THE GEOLOGICAL EVIDENCE FOR RECENT SUBMERGENCE OF THE ASSAM-MALAY-AUSTRALIA REGION.

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INTRODUCTION.

In his presidential address to the Indian Science Congress (1935), Dr. J. H. Hutton referred to the marked relationships between the inhabitants of the Naga Hills and those of the Dutch East Indies, and to correspondences in the flora and fauna. He suggested that these indicated a freedom of movement which could best be explained by the existence of a very recent land connection and mentioned local traditions of a volcanic cataclysm accompanied by the submergence of large areas of land. Dr. Hutton added that he felt justified ' in stirring up the geologists to re-examine the possibility of the subsidence of Indonesia after its occupation by man '. The present writer, being familiar with the geology of part of the area, mentioned to Dr. Hutton that there is abundant evidence of a former land connection between Assam-Burma-Malay and Sumatra-Java-Borneo. This led to a request by Dr. Hutton for a note on the subject, and after an interchange of views, an endeavour has been made to state the geological evidence bearing on the problem which Dr. Hutton referred to in his address. The review is intended mainly for those who are not geologists, and contains very little evidence that has not already appeared somewhere in geological literature.

NATURE OF GEOLOGICAL EVIDENCE.

The geologist is familiar with the varied types of evidence which indicate the changes in level of the land, but for the benefit of general readers it may be convenient to make a brief reference to these. In the first place, it is

perhaps desirable to make it clear that we are here dealing with a *relative* movement between the land and the sea. If the sea rises, or if the land sinks, the result will be to submerge the low-lying ground and leave the high ground as islands, and for the moment we need not concern ourselves with distinguishing between the effects of rising sea and the effects of sinking land. If, on the other hand, the relative movement is in the opposite sense (i.e. rising land or falling sea) the area of land will be extended by the conversion of the shallower seas into dry land. We may now consider briefly the kind of evidence which will show whether the land is relatively falling or rising. In the former case, the change will result in the sea advancing up the valleys, leaving the intervening hills as promontories or groups of islands. The coast line will acquire a very irregular shape, with long inlets or ' drowned valleys '. If the rivers are carrying down a large quantity of sediment, some of the ' drowned valleys ' will become partially filled up with alluvial deposits. If, then, we find an area in which the valleys are occupied by thick alluvium extending down far below the present sea-level, and which has a coast line with long estuaries, we may be certain that there has been a relative rise of the sea. If, on the other hand, the land is rising (or the sea falling) we shall not expect these long estuaries and great thicknesses of alluvium, but a more regular coast line, possibly with traces of old sea beaches at different levels above the present high-water mark.

If the relative movement of sea and land is slow, and especially if there is a slow rise of the land, there will be a possibility of the formation of broad comparatively level areas along the coast, as the sea waves will have an opportunity of working on the land to reduce it to a nearly uniform tract almost at sea-level. If there is subsequent rapid relative sinking of the land, the levelled-up coastal tract will form a submerged shelf or platform ; should there be a subsequent rise of the land, the coastal tract will appear as an elevated plain or plateau.

It will perhaps be clear that the nature of the coast line and the types of surface and submerged topography will provide clues to the changes in level of land and sea. A complex series of movements, in which there have been alternating periods of rise and fall, may leave traces that are too difficult to decipher in detail, but prolonged movements in one direction usually leave signs that can be recognized with little doubt.

Evidence Found.

The area with which we are concerned extends from Assam through Burma and Malay to the Dutch East Indies, and we may begin with the evidence from the north-western part of this territory.

In Assam we find that most of the hills are sharply marked off from the plains, i.e. there is no gradual merging of the hill country into the flat country. The profile, in other words, is more like ' a ' than ' b ' in figure 1. Furthermore,

whilst the hills are made of gneiss, sandstone, shale, etc. the valley land is alluvium derived from the denudation of the hills, and (as borings and the geophysical exploratory work carried out by the Burmah Oil Company have shown) the real valley floor extends to great depths below the present surface and in fact much below sea-level. This is indicated diagrammatically in section ' c ' of figure 1. The larger valleys of Assam are without exception examples of river valleys partially filled with alluvium. This is one of the indications of a sinking of the land relative to the sea.

