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LATE FLANDRIAN SHORELINE OSCILLATIONS IN THE SEVERN ESTUARY: THE RUMNEY FORMATION AT ITS TYPESITE (CARDIFF AREA)

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[Plates 1–11]

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The shore of the former tidal wetland northeast of Cardiff, called the Wentlooge Level and reclaimed during the Roman period, exposes a series of late Flandrian lithostratigraphic units dominated by estuarine clays. Chief among these are the (upper) Wentlooge Formation (up to 2.5 m thick) and the Rumney Formation (up to 2.7 m thick).

The (upper) Wentlooge Formation consists of greenish grey slightly silty clays and is capped by an immature palaeosol yielding signs of clay illuviation. Extending down from a level within the palaeosol is a reticulate system of deep drainage ditches, some of which are locally filled with Romano-British cultural debris, regarded as dating their excavation. Such fills are sealed by the soil. Marine erosion after the Roman period but before late mediaeval times destroyed much of the upper Wentlooge Formation together with a presumed Roman sea defence. The then unprotected drainage ditches were invaded during this episode of coastal retreat and widened out to form a series of large embayments that defined flat-topped headlands on which the palaeosol formed a capping.

The overlying Rumney Formation is a series of pink estuarine silty clays with some sands and gravels. It infills the embayments of the coastline cut in the Wentlooge beds and smothers its headlands to a thickness of about 1.4 m. Deposition in the embayments began in the 15th century, but on the headlands was delayed for a further 100–200 years. The outward movement of the shore recorded by the mudflat and marsh deposits of the earlier part of the Rumney Formation was eventually reversed with the formation of a bold mud cliff that has continued to retreat inland to its present position. On the upper part of this cliff are exposed sand sheets which record sand bodies formed during the retreat, at the heads of inlets, as pocket beaches, and as landward-facing bars cast up on to the salt marsh during high tides and storms.

Two younger lithostratigraphic units of recent date, the Awre Formation and the Northwick Formation, have stratigraphical relations similar to the Rumney Formation and record further movements of the strand.

The coastal oscillations recorded by the lithostratigraphy are attributable to fluctuations in the role and strength of waves at the shore, as governed by either medium-term weather changes or the positions of offshore shoals, or by the morphology of the shore itself.

1. Introduction

This paper aims to show that the muddy shoreline of the Severn Estuary in the area immediately northeast of Cardiff in South Wales has proved remarkably unstable over the last two thousand years, at a time when sea level seems to have changed but little. The evidence for instability centres on the Rumney Formation, a newly recognized and largely post-mediaeval body of estuarine muds and some gravelly sands, and on the relationships of this lithostratigraphic unit to the Wentlooge Formation which preceded it. Anthropogenic influences dating at least from the Roman period have complicated the evolution of the coastline under the impact of natural forces.

The post-glacial (Flandrian) sea, rising at first rapidly and then more gradually (Hawkins 1971; Devoy 1979; Heyworth & Kidson 1982; Shennan 1983), drowned in the area of the Bristol Channel and Severn Estuary a bold and intricately dissected bedrock landscape (Hawkins 1971; Kidson & Heyworth 1973, 1976). As the rise slowed, the deposition of estuarine muds and, at times, peats began first at the heads of embayments and then along the straighter and more exposed shores. Simultaneously, the valleys of rivers entering the area became drowned (see, for example, Anderson & Blundell 1965; Williams 1968). The most widespread peats, of fresh water origin, are those of mid Sub-boreal to early Subatlantic date (Godwin 1943; Beckinsale & Richardson 1964; Seddon 1964; Hawkins 1971; Locke 1971; Murray & Hawkins 1976; Allen & Fulford 1986), and point to an important regression over this interval. Inshore, the subsequent deposits are again chiefly estuarine muds.

In this way deposition created tidal wetlands to the extent of several hundred square kilometres along the margins of the Bristol Channel and Severn Estuary. Most of this wetland has since been reclaimed, beginning in the Roman period, to yield the Severn Levels (for example, North Somerset Level, Wentlooge Level, much of the Caldicot Level), criss-crossed by artificial drainage ditches known as reens or rhines. Outside the sea defences, tidal siltation continues on still-extensive saltings, called warths or wharves, and on the adjoining mudflats. From time to time, however, the tide won back some of its lost lands.

2. Geomorphic and stratigraphic summary

The Severn Estuary ranges upstream as far as the neighbourhood of Gloucester roughly from a line drawn between Lavernock Point (Cardiff area) on the Welsh bank and Sand Point (Weston-Super-Mare) on the English shore (see figure 1 inset). Allen (1985) recognized that a distinctive series of late Flandrian geomorphic features and linked lithostratigraphic units could be traced through most of the levels and saltings of this area. These elements are here briefly described, preparatory to a discussion of their character in the Cardiff area (see figure 2).

The Wentlooge Formation, named from the Wentlooge Level northeast of Cardiff (British National Grid Reference ST 22 78 to ST 30 83), is a series of greenish grey estuarine silty clays with gravels, sands and peats locally at the base and a more widespread peat (or peats) toward the top. Deposition began in the early Flandrian, and was essentially completed during the early Roman period, when the Wentlooge Level was first embanked (Allen & Fulford 1986), and the Wentlooge Surface created. The Wentlooge Formation, 5–15 m thick within the wetland area, dominates the lithostratigraphy of the Severn Levels.

The Rumney Formation is named for coastal exposures at Rumney Great Wharf (see figure 1) to the northeast of Cardiff (ST 23 77, 24 78). It too is widespread throughout the estuary, consisting of pink grading up into grey estuarine silty to sandy clays that locally include thin gravels and sands. The Rumney Formation reaches a known maximum thickness of 10–12 m and is seen to overlie the Wentlooge Formation erosively. Its deposition in the upper and middle estuary was partly interrupted by an extensive, probably early to high mediaeval, reclamation (Allen 1986), as the result of which the Oldbury Surface, named for Oldbury-upon-Severn (ST 61 92), came into being. Deposition in the Cardiff area, however, was delayed until the late 15th century (Allen & Fulford 1986). The Rumney Formation continued to accumulate on such saltings as were not enclosed during the mediaeval reclamation, where it underlies the Rumney Surface, the highest of the three modern saltmarsh terraces noticed by Hawkins (1979).

The upstream settlement of Awre (SO 70 08) identifies the Awre Formation and the Awre Surface, a combination of features represented in many parts of the estuary. The Awre Formation ranges to more than 2 m in thickness and consists of mainly grey estuarine silty clays banked against a cliff and sloping wave-cut platform out into the Wentlooge or Rumney formations, or both. Above comes the Awre Surface, the middle saltmarsh terrace. The Awre Formation cannot yet be firmly dated, but the fact that it is banked against the masonry

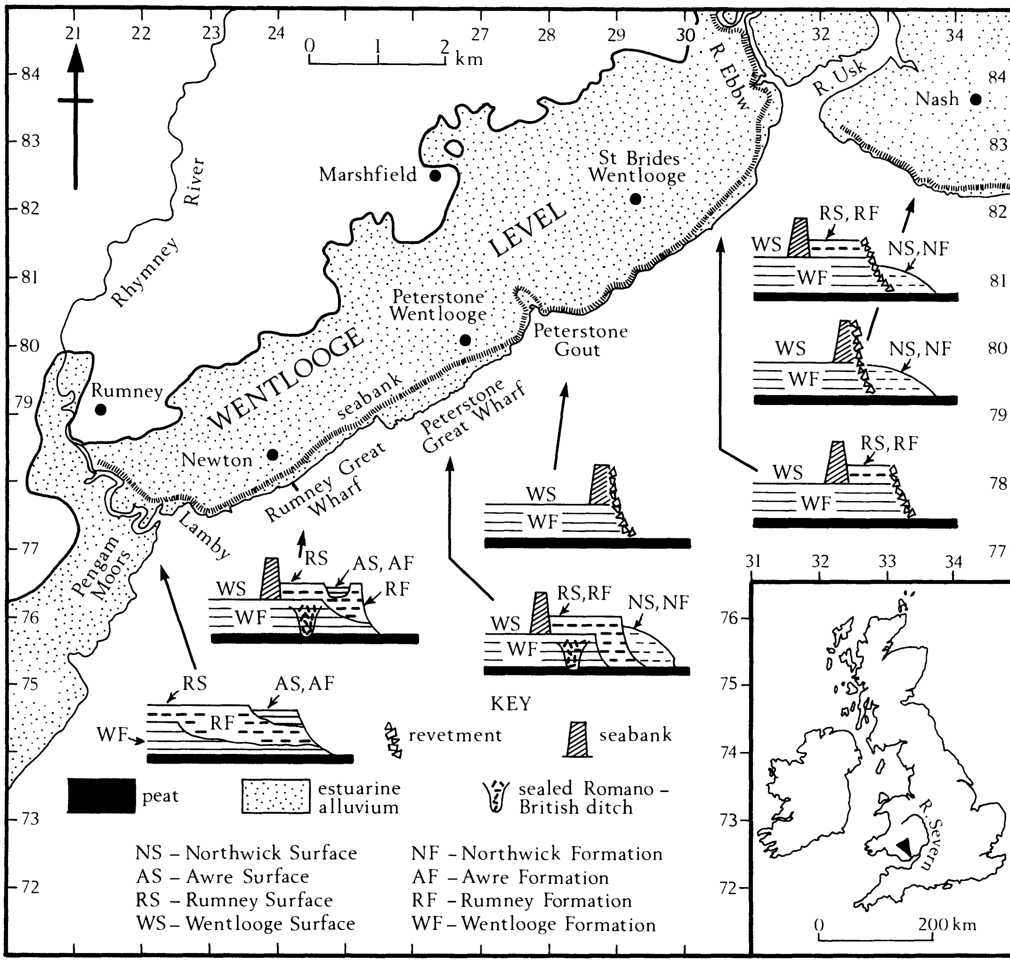


FIGURE 1. The Wentlooge Level in southeast Wales, and a summary of the late Flandrian stratigraphy visible in the coastal area.

revetment of the Gloucester and Sharpness Canal (completed 1827) means that the deposit post-dates the early 19th century.

The Northwick Formation and Northwick Surface are named for Northwick Warth (ST 54 86 to 56 89), a broad salting near the Severn Road Bridge. Up to 1.5 m of grey estuarine silty to sandy clays are present, banked upon a cliff and gently sloping wave-cut platform cut into one or more of the older formations. The overlying Northwick Surface is the lowest of the modern saltmarsh terraces. To judge from historical coastal changes, and the presence of abundant coal dust and fly-ash, the formation accumulated over the last 50 or so years.

Figure 1 summarizes the character of the coast and the distribution of these formations along the Wentlooge Level. East of the River Usk, and in the northeast part of the level, the Awre Formation is poorly represented. The Rumney or Wentlooge formations, or both, are concealed at the coast beneath a tall rubble revetment dating from the late 18th and early 19th centuries. Locally, the Northwick Formation is banked against this revetment and upon the Wentlooge peat. Relationships are more complex over the southwestern part of the level. Here the Northwick Formation accumulated extensively against a cliff cut in the Rumney Formation,

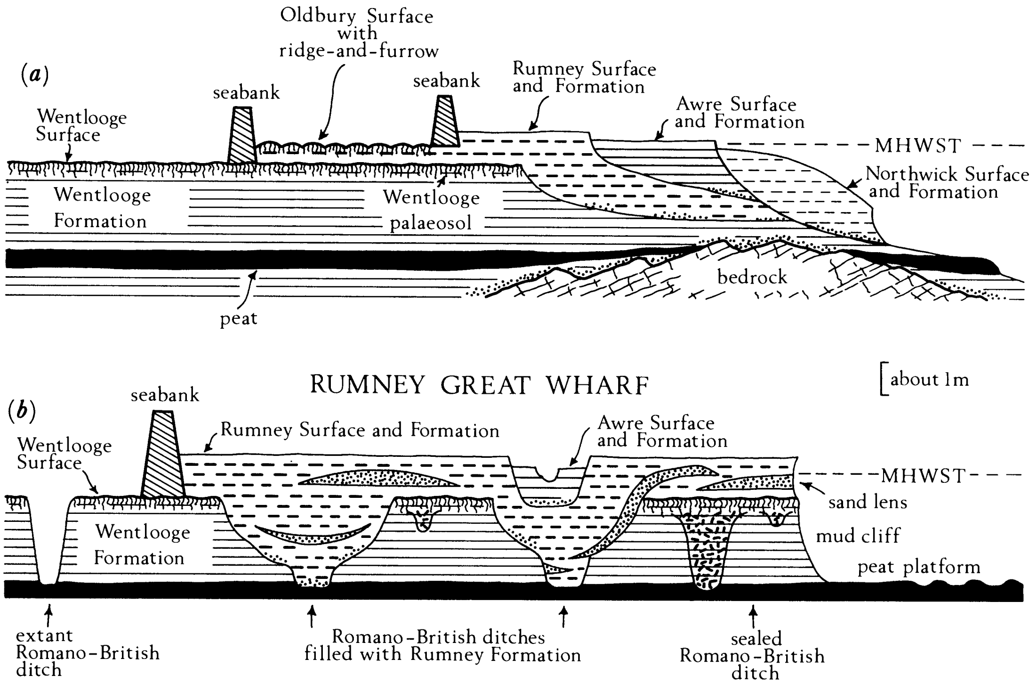


FIGURE 2. Late Flandrian lithostratigraphy and geomorphology of the Severn Levels. MHWST, mean high water of spring tides. (*a*) Schematic summary of geomorphic surfaces, lithostratigraphic units, and relationships in the Severn Estuary generally. (*b*) Summary of lithostratigraphy, Rumney Great Wharf (Wentlooge Level).

which in turn lies against and drapes over a cliff eroded into the Wentlooge Formation. The Awre Formation is ill-exposed and restricted to the mouth of the Rhymney River and to a few of the creeks and gullies that dissect the Rumney Surface. A major feature of the southwestern portion of the level is the presence of Romano-British drainage ditches cut into the Wentlooge Formation. As sketched in figure 2*b*, whereas most of these appear to have remained as open drains into Rumney Formation times, a few had become sealed within the Roman or sub-Roman period by a soil, the Wentlooge palaeosol (Allen & Fulford 1986).

3. Wentlooge Formation

(*a*) *General character*

The Wentlooge Formation underlies the entire Wentlooge Level. Between the Rhymney River and Peterstone Gout (see figure 3), the upper beds can be seen in the many reens that criss-cross the level, and all except the basal measures are well exposed on the broad foreshore off Peterstone Great Wharf and Rumney Great Wharf, and on the deeply embayed mud cliff 2–3 m high at Rumney Great Wharf. Anderson & Blundell's (1965) shallow borings, and another series commissioned by Cardiff City Council, show that the formation near Rumney rests on a dissected bedrock surface, perhaps created by late Pleistocene marine planation (Hawkins 1968), that slopes gently seaward (see figure 4). The marine Silurian and Old Red Sandstone rocks of the Rumney inlier extend beneath the Level as a broken ridge. Sandy gravels and gravelly sands, and at one site a peat, occur at the base of the Wentlooge Formation on the southwestern side of this feature (see also Anderson 1968). These gravels are similar in elevation to Pleistocene beach gravels associated with the Wentlooge Formation at Llanwern in the Caldicot Level (Andrews *et al.* 1984), but whether these occurrences should be correlated is unclear. The base of the Wentlooge Formation is locally sandy on the crest of the Old Red Sandstone ridge. Just within the sea defence at Rumney Great Wharf, and along the Rhymney River (see figure 3), the Wentlooge Level (that is, Wentlooge Surface) has an elevation of about 7 m O.D., falling gradually inland to 4–5 m O.D. Hence the Wentlooge Formation is about 5 m thick near the inner margin of the level but 15 m or more in thickness at the coast.

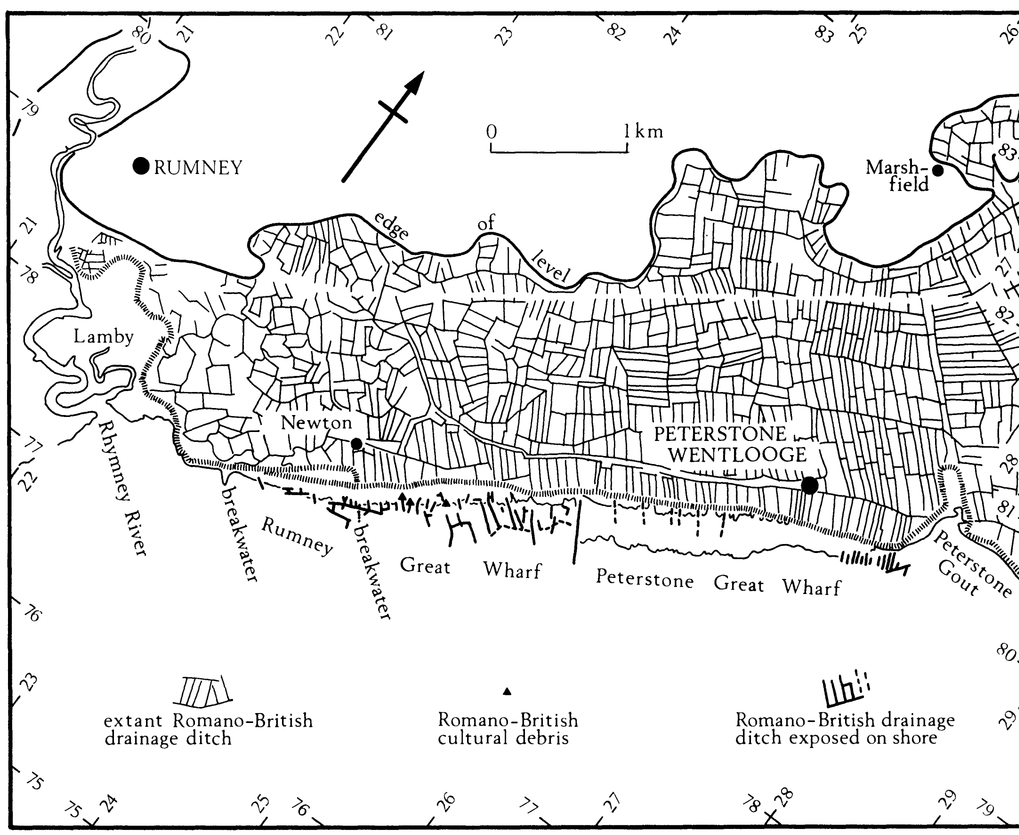


FIGURE 3. The Wentlooge Level, to show the geomorphology, the system of Romano-British drainage ditches (extant and abandoned on the shore) and the known sites of Romano-British cultural debris.

(*b*) *Upper Wentlooge Formation*

Only the upper part of the Wentlooge Formation is of further interest. Figure 5 shows the distribution on the mud cliff at Rumney Great Wharf of the Wentlooge Formation above the upper peat (see figure 2*b*). The peat itself, in which broad-leaved trees (especially birch) succeed reeds, becomes thin and patchy towards the Rhymney River (see figure 3). Above lie up to about 2.5 m of greenish grey slightly silty clays which include at the top a palaeosol reaching 0.8 m in thickness overlain erosively by the Rumney Formation. The silty clays are unlaminated and poorly stratified, bedding surfaces appearing only here and there.

The chief components of the silty clays, as shown by thin sections, dispersions sedimented on to microscope slides, and X-ray diffraction analysis, are quartz, feldspars, calcite, siderite, dolomite, illite, mixed-layer clays, kaolinite and chlorite. Calcite occurs chiefly as shell fragments and as a product of shell disaggregation. Siderite forms rounded to irregular, millimetre-scale concretions dispersed within the sediment, as well as tube-like concretions formed around the margins of root channels and invertebrate burrows. Dolomite (includes calcian dolomite) occurs as perfect small rhombohedra. Tiny sherd-like grains of coal, fragments of charcoal, and dull-looking and commonly frayed particles of peat, occur in trace amounts.

