under pressure along lines of least resistance. On the other hand, if the rock is really a granite all through, that is to say, the product of a molten magma drawn from some unknown underground reservoir, then its activities as an intrusive rock have been kept well under control."

Whichever of the two views stated by the author be adopted, it is clear that there must have been a reservoir of molten or semi-molten rock at the root of the Himalayas sufficiently capacious to have supplied the enormous masses of gneissose-granite now to be found along the whole length of these mountains, for it is admitted that the granite came into place as an intruder, and it is not suggested that sedimentary rocks were heated up and converted into granite *in sitû*. The author speaks of the "granitic foundations out of which the Himalaya were ultimately to rise" (p. 275)—that, by the way, sounds rather like my own view which the author contests—and he contrasts them with the "gneissic foundations of the peninsula of India" (p. 275); and the author remarks with reference to the theory of those who assert the Archæan age of the gneissose-granite, "even they must admit a pretty thorough mixing of the material by some agency before it quietly found its way in an intrusive capacity among the ancient sedimentary rocks" (p. 276).

The author's views, then, involve the supposition that immediately preceding the intrusion of the granite there was a reservoir of molten or semi-molten rock forming "the granitic foundations out of which the Himalaya were ultimately to rise." That being so, what, I would ask, would be the result of powerful tangential pressure applied to the sides of this reservoir? Would not the granite "rise along the line of least resistance"? This rise of the granite, the author tells us, took place "under such enormous pressure of the superincumbent rocks that an eruptive function was generally denied it" (p. 274), and "it was formed as great laccolites." That being so, would not granite moved upwards with sufficient force to overcome the "enormous pressure" that tried in vain to keep it down, have elevated the rocky cover? I think such elevation would, under the conditions supposed, be inevitable, and that I was therefore fully justified in stating that "the contortion, compression, and upheaval of the Himalayas were connected with the intrusion of the gneissose-granite."

(*To be continued.*)

NOTICES OF MEMOIRS.

I.—A New Fossil Cycad from the Isle of Portland.

(PLATES XIII AND XIV.)

An example of a Jurassic Cycadean stem of exceptional interest has lately been added to the Fossil Plant Gallery of the British Museum. The specimen is described in detail by Mr. A. C. Seward in the Quarterly Journal of the Geological Society for February of this year.

Geologists have long been familiar with the short and thick Cycadean stems described by Buckland and others from the Purbeck beds of Portland, but the recently acquired fossil differs in many respects from the shorter stems or "crows' nests" hitherto recorded as the common type of Cycads from this locality. The specimen was found in one of Mr. Barnes' quarries, and, as shown in Fig. 1, it was obtained from a bed of shaly clay 17 feet higher in the Purbeck series than the Great Dirt-bed which has yielded most of the Portland plants. Mr. A. M. Wallis, a local guide and quarryman, who at once recognized the value of the specimen, saved it from destruction, and Dr. Woodward was fortunate enough to obtain the magnificent stem for the National Collection.

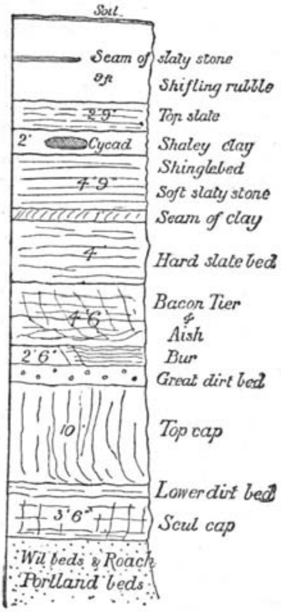

Fig. 1.—Section of the quarry on Portland in which the Cycadean Stem was discovered by Mr. A. M. Wallis.

The trunk is shown in its natural position in Plate XIII, which is reproduced from a photograph taken by Mr. Gepp of the British Museum. The total height is nearly four feet (1 m. 18·5 cm.), and the girth at the broadest part about 1 m. 7 cm. The surface features are best seen close to the base (Plate XIV, Fig. 2); there is a prominent network with meshes arranged in regular rows and passing spirally round the stem. Each mesh marks the position of a leaf-stalk base; the substance of the petiole has disappeared in most cases and left a cavity; the reticulum consists of ridges of silicified tissue, which existed between the individual petioles. In the living plant numerous scaly or laminar appendages were attached to the surface of the petiole base, and these formed a kind of loose packing between the fronds. The chaffy scales or paleæ on the leaf-stalks of many recent ferns are almost identical structures, and among existing Cycads somewhat similar appendages are occasionally met with. The mineralizing solution was apparently absorbed more readily by the interpetiolar tissue than by the less porous petioles; the former was therefore more frequently preserved, and in a better condition than the latter.

