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John Hopkinson, Esq., of 8 Lawn Road, Haverstock Hill, N.; Samuel John Sanders, Esq., M.A., Vice-Master of the Beds. Middle-Class Public School; and Jabez Church, Esq., C.E., of 17 B Great George Street, Westminster, S.W., and Chelmsford, Essex, were elected Fellows of the Society.

The following communications were read:—

1. *On the IRON-ORES associated with the BASALTS of the NORTH-EAST of IRELAND.* By RALPH TATE, Esq., Assoc. Linn. Soc., F.G.S., and JOHN SINCLAIR HOLDEN, M.D., F.G.S.

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THE recent development of a new branch of mining industry in the north of Ireland has given us ample facilities for ascertaining the

nature and geognostic relations of the iron-ores associated with the basalts, and the present seems a fitting occasion to submit to the Geological Society the results of our observations.

The occurrence of ferruginous ochres in the midst of the basalt of the Giant's Causeway was pointed out at an early period by the Rev. Dr. Hamilton*, and has been noticed by subsequent writers on the geology of the County Antrim. Dr. Hamilton, in his section of the Pleaskin, represents "a thin course of iron-ore amid a bed of ochre;" and it is to beds of this character that we would now direct attention; for beyond the mere record of the occurrence of an iron band in the basalt of the Giant's Causeway, no further account of this phenomenon has been brought before the notice of geologists.

The railway-cutting at Ballypalidy, near Templepatrick, exposed an extensive ochreous mass, the working of which was commenced by Dr. Ritchie, of Belfast, in 1861; but within the last three years new and richer deposits have been discovered and worked in other parts of the county. A list of the localities where operations are now carried on will be found appended. Shortly after the discovery of the ferruginous beds at Ballypalidy, our attention was directed to the nature of the ore there; and in the spring of 1868 one of us communicated to the Belfast Naturalists' Field Club an abstract of this paper in part, which is published in that Society's Proceedings for that year.

We may be allowed to state that the examination of these iron-ores, the subject of the present communication, has been undertaken solely in the interest of science. And we would record our obligations to the Earl of Antrim, Dr. Ritchie, and Mr. T. Fisher for permission to inspect the mines respectively worked by them, and for statistics of produce relating to the same, also to Dr. Apjohn and Professor Hodges for analyses of basalt and iron-ores.

II. PETROLOGY OF THE IRON-ORES AND ASSOCIATED ROCKS.

As regards the origin of their present condition, the iron-ores may be divided into two groups; to the one belongs the ore of Ballypalidy, whilst all the others known to us are included in the second group. The former is of sedimentary origin, but the latter are the direct products of metamorphic agencies.

As a remarkable similarity is exhibited by all the sections of the iron-ores of the second group and their associated rock-masses, it will be unnecessary to describe each of them; we select, therefore, for illustration the following, which are the most instructive of the series.

1. *Section on Slievananee.*—On the south slope of Slievananee mountain, situated 6 miles from Cushendall, on the road to Ballymena, a rich mine of iron-ore was opened three years ago beneath the basalt, at an elevation of 1095 feet above the sea, and 687 feet vertically below the summit of the mountain. The present face of the workings presents a horizontal section of nearly half a mile; the

* Natural History of the Basaltes and its attendant Fossils in the Northern Counties of Ireland, 1790.

iron band is seen gently undulating, and is traceable for a further distance of a mile in both an easterly and westerly direction. The "mineral" is mined by approximately level drifts, running N. 40° E. and at right angles to the face of the workings; many of the levels have reached to a distance of two hundred yards.

