GEOLOGY FOR ARCHAEOLOGISTS

By F. J. NORTH

The overlap of the fields covered by archaeology and geology was recognised long before either of those branches of science attained to separate existence. In his *Naturall Remarques on the County of Wilts*, published in 1695, John Aubrey suggested that the occupations and even the characters of men might be determined by the soil of the district in which they lived, and, for the better discussion of such matters, he 'wished for a mappe of England coloured according to the colours of the earth, with markes of the fossiles and minerals.'

Aubrey realised that 'a *true account* of the severall humours of our country' might prove 'too sarcasticall and offensive' to be published, but he pointed out, in support of his thesis, that, in the north of Wiltshire, 'a dirty clayey country,' where 'there is but little tillage or hard labour . . . the Indigenae feed chiefly on milke meates which coole their braines too much and make them melancholy, contemplative, and malicious, by consequence whereof come more law suites out of North Wilts, at least double to the southern parts . . . and they are generally more apt to be fanatiques.' By contrast, he noted that in the south of the county, 'on the downes, where 'tis upon tillage, and where the shepherds labour hard . . . they have not leisure to read, and contemplate religion, but go to bed to their rest.'

Anthony à Wood, the Oxford historian, did not approve of Aubrey's works and described their author as 'magotie headed,' but John Ray, the naturalist, after reading the manuscript containing the passage quoted above, wrote, 'Whatever you conceive may give offence, may, by ye wording of it be so softened and sweetned as to take off ye edge of it, as pills are gilded to make them lesse ungratefull,' pointing out that, if the soil alters men's nature, 'it accures not to them by their own fault.'

We may not be able to go all the way with Aubrey, and see a geological basis for the distribution of witches and of religious instability, but it is certain that many of the factors that determined the trends of history—factors such as coastal access and surface relief, climate and water supply, natural vegetation and agricultural potentialities, facility for movement and for the exploitation of mineral wealth—are influenced either directly or indirectly by the nature and distribution of rocks, and of the soil which has resulted from the destruction of rocks.

This being the case, it must often happen that reference to geological considerations will add interest to an archaeological investigation, will facilitate its completion, or will remove some of the difficulties by which the excavator or the field worker is confronted.

The work of the late H. H. Thomas on the origin of the megaliths at Stonehenge[1] affords a striking example of the assistance which geology can afford to archaeology, but the study of the petrological characters of the stones which early man pressed into his service does not always yield results as important as that, and there are many other less spectacular ways in which a knowledge of the principles of geology may help an archaeologist to interpret or to co-ordinate his discoveries.

Some of these less striking aspects of the matter are discussed in the following pages, and to deal first with problems of a general character, we may take :—

THE STUDY OF A ROAD SYSTEM

It is impossible to study a geological map without realising that, in one way or another, rocks have influenced road-patterns all through the ages, from the days when men knew nothing of geological principles and followed a track simply because it offered easy passage, to the present time, when roads are often triumphs of man over nature.

[1] H. H. Thomas, 'The Source of the Stones of Stonehenge,' *Antiquaries Journal*, vol. iii (1923), pp. 239–260.

Roads that have developed by the linking up of tracks connecting neighbouring places, and through-roads that came into existence at times when there was neither the necessity nor the skill for construction in difficult regions, are usually closely related to outcrops (e.g., the 'Pilgrims' Road' in Kent, Fig. 1), but roads that were definitely planned by competent folk, with a view to expediting communication between widely separated places, sometimes ignore more or less completely the geological structure of the areas they traverse.

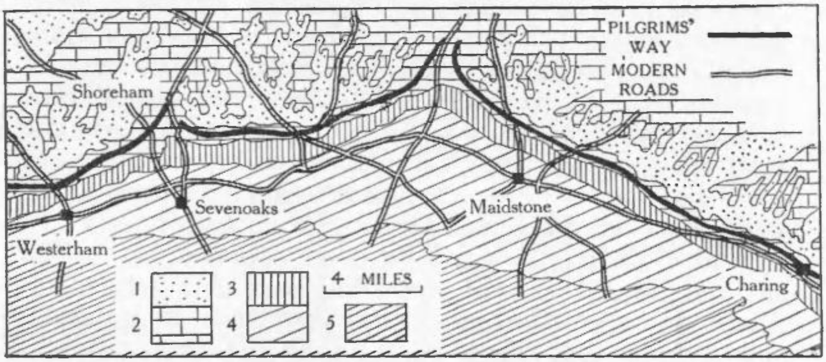

FIG. 1. PART OF THE PILGRIMS' ROAD IN KENT

An ancient track that follows a narrow outcrop of the Chalk, where that rock presents an escarpment towards the south. 1, Superficial deposits. 2, Chalk. 3, Upper Greensand and Gault. 4, Lower Greensand. 5, Weald Clay.

We find, however, that early roads made in defiance of geological considerations often failed to survive the neglect of the Middle Ages, and modern roads that have to go where the rock structures are unfavourable are costly to make and expensive to maintain.

It would be possible to give many examples of roads that have been subject to geological control, but one will suffice to illustrate the general principle, and I have chosen for the purpose part of a road in Dorsetshire (Fig. 2), that follows a curiously irregular course in order to keep upon a 'favourable' outcrop;

the reason for the choice of that particular outcrop does not for the moment concern us, but that the road and the outcrop are related is obvious enough.

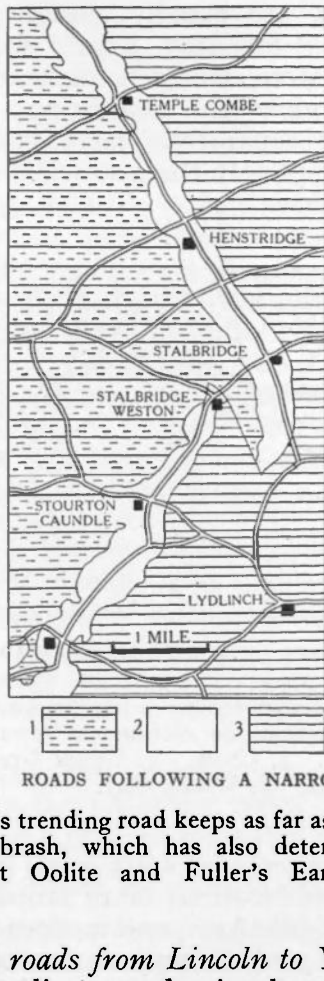

FIG. 2. ROADS FOLLOWING A NARROW OUTCROP

The northwards trending road keeps as far as possible on the outcrop of the Cornbrash, which has also determined the sites of villages. 1, Great Oolite and Fuller's Earth. 2, Cornbrash. 3, Oxford Clay.

The Roman roads from Lincoln to York. Taken as a whole, the earliest roads simply came into being as a result of continual traffic, but the Romans inaugurated a new era of roadmaking, for they possessed the skill and could command the resources necessary for the construction of roads in places that were practically impassable to the people over whose territory they assumed control. While the Ridgeways tended to follow escarpments and water-sheds, and the Hillside roads the contours, and both were, therefore, more or less sinuous, it is a feature of Roman roads that they take the shortest course from one place to another, and often for many miles are actually straight, in spite of obstacles such as those introduced by hills and forests.

Closer examination shows, however, that Roman engineers were not able entirely to escape the domination of rock distribution. Some of their roads, like that from Lincoln to the Humber, continued for long distances on the outcrop of a rock that afforded good going ; others, like that from Silchester to Cirencester, were deflected to make the shortest possible crossing of an outcrop that afforded unfavourable surface conditions, but rarely were those early road makers able to overcome the difficulties imposed by an extensive tract of waterlogged alluvial deposit ; usually they were compelled to go round it.

The Roman roads between Lincoln and York (Fig. 3) provide an interesting illustration of the principles that are involved. From Lincoln to the crossing of the Ouse (about midway between South Ferriby and the Trent, the road goes almost due north and is straight for nearly 30 miles ; incidentally, this, like many other stretches of Roman road that were not constructed in defiance of geological principles, survived the long period of neglect that began with the withdrawal of the Romans, and was made use of by the pioneers of our present road system, so that the motor-cars of to-day follow in the wake of the soldiers of long ago, sometimes on a road beneath which traces of the Roman foundation still remain.

The road lies on the outcrop of certain limestones (the Lincolnshire Limestone Series) that represent, in this region, the Inferior Oolite of the Bath and Cotteswold country. On either side of this narrow, elevated, dry, and relatively open belt, there are tracts where clayey rocks (the Lias on the west and various divisions of the Middle and Upper Oolites on the east), give rise to muddy conditions in wet weather; they were formerly occupied by forests or marshes. Prior to the control of the drainage of the Ancholme river by the construction of the new Ancholme canal, there must have been a large area of almost impenetrable marsh east of the limestone ridge, while in the west there lay the valley of the Trent, also, and to this day, liable to flooding.

