# CORRELATION OF CHESHIRE PLAIN AND DERBYSHIRE DOME GLACIAL DEPOSITS

by

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## Summary

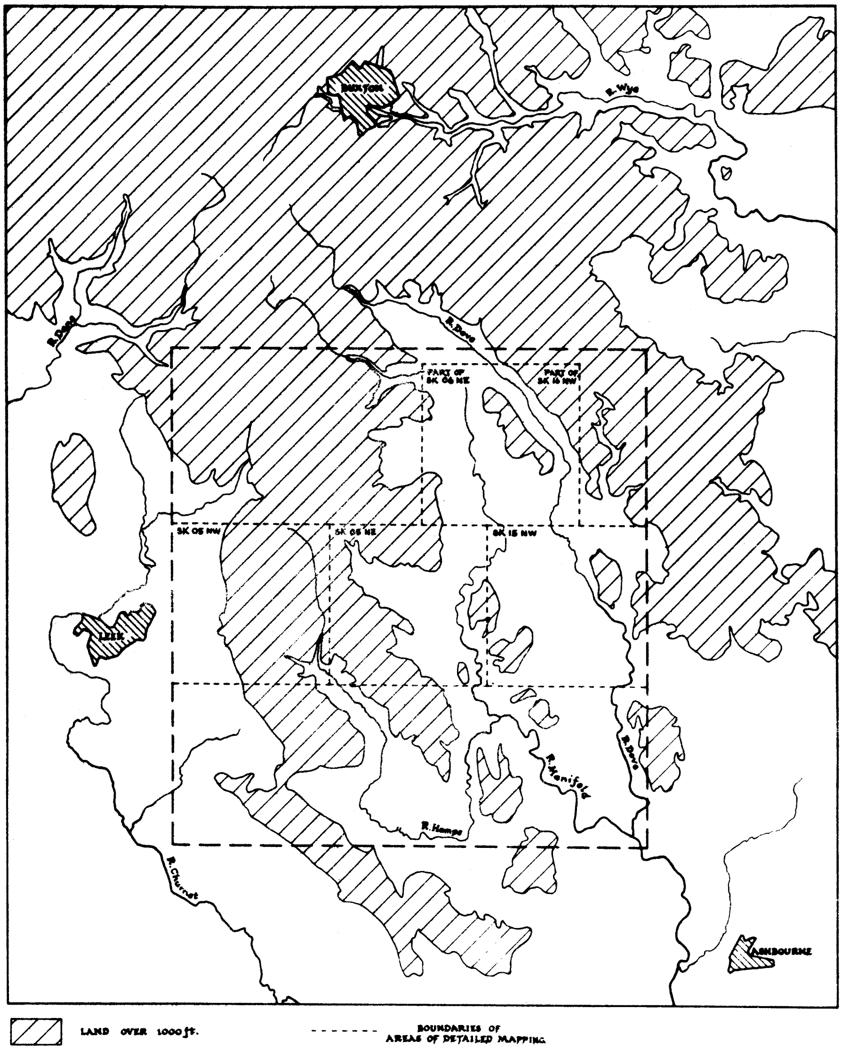
Two boulder clays are present in the Cheshire Plain. On the Derbyshire Dome there is a single boulder clay which underlies loess. There is evidence in the soils on the Derbyshire Dome of two phases of post-loess clay translocation, separated by an interval of soil erosion. The amount of translocated clay in profiles affected by both clay translocation episodes is about twice that found in profiles only influenced by the later phase. This is analogous to differences in depth of decalcification reported by Boulton and Worsley (1965), in glacial deposits on each side of the Late Weichselian moraine in the Cheshire Plain.

It is suggested that the till and loess on the Derbyshire Dome and the earlier till in the Cheshire Plain are of the same age and were deposited no earlier than the Early Weichselian (Warthe) stadial; that the two phases of clay translocation represent soil formation during the Warthe - Late Weichselian interstadial and Postglacial respectively; and that the soil erosion episode occurred during the Late Weichselian stadial.

## Introduction

Investigations of the extensive glacial deposits in the Cheshire Plain have revealed at least two depositional episodes. Boulton and Worsley (1965) have dated at about 20,000 years B.P. the most recent of these, represented by deposits north of the Wrexham - Whitchurch - Bar Hill moraine. Deposits to the south of the moraine are of uncertain age but, according to Holmes (1965, p.690, fig. 519), may be equivalent to the Early Weichselian Warthe moraines in Europe.

Glacial deposits on the central part of the Derbyshire Dome have received little attention.




Text-Fig. 1. Location of the study area. The general area of study is bounded by the thick broken line. Thin broken lines, which are the boundaries of 6" Ordnance Survey quarter-sheets, outline the areas in which detailed soil studies were carried out.

Their distribution is not fully known, neither is it certain when they were deposited. In particular, the relationship between these deposits and those in the Cheshire Plain is obscure. Jowett and Charlesworth (1929) postulated an 'Older Drift' glaciation of both areas, followed by a 'Newer Drift' glaciation largely confined to the Cheshire Plain. Charlesworth (1957, p.776) suggested that the Pennine till was deposited during his Second Welsh glaciation (Riss, Saale) but also mentions an Early Pennine glaciation during the Mindel/Elster glacial episode (1957, p.1016). Pigott (1962) found evidence of loess on the Derbyshire Dome, overlying till and limestone residues with evidence of interglacial weathering.

During studies of soil development in the areas shown in Text-figs. 1 and 2, the present author (1968) has obtained information on the glacial deposits on the Derbyshire Dome which suggests correlations with glacial events in the Cheshire Plain.

## Definition of terms

Clay translocation. A soil-forming process involving the movement of clay minerals and other colloidal materials. In profiles where this process has operated, the upper soil layers (horizons) are depleted and the lower enriched in clay-size particles.

