PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Climate, Soil and Man [and Discussion]

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Climate, soil and man

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[Plate 5]

The practice of agriculture, whether pastoral or arable, represents an imposed change of the ecosystem. Ecosystems vary in their stability and such influences, by altering the components of microclimate and vegetation, may produce effects which early man may not have foreseen. In certain circumstances of climate and soil, even swiddening can produce detectable effects in soil chemistry, as reflected in the soil profile, and in the secondary vegetation. Once clearance and land use become more extensive, change of the soil–vegetation complex may become more marked, leading to soil degradation and even wind or water erosion. Accompanying changes in microclimate may make it more difficult for regeneration processes to take place. The continued impact of periodical burning and the grazing of man's chosen domestic stock can produce changes no less important than those brought about by arable farming.

One of the fundamental principles of ecology is succession; that is, the natural progression of communities of plants and animals, which flourish and then give way to the next stage, until ultimately a climax is reached. The climax represents a condition of relative equilibrium between the living community and its physical environment, particularly the climate and the soil. The time scale of such a process may be long, perhaps covering thousands of years; consequently the establishment of equilibrium may be affected by such factors as climatic change or even progressive soil degeneration (Iversen's (1964) 'retrogressive succession'). Equilibrium therefore may only be relative and not necessarily an absolute balance.

Nevertheless, this pattern of development through more or less ephemeral seral stages towards increasingly long-lived and persistent communities, ultimately culminating in the climax, is an important one when we are considering the impact of man on the environment. Odum (1969) has drawn attention to the contrast between seral stages and mature stages in a succession. He tabulates the differences in broad terms as shown in table 1. His diagram (figure 1) shows how the net production (P_n) varies throughout the succession in relation to the total biomass (B) in the community.

Table 1

young	mature
production	protection
growth	stability
quantity	quality

We shall return to this concept later, but before doing so there is another aspect of climax that needs consideration. Under different climates or in association with different soils the climaxes reached will vary in their character. Thus one may contrast a mixed deciduous forest climax with steppe-woodland and that again with thorn woodland. These climaxes occur in different climates, and though in each case the climax will represent a more stable and protective plant cover than that of the seral stages leading up to it, there are nevertheless wide differences between the mature phases if they are compared directly; they differ in stability and the degree of protection they confer upon the ecosystem as a whole. In other words, the climaxes of some environments are better buffered against change than others. Higgs has used the term 'brittle environments' referring to those in which the equilibrium is precariously balanced. It is remarkable how frequently man's occupation of the land has been concentrated in brittle environments: e.g. savanna woodland, steppe, or light deciduous forest. They often offer a greater variety of resources than the less fragile environments; in this sense they have much in common with the developmental stages of the less fragile environments.

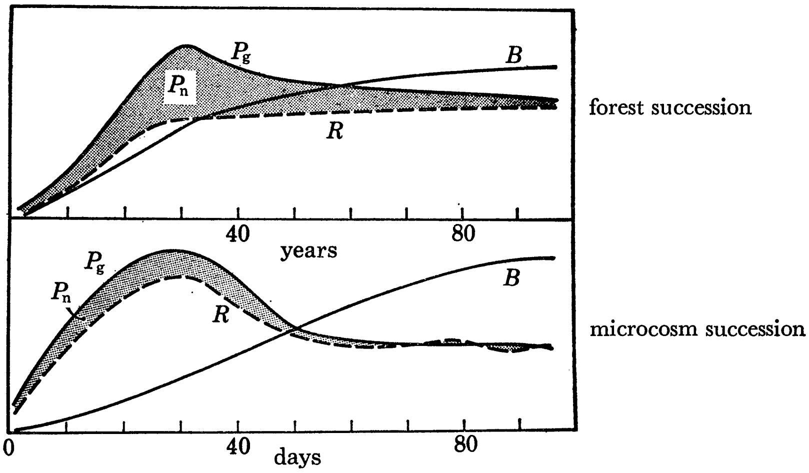

FIGURE 1. Comparison of the energetics of succession in a forest and a laboratory microcosm. P_g, gross production; P_n, net production; R, total community respiration; B, total biomass. (Odum 1969.)

MAN'S IMPACT ON CLIMAX COMMUNITIES

In considering the impact of man on the environment it is usually assumed that this first affected the climax community and that subsequently the pressure was on secondary communities. This is probably widely true, but not necessarily always. The transition from the Pleistocene to the Holocene involved climatic changes which were reflected in vegetation changes. These vegetation changes were, in effect, seral changes leading towards a new climax. In places this transition was accompanied by man who at this time was himself acquiring new means of bringing his environment under some degree of control with the newly emerging agriculture. It has therefore to be asked whether in some areas, such as southeast Europe and southwest Asia, the development of an equilibrium between climate and vegetation in the early part of the Holocene was frustrated by man's increasing impact. It could be that the potential climax has never been reached in such areas.

However, van Zeist (1969) has shown through pollen analyses of Lake Zeribar, in the Zagros Mountans, that at the time (10000–8000 B.P.) that agriculture was first appearing, the climate was still changing. Steppe vegetation occurred where 3000 years later steppe forest was to be found. The difference in climate was probably mainly in the intensity of the summer drought, which would affect tree growth, but agriculture to a less extent since it is dependent on the winter precipitation. What is apparent here is that early agriculture did not prevent the widespread establishment of the steppe-forest; the eventual destruction of this vegetation type followed later. It would be interesting to know whether this was true in the close vicinity of early agricultural settlements, but relevant evidence is not yet available.

