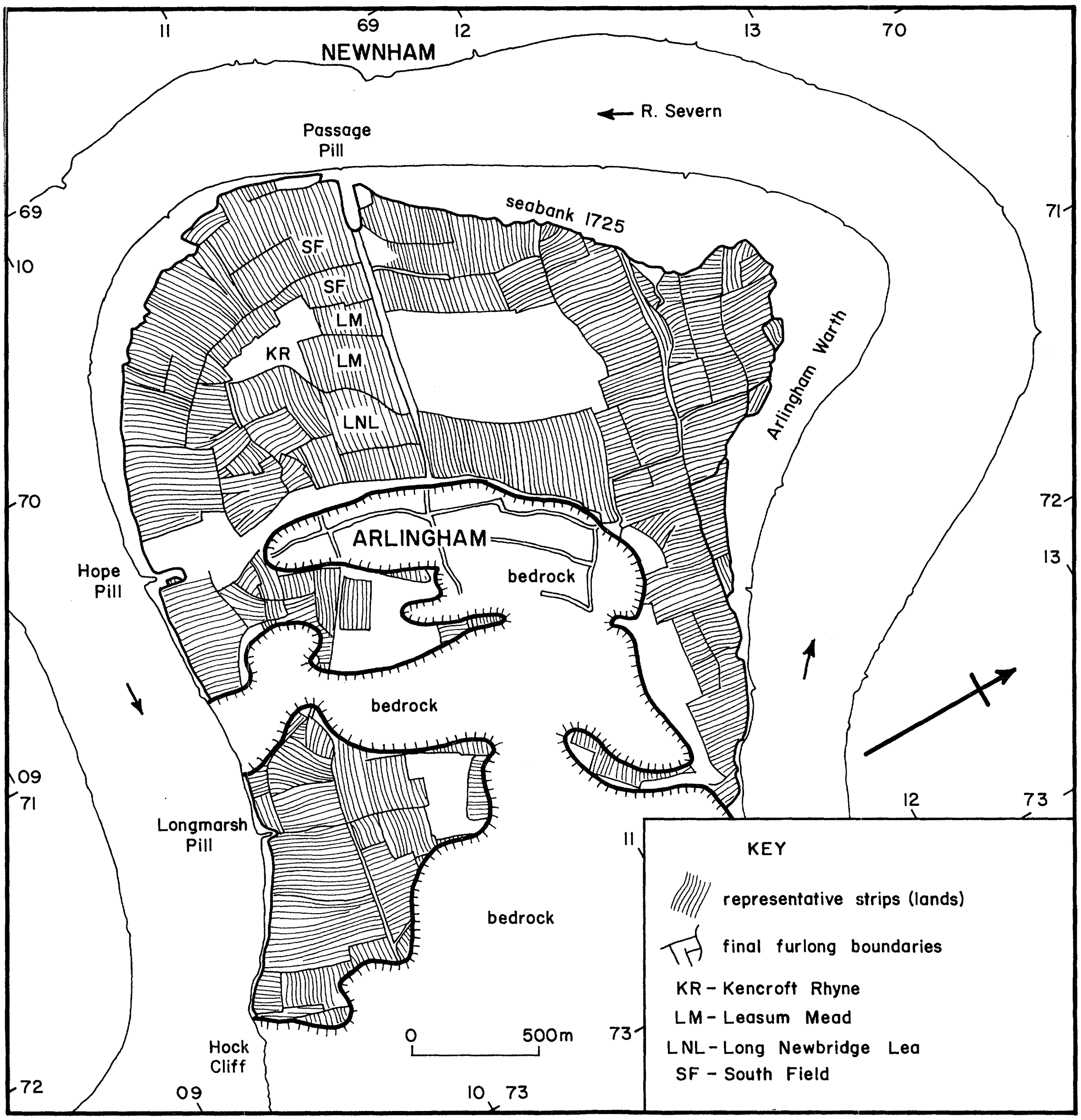

FIGURE 6. Detailed pattern of early fields on the estuarine alluvium of the Arlingham area, as reconstructed from air photographs and early maps.

It is widely accepted that strip fields of the sort found at Arlingham evolved as follows. When arable is laid out in long strips and ploughed, up one side of the strip and down the other, the ploughman chooses the anticlockwise direction, such that the plough invariably casts the soil towards the centre of the land with the consequence that the strip grows in relief with further cultivation. The draught animals and ploughman, however, anticipating the turns at the ends of the land, as they approach each end drift systematically to one side of their course, and so over time give the strip an increasingly hooked form. The morphological series of furlongs (see figures 5*b*, 7–10), together with their modifications (see figures 11 and 12), are therefore evolutionary and successional. Sets of bold, unequal and strongly hooked lands are probably the oldest and longest ploughed. Short-lived cultivation is indicated by the relatively straight, unhooked lands of low relief. Such lands, where bordering unploughed ground, are likely to have been established comparatively late in the development of the open fields.

The fields were already partly out of cultivation when the 1725 map was made. Three named fields (GRO D2998/1) appear in figure 9 (see also figure 6). The grassland of Long Newbridge Lea, bounded by the sinuous Kencroft Rhyne, was originally a furlong of relatively bold and curved lands. The dog-legged boundary between Leasum Mead and South Field is a ditch (RAF 1946 and OS 1969) cut across what was originally a single large furlong laid out as straight, parallel, uniformly wide strips. The grassed-over lands of Leasum Mead retain that character. However, those in South Field, still under cultivation in 1725, are hooked and distinctly bolder, but not as bold or hooked as many lands at Arlingham.

From this summary there can be little doubt that the field system preserved on surface 1 has its origins in Medieval ridge-and-furrow (Hall 1981, 1982; Astill 1988). Hence this surface, together with its surrounding defence, is taken to be definitely not younger than the Medieval Period; in character it may be identified with Allen & Rae's (1987) Oldbury Surface. We cannot, however, exclude reclamation a millenium earlier. Arlingham figures in the Domesday record of A.D. 1086 (Smith 1964), and Roman coins are known from the village (Gloucestershire County Council, Sites and Monuments Record 5286), as well as from Fretherne 3 km to the southeast (GCC SMR 6335, 7014). Romano-British pottery (Dorset black-burnished ware) was found among small amounts of building rubbish dumped along the river bank at Arlingham Warth (see figure 4). On the alluvium south of Passage Pill, and centred on SO 695 110, numerous local dense concentrations of primitive iron-making bloomery slag (see figures 14–16, plate 4) are widely distributed over the arable and are detectable at depths as great as 0.75 m below the surface. A composite sample (table 1 and figure 17) is indistinguishable

TABLE 1. CHEMICAL COMPOSITION OF PRIMITIVE IRON-MAKING TAP SLAG FROM ARLINGHAM

(Analysis by X-ray fluorescence (see Allen (1988*b*) for method) of composite sample of equal masses of three well-preserved slag specimens.)

Na_2O	0.09 mass %	TiO_2	0.24 mass %
MgO	1.28	MnO	0.23
Al_2O_3	3.90	FeO	60.83
SiO_2	30.29	Cu	36 p.p.m. (by mass)
P_2O_5	0.26	Zn	83
K_2O	0.87	Pb	< 10
CaO	2.01		

chemically from known Romano-British tap slags at wetland settlements in the Severn Estuary (Allen 1988*c*). Like these slags, the crystalline component of the composite Arlingham residues is dominated by fayalite (75%) with subordinate wüstite (25%). Furthermore, a small quantity of Romano-British pottery was found to be localized in the area of slag concentrations. The collection consists of four sherds of Severn Valley ware (including the everted rim of a wide-mouthed jar) and a solitary sherd of a coarsely micaceous grey ware, both fabrics being widely known from the Severn wetlands (Allen & Fulford 1988). A final piece of evidence in favour of the Romano-British reclamation of surface 1 is that the elevation differences between it and the highest active salt marshes (see figure 4) are little different from those measured at Elmore 10 km upstream, where two wetland settlements and an elaborate sea defence of the period are known (Allen & Fulford 1990).

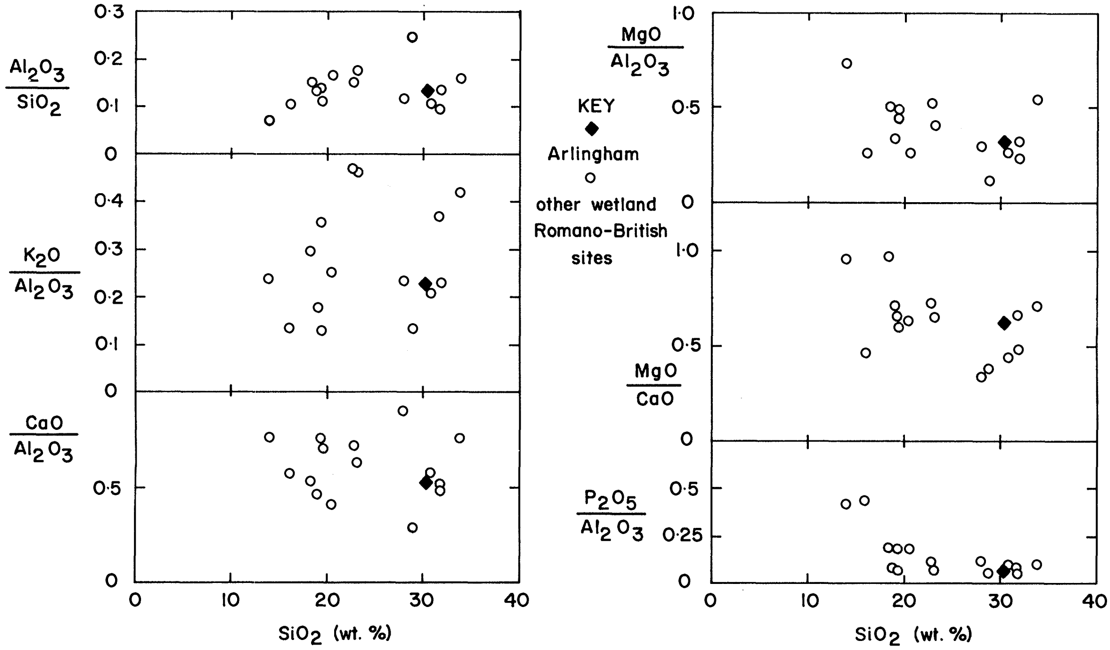

FIGURE 17. Chemical compositional features of primitive iron-making bloomery slag from the Arlingham area compared to bloomery slags of known Romano-British date from wetland settlements in the Severn Estuary generally. See figure 1*c* and table 1 for details of sample location and analysis.