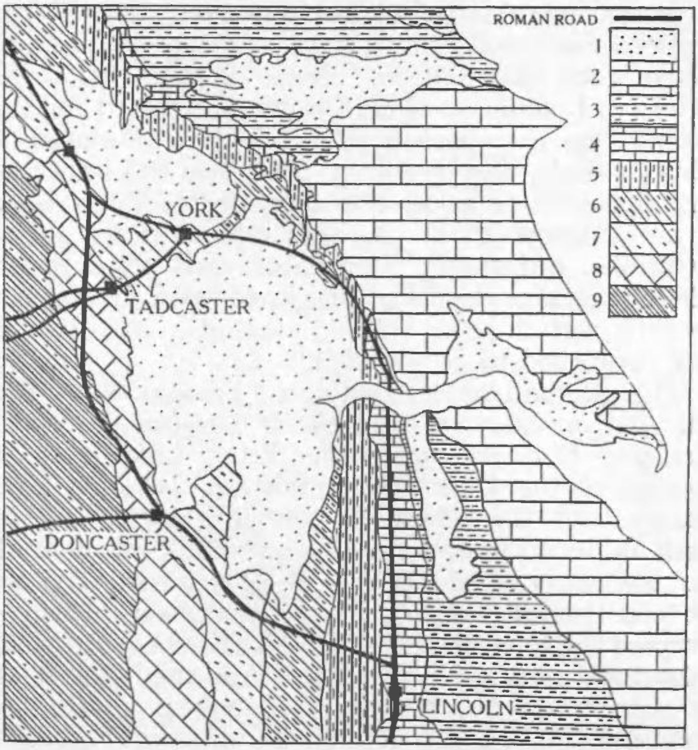

FIG. 3. THE ROMAN ROADS BETWEEN LINCOLN AND YORK

This simplified geological map illustrates (a) the course taken by the roads to avoid the large tract of alluvial deposit in the basin of the Ouse and its tributaries, and (b) the relation of part of the road to the outcrop of the Lincolnshire Limestone Series. 1, Alluvium. 2, Chalk. 3, Upper and Middle Oolites (largely clays). 4, Lower Oolites (Lincolnshire Limestone Series). 5, Lias (largely clays). 6, Triassic marls. 7, Triassic sandstones and conglomerates. 8, Magnesian Limestone. 9, Coal Measures (shales and sandstones). Especially in the east and south of the region, there are tracts of glacial deposit not represented on the map. Scale, 1 inch=22 miles.

In other words, in a strip of country averaging fifteen miles in width, the route followed by the Romans is exactly that which would be selected by a modern roadmaker after an examination of the geological map.

The road meets the Ouse estuary where it is more than a mile wide, and had to be crossed by a ferry, but although a course trending farther west from Lincoln would have made more directly for York and would have permitted a shorter crossing of the river, it would have involved a long passage on strata that gave rise to conditions of insuperable difficulty. Similarly, as Fig. 4 illustrates, a course due north from Lincoln would have caused the road to lose itself in the alluvial marshes near Brigg, and the adoption of the straight course trending a few degrees west of north suggests that the whole road was planned before any part of it was made.

There are other features of interest connected with this particular stretch of road, but before studying it in detail, it will be convenient to consider the road system between Lincoln and York of which it forms a part, and reference should again be made to Fig. 3.

A few miles north of Lincoln the Roman road divides into two branches; they enclose between them a somewhat rhomb-shaped area about a thousand square miles in extent, and they ultimately converge and unite a few miles north of York. It is obvious that the roadmakers found here a tract of country to be avoided, even at the expense of a longer route; the eastern road from Lincoln to York was 14 per cent. longer, and the western road 28 per cent. longer than the direct route.

The geological map shows that the average direction of the strike of the rocks is from north to south, so that there is a series of roughly parallel outcrops, comprising various strata from the Chalk to the Coal Measures. In the basin of the Ouse and its tributaries, the "solid" rocks are, to a large extent, concealed beneath a covering of alluvium which forms a level tract that is liable, even at the present day, to local flooding, and that must, in Roman times, have been extensively waterlogged.

Among natural obstacles to human movement, marshes present the greatest difficulties, for neither vehicles nor vessels can negotiate saturated alluvial soils with their attendant vegetation, and the Roman roadmakers had to modify their route accordingly. The eastern road, after following the outcrop of the Lincolnshire Limestone, as far as the Ouse, was continued on the other side of the river, on the outcrop, *here less than a mile wide,* of the same set of strata. In the south of Yorkshire, the divisions of the Oolitic rocks are thinner and less constant in their lithology than in Lincolnshire, and the road is somewhat sinuous (the scale of Figure 3 is too small to show that character). About two miles north of South Cave the road turns north-north-west, and takes a straight course across the outcrops of the Liassic clays and the Triassic marls, and eventually swings round, crosses the edge of the alluvium in the valley of the Derwent, and enters York from the east.

The western road, going west-north-west, crossed the Liassic outcrop almost at right angles (that is, by the most direct route), veered north-westwards across the Trias, and continued for many miles on the outcrops of the Magnesian Limestone and the Coal Measures, both of which offered good going. Near Tadcaster it was crossed by another road coming from the west, following the outcrops of the Magnesian Limestone and the Triassic sandstone, to York. A few miles north-west of York both roads from Lincoln met, and continued on a sandy sub-division of the Trias, after the eastern road had again crossed the edge of an alluvial tract.

Closer attention may now be given to the roads between Lincoln and the Ouse. As we have already seen, the Roman road ran northwards from Lincoln, along the outcrop of the Lincolnshire Limestone, and except for a few miles near Brigg, it has become the basis of the modern main road (Fig. 4). There are, also, other roads on either side of, and more or less parallel to, the Roman road : of these, that on the west is sinuous, while the course of that on the east can best be described as 'jerky.' All three are connected

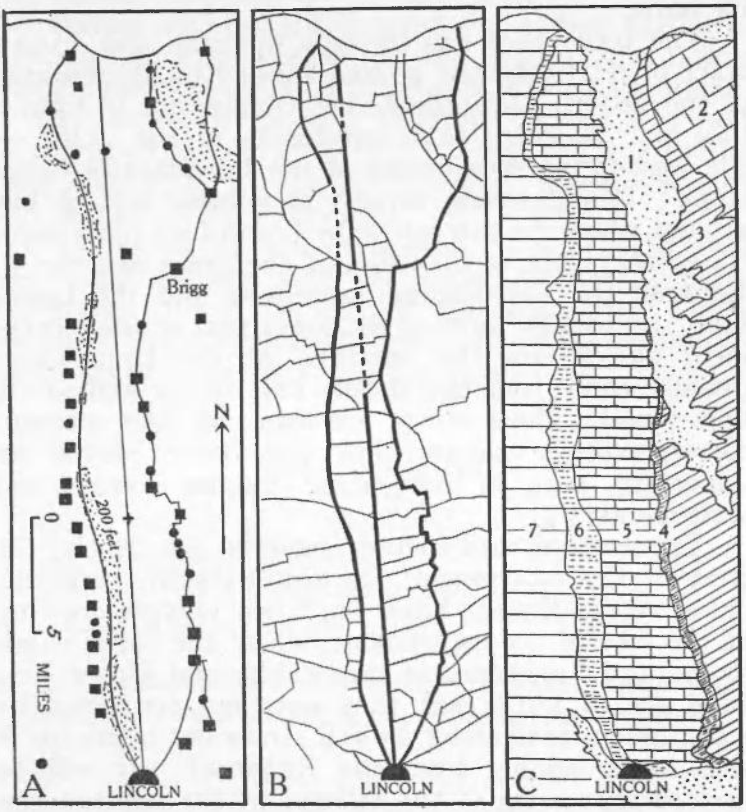

FIG. 4. ROADS, VILLAGES, AND GEOLOGY OF AN AREA NORTH OF LINCOLN

In A the Roman road (centre) is contrasted with the eastern road connecting a number of villages, and the western road, running near to, but not actually through another line of villages. B is the road plan, emphasis being placed upon parts of the early roads that have survived; C, a simplified geological map, shows the distribution of the rocks.

Square dots represent villages with Saxon names, round dots villages with Danish or Scandinavian names, and the cross on the Roman road is the site of Spital-in-the-Street.

1, Alluvium. 2, Chalk. 3, Oxford Clay and Kimmeridge Clay. 4, Cornbrash. 5, Lincolnshire Limestone. 6, Middle and Upper Lias. 7, Lower Lias.

by irregularly spaced cross roads, so that the modern local road-map (Fig. 4B) suggests a diagrammatic representation of part of a leaf, with its mid-rib and its veins.

The rocks here dip towards the east, and, from a tract of relatively low ground formed by the outcrop of the Oxford Clay, the Lower Oolites rise to form a long narrow ridge that terminates in the 'Cliff'—the west-facing escarpment of the Lincolnshire Limestone; this descends rapidly to another belt of low ground, where the outcrop of the Lower Lias marls forms the eastern slope of the valley of the Trent (see Fig. 5). Between the Lincolnshire Limestone and the Lower Lias, and usually forming the lower part of the escarpment slopes, are the outcrops of the Upper Lias (mainly clays) and the Middle Lias (clays and sandy limestones); these strata are thin and their outcrops correspondingly narrow, but they have played an important part in influencing human routes and settlements.

The western road follows, more or less closely, the crest of the escarpment; it is a Ridgeway and the oldest of the three. Later on, when villages grew up at the foot of the escarpment, where the clays, sandstones and limestones of the Middle and Upper Lias gave rise to fertile soil, they were not connected by a continuous road along the soft strata but by means of side roads leading from the Ridgeway. It will be noticed that none of the villages of the western row is actually *on* the road trending north, although the largest of them, Kirton in Lindsey, is skirted by it, whereas the eastern road passes *through* nearly all the villages it is intended to connect (see Fig. 4A).

There were no villages along the line of the Roman road, and except for an early settlement that is perpetuated in Spital-in-the-Street, none has since been established. The *absence* of villages along the line of the Roman road is closely connected with their *presence* in others; it is largely a question of water supply and soil condition. Water falling on the outcrop of the Lincolnshire limestone tends, as is usually the case with limestone, to pass underground, and, owing to the geological structure of the district, springs arise where the limestone gives place to the impervious clays on either side (Fig. 5). Many of the eastern villages are situated on or near the little streams that originate on the dip slopes of the Lower Oolites, and that enter the northward flowing Ancholme, or the southward flowing Witham. Along this belt of country the mixed character of the soil due to the close association of clays, limestones, and sandstones was favourable to cultivation.