The process is thought to take place under slightly acid conditions and in an environment where soil organisms rapidly decompose plant debris. Organic decomposition products are thought to be involved in the mobilization and transport of clay, and the size and distribution of soil pores to be an important factor influencing clay deposition (Dalrymple, 1967).

Translocated clay is detectable in the field by estimates of clay content and by the presence of wax-like coatings on structure faces, stones or the walls of soil pores.

In the laboratory, translocated clay may be confirmed from thin soil sections and should typically have the following properties:

i) The material should be quite distinct from residual materials in the horizon of deposition.

ii) The material should show strong birefringence under crossed polarizers.

iii) The material should be finely laminated.

iv) The material should be associated with water-movement pathways, such as structure faces, soil pores, etc.

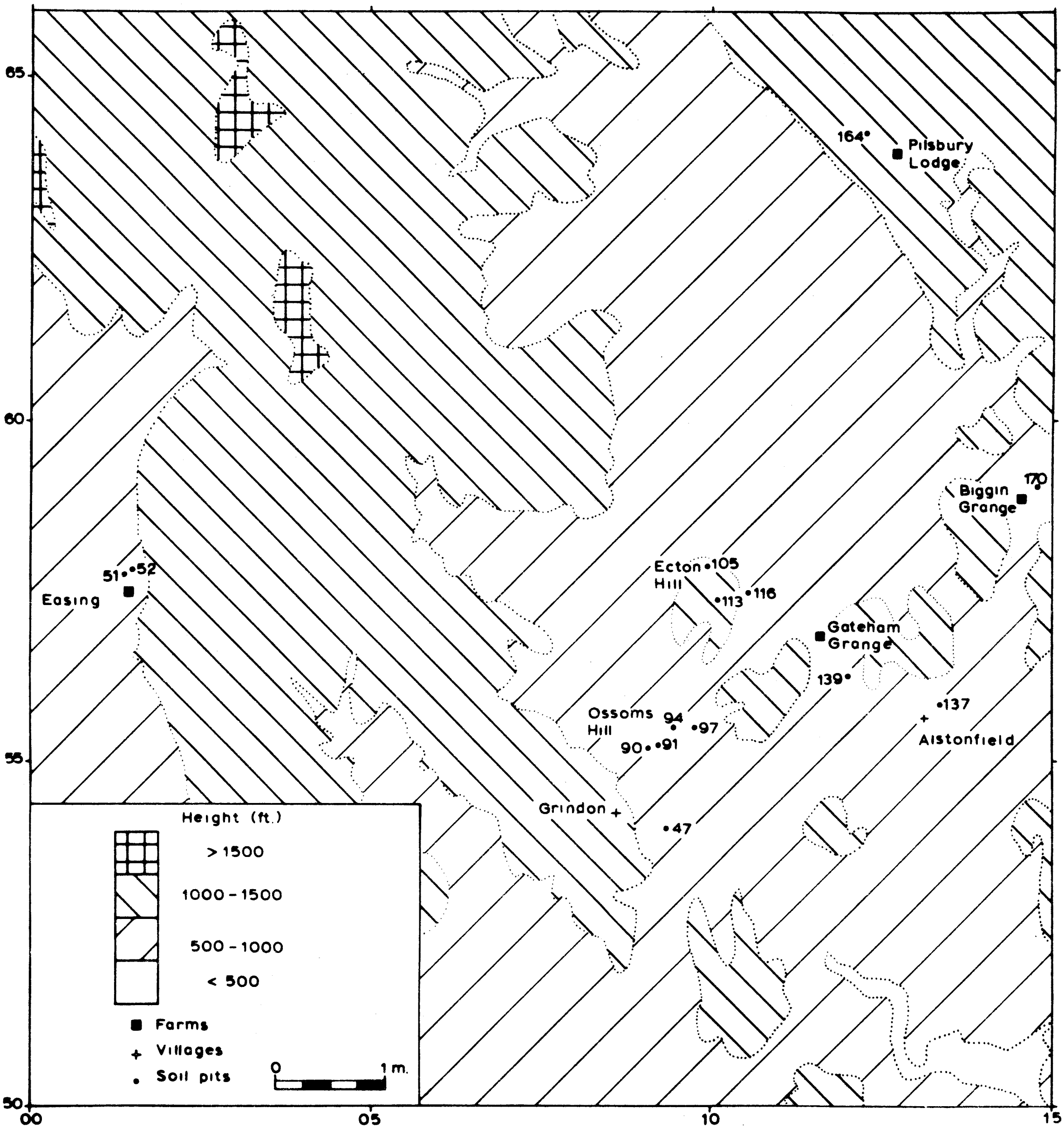
Brewer and Haldane (1957) have demonstrated that artificially produced clay translocates have such characteristics.

Other terms relating to clay translocation in the text are:

Matrix. Residual material in a horizon of clay deposition.

Non-matrix clay. Birefringent clay-size material distinguishable from the matrix.

Laminated clay. Non-matrix clay with all the features of typical translocated clay listed above.




Text-Fig.2. Location of soil pits mentioned in the text. The area shown in an enlargement of the area bounded by thick broken lines in Text-fig.1.

Unlaminated clay. Non-matrix clay distinguished from laminated clay by weaker birefringence and less obvious lamination or association with soil pores etc., sometimes with an eroded appearance.

## Methods of Study

Samples were collected from the different soil horizons exposed in pits dug for the examination and description of soil profiles. The location of the soil pits referred to in the text is shown in Text-fig. 2. After drying, part of each sample was lightly crushed in order to disintegrate the soil structures. The material coarser than 2 mm. was then removed by sieving and discarded.