The following section is in descending order, numbered from above:—

1. *Hard, compact, columnar basalt.* Where exposed to weathering influences, it is decomposed at the lower surface for a foot or so, within which there is an argillaceous mineral, probably a magnesian clay, termed by the miners "rock-grease."
2. *Pisolitic iron-ore.* This band consists of a dense red ochreous paste, with included spheroids, composed chiefly of a mixture of magnetite and red hæmatite. In the upper part of the band the spheroids are occasionally as large as hazel nuts, but more frequently of the size of peas, and densely crowded. The size and frequency of the nodules diminish downwards; Thickness 2 ft.—2 ft. 6 in. and the ore passes into
3. *Indurated ferruginous ochre,* of a reddish-yellow colour, breaking up into irregular lumps. Thickness 4 ft. It merges insensibly into the underlying band of
4. *Lithomarge.* A variegated rock, with a predominating blue colour and greasy feel, breaking up into small sub-spheroidal blocks. The whole mass might readily be mistaken from a distance for some of the variegated marls of the Keuper series Thickness 25 ft.
5. The lithomarge graduates downwards into a basalt exhibiting a concretionary structure, the outer coats not distinguishable from the lithomarge, while the kernel is a compact basalt.

Fig. 1.—Section at Belumford.

2. Section at Belumford, north-west extremity of Island Mage:—

1. *Columnar basalt,* with two or three inches of decomposed rock below.
2. *Pisolitic Iron-ore.* The upper two inches with little or no ochreous matrix: the spheroids large, and now and then a thin lamina of the ore. The ochre increases in quantity with the increase of depth, and the iron-ore merges into 'bole' Thickness 2 ft. 6 in.

3. *Bole*—an indurated red ferruginous ochre, less compact than that of Slievananee, Thickness 2 ft. passing into and alternating with
4. *Yellow Ochre*, Thickness 3 ft. which graduates into
5. *Blue Lithomarge*. Base not seen, but thickness proved to 29 ft. 6 in.

The several masses in the above section, as, indeed, in others, exhibit a pseudo-stratified arrangement, here dipping at an angle of 34°, E. 50° N. magnetic. The whole mass has been bored to a depth of 45 feet, which gives a minimum thickness for the iron ore, ochres, and lithomarge of 37½ feet.

3. *Enumeration of localities*.—Passing east from Slievananee, the iron-beds are worked from the face of the basaltic escarpment overhanging Milltown, Red Bay, at the entrance to Glenariff Glen; the beds dip west about 5°, and are about 200 feet above the upper limit of the White Limestone. Further to the east, the iron-band has been traced to near Garron Point.

Two miles to the west of Carnlough, the ferruginous series is seen at a height of 600 feet above the sea-level, dipping at an angle of about 40° east (magnetic). The matrix of the pisolitic ore, 22 inches in thickness, is of a bright vermilion-red colour, becoming browner as it passes downward; it then passes into a friable yellowish ochre, four and a half feet thick, which, in its turn, graduates into a blue lithomarge, 35 feet thick. Overlying the pisolitic ore is a semiprismatic basalt, the columns of which are perpendicular, and consequently include, with the underlying strata, an angle of 50°.

Other outcrops are worked at Ballyvaddy and Tully, near Glenarm, and at Anteville, Kilwaughter (3 mines), and Shane's Hill (2 mines), near Larne.

4. *Deductions from the several sections*.—We deduce from the foregoing sections the gradual passage of the underlying basalt into a variegated lithomarge of an average thickness of 30 feet, graduating insensibly into the overlying red or yellow ochre or bole, 5 to 6 feet thick, which passes into, and is surmounted by, a pisolitic iron-ore of an average thickness of two feet. The spheroids of iron-ore increase in number and size towards the upper part, and not unfrequently constitute that portion of the bed. The line of junction between the iron-band and the overlying basalt (which is usually more or less columnar), is well defined, and in a few instances exhibits decided unconformability.

Though a band of iron-ore can be traced with some certainty over a considerable area, yet it is by no means proved that the ore in the various sections, many of which are several miles distant from each other, represents portions of one sheet extending uniformly throughout the basalt. To determine this point will require a laborious survey of the country, chiefly because of the numerous faults—a task too gigantic for us to perform. Still we are justified, from the identity of the phenomena in the many sections examined, in assuming that in the midst of the basaltic rocks there is a continuous band of iron-ore.

Only in two instances have we been able to refer the iron-band

to its position relatively to that of the underlying White Limestone—which, by the way, is of varying thickness, and that often within very limited distances. At Red Bay the iron-ore is about 200 feet above the upper line of the White Limestone, whilst at Galboly, two miles to the east, in the direction in which the White Limestone thickens, it is about 300 feet vertically above that formation.