In the case of the western road the relation of road to villages suggests that the Saxon invaders, coming along the road at the top of the escarpment, found congenial territory near the foot of the ridge and established themselves there, but the eastern road, which is

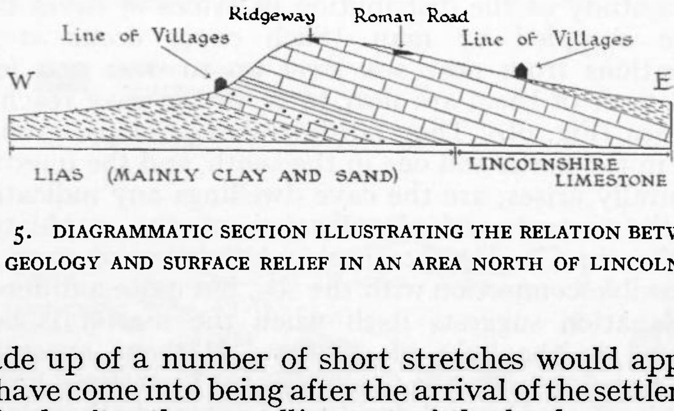

FIG. 5. DIAGRAMMATIC SECTION ILLUSTRATING THE RELATION BETWEEN GEOLOGY AND SURFACE RELIEF IN AN AREA NORTH OF LINCOLN

made up of a number of short stretches would appear to have come into being after the arrival of the settlers—indeed, after the parcelling out of the land.

It is not the function of a geologist to enquire further into the history of this series of roads all going in the same direction, but originating at different times and for different purposes, but I think it will be agreed that whatever may have been the effect of custom upon the distribution of the settlements, and upon the road system connecting them, the fundamental control was geological. If this is indeed the case, then the geological map should form the basis of a detailed study of the activities of man within the area.

PROBLEMS RELATING TO THE DISTRIBUTION OF EARLY MAN

In dealing with problems relating to the distribution and movements of early man it is often necessary to consider to what extent the evidence available can be taken as representative. The absence of a particular type of object from an area may mean that such objects do not occur there at all, or, on the other hand, it may simply mean that none has yet been found. In many cases there may be other evidence which will indicate which of these two alternatives is the more likely, and more often than not, the problem is fundamentally a geological one.

An interesting example of the necessity for considering the scarcity of evidence, and the reason for the existence of such evidence as is available, is offered by a study of the distribution in Wales of caves that were occupied by man. Such caves occur at all elevations from near sea level up to over 700 feet, and most of them are near to or within easy reach of the sea (Fig. 6). They fall into two principal groups, one in the north and one in the south, and the question naturally arises, are the cave dwellings any indication of the extent and distribution of the population at the time? The geographical distribution suggests a possible connection with the sea, but quite a different explanation suggests itself when the matter is considered in the light of geology. Without exception the caves occur in the Carboniferous Limestone, a rock that is affected by well-developed joints and other planes of weakness, and is, in common with limestones generally, readily soluble in atmospheric waters by virtue of the carbon dioxide which they contain. It is, therefore, particularly liable to be honeycombed with caves.

Caves are often produced by the action of the sea, and some of the caves once occupied by man have been in part formed in that way. In the case of Paviland Cave[1] in Gower, for example, which occurs in a cliff

[1] See W. J. Sollas, 'Paviland Cave; an Aurignacian Station in Wales,' *Royal Anthrop. Inst. Great Britain*, vol. xliii (1913), pp. 325–374.

overlooking the sea, marine erosion may have played a large part in the excavation, but it is clear from an examination of the ground plans that most of the caves of occupation were produced by terrestrial

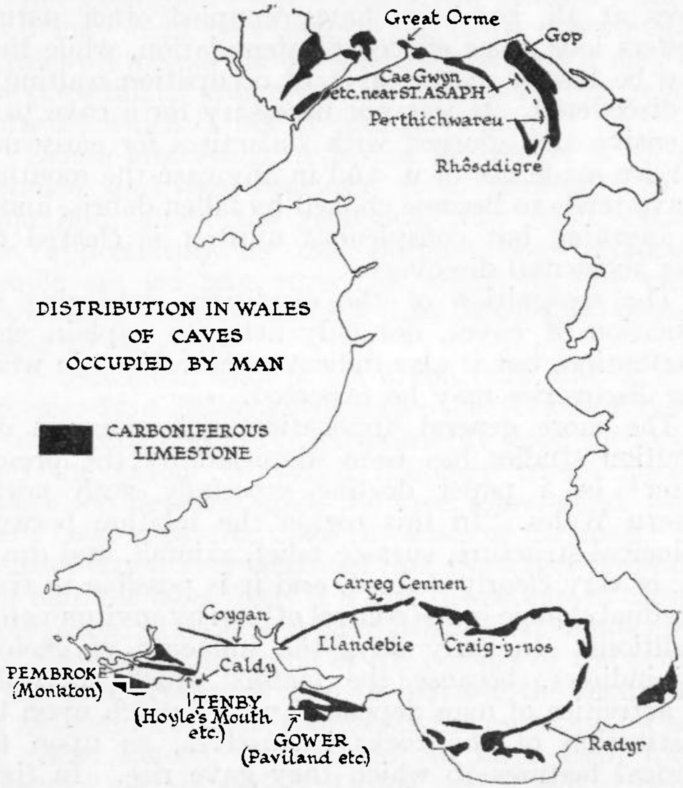

FIG. 6. DISTRIBUTION OF CAVES IN WALES

Sketch map illustrating the relation between the outcrops of the Carboniferous Limestone and the distribution of caves of human occupation in Wales.

agencies,[1] and are just as likely to occur in inland regions as near the sea.

As far as Wales is concerned, it is only in the

[1] E.g., 'Coygan Cave, near Laugharne,' see *Quart. Journal Geol. Soc.*, vol. 38 (1882), p. 283; and W. F. Grimes and L. F. Cowley, in *Archaeologia Cambrensis*, vol. xc (1935), pp. 95–111.

Carboniferous Limestone that extensive caves have been formed, and the few caves in which human remains have been discovered cannot be taken as affording any indication of the magnitude or the distribution of the population in " Cave-dweller " times, for some people may not have lived in limestone caves at all, but may have occupied other natural shelters long since effaced by denudation, while there may be few or many caves of occupation waiting to be discovered. It was not necessary for a cave to be extensive and adorned with stalactites for early man to have made use of it, and in any case the mouth of a cave tends to become choked by fallen debris, and to be anything but conspicuous until it is cleared out after accidental discovery.

The recognition of the conditions governing the formation of caves, not only helps to explain their distribution, but it also indicates the regions in which new discoveries may be expected.

The more general application of geology in distribution studies has been discussed by the present writer[1] in a paper dealing especially with north-eastern Wales. In this region the relation between geological structure, surface relief, rainfall, and drainage, is very clearly defined, and it is possible to trace a gradual change in the control of man by environmental conditions. In early days the influence of geology was indirect, because the factors which controlled the activities of man depended not so much upon the constitution of the rocks themselves, as upon the physical features to which they gave rise. In time, however, as the problems of water supply became more acute, and man became more and more dependent upon mineral resources—stones for building, ores for the production of metal, and finally, coal—his migrations and settlements have been determined almost exclusively by the distribution of the rocks in which those commodities are found.[2]

[1] 'The Background of History in North-Eastern Wales,' *Archaeologia Cambrensis*, June 1932, pp. 1–47.

[2] From the viewpoint of an archaeologist the value of a geological basis for archaeological investigation has been emphasised by Sir Cyril Fox in his *Archaeology of the Cambridge Region* (1923), and in *The Personality of Britain* (1933).

THE USE AND ABUSE OF THE GEOLOGICAL MAP

The foregoing brief references to roads, to caves, and to population movement will, I think, serve to illustrate the general principles of the application of the geological map in historical studies. Such a map may help to explain apparently unaccountable actions on the part of our predecessors, and it may help to co-ordinate fragments of evidence, the relation between which is not at first obvious.

Before proceeding to discuss the matter in its more detailed and local bearings, it is necessary to say something about the geological map itself, because, not appreciating its real purpose and significance, people are led into error, for which, in due course, they blame the map, and not their own failure to understand its language.

A geological map is not a soil map, and it is not necessarily a lithological map—the rock-subdivisions that it recognises are based primarily upon chronology, and the extent to which lithology enters into the indication depends upon the area represented, and in very large measure, upon the scale of the map. In a general way it may be stated that the larger the scale of the map the more likely it is that the colours or the symbols placed upon it will have lithological significance.

Fundamentally, each of the colours or the symbols used on a geological map to indicate the distribution of sedimentary rocks represents the outcrop of a series of rocks known, or believed, to have been formed during a certain period of time, and it will at once be realised that it will rarely happen that similar kinds of deposit will have accumulated simultaneously over an area as large as Great Britain. If such an area were part of an extensive sea, remote from the land in all its parts, then there would probably be a striking uniformity, over quite large tracts, in the nature of the sediments, as there is, for example, in the case of the Chalk; but the region might at any time have been covered in part by deep water and in part by shallow water, and it might have included land as well as sea, and fresh-water lakes as well as dry land.