When a climax ecosystem is disrupted the effect is that the control exercised by the climax dominants is weakened, so that the nature of the community becomes in effect less mature. For instance, the use of fire and grazing in a savanna woodland will result in reduced tree cover, and an increase in the apparent aridity of the site. Similarly the removal of trees from a swamp forest may be to raise the water-table even further. Disturbance of the climax has the effect of shifting the nature of the ecosystem backwards, from mature to immature or young.

Odum's criteria, therefore, predict that man's impact on climax systems will be to create a more productive (in terms of quantity of organic matter) system, but one which is less stable and less conserving of nutrients. Odum lists many other factors which are relevant to a more detailed study of this change. It should be noticed that if, as suggested above, the climax has been prevented from developing by man's influence, those observations would apply to such circumstances, too.

This paper will deal more particularly with the effects of man on soil conditions in different climatic contexts. (The tropics and areas of irrigation agriculture are excluded in order to keep the paper within bounds.) For this purpose we need to concentrate on ecological stability, which Odum also describes as 'resistance to external perturbations' and on the nutrient system, since it is in these terms that soil changes can most clearly be expressed. One of the aspects of protection is protection against the erosive forces of the physical environment. We often speak as though men were the cause of 'accelerated erosion'; in fact the causes of erosion are an ever present factor in the environment. Periodical heavy rain, severe wind conditions, or persistent wetness of the soil can all lead to erosion of one sort or another. In the climax ecosystem this erosive power is held in check. By destroying the protective cover man may allow these powers of erosion to operate. He has only accelerated erosion in that he has taken off the natural brake that was holding it back.

If these premises are correct, one could have expected that the impact of man on previously undisturbed ecosystems would have had a recognizable effect. Moreover, one might have imagined that the greatest areas of instability would be where the growing presence of early farming was impinging on a vegetation which had perhaps never reached an equilibrium; namely in the early Neolithic of southeast Europe and Asia Minor. On these grounds it is therefore surprising that Butzer (1971) can say: 'It would therefore seem that early agricultural land use did not provoke its more unpleasant side-effects such as accelerated run-off, seasonally accentuated stream discharge, soil erosion, gullying and gradual loss of soil moisture attendant upon the destruction or removal of humus. At any rate, both archaeological and geological evidence to this effect is absent.'

Evidence is now building up that in northwest Europe some of these unpleasant side effects did occur. These will be examined below. The fact that these are in a relatively non-fragile environment is remarkable. It may be that they are recognized here because intensive work has been done using methods which can reveal their presence. Moreover, we have some knowledge of the climatic norm in these areas and so can recognize deviations from it. In some of the more fragile environments not only has less intensive work been done, but we also have a less clear conception of the soil norm; indeed, we cannot always be sure whether a mature soil has existed in Holocene times.

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Ecological effects of primary forest clearance in Britain

Pre-Neolithic

The absence of earthworks to preserve old land surfaces makes it difficult to find suitable material for study before Neolithic times. No good example of palaeolithic occupation suitably associated with environmental deposits is known; there are certainly associations of palaeolithic artefacts and pollen-rich deposits in cave sites, but these can hardly serve as a basis for evaluating whether or not man had any detectable effect on the local vegetation in those times. There is no apparent reason why he should not have had some local effect for he had the use of fire, and even if we assume that he did not use it deliberately to modify his surroundings, it probably got out of control sometimes. The much quoted episode of forest clearance of Acheulian date at Hoxne (West 1957), with a parallel occurrence at Mark's Tey (C. Turner 1970) is not conclusive, but is the sort of evidence that should be looked for. Whether this episode was caused by man or not, it shows the characteristic features of clearance: the marked falling off in high forest pollen and the increase in pollen of light-demanding trees, shrubs and herbs, especially the grasses. In due course the forest re-asserts itself and the episode is over.

In the mesolithic period more convincing and varied evidence of clearing is found, though not all sites of this period give any such indication. Star Carr, for instance (Clark 1954) gave no evidence of forest clearance, but as Simmons (1969) points out, this does not mean that a similar culture would not have had a definite effect in a different habitat. He shows that mesolithic man was more likely to affect his environment adversely in upland areas, or areas of nutrient-poor soils – what we would now call brittle environments. The evidence for anthropogenic change in mesolithic sites has been reviewed by both Simmons (1969) and Smith (1970).

The effect of such clearance on the climax forest will depend not only upon the nature of that climax but also upon the methods used to make the clearance and particularly upon whether fire was used. This was probably so in most cases, but the tranchet axe may also have been employed to ring or fell the lighter timber.

The evidence from many peat bog analyses is that clearance in mesolithic times was on a very local scale; indeed it was not until Simmons's (1964) work on Dartmoor that the effect was convincingly demonstrated in peat analyses. This contrasted with the evidence from pollen analyses of actual sites (see, for example, Rankine & Dimbleby 1960) which seemed to indicate considerable clearance around sites, with some suggestion that the forest never fully returned. It is not yet possible to estimate from such data just how extensive such clearances might be.

