difficult in the extreme. The article is of special value at the present moment, when the question of trade routes into South-Western China has assumed so much prominence.

THE BRITISH ASSOCIATION

SECTION C—GEOLOGY

Some Results of a Detailed Survey of the Old Coast-Lines near Trondhjem, Norway, by Hugh Miller, F.G.S., H.M. Geological Survey.—During a short visit to Norway in October, 1884, it appeared to the author that the best way to help to a solution of the vexed questions connected with the coast-terracing of Norway was to execute a careful survey of a few square miles of some suitable coast-region upon a sufficiently large scale. The neighbourhood of Trondhjem is remarkably well suited to this purpose. The map employed was partly a municipal chart on the scale of 1-10,000, and partly an enlargement of the Ordnance map. The limit of all the terraces and marine deposits is the famous "strand line" west of the town, a double range of old coast-cliff cut in the rock of the mountain-side. Its upper line is 580 feet above the sea, and answers to the "marine limit" over Norway generally. Numbers of level terrace-lines have been incised—chiefly in greenish clays, like brick-clays—all along the arable slopes east of the town between this rock-terrace and the sea. Above the Bay of Leangen, two miles east of town and river, and far beyond all erosive influence of the latter, thirty of these lines were mapped one above another in the first 300 feet of ascent, a distance of one and a half mile. Many of these are small but extremely distinct, the earthy clays being well suited to retain sharp impressions of successive sea-margins, which these unequivocally are. The present coast-line, neatly etched out by the waves in Trondhjem and Leangen Bays, is the key to these tiers of older ones. It also resembles them in having made little or no impression where the coast becomes rocky, the lines of incision in both cases stopping short at once when they reach the harder material. The old coast-lines are most numerous in well-sheltered positions. Thus a single pair of large terraces in an exposed situation east from Christiansten, where they face the open water of the fjord and the prevalent north-westerly storms, is represented in the recess above Leangen Bay by ten or twelve. The same fact is brought out on rising from this recess to the higher and more exposed ground. Thus, while thirty-three or thirty-four terraces are mapped below 350 feet (approximate) elevation, only nine or ten appear between that level and the rock-terraces of the upper marine limit, the numerical average height of the terraces thus rising by more than a half. In recesses of the coast further east, but beyond the map, these upper terraces seem to be preserved in considerably greater numbers. The number actually mapped was forty-three, or, with the two rock-terraces, forty-five. The largest number of terraces hitherto described at any one place in Norway seems to have been eighteen. Some of the general conclusions of the author are as follows:—(1) These terraces are all post-glacial, *i.e.* formed since the rock-glaciation of the district. This is confirmed by the condition of the high coast-cliff, which has been cut in ice-rounded rock, but is not itself glaciated. It appears, however, from the fauna of the raised shell-banks of the country (as worked out by Sars and Kjerulf), in which recent shells do not rise above 380 feet, that the seas of the upper levels were still glacial; and, though the Trondhjem fjord was free from land-ice, other deeper fjords and higher coasts may still have had glaciers coming into conflict with the sea, and producing the glaciated rock-terraces described by Sexe. All the evidence obtained discountenances Sexe's view that these rock-terraces were cut out by glaciers, as well as Carl Petersen's that they were rasped out by floating ice coasting the shores. On the clay terraces coast-ice has left no more sign of its presence than the winter freezing of our British rivers leaves upon our river-terraces. (2) If the country was upraised by a succession of elevatory jerks, as supposed by most geologists from Keilhau downwards, most of these would seem to have been small—much smaller, at least, than is supposed by Kjerulf. It is improbable that even Leangen Bay was secluded enough to contain a record of all the original coast-lines. The longer pauses and greater storms may have effaced an unknown number by a process of excision exemplified in all its stages by the map. It is hard to say, in fact, where the subdivision would end if all were preserved. The smaller terraces remind the eye of the incised lines and little planes engraved on the sandbanks bordering the rivers after a flood, in which case there is no periodicity in the subsidence of the waters. (3) The preservation or excision of the terraces thus seems to depend as much upon local circumstances—exposure to storms, resistance of coast-line, &c.—as upon anything else. It is impossible at present to predicate which of them shall in any given place remain. Whether elevation by jerks, therefore, be postulated or not, all hope of correlating these terraces throughout the country must be deferred until their heights have been accurately determined by level. The measurements hitherto made, not even excepting those of Profs. Kjerulf and Mohn, are probably inadequate for the purpose. This observation seems to apply also to the terraces graven in rock. In their aneroid measurements of the upper strand-line at Trondhjem these observers differ by 55 feet. (5) On entering the mouth of the Trondhjem Valley the terraces come under an influence other than that of the sea-waves. The valley was worked out, in deposits partly levelled out by the sea, according to the laws of river-terracing under the accelerating influences of a falling sea-level. The processes of automatic river-terracing are beautifully exemplified within the district mapped in the deep lobe-shaped curve of the river just before it enters the sea. The terraces have been added one after another to the point of the lobe of land thus surrounded, which is known as Öen.

The Glacial Deposits of Montrose, by Dr. J. C. Howden.—These consist, in order of age—(1) a marine clay containing fossils of a purely Arctic type, apparently the bottom of a deep sea. Above this is seen the estuarine clay, beneath which, however, are often found deposits of peat. Over the estuarine clay is a bed of stratified sand, and above that a dense non-fossiliferous Carse Clay, varying in thickness from 4 to 6 feet. The sequence of these deposits was held by the author to indicate interglacial periods.

Irish Metamorphic Rocks, by G. H. Kinahan, M.R.I.A.—This paper is an epitome of what is known as to the age of the Irish Metamorphic rocks.