The chief organic constituents are broken siliceous sponge spicules (styles, tyolstyles, acanthostyles, oxeas) representing marine forms (Bowerbank 1864, 1866, 1882; Bergquist 1978), as Sollas (1883) earlier noted, and occasional marine diatoms (*Melosira westii*; fragments ornamented like *Roperia* and especially *Coscinodiscus* and *Triceratium*) (Hendey 1964). In addition, there are occasional calcareous foraminifera and numerous shreds of pale yellow plant tissue.

(*c*) *Wentlooge palaeosol*

The Wentlooge Formation, where thickest on the mud cliff, is completed by an immature two-horizon palaeosol up to 0.8 m thick (see figure 5, and (1) of plate 1). Scattered Romano-British occupation debris (pottery sherds, worked stone, fire-coloured pebbles, bones

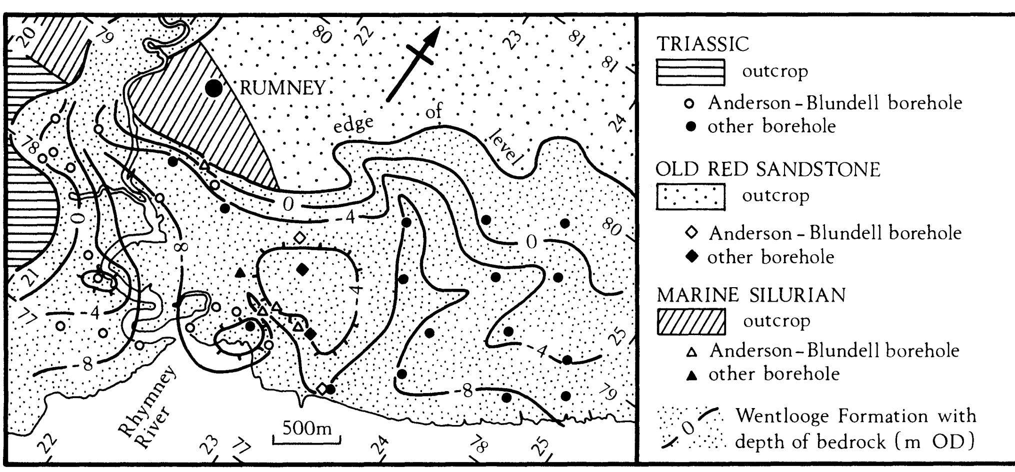


FIGURE 4. Morphology and geology of the bedrock surface underlying the Wentlooge Formation in the vicinity of the mouth of the Rhymney River, as shown by boreholes (see text for details of sources). The geology of the concealed bedrock surface is distinguished by the point symbols.

and teeth) occurs at several localities within the bounds of this soil and for up to 0.3 m below (Allen & Fulford 1986). Such debris when stratified in a drainage ditch may range more deeply below the seal provided by the palaeosol. Figure 3 shows the chief sites of Romano-British cultural debris, transposed as well as sealed in place.

The slightly leached upper horizon (0.25–0.35 m) (see (1) and (2) of plate 1), overlain erosively by the Rumney Formation, consists of massive, coarsely fractured, pale-coloured but orange-mottled, slightly silty clays that resist weathering, and hence in many places create a slight rib on the cliff. It displays two sizes of root channel, most of which preserve traces of an organic lining. The smallest, a millimetre or two thick, are densely matted and closely resemble the roots of grasses seen below the sward of the higher saltings (Rumney Surface) and on undisturbed meadows on the Wentlooge Level. The larger root channels, attributable to

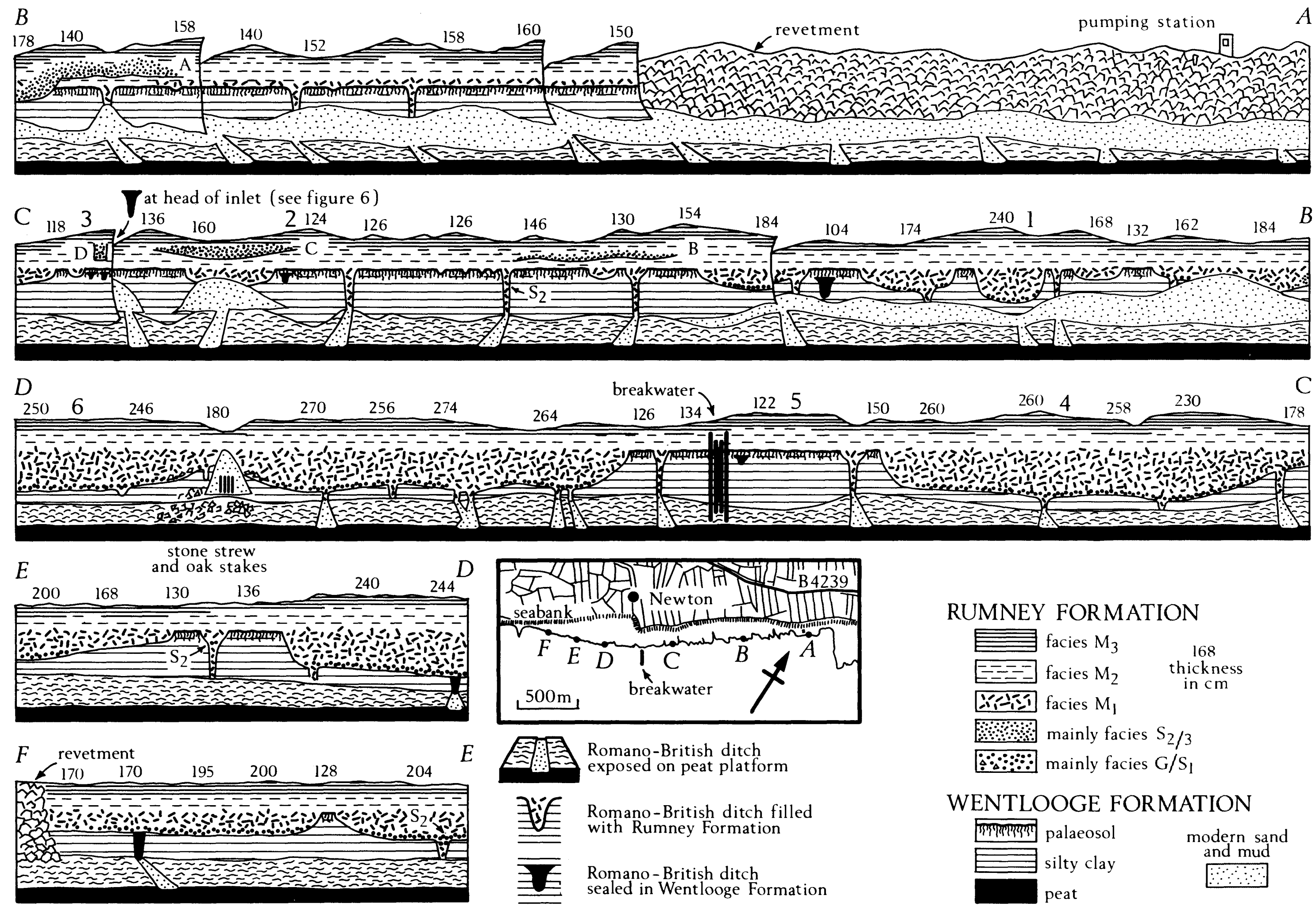


FIGURE 5. Simplified perspective view of the mud cliff bordering Rumney Great Wharf, to show the distribution and relationships of the (upper) Wentlooge and Rumney formations. The reader sees the cliff (up to 3 m high) as if looking inland from some distance out on the peat platform on the foreshore. Vertical exaggeration approximately 1:15. Sedimentological profiles (see figure 7) marked 1–6. Sand bodies (see figure 9) marked A–D.

Phragmites, are oval to irregular in cross-section and up to 12 mm wide. Invertebrate burrows, with no organic lining, are locally conspicuous.

Samples from the upper horizon prepared in thin section show a random scatter of quartz silt, a locally churned appearance, and large textural mottles. The orange mottles seen in the field prove to be concretions of iron compounds including siderite (see (1–3) of plate 2). They range up to 18 mm across and present four types of appearance in cross-section: (i) rounded to ovoid with diffuse margin and strongest colours in the centre; (ii) rounded to ovoid with diffuse margin and strongest colours bordering a root channel or burrow; (iii) ring-like with diffuse inner and outer margins and colour concentrated in a band which may show crude arborescences; and (iv) rounded to irregular with sharp borders and a uniform, generally strong coloration. A rare type of microconcretion consists of black, arborescent, manganiferous growths. The association of the concretions with root channels and burrows, and their inclusion of quartz silt and clay-mineral grains, points to their early diagenetic origin. The burrows and root channels conspicuous in the field are also plentiful in thin section. The more platy mineral grains surrounding particularly the burrows are aligned parallel with the surface of the void, the strength of the fabric declining outward into the sediment (see (4) of plate 2). Brewer's (1964) bimasepic fabric is weakly developed toward the bottom of the upper horizon.

The lower horizon (0.25–0.45 m), grading down into unaffected clays (see (1) of plate 1), possesses a mid to dark grey colour, a close almost vertically prismatic jointing, and at many places *Phragmites* roots and stems (see (3) of plate 1) in addition to numerous burrows. Thin sections reveal no laminae, a churned to mottled appearance, and a scattering of ferruginous concretions like those above. Flaky detrital minerals are again aligned parallel with the margins of root channels and burrows (see also (4) of plate 2), but some of these voids are also lined with a just discernible skin of darker coloured and much finer grained, well-oriented clay minerals, resembling Brewer's (1964) channel argillans and presumed to be illuvial. Brewer's (1964) masepic (see (5) of plate 2) and bimasepic fabrics (see (6) of plate 2) are strongly developed, particularly in the middle and upper parts of the horizon.

Dispersions prepared from clays throughout the Wentlooge palaeosol reveal the same organic components as are present in the underlying sediments above the peat. The foraminifera and shell fragments, however, are distinctly corroded but a scattering of insect remains (body hairs, limb segments, mandibles) introduces a novel element.

Over the central and northeastern parts of the cliff at Rumney Great Wharf shells of the meadow snail *Cepaea nemoralis* are scattered throughout the lower horizon of the palaeosol and for up to 0.5 m below.

4. Drainage ditches in the Wentlooge Formation

Probably under military direction (Legio II Augusta at Caerleon), the entire Wentlooge Level early in the Roman period was drained and presumably also embanked. Allen & Fulford (1986) give an archaeological account of this important event, the chief evidence for which is (i) a pattern of ditches visible on the shore which is similar in scale and alignment to the reens that criss-cross the level today; and (ii) the presence, sealed beneath the Wentlooge palaeosol, of Romano-British cultural debris, in particular filling one of the ditches. The modern seabank, probably of mediaeval origin, is significantly further inland than the presumed Roman defence. Sedimentologically, these man-made ditches are of critical importance, because they have guided coastal processes at all subsequent times. Drainage ditches of at least two sizes were cut into the upper Wentlooge Formation down from a horizon apparently high in the Wentlooge palaeosol.

The largest and most extensive of the ditches are 2.0–2.5 m deep and were systematically bottomed out within or just below the upper peat (see figure 2*b*). They are strikingly displayed near the central breakwater on Rumney Great Wharf (see figure 3) as shallow, reticulate grooves on the upper surface of the peat, which here as elsewhere on the shore has defined a broad wave-cut platform (see (1) and (2) of plate 3). Further examples appear to the northeast off Rumney Great Wharf (see (1) of plate 4) and south of Peterstone Gout (see figure 3 and (2) of plate 4), where the *Spartina*-covered muds of the Northwick Formation patchily obscure the peat. There are indications from the mode of coastal retreat revealed by historical maps of the presence of ditches beneath the thicker Northwick Formation at Peterstone Great Wharf. Figure 3 summarizes their distribution as established by ground survey and from map evidence and air photographs (1971, 39 R.A.F. 3764 F42, F43).

The ditch bottoms at the peat are rather variable in width, but a sample of 23 of the more constant gave a range of 0.8–5.0 m and an average width of 2.06 m. The only large ditches with the original profile at all well preserved are one infilled with mud-bound Romano-British cultural debris and sealed beneath the Wentlooge palaeosol (ST 2442 7827) (see figure 6), and

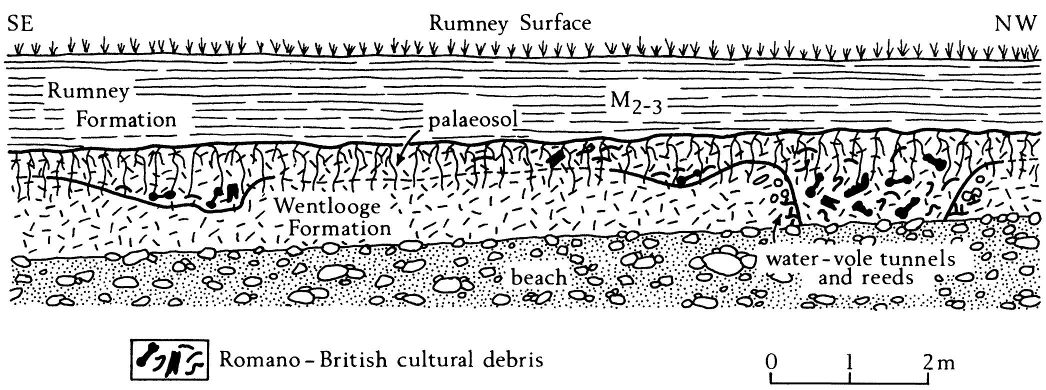
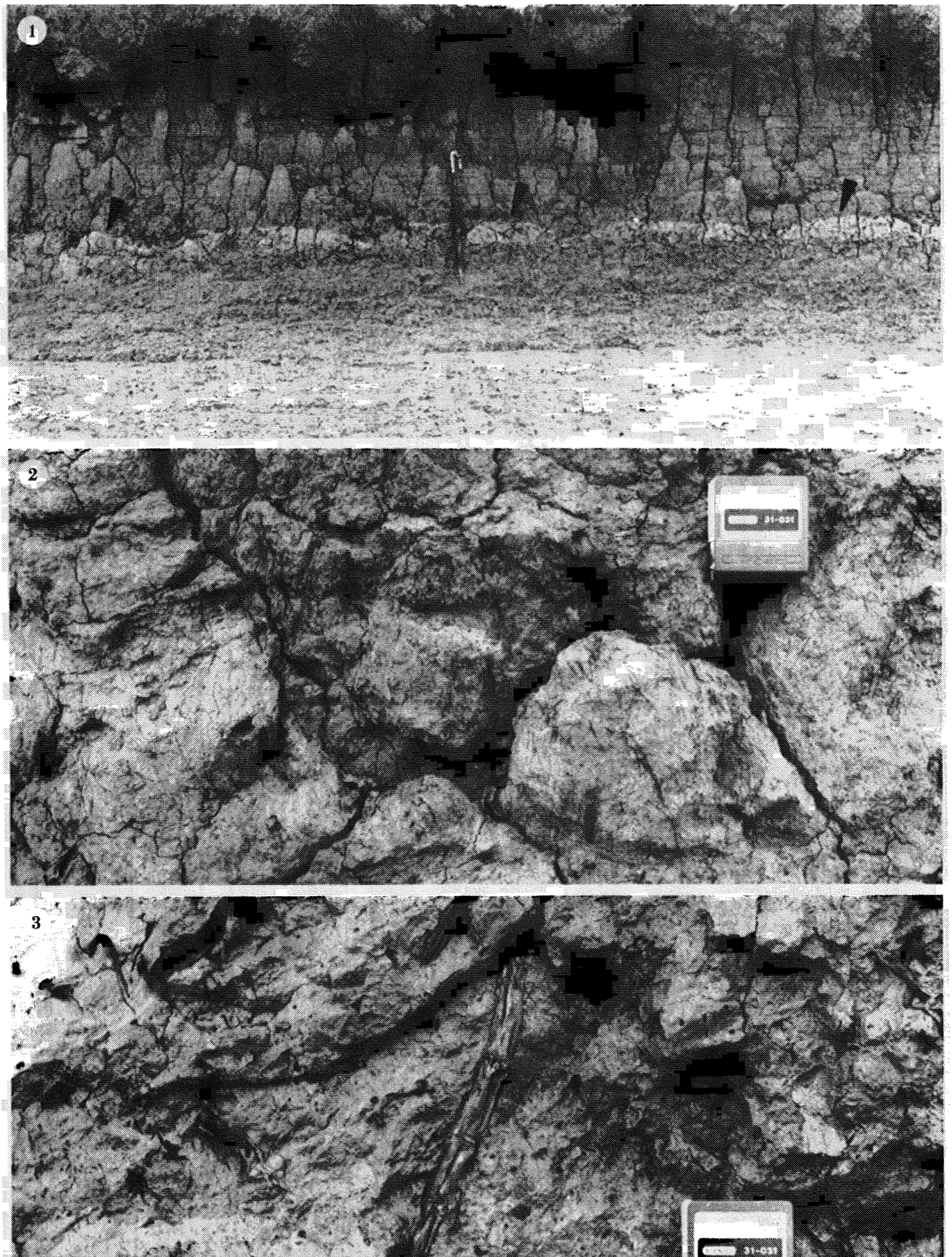


FIGURE 6. Cliff profile of Romano-British ditch and (?)occupation surface sealed in the Wentlooge Formation at ST 2441 7829. See also figure 5.

another, truncated by the Rumney Formation, at the southwestern end of Rumney Great Wharf (ST 2350 7775) (see (1) of plate 5). Within the Roman period, the latter appears to have been realigned and silted up at least twice with dark-coloured organic-rich sediments yielding profuse *Phragmites* (see (2) of plate 5). Side slopes on these and less fully preserved large ditches range between 50° and 80°.

DESCRIPTION OF PLATE 1

PLATE 1. The Wentlooge palaeosol (ST 245 783). (1) General view of palaeosol, with ferrule of umbrella (0.85 m long) resting on lower, dark soil horizon and handle on facies M_2 of Rumney Formation. Top of soil arrowed. (2) Pale-coloured upper horizon with roots and rootlets, sharply overlain by a few centimetres of the Rumney Formation. Scale box 50 mm square. (3) Dark-coloured lower horizon with the roots of reeds. Scale box 50 mm square.