The complete particle size distribution of the less than 2 mm. fraction of each sample was determined using the method described in Cazalet (1968). Three grades, covering the range 75 - 2000 $\mu$, were separated by sieving and weighed. Weight data for 12 grades, covering the range 75 - 4 $\mu$, were obtained by Coulter Counter analysis, which measures particle size distributions electronically. After plotting the combined data as cumulative weight per cent. (of the less than 2mm. fraction), the graph was interpolated to 2 $\mu$ in order to determine the amount of less than 2 $\mu$ clay.

Although the size distribution of the whole less than 2 mm. fraction was determined, the only data quoted here are for the 'loess' (10 - 70 $\mu$) and clay (less than 2 $\mu$) grades. At the 95% confidence level, the precision of the method is better than 6% of stated value for both fractions (see Text-figs. 4 and 5).

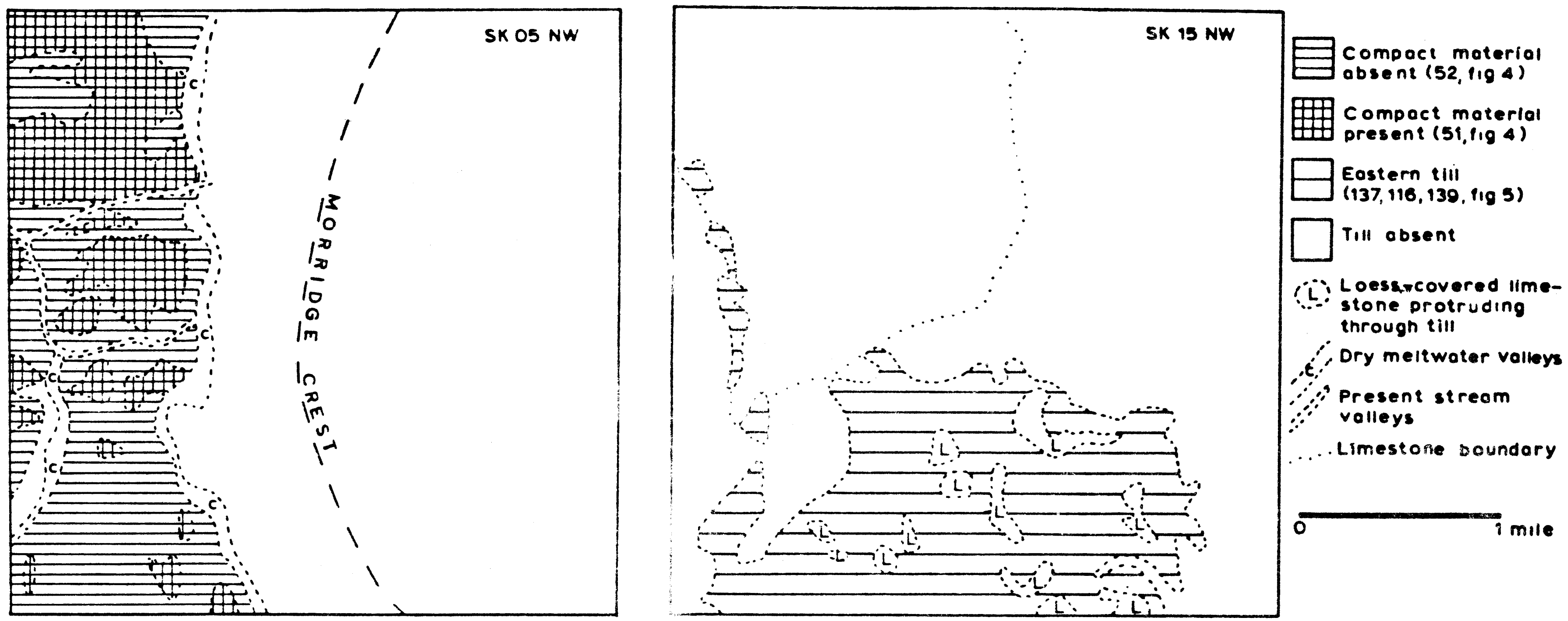
The particle size information suggested that, in the lower horizons of some profiles, there were accumulations of translocated clay. Thin sections of uncrushed material from these horizons were therefore prepared to confirm this, using the Dammar Gum-Lakeside resin impregnation procedure described by Dalrymple (1957). Two or three sections were prepared of material from each horizon. The relative amounts of laminated and unlaminated clay and of matrix were determined by point count and the results expressed as a percentage of total points counted, usually based on a total of 200 - 300 points.