At the top of the stem an apical bud has been clearly preserved. It is very unusual to find fossil Cycadean stems in which the apical portion has been left intact. The bud is covered with numerous bud-scales, and at the summit there is a terminal cap, shown in Plate XIV, Fig. 1, as a lighter-coloured patch. In Fig. 2, p. 319, this cap presents the appearance of a mass of numerous fine hairs covering the tips of the linear bud-scales.

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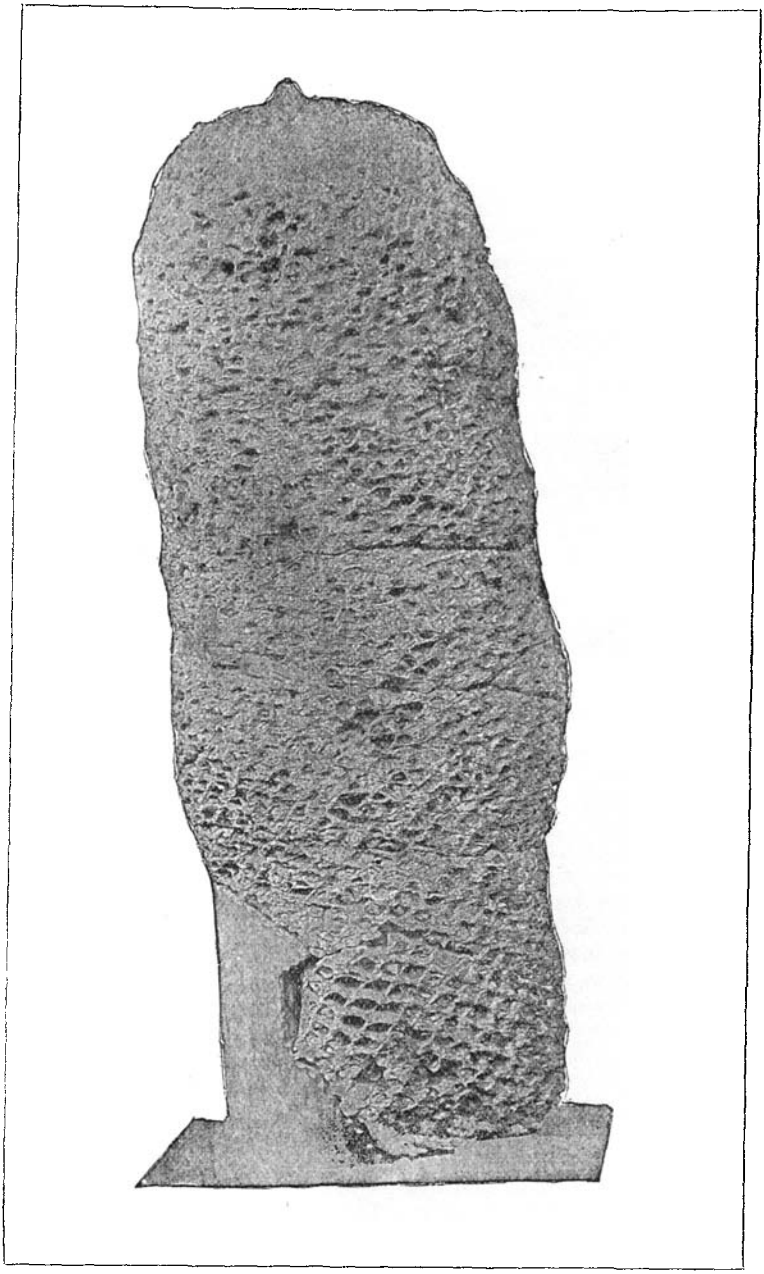

Stem of a new Fossil Cycad, *Cycadeoidea gigantea*, Seward.

Purbeck Beds, I. of Portland. $\frac{1}{8}$ nat. size.

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FIG. 1.