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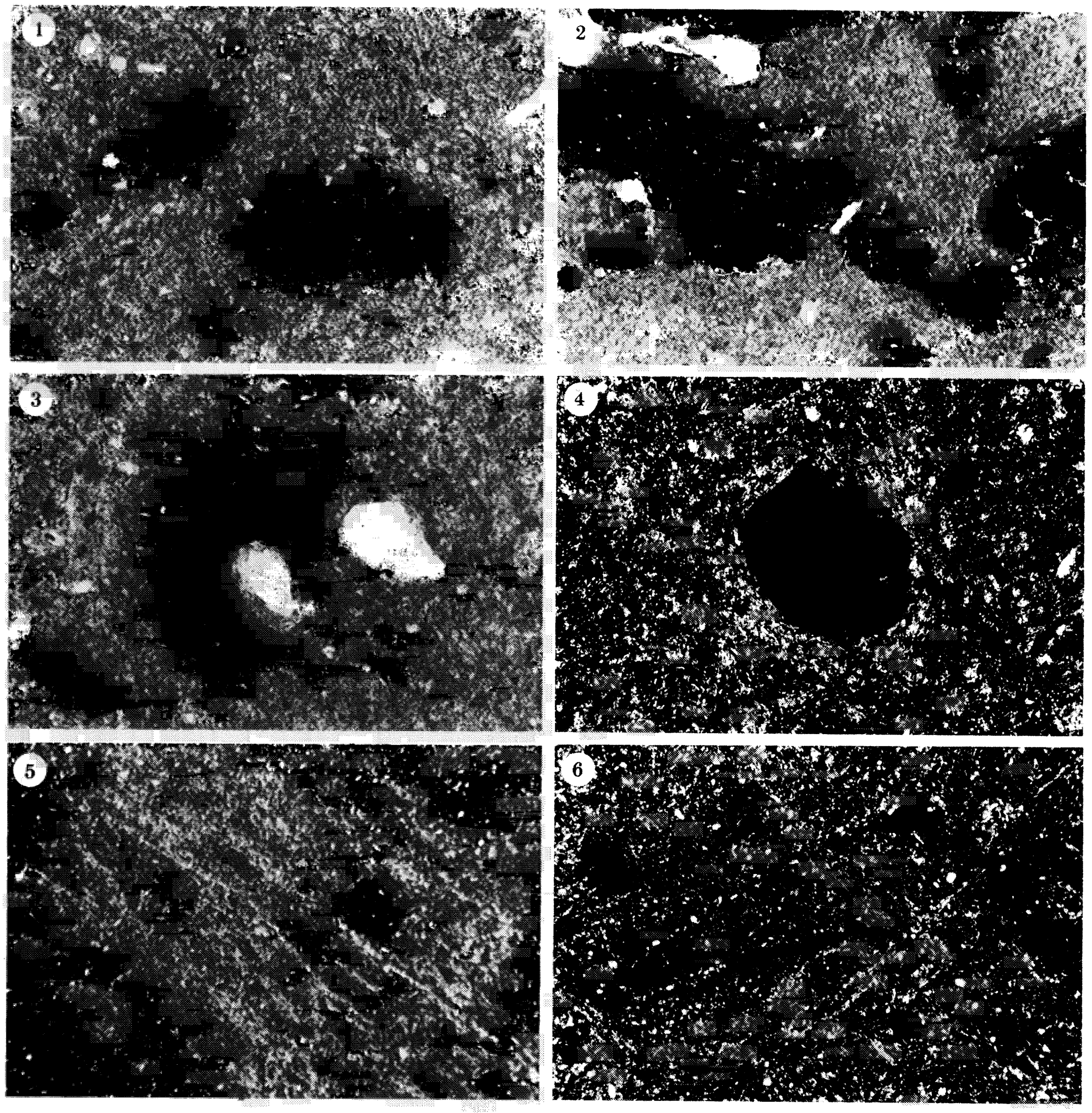

PLATE 2. Photomicrographs from the Wentlooge palaeosol. (1) Dark-coloured authigenic sideritic concretions in groundmass of clay minerals and quartz silt, pale horizon, ordinary light ×60. (2) Ring-like and diffuse-margined authigenic sideritic concretions, pale horizon, ordinary light, ×29. (3) Diffuse-margined authigenic sideritic concretion concentrated around a burrow or root channel, pale horizon, oridinary light, ×60. (4) Reoriented clay-mineral fabric around a burrow, pale horizon, doubly polarized light, ×97. (5) Masepic fabric displayed by clay minerals, dark horizon, doubly polarized light, ×29. (6) Bimasepic fabric shown by clay minerals, dark horizon, doubly polarized light, ×37.

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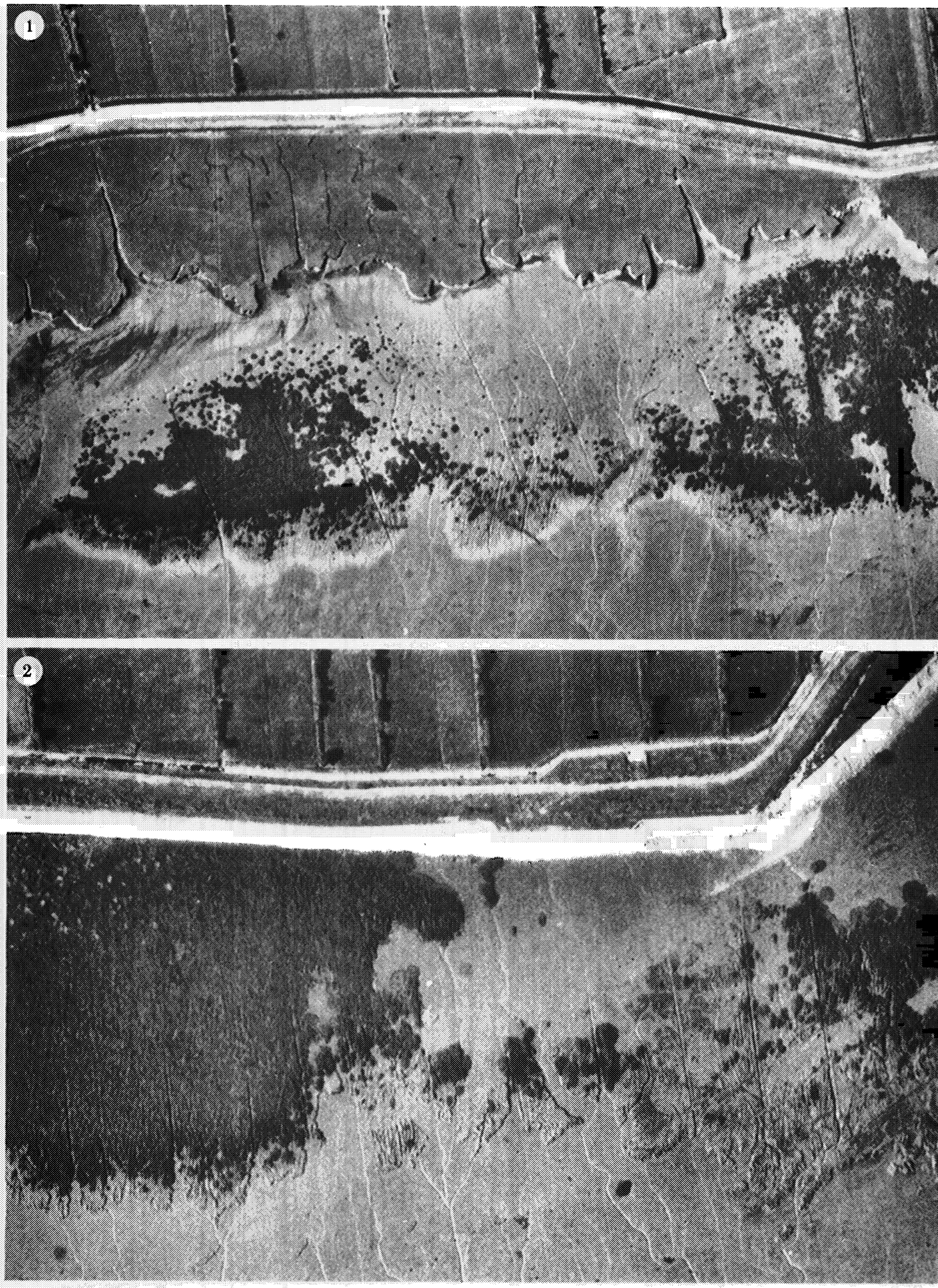
For description see p. 167.



For description see opposite.

Small ditches, some yielding cultural debris, that cut a short way down into the Wentlooge Formation are not uncommon beneath the Wentlooge palaeosol (see figure 5). Part (1) of plate 6 illustrates a type of small ditch that retained a limited morphological expression until the formation of the Wentlooge soil. The structure is 0.4 m deep and approximately 2.25 m wide at the rim. Although thinned slightly, the pale soil zone can be traced beneath the whole of the structure. By contrast, the dark horizon thickens considerably toward the axis of the surface feature. The ditches shown in (2) and (3) of plate 6 had been completely filled by Wentlooge palaeosol times. The first, measuring 1.8 m wide and 1.0 m deep, is lined with a dense mass of fragmentary charcoal, coal and daub, and is infilled with dark grey clay (see also figure 6). The second measures 1.0 m wide and 0.9 m deep and has a V-shaped profile. It too is filled with dark grey clay but yielded only a few charcoal specks. Part (4) of plate 6 shows a ditch of U-shaped profile (see also (1) of plate 6) and truncated top. The width measures 1.25 m and the depth 1.0 m, a layer of matted plant debris and some charcoal lining the bottom. From the floor and sides *Phragmites* roots fan downward and outward into the surrounding clays.

5. Rumney Formation

(*a*) *Age*

The Rumney Formation underlies the Rumney Surface, the highest level on the salting called Rumney Great Wharf, to seaward of the bank defending the southwestern portion of the Wentlooge Level (see figure 3). As this surface is inundated by the higher spring tides, the accumulation of the Rumney Formation is continuing.

Deposition at Rumney Great Wharf seems to have begun in the 15th–17th centuries. A composite sample of *Scrobicularia plana* valves, some still hinged, from the base of the formation infilling embayments (see below) northeast of the central breakwater (see figure 3) gave an apparent radiocarbon age of 840 ± 90 years BP (relative to 1950) (N.E.R.C. Radiocarbon Laboratory SRR-2677). When a latitude-dependent correction is applied for the natural

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Descriptions of plates 3 and 4

Plate 3. Romano-British drainage ditches abandoned on the shore. (1) Bottom of ditch exposed on top surface of peat in the upper Wentlooge Formation, with cliffs largely of Rumney Formation in distance (ST 240 779). Spade 0.94 m long. (2) Air photograph of part of Rumney Great Wharf showing seabank (linear feature), saltmarsh with meandering gullies (Rumney Surface), and foreshore peat platform (with meandering natural channels and bottoms of straight Romano-British ditches), to the NE of central breakwater (see also figure 3). Note relationship of ditches to embayments and the alignment of ditches on shore with extant drainage landward of the seabank. Area measures approximately 450 × 350 m. North towards upper right. R.A.F. photograph, Crown copyright reserved.

Plate 4. Romano-British drainage ditches abandoned on the shore. (1) Northeastern portion of Rumney Great Wharf (see also figure 3). Air photograph shows ends of rectangular fields, the seabank, salt marsh (Rumney Surface) and embayed mud cliff, and the mud- and vegetation-obscured peat platform with the positions of the bottoms of the Romano-British ditches just detectable. Note the strong relationship of ditches to embayments in mud cliff. Area measures approximately 800 × 600 m. North towards upper right. R.A.F. photograph, Crown copyright reserved. (2) Part of Peterstone Great Wharf, east of Peterstone Wentlooge and southwest of Peterstone Gout (see also figure 3). Air photograph shows the ends of rectangular fields, the sea bank, the salt marsh (Northwick Surface), and the partly obscured traces of the bottoms of the Romano-British ditches. Note the alignments across the seabank. Area measures approximately 650 m by 500 m. North towards upper right. R.A.F. photograph, Crown copyright reserved.

deficiency of ^{14}C in British coastal bivalves (Harkness 1983), the true radiocarbon age becomes 470 ± 98 years BP suggesting that deposition in the then coastal embayments began in the 15th–16th century. Accumulation apparently commenced slightly later on the headlands (see below) between the embayments. From the base of the formation at the broad headland by the central breakwater (see figure 3), Allen & Fulford (1986) described a well-preserved rim sherd of 16th–17th century type. This evidence is supported by Boon's (1978, 1980) discovery that the 'grey-blue alluvium' (Wentlooge Formation), in which was embedded the Romano-British quay at Caerleon on the tidal River Usk, was sharply surmounted by 'brown alluvium' (Rumney Formation) which yielded only 16th–19th century pottery. From the topmost few centimetres of the Wentlooge Formation he recovered 13th to early 14th century pottery.

(*b*) *Embayments and headlands*

The most striking feature of the Rumney Formation is the fact that it smothers what is with little doubt a cliffed coast formed of flat-topped headlands and wide-bottomed embayments cut into the upper Wentlooge Formation (see figure 5). Although it had not escaped erosion, the pale horizon at the top of the Wentlooge palaeosol largely determined the character of the headlands, because of its resistance to weathering. Just as on the coast today, the peat in the upper Wentlooge Formation defined the ultimate downward limit to the scouring of the embayments. Again, as on long stretches of the modern shore, the Romano-British ditches guided erosion, and thus determined the locations of many of the embayments and headlands preserved beneath the Rumney Formation.

Figure 5 depicts in plan and in perspective elevation the distribution of the Rumney Formation. Between roughly 1 and 1.75 m of sediment surmounts the Wentlooge palaeosol on the headlands, whereas as much as 2.5–2.7 m of the Rumney Formation, reaching almost to the peat, occurs within the embayments. The tendency for headlands to predominate at the northeastern end of Rumney Great Wharf, and for the Rumney Formation to be thickest in the southwest, suggests that the pre-Rumney coast was of a slightly more easterly trend than the present shore. A pair of particularly wide and deeply penetrating embayments may have existed southwest of the central breakwater (see figure 3), where the mediaeval seabank cuts sharply back toward Newton (the present defence here follows a straighter course) and the Rumney Formation is mostly more than 2.25 m thick (see figure 5).

A distinctive concave-up cross-sectional profile is assumed by the buried cliffs that flank the headlands. The pale horizon of the Wentlooge palaeosol gives rise to an almost vertical slope about 0.3 m high at the cliff top. The dark horizon and the clays below underlie gentler slopes of 30–50°, much as they do on the modern cliff. A similar profile, combining near-vertical slopes above with less steep ones below, occurs where on the present-day salting the sod has experienced wave attack.

(*c*) *Erosional structures on the headlands*

Wherever the flat tops of the smothered headlands are exposed, the Rumney Formation is seen sharply to overlie an undulose surface cut into the massive, root-bound clays that form the pale horizon in the Wentlooge palaeosol. The undulations (see (1) of plate 7) are smoothly rounded elevations and hollows 0.6–1.2 m apart transversely and with a relief of about 0.1 m, exceptionally reaching 0.25 m. These structures are with little doubt erosional because (i) the diffuse boundary between the pale and dark horizons in the Wentlooge palaeosol below is level;

(ii) the ends of root channels and invertebrate burrows exposed on the undulating surface are slightly enlarged and possess smoothly rounded rims; and (iii) the lowermost laminae in the sharply overlying Rumney Formation thicken into the hollows and are locally sandy or even gravelly (see (2) of plate 7).

These ubiquitous structures closely resemble in shape, but are not as large as, erosional features that are equally widespread on the modern wave-cut platform underlain by the Wentlooge peat (see (3) of plate 7). The peat structures are 0.8–2.0 m in wavelength and normally about 0.25 m in height. They vary considerably in length but tend to be elongated perpendicular to shore. The fact that the peat structures belong to a well known class of wave-related ridges and furrows (Allen 1982) suggests that wind waves also shaped the undulations surmounting the Wentlooge palaeosol.

(*d*) *Sedimentary facies*

The eight sedimentary facies recognized in the Rumney Formation of Rumney Great Wharf encompass gravelly (code G) and sandy (code S), as well as muddy (code M) sediments.

Facies G_1, of local development only, is typified by the presence of introduced rocks (chiefly by man) in gravel-sized pieces, set in a subordinate to generally much more abundant, normally shelly matrix of muddy sand to sand (see below). In most developments the clasts are well rounded pebbles and occasionally small cobbles of mainly Carboniferous sandstones and quartzites with some vein quartz and flint. Accompanying them are occasional quarried and little-abraded pieces of platy sandstone (chiefly Pennant Group, some Old Red Sandstone), rare teeth and worn pieces of bone from domestic animals, and very rare abraded pottery sherds of Romano-British date. Abraded fragments of medieval and early modern pottery found loose on the shore may also have been released from these sediments. The shelly component, chiefly *Macoma balthica* and *S. plana*, ranges from sand-size fragments, through partly broken separated valves, to still paired but gaping shells. At two localities the pebbles are subordinate to large angular to slightly abraded lumps and blocks of Lias limestone. On the peat platform adjoining the southwestern occurrence (shown in figure 5), similar rubble forms a dense and widespread strew focused on an L-shaped cage of oak stakes of mid 16th century date that may represent either a revetment or landing place (Allen & Fulford 1986).

Facies G_2 grades from facies G_1 by an increase to dominance in the proportion of gravel-sized intraformational clasts (see (1) of plate 8). These vary from only slightly abraded to well rounded pebbles and small cobbles of (i) greenish grey slightly silty clays indistinguishable from those of the Wentlooge Formation; and (ii) laminated to massive pink silty clays resembling sediments bedded in the Rumney Formation. Accompanied by occasional sandstone and quartzite pebbles, bones, teeth, and Romano-British and mediaeval pottery sherds, this debris is contained in a generally ill-stratified matrix of muddy to clean sand (see below). Deposits similar to facies G_2 are being formed by erosion today along the foot of the mud cliff at Rumney Great Wharf.

The sands present in the Rumney Formation, like much of the sandy sediment found as sheets and pocket beaches on the modern shore, are dominated by a well-sorted mixture of slightly abraded irregular fragments of siderite–clay mineral concretions up to 5 mm across, and spheroidal manganiferous concretions reaching 8 mm in diameter. The minor components of sand size are shell fragments, very fine to coarse quartz sand grains and, where lumps of iron-making slag are present (see below), spherules and scales of magnetic slag representing iron smithing. Coarser debris, present in variable but generally small amounts, and probably for the most part of cultural origin (Allen & Fulford 1986), is represented by broken to whole mollusc shells (non-cultural), chiefly *M. balthica*, *S. plana* and *Hydrobia ulvae*; well-rounded pebbles of sandstone, quartzite, vein quartz and flint; quarried pieces of platy sandstone; angular pieces of coal and charcoal; lumps of primitive iron-making slag (mainly found northeast of the central breakwater); the bones (commonly fragmentary) and teeth of domestic animals (cow, horse, sheep, pig, fowl); and abraded pottery sherds ranging from Romano-British (predominant) to post-mediaeval (rare).

Facies S_1 consists of sand and gravelly sand interbedded on a centimetre to (rarely) decimetre scale with silty to sandy-silty clay (see (2) of plate 8). Most of the sand beds are cross-laminated internally, with wave-rippled tops, but some are parallel-laminated. The bedding is disturbed by numerous burrows and, locally, densely arrayed bovine footprints. The latter are definitely contemporaneous with the sediment, as they extend into the interior of the cliff and are pierced by concreted burrows.

Facies S_2 is represented by cross-bedded sands, in either solitary (predominant) or grouped (rare) sets (see (3) of plate 8). Internal mud drapes and discordances between bundles of cross-strata abound. Some grouped sets are accompanied by a little parallel-laminated sand.

Facies S_3 is dominated by parallel-laminated sands in thick sets (see 4 of plate 8). The laminae vary from horizontal to gently inclined, and from plane to slightly convex-up to gently rolling. Upward and laterally in developments of facies S_3, and occasionally internally, the parallel lamination, normally of the rolling type, may grade to internally cross-stratified bar-like features and near-symmetrical wave ripple marks with a wavelength of up to several decimetres.

The three mud facies, distinguished chiefly on colour and degree of stratification, share many compositional features. X-ray diffraction analysis of air-dried whole samples shows that clay minerals generally dominate over quartz plus feldspar (9–16 %), calcite (2–12 %), and siderite (5–10 %). The under 2 μm fraction varies little from sample to sample, consisting of illite (52.2 %, or less), mixed layer mineral (39.5 %, or less), kaolinite (10.4 %, or less) and chlorite (8.5 %, or less). The microscopic examination of samples sedimented on to glass slides shows that many of the silt- to sand-size quartz grains preserve traces of a red, ferruginous skin, pointing to their derivation from either the Old Red Sandstone or the New Red Sandstone. The feldspars, chiefly plagioclase, occur mainly as small, perfectly shaped rhombs. Calcite is present largely as fragments of molluscan and other shells, with some irregularly cleaved and corroded coarsely crystalline particles. Rhomb-shaped crystals of what proved on scanning electron microscope examination and by energy-dispersive analysis to be calcian dolomite and dolomite form a noticeable but minor proportion of all the dispersed samples (see 1–4 of plate 9). The main varieties recognized are (i) perfectly shaped clear rhombs with a few minute central inclusions, (ii) perfectly shaped clear rhombs shaped around either a diatom valve or recognizable mineral grain as nucleus (presumed to be authigenic), (iii) perfectly shaped clear rhombs built around a nucleus formed by a corroded rhomb with traces of a ferruginous surface skin (presumed to be partly authigenic), and (iv) somewhat larger and slightly corroded, red-stained rhombs resembling those present in dispersions of Triassic marls bordering the Severn Estuary (see Jeans 1978) and presumed to be derived. In dispersions from Rumney Great Wharf, siderite appears as irregular grains formed of tiny crystals interspersed with clay mineral flakes and other ferruginous compounds. Thin sections show that, in the undisturbed sediments, the siderite is concretionary, occurring chiefly around root channels and invertebrate burrows, and in places as large, partly arborescent nodular growths associated with manganiferous compounds (see (5) and (6) of plate 9).