In such circumstances it is obvious that if we use one tint to represent all the rocks formed during one period of time, the map cannot be taken as an indication of the lithology of the strata so represented. For example, on the twenty-five-miles-to-the-inch geological map, a blue tint represents the outcrop of a rock described in the Table of Strata as Carboniferous Limestone. The rock occupies a very large area in the Pennine country from Derbyshire to Northumberland, and occurs in smaller patches in North Wales, South Wales, and the Mendips. In the Peak District, the Carboniferous Limestone is a more or less fossiliferous limestone many hundreds of feet in thickness, and it gives rise to typical limestone scenery—open country on the higher ground with wooded valleys and gorges. In Wales and the Mendips, also, the Formation is predominantly limestone, but in Northumberland it consists mostly of sandstones and shales, the limestones being merely subordinate beds within a thick series of non-calcareous deposits.

The explanation is that, during Carboniferous Limestone times, most of the British area was the site of a comparatively clear sea in which many kinds of marine animals thrived, and on the floor of which they built up thick layers of their calcareous skeletons or supporting structures, but a land mass lay to the north. The rivers draining that land brought down sand and mud, which were deposited in the regions that are now Northumbria and the south of Scotland, while the calcareous material (which is now limestone) was deposited in the more open parts of the sea. On a geological map on the scale of one inch to the mile some differentiation of the outcrop of the Carboniferous Limestone into its calcareous and non-calcareous portions is possible, while, if the scale is six inches to the mile, the outcrops of individual limestone beds in an otherwise non-calcareous series can be separately indicated.

Another example of the generalised character of the information given on a small scale map is provided by the coal-bearing strata of the South Wales Coalfield. On the twenty-five-miles-to-the-inch map these are given one tint and described as Coal Measures, but the strata are far from being homogeneous. This is indicated in some measure upon the four-miles-to-the inch map, where three subdivisions are recognised—the Lower Coal Series, the Pennant Series, and the Upper Coal Series.

In the eastern part of the Coalfield the Pennant Series consists very largely of sandstones and grits with some subordinate shales, and it is responsible for the bare rounded hills that form so striking an element in the scenery of this part of South Wales. In this region the two Coal Series which it separates consist very largely of shales with coal seams, but each of the Series includes beds of sandstone. The outcrops of two coal seams that can be recognised with reasonable certainty have been taken as the upper and lower limits of the Pennant Series, and since the massive Pennant Sandstone is regarded as typical of the Pennant Series, and the shales and other argillaceous materials that one sees in colliery tips are regarded as characteristic of the Lower Coal Series and the Upper Coal Series, it is easy to form the impression that the tint used to designate the Pennant Series represents a vast sandstone area that is encircled by a shale area (the outcrops of the Lower Coal Series) and that itself encloses island-like masses of shales, where rock folding has resulted in the formation of basins preserving some rocks of the Upper Coal Series.

Locally this may be true, and there may be a marked difference between the open, uncultivated moorland occupied by the Pennant Sandstone and the more fertile grass lands of the argillaceous Coal Series, but the boundary between the Pennant Series and the Lower Coal Series, for example, cannot be taken, over a large area, as sharply delimiting two types of scenery and of agricultural potentiality, for in some places the uppermost beds of the Lower Coal Series contains many beds of sandstone that are lithologically like the Pennant Sandstone (Fig. 7). Indeed, the difference between the Pennant Series and the Lower Coal Series becomes less marked as one goes westwards, and in the extreme west of the coal-field, the determination of the boundary between them has been a matter of no little difficulty.

What applies to the South Wales Coal Measures and the Carboniferous Limestone applies also in greater

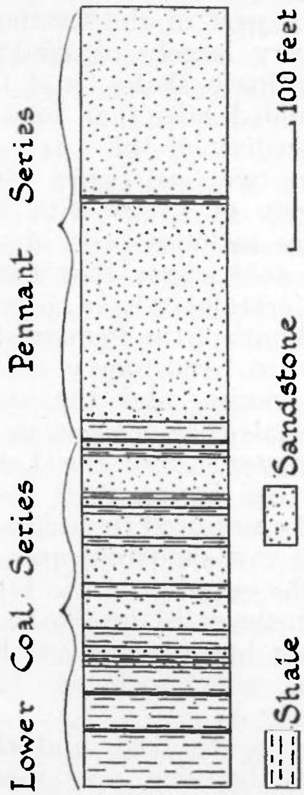

FIG. 7. VERTICAL SECTION OF THE CARBONIFEROUS STRATA NEAR PONTYPOOL,

to show that the boundaries drawn upon a geological map are not necessarily coincident with marked lithological changes in the field.

or lesser degree to other geological formations and to other localities, and it will be evident that care must be exercised when using a geological map as the basis for generalisations concerning the conditions in an area when man first began to settle therein. Such generalisations may be dangerous if unsupported by

1A. THE CARBONIFEROUS LIMESTONE AT CLYDACH, NEAR ABERGAVENNY

The Carboniferous Limestone, which is inclined gently to the left and gives rise to the rocky escarpment, has resisted denudation to a greater extent than the marls of the Old Red Sandstone, which occupy the lower cultivated ground.

1B. FFOREST FAWR, BRECKNOCKSHIRE

The distant hills are of Old Red Sandstone, and the cultivated area in the middle distance is situated for the most part upon drift-covered Carboniferous Limestone. In the foreground the limestone is free from drift, and its surface is pitted with "swallow holes," due to the collapse of the roofs of solution-cavities.

a knowledge of the stratigraphy of the area, or by personal examination in the field. By way of illustration we may compare two areas in South Wales where the junction between the Carboniferous Limestone and the Old Red Sandstone is involved.

At Clydach, near Abergavenny (Pl. i A), the Carboniferous Limestone rises to the surface, and is exposed in the sides of a valley that opens out towards that of the Usk. The Carboniferous Limestone gives rise to an escarpment, and the open grass lands on the dip slopes of that rock contrast strongly with the enclosed fields on the outcrop of the Old Red Sandstone in the bottom of the valley. The boundary between the two types of surface follows very closely the junction between the two Formations.

Farther westwards, looking towards the hills that connect the Brecknock Beacons with the Carmarthenshire Fans (Pl. i B), one has, again, the transition from open country to enclosed fields, but in this case the open country occurs on the outcrops of both the Carboniferous Limestone and the Old Red Sandstone —the fields have been established where there is a superficial covering of glacially transported debris or 'drift.' It thus transpires that while it may be true that in one area the Carboniferous Limestone and the Old Red Sandstone are characterised by very different types of scenery, in another the difference may be less pronounced, or may not occur, or the situation may be complicated by the presence of glacial 'drift'—a type of deposit sufficiently important in the geological aspects of archaeology to be made the subject of a separate section of the present paper.

In the foregoing notes upon the geological map, no reference has been made to the igneous rocks, which play so important a part in the building up of the earth's crust.

Igneous rocks are those which were once in a molten condition and represent material which was either poured out on the surface of the earth during volcanic eruptions, or was injected into fissures within the rocks of the earth's crust, or that cooled in great deep-seated reservoirs. The boundary between the igneous rock and those with which it is associated is usually sharp and clearly defined, but it has sometimes happened that, in the case of a great subterranean reservoir of molten matter, which on cooling became an igneous rock like granite, some of the surrounding strata have been changed as a result of the heat to which they were subjected, or as a result of intermingling with the liquid magmas injected into them, while some of the igneous rock may have acquired a peculiar composition near its margin, as a result of the incorporation of material from the walls and roof of the reservoirs it occupied.

In the south of Britain the outcrops of igneous rock are comparatively small, and their relation to archaeological problems arises not so much from variations in the surface conditions to which they give rise, as to the use which early man made of them as materials from which to fashion his weapons and his tools—but this matter will be discussed more fully in subsequent paragraphs.

What has been said in regard to the igneous rocks applies also to the rocks which originated as volcanic dusts and ashes, spread about on land or in water, and now intercalated with the sedimentary rocks ; and to the metamorphic rocks, which occur, for example, in Cornwall and in Anglesey, and are so magnificently displayed in the Scottish Highlands. As their name implies, the metamorphic rocks have undergone a change of form ; they represent sedimentary rocks or igneous rocks that have been more or less completely altered in texture as a result of heat and/or pressure operating at a time when they were buried deeply within the earth's crust. The changes of texture are often accompanied by alterations in mineralogical constitution, and the original character of the rock may be obscured, as in slates, or completely obliterated, as in many crystalline schists and marbles.

DRIFT MAPS

The ordinary geological map concerns itself only with the rocks that enter into the essential structure of the earth's crust, and does not indicate the deposits which were formed and distributed during the last great glacial episode of earth history. Apart from the formation of sand dunes and the building up of peat beds and stretches of alluvium, the final touches were put to the surface features of much of the northern hemisphere during the Ice Age. During that period snow accumulated on the mountains, glaciers descended into the valleys, and ice sheets moved slowly across the land, scraping away the soil and the sub-soil, and picking up loose stones, and generally transporting a vast amount of debris ; then, later on, when the ice began to melt, this heterogenous burden was deposited in an irregular fashion in regions where the ice had once held sway.

In places, the transported material covered the surface with mounds and ridges, or else it filled hollows in the surface over which the ice had passed, or was spread as extensive sheets over level regions, generally obscuring the solid rocks by a mantle of 'drift' as, collectively, these superficial deposits are called.

Where the 'drift' was deposited merely because the melting of the ice caused the deposition of the burden of transported débris, the resulting deposit consists of stones of all kinds and sizes indiscriminately mixed together in a matrix of rock-flour, and is called 'boulder clay,' but often, the material was more or less effectively sorted out by the action of the water which resulted from the melting of ice, and this gave rise to deposits of gravel, sand, or clay.

Whatever its nature, the drift tends to be very variable in character on account of the wide range of materials from which it is derived, and in thickness on account of the irregularity of the floor on which it accumulated and the extent to which it has been disturbed by natural agencies.

