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Investigations into the Drift Deposits near Cannock, Staffordshire

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1. Introduction.
2. The Boring Method.
3. The Composition of the Drift.
4. The Base of the Drift.
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SUMMARY.

A series of 200 boreholes drilled over an area of $2\frac{3}{4}$ square miles by the Cannock Chase Area of the National Coal Board has provided valuable information on the composition and distribution of the Drift. Apparently the Drift has been deposited upon a surface having a well developed valley system, undamaged by the processes of deposition and essentially the same as the present day pattern.

The aspect of the Drift most important to the Board, its water content, is described and commented on.

1. INTRODUCTION.

This drift-covered area traversed by the Watling Street and adjoining the Cannock Chase margin of the exposed coal field of South Staffordshire extends some $2\frac{1}{2}$ miles east and south east of Cannock Town. The deeper and higher quality seams have been wrought beneath this drift for three quarters of a century, and it was for safeguard against the hazards of water and " running sands " to present and future workings approaching the sub-drift outcrops in the remaining upper, mostly lower quality, seams that this boring campaign was undertaken. That the thickness of the Drift varied over a wide range had been discovered very early in the history of the coal field, when the Grove, Conduit and other shafts were sunk ; but until this present boring programme the pattern of the thickness variation remained unknown and unsuspected. By this grid system of provings, commenced in 1951 and totalling over 200 boreholes to date, a well developed pre-Drift valley system draining predominantly southwards across the Watling Street and deepening very rapidly in the area near Gt. Wyrley Colliery has been proved.

2. THE BORING METHOD.

The percussive method used produced a 2″ diameter borehole lined with steel tubing, which being kept close behind the drilling bit prevented caving and reduced contamination of the samples. Sampling was continuous, the chippings being removed by uninterrupted circulation of water during boring.

3. THE COMPOSITION OF THE DRIFT.

The composition of the drift is very variable both laterally and vertically, the lens-like irregular stratification making interborehole correlation of the drift extremely difficult. From the wider aspect it is unexpectedly uniform, being made up almost completely of sands and gravelly sands with very little clay material. Although the material includes every grade of sediment from fine silts to beds of pebbles with very little sand matrix, in only one instance was a bed of true clay encountered, this being less than two feet thick and not present in any of three neighbouring boreholes within a distance of 100 yards. In one or two other cases beds of very sandy clay were seen, one of them having a total thickness of fourteen feet. The complete absence of pebbly inclusions, however, prevents their being accepted as "boulder clay" or "till." As indicated by the caking of the samples upon drying, a small proportion of clay grade particles was encountered in most boreholes. Further, boulder clay associated with gravel and sand has been recorded at several places in the Cannock area and it may be that the sampling technique is insufficiently refined to collect the finer fractions.

This type of material suggests its deposition either by a retreating ice front or by turbulent thaw water streams throwing out fluvioglacial fans among ponds along its front. In either event, being a late stage in the process of deglaciation, the initial form of the glacial deposits is not likely later to have been seriously modified so that existing topography now closely simulates the immediate post glacial topography.

The material forming the Cannock drift appears to be mainly derived from the Bunter Pebble Beds, the ice in the last stages of its southerly journey having travelled for a considerable distance over this formation with little chance of accumulating large quantities of Coal Measures strata from the narrow strip available south of the Pebble Bed "scarp." Notwithstanding the rarity of Coal Measures, sandstones, mudstones, shales, etc., coal chippings have been seen in 66% of the boreholes, being in places sufficiently abundant to suggest the penetration of a not insignificant band of coal. Further, abundant coal is almost restricted to the non-gravelly beds. Coal in water has little weight and quite large pieces tend to be graded with the finer sand grains. A proportion of mudstone must inevitably have been picked up with the coal during the ice/water passage over the narrow Coal Measures outcrop but the fluvioglacial streams held this finer material in suspension and carried it beyond the area under consideration, or alternatively it disintegrated more rapidly than did the more stable fragments of coal.

4. THE BASE OF THE DRIFT.

(*a*) *Its Nature.*

In most instances no difficulty was experienced in recognising and accurately plotting the level of this horizon. Even in extreme cases where a fossil regolith existed below the drift, the transitional zone never exceeded one or two feet in thickness. No systematic distribution of these transitional borings was recognised, the cleaner eroded junctions having no preference for the higher parts of the sub drift topography, and this may be some evidence that levelling of the local topography was a very minor phase in the glaciation of this area. As the immediate sub-drift measures in these and other doubtful borings may also be locally ice-disturbed and redeposited, taking on some of the unconsolidated and water bearing characteristics of the drift, it is advisable to take the lowest recorded limit of apparent chemical and physical disturbance as the base of the unconsolidated deposits when calculating safety of workings.

At five places it was found impossible to locate the true base of the Drift because there appeared to be " more than one base." In the early stages of the boring programme the false impression created by encountering a sizeable Coal Measures " boulder " within the drift determined the practice of continuing each boring well into the Coal Measures to ensure that the Drift had been truly " bottomed." That this was justified can be seen from an examination of the sections shown on the lower half of Fig. 1, these boreholes having encountered a second bed of Drift beneath undoubted Coal Measures strata.

Several possible explanations for this sequence repetition have been considered.

1. Boulders or " Rafts." (Fig. 1A).

This is not thought to be a probable explanation although in soliflucted areas included boulders and " rafts " are a common characteristic of drift accumulation, the fact that only five slabs have been encountered in the 200 borings and none shows the hundreds of smaller slivers generally associated with the larger floats suggests that for these few there must be more local causes.

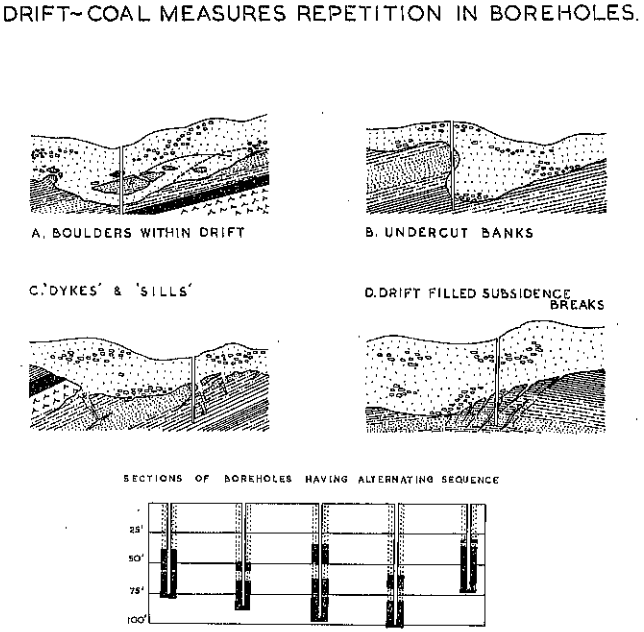


Fig 1.

Further, because drift below the blocks is thinner than above them it is suggested that in some way they remain " tied " to the main body of the Coal Measures.

2. Undercut Banks. (Fig. 1B).

Even though we have every indication of a well developed river system on the Pre Glacial surface of the Coal Measures, the general weakness of such strata and the gentle slopes of the sides of these old river valleys precludes the possibility of such stream undercuts, or their survival unsupported when being buried under drift deposits.

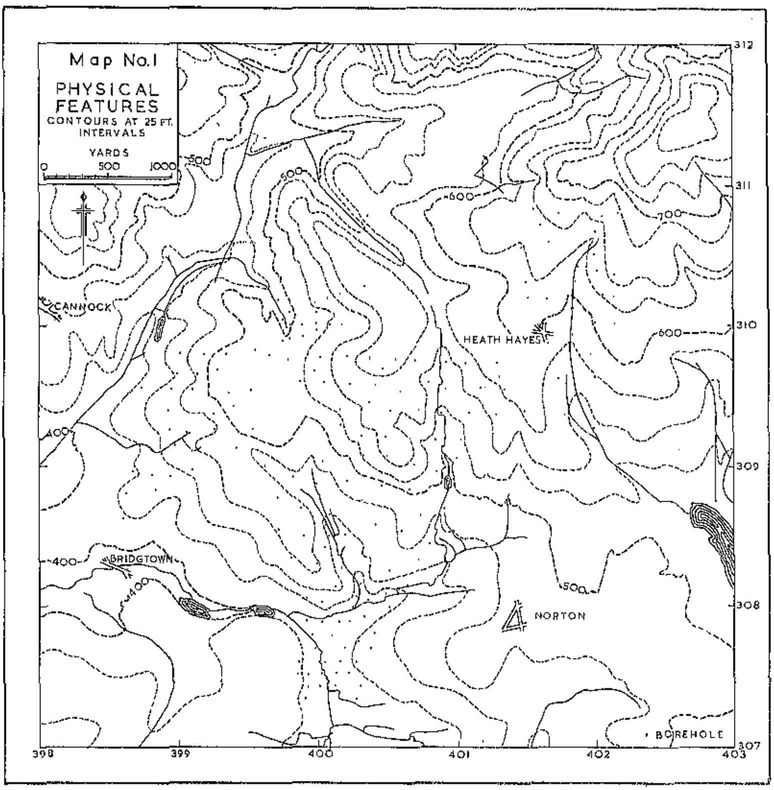
3. " Dykes " and " Sills." (Fig. 1C).

