intermediate between the Neocomian and Kimmeridge clay of the district. This being the case, there can be little doubt that a considerable mass of such Oolitic strata has been broken up by the eastern drift; and what is more interesting is that this very same action was going on at the time that the Greensand sea spread its numerous Brachiopoda over the Upware shore; then, as in the far later period, this Portlandian deposit furnished its fossil *Terebratula*, such as those from Upware, to mix with the reptiles from the Kimmeridge below and the yet recent shells and the bits and pebbles from all the northern coast-line.

EXPLANATION OF FIGURES (page 412).

- FIG. 1. *Terebratula rex*, Lankester, from "Drift" Gravel-pit, Thorpe, Suffolk, in the collection of Mr. Roper, Lowestoft.
 ,, 1a. Side view of same.
 ,, 2. *T. rex*, from Upware, in the collection of Mr. Earwaker, Merton College, Oxford.
 ,, 3. *T. rex*, Hermiere on the Cam, near Upware.
 ,, 4. *T. ovoides*, Sby. "Drift" Stow-Bardolph, Downham. Collected by C. B. Rose, Esq., and presented to the British Museum.
 (All natural size.)

V.—CATALOGUE OF THE MAMMALIAN FOSSILS WHICH HAVE BEEN HITHERTO DISCOVERED IN IRELAND.¹

By ROBERT H. SCOTT, M.A., F.R.S.

[NOTE.—In the June Number of the GEOLOGICAL MAGAZINE for the present year, page 253, we published an article by Prof. Harkness, F.R.S., "On the occurrence of Elephant-remains in Ireland." Having since had our attention directed to the sub-joined paper by Mr. Robert H. Scott, F.R.S., we have requested and obtained the author's permission to publish it in our Journal, as we believe it to be the only Catalogue of Irish Fossil Mammalia extant, and it well deserves to be more widely known.—EDIT. GEOL. MAG.]

INASMUCH as the subject of the Fossil, or rather Sub-Fossil Mammalia of Ireland, has been brought rather prominently before the notice of the Society during the past two sessions, I have considered that it might not be devoid of interest to our members, if I were to place on record the various genera and species of that class of which remains have been hitherto found in Ireland. Such a communication as this does not make any claim to originality, and I shall endeavour, as far as I can, to give my authority for every statement of a fact which will be embodied in this Catalogue. The chief sources from which the information has been derived are Dr. Scouler's papers, in our "Journal," and those by Dr. Ball and Sir W. Wilde, in the "Proceedings of the Royal Irish Academy."

The following list contains those of which notices remain on record:²

1. <i>Ursus arctos</i> .	3. <i>Ursus maritimus</i> .
2. — <i>spelæus</i> .	4. <i>Canis lupus</i> .

¹ Appendix to the Annual Report for 1864, read before the Geological Society of Dublin, February 10, 1864.

² For a list of British Fossil Mammalia, etc., see paper by H. Woodward, entitled "Man and the Mammoth; being an account of the animals found associated with early man in prehistoric times." GEOL. MAG., 1869, Vol. VI., p. 58.—EDIT.

5. <i>Elephas</i> , sp.	11. <i>Cervus elaphus</i> .
6. <i>Hippopotamus</i> .	12. <i>Megaceros Hibernicus</i> .
7. <i>Sus scrofa</i> ,	13. <i>Tarandus rangifer</i> .
8. <i>Bos frontosus</i> .	14. <i>Ovis</i> , sp.
9. <i>Bos longifrons</i> .	15. <i>Cetaceans</i> .
10. <i>Cervus alces</i> .	

In this Catalogue I do not attempt to place on record the circumstances under which the remains have been found, unless in a few instances. To the list which I have given some more might be added; but these I do not consider to deserve the title of fossils,—such are the Fallow Deer, with many instances of Cetacean remains. On this point I need only remind the members that a few years ago an Armadillo was discovered walking about in a field in the county of Meath, having been thrown out of a travelling menagerie, in an apparently dying condition. Another similar instance is to be found in the case of the skeleton of the Lion which was found in the county of Carlow. Fortunately, before the account of this addition to our Irish fossil Fauna was quite ready for publication, an old man turned up who remembered the fact of a dead Lion having been thrown out of a menagerie some sixty years before, which, after being skinned, was buried in the field.

