compound cylinders, variable expansion, surface and jet condensers, and bucket and plunger pumps. The aggregate horse-power is 660. Another party will visit Wells and Glastonbury (11). Apart from the architectural and historic interest of these places there is the special attraction of the marsh-village, which will be visited under the guidance of Mr. Arthur Bulleid, whose name is so intimately associated with its discovery. On the edge of the ancient (but now reclaimed) meres stood a village consisting of about seventy dwelling-mounds covering some $3\frac{1}{2}$ acres. The foundation of the village is composed of layers of timber and brushwood resting on the peat, and is surrounded by a palisade. On the wood circular areas of clay are spread, and on these wattle huts were erected, the clay forming the floor of the dwelling. A number of interesting relics of the old British community who dwelt there are preserved in the little museum at Glastonbury. The excursion to Stroud and Nailsworth (12) combines a visit to an industrial district of considerable importance, and a drive through some of the finest scenery of the Cotteswold district. At the Stanley and the Dudbridge Mills all the processes of making raw wool into the finest plain and fancy coloured materials can be seen, and the best and most improved textile machinery can be inspected. Sir W. H. Marling, Bart., gives in the guide-book a concise history of the industry in the district. Minchinhampton Common, with its so-called "pit-dwellings" and ancient encampments, Nailsworth, Woodchester Park, Uleybury and Frocester Court are included in this excursion. The excursion to Swindon Works, Marlborough and Savernake (13), again combines industrial processes and scenery, while the inspection of Marlborough College, and its mound, will no doubt prove an additional attraction; while that to Frome, Longleat, and Shearwater (14), combines a visit to the Art Metal Works of Messrs. Singer and Sons; an inspection of the residence of the Marquis of Bath, built in the middle of the sixteenth century, on the site of an Augustinian Priory, and containing a fine collection of pictures; and a charming bit of Wiltshire scenery. The excursion to Bowood and Avebury (15) affords, besides a visit to the residence of the Marquis of Lansdowne, with its pictures and mementoes of the owner's sojourn in India and Canada, an opportunity of seeing the megalithic remains and enclosing earth-bank and ditch (the latter on the *inner* side) at Avebury, and the huge mound, 126 feet high, of Silbury. The moat or fosse surrounding this hill has been silted up by fine detrital matter from the Kennet. Avebury Church, with its Saxon work, Norman work, twelfth century font, and later fifteenth century rood-loft, is of considerable interest and most picturesquely situated. Salisbury, Stonehenge, and Old Sarum (16), including the Blackmore Museum in Salisbury, open up, in one long day, a perhaps unparalleled range of historic and prehistoric retrospect; while for those who seek the yet earlier records of geological times the excursion to Tortworth (17), by special invitation of Earl Ducie, is of special interest. Strata of Silurian age, with remarkable beds of trap-rock in the Upper Llandovery series, quarries in Old Red Sandstone and Carboniferous Limestone, and pits for the winning of Celestine (sulphate of strontium) in the Keuper beds, provide a sufficiently varied geological bill of fare. The approach to Tortworth Court, through a picturesque, well-wooded valley in the Carboniferous Limestone, occupied by an artificial lake, is remarkably beautiful. Some of the Silurian quarries have been specially opened up by Earl Ducie. Prof. Lloyd Morgan has written the guide to the excursion, and Mr. Edward Wethered will describe the micro-organisms which occur in the limestones.

At the close of the meeting a long excursion (18), specially arranged for our colonial and foreign visitors, will comprise Exeter, Torquay (including Kents Cavern), Dartmouth, Plymouth, Mount Edgcumbe, Devonport, and a trip across Dartmoor.

For all these excursions guide-books have been prepared by the leaders and those specially acquainted with the localities. And it need hardly be added that, largely through the courteous hospitality of many hosts, corporate and private, there will be no lack of refreshment by the way.