This type of structure might be contemporaneous with the deposition of the Drift. Drift laden melt waters could penetrate and enlarge fractures in the surface of the Coal Measures, or there may be more recent infilling of fractures caused by strata collapse. If the latter then they would be synonomous with :—

4. Drift filled Subsidence Breaks. (Fig. 1D).

This is thought to be the most likely explanation for the tucked-in lower beds of drift. The steep hade of gaped fissures would permit the recording of a not inconsiderable thickness of drift pierced by vertical boreholes and the multiple fracturing associated with temporary or permanent cessation of underground workings would allow for more than one fracture being encountered in one borehole. The outcrop of a fault beneath the drift might give identical phenomena being not dissimilar in both cause and effect.

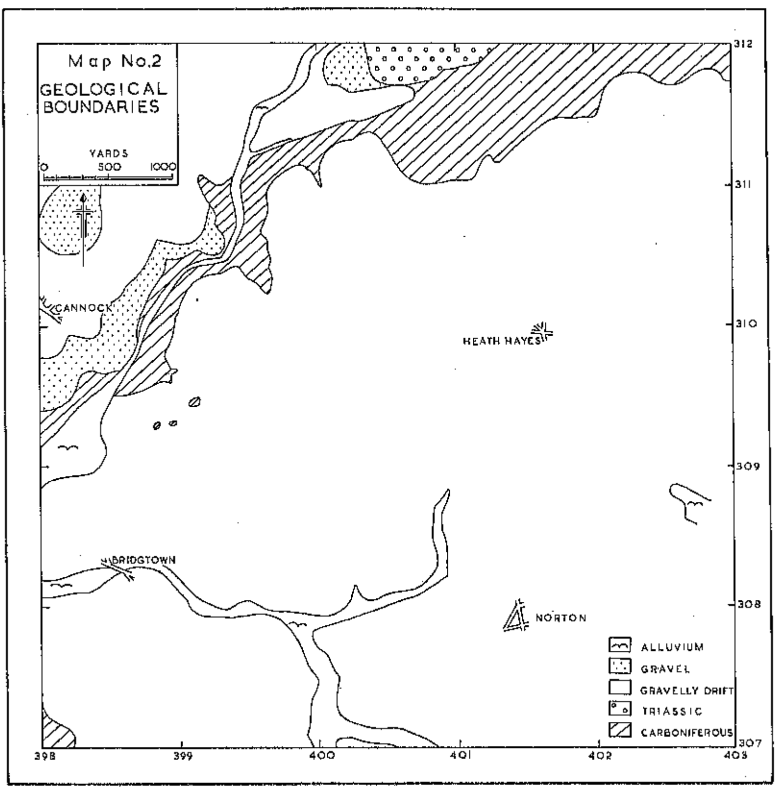
Of the five boreholes recording repetitions, two are above the expected incrop positions of faults, while two others lie close to the edges of colliery shaft pillars. In the maps and sections explanation No. 4 has been accepted but for mine plans it is advisable to accept explanation No. 1 to ensure that, when calculating the safety limits for seam workings, the lowest limit of unconsolidated deposits is taken into account.

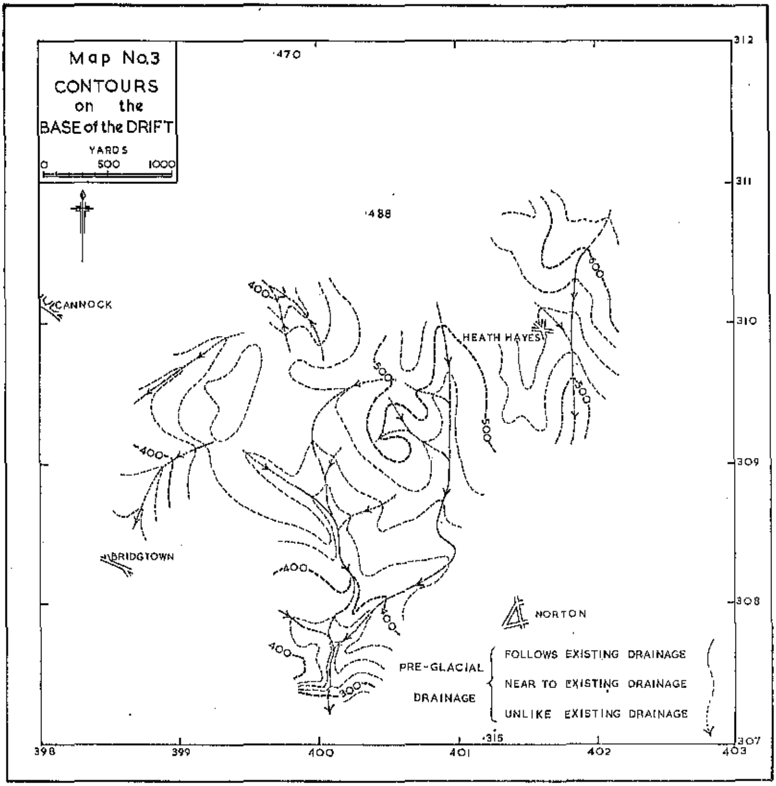


(*b*) ITS GEOMETRY.

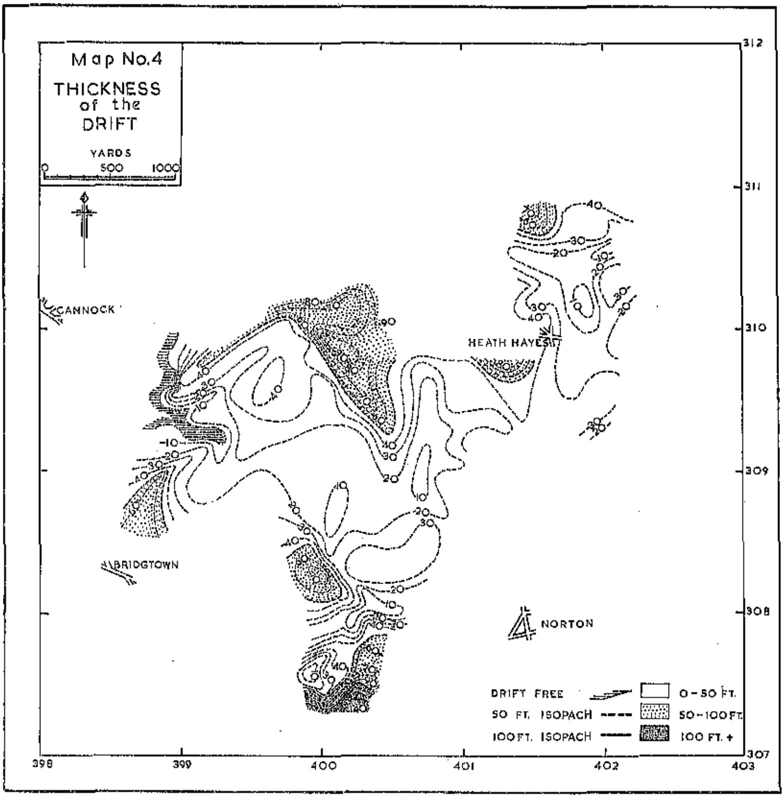
That the Drift was deposited on an area having a well developed drainage system is immediately obvious from an examination of the contoured base of the drift shown on Map 3. Comparison of this map with that showing the present day topography will demonstrate the striking similarity between the local pre-Drift and post-Drift land forms.

Had the pre-Drift pattern been obliterated by erosion, as it must have been if the ice sheets had ploughed their way across the area, the likelihood of the drainage developing a pattern almost identical with that previously in existence is remote. Accepting, however, as above suggested, that the bulk of the drift represents thaw water deposits from an ice front then standing only a short distance to the north, the drift could have been spread over the area by streams which ran to valleys already in existence and did not seriously modify their courses. The general levelling of the area, indicated by the spreading of deposits over the valley divides, could have been since partly neutralised by post glacial erosion re-excavating the valleys.