Facies M_1 consists in the field of pink-weathering, slightly silty to silty clays that generally lack visible laminations but which locally present horizontal partings a few centimetres apart vertically (see (1) of plate 10). Largely vertical burrows attributable mainly to *Nereis diversicolor* are plentiful. Here and there, U-shaped burrows due to *Corophium volutator* lie crowded together. Locally, nests of *H. ulvae* shells, and groups of *S. plana* and *M. balthica* valves in life position, are found. Large mud-filled desiccation cracks (see (2) of plate 10) mark the facies at many places chiefly towards the upper limit of its stratigraphical range. Thin sections show occasional disturbed laminae of clayey silt and even sand, textural mottles and pockets of faecal pellets related to bioturbation, and many open burrows fringed by concretionary siderite (see (7) of plate 9). Dispersions reveal the presence of the same indigenous and transported groups of foraminifera as were recognized by Murray & Hawkins (1976; see also Murray 1971, 1973) in the Wentlooge Formation of the Severn Levels. The larger forms, chiefly authochthonous, are dominated by *Elphidium articulatum*, *Protelphidium anglicum*, and *Ammonia beccarii*. Accompanying them is a diverse assemblage of mixed benthonic and planktonic small forms, including bolivinids, brizalinids and globigerinids. The dispersions also show a rich assemblage of generally fragmentary, siliceous sponge spicules (styles, tylostyles, acanthostyles, oxeas, acanthomonaxons, triaxons, tetraxons), attributable to marine groups (Bowerbank 1864, 1866, 1874, 1882; Bergquist 1978). Diatoms are represented by mainly fragmentary, mixed brackish to open-marine forms (*Actinoptychus favus*, *Melosira monoliformis*, *M. westii*, *Triceratium favus*) (Hendey 1964). A few naviculid valves appear in samples from toward the upper limit of the facies. The occasional coccolith has been seen. Shreds of peat and silt-sized grains of coal form a rare component.

Facies M_2, composed of pink silty to sandy-silty clays, is marked in the field by closely set irregular laminations of muddy to clean quartz silt and even sand (see (3) of plate 10). Subvertical burrows and root channels, including matted fine examples, are abundant. Here and there, *H. ulvae* shells, single valves of *M. balthica* and *S. plana*, and pieces of driftwood lie strewn over the bedding. The scattered bones and teeth of cow, horse and particularly sheep occur sporadically. Thin sections reveal delicate, silty to sandy laminae much disturbed by burrows, root channels and numerous siderite concretions (see (8) of plate 9). Dispersions prepared from the muds reveal a similar assemblage of foraminifera to facies M_1, in addition with *Jadammina macrescens* in its typical, collapsed form, as well as a rich association of siliceous, marine sponge spicules (styles, tylostyles, acanthostyles, oxeas, acanthomonaxons, triaxons, acanthotriaxons, tetraxons). The assemblage of mixed marine to brackish diatoms is generally much more abundant and diverse than in facies M_1. It includes *A. senarius*, *Coscinodiscus spp.*, *M. monoliformis*, *M. westii*, *Pinnularia ambigua*, and *T. favus*, accompanied by caloneid, diploneid and particularly naviculid forms (Hendey 1964). It is only occasionally that coccoliths and insect remains (mandibles, limb segments, body hairs) are seen. Coal particles of silt to sand size and peat shreds are rare constituents.

Facies M_3 represents a slight increase in coarseness over both M_2 and M_1. It consists of well laminated, pinkish grey to dark grey silty clays, silty-sandy clays and sandy clays, with local stringers and bands of concretion sand (see above) accompanied by plentiful shell fragments (*M. balthica*, *S. plana*), rounded lumps of coal and coke, and a variety of other cultural debris (various kinds of slag, metal and glass objects, ceramic and plastic wares) ranging in age from

Romano-British to modern (see (4) of plate 10). The laminae are disturbed by roots and rootlets and by some burrows. Siderite concretions are less plentiful than in facies M_2 and M_1, but some pyrite framboids (presumed authigenic) have been seen in association with partly decayed plant tissue. The same rich assemblages of transported and indigenous foraminifera and diatoms, and of transported sponge spicules, as occur in M_2 are repeated in this facies. Important additional components, conspicuous in both thin sections and mounted dispersions, are mainly anthropogenic coal in the form of sherd-like grains of silt to sand size (see (9–12) of plate 9) and, less abundantly, coarsely vesicular grains of coke (see (13–16) of plate 9). The uppermost sediments also include noticeable amounts of anthropogenic fly-ash, chiefly silvery aluminosilicate spherules (Raask & Goetz 1981; Raask 1984) (see (17–20) of plate 9). Insect remains are extremely rare.

(*e*) *Facies distribution*

Both temporal and spatial factors have controlled the general distribution of these facies at Rumney Great Wharf (see figures 5 and 7).

Muddy facies are predominant, occurring in the upward stratigraphical order M_1, largely restricted to the embayments, then M_2, spreading over embayments and headlands, and finally M_3 immediately beneath the sward. The gravel facies (G_1, G_2), restricted to the base and lowermost measures of the Rumney Formation, occur mainly in embayments. The concretion sands as such have no preferred distribution, but S_1 is not seen other than in embayments and at the base of the formation. Facies S_2 occurs at or near the bottoms of Romano-British ditches infilled with the Rumney Formation (see below). Locally, facies S_2 and S_3 contribute to lenticular sand bodies within M_2 (see below).

(*f*) *Facies patterns at the Romano-British ditches*

Most of the Romano-British ditches are infilled by the Rumney Formation and, to judge from the highly resistant character of the few complete infills known of that period (see above), were open channels when the Rumney muds were deposited.

In the embayments, where the ditches are extensively widened out and deeply truncated, the facies pattern is little affected by these prior features (see figure 8*a–c*). The greenish-grey reed-bearing slightly silty clays of the Wentlooge Formation that line the bottoms and sides of the ditches are sharply overlain by a lenticular development of facies M_1. This in turn, together with the adjoining Wentlooge Formation, is erosively truncated by an association of facies M_1 with some gravel or sand. The erosion surface is slightly concave-up and is followed by whatever bedding is visible in the immediately overlying muds. Speaking generally, the ditches do not influence the bedding pattern in developments of M_2 and M_3 higher up.

Patterns and relationships are different where the ditches either pass between or cross into the buried headlands (see figure 8*d–f*). The upper part of the ditch appears in many cases to have been widened out somewhat, the flat-lying Wentlooge palaeosol having been worn back to form the characteristic concave-up cliff. The undulose top of the soil is either directly overlain by facies M_2 or by thin M_1 succeeded by thick M_2. Any visible stratification drapes down over the widened shoulder of the ditch, dying out toward the axis of the structure, occupied by a subvertical mass of M_1. This relationship, which in places even affects the overlying M_3 beds, suggests that some ditches lingered on as shallow depressions on the salt marsh until

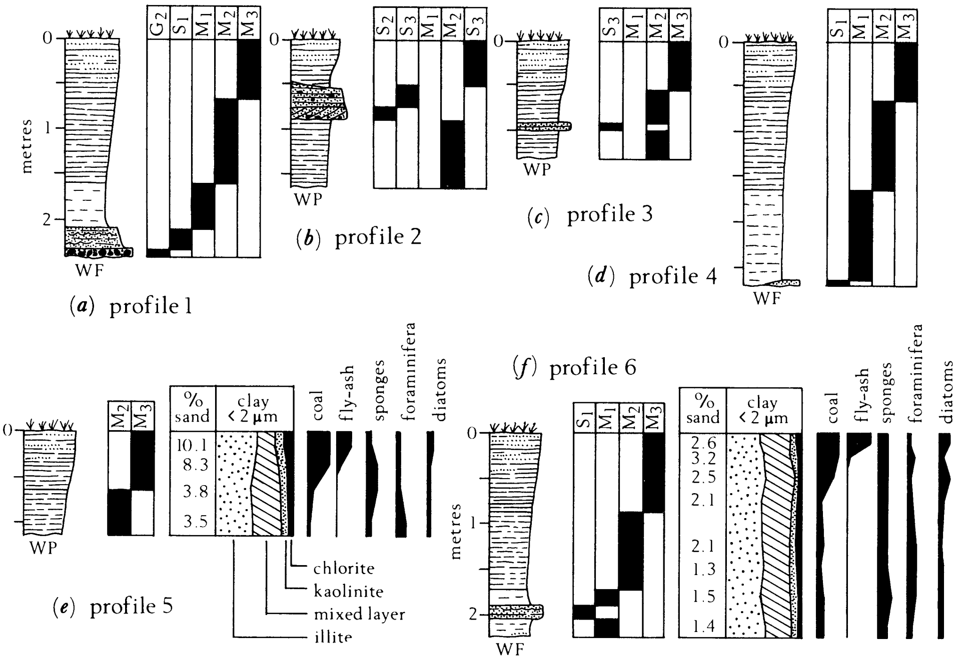

FIGURE 7. Representative measured and sampled sediment profiles through the Rumney Formation on Rumney Great Wharf (see figure 5 for location). (*a*) Embayment E of Newton (WF, Wentlooge Formation). (*b*) Section above the Wentlooge palaeosol (WP) and through the northeastern end of sand body C. (*c*) Section above the Wentlooge palaeosol (WP) ESE of Newton. (*d*) Embayment SE of Newton (WF, Wentlooge Formation). (*e*) Section above the Wentlooge palaeosol (WP) near breakwater SSE of Newton. (*f*) Embayment almost due south of Newton (WF, Wentlooge Formation).

comparatively late in Rumney times, as is also attested by air photographs of Rumney Great Wharf.

Facies S_2 appears in places within the ditch fill (see figure 8*g*–*i*), particularly toward the southwest on Rumney Great Wharf, where many ditches join (see figure 3). The cross-bedding sets are invariably solitary and, in shore-perpendicular ditches, appear to represent lobe-shaped swash bars that faced landward up ditch-defined inlets, just as can be seen after high storm and spring tides in some of the clefts that penetrate beyond the modern mud cliff. Where ditches joined, most branches of the complex inlet so formed contained a bar, facing either landward or along the shore, according to the orientation of that branch.

(*g*) *Sand sheets in the upper Rumney Formation*

Substantial bodies of sand (facies S_2, S_3) occur in the uppermost Rumney Formation at four localities toward the northeast of Rumney Great Wharf (see figure 5). Their bases assume two positions relative to the top of the Wentlooge palaeosol and the Rumney Surface; three of the sand bodies may be of the same age.

Sheet A, in two parts, lies across the northeastern margin of a wide buried embayment (see figures 5, 9*a*). The lower part appears on each side of a modern inlet and consists of slightly to moderately pebbly, mainly parallel-laminated sands. Locally, flat bar-like features and round-topped wave ripples of large wavelength are seen. The base of the sands is level and sharp, lying 0.3–0.4 m above the top of the Wentlooge palaeosol. Upwards, the sands become

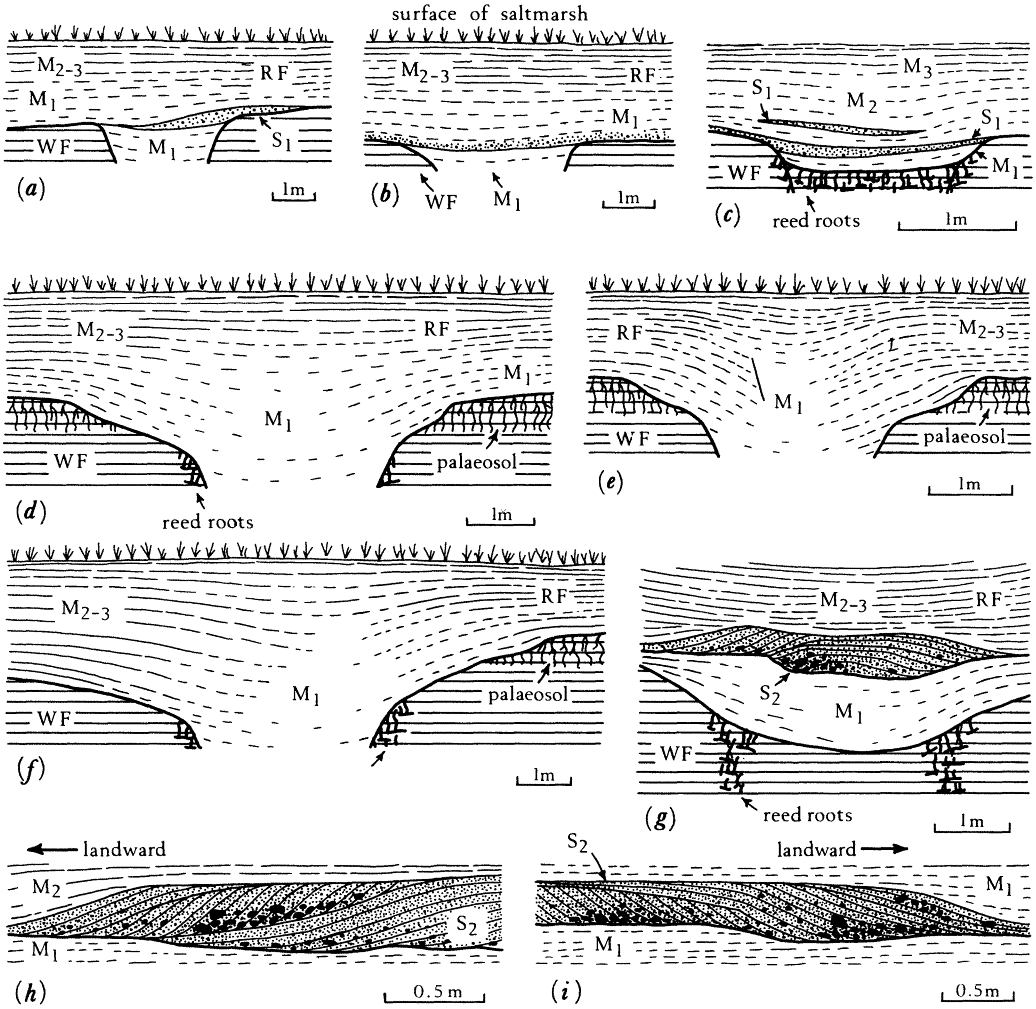

FIGURE 8. Facies relationships at Romano-British ditches infilled with the Rumney Formation. (*a*) Deeply truncated ditch with unexposed base (ST 244 782). (*b*) Deeply truncated ditch with unexposed base (ST 238 778). (*c*) Deeply truncated ditch with base containing reed-filled Wentlooge clays (ST 238 778). (*d*) Reed-lined ditch widened at the top (ST 250 786). (*e*) Ditch widened at the top with core of poorly laminated facies M_1 (ST 249 786). (*f*) Reed-lined ditch considerably widened at the top and with an axial plug of facies M_1. (*g*) Lens of cross-bedded concretion sand above site of partly exhumed ditch sealed in the Wentlooge Formation (ST 246 787). (*h*, *i*) Distal portions of landward-facing bars of cross-bedded concretion sand preserved near the bottoms of Romano-British ditches infilled with the Rumney Formation (ST 238 778, 237 788).

DESCRIPTIONS OF PLATES 5 AND 6

PLATE 5. Romano-British ditches sealed in the Wentlooge formation (ST 235 777). (1) Ditch cut in two stages and erosively overlain by the Rumney Formation (with spade, 0.94 m tall). (2) Dense mat of reed roots (partly arrowed) in dark organic-rich silty clays contributing to fill of second-stage ditch. Scale box 50 mm square.

PLATE 6. Small ditches attributed to the Romano-British reclamation. (1) Ditch retaining relief on the Wentlooge Surface. Dark lower soil horizon thickens, but pale upper horizon thins, beneath site of ditch (ST 250 787). (2) Steep-sided, flat-bottomed ditch sealed beneath Wentlooge palaeosol (pale horizon towards upper left). This ditch gave pottery sherds, bones, teeth, coal and charcoal (ST 244 782). Trowel 0.28 m long. (3) Ditch with V-shaped profile infilled with dark, organic-rich silty clays including bones, teeth and a little pottery (ST 245 783). Trowel 0.28 m long. (4) Shallow ditch with organic-rich fill. As in (1) the pale horizon of the Wentlooge palaeosol thins over the ditch axis (ST 242 780). Spade 0.94 m long.

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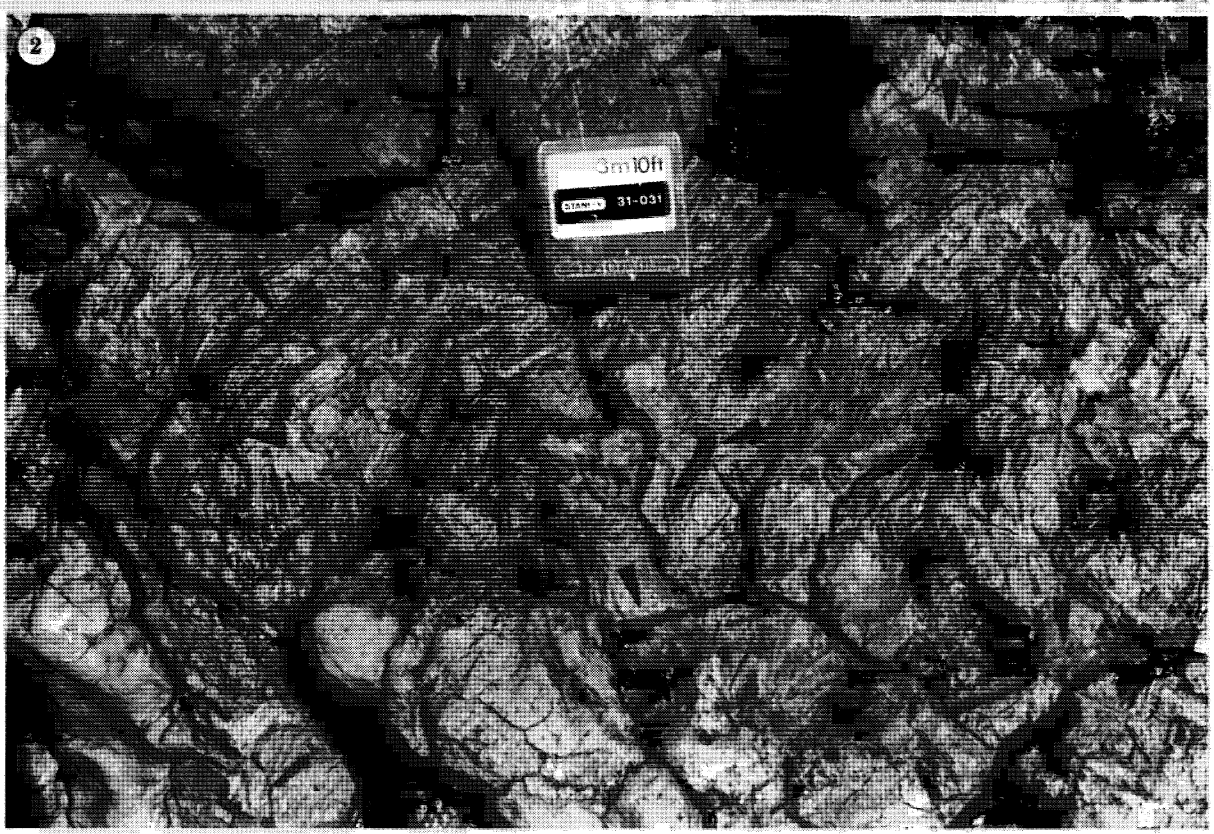