5. Reclamation of surface 2

This geomorphic element (see figures 1*c* and 4) ranges from between the innermost seabank of 1725 (GRO D2998/1) to an extensive clifflet visible in the early air photographs (RAF 1946) (see figures 18–20, plate 5). The clifflet corresponds to the shoreline plotted on the maps of 1802 (GRO Q/RI7) and 1835 (GRO D272/9/3). Where unaffected by further reclamation, surface 2 is the highest of the external elements present at Arlingham.

Tidal accretion on surface 2 between Passage Pill and the neighbourhood of Longmarsh Pill (see figure 4) was unimpeded until the recent construction of a seabank, at various times between 1969 (OS 1969) and 1978–81 (OS SO 60 NE, 61 SE, 70 NW). Levelling shows that the surface lies 1.00–1.38 m above the outermost part of surface 1 (see sites 1–6, figure 4), of Medieval or greater age. Upstream from Passage Pill, however, surface 2 is much more complicated.

Labelled surface 2A in figure 4 (see also figure 6), three ridge-and-furrowed fields north of Arlingham represent the next phase of reclamation after the creation of surface 1. The largest field, called Old Wharf (see figure 5*a*), in 1725 (GRO D2998/1) and 1802 (GRO Q/RI7) was wholly surrounded by a sea defence, little of which now survives. This field bears the subdued traces of regular lands in two furlongs (arable in 1725) (see figure 13), but lies a puzzling 0.90 m above the nearby surface 1 (see site 14, figure 4), whereas the marsh rises by only 0.30 m across its outer defence (see site 15, figure 4). Across the nearby seabank, in place by 1969 (OS 1969), the elevation of the marsh increases again by 0.18 m (see site 16, figure 4). Slightly further east (see site 17, figure 4), the rise in elevation from surface 1 to surface 2 is 1.21 m in a single step, agreeing well with the total from sites 14–16. Surface 2A represents reclamations not later than the Early Modern Period, to judge from the map evidence as well as the ridge-and-furrow.

By 1802 (GRO Q/RI7) a long, narrow reclamation (surface 2B) had been added between Arlingham Warth and Passage Pill. It is less elevated above surface 1 (see sites 8 and 11, figure 4) than Old Wharf, although later in date. The original defence survives locally as a low bank (SO 701 121 to 702 123) but otherwise appears as a slight ramp.

Surface 2C (see figure 4), established on Arlingham Warth between 1802 and 1835 (GRO Q/RI7, D272/9/3), is a substantial reclamation standing 0.84 m above surface 1 (see site 12, figure 4). Subsequently, erosion of the river bank to the northeast caused its defence to be repositioned inland in a series of steps (see figure 21), a process that began before 1835, to judge from the two spur banks mapped as projecting from the sea wall (see figure 21 *b*). About 1.5 km

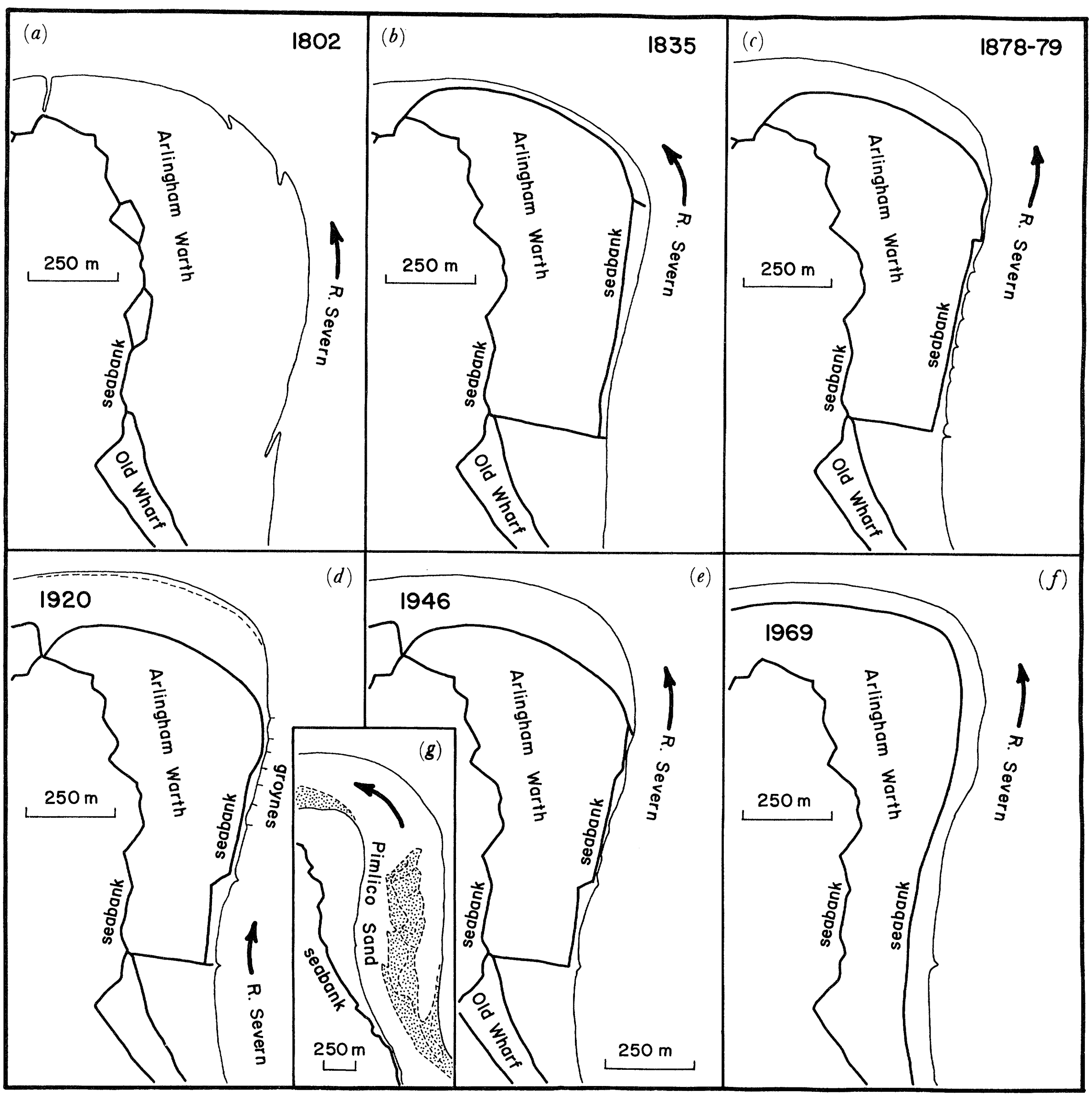

FIGURE 21. Development of Arlingham Warth. (*a*)–(*f*) Sequence of reclamations as reconstructed from maps and air photographs. (*g*) The Pimlico Sand at the present day.

of river bank was affected, the greatest retreat amounting to about 220 m. Erosion was at first rapid, but groynes constructed in the mid-nineteenth century (see GRO D18/413) slowed the process. The cause seems to have been the growth of the Pimlico Sand as a mid-channel bar complex (see figure 21*g*). The 1835 seabank survives today only as a ramp, across which the ground rises by 0.18 m (see site 13, figure 4), and the soil changes in colour from brown outward to grey.

There was little later reclamation of surface 2, small areas (surfaces 2D, 2E in figure 4) having been enclosed by 1878–79 (OS Gloucestershire XXXII SW and XL NW, 1st edn) and by 1920 (OS Gloucestershire XXXII SW, and XL NW, 2nd and 3rd edns). Surface 2E lies 0.68 above surface 2B (see site 10, figure 4) but only 0.15 m below the remaining external part of surface 2 (see site 9, figure 4). Surface 2D lies 0.20 m below surface 3 (see site 7, figure 4). The defences in question are no longer extant.

Just as ground was lost at Arlingham Warth, the coast immediately southwest of Passage Pill by 1802 (GRO Q/RI7) lay dangerously near the seabank of 1725 (GRO D2998/1), causing the main defence to be moved back (see figure 4). The ridge-and-furrow thus abandoned to the tide is just detectable in the early air photography (RAF 1946).

6. The estuarine alluvium beneath surfaces 1 and 2

Near Longmarsh Pill (see figure 1*b*, *c*), the Lias, outcropping at Glass Cliff and Hock Cliff, surrounds and underlies the alluvium (see borehole 1, figure 1*c*). As seen in borehole 2 (see figure 1*c*) and in the deeper drainage ditches, the alluvium includes a laterally extensive peat overlain by grey–green and then gradationally by brown silty clays and clayey silts.

The main outcrop of alluvium (figure 1*c*) is underlain in the east by the Lias (see boreholes 3, 10, 16) and in the west by the Trias (see boreholes 14, 18–21), a distribution supporting an inferred fault (BGS 234) (see figure 1*e*). The deposit appears to be in two parts, designated units 1 and 2, in what is considered to be an erosional and offlapping relationship (see figure 1*d*). The position of their contact (see figure 1*e*) is largely conjectural, in view of the lack of a surface clifflet separating the two and the sparse and uneven distribution of boreholes, but is considered to lie riverward of the 1725 sea defence but furthest inland at Arlingham Warth (see below).

Unit 1 is well defined by a string of boreholes ranging from Hope Pill toward Arlingham church (see boreholes 3–11, figure 1*c*). The sequence, of the order of 10–15 m thick, begins mainly with thin sands and gravels. These are overlain by grey–green silty clays and clayey silts with peat(s) that grade up into similarly textured brown silts. Comparable deposits are recorded from boreholes 12–14 nearby, in trial-pit 1 near Passage Pill, and from boreholes 15 and 16 east of Hope Pill (see figure 1*c*). The beds are exposed on the river bank north of Arlingham. At the site of geochemical profile 1 (see figure 1*c*), a peat above clay in the river bed at 4–5 m O.D. is overlain by grey–green clayey silts which grade up into brown then dark grey silts and sandy silts. All three of Allen & Rae's (1986, 1987) geochemical zones are represented (see figure 22*a*), the two youngest being comparatively thin, as befits silts deposited on a relatively mature and elevated marsh (surface 2).