The effect of such clearance on the ecosystem would be threefold.

(i) There would be a change in microclimate at soil level as a result of the removal of the overhead canopy. On the wet upland sites such as those on Dartmoor the result could be an increase in surface wetness. On the Pennines there is evidence (Dimbleby 1969) that soil gleying took place following mesolithic clearance. On the freely draining sands of southern England, however, sand blowing seems to have followed clearance (Keef, Wymer & Dimbleby 1965).

Soil instability in this environment could result from loss of soil humus and structure, so accentuating the naturally poor water-holding capacity of such soils. The increased exposure would lead to desiccation and then wind blow. One mechanism by which this process may occur can be seen on heathlands today. Where destruction of the surface humus reveals bleached sand beneath, temperature differences associated with the contrasting colours can cause dustdevils which tear open the exposed soil over considerable areas. Ordinary windblow may then follow.

(ii) The second effect of clearance would involve the nutrient cycle. I have discussed this elsewhere (1962) and need only point out here that clearance involves the destruction of the deep roots of the forest trees which were instrumental in bringing the nutrient reserves from the deeper layers of the soil profile into circulation, so offsetting the losses by leaching. Their destruction leads to an overall excess of leaching, resulting in podzolization.

(iii) Thirdly, there is the 'assart effect'. This term was used by Romell (1957) to describe the enrichment of the soil by the sudden death of a mass of nitrogen-rich roots, so making an abundance of nitrogen available. This will enhance fertility, but whether it is exploited by crops or not, it will be transient. Microbiological activity will mineralize the organic nitrogen which will no longer be held in the soil.

These effects of clearance have been discussed in a mesolithic context to make it clear that they, or other related effects, are the consequence of clearing alone. They are not dependent upon the subsequent land-use in the clearings and to some degree they will apply to all clearings in woodlands of whatever age. If fire is used, there will be a liberation of bases in soluble form which may provide a benefit to a crop, but will ultimately be lost in drainage. This may leave an overall deficit on soils of low base status, but Wright (1974) has recently shown that repeated burning of the forest in the Lake States has had no progressively adverse effect on the forest composition; nor is there evidence that adjacent lakes have been enriched by leached nutrients. If crops are grown and harvested or if stock is raised and exploited, losses will be accentuated, so exacerbating any tendency to nutrient deficiency there may be. On calcareous soils such losses will be unimportant, and in low rainfall areas they may be insignificant anyway.

Apart from the ecological changes brought about in the clearings themselves, there seems at times to be some effect on the surrounding forest. A single clearing in a vast continuum of forest may not have any noticeable effect, but if clearings are multiplied (bearing in mind that regrowth may take decades) there may be an overall effect on the forest microclimate.

Such microclimatic change may be an explanation of floristic changes in the forest pollen rain as recorded in analyses from both peat deposits and buried soils. Pollen analyses from Bronze Age sites in Cornwall (Dimbleby 1963) showed a progressive decrease in the alder/oak pollen ratio as clearance spread. Alder, which is today found mainly in habitats with high water-table, appears to have been a component of the mixed forest before clearance; it can still be found in normal mesic sites even today, and is a successful species in heathland reclamation (Dimbleby 1958). Nevertheless, it apparently requires constant soil moisture, and it is possible that the disruption of the forest canopy brought about seasonal soil drying, to the detriment of alder. Other species whose frequencies are reduced are lime and elm; probably actual exploitation affected those species, but changes in site character could have been contributory. Selective browsing, competition between an enriched field layer and tree seedlings, or perhaps changes in the humus type could all have contributed, separately or in conjunction, to such changes. Some species such as birch and ash might be favoured by a lighter canopy. Oak, on the other hand, is relatively unaffected by both anthropogenic and ecological influences and would remain the dominant forest tree, consequently increasing its proportional representation in the pollen rain (Godwin & Deacon 1974).

Some of these effects of clearance, as has been said, could be associated with pre-agricultural clearance; others are only recorded in association with neolithic clearance. In either case it is to be expected that clearance will be localized, though Simmons (1975) has pointed out that mesolithic activity at the tree line could have a greater effect than within the forest mass. It is therefore significant that in-wash stripes of mineral deposit have been recorded (Jones 1976) in a mesolithic context in peat filled glacial drainage channels in North Yorkshire. If mesolithic man could produce soil erosion, then the same effect would be even more likely in early neolithic times.

Neolithic and later

Neolithic man, like his predecessors, also concentrated his activities on what in effect are the more brittle environments. They were easier to clear and were often associated with lighter soils. Greig & Turner (1974) refer to the preference for light forests in neolithic Greece; in Britain the chalk lands and gravel terraces were favoured, though not exclusively. Choice of land was not always related to the inherent fertility of the soil. In Britain neolithic clearance of the base-poor soils seems to have been rare, but in Holland, for instance, acid sands were certainly cleared (Waterbolk 1954). The pollen and molluscan evidence from neolithic sites on the chalk in Britain suggests that once clearance started it progressed to total clearance. Only inconclusive evidence is available to suggest re-growth of forest or woodland. In contrast, the sequence of clearings demonstrated at a number of places in the west and north of Britain (J. Turner 1965) shows that forest regeneration took place repeatedly, though Smith (1975) suggests that in the wetter upland habitats re-growth weakened progressively until it failed altogether.