Bears.—Three species of bears have been hitherto discovered in Ireland, and the progress of geological discovery has been more rapid in respect of this animal than of any other. In 1843, Dr. Scouler noticed that no Bears had been observed in Ireland, and in the year 1846 the discovery of no less than four skulls had been placed on record. There is no record of the existence of Bears in Ireland, as is remarked by Dr. Scouler in his paper on the animals which have disappeared from Ireland.¹ The oft-quoted statement of St. Donatus, who died in 840, is considered conclusive on this point:—

“Ursorum rabies nulla est ibi, sæva leonum
Semina nec unquam Scotica terra tulit,
Nulla venena nocent, nec serpens serpit in herbâ
Nec conquesta canit garrula rana lacu.”

The remaining evidence on the subject is entirely negative, and is derived from Giraldus Cambrensis and others. On the other hand, Sir W. Wilde² mentions that there is an Irish name for the animal in an old glossary in the Library of Trinity College, and Thompson mentions the existence of traditions of the animal.

In tracing the fossil Bears, I have derived much assistance from my friend, Dr. W. Frazer, one of our members, who has interested himself much in the matter.

Ursus arctos.—The first Bears' skulls were obtained by Mr. Underwood, who said that he found two in the county of Longford, in 1846. These were bought by A. W. Baker, Esq.

Dr. Ball was permitted to take casts of the two skulls, which he presented to the Royal Irish Academy in 1846;³ and at the same time he presented a cast of a third skull, which was in the possession

¹ “Journal of the Geological Society of Dublin,” vol. i., p. 228.

² “Proceedings of the Royal Irish Academy,” vol. vii., p. 193.

³ “Proceedings of the Royal Irish Academy,” vol. iv., p. 416.

of Mr. Cooke, of Parsonstown, and is now in the British Museum. It was found in deepening a river near Colonel Bernard's property, in the King's County. These casts are now at the Royal Dublin Society. These skulls Dr. Ball pronounced to be those of the brown Bear, *U. arctos*, and in this opinion he was confirmed by Professor Owen, to whom he submitted casts of the skulls.

Mr. Gray discovered the skull of a bear, as described in the accompanying letter :—

“Clonliffe Parade, January 24, 1863.

“MY DEAR DOCTOR,—The bear's head, to which you referred in your letter of the 10th instant, was found a little above Leinster Bridge, in the barony of Carberry, and county of Kildare. It was imbedded in peat or sand, about 4 feet below the surface, in a sort of valley or hollow, through which the River Boyne flowed; and if you refer to the fifth volume of the ‘Proceedings of the Royal Irish Academy,’ p. 53 of the Appendix, you will find a report of mine, describing a lot of articles found while engaged in the arterial drainage of some important rivers in Kildare, Meath, Westmeath, and the King's County. These are all in some degree descriptive of the locality; and if you are following up the subject, you may derive some ideas from the facts I have stated. The bear's head was got along with a great quantity of the bones and heads of the deer; and they were collected together in a position that would give the idea of their having been floated together, and deposited in an eddy or still bend of the river. There were a quantity of the bear's bones along with the head when it was found, but they were destroyed by the men who found them, *although they were not much decomposed*. Some of them were very short and strong—not such as you mentioned to me, but were, perhaps, nine inches in circumference, and about 15 inches in length. They were destroyed by the men having used them to knock the earth out of the barrows, etc., by striking them till broken.

“There was no marl in the neighbourhood. If you refer to page 35 of Appendix to vol. v. of the Royal Irish Academy's ‘Proceedings,’ before referred to, you will have a description of the locality. The bone dirk (No. 15) alluded to was found about half a mile or less below where the bear's head was got, and in the same river-course.

“I suppose you have seen the skull; it is in the Museum of the Academy, and I suspect about the most perfect of its class. Any other information I can afford you relative to such matters will afford me much pleasure; and I trust you will excuse my not having replied to your letter before this.—Yours faithfully,

“William Frazer, Esq., M.D.”

“RICHARD A. GRAY.

It was presented by him to the Royal Irish Academy, among the donations from the Board of Works, and is now at the Royal Dublin Society. It is figured by Sir W. Wilde.¹

In March, 1859, Mr. Brennan and Dr. Carte discovered some remains of *U. arctos*; among others, a mutilated cranium, in the cave at Dungarvan.² The other bones were—the left lower jaw, the atlas, two cervical, two dorsal, and two lumbar vertebræ, with several broken ribs.