III. ORIGIN OF THE PISOLITIC IRON-ORE.

1. *Suggested Theories.*—Four theories may be suggested to account for the origin of the iron-ore; these are:—

(1) *Sedimentary theory*, which implies a derivative origin, but is at variance with the petrological features—the distribution of the mineral particles has evidently been regulated by some other force than that of gravity. Mr. Du Noyer, in a paper on the Geology of Island Magee, read before the Natural-History and Philosophical Society of Belfast, November 25, 1868, endeavoured to demonstrate that the iron-ore in the basalt of Island Magee was entirely due to the action of water, “that it was as true an aqueous conglomerate as if it had been found in the heart of the Old Red Sandstone.” From this opinion we most emphatically dissent, though at the same time we fully concur with him when he assigns such an origin to the iron beds at Ballypalidy.

(2) *Theory of Deposition*, implying either a precipitation of the ferruginous material from chemical solution, or segregation by organic agency. We believe that the state of combination of the oxides of iron, the intimate structure of the spheroids, and the petrology necessitate some other explanation.

(3) *Igneous theory*, implying production by direct volcanic action. Though specular iron is enumerated among the minerals emitted from active volcanoes, and magnetite and iron pyrites are accessory constituents of several of the basaltic strata, yet such an origin does not meet the requirements of the case in point. The distribution of the spheroids of pisolitic ore demands either a shower of the ferrous nodules over a large area, the smaller ones falling before the larger, or a flow of volcanic mud with suspended spheroids, the smaller sinking first in the mass—both assumptions being highly improbable.

(4) *Metamorphic theory.*—It is only by metamorphism that all the phenomena connected with the pisolitic ore can be interpreted. By metamorphism we understand something more than the effects of heat, and employ the term in its widest significance. We will now proceed to point out what appear to have been the several stages of metamorphic action by which the pisolitic ore has been elaborated out of basalt.

2. *Origin of Bole and Lithomarge.*—There can be no doubt that the lithomarge and bole alternating with compact basalts are but decomposed basalts. The passage from basalt to lithomarge and bole can be traced in all cases; not unfrequently large masses of basalt are to be seen in the midst of the lithomarge, the concentric layers presenting all the varieties of texture and colour between

the hard and black basalt of the interior and the purple or yellowish argillaceous masses in which the basalt appears to be imbedded. Again, the boles often contain cavities filled with the ordinary zeolites of the amygdaloid basalts. Portlock* gives an analogous case of the production of ochre from an allied rock. "The greenstone in the Glenrandal river in Upper Cumber," he says, "is so highly charged with iron as to disintegrate into extensive beds of a very rich ochre. The ochre is sometimes in the state of hydrate and yellow, and at other times red. The mode of alternation is:—felspathic mica-schist, or gneiss, compact below, but quite rotten and decomposed at the top; ochre graduating into a decomposing greenstone. * * * The greenstone also occurs within the ochre, and by its decomposition gradually merges into it. * * * In a branch stream to the west, the ochre is met with alternating with less altered greenstone, the thickness of the greenstone being 26 feet, and of the ochre 18 feet. And in the townland of Aughlish, in Banagher, it is upwards of 50 feet thick, several patches of greenstone within the mass being still solid, and merging into ochre."

Observations in the field and the following comparative analyses go far to prove that the bole and lithomarge are the resultants of aqueous action in combination with acidulated gases, which, dissolving out certain mineral substances, has effected the decomposition of the basalts, especially the more felspathic ones.

Table of Analyses of Basalt, Lithomarge, and Bole.