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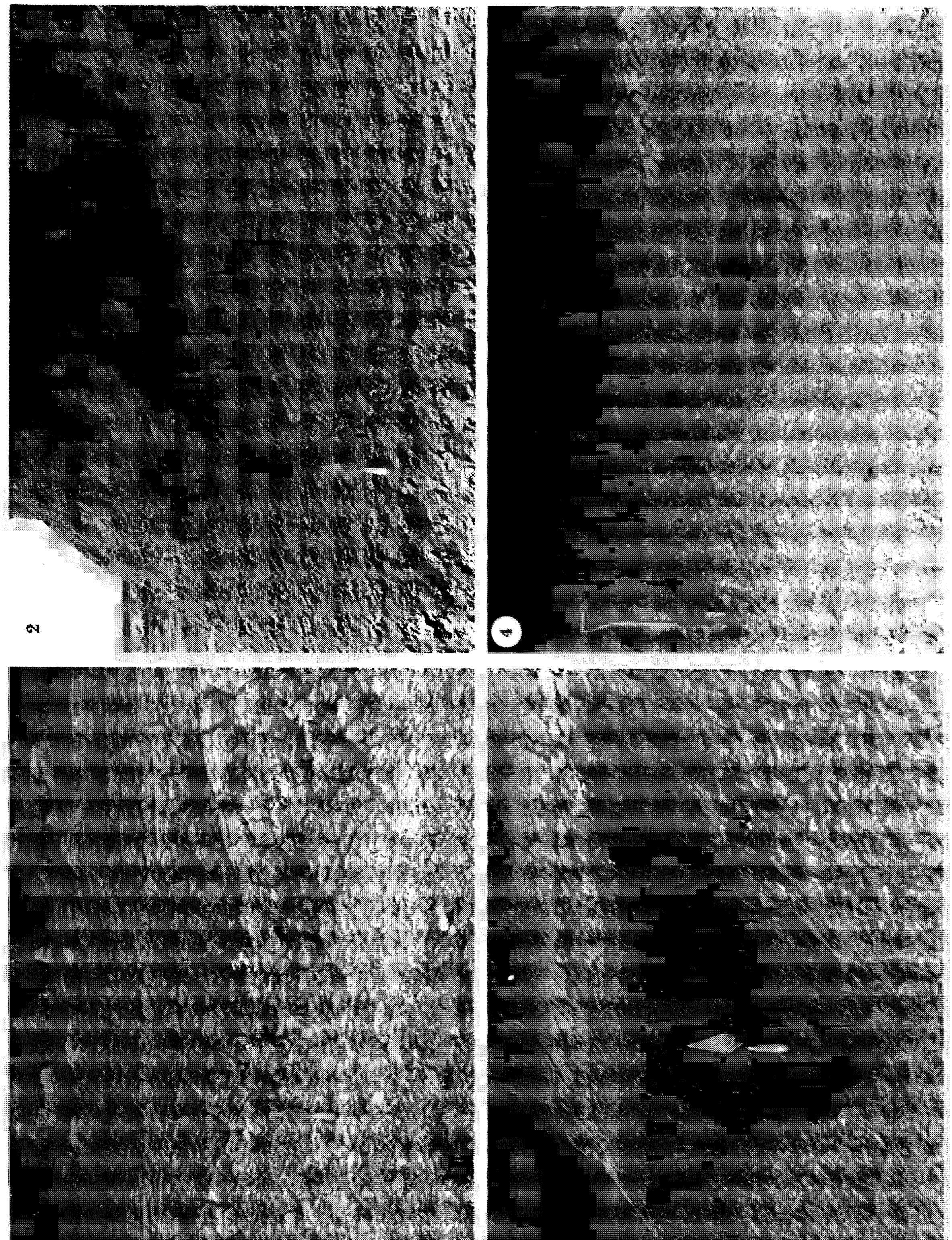

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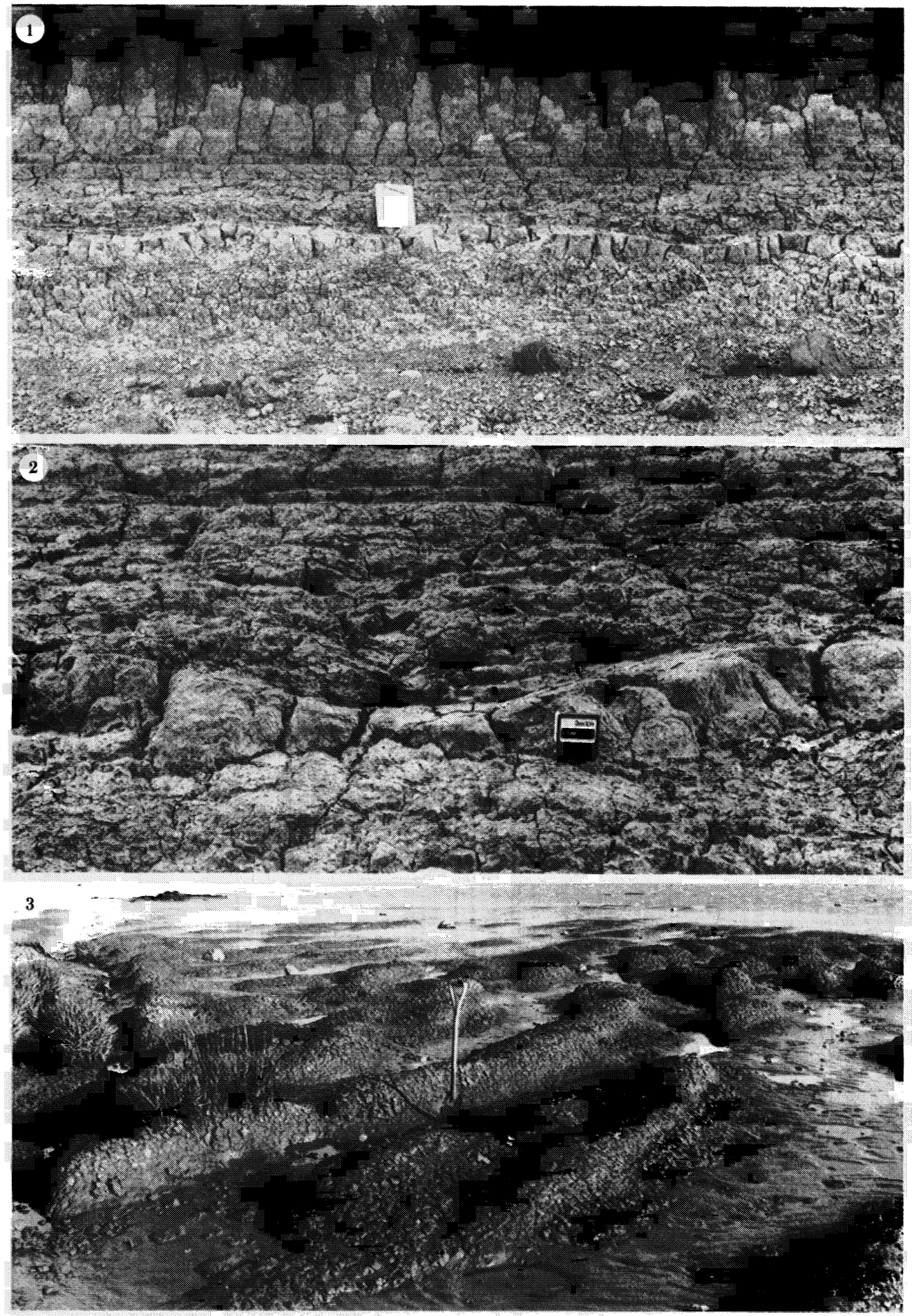

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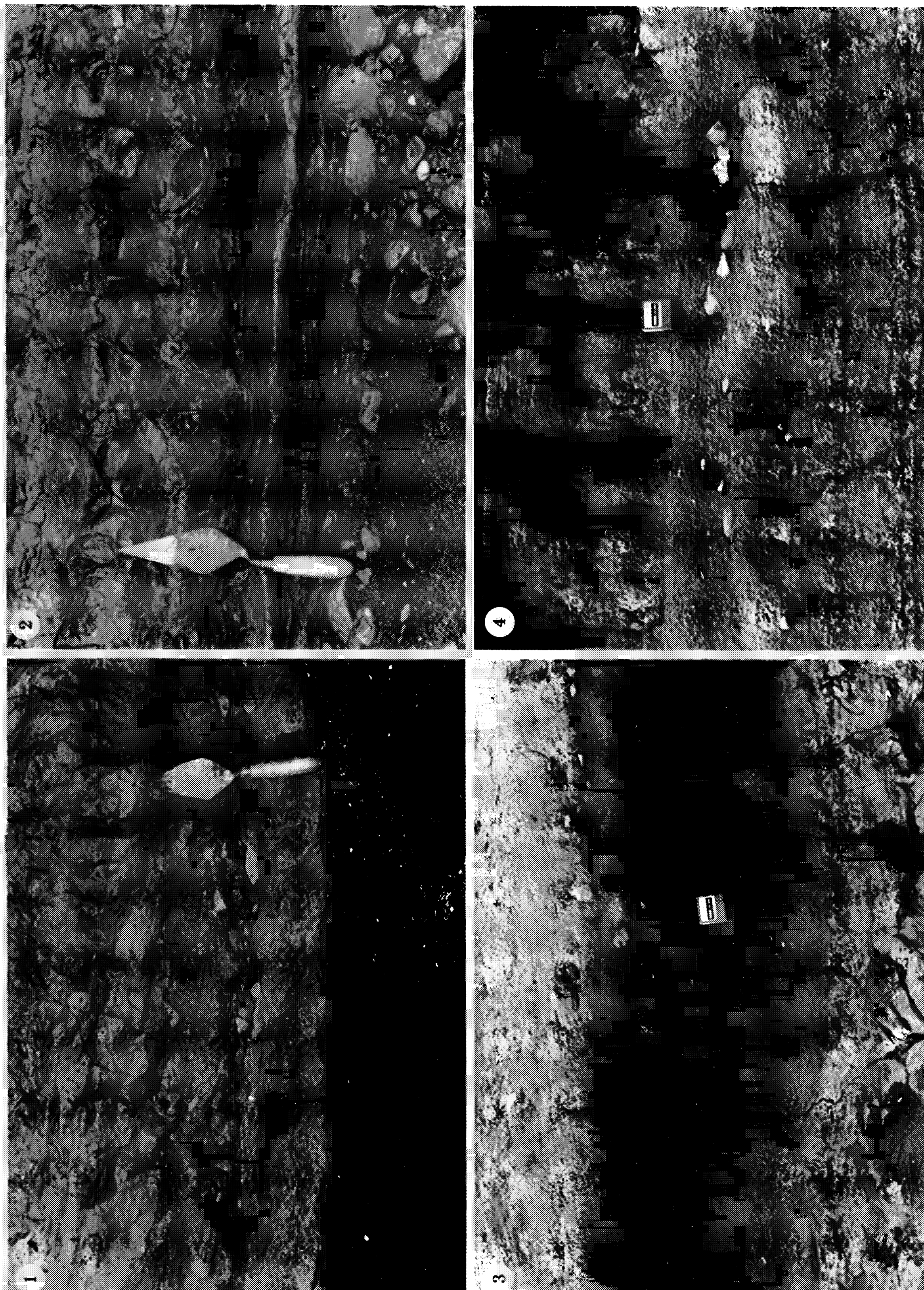

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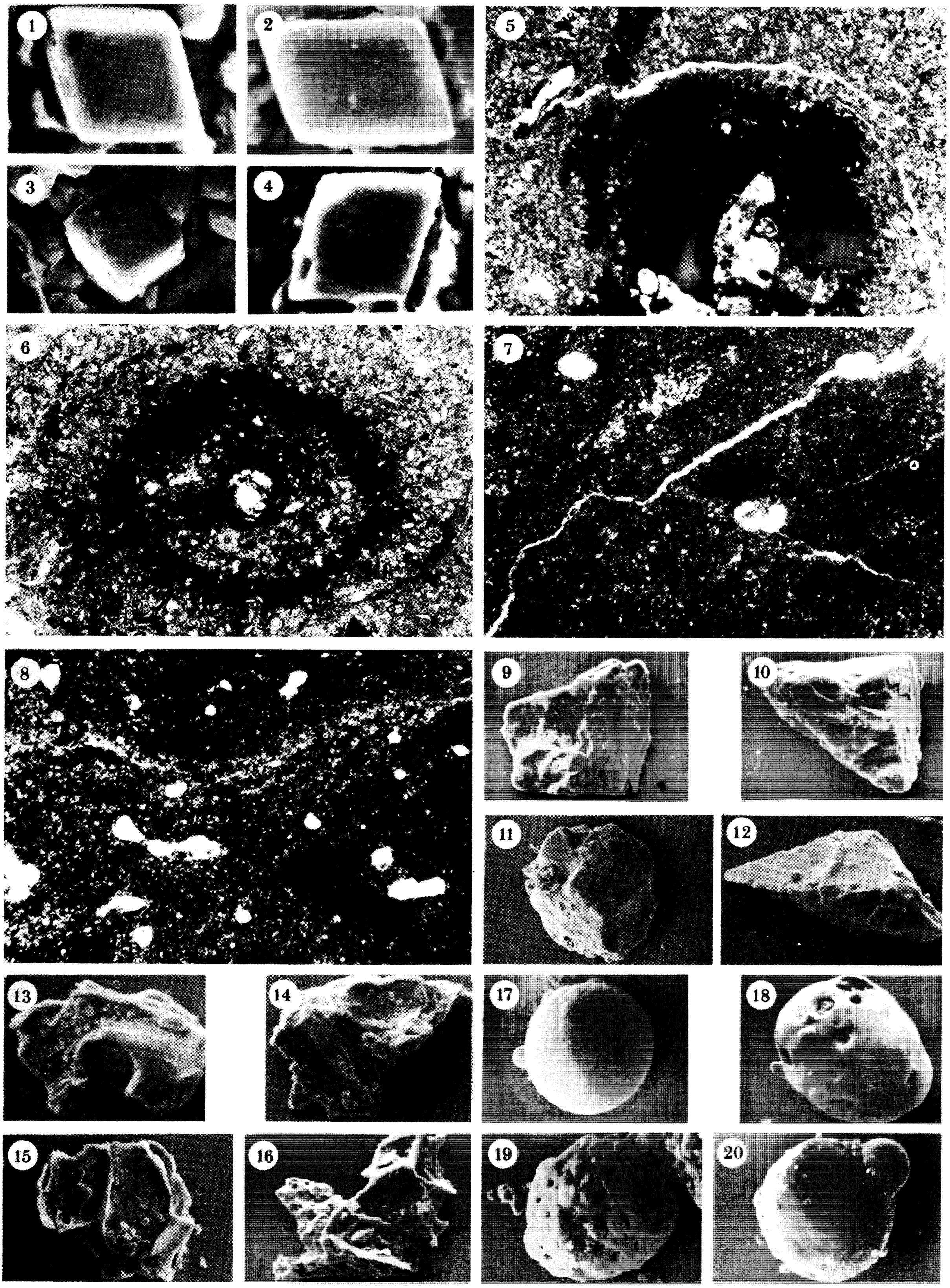
Descriptions of plates 7 and 8

Plate 7. The erosional top of the Wentlooge palaeosol. (1) General view of sharp, hummocky top of palaeosol, overlain by facies M_2 of the Rumney Formation (ST 243 782). Clipboard measures 0.25 m by 0.35 m. (2) Hollow on upper surface of Wentlooge palaeosol discordantly filled by laminated silty clays (facies M_2) of Rumney Formation. As in (1) the contact between the dark and light soil horizons remains unchanged in level as it passes beneath this erosional structure (ST 250 786). Scale box measures 50 mm square. (3) Wave-scoured hummocks and hollows on top of upper Wentlooge peat exposed on shore (ST 248 783). Spade 0.94 m tall.

Plate 8. Sedimentary facies of the Rumney Formation (trowel 0.28 m long; scale box 50 mm square). (1) Thin intraformational conglomerate (facies G_2) rests sharply on the Wentlooge Formation (handle of trowel) and passes up into facies M_1 (much burrowed) of the Rumney Formation (ST 239 779). (2) Facies S_1 overlying a thin development of G_2, partly obscured by modern beach sediment, capped by facies M_1. Mud-draped wave ripples occur at two horizons and the uppermost S_1 beds are cattle-trampled (ST 240 779). (3) Complex cross-beds of concretion sand (facies S_2) with a variety of coarser debris. Three thin mud drapes have been weathered back slightly. Sand body C (see figure 5 for location). (4) Mainly parallel laminated concretion sand with some wavy bedding (? large wave ripples) at the level of the pebbles. Sand body A (see figure 5 for location).



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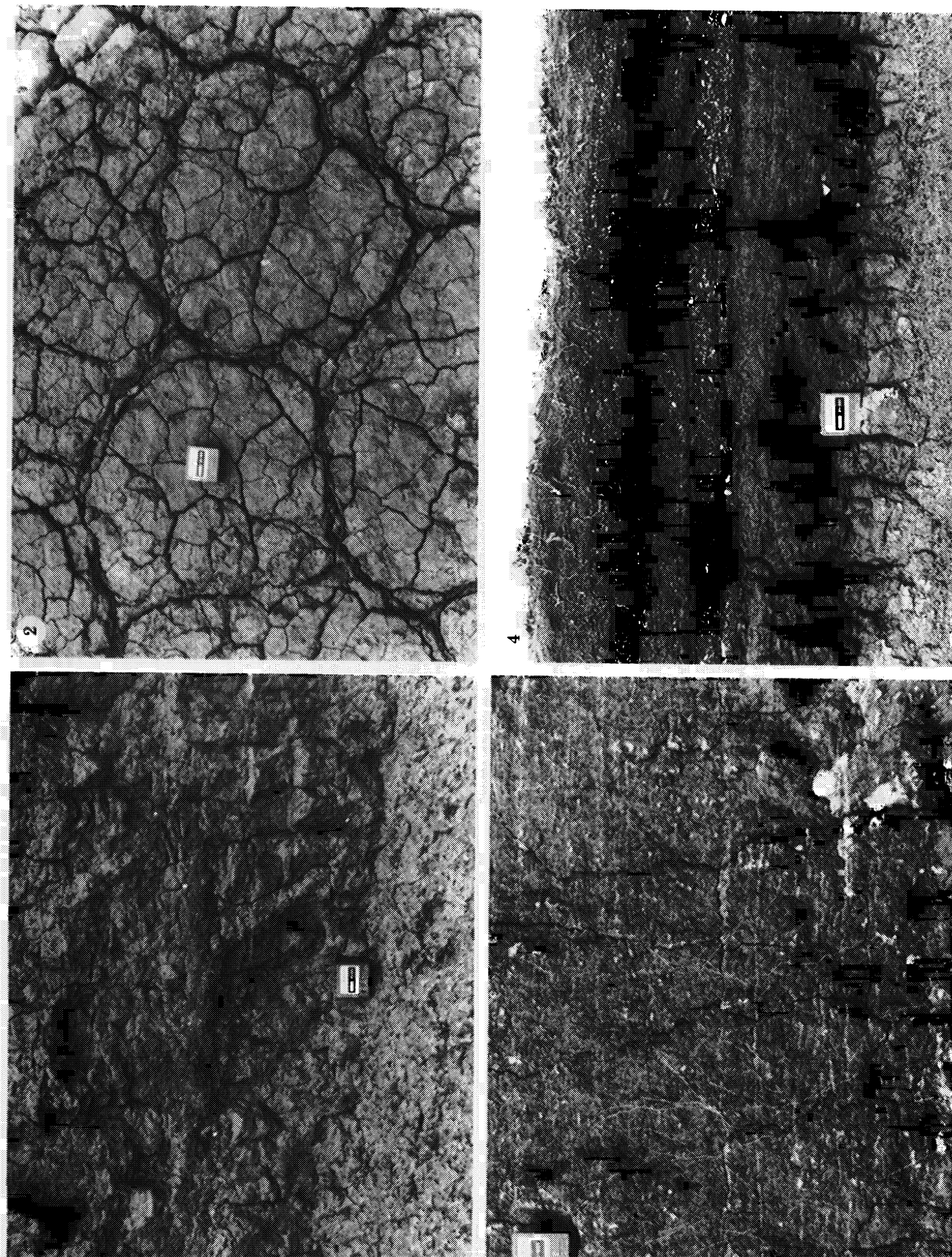

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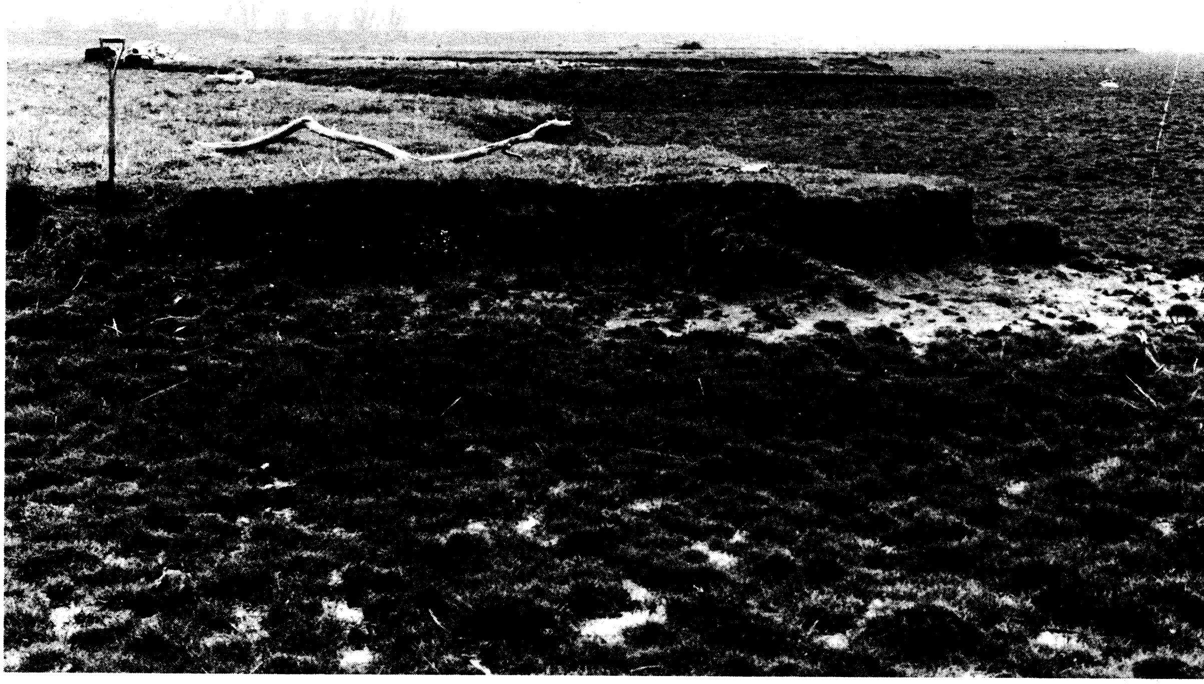

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For description see opposite.

finer grained and muddier. The upper part of the sheet consists of slightly pebbly to silty sands which overlie a smoothly curved erosion surface that cuts across the sands, muds and palaeosol beneath to form the margin of the concealed embayment. To judge from the shape of their bedding, these upper sands originated as mounds and bars. They pass southwestwards towards the axis of the inlet into well laminated sandy muds which in turn grade to silty clays of facies M_2. There is an upward passage into finer grained sediments (M_2).