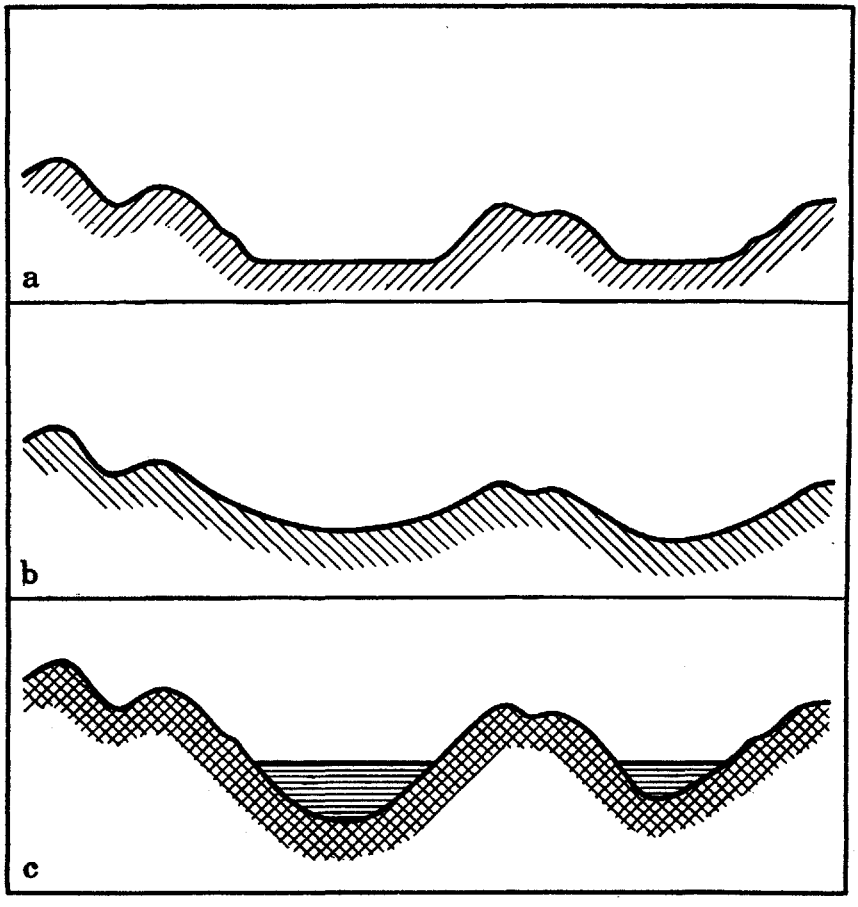

FIG. 1.

Coming further south into Burma, we find that the Arakan coast is an excellent example of an area of drowned valleys, as may be seen from figure 2. The Irrawaddy valley of Burma is another example of an alluvium-filled valley with the old rock floor far below sea-level. Still further south-east, in Tavoy and beyond, are more good examples of drowned valleys. In some of these

the occurrence of alluvial tin deposits beneath the present sea-level gives a definite proof of relative subsidence of the land. These drowned valleys continue as a feature of many of the coasts right through the Dutch East Indies.

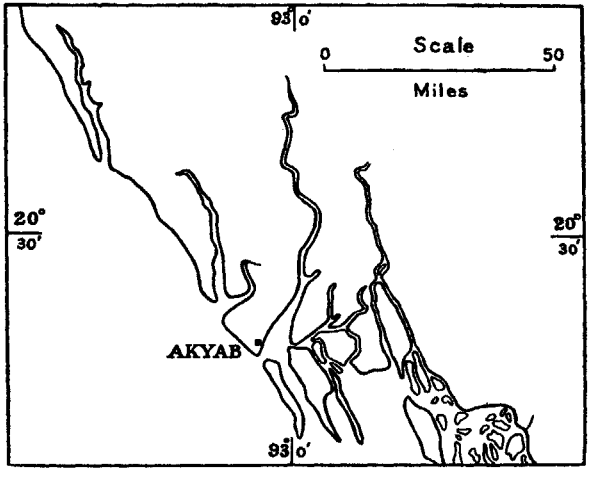

FIG. 2.