About the year 1860, Mr. Going,³ of Violet Hill, Broadford,

¹ “Proceedings of the the Royal Irish Academy,” vol. v., App., 54, vii.

² “Journal of the Royal Dublin Society,” vol. ii., p. 451.

³ On applying to Mr. Going for further information on this subject, I received the following letter, which he has kindly permitted me to print :—

“Violet Hill, Broadford, June 20, 1864.

“SIR,—I beg to acknowledge the receipt of your letter of the 17th inst., and will feel happy at affording you all the information I can relative to the finding of the animal remains you allude to in this locality.

“Some years since, my men, in draining a small boggy hollow, found a quantity of bones under the bog, in the blue clay. The bones were evidently those of some animal *much* larger than any dog, being stronger in proportion to their length, and

county of Clare, discovered a skull, about twelve inches long, and of the shape of the skull of *U. arctos*.¹

Lastly, within the last year, Mr. W. H. Gregory, M.P., of Coole Park, near Gort, kindly offered to examine the caves in his park with Mr. Jukes, who has furnished me with the following account. About 100 yards from the mouth of the cave, which is in low ground, and full of water in wet weather, a crust of stalagmite was broken through. This was in some places eight or ten inches thick; underneath it was an irregular mass of fine brown clay, from two to four feet thick. After digging out a great quantity of this clay, without finding anything at all, the bones of a small animal were at length met with, and among them a small fragment of a jaw, with two teeth in it. This fragment was afterwards examined by Mr. Blyth, and the teeth said to be the hindmost false molar (or carnassial), and the next false, or premolar, of a young Bear (*Ursus arctos*), being the deciduary or milk teeth of the right side of the upper jaw.²

U. spelæus.—Portions of the skeleton of this species, probably of a female specimen, were discovered among the other bones found at Shandon, Dungarvan. The cranium was not discovered, but the bones which were found exhibited the marked characteristics of *U. spelæus*.

U. maritimus.—At the January meeting of the Society, Dr. Carte announced the discovery of a few bones of an animal belonging to this species at Lough Gur. The recollection of this paper is so fresh, that I need hardly remind you of it. The account will be found at p. 114, vol. x., of the "Journal." In this case, as in the foregoing, the cranium has not yet been found.

In Archdeacon Maunsell's well-known letter about the skeleton of

exactly similar, as far as I and some friends could judge, to the skeleton of a large bear. The skull was about twelve inches long, but the nose part was broken off, and very much resembled the *shape* of a Badger's skull, but about the *size* of a large Bear's. Most unfortunately, I regret to state, these bones were not preserved. The skull was kept for some time, but has been lost; but for which I should have much pleasure in sending it for your examination. Near the place where these bones were found, in a few days after, two large *tusks*, about eight or nine inches long each, were also turned up, with several teeth also, besides some bones and skulls of other animals, which were found in a bog, in a wood, when raising some large *black* oak trees, several feet under the surface. The latter skulls resemble the first alluded to, but were of smaller size. I regret very much now that I have not preserved them, with the exception of an Elk's head and antler, which I have heard stated is the largest found in this county, but not in the same place in which other remains were discovered. All those alluded to were clearly belonging to extinct animals.—I have the honour to remain, Sir, your obedient servant,

"R. H. Scott, Esq."

"W. QUIN GOING.

¹ Explanation to Sheet 133 of the Map of the "Geological Survey of Ireland," p. 34.

² With reference to this identification, I have to subjoin the following letter, received since from Mr. Jukes:—

"Dublin May 10, 1864.

"MY DEAR MR. SCOTT,—I took over to London the other day the teeth which were found in Coole Park, and which Mr. Blyth informed me were those of a young brown Bear, and asked Professor Huxley to give me an opinion upon them. He examined them, and said they belonged to a young pig. So this case of the occurrence of *Ursus arctos* in Ireland fails.—Yours very truly,

"J. B. JUKES."

the *Megaceros* at the Royal Dublin Society's Museum, printed in Dr. Carte's pamphlet, he mentions the discovery of a head of a large dog, at least of a carnivorous animal, which was found with the Deer at Rath-cannon, county of Limerick. It has been supposed by some to have been a Bear; but Archdeacon Maunsell would hardly have called it a Dog, if it did not closely resemble a Dog's skull.