The key to the relationship between units 1 and 2 comes from borehole 17 northeast of Arlingham (see figure 1*c*). A thin peat at 1.75 m O.D. above gravels and blue–grey to green–grey clayey silts is sharply and with little doubt erosively overlain by pebbly sands

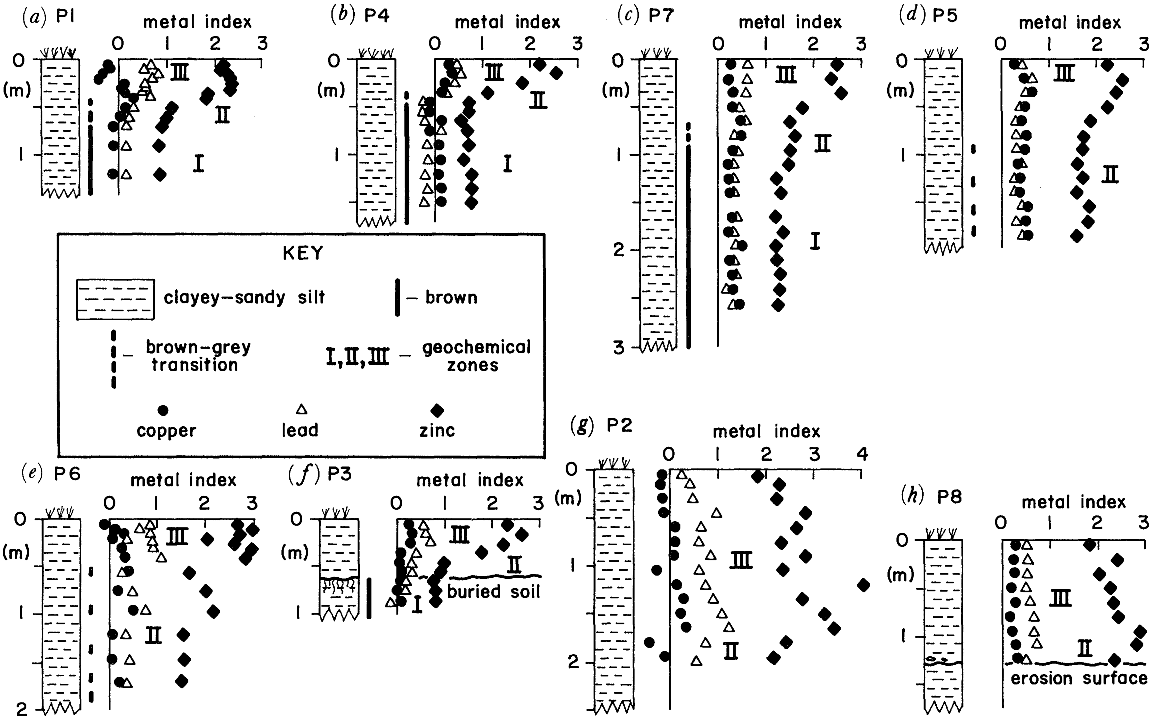

FIGURE 22. Details of geochemical profiles measured from units of estuarine alluvium in the Arlingham area. See figure 1*c* for site positions.

followed by thick silty sands and grey–green to brown clayey to sandy silts with sand stripes. The relationship of the pebbly sand (base of unit 2) to the peat (local top of unit 1) can be matched from a modern context at Oldbury Flats (ST 600 935) lower down the estuary. Here tidal scour has extensively exposed a post-glacial sequence of peats interstratified with grey–green estuarine silty clays. The peat beds resist erosion and create extensive ledges. Across these sand and pebbles are drifting in the form of current-rippled sheets and trains of starved dunes. Sand accumulated permanently here would mimic in its relationship to the peats the contact seen in borehole 17.

Sequences similar to borehole 17, but with generally even more sand, mark boreholes 18–22 from within the bounds of surface 2 near the river's edge (see figure 1*c*). As in borehole 17, sand is prevalent and peats are lacking at those levels which, in unit 1 (boreholes 1–16), are typified by silts and peat(s). Only unit 2 seems to be present in boreholes 18–22 and also in geochemical profile 4 (see figures 1*c*, 22*b*), measured from a river-bank exposure at Arlingham Warth.

The bulk of the estuarine alluvium below surfaces 1 and 2 is confidently attributed to Allen & Rae's (1987) Wentlooge Formation, composed of basal sands and gravels followed by silts and peats formed between roughly 4000 B.C. and 500 B.C. and ranging for the most part from about O.D. to several metres above (see, for example, Hawkins 1971; Locke 1971; Murray & Hawkins 1976). The lithological correspondence is especially close in the case of unit 1 at Arlingham. Unit 2, presenting a quite different lithological sequence from unit 1, yields at Arlingham no direct evidence for its age, except that it postdates the first unit. It may be confidently correlated, however, to a thick (maximum *ca.* 10 m) sequence of tan-coloured sands grading up into brown and then grey silts at Hock Cliff (SO 731 089) and Hock Ditch (SO

736 085) at the root of the Arlingham peninsula on its southern side. At Hock Cliff, the gravels at the erosional base 1.5–2.5 m below the marsh capping these deposits yield a hitherto unrecorded rich assemblage of earlier Medieval pottery (kindly examined by Dr A. Vince, City of Lincoln Archaeological Unit). To the south of Hock Ditch (Allen 1988*a*), the deposits are less complete upward and are capped by a ridge-and-furrowed ploughsoil thickly buried beneath silts of late nineteenth century and younger date. The presumed cliff that ultimately bounded the inner margin of unit 2 is therefore taken to have been already in existence when the innermost defence was constructed, not later than the Medieval period and probably as early as Roman times. As this defence, to the northwest and northeast of the village, makes large curves away from the present tidal channel (see figure 1*c*), the cliff may similarly have lain well inland. Exactly when the accumulation of unit 2 began is not known, but it is taken to be early, as surface 2 shows changes in elevation related only to the presence of sea defences. The evidence from Hock Cliff and Hock Ditch strongly suggests that the unit spans the Medieval Period.

7. Surface 3 and its alluvium

The morphostratigraphic element ranges as a well-defined, clifflet-bound terrace (RAF 1946) from Arlingham Warth to Hope Pill (see figures 1*c*, 18–20). Signs of it appear in the later photographs (OS 1969), but widespread ploughing and seabank construction have since obliterated all traces from the ground. Surface 3 is widest at Arlingham Warth (70 m) and Hope Pill (60 m), narrowing to about 15 m near Passage Pill. It is bounded inland by the shoreline mapped in 1802 (GRO Q/RI7) and 1835 (GRO D272/9/3) and on the outer side by a clifflet almost coincident with the high-water mark of ordinary tides of 1878–79 (OS Gloucestershire XXXII SW and XL NW, 1st edn). Both clifflets are locally embayed, typically at mapped drainage ditches.

The estuarine alluvium beneath – unit 3 of figure 1*d* – is exposed on the bold river cliff at several places southwest of Passage Pill. The oldest deposits visible are 2–3 m of brown silty clays with desiccation cracks, cattle footprints and millimetre- to centimetre-scale stripes of very fine sand (parallel laminations, wave and current ripple marks). These grade up into 0.7–0.8 m of dark grey clayey to sandy silts rich in coal dust and, towards the top, in fly ash particles. The geochemical profile (see profile 7 of figure 1*c* and figure 22*c*) is much less compressed than those from the alluvium below the more mature surface 2 (see figure 22*a*, *b*) and is compatible with that of Allen & Rae's (1987) Rumney Formation, an estuary-wide unit whose accumulation began not earlier than the mid to late seventeenth century and most probably in the early eighteenth century. The archival evidence also supports the attribution of unit 3 to the Rumney Formation, for the shoreline sketched in 1725 (GRO D2998/1) lies close to the seabank and is clearly in substantially the same position as that mapped with greater accuracy in 1802 and 1835 (GRO Q/RI7, D272/9/3).

8. Surface 4 and its alluvium

This combination appears on the early air photographs (RAF 1946) as a broad terrace that ranges from Arlingham Warth, where it is about 60 m wide, to near Passage Pill, southwest of which the feature peters out (see figures 1*c*, 18–20). The inner margin is the embayed clifflet on the outer side of surface 3; its present riverward margin was established as a clifflet by 1920 (OS

Gloucestershire XXXII SW and XL NW, 3rd edn). Surface 4 appears never to have existed in the Arlingham area further downstream than the vicinity of Passage Pill.

Alluvial unit 4 is well exposed for up to 2 m below the marsh on the river cliff at Arlingham Warth and just upstream from Passage Pill. It consists of dark grey clayey silts with many cattle footprints and numerous bands of mainly rippled-marked very fine sand, a brown tinge marking the lowermost beds. Coal grains abound throughout and the topmost few decimetres also yield fly ash particles. Geochemically, the exposed sequence is rich in heavy metals (see profiles 5 and 6 of figure 1*c*, and figure 22*d*, *e*) and even less compressed than the profile of unit 3 (see figure 22*c*). Only chemozones II and III of Allen & Rae (1986, 1987) are recognizable. These features, combined with the archival evidence noted above, assign unit 4 to the Awre Formation (Allen & Rae 1987), a deposit that began to form throughout the Severn Estuary from the second half of the last century.

A unit of estuarine silt of only local significance, but allied to unit 4, is exposed continuously along the river bank northeast of Arlingham Warth (SO 714 122 to 700 128), where the seabank protecting surface 2C had been moved back (see figures 4, 7). For example, at the site of geochemical profile 3 (see figures 1*c*, 22*f*), 0.61 m of dark grey silt with sand stripes sharply overlies brown silty clays exposed for up to 0.5 m below a slightly uneven top. The well-laminated lowermost brown silts rapidly grade up into structureless brown silts rich in root channels, interpreted as a buried soil. The brown silts (unit 2, see figure 1*d*) give low metal values and clearly belong to Allen & Rae's (1986, 1987) chemozone I. Metal values increase sharply across the top of the soil and upward increase even more, in a pattern typical of chemozones II and III. The map evidence is consistent with these data, suggesting that the site was re-exposed to the tide some time after 1878–79 (see figure 7). In its character and relationships, the local unit contained in profile 3 corresponds to sequence (*j*) of the morphostratigraphic model (see figure 3).

