SOME ASPECTS OF THE DENUDATION OF THE CHALK IN THE COUNTY OF WILTSHIRE

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To Jeanie

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INTRODUCTIONS

INTRODUCTION

Geomorphologists working on the unglaciated ground in southern England have betrayed an unfortunate complacency, a feeling that:

> "No important gap remains to be bridged to account for the major features of the present landscape." George, 1955.

This view reflects a regrettably uncritical acceptance of theories elaborated in the London Basin, a tract extending from the Weald of Kent and Sussex northward to the Chiltern escarpment. During the present century the geomorphological discipline took shape in this area. The body of essentially geological evidence, gathered there during the Nineteenth Century, was supplemented, and fashioned into an account of landscape evolution. This work culminated in the synthesis of Tertiary events elaborated by Wooldridge (1927) and refined by Wooldridge and Linton (1938, 1955).

Views on the origin of landforms elsewhere in Britain have often sought merely to reproduce the conclusions suggested by Wooldridge.

> "His work leaves little doubt that from the Chiltern slopes to the South Downs and into Dorset, late Pliocene marine erosion with falling sea level planed a series of stepped platforms at

various heights from about 650'; that these platforms emerged under conditions of effective eustacy without significant warping and that from them the present river system has been superimposed." George, 1955.

The history of the Tertiary period in Wessex has never aroused the interest which, in the London Basin, constantly promotes the collection of useful descriptive evidence. The attempt made by Wooldridge and Linton (1955) to extend their account of the Tertiary period into Wessex is therefore largely dependent on an extrapolation of events in the London Basin. In the London Basin the geological record provides the foundation for geomorphological study and tends to substantiate its conclusions. In Wiltshire the geological evidence has scarcely been examined and the application of concepts evolved in the London Basin is of correspondingly doubtful value, especially if it is realised that even in the relatively well documented London Basin the interpretation of the Tertiary period remains problematic.

A careful reading of the scattered literature dealing with the evolution of the Wessex landscape indicates certain details which are not readily accommodated in the account suggested by Wooldridge and Linton. The problematic evidence consists of records, which are often incidental and incomplete, of superficial geological deposits, preserved in outcrops of slight extent and disturbed aspect. In this thesis the historical background to the several aspects of the study are interpolated at appropriate points in the main body of the text.

The failure to treat the problematic geological material in the most recent geomorphological account of the Wiltshire Chalk (Wooldridge and Linton, 1955) reflects a trend which has misguided the work of geomorphologists in this country. A.E. Salter writing in 1905 could suggest that:

> "There is probably no branch of British Geology which has excited so much controversy or has more special literature devoted to it than that dealing with superficial deposits."
> Salter, 1905.

H.J.O. White, a few years previously, had indicated the nature of the problems involved and the scope for future work:

> "The whole subject of transported rock fragments in the drifts of southern England is full of interest and much work remains to be done in the direction of tracing the routes and determining the agencies by which these material have been carried to their present positions." White, 1897.

Thirty years later the diagnostic value of the drift was forgotten and largely superseded by work on the interpretation of planation surfaces. Henri Baulig argued that:

> "When the proper relationships are

determined these features offer a
veritable chronology of denudation
which is independent of the doubtful
witness of the superficial deposits."
Baulig, 1935.

The determination of geomorpholigists to assert their independence of the geological discipline has undoubtedly favoured the trend, which these views illustrate. Unfortunately the independence which has been achieved proves to be an estrangement which the nature of the landscape by no means justifies.

The deliberately geographical treatment of Tertiary planation surfaces in Britain has been guided by a view that southern England has not been appreciably deformed by folding or tilting since the Oligocene period. In this context horizontal elements in the landscape have been extensively correlated in terms of concordant height above sea level and have been referred to inherently horizontal planation features of marine or subaerial origin and to specific eustatic elevations of sea level.

This approach to the interpretation of the British landscape has been criticised by Lester King:

"Attempts to systematise ancient erosional remnants were foredoomed to failure when their authors attempted to classify such remnants upon a basis of equality of height above sea level. No synthesis of British topography is possible without a clear understanding of the differential movement involved." King, 1962.

Whether the generally accepted structural premisses are correct, or not, it seems unwise to rely so exclusively on the witness of altitude and in 1957 Professor Linton had already urged British geomorphologists to attempt the comparative study of landscape features using the whole geographical context of the feature: the dissection and weathering of the surface, the drifts and soils which rest upon it, and the relation of the ground to relief both above and below it.

This thesis describes a study of this type undertaken in southern Wiltshire. The area examined has been discussed by Wooldridge and Linton (1955) but lies on the periphery of the tract with which they deal, and their treatment is essentially theoretical and not circumstantial.

Checking and cross-checking of altitude frequency analyses suggests that any concept of extensive undeformed planation surfaces is likely to prove illusory, although contour maps show that well defined breaks of slope, and bevelling of the geological outcrop are widespread. Attention has been concentrated therefore on surfaces conspicuously bevelled across the geological outcrop, to establish particularly whether any trace of drift is preserved on these surfaces.

This enterprise proved very rewarding, partly

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perhaps because the work of the Geological Survey is incomplete in this area (Sheets 281 and 297 of the New Series have not yet been published) but largely because, in the time available, a much more thorough examination of the drift was possible than would have proved economical during the original survey of the ground.

Beyond the main Tertiary outcrop in the Hampshire Basin the Tertiary geological record in Wessex has largely disappeared and the relics which do survive are shallow superficial deposits or 'drifts' of slight extent and disturbed aspect. During the present century this material has attracted the attention of geologists to a sadly decreasing extent, but for the geomorphologist it contains the key to Tertiary landscape evolution. The concern of this investigation has been to examine the drift in southern Wiltshire and to consider its distribution in relation to the accepted interpretation of the landscape. Samples were collected from over two hundred sites, surface indications of the geology were examined at a substantially larger number of sites and more than thirty sections were excavated in particularly interesting locations. The rocks identified in the superficial deposits prove to be a useful definitive measure of the contemporary geological outcrop at the period of deposition, and therefore of the extent to which the land had been worn down by erosion at that time. The character of the gravel included in the drifts shows how the material has been derived, whether in streams or in beach material or derived unchanged from the underlying rock; evidence which yields a clue to the nature of process.

The results of the investigations described in this thesis indicate conclusions inconsistent with those generally accepted in southern England and the ground has been compared with the Paris Basin; a geosynclinal tract where sedimentation persisted throughout the greater part of the Tertiary period and which in this respect is analagous to the Hampshire Basin in Wessex. The comparison with the Paris Basin is essentially a comparison with the conclusions reached by Cholley (1957) and is not based on a re-examination of the evidence on the ground.

In France the estrangement between geology and geomorphology has not prevailed so effectively as in this country and techniques of inverse correlation have led to the recognition there of a progressive evolution of structure and landform during the Tertiary period. The application of these techniques to some of the material collected during the present investigation has assisted the task of correlation, but so large a volume of material has been involved and so fundamental are many of the conclusions that the work has depended not on the application of refined geological techniques but on a faculty for careful observation and the ability to distinguish, in hand specimens of rocks, between such types as chert and flint, or to identify such distinctive materials as vein quartz, Purbeck shelly limestone, schorl or veined Palaeozoic grits. Although some of the individual examples encountered are problematic the conclusions have invariably been based on a significant volume of unmistakable material. The use of refined correlative techniques to confirm the results has not been attempted. This omission to some extent reflects the nature of the present investigation which has proved, of necessity, to be a reconnaissance of a large area, describing evidence not only in Wiltshire but on the Chalk and Eocene outcrops elsewhere in Wessex, for the most part on ground lying to the West of the Salisbury Avon.

INTRODUCTORY ACCOUNT OF THE WORK UNDERTAKEN AND OF THE METHODS EMPLOYED

The work described in this thesis was originally expected to be a study of planation surfaces based largely on an exact survey of the sensibly horizontal remnants which are undoubtedly preserved in the landscape. This programme was discarded when cartographic analyses indicated unpromising results. The altitude frequency diagrams upon which this decision was based are presented in figures eight and nine.

During the 1963 field season, drifts and soils on the outcrop of the Chalk in Wiltshire, South of the Kennet, were the subject of a preliminary survey. Attention was particularly directed to conspicuous isolated summits and to surfaces obviously bevelled across the geological outcrop, or to sites occupied by a distinctive flora. Where exposures were not available, pits (6"- 12" across) were dug to depths usually between 12" and 36". The very stoney nature of almost all the drifts and soils examined precluded the extensive use of an auger. Wherever auger records are presented the instrument was a 1" wood auger mounted on a 4' shaft. The small pits excavated during this preliminary

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survey were intended solely to provide samples of the C horizon (weathering parent material) of the soil. Samples of about 2 lbs weight were broken down into three fractions (1/32"- 1/16"; 1/16"- 1/2"; 1/2" upwards) which were analysed qualitatively in terms of composition. The results of this work indicated the scope for more extensive investigations of drifts at several sites.

During the 1964 field season these investigations were undertaken. Thirty-two sections were excavated to depths between 3' and 7' in pits usually about 6' long and 4' wide. So far as possible all the excavated material was carefully examined and the sections measured. Black and white photographs of some freshly excavated sections were prepared but lacked sufficient definition to be of value. Colour photography was not attempted but might have been of more value. Samples of from 6 lbs to 20 lbs weight were secured in these sections and from existing sections at nine other sites. The samples were broken down into three fractions (1/16"- 5/32"; 5/32"- 1/2"; 1/2" upwards). Exact counts of the component materials were carried out for the two coarser fractions.

During the 1964 season the basic survey of soils and drifts in Wiltshire was extended.

Throughout the investigation geological material has been interpreted by actual comparison with well documented sections.

A good deal of attention has been paid to the shape of pebbles included in the drifts examined and samples of pebbles or cobbles have been collected from twenty-five additional sites. For comparative purposes photographs of this material have been prepared.

THE CHALK IN WILTSHIRE: A GEOLOGICAL AND STRUCTURAL INTRODUCTION TO THE STUDY OF DENUDATION

This account deals briefly with factors bearing on the denudation of the Chalk and no attempt is made to deal with details of palaeontological zonation. The conclusions, particularly of Rowe, Brydone and Gaster, concerning the zones of the Upper Chalk have been applied in Wiltshire only by Williams-Mitchell (1956) in a study of the Dean Hill anticline. Elsewhere the obsolete zonal terms employed by the Geological Survey, in the Memoirs treating this area, are necessarily retained (fig. 6).

Thickness: the Datum in a Study of Denudation

The variation in thickness of the several zones of the Chalk in Wiltshire is neither large nor abrupt. The Lower Chalk seems to decline in thickness towards the London Basin in the North and the Hampshire Basin in the South. In the Middle Chalk, on the other hand, the zone of *Terebratulina lata* thins westward and the Middle Chalk is correspondingly thinner in the West than in the East. At the base of the

Upper Chalk the Micraster zones are not subject to much variation. The important zone of Micraster cor-anguinum has a widespread outcrop, and "is believed to occupy the larger part of the surface of Salisbury Plain" (Jukes-Browne, 1904/a). Denudation has commonly removed part of the zones above Micraster cor-anguinum in Wiltshire and largely disguised any original variation of their thickness.

Lithology: a Guide to Rates of Erosion

More important in the present topography than the thickness of the zones are their distinctive and contrasting lithologies. Topographic features, developed in response to these contrasts, are rather consistently encountered.

In North Wiltshire a well defined scarp is formed on the unusually tough and rocky Lower Chalk. Further South the scarp is replaced by a broad but inconspicuous undulating bench.

The Middle Chalk is generally very nodular, hard and gritty below (zone of Inoceramus Labiatus) but finer grained, blocky and massive above (zone of Terebratulina lata). These zones form the face of the prominent Chalk scarps in Wiltshire. The summits of these scarps are commonly protected by the Chalk Rock, a tough compact, often nodular, semi-crystalline limestone, at the base of the Upper Chalk.

Wooldridge and Linton (1955) and Small (1964) believe that extensive tracts of ground in southern Wiltshire approximate closely to the structural surface (fig. 7) of the Micraster Chalk:

> "from which the overlying weaker Chalk has been removed by denudation."
> Small, 1964.

The Micraster Chalk is rather coarse, nodular and marly below (zone of Micraster cor-testudinarium) but fine grained, softer and more massive above (zone of Micraster cor-anguinum).

The concept of a structural surface developed on the Chalk of the Micraster cor-anguinum zone no doubt reflects the obvious weakness of the overlying Chalk of the zone Marsupites testudinarius, an homogeneous, soft, fine grained, massive Chalk with a few seams of marl. This zone forms the face of a conspicuous but fragmentary escarpment where it is capped by the harder chalk of the zone Actinocamax quadratus.

Above the Actinocamax chalk in Wiltshire, the softer chalk of the zone of Belemnitella mucronata is identified only about the northern rim of the Hampshire Basin where it is greatly denuded. That the Belemnitella mucronata chalk was formerly complete in parts of southern England and was perhaps succeeded by even higher zones, is suggested by outcrops, in the English Channel, of Maastrichtian Chalk (Curry, 1962; 1963/a); and by the occurrence of possibly Upper Maastrichtian flint in the Eocene at Southbourne, Hampshire (Curry, 1963/b).

The extensive preservation of the *Micraster* Chalk in the present landscape and the relatively effective denudation of the Lower and Middle Chalk exemplifies a lithological contrast which is shown to be of fundamental significance in the formation and dissection of Tertiary and Pleistocene planation surface. The lithological contrast between the *Marsupites* and *Actinocamax* Chalks appears to have exerted an analogous topographic control during the Tertiary and Pleistocene periods.

Flint: an Interpretative Factor in the Study of Superficial Deposits

In a study of denudation and superficial deposits, the provenance of the abundant derived flint in southern England is of prime importance. Jukes-Browne (1903) seems to have hoped that definite and systematic variation of flint types could be established in the Chalk zones, but his account of the Chalk in southern Wiltshire and in the Hampshire Basin, supplemented and summarised here, indicates that such a concept is only loosely applicable. Zonal contrasts in terms of abundance do prove however to be significant.

In the Lower Chalk, flint is not common and is of a distinctive bluish, rather cherty character. In the Middle Chalk flints of more typical aspect are scattered in the zone of Inoceramus labiatus. In the Terebratulina lata zone, three or four courses of tabular flint have been identified and a limited amount of grey nodular flint, rather small below (1/2"- 2/3") but larger above (6" diam.).

At the base of the Upper Chalk the zone of Holaster planus is particularly characterised by grey or dark grey sub-spherical and digital flints with a thick rather rough and sometimes friable rind. Flint is not, however, abundant. In the Micraster cor-testudinarium zone the character of the flint seems rather variable. Tabular flint is common; nodular flint, dark grey and usually solid but occasionally cavernous, is less common.

Flint is most abundant in the zone of Micraster cor-anguinum, where it is largely nodular. In the lower part of the zone flints are rather small, often reddish in colour and may be pitted without and cavernous within. In the middle of the zone, tabular flint is definitely uncommon, nodules are large and smooth with a solid black core, often distinctively marked by agatey banding (pale violet or carnelian) near the rind, which is usually thin. In the topmost beds of the zone, flint is less common again, grey in colour and smaller, but very large nodules with large drusy cavities may be encountered.

In the Marsupites testudinarius zone nodular flint is small and scarce and tabular flint also rare. In the zone Actinocamax quadratus flint is rare below but increases in quantity above. Nodules are usually small and solid with a thin rind and dark core. In the Belemnitella mucronata zone flint is characteristically black, with a smooth, thin or very thin rind, often stained yellow. Nodular flint is locally abundant but the nodules are small.

Structure

In Wiltshire the present pattern of the geological outcrop and certain basic elements of the relief are determined by structures of Mesozoic and Tertiary age (fig. 5).

Two groups of short arctuate axes traverse the country from East to West. These flexured zones are separated by a shallow structural depression underlying Salisbury Plain.

The northern flexured zone comprises an axis of moderate amplitude in the Vale of Pewsey, which curves southward at its eastern end through the Vale of Grafton, possibly a separate structural unit, and is aligned but not continuous with the less intense Haydown Hill flexure.

The Pewsey anticline exhibits an assymetry characteristic of the Tertiary structures in the Chalk of southern England. The dip of the southern limb is gentle (2 degrees - 3 degrees); the northern limb dips steeply at its eastern end (45 degrees) but further West displays "abrupt lateral changes of inclination" marking "oblique structural troughs" (White, 1925). The dip here is generally between 10 degrees and 25 degrees. Between Woodborough and Potterne the uplift is weak and the well marked axis is replaced by several feeble undulations. Beyond Potterne the Jurassic rocks are apparently undisturbed.

The Vale of Wardour marks the principal axis in the southern flexured zone. The Vale of Warminster marks a less intense flexure faulted on the northern limb and closely aligned with the Stockbridge axis further East. A short weak flexure lies near the axis of the main synclinal tract, or Andover depression; and in the South the northern rim of the Hampshire Basin is defined by axes of moderate tectonic elevation: the Dean Hill, Knighton Hill and Bower Chalke anticlines.

In the southern flexured zone only the structure of the Vale of Wardour has been the subject of exact investigation (Mottram, 1961). The amplitude of this fold is probably rather more than 1200'; the southern limb dips at between 3 degrees and 5 degrees but the northern limb is characteristically steeper: 10 degrees to 15 degrees near Fovant; the inclination gradually increases westward and measures 55 degrees at West Knoyle, where the fold is abruptly replaced by a steeply haded reversed fault with southward hade. The eastern termination of this fault is unfortunately obscured by a fan of river gravel. Mottram believes that it is defined by a short oblique tear fault but may be replaced beyond this point by numerous slide planes in the Chalk. Mottram considers the evidence too slight to vindicate the supposed extension (e.g. Jukes-Browne, 1900; Linton, 1931) of this fault as far as Dinton where a separate fault is indicated by the Geological Survey. The downthrow on the northern side of the fault is estimated to be about 600' at West Knoyle, but diminishes westward to 400' at Holwell Springs beyond Mere and 150' at the foot of

Penselwood Hill. Its exact alignment in the Jurassic country beyond this point is less perfectly known.

It has been suggested (Williams-Mitchell, 1956) that flexures of moderate amplitude may have escaped notice in the Chalk of the Micraster cor-anguinum zone underlying the synclinal tract of Salisbury Plain. Varney (1921) believes that the passage of the Salisbury Avon, southward through the Chalk escarpment at Upavon, had been controlled by a shallow syncline of Charnian aspect (cf. Jukes-Browne, 1904/b; Bury, 1910). He considers that outliers of the Lower Chalk, within the Vale of Pewsey, mark the northward extension of this flexure. White (1925) confirms that gentle undulations of this type can be detected on the southern limb of the Pewsey anticline.

PART I

PART I: SUMMARY AND NOTES ON THE ORIGINALITY OF THE WORK

1. Controversial views on the Tertiary denudation of the Wiltshire Chalk are introduced in their historical context.

2. An account of the Eocene outcrop adjoining Salisbury Plain provides a summary of the descriptive literature (effectively the Memoirs of the Geological Survey) and establishes the immediate geological context of the present investigation.

3. The method employed in the present approach to the problem of Tertiary denudation is described. The method, a study of Pleistocene river gravels, has been suggested by Pinchemel (1954) but does not appear to have been applied or to have yielded quantitative results either in France or in this country.

4. The composition of the gravels examined is described; this is an account of original work. The possible sources of some problematic elements in the gravels are discussed.

5. Tertiary outliers on Salisbury Plain, probably contributory to the Pleistocene gravels in question are described; this is an account of original work at two important sites, Clay Pit Hill and Cley Hill, which have not hitherto been the subject of careful investigation.

6. An original interpretative account of the gravels encountered in the Tertiary outliers on Salisbury Plain is based on a comparison with gravels in the main Tertiary outcrop in Dorset. The account of the Cley Hill gravel includes an original re-assessment of the scope of the Oligocene period in southern England. The interpretation of the Tertiary outliers suggests comparisons with the scheme of Tertiary denudation which has been inferred in the Paris Basin.

7. A brief descriptive and interpretative account, in part original, of some other Tertiary outliers, concludes the work on the Palaeogene period undertaken on Salisbury Plain during the present investigation.

8. Sites on the Tertiary outcrop in the Hampshire Basin are discussed; the account which is essentially descriptive is based on original work at several sites in North Dorset and adjacent Hampshire. The interpretative passages are based on comparisons with South Dorset.

9. Some problematic Tertiary drifts are briefly considered and their possible significance suggested; most of the descriptive passages are not based on original work but some original conclusions are reached.

PART I: A NEW CONCEPT OF PALAEOGENE EVENTS IN SOUTHERN ENGLAND

"The understanding of our landscape
involves nothing less than the tracing
of its history in all its aspects
throughout the whole span of Tertiary
time." D.L. Linton, 1951.

A QUANTITATIVE RE-EXAMINATION OF THE SUB-EOCENE CONTROVERSY

Introduction: The Historical Perspective

The study of denudation on the Wiltshire Chalk illustrates the fundamental character of Tertiary problems. The controversy regarding the nature of the sub-Eocene surface, particularly on Salisbury Plain, remains unresolved, although our concept of denudation during the Tertiary period must be determined largely by the solution which is adopted.

The wholly irreconcilable views on the nature of the sub-Eocene unconformity which have at different times been put forward, are still mutually opposed. Jukes-Browne implies that wherever the Clay-with-flints occurs (fig. 28) the sub-Eocene surface originally passed not more than 40' above the present ground level:

> "The surface on which the tracts of Clay-with-flints lie is practically a prolongation of the basal Eocene plane.
>
> "Here and there small quantities of Clay-with-flints may have been let down by landslips, or have subsided into pipes and hollows but the tracts of it which cover long ridges and plateaux are seldom found to be more than 30' or 40' below the datum above mentioned, whenever an estimate can be made."
>
> Jukes-Browne, 1906

The distribution of the Clay-with-flints led Jukes-Browne to believe that the Pewsey anticline had been truncated by the sub-Eocene surface. On this account his views were rejected by White (1907) who favoured a gradual and uniform overstep of the base of the Eocene, from the Hampshire Basin northward, onto successively lower zones of the Chalk. White clearly believed that the sub-Eocene surface on the tract intervening between the Hampshire and London Basins could safely be extrapolated from the sub-Reading Beds surface in the Basins themselves.

The prevailing interpretations

King evidently accepts White's view. He notes the great thickness of Eocene sediments in the Isle of Wight and assumes:

> "What sedimentation of this extent spread over a much greater area and that in most places it has been removed by erosion." King, 1954.

Wooldridge and Linton regard the sub-Eocene surface as:

> "A peneplain locally trimmed by the waves of the Eocene sea."
> Wooldridge and Linton, 1955, p.9.

Their treatment of it implies a substantial measure of agreement with the views established by White. A contour map (fig. 10) of the sub-Eocene surface published by Linton (1931) and subsequently by Wooldridge and Linton (1955) defines their position. It shows a sub-Eocene surface intact, but deformed by the corrugations of Alpine aspect. In the context of their views this arrangement implies a sub-Eocene surface intact at "about the end of Oligocene times."

Wooldridge and Linton tend to avoid a concept of appreciable deformation since the Oligocene period; it is possible therefore to infer the extent of the denudation, since the Oligocene period, which their concept involves. Their sub-Eocene contours (fig. 10) above the western escarpment of Salisbury Plain indicate a level between 1,200' and 1,400' O.D. This level is between 450' and 600' above the present base of the Upper Chalk and suggests that at this point the sub-Eocene planation formerly truncated the Upper Senonian Actinocamax quadratus Chalk.

> "The period of erosion involved . . . comprises the Maastrichtian, Danian and Montian stages of European stratigraphy." Linton, 1964.

In the scheme visualised by Wooldridge and Linton the remaining volume of Chalk has been largely denuded during their Mio-Pliocene cycle. The present expression of the sub-Eocene surface is confined to a limited facet identified on the dip slope of the Chalk, near the boundary of the Eocene outcrop and rarely extending more than five miles beyond it.

To Pinchemel:

> "Il semble que l'importance actuelle de la surface prétertiare exhumée ait été sous-estimée." Pinchemel, 1954, p.75.

In Wessex he argues a return to the views of Jukes-Browne;

> "La surface prétertiare intéresse encore une partie des plaines et plateaux du Wessex." Pinchemel, 1954, p.75.

Although Pinchemel fails to contribute any new stratigraphic evidence bearing on this controversy in Wessex, he does recognise that the sub-Eocene surface need not necessarily be co-extensive with the sub-Reading Beds surface:

> "Cette surface prétertaire y est devenue une surface composite polygénique a la fois surface d'érosion subaérienne et plate-forme d'abrasion marine qui n'a cessé d'être modifiée à chaque épisode d'émersion de l'Eogène."
> Pinchemel, 1954, p.84.

Nevertheless his view implies that the massive denudation of the Chalk had been wholly effected before or during the Palaeogene period.

Clearly the divergent points of view, introduced here, involve very different concepts of the nature and extent of denudation during the Tertiary period. It is important therefore to establish at once a more certain definition of the sub-Eocene surface in Wessex, and to examine the possibility that this area lay near the margin of the Palaeogene basins of deposition, in which case the Chalk may have experienced more than one cycle of extensive planation during the Palaeogene period. This possibility is evidently realised in the Paris Basin (Cholley, 1957, p.112 and fig. 18) where the stratigraphic record is more complete.

The immediate geological context

The Eocene rocks in Wiltshire comprise the western extremity of the Tertiary outcrop in the London Basin and the northern part of this outcrop in the Hampshire Basin. A close equivalence of facies between these areas is recognised, (Hawkins, 1954; Davis and Elliot, 1957) and:

> "There is little doubt that some part of the Eocene cover extended across the Chalk of the Wessex area."
> Wooldridge and Linton, 1955, p.11.

The following introductory account provides a summary of the descriptive literature dealing with the Eocene outcrops adjoining the Wiltshire Chalk, and indicates the immediate context in which the work on Eocene material was undertaken, during the present investigation. Attention is largely confined to the lithology of the formations and particularly to material which is easily recognised in a derived condition, or which proves distinctive for correlative purposes.

<u>The Reading Beds</u>

In the main outcrops the Reading Beds are at the base of the Eocene succession. Two divisions can generally be recognised. At their base, corresponding to the marine Landenian on the European continent, two feet to eight feet of dark green or speckled grey-green glauconitic loamy sand occur with seams of grey-greenish or brown clay, often roughly laminated. Slightly worn and pitted flint nodules almost invariably occur at, or a few inches above, the surface of the Chalk. The nodules generally have a thin coating of green material, probably glauconitic, and are usually associated with well rounded smooth black flint pebbles and sub-angular chips of flint, which also have a glauconitic coating. Concretions of iron oxide, small granular aggregates of 'race' and fine seams of chalky material, sometimes with abundant derived Chalk fossils, are not uncommon in the same position .

In his paper on the western part of the London Basin, Whitaker states that pebbles in the Reading Beds are practically confined to the green sands at their base; in this position:

> "They are not always found and when they do occur it is not in great numbers nor of large size (½"- 2" diam.)."
>
> Whitaker, 1862.

Prestwich (1854) believes that pebbles are restricted to a thin seam immediately above the green coated flint nodules which repose on the Chalk itself, or are intermingled with these nodules. In the London Basin pebbles of material other than flint have not been recorded in the Reading Beds.

In the northern part of the Hampshire Basin, in the sands at the base of the Reading Beds, more frequent seams of flint shingle are encountered and may be associated with beds of tough ironstone and ferruginous conglomerate. At Damerham Knoll quartz and chert are recorded at the base of the Reading Beds (in Reid, 1902).

The upper division of the Reading Beds, which correlates with the continental Landenian, is irregular in composition. Stiff, very pure, more or less structureless plastic clays, grey or brown in colour but conspicuously mottled red, alternate vertically and horizontally with brown loams and grey, buff or orange sands, patchily stained crimson. There is considerable evidence of intra-formational erosion. In the London Basin, the Enbourne cores (Hawkins, 1954) demonstrate an average thickness of 69' for the entire Reading Beds (range 62'- 76'). At the western limit of the London Basin the thickness of the beds diminishes abruptly to about 15' near Great Bedwyn. This decline is attributed to intra-Eocene erosion.

In the western part of the London Basin conspicuous or regular seams of pebbles are reported to be absent in the upper Reading Beds (Whitaker, 1862) or are confined there to beds of sand (Prestwich, 1854). Whitaker (1862) was perhaps the first to recognise that the seams of exclusively well-rounded pebbles in the Eocene are not compatible with intertidal conditions. It has subsequently been argued that these pebbles have been reworked in offshore features during transgressive marine conditions (Wooldridge, 1924; Davis and Elliot, 1957). Thin seams, in the Reading Beds, where intraformational erosion is recognised, may of course be derived.

The London Clay

The marine Ypresian is represented in southern England by the London Clay. Davis and Elliot (1957) have suggested that the base of the London Clay is diachronous and that part of the Upper Reading Beds in the western province may be correlative with the lowest part of the London Clay further East. In the western part of the London Basin the Lower Silts (Hawkins, 1954) form a thick (35'- 50') basement bed, sandy and dark green below but silty above; at their base incorporated fragments of chalk and rolled clay of Reading Beds derivation indicate inter-formational erosion. Black flint cobbles are sometimes present and in the London Basin these are occasionally distinguished by their large size (up to 14" diam.).

In the northern part of the Hampshire Basin this bed is described as a slightly glauconitic loam with discontinuous seams of flint pebbles. White (1912) records rare pebbles of vein quartz in the London Clay. Near Cranborne (SU 055133) in Dorset, the overstep of the London Clay onto the Chalk is recognised and indicates the substantial extent of inter-formational erosion.

At Enbourne the basement bed is overlain by about

60' of stiff clays. In the Hampshire Basin the clays are accompanied by brown ferruginous loams with calcareoferruginous doggers, and in the clay itself calcareous concretions develop locally into seams of cementstone. In both outcrops discontinuous seams of flint pebbles occur.

Above the clays at Enbourne about 70' of Upper Silts merge conformably and often imperceptably with the overlying formation and thick seams of flint pebbles, often associated with shell banks are more frequent in this division than in those below. In both the main outcrops the London Clay appears to be a shallow water-facies and its total thickness is between 100' and 150'. The formation is thinner in the extreme West of the London Basin and appears to be entirely absent beyond Great Bedwyn (SU 279645). This perhaps indicates proximity to the shore of the London Clay sea rather than the result of subsequent denudation.

The Bagshot Beds

The London Clay is succeeded by the Lower Bagshot Beds of Cuisian age which in the Hampshire Basin may be correlative with the uppermost London Clay further East. In both the main outcrops the formation comprises fluviatile or estuarine false bedded more or less ferruginous buff coloured sands with occasional thin seams of flaggy sandstone and rather frequent lenticular beds of pipe clay. The sands, which are commonly micaceous and sometimes rather clayey, may include several discontinuous seams of flint pebbles. In the northern part of the Hampshire Basin a few pebbles of lignite occur; apart from these no pebbles of material other than flint have been recorded, although a very distinctive suite of Palaeozoic and Mesozoic rocks occurs in this formation in South East Dorset.

In the western part of the London Basin, where the Middle Bagshot Beds (?Lutetian) are not preserved, the Lower Bagshot Beds (?Cuisian) are incomplete. They are deeply weathered and their junction with the London Clay is often difficult to detect. Seams of flint pebbles occur in the Lower Bagshot Beds of the London Basin, but pebbles of any material other than flint are very rare in the Eocene of the London Basin below the Upper Bagshot Beds (?Auversian), in which vein quartz and chert are recorded (Dewey and Bromehead, 1915).

Method in a Study of Derived Eocene Material

The scope of Pleistocene denudation

The present investigation sought initially to establish the significance of Eocene material in certain

Pleistocene gravels of the Salisbury Avon and its tributaries. It was thought that if the contours of the sub-Eocene surface do in fact approximate to the generalised contours of the present surface then the earlier gravels might contain a larger proportion of Eocene material, reflecting the progressive denudation of the Eocene outcrop and dissection of the sub-Eocene surface during the Pleistocene period. If on the other hand the sub-Eocene surface delineated by Wooldridge and Linton (1955) is definitive, and if their denudation chronology is accepted, it seems unlikely that any part of the Eocene outcrop, particularly in the western quarter of Salisbury Plain, should have escaped denudation before the final regression of their early Pleistocene (Calabrian) sea. The delineation on Salisbury Plain of the planation surface associated with this marine transgression shows that after this event the Eocene outcrop West of the Avon must have been restricted to a very small area in the eastern extremity of the Grovely syncline (fig. 12)

> "Only in the synclinal trough which runs beyond Salisbury to Wilton did such deposits actually outcrop either on the Pliocene plain or on the Mio-Pliocene peneplain."
>
> Wooldridge and Linton, 1955, p.69.

The diagnostic Eocene material

The recorded prevalence of flint pebbles in the Eocene outcrops adjoining Salisbury Plain suggests that a useful measure of the volume of Eocene material in the Pleistocene gravels might be the ratio of subangular flint (Plates 40 and 41) to well rounded flint pebbles (Plates 1 and 12). The subangular flint is derived directly from the Chalk and is recorded in the local Eocene formations only in small and for this purpose insignificant quantities at the base of the Reading Beds. The flint pebbles are of marine origin and undisputed Eocene age. The significanee of this ratio in a study of the former extent of the Eocene outcrop in the basin of the Somme has been demonstrated by Pinchemel:

> "A l'époque de la dernière glaciation Wurmienne les couches d'argile plastique et de sables landeniens, étaient beaucoup plus étendues qu'elles ne le sont aujourd'hui . . . L'examen des alluvions des terrasses quaternaires de la Somme confirme cette thèse. Les alluvions sableuses proviennent toutes de sables éocènes remaniés; quant aux galets, l'oeil distingue immédiatement deux groupes, les cailloux de silex à patine jaune aux angles seulement émoussés, s'opposant aux galets noirs ou gris parfaitement roules. Dans certaines carrières . . . la proporti on des galets directement issus des terrains éocènes dépasse soixantes-quinze pour cent." Pinchemel, 1954, pp. 343-44.

Sarsen

During the present investigation work on the Pleistocene gravels sought also to establish how much sarsen they incorporate and whether this material confirms the Eocene figures or whether it appears in some other, unexpected light.

Account of the Investigation

The gravels examined on Camp Hill

The extensive tracts of river and plateau gravel, indicated by the Geological Survey in the angle between the Avon and the Nadder northwest of Salisbury, seem to offer ideal conditions for a study of the type recommended by Pinchemel. They have clearly been derived from the area occupied by the critical western extension of the sub-Eocene surface and they comprise a succession of gravels at levels up to rather more than 300' above the present stream, at which level the highest are some 50' below the projected sub-Eocene surface.

Ten samples were secured from seven pits on this tract of ground. (A full interpretative account of these sites in their Pleistocene context is given in Part Five of this thesis.)

(1) SU 112339, above 325' O.D.

Sample of a gravel exposed in pipes in a disused chalk quarry (Plate 44): The gravel is obviously disturbed but does not appear to have been redistributed.

(2) SU 111333, at 425' O.D.

Gravel from a section excavated in an overgrown pit (perhaps formerly exploiting brick-earth): The gravel occurs in irregular seams, at a depth of about 6'.0" below the ground level outside the pit, in a bed of bright reddish brown mottled clay (fig. 72). It appears to be essentially undisturbed.

(3) SU 108328, at 400' O.D.

Gravel from a depth of 3'.6" in an excavated section: This gravel is evidently redistributed.

(4) SU 108323, at 365' O.D.

Gravel from a section cleared in an overgrown chalk pit: This gravel is evidently redistributed. The sample was secured at a depth of about 3'.6" below the ground level outside the pit.

(5) SU 107319, at about 330' O.D.

Gravel from a depth of 4'.9" in an excavated section: This gravel appears to be essentially undisturbed.

(6) SU 108318, at 300' O.D.

Gravels from an excavated section (fig. 81):

a. Sample from top soil

b. Sample from base of disturbed upper gravel

c. Sample from seam of essentially undisturbed gravel at a depth of 4'.6"

(7) SU 126309, at 230' O.D.

Gravel from a section excavated near the abandoned Bemerton gravel pit (Reid, 1885):

a. Sample from essentially undisturbed gravel at a depth of 3'.0"

b. Sample from essentially undisturbed gravel at a depth of 6'.0"

Results

Flint pebbles

Table (3/a) shows that although well rolled flint pebbles of Lower Tertiary aspect may occur in the coarse gravel fraction (more than ½" diam.), their numbers in samples of between 90 and 420 undifferentiated fragments are in all cases so small that no reliable comparative results could be obtained. The gravel from site (1) is shown in Part Five of this thesis to be a gravel of the Avon and is not therefore strictly comparable with the other gravels, which may confidently be referred either to the Nadder or to the Wylye. However the figures for the Avon gravel, and for others even less strictly comparable (Table 3/b), create a general impression that flint pebbles of Lower Tertiary aspect are more common in the higher gravels.

Sarsen

No sarsen was identified in the coarse fraction of the samples examined, although pebbles and cobbles of this material (up to 7½" long)(Plate 16) were collected at several sites during the excavation of the sections, and are commonly observed on the ploughed surface of Pleistocene gravels here and elsewhere.

Quartz

An unexpected result of this work is the recognition that the proportion of vein quartz, in the fine gravel fraction (5/32"- 1/2"), increases substantially from lower to higher levels both at Camp Hill and in other gravels about Salisbury. A few larger pebbles of quartz also occur in the higher gravels: (a) seen in the soil on the summit of Camp Hill (up to 1½" diam); (b) at site (5) on Camp Hill, one example (2 1/16" long); (c) picked up on the ploughed surface of the spread of gravel at Paul's Dene (SU 145324).

Quartzite

Rare pebbles of quartzite, possibly foreign to the basins of the Nadder and Wylye were recovered in the higher gravels at Camp Hill. The larger examples include: (a) at site (3) a translucent white pebble (1⅞" long); (b) at site (6c) a pebble of bluish translucent quartzite (⅝" diam.); In the finer gravel fraction although the percentage of quartzite pebbles is small it apparently increases from lower to higher levels. Some of the smaller pebbles might be sarsen, but others nevertheless are not.

Grits

A pebble (1 1/16" diam.) of greyish grit traversed by a quartz vein, recovered at site (2) on Camp Hill, and a pebble of dark grit (⅝" diam.) recovered at site(3), are definitely foreign to this area.

THE DERIVATION OF THE PROBLEMATIC MATERIAL IN THE PLEISTOCENE GRAVELS

Pre-Tertiary Sources

The provenance of the quartz and foreign rocks in the Pleistocene gravels on Camp Hill is not at once obvious. The small amount of quartz in the modern gravel of the Nadder (about 0·1%) seems to preclude the derivation of larger amounts from the base of the Gault in the Vale of Wardour:

> "Blue clay with small quartz pebbles towards the base."
> Mottram et al., 1957.

Or from the Aptian there:

> "A thin seam of quartz and lydite pebbles at the base of the Lower Greensand."
> Reid, 1903.

Nor is it satisfactory to postulate a former extension during the Pleistocene of the basins of the Nadder or of the Wylye so that these streams might derive quartz and pebbles of foreign rock from some more remote outcrop. In fact no lithologically suitable outcrop comes to mind within a distance which may be regarded as at all reasonable.

Tertiary Sources I: Clay Pit Hill

The doubtful provenance of the quartz and foreign rocks in the Pleistocene gravels of the Avon and its tributaries led to a re-examination of the Eocene outliers indicated by the Geological Survey on Salisbury Plain. Accounts of the outlier at Clay Pit Hill (ST 994425) suggest a possible source of the problematic quartz.

History of investigation

On the Old Series Geological Map (Sheet 14) an outlier of Reading Beds is indicated at Clay Pit Hill on the Chalk at a height of 575'. This has never been inserted on the New Series Geological Map (Sheet 298) nor described in the accompanying memoir (Reid, 1903) possibly because of the difficulty of reconciling it with the projected sub-Eocene surface at this point. On Linton's map (1931; and in Wooldridge and Linton, 1955) the sub-Eocene surface passes some 250' above the outlier (fig.10). The outlier is described by Jukes-Browne (1905) in the Memoir accompanying the adjacent Sheet (282)(perhaps a reflection of Jukes-Browne's views on the sub-Eocene surface). His account relies entirely on Prestwich's earlier descriptions.

Pits working pipeclay here in the seventeenth century are mentioned by Aubrey. Bennett in the early nineteenth century records that:

> "The plastic clay occurs on Chitterne Down near Heytesbury and the beach pebbles found there form the pavements of the ladies grottoes of the surrounding neighbourhood." Bennett, 1831.

(n.b. Chitterne Down is now shown by the O.S., 1" map, sheet 167, 7th Series, 1960, at two separate places respectively North and East of Chitterne; however on the 1773 map of Andrews and Dury, 1952, and on the O.S. 1st edition of 1817, Chitterne Down is indicated on the site now shown as Clay Pit Hill.)

Prestwich visited the site in 1857 when the pit was already disused and largely overgrown. In his notebook, published posthumously he describes a gravel at Clay Pit Hill:

> "Of perfectly rolled (although some broken) largish pebbles of white coated flints very light, of a few small black flint pebbles in a white and light yellow coarse sand full of small white quartz pebbles with a few quartz and black slate (?) pebbles." Prestwich, 1898.

The account of this gravel in Prestwich's paper on the Westleton Shingle is slightly revised:

> "1. Tertiary pebbles - the larger proportion much decomposed and very light. 2. White quartz pebbles and a few rose coloured ones. 3. Worn

> fragments of light coloured sandstone (Upper Greensand?). 4. Pebbles of dark chert and Lydian stone."
> Prestwich, 1890.

The 'small white quartz pebbles', 'quartz and black slate (?) pebbles', sandstone', 'chert' and 'Lydian stone' described by Prestwich do not resemble anything in the Eocene outcrop adjoining Salisbury Plain, in which pebbles are exclusively of flint. Prestwich considered the gravel to be part of a drift (the Westleton Shingle) overlying a "patch of Lower Tertiary white sands and mottled clay". In an earlier paper (1875) he attempted to differentiate the gravel at Blackdown (SY 612875) in Dorset in this way but his error in this case was subsequently demonstrated by Reid (1896). Reid's conclusion on the Dorset material tends to indicate an Eocene age for all the material at Clay Pit Hill. The accounts of the gravels there contain however no irrefutable evidence of an Eocene date. The recognition of appropriate evidence is obviously fundamental in a study of the sub-Eocene surface on Salisbury Plain.

<u>Account of work undertaken at Clay Pit Hill</u> (fig. 13)

During the present investigation at Clay Pit Hill the ground was examined along two lines traversing the overgrown working face of the pit.