Sheet B ranges across a set of narrow headlands and inlets concealed by the Rumney Formation (see figure 5). It consists of slightly pebbly sands and silty sands up to 0.25 m thick which rests on a sharp, level base 0.35 m above the eroded top of the Wentlooge palaeosol. The bedding is obscure, but the sheet appears to consist mainly of a series of large, sharp- to round-crested wave ripples reaching 0.4 m in apparent wavelength (see figure 9*b*). These are draped by silty sands and sandy silts which represent an upward passage into the overlying facies M_2.

The best-exposed sand body is sheet C (see figures 5, 9*c*). It lies at the buried site of a narrow inlet developed around one of the large Romano-British ditches, and is seen today at the head and on the bordering cliffs of a small sandy bay, Allen & Fulford's (1986) archaeological site C (transposed cultural debris chiefly of the Roman period). The base is sharp and level, except where the sands step abruptly up and down a few centimetres, as if infilling shallow flat-bottomed depressions. Approximately 0.75 m of facies M_2 lies below the sheet, in contrast to bodies A and B, and a maximum thickness of about 0.6 m of sand is visible at the head of the bay. The upper surface of the sand lens experienced scour on the flanks of the structure, but elsewhere there is a rapid gradation upward through muddy sands and then sandy muds into a variable development of facies M_2. There are signs on the flanks of the body that these muds also underwent erosion before the emplacement of some of the sandier beds present here in facies M_3.

Descriptions of plates 9–11

Plate 9. Microscopic features and photomicrographs of the Rumney Formation. (1–4) Calcian dolomite or dolomite rhombs. (1) 20 μm long; (2) 15 μm long; (3) 18 μm long; (4) 20 μm long. (5) Part of large dense authigenic concretion of siderite, clay minerals and manganiferous compounds with arborescent margin and central burrows or root channels, facies M_2, ordinary light, ×37. (6) Authigenic sideritic concretion in the form of multiple rings (inner also arborescent) developed around a burrow, facies M_2, ordinary light, ×60. (7) Mottled and ill-laminated silty clays of facies M_1 with burrows and scattered foraminifera, ordinary light, ×23. (8) Silty clays of facies M_2 with some silty laminae, abundant burrows and root channels, and scattered sideritic concretions, ordinary light, ×23. (9) Slightly rounded coal grain, 140 μm long. (10) Slightly rounded, sherd-like coal grain, 220 μm long. (11) Equidimensional coal grain, 195 μm across. (12) Sharply angular sherd-like coal particle, 240 μm long. (13–16) Irregular vesicular grains of coke. (13) 120 μm long; (14) 150 μm long; (15) 135 μm long; (16) 210 μm long. (17–20) Smooth or vesicular and in two cases paired aluminosilicate fly-ash spherules. (17) 75 μm long, (18) 145 μm long, (19) 115 μm long; (20) 105 μm long.

Plate 10. Sedimentary features and facies of the Rumney Formation. Scale box 50 mm square. (1) Poorly laminated silty clays of facies M_1 divided by an erosively based lens of slightly pebbly and shelly concretion sand (ST 239 778). Scale box rests on base of formation. (2) Mud-filled desiccation cracks formed contemporaneously with sedimentation, facies M_1 (ST 244 782). (3) Silt- and sand-striped silty clays of facies M_2 (ST 245 782). (4) Grey silty clays of facies M_3 with included strips and bands of shelly coarse debris (see text for details of constituents) (ST 244 782).

Plate 11. The Northwick Formation and its relationships, Peterstone Great Wharf. Spade 0.94 m tall. (1) Northwick formation and surface (right) banked against a deeply embayed cliff cut in the Rumney surface and formation (left) (ST 257 792). View towards NNE. (2) The seaward margin of the Northwick Surface (ST 263 792). View towards NE. The ragged cliff consists mainly of the Northwick Formation, the paler coloured Wentlooge and Rumney beds being thinly exposed in the bottoms of the wave-scoured gullies.

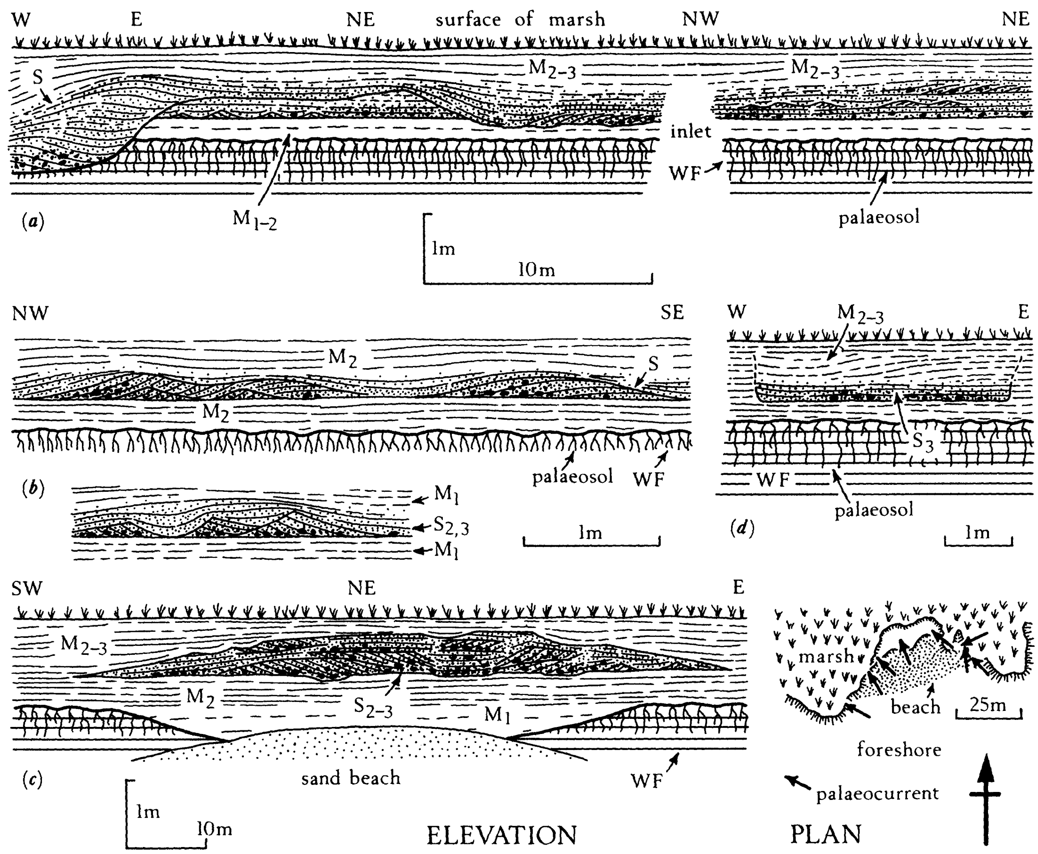

FIGURE 9. Features of bodies of concretion sand preserved in the Rumney Formation (see figure 5 for location and relationships). (*a*) Simplified profile in sand body A, traced (from the W) around a headland and into a wide inlet. (*b*) Two details from sand body B. (*c*) Sand body C in elevation and plan, together with palaeocurrents measured from the landward-facing cross-bedding. (*d*) Sand body D in cross-section.

The sands forming the lens contain all of the gravel-size elements (mainly cultural in origin) listed above and are chiefly cross-bedded (see figure 9*c*). The cross-bedding sets (see (3) of plate 8) are all bar-like, with frequent internal discordances and, toward the landward side of the sand body, mud-draped foresets. On the flanks they are solitary but are piled two or three above the other where the sand sheet is thickest. Readings of foreset azimuths in eight different bars gave a vector mean of 316° (range 245–355°), that is, landward and at right angles to the general trend of the shore. A little parallel-laminated sand is also present, chiefly in the upper levels of the sand body.

Sheet C yielded not only abraded Romano-British pottery sherds, but also the strap handle of a 13th–14th century jug (Allen & Fulford 1986). It is therefore not earlier than early mediaeval in date and probably rather younger, in view of the occurrence near the central breakwater of a 16th–17th century rim sherd at the contact between the Wentlooge palaeosol and the Rumney Formation (Allen & Fulford 1986).

When storms coincide with high tides, quantities of gravel and sand are scoured up from the bay exposing sheet C and flung on to the salting above (Rumney Surface) to form large linear to lobate bars. These bars, ranging inland over the sward for up to 25 m, are flat structures with landward-facing avalanche slopes up to 0.35 m high where they encroach on shallow marsh pans. It is partly as such spreads that Romano-British pottery and coins continue to be reworked on Rumney Great Wharf (see also Boon 1980).

Sheet D is not only small but differs in another major respect from the others (see figures 5, 9*d*). Its level base lies approximately 0.3 m above the top of the Wentlooge palaeosol but the top and bottom are parallel and the sides nearly vertical. The body consists of slightly pebbly parallel laminated sands inclined inland at 3–5°. Sheet D probably records a spread of sand carried at high tide by powerful waves to the extreme inland limits of a narrow inlet, such as can be seen in places today on Rumney Great Wharf.

(*h*) *The Rumney Formation at Peterstone Great Wharf*

The Rumney Formation here is largely concealed beneath an extensive blanket of the Northwick Formation (see figure 3).

The lowermost beds, overlying an uneven surface scoured into the Wentlooge Formation, are sporadically exposed at the base of the low but deeply dissected cliff that limits the Northwick Formation on the seaward side of Peterstone Great Wharf. The sediments visible are chiefly ill-stratified, pink-weathering silty clays with scattered *S. plana* in growth position (facies M_1), accompanied here and there by spreads of shelly and pebbly concretion sand, mainly at the erosional base. These deposits are in turn erosively succeeded by the grey-coloured Northwick Formation.

The highest beds of the Rumney Formation appear on the unburied remnants of a deeply embayed cliff on the marsh immediately adjoining the southwestern portion of the modern sea defence (see figure 3 and (1) of plate 11). Here a thin development of facies M_3 emerges from beneath the Rumney Surface, together with a little pink silty clay of facies M_2.

6. Awre and Northwick Formations

Inextensive developments of the Awre Surface (0.1–0.2 m below the Rumney Surface) fringe the lower reaches of the Rhymney River at Little Wharf and Pengam Moors (see figures 1 and 3) and occur within some of the larger gullies that reach inland across Rumney Great Wharf. The Awre beds are poorly exposed on Rumney Great Wharf and were not examined in detail. They are at least 0.75 m thick and consist of well laminated mainly grey silty-sandy clays with abundant roots and rootlets, some invertebrate burrows and, towards the top, occasional seams of well rounded coal, coke and other debris. Dispersions reveal an association of foraminifera, sponge spicules and diatoms similar to that in the upper Rumney Formation (see above).

Aside from the fragments of the Rumney Surface noted above, most of Peterstone Great Wharf is occupied by the *Spartina*-covered Northwick Surface (0.5 m, or more, below the Rumney Surface), underlain by the Northwick Formation (see figure 3 and (2) of plate 11). This deposit was not examined in detail. If the Wentlooge Formation here was eroded to the same extent as on Rumney Great Wharf, the Northwick beds may be 1.5–2 m thick near the seabank opposite Peterstone Wentlooge. To the northeast and southwest, however, the Northwick Formation gradually thins as the Northwick Surface descends towards the Wentlooge peat. At the outer edge of the salt marsh, up to 350 m away from the seabank, the Northwick Formation (see (2) of plate 11) is exposed above the Wentlooge and Rumney beds for up to 0.75 m on a ragged cliff reaching 1 m in height. The uneven and sharply erosional base is overlain by patches of shelly to pebbly concretion sand. Above come poorly to moderately well laminated, dark grey silty clays cut by a profusion of root channels and burrows, which yield occasional specimens of *M. balthica* and *S. plana* in life position. Under the microscope, rich assemblages of foraminifera (indigenous and far-travelled species), siliceous sponge spicules, and mixed brackish and marine diatoms are seen. Coal and fly-ash particles abound.

The presence of fly-ash indicates that the Northwick Formation at Peterstone Great Wharf is a very late modern deposit. In confirmation, a basal sample of *S. plana* shells gave an apparent radiocarbon age (relative to 1950) of 390 ± 40 years BP (N.E.R.C. Radiocarbon Laboratory SRR-2676). The true age of the shell sample becomes 20 ± 57 years BP, that is, 1930 or thereabouts, on applying Harkness's (1983) latitude-related correction for ^{14}C deficiency.

7. Discussion

(*a*) *Conditions of deposition of the Rumney Formation*

The sedimentary processes operating today on the Rumney–Peterstone shore, together with the deposits being accumulated there, afford a more than sufficient model for the interpretation of the Rumney Formation.

A close match in both stratigraphical position and general character with the gravel facies (G_1, G_2), and with the sand facies S_1 and some occurrences of S_3, is afforded by the gravels, pebbly concretion sands, and concretion sands being deposited today in the embayments of the modern coast and locally on top of the peat wave-cut platform. Erosion of the Wentlooge and Rumney beds on the mud cliff is yielding gravel sized lumps of silty clay which, under further wave action, become rounded and incorporated with other debris to form an apron of partly intraformational coarse sediment along the cliff base. Outward over the wave-cut platform, these coarse deposits grade into either smooth or wave-rippled sheets of concretion sand (windy conditions) interbedded with millimetre- to centimetre-scale layers of mud (fair weather). The heads of the shallower and also the smaller embayments contain thin pocket beaches composed of gravelly sand and shelly sand at the bottom of the beach and better sorted and finer sand toward the top.

In the narrower and more deeply penetrating inlets, wave action during storms and the higher spring tides creates solitary, landward-facing bars similar in scale and orientation to the solitary cross-bedding sets assigned to facies S_2, located within buried inlets. These bars survive over many tides and, after becoming draped with mud during fair weather, may be reactivated on the reappearance of windy conditions.

The silty clays at present rapidly accumulating on the lower parts of the Northwick Surface and on the adjoining unvegetated areas are closely similar in composition, and broadly similar in texture, to facies M_1 and M_2 in the Rumney Formation. Texturally, these poorly to moderately well laminated muds are closest to facies M_1, and the two also share the occurrence of *S. plana* and *M. balthica* in life position. Except for its pink colour and slightly finer grain size, facies M_2 is otherwise similar to facies M_3, which today is accumulating beneath a high salt marsh as a well laminated silty-sandy clay with transported coarse debris, in response to the higher spring tides and to storms. Facies M_2 would therefore seem to be a salt-marsh deposit, in contrast to M_1 which seems to represent a high intertidal mudflat environment closer to the mean level of neap high waters. A further close parallel, confirming the attribution of M_2 to a salt-marsh environment, is afforded by the excellent match between the sand lobes cast up by storms today from the wider inlets on to the Rumney Surface, and the level-based sand sheets with either large wave ripples or landward-facing cross-bedding visible at several places on the mud cliff. In future, it may even prove possible to link some of these buried sand bodies to major storm surges, those of 1607 and 1703 being obvious candidates (Brooks & Glasspoole 1928).

In summary, the Rumney Formation seems to be a regressive–transgressive unit. The regressive phase, considering stratigraphical relationships (see figure 5), is represented by the growth of intertidal mud flats (facies M_1) and their eventual colonization by plants to form a salt-marsh (early facies M_2). The evidence for a subsequent transgressive phase, expressed wholly within the context of this salt-marsh environment, is taken to be (i) the upward increase in grain size (late M_2, M_3) (see figure 7), (ii) the appearance of inlet-related sand sheets within M_2 (see figure 9), and (iii) the cutting back of the mud cliff to its present position (facies M_3), where inlet-related sand spreads continue to be formed but in positions landward of the older ones.

(*b*) *Shoreline movements*

The Rumney Formation and its associated strata give evidence at Rumney Great Wharf and Peterstone Great Wharf for a number of substantial shoreline oscillations over the last few thousand years.

The mid or late Sub-boreal to early Subatlantic freshwater peat with broad-leaved trees toward the top of the Wentlooge Formation finds parallels elsewhere in the Severn Estuary (Beckinsale & Richardson 1964; Seddon 1964; Hawkins 1971; Locke 1971; Murray & Hawkins 1976), as well as on other British coasts (Godwin 1943). It clearly represents a period of regression, but where the coastline lay off Rumney and Peterstone is not clear. The succeeding upper Wentlooge Formation, with its varied marine microfauna, represents a transgression and the retreat of the coastline to a line inland, perhaps far inland, of the present shore. However, the fact that large-scale drainage and presumed embankment could occur early in the Roman period (Allen & Fulford 1986), implies that the post-peat invasion was quickly reversed in favour of the build-up of mud to the level of a marsh, perhaps salt only in a seaward zone in view of its likely width. Where this Roman strand was positioned is also uncertain, but it cannot have lain nearer than 500 m seaward of the present defence, in view of the distribution of Romano-British ditches (see figure 3), and could have stood off by a kilometre or more, on account of the relatively fine grade of the exposed upper Wentlooge Formation and the signs of terrestrial influence (*Phragmites*, *Cepaea nemoralis*).