9. Surface 5 and its alluvium

Surface 5 caps the youngest unit of estuarine sediments to have accumulated at Arlingham (see figure 1*c*, *d*). It is wide enough to be depicted on the map only to the southeast of Arlingham Warth and along the southern reach of the channel (see figure 23, plate 4), but forms a narrow, broken fringe along much of the bank (see figure 24, plate 4), obscuring deposits initiated earlier. The inner part of surface 5 is approximately level and lies 0.4–0.8 m below the adjoining marsh, whereas the steep outer portion falls unevenly to the sand flats exposed at low tide.

Unit 5 is exposed to thicknesses of up to 2 m and consist of dark grey clayey to sandy silts with laminae and bands of ripple-marked and parallel-laminated very fine sand. Root traces are plentiful and wrinkle marks (Allen 1984) and infilled desiccation cracks locally abundant. Coal dust abounds at all levels and fly ash is also plentiful. Geochemical profile 2, from Arlingham Warth (see figures 1*c*, 22*g*), reveals somewhat erratic high to very high metal values throughout an unbottomed vertical sequence almost 2 m thick. Unit 5 is fully exposed near Longmarsh Pill, again revealing high metal values (see profile 8 in figures 1*c*, 22*h*). Spot samples from the unit upstream and downstream of Passage Pill (see figure 1*c*) also have metal contents similar in value to profiles 2 and 8, as well as fly ash and coal dust.

Geochemically, unit 5 conforms to Allen & Rae's (1987) Northwick Formation, an estuary-wide deposit representing chemozone III and uppermost part of chemozone II (Allen & Rae 1986, 1987), initiated in the second quarter of the present century. The metal maximum lies close to the erosional base in profile 8 and within the lower half of the incomplete profile 2 (see figure 22*g*, *h*). By 1946 unit 5 had already begun to accumulate at Arlingham (RAF 1946), and the limited map evidence (OS Gloucestershire XXXII SW and XL NW, 3rd edn) clearly puts the start largely after 1920.

10. Discussion

It is clear from the above that the complicated recent sedimentary history of an aggressively reclaimed and intensively cultivated wetland area like the Arlingham alluvium can be understood only when archival evidence is used to guide, and combined with the results from, conventional field surveys. Little of the sea defences constructed over a long period at Arlingham survive today as actual banks or even as ramps after being grubbed out and graded. Many natural features, especially the clifflets between successive phases of salt marsh, have disappeared either through ploughing or during the construction of new defences. The material evidence of early agricultural practices is similarly being rapidly destroyed.

The continuing upward trend of relative sea level in southwest Britain during the later Flandrian (Allen & Rae 1988) seems to be forcing the Severn Estuary, as a complex of sedimentary environments, bodily northeastward up the Severn Vale. Perhaps the most telling evidence for this erosive marine transgression (Allen & Fulford 1988) is (i) the widespread transposition of Romano-British occupation debris from former wetland settlements into the modern intertidal zone of the estuary, and (ii) the extensive intertidal exposure, from Cardiff and Weston-super-Mare upstream almost to Gloucester, of rooted reed-woodland peats of broadly mid Flandrian age. Today, furthermore, intertidal sand flats range from the lower to the upper estuary, extending much further upstream than Arlingham. In the lower estuary, for example, the modern sand flats erosively off-lap the broadly mid Flandrian peats and associated grey–green estuarine silts. Unit 2 at Arlingham, substantially post-dating the local peats and probably spanning the Medieval Period, seems to record the start, after erosion, of this substantial influx of sand into the upper estuary. The beds are altitudinally equivalent to unit 1, at Arlingham itself and exposed also on the opposite bank of the river (e.g. SO 697 093, 711 134) (Prevost *et al.* 1901).

A new note of caution is necessary with regard to the age of the extensive geomorphic surfaces representing early reclamation on the wetlands that border the Severn Estuary. Allen & Rae (1987) found that the earliest reclamations in the middle and upper estuary abounded in ridge-and-furrow, in contrast to the great majority in the lower estuary, with their plentiful near-surface evidence for Romano-British settlement (see also Allen & Fulford 1986). They accordingly distinguished the ridge-and-furrowed surface as the Oldbury Surface and attributed it to Medieval activity (see also Allen 1987*b*). The subsequent discovery on the wetland at Arlingham of a substantial spread of apparently Romano-British iron-making slag, together with a little pottery of the period, while not proving Romano-British reclamation and settlement there, undoubtedly introduces the possibility of a pre-Medieval date for surface 1. Whether continued archaeological prospection will provide conclusive evidence cannot be foretold, but the issue of age is important for two reasons. Firstly, the Oldbury Surface represents the earliest and by far the largest of the wetland reclamations in the middle and upper estuary. Secondly, the Oldbury Surface is a major datum in the elucidation of the rate of sea-level rise in the Severn Estuary, as estimated by determining the amount of marsh accretion after seabank construction (Allen & Rae 1988). At Arlingham, between 1.00 and 1.38 m of silt accreted on the marshes following the isolation of surface 1. Present estimates of the longer-term rate of rise would be more than halved should the Oldbury Surface prove to be of Romano-British origin.

Units 2, 3, 4 and 5 define on the inner bank of the great bend of the tidal Severn at Arlingham a pattern of episodic off-lap that superficially resembles the growth of a river point bar, as expressed in a sequence of meander scrolls. However, there are important differences of timescale and control between the two cases. Unit 2 is not yet well known but, while appearing erosively to encircle a core of unit 1, seems to have taken of the order of 10^3 years to form; it is present outside the Arlingham bend but may be restricted to localities in the upper estuary. Units 3, 4 and 5 may be confidently attributed on the basis of archival and geochemical evidence to Allen & Rae's (1987) Rumney, Awre and Northwick Formations, representing estuary-wide erosion-accretion events on a timescale of the order of 100 years. In contrast, the meander scrolls that decorate river point bars have a much smaller timescale, as dendrochronological studies show (see, for example, Hickin & Nanson 1975), and record events restricted to the channel sector in which they grew (Sundborg 1956).

The complicating factors at Arlingham are both human and natural. Piecemeal reclamation after the creation of surface 1, combined with the destruction of much of the evidence for that later activity, has created an external surface of complex morphology that is difficult to interpret on the basis of the evidence remaining on the ground. Reclaimed land was lost at Arlingham Warth as a consequence of erosion attending the growth of the Pimlico Sand as a mid-channel bar complex. A locally important stratigraphical consequence was the resumption of tidal siltation on a marsh surface that had been reclaimed some time earlier, a type of event recorded from at least three other places in the estuary (Allen 1987*a*, *b*, 1988*a*). Other reclamations at Arlingham may have been similarly affected, for example, the area abandoned by 1802 southwest of Passage Pill . Although surface 2A represents an early reclamation, its great elevation above surface 1 points to some further tidal siltation, perhaps because the outer seabank was either never sufficiently tall to prevent all flooding or periodically fell into neglect.

11. Conclusions

(i) The post-glacial alluvium enclosed within the great bend of the Severn at Arlingham consists of at least five, off-lapping morphostratigraphic units which have evolved together under the influence of human forces as well as natural processes. Unit 1 (Wentlooge Formation), the innermost and volumetrically the largest, is mud-dominated and includes peats. Unit 2 appears to post-date the peats erosively and sees the start of a substantial influx of sand into the upper estuary where Arlingham lies. Its accumulation probably spans the Medieval Period. The succeeding units, each erosively related to its predecessor, are the local representatives of younger bodies of estuarine silt of estuary-wide distribution (Rumney, Awre and Northwick Formations).

(ii) Unquestionably by the Medieval Period, but possibly in Romano-British times, a major reclamation (surface 1) had been made involving almost all of the marsh on which unit 1 had up to then been accumulating. The subsequent piecemeal reclamation of the remainder, against the background of an upward trend of relative sea level, has created in many parts of the area a complex flight of geomorphic surfaces which increase in elevation above surface 1 as they become younger. Between 1.00 and 1.38 m of estuarine silt has accumulated on the marsh since surface 1 was formed, implying a similar upward movement of relative sea level.

(iii) Local changes in the configuration of the tidal sand banks and channels have forced the repositioning of sections of the sea defences and, in at least one case, to the demonstrable loss of reclaimed land. At Arlingham Warth, the stratigraphic record of such an event is a sequence of estuarine silts that thickly overlies a buried soil.

I am indebted to the officers of the Severn-Trent Water Authority for their interest over the years and for permission to publish the Authority's subsurface data, to the landowners and farmers of Arlingham for allowing me access to their land, and to Franz Street and Graham Patterson (University of Reading) for the analyses of the sediments and slags. The presence of Romano-British industrial waste at Arlingham was brought to my attention by Dr T. R. Astin and his students, whom I warmly thank. The work was partly supported by a Research Grant from the Natural Environment Research Council, which is gratefully acknowledged. This paper is Reading University PRIS Contribution no. 032.

Appendix A. List of archival, photographic and map sources

British Geological Survey (formerly Institute of Geological Sciences)

BGS 234, Geological map of Gloucester (1972)

Ordnance Survey (maps on 1:10560 scale)

Gloucestershire XXXII SW, 1st edn (1878–79), 2nd edn (1901), 3rd edn (1920)
Gloucestershire XL NW, 1st edn (1879), 2nd edn (1901), 3rd edn (1920)

Ordnance Survey (maps on 1:10000 scale)

SO 60 NE (1978), SO 61 SE (1978), SO 70 NW (1981), SO 71 SW (1979)

Ordnance Survey (air photography)

OS 1969, prints 160 003, 160 004, 160 005, 160 007, 160 009, 160 015 from sortie of June 1969, at approximately 1:20000 scale

Royal Air Force (air photography)

RAF 1946, prints 3032, 3034, 3036, 3038, 3040, 3142, 3144, and 4032, 4034, 4036, 4038 and 4040 from sortie of 30 December 1946, at approximately 1:10000 scale

Gloucestershire Record Office

GRO D2998/1, A map of the Mannor of Arlingham in the County of Gloucester; surveyor: J. Walton (1725)

GRO Q/RI7, Map accompanying inclosure award (1802)

GRO D272/9/3, Map of the Lower Level of the County of Gloucester (taken by order of the Commissioners of Sewers; part of the Upper Division)

GRO D18/413, Arlingham shores showing situations of breakwaters immediately required; surveyor: J. Sayer (*ca* . 1857–58)