Soundings have shown that near Sumatra, Java and Borneo, there is a large area of shallow water (termed the Sunda Shelf) which appears to be a submerged coastal flat. The deposits on this flat are not normal sea deposits, but give evidence of having been laid down by rivers flowing on the flat before the submergence took place.

The possibilities of ancient land connections in this area have been investigated by examining the distribution of the fauna and flora, and this work, as Dr. Hutton mentioned, has brought to light very strong evidence of the existence, at no very distant date, of large land areas in the Malay Archipelago. There is always a difficulty in ruling out occasional accidental transmissions of species, but in this instance several independent lines of investigation unite in support of the conclusions reached on purely geological grounds.

APPLICATION OF THE EVIDENCE.

Thus we have clear evidence that, in the region under discussion, either the sea has risen or the land has subsided. We must next enquire—

(*a*) whether the previous limits of the land can be determined, and

(*b*) whether there is any evidence of the age of the submergence.

Former Limits of the Land.

An examination of a map showing the relief of the sea floor in the Bay of Bengal, Java Sea, etc. will reveal that the submerged shelf includes a broad

strip along the Tavoy coast, the Straits of Malacca, and a large area of sea north of Sumatra, Java and Borneo, and that the shelf ends abruptly on the seaward side somewhere near the 50-fathom line. Beyond this, the sea bed falls away rapidly to great depths. The extent of the Sunda Shelf, the nature of the deposits formed on it, and its mode of origin, have been studied by Molengraaf, and his map shows that before the changes in level took place, Sumatra, Java and Borneo, together with many smaller islands were all joined to the Malay Peninsula. It is evident that denudation produced a very nearly flat ' platform ' which has been submerged to a depth of over 200 feet. It is probable that the marine planation was assisted by several fluctuations in level prior to the final submergence. The extreme eastern extension of this tract of land is difficult to determine ; there is a very similar shelf connecting New Guinea and Australia, but it is doubtful if this was actually connected to the Sunda Shelf.

Date of Submergence.

It is now desirable to consider the date of this submergence. The fact that it is geologically very young is not of much help to the anthropologist—something more definite is needed. In order to discuss this point it is necessary first of all to find out the origin of the feature. Did the land sink or was there a rise in the sea-level ? If the former, then the changes in level should be limited in areal extent and variable in degree ; if, on the other hand, the sea-level rose, this must have had a world-wide effect and the changes in level should be more nearly uniform in degree. It is clear that at this stage we must go further afield for evidence.

We have already seen that there is a very large submerged shelf bordering part of Australia, and similar (although smaller) features are found in many parts of the world, although it is not possible to claim that all these are of similar origin, since such factors as the accumulation of sediment brought down by the large rivers must be taken into account. A glance through a fairly large scale atlas will show how numerous are drowned valleys—an important criterion of submergence. Such well-known harbours as Sydney, Milford Haven, and New York are examples of submerged valleys. Furthermore, the evidence from coral reefs is extremely strong support for the view that there has been widespread submergence. We must of course be on our guard against assuming that all these examples are part of the same world-wide phenomenon, but there is good reason to believe that a nearly world-wide change in level has taken place and that this was due to a general rise in sea-level and not to a series of local sinkings of the land.

Superimposed on any general rise or fall of the sea there will be changes of level due to local rising or sinking of the land ; these may in certain localities mask the effects of the more widespread change due to a general alteration in sea-level. The remarkable uniformity of the level of the extensive Sunda Shelf and its correspondence with the Australian Sahul Shelf, the submerged

shelves round the Philippines, and the smaller shelf off Karachi and Bombay, show that the Sunda Shelf can hardly have been greatly affected by local changes in level, and the Malay-Sumatra-Java-Borneo submergence is, in the main, to be regarded as part of a general rise in the level of the sea.