THE BERLIN GEOGRAPHICAL SOCIETY'S GREENLAND-EXPEDITION.[1]

IN 1891 Dr. Drygalski and Herr Baschin visited Greenland under the auspices of the Geographical Society of Berlin, and the results they obtained were so interesting and suggestive that the Society was encouraged to despatch another expedition in the following year. On this second and longer visit Dr. Drygalski was accompanied by Dr. E. Vanhöffen as zoologist, and Dr. Hermann Stade as meteorologist. They left Copenhagen on May 1, 1892, and returned on October 14, 1893. The principal object of the expedition being the study of the ice of Greenland, it was desirable that selection should be made of some region in which both the "inland ice" and the independent glaciers of the west coast mountain-tracts could be conveniently examined. On the advice of those experts, Dr. K. J. V. Steenstrup and the late Dr. Rink, Dr. Drygalski proceeded to the region of the Umanak Fiord, which he found admirably suited for his purpose. There the land lying between the margin of the "inland ice" and the coast attains its greatest width, and the mountains nourish a number of independent glaciers. Broad areas over which the "inland ice" had formerly passed could be traversed with ease, and the terminal edge of the ice was readily examined. Again the numerous branches of the fiord, penetrating the territory occupied by the ice-sheet, are invaded by great tongues protruded from the latter, so that the calving of icebergs and other phenomena could be closely studied. That Dr. Drygalski would make good use of his opportunities was only to be expected, and the elaborate monograph he has produced is unquestionably a most important contribution to our knowledge of the physics of ice and glacial action.

The author, we need hardly say, finds himself unable to agree with Dr. Rink, who believed that the "inland ice" is essentially a product of the low grounds—that it originated in the valleys by the freezing of the streams and rivers, and thus gradually increased from below upwards, until eventually it overtopped the water-sheds and covered the whole land. Dr. Drygalski takes the generally accepted view that the "inland ice" had its origin in the mountains, descending from these at first in the form of separate glaciers which gradually coalesced, and so filled up the valleys and smothered height after height until the whole land disappeared. Rink's notion appears to have been suggested to him by the structure of the ice, which he thought was rather like that of lake- or river-ice than snow-ice. But Dr. Drygalski shows that this is not the case. According to his observations river-ice and snow-ice have the same structure. He is inclined also to dissent from Dr. Nansen who, as is well known, holds that the general form of the great ice-sheet is independent of that of the underlying land-surface—and that the ice-shed need not coincide at all with the buried water-shed. Dr. Drygalski, on the contrary, is of opinion that the ice-shed is determined by the presence of a mountain-range, supposed by him to be connected with the mountains of the east coast, and to extend in a parallel direction between them and the centre of the

[1] "Grönland-Expedition der Gesellschaft für Erdkunde zu Berlin, 1891-93," unter Leitung von Erich von Drygalski. 2 vols. royal 8vo; with 53 plates, 10 maps, and 85 illustrations in the text. Pp. 556 and 571. (Berlin: W. H. Kühl, 1897.)

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country. Dr. Nansen, however, might reply that, after all, the existence of this mountain-range is problematical, and that neither in Scandinavia nor the British Islands did the ice-shed and the height of land coincide. Thus, in the north of Ireland the ice-shed of Pleistocene times lay over the central low grounds, while in the north-west of Scotland it occurred east of the water-shed, and the same in a more marked degree was the case in Scandinavia.

Turning to the much-discussed subject of glacier motion, we find that Dr. Drygalski comes to the conclusion that movement is the result of variations in the mass of the ice. Numerous observations and measurements demonstrated that there is both a vertical and a horizontal movement in the "inland ice," the former being the primary movement of the two. Over the marginal zone he observed a well-marked bulging of the surface, while further inland, where the ice is thicker, the surface appears relatively depressed—a condition sometimes obscured, however, by the heaping-up of snow. These differences in the configuration of the ice-sheet are due to variations of mass within the ice, the sinking or depression being the result of internal shrinkage, which is always greatest at the bottom, and progressively diminishes upwards. Had the whole mass shrunk in the same proportion as the ice at the bottom, the sinking at the surface would have been more pronounced.