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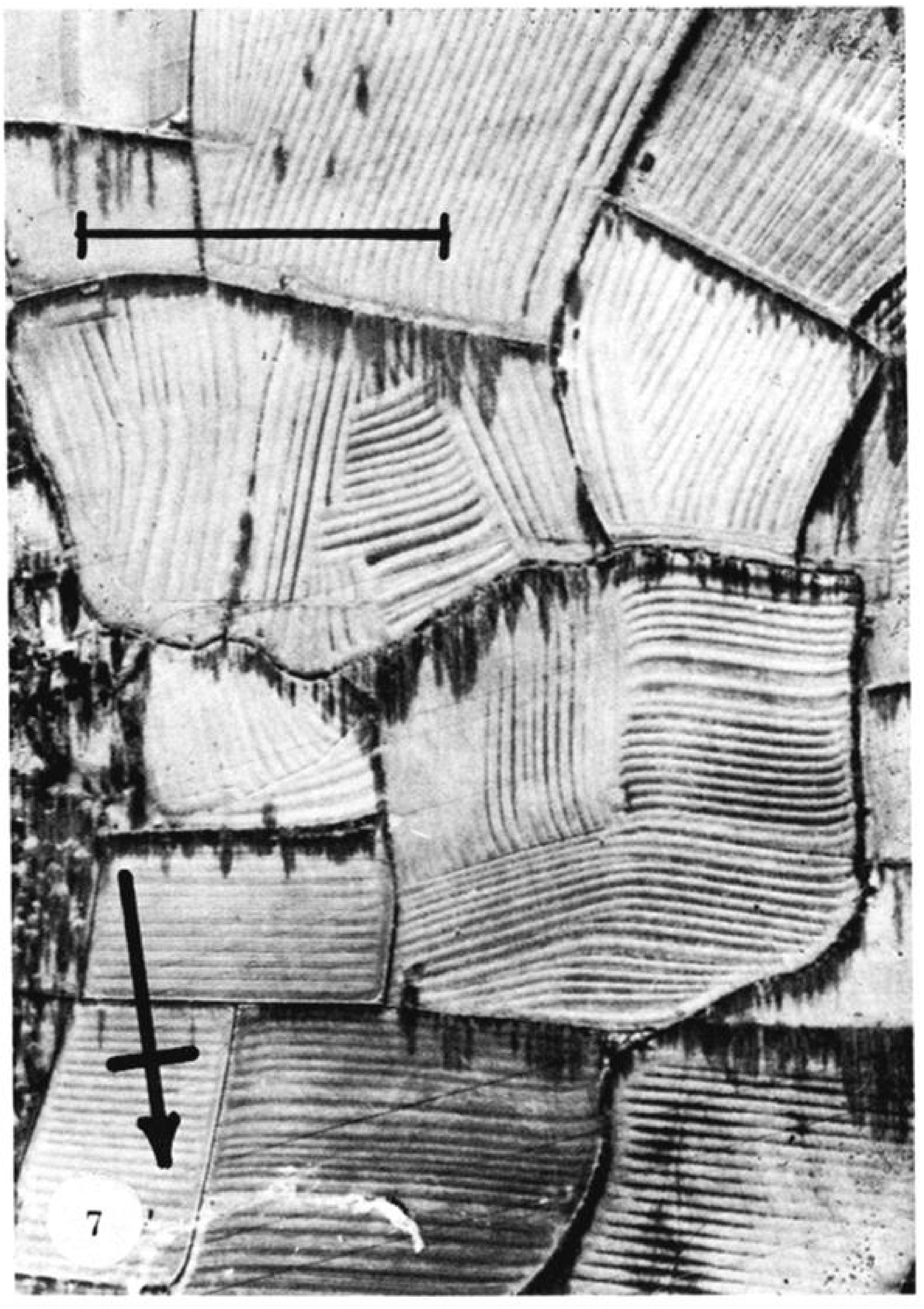
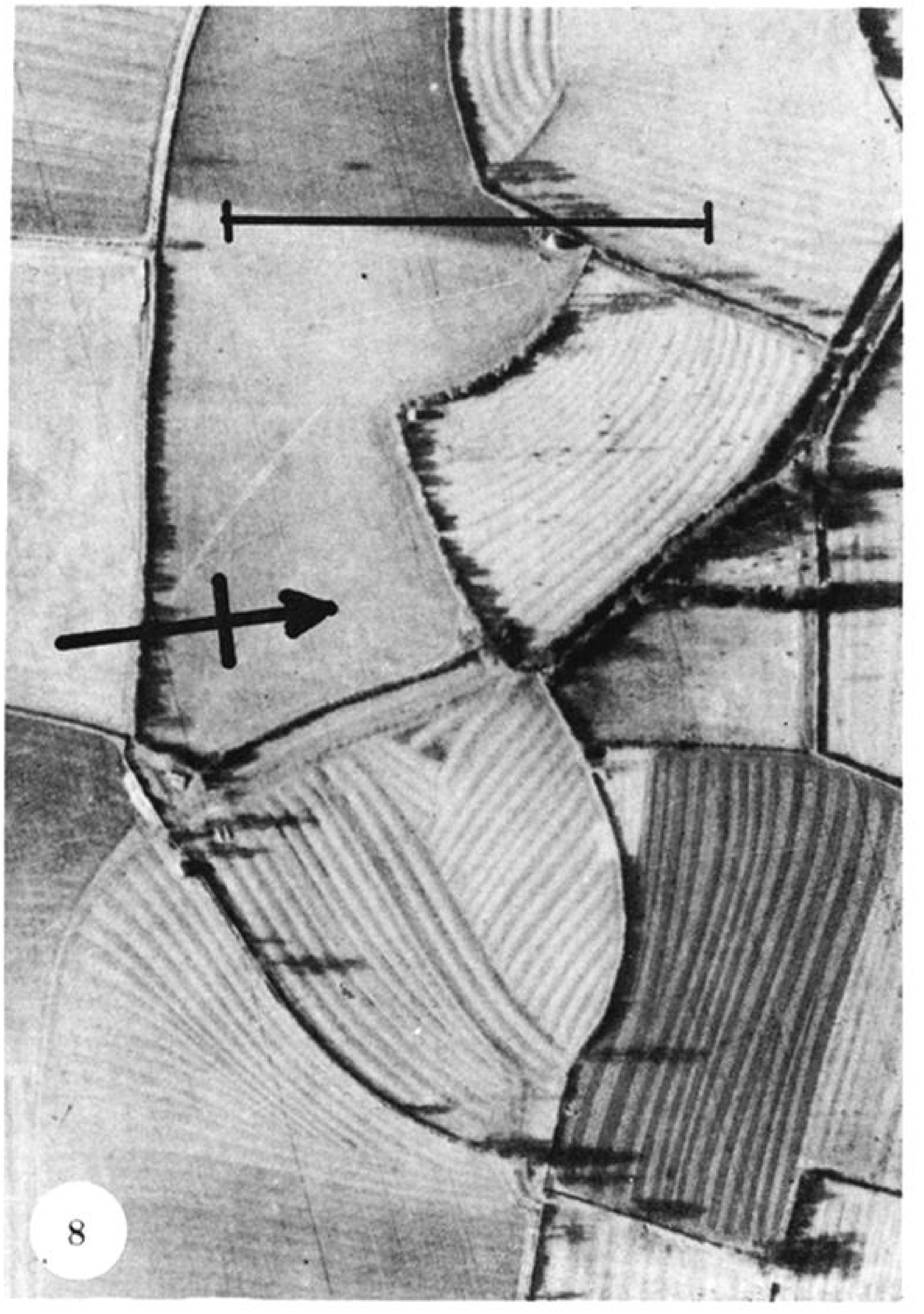
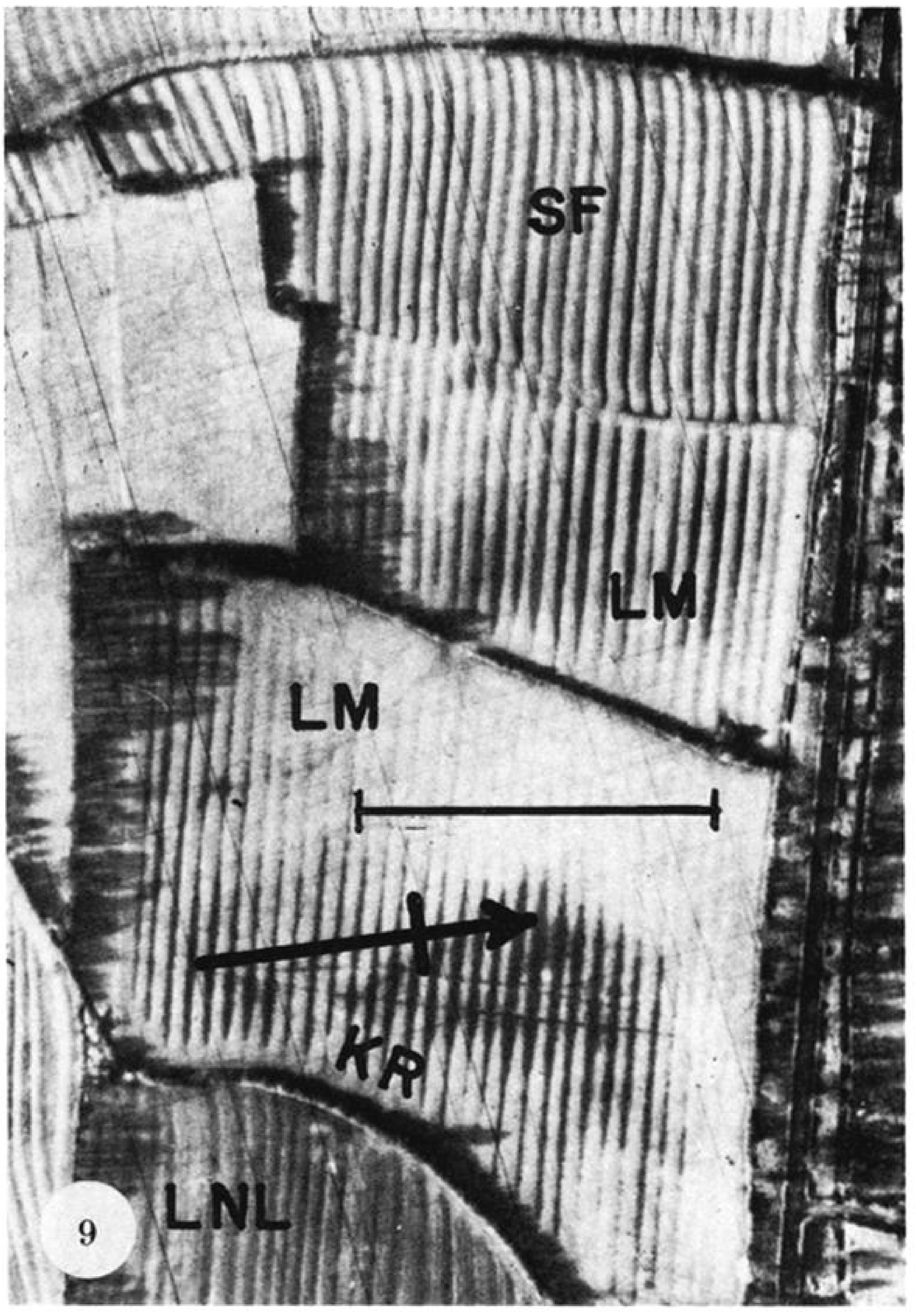
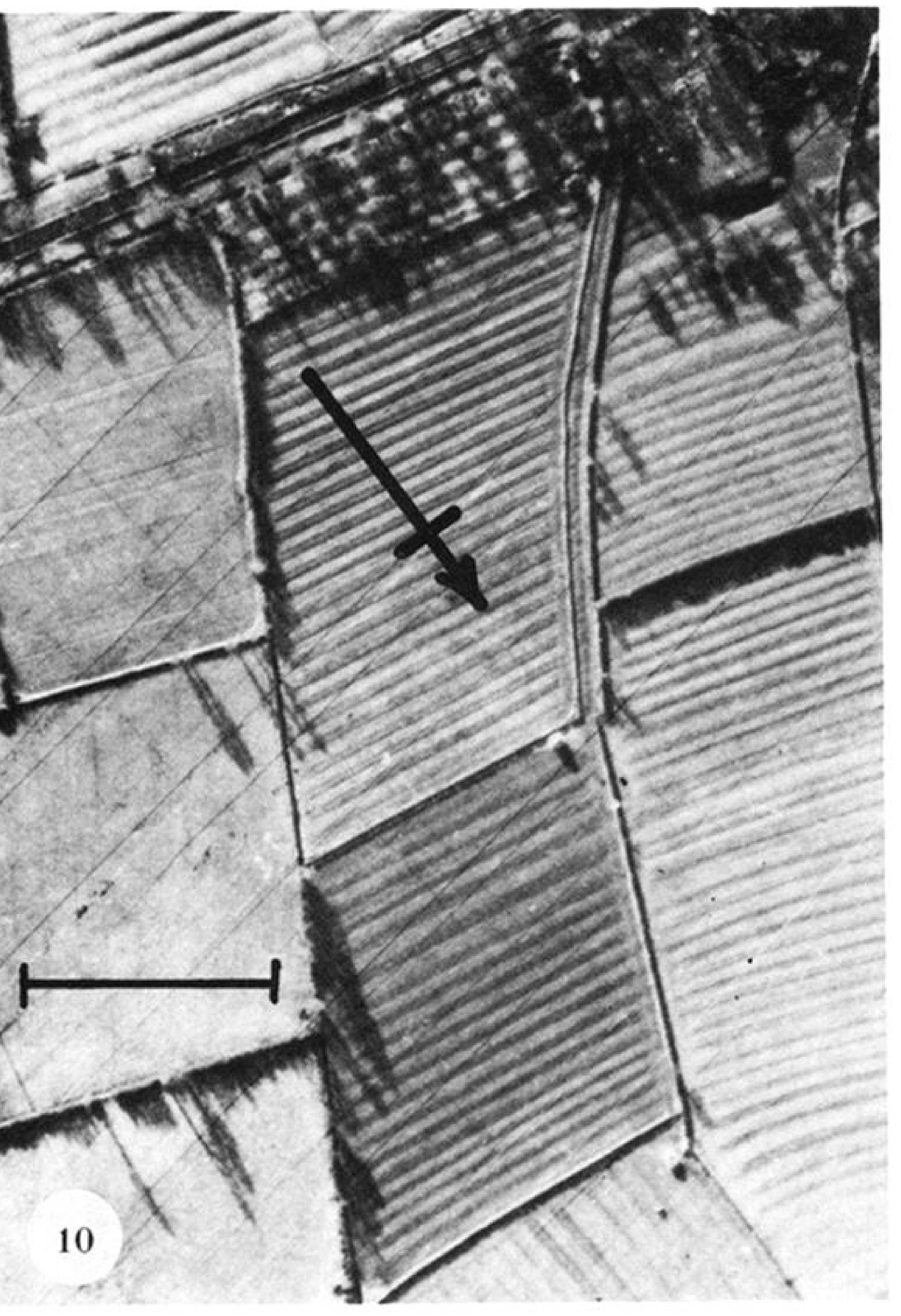
FIGURE 2. Air photograph (June 1969) of the Arlingham peninsula and river bend showing general features of sea defences and field patterns. Scale bar represents 500 m. Note that the light in the photograph is from the bottom and not from the conventional top. (Ordnance Survey photograph: Crown copyright reserved.)