The eastern traverse (fig. 14)

Pit 1

This section was excavated on the slope between the working face and the ground level outside the pit. The pit has been abandoned for so many years that no well defined break of slope now marks this feature.

About a foot of dark brown sandy soil becomes increasingly stoney downward and merges without a well defined lower boundary into a very confused yellowish brown drift, incorporating sharply angular flint, unbroken flint nodules, well rolled pebbles of Lower Tertiary aspect and an assortment of finer gravel (Table 4). The finer gravel (5/32"- 1/2") includes small pebbles of quartz, quartzite, sandstone, grits, cherts and other unidentified hard silicious rocks. The gravel is packed in a rather scanty matrix of more or less sandy clay; at the downslope end of the pit irregular inclusions of pure pinkish or greyish sand occur (6" diam.). This confused horizon passes downward without any clear boundary into a paler yellowish brown clay, seen to the bottom of the excavation at a depth of 2'.6".

The clay incorporates scattered grains of quartz sand and a few broken and unbroken flint nodules. The flints in this horizon have a thin skin of pure clay.

Pit 2

This section on the steepest part of the working face shows only 4" of dark sandy soil over 6"- 12" of the confused stoney drift described in Pit (1). As in Pit (1) this confused horizon incorporates irregular masses of pure sand, and passes downward into a very clayey, relatively stoneless drift. The stoney material largely comprises the flinty residuum of the Chalk (Table 5). The Chalk is encountered only 2'.0" from the surface of the ground; the chalk occurs in a rubbly pinnacle (Plate 5); the boundary between the clay and the chalk is marked by a seam of darker clay ¼"- 1" thick.

Pit 3

Near the bottom of the working face this section shows a deeper soil (1'.2") resting on a thin (3"- 6") bed of the confused drift seen in the higher pits. This rests with a very shapp boundary on pale yellowish quartz sand. In the upper part of the sand, large (4" long), well rolled flint pebbles were recovered together with broken pebbles more or less re-rolled (Plate 3) and some slightly abraded flint and undamaged flint nodules. The coarser gravel also includes one small pebble of whitish cherty sandstone, almost certainly Upper Greensand and two other pebbles, a greyish quartzite and a grey (?) metamorphic rock. The sand also incorporates a substantial quantity of fine gravel (Table 6) similar in composition to the gravel in the stoney drift of Pit (1) but also including a few fragments of undoubted silicified Purbeck shell limestone. The sand was seen to a depth of 11" and augered to a depth of 3'.4" from the floor of the excavation; although the auger touched several stones it also passed through thick seams (6"- 8" of pure white stoneless quartz sand.

Four

At a distance of about ten yards, West of the auger hole in Pit (3) the auger passed unimpeded to a depth of 4'.3" in coarse quartz sand.

The suggested reconstruction of the outcrop examined in this traverse shows gravelly sand with seams of purer sand resting directly against the Chalk. It is not quite clear whether the confused stoney clay represents the debris of the outlier on ground adjoining the outcrop or whether it represents a blending of the gravelly sand with the flinty residuum of the Chalk, at the junction between the two. The writer favours the latter view.

The Southern traverse (fig. 15)

Pit 5

This section was excavated thirty yards South of the working face and outside the pit on almost certainly undisturbed ground. The Chalk is encountered at a depth of 1'.7" in a rather rubbly but level surface. Above the Chalk a stoney drift occurs. The drift incorporates well rolled flint pebbles of Lower Tertiary aspect; abraded flint nodules (Plate 4); sharply angular fragments of flint; a few small (less than ¼" diam.) quartz pebbles and rare (one collected) pebbles of quartzite. A fragment of a larger quartzite cobble, resembling saccharoidal sarsen, was also collected. The stoney material occurs in a scanty matrix of dark brown earthy sand.

Pit 6

This section was dug about three yards North of the working face and outside the pit. The section shows 2'.0" of very confused stoney soil incorporating wisps and bands of whitish ironstained sand. Below this material a very stoney horizon (about 6" thick) occurs incorporating well rolled flint pebbles, sharply angular flint fragments, unbroken nodules and one quartzite pebble (possibly fine-grained sarsen). Much of the flint in this stoney seam is patinated a shade of brown or ochreous red. One undoubtedly artificial flint flake, fresh and unpatinated, suggests that this horizon may be an 'erosion pavement' (see Appendix I). Below this 'pavement' about a foot of slightly sandy clay is encountered, grey or very pale grey in colour with bright rust stains. The clay incorporates scattered flint pebbles (Plate 2), largely unbroken; the larger pebbles display a patchy white and bluish patina, the smaller ones are often black. The clay also incorporates undamaged nodules and sharply angular flint; this material is often very rotten and powdery (cf. Prestwich, 1898). The clay which appears to be <u>in situ</u>, but may well not be, was seen for four inches and augered for a further eight. Below this level 6" of coarse sand are encountered in which wisps of black staining occur, (possibly analagous to a "Carbonaceous sand" described by Prestwich, 1898). The sand rests on a very tenaceous greenish-grey sandy clay from which the auger could not be withdrawn at a depth of 10".

<u>Seven</u>

The auger failed to pass through a stoney soil at the top of the working face.

<u>Eight</u>

On the upper part of the working face the auger passed through 10" of sandy soil into a very tenaceous grey iron stained clayey sand and could not be withdrawn from a depth of 1'.10".

<u>Nine</u>

On the steepest part of the working face the auger passed through 2'.0" of soil into a tough grey fine sandy clay; it could not be withdrawn from a depth of 3'.6"

<u>Ten</u>

Near the foot of the working face the auger encountered 18" of dark sandy soil, and passed into alternating thin beds of brightly coloured clay and sand (grey, white, purple and orange) to a depth of 3'.9"

Eleven

On a slight bench at the foot of the working face the auger reached a depth of 3'.9" through coarse sand with flakes of flint and infrequent thin seams of rather clayey sand.

Twelve

Below the bench feature the auger reached a depth of 3'.9" in a confused mixture of mottled clay and coarse sand, encountering a slight gravelly seam at a depth of 2'.0"

Pit 13

This section was excavated between the foot of the working face and a low mound on the floor of the pit (probably an overgrown spoil heap). About 15" of dark sandy soil rest on a coarse greyish white sand incorporating a certain amount of mainly fine gravel (Table 7). The composition of the fine gravel (5/32"- 1/2") closely resembles that of the gravel in Pit (3), including fragments of silicified Purbeck shell limestone. The hard silicious rocks include a few small pebbles of fossiliferous (radiolarian) chert (possibly the Lydian stone* of Prestwich, 1890). In the coarse gravel (more than ½" diam.) small black pebbles of flint and rare quartz pebbles (up to 1¼" diam.) occur. Inclusions of pure very tenaceous grey and orange clay, of the nature of pipe clay, occur in the sand which was seen to a depth of 3'.4" and augered for a further 15". At this depth the auger reached pure very tough grey pipe clay but failed to pass into it more than three inches.

Fourteen

On the floor of the pit, beyond the spoil heap and thirteen yards North of Pit (13) the auger passed through 18"- 24" of black peaty soil into chalk, probably *in situ*

---

* "Black silicious pebbles known as 'lydites'. These . . . may be derived, some from Palaeozoic cherts, others from indurated silicious beds of mechanical origin, such as are found in these old rocks." (Woodward, 1895, p.225). Material formerly known as Lydian stone is now often referred to as tourmaline grit.

It is very difficult to be sure which of the material examined in the southern traverse is <u>in situ</u> and the suggested reconstruction of the outcrop is correspondingly tentative. A tenaceous slightly sandy grey clay (possibly the economic incentive in the pit) is encountered consistently in the upper part of the succession; a bed about 8' deep seems to be present. The clay becomes increasingly sandy downward and there is some indication that a gravelly sand rests on the Chalk at the base of the succession. Sand and gravelly clay of doubtful significance overlie the clay.

Neither in this section nor in the eastern traverse is there any real indication of the successions observed or inferred by Prestwich in 1857:

"The order of superposition appeared to be:

	feet
yellow clayey and sandy drift full of quite angular yellow flints and small quartz pebbles	1 to 2
white flint pebbles and quartz pebbles	6
white sand) carbonaceous sand) .. .. mottled clay)	10

"In one hole however the section was clear:

	feet
white gravel	2 to 10
white silicious sand	10

(in Prestwich, 1898)

Conclusion

Perhaps the most important new discovery at Clay Pit Hill is the presence in the gravel of silicified Purbeck shell limestone, and it becomes important to decide from where this may have been derived and whether it provides ground for correlation with formations elsewhere in southern England which are known to include this material.

Tertiary Sources II

The occurrence of silicified Purbeck shell limestone at Clay Pit Hill is not unique upon the Wiltshire Chalk, and evidence, which appears to confirm and supplement the findings there, is now discussed.

Cley Hill

Cley Hill (ST 837477) is a very distinctive and prominent hill of Middle Chalk capped by an outlier of the Chalk Rock. Situated on the northern limb of the Warminster anticline and only about a mile from the axis of the fold, it rises to a height of 800' O.D. Manley records:

> "Funnels of brown Tertiary sand showing in the top of the chalk quarry."
> Manley, ?1927, vol.2, p.101.

Irregular pipes are still exposed in the quarry (Plate 6/a) and prove to contain relics of an interesting gravel (Plate 6/b). The deepest pipes seen in the face of the quarry extend to a depth of about 7'. At one point (A in Plate 6/a) a very gravelly whitish quartz sand (Table 8) is exposed. Although this material appears to be somewhat disturbed it is not mixed with the flinty residuum of the underlying Chalk which is in-corporated in a well defined bright reddish brown very clayey seam (6"- 10" thick)(Plate 6/b) separating the gravelly sand from the Chalk itself. In other pipes (B in Plate 6/a) this same distinction is apparent although the gravel occurs here in a matrix of reddish brown clayey sand.

Attempts to locate additional pipes on the summit of Cley Hill proved unsuccessful. The auger generally failed to pass through the flinty soil. Six small pits on the summit showed about 9"- 12" of flinty soil, resting on the Chalk or on a very tenaceous dark reddish brown clay with angular flint fragments and occasional traces of gravelly sand. Unpatinated or slightly patinated artificial flint flakes occur in this flinty clay down to the surface of the Chalk.

The coarse gravel (larger than ½" diam.)(Table 8/a) consists largely of abraded flint (Plate 7) which is indistinguishable in form from flint in the Pleistocene gravels of the Avon (e.g. Plate 40); it includes however several fragments rotted to powder (cf. Clay Pit Hill). The coarser Cley Hill gravel also includes a substantial proportion of Upper Greensand chert and sandstone (plate 8) which is indistinguishable from this material in the Pleistocene gravels of the Avon (Plate 47). Well rolled flint pebbles of Lower Tertiary aspect are small and very infrequent (Plate 7). In the fine gravel (5/32"- 1/2") pebbles of vein quartz are most common with subangular and sharply angular flint forming the greater part of the balance. There is however a significant amount of Upper Greensand, and a very few fragments of silicified Purbeck shell limestone are present. Among the small pebbles of hard silicious rock which occur in the gravel, grits, quartzites and cherts can be identified. In addition to the material recognised in the sample, small pebbles of veined grits and fossiliferous (radiolarian) chert have been collected from the exposure. Some of the small quartzite pebbles in the gravel might be fine grained sarsen.

THE INTERPRETATION OF THE TERTIARY GRAVELS ON SALISBURY PLAIN

Relations with the mid-Tertiary Surface

Cley Hill

The high level of the gravel at Cley Hill provides the first clue in the elucidation of its origin and relation to the deposit at Clay Pit Hill, and the origin of the deposit there. It is not possible to be sure of the original topographic relation between the summit of Cley Hill, at a height of 800' O.D., and undisputed remnants of the mid-Tertiary surface (see Part Two of this thesis) preserved at heights between 730' and 790' O.D. on neighbouring summits of the Chalk (fig. 16). It will subsequently be suggested however that the gravel at Cley Hill rests on a remnant of a Palaeogene surface. In this case preservation as a residual summit above the mid-Tertiary surface is a reasonable inference. Waters (1960) has shown that this relation prevails in southwestern England (fig. 18).

Cold Kitchen Hill

At Cold Kitchen Hill the residual nature of the summit above the mid-Tertiary surface is more readily appreciated. Unfortunately the gravel which occupies the summit is poorly characterised.

At one point (ST 841381), at a height of 830' O.D., a small pit to a depth of 3'.0" showed a confused drift, probably the flinty residuum of the Chalk incorporating the debris of an overlying gravel. (Elsewhere on the summit the Chalk is masked by more or less extensive patches of rather earthy, dirty yellowish brown sand, usually only a few inches deep. At a level slightly above 800' O.D. somewhat below the summit, at 845' O.D., a large boulder (Plate 9) of fine grained, banded sarsen (see Appendix II) rests on the Chalk.)

The gravelly debris (Table 9) on the summit of the hill consists largely of flint (rarely more than ½" diam. in sample) which is so grotesquely pitted and rotten that its original condition cannot be determined. The greater part of the balance of the sample is ferruginous material, including tough concretions and earthy particles; and probably also inadvertantly including some iron-stained fragments of rotten flint. The debris includes a quantity of small quartz pebbles; two pebbles of intricately veined grit or chert; three pebbles of quartzite and an indeterminate cherty fragment.

The composition of the gravel is by no means diagnostic (Table 11) but in the absence, at present, of any more satisfactory data some sort of correlation with the gravels at Cley Hill or Clay Pit Hill is provisionally suggested.

The summit of Cold Kitchen Hill on which the gravel rests is separated by a well marked break of slope from the mid-Tertiary surface of Wooldridge and Linton and topographic considerations persuade Wooldridge and Linton that the summit is a residual eminence 'slightly but definitely above the peneplain' (fig. 17).

The Correlative Significance of the pre-Cenomanian Material in the Gravels

In the absence of any palaeontological criteria, the distinctive composition of the gravels at Cley Hill and Clay Pit Hill, and particularly the occurrence in them of silicified Purbeck shell limestone, suggests an alternative approach to the problem of stratigraphic correlation.

<u>The derivation of the Purbeck material</u> (fig. 19)

An examination of the outcrop of the Purbeck Beds demonstrates that Purbeck material is unlikely to have reached the sites on Salisbury Plain from any source other than the main Purbeck outcrop in southern Dorset. The Purbeck beds now outcrop elsewhere in southern England, in the Vale of Wardour and at Swindon, and about Aylesbury, Leighton Buzzard and Oxford. These outcrops are of small extent and their character suggests the imminent overstep of Lower Greensand or Gault. They occur at levels between 400' and 600' O.D. substantially below the neighbouring Chalk escarpments and are not therefore in a position to supply material to sites on the outcrop of the Chalk. Nor indeed are they likely to have been exposed from beneath the Cretaceous cover when the gravels incorporating Purbeck material were deposited on Salisbury Plain. It is therefore accepted that the Purbeck material has been derived from the outcrop in southern Dorset. This establishes that the gravels on Salisbury Plain reached their present position either before the development of the folds of Alpine aspect in southern England or during a period when the expression of these folds had been obliterated by planation. In this case, if the gravels at Cley Hill and Cold Kitchen Hill are in fact preserved on residual remnants of a surface more ancient than the mid-Tertiary surface of Wooldridge and Linton, then they may reasonably be referred to the Palaeogene period and one is led to consider the possibility of correlation with the Agglestone Grit in the Lower Bagshot Beds, of suggested Cuisian age, in South East Dorset.

In Dorset Reid (1896) has shown that the Bagshot Beds (probably only the Agglestone Grit of Arkell, 1947) overstep the London Clay and Reading Beds to rest directly on the Chalk and Upper Greensand. The Tertiary gravels on Salisbury Plain also rest directly on the Chalk and possibly on the Upper Greensand at Park Hill (see below). The definite outcrop of the Reading Beds at the base of the Eocene everywhere on the margins of the main Eocene outcrop in the Hampshire and London Basins, suggests that a similar transgressive relation also prevailed on Salisbury Plain.

The petrology of the Bagshot gravels in Dorset

Reid has described the rocks recognised in Dorset in the Lower Bagshot Beds:

> "The gravels contain in the first place abundance of Chalk flints. Next in abundance come numerous fragments of

> . . . Greensand chert . . . The pieces are usually subangular, and of all sizes up to a foot in diameter; so they are not likely to have travelled far. The chert is probably derived from the Upper Greensand. Numerous pebbles of vein quartz, mostly under an inch in diameter, next attract ones attention, and it is not improbable that these may come from conglomeratic seams in the Wealden strata of the immediate neighbourhood. Fragments of Purbeck marble, sometimes silicified, are fairly common, and are associated with cherts and grits probably also of Purbeck age. All the rest of the material consists of subangular veined grits, hard sandstones, quartzites, quartz, radiolarian chert, and red and green jaspers; in fact, of hard silicious material such as might be derived from the weathering of the Permian breccias of Devon. Black grit with small quartz veins is abundant and, like the radiolarian chert, suggests the Culm Measures as its source, though it is probably also secondarily derived through the Permian breccias. Budleigh Salterton triassic pebbles are however entirely missing."
>
> Reid, 1896.

In a later account, Reid (1899) mentions the occurrence in the Dorset gravels, of schorlaceous material.

Arkell confirms the absence of Bunter quartzites:

> "The Bunter pebble beds must still have been blanketed by Upper Cretaceous rocks." Arkell, 1947, p.232.

A sample (Table 10) from the gravel at Blackdown, referred to the Bagshot Beds by Reid, gives some idea of the relative abundance of the principal components.

<u>The correlation</u>

It is at once apparent (Table 11) that the material in the gravels at Cley Hill and Clay Pit Hill, or in the Pleistocene gravels presumably derived from them, match the selection described by Reid tolerably well, both in the positive and the negative sense, although they incorporate predominantly local material which tends to mask the presence of the foreign rocks. It is however to be expected that in the gravels on Salisbury Plain, the foreign rocks, more remote from their source, will have become more dispersed.

In terms of petrology the correlation is quite as satisfactory as that which originally persuaded Reid (1896) to refer the Blackdown gravels to the Eocene and to the Bagshot Beds.

The character of the silicified Purbeck fragments in the gravels on Salisbury Plain tends to confirm a correlation with the Dorset gravels, of which Arkell writes:

> "The pebbles cannot be matched with any silicified rock known in the existing outcrops of Purbeck Beds at Portisham or eastwards."
>
> Arkell, 1947, pp. 231-32.

Arkell therefore infers a former extension of the Purbeck outcrop:

> "It is possible that South of the intra-Cretaceous Abbotsbury Fault, Purbeck Beds escaped destruction much farther

West and survived until Bagshot times
in the area now occupied by West Bay."
Arkell, 1947, p.244.

Interpretative Account of the Clay Pit Hill Outlier

A correlation of the Clay Pit Hill gravel with the Lower Bagshot Beds of Dorset is definitely supported,by the general aspect of the deposit at Clay Pit Hill, particularly the conjunction of coarse gravelly and sometimes carbonaceous sands with grey or mottled pipe-clays. In Dorset, sections in the Bagshot Beds describe:

"Interlaminated grey sandy clay and sand
"Grey pipe clay
"Mottled clay
"Sand, loose, white
"Coarse quartz grit
"Carbonaceous 'rubbish clay' or sand"
(in Arkell, 1947)

At Clay Pit Hill the association of well rolled flint pebbles, broken and more or less re-rolled pebbles, battered and fresh flint nodules seems to indicate a littoral facies. The rarity and perhaps complete absence of Upper Greensand suggests that this formation was not yet exposed locally and argues an earlier date for the Clay Pit Hill outlier than for the gravel at Cley Hill in which Upper Greensand is common.

In the light of this conclusion it seems remarkable that the Clay Pit Hill deposit should occur at a level so far below the gravel at Cley Hill. However Prestwich recognises that the Clay Pit Hill outlier could well be:

> "Protected by being in a large sand pipe."
> Prestwich, 1898.

The confused flinty drift of residual aspect which apparently separates the sands in the outlier from the adjacent Chalk tends to confirm the substantial dissolution of the Chalk. Reid (1899) has suggested that massive piping of the Chalk surface underlying the Eocene outcrop may be particularly favoured where the Eocene beds are of coarse sand, but include extensive lenticular seams of impermeable clay, which direct and localise the downward flow of groundwater. Reid believes this factor to have been responsible for the considerable downpiping of the Reading and Bagshot Beds in Dorset. The low level of the Clay Pit Hill outlier appears therefore to be some confirmation of its possible analogy to the Bagshot Beds.

Conclusion

Of the Bagshot outcrop in Dorset Arkell writes;

> "Both the clays and sands are deltaic in origin and were probably deposited by currents in a shallow subsiding lake fed by a large river flowing from the

granitic areas of the West."
Arkell, 1947, p.216.

The outlier at Clay Pit Hill may mark a transitory shoreline of this lake; nonetheless the outlier could be of rather more recent Palaeogene date, although the stratigraphic evidence in the main Eocene outcrop in the Hampshire Basin suggests that the succeeding Palaeogene transgressions became progressively less extensive. The probability that later Palaeogene shorelines reached this site is correspondingly reduced.

Interpretative Account of the Cley Hill Gravel

Redistribution of the Purbeck material

The approximate age of the gravel at Cley Hill is less certainly established. The almost complete absence of well rolled flint shingle suggests that the Purbeck material has not been immediately derived from the outcrop in South Dorset. The subangular form of the flint and Upper Greensand fragments (Plates 7 and 8) in fact suggests that the gravel is of fluvial origin; whereas there can be little doubt that the Purbeck material reached the area originally in the course of coastal long shore drift. If this argument is sound the gravel at Cley Hill obviously cannot be correlative with the initial introduction of the Purbeck material, probably during the Cuisian period, but suggests that redistribution of this material has occurred later in the Palaeogene period.

The Purbeck material in the gravel at Cley Hill seems to imply a shoreline further to the West, but, in the light of the existing evidence, we can have no idea whether this inferred western shoreline connotes the original introduction of the Purbeck material or a later redistribution, or how it correlates with the Clay Pit Hill outlier.

The concept of redistribution accords well with that of Cholley on the complexity of Palaeogene events:

> "Les transgressions se sont répetées . . . transgression landénienne, transgression yprésienne, transgression lédienne, transgression lutétienne, transgression ludienne, transgression sannoisienne, transgression stampienne. Ces transgressions étaient séparées par des périodes de régression (le passage de l'une à l'autre étant du reste marqué par des oscillations plus ou moins nombreuses du rivage, d'où l'existence, en bordure des golfes transgressifs, d'une zone plus ou moins large et profonde formée de sédiments marins ou lagunaires, de dépôts lacustre et d'alluvions fluviales)."
>
> Cholley, 1957, pp. 161-62.

and on the nature of the early Tertiary surface:

"Ce n'est pas tant la surface d'abrasion

> marine que la plaine fluvio-marine constituée à ce moment-là par l'action combinée de l'érosion marine et de l'érosion fluviale au cours des régressions et des oscillations de la mer . . . les surfaces constituées ainsi en bordure des golfes de transgression sont non seulement des surface polygéniques, mais aussi des surfaces polymorphes."
>
> Cholley, 1957, pp. 162 and 163.

The possible absence of downpiping

There are certain indications that the gravel at Cley Hill remains at or only slightly below the level at which it was originally deposited on the Chalk.

1. The ratio in the gravel of flint to Upper Greensand chert and sandstone, by comparison with Pleistocene river gravels (Table 8/b), very emphatically suggests that when the gravel was deposited at Cley Hill it was not far removed from the boundary between the Chalk and the Upper Greensand. This arrangement is consistent with deposition at or not far above the level at which the gravel now rests but is difficult to reconcile with deposition on a surface at a level some 400' higher. (i.e. the sub-Eocene surface of Wooldridge and Linton, 1955.)

2. The view that the gravel here is more or less *in situ* is also supported by the occurrence of flint and quartz pebbles on the summit of the Upper Greensand scarp at Park Hill (ST 826433) at a height of about 800'. Although

a fully diagnostic assemblage of pebbles has not been recovered here these relics may well be associated with the Cley Hill gravel and in this case their position cannot be attributed to solution.

3. It is probably also significant that the Cley Hill gravel is underlain by only about 6"- 9" of Clay-with-flints; had the deposit been let down from the surface proposed by Wooldridge and Linton (1955) the residuum of this solution ought to include the abundant flint in the zones of Micraster cor-anguinum and Micraster cor-testudinarium and the less abundant flint of the zone Marsupites testudinarius; a bed of flints perhaps more than 20' thick if the calculations of Jukes-Browne (1906) are accepted. Jukes-Browne showed that 100' of Micraster cor-anguinum Chalk should yield about 7'.0" of flint nodules and 14" of clay. Confused drifts associated with dissolution of this order have in fact been described by White at Okeford Hill (ST 812092) in Dorset:

> "This pebbly deposit as it stands is part and parcel of the Clay-with-flints gravel and the product of an incomplete blending of the flinty residuum of the Chalk with the debris of another and probably older gravel." White, 1923.

At Cley Hill the gravel and the relatively shallow Clay- with-flints of residual aspect, remain discrete (fig. 6/b).

Angular fragments of flint in the gravel are nonetheless often somewhat blunted by minute flaking and it seems likely that this condition refledts slight movement in the gravel in the course of subsidence or periglacial re-arrangement. Similar flint flakes are observed in the gravel at Black Down.

4. The slight elevation of Cley Hill above neighbouring summits referred in Part Two of this thesis to the mid-Tertiary surface, suggests a comparison with Waters' interpretation (1960) of ground in southwestern England on the outcrop of the Upper Greensand where the slight difference of level between his early and mid Tertiary surfaces cannot be attributed to the dissolution of the earlier surface (fig. 18).

5. The evidence in the Pleistocene gravels of the Avon and its tributaries has already been shown in this account (Tables 3/a and 3/b) to imply the more or less extensive preservation of Tertiary gravels on the western quarter of Salisbury Plain at the beginning of the Pleistocene period.

Chronology: the Oligoeene period

If the gravel at Cley Hill is now preserved at or near the level of its original deposition this approximation to the mid-Tertiary level suggests that the gravel may be of a relatively late Palaeogene date. An even later date, during the mid-Tertiary cycle, cannot be entirely excluded but the situation of the gravel on the Warminster anticline, close to the axis of the uplift, argues against this date. There is no reason however why the gravel should not be referred to the Oligocene period.

Oligocene denudation

The scope of the Oligocene period in terms of denudation has generally been neglected in southern England. Wooldridge and Linton recognise that during the preceding Eocene period:

> "The Eocene land surfaces surrounding the basins of deposition must have been far advanced towards peneplanation."
> Wooldridge and Linton, 1955, p.11.

Linton (1964) suggests that relics of a Palaeogene surface may be extensively preserved in Highland Britain but he believes that the operative planation culminated in the early Oligocene period. Of the Oligocene, Wooldridge has said:

> "Of the progress of denudation during the following relatively short epoch we know nothing." Wooldridge, 1927.

Oligocene earth movements: the Alpine analogy

To the Oligocene epoch has been referred a structural episode during which the corrugation of the Chalk in southern England took place. It is understood (e.g.

Linton, 1932) that individual folds of Alpine aspect in southern England cannot, in most cases, be accurately dated; nevertheless the explanation of tectonic behaviour in this area during the Tertiary period has been confused by a persistent belief that:

> "The great Oligo-Miocene anticlines began their rise during the early part of the Oligocene period . . . and that the process was continued spasmodically with increasing vigour and growing complexity toward a climax about the end of Oligocene times."
> Wooldridge and Linton, 1955, p.11 and p.14.

The alternative concept of progressive deformation associated with the margins of active geosynclinal tracts, particularly those established in the Triassic period (fig. 43) has been discussed from time to time by geologists in this country (e.g. King, 1954). Only during the last few years has the possible geomorphological significance of this essentially European tectonic model been recognised (e.g. King, 1963; Small, 1964; West, 1964).

The folds in southern England have been termed 'the outer ripples of the Alpine storm'; if the analogy is in any sense correct it seems unwise to confine activity on these axes to the Oligocene period. The record in the Alpine orogenic province (Collet, 1935; Termier and Termier, 1957; Brinkmann, 1960; Goguel, 1962) indicates recurrent activity at least since the Upper Cretaceous period and persisting through the Tertiary period into the Pleistocene. The evidence described in this thesis suggests that in southern England the fold axes were already defined in the pre-Tertiary interval and that activity on the axes has taken place since the Oligocene period (see Part Four of this thesis).

Stratigraphic evidence on the Isle of Wight

The folding of the Oligocene strata in the Isle of Wight, which has almost invariably been the foundation of Tertiary structural concepts in southern England is by no means unequivocal and could be understood to indicate a climax of tectonic activity in the Upper Eocene or Lower Oligocene and relatively less intense activity since that period:

> "The Oligocene beds as usual are less disturbed
>
> "Increase in dip from the highly inclined Chalk to the vertical and slightly overturned members of the Eocene system and subsequent dedrease through the Upper Eocene and Lower Oligocene
>
> "The dips in the Upper Chalk remain steep and the Tertiary beds below the Bembridge limestone (Oligocene) continue approximately vertical."
>
> (in White, 1921)

Analyses of heavy minerals in the Tertiary formations on the Isle of Wight (Walder, 1964) also suggest that the sedimentary environment changed in some way during the Upper

Eocene - Lower Oligocene interval.

The Creechbarrow evidence

On the mainland the preservation of large (30 lbs) unrolled Chalk flints in the Oligocene outlier at Creechbarrow in Dorset, suggests to Arkell that:

> "The Upper Chalk was undergoing erosion in the immediate vicinity of Creechbarrow before the deposition of the Bembridge limestone; namely in the early Oligocene, or as some stratigraphers would maintain, in late Eocene times." Arkell, 1947, p.241.

The Chalk immediately accessible to the Creechbarrow site outcrops in the Purbeck anticline, a typical flexure of Alpine aspect. Arkell admits that:

> "Some folding in Purbeck before the Bembridge Beds (Oligocene) were deposited . . . seems indicated by the strata on Creechbarrow."
> Arkell, 1947, p.244.

The Paris Basin

The concept of material denudation during the Oligocene period is substantiated in the Paris Basin where Cholley has recognised an intra Oligocene (sub-Stampian) planation surface, extending indifferently across the Tertiary outcrops and onto the outcrop of the Chalk (Cholley, 1957, fig. 18 and pp. 112 et seqq.). Cholley admits that in some places the Oligocene surface may be distinguished from the later mid-Tertiary surface, only with difficulty:

"Le seul moyen qui s'offre de faire la distinction entre la surface meulièrisée sannoisienne et la surface meulièrisée miocène dans la Brie orientale est de trouver sur la première des restes de sables stampiens."
Cholley, 1957, p.113, footnote.

This close approximation of the Oligocene surface in the Paris Basin to the mid-Tertiary level recalls to mind the situation of the gravel at Cley Hill and suggests the possibility that it may rest on an Oligocene planation surface.

A Note on the Evidence of Silica Mobilisation at Cley Hill and Clay Pit Hill

The occurrence of rotten flint in the gravels on Salisbury Plain at Cley Hill and Clay Pit Hill tends to confirm the Palaeogene dates which are inferred in this account.

Rotten flint pebbles have been recorded elsewhere in the Palaeogene of southern England (in Curry, 1963) from the (?)Blackheath Beds and London Clay in the London Basin and from the Bracklesham, Barton and Brockenhurst Beds in the Hampshire Basin. A new locality has been identified in the course of the present investigations; in the Bagshot Beds of the Geological Survey (Sheet 314) at Godshill

(SU 178160) in Hampshire. Here the discontinuous seams of flint pebbles, almost all rotten, occur in sands which must be within 20' of the junction, indicated by the Geological Survey, of the Bagshot Beds with the overlying Bracklesham Beds. The sands may therefore be of Cuisian age and possibly correlative with the sands at Clay Pit Hill. This correlation is not however of definitive value as it is known that:

> "The alteration . . . has occurred subsequently to the burial of the pebbles." Curry, 1963.

In this context it is worth recording that in the Pleistocene gravel at site (2) on Camp Hill much of the flint is deeply or entirely weathered and that the surface of individual fragments is often powdery.

There is some additional evidence in the Cley Hill gravel of silica mobilisation and redeposition. Fragments of Upper Greensand chert are often more or less vesicular and may be soft and crumbly. But, on one well rolled but broken pebble of Upper Greensand the broken face is covered by a film of chalcedonic silica. The undamaged condition of the delicate mammilation suggests that the film has been precipitated since the deposition of the gravel.

In the Bagshot gravels at Moreton (SY 779892) in Dorset Reid records that:

> "The chert-fragments found in the lower
> part of the pit are often quite soft,
> so that they were at first mistaken
> for pebbles of pipeclay." Reid, 1896.

Reid adds that the pebbles 'soon harden on exposure to the air'; which is not the case at Cley Hill where the chert has become friable rather than plastic.

Tertiary Outliers on the Summits of the Belemnite Chalk on Salisbury Plain

The results of the investigations at Clay Pit Hill and Cley Hill have been supplemented by a re-examination of the Eocene outliers indicated by the Geological Survey on Salisbury Plain, and referred by the Survey to the Reading Beds.

Cockey Down

This outlier (SU 171313)(Geological Survey Sheet 298) resting on the Chalk at a height of about 475' O.D., is rather more than 1½ miles to the North of the main Eocene outcrop in the Alderbury syncline. A pit to a depth of about 3'.6" was dug near the southern edge of the outcrop. The pit was in reddish brown plastic clay with scattered well rolled flint pebbles. The flint pebbles seen in the soil here are of all sizes from less than ¼" diam. up to 5" diam. At and below a depth of 2'.0" small calcareous concretions ('race') were encountered. Concretions of this type have not been recorded in the Clay-with-flihts but are fairly common in the clays of the Reading Beds. They are also recorded near the base of the London Clay in the London Basin (White, 1907) and in the Alderbury syncline (White, 1912) at East Tytherley Pottery (SU 292282). The geographical situation of the Cockey Down outlier appears to favour its inclusion in the Reading Beds, but it is not impossible that is should represent the base of the London Clay. On the southern limb of the Alderbury syncline above West Dean (SU 257270), pipes in the Chalk contain yellow sand with "ill-preserved casts of shells" resembling forms in the London Clay at East Tytherley Pottery (White, 1912). Whether a Reading Beds or London Clay date is accepted for the Cockey Down outlier, the preservation of calcareous race suggests that the deposit is not greatly disturbed. At Cockey Down quartz sand occurs in the 1/32" to 1/16" fraction but no larger pieces of quartz were recovered, nor were any detected on the ploughed surface of the outcrop. This presents a very significant contrast with the large volume of quartz observed in a gravel of Pleistocene age some 500 yards distant to the South and at a level only about 40' below the Eocene outlier (fig. 79). (This gravel is the 'gravel above Laverstock' mentioned in Part Five of this thesis.)

Thorney Down

This outlier (SU 213342)(Geological Survey Sheet 298) at a height of 535' O.D., some 3 miles North of the Eocene outcrop in the Alderbury syncline, is now on land occupied by the Defence Establishment at Porton and access to it was not obtained. Reid (1903) records "red mottled clay and pebbly soil." Gifford (1957) confirms "red clay with pebbles and shattered flint."

Beacon Hill

A section was cleared in the side of a small long disused pit (SU 195428) at a height of 668' O.D. Two feet, six inches of rather sandy soil are seen resting on the Chalk. Numerous well rolled flint pebbles occur in the soil but there is no evidence of Eocene material in situ nor are any pebbles of quartz seen.

Sidbury Hill

Two patches of Reading Beds are indicated (SU 215505) by the Geological Survey (Sheet 282) between 700' and 735' OD. and about 9 miles South of the most westerly outlier of Reading Beds in the London Basin. This site is on Ministry of Defence land and the manoeuvres of track-laying vehicles have provided extensive but usually very much disturbed sections, up to 3' deep. Flint pebbles (Plate 1) are very abundant in a matrix of yellowish or reddish sandy clay, but pebbles of quartz or of any other material are entirely absent. Jukes-Browne (1905) records 8' to 10' of pebbles in a red sandy matrix in the southern outlier. If we accept Prestwich (1854) and Whitaker (1862) on the rarity and small size of flint pebbles in the main outcrop of the Reading Beds which adjoins Salisbury Plain to the North, the abundance and large size (up to 4½" long) of the flint pebbles in the Sidbury outliers seems inconsistent with their inclusion in the Reading

Beds. The basement bed of the London Clay appears to offer a more satisfactory correlation. The London Clay is believed to rest directly on the Chalk in the Hampshire Basin and the inclusion of rolled chalk fragments at the base of the London Clay in the London Basin implies a similar overstep further North. Although the Sidbury correlation is extremely tentative it is a reasonable inference in the context of the undoubted overstep indicated by the Clay Pit Hill and Cley Hill outliers. There is no indication however at Sidbury, or at any of the other Eocene outliers on the outcrop of the Belemnite Chalk of the petrologically distinctive gravels encountered in the two more westerly outliers.

THE WESTERN MARGIN OF THE TERTIARY OUTCROP IN SOUTHERN ENGLAND

Anomalous Outliers in the Hampshire Basin

The Bagshot gravels in East Dorset

Reid believes that in South East Dorset the peculiar character of the Lower Bagshot Beds reflects strictly local tectonic conditions. He speaks of 'an era of local disturbance' and believes that:

> "The district between Dorchester and Weymouth is one of those areas of weakness which are affected again and agsin by similar disturbances."
> Reid, 1896.

He even conceives the:

> "Reading and Bagshot gravels . . . to occupy a valley eroded in the Secondary strata." Reid, 1896.

These views, if they are correct, render the correlation of the Salisbury Plain gravels with those in the Lower Bagshot Beds of South East Dorset much less likely. It is imperative therefore to establish whether any trace of the distinctive gravels can be identified on the intervening tract of ground.

In South East Dorset not only is the character of the Bagshot Beds unusual, the Reading Beds also show evidence of an overstep across the Chalk onto the Upper Greensand. Reid describes gravels near the base of the Reading Beds about Dorchester with flint and chert (Table 11); he emphasises however the:

> "Character which enables us easily to distinguish between the Bagshot and Reading gravels. The Reading gravels consist of flint and chert with an occasional quartz pebble, careful search yielding nothing else except one or two quartzite and grit pebbles. Bagshot gravels on the other hand contain besides flint and chert so much quartz and hard subangular Palaeozoic rocks as to make the finer screened material look like a Cornish beach." Reid, 1896.

The validity of this contrast has at no time been disputed (e.g. Chatwin, 1960).

Some newly described anomalies in northern Dorset and adjacent Hampshire

Damerham Knoll

In spite of the criteria suggested in 1896 to distinguish between the gravels of the Reading and Bagshot Beds, Reid in the Memoir on the Country around Ringwood (1902) subsequently assigned to the base of the Reading Beds an outlier at a height of 400' O.D. at Damerham Knoll (SU 099186) with 'much quartz'. This contrasts significantly with the 'occasional quartz pebble' of the 1896 paper and the site was therefore re-examined.

So pebbly is the outcrop on much of the summit of the Knoll that the soil is thin and in several places completely absent (cf. Plate 14/a). Here it is seen that the gravel includes elements of the suite of pebbles which distinguishes the Lower Bagshot Beds further South:

vein quartz
dark grits
cherts (including Upper Greensand chert)
veined chert
veined grits
quartzites
schorlaceous quartz
silicified Purbeck shell limestone (rare)
unidentified hard silicious rocks

The presence of these rocks in the pebbly soil is difficult to reconcile with Reid's account of the Reading Beds, and encouraged a more thorough examination of the Knoll (fig.20).

Pit 1

A section excavated near the boundary of the outlier showed a few inchew of sandy and pebbly soil merging downward into a buff coloured and mottled sand, grey and ironstained in places with occasional black flecks. The sand is slightly clayey and incorporates ferruginous concretions and irregular masses of grey clay. The base of the sand is approximately parallel with the slope of the ground and leads one to believe that the sand is not in situ. At a depth of 18" the sand rests with a well defined boundary on a shingle; largely composed of unbroken flint pebbles (Plate 10)(Table 12); but including small amounts of quartz and chert (probably Upper Greensand), and rare grits, veined grits and quartzites. The shingle, which was seen to a depth of 5'.9" in the section, is in a scanty matrix of ferruginous sand with numerous flecks of black staining. The individual pebbles have a very distinctive rusty patination. There is some evidence in this pit of the formation of a pebbly ferruginous conglomerate, and on the neighbouring slopes of the Knoll large blocks of such a conglomerate are scattered on the surface. The pebbles which comprise the shingle are of a moderately well rounded to sub-angular form but are not typical well rounded pebbles of Lower Tertiary aspect (e.g. Plates 1 and 12).

Two

On a direct line between Pit (1) and the outcrop of the Chalk, and ten feet from the Chalk boundary, the auger passed through 3'.9" of coarse dark ferruginous sand and at this depth encountered the Chalk. The sand includes some stoney material but is not sufficiently shingly to check the auger.

Pit 3

A shallow section excavated nearby, showed 2'.6" of greyish pink stoneless clay, similar to the inclusions in the horizon overlying the shingle in Pit (1) and therefore perhaps not in situ.

Pit 4

This section excavated on the summit of the Knoll showed 3"- 8" of sandy soil full of bracken roots over a confused horizon of rather variable depth (3"- 18"). This horizon consists largely (Table 13/a) of broken and unbroken flint pebbles (Plate 11) in a matrix of pale brown sand, together with smaller amounts of quartz and Upper Greensand chert and rare grits and quartzites. There is in fact nothing to distinguish this material, in terms of composition, from the shingle described in Pit (1). In the finer gravel

($\frac{5}{32}$"- $\frac{1}{2}$") there is however an abundance of ferruginous material, including some fragmentary leaf impressions. Below this pebbly horizon is a rather more compact greyish sandy clay (4"- 6" thick) in which pebbles are less frequent. This is perhaps a zone of clay accumulation in the soil profile. It is underlain by another confused horizon (4" thick) of ferruginous clayey sand, incorporating small flint pebbles and broken flint. This material rests with a well defined boundary on a tough reddish brown slightly stoney clay, seen for 9" and augered for a further 2'.0" below the floor of the excavation. Most of the stoney material in this clay is small (less than ½" diam.) and its composition (Table 13/b) is not essentially different from the shingle in Pit (1).

In terms of composition the shingle examined at Damerham Knoll can be correlated with Reid's account of shingle in the Reading Beds about Dorchester which has been confirmed during the present investigation in a shingle near the base of the Reading Beds at Tincleton in Dorset (SY 771922) (Table 13/d). In terms of abrasion also, individual pebbles in the shingle at Damerham Knoll resemble forms observed in the shingle at the base of the Reading Beds at Morden (SY 909974) in Dorset (Plate 13). The occurrence of a subangular gravel in the Reading Beds in the neighbourhood of Damerham Knoll is indicated in the Geological Survey summary of progress for the year 1899, but is not elaborated by Reid in the appropriate Memoir (1902).