The stratified or bedded structure of the ice has the same tale to tell. That structure is the result of the freezing of water under pressure, and since the individual layers diminish in thickness from below upwards, while the cold at the same time increases, it is clear that the internal shrinkage under which refreezing takes place must likewise lessen towards the surface. It is evident, indeed, that the layers must become thinner upwards, seeing that the pressure necessary for their formation diminishes in that direction. Melting, no doubt, does take place at the surface, and the released water trickling downwards is again frozen, but stratification does not result from this process. It is at lower levels in the ice that the structure is developed. And as water cannot possibly filter down from the surface through a compact ice-mass, the obvious conclusion is that the water necessary for the production of the structure in question originates within the "inland ice" as the result of pressure. The presence of stratification, then, shows that liquefaction and re-solidification take place in the "inland ice." But the water set free under pressure cannot, as a rule, refreeze in exactly the same place, otherwise it would be difficult to account for vertical movement in the ice.

Depression of the surface indicates a diminution, and bulging of the surface an increase in the volume of the ice. Under the weight of the overlying mass material is squeezed out from the thicker into the adjacent thinner portion of the ice. In short, an outflow takes place, and will continue as long as a sufficient degree of melting is kept up in the former, and the same degree of mobility is not attained in the latter. The ice-sheet, therefore, moves from the interior, where it is thickest, to the marginal area, where it is thinnest. And observation showed that under these conditions it could move up slopes.

Dr. Drygalski points out that many complications arise from the varying distribution of heat in the ice-masses, and from other causes which need not be referred to here. He found that the temperature of the thinner ice of the marginal area was generally lower than that of the thicker ice stretching inland. In the latter the ice is at, or nearly at, the melting-point. There is thus again a tendency to movement from the interior outwards. Water is forced from the thicker into the thinner masses, but, because of the low temperature of the latter, it quickly freezes, and thus gives rise to the formation of new ice-layers. The abundant presence of stratification in the thinner ice of the marginal area shows that this process is very active there, while the bulging of the surface proves that the bedded structure is intimately connected with increase of volume.

Sometimes the horizontal movement is so pronounced as to obscure the vertical movement more or less completely. In other places only the latter may be noticeable. The rate of the former depends on the thickness of the ice and the intensity of the vertical movement. The greater these are the more rapid it becomes. In the independent glaciers of the coastal tracts it was found that the rate of motion diminished as the rock débris included in the ice increased in quantity. This was to have been expected, since the mass of the ice, and therefore the whole thickness of the glacier, diminished at the same time. In the longitudinal section of such a glacier the rate of motion lessens towards the end, but with the "inland ice" the reverse is the case—it increases. In the former the ice loses bulk absolutely owing to ablation at the surface, and relatively because of the inclusion of rock-rubbish. But the great ice-streams that flow from the interior into the deep fiords increase in thickness towards the end. In glaciers and "inland ice" alike the horizontal movement of the surface depends upon that of the lowest layers. At Asakak, for example, the horizontal movement at the bottom was measured and compared with that of the surface, and this proved to be less than it ought to have been if all the layers of like thickness between the bottom and the surface had been moving at the same rate. The differential movement of the individual layers, therefore, decreases from below upwards.

The movement at the surface of a great ice-stream coming from the "inland ice" increases towards the end. Were it not for the rapid movement of its lower layers, therefore, the ice-flow would lose its continuity. When the ice enters the sea, it eventually reaches a point where the pressure of the mass itself no longer affects the lower layers—the primary vertical and secondary movements cease, the squeezing-out process comes to an end, and true glacier motion is succeeded by the purely passive movement of the iceberg.

In his discussion of the mechanics of glacier motion, Dr. Drygalski, as will be seen, upholds the well-known theory of Prof. James Thomson. He points out how the water set free under pressure is transfused into air vesicles, cracks, &c., in the ice, where it freezes again, so that the ice eventually becomes clearer. As this process goes on most rapidly at the greatest depths, the ice at the bottom is necessarily the clearest—clearness, in short, increases from the surface downwards. Further, since refreezing takes place under pressure, the ice crystals arrange themselves with their chief optic axes perpendicular to the lamination or bedding of the ice. As a result of these changes, the volume of the ice is diminished- the shrinkage being greater in the thick than the thin layers, and more marked in the inland tracts than in the marginal area of the ice-sheet. But we need not follow the author further into this part of his discussion. When he states that the horizontal motion depends upon the movement of water within the ice, he will not be misunderstood. He does not mean free flowing streams of water, but mechanical changes in the mass and transference of conditions. Perhaps also it may be as well to add that, although measurements prove that differential movement of the ice-layers increases from the surface to the bottom, it is not to be supposed that one layer flows out from under the layer above it. There is a certain loosening of the connection between them, the author remarks, but not an actual separation. In consequence of this some of the motion of the lowest layer is added to that of the next above, the rate of which is thereby

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increased. And so the process continues from layer to layer up to the surface, the motion of which is not the sum of the differential movements of all the underlying layers, but of part of the same. The surface as a whole, therefore, has the greatest motion, although the proper motion of the superficial stratum itself is the least of all.