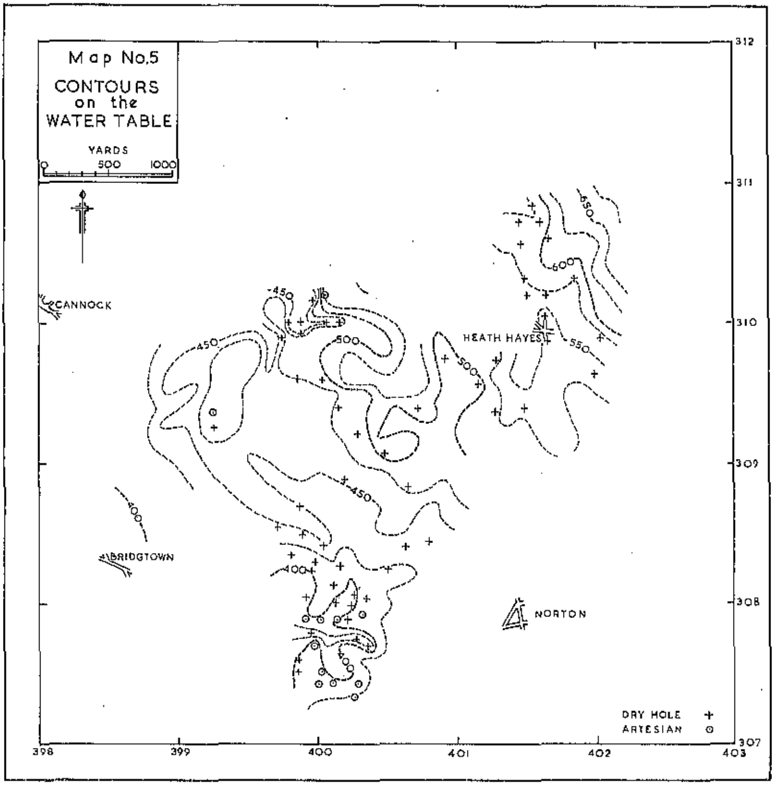


The wide range of the local thickness of the Drift, 0′—150′, and its irregular deposition preclude the possibility of the whole topography having developed in this manner. The thick deposits 900 yards north of Heath Hayes, north north east of Bridgtown and 2,000 yards east of Cannock, could have come in by valley fill subsequent upon a partial blocking of the lower reaches of the valleys by ice or its moraine material. The thick deposits over the watersheds 400 yards south west of Heath Hayes, 2,500 yards east south east of Cannock and 1,500 yards east of Bridgtown, however, suggest that the original thickness of the drift has been much greater than it is at present and that what remains represents only the as yet uneroded portions. Alternatively material pushed in by ice may have played a larger part than has been suggested, the watersheds acting as temporary local barriers against which the ice was checked and, subsequently melting, left these thicker deposits.



The very thick drift in the Wyrley area, west south west of Norton (Map 4), must be associated with the drainage reversal evidenced by Maps 1 and 3. These indicate that a stream originally flowing southwards reversed its drainage and now flows out to the west by a valley which originally drained eastwards into the system. Although this present outlet has valley sides steeper than appear elsewhere in the system the pre-Drift valley floor is now covered with ten feet or more of drift. With a block of outlet at the south end the lake so formed would have overflowed west north west along the Watling Street by this, its lowest outlet, the silting up of the lake providing a thickness of drift deposits sufficient to maintain the northerly and westerly drainage after removal of the temporary dam ; the drift in the overflow channel is explained by spill from the lake.

The form of the pre-Drift southern outlet, a fairly gentle south-flowing stream abruptly increasing its gradient over a



notched east-west striking slope, suggests that the continuation of the drainage from the area may be sought in an easterly or westerly direction. Although there is a doubtful borehole record of +280′ for the base of the drift ½ mile south east of the present borings, it is extremely difficult to find justification for continuing the trend further. Accepting however the east west trend to predominate it is possible to take the valley W.N.W. towards Bridgtown, and thence to the Penk as at present, *via* Gt. Wyrley and Churchbridge.

Eastwards all existing boreholes and shaft records prove the base of the drift to lie between +425′ and +500′ and it is unlikely that a channel at least 150′ deeper passes through the district.

The possibility of this southern " deep " being an ice eroded rock basin must not be overlooked. This is the hazardous alternative as from the aspect of the safety of the underground

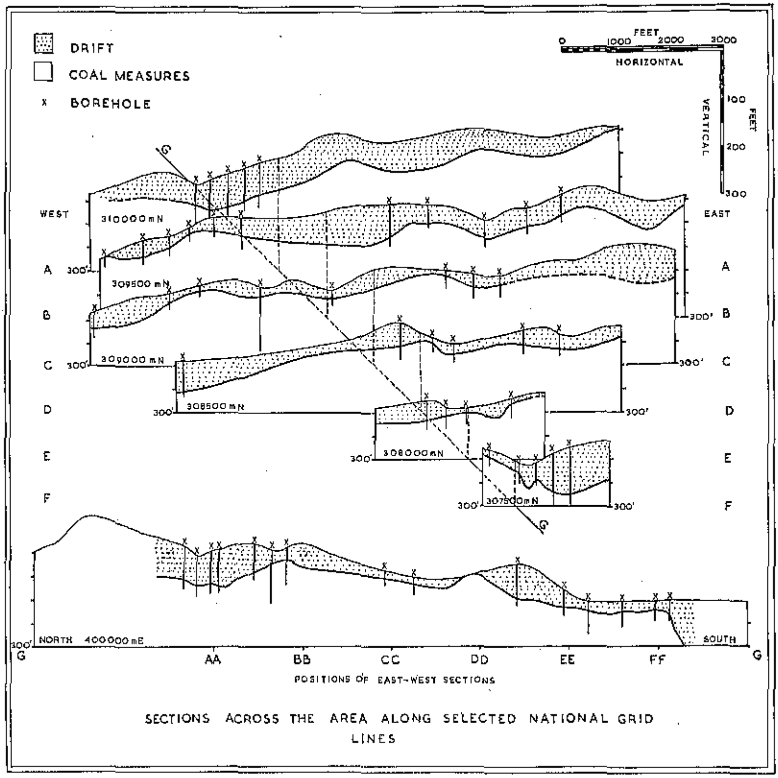


Fig. 2

workings to the immediate north of Wyrley any break through would deliver not only all the water in the basin and the total northern drainage, of which we now have knowledge, but any other drainage from tributaries west, east and south. At best, assuming there is through drainage, the quantity of water available in the drift from the $1\frac{1}{2}$ square miles of country up drainage from this point is likely to be at least 2,000 million gallons.

5. Water in the Drift.

Map 5 represents the contours on the water table. At those boreholes in which no water was recorded the base of the drift has been accepted as the water table level. It is thought likely that there is continuous seepage of water over the whole of the Coal Measures surface, being perhaps no more than a thin film at these points which are recorded dry. There being no apparent change in the texture of the drift it is suggested that the dryness at these points is caused by local more effective drainage.

The form of the water table in the extreme south indicates that the inter Drift water is escaping from the area by the same westerly route followed by the surface drainage and provides some clue as to the nature of the southern deep. With water drainage through to a western outlet at a height of only 375′ A.O.D. and the water table rising southward to a maximum recorded height of 425′ A.O.D. it must follow that this trough, at a point outside the bored area, is completely filled with impermeable clay and till such as has not been encountered anywhere in the bored area. A less likely explanation is that the sub-drift surface of the Coal Measures rises on all three sides of the southern borings to a height of 425′ A.O.D. forming a rock basin with a depth exceeding 75′. That the water is in some way impounded is proved by the many artesian borings which have tapped it along both sides of the Watling Street. These, although they have no great head of water, gave a steady and continuous supply throughout the drilling of the boreholes. They are probably artesian because their sites have been let down during the extensive mine subsidence which has affected this area.

The two isolated artesian borings to the north and west are probably due to other very local conditions. The one to the west was drilled between a large pit mound and the outcrop of the base of the drift where the drift is very thin but permeable enough, between two impermeable layers—the Coal Measures and the pit mound, to account for the artesian effect. The other northern boring, which is close to many dry holes, soon exhausted its supply.

It may have entered a small trapped pocket of water or found a perched water table. A patch of impermeable drift must outcrop between this boring and the dry hole to the immediate south west. Comparison of Maps 3 and 4 show that the three valley outlets from the large western section, which each fall below 400′ A.O.D. are not only similar in having exceptionally thick drift but are notable also for their high water content. It is likely that further downstream each of the north and west valleys will have conditions comparable to those at the southern one containing impounded artesian water. Of the few remaining areas of thick drift, three are on watersheds and one on a minor valley in the extreme north, only one has high water content. It is the one lying to the east of Leacroft Colliery and between it and the saturated valley to the north is a completely dry belt. Its elongation in a N.W.—S.E. direction would suggest that the impounding dam lies either to the N.E. or S.W.

In connection with Map 5 mention must be made of certain holes in which the water was not met with until the borehole had penetrated some distance into the Coal Measures, the rest water level being below the level of the base of the drift. These levels have been recorded as, at certain points it is highly probable the sub-drift Coal Measures are sufficiently permeable to behave with the drift and allow water passage. They may however equally well be mistaken readings due to inadequate casing off of the overlying drift which, although having insufficient water in itself to be recorded, could build up a water level in the sump below.

In conclusion the author wishes to express his thanks to the National Coal Board for permission to publish this paper, and would point out that the opinions expressed therein are his own, and not necessarily those of the Board.