> "Sub-angular gravels containing Greensand chert and fragments of Palaeozoic rocks make their appearance as far northeast as Downton (SU 182215), though they are scarcely so angular as they become nearer Dorchester."
> Summ. Prog. Geol. Surv., 1899.

The evidence examined at Damerham Knoll suggests that a gravel which may be assigned to the base of the Reading Beds is <u>in situ</u> but that there is no evidence of later formations <u>in situ</u>. Nevertheless the apparent abundance and evident variety of the rocks in the pebbly soil on the summit of the Knoll are difficult to reconcile with descriptive accounts of the Reading Beds. Reid considered Palaeozoic rocks to be so rare in the Dorset Reading Beds that he infers their derivation from the base of the Chalk:

> "I could find no trace in the gravel of the Reading Series of cherts or other hard rocks belonging to the Jurassic strata, and Palaeozoic grits are too few to be of much importance, especially as such fragments occur occasionally towards the base of the Chalk." Reid, 1899.

It is conceivable that the incongruous material in the soil on Damerham Knoll represents the debris of overlying Bagshot Beds. Bearing in mind the more or less co-extensive distribution of the distinctive gravels in the Reading and Lower Bagshot Beds about Dorchester, the evidence in northern Dorset and in adjacent Hampshire is consistent with a similar association of the beds there. The occurrence of silicified Purbeck shell limestone seems particularly significant in this respect. Alternatively, Ried may have somewhat underestimated the assortment of material in the Dorset Reading Beds. If this is the case, bearing in mind the Purbeck material at Damerham Knoll, Jurassic rocks must already have been subject to denudation during the Reading Beds period.

There is definitely no indication that any of the material in question has been introduced during the Pleistocene period. Battered flints, of the type which invariably accompanies river gravels of Pleistocene age elsewhere in the Hampshire Basin, are not seen on Damerham Knoll.

Pentridge Hill

The problematic relics at Damerham Knoll are matched (Table 11) in the Eocene outliers on Pentridge Hill (SU 040171) assigned by the Geological Survey to the Reading

Beds. Here the conditions of exposure (Plate 14/a) are similar to those on Damerham Knoll and a closely similar suite of pebbles may be picked up on the surface of the ground:

vein quartz
quartzites
dark grits
veined grits
cherts (including Upper Greensand chert)
silicified Purbeck shell limestone (rare)
unidentified hard silicious rocks

Shallow sections (Plate 14/b) in the northern outlier, at a height of about 550' O.D., show a ferruginous shingle which closely resembles the shingle in Pit (1) at Damerham Knoll. A sample of this shingle (Table 13/c) consists largely of subangular flint pebbles (Plate 14/c), mostly unbroken. In the coarse gravel (more than ½" diam.) any other material is uncommon but in the fine gravel, chert (probably Upper Greensand) and vein quartz are present in significant quantities and a few other hard silicious rocks are identified.

Where vegetation has broken down on the northern outlier (Plate 14/a) the soil is seen to incorporate in some cases the subangular flint pebbles with ferruginous patination which characterise this shingle and the shingle at Damerham Knoll. In other cases black, dark grey and pale grey well rounded flint pebbles of more typical Lower Tertiary aspect largely predominate (Plate 14/d).

A shallow section near the summit of the main outlier at a height of 600' O.D. shows whitish quartz sand with seams of white and bright red mottled clay.

In terms of composition and abrasion the shingle examined on Pentridge Hill resembles the shingles on Damerham Knoll and at the base of the Reading Beds in Dorset, and is probably of the same age. The outcrop of a distinctive well rolled shingle on Pentridge Hill suggests the operation of conditions rather different from those to which the subangular gravel relates, but it is impossible to estimate the stratigraphic significance of this contrast, or to show whether any formation other than the Reading Beds need be identified on Pentridge Hill. The aspect of the clays and sands seen in the main outlier is consistent with their inclusion in the Reading Beds.

Bowerchalke Ridgeway

The Clay-with-flints of the Geological Survey above Bowerchalke (SU 005210), at a height of about 635' O.D., incorporates subangular flint pebbles with ferruginous patination (Plate 15). The flint pebbles are seen in the ploughed surface of the outcrop, together with a great deal of sharply angular flint and a few small quartz pebbles. Pebbles of any other material are very rare; one small quartzite, a few cherts (probably Upper Greensand) and one silicified Purbeck shell limestone have been collected. This assortment appears to be the debris of a shingle resembling the shingles at Damerham Knoll and Pentridge Hill, which are referred in this thesis to the Reading Beds.

The recognition of silicified Purbeck shell limestone in this very disturbed relic, from which abundant or varied silicious rocks are apparently absent, tends to confirm the exposure and denudation of the Purbeck outcrop during the Reading Beds period.

Other sites examined

A re-examination of the Reading Beds outcrop, in the neighbourhood of Damerham Knoll demonstrates the general development, near their base, of the distinctive subangular shingle detected at Damerham Knoll

1. The Mizmaze (SU 142202): the soil incorporates subangular flint pebbles with ferruginous patination, pebbles of chert (probably Upper

Greensand), small quartz pebbles and subangular tough ironstone.

2. On the Reading Beds outlier (SU 100156), near South Damerham, subangular flint pebbles are seen in the soil together with rare and small quartz pebbles.

3. On the main Reading Beds outcrop, near Ashes Farm (SU 080136), subangular flint pebbles occur in the soil.

4. On the summit (SU 064164) of the extensive Reading Beds outlier occupied by Martin Wood and Boulsbury Wood, rare pebbles of quartz occur but the associated flint pebbles are well rounded.

5. On the Reading Beds outlier, occupied by Braemore Wood (SU 149197), the soil is seen to include subangular flint pebbles with ferruginous patination, small quartz pebbles, chert and subangular ironstone.

Further North and East in the main Eocene outcrop, subangular flint gravel has not been detected in the Reading Beds (cf. Plate 12) nor is there any evidence of the distinctive suite of rocks which seems to be more or less closely associated with the subangular gravel.

Derived material in Pleistocene gravels

A rapid preliminary examination of some Pleistocene gravels lying on the right bank of the Avon, indicates the common occurrence in them of elements of the distinctive suite of pebbles recognised at Damerham Knoll and Pentridge Hill:

1. Pistle Hill: SU 096105, (315' O.D.)
   - vein quartz
   - Upper Greensand chert
   - grits
   - veined grits
   - schorlaceous quartz
   - quartzites
   - veined quartzites
   - radiolarian chert
   - unidentified hard silicious rocks
2. Holt Heath: SU 050044, (185' O.D.)
   - vein quartz (up to 1⅝" diam.)
   - veined grits
   - Upper Greensand chert
3. Clump Hill: SU 065062, (177' O.D.)
   - vein quartz (up to 1⅛" diam.)
   - veined grits
   - chert (probably Upper Greensand)

This evidence suggests that before and during the Pleistocene period the Tertiary outcrop incorporating these pebbles was more extensive here.

Conclusion

Although the investigation in northern Dorset and in adjacent Hampshire does not provide any unequivocal evidence on the character of the Bagshot Beds on this tract of ground, it does show that the distinctive composition of the Lower Tertiary gravels in Dorset is not a local phenomenon, confined, as Reid believed might be the case, to the immediate neighbourhood of Dorchester. Conditions during the Reading Beds period clearly admitted the northward passage of material from the neighbourhood of Dorchester and there is no reason to suppose that conditions changed in this respect during the succeeding Bagshot Beds period.

The character of the gravels or shingles referred to the Reading Beds at Damerham Knoll and on Pentridge Hill is consistent with intertidal marine conditions. Further South in Dorset the gravels both in the Bagshot and Reading Beds become increasingly angular when traced westward, and Reid recognises that:

> "Between Wareham and Dorchester sub-angular gravels more like river gravels than beach deposits come in."
>
> Reid, 1899.

In the light of this evidence it is perhaps legitimate to argue that the subangular shingles further North in Dorset and Hampshire mark the shore of an estuary at the mouth of the river inferred by Reid.

The apparent configuration of this shoreline suggests that it may have been defined by uplift of the anticlinal Wardour and Dean Hill axes. Work by Williams-Mitchell (1956) shows that on both the northern and southern flanks of the Dean Hill anticline the base of the Reading Beds oversteps from the Belemnitella mucronata zone onto the sub-adjacent zone of Goniatites quadratus: the anticline seems therefore to have had slight expression, and to have suffered planation, at some time during the pre-Tertiary interval.

New Light on some Problematic Deposits elsewhere in Southern England

Deposits of Palaeogene aspect, and evidence bearing on the nature of the sub-Eocene unconformity have been recognised elsewhere in southern England (Table 11)

Dorset

From the residual gravel on the summit of Bullbarrow (ST 787067) in Dorset, at a height of over 900' O.D., Green records that:

> "Mixed with the flints are the sparse remains of a shingle . . . including well rounded beach hammered flints, vein quartz, tourmaline grit, tourmaline breccia, quartzite and graywacke." Green, 1941.

A distinctive assemblage of pebbles also occurs in a gravel described by White at Okeford Hill (ST 812092) in Dorset:

> "Flints: angular and sub-angular
>
> "Flint pebbles: a common Eocene type
>
> "Vein quartz: white and pink up to 2" diam.
>
> "Upper Greensand chert: brown and white, nearly all well worn and mostly sub-angular but also roughly rounded cobbles up to 6" diam.
>
> "Quartzites and hard sandstones: all well rounded pebbles up to 4½" diam.
>
> "Lydianite or tourmaline grit: all well worn but often with one flat surface.
>
> "A few other compact silicious rocks in small pebbles."
>
> White, 1923.

White tentatively refers this gravel to the Bagshot Beds which he observes:

> "Contain a similar but not identical assemblage of material in their gravelly bands near Dorchester."
>
> White, 1923.

During the present investigation this site was briefly re-examined and in addition to the material specifically described by White, veined grits, fine grained sarsen, and an unidentified breccia were collected.

The overstep of the Lower Bagshot Beds onto the Chalk, which is evident in their locus classicus about Dorchester, is indicated further North by the composition of the Clay-with-flints on the dip-slope of the Dorset Downs. At the Folly on the top of the ridge southwest of Durweston (ST 860085), an outlier of Reading Beds was formerly indicated by the Geological Survey (Old Series, Sheet 15) but to White:

> "The pale clays seen in the Folly Pit and their association with coarse quartz sand are much less suggestive of the Reading Beds than of the Bagshot Sands as developed for instance at Broadstone about eleven miles to the south-east."
> White, 1923.

White's view on the nature of the sub-Eocene surface constrained him to add:

> "The clays and sands evidently occupy a pipe in the Chalk and may be far below the original position of the beds whence they were derived." White, 1923.

The conclusions adopted in this thesis on the nature of the sub-Eocene unconformity suggest that White's view in this case may be unnecessarily complicated.

The English Channel

The character of the sub-Eocene unconformity observed or inferred on the mainland is confirmed in an outlier of Lower Tertiaries in the central English Channel. In the suggested Lower Bracklesham (Cuisian) Beds of the outlier, Curry (1962) has described foraminifera of Upper Cretaceous (Campanian, Maestrichtian and Danian) age, and he suggests that the Cuisian beds may have overstepped onto the outcrop of these formations.

Somerset

Waters (1960) has identified a probably marine Tertiary planation surface at a level of 1,035' O.D. on Staple Hill (ST 240167) in Somerset. On this surface he has detected a gravel with:

flint

quartz

tourmalinised rocks (schorl)

graywacke

Palaeozoic pebbles

This material Waters refers to a late Eocene or Oligocene marine transgression. Linton regards this gravel as:

> "The remains of an Eocene formation, probably the lateral equivalent of the Bagshot Beds." Linton, 1964.

The Vale of Pewsey, the Kennet Basin and the Midlands

The Vale of Pewsey and the Kennet Basin

Historical background

Whitaker at an early date (1862) recognised that the declining thickness of the Reading Beds and London Clay, West of Newbury, favours an overstep of the Bagshot Beds onto the Chalk in the neighbourhood of Marlborough. It was essentially for this reason that he considered the sarsens, impressively accumulated near Marlborough, to be of Bagshot Beds age. In the same area extensive tracts of Clay-with-flints are indicated by the Geological Survey (New Series Sheet, 266). On the Old Series map (Sheet 14) 'potholes of yellow sand' and 'yellow sandy clay' are indicated respectively on Huish Hill (SU 153641), and on Martinsell Hill (SU 177638), where Prestwich (1890) has recognised traces of his Southern Drift. Prestwich in the same paper tentatively recognised traces of his Westleton Shingle on neighbouring summits of the Chalk; and White (1925) records fragments of quartzite in the Clay-with-flints. Varney in his treatment of the Vale of Pewsey states, with positively nineteenth century disregard for detail, that:

> "Occasional far-travelled pebbles of rock quite foreign to the district can be found on the North side of the Vale."
>
> Varney, 1921.

It is by no means clear whether Varney means in the Vale, or upon the Chalk escarpment by which it is bounded.

The limited scope of the present investigation

The superficial geology of the ground about the Vale of Pewsey is obscure but interesting, and largely beyond the scope of this thesis. Only a few sites have been reconnoitered, to establish how the behaviour of the Lower Tertiaries here compares with the conditions recognised in the Hampshire Basin.

Sites examined

On the summits of the Chalk which forms the northern escarpment of the Vale of Pewsey, the soil on the Clay-with-flints of the Geological Survey has been examined at several points.

1. Oldbury Hill, (SU 051690)(about 850' O.D.)
2. Tan Hill, (SU 078649, SU 081648, SU 082647) (900'- 950' O.D.)
3. Milk Hill, (SU 108638, SU 109635)(850'- 925' O.D.)
4. Martinsell Hill, (SU 177638, SU 175638)(about 925' O.D.)
5. Morgan's Hill, (SU 030668, SU 029672, SU 032672) (800'- 850' O.D.)
6. Huish Hill, (SU 153641)(about 850' O.D.)

Samples of soil from these sites suggest that the drift consists largely of sharply angular flint with subsidiary amounts of ferruginous material, including ferruginous sandstone; and small pebbles (less than ½" diam.) of vein quartz. Here and there the soil incorporates small well rolled flint pebbles of Lower Tertiary aspect (less than 1½" diam.). Small deeply weathered, slightly abraded flint fragments patinated a shade of yellow or brown occur infrequently. A substantial amount of secondary silica occurs and a few fragments of quartzite (probably sarsen). More or less massive blocks of sarsen are commonly associated with the drift.

The most distinctive site examined in this area during the present investigations is on the spur leading down from Martinsell Hill, which culminates in the Giant's Grave, a prehistoric earthwork.

7. (SU 168633)(810' O.D.)

It proved impossible to clear a fresh section in the long-disused pit in this material, but in several small exposures coarse white sand was seen, often mottled bright red and associated with white and brightly coloured clays. The material definitely has the aspect of the Bagshot Beds of the Hampshire Basin. At one point a thin and discontinuous seam of fine gravel was observed and a sample secured; this proved to consist (Table 14) very largely of small pebbles of vein quartz. Flint and ferruginous material comprise the larger part of the balance. There are a few quartzites, grits, cherts and indeterminate fragments of Palaeozoic aspect, not enough however, nor sufficiently distinctive to be of any value for correlative purposes.

Summary

Although the evidence about the Vale of Pewsey does tend to support an overstep of the Bagshot Beds onto the Chalk; the occurrence of the Bagshot Beds *in situ* is nowhere demonstrated and no definite trace of the distinctive association of pebbles which characterises this formation in Dorset has been encountered.

A comparative study of the Pleistocene Gravels of the Kennet might provide some additional evidence on the former extent and composition of the Eocene formations here;

indeed White (1907) has already alluded to the problematic derivation of the quartz in these gravels.

A note on the sarsen problem

Perhaps the most useful result of the investigations conducted in this area is the demonstration of a significant contrast between the sandy drift in the Clay-with-flints and the Sarsen sandstone. On no occasion have pebbles of quartz, relatively common in the sandy drift, been recorded in the sarsens of the Marlborough area.

This seems to suggest that these two controversial relics are the traces of two separate geological formations; namely, in the case of the sarsens, the Reading Beds and in the case of the sandy drift in the Clay-with-flints, the Bagshot Beds. The Reading Beds age of the sarsen sandstone here has from time to time been assumed (e.g. Kerr, 1955) but the present conclusion increases the body of circumstantial evidence upon which such assumptions must be based.

The Marlborough Downs

On the Marlborough Downs only one record has a direct bearing on the problem under discussion. At Hackpen Hill, Kendall, H.G.O (1909) has recorded chert, quartzite and vein quartz in the Clay-with-flints.

The Oxford district

In the context of this study it may profitably be observed that Kendall, P.F., Jones, O.T. and Hawkins, H.L., in discussion of Sandford's 1929 paper on the drifts about Oxford, all urged that much if not all of the material, in these drifts, foreign to the Oxford area, had been derived from an extension of the Eocene beds. Sandford himself had enquired in this paper:

> "Could the material have arrived in Cretaceous or in Tertiary times? The answer is a doubtful affirmative that is worth investigation." Sandford, 1929.

Regrettably no-one has undertaken this investigation and the extension of the Palaeogene outcrop into the Midlands and further afield remains problematic.

PART II

PART II: SUMMARY AND NOTES ON THE ORIGINALITY OF THE WORK

1. The well established concept of a mid-Tertiary 'summit' surface is introduced; the problem of the chronological age of the surface is admitted and the scope for a re-examination of the 'type area'of Wooldridge and Linton (1955) is intimated.

2. Drifts on the Upper Greensand and Portland outcrops in the Vales of Wardour and Warminster are described; this is an account of original work and the short interpretative passages are correspondingly original.

3. An introductory account of the Clay-with-flints in Wiltshire provides a summary of the very slight descriptive literature on this subject.

4. Drifts on the Chalk, on the mid-Tertiary surface of Wooldridge and Linton are described; this is largely an account of original work. The interpretation of the drifts confirms the views of Wooldridge and Linton.

5. Drifts on the Chalk, on the mid-Tertiary surface of Wooldridge and Linton are described: this is an account of original work based in part on allusions to 'relics of gravels' in Andrews (1892).

6. An original interpretative account of the 'relics of gravels' is based, in part, on views expressed by Prestwich (1891) and Bury (1910) on evidence in the Weald.

7. In an original conclusion it is suggested that the interpretation of the Vale of Wardour adopted by Wooldridge and Linton is unsatisfactory.

PART II: THE SUMMIT SURFACE IN SOUTHERN WILTSHIRE

INTRODUCTION

The Historical Perspective

The proposition "that late Miocene times witnessed the progress and virtual completion of a great phase of planation" (Wooldridge, 1926) was generally accepted by geologists confronted, at the beginning of the present century, with the classic studies of Jukes (1862), Ramsay (1863), Davis (1895) and Mackinder (1902). This concept was extended and refined by Wooldridge who inferred the subaerial nature of the planation and claimed to recognise its expression on the higher summits of the Chalk:

> "In particular it is on the Chalk uplands of Wessex that the most considerable . ... remnants of the summit plain survive" Wooldridge and Linton, 1955.

The surface is distinguished on largely morphological grounds: a gently undulating plateau is discerned truncating the Tertiary flexures, "rarely if ever does it descend below 700' or rise to 900'"; subsequent dissection encroaches upon it but the encroaching slopes remain topographically discrete.

The Problematic Age of the Summit Surface

The planation of the Chalk summits in southern Wiltshire is convincingly substantiated by Wooldridge and Linton (1955, pp. 38 - 41). The period during which the planation was effected appears less certain. In Part One of this thesis a study of early Tertiary events has not produced a definitive conclusion regarding the plane originally occupied over southern Wiltshire by the sub-Eocene surface. Palaeogene material has moreover been recognised at Cold Kitchen Hill and at Clay Pit Hill on ground respectively above and below the projected level of the summit surface of Wooldridge and Linton (1955)(fig.17). This arrangement and the evidence in Pleistocene gravels that the Palaeogene outcrop was more extensive in the early part of the Pleistocene period suggests that Palaeogene material might be preserved in drifts on the summit surface.

A study of the derivation of these drifts was therefore undertaken to supplement the morphological conclusion and particularly to establish whether the summit surface is of late Tertiary (Neogene) date, as Wooldridge and Linton maintain (1955), or whether it is in fact an extension of the early Tertiary surface (loosely termed sub-Eocene), as Pinchemel (1954) and Small (1964) have suggested.

The Area Investigated

In their account of the downland "on the southern border of Wiltshire", Wooldridge and Linton argue that:

> "In no other part of South East England can the Mio-Pliocene surface be so satisfactorily recognised over so large and continuous a tract of country and its relations to the mid-Tertiary flexures so convincingly demonstrated. We may perhaps even go so far as to regard it as in some sense a type locality."
> Wooldridge and Linton, 1955, p.42.

The summit surface passes westward from the neighbourhood of Salisbury onto successively older zones of the Chalk and seems to have truncated the substantial Wardour anticline (fig.25).

It is upon relics of the summit peneplain in this area and in neighbouring areas of Wiltshire and Dorset that investigations have been carried out. The superficial geology of the surface has been examined at several sites indicated by Wooldridge and Linton (1955, fig.10) on the outcrop of the Chalk and of the Upper Greensand and at one site on the Portland outcrop in the Vale of Wardour (fig. 26).

DRIFTS EXAMINED ON THE OUTCROP OF THE UPPER GREENSAND

The Vale of Wardour

Summary of intentions and results

The investigation of drifts on the Upper Greensand, where the preservation of the summit surface is indicated by Wooldridge and Linton (1955, figs. 10 and 17), has proved disappointing. No descriptive account of the superficial geology or soils in the Vale of Wardour appears hitherto to have been undertaken. The present investigation, on the Upper Greensand, sought particularly to recognise evidence of duricrust or silcrete formation. Silcretes are known to characterise the extensive Neogene (Aquitanian) planation surface on more or less arenaceous outcrops in the Paris Basin (Cholley, 1957) and have been recognised by Waters (1960) on the Upper Greensand in southwestern England, on ground which he refers to the summit surface of Wooldridge and Linton. In the Vale of Wardour no evidence of silica mobilisation was observed at the sites subsequently described. In fact no evidence is recognised of an undisturbed drift associated with the summit surface; nor is there evidence of remanié drifts near the projected level of the surface; nor of drifts at lower levels in the Vale incorporating material which might have been derived from the summit surface on the Upper Greensand.

Account of sites investigated

1. Hart Hill

Where sections in the drift overlying the Upper Greensand have been examined at Hart Hill (ST 867255) at a height of 725' O.D. an angular rubble or head of periglacial aspect up to 6'.0" deep occurs. This drift consists exclusively of fresh Upper Greensand debris; angular fragments of greyish or whitish flint occasionally incorporated in the upper part of the drift, invariably prove to be artificial flakes.

2 - 6. Surface indications

Elsewhere on the Upper Greensand good sections are no longer open and surface indications have been assessed at Beacon Hill (ST 912301)(775' O.D.), Tittle Path Hill (ST 892256)(775' O.D.), Little Hill (ST 868247)(800' O.D.), Saint Bartholomew's Hill (ST 905256)(650' O.D.) and Aaron's Hill (ST 748334)(790' O.D.).

7 - 9. Soil pits

Surface indications have been supplemented at several sites in the Vale of Wardour by the excavation of small pits. Samples of the sub-soil have been collected and their compositions examined:

7. From a pit on Haddon Hill (ST 875316)(737' O.D.) a sample of the sub-soil at a depth of 19" was obtained.

8. A sample of the sub-soil was also collected from a depth of 13" at Alfred's Tower (ST 746352) (850' O.D.).

9. A deeper section in head was examined in a disused gravel pit in West End Wood (ST 762376) at a level (700' O.D.) below the summit of the escarpment at 800' O.D. A sample was secured

here from a depth of 36"

10. Knoyle Corner

Special attention was given to the unusual terrain at Knoyle Corner (ST 898307)(fig.49); the junction between the Chalk and the Upper Greensand outcrops here at about 700' O.D. at or near the level of the mid-Tertiary surface but is not indicated on the ground as it usually is in the Vale of Wardour by a well defined scarp or indeed by a topographic feature of any sort. As might be expected the soil on the Upper Greensand here contains a certain amount of flint; and Upper Greensand debris spreads for some distance onto the outcrop of the Chalk. There is no indication however that this distribution is not the result of local periglacial redistribution during the Pleistocene.

11. Castle Ditches

In their account of the mid-Tertiary surface, Wooldridge and Linton draw attention to certain summits further East and at a lower level in the Vale of Wardour which they regard "as having conformed to the general level in the fairly recent past" (1955, p.41). During the present investigation surface indications were examined on the summit of Castle Ditches (ST 962284)(about 630'). Here a large number of well rounded flint pebbles of Lower Tertiary aspect are seen on arable within the ramparts of the impressive prehistoric earthwork which crowns the summit. These pebbles seem to have been introduced during the prehistoric period (see Appendix II), and there is no trace of any unequivocal drift material.

Conclusion

There is no indication at any of the sites investigated either at the surface or in the composition of the samples examined, of a drift containing any material other than the freshly weathered debris of the Upper Greensand itself.

The Vale of Warminster

Summary of results and background to the investigation

The examination of drifts on the Upper Greensand in the Vale of Warminster suggests a rather similar conclusion. The drifts there are of periglacial aspect but they incorporate some material possibly derived from formations of Palaeogene age and perhaps also from residual deposits on later Tertiary surfaces. In this respect they appear to differ from head on the Upper Greensand in the Vale of Wardour. This contrast may reflect the much more satisfactory nature of the exposures examined in the Vale of Warminster or it may reflect the smaller scale of the anticlinal structure there and a real contrast in the structural evolution of the Warminster axis and in the progressive exposure of the Upper Greensand outcrop during the denudation of the anticline.

The only account of the drifts in the Vale of Warminster is found in Manley's unpublished notes (? 1927). He has recorded 'half way up the hill from Rehobath to Folley' (ST 856445) at a height of about 450' O.D. a sandy drift with 'chipped pebbles'. He considers that the pebbles are of 'Tertiary, Woolwich and Reading Beds' origin. In a more general vein he states that in the Vale of Warminster:

> "Either incorporated in the soil or forming a distinct stratum below the soil is found considerable quantities of drift material of fluvio-glacial origin, the pebbles which characterise it are derived largely from the Woolwich and Reading (Eocene) beds."
>
> Manley, ? 1927.

The relics of a problematic gravel have already been described in Part One of this thesis on the Upper Greensand at Park Hill, and are very tentatively correlated with the gravel at Cley Hill which is almost certainly of Palaeogene age.

Account of the sites investigated

1. The Vicarage (fig. 27)

The nature of the drift on the Upper Greensand in the Vale of Warminster has been very carefully examined during the present investigations in a pit dug in the garden of Christ Church Vicarage, at Warminster (ST 872446) at a height of 425' O.D.

The section excavated here showed 10"- 12" of disturbed garden soil, dark brown in colour, with quantities of introduced material (brick, drive gravel, ash, etc.), resting with a well defined boundary on a stoney drift. Near the boundary several flint flakes of human origin were recovered (see Appendix I). The drift itself consists very largely of angular fragments of Upper Greensand chert and sandstone (up to 8" long), closely packed in a groundmass of rather sandy bright reddish-brown clay. A few angular and subangular, possibly abraded pieces of flint (up to 3" long) are encountered, usually deeply weathered with a pale yellowish patination. In the 1/16" to 1/4" fraction there are ferruginous concretions and pieces of quartz (mostly less than 1/8" diam.) but the bulk of the material, about 95% by volume, is fragmentary chert and sandstone. In the 1/32" to 1/16" fraction, quartz sand predominates, about 80% by volume, with subsiduary quantities of chert flakes, flint flakes and ferruginous concretions. At one point this stoney drift passes laterally with a sharp boundary into a more or less stoneless, paler, pinkish brown, sandy loam. The arrangement of the boundary suggests that the loam may form a wedge-shaped inclusion at least 4'.3" deep in the stonier clay. The whole wedge was not excavated however. At a depth of about 5'.0" the stoney drift rests on, or cuts through, a seam (10"- 15" thick) of sand. The lower part of the sand (about 6"- 10") is dark green in colour and entirely free from stones; the upper part, separated by a sharp boundary, is brown and incorporates wisps and masses of the overlying drift; the upper part of the sand is penetrated by numerous (?)root holes and might represent a fossil soil. The sand rests on a stoney drift generally similar to the upper stoney drift but only a few inches thick; 4" of green sand are again encountered below this but rest on rubbly Upper Greensand which is indistinguishable from Greensand weathering in situ.

2 - 5. Correlative sites

This drift sequence is confirmed in graves in the neighbouring churchyard but has nowhere been observed on ground lying below this level, although new building in Warminster has lately provided excellent opportunities to examine the superficial geology on the Upper Greensand outcrop. On the other hand there is evidence that, at levels above the Vicarage site, this drift is widespread.

2. Botany Farm (ST 859434) at a height of about 575' O.D., seen in an excavation (about 15' square) for the West Wilts Water Board: a foot or two of disturbed soil rests on a stoney drift indistinguishable, either in appearance or composition from that at the Vicarage section.

The stoney drift extends to a depth of about 5'.0" becoming increasingly sandy downwards; at this depth it is possible to recognise a discrete bed of brown sand some 15" thick, from which rubbly Upper Greensand is absent. Below the sand a stoney drift extends to the base of the excavation at a depth of 6'.6"

3. Life of Man Plantation (ST 856428) at a height of rather more than 575' O.D., seen in a trench cut for the West Wilts Water Board: four feet of stoney drift (cf. Vicarage site) resting on irregularly interbedded green and brown sands.

4. Aucombe (ST 832429) at a height of about 700' in a largely overgrown wartime excavation: three feet of bright reddish-brown stoney drift seen below a few inches of disturbed soil.

5. Gare Hill (ST 770385), at a height of rather more than 800' : a rubble with fragments of deeply weathered flint seen to about 2'.6" among the roots of a fallen tree.

The significance of the periglacial drifts

Undoubtedly the main interest of these drifts in the Vale of Warminster is their bearing on the history of the Pleistocene period in the area, a study which is beyond the scope of this thesis. At the same time the record of flint pebbles of lower Tertiary aspect in the head (Manley ? 1927) and of possibly Lower Tertiary debris at Park Hill suggests that Lower Tertiary formations may have been more extensively preserved on the Upper Greensand here in the early part of the Pleistocene period. Moreover the distinctive reddish colour of the clay in the head is not easily explained and might reflect derivation from a pre-existing drift in which a braunlehm or rotlehm fabric had developed, possibly a residual deposit of Tertiary date, although an early Pleistocene interglacial date cannot be excluded. The deeply weathered flint in the head tends to confirm a residual origin and the colour of the clay is closely matched in Clay-with-flints on the summit surface of Wooldridge and Linton, and on later Tertiary and early Pleistocene surfaces. It is not seen to be associated with weathering on the Upper Greensand at the present time, nor is it observed in drifts on the Upper Greensand in the Vale of Wardour.

Conclusion

Although the evidence examined here is in no sense definitive it does suggest that in the Vale of

Warminster relics of the early and mid Tertiary surfaces may have been preserved either on the Upper Greensand or on the Chalk after they had been more extensively consumed in the Vale of Wardour.

DRIFT EXAMINED ON THE PORTLAND OUTCROP IN THE VALE OF WARDOUR

In the Vale of Wardour:

> "No point on the Portlandian outcrop actually attains the presumed full altitude of the summit plain although in rising to 700' (2 miles West of Tisbury) it is perhaps only 70' short of it."
>
> Wooldridge and Linton, 1955, p.41.

At the point to which Wooldridge and Linton refer, near Pythouse (ST 909292), the soil incorporates a quantity of well rolled quartz pebbles up to 2·5" diam. (Plate 17) associated with abundent chert debris. Quartz has not previously been described at this site but is recorded, in association with chert debris, by Mottram (1961) on the Portland outcrop at a lower level (about 530' O.D.) a short distance to the East (near ST 924293). In this case

Mottram suggests that:

> "The post-Jurassic material on the Portland Beds is the ultimate remains of the combined residue of the Lower Greensand and basal Gault."
>
> Mottram, 1961.

The Lower Greensand and Gault have been shown (Reid, 1903) to overstep independently onto the Jurassic rocks in the Vale of Wardour. A thin seam at the base of both these formations is known to contain small pebbles of quartz but at the sites described here the quartz could well be derived from either or both sources. This evidence suggests that the point to which Wooldridge and Linton refer, on the Portlandian outcrop near Pythouse, may in effect be an exhumed portion of an intra-Cretaceous surface. In any case it will subsequently be suggested that the mid-Tertiary surface passed here at a level definitely more than 70' above the present summit.

DRIFTS EXAMINED ON THE CHALK ABOUT THE VALE OF WARDOUR

The Deep Residual Drifts

Historical background to a study of the Clay-with-flints

On the Chalk attention was first directed during the present investigations towards "the drifts which cap the Great Ridge (ST 930363) continuously for many miles" (Wooldridge and Linton, 1955, p.37). At the eastern end of the ridge Clay-with-flints has been mapped by the Geological Survey (sheet 298) and the extent of this drift further West has been indicated by Mottram (1961). The term Clay-with-flints has been applied indiscriminately to deposits in which uniformity of composition is evidently lacking and for which uniformity of origin has never been demonstrated.

Composition

An examination of the haphazard literature dealing with the Clay-with-flints on the Wessex Chalk (fig.28) suggests certain consistent diagnostic features: the nature of the clay corresponds with Whitaker's original description:

> "Stiff unctuous brown or reddish brown . . . usually without any visible admixture of sand." Whitaker, 1861.

In this essentially unstratified material are unworn, sharply angular flint fragments and unbroken flint nodules. The junction of the clay with the underlying chalk is uneven and the drift is often isolated in irregular hollows and deep cylindrical pipes. Flints are most abundent near the base of the deposit and the proportion of unbroken nodules is greatest there. A very flinty marginal drift is encountered in which the flints are shattered and weathered. Dark brown or black manganiferous stains in the clay and marking the fragments and nodules of flint, are common and may give the impression of a discrete black seam at the surface of the chalk where the physico-chemical conditions particularly favour the segregation of manganese (Brajnikov, 1937).

Isolated grains of sand occur throughout the clay. The sand is largely of quartz, minute particles of flint, secondary silica and ferrimanganiferous concretions.

Flint pebbles, fragments of silicified Chalk fossils and tabular pieces of secondary silica may be scattered throughout the deposit.

<u>Origin of Component Material</u>

In Wiltshire the composition of the drift has rarely been described and the significance of its distribution is uncertain. In spite of this unsatisfactory situation several views on the origin of the Clay-with-flints have been proposed.

The problem is to determine the nature and source of the material and to define the period at which its present condition and distribution became established. Most geologists in the nineteenth century believed that the Clay-with-flints represents the insoluble residue of the Chalk-with flints. Avery et al. (1959) have shown that in some profiles particle size distribution and the mineral composition of the Clay-with-flints are consistent with this view, but that oxidative weathering, which must be presumed to have accompanied the formation of the drift in such a case, would preclude the survival of the mineral collophane which in fact is relatively abundent in samples collected on the Chilterns. Whitaker (1864) accepted the view, advanced by Trimmer (1851) and perhaps originated by Lyell, that inclusions of Eocene material might be encountered in the Clay-with-flints. Codrington (1866) argued that the drift represents clay which has migrated downward from a more or less permeable overlying formation into the interstices created by the dissolution of the chalk.

Slickensiding and flowstructures in the clay near the surface of the chalk tend to substantiate a concept of irregular subsidence in a mobile mass "but it is questionable whether this would be sufficiently selective to allow clay accumulation from overlying deposits, generally of a sandy clay character" (e.g. the Reading Beds) (Loveday, 1962), and the possibility of clay movement in colloidal suspension from such a formation has been envisaged.

Heavy mineral analysis (Avery et al., 1959) of Clay-with-flints at several sites on the Chilterns yielded a suite typical of the neighbouring Reading Beds at Cowcroft (SP 983017) and Lane End (ST 808918), and an analysis of clay minerals near the junction with the chalk revealed an assemblage dominated by montmorillonite. The clay minerals could be derived from the Reading Beds which at Lane End and Harefield (TQ 053906) yield an analagous assemblage, but in an unweathered condition the Reading Beds are virtually impermeable and it is known that no Clay-with-flints is forming beneath them. Jukes-Brown (1906) recognised moreover that a theory of immediate derivation from the Lower Eocene failed to account either for the abundance of shattered flints and minute flint flakes or for the complete disappearance of the glauconitic marine sands at the base of the Reading Beds. Fragments of unweathered Reading Beds incorporated in a permeable drift resting on the Chalk might constitute the source of the montmorillonite; or "the cation gradients associated with the chalk junction may lead to the reconstitution of clay minerals especially montmorillonite from weathering products dissolved or suspended in the drainage water" (Avery et al., 1959) and derived from an overlying drift so far unidentified.

Bearing in mind the conspicuously shattered nature of much of the flint, the highly confused structures and indistinct stratification seen at many of the classic exposures, earlier writers proposed a periglacial (Reid, 1903; Jukes-Brown, 1906; Dines et al., 1933) or even a glacial (Sherlock and Noble, 1912) origin for the present form of the Clay-with-flints. On the other hand recent studies of soil fabric in the Clay-with-flints (Dalrymple, 1958; Avery et al., 1959) indicate weathering in tropical or sub-tropical conditions. This result accords with the view proposed by Wooldridge and Linton that:

> "We should probably regard (these drifts) as relics of the regolith or mantle of deeply weathered rock waste which would naturally be associated with the Mio-Pliocene peneplain."
> Wooldridge and Linton, 1955, p.57.

It is recognised however that these features could be inherited from the Reading Beds.

The accepted interpretation of the Great Ridge

Attention was initially confined during the present study, to the western part of the ridge which is generally thought to have been unsubmerged during the Pliocene transgression. Wooldridge and Linton argue that:

> "The crest regions have been exposed continuously to the atmosphere since the early Tertiary emergence of the region. It is here that we should expect . . . the greatest development of true residual Clay-with-flints."
> Wooldridge and Linton, 1955, p.55.

The maximum extent of the marine transgression here has been indicated by Wooldridge and Linton (1955, figs. 10 and 17) and their shoreline is accepted, without significant modification at this point, by Pinchemel (1954) and Small (1964). Small equates the shoreline of Wooldridge and Linton with a 690' early Pleistocene (Calabrian) level.

Account of the sites investigated

1. Rowdean Hill

On Rowdean Hill (ST 933368) a pit (fig.35/a) excavated by the West Wilts Waterboard, at a height of about 730' O.D., during the preparation of a reservoir site, furnished the most satisfactory results obtained in the survey of drifts on the Great Ridge. This survey suggests that the pit in fact provides a type section for this tract of ground.

The pit showed 7'- 9' of very flinty clay (Table 15) overlying an uneven surface of the Chalk. The flints are largely unrolled (Plate 18) but broken and more or less patinated, usually a shade of grey. Flints, with matt white patination suggesting exposure at the surface at some time, are scattered irregularly throughout the mass, right down to the surface of the chalk, although they are seen to be more common near the upper limit of the flinty clay. The flint occurs in a scanty matrix of reddish-brown clay, packed with small flakes of flint and minute flint chips. The ratio of flint to clay, estimated in terms of volume, closely approaches the figure of 6 : 1 calculated by Jukes-Brown (1906) to be an average figure for the unadulterated residuum of the Chalk.

Nothing but flint was retained by a ½" mesh. This material included a quantity of subangular fragments, almost certainly battered on the angles, patinated a shade of yellow or brown, and in all cases more deeply weathered than the associated angular flint. The form of the sub-angular material is indistinguishable from water-worn material in Tertiary and Pleistocene gravels (Plates 7 & 41).

Flint comprises more than 95% of the fine gravel fraction ($\frac{5}{32}$"- $\frac{1}{2}$"), a few pieces of tabular secondary silica, and irregular ferruginous material comprise the balance. A fragment of a small, well rounded quartz pebble was collected from the exposure but no quartz occurred in the sample (of about 4,000 fragments). The flint in this fraction occurs in various states of abrasion and patination, from fresh grey and sharply angular to deep brownish red and considerably abraded. However the bulk of the flint is patinated creamy white and the angles have been very slightly blunted. (These fragments match material distinguished in the gravels at Black Down (Table 10) and Cley Hill (Table 8) which have been attributed in Part One of this thesis to slight movement in the drift, either in the course of subsidence or as a result of periglacial disturbance.) In the Rowdean Hill sample the large volume of indeterminate material has precluded an accurate count of flint types in this fraction.

In the finer fractions ferruginous material becomes increasingly common and predominates in the finest fraction examined ($^1/_{32}$"- $^1/_{16}$"). Ferruginous concretions occur, either fragmentary or developed on sand grains and on particles of flint and secondary silica. Sharp and slightly blunted flakes of flint remain common but creamy white patination is very largely, if not exclusively, predominant. Secondary silica is also common but is probably often indistinguishable, under the hand lens, from weathered flint. The secondary silica no doubt largely represents particles derived from the Chalk but could include some authigenetic material (Avery et al., 1959), Quartz in well rolled grains is increasingly common in the finest fraction examined ($^1/_{32}$"- $^1/_{16}$") but obviously forms much less than 1% of the sample.

Only at the surface of contact between the clay and the underlying chalk was manganese staining significantly developed and here large unbroken flints were also observed; and a thin (½"- 1") and discontinuous seam of bright reddish clay contrasted with the uniform yellowish brown aspect of the clay matrix elsewhere. The flinty clay was overlain in the Rowdean Hill pit by a well defined but discontinuous gravelly seam. An examination of a sample from this seam shows that it consists exclusively of material derived from the underlying flinty clay, and suggests that it may correspond with the 'erosion pavement' described by Avery et al. (1959) on Clay-with-flints in the Chilterns (see Appendix I). This 'pavement' is overlain in the Rowdean Hill pit by 7"- 9" of dull yellowish brown more or less stoneless loam, possibly analagous to the loessic deposits also described by Avery et al. (1959) on Clay-with-flints in the Chilterns.

2. The Value of surface indications

The excavation of pits to extend the investigations on the Great Ridge was discouraged by the landowner and only four small pits were dug. Elsewhere at the western end of the Great Ridge the nature of the drift was largely assessed from surface indications. This limitation was somewhat offset by the arrangement in the drift itself; particularly the recognition in the excavation on Rowdean Hill of a distinctive seam in which material from the underlying flinty clay had become concentrated. It was accepted that the composition of this erosion pavement provides an adequate guide to the nature of the underlying drift. The widespread development of the pavement is evident on the Great Ridge, where traces are commonly exposed in drainage ditches and by fallen trees.