On the other hand, the submergence of Assam and Burma was much greater in degree, and although it affected a very large territory, it does not seem to have extended so far south-east as Malay. Evidently we have to take into account two distinct events, a world-wide rise in the sea-level and a more local subsidence in the Assam-Burma region.

This widespread evidence of submergence has recently received much attention from geologists who have been concerned with its causes and with its effects on the development of coral islands. During the glacial period, a large part of the surface of both hemispheres was covered with ice, which certainly attained a thickness of many hundreds of feet. This must necessarily have been accompanied by a reduction in the amount of water in the sea, so that during the glacial period the sea-level was much lower than it was previously or is now. As the ice slowly melted, the sea-level gradually rose and submerged the low-lying coastal regions. Attempts have been made to calculate the volume of water added to the sea as the result of the diminution of the two polar ice-caps to their present size; obviously such calculations can be little more than guesses, liable to gross errors, but it can be said that they indicate a rise of the sea-level of the right order of magnitude.

It is well known that the glacial period was one of alternating warm and cold climates; the sea-level must have been constantly fluctuating, but we are concerned only with the last rise, and a rough guess at the date of this is possible without going too far into the realms of conjecture.

The Pleistocene period is divided up in various ways; we have the evidence of human artefacts from which we get the Chellian, Acheulian, Mousterian and other divisions; we have the separate glaciations such as the Riss and the Wurm. Some attempts have been made to correlate the two systems, for example the Mousterian culture has been associated with the interglacial period between the Riss and Wurm glaciations. Attempts have also been made to get some idea of the number of years occupied by the various divisions of the Pleistocene. This has been done in two ways: the deposits from retreating glaciers often show annual banding due to the different conditions in winter and summer; these bands or 'varves' have been studied by de Geer who has compared them with the annual growth rings of a tree, and just as the annual rings in trees vary from year to year with the vagaries of the climate, so too do the annual layers or 'varves' of glacial deposits, and it has proved to be possible to correlate the 'varves' of different areas. Since each one represents a year, the period of retreat can be measured in years. The other method of approach is based on astronomical data from which it is possible to estimate cyclic changes in the amount of radiation received from the sun.

Although a beginning has been made, there still remains very much to

be done in the investigation of the time basis for the Pleistocene. De Geer's work on the Scandinavian ice sheets shows that 15,000 years ago cold conditions prevailed to such a widespread extent as to justify our regarding that date as within the glacial period. Zeuner, on the astronomical evidence, placed the Wurm glaciation as extending from 112,000 to 18,000 years. The dividing line between the Palæolithic and Mesolithic is taken as being about the end of the Wurm glaciation. If these figures are approximately correct, then 15,000–20,000 years ago the general sea-level must have been much lower than it is now. The astronomical estimates suggest that the last important minimum of temperature occurred about 23,000 years ago, and from this it would seem that, on the whole, the sea has been rising for about 20,000 years. It is impossible to say when the most rapid rises took place; the subject is complicated by the impossibility of knowing much about the rate at which the ice sheet disappeared and by the possibility that cyclic movements of the land were superimposed on the main changes of level. In high latitudes some movement of the land will have been caused by the varying load as the thickness of the ice sheets changed, and this movement, which lagged behind the melting, will also have had an effect on the sea-level. Along some coasts, as for example California and Japan, there is evidence of local land movement at the present time, and it is not to be expected that the effects of the postulated world-wide submergence will be recognizable everywhere.

From this type of evidence we reach the conclusion that within a period measureable by thousands of years, there has been a considerable rise in the level of the sea, especially in tropical regions.