Canis lupus.—The remains of Wolves and Dogs can hardly be distinguished one from the other. There are several skulls of a canine type which have been found in Ireland; some of them are said to be those of Wolves. Several of those specimens were obtained from Dunshaughlin.

The date of the extinction of Wolves is well known. In 1641, they were extremely troublesome. In 1652, a council order of Cromwell's government was made at Kilkenny, which prohibited the export of Wolf-dogs; and the reward for a bitch Wolf was £6; for a dog, £5. Smith, in his "History of Kerry," says the last was killed there in 1710. Mr. Hardiman, the editor of O'Flahertie's "Description of Iar-Connaught," pp. 10 and 180, gives some information on the subject, and says that the date of the death of the last Wolf in that district was 1700, as far as he could ascertain.

Elephas primigenius.—In the year 1715,¹ four teeth of an Elephant were found by Mr. Francis Nevil, at Maghery, eight miles from Bel-turbet, in sinking for the foundation of a mill. The finder did not know to what animal the teeth belonged, but suspected them to be Elephants' teeth; and this opinion was placed beyond a doubt by Dr. Thomas Molyneux, in an interesting letter, which follows the original communication.

In the year 1859,² Mr. E. Brenan, of Dungarvan, discovered a considerable portion of the skeleton of an Elephant in the cave at Shandon, near that town. The bones were associated with those of Bears and numerous other mammals.

In addition to these remains, Smith, in his "History of Waterford," p. 58, mentions the discovery of the rib of an Elephant within a mile of Whitechurch, not far from Dungarvan. He gives a figure of the rib, on a reduced scale, and it appears to resemble the rib of a Whale. It is quoted by Professor Oldham, in a paper read before the Geological Society of Dublin, on the 12th of June, 1844,³ as the rib of a Whale, without any reason being assigned for its being so called.

Hippopotamus.—When the Ordnance Survey was in progress in the county of Antrim, in the vicinity of Carrickfergus a tusk of a Hippopotamus was found by a son of Mr. P. Doran, as will be seen from the accompanying letter, which I have received from my friend, Dr. David Moore, the Curator of the Glasnevin Botanical Gardens:—

"Glasnevin, February 5, 1864.

"MY DEAR SIR,—I have a clear recollection of the circumstance you mention about the tooth being found near Carrickfergus. Mr. Jukes applied to me some time ago to furnish him with all the information I could on the subject, which I did. The

¹ Boate, "Natural History of Ireland," p. 128. See also Phil. Trans. vol. xix.

² "Journal of the Royal Dublin Society," vol. ii., p. 251.

³ "Journal of the Geological Society of Dublin," vol. iii., p. 70.

occurrence happened as follows:—In 1837, our office was in the Infantry Barracks, at Belfast. I had attached to my party several assistants, one of whom was the son of Mr. Patrick Doran, the mineral collector, whom I sent to Carrickfergus to collect plants, birds, fossils, etc. In his peregrinations he picked up the tooth in question, on the side of a stream, about a mile or less north-west of the town, on the rising ground towards the mountain. He described it to me as having been partly sticking out from a bed of gravel. I went to see the place afterwards, and, unless the locality be greatly altered since, would easily find it again. I gave the specimen (as was my duty) to General Portlock, who was then the commanding officer of the Geological and Natural History Departments.—Faithfully yours,

“R. H. Scott, Esq.”

“D. MOORE.”

Sus.—A great number of Pigs' skulls have been discovered, especially in Lough Gur. These all belong to the old Irish long-faced variety, which is now fast disappearing. Many of them show the mark of the pole-axe on the forehead.

Bovidæ.—As regards the bovine animals, it has long been known that there are in Ireland two well-marked species of Oxen, whose remains are found fossil.

The gigantic species which is found in England, *Bos primigenius*, does not occur here, or at least has not been as yet discovered. The two species which are found, and of which specimens were presented by the Royal Irish Academy to the Royal Dublin Society, are the *Bos frontosus* of Nilsson, and the smaller species, *Bos longifrons*. Several of the skulls exhibit the mark of the pole-axe.

In a recent communication made to the Royal Irish Academy,¹ Mr. Blyth stated that the skulls which he found here were exactly similar to those found at Uriconium.