3. Supplementary soil pits

Small pits were dug where surface indications at present are poor. The samples obtained in these pits confirm, at scattered points on the upland, the widespread impression gained during a careful examination of the area that the drift can, at no point on the summit of the Great Ridge, be distinguished from the material recovered in the Rowdean Hill pit and already described.

The four pits dug on the Great Ridge at Snail Creep Hanging (ST 947358)(710' O.D.), Point Pond Wood (ST 932359)(710' O.D.), Cratt Hill (ST 908350) (730' O.D.) and on another part of Rowdean Hill (ST 931367)(730' O.D.), all demonstrated the presence of a more or less well marked 'erosion pavement'. At Snail Creep Hanging a pebble of quartz (⅜" diam.) was recovered; at Rowdean Hill one small piece of quartz was retained by a 1/16" mesh, from a sample of about 2 lbs. weight. At all the sites a few pieces of flint possibly abraded, deeply weathered and with a yellow, brown or reddish patina are detected. Small (less than ½" diam.) apparently abraded ferruginous concretions may also occur in small numbers. The very great bulk of the material retained in a 1/16" mesh is sharply angular flint, patinated a shade of grey, or occasionally white; there is also a good deal of indefinite, probably concretionary ferruginous material. At all the sites the quantity of sand even in the 1/32"- 1/16" fraction is barely significant and is invariably less than 1%. The individual grains are particularly distinguished by their well rounded and often polished character and it may be suggested that, at least in the upper part of the drift, some are of aeolian origin and may have been introduced during the periglacial interludes in the Pleistocene. It should be pointed out however that scattered grains of this type are encountered in the underlying flinty clay.

Sections in Clay-with-flints of the very flinty type encountered on the Great Ridge seem rarely to have been described, probably because the material is of negligable economic value either as clay or gravel, and ready made sections are correspondingly infrequent.

The profiles observed on the Great Ridge display some features associated by Avery et al. (1959) with their Winchester series. A relatively shallow loamy horizon occurs near the surface, not much contaminated by extraneous material and defined by a sharp lower boundary, marked in some profiles by a distinctive 'erosion pavement'. The underlying clay on the Great Ridge is however very much more flinty than in profiles described on the Chilterns.

The significance of the drift on the Great Ridge

Poor characterisation

This account of the superficial geology on one of the most clearly defined remnants of the summit peneplain of Wooldridge and Linton emphasises the very indefinite characterisation of the drift here. It would be correspondingly unwise to regard the deposit as in any sense a useful stratigraphic unit for correlative purposes. At the same time certain significant conclusions are indicated.

Distribution

The distribution of the drift, particularly its absense on level interfluvial tracts below the summit of the upland, clearly implies that it is associated with the surface of the summit itself.

Depth

On the basis of the results obtained by Jukes-Brown (1906) the volume of flint in the drift represents the dissolution of about 100' of Micraster chalk. Wooldridge and Linton (1955, fig. 5) show the sub-Eocene surface here at a level of about 800'. It has already been shown in Part One of this thesis that this level may if anything be rather too high (fig. 17); the volume of flint is therefore consistent with the view that this tract has "been exposed continually to the atmosphere since the early Tertiary emergence of the region."

Absence of Eocene associations

On the other hand the composition of the drift entirely fails to support the view, proposed by Pinchemel (1954) and accepted by Small (1964) that the drift here rests on a sub-Eocene surface. Pinchemel claims to have recognised on the Great Ridge "des traces d'Eocene" (Pinchemel, 1954, p.110); this view presumably reflects a scheme which refers the formation of the Clay-with-flints largely to the Sparnacian period.

> "Durant ces multiples vicissitudes de la paléogéographie éocène, nous avons montré L'existence de mouvements tectoniques provoquant le déblaiement de la couverture sableuse et

> l'affleurement puis l'érosion de la craie, dans le temps où se déposaient de sediments lagunaires, fluviatiles, puis marins (Yprésien). C'est de cette époque que date sans doute la formation sous un climat de type tropical d'une argile à silex sur les régions anticlinales, argile qui par solifluction, par coulées, a glissé en entraînant dans son sein les silex sans les émousser. Les silex de l'argile à silex et l'argile à silex elle-même d'ailleurs, ont pu alors se mélanger à L'argile plastique proprement dite qui se déposait dans les lagunes sparnaciennes."
>
> Pinchemel, 1954, p.111.

Diagnostic Sparnacian material is absent in the drift on the Great Ridge. The very small amounts of quartz and occasional battered and deeply weathered flints which are encountered can be regarded as the debris of a gravel associated with the planation of the surface and are consistent with the process of pediplanation which is believed to have effected this planation. (This view is elaborated in Part Four of this thesis.) In any case the preservation at Clay Pit Hill of Eocene material of marine origin and undoubtedly post-Sparnacian age, and the preservation of other obviously post-Sparnacian material further West on the Wiltshire Chalk, suggests that this area suffered marine and subaerial erosion during the Palaeogene period, inconsistent with the preservation of a shallow and poorly consolidated residual drift of early Palaeogene date.

Conclusion

The drift appears to be a "mantle of deeply weathered rock waste". There is moreover no trace in the drift of Lower Cretaceous or Jurassic material which might have been derived during the denudation of the Wardour anticline. There is therefore no reason to reject the interpretation of Wooldridge and Linton that the surface here is a subaerial planation surface of mid-Tertiary age. In any case the preservation of gravels of suspected Palaeogene date on residual summits above the surface, particularly at Cold Kitchen Hill, militates strongly against an Eocene date. However, the study of the superficial geology on the remnants of the mid-Tertiary peneplain indicated by Wooldridge and Linton elsewhere about the Vale of Wardour suggests that the development of a residual Clay-with-flints is not uniformly characteristic of the ground examined.

Sites correlative with the Great Ridge group

1. Rook Hill and Parsonage Down

Certain features of the drift studied on the Great Ridge are encountered on Rook Hill (ST 854380) and on the neighbouring Parsonage Down (ST 895387). Here arable land gives excellent surface indications of the nature of the drift, which is a reddish brown flinty clay. Battered flints up to 4" long with yellow or brown patina matching examples from the Great Ridge may be picked up on the surface (Plate 19). No significant concentration of material other than flint is observed. (In fact one pebble of quartz, one flint pebble of Lower Tertiary aspect and one piece of Upper Greensand chert have been recovered.) On the summits of this upland the underlying chalk is not turned up by the plough, even where inequalities might be expected to bring it to the surface. This fact suggests that several feet of drift may be present here.

The nature of the drift resting on these summits provides substantial confirmation of the view indicated by Wooldridge and Linton (1955, fig. 10) that the ground in question is part of the mid-Tertiary surface. It may be objected to this correlation that the summit of Rook Hill (784') rises substantially above the level of the Great Ridge (731') and is separated from it by a well defined break of slope (fig. 17). It will subsequently be suggested in Part Four of this thesis that this discrepency reflects movement associated with the Mere fault during the late Tertiary or Pleistocene period.

2. Cranborne Chace

The deep very flinty drifts described on the northern side of the Vale of Wardour, and thought to be resting on the mid-Tertiary surface there, are closely matched on summits in the area North of Cranborne Chace (ST 940180).

> "On the crest of the Downs South East of Shaftesbury the Clay-with-flints is represented mainly by loose gravel composed of unworn flints in a scanty ground mass of sandy loam and flint grit. The gravel is dug in shallow pits near the line of the Ridgeway or Ox Drove on Charlton Down (ST 905203), at Win Green (ST 925206) and on Winklebury Hill (ST 952215)"
> White, 1923.

White considered that the drift here is the lateral equivalent of a more argillaceous Clay-with-flints, elsewhere on the dip slope of the Chalk in Dorset.

> "On the Dorset Downs, as elsewhere, the Clay-with-flints passes laterally into loose gravel . . ." White, 1923.

White recognises that the flint gravel is of strictly residual origin. He compares it with the hypothetical residual gravel envisaged by Jukes-Brown on the Chalk:

> "A bed of flints with about just enough

> clay to fill up the intersteces
> between the nodules."
>
> Jukes-Brown, 1906.

There are at present no satisfactory sections in this gravel but there are surface indications that it has been dug to a depth of about 6'.0", and an examination of the ploughed surface of the drift confirms White's account of its composition, particularly the absence of Lower Cretaceous or Jurassic material which might have been derived during the denudation of the anticline. The drifts here are provisionally correlated with those on the Great Ridge - Rook Hill Upland and it is suggested that they rest on the summit surface. Wooldridge and Linton (1955, p.42) have defined these summits North of Cranborne Chace as "the culminating points of subdued but definite rises above the plateau." Although this view may be correct, its unqualified application is impaired by evidence discussed elsewhere in this thesis (Part Four), that the levels to which the Chalk summits rise about the Vale of Wardour reflect, to some extent, a deformation of the mid-Tertiary surface, associated with movement on the anticlinal Wardour axis during the late

Tertiary or Pleistocene period. It may also be noticed that there is no suggestion on these summits of Palaeogene material, which has been tentatively identified on Cold Kitchen Hill, where a residual relation to the mid-Tertiary surface is more clearly demonstrated.

The Shallow Residual Drifts and Associated Gravels

Introduction

On the Chalk summits intervening between the Great Ridge - Rook Hill Upland and the area North of Cranborne Chace the drifts are consistently shallow and are often entirely absent. Clay-with-flints of residual aspect is superceded at several sites in the South of the Vale of Wardour and at one site, at least, in the North of the Vale by the relics of a remarkably interesting gravel incorporating Jurassic and lower Cretaceous material.

Account of sites investigated in the North of the Vale

On the North side of the Vale of Wardour the outcrop of the Chalk South of the Great Ridge - Rook Hill Upland has been examined during the present investigation in the areas where the preservation of the mid-Tertiary peneplain is indicated by Wooldridge and Linton (1955, fig. 10).

1. Long Knoll and Little Knoll

> "At the western end of the Great Ridge the plain attains a height of 784' on White Sheet Hill where it is interrupted by the main Chalk escarpment. Rising from the Malmstone dip slope beyond are the Lower Chalk outliers of Little Knoll (ST 807378) and Long Knoll (ST 791377). The former and the greater part of the latter rise just over 800' and appear to be detached remnants of the summit plain but at the western end of Long Knoll the ground rises in 200 yards smoothly but quickly to 945'. The final eminence can hardly be part of the plain being marked off from it by slopes of 10°- 20°. If the plain be of subaerial origin this rise is best explained as a residual hill some 120' high."
>
> Wooldridge and Linton, 1955, p.42.

At both Long Knoll and Little Knoll the summit areas are of negligable extent and no significant trace of drift resting on the Chalk was recognised during the present study, either on the 'detached remnants of the summit plain' or on the 'residual hill' which rises above them. Samples obtained in three small pits on Long Knoll and in one pit on Little Knoll show that the chalk is everywhere within a few inches of the surface and that evidence of drift is confined to a few grains of well rounded quartz.

The occurrence of well rounded quartz grains in small quantities in most rendzinas examined during the present investigation suggests that the derivation of quartz at individual sites cannot usefully be determined. It certainly seems unwise to regard the quartz as a vestigial superficial deposit of real stratigraphic value (cf. Stevens, 1959). The grains are in some cases large (more than 1/16" diam.) but this by no means precludes aeolian origin especially during periods of periglacial climate (cf. Sparks and Groves, 1952).

2. The Mere Downs

On Whitesheet Downs (ST 807349) and on the summit of the Downs as far East as the road between Mere and Kingston Deverill (B 3095), at levels between 750' and 800' O.D., the Chalk was exposed during the summer of 1963 in a trench excavated for the West Wilts Water Board. The Chalk was also exposed during the same period in trenches parallel to the B 3095 between Mere Down and Middle Hill (ST 840357)(700' O.D.). At no point in these trenches was there any indication of a residual Clay-with-flints. On the summit of the Downs East of the B 3095 and as far East as Chaddenwick Furze (ST 849343), at levels between 700' and 730' O.D., there is no surface indication of residual Clay-with-flints; the chalk is everywhere turned up by the plough. Nor is there any sign of drift where the Chalk is exposed in a shallow disused quarry, at a height of 710' O.D., lying North of the main road (A 303) on the level summit to the East of Chaddenwick Furze.

Wooldridge and Linton believe that:

> "In the western part of the Vale Cleeve Hill (700')(ST 867326) and Haddon Hill (737') developed on Malmstone near West Knoyle continue the summit plain at the 700' level from the Chalk right across the major fault which forms the northern boundary of the Vale."
> Wooldridge and Linton, 1955, p.41.

Mottram (1961) has shown that the suggested extension of the fault into this area is problematic (fig. 29). On the ground the Chalk in fact rises here rather shapply to 748' and forms a low but definite scarp above the outcrop of the Upper Greensand at Cleeve Hill (fig. 49). There is no trace of drift on the Chalk at this point.

3. Willoughby Hedge: Jurassic and Lower Cretaceous debris

Further North near Willoughby Hedge (ST 872337) there are clear surface indications of an interesting drift at a height of about 710' O.D. The exposed roots of an ancient oak (Plate 20) suggest that about 2'.6" of soil may have been removed from the surface at this point during the historic period. Nevertheless chalk is not turned up by the plough and it seems likely that several feet of drift may be preserved here. The reddish clayey soil bears a superficial resemblance to the residual Clay-with-flints on the Great Ridge - Rook Hill Upland. It incorporates a large volume of broken flint; here and there the ground is masked by several inches of fine sandy loam and there are traces of a gravelly erosion pavement. The drift is distinguished however by the inclusion of abundent Upper Greensand chert and sandstone, pieces of tough ironstone possibly derived from the Lower Greensand in the Vale of Wardour, a few pebbles of quartz possibly also from the Lower Greensand or from the base of the

Gault and a substantial quantity of shelly Purbeck material (Plate 21) together with pieces of unidentified chert and sandstones. Unfortunately the peculiar character of the drift here was only recognised in December, 1964 and it has not been possible to dig an exploratory pit at this site. Samples of the material included in the drift have been picked up on the surface and the nature of the drift has been assessed from surface indications. No attempt has been made to produce a quantitative analysis of the composition of the drift. The significance of this gravel is treated in the account of similar gravels identified on the South side of the Vale of Wardour.

4. The Pertwood Downs

The limited extent of this relatively deep drift near Willoughby Hedge is indicated by a section observed in a roadside exposure near the cross roads where A 303 crosses A 350 (ST 884340) (650' O.D.). A reddish flinty clay rests here on an uneven surface of the Chalk, to a depth of about 15" in the deeper inequalities (Plate 22). There are good surface indications of a drift of this type on the high ground about Pertwood

(ST 889358) and to the North East and South West of this hamlet at levels between 675' and 695' O.D. Here chalk is commonly turned up by the plough but the soil is of a distinctive reddish colour not generally associated with an uncomplicated rendzina.

Account of sites examined in the South of the Vale

On the Chalk escarpment on the South side of the Vale of Wardour a deliberate search was made for the:

> "Relics of old gravel with pieces of Upper Greensand chert along the top of the Downs" Andrews, 1892.

recorded without further descriptive comment by Andrews and believed by him to be correlative with the drifts on the Great Ridge - Grovely Upland, and to represent evidence of a marine planation of the Chalk. Wooldridge and Linton (1955) reject this interpretation and refer the gravel to the sub-aerial mid-Tertiary surface.

During the present investigation relics of the chert gravel were identified on four separate tracts of limited extent, and prove to include material more or less correlative with the relics of gravel at Willoughby Hedge.

1. Swallowcliffe Down

A well defined patch (ST 968255), about 200 yds. (East to West) by 100 yds. (North to

South), near the crest of the escarpment, upon which subangular blocks of Upper Greensand sandstone and chert (up to 10" long) are rather common and are mixed with rocks of Jurassic age, including a block of dark grey Purbeck material (Plate 23) packed with Cyprid fossils, several pieces of shelly Purbeck material (Plate 23) and a piece of (?) Purbeck fossil wood (Plate 24). Subangular blocks of several less well characterised rocks are fairly common (Plate 26) but are much less abundent than the Upper Greensand material. One rounded fragment of a chalk breccia with a crystalline calcite cement was collected (Plate 25) and three small flint pebbles of Lower Tertiary aspect. This site lies at a level of about 727' and substantially below the highest part of the escarpment further West at White Sheet Hill where it rises to 775' O.D.

2. The summit above Berwick Coombe

On the isolated summit (ST 938231) South of the western end of White Sheet Hill blocks of Upper Greensand sandstone (Plate 27) and chert are observed and several large blocks of chalk breccia (about 10" long) were collected (Plate 28). This summit reaches a level of rather more than 700'; the relics of the gravel and chalk breccia are spread from the summit for some distance down the eastern flank of the hill.

3. The Zig Zag

On a small bevel near the Zig Zag (ST 895209) on the face of the escarpment below the summit of Breeze Hill blocks of Upper Greensand chert and sandstone are observed. The bevel lies at a height of about 700'.

4. Near Chiselbury Camp

On ground, to the West of, and slightly below Chiselbury Camp (SU 016277), few pieces of Upper Greensand sandstone are seen, one piece of chert (not Upper Greensand), and a large mass (3" diam.) of calcite crystals possibly derived from some Jurassic formation have been collected. This assortment of material is scattered on the surface of the Chalk at a height of about 635' O.D. but even fragments of Upper Greensand are uncommon.

5. White Sheet Hill and Chiselbury Camp

Residual Clay-with-flints is absent on the remnant of the Mio-Pliocene surface indicated by Wooldridge and Linton (1955, fig. 10) between

White Sheet Hill (ST 945242) and Sutton Down (ST 990260); and traces only are turned up here and there by the plough, about Chiselbury Camp (SU 017279)(659' O.D.)

THE HIGH LEVEL GRAVELS IN THE VALE OF WARDOUR : THEIR CHARACTER AND SIGNIFICANCE : AN ORIGINAL STUDY

The Possibility of Human Interference

The gravels described on the White Sheet Hill - Chiselbury Upland and at Willoughby Hedge are in a remanié condition and it might be argued that the material has been introduced to the position in which it is now found for some purpose during the historic or prehistoric period. This possibility has not been ignored but a study of introduced material encountered elsewhere during the present investigations suggests that it is entirely unreasonable.

The historic period

Isolated pieces of Upper Greensand chert and sandstone are not unknown elsewhere on the Chalk in Wiltshire but in the present study have been ignored where-ever they occur in association with and in the same relative abundence as pieces of brick, tile, concrete or road metal. It may be assumed that these incongruous elements, and with them the isolated fragments of Upper Greensand, have been introduced largely either in farmyard manure or in the treads of heavy duty tyres fitted to agricultural or military vehicles. In the present case the volume and localisation of the material and its uncontaminated condition seem to preclude introduction by these means. At Willoughby Hedge, where Jurassic and Lower Cretaceous material seems to be incorporated in an erosion pavement of indefinite but possibly prehistoric origin (see Appendix I), introduction during the historic period is inherently unlikely.

The prehistoric period

Numerous blocks of Upper Greensand and a few pieces of saccharoidal sarsen have been observed during the present study, on the surface of the Chalk at Whitecliff Down (ST 832387) at a level of about 850' O.D. (Plate 29). This material is scattered over ground which is thought to be the site of a Romano-British settlement. It seems reasonable to assume that it was introduced during the prehistoric period; and it is not readily accommodated in any reasonable scheme of drainage evolution.

(Notes on some other examples of material introduced during the prehistoric period are presented in Appendix II.)

Although round barrows are not far distant from the traces of gravel at Swallowcliffe Down and above Berwick Coombe, there is no evidence of prehistoric activity near the traces at the Zig Zag nor at the site in the North of the Vale near Willoughby Hedge. There is in fact no reason to believe that the material was introduced for some purpose during the prehistoric period. The gravel has been discussed by Wooldridge and Linton (1955, p.37) and there is no suggestion in their account that it is of doubtful authenticity. The relation of the chert gravels about the Vale of Wardour to the scheme of drainage evolution, subsequently described in this thesis, substantiates the view that the gravels have reached their present positions during the course of the denudation of the vale. (see Part Four of this thesis and fig. 45.)

The significance of the Chalk breccia

The recognition of a distinctive chalk breccia (Plates 25 and 28) associated with the gravel itself also tends to vitiate any theory of human interference. Prestwich (1891) has described a chalk breccia in the valley of the Darent which closely matches that recovered during the present study in the Vale of Wardour. Prestwich has considered the possible origin and significance of this breccia in the Darent valley:

> "Another minor factor pointing to an early stage in the erosion of the valley is the indication which exists on the bare sides of the hill West of Shoreham, of an old line of water level at a height of 400' O.D. or about 200' above the present stream. At the point * (fig. 30) is a band of a compact breccia about 10'- 12' broad extending horizontally for some distance along the brow of the hill. It consists of angular fragments of chalk consolidated by a calcareous infiltration and rendered so hard that it requires a smart blow with a hammer to break it. It appears to have been originally a talus of chalk fragments such as would accumulate at the foot of a chalk slope or cliff and to have been concreted by a calcareous cement into this brecciated rock in the manner of an ordinary travertine. But at this spot there is no impermeable stratum to give rise to a spring. The Chalk which rises to a height of 120' above the point * is perfectly homogeneous and allows the surface water to pass through it and descend to the under-

> ground water level W L (fig. 30); a level governed by that of the adjacent stream; and I can only account for a spring in the high position of * by supposing that one may have broken out there at the time when the bed of the valley had not been excavated to below that point, when the line W_1L_1 would represent the then level of the underground water and consequently of the spring; for in that case the springs would be thrown out at the higher level W_1L_1 as they are now on the lower level W L independently of any imperveous stratum. This therefore may be taken as some evidence of the higher level occupied by the stream at that period." Prestwich, 1891.

In the Vale of Wardour the chalk breccia has nowhere been observed in situ and it remains correspondingly uncertain whether the blocks associated with the gravel have reached the positions in which they are found, with the Jurassic and Upper Greensand material, or whether they represent the disintegration in situ of local seams of breccia possibly associated with drainage lines which the gravels are thought to indicate. In either case the breccia "may be taken as some evidence of the higher level occupied by the stream."

The Origin of the Gravels

Relation to the mid-Tertiary surface

The remanié character of the material at all the sites examined in the Vale of Wardour, the consistent aspect of the components and the more or less accordant levels at which traces have been recognised suggest that the gravels are of uniform origin. Wooldridge and Linton (1955) have accepted the view originally proposed by Andrews (1892) that the gravel is correlative with the residual Clay-with-flints elsewhere about the Vale of Wardour and that these problematic drifts all rest on the same planation surface, the marine surface of Andrews, the Mio-Pliocene peneplain of Wooldridge and Linton. In this case it is difficult to see how the gravels reached their present positions on the Chiselbury - White Sheet Hill Upland or at Willoughby Hedge. It might be argued that the Chalk escarpments would lack topographic expression on the Mio-Pliocene peneplain and that streams meandering across this surface might be responsible for the deposition of the gravel. In an account of the chert gravels on the North Downs, which present the same problems, Bury has dismissed this speculation on the grounds that:

"Rivers meandering in such wide curves

> could scarcely have the necessary transporting powers." Bury, 1910.

This objection is no less final in the Vale of Wardour where some of the chert blocks weigh more than 7 lbs; and where, if Small's reconstruction (1961) of the geological outcrop on the mid-Tertiary surface is accepted, the Upper Greensand blocks on Swallowcliffe Down are more than two miles from the former Upper Greensand outcrop (fig. 31). The situation of the gravel at the Zig Zag in fact demonstrates that the correlation proposed by Andrew's is most unlikely. The Upper Greensand blocks rest here on a bevel cut in the face of the escarpment at a height of about 700' O.D., some 150' below the summit (which rises here to 859'), and about 100' below the inferred level of the Mio-Pliocene peneplain of Wooldridge and Linton, from which it is separated by the upper part of the escarpment (fig. 47). It can also be seen that on the White Sheet Hill - Chiselbury Upland the gravel lies slightly but definitely below the summit level (fig. 33).

The denudation of the Wardour anticline

The possibility remains that the Jurassic and Lower Cretaceous material was in fact derived from the denuded anticline during a first cycle of erosion and survives in a remanié condition, having reached the position in which it is now found, as a result of the dissolution of the underlying Chalk. Bury has discussed this possibility in connection with chert gravels on the North Downs:

> "In the maturity of the first cycle there might be much transference of this material across the Chalk by consequent rivers more numerous than those surviving at the present day, but a prolonged period of old age followed during which the consequent streams were reduced in number and the hills were gradually degraded to mere elongated mounds. Having regard to our experience elsewhere as to the disappearance of drift materials it seems to me impossible that any appreciable remnants of the earlier river gravels could have survived such extensive denudation as this."
>
> Bury, 1910.

Bury's slightly subjective view is substantiated in the Vale of Wardour, where a chalk breccia seems to be associated with the gravel and tends to preclude any considerable dissolution of the Chalk itself, suggesting that the gravel is not far removed from the level at which it was deposited.

A theory of derivation during the mid-Tertiary cycle implies the preservation of Lower Cretaceous and Jurassic material on the outcrop of the Chalk, on the mid-Tertiary surface, to the North of the Vale. In fact no trace of Jurassic or Lower Cretaceous material has been detected at appropriate sites on the Great Ridge - Grovely

Upland (see Part Three of this thesis).

The dissection of the mid-Tertiary surface

Wooldridge and Linton have inferred that the gravels on the South side of the Vale of Wardour have:

> "The characters of a land wash rather than those of a fluviatile gravel."
> Wooldridge and Linton, 1955, p.37.

Bearing in mind the sub-angular nature of the material in question (Plate 26) this view may well be preferred, but the fact remains that at the stage in the denudation of the Vale to which the gravels are referred, there is evidence of transverse gradients which are not consistent with the view of Wooldridge and Linton that the drainage of the Vale "is essentially longitudinal and has evolved by adjustments through two cycles of erosion" (p.68). This discrepency is very clearly expressed in a comparison between the original form of the Tertiary flexures in southern Wiltshire (Wooldridge and Linton, 1955, fig. 5) and their present state of dissection (fig. 34). It can be seen that a longitudinal consequent flowing in the initial Great Ridge Grovely syncline is ideally situated to perform the denudation of the Wardour anticline. White (1921) has described a similar arrangement in the Isle of Wight:

"White has not unnaturally assumed that

> the major share of the demolition of the original Chalk arch would be effected by the short streams flowing down the steep northern limb of the fold and that the water parting would be pushed back from the initial anticlinal crest to the scarp limiting the vale in the South." Linton, 1932.

This view is accepted by Wooldridge and Linton in their account of the Vale of Wardour:

> "Originally we may imagine longitudinal consequents to have followed the synclinal axes of Salisbury Plain and the Great Ridge, but during the first cycle their short and steeply graded right bank tributaries unroofed the Chalk and Malmstone of the anticlines to lay bare the Gault below."
> Wooldridge and Linton, 1955, p.67.

There is no reason to reject this scheme even if a rather less dramatic upheaval of the Wardour anticline is predicated at the period in question, and the effective process on the summit surface is shown to have been pediplanation rather than peneplanation. It is correspondingly difficult to understand how the Upper Greensand and Jurassic debris can have become lodged on the "scarp limiting the vale in the South"; or to explain the evidence of transverse gradients on the southern limb of the anticline.

The Significant Composition of the Gravels

The inclusion of Purbeck material

The inclusion of Purbeck material in the gravel favours deposition during a late rather than an early stage in the denudation of the Vale. In fact the inclusion of Purbeck material appears at first sight altogether remarkable as the Purbeck outcrop now rises nowhere above the level of 520' at Lady Down; nor is there any Purbeck outcrop at all within four miles of the gravel at Willoughby Hedge. An examination of the periphery of the Purbeck outcrop elsewhere in southern England (fig. 19) shows, however, that extensive outliers may be preserved at a considerable distance from the main outcrop (e.g. at Swindon and about Aylesbury, Oxford and Leighton Buzzard.) In the Vale of Wardour the main Portland outcrop rises to 700' near Pythouse and it seems reasonable to believe that outliers both of the Portland and the Purbeck outcrop may formerly have been preserved at and even somewhat above this level near here and further to the West

The absence of abraded flint

Finally, had the gravels been formed during the initial denudation of the anticline it is reasonable to suppose that flints derived from the Upper Chalk might occur in the gravel in an abraded condition. In fact no such flints have been encountered and it must be concluded that the Jurassic and Lower Cretaceous material reached the position in which it is now found when the Upper Chalk had already been denuded on ground lying nearer the axis of the anticline. This conclusion implies effective transverse gradients at a relatively late stage in the denudation of the anticline and the passage of the Jurassic and Lower Cretaceous material, at this stage, across the outcrop of the Lower and Middle Chalk, in which flint is relatively uncommon, but barely onto the outcrop of the critical Upper Chalk.

THE INTERPRETATION OF THE SUMMITS : THE DOUBTFUL UNITY OF THE SUMMIT SURFACE

The evidence presented here is consistent with only one conclusion: that at some time during the period after the dissection of the mid-Tertiary surface had begun, material was being transported from the Jurassic outcrop presumably exposed near the axis of the anticline, across the Lower Cretaceous outcrop and onto the Chalk, apparantly converging in the South towards the synclinal tract now occupied by the River Ebble. The immediate destination of the gravel at Willoughby Hedge is less easily discerned. The gravel there clearly relates to a gradient with a northward component but no evidence of Jurassic or Lower Cretaceous material has been recognised in the drift a short distance to the North of Willoughby Hedge on the Great Ridge - Rook Hill Upland, a synclinal tract analagous in some respects to the valley of the Ebble. This problem is dealt with more fully in the subsequent account of drainage evolution on the Chalk in southern Wiltshire (Part Four).

The study of the drifts on the Summits about the Vale of Wardour suggests the possibility that the ground examined is not everywhere correlative with the mid-Tertiary surface of Wooldridge and Linton. Linton has outlined the features which characterise this surface in southern England:

> "Residual elevations that have local relief 100'- 150' . . . a revived and adjusted drainage of generally longitudinal and accordant character . . . deposits mapped as 'Clay with Flints' or 'Clay with Chert' that are certainly polygenetic but include materials most satisfactorily regarded as residues of the regolith developed

on a former land surface."
Linton, 1964.

On the White Sheet Hill - Chiselbury Upland and on the associated surface at the Zig Zag the recognition of these features is very doubtful. There is no suggestion of residual elevations here; the nature of the drainage is problematic and the traces of residual drifts are meagre and the most significant are not strictly regolithic. On the Chalk outcrop in the North of the Vale, on the Mere Downs, the nature of the relief and of the drainage pattern is also inconclusive and residual drifts are generally thin or entirely absent.

On the basis of the evidence presented here one hesitates to correlate either of these areas with summits where a deep flinty drift rests on the Chalk and where no material derived from the denuded anticline has been recovered. Evidence presented subsequently in this thesis shows that this hesitation is justified, and that we are in fact dealing here with the remnants of two well defined and separate surfaces which can be recognised on the Chalk elsewhere in southern Wiltshire.

PART III

PART III: SUMMARY AND NOTES ON THE ORIGINALITY OF THE WORK

1. Problematic aspects of a 'Pliocene' marine transgression in Wiltshire are introduced.

2. Drifts on the 'Pliocene marine plain' on the Grovely Upland are described; this is an account of original work, the interpretative passage is brief but original.

3. Specific evidence of a 'Pliocene' transgression in Wessex is reviewed; a slight original study of supposed Pliocene material is described.

4. Problematic aspects of Pliocene stratigraphy in southern England are reviewed.

5. The concept of superimposition from a Pliocene surface is reviewed. Pinchemel's objections (1954) to a depositional surface are accepted but his views on fluvial aggradation are rejected in a slight original study of gravel referred to this aggradation. Difficulties inherent in the concept of marine planation are recognised.

6. An original re-interpretation of the 'Pliocene marine plain' is presented; this includes an original descriptive account of drifts on the surface in question at several sites in southern Wiltshire.

7. An original qualitative definition of the mid-Tertiary surface in southern England is proposed; this account is based on a very satisfactory comparison with the conclusions of Cholley (1957) regarding the nature of the mid-Tertiary surface in the Paris Basin.

8. The status of the mid-Tertiary surface in the pattern of Tertiary events is discussed and some original conclusions are suggested.

PART III: THE PLIOCENE MARINE TRANSGRESSION IN WESSEX

THE GREAT RIDGE - GROVELY UPLAND

Some Unresolved Problems: an Introductory Account

Evidence of discordant elements in the drainage pattern

The extension of the Pliocene transgression onto the Wiltshire Chalk is inferred by Wooldridge and Linton. Where topographic evidence of Pliocene coastal features has not been recognised Wooldridge and Linton have defined the extent of the transgression in terms of drainage morphology. They have for this purpose recognised two groups of streams in southern Wiltshire:

> "The one group is markedly transverse and seems best regarded as epigenetic and in its first cycle; the other is essentially longitudinal and has evolved by adjustment through two cycles of erosion. Between the two is a line, which on other grounds we should regard as marking the approximate position of the Pliocene

shoreline"
Wooldridge and Linton, 1955, p.68.

The evidence discussed in the foregoing account of drifts on the Mio-Pliocene peneplain of Wooldridge and Linton (Part Two of this thesis), particularly the interpretation of the gravels incorporating Jurassic and Lower Cretaceous material, suggests that the present drainage pattern in the Vale of Wardour cannot be regarded as the rejuvenated expression of a longitudinal and accordant pattern which had evolved on the mid-Tertiary surface. The evidence suggests rather, that the drainage at some time during the dissection of this surface was neither accordant nor longitudinal. If this view is accepted the basis employed by Wooldridge and Linton to establish the extent of the Pliocene transgression is invalidated.

The site of the Pliocene shoreline and the pattern of post-Pliocene consequent drainage

In spite of the established criteria the exact limit of the Pliocene transgression, adopted by Wooldridge and Linton in southern Wiltshire, is not clear (1955, figs. 10, 17, 18, 19). Pinchemel (1954) and Small (1964) have already drawn attention to these discrepencies and Pinchemel has suggested an alternative reconstruction:

> "Nous voyions . . . dans la Wylye comme d'ailleurs dans la Nadder des rivières conséquentes à une déformation vers l'Est de la plaine de niveau de base Pliocene localement réadaptées à une structure anticlinale préalablement nivelée. Une interprétation voisine avait curieusement été proposée voici cinquante années par le Révérend Andrews (1892)."
>
> Pinchemel, 1954, pp. 405-406.

Pinchemel's concept of 'une deformation vers l'Est' reintroduces the problematic discord between the southward gradient of the Avon and the eastward gradient of its right bank tributaries, a difficulty which Linton's scheme of superimposition (1932) sought originally to resolve. Small (1964), who accepts Pinchemel's view is clearly aware of this difficulty and he infers "a comparatively undisturbed 'structural saddle' near Salisbury", which he presumably considers to have determined the site of the Avon. Small suggests that the Calabrian transgression in southern Wiltshire reached a level of 690' O.D. This is substantially above the level proposed by Linton:

> "Where the shoreline can be traced most definitely . . . it shows no significant or systematic variation in altitude and may be represented by the generalised contour of 650' O.D."
>
> Linton, 1964.

Even if a transgression of the order suggested by

Small is accepted, the evidence remains that gradients above this level on supposed remnants of the mid-Tertiary planation surface had not become adjusted to the anticlinal structure of the Vale of Wardour but were in fact consequent upon it. This arrangement accords so badly with the views of Wooldridge and Linton and with those of Pinchemel, and Small, that a careful examination was made of the superficial deposits resting on the eastern part of the Great Ridge - Grovely Upland.

A Re-examination of the Superficial Geology

The context of the investigation

The area which has been examined is delineated by Wooldridge and Linton (1955, figs. 10, 17) as a remnant of the Pliocene marine plain. In their account of the Pliocene marine deposits in the London Basin Wooldridge and Linton state that:

> "Over wide areas traces of these deposits remain at least in sufficient bulk to modify soil conditions and true Clay-with-flints is absent or subordinate though the surface covering is often mapped as such."
>
> Wooldridge and Linton, 1955, p.55.

In Wessex they suggest that:

> "Morphological evidence corroberative of the testimony of the drainage system may be cited . . . and provides at the same time clues which may lead to the discovery of relics of Pliocene sand and shingle."
> Wooldridge and Linton, 1955, p.65.

(The 'couverture sableuse' from which Pinchemel envisages the superimposition of the drainage.)

The possible preservation of Pliocene marine deposits encouraged the excavation of twelve pits on the Grovely Upland, into the Clay-with-flints of the Geological Survey. Hitherto only surface indications of Clay-with-flints have been described from this area (Gifford, 1957). The relation between the inferred Pliocene coast in Hampshire and Dorset, and the existing geological outcrop, suggests that traces of marine gravels on the Grovely Upland might largely comprise cobbles or pebbles of flint; chert and sandstone from the Upper Greensand outcrop, both in the Vale of Wardour and further South and West; some other Lower Cretaceous material and a little Jurassic material from the Vale of Wardour and perhaps also from these outcrops in Dorset; flint pebbles of Lower Tertiary aspect and other derived material from Tertiary formations which are shown in Part One of this thesis to have been more extensively preserved in Hampshire and Dorset at the period in question.

In the London Basin material incorporated in supposed Pliocene gravels is heavily battered but not usually well rounded.

Preliminary studies

1 - 4. Soil pits

Four small pits (SU038344, SU 014349, SU 011351, ST 968357) were dug to a depth of one or two feet during a preliminary examination of the area. These pits showed a few inches of rather pale, more or less stoneless, loam over a mass of angular flint in a scanty clay matrix of yellowish brown aspect full of sharp flint chips. Samples from the flinty clay include a trace of well rounded quartz sand, invariably less than 1%, and some rather indefinite ferruginous material; but otherwise the drift is exclusively of flint, broken, for the most part obviously unrolled and usually patinated, grey and occasionally white. The material examined in these pits may have included some slightly abraded fragments of the type encountered on the Great Ridge and elsewhere in Grovely. Abraded fragments were not in fact noted and are likely to have been small.

5. Stockton Wood Reservoir section

In a larger excavation (10' x 15')(ST 964361) to accommodate a new reservoir near Stockton Wood a drift of rather different aspect was observed (fig. 35/b). Here up to 18" of confused and probably disturbed yellowish brown stoney loam rest on a very well marked gravelly seam which appears to be a typical 'erosion pavement'. The gravelly seam (2"- 6" thick) consists mainly of small angular flint fragments, much of the material less than 1" in diameter, some fragments of tabular silica and a few fragments of deeply weathered and possibly abraded flint. The seam also includes a trace of quartz sand and a few small pieces of rolled quartz 1/16" to 1/4" diameter (7 counted in a sample of about 2 lbs. weight, i.e. several thousand undifferentiated fragments). Abraded and unabraded ferruginous material up to ½" diameter also occurs. The 'erosion pavement' rests on a reddish brown clay which was seen to a depth of 4'.0" in the excavation but was seen to be resting on the Chalk at a depth of 3'.6" at one point in an associated trench some fifteen yards to the West. A sample of the clay proved to include a trace of quartz sand, indefinite ferruginous material and angular flint fragments; but these components formed less than 5% by volume of the drift. Ferruginous material, and ironstained fragments of flint and secondary silica are increasingly common in the finer fractions (less than 5/32"). At the base of the clay examined in the trench, large unbroken nodules of flint were seen.

6. Grovely Lodge

A clay apparently more or less free from coarse stoney material and of similar aspect to that in the Stockton Wood Reservoir Pit was seen in an existing pit to a depth of 3'.6" further East near Grovely Lodge (SU 047341).

The profiles at sites five and six seem to be good examples of the Winchester series described by Avery et al. (1959) on the Chilterns.

Excavated sections

Seven further pits were excavated in the drift and proved the underlying Chalk.

1. Stockton Wood

(ST 968358)(680' O.D.)(fig. 35/c)

Here 12" of yellowish brown almost stoneless loam rest directly and with a well defined lower boundary on a reddish brown flinty clay. There is no indication in this pit of an 'erosion pavement'. In a sample of the flinty clay nothing but flint was retained by a ½" mesh. This material (Plate 32) is indistinguishable from stones in the drift at the Rowdean Hill site (see Part Two of this thesis and Plate 18) and includes some deeply weathered and apparently abraded fragments with brownish or yellowish patinas. In the drift the individual fragments are commonly coated with a thin film of pure bright reddish brown clay. In the fine gravel fraction (5/32"- 1/2") flint comprises more than 99% of the material; a few pieces of ferruginous material comprise the balance. In terms of abrasion and patination this fraction is also indistinguishable from the Rowdean Hill material. Patination of the larger fragments of flint seems to be wholly unsystematic, ranging from fresh grey to matt white; two and even three distinctive stages of patination may occur on one fragment. (There does seem however to be some sort of correlation between patina and type of fracture: creamy white patination is commonly associated with smooth and extensive fracture surfaces (Plate 33/a), fresher patinations with minutely chipped and flaked surfaces (Plate 33/b). The significance of this correlation is not apparent, but might reflect the zonal derivation of the flint.) In this pit the clay is rather less stoney than at Rowdean Hill and here and there the clay is blocky with evidence of slickensiding in the lower part of the drift.

At the base of the flinty clay large, (1'0" diam.) apparently unbroken nodules rest on the surface of the Chalk which is initially encountered here at a depth of 2'.6". In fact many of the large nodules are traversed by numerous cracks and fall into blocky fragments when removed from the clay. The fracture surface is usually iron-stained but in some cases a thin layer (1/10" thick) of clay separates the fragments. Elsewhere in the drift the broken fragments of nodule seem to have been widely dispersed and all attempts to identify matching fragments failed, not only in this pit but at other pits on the Great Ridge - Grovely Upland.

Although the Chalk was encountered in this pit at a depth of 2'.6" (Plate 31), the Chalk at this point is clearly the summit of a pinnacle and the drift may be somewhat deeper in neighbouring hollows. The boundary between the chalk and the flinty clay is very sharp and is marked by a thin seam (¼"- ½") of rather darker clay. At the top of the chalk pinnacle the chalk is rather rubbly, consisting of rounded pellets in a damp buff coloured paste of gritty chalk. In the lower part of the pinnacle the chalk is blocky and clearly <u>in situ</u>. The whole profile is penetrated, down to and into the Chalk by tree roots.