	I.	II.	III.	IV.	V.
	Bas.	Bas.	Lith.	Och.	Bole.
Silica	39.72	53.70	49.75	56.40	30.88
Alumina	14.32	25.41	29.88	3.46	20.76
Peroxide of iron	27.87	8.95	6.61	24.14	26.16
Lime	4.15	4.55	0.43	0.90	2.60
Magnesia	4.00	.....	1.47	.....	.....
Sulphuret of iron .....	.....	tr.	.....	.....	.....
Soda	9.94	.....	.....	.....	.....
Potash .....		.....	6.35	15.10	.....
Water		4.30	4.48	.....	19.60

I. *Basalt*, Slieve Gallion (Dr. Apjohn). II. *Basalt*, Antrim (Prof. Hodges). III. *Lithomarge*, Germany. IV. *Ochre* of the Basalt, Drumrankin, near Ballymena (Dr. Apjohn). V. *Bole*, Germany.

The chief differences in the chemical composition of bole, lithomarge, and basalt are the increased percentage of peroxide of iron and water, and the less quantity of alkalies in the boles and lithomarges as compared with the basalt.

The alternation of basalts and boles indicates successive lava-flows of the more easily decomposed and the crystalline materials, the former having subsequently disintegrated into bole or lithomarge, while the latter has persisted tolerably well. In those instances where there is a passage from the hard rock below to the soft, and from the soft to the hard above, the basalts overlying and underlying

* Geol. Survey, Derry, p. 173.

the bole have been ejected in rapid succession, the decomposition of the intervening volcanic flow being subsequent to the eruption of the superimposed rock; or, in cases where the bole has been indurated, if such do occur, the decomposition of the original rock was effected before the subsequent volcanic outburst; but as these effects were limited to simple induration, except in the case of the production of the pisolitic iron-ore, hereafter to be mentioned, it is extremely probable that these eruptions were subaqueous.

3. *Absence of Boles above the horizon of the Iron-ore.*—Though boles and lithomarges unaccompanied by an iron-ore occur below the iron-ore series, yet no such beds have been met with above the pisolitic ore, though many hundred feet of basalt have been examined.

Fig. 2.—Section of Galboly Mountain.

1, 2, 3, 4, 5. Beds of bole and lithomarge.

a. Pisolitic iron-ore.

H.C. Hard chalk.

On the face of the Galboly mountain three hundred feet of basalt intervene between the pisolitic ore and the White Limestone; and four masses of lithomarge and bole are seen within that thickness, underlying different basaltic terraces (see fig. 2). A similar interstratification is also seen at Slievenanee, below the section given at p. 153.

The section of Cape Pleaskin presents five thin strata of ochre below the iron-band, and unassociated with iron-ore, in the lower 180 feet; while that portion of the basaltic escarpment (of the thickness of 172 feet) above the iron stratum does not exhibit a single ochre-bed.

A section at Carnowry, Rock Head, given by Portlock*, shows three thin beds of ochre or bole in a thickness of basalt above the

* *Loc. cit.* p. 142.

hard chalk of 125·5 feet, the remaining 78 feet of basalt being hard, compact, and columnar. No iron-ore is exhibited in this series.

4. *Metamorphism of Bole, and origin of the Pisolitic ore.*—The spheroids of iron-ore are powerfully attracted by the magnet; and the following analysis by Dr. Apjohn proves that the iron is in the states of per- and protoxides. The source of the iron is to be sought for in the hydrous peroxide of the bole, originally in combination with the silicated minerals of the basalt, and probably also in the hydrous oxide resulting from the decomposition of included magnetite and iron pyrites.

Analysis of Spheroids from Pisolitic ore, Red Bay.

Magnetic oxide of iron	11·74
Peroxide of iron	51·37
Silica, alumina, &c. (by diff.)	36·89

100·00

Percentage of metallic iron 44·45

If we compare the analyses of basalt and ochre (given on p. 156), with those of the iron-ores (p. 159), we shall not fail to notice the general similarity between them; the chief differences observable are the proportions of the several constituents, and, in the case of the pisolitic iron-ore, the different degrees of oxidization of the iron. But these differences do not militate against the presumed origin of the bole and iron-ore—that they are several stages in the metamorphism of one original mass: the addition of water to the basalt, and loss of lime, other alkaline earths, and alkalies, produced bole; the loss of water and oxygen from the ferruginous materials of the bole resulted in an increased percentage of iron in the pisolitic ore. Though aqueous agency may have effected the first change, it could not have produced the second; and heat is the force we must call to our aid in the alteration and concentration of the oxides of iron; and by it the phenomena exhibited by the iron-band are then easy of explanation. We assume that the underlying bole or ochre was a wet or sodden terrestrial surface; in fact many circumstances necessitate such a condition; and the subsequent overflow of basalt effected, by its heat, pressure, and possibly evolved gases, a reduction of the contained oxides of iron into the more concentrated form in which they occur in the iron-band, the aggregation of the ferruginous particles being a result of the same action *. This metamorphism is analogous to the development of new minerals by the intrusion of igneous masses among schistose and stratified rocks. It will be observed that the accumulation of the oxides of iron to certain centres diminishes as we recede from the exciting cause.