The various kinds of drift tend to merge into one another, and only on a large-scale map is it possible to indicate the precise nature of the material, especially when it is of mixed origin.

It is important to recognise the existence of the drift when making use of a geological map, for it is obvious that where there is a covering of glacial material the soils bear no direct relation to the underlying rocks that enter into the structure of the area.

For many areas the Geological Survey prepares two geological maps, one showing the distribution of the superficial deposits of glacial origin, and another showing the area as it would appear if all such deposits were cleared away. The former is called a *drift* map

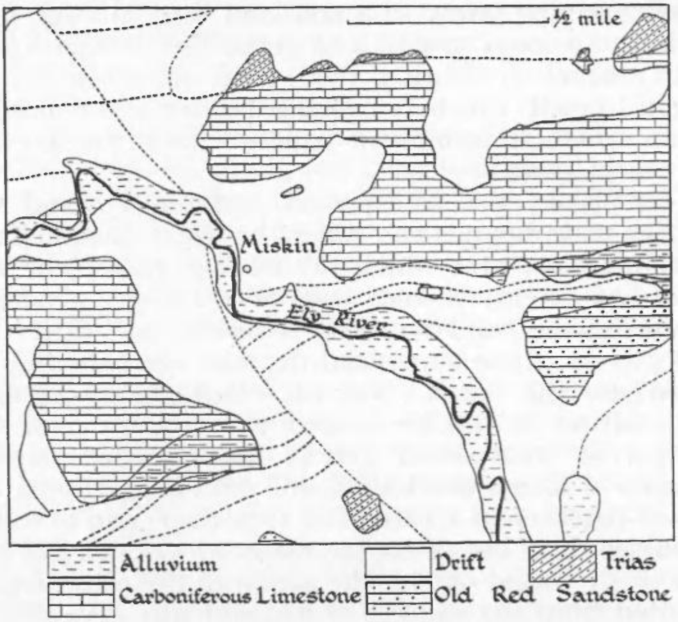

FIG. 8. A "DRIFT" GEOLOGICAL MAP

Outline map based upon the six-inch map of the Geological Survey, illustrating the extent to which thin superficial deposits, mostly of glacial origin, conceal the rocks that make up the essential structure of the country. The drift-covered areas are left blank, and the concealed geological boundaries are represented by broken lines.

and the latter a *solid* map, and the relation between them is illustrated in Fig. 8, which depicts an area in Glamorgan.

It is obvious that problems involving reference to the conditions under which early man lived, and discussions concerning the distribution of types of vegetation, or the facilities for movement across the country, must be considered in relation to the *drift* map and not to the *solid* map, and to do this satisfactorily the variability of the drift must be taken into consideration. It must also be recognised that while the representation of drift on a geological map may be taken as a safe indication of its presence, the fact that it is not recorded is not necessarily proof of its absence. There are, for example, on the hills and moorlands of South Wales, important patches of drift that are not indicated on the Geological Survey drift maps—not because the surveyors were inefficient, but because, where the nature of the deposit is not such that it gives rise to characteristic surface conditions, the presence of the drift may only be revealed when excavations are made.

It is because of the bearing which these matters have upon generalisations concerning the soil conditions and vegetation during remote epochs of the human era, and therefore, upon attempts to envisage the environment of early man, that I have enlarged upon the importance of appreciating the distribution and variability of the drift, and upon the necessity for recognising that boundaries upon the solid map are not necessarily lithological.

It might be urged that the foregoing remarks concerning geological maps merely serve to indicate that they may be so misleading as to be of little use in archaeological work ; on the contrary, they show how informative such maps can be, and emphasise the necessity for understanding them, so that full advantage may be taken of what they have to offer, and so that they shall not be blamed if they do not afford information which it was never intended that they should give.

PROBLEMS INVOLVING REFERENCE TO LOCAL GEOLOGICAL CONDITIONS

If a proper appreciation of the nature and the extent of the information to be obtained from geological maps on various scales can help the worker who is concerned with problems of a general nature affecting large areas, it is equally true that it can contribute to the solution of many problems of a purely local character.

Two imposing burial chambers in South Wales (near St. Nicholas and at St. Lythans a few miles south-west of Cardiff) stand upon the outcrop of the Keuper Marl division of the Triassic Series of strata. Now the soil on the Keuper Marl is usually a stiff red calcareous clay, given over to permanent pasture and dairy farming. The soils are usually difficult to work and need deep drainage, so that, all things being considered, sites on the Keuper Marls are not what one would have expected the builders of 'cromlechs' (as the burial chambers have been popularly but inadvisedly called) to choose, both from the nature of the environment, and the difficulty of obtaining suitable material. This is especially so in the district cited, but less than half a mile away in one case, and even nearer in the other, the Carboniferous Limestone occurs, and that rock would have provided good stone and a well-drained surface. Why then, should the builders have chosen to erect their burial chambers upon the outcrop of the Keuper Marls?

The answer is that just hereabouts the Trias is of anomalous character: it provided (Fig. 9) not only a suitable site but also beds of durable rock from which really large masses could be obtained even more easily than from the neighbouring Carboniferous Limestone outcrops.

A long interval of time elapsed between the formation of the upper beds of the Carboniferous System in this country, and the accumulation of the Triassic strata. During that period land conditions existed over much of the British area, and the rocks that had already been formed were subjected to severe denudation under subaerial conditions. They gave rise, in the part of Glamorgan with which we are concerned, to an uneven surface, with hills of Carboniferous Limestone rising above the general level of the district. When, eventually, the area sank, and water returned to cover it, these hillocks of Carboniferous Limestone became islands in the Triassic sea, and around them the deposits that were formed were of distinctive character. They are breccias and conglomerates made up, in some places, of the debris that had resulted from the subaerial disintegration of the limestone hills, and in other places of masses of rock dislodged by the waves, together with the pebbles resulting from the destruction of such masses.

Locally, where the destruction of the limestone was more complete, the Triassic material is a more or less homogeneous fine-grained deposit, made up of

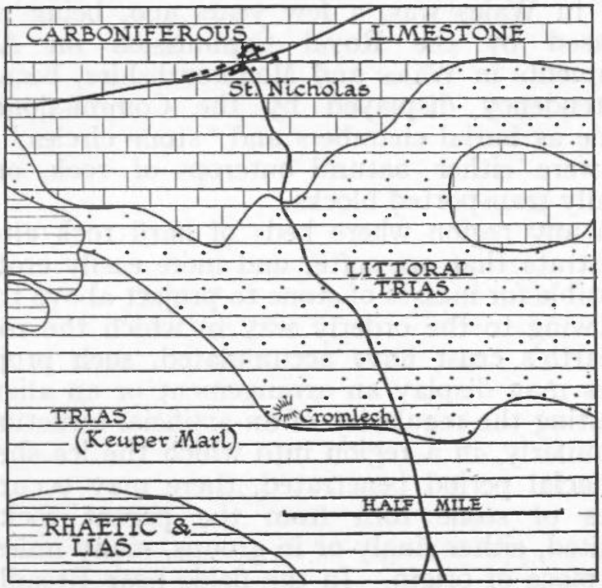

FIG. 9. SKETCH MAP ILLUSTRATING THE LITHOLOGICAL SIGNIFICANCE OF THE SITE OF THE CROMLECH NEAR ST. NICHOLAS, GLAMORGAN

limestone detritus, and in such cases it is often difficult to distinguish it, macroscopically, from the Carboniferous Limestone.

When weathered, such reconstructed limestones tend to be softer than the Carboniferous Limestone, but they are tough, and less are affected by strong vertical joints than the rock from which they were derived. It is a rock of this type that constitutes the Keuper deposits near St. Nicholas and St. Lythans, so that, although the boundary between the Trias and the Carboniferous Limestone separates rocks of different ages, the rocks on either side of the boundary have much in common lithologically, and consequently in their influence upon the activities of early man.

Reference to the St. Nicholas 'cromlech' suggests another problem associated with megalithic monuments in general, and that is the determination of their authenticity. As W. F. Grimes[1] recently pointed out, the number of megalithic monuments supposed to occur in Wales was, a few years ago, being rapidly increased by the Royal Commission on Ancient Monuments in Wales and Monmouthshire, because of the tendency displayed by the Commissioners to include as burial chambers and 'stone circles,' stones that were either natural outcrops of rock, or were glacially transported blocks.

In any region where beds of hard rock alternate with strata that are softer and more easily eroded, it is possible for masses of stone to project above the soil, and owing to the orderly way in which the rocks of the earth's crust have accumulated, such projecting masses may display an arrangement or an alignment suggesting the regularity of an artificial structure.

Similarly, in a region into which the ice sheets of the glacial period penetrated, there may occur large masses of stone torn from the parent rock, and deposited, either singly or in groups, many miles from their place of origin. In the fields near Broadhaven, in Pembrokeshire, for example, there are many large blocks of igneous rock that were carried by ice from the neighbourhood of St. Davids.

As an example of a glacially transported boulder that has been mistakenly identified as a megalithic monument we may cite a so-called Cist-faen, near a farm called Pen-y-cefn in Merionethshire. In the *Inventory of the Ancient Monuments of Merioneth*[2] it is recorded that, in a field called Y Gist Faen, a few miles from Corwen, there are " five large stones which

[1] 'The Megalithic Monuments in Wales,' *Proceedings of the Prehistoric Society* (1936), pp. 106–139, and National Museum of Wales.

[2] Royal Commission on Ancient and Historical Monuments: *County of Merioneth*, 1921, p. 116.