<u>2. Heath Wood</u>

(SU 079331)(510' O.D.)(fig. 35/d)

Here 8"- 9" of stoneless yellowish brown loam rest on a thin (3"- 4") seam of shattered flint (Plate 34) which probably corresponds with similar 'pavements' elsewhere on the Great Ridge - Grovely Upland. The flint in the 'pavement' is largely patinated a shade of grey or greyish white. On the surface of the 'pavement' two unpatinated artificial flakes were recovered. The 'pavement' rests on a deeper (1'.0") yellowish brown loam with few stones (cf. site 5, below). At the base of the drift 1'.9" of reddish brown gritty clay, incorporating angular fragments of flint, rests on the Chalk. The flint consists exclusively of angular fragments (Plate 35) indistinguishable from the material at site one (above) except that no abraded and deeply weathered examples were observed. The broken surfaces of the flint fragments are for the most part minutely chipped and flaked. At the base of the drift the fragments of flint are large and the interstices packed with flint grit; nearer the top of the clay the stones are smaller and the matrix less gritty; here and there the clay is blocky. The Chalk is encountered here at a minimum depth of 3'.9" from the surface, but this level appears to be the summit of a pinnacle. The boundary between the Chalk and the flinty clay is marked by a thin seam of darker and less gritty clay (¼"- ½" thick). The chalk in the pinnacle was damp and pastey and incorporated shattered flint, sharply angular and entirely unpatinated.

3. Shortengrove

(SU 070334)(515' O.D.)(fig.35/e)

A variable depth of yellowish brown generally stoneless loam rests here with a well defined lower boundary on a reddish brown gritty clay incorporating angular flint. The boundary between the loam and the clay is marked by involutions, and isolated inclusions of loam are observed in the upper part of the flinty clay. In the involutions the loam reaches a depth of 1'.9". At this site no evidence of an 'erosion pavement' is observed. In the underlying clay the flint is invariably angular (Plate 36) and is indistinguishable from the material at site one (above), the broken surfaces minutely chipped and flaked; no abraded flints are observed however. At the base of the clay a layer of large flint nodules (Plate 37), only slightly damaged rests on the Chalk. The Chalk is encountered here at a minimum depth of 4'.2" in the summit of a pinnacle. The chalk/clay boundary is marked as usual by a thin seam of darker clay. The chalk in the upper part of the pinnacle is rubbly, consisting (as at site 1) of rounded pellets in a gritty buff-coloured chalk paste (Plate 38); this material incorporates shattered flint fragments which could not be matched one to another. At a depth of about 1'.0" below the summit of the pinnacle the chalk becomes increasingly blocky and is clearly in situ.

4. Hadden

(SU 057338)(565' O.D.)(fig. 35/f)

Here 1'.3" of rather stoney yellowish brown loam rests with a sharply defined lower boundary on a reddish brown gritty clay, incorporating angular flint. The bulk of the flint in this pit is characterised by extensive smooth fracture surfaces (cf. Plate 33/a). No abraded material is seen, nor is the base of the clay marked by a layer of larger fragments or nodules; there is however a thin seam (¼"- ½") of darker clay at the boundary with the Chalk, which is encountered here at a minimum depth of 3'.6".

5. Tare Coat

(SU 034347)(600' O.D.)(fig. 35/g)

Here 10" of yellowish brown loam, incorporating a few angular pieces of flint, rests on the level surface of a 'pavement' feature. The 'pavement', about 3" to 4" thick consists of angular flint fragments, more or less patinated a shade of grey or greyish white, and a few slightly abraded fragments. Both on, and incorporated in, the 'pavement' artificial flint flakes occur, together with a few small flint pebbles of Lower Tertiary aspect. Bearing in mind the association at this site of these pebbles with a quantity of artificial flakes, it is difficult to decide whether the pebbles have been derived from the underlying drift, or have been introduced for some purpose during the prehistoric period. (see Appendix II) Below the 'pavement' pockets of a lower yellowish brown stoneless loam are preserved, extending in some cases to a depth of 1'.10" from the surface. One artificial flake and a fragment of a flint pebble were recovered near the base of the lower loam. At the base of the drift a variable thickness of reddish brown clay occurs incorporating largely angular flint, but also a few slightly abraded fragments. The chalk/clay boundary is marked by a thin seam of darker clay. The Chalk is encountered here at a minimum depth of 2'.4" and resembles the rubbly pinnacles seen at sites one and three (above).

6. Langford Long Coppice

(SU 021351)(620' O.D.)(fig. 35/h)

Seven inches of rather stoneless loam rest here on a stoney 'erosion pavement'. The 'pavement' consists of flint fragments, more or less patinated a shade of grey or greyish white. One unpatinated artificial flake was recovered in the upper part of the 'pavement'. Below the 'pavement' and not separated from it by a well marked boundary, occurs the reddish brown gritty clay encountered elsewhere on the summit of the Grovely Upland. The flint fragments in the clay are for the most part distinguished by a blocky fracture (cf. pit 4 above). The clay extends to a depth of 2'.4" from the surface. The boundary with the underlying Chalk is marked by a thin seam of darker clay. The Chalk is seen in a rubbly pinnacle.

7. Sandgates

(SU 037343)(575' O.D.)(fig. 35/k)

Here 6" of stoneless yellowish brown loam, incorporating one unpatinated artificial flake, rest on a rather thick (6"- 8") stoney 'pavement'.

The flint in the 'pavement' is largely patinated a shade of grey or greyish white. Below the 'pavement', in a shallow reddish brown clay, flint is largely confined to a discontinuous layer of slightly broken nodules resting on the Chalk. The boundary between the chalk and the clay is not marked at this point by a seam of darker clay. The Chalk is encountered here at a minimum depth of 1'.2" from the surface. The Chalk is seen in rubbly pinnacles which rise from a more general level at a depth of 2'.6" from the surface.

Although the drifts described here are for the most part rather shallow and flinty, they approximate to the Winchester series of Avery et al. (1959) and are indistinguishable in terms of composition and morphology from the drifts further West, on the summit of the Great Ridge (see Part Two of this thesis).

OBJECTIONS TO A CONCEPT OF SUPERIMPOSITION IN WESSEX

The Grovely Upland: Some Conclusions and their bearing on the Recognition of Pliocene Material

The subaerial character of the Grovely drifts

As a result of these investigations on the Great Ridge - Grovely Upland certain important conclusions take shape. In the composition and arrangement of the drift on the Grovely Upland there is no hint of a marine transgression across this tract of ground. Particularly significant in this respect is the absence in the drift of material derived from sources other than the outcrop of the Chalk and of any material bearing distinctive evidence of marine activity. The infrequent abraded fragments which are detected are indistinguishable from material recovered in drifts on the Great Ridge and at Rook Hill, on ground across which the Pliocene transgression is not supposed to have penetrated. The abraded flint is in any case of a type associated with fluvial rather than marine activity.

The Pliocene hiatus in Wessex and in the Paris Basin

The circumstantial evidence for a Pliocene transgression onto the Wessex Chalk has never been satisfactory. The problematic extent of the Pliocene transgression in the Paris Basin confirms the real nature of the difficulties in Wessex. Pinchemel (1954) has referred to a transgressive Pliocene sea certain unfossiliferous sands and gravels on the southern limb of the denuded Artois anticline, and even further South and West about the denuded Bray anticline (fig. 36). Cholley however argues that:

> "Les dépôts diestien ne semblent pas avoir beaucoup dépassé vers le Sud l'accident de l'Artois."
> Cholley, 1957, p.167, footnote.

This observation is essentially applicable on this side of the Channel. White writing in 1921 alludes to the "sands of Diest and Lenham" but admits that:

> "The Uplands of Hampshire and other southern counties have been searched in vain for traces of contemporary marine deposits." White, 1921.

Wooldridge and Linton discussing the extension of the Pliocene transgression beyond the London Basin recognise that "the survey of the Wessex uplands from this point of view is admittedly still (1938) incomplete." This deficiency has to some extent been rectified in Wiltshire by the work of Mrs. Joyce Gifford who has carried out a survey of superficial deposits on the Chalk there (Gifford,

1957) including the extensive and critical tracts of Salisbury Plain at present occupied by the Ministry of Defence. Mrs. Gifford states (in discussion) that although she paid specific attention to the possible preservation of Pliocene marine deposits, no trace of these was recognised.

Derived Pliocene material in Pleistocene gravels

Pinchemel (1954) claims to have recognised "des galets chamois typiques du Pliocene" in Pleistocene gravels at two sites near Salisbury (1. SU 123335; 2. SU 111328):

> "Preuve de la pénétration de la mer Pliocène dans le Wessex."
> Pinchemel, 1954, p.139.

During the present investigations nothing, in the way of flint cobbles or well rolled flint shingle, which cannot be referred to the Eocene, has been detected at either of these sites. Cobbles, which are matched in the Palaeogene outlier at Clay Pit Hill are very commonly observed on the ploughed surface of the Pleistocene gravel (Plate 39). Their dull yellowish brown patination to which Pinchemel attaches special significance ("la teinte fauve caractéristique est un des meilleurs repères stratigraphique") can almost certainly be attributed in this case to the ferruginous character of the Pleistocene gravel in which the cobbles have been incorporated. The 'galets' to which Pinchemel alludes are in fact uncharacteristic of the

Pliocene in this country. Bury (1910) has actually drawn attention to "the absence of well rolled shingle from beds supposed to be Diestian."

Linton (1932) argues that the large amount of flint in the Pleistocene gravels associated with the Hampshire Avon implies a period of Pliocene aggradation in response to transgressive marine conditions. He recognises however that the flint is ultimately derived from the regolithic drifts which characterise the mid-Tertiary planation surface. The implication of transgressive marine conditions during the Pliocene is not therefore inescapable.

Some difficult aspects of 'Pliocene' stratigraphy (fig. 37)

The doubtful nature of the Pliocene transgression in Wessex is perhaps a reflection of substantial difficulties which remain unresolved in the London Basin itself.

The Coralline Crag and Lenham Beds

The stratigraphy of the Pliocene in England is problematic. . In East Anglia a substantial outcrop of the richly fossiliferous marine Pliocene Coralline Crag is preserved, but the range of the marine transgression elsewhere in southern England is indicated only by small and scattered outliers which, in a few instances, have yielded the very poorly preserved fossils of an ambiguous marine fauna. At a height of about 680' O.D. near the crest of the North Downs at Lenham in Kent and elsewhere at levels between 500' and 680' O.D., on the Chalk between Folkestone and Guildford and on the South Downs at Beachy Head, masses of ferruginous and slightly glauconitic sand and flint gravels are deeply piped into the Chalk surface. Reid (1890) supposed that this material had been piped down not more than 80'.

> "The majority of investigators have agreed that the Lenham Beds are equivalent to the Diestian deposits of Belgium." Newton, 1916.

The Belgian deposits are now thought, in that country, to represent the final stages of the Miocene (Henzelin and Glibert, 1958) and are overlain in Belgium by beds which are correlated with the East Anglian Coralline Crag.

The Netley Heath and Rothamsted faunas

One hundred and eleven fossils laboriously recovered from material at Netley Heath include none of the characteristic elements of the Lenham fauna and have been exactly matched (Chatwin, 1926) with examples from the Scaldisian in the Low Countries; this stage is loosely correlative with the Lower Pleistocene, Lower Red Crag (Waltonian and Newbournian) in East Anglia and with the Calabrian of the Italian succession. A fauna of rather different aspect, and possibly of a rather earlier date (Waltonian) than that at Netley, has been recovered from material at Rothamsted at a height of about 430' O.D. (Dines and Chatwin, 1929).

The interpretation of the 'Pliocene' outliers in the London Basin

Shotton (1962) states that the Netley Heath fauna is a shallow water and possibly an intertidal association. Chatwin recognises that:

> "The comminuted condition of the shells and the conglomeratic nature of the matrix in which they are enclosed are not discordant with the possibility of their having been transported from a distant source." Chatwin, 1926.

Nonetheless it is difficult to reconcile Shotton's statement on the ecology of the Netley Heath fauna with that of Reid (1890) on the ecology of the Lenham fauna. Reid shows that truly littoral forms are absent there, and he identified the tubes of the anellid Ditrupa subulata, a species commonly living at depths between 60 and 120 fathoms; he observes that the valves of bivalve species are often united and that broken shells are rare and worn shells unknown. He concludes that:

> "Taking everything into consideration I think we cannot place the depth of water at less than 40 fathoms." Reid, 1890.

In spite of these discrepencies Wooldridge and Linton state that in the London Basin:

> "There can be no doubt that the ('Pliocene') outliers are the remains of a once continuous sheet of sand and shingle
> Wooldridge and Linton, 1955, p.48.

As a corollary, they argue that this material is preserved on a morphologically distinctive wave-cut platform. In the light of these conclusions an early Pleistocene (Calabrian) shoreline has been extensively recognised at levels between 550' and 690' O.D. in southern England and South Wales.

The Concept of Superimposition

The Origins of the concept

In Wessex the recognition of the Pliocene transgression is not without inherent difficulties. The extension of the Pliocene transgression onto the Wessex Chalk was originally argued in terms of drainage morphology:

> "After re-examination of the Wessex area in the light of evidence from the London Basin Wooldridge and Linton concluded in 1938 that marine transgression had occurred throughout the area in which epigenesis could be established." Linton, 1964.

The area in question:

> "comprises the whole terrain bordering the English Channel as far West as the Isle of Portland and extends inland across Wessex to the western end of the London Basin."
> Wooldridge and Linton, 1955, p.65.

The weakest aspect of this massive extrapolation is the problem of process. The nature of the process which rendered the effective surface, "the floor of the Pliocene sea", an uninterrupted plain remains controversial.

The ineffective character of marine deposition

Pinchemel (1954) has convincingly discredited the concept of widespread marine deposition capable of creating an effectively plane floor beneath the Pliocene sea. His arguments are therefore submitted in detail:

> "La surimposition sur une couverture marine généralement admise, se prête en effet à quelques objections, théoriques, mais qui nous paraissent cependent importantes. De la présence de sables ou de graviers, à une altitude donnée est à juste titre déduite la présence passée d'une mer; si les dépôts ont un faciès littoral, on fait coincider avec eux le tracé de la ligne de rivage. Mais il nous semble qu'il y a erreur à partir du moment où on admet implicitement que la totalité des régions submergées était récouverte par des sédiments marins. Car cette mer était une mer épicontinentale très peu profonde et il est normal de la comparer à la

Manche ou à d'autres mers. Or, que montrent-elles? Si on bordure de la côte, des dépôts sableux ou caillouteux existent, ils disparaissent plus ou moins vite en direction de la mer suivant la pente de la plage, parfois c'est une épaisseur de quelques décimètres de sables qui recouvre la roche sous-jacente. Si les sondages faits dans la Manche ont permis de dessiner une carte géologiques c'est bien parceque les terrains tertiaires ou crétacés y 'affleurent' encore; l'existence d'autre part d'une topographie sous-marine avec des thalwegs encore nettement marqués prouve que le fond de semblables mers est loin d'être une surface régulière et plane composée d'un manteau de sédiments recouvrant les roches. Si les eaux se retiraient actuellement de la Manche, les conditions propres à un processus de surimposition seraient loin d'être réalisées. C'est pourquoi l'extension de la mer diestienne ne nous paraît pas entraîner une surimposition générale de toutes les régions qu'elle a recouverte."

Pinchemel, 1954, pp. 317-318.

The unsatisfactory evidence of fluvial aggradation

Pinchemel concludes that:

"Une plaine de remblaiement alluviale par contre implique une masse de matériaux et une topographic plane, une hydrographie d'un type nouveau, qui réalise véritablement les conditions d'une surimposition."

Pinchemel, 1954, p.318.

This concept was originally examined in 1932 by Linton but is not generally accepted now by geomorphologists in this country:

> "Il est curieux de constater que cette notion de plaine fluvio-marine pliocene ne se retrouve pas dans le travail publié par S.W. Wooldridge et D.L. Linton ."
>
> Pinchemel, 1954, p.155, footnote.

Pinchemel believes that the relics of the Pliocene aggradational plain in Wessex can be recognised at Alderbury (SU 185274). The material evidence is unconvincing. The gravel there which rests on the Eocene outcrop at a level of about 310' O.D. has been examined during the present investigations and there is no reason to differentiate it in terms of composition or morphology from gravels of fluvial origin at higher and lower levels (Plates 40 and 41) which apparently form a series of increasing antiquity from the lowest to the highest levels (Tables 16 to 21) and which are definitely associated with the Hampshire Avon and seem to be of Pleistocene age. Oakley (1963) accepts the correlation of the Alderbury gravels with the Pleistocene Ambersham terrace of Green (1936, 1946)

The contradictory evidence of marine planation

A careful reading of Wooldridge and Linton (1955) suggests that Pinchemel is deceived when he speaks of "surimposition sur un couverture marine generalement admise". Wooldridge and Linton in fact refer consistently to a "marine abrasion surface" (e.g. p.52) and suggest that the inequalities of the sub-aerial mid-Tertiary surface were "planed across". They consider that:

> "Over most of Wessex, as over most of the London Basin, the marine plain must have been cut in the soft Eocene rocks and only locally near the coast, was an abrasion platform cut in the more durable Chalk. In this formation moreover it seems to have been at best narrow and is usually only a mile or two broad."
>
> Wooldridge and Linton, 1955, p.66.

The restricted expression of the Pliocene feature in Wessex suggests to Wooldridge and Linton:

> "That the period during which erosion was operating in Wessex may have been shorter or that the waves possessed a shorter length of fetch than in the more easterly regions."
>
> Wooldridge and Linton, 1955, p.66.

This conclusion is not altogether substantiated in their delineation of the Pliocene marine plain in southern Wiltshire (fig. 12). The distribution of the remnants of the plain on the Chalk indicated here by Wooldridge and Linton suggests that the abrasion surface cut in the Chalk must have been between five and fifteen miles wide. It is difficult to reconcile this evidence, pertaining to a relatively sheltered situation on the Pliocene coastline, with the widespread absence of the Pliocene marine bench on the dipslope of the Chalk in Sussex, Hampshire and Dorset, where it may reasonably be assumed that the coastline was relatively exposed.

Wooldridge in an account of the Pliocene transgression in southern England suggests that:

> "Throughout the greater part of the area the Pliocene shelf or platform is backed by a low bluff separating it from the higher ground."
>
> Wooldridge, 1952.

The failure to identify this feature at the appropriate level on the Grovely Upland might have appeared fortuitous had alternative evidence of the transgression been forthcoming, but in the light of the evidence presented here it tends to emphasise the doubtful reality of the transgression (fig. 17).

Conclusion

Wooldridge and Linton suggest that "the most compelling arguments for a former widely extended Pliocene sea in South East England are indeed morphological" (1955, p.48). In the demonstrated absence of consistent morphological evidence and confronted with circumstantial evidence, in the composition of the drift on the Grovely Upland, that no marine transgression occurred there, the concept of a Pliocene transgression that extended onto the outcrop of the Chalk in Wessex is provisionally rejected.

A REINTERPRETATION OF THE 'MARINE' PLANATION SURFACE IN SOUTHERN WILTSHIRE

The Grovely Upland

In the light of the conclusion just adopted it becomes much more plausible to admit the obvious affinity of the Grovely drift with the drift on the neighbouring mid-Tertiary surface; and to suggest that the summit of the Great Ridge - Grovely synclinal upland represents an undifferentiated remnant of the mid-Tertiary surface. This possibility seems to be admitted by Wooldridge and Linton:

> "The upland comprises one of the largest and most instructive remnants of the Mio-Pliocene peneplain. At its eastern end it pitches rather more definitely than elsewhere. If we except these easternmost two miles, the ridge rises gently from 600' near Grovely Lodge in a WNW direction for some eleven miles to 784' near Brixton Deverill."
>
> Wooldridge and Linton, 1955, p.38.

This account which clearly recognises that there is no topographic evidence of the Pliocene marine bench or bluff on the ground here, is hardly consistent with the view submitted elsewhere by Wooldridge and Linton (1955, p.66) that where the Pliocene marine transgression extended into Wessex the contours of the Mio-Pliocene surface were so effectively obliterated either by planation or burial that an epigenetic drainage pattern subsequently arose on the emerging floor of the Pliocene sea.

The undifferentiated character of the synclinal upland has lately attracted the attention of Small (1964) who delineates it as a remnant of the sub-Eocene surface (fig. 38); a speculation which the composition of the drifts examined there during the present investigations does not sustain (see Part Two of this thesis). At the same time Small shows that the planation of the Grovely Upland is not likely to have been effected by peneplanation in the final stages of a 'normal' fluvial cycle. He believes that the present topography of the Ebble syncline confirms this view. The Ebble is now denuding the Bowerchalke and Knighton Hill anticlines and it is generally supposed that a river formerly occupying the Grovely syncline denuded the initial Wardour anticline in this way. Small shows that the present form of the Grovely syncline cannot in fact have been achieved by a process analagous to that now going on in the Ebble syncline, and for this reason he argues in favour of a marine transgression effectively trimming the surface during the Pliocene period.

In this thesis the concept of a Pliocene marine transgression across this area is abandoned. The problem recognised by Small cannot however be ignored and the planation of the problematic surface here is attributed to the process of 'pediplanation' (see Part Four of this thesis).

If the uninterrupted preservation of a regolithic drift on this synclinal upland is accepted, it presents important confirmatory evidence that no marine transgression has affected the area. It seems most unlikely that an unconsolidated drift of this type should survive a period of marine erosion which elsewhere is believed to have cut a substantial platform indifferently across the Chalk and Eocene formations and to have deposited on this platform a coarse shingle of heavily battered flint and chert. It may reasonably be argued that the drift on the upland has been disturbed and perhaps to some extent redistributed during the Pleistocene period; it is nonetheless remarkable that no trace either of the marine abrasion platform or of the associated shingle can be recognised. It may also be objected that the drift at the eastern end of the upland is shallow and incorporates relatively little flint suggesting that correlation with the deeper very flinty drifts further West is doubtful. In fact the arrangement is entirely consistent with the projected plane of the sub-Eocene surface and with the inferred zonal outcrop of the underlying Chalk. The sub-Eocene surface is thought to have passed here less than 100' above the present summit level; the volume of Chalk contributing flint to the drift was correspondingly limited and may moreover have largely comprised the zone of Marsupites testudinarius; "it is not improbable that the zone of Marsupites is represented above Grovely Wood" (Wooldridge and Linton, 1955, p.40), a zone in which flint is relatively uncommon.

It is accepted at this stage that, in the case of the Great Ridge - Grovely synclinal upland, the ground believed by Wooldridge and Linton to represent "remnants of the Pliocene marine plain" is in fact largely indistinguishable from their Mio-Pliocene peneplain.

Salisbury Plain

A re-examination of the drifts on the fragmentary marine plain indicated elsewhere in southern Wiltshire by

Wooldridge and Linton suggests no reason why in certain cases the ground in question should not be regarded as part of the subaerial surface.

1 - 9. Remnants of the mid-Tertiary surface

More or less definitive results have been obtained, during the present investigation, at six sites.

1a. Ashdown Copse

An extensive remnant of the Pliocene marine plain is indicated on the high ground above Tidworth, at levels between 500' and 600' O.D., on the summits of the Belemnite Chalk, East of the River Bourne. The Clay-with-flints of the Geological Survey here proves to be a bright reddish brown clay, incorporating a small quantity of broken but unabraded flint, some ferruginous material, a few flint pebbles of Lower Tertiary aspect and a trace of very coarse quartz sand (more than 1/32" diam.). In the finer fraction (less than 1/32" diam.) ferruginous material predominates. Quartz sand and minute flint chips occur but flint is rather scarce. This material was identified in a sample recovered in a pit (SU 241461) dug to a depth of 3'.6"; there are surface indications that the drift is substantially deeper than this.

1b. Kimpton Gravel Pit

Gravel examined in an abandoned gravel pit near Kimpton (SU 258461), in a dry valley draining this high ground, confirms the composition of the drift. The coarse gravel (larger than ½") consists largely of broken and subangular flint; a few flint pebbles of Lower Tertiary aspect comprise the balance. The finer gravel (5/32"- 1/2") includes a large quantity of rolled and unrolled ferruginous material (including conspicuously octahedral fragments), some well rolled flint pebbles of Lower Tertiary aspect and a few small pieces of quartz. In the finest fraction examined (1/32"- 1/16") ferruginous material appears to predominate in the coarser phase and quartz sand in the finer phase.

2. Quarely Hill

Quarely Hill (SU 262423) is specifically referred to the Pliocene surface by Green (in Boswell, 1946) and correlated by him with the Netley Heath (Red Crag) stage in the London Basin. No drift is indicated here by the Geological Survey, but irregular and largely overgrown diggings on the summit provide sections in Clay-with-flints. If the pits here worked the Clay-with flints itself, which seems most probable, their arrangement suggests that the drift may have reached a depth of about 10' in places. The drift, a bright reddish brown clay, incorporates broken flint and flint pebbles of Lower Tertiary aspect; a certain amount of fine quartz gravel (5/32"- 1/2") is also present. There is however no trace of battered flint of the type which characterises supposed Pliocene outliers in the London Basin, and it seems wisest to accept the Lower Tertiary derivation of the quartz. Small quartz pebbles have, for example, been identified by White (1910) in the sands at the base of the Reading Beds at East Stratton (SU 541400) some seventeen miles to the East of Quarely. In the finest fraction examined at Quarely (1/32"- 1/16"), minute chips of flint are relatively uncommon. Ferruginous material predominates and quartz sand is abundant

3. East Winterslow

The ground here (SU 242336) at a level of 532' O.D. (and at site 4, below) has not in fact been referred to the Pliocene marine plain but the drift encountered at these sites suggests that the ground is correlative with the summits further North (sites 1a and 2). A pit in the Clay-with-flints of the Geological Survey here has unfortunately been backfilled within recent years and it proved necessary to dig anew into the drift. The section excavated here to a depth of 3'.9" showed a disturbed yellowish brown loam resting at a depth of 10" on a stoney 'erosion pavement' about 4" thick. The 'pavement' incorporates angular flint fragments, mostly patinated white or greyish white and more or less stained black (probably by manganese). Rare flint pebbles of Lower Tertiary aspect occur. Rolled and unrolled ferruginous material (up to ½" diam.) is present and a quantity of quartz sand (rarely larger than 1/16" diam.). Below the 'erosion pavement' a bright reddish brown clay is observed to a depth of 3'.9" (the bottom of the pit, where the Chalk had not been encountered). The clay incorporates a few well rolled flint pebbles of Lower Tertiary aspect, including green-coated examples which suggest derivation from the base of the Reading Beds without much intervening disturbance or redistribution. The clay also incorporates angular and subangular flint fragments. The subangular examples probably match material recovered in the Great Ridge and Grovely pits. Abraded and unabraded ferruginous material and fine quartz gravel (less than 5/32") also occur. Quartz is uncommon even in the sand fractions (less than 1/16") in which minute flakes of flint predominate. The arrangement of the ground about the site of the old diggings suggests that the drift was about 6'.0" deep in places.

4. Burrets Grove

A small pit dug into the Clay-with-flints of the Geological Survey here (SU 262344) to a depth of about 3'.0" showed a few inches of loam over a mass of angular flint in a scanty matrix of yellowish brown gritty clay; a drift indistinguishable in aspect from Clay-with-flints described in several pits on the Grovely Upland. It proved impossible to establish the depth of the drift at this site.

5. Thorny Down

This site is described in Part One of this thesis. The drifts there were not examined during the present investigations but from the available accounts (Reid, 1903; Gifford, 1957) it seems possible that the sub-Reading Beds surface coincides here with a later Tertiary surface characterised by Clay-with-flints of residual aspect.

6. Dean Hill

A very shallow drift, little more than a scattering of debris, rests here (SU 243257) on the Chalk. It includes angular and sub-angular flint; flint pebbles of Lower Tertiary aspect, including broken and slightly re-rolled examples; ferruginous material, including large sub-angular blocks of dark very tough grit (5" diam.); and one pebble of (?)banded sarsen. Further East (SU 254254), on the outcrop of the Clay-with-flints of the Geological Survey, surface indications suggest a flinty clay with Lower Tertiary (Reading Beds) debris.

7 - 9. Some other inferential correlations

Three sites which have not been examined during the present investigations are referred (fig. 40) to the mid-Tertiary surface; Isle of Wight Hill (SU 249373), Clarendon Hill (SU 224489) and Dunch Hill (SU 211482). In the literature no drifts are described at these sites.

10 - 18. Other locations examined

Several other tracts, referred by Wooldridge and Linton to the Pliocene marine plain, have been studied during the present investigation. No evidence of the marine transgression is recognised but neither is the ground correlated in this account with the mid-Tertiary surface.

10 - 12. North and East of Salisbury Plain

Three sites to the North of the main area of investigation have been examined; (10) Wick Down (SU 261530)(605' O.D.), (11) Hill Barn (SU 191645) (650'- 675' O.D.) and (12) The Plain (SU 248695) (575'- 600' O.D.). At sites (11) and (12) the bevelling of the Chalk is remarkably conspicuous but in all cases surface indications suggest the debris of Lower Tertiary formations and there is no evidence of Pliocene shingle. At Wick Down a small (2" diam.) rounded fragment of chalk breccia with crystalline calcite cement was collected. No attempt is made in this thesis to evaluate the actual significance of these sites.

13. Pentridge Hill and 14. Beacon Hill

These two sites have been described in Part One of this thesis and appear to represent fragments of the sub-Eocene surface. There is no reason to believe that the drifts described in Part One might be of Pliocene age.

15. Vale of Wardour and 16. Ebble Valley

Work on the identification of Pliocene material in drifts on the Grovely Upland was supplemented in an examination of some Chalk summits on the South side of the Vale of Wardour on ground referred by Wooldridge and Linton (1955) to the Pliocene marine plain. No trace of drift, other than the flinty residuum of the underlying Chalk, is detected at the appropriate level either on the escarpment bounding the Vale of Wardour in the South (surface indications and samples from two sites above Burcombe Ivers (SU 040285; SU 046286) or on the summits lying to the South of the Ebble valley (surface indications about Cutlers Corner, SU 024215, and on Knowle Hill, SU 035231).

17. Newton Barrow

No surface indications of drift are seen at this point (SU 101355)

18. Oldbury Camp (Codford Circle)

This site has not been examined during the present investigations. Jukes-Brown states that the Clay-with-flints occurs:

> "in connection with the Eocene outlier at Clay Pit Hill and extends thence along the ridge to the Southwest as far as Oldbury Camp."
>
> Jukes-Brown, 1905.

Conclusions

The objections which have been maintained to disprove the concept of a marine transgression across the Grovely Upland are inherent in the evidence presented here: 1. The failure to recognise any trace of the appropriate Pliocene sand and shingle. 2. At sites one to six the preservation on the abrasion surface of an unconsolidated residual drift indistinguishable from drift on the undisputed relics of the mid-Tertiary surface. The nature of the drift in fact suggests that correlation with the mid-Tertiary surface is as plausible in these six cases as it appears to be on the Grovely Upland. The nature of the drift is however only one of several independent circumstances which tend to substantiate this correlation and which are adopted in this account to characterise the mid-Tertiary surface in Wessex. This characterisation is supported more or less in detail by Chorley's descriptive accounts (1957) of the mid-Tertiary surface in the Paris Basin.

DEFINITIVE FEATURES ON THE MID-TERTIARY SURFACE IN WESSEX AND SOME COMPARATIVE ALLUSIONS TO THE PARIS BASIN

Deformation of the Surface

Wessex

Profiles drawn through the summits referred to the mid-Tertiary surface (fig. 40) suggest a feature broadly downwarped in the South and East. Small (1964) has already suggested some of the correlations proposed here and we are concerned only to dispute again his view that the ground in question is part of the sub-Eocene surface (fig. 38). The point may perhaps be made that the uniform origin of this surface seems also to have been inferred by Wooldridge and Linton (1955) although their final interpretation of this ground is rather ambiguous. Discussing the uniform aspect of the Chalk uplands in southern Wiltshire they state that:

"Ridges of markedly contrasted structure,

> respectively synclinal, homoclinal and anticlinal thus exhibit the common feature of bevelled summit areas which decline gently eastwards. If points of corresponding altitudes on each ridge be joined the resulting contour lines run smoothly across the map and may be taken as at any rate a first approximation to the contours of the Mio-Pliocene peneplain."
>
> Wooldridge and Linton, 1955, p.40.

It is subsequently extablished in their account that the peneplain declines here to a level below 600' O.D. Elsewhere however in the same account (figs. 10 and 17) a substantial tract at the eastern end of each of these ridges is shown to be correlative with the Pliocene marine abrasion surface. The results obtained during the present investigations and a consideration of Pliocene coastal morphology in the London Basin, suggest that these conclusions are mutually inconsistent. If however the transgression of the Pliocene sea onto the Wessex Chalk is illusory, the correlation of certain problematic summits with the mid-Tertiary surface proves eminently reasonable. The suggested reconstruction conforms well with views formerly expressed by Wooldridge and Linton on downwarping of the mid-Tertiary surface in Wessex. Writing of the relation between the sub-Eocene and mid-Tertiary surfaces in southern Wiltshire, they state that:

> "The older surface is thus tilted along this

particular line of section four times
as steeply as the newer one."
Wooldridge and Linton, 1955, p.41.

Their figures are in fact 120' per mile and 30' per mile. However the concept of an appreciable deformation of the mid-Tertiary surface seems now to have been rejected by Linton (1964).

The Paris Basin

Deformation of the mid-Tertiary (Aquitanian) surface in the Paris Basin has been established by Cholley:

"Le Miocène paraît avoir réalisé une surface d'aplanissement étendue incorporant tous les éléments de surface plus ou moins discontinues ésquissés anterieurement. Au moment ou la pénéplaine est en voie d'achèvement, de nouvelles déformations tectoniques entrent en jeu, provoquant une reprise d'érosion, vraisemblablement à l'aube du Pliocène."
Cholley, 1957, p.166.

Conflicting views on late Tertiary tectonic movement

Linton argues that in this country the mid- Tertiary cycle was terminated by:

"A true transgression submerging ground already eroded to a lower level and sparing areas less thoroughly degraded." Linton, 1964)

Linton's conclusion reflects the prevailing tendency in

British geomorphology to extend the period of structural stability back towards the conclusive deformation of the Oligocene strata and to recognise unequivocal evidence of later deformation only upon the margin of the active North Sea geosyncline where it is clear (Shotton, 1962) that deposits of Red Crag (Lower Pleistocene) age have been downwarped (cf. also Boswell, 1952; Coleman, 1952; Kellaway and Taylor, 1952)(see fig. 37).

In the light of this attitude Pinchemel (1954) discerns:

> "Un point de divergence fondamental entre les morphologues anglais partisans d'une pénéplanation Néogène et leurs confrères du continent. Ces derniers estiment tous, à juste titre croyons-nous que le cycle d'érosion qui a abouti à l'élaboration d'une topographie sénile se place entre deux périodes orogéniques, celle qui marque l'exondation du Bassin Parisien à la fin de l'Oligocène et le paroxysme pontien (Upper Miocene - Lower Pliocene) qui est responsable de la deformation de cette surface miocène"
>
> Pinchemel, 1954, pp. 129-130.

To this view Pinchemel opposes that of Wooldridge and Linton who in his opinion:

> "Considèrent que cette surface est postèrieure aux derniers mouvements tectoniques tertiaires qui seraient fini-oligocènes."
>
> Pinchemel, 1954, p.130.

Pinchemel accepts the continental reading of events and concludes that:

> "Il paraît cependent difficile d'admettre que les mouvements de la fin du Miocène ne se soient pas propagés en Angleterre." Pinchemel, 1954, p.130.

A conclusion with which the results set out in this thesis are essentially in agreement.

The Superficial Geology of the Surface

The Clay-with-flints problem

A residual drift is preserved on the tracts of ground referred in this account to the mid-Tertiary surface. Where this drift has been detected by the Geological Survey it has invariably been mapped as Clay-with-flints. Unfortunately the term Clay-with-flints has been applied to a number of other doubtful and ill defined relics, but a study of the Clay-with-flints during the present investigations shows that this indiscriminate usage is a relatively trivial problem. Even on the ground referred to the mid-Tertiary surface, where uniform origin and development might be expected to impose a certain uniformity of composition and morphology in the drift, the character of the Clay-with-flints is far from consistent. At the same time the residual drift on the mid-Tertiary surface proves indistinguishable from residual drifts of more recent origin and it must be appreciated that the preservation of a residual drift is of diagnostic value in the recognition of the mid-Tertiary surface only where it is substantiated as it is in this case by convergent evidence. These difficulties have been encountered in the interpretation of the mid-Tertiary surface in the Paris Basin and are described by Cholley:

> "Les dépôts de pénéplaine sont assez rares ou très difficile a discerner . . . ce sont surtout les restes de 'pavage' que nous devrions y retrouver."
>
> Cholley, 1957, p.165.

On the Plateau du Thimerais Cholley has recognised the extension of the mid-Tertiary surface onto the Chalk. Of the Clay-with-flints here he writes:

> "C'est la formation la plus repandue; elle constitue le sous-sol de toute la region. On peut faire, à son sujet, deux remarques: 1. Son épaisseur est très variable . . . ; 2. Sa structure n'est pas homogène."
>
> Cholley, 1957, p.70.

The significance of Eocene material in the Clay-with-flints

For southern Wiltshire a tentative rationalisation of the inconsistencies in the drift on the mid-Tertiary surface can be attempted. It suggests that as the boundary is approached where the mid-Tertiary surface might originally have been expected to intersect the sub-Eocene surface and pass onto the Eocene outcrop, the Clay-with-flints tends to contain an increasing volume of Eocene material and in some cases is only with difficulty distinguished from the clays of the Eocene Reading Beds. On the other hand at sites on the Chalk remote from this critical boundary the Clay-with-flints consists almost exclusively of the residuum of the Chalk itself.

An affinity between the Clay-with-flints and the Eocene Reading Beds was recognised by Jukes-Brown (1906) and has often been argued in accounts which deal with ground near the Eocene boundary (e.g. White, 1925); that proximity to the Eocene outcrop might be a significant limitation was not recognised by Jukes-Brown who proposed that the Clay-with-flints rests upon an extension of the sub-Eocene surface; a view which has more recently (1954) been argued by Pinchemel but is demonstrably false in the case of the Great Ridge - Grovely Upland.

The Relation of the Surface to Earlier and Later Features

Early Tertiary residuals

The mid-Tertiary surface is surmounted in southern Wiltshire by residual eminences upon which traces of Palaeogene formations are preserved. The partial nature of the mid-Tertiary planation was suspected by Wooldridge and Linton who showed the summits of Cold Kitchen Hill and Brimsdown Hill in their type locality to be:

> "residual eminences rising slightly but definitely above the peneplain."
> Wooldridge and Linton, 1955, p.42.

In this thesis a similar residual relation to the mid-Tertiary surface is argued in the case of Sidbury Hill and Beacon Hill and is suspected in the case of Cley Hill. A relationship of this type has been demonstrated by Waters (1960) in southwestern England, where a surface "bearing the remains of an Eocene formation" rises above a more extensive surface which "carries only an angular drift of subaerial origin" (fig. 18). The lower surface is correlated by Waters with the mid-Tertiary surface of Wooldridge and Linton in South East England. The imperfection of the mid-Tertiary surface in the Paris Basin has been described by Cholley:

> "La surface miocène n'a pas dû s'achever

partout; sur certains interfluves,
des reliefs non réduits ont persisté."
Cholley, 1957, p.165.

Late Tertiary dissection

It will subsequently be shown that the several tracts of ground referred in this account to the mid-Tertiary surface also bear a uniform relation to a surface of more recent origin at a lower level; a circumstance tending to confirm the uniformity of the mid-Tertiary surface itself (see Part Four of this thesis).

CONCLUSION

The mid-Tertiary Surface in the Tertiary Context

Although the evidence at present available is insufficient to establish the exact plane occupied over southern Wiltshire by the sub-Eocene surface, an acutely convergent relation with the mid-Tertiary surface is indicated particularly by the relatively slight elevation of the residual summits at Cold Kitchen Hill, Sidbury Hill, Beacon Hill and in a more problematic vein at Cley Hill. The declination of the mid-Tertiary surface is evidently towards the centre of the Hampshire Basin and maintains the pattern already established there at the beginning of the Tertiary period. At its northern margin in the Hampshire Basin the Tertiary outcrop rests extensively upon the Belemnitella mucronata zone of the Chalk, but at the western end of the London Basin largely upon the sub-zone of Uintacrinus westphalicus. This broad discrepancy seems to demonstrate a planation, in late Cretaceous or early Tertiary times, across the zones of the Senonian Chalk;

> "And we are thence led to infer that the Chalk itself prior to or during its planation . . . had acquired a slight convergent inclination towards a depression which centred in or to the South of the area now occupied by the Isle of Wight and Bournemouth Bay."
>
> White, 1921.

This regional downwarp seems to have persisted during the Palaeogene period, independently of suspected activity on local fold axes (see Part One). Bearing in mind this recurrent pattern in the Hampshire Basin, it is arguable that the mid-Tertiary surface itself is indistinguishable in terms of origin and morphology from the older elements of the polygenetic surface, loosely termed sub-Eocene (fig. 42). It seems permissable to recognise in

Wessex an indication, perhaps not altogether surprising, of the sequential arrangement convincingly elaborated in the Paris Basin by Cholley:

> "Dans le partie centrale de la cuvette Parisienne les différentes surfaces sont superposées, c'est-à-dire divergentes et séparées les uns des autres par les dépôts marines, lagunaires ou lacustres intermédiaire et ce n'est que sur les bordures qu'elles sont convergentes (surfaces polygeniques)." Cholley, 1957, p.162.

The Significance of Differential Tectonic Movements during the Tertiary Period

If it is correct to argue that late Tertiary events maintained the rhythms realised in the Palaeogene, it seems reasonable to suggest at least tentatively that the failure of the Pliocene (Diestian) marine transgression or of the early Pleistocene (Red Crag) transgression to penetrate extensively into the Hampshire Basin may indicate the recurrence of a tendency which appears to have characterised the marine incursions of the Palaeogene. The Tertiary stratigraphic record, particularly the extensive development of continental facies in the Hampshire Basin suggests that marine conditions there had, on more than one occasion during the Palaeogene, been less widespread and of shorter duration than in the London Basin (e.g. during the Sparnacian and Ypresian). This contrast reflects to some extent the approach of the Palaeogene transgressions from a northern or northeastern quarter and their eventual withdrawal towards the same quarter (cf. Pinchemel, 1954, p.78: "Les épisodes continentaux . . . ont donc été plus prolongés dans le bassin de Paris et le Hampshire que dans le bassin belge et le bassin de Londres.").

The implication of this arrangement seems to be that, the downwarping of the synclinal tracts had been a differential affair during the Palaeogene; and there is no good reason to discount analagous differential movement later in the Tertiary period, admitting a Pliocene (Diestian) transgression, and a possibly separate early Pleistocene (Red Crag) transgression, to the London Basin where there is acceptable stratigraphic evidence of these events but not to the Hampshire Basin where there is no unequivocal evidence of marine transgression.