Cervidæ. *Cervus alces*.—A horn of the true Elk is said by Thompson to have been found, in the county of Tyrone, by a relative of his own. It was dug out of a bog near Stewartstown, and was presented to the Natural History Society of Belfast. Mr. Thompson mentioned the discovery in the “Proceedings of the Zoological Society of London” for 1837, and this notice was copied into his “Natural History of Ireland.”²

Cervus megaceros.—The instances of the discovery of this animal

¹ “Proceedings of the Royal Irish Academy,” vol. viii, p. 472.

² With reference to this, Dr. Carte has received the following letters from Mr. Robert Patterson, of Belfast, which he has permitted me to print:—

“Belfast, February 10, 1864.

“MY DEAR SIR,—As my friend, Mr. Hyndman, knew better than myself about the elk's horn in the Museum, I sent him your letter, and enclose his reply.

“Dr. Carte.”

“Yours very sincerely, ROBERT PATTERSON.

“February 9, 1864.

“MY DEAR SIR,—I have examined the elk's horn in the Museum, and I think the freshness of it, and the perfection of the points or tangs, forbid the supposition that it could ever have remained any lengthened time in the bog. Besides the point upon it, mentioned by Thompson, there is a round hole bored through the broad plate of the horn, showing that at some period it had been put up as an ornament in some person's hall. It must have got into its position in the bog by some accident.

“Robert Patterson, Esq.”

“Yours very truly, GEORGE C. HYNDMAN.

This opinion of Mr. Hyndman has derived additional confirmation from a communication which I have received from a friend of mine, Mr. Bernard R. Ross, F.R.G.S., of the Hudson's Bay Company's Service, who, on examining the horn, pronounced it to be a North American specimen, and of no great antiquity.

are so numerous, that I shall only give a few cases of their being found in juxtaposition with bones of other animals and with other articles.

It is, however, necessary to examine evidence of this nature with great care before receiving it. In the course of a discussion which took place before this Society on the 11th December, 1861,¹ some facts of interest were elicited. Dr. Petrie said that he had in his possession an iron sword which had been found, with the bones of a *Megaceros*, in the county of Meath; and Mr. Baily referred to the discovery of remains of the *Megaceros* which were found with spear-heads and pottery in a lake, in the canton of Berne, in Switzerland, as mentioned by Professor Morlot. The discovery of jet rings with the specimen in the Museum of the Royal Dublin Society, as noticed by Archdeacon Maunsell, was also alluded to. Two quotations from the "Book of Lismore" have also been recently brought under our notice, in which the chase of a large deer, supposed to be the *Megaceros*, is described. One of these was read on the evening to which we are referring, and the other in the course of Dr. Carte's paper on Lough Gur, which appears in this volume of the "Journal."

In a paper by Mr. H. Denny, of Leeds,² "On the Claims of the Gigantic Irish Deer to be considered as contemporary with Man," there is a long discussion on this subject, from which I extract the following statements, which I have not verified personally:—The leg of a *Megaceros*, with a portion of the tendons, skin, and hair on it, was found in the county of Wexford, on the estate of H. Grogan Morgan, Esq., at Johnstown Castle. This specimen was sent to the Royal Dublin Society, and was exhibited by Mr. Peall, Professor of Veterinary Surgery, at his lectures.³

A very scarce book—a "History of Ireland," which is said to be by Peppard, published in the seventeenth century—contains a statement to the effect, that the ancient Irish lived on the flesh of a great black Deer; and similar information is said to have been obtained by the late Sir W. Betham from some brass or bronze tablets containing an inscription. This fact was mentioned by Mr. Glennon, of Suffolk-street, who with Mr. Richardson, carried on a long discussion on this subject in 1846, in the "Zoologist," and elsewhere. Several instances of the finding of bones of the *Megaceros* in company with other remains, are given by Mr. Denny, to whose paper I must refer you. In addition to the facts and statements just quoted, there is the evidence which may be derived from the existence of outs, &c., on antlers and bones of the giant deer, which was discussed at considerable length by Mr. Jukes, and by the members who were present when his paper was read, in December last.⁴

It will be seen from what I have mentioned, that the evidence on

¹ "Journal of the Geological Society of Dublin," vol. ix., p. 339.

² "Proceedings of the Geological and Polytechnic Society of the West Riding of Yorkshire," vol. iii., p. 400.

³ Unfortunately, this specimen appears to have been mislaid, and cannot now be found.

⁴ Journal Geol. Soc. Dublin, vol. x. p. 127.

this subject is in an unsatisfactory state: and although it is certain that the date of the extinction of the *Megaceros* in Ireland is, geologically speaking, very recent, yet it is a matter of opinion as to whether man was or was not the agent of its extermination.