Where clearance persists there is time for other factors to operate. A new vegetation type may become established: grassland; heath; garigue; macchia. Soil and climatic conditions are the determining factors. More prolonged clearance gives time for soil factors to operate, and these may be accelerated by the use (or misuse) to which the land is being put. Where grazing is taking place there may be differential pressure on the more palatable plants; the disappearance of legumes is a feature of grazing in this country (especially if accompanied by soil acidification) and in widely different environments. Hole & Flannery (1968) draw attention to the depletion of small legumes by domestic animals grazing in the Deh Luran plain. As these plants are nitrogen-fixers, their elimination would inevitably result in a lower availability of nitrogen.

Actual evidence of soil deterioration connected with neolithic farming in Britain is scarce, but one particular example is of outstanding interest. The neolithic site at Goodland, Co. Antrim (Case *et al.* 1969) has been shown to have undergone the following sequences of changes:

(i) clearance of forest associated with a brown podzolic soil,

(ii) cultivation of a soil in which earthworms were active,

(iii) conversion to pasture, the soil progressively acidifying,

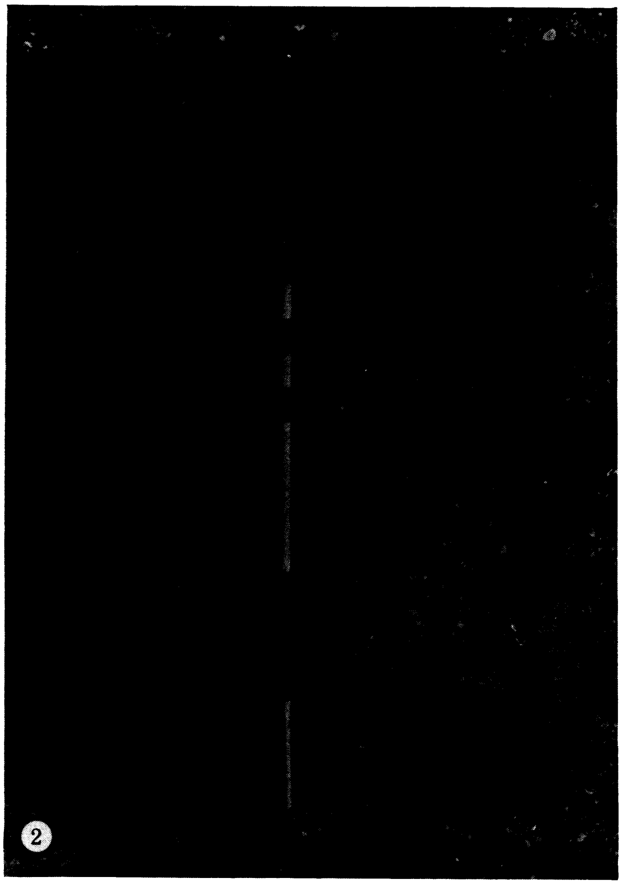
(iv) the disappearance of the earthworms and the development of a leached soil with thin iron pan,

(v) the development of surface wetness, probably due to deterioration of soil structure,

(vi) the onset of peat formation at a date still within the Neolithic.

Recent work by Moore (1973, 1974) has shown that man's influence is apparently widely detectable in the pollen at the base of hill peat deposits, suggesting that such influence was a common, if not component, factor in bringing about the onset of peat growth.

It was mentioned above that one of the favoured areas of Britain for neolithic land use was on the chalk of southern England. Buried soils under long barrows provide pollen and molluscan



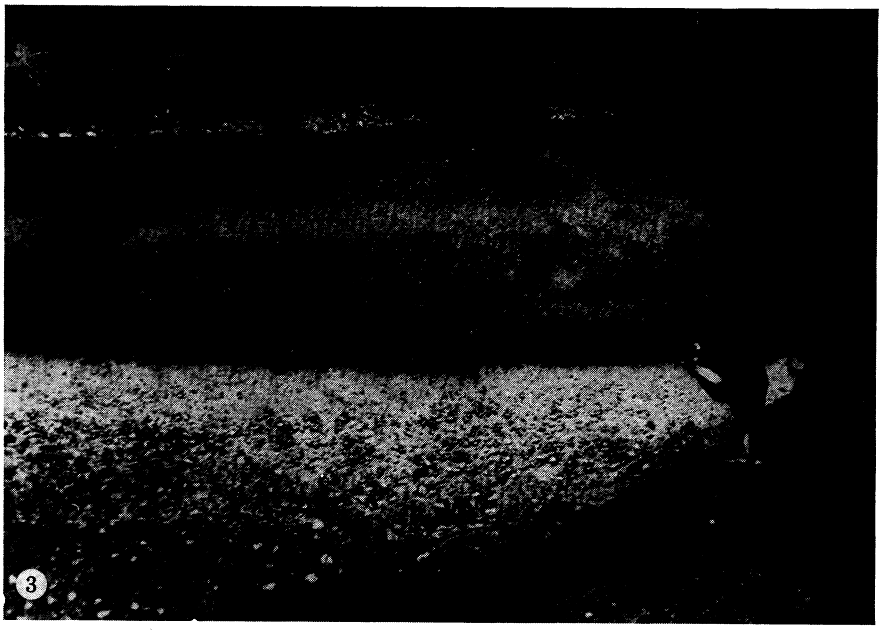


FIGURE 2. The buried soil beneath the South Street long barrow (photo. J. G. Evans).