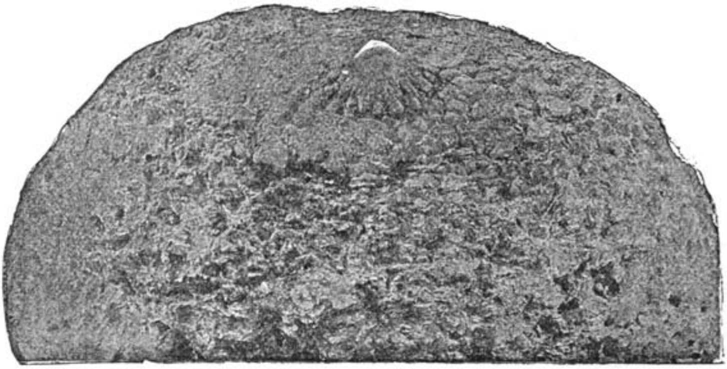
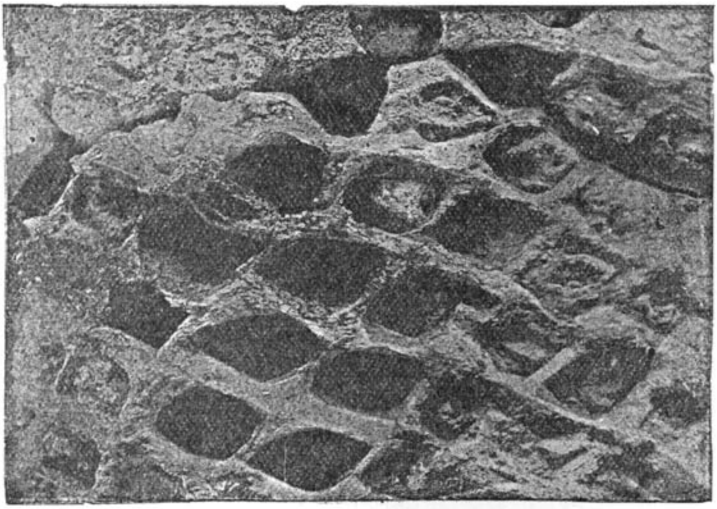


FIG. 2.



FIGS. 1 AND 2.—*Cycadeoidea gigantea*, Seward.

FIG. 1. The apex of the stem shown in Plate XIII; about ¼ nat. size.
FIG. 2. Leaf-bases and ramenta from the lower portion of the stem; about ½ nat. size.

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The apical bud of recent Cycads is occasionally capped by a mass of loose hairs, and there is the closest possible resemblance between the bud of this Portland stem and that of such a recent Cycad as *Encephalartos Altensteinii*, Lehm., a species well represented in the tropical-house at Kew.

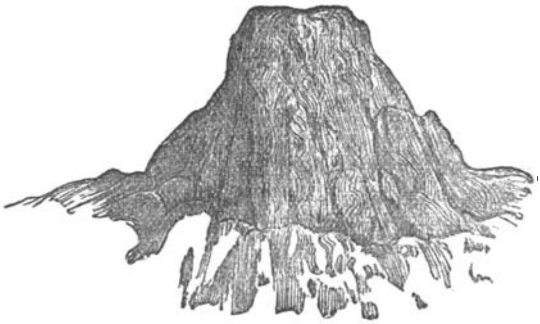

FIG. 2.—Apical bud of *Cycadeoidea gigantea*, Seward.

The material of which the specimen consists is highly siliceous; the central portion exhibits no trace of plant-structure, and is composed of cherty rock, but portions of the more external tissues are in some places exceedingly well preserved. The description of the structure of the petiole bases, and that of the mass of interpetiolar tissue, as given in the more detailed account of the stem, demonstrates a striking similarity between the anatomy of the genus *Bennettites* and that of the new fossil. In the absence of any definite trace of reproductive organs, the Portland stem has been placed in Buckland's genus *Cycadeoidea*, and named *Cycadeoidea gigantea*. As regards the exact affinities of the species, it is impossible, without the evidence of the reproductive organs, to speak with certainty as to its precise position. There is, however, no sufficient reason for regarding the stem as essentially distinct from such a type as is represented by *Bennettites Gibsonianus*, so far as concerns its position in a system of classification.

II.—THE PLEISTOCENE ICE-SHEET IN NORTH AMERICA: ENGLACIAL DRIFT. By W. O. CROSBY.[1]

Probable Early History of the Pleistocene Ice-sheet.

RECENT researches in North America tend to show that an ice-sheet may over a considerable part of a glaciated area have been formed *in sitû* by snow accumulation.