PART IV

PART IV: SUMMARY AND NOTES ON THE ORIGINALITY OF THE WORK

The greater part of this account is essentially the result of original thought. This summary gives some indication of the views which have guided the work.

1. The history of the concept of superimposition is discussed.

2. A re-interpretation of the drainage pattern in the Vale of Wardour is based on conclusions regarding the drifts described in Part Two of this thesis (and particularly the 'relics of gravels') and on ideas suggested by Small's concept of 'piedmont slopes' (1961).

3. The concept of a widespread structural surface occupying Salisbury Plain is rejected.

4. A concept of erosional planation on Salisbury Plain is based on an adaptation of Gifford's 'Higher Plain' (1957). Treatment of this surface includes an original descriptive account of the drifts by which it is occupied.

5. Views on the nature of the 'Higher Plain' are based on comparisons with evidence presented by King (1962).

6. Views on the chronological age of the 'Higher Plain' and its analogues are based on a European Tertiary structural model. Very original conclusions are suggested regarding the nature of late Tertiary and early Pleistocene events in southern England.

7. An interpretative account of the origin of the present drainage pattern includes descriptive details of original work on various river gravels.

PART IV: EVIDENCE OF A LATE TERTIARY SUBAERIAL PLANATION IN SOUTHERN WILTSHIRE: THE KEY TO THE DRAINAGE PATTERN

HISTORICAL BACKGROUND TO A STUDY OF EPIGENESIS IN SOUTHERN ENGLAND

The concepts of a Mio-Pliocene summit peneplain and a subsequent Pliocene marine transgression were extended into Wessex largely in an attempt to explain the conspicuously discordant nature of the drainage there with respect to the flexures of Alpine aspect and supposed mid-Tertiary date (fig. 60). These concepts represent the latest progress in a long history of investigation.

During the nineteenth century several important papers on the drainage of Britain (Ramsay, 1863; Foster and Topley, 1865; Topley, 1875), guided by the work of Jukes (1862), and dealing principally with the Weald, proposed that the rivers there had originated on a slightly inclined plain of marine denudation. Davis on the other hand believed that:

> "The adjustment of streams to structures has been carried to a higher degree of perfection than it could have reached in the first cycle." Davis, 1895.

and he concluded that:

> "The land has been at least once worn down to a lowland of faint relief and afterwards broadly uplifted, thus opening a second cycle of denudation.
> Davis, 1895.

This view implies however a measure of adjustment between drainage and geological structure which was subsequently seen to be absent in parts both of the Weald itself and of Wessex. In the light of this discrepancy Bury (1910) and White (1912) resorted again to the earlier concept of superimposition from a surface of marine planation on which the topographic expression of the geological structure had been obliterated. Wooldridge and Linton (1955) refine the concept of marine planation and infer the partial extent of the operative marine transgression. This inference appears to reconcile the conflicting views of earlier authorities.

The events visualised by Wooldridge and Linton, and particularly the transgression of the Pliocene sea across the Wiltshire Chalk, are disputed in Parts Two and Three of this thesis and it is imperative that an alternative scheme of drainage development be supplied. In the light of the evidence so far considered, and by an examination of the existing relief and drainage pattern, such a scheme can be inferred.

THE SUBAERIAL SURFACE IN THE VALE OF WARDOUR

Introduction

The drifts about the Vale: Summary of conclusions

It is accepted that the Jurassic and Lower Cretaceous debris resting on the Chalk escarpment to the South of the Vale of Wardour and in the North at Willoughby Hedge, represents evidence of gradients respectively southward and northward from the axis of the anticline. The transverse gradients of these streams can be explained only by renewed uplift on the anticlinal axis in the Vale of Wardour. It has already been shown in Part Two of this thesis that transverse gradients are not likely to have survived during the denudation of the Vale; and that the distribution of the debris would in any case be difficult to reconcile with a concept of transverse gradients which had persisted in this way. The same factor precludes a concept of transverse gradients initiated during the deformation of the mid-Tertiary surface which is believed to have terminated the mid-Tertiary cycle. Had a planation surface extended indifferently across the geological outcrops at the effective period of uplift on the axis of the anticline, evidence might be expected of unrestricted transverse gradients southward and northward into the neighbouring synclinal tracts.

The failure to recognise any trace of Jurassic or Lower Cretaceous debris in the drifts on the Great Ridge Grovely Upland, on the ground referred in this thesis to the mid-Tertiary surface, suggests that some restriction interfered with the northward inclination of the transverse gradient on the northern limit of the anticline. On the southern limb, the situation of the Upper Greensand debris at the Zig Zag on a bevel cut in the scarp face suggests the possibility that the southward gradient was in fact interrupted by a pre-existing scarp. It must therefore be assumed that the Jurassic and Lower Cretaceous debris represents evidence of gradients initiated on a planation surface elaborated in the Vale of Wardour during the dissection of the mid-Tertiary surface.

<u>The drainage pattern in the Vale: Some controversial aspects</u>

The modern drainage pattern in the Vale of Wardour tends to confirm the competence of transverse gradients during the present cycle. The arrangement of the principal streams tributary to the Nadder, and in three cases their alignment with the relics of gravel on the Chalk escarpment in the South (fig. 45), suggests that the streams in question indicate the courses of streams consequent on the inferred southward gradient in the Vale. If this argument is correct the consequent streams must have been dismembered by subsequent tributaries which now comprise the Nadder itself.

> "The Vales of Wylye and Wardour are well known to be anticlinal and the streams by which they are drained cannot therefore have always occupied their present sites."
>
> Wooldridge and Linton, 1955, p.67.

The relatively well preserved traces of the original pattern seem to indicate that the entire adjustment has taken place during the present cycle. Wooldridge and Linton (1955, p.67) have argued conversely that the degree of adjustment is sufficiently complete to substantiate a view that the accordant elements in the drainage pattern have survived from the mid-Tertiary cycle:

> "Revived and matured successors of a well adjusted system of consequent and

> subsequent drainage inherited from an earlier and far advanced cycle of denudation." Davis, 1895.

Bury (1910) has shown, however, with convincing examples in the Weald, that the integration of subsequent drainage dows not necessarily reflect continuity of evolution during two erosional cycles. He condemns an uncritical acceptance of:

> "Prof. Davis's individual judgement as to the rate at which a subsequent system is likely to be formed." Bury, 1910.

The Origin of the River Ebble: The Upper Reach

The recognition that the drainage pattern in the Vale of Wardour might be of epigenetic origin provides scope for a new approach to the whole problem of epigenesis on the Wiltshire Chalk; scope which is particularly opportune, since the effective concept of marine planation during the Pliocene can no longer be sustained in southern Wiltshire (see Part Three of this thesis). We are bound therefore to consider the possible significance of subaerial planation during the late Tertiary period.

<u>The piedmont slope concept</u>

Small (1961) in an important theoretical study of the Chalk esdarpments has recognised that during the 'middle stage' of peneplanation:

> "Once downward corrasion is virtually halted the escarpment will not of course cease to evolve; though it will now do so in a special manner. Hitherto the base of the scarp slope will have been continually migrating both backwards and downwards, that is, roughly along the junction line between the Chalk and the underlying clay/sandstones. With the restrictions imposed by proximity to base level, the downward element in the migration will be eliminated, and backwearing therefore becomes the main process moulding the scarp face. The slope of the latter will be further eroded, and will either slowly lose its angle, or, more probably will retreat whilst retaining its steepness owing to the continued action of springs at its base and perhaps even to lateral corrasion of a strike stream beyond the escarpment. If such parallel retreat does take place, a piedmont slope of low angle and ever increasing breadth will form on the Chalk outcrop at the foot of the scarp slope." Small, 1961.

Small's account describes a process (fig. 46) which in its later stages is not readily distinguishable from the process of 'pediplanation' envisaged by King (1962, pp. 135 et seqq.). This analogy is more explicitly developed later in this thesis.

Drifts and drainage on a piedmont slope in the South of the Vale

The distribution of Jurassic and Lower Cretaceous debris on the outcrop of the Chalk to the South of the Vale of Wardour proves to be consistent with deposition on a Chalk piedmont slope of the general type visualised by Small. This conclusion is not altogether self-explanatory; Small's concept implies essentially northward transverse (obsequent) gradients on the tract in question. The southward gradients which have in fact been recognised (in Part Two of this thesis) must therefore reflect uplift on the axis of the anticline.

The inferred interruption of the southward gradient is equated with the erosional escarpment predicted in association with the piedmont slope by Small, and recognised on the ground between Melbury Hill and Marleycombe Hill and possibly further East as well. At or near the foot of this escarpment the ancestral Ebble appears to have flowed eastward (fig. 48).

The ancestral passage of the Ebble, eastward, from the outcrop of the Upper Greensand, across the Lower and Middle Chalk and onto the Upper Chalk is indicated, if not conclusively demonstrated, in the present valley of the Ebble at Barrow Hill.

Barrow Hill

On this summit (ST 994235) at a level of rather more than 600' O.D. abundant sub-angular Upper Greensand debris is seen scattered on the surface of the Chalk. A large fragment (6" long) of chalk breccia with crystalline calcite cement was picked up here during the present investigation; it resembles the material collected on Swallowcliffe Down and above Berwick Coombe.

The extent of the piedmont slope

The prolongation of the southward gradients towards an escarpment beyond the axis of the Ebble syncline (fig. 47) implies that the summit of the White Sheet Hill - Chiselbury Upland must be referred to the piedmont surface. This view does not accord with Small's own reconstruction of the piedmont slope in this part of the Vale of Wardour. Small argues that the piedmont slope cut in the Chalk here did not extend southward beyond the Whitesheet Hill - Chiselbury escarpment. A consideration of the geological outcrop shows that in this case the piedmont slope was cut in the relatively incompetent Lower and Middle divisions of the Chalk. In the North of the Vale however Small infers a broad piedmont slope cut in the intractable Upper Chalk, which seems to be a much more impressive achievement.

It might be objected to the reconstruction of the piedmont surface proposed in this account that, whereas only a very small fragment is preserved at the Zig Zag, the preservation of a broad remnant may be inferred between White Sheet Hill and Winklebury Hill (fig. 47). This disparity implies that the surface has been effectively dissected, and in fact almost entirely consumed in one place but not in another only three miles distant. It seems correspondingly difficult to accept the inference of an uninterrupted surface. A consideration of the geological outcrop shows however that whereas the surface is preserved on the Upper Chalk at the White Sheet Hill - Chiselbury Upland, at the Zig Zag it is preserved on the relatively incompetent Middle Chalk which is brought up to a level of 700' O.D. at this point in the Bowerchalke flexure. The remnants of the piedmont surface on the White Sheet Hill - Chiselbury Upland evidently lie very dose to the feather edge of the Upper Chalk and it may therefore be inferred that the piedmont surface was also cut in the Middle Chalk at this point but has been destroyed as effectively here, as it has at the Zig Zag, by the subsequent erosion of the Middle Chalk.

The relative age of the piedmont slope

Small believes that the piedmont slopes in the Vale of Wardour were elaborated during the final stages of a Mio-Pliocene subaerial peneplanation. His theoretical considerations show that at this stage:

> "The various piedmont slopes will themselves become graded into the very gently inclined back-slopes of the Chalk. They will, in fact, have become part of a peneplain surface; and they will no longer be recognisable as separate entities."
>
> Small, 1961.

It has already been shown however in Part Two of this thesis that if a correlation is accepted between the Jurassic and Lower Cretaceous debris on the White Sheet Hill - Chiselbury Upland and the Upper Greensand debris on the Zig Zag bevel, then the piedmont slope is cut at a level some 150' below the mid-Tertiary surface and is therefore likely to be of a correspondingly later date.

The Origin of the River Nadder

The interpretation of the drifts

The character of the drainage pattern in the North of the Vale tends to confirm the suggested reconstruction of the piedmont slope in the South. To obtain a gradient sufficiently steep to permit the transport of the largest elements among the Jurassic and Lower Cretaceous debris on the South side of the Vale, the axis of the anticline must have been uplifted to a level substantially above the remnants of the mid-Tertiary surface on the Great Ridge - Grovely Upland. In fact the Upper Greensand at Beacon Hill does rise some 50' above the mid-Tertiary surface on the Chalk at Cratt Hill (fig. 49). In spite of this arrangement, and notwithstanding the recognition of Jurassic and Lower Cretaceous debris on the Chalk at Willoughby Hedge, implying a northward gradient at this point, there is no evidence in the drifts on the Great Ridge - Grovely Upland of Jurassic or Lower Cretaceous material which might suggest a prolongation of the northward gradient across the upland. There are however the extensive relics, originally recognised by Small (1961), of a piedmont slope cut in the Upper Chalk. This surface proves to be at a level below the summit surface and is separated from it by an obscure but effective scarp (fig. 51).

The interpretation of the anomalous drainage pattern

On the piedmont slope here the East - West components in the drainage pattern are conspicuous and indeed remarkable (fig. 50). It is difficult to imagine how this peculiar drainage pattern may have arisen on the outcrop of the Chalk, either during the mid-Tertiary cycle or during the present cycle. In fact it is at first difficult to see why drainage on the outcrop of the Upper Chalk, theoretically 'outside' the Vale, should be so well integrated with the subsequent drainage 'inside' the Vale. Small (1961) has ingeniously suggested that the streams in question are obsequent developments on the piedmont slope but his account fails to explain the conspicuous East - West alignments in the pattern and was not prepared to account for the preservation of Jurassic and Lower Cretaceous debris on the Chalk at Willoughby Hedge.

These difficulties are obviated, if, at the period of renewed uplift on the anticlinal axis which created a gradient southward from the axis, a complementary northward gradient is visualised. Drainage guided by this gradient passed northward across the piedmont slope cut in the Upper Chalk, but its course was interrupted here, as it was in the South of the Vale, by a low erosional scarp, separating the piedmont slope from the mid-Tertiary surface on the Great Ridge - Grovely Upland (fig. 51). At or near the foot of this escarpment the ancestral Nadder appears to have flowed eastwards. The conspicuous East - West components in the drainage pattern on the outcrop of the Upper Chalk referred to the piedmont slope comprise the dismembered relics of this former course (fig. 48).

The Planation of the Jurassic and Lower Cretaceous Outcrops

The widespread recognition of the piedmont surface in the Vale of Wardour may well explain the problematic absence of residual drifts on the summits of the Upper Greensand and Portland outcrop in the Vale. Where the piedmont slope is preserved on the outcrop of the Chalk it is generally distinguished by the absence or very slight development of residual drifts. The high levels to which the summits of the Upper Greensand and Portland outcrops rise are consistent with the predicted uplift of the piedmont surface above the axis of the anticline (fig. 49).

Drainage on the Northern Dip Slope of the Chalk

If this interpretation of drainage evolution in the Vale of Wardour is accepted evidence must be sought of a separate system of drainage, consequent on the dip slope of the Chalk to the North of the escarpment which separates the piedmont slope from the mid-Tertiary surface. This evidence is in fact forthcoming.

Historical background

Geographers studying the drainage pattern on Salisbury Plain (Wooldridge and Linton, 1955; Pinchemel, 1954) have been impressed by the unusual character of the principal left bank tributaries of the Wylye and have offered explanations of their form. Wooldridge and Linton note that the upper courses of the tributaries are:

> "Essentially synclinal flowing down the pitching western end of the trough which underlies Salisbury Plain."
> Wooldridge and Linton, 1955, p.67.

But both streams make an abrupt inflexion and cut their way against the dip out of the synclinal tract. Wooldridge and Linton suggest that the inflexion marks the position of the Pliocene shoreline here.

> "It is possible that these sharp bends in the two valley systems actually mark points in the Pliocene shoreline."
> Wooldridge and Linton, 1955, p.67.

Pinchemel (1954) has already objected to this view on the very reasonable grounds that, to accommodate it the Pliocene shoreline has been indicated at a level below 600'. He suggests an alternative view (fig. 52) that the upper reaches of the streams in question mark the former course of a river consequent upon the eastward inclination of the Pliocene marine planation surface and more or less adjusted towards the axis of the Salisbury Plain syncline. Pinchemel concludes that this consequent has been dismembered by left bank tributaries of the anticlinal Wylye 'par un processus de capture classique'.

Re-interpretation

It has already been established in this study that the Pliocene marine transgression, upon which Pinchemel's concept of epigenesis depends, cannot be substantiated on the Wiltshire Chalk. It is therefore proposed that the lower courses of the streams in question are consequent upon the renewed expression of the Wardour anticline and formerly flowed, not southward as they now do, but northward to join a stream occupying the axis of the Salisbury Plain syncline. The arrangement of the dry valleys tributary to the lower courses of the Till and Imber Brook (fig. 53) strongly support the belief that these problematic streams formerly flowed in the opposite direction. (cf. figs. 86-89, showing behaviour of tributaries in cases of capture undoubtedly effected during the Pleistocene period.)

The rather well preserved traces of the original pattern tend to confirm the view that the initiation of these streams was correlative with the initiation of drainage on the piedmont surface in the Vale of Wardour where evidence of the original scheme has also been discerned.

Structural implications

This correlation suggests that the activity on the Wardour anticline, responsible for the deformation of the piedmont slopes, was not accompanied by activity on the Warminster flexure sufficiently effective to re-establish the synclinal role of the Grovely axis. This evidence only confirms the complexity of the tectonic model which has been discussed in Part One of this thesis.

The Mere Fault

The context of the investigation

The northward course of the Wylye above Warminster is against the dip of the underlying Chalk and appears to reflect the northward gradient inferred on Salisbury Plain; but it is interesting to observe that the Wylye cuts through the ridge of high ground referred to the mid-Tertiary surface which, further East is inviolate throughout an extent of some fifteen miles. It seemed possible that this contrast might somehow reflect the proximity of the Mere fault and a study of this possibility has drawn attention to certain features which do distinguish the ground associated with the evolution of the fault from ground further East associated with the evolution of the main anticlinal axis. The contrast is interesting and its elucidation has shown that the piedmont slope and associated scarp identified elsewhere in the Vale of Wardour can be recognised and confirmed here in circumstances which appear to be rather different.

The character of the Chalk escarpment (fig. 29)

East of the oblique fault, inferred by Mottram (1961) to terminate the Mere fault at its eastern end, a piedmont slope cut in the Upper Chalk is extensively preserved and the Middle Chalk forms an inconspicuous scarp. West of the oblique fault the outcrop of the Upper Chalk has largely been referred to the Mio-Pliocene peneplain by Wooldridge and Linton (1955, fig. 10) and the Middle Chalk forms a bold and impressive scarp, which, although it is close to the Mere fault is not a fault scarp but rises, at Mere, from a bench of Lower Chalk about a mile wide which separates the scarp from the site of the fault itself (fig. 54). This arrangement clearly illustrates an initial stage in the development of a piedmont slope cut indifferently across the Kimmeridge Clay and Lower Chalk. Edmunds (1938) has drawn attention to very conspicuously bevelled spurs on the face of this escarpment at a level of about 550' O.D. (fig. 54). He mentions marine origin in the Pliocene but an examination of the ground, and of a sample of material obtained from an exposure in Chalk rubble on the surface of the bevel, has not yielded any trace of appropriate sand or shingle and it therefore seems more likely that the bevel represents the development of a piedmont slope adjusted to a Pleistocene base level. The extent of this feature, and of the piedmont slope adjusted to the present base level, suggests that a much broader piedmont slope could have been cut here in the Chalk during the same period that it was in fact being cut further East beyond the oblique fault inferred by Mottram, and on the South side of the Vale. Its apparent absence here definitely requires an explanation.

The recognition of the piedmont slope on the Mere Downs

The summits of the Chalk North of Mere, between White Sheet Downs and Willoughby Hedge, have been referred by Wooldridge and Linton (1955, fig. 10) to the Mio-Pliocene peneplain; but it has been suggested in Part Two of this thesis that the absence of deep residual drifts on these summits tends to impair this correlation. It is consistent however with the character of the piedmont surface on the White Sheet Hill - Chiselbury Upland in the South of the Vale where deep residual drifts have not been recognised during the present investigations.

Profiles drawn through the outcrop of the Chalk near Mere tend to support this correlation (fig. 55). They appear to indicate a piedmont slope cut in the Upper Chalk and separated from the mid-Tertiary surface by a low scarp. Not only does this general arrangement conform with the pattern deduced on the outcrop of the Chalk further East but the width of the piedmont slope and the site of the associated scarp correspond very elegantly and it seems reasonable to argue that these features were formerly uninterrupted (fig. 48).

<u>The faults</u>

It is therefore suggested that when renewed movement on the Wardour axis initiated transverse gradients in the Vale, uplift at this point was accompanied by a reversed movement on the Mere fault. (Reversed movement of the order of 150' during the Tertiary period has been demonstrated by Arkell, 1947, on the intra-Cretaceous

Abbotsbury fault about Sutton Poyntz in South Dorset.) The movement on the Mere fault seems to have been associated with movement on a line between West Knoyle and Pertwood and probably beyond this hamlet. There is reason to suppose that this line indicates an extension of the short oblique fault inferred by Mottram (1961).

1. The East - West components in the drainage pattern on the piedmont slope originate at this line; West of the line drainage on the Chalk is essentially northward to the upper Wylye.

2. The profile of the mid-Tertiary surface on the Great Ridge - Rook Hill Upland at the inferred site of the West Knoyle - Pertwood fault indicates a gradient substantially steeper than that observed throughout the whole extent of the ridge East of the inferred fault (fig. 17). The low point in the mid-Tertiary surface between Cratt Hill and Rook Hill may well represent the actual site of the fault line.

3. An examination of the drainage pattern here suggests structural control of minor valley sites along the line of the fault (fig. 56)

The problematic gravel at Willoughby Hedge

The Lower Cretaceous and Jurassic debris at

Willoughby Hedge lies very close to the line of the West Knoyle - Pertwood fault and might well prove to be on the upthrow side; its situation at a level above 700' tends to confirm this possibility, in which case the gravel had reached its present position before the faulting occurred, but nonetheless obviously after renewed uplift on the Wardour axis had initiated a northward gradient at this point.

The unresolved problem of the Upper Wylye

In spite of this evidence that the behaviour of the Mere fault has had a controlling influence in the shaping of the present landscape, and has distinguished the outcrop of the Chalk near Mere from this outcrop further East; the contrast which had been discerned does not seem to explain the course of the Wylye across the residual mid-Tertiary surface at Monkton Deverill. It is provisionally assumed therefore that when uplift initiated the transverse drainage pattern on the piedmont surface in the Vale of Wardour, the ancestral upper Wylye was prevented (by the upwarped eastern margin of the faulted block) from pursuing the eastward course which characterises drainage on this surface elsewhere in the Vale. Instead the Wylye seems to have escaped northward across a low point on the mid-Tertiary surface.

Some Conclusions

The study of drainage evolution in the Vale of Wardour suggests that an original drainage pattern took shape there on a surface of subaerial origin, and although the pattern was initially of transverse aspect, reflecting the deformation of this surface, it very rapidly became adjusted to the outcrop of weak geological formations which had already been exposed during the elaboration of the surface. Apart from this early adjustment it is fairly clear that the present drainage pattern in the Vale has largely been created during superimposition from this surface.

During the deformation of this surface renewed uplift on the Wardour axis seems to have been accompanied by downwarping towards the East. The level of the inferred piedmont slope on both sides of the Vale declines in an easterly direction (fig. 57) and substantial elements in the drainage pattern reflect this slope which approximately coincides with the strike of the geological outcrops in the Vale and therefore with subsequent members in the present drainage pattern. The competence of this gradient no doubt explains the early elimination of discordant components in the initial pattern.

The mid-Tertiary surface has also been shown to decline eastwards but it is difficult, on the basis of evidence in the Vale of Wardour alone, to decide whether this is a reflection of the same movement or whether a convergent relation subsists between the two surfaces (see below).

THE SUBAERIAL SURFACE ON SALISBURY PLAIN

The Scope of the Study

It has been argued in this account that some elements in the pattern of streams and dry valleys on Salisbury Plain are contemporary with the transverse pattern in the Vale of Wardour. This suggests that a feature contemporary with the piedmont slopes in the Vale might be identified on Salisbury Plain and might not only provide additional evidence on the nature of this planation surface but might also explain the origin of the strikingly discordant drainage pattern on Salisbury Plain (fig. 60); a pattern which Linton (1932) has shown cannot have originated on a surface corrugated by the Tertiary flexures (fig. 59).

The Character of the *Micraster* Outcrop

A re-examination of the structural concept

The origin of Salisbury Plain has never been adequately elucidated. Wooldridge and Linton argue that:

> "The Plain as we see it now is largely the exhumed structural surface of the *Micraster* Chalk."
> Wooldridge and Linton, 1955, p.69.

Small (1964) perpetuates this view and he has actually delineated substantial tracts which he refers to the structural surface (fig. 7).

Although the zonation of the Chalk outcrop in this area is not well known, the sub-Senonian surface, at the base of the Upper Chalk, does provide a satisfactory datum defined by the unmistakable Chalk Rock (fig. 61). The concept of a structural surface on Salisbury Plain is not substantiated in a comparison between the contours of this surface and the generalised contours of the present surfade (fig. 62). The generalised contours suggest rather a surface which bevels across the zones of the Micraster Chalk.

A revision of the planation concept (fig. 58)

Gifford (1957) has recognised a surface on Salisbury Plain at levels between 450' and 650' O.D., the Higher Plain (fig. 63), to which the problematic parts of the Micraster outcrop are largely referred. Gifford's treatment of the Higher Plain shows that she does not regard it as a structural surface, but as an expression of the Pliocene marine plain. She has therefore been obliged to correlate it with the summits of the Belemnite Chalk East of the Avon which had been referred to the Pliocene marine plain by Wooldridge and Linton (1955, fig. 17).

Profiles drawn through the Higher Plain show that this correlation involves a quite unacceptable distortion of the surface (fig. 64). In Part Three of this thesis the summits of the Belemnite Chalk have been referred to the mid-Tertiary surface and it seems reasonable to regard the distortion in question as a low scarp separating the Higher Plain from this surface. An examination of the ground on the South side of the Wylye shows that here Gifford's Higher Plain is also separated from the mid-Tertiary surface by a well defined break of slope (fig. 65). We are beginning, in fact, to recognise evidence of the arrangement associated with the piedmont slopes in the Vale of Wardour. Gifford, on purely morphological grounds has already correlated (fig. 63) the tract of Upper Chalk referred to the piedmont slope in the North of the Vale (and of course East of the inferred Knoyle - Pertwood fault) with the Higher Plain, a very astute correlation which is accepted here (fig. 66). On Salisbury Plain, as in the Vale of Wardour, the residual drifts on the surface are thin or absent. Gifford speaks of:

> "A few exceptional places where patches of loamy clay overlie the Chalk."
> Gifford, 1957.

Some Drifts examined on and about Salisbury Plain

During the present investigation Gifford's account has been confirmed.

1. The Codford Circle - Yarnbury Castle Upland

On the high ground between the River Till and the Imber Brook Prestwich has recorded Clay-with-flints on the summit between Clay Pit Hill and Codford Circle:

> "Top covered with flints one to two feet

deep in an earthy coloured sand and
clay occasionally also small white
quartz pebbles." Prestwich, 1898.

This ground has not been re-examined but further East as far as Yarnbury Castle chalk seems invariably to be turned up by the plough, although here and there (sample from small pits dug near Bushes Farm SU 016422 and above Deptford Down Barn SU 025416) the soil is of a reddish brown aspect and proves to contain rather more fine quartz sand and ferruginous material than is encountered in darker, uncomplicated rendzinas. At Bushes Farm one pebble of quartz (⅜" diam.) was recovered. No doubt in this case and in the drift described by Prestwich the quartz reflects proximity to the Palaeogene outlier at Clay Pit Hill.

2.-4. The Vale of Warminster

No drifts are seen on the Chalk summits at (2) Arn Hill (ST 877465), (3) Battlesbury (ST 898455) and (4) Scratchbury (ST 912443). Manley (?1927) has described sand in pipes of limited extent at Arn Hill. He refers the sand to the Bagshot Beds and correlates it with the 'sand' at Cley Hill.

"On Arn Hill (just above the middle curve

> of Kidnappers Hole) it is dull brown on top, large grained and with minute flint chips polished by wave action till lustrous; beneath this is a fine yellow sand." Manley, ?1927.

At the site to which Manley refers (ST 877464) no trace of this sand is now visible and it seems possible that the deposit has been buried or cut out during the extension and improvement of the Golf links which occupy the site.

These summits about the Vale of Warminster might prove to be correlative with the Higher Plain, although Gifford (1957) has referred them to her High Summits group (loosely correlative with the Mio-Pliocene peneplain of Wooldridge and Linton, 1955). The possible preservation of Palaeogene material on Arn Hill does not preclude either correlation. Palaeogene gravel occurs at Clay Pit Hill below the level of the Higher Plain. In fact the morphological context of these sites has not been adequately evaluated during the present investigation.

5 - 8. The Avon / Till interfluve

Four sites are considered, which rise to or approach the level of the Higher Plain.

5. Newton Barrow

Only the flinty residuum of the Chalk is seen at Newton Barrow.

6. Chain Hill

On Chain Hill (SU 087371) at a level somewhat above 475' O.D. a reddish brown flinty soil rests on the Chalk, but chalk is generally turned up by the plough.

7. Heale Hill

At Heale Hill (SU 109369) at a height of 450' O.D. a rather deeper reddish brown drift (Clay-with flints of the Geological Survey) masks the Chalk. In a small pit dug to a depth of 2'.6" chalk is not seen. A sample from this pit consisted of angular fragments of flint in a scanty matrix of clay, packed with flint grit. Apart from one sub-angular fragment of quartz all the material retained in a 1/16" mesh proved to be flint, patinated a shade of greyish white. In the finer fractions minute flint flakes predominate with subsidiary quantities of ferruginous material and quartz sand.

8. Boreland Hill

Clay-with-flints is indicated here (SU 117377) by the Geological Survey on a summit rising above 450' O.D.

9 - 11. The Brimsdown and Great Ridge Uplands

On bevels apparently encroaching on the

northern flank of the Uplands (fig. 65) only the flinty residuum of the Chalk is seen. (9) Fir Clump (ST 854393)(657' O.D.); (10) Tytherington Hill (ST 915395)(600' O.D.); (11) Corton Down (ST 938385)(610' O.D.).

12. The Grovely Upland

At the eastern end of the Upland the mid-Tertiary surface and the Higher Plain of Gifford are indistinctly separated from one another and there is an indication in the profile of the Upland (fig. 17) that the mid-Tertiary surface has been to some extent consumed. At the same time the inferred behaviour of the drainage initiated on the deformed piedmont slope in the Vale of Wardour (fig. 48) shows that the planation of this tract was imperfect and that the upland still formed an effective watershed on the deformed surface (cf. King, 1962, fig. 58, p.147). The drift described at the eastern extremity of the upland (in Part Three of this thesis) is consistent with this interpretation although it is in fact almost indistinguishable from drifts on ground confidently referred to the mid-Tertiary surface. The observed absence of abraded flint fragments in the drifts on ground tentatively referred to the lower surface might prove to be a significant distinction but at present too few sites have been described.

THE CHARACTER OF THE SUBAERIAL SURFACE

Before discussing the role which the 'Higher Plain' has played in the evolution of the present drainage pattern on Salisbury Plain, it will be useful to establish a working hypothesis regarding its age and the nature of the process by which it was elaborated.

Process

A more or less perfect planation of the surface is implied by the discordant drainage pattern which was initiated on it in the course of its deformation. The surface is occupied here and there by shallow Clay-with-flints of residual aspect which, according to King:

> "Corresponds to a duricrust developed upon the Chalk." King, 1962, p.390.

The chalk breccia cemented by crystalline calcite cement which has been identified at several sites near the level of the Higher Plain in the Vale of Wardour could well be the debris of a 'calcrete' associated with this surface.

This surface is separated from the mid-Tertiary surface by an erosional scarp which in the Vale of Wardour has evidently worked from the Jurassic and Lower Cretaceous outcrops onto the outcrop of the Upper Chalk. King states that:

> "Cyclic scarps have in nearly all instances transgressed from weak onto resistant formations."
> King, 1962, p.163.

The conjunction of these circumstances suggests obvious comparisons with the extensive planation surfaces recognised by King and ascribed by him to a process of pediplanation (1962, pp. 135-177). Comparable circumstances in the case of the mid-Tertiary surface have already been described in Part Three of this thesis and favour a view that this planation was effected by the same process (whether or not this was in fact the process of pediplanation visualised by King is less certain). King himself argues that the English landscape:

> "Exhibits some clear pediments in the non-glaciated southern counties, e.g. Wiltshire Downs." King, 1962, p.139.

Chronological Age

The essential evidence

The Higher Plain evidently encroaches on the mid-Tertiary surface and must therefore be of more recent origin;

it is dissected however by valleys which are generally agreed to be of Pleistocene age (Wooldridge and Linton, 1955). It seems reasonable therefore to suggest, at least provisionally, a late Tertiary date. The considerable extent of the surface implies a cycle almost as complete as the earlier mid-Tertiary planation. It seems inevitable therefore that a correspondingly prolonged interval should have been occupied in the planation of the later surface.

History of the Neogene period: the European model

It has been customary to refer the mid-Tertiary surface in this country rather vaguely to the Mio-Pliocene period. Cholley (1957) suggests however that in the Paris Basin the planation of the mid-Tertiary surface was initially adjusted to a late Upper Oligocene (Chattian) base level. Cholley believes that planation persisted in the Paris Basin during the Miocene and was gradually terminated by deformation of the surface which culminated during the Pontian period (a poorly defined stratigraphic unit in the Upper Miocene - Lower Pliocene interval). The period occupied by the planation of the surface appears in this case to have been something like thirteen million years (Kulp, 1961) and coincides, perhaps significantly, with a relatively quiescent tectonic interval in the western Alpine orogenic province.

There is no good reason to reject a similar chronology for the mid-Tertiary surface in this country; in which case the whole of the Pliocene period, an interval of about ten million years (Kulp, 1961), is available for the rather less complete planation of the lower surface.

The definitely southern aspect of faunas described in the Pliocene of this country is not inconsistent with this correlation, in fact it is entirely compatible with the semi-arid climatic conditions in which 'pediplanation' is 'at its best' (King, 1962, p.166).

The obvious objection to this chronology is the approximately equal values assigned to the mid and late Tertiary cycles. This objection can be sustained however only in a scheme which conceives the mid-Tertiary cycle to have effected ab initio the planation of the Tertiary corrugations of the Chalk; but conceives the later cycle merely to have trimmed the earlier surface. This scheme reflects a mistaken view that the folds of Alpine aspect in southern England are the expression of exclusively Oligocene deformation. In Part One of this thesis the arguments against this view are discussed. The evidence of progressive deformation throughout the Palaeogene period cannot be dismissed and although the evidence of extensive denudation during the Oligocene period is largely based on the character of the very small Oligocene outlier at Creechbarrow in Dorset, it is nonetheless irrefutable and admits a view of subsequent Miocene events which accords with the scope of the Miocene (mid-Tertiary) cycle in the Paris Basin:

> "Le Miocène paraît avoir réalisé une surface d'aplanissement étendue incorporant tous les éléments de surface plus ou moins discontinus esquissés antérieurement."
> Cholley, 1957, p.166.

Relation to the mid-Tertiary surface

On Salisbury Plain the evidence of a convergent relation between the mid and late Tertiary surfaces is substantial. In the valley of the Wylye (fig. 65) it can be seen that in the West, about Brixton Deverill, the ground referred to the late Tertiary surface lies some 100' below the earlier surface, whereas near Great Wishford the difference is clearly less than 50' and further East beyond Salisbury the mid-Tertiary, late Tertiary and Pleistocene levels are so close together that the interpretation of the ground proves difficult (fig. 67). The manner in which the late Tertiary surface encroaches on the northern flank of the Wardour anticline suggests that the initiation of the late Tertiary cycle witnessed a slight differential uplift on the Wardour axis, and there can be little doubt that this cycle, at least in southern Wiltshire, was preceded by a phase of mild tectonic activity; a result which accords well with the evidence of intensified tectonic activity at this time on the European continent, not only in the Alpine orogenic province itself (Termier and Termier, 1957; Brinkmann, 1960; Goguel, 1962) but also in peripheral sedimentary provinces (Pinchemel, 1954; Cholley, 1957).

Deformation

Late Tertiary or early Pleistocene movement: the historical background

The evidence in the Vale of Wardour that the initiation of the drainage pattern there was consequent upon folding and tilting of the late Tertiary surface suggests that contemporary deformation of this surface might be recognised on Salisbury Plain. In fact the low level at which the Higher Plain is identified about Amesbury matches a prolongation of the easterly gradient inferred in the Vale of Wardour (fig. 57).

There is good reason to believe that the deformation of the Pliocene surface occurred in the

Plio-Pleistocene interval, or early in the Pleistocene period.

> "One of the most impressive phenomena of the Pleistocene as it is represented in the Old World is the wide distribution of powerful crustal movements."
> Hopwood, 1940.

The concept of deformation in this country during the Pleistocene period is not new, but in recent years its significance has rarely been urged. King in his brief account of Tertiary events in Britain has suggested however that the:

> "Main phase of arching on the British cymatogen seems to have been enacted towards the close of the Cainozoic, though displacements in the same sense obviously occurred both before and after the main movement."
> King, 1962, p.392.

The alternative and prevailing view confines post-Pliocene (and in effect post-Oligocene) deformation to downwarping North and East of an axis passing through Braintree in Essex (fig. 37).

The Tertiary context: structural patterns in Southeastern England

The Braintree axis is more or less parallel with the 'London Ridge' of Wooldridge and Linton:

> "In this great cross-warp which effectively divides the London Basin in two, we see one of the ancestral

traits of the region."
Wooldridge and Linton, 1955, p.9.

It seems reasonable to argue that the Braintree axis reflects a persistence of the structural control exerted by the 'London Ridge' during the earlier part of the Tertiary period, when:

> "The thickness and lithology of the several formations reflected posthumous movements along . . . the main transverse axis (corresponding to the London Ridge)."
> Wooldridge and Linton, 1955, p.11.

If downwarping is accepted during the Neogene period towards the geosynclinal tract underlying the North Sea, to the North and East of this axis, it is difficult to accept structural stability to the South and West of the axis where in the earlier part of the Tertiary period more or less complementary movements have occurred. In fact the evidence presented in this thesis suggests that activity persisted there on fold axes of Alpine aspect, accompanied by slight downwarping towards the geosynclinal tract underlying the Hampshire Basin. At the same time the relative structural stability of the 'London Ridge' proved an effective barrier to late Tertiary or early Pleistocene marine transgressions, of which stratigraphic evidence is preserved in the London Basin, essentially to the North and East of the effective axis (fig. 37).

The significance of the Calabrian sea level

If a Calabrian sea level of 690' O.D or even 650' O.D. is accepted, it is obvious that downwarping to the low levels in question on Salisbury Plain has occurred since the Calabrian period. However the concept of tectonic movement in the late Pliocene or early Pleistocene tends to impair the original premisses from which this level has been deduced, and it is suggested that a re-examination of the evidence might indicate a somewhat lower Calabrian sea level.

This possibility is now apparently recognised in the South West peninsula of Britain; Waters (1960) argues that surfaces at levels below the mid-Tertiary peneplain are without exception fluvial, and of Pleistocene age. Linton observes that:

> "Only locally . . . does it appear that any shoreline earlier than that at 430' (130 m.) can be recognised as having transgressed notably within the present coastline." Linton, 1964.

DRAINAGE EVOLUTION IN THE BASIN OF THE SALISBURY AVON

Introduction to the Problem

In the light of the foregoing account which indicates the progressive evolution of the Tertiary flexures, and rather slight activity on these axes during the Plio-Pleistocene interval, it is not difficult to visualise the emplacement of the discordant elements in the drainage pattern on Salisbury Plain.

The subaerial and marine alternatives

It has already been suggested that the principal left bank tributaries of the Wylye originated during the deformation of the late Tertiary surface. The possibility that the greater part of the drainage pattern elsewhere on Salisbury Plain originated in the same way, provides a very plausible scheme for Pleistocene events. An alternative scheme has been visualised by Wooldridge and Linton (1955). They suggest that the Pliocene sea withdrew early in the Pleistocene period and that the present drainage pattern was initiated at that time on the uplifted sea floor:

"The summit plain at about 550' represents

the elevated sea floor."
Hodson and Shelford, 1964.

During the period immediately succeeding the withdrawel of the Pliocene sea, the rivers exhumed the structural surface of the *Micraster* Chalk. Subsequently the excavation of confined valley troughs has dissected this surface.

Some difficulties inherent in the marine concept

This scheme does not appear to have been seriously disputed at any time. But, quite apart from the evidence, already examined in this account, which tends to refute the concept of a Pliocene marine planation or of a structural surface developed on the Micraster Chalk, the scheme involves inherent difficulties which are obviated if the concept of a subaerial late Tertiary surface is accepted:

1. It is remarkable that no gravels of fluviatile aspect have been detected which might be referred to the period during which the supposed exhumation of the *Micraster* Chalk took place; whereas the highest level at which gravels do occur is on, or only slightly below, the inferred late Tertiary surface, and below this level gravels are common.

2. It is remarkable that no evidence is forthcoming of any adjustment to the drainage pattern, by

capture or uniclinal shifting, during the exhumation of the *Micraster* Chalk, although the lateral erosion involved might be expected to favour both mechanisms; if however the valleys are excavated in the surface on which they were initiated without an effective intervening phase of lateral erosion, then no complication of the pattern can be expected.

3. Our knowledge of the Pleistocene period suggests no event which might explain the abrupt change of erosional behaviour implied by the contrast between the planation which, in effect, the exhumation of the *Micraster* structural surface represents, and the subsequent dissection of the *Micraster* outcrop. Bearing in mind the interpretation of the *Micraster* outcrop which is actually adopted in this thesis, this contrast seems to be a convincing reflection of the nature of the Plio-Pleistocene boundary, which is defined in stratigraphic terms by the intrusion of colder faunas, from which the possibility of intensified fluvial activity may reasonably be inferred.

The Origin of the River Avon

The exact lineaments of the drainage pattern initiated by the early Pleistocene deformation in southern

Wiltshire are not in all cases entirely clear; and the relief which guided their emplacement is largely conjectural. The effective inequalities seem to have been slight particularly to the South and East of Salisbury where the mid and late Tertiary surfaces converge. The discordant course of the Avon is perhaps the most problematic aspect of the pattern.

In the Hampshire Basin

South of Downton (SU 182215) it is no doubt guided by a gentle downwarp towards the centre of the Hampshire Basin; a gradient which was the final expression of a tendency that is seen to have persisted throughout the Tertiary period.