The headlands and embayments smothered by the Rumney Formation point to the occurrence of another major but this time erosive transgression which, some time after the Roman period and before late mediaeval times, brought the coastline at Rumney and Peterstone to a general line in places further inland even than the present mud cliff. No pottery younger than the mid 4th century has so far been recovered from the sealed Romano-British ditches exposed on Rumney Great Wharf, and the lowest deposits in the Rumney Formation are at least of 15th–16th century date. The presumed Romano-British sea defence was destroyed during this event; a powerful influence on the morphology of the retreating coast was exerted by the location and alignment of the many surviving drainage ditches thus exposed to wave attack. A deeply embayed mud cliff roughly 2 m high would have been visible, the flat-topped headlands being capped by a root-bound and so resistant soil, at times exposed to wave scour and consequently ridged like the peat today.

This post-Roman coastal retreat may have been even briefer than the above datings suggest. The Roman seabank could have remained effective into sub-Roman and even Saxon times, and the 12th century date of Peterstone Wentlooge church implies that a viable defence, although not necessarily on the site of the present one, existed in the early mediaeval period (Allen & Fulford 1986). On pottery evidence the present defence is not younger than the 16th–17th century.

The earlier sediments of the Rumney Formation point to the re-establishment of high intertidal mudflats and salt marshes, and to the readvance of the shore, although perhaps on a lesser horizontal scale than before.

The subsequent underlying trend of shoreline movement has been transgressive, for the modern coastal cliffs both transect the Rumney Formation and re-expose the late mediaeval to early modern shoreline. Superimposed on this underlying movement, however, were at least two subordinate transgressive–regressive episodes of an as yet uncertain but apparently short time scale.

The best-defined and youngest of these episodes involves the Northwick Formation. In the early 1880s the Rumney Surface at Peterstone Great Wharf ranged about 120 m further out from its present position (Ordnance Survey six-inch map of 1886). A deeply embayed cliff defined the seaward limit of this surface, many of its numerous inlets aligning precisely with Romano-British ditches surviving on the adjoining Wentlooge Level. Of the Northwick Formation there is no sign. A similar coastline, again standing further off than its present line, was mapped at Rumney Great Wharf. By 1910–12, when the second edition of the map appeared, a retreat of the mud cliff at a rate of the order of 1 m a^{-1} had brought the shore at both places significantly nearer the seabank. There is again no sign of the Northwick Formation. The next reliable edition (1970) shows the edge of the Rumney Surface a further 50–120 m landward, and the Northwick Formation as already emplaced off Peterstone Wentlooge. The proven late 19th century transgression, creating a wave-cut platform and now largely buried cliff (see (1) of plate 11), was thus reversed some time in the present century in favour of the regressive depositional episode that continues to promote the upward building and spread along the shore of the Northwick Formation. A supporting and independent estimate of the timing of the change-over comes from the above-cited radiocarbon age of shells from the base of the formation.

The Awre Formation and Awre Surface at Rumney Great Wharf and its vicinity antedate the Northwick elements and also denote a transgressive–regressive episode. When the erosional event occurred, however, is not yet known, but it may be presumed to date from the 18th or 19th century, in view of the relationship of the Awre to the Rumney and Northwick beds.

(c) *Controls on shoreline movement*

What factors control the continuing shoreline oscillations described from the Rumney and Peterstone salt marshes? Are these factors external to the Severn Estuary, and therefore of possibly nationwide significance, or are they inherent in the régime of this unusually dynamic estuary?

Currents are clearly involved, as the inferred oscillations require either the removal or emplacement of substantial volumes of muddy sediment. The only agencies capable of effecting such transports are the estuarine tidal streams and waves. The former are notoriously vigorous, peaking in excess of 1 m s^{-1} in many places (Crickmore 1982; Uncles 1984). Being large and open to the west and southwest, the estuary experiences at times a moderately severe wave climate (Shuttler 1982). In the inner Bristol Channel the modal wave period is 3–4 s and a significant wave height of 1 m is exceeded 15% of the time.

Tidal currents probably exert little direct influence on shoreline movement, since these currents are weak to lacking at the times when the estuary is filled to between the levels of the high mud flats (approximately mean high-water neaps) and the uppermost salt marshes (approximately mean high-water springs), represented wholly or in part by the upper Wentlooge, Rumney, Awre and Northwick beds of the Wentlooge Level. Wind waves, however, are likely at these times to be at their most effective, for the water depth and fetch are then greatest. Two effects seem especially important. At Rumney Great Wharf, waves at high tide undermine the cliff and topple large blocks of root-bound muddy sediment on to the foreshore, particularly when the tide is moving from neaps to springs and the marsh deposits have become deeply fissured through prolonged drying. The less obvious but perhaps more important effect concerns the ability of wave-induced bottom currents to resuspend mud or prevent its deposition altogether as their strength is increased, as shown theoretically by Thimakorn (1984) and by observation of many natural systems (Shideler 1984; Gabrielson & Lukatelich 1985; Ward 1985).

The indication that wave rather than tidal currents determine what happens in the estuarine upper intertidal zone suggests that the shoreline oscillations documented above were determined by the factor that controls the wave climate, namely, the weather. An increase over the medium term in the annual frequency of westerly and southwesterly winds should promote a net loss of sediment, which could be expressed by the retreat of a marsh cliff. A decrease, however, should promote a net gain, as less mud is resuspended than deposited, with the consequent build up in the upper intertidal zone of a mud blanket and eventually a marsh.

Waves may alternatively control shoreline movements ultimately through the operation of a tidal cause. The estuary off the Wentlooge Level today is comparatively deep, with the result that waves at high water are little damped; it is perhaps not surprising that this coast is experiencing widespread erosion. A depositional régime could result, however, if the tidal streams were to shift southwestward the large shoals known as the Welsh Grounds and Middle Grounds. The waves that reached the coast then would have been significantly damped in crossing the sand banks.

A third possibility is that the shoreline oscillations reflect a self-regulating cycle driven by the changing role of waves in the upper intertidal zone. As a mudflat builds up towards the level of mean high-water springs, it becomes (i) exposed increasingly frequently and for longer periods, leading to increasing fissuring through desiccation; and (ii) more densely vegetated and strongly bonded by roots, promoting a tendency to failure in large masses. Beyond a critical level of upbuilding, a cliff may inevitably form on the seaward side of a marsh, and thence propagate inland. The creation of the cliff, however, means that deep water prevails offshore at high tide and that a tendency towards deposition is restored, repeating the cycle.

These notions all find some support. For example, Lamb (1972, 1977) points to small but significant medium-term changes of wind régime in Britain, and Hawkins (1979) shows that sand shoals in the Severn Estuary are subject to considerable movement. However, a choice between them is not possible without evidence from the estuary as a whole. What cannot be denied is that the shoreline of the Wentlooge Level has experienced more than one substantial retreat and advance at a time when sea level has by comparison changed but little (Shennan 1983). The possibility that *small* fluctuations of sea level (Shennan *et al.* 1983) controlled these movements cannot be entirely excluded, but it is certainly difficult at present to see how these could have shaped the bold mud cliffs and blankets described here.

8. Conclusions

Four lithostratigraphic units with complex relationships make up the late Flandrian sequence exposed on the shore of the Wentlooge Level northeast of Cardiff. The most important are the (upper) Wentlooge Formation and the succeeding Rumney Formation.

The (upper) Wentlooge Formation accumulated on high tidal mudflats and marshes to give an extensive wetland that was reclaimed during the Roman period through the excavation of a reticulate system of deep drainage ditches and the presumed construction of a seabank. A soil began to horizonate on the former wetland.

At some time after the Roman period but before late medieval times, the coastline retreated landward, perhaps by a total extent of about 1 km, with the result that the presumed Roman seabank was destroyed and the ditches became open to the sea.

The extreme landward position of the post-Roman coast is marked by a bold mud cliff shaped into flat-topped headlands capped by the soil, between which lie inlets and broad embayments fashioned by the widening out of the Roman drainage ditches.

The Rumney Formation infills the inlets and embayments and smothers the headlands of the post-Roman coastline. The earlier part of the formation records the upbuilding and seaward movement of the strand. Deposition in the embayments began in the 15th century, on high tidal mudflats passing up into the beginnings of a salt marsh. The headlands were not smothered for a further 100–200 years, by which time the marsh had become firmly established.

The later Rumney Formation, extending up to the present time, reflects an overall landward retreat of the shore. It is formed of marsh muds which include sand sheets similar to, but lying further seaward than, landward-facing sand bars cast up today on to the marsh top during high tides and storms.

Two other lithostratigraphic units, the Awre Formation and the Northwick Formation, are locally present on the Wentlooge Level. These began to be deposited during the later part of the history of the Rumney Formation, the Northwick beds dating from the present century. Stratigraphical relationships show that these units also record the landward propagation of a bold mud cliff, followed by its partial burial under first mudflat and then marsh deposits, causing an outward shift of the strand.

The movements of the muddy coastline can be explained by changes in the role and power of waves in the estuary at times of high tide, governed either by external agencies or by factors inherent in the estuarine regime.

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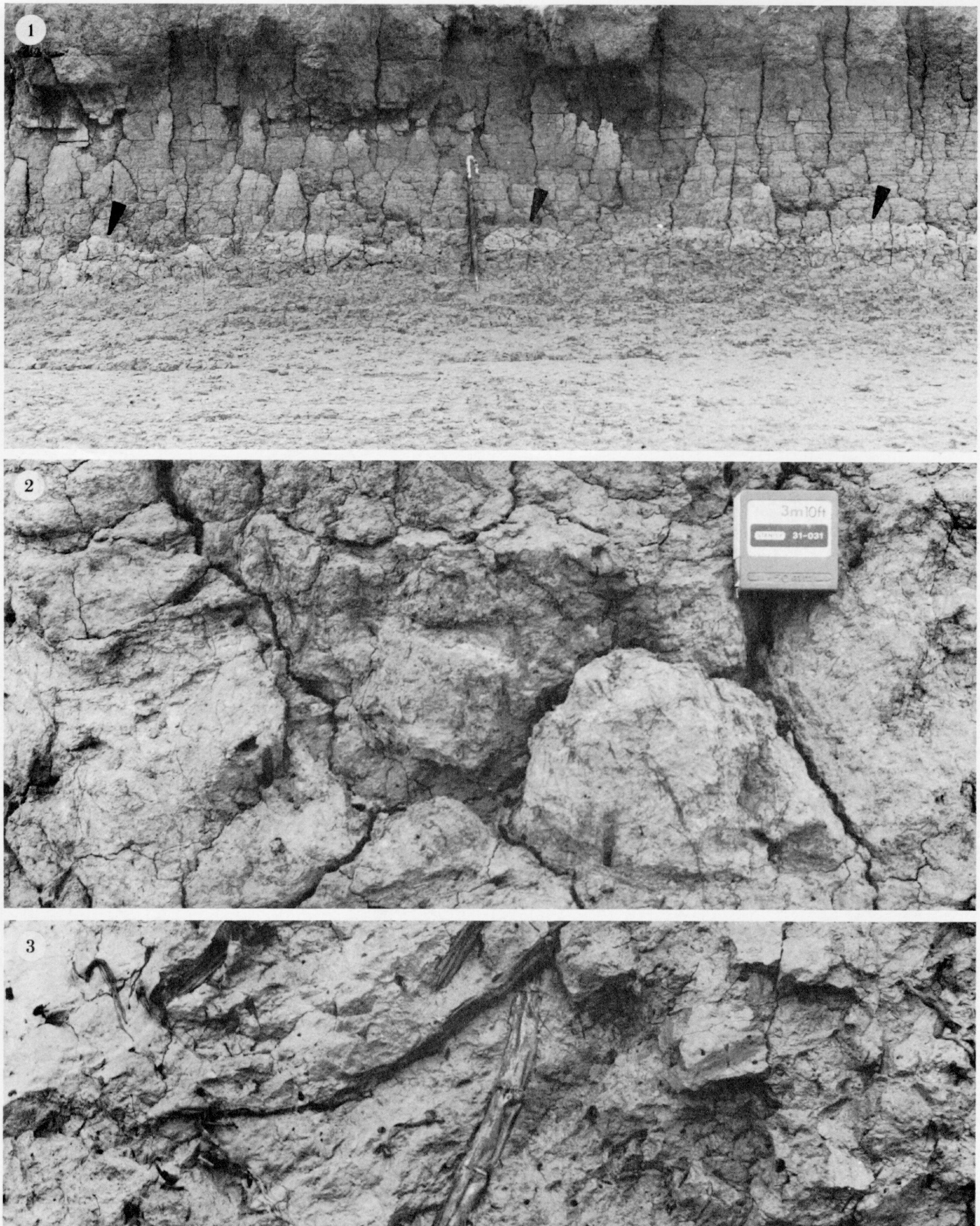

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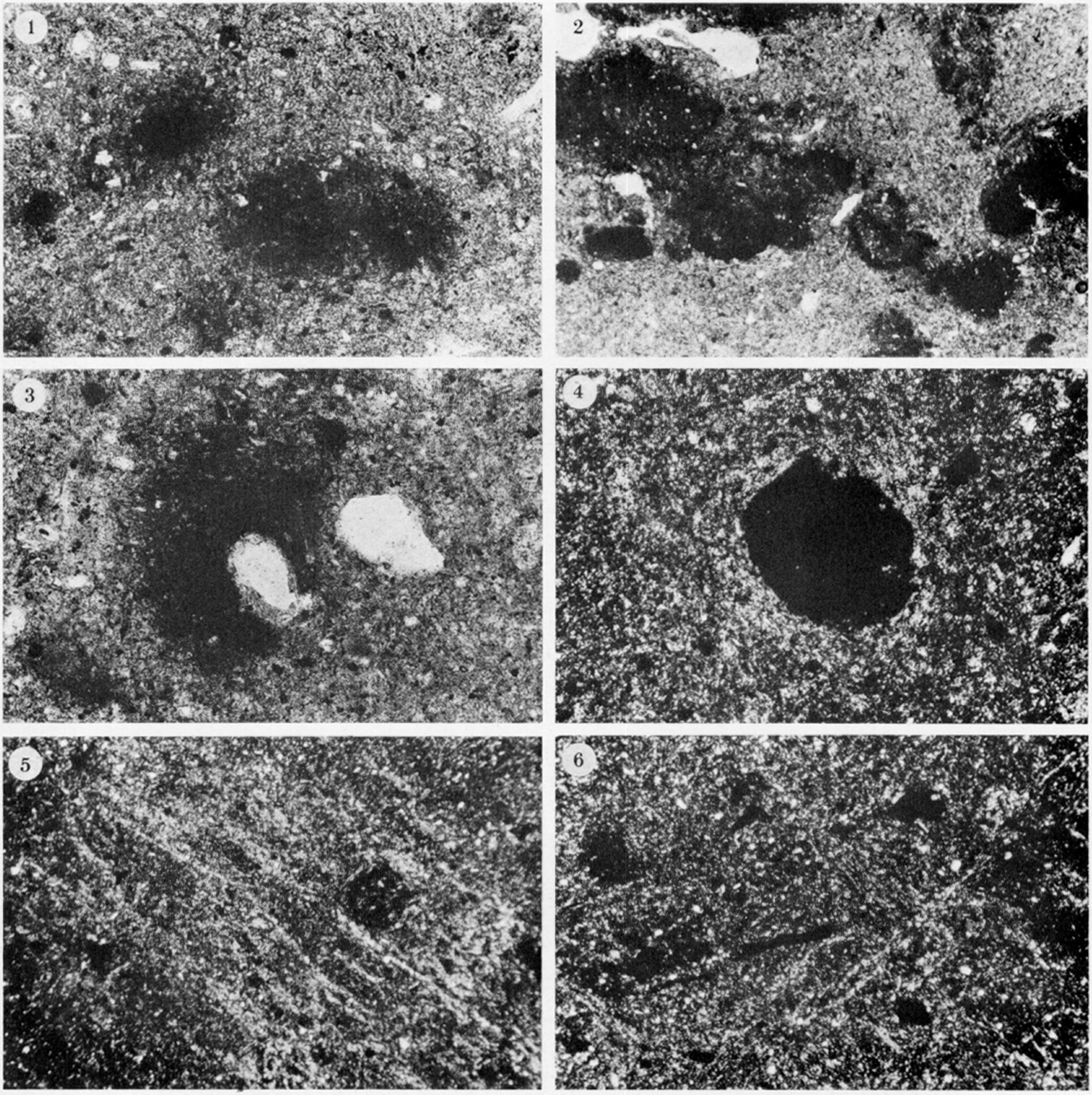
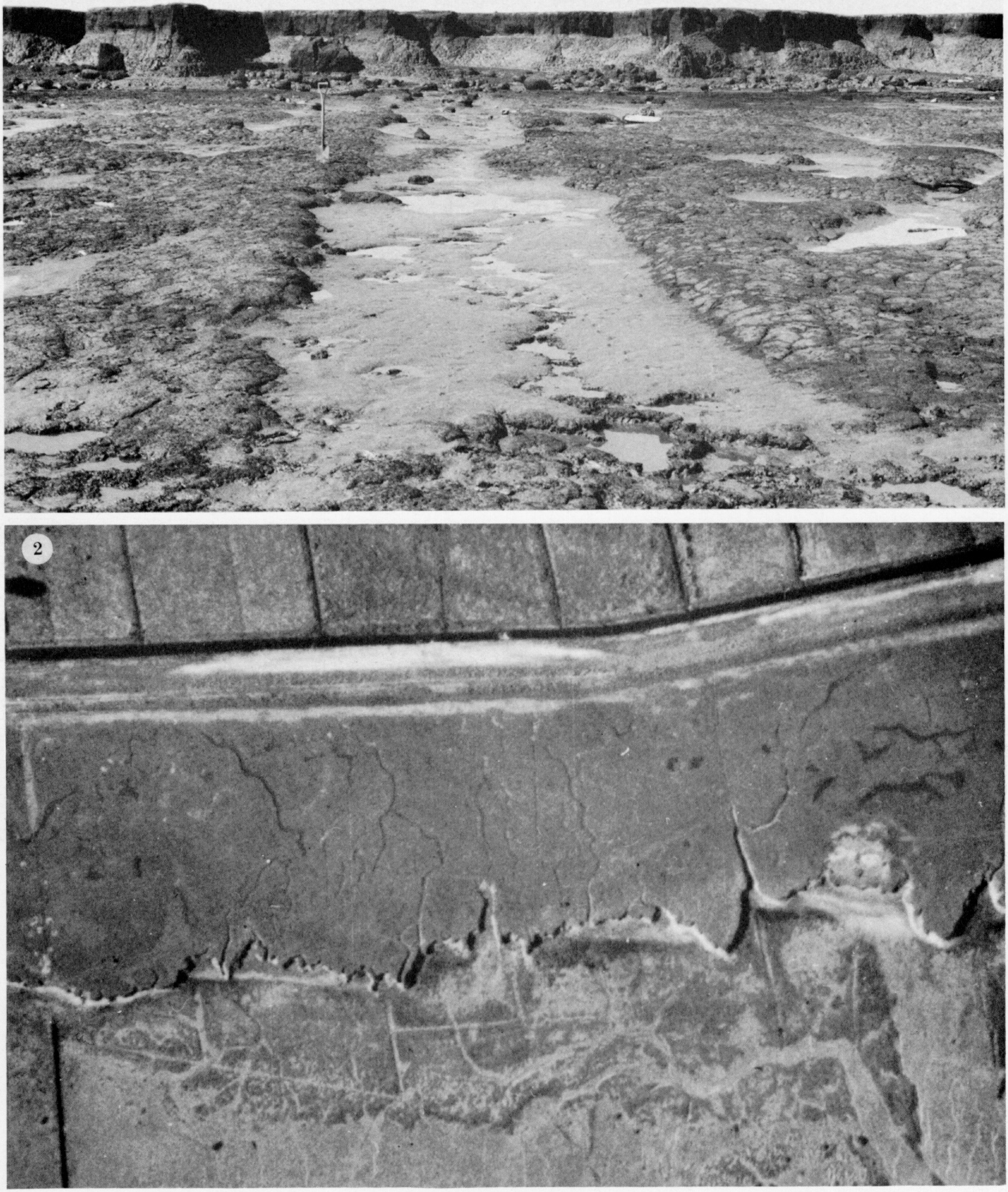


PLATE 2. Photomicrographs from the Wentlooge palaeosol. (1) Dark-coloured authigenic sideritic concretions in groundmass of clay minerals and quartz silt, pale horizon, ordinary light ×60. (2) Ring-like and diffuse-margined authigenic sideritic concretions, pale horizon, ordinary light, ×29. (3) Diffuse-margined authigenic sideritic concretion concentrated around a burrow or root channel, pale horizon, oridinary light, ×60. (4) Reoriented clay-mineral fabric around a burrow, pale horizon, doubly polarized light, ×97. (5) Masepic fabric displayed by clay minerals, dark horizon, doubly polarized light, ×29. (6) Bimasepic fabric shown by clay minerals, dark horizon, doubly polarized light, ×37.