He would also like to thank Professor W. G. Fearnsides for the great interest he has shown in this report, and the very many helpful suggestions made during its preparation.

The Warwickshire County Flora Revision Mapping Distribution

By J. G. HAWKES, R. C. READETT and A. D. SKELDING.

1. INTRODUCTION.

In the last part of these Proceedings (Vol. XVIII, Part IV, pp. 61-74) an account was given of the work being done by the Birmingham Natural History and Philosophical Society and the University of Birmingham Botany Department on the Warwickshire County Flora Revision: the origin of the project and the lines on which it is being carried out. Reference was made to Species Cards on which records received were to be entered and to transparent Outline Maps on which the distributions were to be recorded (by means of dots). In the paragraph on Distribution Maps it was pointed out that it was hoped that it would be possible to publish with the Flora at least the more interesting of these maps; and a scheme was suggested for the use of symbols which would designate the principal habitat groups, and which could be combined when a species was recorded for two or three distinct habitats in one square.

2. THE NEW METHOD OF AREA RECORDING.

As the new method of area recording outlined in the paper referred to (in the above paragraph) came into operation and gathered momentum it soon became apparent that the Species Cards and transparent Outline Maps were inadequate and inconvenient. The Species Cards were not easy to refer to and the mapping by means of dots on the transparent Outline Maps was tedious work. Moreover, no deductions could be drawn from the data on the Species Cards until the Outline Maps had been posted up-to-date.

3. MAP-INDEX CARDS.

The difficulties were solved by the use of combined Map-Index Cards. Each such card represents a Major square 10 km. × 10 km. on the O.S. map and is cut exactly the size of that unit on the 1″ O.S. map with a narrow margin at the top and right-hand sides. The 10 km. × 10 km. square is sub-divided into 1 km. × 1 km. squares the numbers 0 to 9 being printed in the margins and a space being provided at the top for the two figures designating the Major Square. Each small square is divided vertically to give a column for habitat and one for frequency, and horizontally to provide for up to four entries being made in respect of each such square.

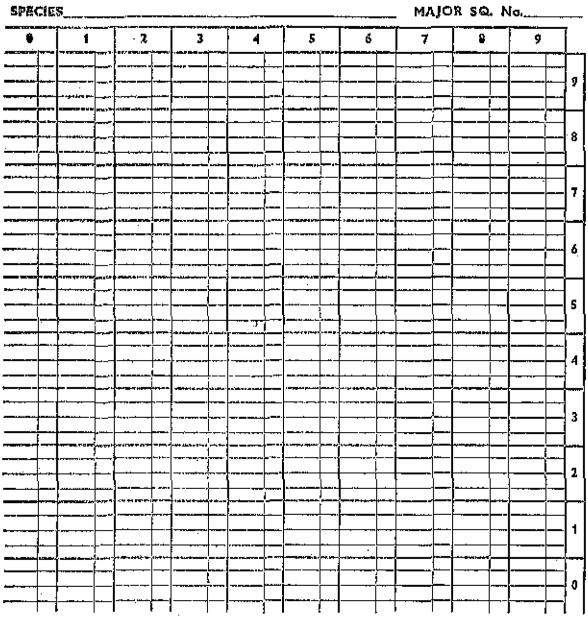


Fig. 1 : *Map-Index Card*

4. Using the Cards.

Vice-county 38 (Warwickshire) consists of 40 Major Squares (or parts thereof). A separate file is being kept for each of these major squares, the cards in each file being in alphabetical (species) order. It will be realised that cards relating to one particular species from all the 40 major squares may be laid on the table in position with margins overlapped to present immediately a map of the distribution recorded throughout the vice-county of the particular species. Correlations with soils, elevation, rainfall and other natural features will be possible if these are mapped to the same scale on transparent material. At any stage of the work it will thus be possible in a few minutes to refer to the information recorded at that time in respect of any species and to have that information as a clear distribution picture. Figures 2 and 3 show cards representing four contiguous major squares involving a section of the vice-county boundary ; the former showing the boundary realistically and the latter conventionally. Both have entries illustrating their use.

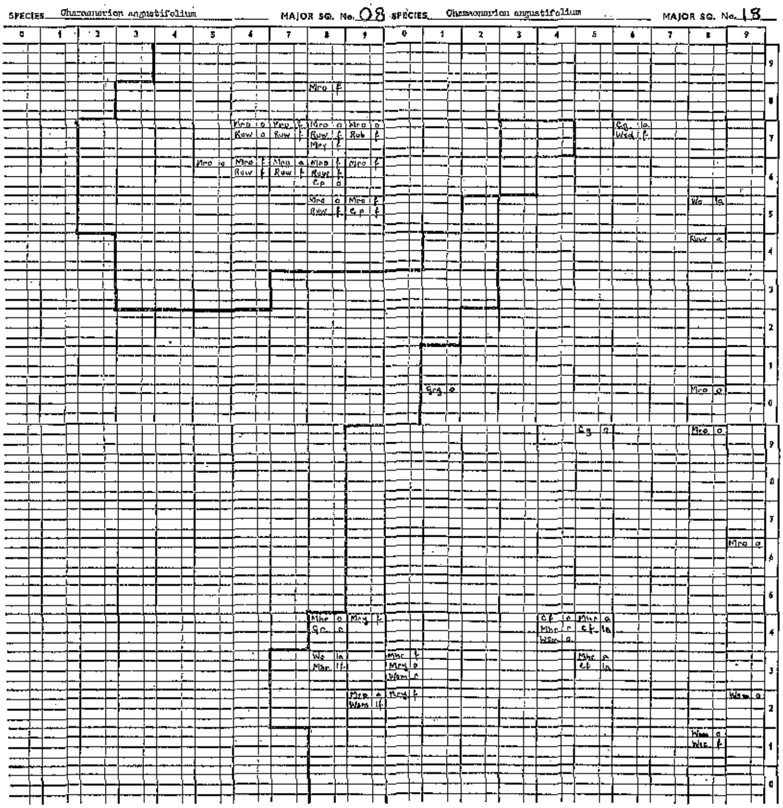

SPECIES Chamaenerion angustifolium
MAJOR SQ. No. 08
SPECIES Chamaenerion angustifolium
MAJOR SQ. No. 18

Fig. 3

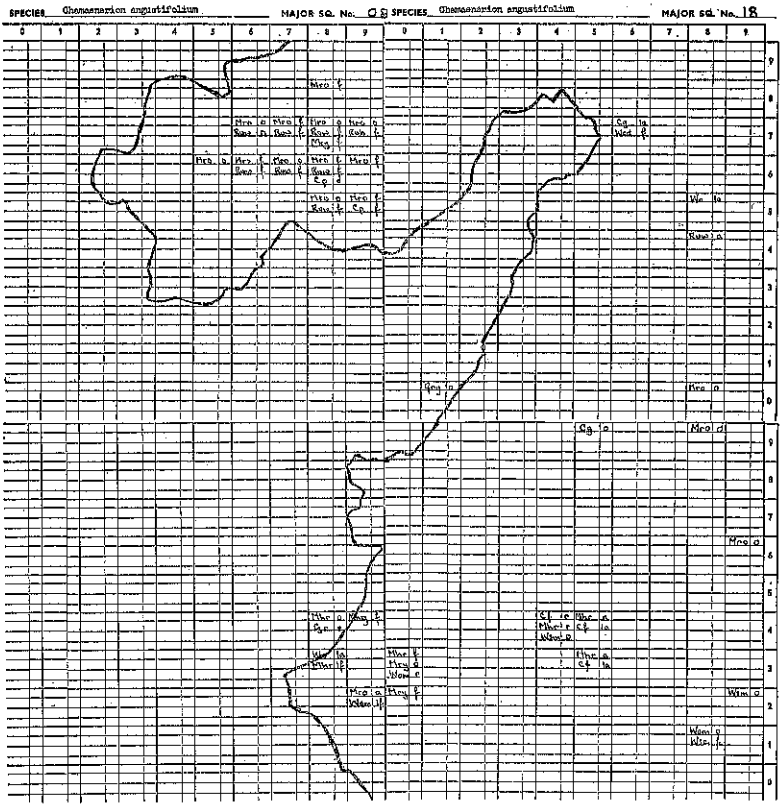

SPECIES Chamaenerion angustifolium
MAJOR SQ. No.
SPECIES Chamaenerion angustifolium
MAJOR SQ. No. 18

Fig. 2

Some Leguminous Plants and the Lepidopterous Insects which feed on them

By S. E. W. CARLIER, F.R.E.S.

(*continued from page* 79)

IV. BIRD'S-FOOT TREFOIL—*Lotus corniculatus* Linn.

Stock with a long taproot, perennial.

Stems spreading in a circle, numerous, four to eighteen inches long, prostrate at base then ascending, forming roundish tufts.

Leaves pinnate with five leaflets, two close to the stem taking the place, and more or less having the appearance of stipules separated from the terminal three, which are ovate or obovate, by a stalk of about the length of a leaflet.