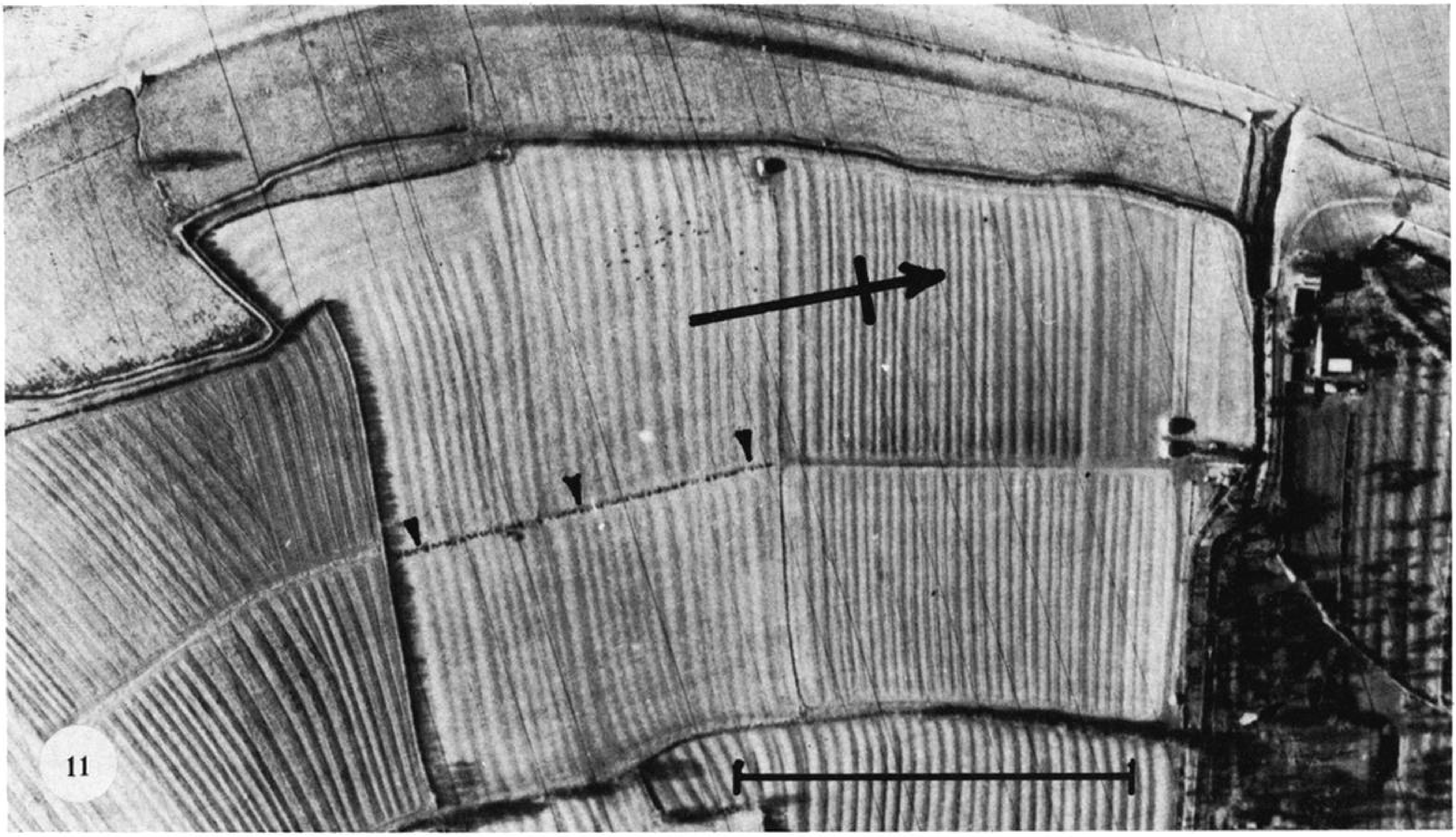


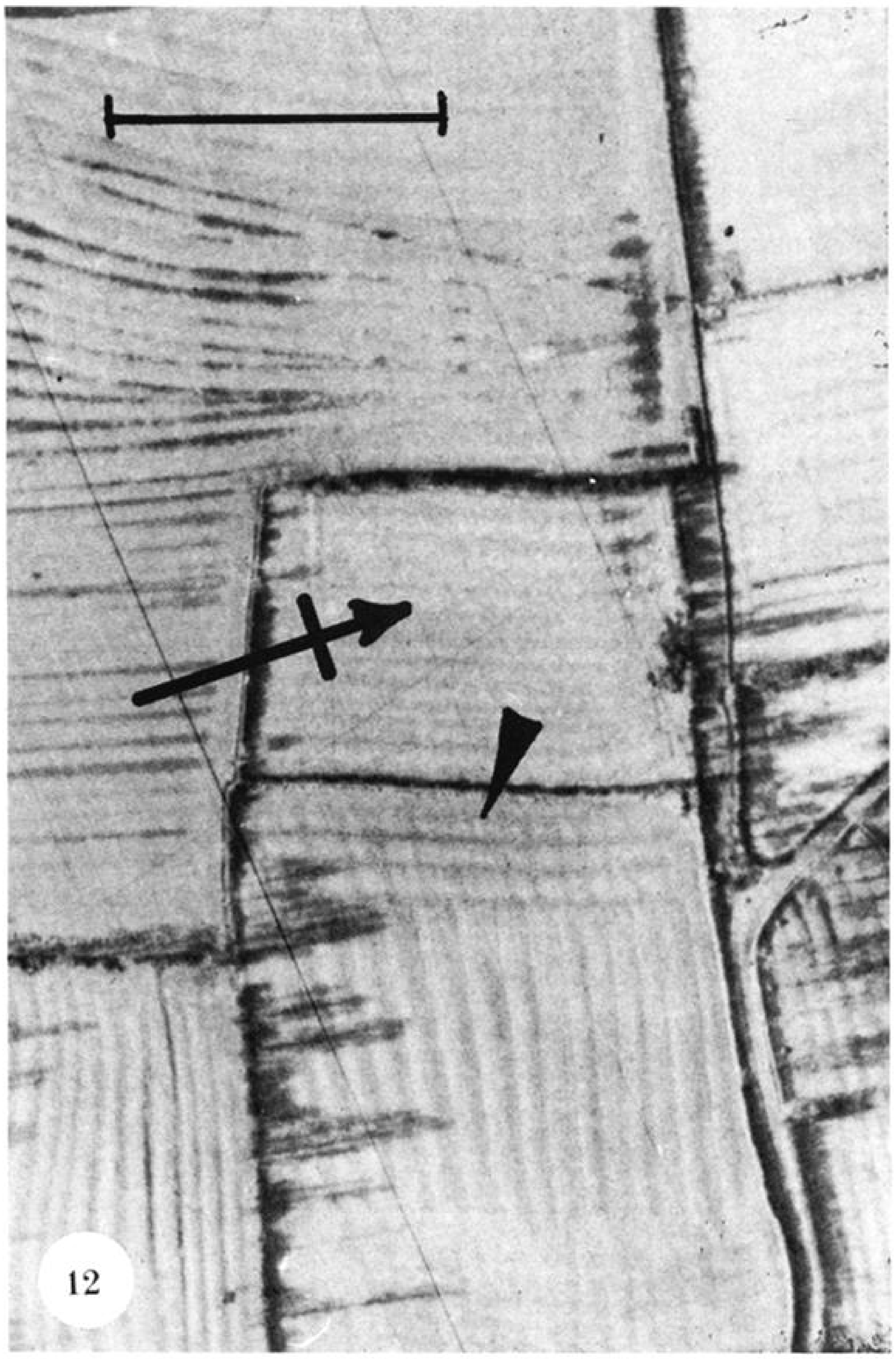


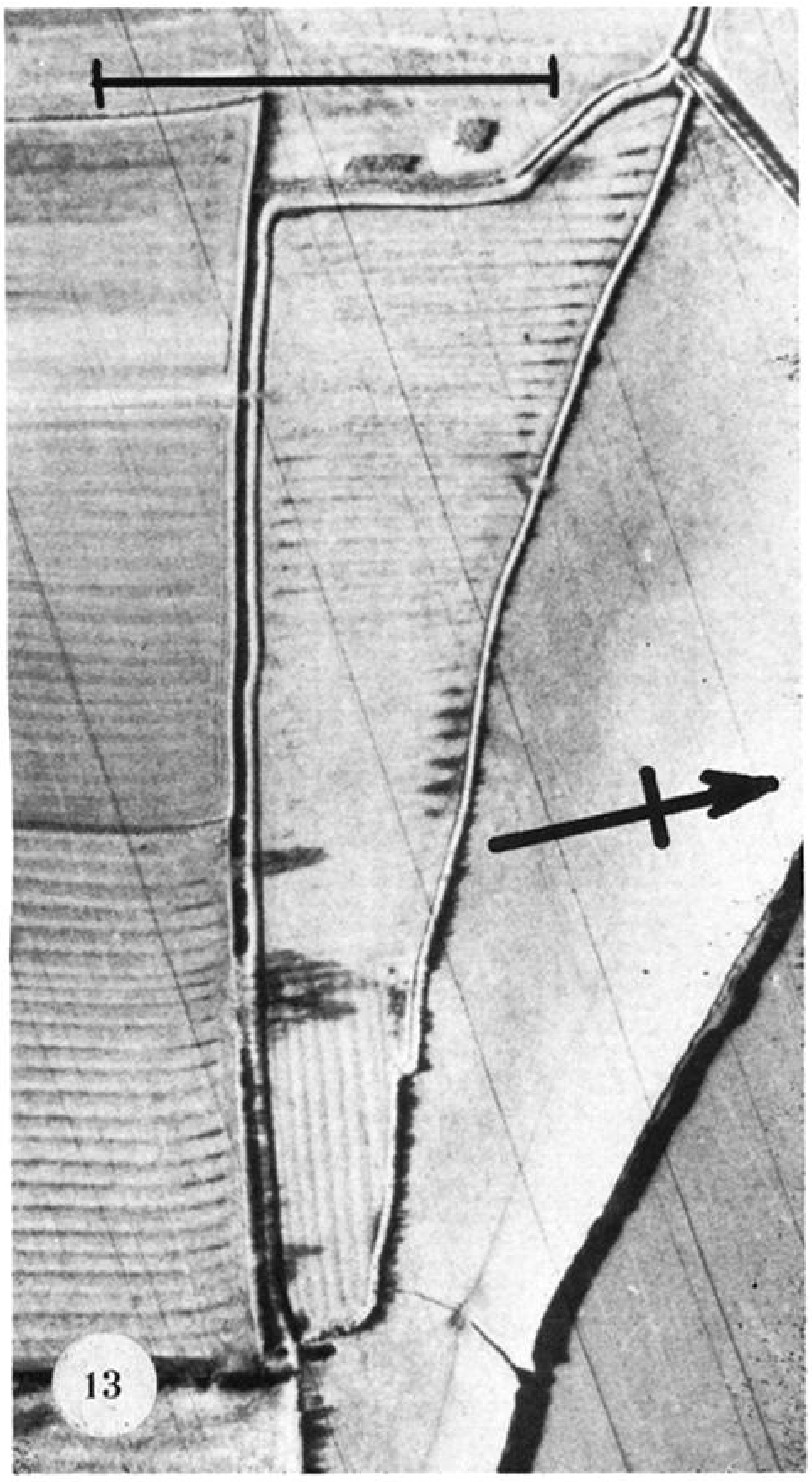




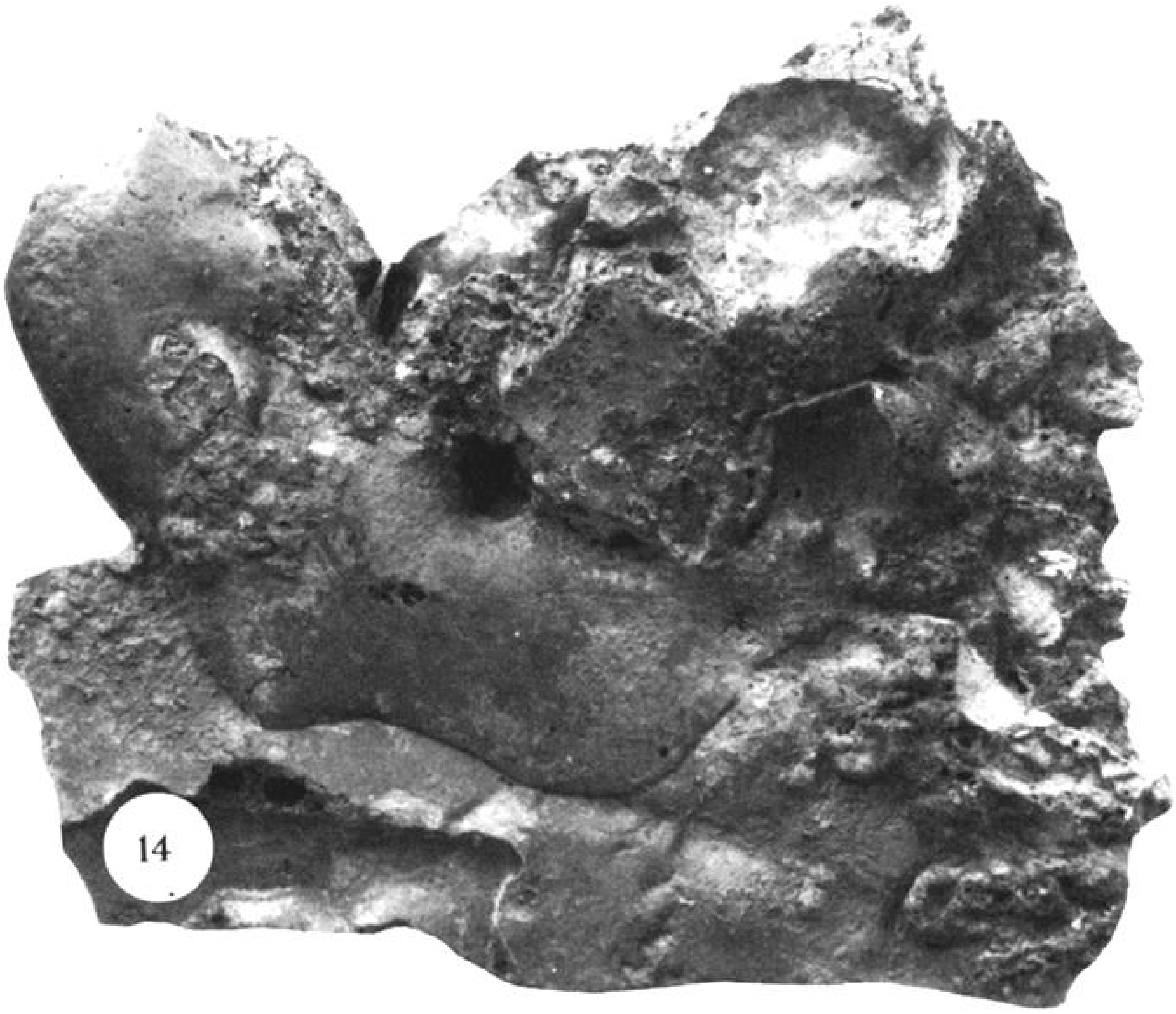
FIGURES 7–10. For description see p. 316.