Helmholtz would appear to have been the first physicist abroad to recognise the significance of Thomson's theory, and he set forth its application in such a form as could not fail to attract attention. Since the publication of his "Populäre Wissenschaftliche Vorträge," however, so much has been written on the subject of glacier motion —so many conflicting explanations and criticisms have appeared—that laymen may be excused if they confess to a feeling of confusion in regard to the whole question. We feel sure, therefore, that Dr. Drygalski's work will be welcomed not by physicists only, but by all who desire to have clear views on the subject with which it deals. They will find in its pages excellent descriptions and illustrations of the varied glacial phenomena, so that even those who may not quite agree with some of his conclusions will yet thank the author for the abundant data he has supplied.

To geologists, not the least interesting portions of Dr. Drygalski's work are those that deal with glacial action. He shows that the conclusion reached by them as to the former existence of a great ice-sheet in Northern Europe is justified, and that the conditions under which they believe the "diluvium" was accumulated are reproduced in Greenland at the present time. In Europe the ice-sheet occupied the basin of the Baltic, its source being in the lofty heights of Scandinavia to the north-west, and its termination in the regions lying south and east —regions that slope up to heights of several hundred metres and more above the bottom of the Baltic basin. In Greenland the "inland ice" fills the depression between the mountains of the east and west coasts, the former of which constitute a broad belt of high ground that possibly extends into the very heart of the country. This mountain-tract is the source of the "inland ice," the terminal front of the latter thinning off upon the slopes of the less elevated mountains of the west coast. The numerous deep fiords by which that coast is indented, penetrate to the inland depression, and into these, therefore, enormous ice-streams make their way. To the great fiord-glaciers of Greenland there was nothing analogous along the southern and eastern margins of the old "inland ice" of Northern Europe. Between the fiords of Greenland, however, the ice-sheet thins out upon the mountain slopes in the same way as the European *mer de glace* must have done upon the flanks of the Riesengebirge and other ranges of Middle Germany.

The smoothed and striated surfaces observed underneath the edge of the "inland ice," and in the areas from which it has retired, exactly recall those of Europe. Their origin, Dr. Drygalski remarks, is not hard to understand when we remember that the chief work of ice-movement is carried on at the bottom, where the relative motion is greatest. The bottom-layers of the ice are crowded with rock-débris, which under glaciostatic pressure is carried from areas where the ice is thickest to regions where it is thinnest, and in this way it often travels from lower to higher levels. Armed with this material, the "inland ice" is a most effective agent of erosion. As the included material increases in quantity, the relative thickness of the ice is correspondingly diminished, and thus changes in the direction of ice-movement must take place. Hence erratics, after travelling for some distance in some particular direction, may change their course again and again. And so in like manner divergent striæ may be engraved upon the rock-head over which the ice is moving. The varying configuration o. the land-surface is thus not the only cause of changes in the direction of ice-flow.

The author is convinced that "inland ice" is quite capable of producing the contortion and disturbance which so frequently characterise the diluvial deposits of North Germany. Powerful pushing and shoving are effected by the horizontal movement of the lowest layers of an ice-sheet. Any water-saturated deposits underlying such a mass would be influenced in the same way and subjected to the same disturbance as the débris-laden portions of the ice itself. Where the ice is free from inclusions the internal changes which result in horizontal movement are not interfered with—the ice-layers remain undisturbed. But when débris is present the movements due to pressure are hindered and impeded, and the ice-layers amongst which it lies become bent and folded. In alluvial or similar deposits underlying the ice folding would be still more readily produced, since in their case pressure is no longer relieved, as in the ice, by transference of conditions, but is entirely converted into mechanical deformation.