Cervus elaphus.—The fossil Red Deer is as abundant as, and even more so than, the preceding species. Some of the antlers found are very magnificent. One obtained from Ballinderry Lake, county of Westmeath, presented to this Society by Mr. Hamilton, in 1843, had nineteen points. A hundred years ago they were still very abundant in Erris and in Kerry. In the ninth century, Giraldus speaks of them as very fat, and therefore unable to escape from their foes; and O'Flahertie, in his "Description of West Connaught," written in 1684, mentions them, p. 121. They are generally known under the name of Marsh Deer, and Professor Haughton is of opinion that they are a variety of the Red Deer.

Cervus Dama.—Among the bones presented by the Royal Irish Academy to the Royal Dublin Society, there is a fragment of an antler of a Fallow Deer, described as an antler of a young Red Deer in the "Catalogue of Unmanufactured Remains." This is evidently not a fossil, as the date of the introduction of the Fallow Deer into the Continent of Europe is known. Thompson mentions the discovery of a Fallow Deer in a bog in the county of Antrim. The specimen was in his possession.

A skeleton of a Fallow Deer, with a silver collar round its neck, was found at the same time as Mr. Cook's Bear's skull, before referred to. It had belonged to some member of Lord Rosse's family.

Tarandus rangifer.—The history of all the specimens of this animal which have been discovered in Ireland was read before the Society in May, 1863, by Dr. Carte, and is, printed in vol. x. of the "Journal," p. 103.

Ovis.—In the collection of Mammalian remains at the Royal Dublin Society, which have been deposited there by the Royal Irish Academy, there are several skulls of Sheep, and a few Goats' skulls. Of the Sheep there are two well marked types—one possessing several horns, like the polycerate Sheep, at present existing in Iceland, and the other identical with the horned Sheep of the Highlands of Scotland, according to the notice published by Dr. Blyth, and before referred to. The same authority considers the Goat's skulls to be very recent.

Cetaceans.—Professor Scouler found the rib of a Whale in the marl beds of Wexford, as mentioned in his Presidential Address for 1844.¹ In addition to this, remains of the smaller Cetaceans are not uncommon in localities near the sea-side. There is a vertebra of a small Whale, or perhaps of a Porpoise, among the fossil bones in the Royal Irish Academy's collection. On this subject I may observe that a shoal of Ca'ing Whales was driven ashore some years ago on the sands to the west of Horn Head; the skeletons were buried in the sands.

¹ Journal Geol. Soc. Dublin, vol. iii. p. 18.

VI.—REPLY TO M. DELAUNAY'S OBJECTIONS TO THE LATE MR. HOPKINS' METHOD OF DETERMINING THE THICKNESS OF THE EARTH'S CRUST, BY THE PRECESSION AND NUTATION OF THE EARTH'S AXIS. By Archdeacon PRATT, M.A., F.R.S., ETC.

To the Editor of the GEOLOGICAL MAGAZINE.¹

SIR,—Having lately read the translation of a paper by M. Delaunay in your MAGAZINE of November, 1868, Vol. V., p. 507, and your commendatory notice of that gentleman's views regarding the late Mr. Hopkins' method of estimating the thickness of the earth's crust by Precession and Nutation, I beg to send you a paper in which I have endeavoured to vindicate that method and to point out where M. Delaunay appears to have mistaken it. Mr. Hopkins was no average mathematical physicist, and was not likely to have advanced a theory to be so easily refuted, as M. Delaunay's paper would impress readers not well versed in mathematical physics.—I am, etc.,

MURREE, HIMALAYAS.

May 29, 1870.

JOHN H. PRATT.

It is only two days ago that I saw for the first time M. Delaunay's strictures¹ upon the late Mr. Hopkins' method of ascertaining the least thickness of the Earth's Crust by means of the phenomena of Precession and Nutation, although I had previously seen a notice that such strictures had been laid before the French Academy. Having now that gentleman's paper before me, I write to endeavour to convince your readers that the point of Mr. Hopkins' reasoning has been altogether missed, and that his method stands altogether unimpaired by these strictures.