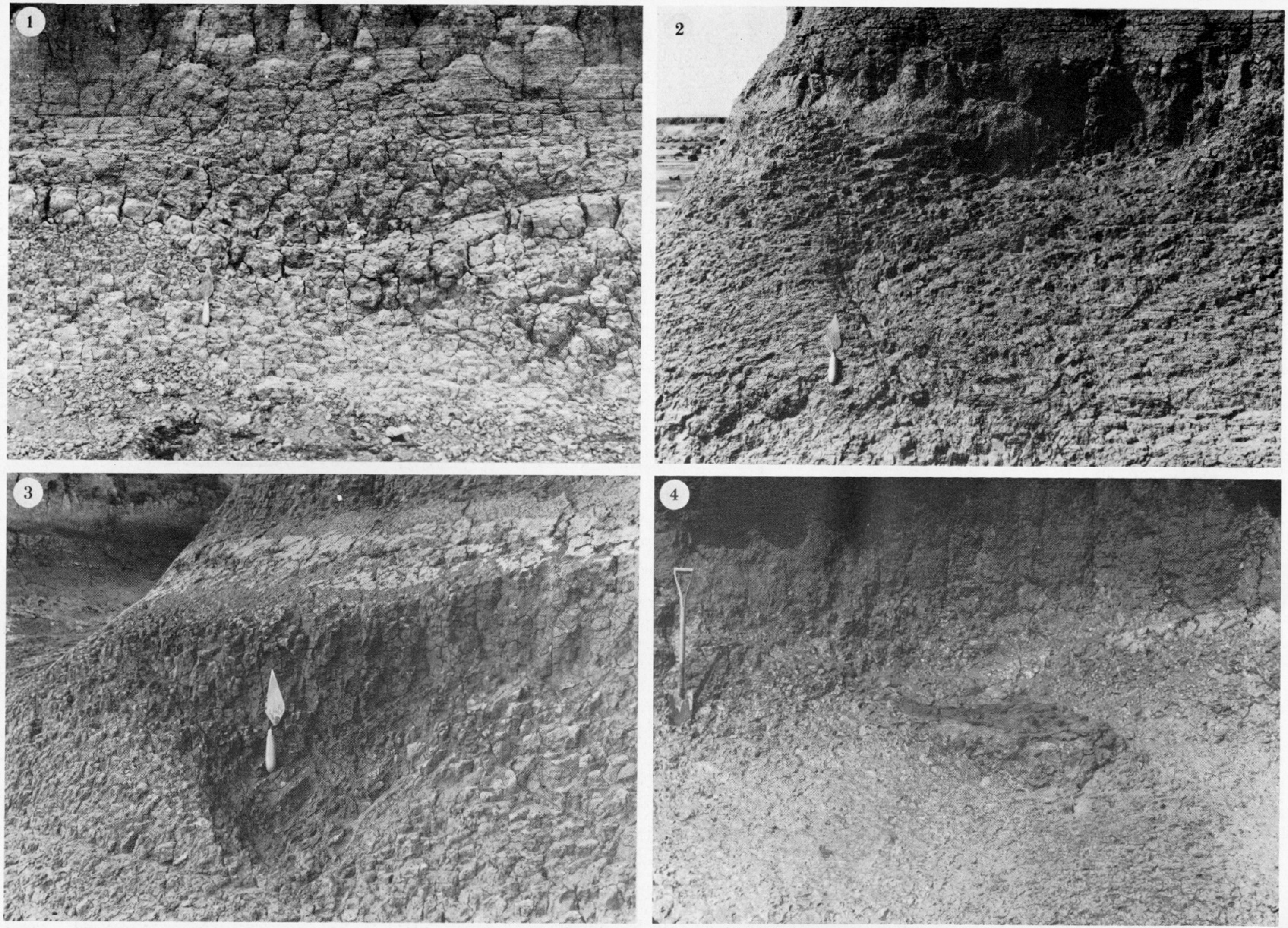
For description see p. 167.

For description see opposite.

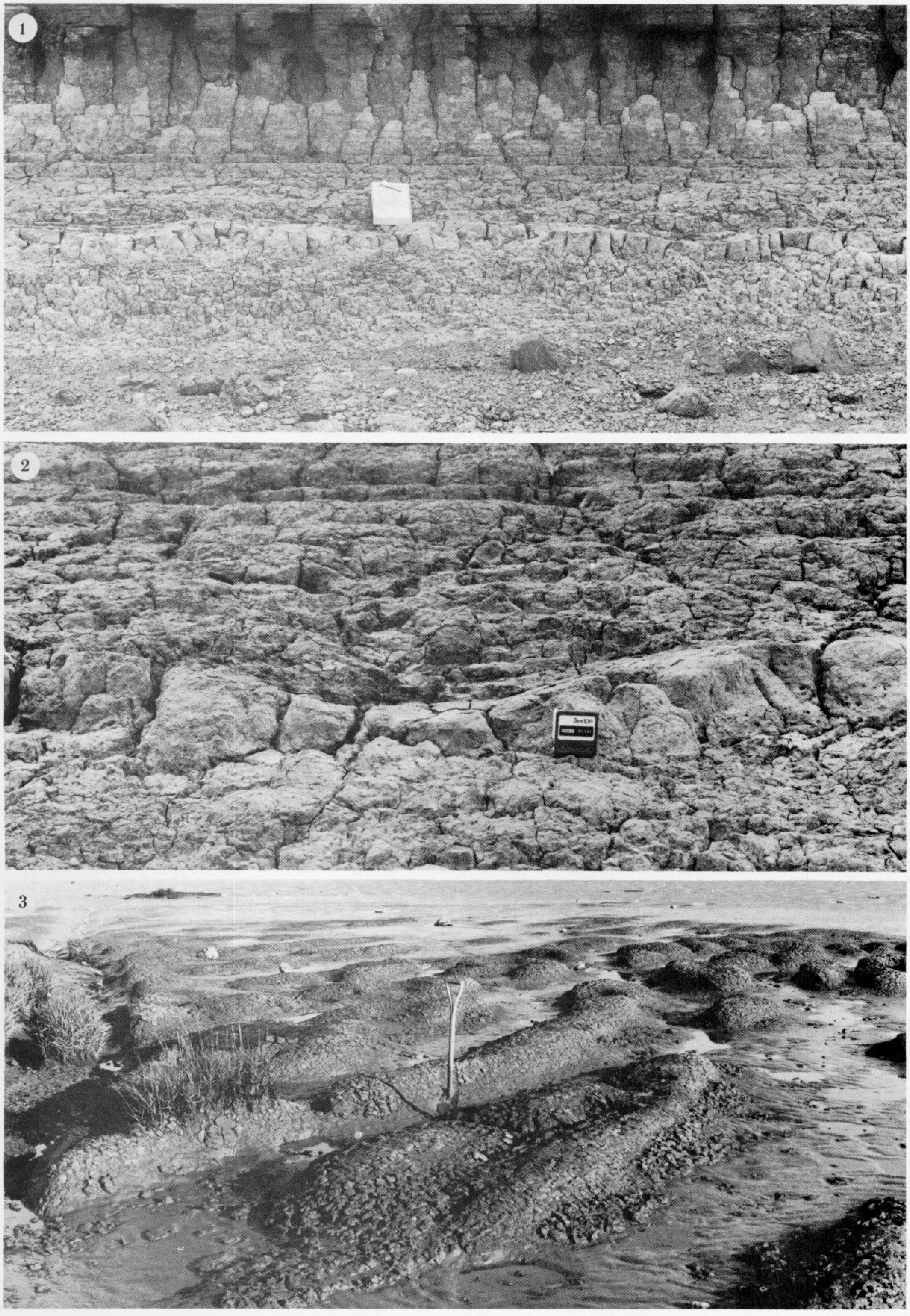
1

2

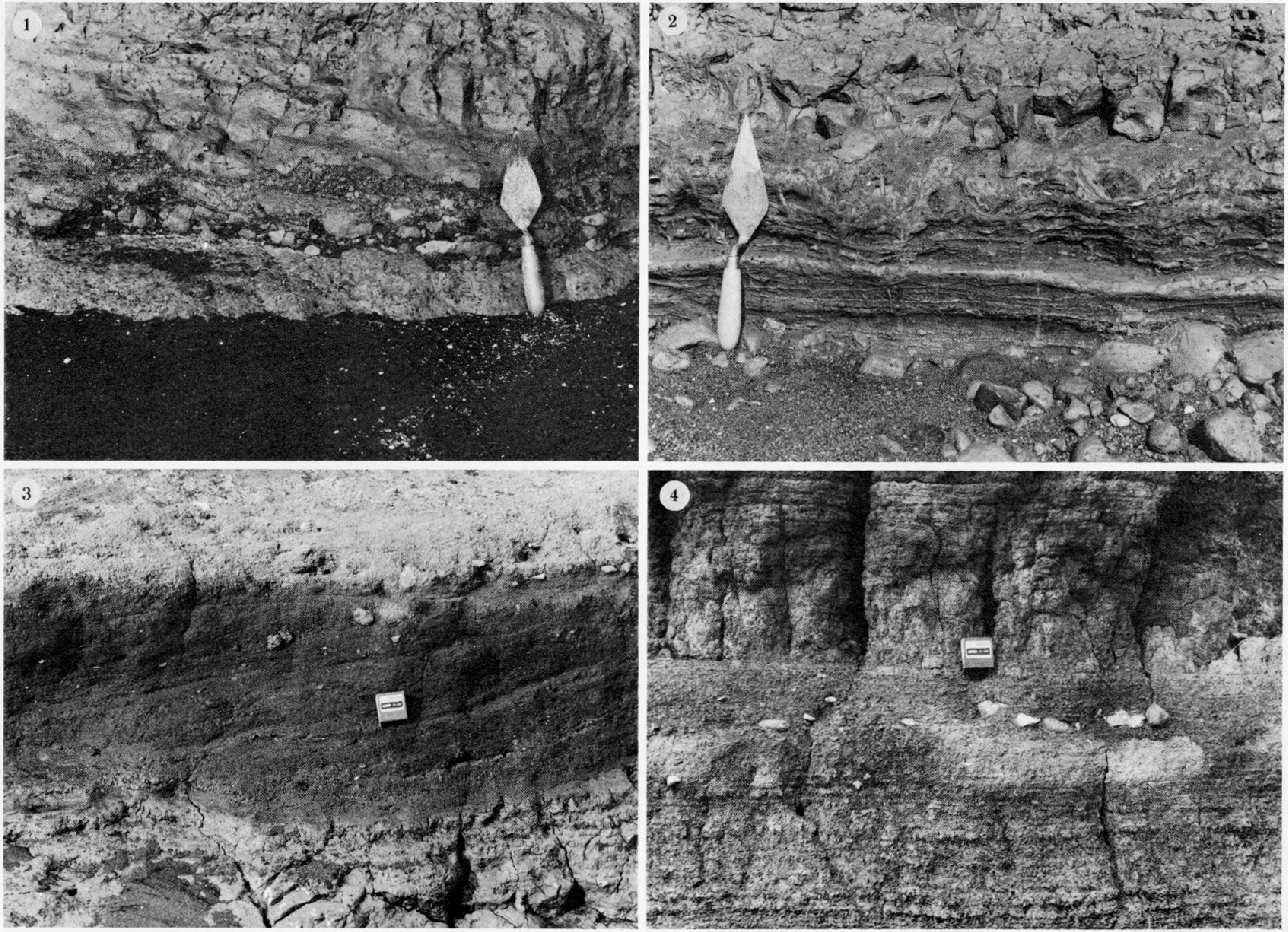
For description see opposite.



For description see p. 174.



For description see facing plate 8.



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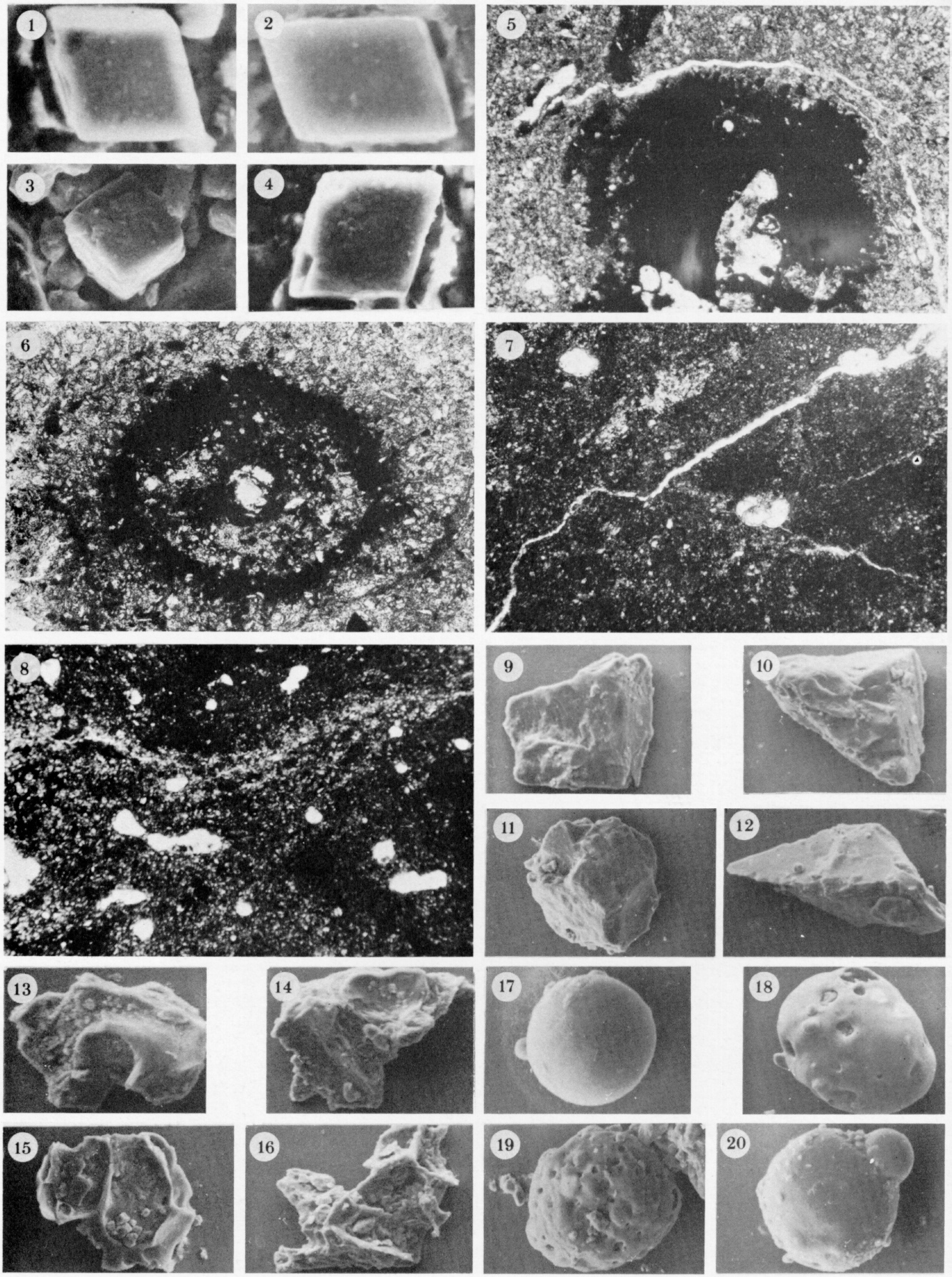
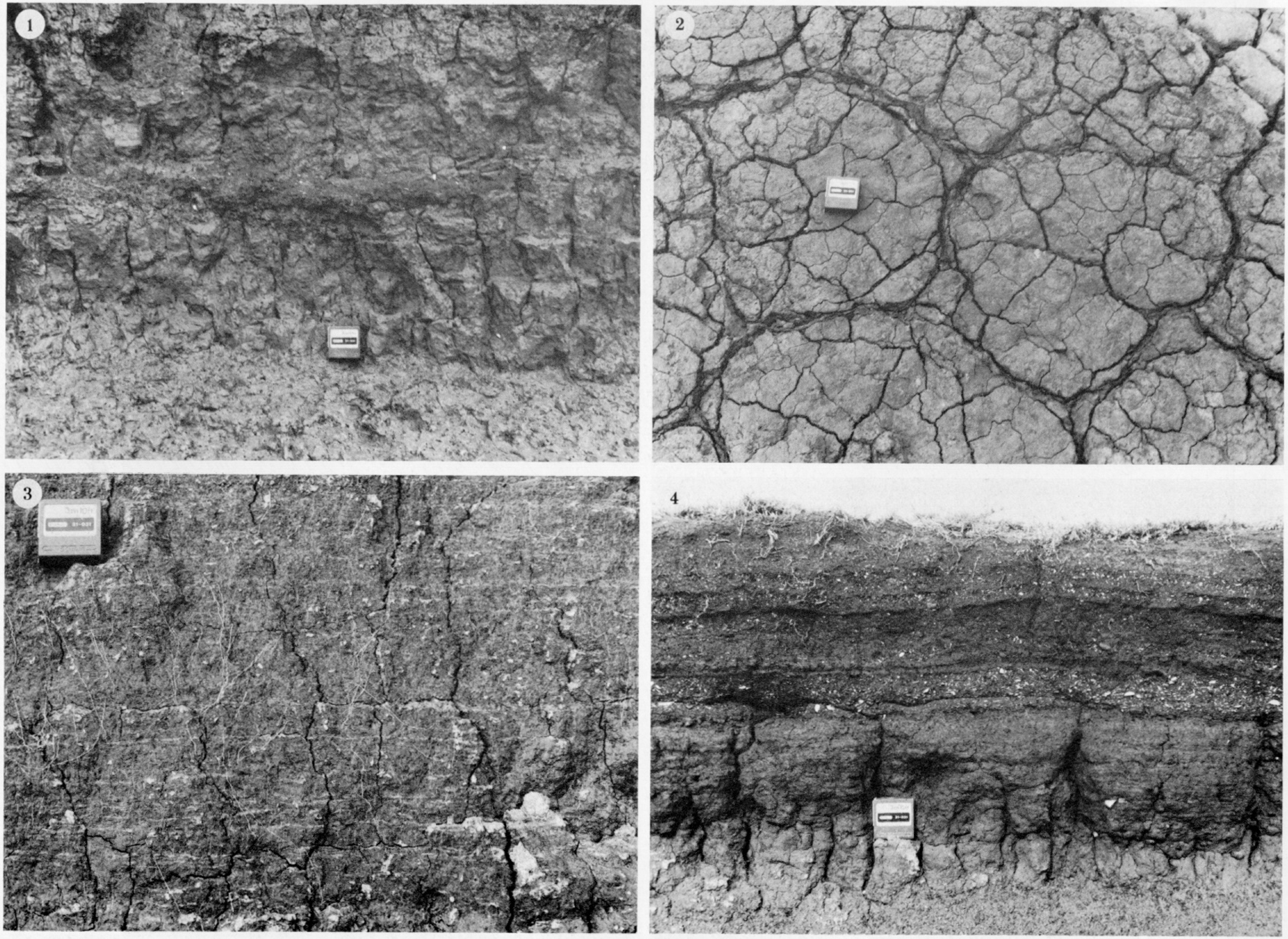


For description see p. 175.



For description see p. 175.

1

2

For description see opposite.