Flower stalks axillary, two to four inches long, each bearing a loose umbell of from five to ten bright yellow flowers with a trifoliate bract at its base. The standards of the flowers are usually streaked or suffused with red.

Pods cylindrical and straight (not beaded) about an inch long and brown when ripe, spreading horizontally so that the cluster of pods more or less resembles a bird's foot—hence the English name.

Habitat—Pastures, heaths, waste-places, etc., common and generally distributed. (Not restricted to chalk or limestone districts).

The chief food plant of *Polyommatus icarus Rott.*, Common Blue and *Erynnis tages Linn.*, Dingy Skipper. Other butterflies which sometimes feed on it are *Lysandra coridon Poda.*, Chalk-hill Blue; *Colias croceus Fourc.*, Clouded Yellow; *C. hyale Linn.*, Pale Clouded Yellow; and *Leptidea sinapis Linn.*, Wood White. (Plates 1 and 2).

It serves as the food for a wide variety of moths, particularly—*Lasiocampa trifolii Schiff.*, Grass Eggar; *Eilema, caniola Hb.*, Hoary Footman; *Ectypa glyphica Linn.*, Burnet Companion; *Ortholitha chenopodiata Linn.*, Shaded Broad-bar; *O. bipunctaria Schiff.*, Chalk Carpet; *Ematurga atomaria Linn.*, Common Heath; *Chiasma clathrata Linn.*, Latticed Heath; *Aspitates gilvaria Schiff.*, Straw Belle; *A. ochrearia Rossi.*, Yellow Belle; *Zygaena purpuralis Bruen.*, Transparent Burnet; *Z. filipendulae Linn.*, Six-spot Burnet; (Imago, Larva and Pupa-case on Plate 4); *Z. trifolii Esp.*, Five-spot Burnet; *Z. lonicerae Esp.*, Narrow-bordered Five-spot Burnet; *Z. meliloti Esp.*, New Forest Burnet (? now extinct); *Dipsosphecia scopigera Scop.*, Six-belted Clearwing, on the tap-root; the PHYCITID *Salebria semirubella Scop.*, the TORTRICIDS—*Eulia cinctana Schiff.*, *Cnephasia incertana*

Tr., the TINAEINA—*Aristotelia quaestionella H.Sch.*, *A. pulveratella H.Sch.*, *Gelechia distinctella zell.*, *Stomopteryx sangiella Sta.*, *S. ligulella Zell.*, *S. taeniolella Zell.*, *Coleophora discordella Zell.*, *Leucoptera lotella Sta.*, *Nepticula eurema Durr.*, and *N. cryptella Sta.*

Xylomiges conspicillaris Linn., Silver Cloud is said to feed on the flowers of this plant, but it is far more easily reared on the leaves of Damson, Plum or Elm.

In addition, most if not all, the insects said to feed on Clovers and Trefoils will eat this plant.

V. HORSESHOE VETCH—*Hippocrepis comosa Linn.*

Rootstock perennial and much branched.

Stems numerous, somewhat woody at base, decumbent and branching, about six inches to a foot long.

Leaves one to three inches long with nine to fifteen elliptical practically glabrous leaflets which are often truncate at the apex.

Flower stalks axillary, about twice as long as the leaves, bearing an umbel of from five to ten yellow flowers, rather like those of Bird's-foot Trefoil but rather smaller (narrower), slightly paler with the standard finely streaked or veined with grey and no orange-red colour.

Pods—one to one and a half inches long, curved, with a series of crescentic or horseshoe shaped notches along the inner edge. They contain two to six seeds, one to each crescent.

Habitat—Banks and pastures in chalk or limestone districts. Abundant on some Cotswolds hill-sides.

The only food-plant (in England) of the butterflies—*Lysandra bellargus Rott.*, the Adonis or Clifden Blue (male flying, female at rest, plate 5), and *Colias australis Verity.*, Berger's Clouded Yellow. Other butterflies which feed on this plant are : *Lysandra coridon Poda.*, the Chalk-hill Blue and *Erynnis tages Linn.*, the Dingy Skipper.

The moths—*Scopula marginepunctata Goeze.*, Mullein Wave and *Ortholitha bipunctaria Schiff.*, Chalk Carpet feed on this plant and in all probability many of those said to feed on Clovers and Trefoils do, in chalky or limestone districts where the plant is abundant.

I am certain that in the Gloucestershire Cotswolds, at least, and probably elsewhere *Hippocrepis comosa* and not *Anthyllis vulneraria* (as stated in Dr. Joy's " Practical handbook of British Beetles "), is the food-plant of the weevil *Apion waltoni Steph.* I have taken this small weevil in abundance wherever I have found *Hippocrepis* in the Gloucestershire Cotswolds but have completely failed to find it on *Anthyllis* except once, where the two plants were growing intermixed! I have also taken it on *Hippocrepis* in Dorset, but in much smaller numbers than in the Cotswolds.

VI. BIRD'S-FOOT—*Ornithopus perpusillus Linn.*

A slender spreading annual.

Stems numerous, slender, spreading along the ground to a length of six inches.

Lower leaves stalked, upper ones sessile, with from five to twelve pairs of softly hairy small oval or oblong leaflets and one odd (terminal) one. Stipules minute, triangular.

Flowers about 1/6 inch long, in heads of three to seven with a leaf-like bract at the base of the umbel. The standard and wings are white with pink lines or veins and the keel is orange-pink.

Pods slightly downy, $\frac{1}{2}$ to $\frac{3}{4}$ inch long, curved into a bow and constricted into from five to nine single-seeded joints and ending in a " beak " nearly as long as the last joint.

Habitat—Dry pastures and waste places, chiefly in sandy soils.

One of the usual food-plants of *Plebeius argus Linn.*, the Silver-studded Blue butterfly (male flying, female at rest on flower and larva on Plate 6). *Polyommatus icarus Rott.*, the Common Blue and *Lysandra coridon Poda.*, the Chalk-hill Blue sometimes feed on this plant, as will the moths—*Lasiocampa trifolii Schiff.*, Grass Eggar and *Zygaena filipendulae Linn.*, Six-spot Burnet.

It is quite likely that some of the insects which feed on Clovers and Trefoils generally, also occur on this plant.

Some entomologists seem to be unable to distinguish Horse-shoe Vetch, *Hippocrepis comosa* from Bird's-foot Trefoil, *Lotus corniculatus*—but the shape of the leaves—with nine to fifteen leaflets in the former, and five only in the latter, aranged two, a stalk then a terminal bunch of three or the shape of the pods—curved and convoluted in *Hippocrepis* ; straight and cylindrical in *Lotus* should be sufficient for anyone to separate them by. Any confusion which may exist between *Lotus corniculatus* and *Ornithopus perpusillus* can only be due to their popular names, Bird's-Foot Trefoil and Bird's Foot, as the two plants are totally dissimilar.

The insects and plants in Plates 4, 5 and 6 are all approximately life sized.

Plate 5
(LIFE SIZE)

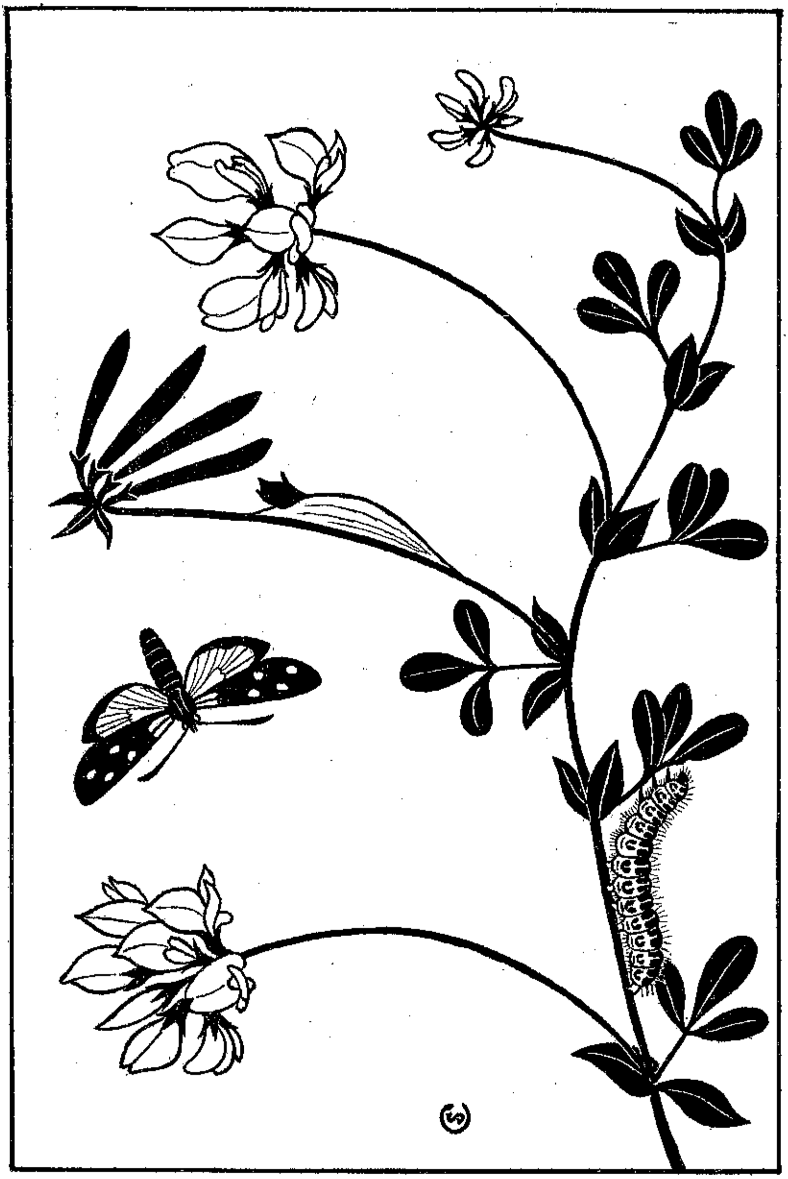


Plate 4 (LIFE SIZE)