## Western deposits

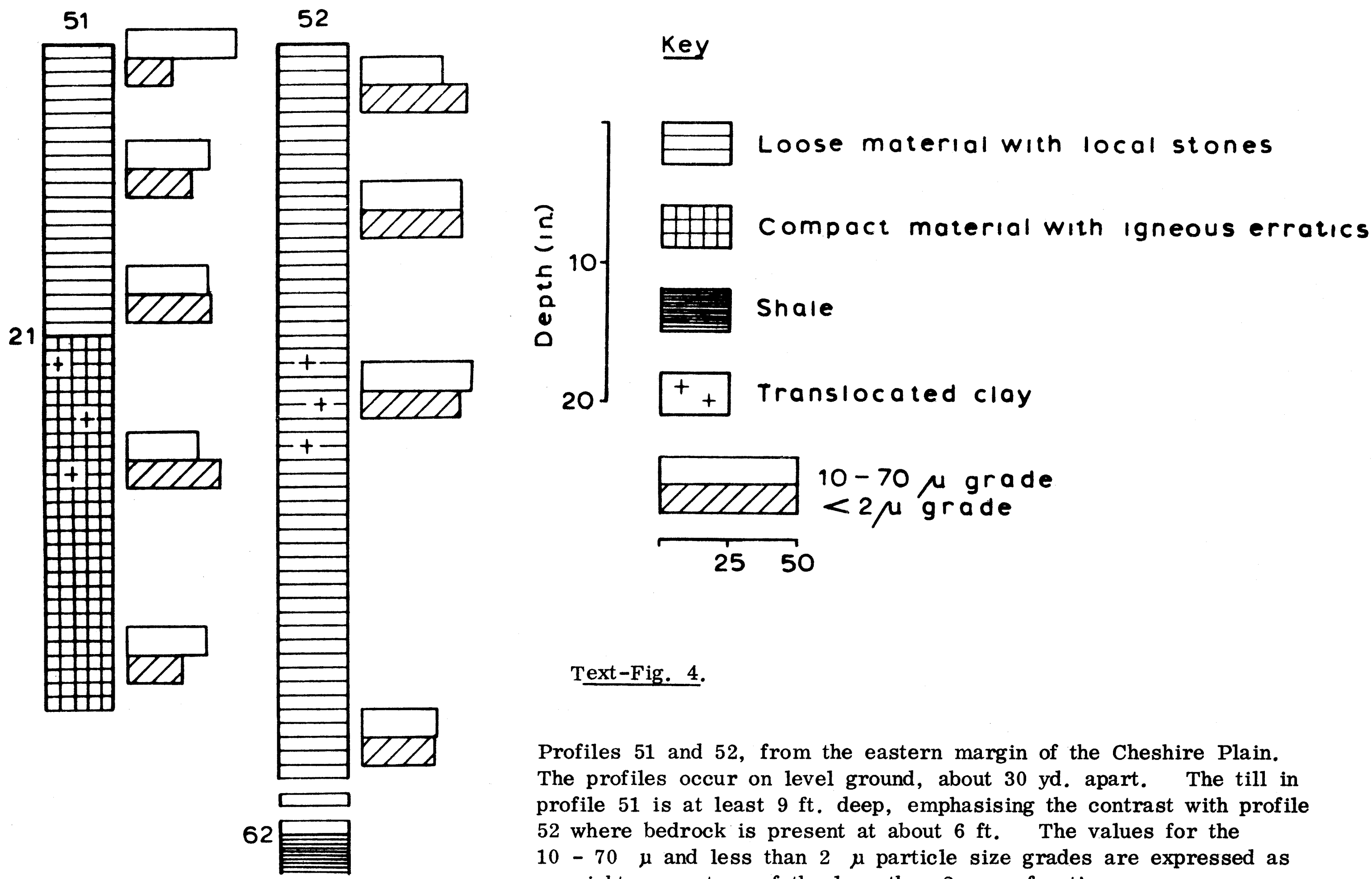
Till is present in the study area at altitudes below 1000 ft. to the west of Morridge (Text-fig. 3). This till therefore lies on the eastern margin of the Cheshire Plain. The Late Weichselian moraine lies to the north of the study area, so the till is pre-Late Weichselian in age. According to Boulton and Worsley (1965), it is thinner and more dissected than the Late Weichselian till. Furthermore, it is decalcified to about twice the depth found in Late Weichselian deposits. Both these observations suggest deposition some time before the Late Weichselian glacial episode.

The two profiles examined (profiles 51, 52 at 014578*) occur on level ground and are developed in deposits of two types. The first type is a compact, red-brown material containing numerous quartz and igneous pebbles. It has polygonal cracks resembling those in North Welsh till of Riss age, ascribed to periglacial freeze-drying by Stewart (1961). The second material is a looser,

* All map references are on Sheet 111, O.S. 7th Edition.
These are only quoted for the more important sites mentioned in the text.




Text Fig. 3. Distribution of till in the western and central parts of the study area. In the western sector, the distribution of locally-derived material is included in order to demonstrate the relationships between this deposit and the pre-Late Weichselian till.




Text-Fig. 4.

Profiles 51 and 52, from the eastern margin of the Cheshire Plain. The profiles occur on level ground, about 30 yd. apart. The till in profile 51 is at least 9 ft. deep, emphasising the contrast with profile 52 where bedrock is present at about 6 ft. The values for the 10 - 70 μ and less than 2 μ particle size grades are expressed as a weight percentage of the less than 2 mm. fraction.

yellow-brown deposit containing mainly local stones with rare quartz and igneous pebbles. In some places it overlies red-brown till, and in others, bedrock (Text-figs. 3, 4). Both deposits are poorly sorted. The red-brown material is clearly pre-Late Weichselian till. The yellow-brown material is probably a locally-derived Late Weichselian sludge deposit.

Evidence for the presence of loess in these profiles is inconclusive. Although the typical loess particle size grade is moderately well represented (Text-fig.3) the local rocks all contain considerable amounts of silt, which in particle size analysis is indistinguishable from loessial material.

Particle size evidence suggests the presence of a weak clay peak at the junction of yellow-brown and red-brown materials in profile 51 (Text-fig.4). This is confirmed by thin section evidence which shows that mainly unlaminated clay (8%) is present in the horizon with the highest clay content (Tab. 1; Plate 6, Figs. A, B).

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Particle size evidence also shows a very weak clay peak in profile 52; and this is also confirmed from thin sections which show about 6% of unlaminated clay. By analogy with some of the Derbyshire Dome soils described below, the translocated clay shows evidence of disturbance and clay translocation seems to have ceased.

If the material west of Morridge was not stabilised until the Postglacial, the small amount of translocated clay represents Postglacial clay movement. The values of 6 - 8% are of the same order as those found in Postglacial soils developed in Wisconsin till (Buol and Hole, 1961).

## Central Pennine deposits

There are three deposits overlying the limestones of the gently undulating central plateau (Derbyshire Dome) at altitudes between 900 and 1100 ft. - silt, residual clay and till.

The silt, by far the most extensively distributed material, has he following properties:

i) More than 50% of the particle size distribution lies between 10 and 70 $\mu$.