Barium Sulphate as a Cementing Material in Sandstone, by Prof. Frank Clowes, D.Sc.—The author described the "Hemlock stone" and other similar blocks of Lower Keuper sandstone in the neighbourhood of Nottingham. They stand out in hard masses from the more easily denuded sandstone around them. Analysis has shown that the cementing material of the upper part is barium sulphate. This being practically insoluble withstands denudation and protects the lower part from waste, this lower part being mainly cemented by calcareous matter. Bischof has proved the occurrence of barium sulphate as a cementing material in some foreign sandstones, but the fact is probably new in Britain.

On Deep Borings at Chatham. A Contribution to the Deep seated Geology of the London Basin, by W. Whitaker, B.A., F.G.S., Assoc.Inst.C.E.—A few years ago the Admiralty made a boring in the Chatham Dockyard extension, to the depth of 903½ feet, just reaching the Lower Greensand, and in 1883-84 followed this by another boring near by. After passing through 27 feet of Alluvium and Tertiary beds, 682 of chalk, and 193 feet of Gault, the Lower Greensand was again reached; but, on continuing the boring, was found to be only 41 feet thick, when it was succeeded by a stiff clay, which, from its fossils, is found to be Oxford clay, a formation not before known to occur in Kent. At its outcrop, about seven miles to the south, the Lower Greensand is 200 feet thick, and is succeeded, a little further south, by the Weald Clay, there 600 feet thick. Not only, however, has this 600 feet of clay wholly disappeared, but also the whole of the next underlying set of deposits, the Hastings beds, which crop out everywhere from beneath the Weald Clay, and are also some hundreds of feet thick. More than this, the Purbeck Beds, which underlie the Hastings Beds near Battle, are absent, and also the Portlandian, Kimmeridge Clay, Corallian, &c.; beds which have been proved above the Oxford Clay in the sub-Wealden Boring, to the great thickness of over 1600 feet. We are therefore faced with a great northerly thinning of the beds below the Gault, a fact agreeing in the main with the evidence given of late years by various deep wells in and near London. Three other deep borings have been made or are being made near Chatham, all of which have passed through the Chalk into the Gault, and one has gained a supply from the sand beneath. The practical bearing of the Chatham section is, however, to enforce the danger of counting on getting large supplies of water in the London Basin from the Lower Greensand by means of deep borings at any great distance from its outcrop. Even if Lower Greensand occur at all in such places, it will probably be in reduced thickness, and therefore with reduced water-capacity.

American Evidences of Eocene Mammals of the "Plastic Clay" Period, by Sir Richard Owen, K.C.B., F.R.S., G.S., &c.—In the year 1843 a fragment of a lower jaw with one entire molar of a mammal was dredged up off the Essex coast. A canine tooth of the same was found in a well-sinking near Camberwell, in piercing the "plastic clay." The author had described the above as belonging to an animal of the Lophiodont family, and proposed for it the generic name Coryphodon. Shortly afterwards De Blainville had noticed certain fossils as "probably Coryphodont," but had referred them to *Lophiodon anthracotherium*. Ten years later Prof. Hébert had recognised two species of *Coryphodon* in the plastic clay of France. Explorations by Leidy, Marsh, and Hayden, in the "Mauvaises Terres" of Nebraska had led to the discovery of a large hoofed mammal allied to *Coryphodon*, to which the name *Titanotherium* had been given, and Prof. Cope has now recognised, from Evanstown, Wyoming, seven species of *Coryphodon*. From these materials, which have been rendered accessible to European palæontologists by the superb volume of reports recently issued by the United States Government, the author is enabled to give a general description of this family of hoofed mammals of large size which flourished in early Eocene times. To the details of this the major part of the paper is devoted.

Some Results of the Crystallographic Study of Danburite, by Dr. Max Schuster.—In studying the characters of the faces and the structure of the Danburite crystals found in Switzerland the author has met with vicinal faces of a peculiar kind, for which he proposes the term "transitional faces" (*Tschermak Min. Mittheil.*, vi., 1884, p. 511). Attention is called to the fact that these faces are easily affected by those causes which produce an unequal development of faces otherwise symmetrically disposed, and an illustration is given of the way in which their indices are numerically related to those of the principal faces of the crystal.

Notice of an Outline Geological Map of Lower Egypt, Arabia Petræa, and Palestine, by Edward Hull, LL.D., F.R.S., F.G.S. The map exhibited was enlarged from that which accompanies the author's book, "Mount Seir, Sinai, and Western Palestine," giving a narrative of the expedition sent out into these countries by the Palestine Exploration Society in 1883–84. It embraces a region extending from the valley of the Nile on the west to the table-land of Edom (Mount Seir) and Moab, including the Jordan, Arabah Valley, and the mountains of Sinai. Its northern limit is the Lebanon. The main lines of fault and dip of the strata are also indicated. A topographical and geological map of the Arabah Valley on a scale of about six miles to one inch was in preparation, and would accompany the Geological Report now in the press for the Palestine Exploration Society.

A Preliminary Note on a New Fossil Reptile recently discovered at New Spynie, near Elgin, by Dr. R. H. Traquair, F.R.S.—Of this most important fossil the author had as yet only seen a photograph submitted to him by Prof. Judd, the President of the Section. This photograph represents pretty nearly a vertical longitudinal section of a reptilian skull, of which one very prominent feature is the presence of a large conical tusk in the upper jaw, projecting downwards and forwards, immediately behind the premaxillary part of the skull. This tusk is seen only in impression, but the cast of the internal cavity which is well shown indicates that it grew from a permanent pulp. No evidence of any other teeth is visible, and the whole appearance of the skull as seen in the photograph, with the position and shape of the tusk, indicate that the reptile here represented, if not actually belonging to the genus Dicynodon, is certainly a member of the group of Dicynodontia. Geologists will not underrate the importance of this discovery in its bearing on the question of the age of the reptiliferous sandstone of Elgin.

On the Average Density of Meteorites compared with that of the Earth, by the Rev. E. Hill, M.A., F.G.S.—The average density of the meteorites which fall on the earth is attempted to be calculated. Different methods give as results 4·55, 4·58, 4·84, 5·71, the last value being influenced by the size of one particularly large metallic specimen. The average density of the earth is usually regarded as 5·6. Meteorites are samples of the materials of space. A mass of them would aggregate into a body of density not widely differing from that of the earth. The densities of the other planets are not inconsistent with a like origin. Consequently any theory of the genesis of the earth from pre-existing materials involves a probability that an important part of its nucleus is metallic.