FIGURE 3. Accumulated hillwash in valley near Lewes. Note buried soil at base, with a less well developed secondary soil above it (photo. J. G. Evans).

(*Facing p.* 202)

evidence of the state of the landscape at that time (Dimbleby & Evans 1974); the results of the two approaches are not always easily reconcilable in detail, but they both show that around such sites there was extensive forest clearance. These buried soils also show that the soils of the neolithic land surface were shallow rendzinas, sometimes shallower than present-day soils (figure 2, plate 5). They have the appearance of having been truncated, and in the case of the Windmill Hill causewayed camp this was corroborated by the mollusca and pollen evidence (Evans 1972). Whether this truncation is artificial, or whether it results from erosion cannot be established for certain.

In the later prehistoric period massive erosion from chalk slopes has been demonstrated by Evans (1966) (figure 3, plate 5). It has been maintained by Godwin (1967) that erosion could not take place on chalk slopes because of the porous nature of the subsoil and bedrock, but clearly this view must now be revised. If so, then hillwash can now be accepted as a factor in lynchet development in Celtic field systems (Bowen n.d.). Lynchet development is not confined to the chalk, which shows that such soil movement was a common phenomenon in the British climate. Its prevalence in Iron Age to Romano-British times as compared with the Neolithic is probably linked to two factors: first the clearances in neolithic times were not extensive, whole hillsides only being farmed in the later periods; and secondly the greater emphasis on arable agriculture in the later prehistoric times would create greater soil instability. It should be noted, however, that Evans & Valentine (1974) have now obtained evidence of hillwash with an associated radiocarbon date of 1960 ± 220 B.C.; they believe this represents erosion following primary clearance on the scarp slope of the Chiltern Hills. The date lends no support to the view that such hillwash is associated with a worsening of climate; it seems to be quite clearly anthropogenic in origin.

Evidence of site deterioration outside Britain

Within the British Mesolithic and Neolithic it has been possible to find evidence of soil deterioration showing itself in the form of chemical and biological degradation, and even as erosion by either wind or water. It should be remembered that it has been argued, with some justification, that the presence of fertile parent materials and the absence of extremes of climate which could lead to soil destruction have been factors which allowed agriculture to develop by trial and error in western Europe without destroying its environment in the process (Hyams 1952). If what we have already seen is the legacy of the young agriculture in such a relatively non-brittle environment, then how much more serious the effects should be in other climates? Hyams gives an interesting analysis of much indirect evidence, as known at that date; yet as we have seen, Butzer can claim that even now direct evidence is remarkable by its absence.

In northwestern Europe evidence of soil change parallel to that found in Britain can be found. In Holland, for instance, soils under neolithic barrows are commonly unpodzolized, while those under Bronze Age barrows have well developed podzol profiles (Waterbolk 1954). Here the ecological factors at work are closely similar to those in Britain. The difference, as already mentioned, is that neolithic man has generally avoided the base-poor sands in Britain, where the first major inroads for agriculture were made in the Bronze Age. In other cases, however, parallels with British conditions are found further afield; mesolithic sites in unstable sands may be associated with dune systems, (see, for example, Parent & Planchais 1972). The question of whether dune movement was instigated or activated by mesolithic influence is seldom asked, and appropriate methods of investigation are not applied to the possibility.

In the Landes in southwest France the development of heathland following neolithic clearance of oak forest, with accompanying podzolization of soil, has been demonstrated by Duchaufour (1948), a change very comparable with those found further north, but here occurring in a climate approaching Mediterranean, though still with an element of oceanicity.

In the Mediterranean area itself the evidence of early soil erosion is so far sparse. Classical writers describe the erosion of soil in areas like Attica (Darby 1951), but Vita-Finzi (1969) shows that the massive erosion which has undoubtably occurred in this region is referable mainly to the historical period and to a negligible extent to the prehistoric period. Nevertheless, it is interesting that when discussing the role of factors such as eustatic changes, earth movements and, later, climatic change in producing the older valley fill, he goes on to say: 'Now and then one meets with the suspicion that a fourth factor normally not considered for periods earlier than the Neolithic may have played some part in the shaping of land forms known to Palaeolithic man, namely changes in the relationship between rainfall and run-off promoted by devegetation. In the days before domestication and cultivation this would have been effected by fire.'

Evidence is accruing that the primary forest clearance in the Mediterranean region did indeed result in environmental damage. The application of pollen analysis to deposits in this region is a relatively recent development, and most of this application has been directed to establishing the sequence of vegetation, and hence of climates, from the Würm into the Holocene. Relatively little has yet been done on the period during which the first impacts of neolithic man were being made. One such analysis is that carried out by Greig & Turner (1974) at Kopais in Macedonia; they report muddy and peaty layers in the lake sediment at a time coeval with the neolithic forest clearance.