A general refrigeration of the climate in mountainous districts, due chiefly perhaps to a marked elevation of the northern part of the continent, had led to the development of glaciers of the Alpine type in the higher valleys. These glaciers became confluent

[1] Abridged from the *Technology Quarterly*, vol. ix, Nos. 2 and 3. (Boston, 1896.)

as the cold increased, deploying upon the plains and forming sluggish or stagnant Piedmont glaciers. With progressive refrigeration the annual snowfall finally exceeds the annual melting of the ice. This cumulative snowfall, which mantled alike hills and valleys, and changed slowly through *névé* to glacial ice, must have tended in some measure to check or arrest the motion of the ice which had flowed outward from the mountains. Owing, however, to the forward motion of the Piedmont glaciers, as well as to their termination on tracts where a short time before ablation (or melting) had been in excess of snowfall, they must have terminated somewhat abruptly or with high marginal gradients; and the conditions, therefore, were extremely favourable for their overriding the new and still stationary ice-fields by which they were invested. The overridden tract of ice must slowly acquire the motion of the overriding sheet, and thus in its turn come to override other tracts. In fact, it seems very probable that this process of overriding and absorption would continue almost indefinitely, extending, possibly, over a large part of the glaciated area.

Assuming a uniform annual snowfall over the area of the sedentary ice-sheet, it is obvious that since its area is gradually extended southward by the progressive climatic refrigeration, while the annual ablation as gradually diminishes northward, its thickness must increase backward from the margin. If, however, as Upham holds, and as certainly seems most probable, the precipitation of snow over the growing ice-sheet was not uniform, but greatest from the first one hundred to two hundred miles inward from the margin, the surface-gradient must have culminated on these peripheral tracts, diminishing gradually backward. This condition would, obviously, favour an early beginning of outward movement or flow in the marginal zone, and tend in an equal degree to retard motion in the central area.

We should hardly be justified in supposing that the great crustal movement which gave us the Ice Age, was steadily progressive, without interruption or reversal, until its final culmination. No doubt the period of the growth and culmination of the ice-sheet, equally with that of its waning and disappearance, was attended with marked climatic oscillation. During these changes the precipitation and ablation would co-operate in accentuating the frontal slope of the ice-sheet. The chief factors in determining movement of the ice-sheet were its thickness and marginal gradient.

The absence from a large part of the glaciated area of mountains or dominant heights of land, requires us to assume that over considerable tracts the sedentary ice-sheet did eventually begin to flow without having experienced the overriding or shearing thrust of the Piedmont ice-fields. The outward movement thus originating in the peripheral tracts during a period of excessive ablation must have extended backward, perhaps until it met the forward thrust of the Piedmont glaciers.

Assuming therefore that the movement of the ice-sheet was inaugurated during a warm period, and that the southern margin of the ice has retreated far to the north through ablation, developing a bold and aggressive front, it is obvious that the succeeding cold period must have caused a rapid extension of sedentary ice southward from the front of the moving sheet, and the former would inevitably be progressively overridden and absorbed by the latter.

Basal Relations of a Sedentary Ice-sheet.

During the slow accumulation of the ice-sheet, and before it began to move, the ground beneath it, which must have been saturated with water, was probably frozen solid to a considerable depth, possibly nearly, if not quite, to the bottom of the residuary soil or other surface detritus; that is, down to the firm rocks. There could have been no original plane of separation or movement between this frozen soil and the overlying ice-sheet, for the ice did not merely rest *on the detritus*, but extended down through it to the lower limit of frost.

With increased thickness the ice-sheet became a more and more efficient protection to the ground against the climate of the Ice Age, and the steady efflux of heat from the earth's interior would thus tend to gradually loosen the hold of the frost upon the rocky substratum.

Observations in the Arctic regions and at higher altitudes show that the ground may become frozen to a depth of several hundred feet; but it is well known that glaciated areas are not in general those of most extreme cold. A humid climate is the first essential, whereas extremely frigid areas, such as the interior of Alaska and northern Siberia, are relatively dry and non-glaciated. A mean annual temperature a few degrees only below freezing is all that is required for active glaciation; and as the increasing thickness of a sedentary ice-sheet would tend to neutralize the downward penetration of frost, we need not suppose that the ground beneath the ice would be frozen to any great depth or far below the detrital layer.