2A. GRANITE TORS NEAR BRIDESTOWE, DEVON

2B. THE HEN BLAS "DOLMEN," LLANGRISTIOLUS, ANGLESEY

(Reproduced by kind permission of Miss A. M. Griffiths)

almost certainly represent the supporters of a cist faen . . . The stones still standing should receive early attention and the whole should be protected.'

Actually the stones are parts of a large erratic boulder that has split and fallen to pieces. If it is asked how such a mass of rock could be split by natural means, the answer is that it might have been due merely to gravity, which, when weathering along joints or other planes of weakness in the original mass left portions in a state of instablilty, allowed fragments to fall away, or it may have been due to the growth of a tree which sent its roots wherever it found fissures in the stone, ultimately prising its component masses apart. Such a process, in an early stage, is illustrated by a huge mass of mica schist at Trefarthen in Anglesey, which has been split into two by a small tree.[1]

As an example of natural outcrops mistakenly regarded as erections by early man, may be cited the so-called Glandwr Cromlech near Mathry, which, in the Pembrokeshire volume of the Royal Commission's report is described as a Chamber formed of four stones. 'The capstone,' continues the report, 'is said to have disappeared and the grave to lie due north and south.'

The absence of the capstone is due, not to the use of the site as a quarry, but to the fact that it never was there, for the masses of stone are simply parts of a natural outcrop of rock, in which weathering along planes of weakness produced features that suggest separate blocks that have been artificially placed together.

The possibilities of mistakes in the interpretation of rocky outcrops, will, I think, be best realised if one studies the granite tors of Devon and Cornwall (Pl. ii A), where weathering along the joints within the granite, and the removal by erosion of the resulting debris, often creates the impression that one is dealing with stones that have been placed in position by human agencies. I have chosen, for purposes of illustration, an example in which the natural origin

[1] Figured in 'The Geology of Anglesey' (*Memoirs Geol. Survey*), E. Greenly, 1919, p. xlviii.

of the mass is quite clear, but when denudation has been less complete the risk of error is correspondingly greater.

The foregoing examples show how necessary it is to recognise that, in certain circumstances, the results of the operation of natural processes can simulate the handiwork of man. It may not always be easy to determine, for certain, whether man or nature was responsible for the transport or the exposure of a stone, but if the fact that nature *can* accomplish both these tasks is not realised, it is inevitable that distribution-maps will show many spots to which they are not entitled.

It is not for one moment suggested that reference to geology will solve all the difficulties that confront the archaeological field worker. Sometimes it may fail, and sometimes it may appear to make the problem even more complicated. As a case in point we may take a group of large boulders, known as Hen-blâs, near the Church of Llangristiolus in Anglesey.[1] It had long been a matter of doubt as to whether these boulders represented a ruined 'dolmen' or had come into their present position by natural means, but during the course of a geological survey of Anglesey, Greenly discovered that the thinnest of the stones, which had been regarded as the capstone by those who favoured the 'dolmen' view, had glacial striae on its underside, although the upper surface was rough and uneven like the rest of the stones. He also inferred from the nature of the striae, that the mass was part of a rock floor over which the ice had passed, and was not a transported boulder, and observed that the material was quartzite of immediately local origin.[2]

The position of the striated surface indicated that the mass had been turned over, and since, in the circumstances, natural means could not be invoked, Greenly argued that the stones must have been deliberately placed in position, and suggested that because the direct outlook between the two principal stones

[1] See the 'Megalithic Remains of Anglesey,' E. Neil Baynes, *Trans. Soc. Cymmrodorion*, 1912, p. 39, Fig. 16.

[2] *Nature*, 1905, p. 152.

is due east the erection was probably an equinoctial monument.

In this case the intervention of a geologist did not remove the difficulty, but increased it, because there are those who believe that on typological grounds the group of stones does not appear to be one that can be attributed to the activity of early man. This is not, however, an argument against the value of geological co-operation, but an example of the need for closer collaboration in the field—for the discussion on the spot, by representatives of geology and archaeology with sufficient knowledge of each others subject to recognise the significance of the evidence that is available. This paper is, in large measure, the outcome of such collaboration, for, until they were brought to my notice by Sir Cyril Fox, and Messrs. V. E. Nash-Williams and W. F. Grimes, during the course of our work in the National Museum of Wales, I was, as a geologist, unaware of the existence of many of the problems to which I am able to refer, and I could certainly have done little towards solving them without the insight into matters archaeological afforded by discussion with my colleagues.

Reverting to the Hen-blâs problem, it should be noted that the stones provide an illustration of the danger of relying only upon photographs when discussing objects like 'cromlechs,' for as Pl. ii B illustrates, the group of stones assumes very different appearances when viewed from different positions. The photograph reproduced in 'The Megalithic remains of Anglesey,' Fig. 16, would present a much better case for an artificial erection than the accompanying Pl. ii B.

PROBLEMS INVOLVING REFERENCE TO THE PROPERTIES AND PROVENANCE OF ROCKS

Hitherto we have been concerned chiefly with problems relating to the stratigraphical and physical aspects of geology, but problems frequently arise that involve the close study of the petrological and structural characters of an individual specimen, with a view to determining its provenance, to explaining some peculiarity which it presents, or to elucidating its history since it ceased to be part of the parent mass from which it was derived.

As an example, we may take a case in which reference to the constitution of a rock made it possible to provide a positive answer to a vital question for which all the other evidence was of a negative character. It relates to the excavation of an early house-site near Bedlinog on Gelligaer Common in Glamorgan, which was undertaken by Lady Fox in the summer of 1936, and concerns the identification as hearths, of certain groups of flat stones, laid pavement-fashion. Most of the stones were slabs of sandstone, Pennant Sandstone of immediately local origin, but a careful examination failed to reveal any signs of extensive burning. The sandstone contains various iron bearing minerals, and tends to redden on being heated in the presence of oxygen, owing to the formation of ferric oxide, but in one of the 'pavements' only one corner of one slab showed any trace of reddening.

In another hearth there were at least three red stones, but these proved to be slabs of Old Red Sandstone. The colour was natural, and had not been caused by burning, while the associated slabs of Pennant Sandstone exhibited the tints that are due to weathering, and not those due to the application of great heat.

All the evidence was negative in its character, and since it was natural to suppose that there should have been a hearth somewhere in the house, it was desirable, if possible, to confirm the view that the slabs of Pennant Sandstone, which did not show obvious signs of having been burnt, had, indeed, not been subjected to any considerable degree of heat.

Reference to the lithological characters of the Pennant Sandstone suggested a possible line of investigation. Minor earth movements were in progress during the accumulation of the Coal Measures, the stratigraphical series to which the Pennant Sandstone belongs, and some of the coal seams that had been formed during the earlier part of the epoch were subject to denudation, and their detritus was incorporated into the deposits of the later parts of the Period. On this account the Pennant Sandstone frequently contains small particles or even pebbles of coal, as well as fragments of carbonaceous material, resulting from the alteration of plant debris that was buried as the sands accumulated.

On examining the sandstone slabs exposed in the pavements that might have been hearths, it was found that the rock contained particles of coal, which, even on the surface of the stone, were only altered to the extent that coal is usually altered when exposed to atmospheric weathering. Exposure to heat would have resulted in the removal of the coal, or at least in its partial carbonisation, and its relatively fresh condition indicated that the stone had not been burnt.

Although no further proof was really necessary, pieces of the stone were placed in a porcelain dish and heated over a Bunsen burner until the bottom of the dish was red hot ; on cooling it was found that the particles of coal had completely burnt away leaving pits where they had originally been, and also that the stones had assumed a dark red hue, different from the tints exhibited by any of the stones as they lay upon the site.

The fragments of Old Red Sandstone had been transported by glacial action, from the outcrops of that Formation, eight or nine miles away to the north.

Another problem in which fragments of coal were concerned, was brought to my notice when Messrs. O'Neill and Foster-Smith examined a mound of the conical *motte* type near Llanarth in Monmouthshire.[1]

Quarrying operations were cutting into the mound, until they were, fortunately, stopped by the late Lord Treowen. Although the quarry had destroyed part of the site, it had resulted in the exposure of what appeared to be a counter-scarp bank outside the ditch. In the section thus exposed certain black layers were observed, and it appeared reasonable to the excavators to assume that these lines represented the debris of burnt or decayed timbers—the remains of a palisade adjacent to the ditch.

[1] 'Excavations at Twyn-y-Cregen-Llanarth, Monmouthshire,' *Archaeologia Cambrensis*, December 1936, pp. 246–258.

There was probably a time when such evidence would have been assessed at its face value, and the existence of such a palisade taken for granted, but in this case the investigators decided to examine the black layers in detail, and further excavation showed that the disposition of the layers militated against the hypothesis that they were the remains of artifically placed timber ; and it was also noticed that the black material bore a closer resemblance to coal than to burnt wood. Subsequently small pebbles an inch or more across were found, and these were undoubtedly coal, although some of the surfaces were dull and porous looking, and had the appearance of having been charred.

If the discovery that the material resembled charred coal made the palisade hypothesis untenable, it suggested two other questions ; namely, how did charred coal come to be in such a position ? and why was the substance ever thought to be wood ?

It is usually dangerous to try and settle a field problem from the arm chair, but the circumstances were such that I could not visit the site while work was in progress. Fortunately, however, this proved to be one of the cases which illustrates the truth of Emerson's observation that everything in nature is engaged in writing its own history, for all the information necessary to explain the situation was preserved in the pebbles of coal.