The "inland ice" where it thins off upon the flanks of the west coast mountains is bordered by moraines. These are composed of materials derived from the bottom of the ice-sheet, and are continually being added to; the moraines, in short, are gradually heaped up at and underneath the thin edge of the ice-sheet. In other places where the ice is bordered by precipitous land no moraines are extruded, the steep rock-declivities causing a deflection of the ice-flow. The moraines, according to Drygalski, present the same appearances as the "end-moraines" of North Germany. Although for the most part unstratified, they yet now and again consist in part of water-arranged materials. Scratched and polished stones were common. It is clear, indeed, from the author's descriptions that the morainic matter extruded from the "inland ice" of Greenland has essentially the same character as our boulder-clays.

Dr. Drygalski draws attention to the interesting fact that not only in the marginal tracts of the "inland ice," but in certain independent glaciers the "blue bands," which are the result of pressure, trend in the general direction of ice-movement. This shows that there must be pressure in the direction of the high grounds overlooking the ice, and perpendicular to the trend of ice-flow. The author thinks it probable, therefore, that under these conditions subglacial morainic materials might well be heaped up in banks and ridges having a direction parallel to that of glacial movement.

With regard to the ground-moraine itself, there can be no question that this is partly carried in the lower portions of the ice, and partly pushed forward underneath, and, further, that the forward movement must result in the deformation of underlying unconsolidated formations. The moving force is, of course, in the ice itself. With the augmentation of included débris the mobility of the mass is impaired, internal friction increasing the more closely the materials are crowded together. It is only when débris is well-saturated that under pressure movements like those of the ice itself can take place. In a compact subglacial mass of débris the movement communicated by the flowing ice above must, owing to friction, quickly die out downwards. Only a relatively thin layer of ground-moraine, therefore, can travel onwards underneath the ice. Immense quantities of material, however, are interstratified with the lower layers of the "inland ice," and these are eventually added to the ground-moraine. The amount of this included or intraglacial débris depends upon the thickness of the ice, and must thus vary from place to place As the ice diminishes in thickness, its ability to trans port rock-materials declines, and the rubbish begins to be deposited below. Dr. Drygalski thinks that the boulder-clays of North Germany were in all probability

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deposited in this way. Thus wide sheets of boulder-clay and the "end-moraines" of a great ice-sheet have had the same origin—they consist of ground-moraine accumulated under the thinner peripheral portions of the ice.

According to the author there is no doubt that the action of the ice favours the formation of rock-basins. Should a depression or hollow occur underneath an ice-sheet, and the ice be thicker in the hollow than over the adjacent tracts, the hollow will tend to be progressively excavated. He thinks, however, that the erosive work of the ice will tend rather to the lengthening of the hollow in the direction of glacial movement than to its deepening. Wherever the ice is thickest there erosion will be most pronounced, no matter what the form of the land-surface may be. Thus rock-basins may be hollowed out even in relatively flat land, as for example, by a glacier upon the low ground opposite the mouth of a mountain valley.

Such are a few of the many interesting points connected with glacial action which are discussed by Dr. Drygalski. He concludes his work by some very suggestive remarks on the wonderful resemblances that obtain between the old gneiss-formation and the "inland ice"—the oldest and the youngest *Erstarrungsprodukte* of the earth's crust. When he had surveyed the steep gneiss-walls of the fiords, with their folded, contorted and confused bedding, their bands of crystalline schist, their veins and dykes, their fissures and fractures, he was astonished to encounter the same appearances in the "inland ice," and he follows the analogy into minute details of structure. But enough has been said to show that Dr. Drygalski's monograph is of no ordinary interest to geologists.

The chief object of the expedition being the study of ice in general and of the movement of the "inland ice" in particular, the opportunities for biological investigation did not at first appear to be very promising to Dr. Vanhöffen. But in this he was happily disappointed, for he succeeded in bringing home much material for study. His contribution to the work before us occupies the greater portion of the second volume. In this he does not confine himself to a mere description of his own investigations and their results, but gives us an exhaustive account of the fauna and flora of Greenland, including of course the life of the adjacent seas. For the benefit of those who are not specialists he illustrates his work with a number of beautiful coloured plates of some of the crustaceans, pteropods and jelly-fish which swarm in the waters of the far north. A copious bibliography is appended—great pains, indeed, have been taken to give a complete survey of the natural history of Greenland. A more special and detailed account of his own investigations is to appear in the *Bibliotheca Zoologica* and *Bibliotheca Botanica* (Stuttgart).