In their recent work in central and southern Italy Barker (1975) and Jarman & Webley (1975) have made detailed site investigations of the prehistory of areas which today have a brittle ecological balance – and there is no reason to suppose it was less so in prehistoric times. However, they report no clear-cut link between early agriculture and environmental deterioration. Jarman & Webley (1975) do mention hillwash in some of their soil profiles, but they do not explain its origin. In contrast, Dennell & Webley (1975) found quite dramatic evidence of soil deterioration in Bulgaria in the Neolithic. Smolnitzas, clay-rich soils accumulating in valley bottoms, pre-dated the Neolithic, but there was some indication that there had been a secondary phase of smolnitza formation during the Early Bronze Age. There were other geomorphological changes in this period of quite massive proportions: at Djadevo pottery-laden gravels had been deposited to a depth of 18 m, of which only the top 3 m represent archaeological deposit. The rest derives from erosion from the surrounding plain. The implications of this in terms of the original vegetation and soils of the plain are profound. These authors also refer to an acidified and leached form of the Cinnomomic Forest Soils and other soil characters which also could be manifestations of site deterioration. As they say, it had marked social and cultural repercussions.

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Anthropogenic effects in areas of summer drought

The lack of evidence of soil changes associated with the activities of early agricultural man in areas with summer drought may indeed mean that such effects were insignificant, though for reasons given above it is difficult to see why they should be. Before we assume that this is so we should perhaps consider the possibility that the evidence is there but that archaeologists are not yet finding it.

Archaeologists, of course, are primarily concerned with archaeological sites. Such sites, however, can only produce indirect evidence about what was going on in the surrounding landscape. They provide information about contemporary use of crops and animals, and these, together with more accidental finds, such as weed seeds, make it possible to infer what the local pattern of agriculture was. By studying successive occupations through a tell, for example, it may be possible to demonstrate trends in agriculture. It is unlikely, however, that such a method of study will produce good evidence of environmental damage. If an area of cultivation brings about soil erosion, for instance, the likelihood is that a new area will be brought into cultivation. Such a change, dramatic as it could be on the ground, would leave little or no impression in the tell deposit; the supply of agricultural produce to the settlement would continue, but there is no means of saying for certain where it came from unless one extends one's horizon beyond the tell itself. Not until the environmental damage was so extensive that the settlement could no longer be supplied would any impact be noticeable at the settlement itself; and if this led to the abandonment of the settlement, direct evidence of the reason would be rare.

The concept of site-catchment analysis developed by Jarman, Vita-Finzi & Higgs (1972) goes a long way towards rectifying this limitation of traditional archaeological method. Here is an attempt to understand the life of people not just in terms of a site but in terms of their use and exploitation of the surrounding countryside for essential resources. This approach has now developed considerably and has been given the name palaeoeconomy. As with modern economies, there is a danger that it may be so concerned with man's demand and supply that it takes for granted that the land can supply his means without damage to itself. This is an approach which must be multi-disciplinary; it cannot be effectively carried out by the archaeologist in isolation. The evidence about a site-catchment area may depend upon specialist studies by geomorphologists and pedologists as well as pollen analysts. Some recent studies have tended to be 'one-man bands'. In view of the findings of Greig & Turner referred to above it is particularly important that conventional pollen analyses should be applied wherever possible. It is not enough to extrapolate present-day conditions back into time – to say, for instance, that present day forest land can be regarded as potential arable land in neolithic times. This is tacitly assuming one of the questions we should be investigating.

The evidence of soil and deposits must be read fully and with care. If hillwash is found it must be ascertained when it occurred This may be done on a geomorphological basis, such as its relationship to a dated terrace; or biological evidence such as analysis of contained mollusca, pollen, charcoal, etc., may provide a clue. The rates of hillwash under mature ecosystems are probably smaller than we often assume (see Wright 1974): hillwash should be suspected as possibly the result of a disruption of the mature ecosystem and therefore worthy of investigation in this context.

Soil types seen today should also be closely considered before we assume that they are the 'natural' soils of the region. It is not long ago that it was widely accepted that most of the podzols in Britain were the natural soils developed on base-poor sands. We know now that they are often secondary soils, and in some forms, e.g. the thin iron-pan soil, could not have existed under primeval forest conditions. The same may well apply to soils in the Mediterranean, for instance. If pollen analysis confirms that an area was forested up to the neolithic period we must look for soils that could have borne forest of that type. Many of the present soils certainly could not.

Other forms of soil deterioration are less easy to recognize. The displacement of the small legumes from steppe communities has already been referred to and focuses attention on the nitrogen status of soils in warm climates where oxidation of organic matter is rapid. Direct evidence of this factor is difficult to obtain, but palaeobotanical evidence of the presence of legumes should be given special attention. Flannery (1969) has also drawn attention to the replacement of the original plants of the ecosystem by weeds such as *Malva*, *Plantago*, *Fumaria* and *Galium* as the result of leaving cultivated land fallow. Other weeds, especially rosette hemicryptophytes, may be indicative of heavy grazing and therefore possibly linked with soil damage. Both groups of weeds lack members of the Papilionaceae.