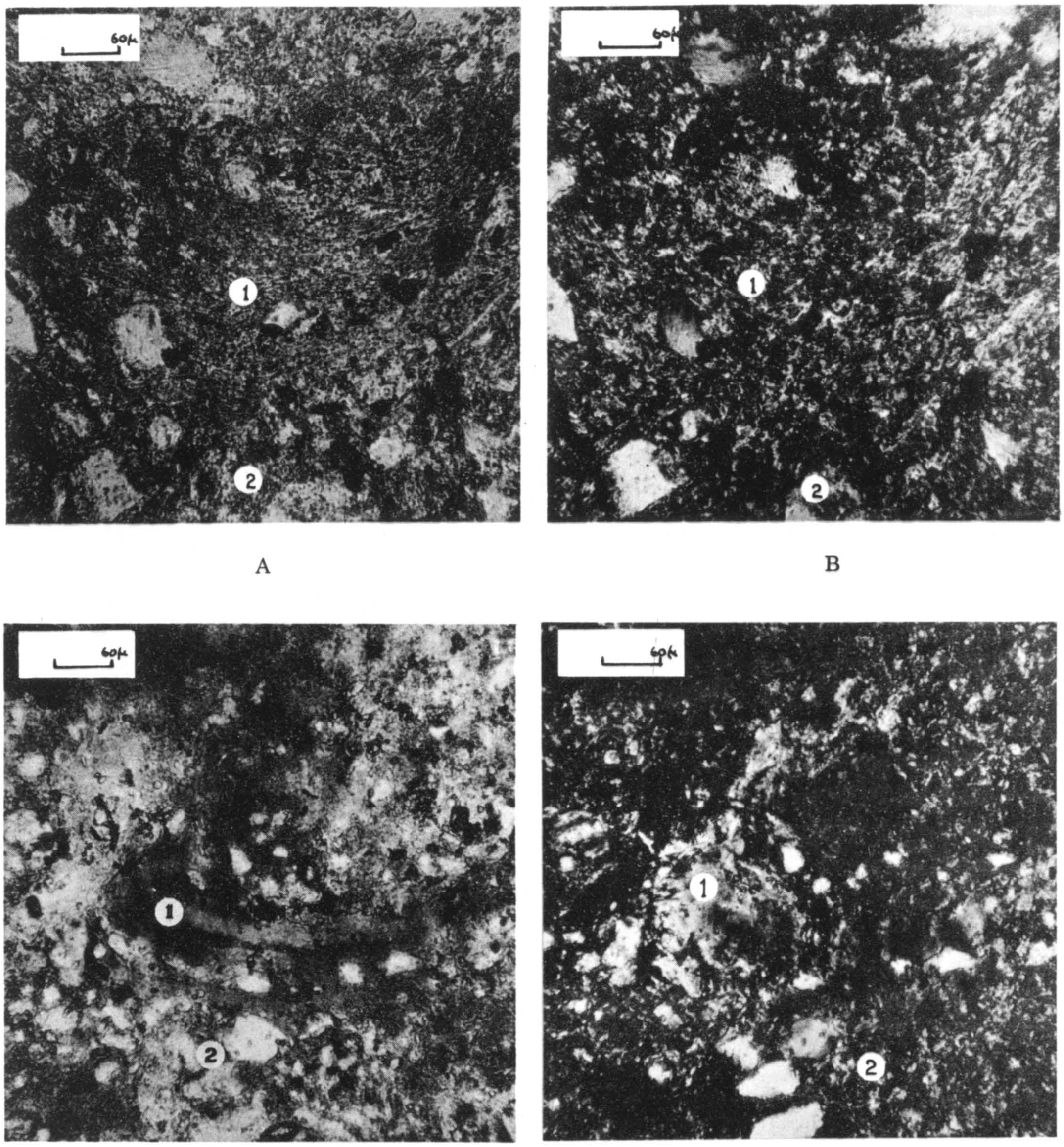
ii) The clay content is less than 25%.

iii) The silt is much better sorted than any other parent material in the area. Of the 41 silt samples analysed, the 10 - 70 $\mu$ grade medians of 30 (75%) lie between 26 and 30 $\mu$

iv) Silt with these characteristics is detectable at least in the upper horizons of all soils on the limestone and also on other parent materials which weather to produce mainly clay-size residues.

This combination of properties is characteristic of loess (Bagnold, 1941, pp. 88-92; Cailleux, 1953; Swineford and Frye, 1945). The deposit will therefore be subsequently referred to as loess.

The loessial soils form a morphological sequence in which the depth of the deposit is closely correlated with slopes of different intensity. The soils are associated with pure limestones contain-