On the Occurrence of Lower Old Red Conglomerate in the Promontory of the Fanad, North Donegal, by Prof. Edward Hull, LL.D., F.R.S., Director of the Geological Survey of Ireland.—The district in which the Old Red Conglomerate occurs is formed of ridges and valleys of metamorphic rocks, consisting of beds of quartzite, schist, crystalline limestone, and trap, chiefly diorite. It lies between Lough Swilly and Mulroy Bay, and is washed on the north by the waters of the Atlantic. The remarkable tract of the Old Red Conglomerate, recently discovered by the officers of the Geological Survey, is far remote from any mass of the same formation, and it is unrepresented on any geological map hitherto published. The beds consist of red and purple sandstones and conglomerates, made up chiefly of quartzite pebbles and blocks, but also containing others of limestone and trap; all derived from the surrounding metamorphic series. They occupy an area of over two miles in length and half a mile across, extending along the northern base of Knock Alla, a ridge of quartzite which traverses the promontory from side to side. The beds dip against the base of the mountain, against which they are let down by a large fault, and they terminate along their northern edge by an unconformable superposition on beds of quartzite and limestone. They reach a total thickness of about 800 feet. From the position of these beds it becomes evident that they are unconnected with any of the recognised basins of Lower Old Red Sandstone, either in Scotland or Ireland, and may, therefore, be regarded as having been formed in an isolated basin, which, following the example of Dr. Geikie, I may be allowed to name "Lake Fanad." The tract will be a new feature on geological maps of Ireland.

On Bastite-Serpentine and Troktolite in Aberdeenshire; with a Note on the Rock of the Black Dog, by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., Pres. G.S.—Bastite-serpentine (as noticed some time since by Prof. Heddle) occurs near Belhelvie and on the shore near the Black Dog. The author describes the microscopic structure of this, showing that it consists of olivine and its alteration products, enstatite in various stages of alteration, and a mineral of the spinellid group. Associated with this in the Belhelvie district is a fairly normal troktolite, consisting of a plagioclastic felspar allied to anorthite, olivine, more or less altered, and a little diallage. It closely resembles the typical Volpersdorf rock, but has rather less magnesia and more alumina, corresponding chemically more nearly with a rock described by the author from Coverack Cove, Cornwall. He is of opinion that the two rocks differ somewhat in age, though probably the earlier was still at a high temperature when the latter was intruded, and he inclines to the view that the serpentine is the older rock of the two. The Black Dog has been incorrectly described as consisting of "crystals of *talc* matted in such confusion as to form both a tough and hard rock." The rock really consists of quartz, sillimanite, two kinds of mica, an iron oxide (hematite?), and most probably some dichroite, with perhaps a little kyanite. In short, the rock presents a very close resemblance under the microscope to some specimens of the well-known "cordierite gneiss" of Bodenmais.

On the Re-discovery of Lost Numidian Marbles in Algeria and Tunis, by Lieut.-Col. Playfair, H.M. Consul-General for Algeria and Tunis.—The author explained that the name itself was a misnomer, as they are not found within the limits of Numidia proper, but in the province of Africa and in Mauritania. Most of the "Giallo antico" used in Rome was obtained from *Simittu Colonia*, the modern Chemton, in the valley of the Medgérda, the quarries of which are now being extensively worked by a Belgian company; but the most remarkable and valuable marbles are found near Kleber, in the province of Oran, in Algeria. There, on the top of the Montagne Grise, exists an elevated plateau, 1500 acres in extent, forming an uninterrupted mass of the most splendid marbles and breccias which the world contains. Their variety is as extraordinary as their beauty. There is creamy white, like ivory; rose colour, like coral; Giallo antico; some are as variegated as a peacock's plumage; and on the west side of the mountain, where there has been a great earth-movement, the rock has been broken up and re-cemented together, forming a variety of breccias of the most extraordinary richness and beauty.

On some Rock-Specimens from the Islands of the Fernando Noronha Group, by Prof. A. Renard, LL.D.—The rock-specimens described in this communication were collected by Mr. J. G. Buchanan, during the voyage of the *Challenger*. The islands have been described by Darwin in his "Geological Observations on Volcanic Islands" (2nd edition, p. 27). The author, after having explained the geological structure, gives lithological descriptions of the chief types of the rocks, which may be referred to the phonolites (St. Michael's Mount). These phonolites are composed of sanidine, augite, nepheline, hornblende, magnetite, nosean, and titanite. The rocks of Rat Island are basalts with nepheline. The constituent minerals are augite and olivine. The ground-mass is almost entirely composed of nepheline. Biotite and apatite occur as accessory constituents. The little island known as Platform Island is also basaltic, with a doleritic texture. It is composed of labradorite, augite, olivine, magnetite, and biotite. This rock has undergone alterations.