Little attention has been paid to the physical effects of soil exposure in summer-drought areas. Mention has already been made of the turbulence effects which colour contrasts in the exposed soil can create, but recent work on the albedo effect in arid areas such as the Sahel is suggesting that soil exposure as the result of reduction of plant cover may have an unexpectedly large effect on precipitation when large tracts of land (such as the Sahara) are considered (Charney, Stone & Quirk 1975). Even on a local scale of overgrazing (and presumable exposure of soil by cultivation) the brittle equilibrium between rainfall and plant growth can be upset. Seen in the context of areas such as Mesopotamia or other regions where man has caused extensive reduction of vegetation in a warm climate, a potential factor of critical importance is clearly involved. It should be remembered that this effect will be intensified by the light-reflecting character of the limestone rock which figures extensively in the area sometimes called the 'cradle of agriculture'.

Studies such as those by Odum, Charney and co-workers, or by Wright, all mentioned above, have been made because of the urgent need to understand the pressures of man on his environment today. Charney and his colleagues are dealing not with the impact of urbanism or industrialism, but of a simple culture operating in a brittle environment, exacerbated by increasing population. Such conditions have their parallel in the archaeological context of this paper. The striking point of such studies, however, is that they reveal our ignorance about the detailed processes at work in ecosystems and the unforeseen consequences that follow their disruption. The first essential is to obtain observed facts; we still have too few for much of our theorizing. Archaeology can produce such facts, as we have seen from intensive work in the cool-temperate parts of Europe, even where environments are less brittle. It must seek to do the same in other climatic regions, some of which hold ecological problems of crucial importance to man today. At present we go into such areas assuming there was no early impact of man on the environment. It would be more in accordance with the probabilities if we assumed that there had been environmental damage in early times. This would force us to use appropriate techniques of study which at the moment is being done only in exceptional cases.

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Discussion (answer to a question by Sir Joseph Hutchinson, F.R.S.)

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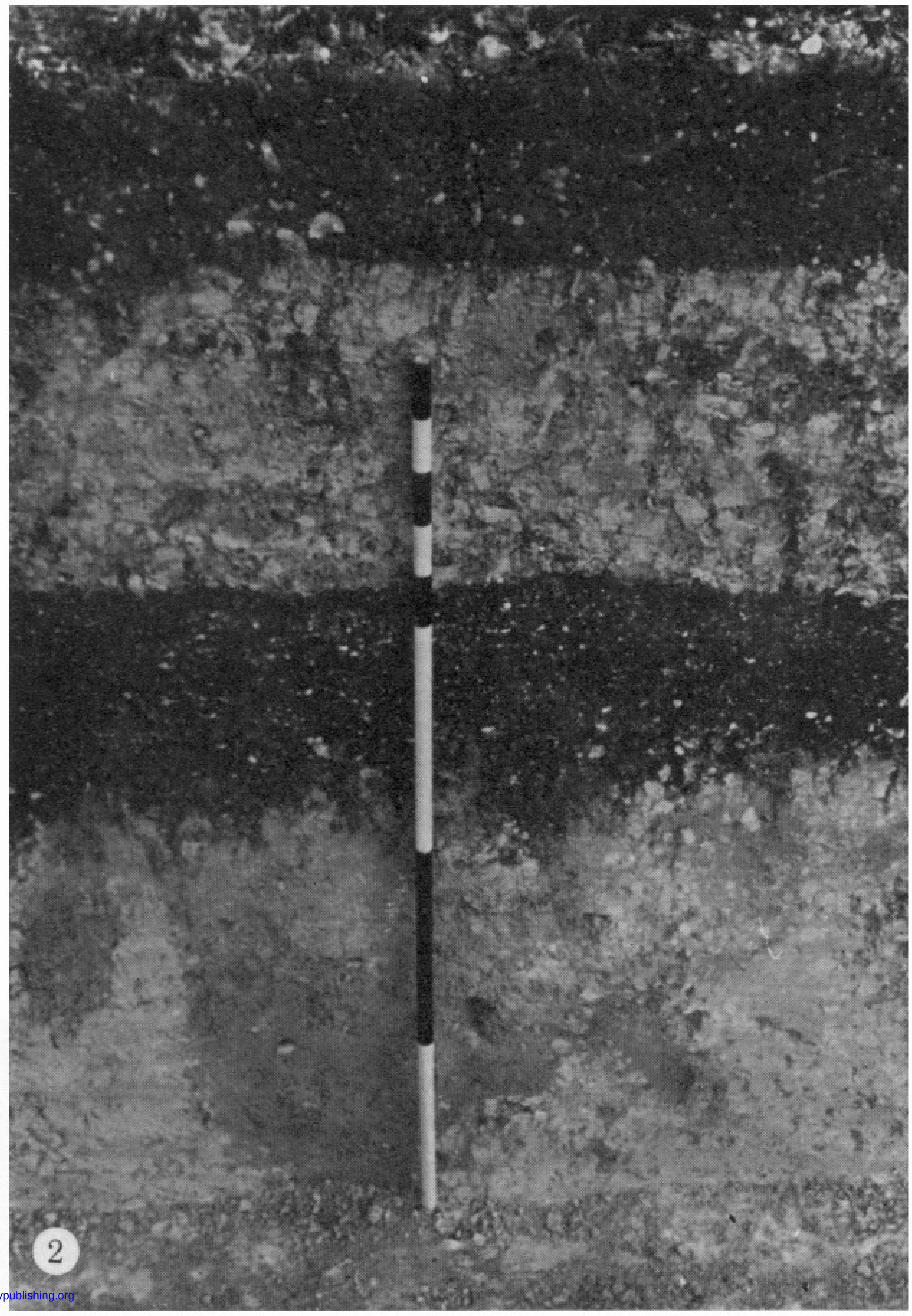
Sir Joseph Hutchinson is of course correct in saying that man's influence on the soil can often be markedly beneficial. Apart from the examples he gives one could quote the plaggen soils of the Netherlands. Such examples, however, tend to be of late date, and I was confining myself to the subject of this conference – Early Agriculture. Professor Bunting's observation that soil erosion is not always harmful is also true in some cases. In this country, for instance, I believe that the chalk has been severely eroded in many places, yet both the eroded and silted areas have retained continuous fertility. Nevertheless, environmental disruption of this sort is far more frequently destructive of fertility and has had serious effects on earlier cultures – a point which has scarcely been mentioned in this conference. Professor Bunting chides me for using 'anthropocentric' terms such as 'degradation'. I do not use them in that sense, but to represent the departure from the relatively stable, mature or climax state which I take to be the norm. Against this the man-induced secondary ecosystems can only be seen as reduced or degraded in their level of ecological organization.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES