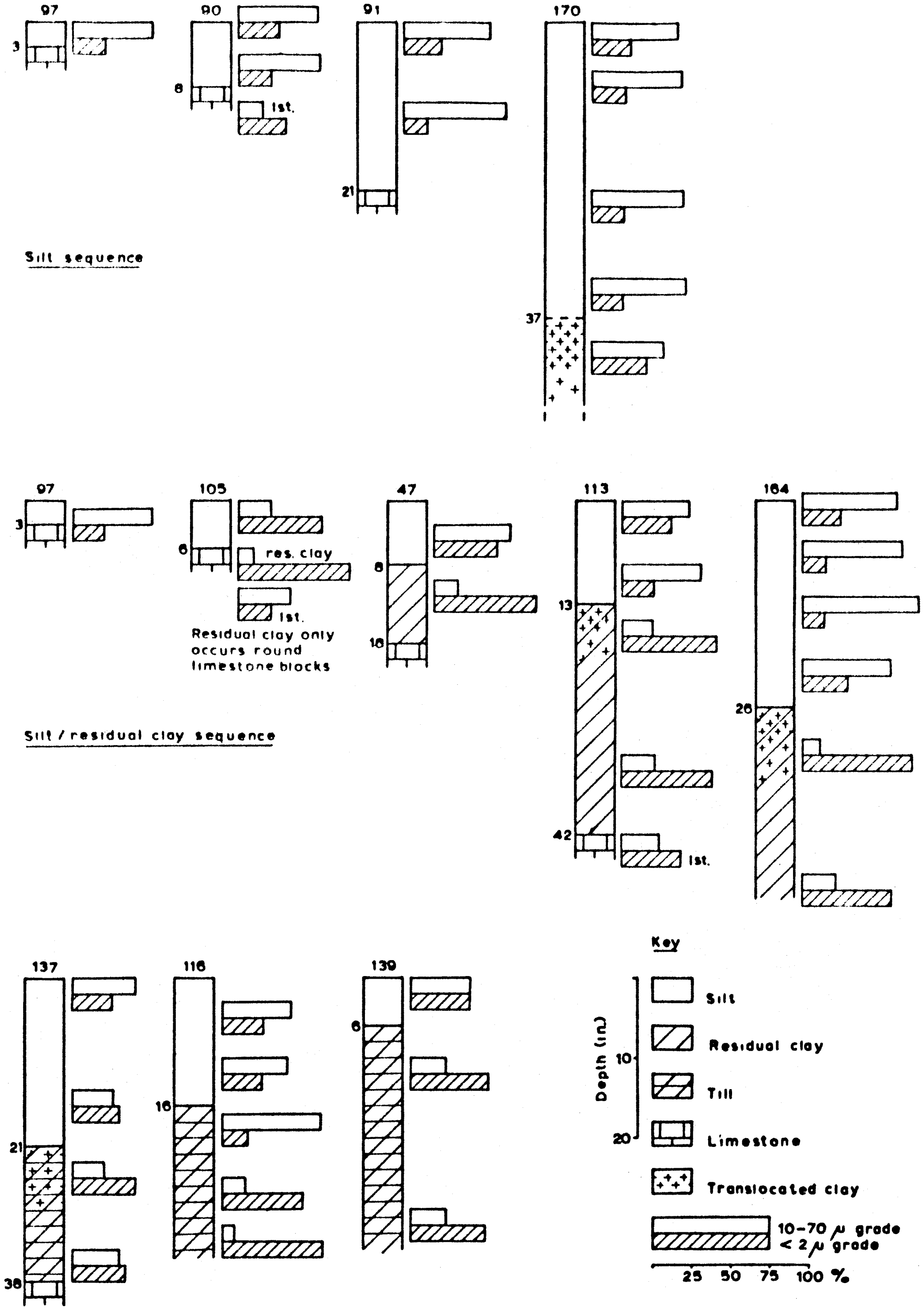


A B C D

Plate 6 figs. A, B. Part of the clay accumulation horizon of profile 51. Note the very weak lamination and birefringence of the non-matrix clay and the absence of an associated conducting channel.

figs. C, D. Part of the clay accumulation horizon of profile 170. Although the clay is more strongly birefringent, lamination is weak and there is no conducting channel present.

1, non-matrix clay; 2, matrix.
A, C, plain polarized light; B, D, crossed polarizers.




Silt/till sequence

Text-Fig. 5. Soil sequences in the central part of the study area. Considerable amount of translocated clay are only found in the deepest soils of each sequence. Profile 97 is considered to be the shallowest member of both silt and residual clay sequences since it consists of a mixture or organic matter, limestone fragments and loess. The particle size data are as in Text-fig. 4.

ing more than 95% carbonates. Only on nearly level sites where the deepest soils occur is non-matrix clay present in the lower horizons (Text-fig. 5). In other profiles on moderate or steep slopes, the absence of clay accumulation may well be explained by solifluction. Point count data of a representative deep profile (profile 170 at 148591) establish that the clay accumulation horizon contains 14% of unlaminated clay (Tab. 1; Plate 6, Figs. C, D).

Stoneless clay overlying less pure limestones (average carbonate content about 80%) is interpreted as limestone weathering product and is referred to as residual clay. The shallowest profile (97) consists of organic matter mixed with limestone fragments and loess. In the deeper profiles, the horizons directly overlying the limestone are formed in residual clay alone, but the upper horizons contain loess. The loess is mixed with residual clay in the profiles of intermediate depth (105, 47) and is only present as a distinct deposit in the deepest soils (113 at 101574; 164 at 123642).

The soils containing residual clay form a morphological sequence in which thickening loess/loess-residual clay/residual clay horizons are related to slope intensity. Only in the deepest soils on nearly level sites are there indications of substantial clay translocation (Text-fig. 5). In the shallower soils, the absence of translocated clay is probably the result of solifluction. These soils have relatively high clay contents throughout the profile, however, and this is thought to inhibit clay movement (Hallsworth, 1963). Point count data (Tab. 1) establish that the mainly laminated non-matrix clay in profile 113 totals 21.5%. The mainly unlaminated clay in profile 164 amounts to 17.5% (Pl. 7, Figs. A, B, C, D. respectively).

Also present in this group of soils are occasional profiles on nearly level ground in which more weakly developed zones of clay accumulation occur. An example of this situation is profile 94 at 094556, in which the volume of non-matrix clay, all unlaminated, totals only 6%.

The central till deposit is confined to a single area between the River Manifold and the River Dove near Alstonfield (Text-fig. 3). Quartz and igneous erratic pebbles are abundant.

All three profiles in this material occur on gentle slopes. The profiles form a morphological sequence in which increasingly poor soil profile drainage is jointly controlled by depth of loess and depth of till. Thus profile 137, at 134559, is well drained, 116 is poorly drained and 139 is very poorly drained (Text-fig. 5). Significant clay translocation is only found in the well drained stage (profile 137), where laminated clay totals 22% (Tab. 1). The absence of clay movement in profiles 116 and 139 is probably due to a combination of low soil porosity and high clay content.