Preliminary Note on some Traverses of the Crystalline District of the Central Alps, by Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., Pres. G.S.—During the past four years I have made several traverses of the Central Alps from north to south, and venture to lay before the Section the general results as bearing in some respect on the geology of the Highlands. (1) The ordinary rules of stratigraphy as learnt from most lowland districts are commonly quite inapplicable to the Alps. The most highly crystalline and the older beds often form the higher parts of a mountain region, the newer the lower. The newer beds frequently appear to underlie and dip regularly beneath the older. Gigantic folds, overturns, and overthrust faults abound. The true stratigraphy of a district can only be worked out by the exercise of patient and cautious induction from observations extended over a wide area. (2) The non-crystalline rocks of the Alps are of various ages. There are some of Carboniferous age, but the great period of continuous deposition generally begins with some part of the Trias. The conglomerates, which often occur at the base of the non-crystalline deposits, indicate that the principal metamorphism of the crystalline series was anterior to both these epochs. There is at present no reason to suppose that either in the Central Alps or for some distance on each side are there any representatives of the earlier Palæozoics. I believe that the conglomerates at the base of the Carboniferous contain fragments of the later crystalline rocks of the Alps as well as of some of the earlier—though I do not assert that these crystalline rocks have undergone no modifications since Carboniferous times. (3) In the heart of the principal Alpine chains, and apparently at the base of everything, are coarsely crystalline gneisses. These differ little from granites, except that they generally—almost always—exhibit a certain foliation, and occasionally seem to be interbedded with thin seams of micaceous schists or flaggy fine-grained beds. (4) On examination we find reason to believe that both the latter are generally due to crushing. Their strike agrees with that of the apparent foliation in these older rocks, and with that of a foliation which is also present in the newer crystalline rocks. This corresponds with the strike of the main physical features of the district, and with the cleavage in the included troughs of sedimentary rock. It runs for great distances with remarkable uniformity. (5) This apparent foliation is due to the devolopment of extremely thin films of a micaceous mineral. In many cases it causes the rock to bear the aspect of a highly micaceous schist; yet, on examining a transverse section, the rock is distinctly seen to be a crushed gneiss—*i.e.* though so conspicuous, it is a mere varnish. As it thus differs materially from a true foliation, it would be convenient to give it a name, and I should propose to call it the "sheen surface." It is, in fact, a kind of "cleavage foliation," that is, a foliation due to cleavage, and subsequent to it. (6) The pressure which has produced this "sheen surface" has in many cases affected the orientation of the minerals, which are present in the true "foliation" layers of the more distinctly foliated, *i.e.* mineral-banded, rocks. (7) In the crystalline schists very commonly the "sheen surface" corresponds with the original foliation surface, as in the slates the cleavage sometimes does with the bedding. This is due to the fact that the axes of the great folds often make a very high angle with the horizon. (8) Thus a non-foliated crystalline rock may be rendered to some extent foliated by pressure (followed by a certain amount of mineralisation): *i.e.* some gneisses may be formed by crushing from granites, some schists out of other igneous rocks. It may obliterate an earlier foliation, or it may intensify it, or it may produce an independent and more fissile foliation. In this sense gneiss may be said to pass into granite, because a rock which is now, both macroscopically and microscopically, a gneiss may prove to be a granite which has in some parts yielded to pressure more than in others. (9) As we pass outwards from the great central granitoid masses we come to gneisses and schists where the evidence of some kind of stratification becomes more marked; bands of crystalline limestone, quartzite, and granulite being associated with mica schist of many kinds—simple, garnetiferous, staurolitic, actinolitic, and the like—the bands of different mineral character and composition varying from mere streaks to layers up to many yards in thickness. In fact the above-named rocks are associated exactly as limestones, sandstones, and clays are associated in the ordinary sedimentaries. (10) Although the crushing of a crystalline rock *in situ*, or the squeezing and shearing of a breccia or conglomerate of crystalline fragments, occasionally gives rise to local difficulties, these are on a small scale, and sedimentary beds belonging to the Palæozoic or later periods of deposition are generally readily distinguishable from the whole of the crystalline series. Though folded and faulted in the most extraordinary manner, the members of the two series can generally be separated and in the Alps there is no evidence of a mingling of the one with the other in the process of rolling out or squeezing together; so that, after patient study and microscopical examination, we can generally decide without hesitation whether a particular set of rocks has originated from the crystalline or the sedimentary series. I do not say that we can always decide whether a schist or a gneiss has originated from an igneous rock or from an older schist or gneiss, but I think that in the Alps we can say that it has originated from one of these. Fortunately, intrusive rocks are very rare in the Palæozoic and later deposits in this part of the Alps. (11) Thus, although the Tertiary metamorphism of the Alpine rocks is very important, it is more pretentious than real, and its effects seem to have been the greatest where it has found a rock already crystalline to act upon. Hence I believe that every true gneiss and schist in the Alps is much older than the Carboniferous, and is probably older than any member of the Palæozoic period.