In considering the most probable plane of shearing when the ice-sheet begins to move—whether in obedience to its own weight or through the overriding thrust of a thicker northern sheet—we have to consider (1) the ice-sheet proper; (2) the frozen soil beneath it, to which the ice-sheet is still firmly united; (3) the unfrozen soil resting upon or passing downward into the solid rocks. At the inception of movement the most probable plane of slipping or shearing would be in the unfrozen soil, the frozen soil and overlying ice moving *en masse*, and the movement being lubricated by the unfrozen soil, which at most points would be of an argillaceous and plastic character.

Observations heretofore made on modern glaciers and ice-sheets are of little value in this connection, because nowhere in the field of observation are realized the conditions that must obtain at the base of a sedentary or recently sedentary ice-sheet. The true glaciers or ice-rivers of Alpine districts, Greenland, etc., are mere lobes of ice descending under the influence of gravity from the edges of *névé* fields and ice-caps into a climatic zone where permanent ice cannot form; and hence they are moving over unfrozen soil, and the ice is wasting by melting on its under as well as its upper surfaces. The great desideratum is a shaft or boring in the interior of Greenland extending through the entire thickness of the ice-sheet and a hundred feet into its rocky bed. The Greenland studies of Professor Chamberlin show the facility with which ice shears along innumerable lines of débris; it slides over the débris instead of dragging it along, as it would if the débris were firmly frozen into the ice. Granting, however, that the frozen soil would be more rigid and indifferent to gravitative stresses than the clear ice above it, the fact remains that the unfrozen soil at the base is more yielding and plastic than either; and hence, although we may reasonably conceive definite shearing-planes as distributed through a considerable thickness of the ice-sheet, the lowest plane, and the true base of the ice-sheet, will still be at the lower limit of frost.

Rectilinear striæ, often scores of feet in length, are an impossibility unless we conceive the entire mass of the ground-moraine as enclosed in the moving ice. These would be produced during the period of active glaciation when the ground-moraine was very scanty or wholly incorporated with the moving ice. A true ground-moraine between bed-rock and ice, and distinct from both, belongs to the waning stage of the ice sheet and to lobes of ice (glaciers) descending from an ice-cap or *névé* field into a climatic zone where permanent ice cannot form.

All this appears to be quite consistent with the local origin of the greater part of the till or ground-moraine of the Pleistocene ice-sheet, and the well-established fact that the total movement of the ice amounted to hundreds of miles, if we simply suppose that through the granular plasticity of the ice, or a series of shear-planes, the basal, drift-laden layer moves much more slowly than the overlying clear ice.

Absorption of Drift by the Pleistocene Ice-sheet.

As the initial shearing-plane of the ice-sheet is normally at the lower limit of frost, a considerable amount of detritus is englacial from the beginning of the movement of the ice-sheet. When a sedentary ice-sheet is overridden by a Piedmont glacier, or by the readvance of an earlier ice-sheet, the conditions must be favourable for the transfer of drift from the base of the earlier sheet to a somewhat elevated position in the composite sheet which results from the overriding. The overriding sheet will carry with it not only its own englacial drift, but will drag along a part of its ground-moraine or subglacial drift.

It is altogether probable that each important recession of the ice-sheet, and not only the final recession, was characterized by numerous glacial rivers and lakes, and an extensive development of modified drifts in the well-known forms of kames, eskers, deltas, with abrupt northern margins, etc. Such loose deposits would be taken up by the succeeding ice-sheet.

Relatively slight obstructions to the flow of an ice-sheet, whether of solid rock or uncompacted drift, are sufficient to originate sharp overthrust flexures and oblique shear-planes, marked by bands of débris. Thus drift is transferred from a subglacial to an englacial position. It may be concluded that from the summit or crest of nearly every elevation with an abrupt lee-slope, a stream of detritus flowed onward and upward into the ice-sheet during its progress over the land. On the stoss-slope glacial erosion reaches its maximum intensity, as both vertical and flowage pressure co-operate, and much basal detritus is carried forward and from the summits of elevations into the body of the ice, and not down the lee-slopes.

During the period of maximum glaciation a large proportion of drifts may have been dragged down the lee-slopes in the bottom of the ice, and thus striation and polishing of those slopes were produced. Later, when the vertical pressure was less and the velocity of flow greater, the ice hugged the lee-slopes less closely, and the conditions became favourable for the detachment of blocks of rock. Thus ice penetrated the joint-cracks of the rocks and severed blocks, and these were eventually carried away by the moving mass of ice to which they became attached. Indeed, we often find a surface train of angular blocks leading away from the lee-slopes.