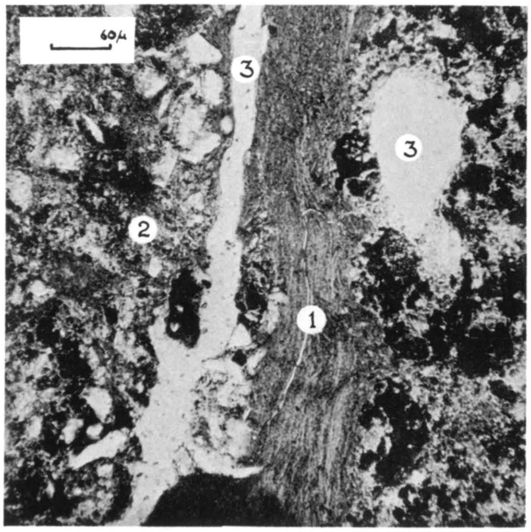
The accumulation zones of profiles 113 and 137 contain about 22% of laminated clay, but in profiles 164 and 170 non-matrix clay totals only 17.5% and 14% respectively and is mainly unlaminated. In these four profiles the total clay content is comparable. The slightly lower values in profiles 164 and 170, however, the lack of lamination and the absence of associated conducting channels are together consistent with disturbance of the clay and suggest that clay translocation is no longer taking place.

It will be noted that significant amounts of non-matrix clay (more than 14%) are only found on well drained, level sites. Occasionally on such sites, as in profile 94, much less clay is evident (6%). Examination of all the soils described from the area suggests very strongly that the distribution of clay translocation values is distinctly bimodal, with a group of values greater than 14% and another group lower than 8%. This bimodal grouping indicates that clay translocation may have taken place in two stages, with profiles 113, 137, 164, and 170 participating in both stages and profile 94 only in the later one. The observation that even on some level sites only the later stage is represented suggests that a phase of parent material redistribution or soil erosion separated the two episodes of clay translocation.

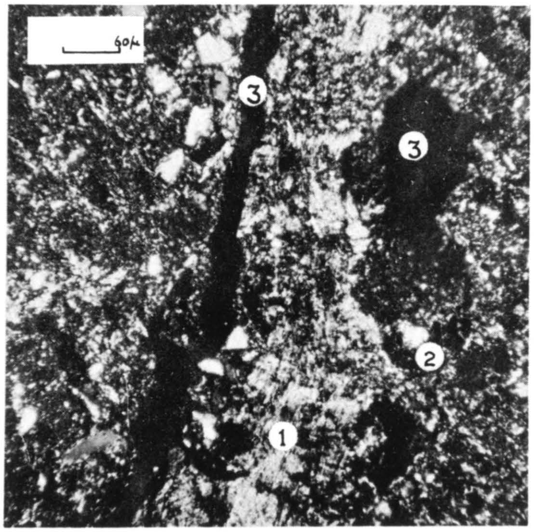
## TABLE 1

| Fabric feature | Profiles with laminated birefringent clay | | Profiles with unlaminated birefringent clay | | Profiles with small amounts of birefringent unlaminated clay | |
|---|---|---|---|---|---|---|
| | 137/25-28" | 113/15-18" | 170/40-45" | 164/30-32" | 94/22-26" | 51/30-33" |
| Matrix (+ voids) | 78.5 | 77.5 | 86.0 | 82.5 | 94.0 | 92.0 |
| Laminated clay | 20.0 | 22.0 | 0.5 | 1.5 | - | 2.0 |
| Unlaminated clay | 1.5 | 0.5 | 13.5 | 16.0 | 6.0 | 6.0 |
| Total clay | 21.5 | 22.5 | 14.0 | 17.5 | 6.0 | 8.0 |
| Total points counted | 276 | 254 | 276 | 139 | 228 | 221 |

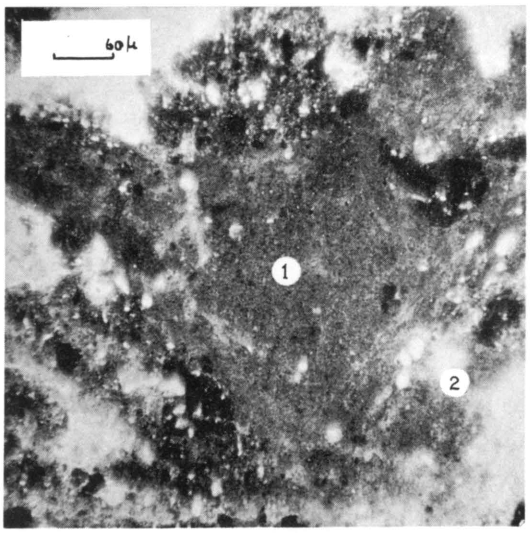
Point count data for the horizons of clay accumulation, suggested by particle size data, of the profiles discussed in the text. The results are expressed as a percentage of the total number of points counted.



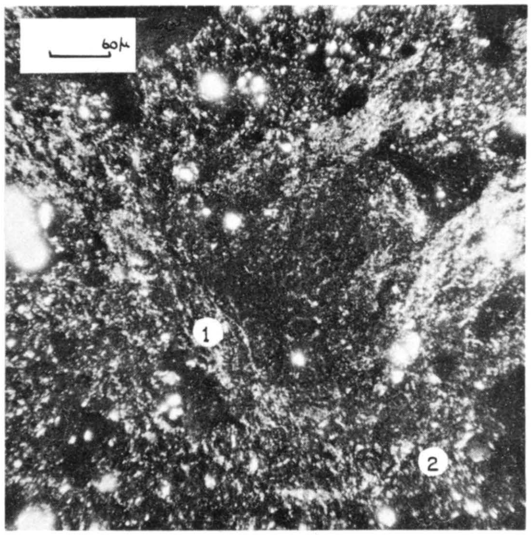

A




B




C




D

Plate 7 figs. A, B. Part of the clay accumulation horizon of profile 113. Note the strong lamination and birefringence of the non-matrix clay and its association with a conducting channel.

figs. C, D. Part of the clay accumulation horizon of profile 164. Note the weak lamination and birefringence of the non-matrix clay and the absence of an associated conducting channel.