FIGURES 11–13. For description see p. 316.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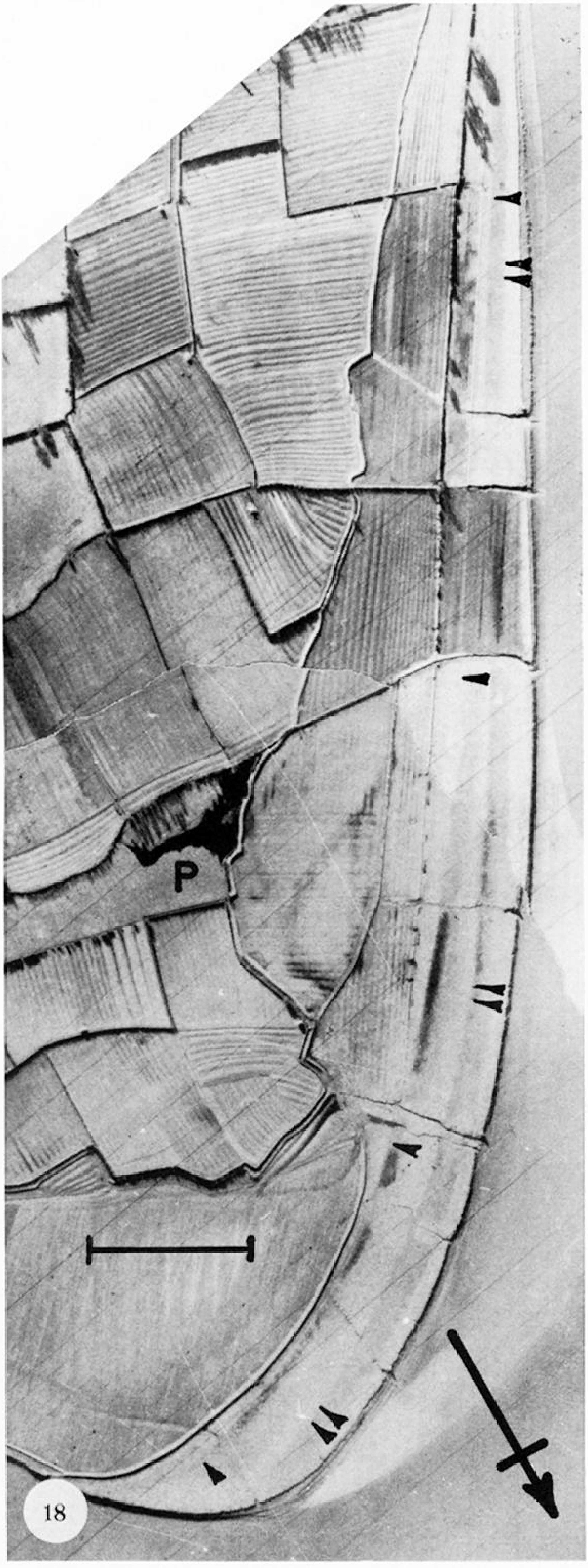
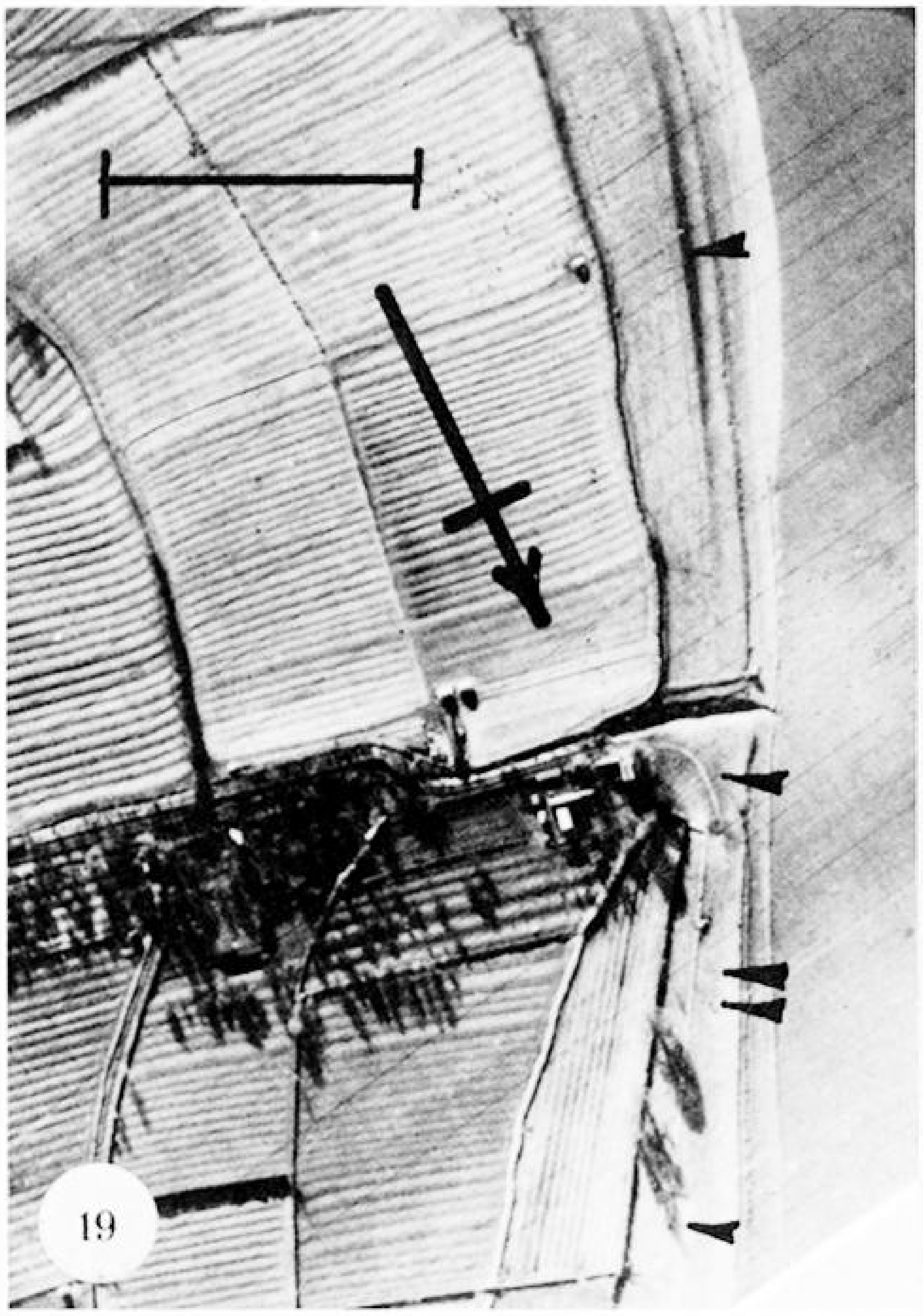
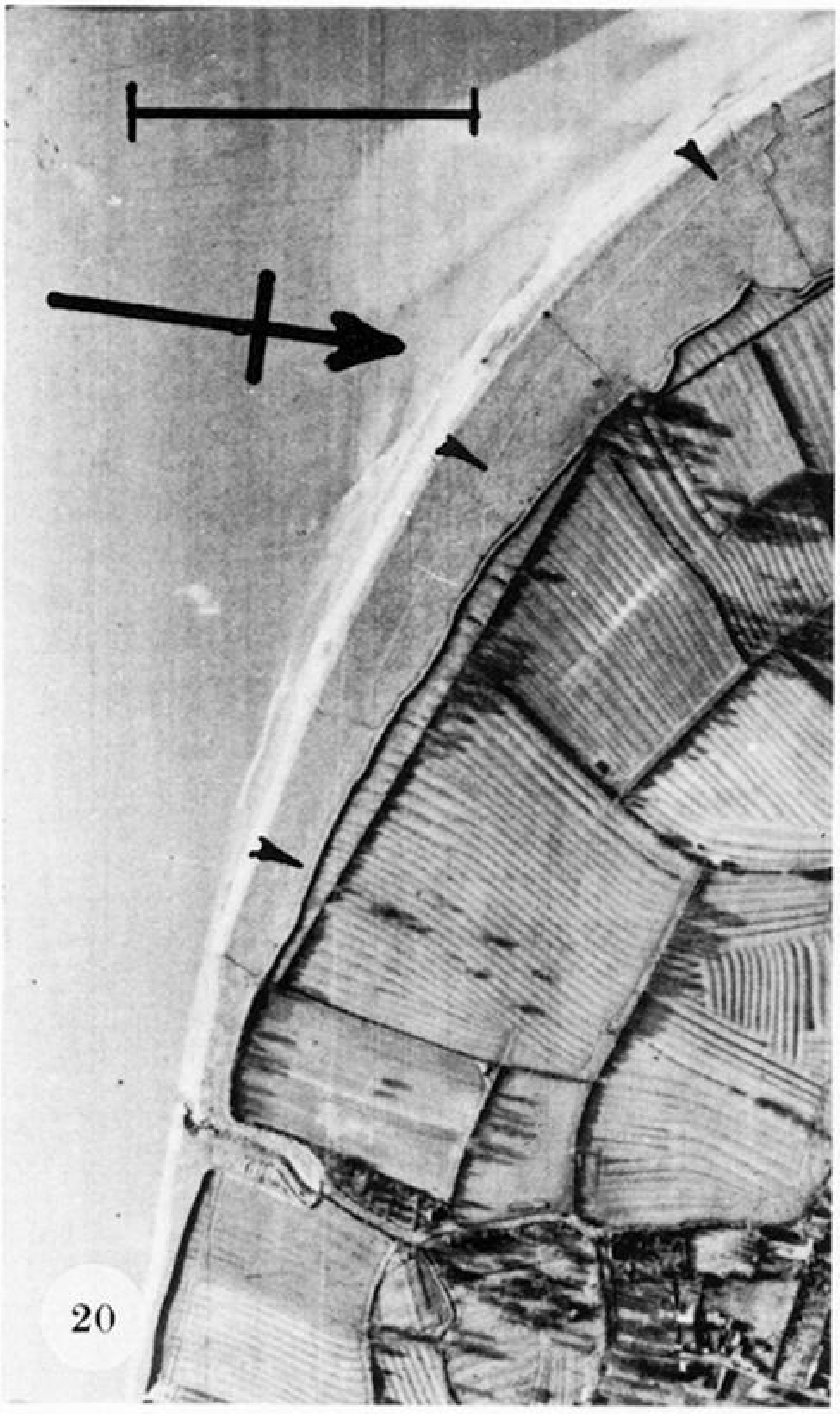
24

FIGURES 14–16, 23, 24. For description see opposite.







FIGURES 18–20. For description see opposite.