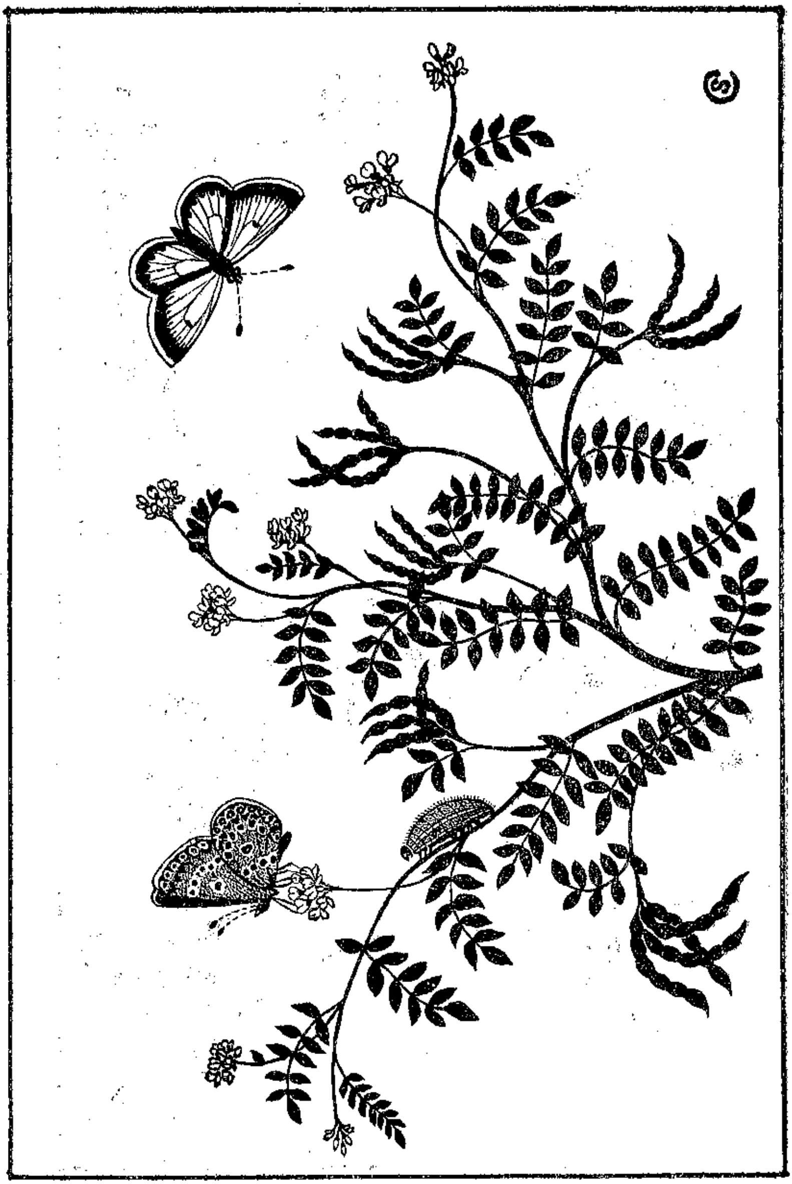


Plate 6 (Life size)

Some Preliminary Observations on the Flora of Derelict Land

By W. J. Rees, B.Sc., Ph.D., Botany Department,
University of Birmingham.

(*With Plates* 1—6).

Although abundant data has been recorded on the artificial replanting of waste lands, there appears to be a singular absence of any true ecological account of the natural regeneration of these regions.

At the present time large tracts of agricultural land are being severely disturbed during surface mining. These areas are likely to produce a serious problem after exploitation similar in many respects to that which arose some fifty years ago in the region about to be described.

This paper is a preliminary account of vegetation which has arisen on neglected industrial spoil during the last half century and serves to emphasise some of the different factors which may affect their flora, and may shed some light on the most suitable plants for use in accelerating revegetation should this be desirable. Much of the data presented has been obtained from the Black Country since this area is perhaps unique in its great variety of waste lands and would appear to serve as an admirable starting point for a detailed study.

The habitats presented by industrial waste will vary greatly with the nature of the spoil, but some of the normal plant requirements which we may expect to be abnormal may be summarised as follows :

1. Adequate moisture for seed germination.
2. Availability of major and minor nutrients.
3. Stability of the substratum for root hold.
4. Suitable aspect and degree of exposure.
5. Freedom of the atmosphere from heavy industrial pollution.
6. Heavy metal excesses.

The water relations of the substratum will be governed by the size and friability of its constituent particles which will in turn be dependent on the speed of weathering of the parent material ; coal measure shales will disintegrate easily, hard igneous rocks with difficulty. Similarly the supply of essential elements will depend on rock structure. Different quarry waste varies considerably in the amount of mineral it can produce ; quartzite is generally lacking in alkalies of the soda-potash group and alkaline earths unless a moderate amount of diorite is present. The converse is true of granite composed as it is of mica and felspars and which gives rise to a satisfactory medium for plant growth.

The stability of the substratum assumes particular importance when the revegetation of the tall coal-measure heaps and the large conical mounds of the china-clay industry is considered. Aspect and exposure are important and the various microclimates produced by the different configurations of wastes require careful investigation. In this respect the surface temperature of the spoil due to excessive insolation may be a limiting factor. Whyte and Sisam (1949) have drawn attention to the observations made by Shirley (1944) in Pennsylvania where high surface temperature precludes seedling development unless the protection of brushwood and grass is given.

The effect of atmospheric pollution on the survival of species have been well illustrated by the activities and reports of the Midland Reafforesting Association 1903-24, who successfully afforested some 600 acres of Midland derelict land and showed that as general rule, conifers with their narrow evergreen leaves were at a disadvantage in heavily polluted atmospheres, whilst certain wide leaved deciduous trees thrived quite well. Rouston (1920) considers that conifers cannot survive where atmospheric pollution is in excess of fifty tons of soot per square mile per annum. It appears that the stomata become blocked with a tar-like substance. By a variety of experiments in connection with the effect of pollution on the general physiology of the plant, this author has demonstrated that photosynthesis and enzyme activity are seriously impaired. Atmospheric acidity also has a deleterious effect on soil micro-organisms, while the disruption due to smoke of normal physiological processes retards germination capacity. It also affects flower colour and causes leaf blotching on wide deciduous leaves. More recent investigations of the effects of atmospheric pollution have shown that atmospheric sulphur dioxide affects leaf physiology. (Bleasdale, 1952).

The historical and geographical background of the Black Country has been adequately described by Beaver (1946) who evolved a system of classification of industrial waste based largely on the composition of the spoil. A similar system has been adopted here, and the vegetation of the following types of spoil are discussed.

(*a*) Coal Measure Shales and Stone.
(*b*) Dolerite waste material.
(*c*) Furnace slag.
(*d*) Subsidence areas.

(*a*) Coal Measure Shale and Stone.

The form of the spoil produced by coal mining activities may be divided into three groups :

1. Low mounds or hills and hollows.

2. Medium sized spoil heaps of about 60 feet in height.
3. Tall conical waste heaps produced by a mechanically operated tramway from deep mining activities.

1. *Low Mounds or Hills and Hollows.*

The medium presented for plant growth consists of very friable blue and grey shales mixed with occasional sandstone, coal and ironstone. The waste has resulted from hand tipping and now remains in the form of undulating mounds. Many areas of this description exist within the Black Country and the type of waste from pits in the vicinity of Willingsworth near Wednesbury which ceased to operate some forty years ago may be taken as a typical example. The area appears to be utilised for many purposes, *e.g.*, as a recreation and playground for local children and grazing for cattle. Consequently the natural establishment of vegetation is modified to a certain extent by these agencies. Nevertheless it is characterised by a dense herbaceous flora in places although shrubs and trees may suffer damage as soon as they produce much wood. The first plants which seem able to establish themselves consist of *Rumex acetosella, Agrostis tenuis, Festuca ovina* (plate 1), while *Tussilago farfara* is a vigorous coloniser when the shales become mixed with coal measure clays. The general successional sequence is outlined below and there it will also be observed that the medium provided for plant growth is extremely acid, and that plant activity in this area has an amelioration effect on soil reaction. It is also noteworthy that bryophytes play no role in the succession and pteridophytes are almost absent.