The Direction of Glaciation as ascertained by the Form of the Striæ, by Prof. H. Carvill Lewis.—As there seemed to be a disagreement between certain Scotch geologists and the Irish geologists regarding the inferences as to direction of glaciation to be deduced from the form of glacial striæ, the author was led to bring forward some observations of his own, made in America and in Great Britain, which threw light upon the disputed point. Well-preserved striæ are frequently blunt at one end and tapering at the other, the shorter ones sometimes resembling the characters used in the cuneiform inscriptions. This form may be seen in striæ of all sizes—from those several yards in length, when the blunt end may be an inch or more in breadth, to the finest scratches, where a microscope is necessary to detect any difference between the two ends. As shown in the Reports of the Boulder Committee of the Royal Society of Edinburgh (Fifth Report, pp. 18–20, 29, 58; Seventh Report, p. 18) and elsewhere, certain Scotch geologists regard the blunt end as the point of impact of the striating agent, and as therefore facing the direction from which the motion came. On the other hand the Irish geologists ("Memoirs of the Geological Survey of Ireland," Explanation to sheets 86, 87, 88, p. 55; Explanation to sheet 193, p. 18, &c.) interpret the shape of the striæ as indicating motion in the opposite direction, believing the tapering end to point to the direction from which glaciation proceeded. The point at issue is of importance, especially in outlying islands and elsewhere, where other indications of the direction of glaciation fail. In Pennsylvania, which is crossed from east to west by the terminal moraine of the great ice-sheet, and where the glaciation is uniformly in a southward direction, the author had observed that the blunt ends of the striæ, where flat surfaces were studied, were always to the south ("On the Terminal Moraine in Pennsylvania and Western New York." Report Z, Second Geological Survey of Pennsylvania, pp. 33, 85, 86, 107, 275). In certain instances the mode of formation of the striæ was also indicated by their shapes, which showed that a stone pushed along under the glacier had ground in deeper and deeper until in some cases it stopped or hopped out, in other cases was ground down to another cutting edge, and in others *turned over*, and began its work of engraving by a fresh and sharp corner. The peculiar gorges at the farther end of certain striæ showed a sort of slow rocking motion in some stones before they finally turned over. The author's observations in Ireland, both at localities where there could be no doubt as to the direction of glacial movement, and at localities where such direction was not previously known, led to conclusions entirely in harmony with those already reached in Pennsylvania and with those held by the Irish geologists. One of the best examples falling under the former category was among the local glaciers in the mountains of the Dingle promontory, a region not invaded by the great confluent ice-sheet of central Ireland. The striated beds of these small glaciers, beginning in a "corey" and bounded below by a semicircular terminal moraine, are beautifully defined and afford good opportunities for striæ study. It was found that *on upward slopes or in flat surfaces the striæ as a rule are blunt at the end towards which the motion was directed, but that in downward slopes the reverse is generally the case*. While this rule does not hold good for every individual scratch at a given locality, it has been found most useful when applied to striated surfaces in general. At Glengariff, where some finely striated surfaces occur, a number of tracings were taken directly from the rock, which clearly show the broader ends of most of the striæ to be to the south, the direction towards which the glacial stream advanced. Similar observations were made at several localities south of the Shannon. Finally, as an instance where the direction of glaciation was previously unknown, certain striæ were described which the author had observed on the top of the cliffs facing the Atlantic at Kilkee. These point N. 58° W. and S. 58° E., and the question to be determined was whether the glaciation proceeded from the Atlantic towards the land or whether it went north-westward and out to sea. The form of the striæ alone decided it. Their broad blunt ends were as a rule toward the north-west, the surface being horizontal, a fact which, taken in connection with other observations made about the mouth of the Shannon, showed that a great ice stream had flowed westward along the valley of the Shannon, and had opened out fan-shaped as it plunged into the sea.

The Geology of Durness and Eriboll, with special Reference to the Highland Controversy, by B. N. Peach, F.R.S.E., and J. Horne, F.R.S.E., Geological Survey of Scotland.—With the permission of the Director-General of the Geological Survey, the authors gave an outline of the geological structure of the Durness-Eriboll region, illustrated by a series of horizontal sections. They showed that the Silurian strata of Durness are arranged in the form of a basin, bounded on the east side by powerful faults disconnecting them from the same series in Eriboll. The order of succession in the two areas is identical, from the basal quartzites to the horizon of the limestone group. On the west side of Loch Eriboll the basal quartzites rest unconformably on the Archæan gneiss, but on the eastern shore there is conclusive evidence of the repetition of various members of the Silurian series by a remarkable system of reversed faults, culminating in a great dislocation which has thrust the Archæan gneiss over the truncated edges of the quartzites, fucoid beds, serpulite grit, and basal limestone. Reference was made to the effects of these mechanical movements on the Silurian rocks, and to the developments of new planes of schistosity in the gneiss above the thrust-plane. At intervals small patches of the basal quartzites are met with throughout this mass of Archæan gneiss, which are abruptly truncated by great reversed faults; but in the district between Eriboll and Assynt the whole Silurian succession from the basal breccia to the lowest limestone occurs repeatedly above the first great thrust-plane, separated by wedges of highly-sheared gneiss. It was shown that the alteration produced by each successive displacement gradually becomes more pronounced as the observer passed eastwards across the area. The old north-west strike of the Archæan gneiss gave place to a new foliation running more or less parallel with the strike of the thrust-planes; the felspathic basal quartzites and the "pipe-rock" pass into quartz schists and mica schists, and the Silurian limestone is felted with the crushed Archæan gneiss. Reference was next made to the outcrop of the great thrust-plane extending from the Whitten Head coast far to the south, which ushers in a highly schistose series with a north-north-east and south-south-west strike. After describing the lithological characters and order of succession of the eastern schists, the authors stated that the new planes of foliation had been superinduced by the mechanical movements that took place between Lower Silurian and Old Red Sandstone time, and that along these new planes a re-arrangement and recrystallisation of mineral constituents took place, resulting in the production of crystalline schists. Applying the knowledge thus obtained from the study of the eastern schists to the undisturbed Archæan masses, they had found conclusive evidence of similar mechanical movements. Each plane of schistosity exhibits the parallel lineation like slickensides trending in the same direction over a vast area, while the minerals were oriented along these lines. From a consideration of these phenomena the authors inferred that regional metamorphism need not necessarily be confined to any particular period, and further that the planes of foliation or schistosity in those areas which had been subjected to regional metamorphism were evidently due to enormous mechanical movements which had induced molecular changes in crystalline and clastic rocks.