That the Malay submergence is due in the main to this general rise in sea-level is shown by the depth of the Sunda Shelf, which corresponds with the depths of many other submerged shelves, and, as Umbgrove points out, by Weber's investigations on the distribution of fresh-water fish in parts of the Malay Archipelago which show that the drowning of the valleys is post-Pleistocene. It therefore follows that within a period of perhaps no more than 20,000 years there has been a great reduction in the land area of the Malay region, and that prior to this a large part of the archipelago was a portion of the mainland.

Turning now to the much greater submergence shown by the Assam rivers, although we find no direct indication of date, geological evidence shows that in Tertiary times there was an immense upward and forward movement along what is now the Himalayas. In front of this (i.e. to the south) the Assam-Burma area was subsiding not steadily but intermittently until the total subsidence reached many thousands of feet. Then followed extensive folding of this tract, after which the sinking was resumed. This latter sinking is indicated by the great thickness of the alluvium which goes down for many hundreds of feet below sea-level. The problem is to date this sinking, and the only evidence seems to be of an indirect nature. It is unlikely that the extensive

sinking revealed by the thickness of alluvium would be suddenly replaced by a movement in the reverse direction, and if we can show any movement at the present day, it will be a reasonable assumption that it is a downward movement. That some movement is in progress is indicated by several lines of evidence: earthquakes are common and are associated with changes of level: lakes have been formed by earth movements which must be very recent, since a number of smaller lakes have been completely silted up or converted into swamps, whilst the larger ones such as Logtak (Manipur) and Nongyong (Patkoi Range) are now greatly reduced in size and are rapidly silting up—i.e. they are of no great age. This merely indicates the probability that downward movement is going on.[1] This is supported by the presence of tree stumps, decayed wood, and peat about 20 feet below the present level near Calcutta.

This downward movement of Assam and Burma may, however, be of no great importance in the discussion, since we are unable to say whether it has extended sufficiently far south-east to affect the Malay area which is the area of greatest importance in this connection.

In the west of India definite evidence of subsidence is given by the submerged trees near Bombay and by the flooding of Cutch in 1819, but these were local downward movements which may perhaps have little bearing on the problem, and there is evidence of a previous period in which the shore line was higher than it now is.

The slow general rise in sea-level postulated on geological evidence does not appear to have any connection with the catastrophic changes suggested by tradition. Although there is no evidence of extensive recent disturbances of level within the area of the Sunda Shelf, the case is different with the southern edge of the Shelf. In that region there is abundant evidence of volcanic action—i.e. in the southern parts of Sumatra and Java, and there is situated Krakatoa, whose eruption was one of the most spectacular of modern times. Possibly to similar but more violent eruptions accompanied by tidal waves and even permanent local changes in level can be ascribed the origin of the widespread traditions referred to by Dr. Hutton.

Summary and Conclusions.

The form of the coast-line often gives an indication of the nature of the recent relative changes in level of the sea and land. A coast-line with numerous estuaries and inlets associated with a submarine shelf is evidence of either general rise of the sea or local sinking of the land. The Malay region provides many examples of this type of coast and it is clear that at some former time Malay extended south-eastwards to include what are now the islands of

[1] There is evidence in Assam of a time when the rivers were at a higher level than they now are, but this probably dates back to far older times. There is also a suggestion of fairly recent local warping and slight uplift in places but this has no bearing on the evidence for a general downward movement throughout Assam and Burma.

Sumatra, Java, Borneo, etc. and possibly even further south-east. The change in levels which submerged the lower ground and left the high ground as islands and peninsulas is thought to have been part of a world-wide change which was caused by the melting of a large part of the polar ice caps as the glacial climate passed into the present climate. It seems likely that a large part of the submergence, possibly even the greater part, has taken place within a period of the order of 20,000 years.

In Assam and Burma there has been a much greater change in levels due probably to a continued sinking of the land. This may possibly have extended sufficiently far south-east to affect Malay but there is no definite evidence of this. This movement cannot be dated, but there is reason to suppose that it is still in progress.

There are therefore geological reasons, quite apart from those based on the distribution of fauna and flora, for believing that there has been a submergence of large areas of land within a period sufficiently recent to have influenced the distribution of human settlements in the region.

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