The concluding part of the second volume is devoted to the discussion of the magnetic, meteorological, astronomical and geodetic work of the expedition by Drs. Stade, Drygalski, and Schumann. Dr. Stade devotes a chapter to the föhn winds of West Greenland, which have long puzzled navigators and excited the superstitious fears of the Eskimo. Coming as these warm winds generally do from the ice-covered land, especially in the coldest time of the year, they seem hard to account for. According to Dr. Stade they owe their origin to depressions passing through Davis Strait from south to north. The approach of a depression is marked by strong to stormy winds from the south-east or east, the temperature of the atmosphere suddenly rising, while at the same time its relative humidity is reduced.

Altogether this most recent of Arctic expeditions has been fruitful in results, and the Geographical Society of Berlin must be congratulated on the great success which has attended the enterprise. JAMES GEIKIE.

THE PRODUCTION AND USES OF OZONE.

THOUGH it has been known for more than a century that air and oxygen acquire a peculiar odour when exposed to the action of electric sparks, and though Schönbein ascertained nearly half a century ago that this odour is due to a distinct form of matter, now called ozone, which is produced by the electrolysis of dilute sulphuric acid, by the action of electric discharge in air, and as a product of the slow oxidation of phosphorus, chemists are still trying to learn the exact conditions of the formation of this substance, and still investigating some of its simplest reactions; whilst inventors are but beginning the work of making it useful to man.

But if the wheels of science grind slowly, in the end they grind true, and various facts now distinctly suggest that ere long ozone will play a useful part in the service of medicine, of surgery, and in the arts.

Ozone has never yet been obtained as a gas in the pure state, but from the properties of mixtures containing it we cannot doubt that gaseous ozone would be blue in colour, and condense at low temperatures to an indigo-blue liquid, which explodes violently on contact with olefiant gas. The ozone in mixtures, such as are produced by the electrification of air or oxygen, is very instable, being resolved into common oxygen with explosive violence if suddenly compressed without previous cooling; and even under atmospheric pressure it cannot long be preserved except at rather low temperatures. This characteristic instability of ozone is at once the cause of its most interesting properties and of its possible usefulness. Molecules of common oxygen contain but two atoms of the element, whilst the molecules of ozone contain three such atoms, and it would seem that the atoms hold together much less firmly in the larger molecules than when they are united in pairs; consequently ozone acts as a powerful oxidiser, readily giving up part of its oxygen to oxidisable substances, whilst the rest returns to the ordinary form of the element, except in certain cases when it is completely absorbed.

Now chemists have, it is true, plenty of powerful oxidisers at their command, and many of them are inexpensive; but not even hydrogen peroxide, which can now be obtained comparatively cheaply, is quite so simple in its action as ozone, for this substance, which consists, as we have seen, of oxygen and of oxygen alone, when used as an oxidiser does not leave any inconvenient residue, such as accompany the action of many other oxidising agents. Hence a field for the employment of ozone may be found whenever a simple oxidising agent is required. Thus, for example, it has been suggested that it might conveniently be used for bleaching beeswax, starch or bones, in the manufacture of *dégras* for leather makers, in preparing drying oils for the manufacturers of varnishes, or again, according to Wiedermann, to hasten the ageing of whiskey.

There are, however, as might be expected, difficulties to be surmounted. Sometimes, as in its action as a bleaching agent, ozone is apt to act too slowly; whilst at others it is difficult to adjust the proper dose of the oxidiser. Thus we are told that port wine treated with ozone forms a deposit which quickly increases, so that the wine soon puts on an appearance which, under ordinary circumstances, it would only acquire in the course of years. But, alas! wine thus rapidly ripened is apt to fade with corresponding rapidity, owing, it is presumed, to the use of too much ozone, and hence, in the absence of any obvious method of estimating the proper dose, ozone does not yet recommend itself to wine makers or wine merchants. It has occurred to the writer, however, that it might possibly be made useful, even at the present stage, in judging unripened wine, since its use might enable the vintner to ascertain without delay

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