The Highland Controversy in British Geology: its Causes, Course, and Consequences, by Chas. Lapworth, LL.D., F.G.S., Professor of Geology and Physiography, Mason College, Birmingham.—The author gave a *résumé* of the views of the earlier geologists respecting the geological age and possible mode of formation of the Highland metamorphic rocks; and sketched, in brief, the rise and progress of the controversy between Sir Rod. Murchison and his followers on the one hand, and Prof. Nicol, of Aberdeen, on the other, till its temporary close in 1861, by the publication of the Highland Memoir of Murchison and Geikie. He then reviewed the reopening of the controversy by Dr. Hicks in 1878, and the work of the Archæan geologists, up to the date of publication of Dr. C. Callaway's paper in 1883, in which Nicol's view of the great physical break between the Palæozoic rocks and the Eastern or Upper Gneissic series was shown to be correct, but the so-called Eastern gneiss was provisionally erected into a new Archæan system, the Caledonian, having the Arnaboll gneiss as its lower member. The author next gave a summary of his own views as deduced from his personal study of the Durness Eriboll district in 1882 and 1883, and published in 1884, illustrating these by coloured maps and sections. He held that (exception being made of the local Torridon Sandstone) the only rock-formations in the Durness-Eriboll area are, as Nicol originally contended: (1) The Archæan or Hebridean gneiss; and (2) The Palæozoic quartzites, fucoid beds, and limestones. But the so-called upper gneiss or eastern metamorphic gneiss appears to be composed of elements derived from one or other of the foregoing. There is no conformable ascending succession from the Palæozoic rocks into this Eastern Metamorphic series. The line of contact is, generally speaking, a plane of dislocation, and where this is wanting the Palæozoic rocks rest unconformably upon one of the members of the eastern gneiss. The present physical relations of the eastern metamorphic series are the effect of lateral crust creep, by which the eastern metamorphic rocks have been forced over the Palæozoic rocks in grand overfaults to the west, often for many miles. This Eastern Metamorphic series is composed of two petrological members, the ***Arnaboll gneiss*** to the west, and the *Sutherland schists* and gneisses to the east, having between them a series of *variegated schists* possessing characters common to both. The Arnaboll gneiss is simply the easterly extension of the Hebridean of the west. The remaining gneisses and schists of the eastern metamorphic series are mainly composed of re-metamorphosed Hebridean, with included patches of igneous and Palæozoic material. The planes of schistosity which divide the layers of the Upper Gneissic series are not planes of bedding, but planes of dislocation. The dip and strike of these planes have been given to them since Silurian times by the agency of the great earth-movements. In some instances the original structures of the rocks are still recognisable; usually, however, they are wholly obliterated: the old minerals have disappeared as such, and new minerals have been developed. The Eastern Gneissic series has thus no pretension whatever to the title of a sedimentary rock-system. It is a petrological rock-massif, a metamorphic compound, composed of local elements of very different geological ages. In all their essentials these views appear to agree with the far more contended and minute results worked out independently, and published by Messrs. Peach and Horne in November 1884.

In the second part of his paper the author gave a summary of the work accomplished among the metamorphic rocks of the Alps and Eastern Germany by Heim and Lehmann; and described the several types of rock-metamorphism found in the Eriboll district, as worked out by himself. The Arnaboll (Hebridean gneiss) can be traced stage by stage from spots where it retains its original strike and petrological characters, to others where it acquires the normal strike and mineralogical features of the ordinary Sutherland schists. The old planes of schistosity become obliterated, and new ones are developed; the original crystals are crushed and spread out, and new secondary minerals, mica and quartz, are developed. The most intense mechanical metamorphism occurs along the grand dislocation (thrust) planes, where the gneisses and pegmatites resting on those planes are crushed, dragged, and ground out into a finely-laminated schist (*Mylonite*, Gr. *mylon*, a mill) composed of shattered fragments of the original crystals of the rock set in a cement of secondary quartz, the lamination being defined by minute inosculating lines (fluxion lines) of kaolin or chloritic material and secondary crystals of mica. Whatever rock rests immediately upon the thrust-plane, whether Archæan, igneous, or Palæozoic, &c., is similarly treated, the resulting mylonite varying in colour and composition according to the material from which it is formed. The variegated schists which form the transitional zones between the Arnaboll gneiss and Sutherland mica-schists are all essentially mylonites in origin and structure, and appear to have been formed along many dislocation planes, some of which still show between them patches of recognisable Archæan and Palæozoic rocks. These variegated schists (Phyllites or Mylonites) differ locally in composition according to the material from which they have been derived, and in petrological character according to the special physical accidents to which they have been subjected since their date of origin—forming frilled schists, veined schists, glazed schists, &c., &c. The more highly crystalline flaggy mica-schists, &c., which lie generally to the east of the zones of the variegated schists, appear to have been made out of similar materials to those of the variegated schists, but to have been formed under somewhat different conditions. They show the fluxion-structure of the mylonites; but the differential motion of the component particles seems to have been less, while the chemical change was much greater. In some of these crystalline schists (the augen-schists) the larger crystals of the original rock from which the schist was formed, are still individually recognisable, while the new matrix containing them is a secondary crystalline matrix of quartz and mica arranged in the fluxion-planes. While the *mylonites* may be described as microscopic pressure-breccias with fluxion-structure, in which the interstitial dusty, siliceous, and kaolinitic paste has only crystallised in part; the *augen-schists* are pressure-breccias, with fluxion-structure, in which the whole of the interstitial paste has crystallised out. The *mylonites* were formed along the thrust-planes, where the two superposed rock-systems moved over each other as solid masses; the *augen-schists* were probably formed in the more central parts of the moving system, where the all-surrounding weight and pressure forced the rock to yield somewhat like a plastic body. Between these augen-schists there appears to be every gradation, on the one hand to the mylonites, and on the other to the typical mica-schists composed of quartz and mica. Like the mylonites, the crystalline augenites and micalites present us with local differences in chemical composition (calcareous, hornblendic, quartzose, &c.), suggestive of Archæan, igneous, or Palæozoic origin. They also show similar structural varieties due to secondary physical changes (frilled, veined, glazed, &c.), as well as others due to the presence of special minerals (garnet, actinolite, &c., &c.).

On certain Diatomaceous Deposits (*Diatomite*) *from the Peat of Aberdeenshire*, by W. Ivison Macadam, F.C.S., F.S.C., &c., Lecturer on Chemistry, School of Medicine, Edinburgh.—The material was found below the peat in certain districts of Aberdeenshire, but principally in the basin in which lie Lochs Kinnord and Dawin. After removal of the surface peat-fuel, the lower and more highly mineral portion was cut in blocks and air-dried. The substance then consisted of almost pure Diatomacea bound together by the remains of Spragnum, Equisetacea, &c. Besides being found underlying peat the substance was also obtained on the shores of Loch Kinnord, and the more pure Diatoms were thickly distributed over the bottom of the deeper portions of the lake; these latter, however, from the want of the binding obtained from the marsh plants above mentioned could not be rendered readily available for market. An interesting point regarding these deposits was that whilst in Loch Kinnord an abundant supply of the Diatoms could be obtained, in the neighbouring Loch Dawin scarcely a single Diatom (recent or fossil) was found. This was probably due to the fact that whilst the feeding waters of Loch Kinnord flowed from hills consisting of a coarse and much disintegrated granite, and consequently contained a considerable portion of soluble silica, the Loch Dawin waters were obtained from hornblendic mountains, and held much less soluble silica in solution. The material was principally used for the manufacture of dynamite, and a considerable quantity had been forwarded to the works for this purpose. Unfortunately, however, dynamite had fallen to a great extent out of use, being replaced by the more powerful blasting gelatine, and thus what had at one time appeared as if it would prove an important local industry had entirely fallen away. Other uses, however, could be found for the material, such as the manufacture of ultramarine, for which, from the very small proportion of iron present, the diatomite has more especially to be recommended. As an absorbent it was of fully double the value of the ordinary German varieties of "kieselguhr."