1, non-matrix clay; 2, matrix; 3, conducting channel.
A, C, plain polarized light; B, D, crossed polarizers.

The loess covers all other deposits; its deposition must therefore post-date deposition of the till. The presence of loess also seems to have been a prerequisite of clay movement, for there is no evidence of clay movement either in the shallower residual clay soils or in the deeper till profiles. In profile 170, furthermore, translocated clay has been deposited in a horizon with clear loessial characteristics. Clay translocation must therefore post-date loess deposition.

This evidence, together with the above interpretation of the clay translocation data, seems to establish that six events have influenced the formation of the present-day soils on the Derbyshire Dome:

i) Deposition of till.

ii) Deposition of loess.

iii) Clay translocation, initial phase, in profiles 113, 137, 164 and 170.

iv) Soil erosion (but not in the above profiles)

v) Clay translocation, second phase, in profiles 113, 137, 164 and 170; the only phase in profile 94.

vi) Disturbance of translocated clay in profiles 94, 164 and 170 but not in profiles 113 and 137.

## Conclusions

Boulder clays of two glacial episodes are known to be present in the Cheshire Plain. In the central Pennine area there is evidence of only one boulder clay, but this underlies a silt deposit with the particle size attributes of loess. It is therefore tempting to equate the deposition of till in the central area with that of the earlier Cheshire Plain till, and the deposition of loess in the central area with the deposition of Late Weichselian till in the west.

Although these correlations cannot be completely ruled out, they are inconsistent with the evidence presented here, which suggests a rather more complex situation.

In both western and central parts of the study area there is evidence of a phase of soil erosion. In the western sector this is indicated by the dissection of the earlier till, followed by deposition of colluvial material; in the central sector there is no conclusive evidence of till dissection, but the loess has clearly been redistributed and some of the soils eroded. Differences in the amount of translocated clay between profiles 113, 137, 164 and 170, and profile 94 (all on level sites) substantiate this view.

It seems, therefore, that the phase of soil erosion post-dates deposition of the earlier western till and the central till and loess.

Neither area was apparently over-ridden by Late Weichselian ice, so it seems reasonable to suggest that at least part of the soil erosion/redistribution phase occurred during the Late Weichselian.

This suggestion receives support from the clay translocation data. On level sites in the western and locally in the central area, comparable but small amounts of clay translocation (6 - 8%) have been observed.

TABLE 2

| Period | Western area and Cheshire Plain | Derbyshire Dome |
|---|---|---|
| **Warthe stadial (Early Weichselian glaciation)** | Deposition of till (and loess?). | Deposition of till and loess. |
| **Interstadial** | Initiation of decalcification of till.<br>Dissection of till ? | Initiation of clay translocation in profiles 113, 137, 164 and 170.<br>Dissection of till? |
| **Late Weichselian stadial** | Deposition of till.<br>Dissection of Warthe till<br>Deposition of local material on Warthe till and bedrock. | Soil erosion. |
| **Postglacial** | Decalcification of Warthe and Late Weichselian tills.<br>Disturbance of translocated clay in profiles 51 and 52. | Resumption of clay translocation in profiles 113, 137, 164 and 170.<br>Initiation of clay translocation in profile 94.<br>Disturbance of translocated clay in profiles 94, 164 and 170 but not in profiles 113 and 137 |

Summary of the suggested correlations of the Cheshire Plain and Derbyshire Dome glacial deposits.

The fact that, on other level sites in the central area, much larger amounts of translocated clay are present (14 - 22%), together with the evidence that all clay translocation post-dates loess deposition, indicates that the loess was probably deposited some time before the Late Weichselian glacial. So far as is known, clay translocation only takes place in a temperate environment in which organic matter is readily decomposed. Therefore, if 6 - 8% of translocated clay represents the amount of Postglacial clay movement, 14 - 22% is likely to represent this amount plus an increment translocated during a pre-Late Weichselian phase of climatic gmelioration. Deposition of loess and till in the central area must therefore pre-date this phase; the loess is consequently unlikely to be a Late Weichselian deposit.

It seems that either the Warthe or Saale glacial episodes would probably have been sufficiently extensive to have deposited till in the central area. Of the two, the Warthe stadial seems the more likely. The reason for this is that, if the till and loess were deposited during the earlier Saale glacial, it is difficult to envisage why the subsequent, apparently almost as extensive, Warthe glacial episode could have left no trace in the central area. At least two loess deposits should be present, and for this there is no evidence.

Although the actual glacial episode in which central till and loess were deposited is uncertain, it seems that the central and earlier western tills may well have been deposited by the same ice-sheet. Boulton and Worsley (1965) have established that glacial deposits south of the Late Weichselian moraine are decalcified to nearly twice the depth found in materials to the north of the moraine. In the present study, the point count estimates of clay translocation fall into two equally distinct groups, with the values in the higher group being almost twice those in the lower. Given that factors other than time may influence rates of decalcification and clay translocation, the analogy nevertheless seems significant.

It therefore seems likely that the central and earlier western tills were deposited during the same glacial episode, and that this episode was probably the Early Weichselian Warthe stadial.

The chronology thus tentatively established is summarised in Tab. 2.

## Acknowledgement

I thank Dr. J.B. Dalrymple for instruction in the preparation of thin soil sections.

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Manuscript received 28 October 1968.