Coal is a laminated rock, made up of layers of vegetable debris, and the materials of the various layers differ in original character, as well as in the nature and the degree of alteration to which they have been subjected. It is not necessary here to discuss the process of coalification ; it is sufficient to say that one particular ingredient that is present in most coals is a black, porous substance that occurs as lenticular layers. Its name is fusain, and its charcoal-like appearance gave rise to the suggestion that it represents the product of fires in the forests, from the debris of which our coal seams were formed. As indicated elsewhere, this suggestion does not bear the light of investigation[1] but I mention it to show that it would be no reflection upon an archaeologist not familiar with the petrography of coal, if, on first encountering fusain he thought it was charred wood, or if, seeing it on the surface of a piece of coal, he assumed that the coal had been partially burnt.

Actually, in the excavation at Llanarth, the black fragments consisted of coal fairly rich in fusain, and the gravelly material in which they occurred was part of a natural superficial deposit that had been cut into when the ditch or the mound was made.

PROBLEMS CONCERNING INSCRIBED STONES

Inscribed stones and early Christian crosses assume greater interest when considered in relation to the rocks of the regions where they occur. For example, it is more than mere coincidence that in the western extremity of the Lleyn peninsula large waterworn or ice-worn boulders, which are locally abundant, have been used as monuments, while more or less slender shafts, rectangular or rhombic in section, are usual in areas where there are well-jointed igneous rocks or grit stones, and finely ornamented monuments with parallel faces have been fashioned out of flaggy sandstones such as occur in the Old Red Sandstone formation.

The simplicity of a monument of this kind cannot be entirely a criterion of its age, nor the complexity of its decoration necessarily an index of the competence of its makers, because in most cases the makers have had to use stones that could be obtained in the vicinity.

As an example of the value of a close examination of the material used in the making of such a monument we may take the fragmentary head of a cross that is now in the National Museum of Wales. It came from an estate near Cardiff (Coed Riglan)[2] and its previous history was unknown, although its form and ornament were such as to suggest that it was an importation into

[1] F. J. North, *Coal, and the Coalfields in Wales*, National Museum of Wales (1931), p. 31.

[2] V. E. Nash-Williams, 'Some Welsh Pre-Norman Stones,' *Archaeologia Cambrensis*, June, 1937, pp. 7–8, Pl. iv, 2.

South Wales, rather than part of a monument of purely local origin.

The stone was extensively weathered, but the judicious removal of a small fragment revealed that it was an oolitic limestone, recalling the oolites of the Cotteswold Country and of Bath. It had nothing in common with the various kinds of Carboniferous Limestone that occur in Glamorgan, nor was it like the compact argillaceous limestones that are locally characteristic of the Lower Lias, or the tufaceous limestone present in the Triassic Series ; and a superficial examination of the problem seemed to confirm the conclusion that the stone was an importation from the oolitic regions east of the Severn.

It happens, however, that the shore of the sea in which the Lower Lias was deposited, lay, for a time, a little to the south of the hill ridge that now forms the southern limit of the South Wales Coalfield, so that, the Lias, like the Trias, includes littoral developments in this district. Actually there is an outcrop of these littoral deposits near St. Fagans, which is only about two miles north of Coed Riglan, and it includes rocks that are similar to that from which the cross had been fashioned, so that after all the object *was* of local origin.

The littoral varieties of the Lias are comparatively soft and tough, and have, in a measure, the characters of freestone, so that they would be much more suitable for conversion into a monument, like the Coed Riglan cross, than would the normal varieties of the Lias Limestone, which are brittle and are too much affected by joints to yield large blocks.

While this examination showed that the rock was of local origin it does not, of course, settle the question as to whether the cross was originally erected at Coed Riglan. If it was, then its makers must have known a good deal about the rocks of the district, for they ignored the outcrops of the normal Lias south and east of Coed Riglan, and of the Carboniferous Limestone of the immediate vicinity and went to an outcrop, by no means conspicuous, where more suitable material was to be had.

A problem of a different character was provided by another cross of which only the top survives. In this case also, the original site of the monument was in doubt. Sometime prior to 1885 it had been built into a barn at Laleston, near Bridgend, but it was reputed to have come originally from Llangewydd Church, which must have been destroyed before the Reformation.[1] The problem was to determine the provenance of the stone, and to decide whether the specimen as it now stands represents a complete object, or whether it originally capped a shaft, and if so when it was broken.

The rock is a fine-grained pale green sandstone such as occurs in the western part of Glamorgan, as a local littoral development of the Rhaetic strata, and although detailed field examination would be necessary in order to determine its precise place of origin, it had certainly not been necessary for the makers of the cross to go far afield for their material. The back of the stone was rather irregularly rounded, and its contours had been determined by weathering before the face had been carved ; in fact, the cross had been fashioned from a weathered block that had been lying on the surface, sarsen-fashion, and not from a freshly-quarried mass.

The edge of the disc is rounded except at what becomes the lower part when the object stands in its normal position ; in this region there are two distinct fractured surfaces. In Fig. 10, which illustrates the lower edge of the stone, the two outer portions are parts of the surface of the stone as originally left by the makers of the monument, while the two inner portions were determined by fracture. The whole surface of the disc underwent considerable atmospheric weathering after the fracture represented by A was made, but very little weathering has taken place since fracture represented by B was made ; it must, therefore, be of comparatively recent origin.

It would seem reasonable to conclude, therefore, that the disc was originally on a shaft, and that at some remote period it broke off—not an unlikely

[1] See V. E. Nash-Williams, *ibid.*, p. 9–10, Pl. iv, 1.

contingency in view of the brittle character and weathered condition of the stone from which it had been made. The fracture left an awkward projection which, after a long interval, was removed, presumably to restore the symmetry of the object.

Yet another kind of problem is illustrated by an inscribed stone from Clocaenog, Denbighshire.[1] It was derived from an outcrop near the place where the stone had been erected, and one of the problems attached to it was the significance of a stroke in the legend, of which various interpretations had been given.

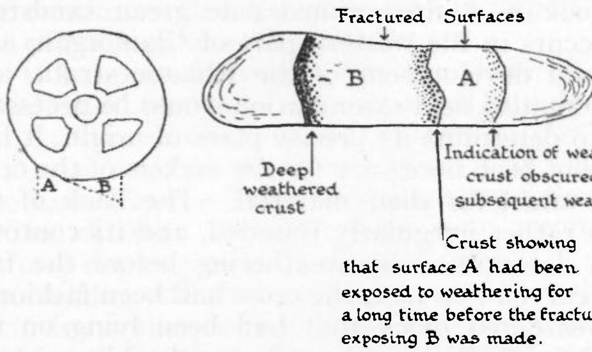

FIG. 10. SKETCH OF THE LOWER EDGE OF THE HEAD OF A SANDSTONE WHEEL-CROSS FROM GLAMORGAN

Differences in the degree of weathering along the edge of fractured surfaces indicate the relative ages of the fractures.

It transpires that the front face of the stone had been one side of a fissure, due to jointing, which had been filled with crystalline quartz, and in such cases it is usual, when fracture takes place, for the quartz to adhere in thin layers, partly to one face and partly to the other. Patches of the quartz layers are clearly visible in the illustration, Pl. iii. The presence of the quartz implies a certain amount of silicification of the surface of the stone, on which account it would be durable, and specially well suited to preserve an inscription.

The more or less vertical cracks which affect the

[1] V. E. Nash-Williams, *ibid*, pp. 1–3, Pl. i, 1.

3. INSCRIBED STONE FROM CLOCAENOG MOOR, DENBIGHSHIRE

(Reproduced by permission of the editor of Archaeologia Cambrensis)

stone are evidence of the pressure which caused the cleavage of the older rocks in North Wales, and the effect of which is seen, in this monument, in the distortion of the thin band of shale (now slate) that stretches across the slab a little above the inscription.

With this brief account of the essential characters of the stone it is possible to consider the inscription, and especially the significance of the stroke following the initial S, concerning which there have been differences of opinion—discussed in the paper by Nash-Williams, cited above. It is clear that the two vertical strokes following the initial S have never been united at the bottom to make a U or a V, because they end off near the edge of one of the superficial patches of quartz. The backward prolongation of the first vertical stroke is a natural feature resulting from weathering along a curved plane of weakness in the stone. The plane of weakness is continued along the line of the vertical stroke and it would appear possible that the engraver, beginning to make a letter I, found that it was obscured by the dislodgement of a fragment of stone along the crack already mentioned, and made another stroke to the right of it.

The inscription may, therefore, have begun SI or SII, but certainly not SV or SU, and there is no mystery at all attaching to the backward swing of the front vertical stroke.

THE USE OF THE MICROSCOPE IN THE IDENTIFICATION OF ROCKS

Up to now we have been considering phases of the relation between geology and archaeology that are not generally recognised, and in respect of which the archaeologist may not realise that there is a geological aspect to his problem, but the desirability of determining the source of the material used in the manufacture of an implement or weapon of stone has long been recognised, although, owing to a reluctance to allow a thin section of the specimen to be prepared for microscopic examination, less progress has been made in this direction than might have been. The value of information concerning the place of origin of a stone that has been fashioned has neither to be indicated nor emphasised here ; it will be sufficient briefly to indicate the possibilities and the limitations of studies in this direction.

We may take as an example, the 'Blue Stone' masses at Stonehenge, which were studied by H. H. Thomas.[1] They proved to be of dolerite, a dark and fine-grained igneous rock that is very widely distributed in association with rocks of all geological ages. The constituent minerals are usually more or less uniformly scattered, but, in the Stonehenge examples certain of the lighter coloured minerals—the felspars—tend to be segregated, giving the rock a blotchy appearance with conspicuous light patches against a darker ground. This character is peculiar to certain dolerites that are found *in situ* only in the Presely Range in Pembrokeshire, and when certain other stones at Stonehenge proved to consist of another igneous rock, rhyolite, which could be matched in the Presely district, it was established beyond doubt that some of the Stonehenge stones had come from Pembrokeshire. Moreover, since Stonehenge lies far southwards of the southern limit of ice-borne boulders in Britain, the masses of stone must have been transported by human agency.