Across the Alderbury syncline

Immediately to the North of Downton, bearing in mind the easterly gradients recognised in the Vale of Wardour it is difficult to understand why the main elements of the drainage did not pursue an eastward course onto the Eocene outcrop in the Alderbury syncline. The evidence shows however that they did not.

1. The drainage pattern in the Alderbury syncline

The pattern of streams and dry valleys in the syncline shows that elements formerly tributary to the Avon have been captured by streams draining to the Test, and there is some indication of the original Watershed between the Avon and Test (fig. 68). Had the Avon originally occupied the synclinal tract it is difficult to visualise a process of capture which might displace it from the weak Eocene outcrop on which the Test is now successfully extending its territory.

2. Common Plantation

This site (SU 201278) is now drained by a tributary of the Test. At a height of about 250' O.D. the gravel here obviously cannot be referred to a former course of the Avon, but, had gravels above this level in the syncline been deposited by an ancestral eastward flowing Avon, the lower gravel might be expected to incorporate material derived from the higher gravels. Upper Greensand chert or sandstone would be of particular diagnostic value. They characterise undoubted gravels of the Avon below its confluence with the Nadder (e.g. Table 20) but could not otherwise reach the Alderbury syncline.

In a pit excavated here the underlying Bagshot Beds are encountered at a depth of 3'.5" from the surface. Below 6"- 8" of humose sandy soil, about 2'.6" of unstratified gravel occur. The gravel includes abraded flint, many of the nodules large (9½" long) and surprisingly unbroken. Well rolled flint pebbles and cobbles of Lower Tertiary aspect and a few cobbles of banded sarsen also occur. No trace of Upper Greensand chert or sandstone is seen in the gravel (Table 22).

At the base of the section the gravel rests with a sharp lower boundary on a seam (5" thick) of bright reddish-brown sand incorporating small fragments of abraded sub-angular flint. Horizontal stratification is well defined in this seam. The flint is patinated matt. white. This seam rests on compact dull yellow stoneless sand from which the auger could not be withdrawn at a depth of 1'.6" from the floor of the excavation. This sand appears to be the Bagshot Beds <u>in situ</u>.

In the gravel at a depth of 23" from the surface a very much abraded artificial flake (2⅞" long) of Palaeolithic aspect was recovered.

3. Clearbury Ring

At Clearbury Ring (SU 152244) at a level of about 450' O.D. the debris of a gravel of Pleistocene aspect has been detected in a pit dug during the present investigations.

The coarse gravel (Table 16) consists largely of angular and sub-angular flint. The sub-angular flint is clearly abraded (Plate 43) and resembles material which forms the bulk of the gravels of undoubted Pleistocene age at lower levels in the Valley of the Avon. (Plate 45) The substantial preponderence of rolled and subsequently unbroken fragments over freshly broken fragments, suggests that the gravel has not suffered effective redistribution (compare essentially undisturbed gravel at Bemerton, Table 31, and contrast probably redistributed gravels on Camp Hill, Tables 29 and 30; see also the account of these gravels in Part Five of this thesis). The coarse gravel at Clearbury also includes a substantial quantity of well rolled flint pebbles and cobbles of Lower Tertiary (Reading Beds) aspect (up to 5½" long)(Plate 42). One well rolled cobble (3½" long) of banded sarsen was recovered during the excavation. A few pebbles of Upper Greensand chert and sandstone occur and some ironstone probably of Lower Tertiary origin.

Angular and sub-angular flint comprises the bulk of the fine gravel fraction (5/32"- 1/2") but small pebbles of quartz are abundent and their frequency suggests that the gravel may be of relatively greater antiquity than those examined elsewhere about Salisbury (Table 3). Flint pebbles of Lower Tertiary aspect, ironstone and Upper Greensand pebbles also occur.

The gravel described here is overlain by 6"- 8" of stoneless yellowish brown loam. It forms a bed only 12"- 15" thick which rests with a poorly defined lower boundary on a reddish brown very flinty clay. In the clay (Table 23) nothing but flint is retained in a ½" mesh. The flint is in unbroken nodules or sharply angular fragments. Flint pebbles of Lower Tertiary aspect and abraded flint of Pleistocene aspect are absent in the clay. In the fine gravel fraction (5/32"- 1/2") a very few pieces of quartz and Upper Greensand occur, but their small size and relative infrequency are probably consistent with illuvial derivation from the overlying gravel, in which case the flinty clay itself appears to be of strictly residual aspect. The clay becomes increasingly flinty downwards but the Chalk is not encountered at a depth of 4'.6" from the surface.

At 450' O.D. the Clearbury gravel must be on or only very slightly below the inferred Pliocene surface. The situation of the gravel near the axis of the anticlinal tract which forms the southern limb of the Ebble - Alderbury syncline, indicates that at this point the structures of Alpine aspect lacked topographic expression capable of directing or impeding the drainage initiated on the tilted Pliocene surface. The gravel is therefore provisionally referred to an early course of the Avon.

Effective relief

The evidence discussed does suggest that the discordant southward course of the Avon is of consequent origin. The nature of the relief which interrupted the easterly gradient recognised in the Vale of Wardour and which determined the actual site of the Avon, remains to be established. Further North, on Salisbury Plain where a more convincing interpretation of the relief is possible, the interruption of the easterly gradient appears to have been associated with the erosional scarp separating the Pliocene pediments from the mid-Tertiary surface (fig. 64). The extension of this scarp southward on the Eocene outcrop is a reasonable inference and there is some indication of a pediment surface and associated scarp on the Chalk South of Salisbury (fig. 69). With the scanty evidence available at present, little more can profitably be deduced.

The Origin of the River Ebble: The Lower Reach

The problem

The doubtful origin of the River Ebble was stressed by Linton in 1932:

> "It is impossible to imagine a folding process that could simultaneously give rise to the Ebble together with an Avon capable of cutting the gap through the Chalk at Downton, so we must needs suppose it to be a subsequent outgrowth of the Avon."
>
> Linton, 1932.

In this thesis a stream has been inferred flowing eastwards at the foot of an erosional escarpment between Melbury Hill and Marleycombe Hill (fig. 48) but to the East of Marleycombe Hill the present relief suggests that the mid-Tertiary surface had been to some extent consumed by the Pliocene pediments (fig. 69) in which case the stream in question might well have turned southward towards the Hampshire Basin, guided by the gradient which is seen to have determined the course of the Avon below Salisbury.

An examination of the ground to the South of the Ebble valley has revealed no evidence of material derived from the denuded anticline which might suggest that streams passed southward here at this stage. The actual site occupied by the lower reach of the ancestral Ebble is nonetheless inferential.

Interpretation of the Clearbury Ring gravel

The gravel of Pleistocene aspect at Clearbury is favourably aligned with the inferred upper course of the stream and might mark an early confluence with the Avon. The subsequent history of the Ebble having been one of adjustment towards the synclinal tract which it now occupies.

The character of the gravel at Clearbury tends to confirm this reconstruction. It includes battered flint nodules weighing up to 5 lbs; a consideration of the supposed Pliocene pediment surface shows that to the North of Clearbury, and upstream in terms of the Avon, no other gravels occur at a sufficiently high level to be considered undoubtedly correlative, and an original gradient from this quarter of only one or two feet per mile at most can be inferred (fig. 77) which does seem inadequate to cope with the cobbles in question. It is correspondingly doubtful whether the gravel can in fact be referred to the Avon itself. The nature of the climatic regime in the Plio-Pleistocene interval is, however, uncertain and the larger cobbles could probably have been moved, even across a relatively shallow gradient, by violent seasonal spates. To the West of Clearbury on the other hand, towards the debris of gravels with Lower Cretaceous and Jurassic material in the Vale of Wardour, a much more substantial gradient of about 20' per mile is indicated. The coarse material at Clearbury might have been supplied across this gradient.

Structural and lithological controls

Small (1964) suggests that the emplacement of the present Ebble was favoured by the preservation of Eocene rocks in the synclinal tract. The abundence of flint pebbles of Lower Tertiary aspect in the gravel at Clearbury does suggest the immediate proximity of the Eocene outcrop, but it is not at all clear whether Eocene rocks were preserved in the syncline at the inferred level of the late Tertiary surface. Wooldridge and Linton (1955, fig. 5) indicate a fault, with a throw at one point of over 400', which brings the sub-Eocene surface there up to a level above 800' O.D. (fig. 10). Faulting has undoubtedly occurred here but the site and throw of the fault have not yet been confirmed on the ground, and until more circumstantial evidence relating to this, and to the several other problems encountered, is forthcoming, the evolution of the drainage pattern here will remain speculative.

The Pattern of Valleys on Salisbury Plain

The evolution of the drainage pattern further North on Salisbury Plain is slightly less obscure (fig. 71). On the western part of the Plain a consequent stream originally occupied the synclinal axis. The eastward course of this stream was deflected southward near the site of Amesbury by inequalities on the late Tertiary surface associated with the erosional escarpment which separates this surface from the mid-Tertiary surface preserved on the summits of the Belemnite Chalk. To the North of the synclinal axis drainage was guided by a southward gradient probably consequent on renewed uplift of the Pewsey axis. (This tract of ground lies beyond the scope of this thesis.) South of the synclinal axis tributaries are inferred, which are consequent on the northward gradient created by renewed movement on the Wardour axis.

Pinchemel (1954) has suggested that certain prominent lineaments of the drainage pattern on Salisbury Plain reflect structural control. On the basis of drainage morphology he identifies a synclinal tract passing North-

North-West to South-South-East through Water Dean Bottom and an anticlinal axis passing from North to South through Tilshead. He defines additional synclinal axes passing through Imber and Shrewton, and by North Farm, Starveall and Deptford Field Barn. The village of Chitterne lies on the site of the intervening syncline. It is perhaps significant that the well marked col above West Lavington coincides with a slight fault (Jukes-Brown, 1905) on which Barron (1956) notes a throw of 100'. Nevertheless the contours of the sub-Senonian surface (fig. 61) do not confirm the structures inferred by Pinchemel.

PART V

PART V: SUMMARY AND NOTES ON THE ORIGINALITY OF THE WORK

Many of the conclusions described in this summary reflect the original views which have been expressed elsewhere in this thesis; they therefore contain a substantial element of originality.

1. Adjustments to the drainage pattern in the basin of the Avon above Salisbury during the Pleistocene period are discussed. This account is based on original work in gravels of the Avon and its tributaries about Salisbury.

2. The concept of marine planation in the Hampshire Basin during the Pleistocene period is considered. This account is based on an original re-examination of the composition and morphology of Pleistocene gravels.

3. The possible scope of early Pleistocene subaerial planation of the Wiltshire Chalk is assessed. This account is based on an adaptation of Gifford's concept (1957) of a Lower Plain, and includes original descriptive and interpretative accounts of gravels and residual drifts about Salisbury.

4. The concept of an early Pleistocene subaerial planation is extended into the Hampshire Basin where evidence of the early Pleistocene feature has been recognised (by Green 1936, 1946, inter alia).

5. The problems of scarp recession and the dessication of the dry valleys are described in historical perspective.

6. An original re-interpretation of the evolution of the Chalk escarpments is proposed and its bearing on the dessication of the dry valleys discussed.

7. Evidence of massive Pleistocene denudation is described. This account includes original descriptive passages and a brief discussion of depositional environments.

8. An original concept of a 'climatic cycle' reflecting Pleistocene glacial fluctuations is very tentatively suggested.

9. Evidence in the basin of the Salisbury Avon is considered in the light of the 'cyclic' concept.

PART V: PLEISTOCENE EVOLUTION OF THE LANDSCAPE

THE PLEISTOCENE RE-ORGANISATION OF THE DRAINAGE PATTERN

The Interpretation of the Camp Hill Gravels: I

Introduction

Since the gentle deformation of the late Tertiary subaerial surface, which effectively initiated the present cycle of erosion, the re-organisation of the drainage pattern in southern Wiltshire has largely been a record of local adjustment to geological structure, or more strictly speaking, to weak geological outcrops.

A substantial re-organisation appears to have taken place during the period immediately following the emplacement of the drainage pattern, possibly in the late Pliocene, or early Pleistocene period. The erosional and depositional record of these early adjustments is fragmentary. The interpretation of this record on the ground about Salisbury remains incomplete and a reconstruction of the adjustments is largely speculative.

The Salisbury Avon

On the summit of Camp Hill, gravel is preserved at a height of about 450' O.D. This is the highest gravel to have been recognised North of Salisbury, which can be associated with the drainage initiated at the beginning of the present cycle. Dissolution of the underlying Chalk may, to some unknown extent, have disguised the level at which the gravel was originally deposited. Nevertheless the preservation of a gravel above Laverstock (SU 169309) at a level of about 440' O.D. suggests a tentative grouping of loosely correlative gravels near this level. If this grouping is in any sense valid, dissolution (if it has been effective) would appear to have been essentially systematic.

Camp Hill

Site 1

The summit gravel is seen in small pipes (Plate 44) in a chalk quarry (SU 112339) somewhat below the summit on the northeastern flank of the hill. A sample from this site consists largely of abraded flint fragments (Table 24), the majority subsequently unbroken. This circumstance suggests that the gravel in the pipes, although probably disturbed by dissolution of the underlying chalk, is not redistributed in slope wash or 'trail'. The balance of material in the coarse fraction (more than ½" diam.) is well rounded flint pebbles of Lower Tertiary aspect together with a pebble of quartz and one of fine grained sarsen. In the finer fraction (5/32"- 1/2" diam.) quartz and ferruginous material occur with a few small quartzite pebbles and some very small fragments of chert (possibly Upper Greensand).

Interpretation of the gravel

Reid (1903) suggests that this gravel is a disturbed Eocene outlier, but in terms of composition it is essentially indistinguishable from gravels of undoubted Pleistocene age at lower levels in the valley of the Avon.

In the sample of gravel examined pebbles of Upper Greensand chert or sandstone are very rare and perhaps entirely absent. This deficiency is characteristic of the gravels of the present Avon (Table 25), upstream from its confluence with the Nadder, and is also observed in earlier gravels to which the Avon has been largely contributory (Table 27). Tresise (1960) has shown that North and East of Devizes the Upper Greensand, across which the Avon flows in the Vale of Pewsey, includes no cherts or firmly consolidated sandstones. This observation explains the scarcity of Upper Greensand fragments in gravels of the Avon, and the particular gravel in question on Camp Hill may be referred with some confidence to an early course of the Avon.

On the actual summit of Camp Hill, the Chalk is commonly turned up by the plough and the gravel is shallow and obviously greatly disturbed. No trace is seen however of Upper Greensand chert or sandstone. Gravel of this aspect spreads for at least 300 yards downslope on the southwestern flank of the hill to a level of about 425' O.D. and possibly to lower levels. It is difficult to recognise on the ground any evidence of the boundary indicated by the Geological Survey between Plateau Gravel near the summit and Clay-with-flints at lower levels.

The origin of the River Wylye

Camp Hill (fig. 72)

On the southwestern flank of Camp Hill, at a level slightly above the 425' contour, sections were excavated during the present investigations in a deposit which included several thin seams of gravel. The site is a depression some 9' deep in a small triangular thicket.

Pit 2/a

One section was excavated on the steeply sloping northwestern side of the depression about 2'.0" below ground level outside the depression. A deep soil (1'.10"), dark brown in colour, rests at the upslope end of the excavation on a seam (4"- 6") of dirty yellowish brown flint including the debris of a fluvial gravel, probably the gravel traced downslope from the summit. This confused seam rests with a sharp boundary on a mottled bright brick red and reddish brown loamy clay. The loamy clay incorporates irregular seams of gravel; the seams are of fine gravel (mostly less than 1" diam.) and are thin above, becoming somewhat coarser (up to 3½" diam.) and correspondingly thicker below.

At the downslope end of the excavation, the confused gravelly seam was not encountered underlying the top soil and the soil rests on a buff coloured loam with inclusions of the underlying mottled reddish brown clay. The loam appears to be a wedge thickening downslope. The excavation reached a depth of 7'.6" below the ground level outside the depression. The auger failed to pass more than 6" below the floor of the excavation.

The gravel

A sample of the gravel in Pit (2/a), from a depth of about 6'.0" below the ground surface outside the depression, consists (Table 17) almost entirely of abraded flint, for the most part subsequently unbroken. The small balance in the coarse fraction (more than ½" diam.) consists of well rolled flint pebbles and pebbles of Upper Greensand chert and sandstone, together with one pebble of veined greyish blue grit. In the finer fraction (5/32"- 1/2" diam.) the balance is of small quartz pebbles, ferruginous material, Upper Greensand fragments and a few small pebbles of quartzite.

On the floor of the depression, some 14' southeast of Pit (2/a), a second section was excavated. This section started from a surface about 18" lower than the floor of Pit (2/a).

Pit 2/b

A confused dark brown gravelly soil extended to a depth of 1'.10". The soil rests with a sharp lower boundary on a buff coloured loam with inclusions of bright reddish brown clay and occasional fragments of sharply angular and abraded flint, well rolled flint pebbles, small pebbles of quartz and fragments of ferruginous grit. The loam was seen for 22" and augered for a further 2'.0" below the floor of the excavation. At this depth the auger encountered a tenaceous bright reddish brown clay, in which small flakes of deeply weathered flint occur together with grains of quartz sand, small (and probably large) flint pebbles and fragments of ferruginous grit. The clay was augered for a further 2'.0".

(The origin of this depression is problematic. It was perhaps occupied by brickearth of which the buff coloured loam is the only trace to have survived economic exploitation, probably at an early date.)

Interpretation of the gravel

The gravel at this site incorporates a significant quantity of Upper Greensand chert and sandstone and on this basis alone is clearly distinguished from the relics on the summit itself. The relative abundance of quartz and scarcity of well rolled flint pebbles of Lower Tertiary aspect in the lower gravel tends to confirm this contrast.

The occurrence in the lower gravel of a substantial amount of quartz, occasional quartzite pebbles and a pebble of veined grit, suggests that the stream by which the gravel was deposited drained some part of the western quarter of Salisbury Plain. More or less extensive remnants of Palaeogene gravels or the debris of these gravels incorporating the distinctive elements in question are believed to have survived on this tract until catastrophic dissection of the Chalk took place during the Pleistocene period.

The quantity of Upper Greensand material in the lower gravel on Camp Hill is too large to be consistent with derivation from the Tertiary gravels on Salisbury Plain. It must therefore have been derived from the main Upper Greensand outcrops either in the Vale of Warminster or in the Vale of Wardour.

The geographical position of the gravel on Camp Hill argues strongly in favour of derivation from the Warminster outcrop, although the alternative possibility cannot be entirely excluded.

The integration of the Wylye

If the Upper Greensand in the lower gravel on Camp Hill has in fact been derived from the Warminster outcrop, it demonstrates the contemporary integration of the subsequent Wylye. The integration of the subsequent Wylye implies a slight dissection of the late Tertiary surface and suggests that the summit gravels on Camp Hill may be associated with a base level somewhat below the late Tertiary surface.

The situation of the gravel above Laverstock seems to confirm this arrangement; the gravel there occurs on ground slightly but definitely below the inferred level of the late Tertiary surface (fig. 79) which at this point apparently coincides with the sub-Eocene surface (sensu stricto).

The higher level at which gravel is preserved further downstream at Clearbury Ring (fig. 77) also suggests that the gravels in question nearer Salisbury may be at a level inherently below the deformed late Tertiary surface and may indeed be associated with a base level which implies some dissection of this surface. The evidence of an erosional surface adjusted to this base level is too fragmentary to admit more than a speculative reconstruction (fig. 79).

Conclusion

Clearly the concepts involved largely occupy the realm of speculation and their final interpretation depends on a more complete treatment not only of the material briefly discussed here but of material which still awaits even the most perfunctory examination.

The Drainage of the Salisbury Plain Syncline

Although the integration of the subsequent Wylye appears to have taken place during the earliest stage of, probably, Pleistocene rejuvenation, the consequent stream occupying the synclinal axis of Salisbury Plain seems to have been finally dismembered at a somewhat later date.

Longitudinal and transverse profiles (fig. 73 and 74) suggest that this stream still reached the Avon near the site of Amesbury when the latter had cut down there to a level of about 350' O.D. The character of the transverse profiles suggests that an extensive erosional surface in the synclinal tract is adjusted to a base level of which this height is locally representative.

Relics of gravels, incorrectly delineated by the Geological Survey as Clay-with-flints, above Lake (SU 133390) and Wilsford, at a height of about 350' O.D., may mark the confluence of the synclinal consequent with the Avon at this stage.

Exact correlation of these gravels with gravels further downstream about Salisbury is a hazardous undertaking and the correlation of the gravels about Salisbury with those extensively preserved on the Eocene outcrop in the New Forest is no less problematic.

A RE-EXAMINATION OF SOME PROBLEMATIC GRAVELS IN THE HAMPSHIRE BASIN

Introduction: the Gravels and the Problem of Erosional Gradients

The problems of correlation reflect an almost complete ignorance of the conditions in which gravel has been laid down, and of the significance of certain associated deposits. This account describes some of the material encountered, indicates some comparisons with material described elsewhere, and suggests some conclusions regarding the nature of Pleistocene events and the effective processes during the Pleistocene period.

The Gravels

The gravels described in this account are distinguished on the maps of the Geological Survey either as Plateau or as Valley and River Gravels. In the Memoirs which accompany these maps this distinction is shown to be arbitrary and of slight correlative significance. It was based on considerations of distribution, on the decalcified nature of the Plateau Gravels and the absence from them either of fauna, or flint implements other than the controversial eoliths. A more useful arrangement is outlined by White (1907), distinguishing bottom gravel from slope and terrace gravel.

Terrace gravel is preserved on the surface of supposed terrace remnants but it often remains to be shown that the deposit is exactly, or even approximately, contemporaneous with the surface on which it rests. Slope gravels seem usually to be degraded terrace gravels, sometimes incorporating material from several surfaces. To these two groups may be referred the Plateau and River Gravels of the Geological Survey which are in most cases gravels, or the debris of gravels, deposited by streams more or less ancestral to the present ones. Bottom gravels are commonly preserved beneath the material being deposited by the existing streams, and may outcrop on either side of this material where they become confused with low lying terrace gravels.

Erosional Gradients

A fundamental source of uncertainty in the attempted correlations of more or less isolated gravel remnants in the basin of the Avon has been the doubtful nature of the gradient to be inferred between them, particularly where it remains controversial whether the gravels are of marine or of fluvial origin.

Reid (1902) based his views on the derivation of the Avon gravels on an assumed fluvial gradient of 5' per mile. Sealy's work (1955) on certain terraces of the Avon below Downton, indicates an average gradient for eight terraces of 4·88' per mile (representing a range from 2·75' per mile to 6·82' per mile). Green had suggested however that:

> "The horizontal part of the Frome - Solent Sicilian terrace goes up the Avon past Salisbury."
>
> Green, in Sparks, 1949.

Sealy agrees that the 300' Sicilian terrace is of 'non-fluvial' origin, although Everard (1954) had demonstrated a gradient of 1·5' per mile at his 300' stage in the valley of the Avon above Ringwood and had affirmed the fluvial origin of the surface. In 1956 however he implies a marine Sicilian stage occupying the Tertiary outcrop in the Hampshire Basin.

The Concept of Marine Erosion

Introduction: the controversy

Wooldridge and Linton (1955, p.141) are disposed to accept stages in the Hampshire Basin at about 330' and 400', but Linton has more recently argued that:

> "The concept of marine excavation of the soft rock infilling of an almost completely enclosed basin is not easy of acceptance." Linton, 1964.

The concept of successive marine stages "like the waves of an ebbing tide" (Bull, 1942) is largely based on the acceptance of a Calabrian transgression to about 650' O.D. and the intermittent eustatic withdrawel of the sea from that level. This thesis shows that the Calabrian transgression cannot be recognised on the Wessex Chalk and suggests that a Calabrian level of 650' O.D. may be illusory.

The alternative conclusions elaborated in this thesis to explain the configuration of the Chalk in southern Wiltshire presuppose an analagous sequence of events on the Eocene outcrop in the Hampshire Basin. On the ground the evidence confirms the pattern on the Chalk.

On Salisbury Plain the late Tertiary surface appears to be downwarped to a level between 450' and 500' O.D. and the drainage pattern appears to have originated on this tilted surface. The downwarping of the late Tertiary surface towards the geosynclinal tract underlying the Hampshire Basin may also reasonably be inferred.

The hypothetical Calabrian sea level

The gravel problem

The highest gravels of the New Forest group are preserved at a level of about 420' O.D. If a Calabrian level of 650' O.D. is accepted, it seems remarkable that no gravels occur at levels above 420' O.D. on the outcrops, either of the Eocene or the Chalk in the Hampshire Basin. The same problem has already been noticed (Part Three of this thesis) on the outcrop of the Chalk further North.

The erosional problem

Perhaps even more telling in this context is the fact that exponents of the 'platform school' have been able to identify only two very minor 'marine' stages at levels between 420' O.D. and the Calabrian datum; these are recognised by Everard (1956) at 480' O.D. and less conclusively at 460' O.D.

The Bunter quartzite problem

The observed absence of liver coloured quartzites from the New Forest gravels tends to militate against a high Calabrian sea level. This material, derived from the Bunter pebble beds in the Triassic of southwestern England, now exposed on the coast at Budleigh Salterton, is commonly encountered in contemporary beach shingle on the South coast. It appears for example to be a common element in the Chesil

Beach (Baden-Powell, 1930) and it is difficult to believe that none was introduced along the Calabrian coast visualised by Wooldridge and Linton (1955) (fig. 37).

The alternative hypothesis

If the highest New Forest gravels rest on or, more probably, somewhat below the late Tertiary surface, the record of denudation is more or less uninterrupted and correlates favourably with the Salisbury Plain evidence.

The controversial gravels

The problem

Quite apart from elusive marine stages above the highest level at which gravel is preserved in the Hampshire Basin, a general impression prevails that the gravels which are preserved are likely to be of marine origin at the higher levels. Everard does admit however that in the case of his 420' stage:

> "The character of the gravel does not conclusively support a marine origin."
> Everard, 1954.

In fact the evidence to be described in this thesis suggests that the gravels are not of marine origin.

The evidence

Bury (1923) has argued that gravels above a level of about 300' O.D. on the New Forest plateaux are coarser than those of obviously fluvial origin at lower levels. He attaches particular significance to the amount of material larger than 4" diameter and he mentions the inclusion in the gravel of well rounded flint cobbles of definitely marine aspect.

<u>The origin of the flint cobbles</u>

The cobbles to which Bury alludes (Plate 40) are probably derived from pebble beds of Eocene age, in which they are occasionally encountered. In the Reading Beds, for example, at Sherfield English (SU 183227), well rounded cobbles, up to six inches long, have been recovered (Plate 12) during the present investigation and Reid (1902) records flint cobbles up to 10" long at the base of the London Clay at Hinton Martell (SU 014062).

<u>The size of the gravel</u>

As for the comparative size of the gravels, Bury supplies no specific figures and in the sections now exposed Bury's views do not appear to be substantiated. Abraded flint nodules up to 10" long are recovered in the undoubted river gravels at Bemerton (Plate 45) at 230' O.D.; up to 9" long in the section excavated at Warren Field Plantation (SU 188243), somewhat above the 250' contour; and up to 8½" at Britford gravel pit (SU 154278), at a height of about 230' O.D. In the working gravel pit at Gorley Hill (SU 165115) at 230' O.D., vast heaps of screened gravel of 4" calibre can be seen.

The distinctive Tertiary contribution to the gravels

The distribution of alien pebbles also suggests that the highest gravels are of fluvial origin. Large (more than ½" diam.) pebbles of vein quartz, and pebbles of veined grits are commonly encountered in the highest gravels on the right bank of the Avon where they are no doubt derived from an extension of the Tertiary formation in which they were formerly incorporated. In the highest gravels on the left bank of the Avon alien pebbles are extremely rare or entirely absent. If the left bank gravels are of marine origin, it is difficult to explain why longshore drift failed to supply alien material to them; if, on the other hand, they are of fluvial origin it would be rather surprising if alien material was encountered in more than the small quantities which might be supplied from the further extension of the Tertiary outcrop on Salisbury Plain.

In an extensive exposure in an abandoned gravel pit (SU 250165) on Longcross Plain, at a level of about 420' O.D., on the left bank of the Avon, only three characteristic alien pebbles were recovered (vein quartz 1 3/16"; grit 1 1/16"; quartzite 1 5/8"). At a level of about 315' O.D. on the right bank of the Avon at Pistle Hill, the alien material, seen in deep plough on Forestry Commission land, is too common to admit individual enumeration.

That this contrast is not a reflection of increasing remoteness from the Tertiary source is suggested by Reid's note on the gravel at a level of about 315' O.D. at Picket Post (nr. SU 191061) on the left bank of the Avon, near Ringwood. Reid records 'Palaeozoic grit' here; this is in fact the only site where alien material is specifically recorded by Reid. The significance of Reid's observation becomes apparent in the light of Everard's view (1954) that the Picket Post gravel may be referred to an early course of the eastward flowing Solent River.

Pebble morphology

A study of the abrasion of pebbles of Upper Greensand sandstone from gravels at various levels in the valley of the Avon suggest no well marked contrasts which might reflect a distinction between fluvial and marine conditions of deposition (Plates 47a-m). Since the gravels at the lower levels are obviously of fluvial origin, it seems reasonable to assume that the highest gravels are as well.

This conclusion is to some extent confirmed in an examination of the behaviour of Upper Greensand pebbles in contemporary beach shingle. At Rousdon, in Devon, Upper Greensand chert on the beach is largely subangular but sandstone pebbles are invariably well rounded (Plate 47n). The sandstone is not of course perfectly identical with the material encountered in the gravels of the Avon.

PLEISTOCENE PLANATION

The excavation of the narrow valley trenches occupied by the present streams appears to have been immediately preceded by a period of less confined linear erosion which probably took place at the beginning of the Pleistocene period after the emplacement of the drainage and after the original pattern had been to some extent adjusted.

Salisbury Plain: the Lower Plain

The evidence of a Pleistocene erosional surface about Salisbury and on Salisbury Plain is fragmentary, but cannot be ignored. Gifford (1957) has recognised on this tract a surface at levels between 250' and 450' O.D. which he terms the Lower Plain (fig. 63). This feature encroaches on her Higher Plain (the late Tertiary surface of this account), and was thought by her to be of composite fluvial origin. The configuration of the Lower Plain is very clearly displayed in the transverse profiles which have been drawn across the axis of the Salisbury Plain syncline to illustrate the behaviour of the consequent stream which originally occupied this axis (fig. 74). The Lower Plain can also be recognised in association with the other principal elements of the present drainage pattern (fig. 79). The character and distribution of the superficial deposits resting on it do not substantiate Gifford's view that it is of fluvial origin, and consists of successive river cut facets. Gravels of fluvial aspect are definitely confined to sites on the lower margin of the surface near the valleys of the present streams. Elsewhere normal rendzinas are typical and Chalk is turned up by the plough. Dealing with drift on ground referred by Gifford to the Lower Plain, Reid had remarked:

> "On the very level plains around Stonehenge it is too thin and irregular to be mapped." Reid, 1903.

Where deeper soils do occur they are formed on reddish loamy clays of residual aspect.

The Interpretation of the Camp Hill Gravels: II

At Camp Hill a very significant succession of drifts is preserved and has been carefully examined during the present investigations (fig. 80). At the highest levels between 430' and 450' O.D. gravels are referred in this thesis to a base level slightly below the late Tertiary surface. At and below this level a complex of Clay-with-flints and river gravels has been indicated by the Geological Survey (Sheet 298). In fact the highest gravels are separated from the main extent of this complex by a low but well marked bluff. The superficial geology of this tract has been re-examined.

Account of the sites examined: I

Camp Hill

A section was excavated in the Clay-with-flints of the Geological Survey some 300 yards below the bluff.

Pit 3

About 16" of confused gravelly soil rest on a thin very stoney seam (3"- 4" thick) in which fine earthy material is not present (?an 'erosion pavement'). The gravel (Table 29) consists largely of abraded flint fragments, for the most part freshly broken since having been abraded. In the coarse fraction (more than ½" diam.), the small balance is of Upper Greensand chert and sandstone with rare pebbles of ferruginous grit and of a dark bluish grit. In the finer fraction (5/32"- 1/2") a significant percentage of quartz and ferruginous material occurs together with a smaller percentage of Upper Greensand fragments.

Below this stoney horizon a bright reddish brown clay is encountered. A few fragments of gravel are seen but the clay also incorporates nodules of fresh flint, unbroken or sharply angular. Below a depth of 3'.9" from the surface, the incorporated stoney material appears to be less common; the auger penetrated a full 4'.0" below the floor of the excavation, in clay throughout, without encountering the Chalk. In the lower part of the clay only a few deeply weathered flint flakes were noticed, and the clay appears to incorporate numerous discrete dark particles, wisps and flecks.

A section was excavated at the top of the overgrown pit (probably a chalk pit) which gives its name to the surrounding copse, Pit Folly. The section is in the River

Gravel of the Geological Survey.

Pit 4

Excavated to a depth of 5'.4" the section shows drifts resting on an uneven surface of the Chalk. At the surface 9" of dark soil are obviously greatly disturbed and include artificial flint flakes, fragments of brick and chalk and pieces of tobacco pipe. This soil rests on a variable depth of confused gravel (9"- 41") in a matrix of fine buff coloured sandy loam. The gravel (Table 30) consists very largely of abraded flint, the majority of the fragments freshly broken since having been abraded. The small balance in the coarse gravel is of Upper Greensand, ferruginous grit, quartz and well rolled flint pebbles. In the finer gravel, ferruginous material and quartz form the larger part of the balance, with a few fragments of Upper Greensand and some small pebbles of quartzite. The gravelly drift rests on a less variable depth of bright reddish brown clay (8"- 22"). In its upper part, the clay incorporates stones, apparently from the overlying drift, but below, it becomes blocky, incorporates wisps and flecks of dark staining and shows evidence of slickensiding. The clay rests with a sharp boundary on the Chalk.

Interpretation of the sections

The profiles described in Pits (3) and (4) seem to be essentially indistinguishable from the Batcombe Series described on Clay-with-flints in the Chilterns by Avery et al. (1959). The Batcombe profile is distinguished from the Winchester profile by a deeper loamy horizon at the surface (up to 29") which incorporates Eocene or later material and merges rather gradually into an underlying flinty clay.

The confused gravelly drifts described on Camp Hill (Pits 3 and 4) appear to be redistributed river gravel, and their composition is consistent with derivation, probably during periglacial conditions in the Pleistocene period, from the river gravels which appear to be in situ nearer the summit of the hill.

These two pits give some indication of an erosional slope declining from the vicinity of the highest gravels on Camp Hill towards the present river valleys. The preservation of Clay-with-flints of residual aspect suggests that the surface has not been elaborated by the lateral component of fluvial erosion and, bearing in mind the configuration of the Lower Plain elsewhere, it seems possible that the gound in question may reflect a process of slope development analagous to pedimentation.

Account of the sites examined: II

Camp Hill

A section was excavated in the River Gravel of the Geological Survey at a level slightly above the 325' contour.

Pit 5

The section showed coarse gravel throughout to a depth of 5'.0". At a depth of 1'.10" the matrix of the gravel becomes rather clayey for a few inches (5" or 6"), possibly in a zone of clay accumulation in the soil profile, although clayey lenses occur below this seam. The coarse gravel (more than ½" diam.)(Table 32) consists almost exclusively of abraded flint, subsequently unbroken. In the fine gravel a significant percentage of ferruginous material occurs and smaller amounts of quartz, Upper Greensand and quartzite in small pebbles. At a depth of 4'.9" one flint flake of doubtfully artificial aspect was recovered. The absence of freshly broken flint in this gravel suggests that it is essentially in situ.

A section excavated on the 300' contour is also in the River Gravel of the Geological Survey:

Pit 6 (fig. 81)

About 1'.0" of dark gravelly soil is obviously very much disturbed and incorporates fragments of Chalk and a few artificial flint flakes. Below this dark horizon a further 1'.0" of confused gravel occurs in a buff coloured matrix of sandy loam. Samples from both these horizons (Tables 33 and 34) suggest that they consist largely of redistributed river gravel, probably derived from the underlying gravel (see below) rather than from gravels preserved at higher levels. The confused gravelly horizon merges without a well defined lower boundary into a more or less stoneless drift which in its upper part is a bright reddish brown clay but which in its lower part incorporates an increasing number of discrete particles of fine buff coloured silty loam (up to ⅜" diam.). This drift also includes a very few unbroken, abraded flints, isolated or in lens like clusters, and minute flakes of weathered flint. This drift extended to a depth of 4'.6" from the surface of the ground. At this depth it merged very irregularly into a seam or wedge of gravel. Pipes of the stoneless drift pass through this gravel seam which is from 6"- 10" thick. The gravel (Table 35) consists very largely of abraded flint (up to 5" long) with subsidiary amounts of Upper Greensand chert and sandstone, quartz and ferruginous material and rare pebbles of quartzite. The majority of the flint fragments have not been freshly broken since their abrasion and the gravel, although probably disturbed by dissolution of the underlying chalk or by peri-glacial re-organisation of the soil, does not seem to have suffered redistribution. Below this gravel the stone-free clay with small loamy inclusions persists but gravel comes in again at a depth of 6'.9" and the excavation was discontinued.

Conclusions

Unfortunately it was not possible to excavate at sites on the ground intervening between Pits Five and Six and Pit Four, so that the level of the upper margin of the river gravels, recognised in the lower sections, remains uncertain and it is not known therefore whether the gravels rest directly on the Clay-with-flints of residual aspect recognised in Pits Three and Four, that is to say directly on the inferred pediment slope, or whether they occupy a fluvial terrace surface cut slightly below this level. The base level to which pedimentation had been effected at this point is correspondingly uncertain. These problems render correlation, even over short distances, most hazardous. Nonetheless the arrangement of the gravels on Camp Hill does tend to substantiate a concept of erosional slopes (pediments or otherwise) adjusted to a base level which at this point appears to be very close to 300' O.D.

The Hampshire Basin

The erosion surfaces

Green (1936, 1946) recognised an extensive planation surface on the Tertiary outcrop in the Hampshire Basin at a level of about 430' O.D. He nevertheless considered that a lower planation surface at a level of about 300' O.D. is:

> "The face of the block from which the scenery has been sculptured."
> Green, 1946.

Everard (1954) working in the same area has attempted to distinguish intervening stages, of marine planation, at 370' O.D. and 390' O.D.(fig.82). He tacitly admits however that his 370' stage, in particular, is rather problematic. It extends upwards at least to 378' and downwards at least to 337'. The inequalities which separate this stage from those above and below it are not convincingly demonstrated and it seems quite possible, and in the light of the evidence on Salisbury Plain, entirely reasonable, to regard the ground in question as an uninterrupted erosional slope extending from a base level close to 300' O.D. up to the (?)earliest Pleistocene level at about 420' O.D. The general configuration of this slope and its relation to the (?)earliest Pleistocene (420') level above it and to the incised valleys below it, provides substantial ground for a provisional correlation with the Lower Plain on the Chalk about Salisbury where the same relationships prevail (fig. 83).

The gravels

The character of the gravels preserved at the 370' and 390' 'levels' is not consistent with their marine origin which has been accepted by Everard. Specific objedtions to their marine origin have already been outlined in the account relating to gravels at the highest (420') level on the left bank of the Avon. The fluvial origin of the gravels must therefore be accepted. However, the evidencd on the Chalk in southern Wiltshire shows that fluvial gravel is <u>in situ</u>

only on the lowest slopes of the Lower Plain. Moreover without resorting to precise methods of correlation it is quite obvious that North of the main Tertiary outcrop, in the Hampshire Basin, there are no gravels of undoubted fluvial origin on the Chalk which might be correlative with 370' and 390' stages in the New Forest. The undoubted river gravels which do occur (seen in the sections excavated at Alderbury and on Camp Hill, and possibly in the railway cutting at Barford, SU 191225) are probably correlative either with Everard's 300' stage (1954) or with the higher stages of Sealy's succession (1955), all of which are considered, by their exponents, to be of fluvial origin.

The origin of the gravels above the 300' stage in the New Forest is therefore problematic.

On the Chalk, surface indications have proved completely inadequate to establish whether gravel of fluvial aspect, seen at the surface, is <u>in situ</u> or redistributed. The sections excavated at Camp Hill, showing up to 3'.6" of disturbed gravel, suggest that material at the (?)earliest Pleistocene (420') level may have been extensively redistributed at lower levels during the Pleistocene period. Everard stresses (1954) that the gravels at the higher levels in the New Forest are shallow. He quotes an average figure of only 4'.0". Everard mentions horizontal stratification but much of the material examined during the present investigation is obviously disturbed and could well be redistributed.

PLEISTOCENE DISSECTION OF THE CHALK : DRY VALLEYS AND ESCARPMENTS

Below the general level at which the Lower Plain has been identified on the Wiltshire Chalk, and at which its analogue is identified on the Eocene outcrop in the Hampshire Basin, the Pleistocene record appears to be essentially one of dissection (fig. 79). Evidence of planation, effectively confined to terrace remnants of very limited extent, is obviously closely associated with the existing river valleys.

Historical Background to a Controversial Problem

Pleistocene dissection of the Chalk has excavated a pattern of valleys, now more or less dry, tributary to the permanent streams. This pattern is of dendritic aspect but is essentially confined to the outcrop of the Upper Chalk.

The Chalk escarpments commonly form an important watershed. This fact has not escaped the notice of geomorphologists, and problems relating to the evolution of the Chalk escarpments and to the dessication of the dry valleys on the Chalk have generally been treated as interdependent.

The Chalk escarpments: alternative explanations

Small shows that on the 325 miles of Chalk scarp examined by him:

> "103 gaps, some by no means impressive, were found." Small, 1961.

In the same distance 314 dip slope dry valleys head within a mile of the scarp face.

The extensive preservation of an unbroken scarp has been understood to admit one or other of two reasonable explanations. Either the present site of the scarp has been determined by a pre-existing watershed which has for some reason acquired new expression (Fagg, 1954; Small, 1960); or the contemporary drainage pattern has been installed since the scarp assumed its present alignment (Reid, 1887).

The cyclic alternative

In point of fact neither explanation has been presented in an acceptable form. Small (1961) has shown that Fagg's views cannot be accepted, but his own conclusions are to some extent based on an understanding of the Vale of Wardour which is shown in this thesis (Part Four) to be incorrect. Moreover Small's general hypothesis contains inherent defects.(fig. 46).