On Some Recent Earthquakes on the Downham Coast, and their Probable Causes, by Prof. G. A. Lebour, M.A., F.G.S.—For the last two years frequent slight shocks, resembling those of earthquakes, and accompanied by rumbling noises, have been felt at Sunderland. Much discussion has arisen as to the cause of these, but that they are due to natural causes is now quite certain. Sunderland stands upon magnesium limestone, from 300 to 400 feet thick beneath the town; the rock is riddled with cavities of every size, some so small as to give a vesicular character to the stone, some large and forming true caverns. These cavities are partly due to the washing out of marly matter, partly to solution of the limestone. Every thousand gallons of Sunderland water contains one pound of stone; in this manner about forty cubic yards of magnesian limestone are yearly pumped up by the Water Company, and of course a much larger quantity is removed by natural channels. This action enlarges the cavities; the sides and roof fall in, thus accounting for the shock. The same explanation applies to the "breccia gashes" which are exposed along the shore. These are fissures filled with breccia. Quite recently similar shocks to those here referred to have been observed at Middlesborough. Pumping the brine from the salt deposits, 1000 to 1200 feet below the surface, may produce cavities into which the rock falls.

Some Examples of Pressure-Fluxion in Pennsylvania, by Prof. H. Carvill Lewis.—The three localities in Pennsylvania described in this paper lie in an area which had been especially studied by the author for some years back and had led him to conclusions similar to some of those recently announced as the result of studies in North-Western Scotland, which have justly attracted widespread attention. (1) a zone of ancient crystalline rocks extends across South-Eastern Pennsylvania, near Philadelphia, which is generally believed to underlie the lowest Cambrian strata and to be of Archæan age. This zone is about a mile wide where it crosses the Schuylkill River, south of Conshohocken, and it is from this point to Westchester, some twenty miles westward, that the present remarks especially apply. Although in many portions exhibiting a distinct gneissic lamination, the rocks of this zone are held by the author to be of purely eruptive origin, consisting of syenites, acid gabbros, trap granulites, and other igneous rocks, often highly metamorphosed. It is the outer peripheral portion of this zone to which attention is here directed. While the rocks are massive in the centre, this outer portion has been enormously compressed, folded, and faulted, with the result of producing a tough-banded, porphyritic *fluxion gneiss* identical with the "milonite" of Lapworth or the "sheared gneiss" of Peach and Horne. So perfect is the fluxion structure that the rock resembles a rhyolite. As in the "banded granulite" of Lehmann, elongated feldspar "eyes" lie in flowing streams of biolite grains and broken quartz, the streams often parting and again meeting around the porphyritic "eyes." Occasional crystalline eyes of hornblende remain, but most of it has been converted into biotite. A point of especial interest is that the feldspar of the eyes is quite colourless and free from inclusions, like the sanidine of recent lavas, while, on the other hand, the feldspars of the inner and massive portions of the zone, out of which this outer portion has been reformed by pressure fluxion, are full of inclusions and have the "dusty" appearance so common in ancient feldspars. The fresh-looking feldspar eyes are therefore believed to have been subsequently formed as a result of a *recrystallisation* of the old material under the influence of *pressure fluxion*. In similar manner the biotite has been made out of the old hornblende, garnets have been developed, and the quartz has been granulated and optically distorted by pressure. The influence of pressure is also seen in certain Cambrian strata in the immediate vicinity, where a sandstone containing cylindrical casts of *scolithus linearis*, apparently identical with the "pipe-rock" of North-Western Scotland, has, like it, been compressed to such a degree that the vertical casts are flattened out and elongated in the direction of lamination to several times their original length. In the same sandstone quartz pebbles have been pulled out and flattened, while sericite has been largely developed along the cleavage planes. The pressure can be shown to have been directed mainly from the south-east. (2) The second locality is in the midst of the Laurentian area of Buck's County, and is known as Van Artsdalen's Quarry. A mass of crystalline limestone is here mingled with an eruptive diorite in such manner as to show that it had actually flowed like an igneous rock, and had caught up inclusions. The results of extreme metamorphism are exhibited in the development in the limestone of graphite, wollastonite, and other minerals. The chemical changes and interchange of elements which might result from a loosening of molecular combinations under extreme pressure and their subsequent "regulation" into new compounds were discussed as among the phenomena of mechanical metamorphism. (3) As an American instance of the conversion of an intrusive diabase dyke into amphibolite schist, analogous to the case recently described by Teall, a long narrow belt of sphene-bearing amphibolite schist in the City of Philadelphia was adduced. This belt with distinctive mineralogical characters cuts across the metamorphic mica schists of the region unconformably, and is believed by the author to be a highly metamorphosed intrusive dyke of Lower Silurian age. The original augite or diallage has been completely converted into fibrous hornblende, and the influence of pressure is shown in the perfectly laminated character of the schist in the close foldings produced, and in the minute structure of the rock. Some interesting details of the latter having been photographed, diagrams constructed from these were exhibited. These showed that the rock was traversed by a parallel series of slips and crushings, and that about such lines of faulting and crushing there was a peculiar arrangement of the lines of hornblende crystals, not very unlike the arrangement of iron filings about the poles of a magnet, such as could not be satisfactorily explained by any theory of aqueous deposition, but pointed to a lamination by pressure.