Another igneous rock that is of interest to archaeologists, and that can be identified beyond doubt, given proper facilities for examination, is the fine-grained intrusive rock (augite-granophyre) which occurs at Graig Lwyd, Penmaenmawr, and which afforded the material used by certain Neolithic makers of stone axes. The 'Factory' was discovered by Hazzledine Warren in 1919,[2] and the distribution of its products has been discussed by T. A. Glenn.[3]

From Mr. Glenn's investigation it appears that while the axes were most thickly distributed in North

[1] H. H. Thomas, 'The Source of the Stones of Stonehenge,' *Antiquaries Journal*, vol. iii (1923), pp. 239–260.

[2] S. H. Warren, 'Excavations at the Stone-axe Factory of Graig-lwyd, Penmaenmawr,' *Journ. Roy. Anthrop. Inst.*, vol. xlix, 1919, pp. 362–65, and vol. li (1912), pp. 165–198.

[3] T. A. Glenn, 'Distribution of the Graig Lwyd Axe, and its associated cultures,' *Arch. Camb.* (December 1935), pp. 189–218.

Wales, they found their way as far afield as Derbyshire, Gloucestershire, and Wiltshire.

In regions where there is much transported glacial material it does not follow that a stone implement was brought, as such, from the place where the rock occurs *in situ ;* it may have been made from a local erratic, and does not necessarily indicate movement by man between the two localities, but in the case of the ' Graig Lwyd ' axes that have been found in England, it transpires that glacial transport cannot be invoked in any instance, so that all the axes yet discovered must have been taken as manufactured objects from North Wales.

The proper identification of a stone from which an implement has been fashioned may prove of importance also in problems of purely local significance. For example, during the excavation of a cairn at Plas-newydd, on Menai Straits, Anglesey, an axe, which macroscopically could be determined as being made of dolerite, was found. Now dolerite frequently occurs as wall-like ' dykes,' penetrating other strata, having originated as molten rock material injected into fissures in pre-existing rocks, and since the outcrop of such a dyke occurs near to the cairn, the first opinion suggested by the identification of the rock as dolerite was that the makers of the axe had used purely local material.

The specimen was referred to Greenly, who has made a close study for many years of the Anglesey rocks, and a thin section was prepared. This showed beyond doubt that the stone was not derived from the dyke near Plas Newydd, but belonged to another group of dykes altogether. The intrusion of molten material such as that which forms dykes was not confined to one geological period : some of the Anglesey dykes resulted from intrusions during the early Palaeozoic era, and some from intrusions during the much more recent Tertiary era, and the rocks of each series have peculiar as well as common features.

The dyke near Plas Newydd belongs to the Tertiary suite, but the axe had been made from stone which had affinities with the dolerites of the Palaeozoic suite, which are also represented in the south of Anglesey.

It transpires, therefore, that although the makers of the axe did not use material from the locality in which the cairn was situated, they did not go outside of Anglesey for it.

While it is usually possible to determine the geological horizon of a sedimentary rock—to distinguish, for example, between a specimen of old Red Sandstone and a sandstone of Carboniferous Age, or between Carboniferous Limestone and the limestones of the Jurassic Formations, and it is possible to discrimate between many of the varieties of limestone that occur in the Oolites of the Jurassic System, the sedimentary rocks are, as a whole, more difficult to localise than the igneous rocks, which, owing to their mode of origin, tend to exhibit more definite local peculiarities. This, however, is not necessarily an indication that no useful results are to be expected from a detailed study of the sedimentary rocks that figure in archaeological problems ; it simply means that the rocks have not yet been studied in the right way, and the work of H. H. Thomas on the altar stone at Stonehenge shows what may be expected when modern methods of examination are brought to bear upon the matter.

This stone was found to consist of micaceous sandstone that was certainly derived from one of the Palaeozoic Formations, and an examination of the hand specimen indicated that it had been derived from the Old Red Sandstone.

Two characters, its greenish tint, and the presence of calcareous material in the interstitial cement, suggested comparison with a division of the Old Red Sandstone, known as the Senni Beds, that occurs in Glamorgan and Brecknockshire, and with the Cosheston Beds, also of Old Red Sandstone age, which occur on the northern side of Milford Haven in Pembrokeshire.

In superficial appearance, in microscopic structure, and in composition, certain members of the Senni beds were indistinguishable from strata in the Cosheston Beds, and ordinary microscopical examination seemed only to indicate that the rock had come from South Wales rather than from Old Red Sandstone outcrops, like those in the Mendips, which were much nearer to Stonehenge. At one time this would have been as far as petrographical examination could have gone, but in recent years it has been realised that most sedimentary rocks contain ingredients, present in very small amount, that are appreciably heavier than those which constitute the bulk of the material; these heavy minerals, which can be isolated by suitable treatment, are frequently of diagnostic value. In the case of the Stonehenge problem Thomas found that a characteristic feature of the sandstones of the Cosheston Beds was an abundance of minute, and often crystalline, grains of garnet, and when it was found that the heavy residue separable after crushing fragments of the altar stone was also rich in garnet grains, some of them with crystalline form, the problem of the origin of the altar-stone would seem to have been solved—like the 'Blue Stones' of the inner circle, it was of Pembrokeshire origin. Here the matter must remain until a more complete knowledge of the petrographical character of the Old Red Sandstone shows whether crystalline garnet grains are confined to the Cosheston Beds or are more widely distributed. In any case the investigation is an indication of what may be expected from the intensive application of geological methods to archaeological problems.

Reference was made in a previous paragraph to 'proper facilities' for the examination of stone objects, and this is a matter that calls for comment on the present occasion. It is often difficult and frequently impossible to identify a rock from the macroscopic examination of a weathered surface such as that presented by the average stone implement. If there happens to be a freshly fractured surface, that often helps, but in many cases satisfactory identification is not possible unless a thin section can be examined under the microscope.

There has been an almost universal reluctance on the part of the owners of implements to allow thin sections to be prepared, from a mistaken notion that the operation necessarily ruins the specimen. It is true that specimens have at times been mutilated, but that is the fault of the individual, not of the principle, and it is to the mutual advantage of the archaeologist who wants accurate information about his material, and the geologist or the petrologist who is called upon to identify the rock, that a suitable technique should be devised.

The preparation of a thin section certainly involves cutting away a small piece of the stone, but this need not disfigure the specimen nor materially alter its shape. Indeed, by a method devised by Professor O. T. Jones and his assistant at Cambridge, and yet to be published in detail, it is possible to obtain a thin section and leave the axe or the implement in such a condition that only a very close examination will reveal that anything had been done to it. Instead of cutting off a slice and so scarring the surface of the implement, a wedge-shaped section is removed, leaving a notch that can be filled in and camouflaged.

The advantage to archaeology of a more rational attitude towards the preparation of specimens for examination has already been emphasised from the archaeologist's standpoint by W. F. Grimes.[1]

CONCLUSION

The foregoing examples of the part which geology may play in the work of the archaeologist are but a few of many that have been brought to my notice in recent years, and other geologists could cite as many more, probably of quite different character. I have, for example, made no mention of the important problems concerning the chronology of the period connecting geological time with the age of man, which were the subject of a recent address by Professor Boswell to the Prehistoric Society,[2] but enough has been written to make it apparent that some of the problems which arise involve reference only to the elementary principles of geology, while in the solution of others, knowledge of a specialised character is necessary.

What, then, is the archaeologist to do? Is an

[1] 'Recent Books on British Archaeology,' *Antiquity*, 1935, pp. 424–34.

[2] P. G. H. Boswell, 'Problems of the Borderland of Archaeology and Geology,' *Proc. Prehistoric Society for* 1936, n.s. vol. ii, pp. 149–160.

advanced course of geology to be regarded as a necessary part of his equipment ? I would suggest that what he needs is sufficient knowledge of geology (*a*) to enable him to deal with straightforward matters such as the interpretation of the geological map, (*b*) to enable him to determine whether masses of stone are likely to owe their shape or their position to natural agencies or to human activities, and (*c*) to enable him to appreciate the geological significance of a site that is under examination, and to decide whether or not a stone is likely to be of local origin.

No ordinary course of geological lectures, and no ordinary text-book will quite meet his needs, for while in some matters a very rudimentary knowledge will suffice, in respect of others it may be necessary to enter into considerable detail. A knowledge of structural geology is desirable, and at least a nodding acquaintance with stratigraphy ; but in the case of the latter it is the lithological character of the strata rather than their fossil contents that matters most to the archaeologist, who has no occasion to consider in detail the faunas and floras of pre-Pleistocene ages.

Whilst profound knowledge of mineralogy and petrology is not necessary, the archaeologist should be able to recognise the rock types most frequently represented among the relics of early man, so that he may be in a position to decide whether critical examination of a particular specimen is likely to throw light upon its provenance, for, as I have indicated, rocks differ greatly in this respect. In other words, the archaeologist wants to be able to pick and choose in the matter of his geological attainments—skimming the surface here and plunging more deeply there—and the ideal way to give him what he wants would be to include in his training some teaching by geologists who have been brought into contact with archaeological problems, and/or to provide him with a text book of geology adapted to his peculiar requirements. This is an ideal state of affairs, and it may never materialise, but it is always open to the archaeologist to seek the collaboration of a geologist, and thus, vicariously, to become aware of, and perhaps, also, to solve, his geological problems.