During the later stages of the decline of the ice-sheet, basal melting set free considerable volumes of the hitherto englacial drift to form the ground-moraine; and just as the frontal or terminal moraine, also composed of material set free by the melting of the ice, records the cessation of the forward movement or invasion of the ice-sheet, so the basal or ground-moraine records the gradual cessation of the glacial abrasion of the bed-rocks. Generally the ground-moraine rests upon striated surfaces of the rocks, and as it accumulated it was pressed down by the ice to form the typical "hard pan."

Thus, in the earlier and maximum stages of the ice-sheet the basal temperature was below freezing, and the freezing of subglacial waters made and kept the detritus a part of the ice-sheet; in the later stages of the ice-sheet, the basal temperature rose above freezing, and the ice relaxed its hold on the detritus and flowed over it.

Transportation of drift by simple drag is relatively unimportant, if not impossible; the transportation is almost wholly englacial, as insisted by Upham (Bull. Geol. Soc. Amer., vi, 348), but highly differential, being extremely slow in the basal layers and more and more rapid at higher levels. The detritus reaching the highest levels in the ice is carried farthest, not only because of the higher velocity, but also because it remains for a longer time in the ice.

The efficiency of glacial erosion is clearly proved by the fact that over practically the entire glaciated area north of the terminal moraine *all* the preglacial soil and partially decayed rock have been worn away, and there has been an extensive erosion of the hard unweathered rocks. The prevailing colour of the ground-moraine below the sharply defined limit of postglacial oxidation is that of crushed rock, and not of residuary or other preglacial detritus.

Probably no feature of the Greenland glaciers revealed to us by Chamberlin's studies is of greater interest than the beautiful stratification and lamination of the ice. This stratification is due chiefly to the mode of distribution of the drift or rock débris, which forms numerous relatively thin and continuous layers approximately parallel with the bottom of the glacier, and often exhibiting flexures and faults where the ground over which the ice moved was uneven. This englacial drift is ground-moraine absorbed by the ice through flexing and shearing movements. The débris is an element of weakness, and tends to give rise to shearing- and gliding-planes. When we consider how intimate this process of lamination-shearing is, producing in extreme cases as many as twenty distinct layers in an inch, it can hardly be doubted that the englacial rock-fragments, more especially if of small size, must suffer faceting and striation after the manner of the ground-moraine. Thus one supposed distinction between subglacial and englacial drift disappears.

Comparison with Modern Glaciers and Ice-sheets.

That glaciers of the Alpine type are generally free from incorporated drift, other than that derived from lateral and medial moraines through the agency of crevasses, is, no doubt, attributable to the facts that their courses were long since swept relatively bare of detritus, and that in their lower courses they are undergoing basal melting, and hence depositing rather than absorbing drift.

The numerous glaciers descending from the margin of the Greenland ice-cap present two types: (1) the drift-laden glaciers which predominate north of latitude 76°; and (2) the apparently drift-free glaciers to the south. In the former, the drift is strictly a basal feature, rarely rising to greater heights in the ice than 100 to 150 feet, even where the glacier may be a thousand feet or more in thickness. Possibly the northern glaciers are more generally drift-laden because the severe climate tends to prevent basal melting, and a considerable part of it may represent the lower, drift-laden portion of the ice-cap itself. The ice-cap virtually spills over the edge of the plateau through deep V-shaped notches; and the conclusion is unavoidable that a much larger proportion of the upper, clear, and relatively mobile ice will flow down, than of the lower, drift-laden, and relatively immobile ice.

It is the general belief of geologists that if Greenland were divested of its ice-cap it would exhibit continental relief—elevated margins and a depressed interior. Probably very little of the englacial drift rises to a greater height than 500 feet, or possibly 1,000 feet, even when the thickness of the ice is one to two miles. None of the suggested processes of absorption seem competent to diffuse the detritus through a more considerable thickness of the ice.

An important exception to this limitation of the range of englacial drift should be made for the case when a later sedentary ice-sheet is overridden by the readvance of an earlier sheet, the height attained by the englacial drift depending then upon the thickness of the overridden sheet.

Relations of Englacial Drift to Modified Drift.