Small argues that in an initial cycle of erosion (which he equates with the Mio-Pliocene cycle of Wooldridge and Linton) during the final stages of planation, the Chalk escarpments and the coincident watersheds will recede across the outcrop of the Chalk. Small suggests no reason, nor is any reason apparent, why this recession should not eventually locate the escarpments in the Upper Chalk. In the North of the Vale of Wardour Small actually infers this to be the case. Small considers that, in spite of Pleistocene rejuvenation, the watersheds established in this final stage of the Mio-Pliocene cycle remain effective and have determined the present alignment of the scarps. But, the main Chalk escarpments are now, almost invariably, held up by the Chalk Rock at the base of the Upper Chalk. In Small's hypothesis this fact implies that the recession of the Chalk escarpments during the Mio-Pliocene cycle failed to encroach on the outcrop of the Upper Chalk or to effect any planation of this outcrop, and that the watersheds in question on the Mio-Pliocene peneplain must therefore have coincided with the boundary on the ground between the outcrops of the Upper and

Middle Chalk. This concept is hardly acceptable.

The climatic alternative

Reid (1887; cf. White, 1924; Bull, 1940) contends that frozen ground water accompanying periglacial conditions might render the Chalk impermeable. He believes that in these circumstances the present drainage pattern on the dip slope of the Chalk might have been carved out by torrential streams. One substantial objection has been directed at this hypothesis. It is argued that dissection of the scarp by streams active during the period preceding the onset of periglacial conditions (and therefore preceding the recession of the escarpments to their present sites) might be recognised. In fact such evidence of a pre-glacial drainage pattern is reckoned to be either absent or irregularly disposed

The dry valleys

Reid's periglacial hypothesis was originally proposed to explain the dessication of the dry valleys. The alternative hypotheses suggest a less catastrophic sequence. Progressive dessication is visualised where the base level, to which the water table is adjusted, has been lowered by trunk streams downcutting at the foot either of the scarp or the dip slope. The level of the water table has been correspondingly depressed, in the tributary valleys, so swiftly that the erosion, necessary to adjust the form of the tributary profile, has been precluded. Chandler (1909) and Fagg (1923) believe that the process effecting the depression of the water table might be the denudation of the impermeable Gault outcropping beyond the Chalk scarp. Sparks (1949) invokes a spasmodically falling sea level, but Pinchemel (1954) suggests that on a permeable outcrop dessication might be a normal response in valleys tributary to a trunk stream which suffers rejuvenation (Pinchemel's term is 'auto-assèchement').

The problem of scarp recession

Unfortunately none of these ingenious concepts can be reconciled with recession of the escarpment. The mechanism of scarp recession has not attracted much attention in a literature largely concerned with a few short but spectacular valleys which dissect the scarps at infrequent intervals. In these cases the roles of glacial meltwater (Sherlock, 1929), obsequent streams (White, 1924; Fagg, 1954; Small 1962) and spring sapping along obscure joints in the Chalk (Oakley, 1936; Sparks and Lewis, 1957) have been variously inferred.

Bull (1940) believes that the undissected portions of scarp have been shaped to a significant extent by nivation during a period of periglacial conditions. Fagg also supposes that:

> "Recession of the scarp has not always been the slow process that it is today . . . it seems rather that large masses of the Chalk have been removed in a comparatively short time." Fagg, 1954.

An Alternative to Scarp Recession

So great are the difficulties evidently inherent in the concept of scarp recession that the only possible alternative must at least be considered. Namely that the scarps have evolved essentially where they now stand and not by a process of recession. In the Vale of Wardour there is some evidence to substantiate this possibility.

The evidence in the Vale of Wardour

In the Vale of Wardour the adjustment of the drainage pattern, following the deformation of the late Tertiary surface must have taken place at an early stage during the present cycle of erosion. The gravels with Jurassic and Upper Greensand debris, referred in this account (Part Four) to transverse streams consequent on the deformed late Tertiary surface, rest only very slightly below the level of the surface itself (fig. 33). Small particularly notices the undissected nature of the southern escarpment in the Vale of Wardour:

> "On the escarpment South of the Vale of Wardour, there are no passes in a distance of 9½ miles." Small, 1961.

In other words the transverse consequents (fig. 48) had been dismembered before they had effectively dissected the outcrop of the Upper Chalk. The failure of these streams to maintain their courses across the Upper Chalk implies successful erosion on the less competent outcrops exposed in the denuded anticline (effectively the Lower and Middle Chalk), and the integration on these outcrops of a longitudinal subsequent ancestral to the modern Nadder.

The situation of the gravels with Jurassic and Upper Greensand debris, on the summit of the escarpment, corresponds with a position, on the late Tertiary surface, on the outcrop of the Upper Chalk near the geographical boundary of this division with the Middle Chalk. The situation of the gravels and the undissected state of the escarpment suggests that denudation of the Middle Chalk isolated the escarpment close to its present position during the initial dissection of the late Tertiary surface, possibly during the stage to which the integration of the Wylye has already been tentatively referred in this account.

The alignment of the escarpment seems to have been exactly determined by the outcrop of the resistant Chalk Rock on the late Tertiary surface, and it is also possible that the integration of the Wylye may reflect the progressive exposure of the Middle Chalk in the axis of the Warminster anticline.

Subsequent erosion in the Vale of Wardour, during the Pleistocene period, associated with falling base levels, has effected further denudation of the Lower and Middle Chalk but has not succeeded in dissecting or displacing the escarpment.

At the Zig Zag (fig. 47) the erosional scarp separating the late Tertiary surface from the mid-Tertiary surface is seen to form the upper part of the main Chalk escarpment and has clearly not been displaced significantly since the deformation of the late Tertiary surface probably during the late Pliocene - early Pleistocene interval. The main escarpment may well coincide in this way with the late Tertiary erosional escarpment both to the East and to the West of the Zig Zag.

The evidence in the Weald

Some confirmation of the possibilities recognised in the Vale of Wardour exists in the Weald. Relics of planation surfaces have been identified (Bull, 1936) on the South Downs on the scarp slope of the Chalk, at levels up to 400' O.D., and it is clear that, if these relics are chronologically significant, the crest of the scarp, where these relics are preserved, has not receded since their formation, presumably in the early part of the Pleistocene period.

Implications in the dry valley controversy

In a concept of scarp evolution from which the mechanism of recession has been excluded, the arrangement of the dry valleys on the outcrop of the Upper Chalk no longer appears problematic. In effect the pattern of valleys has been installed since the scarp assumed its present alignment. In this scheme the dessication of the valleys can be explained either in geological, eustatic or climatic terms and probably in fact reflects the interaction of these factors.

Conclusions

These concepts relating largely to the origin and evolution of the Chalk escarpments in the Vale of Wardour seem to provide a reasonable model for the understanding of the Chalk escarpments elsewhere in southern England. Perhaps particularly relevent in this respect is thepossibility that the Chalk escarpments are not necessarily genetically identical, although their present stature is clearly the uniform reflection of Pleistocene rejuvenation.

PROBLEMS OF PLEISTOCENE DEPOSITION

In a study of the Pleistocene erosion of the Chalk in southern Wiltshire the scarp and dry valley controversies are complicated by evidence of deposition, obviously inconsistent with the processes which are now active on the Chalk.

'Heads' or 'Trails'

The Vale of Pewsey

Jukes-Browne has examined and described exposures in the head or 'ancient landwash' in the Vale of Pewse . He believes that this material, recorded in pockets and patches up to 10' deep, represents "relics of the denudation of the

Chalk, Upper Greensand and Gault" and that "the character of the land had been greatly modified" by it (1905). He suggests that it is of lacustrine origin but his fundamental contribution is the recognition that the material is incompatible with present conditions of deposition. It is clearly the view of the Geological Survey working further to the West, in Wiltshire and in Somerset (Summ. Prog. Geol. Surv., 1954; 1956; 1957) and elsewhere in Britain (Dines et al., 1940) that material of this general type is of periglacial origin.

<u>The Wylye valley</u>

During the present investigation deep drifts of periglacial aspect have been recognised on the outcrop of the Upper Greensand in the Vale of Warminster (see Part Two of this thesis). Deep chalk rubbles have also been examined at a number of sites on the Chalk.

1. At Monkton Deverill a section is visible in a silage pit (ST 862372) at a height of about 450' O.D. some 40' above the present bed of the Wylye. The pit is cut in a steep slope above the floor of a dry valley tributary to the Wylye. The section shows about 8' of chalk rubble. The solid Chalk is not visible in the section. The rubble is

almost exclusively of subangular chalk fragments; included fragments of flint are sharply angular. At a depth of about 5'.6" from the surface of the ground a slightly less compact chalky white rubble above is separated by a well marked boundary from a more compact creamy white rubble below. In terms of composition these two horizons appear to be identical.

2. A section is seen in another silage pit (SU 057363) on the 300' contour some 90' above the Wylye, near Little Langford. The section (Plate 48) is on the right bank of the Wylye and shows a dark rendzina, several inches thick, resting on an uneven surface of chalk rubble. The rubble incorporates a quantity of reddish brown clay or loam which becomes increasingly apparent downwards. At a depth of about 4'.0" a distinctly earthy horizon rests with a very clear boundary on the even surface of a lower chalk rubble. The lower rubble is seen here and there to be at least 3'.0" deep but the lowest part of the section is concealed by talus.

3. A section is exposed in a small roadside quarry (SU 073356) not far from Great Wishford, on

the right bank of the Wylye at a height of about 225' O.D. only some 25' above the river. Detailed measurements of this section have not been made. A rubble of subangular chalk fragments, sharply angular flint, ferruginous material and a few small quartz pebbles, shows a crude sort of stratification. The samples examined came from a distinctive seam at a depth of between 3'.0" and 3'.10" and included fragments of early pottery.

<u>The Vale of Wardour</u>

Reid has noticed that :

> "The soils in the Vale of Wardour are so greatly mixed through downwash from the scarps on each side that in that region there is but little land the soil of which can be said to be the direct product of the rock on which it lies."
> Reid, 1903.

During the present investigation deep drifts of periglacial aspect have been observed on the outcrop of the Upper Greensand (see Part Two of this thesis); and deep chalk rubbles may well occupy the dry valleys on the Chalk.

4. A section was open during the summer of 1964 in Chicklade Bottom (at ST 904344) at a height of about 475' O.D. where the installation of petrol storage tanks was being undertaken. Chicklade

Bottom is a dry valley tributary to the left bank of the Nadder; it displays the East - West alignment characteristic of the principal valleys on the Chalk in the North of the Vale.

The section (Plate 49) showed up to 4'.9" of rather confused reddish brown flinty clay. This drift is of variable depth (usually 18"- 36") and tends to be most clayey in the lower parts of the deepest inequalities. Below the flinty clay is a very irregular horizon of buff coloured loamy chalk rubble in which most of the chalk fragments are small (less than ¼" diam.). This rubble rests with a very deeply involuted boundary on a coarser white chalk rubble. In the involutions the fine buff coloured material is often finely bedded parallel to the boundaries of the involutions. The buff coloured material is not seen in the eastern end of the pit where the upper flinty clay rests directly on the lower chalk rubble. The lower rubble consists largely of subangular chalk fragments and the small balance is of sharply angular flint. The rubble appears to become somewhat coarser downward but at the maximum depth of 11'.7" from the surface of the ground the solid Chalk was not seen.

Conclusions

Drifts of the type described here have not been deliberately considered during the present investigation and the drifts themselves have not therefore been the subject of detailed examination. Nevertheless it is fair to compare the chalk rubble drifts with material described elsewhere on the Chalk in southern England (Kerney, 1963; Brown et al. 1964) and to suggest that the more impressive accumulations reflect periglacial climatic conditions. Lesser accumulations may reflect human interference, particularly cultivation and the ensuing destruction of the protective natural vegetation.

River Gravels

Introduction

Perhaps the most impressive evidence of the greatly superior capacity of Pleistocene erosional processes, by comparison with their modern counterparts, can be recognised in the terrace remnants and the substantial accumulations of river gravel which occupy extensive tracts in the river valleys both above and below the level of the existing streams.

Reid (1902, 1903) notices that the gravel of the Salisbury Avon does not at present include the coarse material observed in the earlier gravels, and that in places gravel has been superceded by peat and alluvial silt. Contrasts in this sense have been observed elsewhere in southern England. In the valley of the lower Severn, Beckinsale and Richardson state that:

> "As the gradient (just over 4' per mile) is only slightly steeper than that of the present rather feeble river, the coarse basal gravels are assumed to denote a much greater run-off than at present."
> Beckinsale and Richardson, 1964.

Problems of process in the Pleistocene climatic context

The excavation of the present valleys has not been a straight forward affair:

> "Changes of base level have been spasmodic rather than continuous." Sealy, 1955.

No attempt seems to have been made however to understand the conditions in which the terrace surfaces were cut or in which the gravels were laid down on them.

If the interglacial character of the present climatic and hydrographic scheme is accepted, certain difficulties emerge. River terraces appear to be a reflection of lateral erosion, successfully encroaching both on the Chalk and on the Tertiary outcrop. The rivers are not at present effecting erosion of this order, but are confined upon their own alluvial plains and in fact, seem, on balance, to have been effecting more aggradation than erosion during the post-glacial period.

Our knowledge of the buried channel of the Salisbu ry Avon is extremely limited but it is known that the gravels in the channel at Salisbury are at least 28' deep. Gravel was proved to this depth in a bore sunk (1896) by Sir Arthur Blomfield, in the Close, to investigate the foundations of the Cathedral (in Reid, 1903).

The character of this post-glacial aggradation is much better known in the valleys of the Severn (Beckinsale and Richardson, 1964) and the Kennet (White, 1907). The aggradation in question is no doubt to some extent a response to a rising sea level accompanying deglaciation but there is no reason to believe that lateral erosion might become effective during a prolonged adjustment to the present or any other base level, so long as the present climatic conditions prevail. In other words it is difficult to visualise the cutting of the terraces during interglacial periods, unless interglacial conditions in the past have favoured brief spells of pedimentation.

Alternatively the terraces may have been cut during the glacial periods. If this were the case the material accumulated during the post-glacial aggradation ought to rest on such a surface. In fact studies of buried channels (e.g. Dury, 1958; Beckinsale and Richardson, 1964) show that their cross profiles generally approximate to a catenary curve of the type associated with fluvial erosion unimpeded by proximity to base level (fig. 84).

It is interesting to observe that the buried channels are commonly 'lined' with a coarse gravel (the 'bottom' gravel of White, 1907) of the general type which is preserved elsewhere on horizontal terrace remnants. This circumstance suggests that during the Pleistocene period, the fluvial capacity to deal with coarse gravel was associated either with an established base level, promoting lateral erosion (pedimentation or otherwise), or with a falling base level and rejuvenation.

Since the evidence already discussed suggests that the fluvial capacity in question cannot satisfactorily be referred either to full glacial or to inter-glacial conditions it is suggested that fluvial processes have been outstandingly effective during the intervening transitional periods. The character of the buried channels presumably indicates the nature of the erosion effected during the waning of the latest glaciation. The terrace features are therefore referred to the onset of successive glacial periods.

A theoretical 'climatic' cycle

A possible scheme of events might be:

1. A deterioration of the climate heralding the approach of glacial conditions. The protective natural vegetation breaks down. Run-off increases and is perhaps supplemented by increased precipitation. The influence of falling sea level accompanying glaciation is not immediately effective and the erosion which takes place is largely lateral. During the preceding interglacial the climate may have admitted pedimentation, in which case the process of lateral erosion enlarges on the work of this process.

2. During the glacial maximum fluvial activity is inhibited, although the sea stands at a low level.

3. At the approach of interglacial conditions fluvial activity is renewed and downcutting is performed before the sea recovers to the interglacial level.

4. During the interglacial, run-off decreases again; sea level recovers and aggradation ensues.

Evidence of a cyclic sequence in the basin of the Salisbury Avon during the Pleistocene period (fig. 85)

Evidence in the basin of the Salisbury Avon might be understood to demonstrate the progress of several 'climatic cycles' during the Pleistocene period, although the sequence has obviously been complicated by minor interstadial oscillations.

The earliest gravels of Pleistocene aspect are recognised at Clearbury Ring at a level which may coincide with the late Tertiary planation surface (fig. 69). Below this level there is some indication of a grouping of gravel relics, at about 420' in the New Forest and rising to 450' above Salisbury (Camp Hill summit). The New Forest gravels have been tentatively correlated by Hare (1947) with the Pebble Gravel stage in the London Basin. On the Wiltshire Chalk the erosion associated with these gravels seems to have been responsible for the original integration of the main subsequent streams, the Wylye and the Nadder. The nature of this evidence and of the gravels in question, suggest the passage of a glacial deterioration (?Gunz).

A rather extensive planation surface, identified (Green, 1936, 1946) on the Eocene outcrop in the Hampshire Basin, is apparently adjusted to a base level slightly above 300' O.D. The analagous surface, detected during the present investigation on the Wiltshire Chalk, is adjusted to base levels up to 350' O.D. In the scheme presented here this surface appears to have been elaborated during the interglacial period preceding the Lowestoft (?Mindel) glaciation. Everard (1956) correlates a 325' stage in the Hampshire Basin with the Sicilian datum and this correlation is accepted by Hodson and Shelford (1964) who argue that the Sicilian stage is of pre-glacial date. This view does not accord favourably with the conclusions reached in the present investigation, nor with the correlations suggested by Hare (1947). Hare proposes that the Sicilian stage may be correlative with the Higher Gravel Train in the Valley of the Thames. There the Higher Gravel Train is probably of more recent date than the earliest local glacial drift (the Chiltern or Western Drift).

At levels near and slightly below the lower margins of the early Pleistocene partial planation surface, identified in Wessex during the present investigation, there are a number of important fluvial terrace remnants with associated gravel relics. These include "the highest of the river terraces" of Sealy's succession (1955), his terrace VIII which he correlates with the Upper Ambersham terrace of Green (1946). Hare (1947) tentatively correlates Green's Upper Ambersham with the Harefield (Lower Gravel Train) stage in the London Basin. Wooldridge (1957) associates the Lower Gravel Train with the Mindel glaciation. Oakley (1963) refers the gravel at Alderbury to Reid's Eolithic terrace (1902) and suggests that this includes both the Harefield and Winter Hill stages. The Winter Hill stage is also identified by Sealy (his terrace VII). Wooldridge (1957, 1960) shows the Winter Hill terrace of the Thames to be probably confluent with the outwash of the Chalky Boulder Clay (Lowestoft, i.e. Mindel glaciation). Erosion on the Wiltshire Chalk associated with this glacial deterioration seems to have finally dismembered the stream occupying the Salisbury Plain syncline.

From levels below the Winter Hill stage in the basin of the Salisbury Avon, a considerable body of palaeolithic and faunal evidence has been recovered and although this evidence has not been the subject of recent, careful investigation, it does appear to indicate two further periods of glacial deterioration.

CONCLUSION

CONCLUSION

Six main problems have been treated in this thesis.

1. It had been accepted (following Wooldridge and Linton, 1955) that the Wiltshire Chalk was buried by Tertiary sediments at the beginning of the Tertiary period and that this mantle protected the Chalk from erosion until after the Oligocene period. On Salisbury Plain, however, during the present investigation, gravel has been identified which appears to be correlative with gravels in Dorset which are dated to the intervening period. This correlation and the position and composition of the gravel on Salisbury Plain suggest that the Chalk suffered extensive erosion during the Eocene and Oligocene periods. The sequence which is inferred accords favourably with evidence in the Paris Basin where the geological record is much more complete.

2. The summits of the Chalk in Wiltshire above a level of about 700' O.D. are referred by Wooldridge and Linton (1955) to an undeformed erosion surface of mid-Tertiary age (the Mio-Pliocene peneplain). The character of the drifts examined during the present investigation, on this surface, and on more or less adjacent ground, shows that a warped surface of Oligo-Miocene age can be identified at levels down

to 500' O.D. At the same time some of the ground which had been referred by Wooldridge and Linton to their mid-Tertiary surface must be reassigned to a surface of more recent Tertiary (Pliocene) origin which in the Vale of Wardour and possibly elsewhere is locally upwarped to levels above 700' O.D.

3. The stratigraphic evidence in the London Basin suggests the transgression of a late Tertiary (Diestian) and/or early Pleistocene (Red Crag) sea to a level of about 650' O.D. The shoreline in the London Basin is generally supposed to be indicated by a wave cut platform and associated sand or shingle. This transgression is inferred by Wooldridge and Linton in Wessex but no trace of appropriate beach material has been identified during the present investigation.

4. The thesis shows that as a result of differential deformation, the late Tertiary and/or early Pleistocene sea of which stratigraphic evidence survives in the London Basin, did not extend onto the Wessex Chalk. In Wiltshire the evidence examined suggests that a subaerial planation surface was elaborated during the late Tertiary period, possibly by processes analogous to those now operating in areas of tropical or sub-tropical climate, and producing a sensibly flat plain. The present drainage pattern is consequent on

a slight deformation of this surface, which appears to have taken place during the late Tertiary or early Pleistocene interval.

5. The correlations which are suggested in this thesis indicate that structural deformation, both folding and tilting, has occurred in southern England both before and since the Oligocene period, and probably as recently as the beginning of the Pleistocene period, if it is not active at present. This conclusion shows that correlation of Tertiary features in terms of concordant height above sea level is not likely to prove useful.

6. The thesis suggests that the excavation of the present valleys took place during the Pleistocene period and is a reflection of peculiar climatic conditions associated with the margins of the Pleistocene ice.

These results suggest an attractive chronological scheme of Tertiary landscape evolution, not without interesting analogies in the Paris Basin and even in the continental episodes visualised by Lester King (1962). The results also suggest that the work of Wooldridge and Linton, which provides an invaluable foundation for the present study, nevertheless includes generalisations which more detailed local studies are bound to revise.

The conclusion to a regional study of landform invariably offers an opportunity to stress the continuity of the denudation chronology which has been discerned and to emphasise the chronological arrangement. This opportunity is particularly attractive now that the great volume of chronological work which has been produced is almost certain to offer a more or less satisfactory correlation. The results of a study which involves the temporal dimension are readily summed up in chronological order and this treatment obviously adds a certain elegance to the work, but the concept of chronology should remain a means to facilitate the manipulation and compilation of the evidence and to render the account more fluent, and should not become the main achievement of the work.

At the moment the real value of each local geomorphological study, is the light which it throws on method, in the interpretation of landform. Professor Linton has lately stressed this point:

> "Discordances between streams and structures or between structure and surface can only be explained in terms of hypotheses of drainage evolution or denudation chronology. Such hypotheses in the present state of our knowledge are not infrequently mutually inconsistent and consequently our prime concern must be not so much to give a plausible account of what may have been the course of Tertiary

> landscape evolution as to indicate the principal forms of evidence that have been brought forward and the conclusions to which they tend."
>
> Linton, 1964.

The conclusions presented in this thesis suggest that some of the fundamental concepts which guide geomorphological research have in the past been applied without sufficient discrimination and without a proper recognition of the complications which may impair their value.

a. Perhaps the most lively source of difficulty has been an enthusiasm to extrapolate results without sufficient grounds to establish whether the material is susceptible to extrapolation.

b. Although the process of extrapolation is not inherently objectionable, geomorphologists have used it incautiously and conclusions have been reached on the basis of individual geomorphological criteria treated in isolation. The widespread correlation of planation surfaces on a basis of concordant height above sea level exemplifies this error; successful correlation is dependent on an understanding of structural behaviour during the Tertiary period, a concept which in this country has become a subject of tradition rather than critical enquiry. Equally unwise is an uncritical reliance on the exclusive testimony of drainage morphology or drifts or any of the other factors which in conjunction provide the key to a sound interpretation of the landscape.

c. Attempts have been made to explain the origin of distinctive and widely distributed landforms, in the belief that comparability of general form implies identity of evolution and origin. The work of Small (1961) on the escarpments of the Chalk is apparently guided by this view but the results obtained during the present study in the Vale of Wardour suggest that his interpretation there is not entirely correct. It seems unwise in any case to treat a feature of the landscape in this sort of isolation.

d. A growing tendency has emerged in recent years to stress the role of Pleistocene periglacial activity in the shaping of the present landscape. C.A. Cotton believes that:

> "The day is long past when it was the fashion to ascribe detailed landscape forms, i.e. any other than the broadest and most generalised features of relief to pre-Pleistocene morphogenesis."
>
> Cotton, 1958.

This view illustrates a recurrent inclination in geomorphology to overestimate the competence of particular processes, thus in the nineteenth century the 'marine' philosophy prevailed in this country for many years. The results obtained during the present study in southern Wiltshire show that individual facets of the landscape, including well preserved residual summits, erosional scarps and planation surfaces, can be referred without very much doubt to the Tertiary period. Impressive dissection of the landscape has been effected by Pleistocene erosion, but periglacial activity has not obliterated the severely simple lineaments of the Tertiary plainlands. It is obviously not wise, at least in this country, to attempt an interpretation of the landscape in terms of a unique process either operating without interruption or obliterating the work of earlier processes.

e. The evidence presented in this thesis shows that during the Pleistocene period the dissection of the Tertiary planation surfaces and the integration of subsequent drainage was a differential affair guided very emphatically by geological outcrop. In the interpretation of landform, contrasts of dissection or drainage morphology evidently do not provide a useful guide to the duration of exposure, independent of the character of the geological outcrop. An interesting commentary on this view is the map published by Wooldridge and Linton (1955, fig. 18) and considered by them to illustrate the contrast between accordant drainage on a mid-Tertiary surface and discordant drainage on a Pliocene marine plain; a pattern which can as satisfactorily be interpreted to show the accordant pattern on the Lower Cretaceous, Jurassic and Eocene outcrop and the discordant pattern on the Chalk.

f. In recent years the feeling has emerged that the interpretation of landform cannot begin, or should not have begun, until we are better acquainted with the processes which are at work in the present landscape; the converse view may be argued however that while the conditions in which the landforms originated are not known it will be difficult to estimate the significance of processes now operating upon them and this controversy introduces a final point which the evidence examined in this study brings to our attention: if the landscape has, in fact, been elaborated by pedimentation during the Tertiary period and by periglacial activity during the Pleistocene it is not likely that the quantitative study of contemporary process will do much to explain the contemporary landscape.

This critical review of geomorphological method suggests two main conclusions.

The nature of the problems encountered is inherently so complex that the elaboration of general principles should be attempted with the utmost caution and inferences drawn from generalised principles only in the light of independent evidence of their probability. Ideally each individual facet of the landscape, each slope and bevel, should be examined on the ground, on its own merits and in its own context and only then considered in the light of evidence obtained elsewhere.

The student of landform must be prepared to deal with a collection of details, not only geographically isolated but also, not necessarily relative to the same aspect of denudation and of correspondingly diverse character. The geomorphologist cannot afford to ignore or neglect any of the evidence; the individual pieces of evidence may be conclusive in the sense that each one establishes a particular point but when the pieces are assembled, the overall conclusions remain, at best, a matter of increasing probability which falls short of certainty simply because the evidence of Tertiary events has been largely destroyed. The nature of the late Tertiary subaerial surface in southern Wiltshire illustrates the use which can be made of independent sources of evidence: there is no question of correlation between concordant levels as the surface has been deformed; the drift on the surface is poorly characterised; the dissection of the surface has been a differential affair; and its relation to residual remnants of the mid-Tertiary surface is only locally evident. The recognition of the surface, for which the credit must largely be Mrs. Gifford's, is a matter of general considerations in the light of a careful study not just of the map but of the ground itself. To this extent Henri Baulig was mistaken when he expressed the view that morphological research is fundamentally a study of maps; unfortunately his is the view which too often has prevailed.

APPENDIX I

APPENDIX I: EROSION PAVEMENTS

The term 'erosion pavement' has been used in this thesis to describe a distinctive horizon in the soil profile, which proves to be developed on a wide range of stoney parent materials and in a wide range of topographic situations. The parent material is usually, if not invariably, a drift deposit.

The horizon is generally between 2" and 4" thick; a greater thickness than 8" has not been observed. The horizon consists of stoney material which seems as a rule to have been derived from the underlying parent material. Individual fragments in the horizon are small, the range ¼" to 1" probably being the most commonly represented, regardless of the size of the fragments in the parent material. Material finer than coarse sand is very largely absent in the erosion pavement and the interstices between the stones are often vacant or occupied only by loose coarse sand.

The pavement in most of the sections examined rests on the surface of the essentially unaltered stoney parent material at depths between 6" and 18". Above the erosion pavement several profiles have been recognised, but where there is reason to believe that the soil has remained essentially undisturbed during the historic period, a few inches (6"- 8" and rarely up to 15") of yellowish brown relatively stoneless loam rest on the erosion pavement; in these cases an A horizon is developed on the loam. At a few sites there is evidence that the erosion pavement overlies a lower loam, indistinguishable in aspect from the loam above the pavement, but preserved only here and there in hollows on the surface of the underlying stoney drift. This evidence suggests that the erosion pavement may have been locally redistributed(fig. 35).

Profiles of the general type described here have been recognised by Avery et al. (1959) on drifts in the Chilterns. Avery et al. compare the stoney horizon to the erosion pavements described by Shaw (1929), who appears to have originated the term 'erosion pavement'.

Avery et al. tentatively accept Shaw's view that the pavement represents evidence of a period of deflation or lateral eluviation.

Particle size analysis of the overlying loams in the Chilterns has shown that they incorporate a high proportion of silt in the 20 - 60 micron range, suggesting aeolian introduction and therefore, probably, periglacial climatic conditions. Heavy mineral analysis of the loams shows an appropriately extended suite of minerals.

If the loams are of aeolian origin, their absence from sites on the Chalk itself must be explained. Gifford (1957) points out that on the Great Ridge - Grovely Upland the loam is not present where clearings in the woodland are kept under the plough and she suggests that the loam has been removed in these cases by soil erosion in the course of prolonged cultivation:

> "Red Clay-with-flints covers the area of the cultivated enclosure in Grovely Woods but beyond this, loam predominates. It is possible that the undisturbed woodland vegetation has helped to maintain a loam capping . . . and that the distinction between this and adjacent cleared areas of shallow soil is the result of soil erosion." Gifford, 1957.

On the Chalk itself the history of cultivation extends into the prehistoric period, and evidence in hill washes suggests that soil erosion has reached destructive proportions on more than one occasion.

During the present investigation artificial flint flakes have been recovered resting on or incorporated in the erosion pavement at several sites; flakes are rarely encountered in the overlying loam and never in the underlying stoney drifts. Unfortunately the flakes are without exception waste material and nothing of diagnostic value was collected. The flakes are however almost completely unpatinated and contrast in this respect with the bulk of the flint in the erosion pavement which is commonly patinated a shade of grey or dirty white. The delicacy and small size of some of the flakes suggests a relatively late prehistoric origin. The work of Englehart in the Vale of Wardour tends to confirm this view. He writes:

> "I find the number of worked flints found on my ground to vary directly with the depth. On the strip dug to 18" they are very abundant, less so on the larger stretch of ground dug only to one spades depth, or about 9" and very few on the acreage which has been cultivated by the plough only (4")."
>
> Englehart, 1909.

Englehart's evidence suggests that deep digging may have turned up an erosion pavement and associated implements. The implements recovered by Englehart he refers to the Neolithic period, but some of the material described could well be of Mesolithic age.

There is a slight suggestion that Palaeolithic material may also be associated with these problematic soil profiles. White (1925) draws cautious attention to the discovery of Palaeolithic implements in the Clay-with-flints on Hackpen Hill (SU 130745). These seem likely to have been at the base of, or incorporated in, a superficial loam.

> "The greater number of the flaked stones were found . . . in yellow drift clay apparently newer than the red Clay-with-flints."
>
> Kendall, 1909.

During the present investigation, only in one case, has a waste flake been recovered below the erosion pavement. This example, from Tare Coat in Grovely Woods, occurred in a loam underlying the erosion pavement. Mr. D.F.W. Baden-Powell states that he knows of no record of implements in the Clay-with-flints itself.

It is tentatively concluded that the erosion pavements and superficial loams recognised during the present investigations are late or post glacial features.

APPENDIX II

APPENDIX II: INTRODUCED MATERIAL

During the studies of drift deposits described in this thesis great care has been taken to discount material which may have been introduced either deliberately or inadvertently since the original deposition of the drifts. This appendix describes some of the problematic and misleading material encountered during the present investigation.

a. Cley Hill (within the Iron Age earthwork): a fragment of pinkish grey quartz conglomerate (Plate 50) resembling conglomerate in the Old Red Sandstone outcrop on the Mendips (e.g. ST 637459); one face of this fragment appears to be worn flat and the Battlesbury evidence (below) suggests that the fragment may be part of a quern.

b. Battlesbury (ditch of Iron Age earthwork): a fragment of pinkish quartz conglomerate (Plate 50) almost certainly part of a quern.

c. Castle Ditches (on ground immediately with the main entrance to the Iron Age earthwork): a very large number of well rolled flint pebbles of Lower Tertiary aspect, also one pebble of hard silicious rock, probably a grit. It is impossible to suppose that these pebbles have been naturally derived during the denudation of Tertiary formations in the Pleistocene period as there is no evidence of flint nodules immediately derived from the Upper Chalk. Evidence from the Iron Age hill fort at Maiden Castle in Dorset, suggests that the pebbles at Castle Ditches may be sling-stones. (Manley, ?1927, records well rolled flint and sandstone pebbles associated with the Iron Age earthwork at Battlesbury and he mentions the recovery of well rolled flint pebbles in several barrows on the Wiltshire Chalk. Other extraneous material has been recorded in Neolithic long barrows; slabs of oolitic limestone at Adam's Grave (SU 113634) in the parish of Alton Priors, and of bluestone (cf. Stonehenge) in Bowls Barrow (ST 942467) in the parish of Heytesbury.)

d. Chalk has been encountered in soils overlying decalcified parent materials at several sites in Wiltshire and was also seen in soils on the Mendips which are not treated in this thesis. Raw chalk is at present occasionally employed as an agricultural dressing on acid soils and has been extensively used during the historic period. At the beginning of the Nineteenth Century, Davis records its use on, among other soils:

> "The red strong lands on the high level parts of the Downs." Davis, 1813.

Davis reports a dressing of 160 carts per acre (16 barrows per cart).

f. Concrete aggregates, often Tertiary or Pleistocene gravels, are occasionally encountered near reservoir sites, often situate on the summits of the Chalk Downs.

g. At a depth of 3'.4" in the drift of periglacial aspect at Christ Church Vicarage, Warminster, a small piece of wood was recovered (about 3/4" x 3/16"). This appears to be a twig of applewood. The site is now overshadowed and has been overshadowed, probably for about fifty years, by an apple tree. The wood has presumably been introduced into the drift by earthworms; their channels penetrate the drift to a depth of at least 5'.4" and are often marked by fragments of brick, ash and charcoal up to about 3/32" diameter. This evidence indicates the need for great care particularly in the selection of material for carbon 14 assay.

h. Cold Kitchen Hill: The provenance of the sarsen block (Plate 9) on Cold Kitchen Hill is problematic. Blocks of sarsen are very rare and perhaps altogether absent on Salisbury Plain. There are however occasional cobbles of sarsen (Plate 16) in the Pleistocene river gravels of the Avon and its tributaries. These, almost without exception, match Reid's description of a fine grained sarsen:

> "Having a peculiar wavy or banded structure"
> Reid, 1902.

Reid notes pebbles of this material at the base of the Bracklesham (Cuisian) Beds near Ringwood and suggests that they may have been derived from the Reading Beds on Salisbury Plain. The sarsen boulder at Cold Kitchen Hill is a similar fine grained rock and is in fact the largest example of fine grained sarsen of this type known to the writer. It might conceivably be the last relic of the beds whence this material has been derived. Its exact stratigraphic significance in this case is very doubtful. Moreover, at the foot of Cold Kitchen Hill, in the field adjoining Kingston Deverill churchyard on the East, two slabs (formerly three according to Manley, ?1927) of saccharoidal sarsen are preserved, which tradition supposes to have formed a megalithic monument on the neighbouring Downs.

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BIBLIOGRAPHY

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ABSTRACT

A B S T R A C T

The concern of the investigation described in this thesis has been to examine certain drift deposits in southern Wiltshire and to consider their distribution in relation to the accepted interpretation of the landscape.

The area examined has been discussed by Wooldridge and Linton (1955) but lies on the periphery of the tract with which they deal, and their treatment is essentially theoretical and not circumstantial.

In the course of the investigations which are described, samples were collected from over two hundred sites, surface indications of the geology were examined at a substantially larger number of sites and more than thirty sections were specially excavated in particularly interesting locations.

The work is based not on the application of refined geological techniques but on the ability to distinguish, in hand specimens, common and distinctive rocks. In important sections, samples of gravel of from 6 lbs to 20 lbs weight were secured and broken down into three fractions (1/16"- 5/32"; 5/32"- 1/2"; 1/2" upwards); for correlative purposes exact counts of the component materials

were carried out for the two coarser fractions. Although some of the individual examples encountered are problematic the conclusions have invariably been based on a significant volume of unmistakable material. The use of refined correlative techniques to confirm the results has not been attempted. This omission to some extent reflects the nature of the investigation, which is best regarded as a reconnaissance of a large area, describing evidence not only in Wiltshire but on the Chalk and Eocene outcrops elsewhere in Wessex, for the most part on ground lying to the West of the Salisbury Avon.

The results of the work are described in a comparative study of landscape features using, so far as possible, the whole geographical context of the ground examined: the dissection and weathering of the surface, the drifts and soils which rest upon it, and the relation of the ground to relief both above and below it.

In Part One of the thesis an attempt is made to establish the nature of the sub-Eocene unconformity.

A study of the Pleistocene river gravels about Salisbury suggests that Eocene formations may have been preserved on the western part of Salisbury Plain at the beginning of the Pleistocene period. This result is inconsistent with the views adopted by Wooldridge and Linton. The composition of the gravels examined suggests that the Eocene formations in question did not resemble formations now recognised in the main Eocene outcrops adjoining Salisbury Plain.

A study of the Palaeogene outlier on Salisbury Plain, at Clay Pit Hill, shows the gravels in the outlier to be closely similar in terms of petrology to the distinctive gravels in the Bagshot Beds about Dorchester in Dorset, and a correlation with these beds is suggested.

A distinctive gravel from another Palaeogene outlier, at Cley Hill, near Warminster, is described. This gravel at a height of about 800' O.D. appears to be preserved at or near the level of its original deposition, and is tentatively referred to the Oligocene period.

The evidence at Cley Hill and Clay Pit Hill is taken to show that the Chalk suffered extensive erosion during the Eocene and Oligocene periods.

A study of sites on the ground intervening between the Palaeogene outliers on Salisbury Plain and the Bagshot outcrop in Dorset provides new evidence on the nature of the Reading Beds, which tends to confirm the results of the investigations on Salisbury Plain.

In Part Two of the thesis drifts on the mid-Tertiary surface of Wooldridge and Linton (1955) are described.

Drifts on the Upper Greensand outcrop in the Vales of Wardour and Warminster are believed to be of periglacial origin and Pleistocene age. Drift on the Portland outcrop in the Vale of Wardour appears to be the debris of Lower Cretaceous formations and probably rests on an intra-Cretaceous surface.

On the Chalk a contrast is discerned between ground occupied by deep very flinty drifts of residual aspect and ground occupied by shallower flint drifts, also of residual aspect. The shallow drifts are shown to be associated with the relics of gravels incorporating Upper Greensand, Lower Cretaceous and Jurassic debris.

The deep very flinty drifts are believed to confirm the views of Wooldridge and Linton concerning the mid-Tertiary surface, but the shallower drifts and associated gravels are thought to rest on a separate surface, and the Cretaceous and Jurassic debris is believed to imply the competence of transverse gradients during the dissection of the mid-Tertiary surface.

The evidence described in Part Two of the thesis is difficult to reconcile with the concept of marine transgression across the Wiltshire Chalk. In Part Three of the thesis drifts on the supposed marine plain are described and the marine origin of the surface is rejected.

Specific evidence of a 'Pliocene' transgression in Wessex is reviewed and a study of supposed 'Pliocene' material refers the material in question to the Eocene period.

Problematic aspects of Pliocene stratigraphy and the concept of superimposition from a Pliocene surface are reviewed. Pinchemel's objections (1954) to a depositional surface are accepted but his views on fluvial aggradation are rejected in a study of gravel at Alderbury, near Salisbury, referred by him to this aggradation. Difficulties inherent in the concept of marine planation are recognised and ground referred by Wooldridge and Linton to the Pliocene marine plain is shown to be essentially indistinguishable from their mid-Tertiary surface and is therefore believed to be correlative with it. This view implies post-mid-Tertiary deformation of the Chalk.

In Part Four of the thesis a theory of drainage evolution is developed to replace the hypothesis based on a concept of late Tertiary marine planation.

Drifts, landforms and drainage morphology in the

Vale of Wardour are shown to demonstrate a deformed, subaerial planation surface, bevelling the outcrop of the Chalk and earlier formations at a level below the mid-Tertiary surface of Wooldridge and Linton. The present drainage pattern is believed to have originated during the deformation of this surface, probably in the Plio-Pleistocene interval.

This subaerial surface is also identified on Salisbury Plain and the origin of the drainage pattern there and in the Alderbury syncline is described.

The available evidence suggests that the subaerial surface was elaborated during the Pliocene period following the deformation of the Oligo-Miocene (mid-Tertiary) surface. The character of the late Tertiary (Pliocene) surface suggests comparisons with the surfaces described by King (1962) and termed by him pediplains, although the nature of the process involved remains doubtful.

In Part Five of the thesis some aspects of Pleistocene erosion are treated.

Adjustments to the drainage pattern in the basin of the Avon above Salisbury during the Pleistocene period are discussed. This account is based on analyses of gravels of the Avon and its tributaries about Salisbury.

The concept of successive stages of marine planation in the Hampshire Basin during the Pleistocene period is rejected in a study of the composition and morphology of the Pleistocene gravels.

An alternative scheme of subaerial planation is suggested and some morphological evidence of this planation on the Wiltshire Chalk and on the Eocene outcrop in the Hampshire Basin is described.

The problems of scarp recession and the dessication of the dry valleys are reviewed and the concept of scarp recession is abandoned. The Chalk escarpments are believed to have evolved where they now stand; the bearing of this idea on the dessication of the dry valleys is discussed.

Evidence of the catastrophic nature of Pleistocene erosion is described and a concept of a 'climatic cycle' reflecting Pleistocene glacial fluctuations is tentatively suggested.

In the conclusion to the thesis it is stressed that the main importance of the work should be recognised not in the chronological treatments of the results but in the evidence that some of the fundamental concepts which have guided geomorphological research in southern England have in the past been applied without a proper recognition of the complications which may impair their value.