2. I am ready to allow, and so would Mr. Hopkins have allowed, that if the crust of the earth revolved round a steady axis, always parallel to itself in space, and if at some particular epoch a difference existed between the rate of movement of the crust and of the fluid within it, the resulting friction would gradually destroy this difference and bring about a conformity in the motion of both parts. I will even go further, and allow that the effect of the internal friction and viscosity of the fluid may be such that the resulting rotary motion may be the same as that which the whole mass would have had at the epoch if it had suddenly become one solid body and thereby suddenly retarded the rotation. This, before proceeding, I will illustrate by an example for the use of your mathematical readers.

3. Suppose a spherical shell or crust of mass C to have within it a solid spherical nucleus, of radius b and mass N, fitting it exactly; and the crust to receive an angular velocity of rotation around an axis fixed in the crust, the nucleus at that moment having no angular velocity; but suppose that a slight force of friction between the

¹ We gladly publish Archdeacon Pratt's reply to M. Delaunay, which appears, by some error on the part of the author, to have been inadvertently sent, in the first instance, to the *Philosophical Magazine*, in which it appeared in *July* last.—EDIT. GEOL. MAG.

² Translated in the GEOLOGICAL MAGAZINE, November, 1868, Vol. V., p. 507.

surfaces gradually generates a rotary motion in the nucleus; and suppose this force to vary as the difference between the angular velocities of the crust and nucleus—that is, of the surfaces in contact. Let ω and ω' be the angular velocities at the time t , k and k' the radii of gyration of the two bodies, $F(\omega - \omega')$ the force at the equator of the nucleus which represents the friction between it and the crust. Then the equations of motion are

$$\frac{d\omega}{dt} = -\frac{Fb}{Ck^2}(\omega - \omega'), \quad \frac{d\omega'}{dt} = \frac{Fb}{Nk'^2}(\omega - \omega') \quad . . . \quad (1)$$

Suppose also that β would have been the angular velocity, when the primitive impulse was given, on the hypothesis of the crust and nucleus being rigidly connected so as to be one mass. Then

$$\beta(Ck^2 + Nk'^2) = \alpha Ck^2 \quad . . . \quad (2)$$

Subtracting the second of equations (1) from the first, putting

$$Fb\left(\frac{1}{Ck^2} + \frac{1}{Nk'^2}\right) = c, \quad . . . \quad (3)$$

and integrating, we have

$$\omega - \omega' = \text{const.} \times e^{-ct}.$$

When $t=0$, $\omega = \alpha$ and $\omega' = 0$;

$$\therefore \omega - \omega' = \alpha e^{-ct}.$$

Hence, by the first of equations (1),

$$\frac{d\omega}{dt} = -\frac{Fb\alpha}{Ck^2}e^{-ct} = -\frac{Nk'^2c\alpha}{Ck^2 + Nk'^2}e^{-ct}, \text{ by (3);}$$

$$\therefore \omega = \alpha - \frac{Nk'^2}{Ck^2 + Nk'^2}\alpha(1 - e^{-ct});$$

and also

$$= \beta\left(1 + \frac{Nk'^2}{Ck^2}e^{-ct}\right), \text{ by (2).}$$

The first of these expressions shows that the angular velocity of the crust begins with α ; and when ct becomes very large indeed, it is reduced to β . Hence the effect of the constant friction of the nucleus against the inner surface of the crust is *at last* to reduce the velocity of the crust to what it would have been at first if the crust and nucleus had been one solid mass.

We may conclude perhaps that the same effect would be produced, though in a much longer time, if the interior were not a solid sphere, but a fluid mass.

The above reasoning shows that if the disturbing force producing precession and nutation did not exist, and the interior of the earth were fluid (whatever the thickness of the crust), it may be fairly assumed that the motion of rotation of the crust would *now*, the earth having existed so many ages, be exactly what it would have been had the earth been one solid mass, all difference of motion having been long ago annihilated by the internal friction and viscosity.