The modified drift, or washed and stratified gravels, sands, and clays, of glacial origin, forming deltas, terraces, overwash or apron plains, eskers, kames, etc., occur almost wholly in valleys or on lowlands. This drift is due in part (1) to the washing and assorting of the till or ground-moraine by glacial streams during and following the waning and disappearance of the ice-sheet; (2) to the englacial drift through the agency of subglacial streams; and (3) to the melting of the ice and liberation of the englacial drift on its surface where it was washed and assorted by superglacial streams.

The Transportation Argument.

While a small part of the drift of the Pleistocene ice-sheet is far-travelled, the great bulk is of local origin.

Much of the preglacial residuary soil was probably swept away by aqueous erosion during the elevation of the continent and before the formation of the ice-sheet. What was left of it probably became incorporated with the ice-sheet in its earliest stage, and it has ultimately been carried by various agencies, glacial, lacustrine, and fluvial, in large part beyond the limits of the glaciated area. There is little indication of the presence of highly oxidized residuary clay in the till: its matrix is chiefly the finely comminuted and unoxidized detritus.

In its earliest stages the ice-sheet wore away and absorbed a considerable thickness of rotten rock underlying the soil, and during its maximum stage the hard rocks suffered glacial abrasion. On the decline of the ice-sheet, as before mentioned, there was a rending of ledges and detachment of fragments and boulders. These must have been, in general, the last material to be absorbed by the ice-sheet and the first to be deposited by basal melting. Under favourable conditions of flexing and shearing a small part of this material attained a high level in the ice and enjoyed a long glacial transport.

Although the total forward movement of the ice, as indicated by far-travelled erratics, appears to have been as much as five or six hundred miles, and even in some parts of the glaciated area perhaps a thousand miles, a basal slipping of one-twentieth of that distance or less would probably be regarded as sufficient to account for the erosion of the bed-rock surface and the normal distribution of the identifiable fragments. Possibly the total movement of the ice has been overestimated, the more distant erratics having been, perhaps, transported in part by water, and not wholly by the ice-sheet, each marked recession of which provided a series of glacial lakes and rivers along its margin.

It is evident that the entire volume of the drift was englacial during the active erosion of the bed-rock, and that an efficient protection was afforded to glaciated surfaces by even a thin layer of till. Hence drag as a mode of glacial transportation is not to be maintained—a conclusion at which Mr. Upham had previously arrived.

REVIEWS.

I.—The Ancient Volcanoes of Great Britain. By Sir Archibald Geikie, F.R.S., D.C.L., D.Sc., etc., Director-General of the Geological Survey. Imperial 8vo. In two volumes. Vol. I, pp. xxiv and 477, with seven maps and 175 illustrations. Vol. II, pp. xvi and 492, with 382 illustrations. (London: Macmillan and Co., Ltd., 1897. Price 36*s*. nett.) (First notice.)

THE author tells us that the present work is intended to offer a summary of what has now been ascertained regarding the former volcanoes of the British Isles. The subject, he says, has occupied much of his time and thought all through life. Born among the crags that marked the sites of some of these volcanoes, he was led in his boyhood to interest himself in their structure and history. The fascination which they then exercised has lasted till now, impelling him to make himself acquainted with the volcanic records all over these islands, and to travel into the volcanic regions of Europe and Western America for the purpose of gaining clearer conceptions of the phenomena.

Sir Archibald Geikie has from time to time communicated his researches, during a period of almost forty years, to the Geological Society of London and the Royal Society of Edinburgh. The present work is intended to combine in a general narrative the whole progress of volcanic action from the remotest geological periods down to the time when the latest eruptions ceased.

An opportunity of partially putting this design into execution occurred when, as President of the Geological Society of London, he delivered the Annual Addresses in 1891 and 1892. Within the limits permissible to such essays, it was not possible to present more than a full summary of the subject. "Since that time," writes Sir A. Geikie, "I have continued my researches in the field, especially among the Tertiary volcanic areas, and have now expanded the two Addresses by the incorporation of a large amount of new matter and of portions of my published papers."

The author's labours have culminated in the production of the two handsome volumes which, if they had been written by any less gifted geologist, would still be of the greatest value to the student, by reason of the wealth of maps and illustrations which they contain, chiefly from the writer's own notebooks and sketches, and photographs taken by Colonel Evans and Miss Thom, of Canna, and by Mr. Robert Lunn for the Geological Survey among the volcanic districts of Central Scotland. When to excellence of illustrations, however, is added the facile pen of Sir A. Geikie, the volumes become as attractive from a literary and scientific point of view as the pictures are from an artistic one.