Vegetation of Coal Measure Spoil. (Hills and Hollows aged about 40 years).

Stage I

Agrostis tenuis	*Rumex acetosella*
Festuca ovina	*Tussilago farfara*

Soil pH 3.44

Stage II

Stage 1 species, together with	*Arrhenatherum elatius*
other grasses, *e.g.* :	*Dactylis glomerata*

Soil pH 3.6

Stage III

Crataegus monogyna	o	*Holcus mollis*	f
Sambucus nigra	o	*Hypochaeris radicata*	f
———		*Linaria vulgaris*	la
Agrostis tenuis	a	*Lolium perenne*	o
Artemisia absinthium	f	*Lotus corniculatus*	a
Arrhenatherum elatius	f	*Luzula campestris*	o
Centaurea scabiosa	o	*Plantago lanceolata*	a
Chamaenerion angustifolium	a	*Poa pratensis*	o
Cirsium arvense	a	*Reseda luteola*	o
Dactylis glomerata	f	*Senecio squalidus*	f
Equisetum arvense	la	*Trifolium arvense*	a
Hieracium sp.	f	*Tussilago farfara*	f
Hieracium pilosella	a	*Vicia sepium*	o

a=abundant; la=locally abundant; f=frequent; o=occasional.

Soil pH 5.56.

In the hollows between the small hills a type of aquatic or semi-aquatic flora is found, the composition of which depends on the degree to which the substrata are waterlogged. These areas should not be confused with the larger hydrosere communities which owe their origin to large scale land subsidence associated with past mining operations and to which reference will be made later. In the former areas, often referred to as swags, such plants as *Typha angustifolia, Glyceria maxima, Sparganium ramosum,* and *Epilobium hirsutum* flourish.

The hill and hollow type of waste varies greatly in the amount of shrub and tree vegetation which it bears. Wherever spoil occurs intermixed with meadows, shrubs such as hawthorn and elder are very plentiful. The coal wastes at London Fields, near Dudley, are an example of this type in contrast to the " Willingsworth " spoils.

Mention has been made of the general absence of naturally developed trees from many areas of coal waste. In some cases, however, where the areas laid waste are in close proximity to woodland, trees may become established in thick masses. A typical example of this is found in the neighbourhood of Netherton, where about ten species were found including *Quercus, Betula, Fraxinus, Ulmus, Alnus* and many others. The neighbouring woodland of Salt Wells contains all these species.

2. *Medium Size Spoil Heaps.*

The flora of this type of waste is dependent on its previous history. The composition of the waste is similar to 1. The so-called live tips which have undergone spontaneous combustion at some period of their existence generally bear a richer flora than the unburnt. Typical examples of the former are found on the border of the Cannock Chase Coalfield in the Wyrley district. The list below illustrates the flora of such a spoil bank where it will be observed that many species of naturally produced saplings occur while *Pteridium* is an active coloniser of the steep sides becoming dominant on the summit. (Plate 2).

Vegetation of Coal Measure Spoil. (Medium spoil heaps, age about 40 years).

Sides

Acer pseudo-platanus	la]	*Dactylis glomerata*	f
Betula pubescens	o	*Digitalis purpurea*	a
Fraxinus excelsior	o	*Equisetum arvense*	f
Quercus robur	o	*Hieracium sp.*	a
Salix caprea	o	*Hieracium pilosella*	la
Sambucus nigra	la	*Lotus corniculatus*	la
————		*Plantago lanceolata*	f
Crataegus monogyna	la	*Pteridium aquilinum* (dominant in places)	
Rubus fruticosus agg.	f		
Ulex europaeus	f	*Rumex acetosella*	a
————		*Solanum dulcamara*	o
Agrostis tenuis	a	*Senecio squalidus*	f
Anthoxanthum odoratum	o	*Taraxacum officinale*	a
Bellis perennis	o	*Trifolium repens*	a
Cirsium arvensis	f	*Tussilago farfara*	la

Summit

Pteridium aquilinum	d	*Deschampsia flexuosa*	a
Chamaenerion angustifolium	f	*Digitalis purpurea*	a
		Rumex acetosella	la

3. *Tall Spoil Banks Produced by a Mechanically Operated Tramway.*

One of the most important factors affecting plant colonisation of this type of industrial waste is the degree of slope of the sides of the conical tent-like spoil heaps. The size of the waste particles, and consequently stability, will also be an important factor controlling plant development. The twenty year old Littleton spoil bank at Huntington near Cannock has a slope of thirty degrees. Surface erosion is an important factor in curtailing the development of a continuous sward of vegetation. (Plate 3).

The first plants to become established are *Tussilago farfara*, *Dactylis glomerata*, *Cirsium arvense*, *Holcus mollis* and *Agrostis canina*. Herbaceous species present are given below :

Herbaceous Species List

Agrostis canina	o	*Echium vulgare*	o
Agrostis tenuis	a	*Hieracium sp.*	a
Arrhenatherum elatius	o	*Holcus lanatus*	o
Chamaenerion angustifolium	la	*Holcus mollis*	f
Cirsium arvense	a	*Sagina procumbens*	o
Dactylis glomerata	la	*Tussilago farfara*	la

Soil pH 4.5 *Angle of Slope* 30°

Plate 4 shows that isolated birch (*Betula verrucosa*) and oaks (*Quercus robur*), from five to ten feet high, have established themselves naturally.

(*b*) Dolerite Waste.

The igneus rocks of the basalt and dolerite heights of the Rowley Regis district have been extensively exploited and are still being used for road metal. The processes involved provide two types of waste : quarries and medium spoil heaps of rejected material. Large deep quarries, often fifty to a hundred feet in depth, with almost perpendicular sides, are almost bare of vegetation.

The rejected waste material from hillside quarries is left in the form of medium spoil heaps somewhat similar in appearance to those produced by mining moderately deep coal, with the exception that the fragments of dolerite waste are much larger.

The following vegetation was found on a fifteen year old quarry waste in the vicinity of Springfield near Rowley Regis.

Vegetation of Dolerite Waste. (Fifteen year old spoil heap).

Pioneers.

Dactylis glomerata *Senecio squalidus*
Festuca ovina

Sides.

Fraxinus excelsior	o	*Dactylis glomerata*	a
Salix caprea	o	*Festuca ovina*	f
———		*Hieracium pilosella*	f
Rubus fruticosus agg.	f	*Lapsana communis*	o
———		*Linaria vulgaris*	o
Achillea millefolium	o	*Lotus corniculatus*	f
Agrostis tenuis	a	*Rumex acetosella*	f
Artemisia absinthium	a	*Tussilago farfara*	f
Cirsium arvensis	f		

Summit.

Achillea millefolium	f	*Linaria vulgaris*	o
Agrostis tenuis	a	*Lotus corniculatus*	a
Artemisia absinthium	a	*Ranunculus repens*	f
Cirsium arvense	f	*Rumex acetosella*	a
Dactylis glomerata	la	*Taraxacum officinale*	o
Festuca ovina	la	*Trifolium arvense*	f
Hieracium sp.	la	*Tussilago farfara*	o

Whereas the effect of plant cover on the coal measure spoil reduces its acidity, the reverse is true of dolerite. The pH of the detritus of an active dolerite tip on which isolated plants of *Senecio squalidus* were growing has a value of 7.36. The effect of fifteen years' plant growth which produced the vegetation outlined above raises soil acidity to pH. 5.72. This action of vegetation is more strikingly demonstrated, however, by the flora of a forty year old disused quarry (Plate 5). The configuration of the old quarry side is such that a weathered convex spur of practically unaltered dolerite rock is adjacent to a concave re-entrant. The latter is thickly populated with shrubs and herbs but the former is colonised with sparsely distributed dolerite pioneers. The two lists given below will illustrate how vegetation affects the pH of this fresh waste material.

Convex Spur

Achillea millefolium	*Hypochaeris radicata*
Agrostis tenuis	*Senecio squalidus*
Artemisia absinthium	*Tussilago farfara*
Dactylis glomerata	

pH 7.38

Concave Re-entrant

Crataegus monogyna		*Holcus mollis*	f
Sarothamnus scoparius	a	*Hypochaeris radicata*	o
Rubus fruticosus agg.	f	*Lathyrus pratensis*	f
———		*Linaria vulgaris*	f
Agrostis tenuis	a	*Lotus corniculatus*	la
Dactylis glomerata	la	*Ranunculus repens*	f
Festuca ovina	o	*Rumex acetosella*	a
Hieracium pilosella	a	*Senecio vulgaris*	f
Hieracium sp.	a		

pH 4.63

(*c*) FURNACE SLAG.