4. But the disturbing force producing precession and nutation does exist. It consists of two parts, one constant and the other variable and periodical. The constant part is that which produces the steady precession of the axis (and which I call for convenience the precessional force); the other produces the nutation. I will consider the precession first. Suppose now, for the sake of argument, that at the present moment, as M. Delaunay imagines, the crust and the fluid are revolving precisely as one mass, all previous differences of motion, even under the action of the disturbing force which produces precession and nutation, having been annihilated by friction and viscosity. I ask, what will be the action of the precessional force from this moment? It tends to draw the pole of the crust towards the pole of the ecliptic: and this tendency, as mathematical physicists well understand, combined with the rotary motion of the crust, produces this singular result, viz., the pole does not move towards the pole of the ecliptic, but shifts in a direction at *right angles* to the line joining the poles towards the west; so that the inclination of the axis to the ecliptic remains constant, but the axis shifts towards the west. The space through which it shifts in an infinitesimal portion of time varies as the length of the time and the force directly, and as the inertia of the mass to be moved inversely. The inertia of the mass depends upon the thickness of the crust only; for the friction of the fluid against the inner surface of the crust (which might, as I have shown, in the course of years produce a sensible effect) cannot do so during the infinitesimal portion of time I am considering before the precession is actually produced. The precessional force has its full effect in producing the precession of the solid crust, the fluid not having time to diminish that effect before the axis has assumed a new position; and in this new position of the axis the precessional force is precisely the same in amount as before, to go on causing the precession as before. The precessional force, is in fact, ever alive and active, and shows this in incessantly producing the effect I have described; and the precession goes on steadily, the amount of it depending upon the mass of the crust thus moved, which the fluid has not time to retard or lessen. M. Delaunay says that "the additional motion due to the above-mentioned cause [the disturbing forces which give rise to precession and nutation] is of such slowness, that the fluid mass which constitutes the interior of the globe must follow along with the crust which confines it, exactly as if the whole formed one solid mass throughout." In reply to this I say that it is not the slowness of the motion, but the want of solid connexion between the crust and the fluid in contact with it which affects the problem. The motion, whatever its amount, is incessantly being generated by the disturbing force; and owing to this want of solid connexion, the friction of the fluid has not time during the successive moments during which the precession is generated, to stop or even sensibly to check it.

It will thus be seen that at every instant the precessional force proceeding from the action of the sun and moon on the protuberant part of the earth's mass will, if the earth be a solid mass, have to

move the whole mass; and if the earth have a solid crust only, with a fluid interior, the force will have to move only the crust, against the evanescent resistance of the fluid within during so short a space of time as it takes to produce precession. The resulting precessional motion will be different in the two cases; and therefore the actual amount of the precession which the earth's axis has (and which is a matter of observation) is a good test of the solidity or fluidity of the interior. This is Mr. Hopkins's method.

The force producing nutation is much smaller, even at its maximum, than the precessional force. Its effect, however, is precisely the same in this respect—that it depends upon the mass of the solid crust, and in no respect upon the friction of the fluid within it, which has not time to influence the nutation before the nutation is actually produced.

5. I do not here undertake to go into Mr. Hopkins's numerical calculations; I simply vindicate his method. I do not here consider what modification the elasticity of the solid material of the earth may have upon his numerical results. I conceive that it would have *no* effect, if the disturbing force were constant and there were no nutation. For under the dragging influence (if I may so call it) of the constant precessional force, the solid material would be under a steady strain, and would communicate the effect of the force, continuously acting, from particle to particle of the solid part as if it were really rigid; and the resulting precessional motion would be greater or less as the mass of the solid part may be smaller or larger—that is, the solid crust thinner or thicker. But as the disturbing force is not constant, but variable, and there is constantly nutation of the axis as well as precession, the action above described will be somewhat modified; and the elasticity of the solid material may be expected to have some influence on the result. This influence, however, will be minute, as the part of the disturbing force which is variable and produces nutation is very much smaller, even at its maximum, than the precessional force. The consideration of this matter, however, has no bearing upon the validity or not of Mr. Hopkins's method, but simply upon the numerical value of his final result, not upon the question of the fluidity or solidity of the earth's mass.

6. It will appear then, I, think to your readers that the strictures of M. Delaunay upon this method, which the genius of Mr. Hopkins devised, betray an oversight of the real point upon which the success of his method depends, and that this method stands unimpaired.

NOTICES OF MEMOIRS.

I.—ON THE DISCOVERY OF A FOSSIL SNAKE, *PYTHON EUBOICUS*.
Roemer, in the Tertiary Calcareous Slates of the Brown-coal formation of Kumi, in the Island of Euboea. By HERR FERD. ROEMER, of Breslau.

[Abdruck a. d. Zeitschr. d. Deutschen geologischen Gesellschaft, Jahrg. 1870.]

FOSSIL snakes are exceedingly rare remains. Prof. Owen has described four species of *Palæophis* and two species of