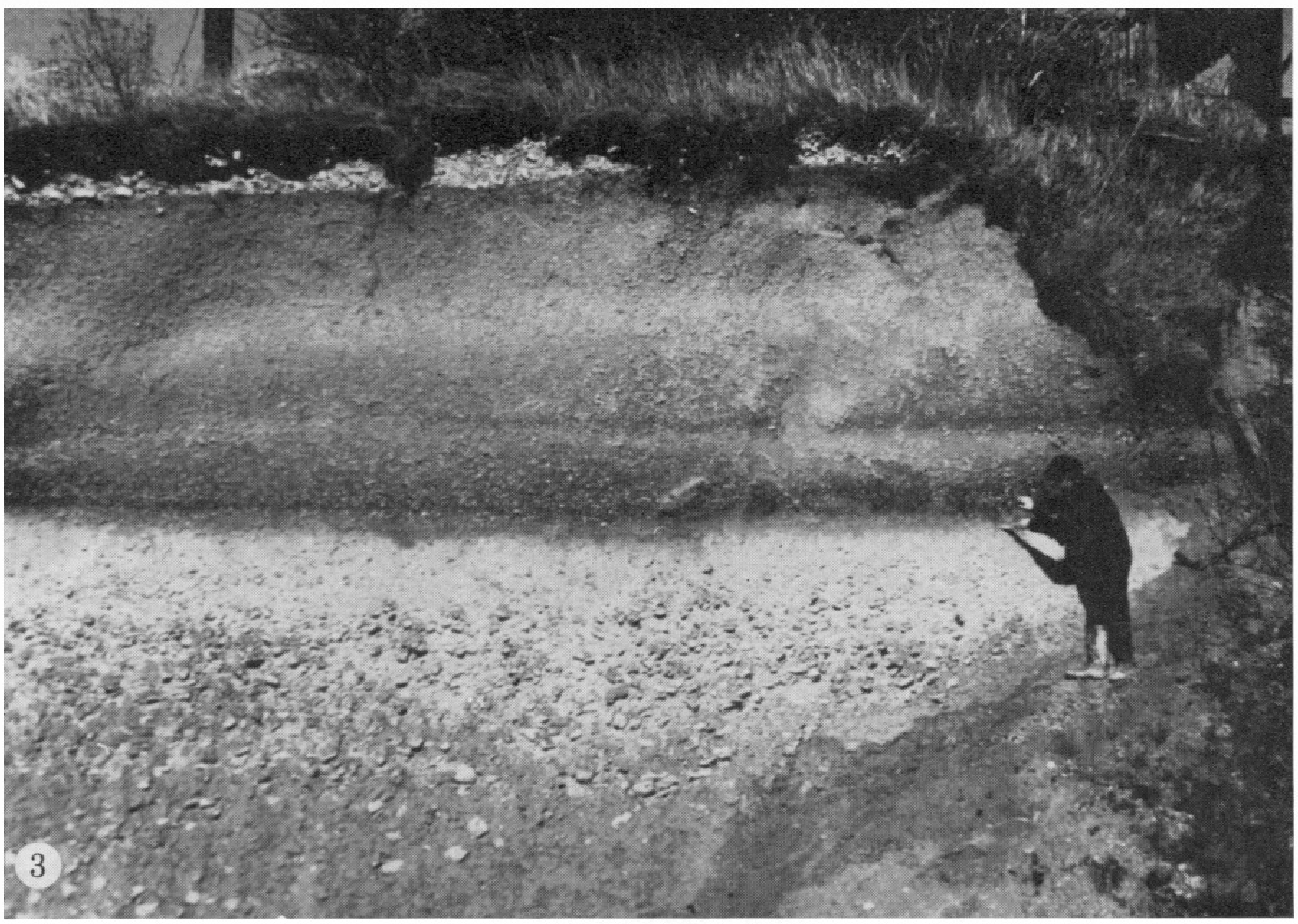


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Figure 2. The buried soil beneath the South Street long barrow (photo. J. G. Evans).

Figure 3. Accumulated hillwash in valley near Lewes. Note buried soil at base, with a less well developed secondary soil above it (photo. J. G. Evans).