This type of waste exists in two forms, low mounds of solidified molten slag and a mixture of the remains of quarried slag and soil. The slag is extensively used for road metal and is first blasted into large pieces before crushing. Consequently, all sizes of rejected material remain, from large rocks of some ten or twenty feet in height and with almost vertical sides to small slag rubble mixed with soil. In all cases the substratum is very alkaline because of the abundance of lime which has been used as a flux in blast furnaces producing this waste product. Three types of habitat are distinguishable :

1. The flat tops of unquarried slag.
2. The slopes of unquarried slag and those remaining after blasting operations.
3. Flat expanses of ground containing rejected slag of all sizes.

A vegetation list of each type of habitat is given below.

Summit

Agrostis tenuis	a	*Dactylis glomerata*	la
Arenaria serpyllifolia	o	*Festuca ovina*	a
Artemisia absinthium	o	*Hieracium pilosella*	a
Carduus nutans	o	*Leontodon autumnalis*	f
Cirsium acaule	o	*Sedum anglicum*	o

pH 8.26

Sloping Sides

Agrostis tenuis	a	*Festuca ovina*	f
Arrhenatherum elatius	la	*Linaria vulgaris*	o
Artemisia absinthium	f	*Lotus corniculatus*	f
		Senecio squalidus	a
Chamaenerion angustifolium	f	*Trifolium repens*	o
Cirsium arvense	f	*Tussilago farfara*	la

pH 7.74

Steep Sides

Salix caprea	o	*Festuca ovina*	f
———		*Hieracium sp.*	f
		Reseda luteola	o
Chamaenerion angustifolium	o	*Senecio vulgaris*	f

pH 7.66

Quarried Remains

Salix caprea	o	*Inula conyza*	o
———		*Linaria vulgaris*	o
Agrostis tenuis	a	*Lolium perenne*	o
Arrhenatherum elatius	a	*Lotus corniculatus*	a
Artemisia absinthium	a	*Medicago sativa*	la
		Melilotus officinalis	la
Chamaenerion angustifolium	a	*Plantago sp.*	a
		Ranunculus acris	f
Chrysanthemum leucantheumum	f	*Rumex acetosa*	o
Dactylis glomerata	a	*Silene cucubalus*	o
Festuca ovina	f	*Trifolium campestre*	a
Hieracium pilosella	a	*Trifolium dubium*	a
Hieracium sp.	a	*Vicia sepium*	o

pH 7.7

The vegetation of the quarried remains of slag is richer in species than any of wastes yet examined except perhaps the neglected quarries of the Black Country Silhurian limestone. These wastes are receiving separate attention and an account of the vegetation will be published shortly.

A relatively large number of leguminous plants are present on slag waste.

The alkalinity of the soil, however, is not reflected by the presence of any true calcicoles although the plant *Inula conyza* may be looked upon as a species preferring a medium with abundant lime. The reason for the absence of many true lime indicators is difficult to explain as yet and requires careful investigation.

The chief operating factors governing plant development on the summit of slag refuse are probably the hardness of the substratum, exposure and drought.

As a general rule, trees and shrubs are not very prolific among slag waste to which public access is restricted. The slag waste within the confines of the Moxley Isolation Hospital contains numerous trees in all stages of development from seedlings to trees of some fifteen to twenty feet in height and includes species of *Fraxinus*, *Betula*, *Alnus* and *Acer*.

(*d*) SUBSIDENCE AREAS.

In the vicinity of disused coal pits all stages from minor subsidences to vast lakes bordered by reed swamp vegetation exist. The village of Clayhanger near Brownhills is one of the better examples of how meadow, houses and gardens alike have become reed swamps containing the following species :

Alisma plantago—aquatica	a	*Mentha aquatica*	o
Cardamine pratense	o	*Myosotis palustris*	f
Equisetum fluviatile	o	*Nasturtium officinale*	la
Glyceria maxima	a	*Ranunculus flammula*	a
Hydrocotyle vulgaris	la	*Trichophorum caespitosus*	f
Lemna gibba	a	*Sparganium ramosum*	o
Lemna minor	a	*Sparganium simplex*	f
		Typha angustifolia	a

This vegetation is bordered by species of *Juncus*. Numerous areas in the vicinity of the active Cannock Chase coalfield are at present undergoing subsidence. A typical subsidence area is shown in Plate 6.

DISCUSSION.

The areas described, although perhaps not of great interest floristically may serve as a useful starting point to contributions to our knowledge of the physiological ecology of the species represented. This aspect will assume particular importance if attempts are made to reclaim these waste lands with crop plants or trees. Whatever adverse soil conditions exist in the various situations, some species can survive them, while others appear to be excluded. The true explanation of this phenomenon of plant selectivity associated with individual waste types will not be forthcoming until a more detailed examination of soil conditions is available. If a deficiency of an essential element is the cause of the exclusion of certain species, it must be of great interest to investigate the physiological conditions within the successful plant which enable them to survive it. Where metal pollution is a controlling factor and the plants present show no symptoms of heavy metal induced chlorosis, either the plant roots reject excess of the metal, or if they absorb it their cells can tolerate a higher level of free metals than is normal. Viewed in this light these areas assume a greater importance than is at first attached to them. This approach to plant problems in derelict areas has already proved useful in interpretation of the plant/waste nutritional problems recently investigated on fly ash dumps. (Rees and Sidrak, 1955).

Many other interesting lines of enquiry suggest themselves. For example, the building up of a tilth and soil profile and the changes in species as this takes place. These and other topics would be a great contribution to serious gaps in our knowledge of soil/plant relationships.

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Plate 1
Agrostis tenuis and *Rumex acetosella* advancing across coal measure shales at Willingsworth. A hawthorn bush is seen in the background on the right.

Plate 2
Slope of a medium coal measure "live" spoil heap becoming colonized by *Pteridium*. The bush in the left background is *Sambucus nigra*.

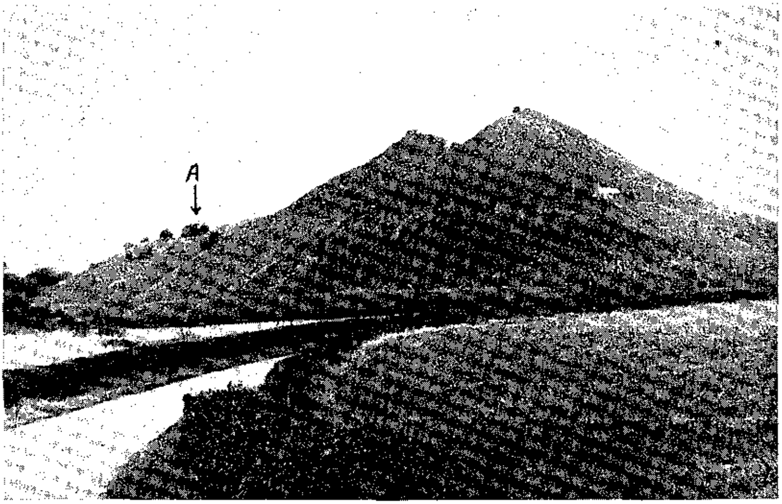

Plate 3

General view of a typical tall spoil heap from the Cannock Chase Coalfield.

Plate 4

Trees of *Quercus robur* and *Betula verrucosa* from " A " Plate 3. The open nature of the ground flora is well shown in the foreground.

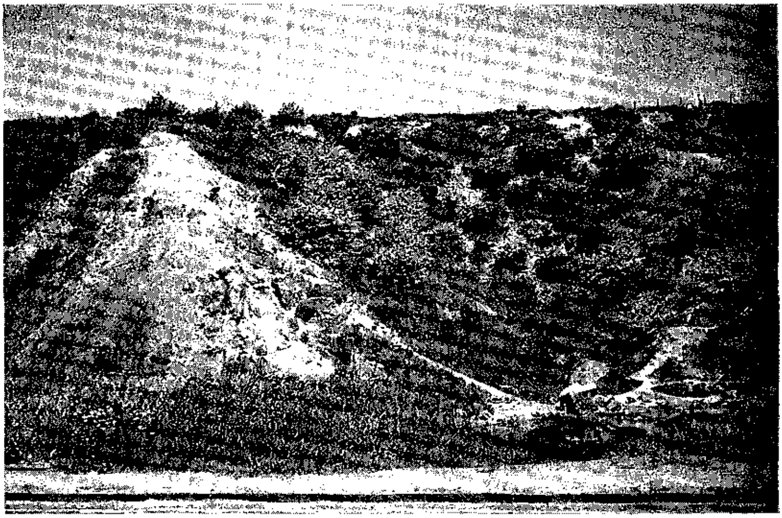

Plate 5

General view of an old dolerite working showing dense shrub on the concave and poor plant development on the convex slopes respectively.

Plate 6

Hydrosere community at Willingworth resulting from subsidence ; bordered with *Glyceria maxima*.