SECTION D—BIOLOGY

On the Cause of the extreme Dissimilarity between the Faunas of the Red Sea and Mediterranean notwithstanding their recent connection, by Prof. Edward Hull, LL.D., F.R.S.—The faunas of the Mediterranean and of the Red Sea are so unlike that if the beds of the two seas were upraised, and their contents examined, naturalists would probably refer them to distinct geological periods. The dissimilarity is greater than was formerly supposed. In Woodward's "Manual of the Mollusca" it is stated that seventy-four species of mollusks are common to the two seas, but Prof. Issel, of Genoa, places the number at eighteen, or about 2 per cent. Equal differences exist if we compare other great groups of life; in fact, as Prof. Haeckel well observes, the fauna of the Red Sea is related to that of the Indian Ocean, the fauna of the Mediterranean to that of the Atlantic. This extreme dissimilarity would not surprise us if it were not for the proofs of recent connection between the two seas. Evidence of old sea margins, up to about 220 feet above the present sea-level, are frequently found along the Nile and in the valleys and plains of Philistria. As many of the marine forms found in these deposits still exist, the date of the submergence may be safely referred to that of the Pliocene; but it continued to a later period, and (in the author's opinion) it to some extent remained to the time of the Pharaohs. The existing fauna probably dates back to Eocene times, when the ocean spread widely over the area in question. In the Miocene period the main outlines of land and sea as we now find them were marked out, the deposits of this age being here small and local. Under the extremely different conditions existing in the two areas, the fauna during and after the Miocene period became differentiated. The connection re-established during and after the Pliocene period was insufficient to destroy these differences, although it allowed a mingling of forms to some extent. The maximum submergence was about 220 feet; but as the summit level between the two seas is about 50 feet, the depth of water would only be about 170 feet at the maximum. Only littoral and shallow-water forms would cross in the adult state; but many forms inhabiting deeper water in the adult state might have crossed when in the free-swimming larval state. When the land again rose, and the marine straits were finally effaced, the different physical conditions of the two seas would again come into effect. The difference of temperature is now very considerable, and probably was much greater during the Glacial period, especially if, as appears probable, the eastern or Levant basin of the Mediterranean were separated from the others; for into this would flow the cold waters of the Black Sea and of Central Europe, whilst the Red Sea would receive warm water, and be itself exposed to the rays of a tropical sun. It would be an interesting subject of inquiry—Which of these faunas most closely resembles that of the original stock?

On the Tay Whale (*Megaptera longimana*) *and other Whales recently obtained in the District*, by Prof. Struthers.—Prof. Struthers gave a description of the various parts of the anatomy of the whale. In addition to the Tay whale members of three other whales recently obtained in the district were exhibited for the purpose of comparison, and the analogy of its structure to that of other animals was specially referred to in order to show its identity with the mammal. Prof. Flower joined in the discussion which followed, and remarked that they now had an idea at least as to the origin of the whale: it carried its pedigree in every part of its body. It had been thought that the mammals that live upon land had been derived from progenitors that formerly lived in the sea, and that the mammals may have passed through an aquatic or marine stage before they took to land, but the observations of anatomy showed that this cannot have been the case. There was no doubt that the whale had been derived from a four-footed land mammal. All observations, for example, had shown that at some period of their life whales have a hairy covering, generally in the region of the mouth, that hairy covering being functionless and very often lost even before birth. In the same way whales at an early stage of their existence are furnished with a complete set of teeth, the rudiments of the teeth of the land mammal. The organ of smell, although in a rudimentary state and in some species almost entirely gone, also points to the origin of the whale.

Some Points in the Anatomy of Sowerby's Whale, by Prof. Turner.—Prof. Turner remarked that *Mesoplodon bidens*, or Sowerby's whale, of which he had dissected two specimens, was now for the first time dissected so that the viscera of this whale were seen by any anatomist, or that its tail and paddle, or fin, had been figured. The tail presents a very material difference from the customary tail in the cetacea in having the posterior border smooth instead of notched. Dr. Turner called attention in detail to the intestinal and limb structure of this species of whale, showing the affinity or resemblance of the cetacea to the reptilious and the amphibious, particularly in reference to the corpus. Prof. Flower said he was glad to find that Prof. Turner had found some intention for the muscles of the corpus. For all that they were very rudimentary as compared with the same muscles in other animals, and he thought that he might have to modify his views on this point as he had had to do in regard to many other things throughout life. Prof. Marsh, of Yale College, said the intermediary bone pointed out by Prof. Turner interested him much.

On the Cervical Vertebræ of the Greenland Right Whale, by Prof. Struthers.—The reduced condition of the upper and lower transverse processes was commented on, and the meaning of their different parts explained; also the completely fused condition of the bodies of the seven vertebræ. A nearly similar condition of the neck of the Pilot Whale (*Globicephalus melas*) was demonstrated, showing in the young condition the two body epiphyses on the rudimentary vertebræ. Other specimens illustrated the fibrous condition of the transverse processes in the Narwhal and Beluga.

On the Development of the Vertebræ of the Elephant, by Prof. Struthers.—The point was that in the anterior vertebræ the neural arches meet behind the body, covering it deeply, and shutting it entirely out from forming any part of the wall of the spinal canal.

On the Development of the Foot of the Horse, by Prof. Struthers.—Dr. Struthers called attention to the fact that the epiphysis of the rudimentary metacarpal and metatarsal bones is not at the upper or functional end, but at the reduced end or "button," from which only a slender ligament proceeded. This he considered a most interesting fact, one which completed the chain of evidence of the descent of the horse. There was a reason why the epiphyses should be there in the hipparion and previous forms from which the horse of the present day was descended. The development of the corresponding bones in man, the cetacea and various other mammals, was given in illustration.