* Since the reading of this paper before the Society, we have examined a large number of the spheroids from the pisolitic bed, but once only found diamons of the *Coscinodiscus* type, and not of the genera which form the bog-ore: they might have got there accidentally.

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Table of Analyses of Pisolitic Ores.

Constituents.	I. Kilwaughter.	II. Tully.	III. Red Bay.	IV. Red Bay.	V. Slievananee.	VI. Slievananee.
Peroxide of iron	45.00	45.50	59.40	77.22	71.00	81.50
Protoxide of iron	...	...	...	...	18.00	...
Oxide of manganese	tr.	tr.	...	...	tr.	2.57
Titanic acid	...	2.00	} 2.80	tr.	...	tr.
Vanadic acid	...	...		...	...	...
Alumina, soluble in acids	...	3.00		...	...	4.20
Alumina, insoluble.....	36.44	32.50	} 10.40	20.65	9.00	8.50
Silica { insoluble	...	3.50				
{ soluble	...	0.50				
Magnesia.....	2.44	...	...	...	...	...
Lime	0.56	0.35	...	...	...	.93
Water of combination	18.00	12.65	8.40	2.13	...	1.96
Percentage of metallic iron	31.50	31.85	41.58	54.05	63.70	65.20
Analyst	J. Cameron.	J. Cameron.	Dr. Apjohn.	J. Cameron.	J. Cameron.	Pf. Hodges.

The above analyses are of specimens selected as fair samples of the iron-ores; the great variation is in a great measure accounted for from the samples having been taken from different parts of the iron-band. Numbers I and II. are of a mixed character, the others containing a greater percentage of iron according to the predominance of the spheroids.

IV. NATURE AND ORIGIN OF THE FERRUGINOUS SERIES AT BALLYPALIDY.

1. *Section at Ballypalidy.*—The iron ochres of Ballypalidy, which are undoubtedly of sedimentary origin, will next occupy our attention. Though references have been made to a section of the iron-ore series at this locality in the pages of Society's Journal*, yet we are constrained to submit further observations on the succession of the beds there exhibited, inasmuch as incorrect impressions regarding the true relationship of the ores to the red bole or ochre-bed and to the lithomarge will be formed from a perusal of the sequence of the beds as given by the author of the paper referred to. Thus, in the section given on p. 358, the beds are enumerated in ascending (and not descending) order; and at p. 361, the plant-remains are stated to occur in the red bole; and, again, Mr. Du Noyer, in a paper read

* Vol. xxv. p. 357: W. H. Baily, "Plant-remains from beds interstratified with the Basalt."

before the Belfast Natural-History and Philosophical Society, states "that the plant impressions are in the red earth or lithomarge lying on and in this hæmatite-conglomerate." These are inaccuracies, and imply that the plants are associated with masses which are the products of metamorphism.

Fig. 3.—Section at Ballypalidy.

The section at Ballypalidy, west side of railway (fig. 3), in descending order is as follows :—

1. Glacial Drift.....	12 feet.
2. Conglomerate-bed, composed principally of spheroids of iron-ore, in a ferrugineo-argillaceous paste, with which are associated fragments of basalt and greenstone. Occasionally thin bands of an arenaceous clay with plant-impressions appear among the conglomerate; otherwise there is no appearance of stratification in this bed	10-12 feet.
3. Plant-bed, a reddish-yellow ferrugineo-arenaceous shale, distinctly laminated, with fragments of plants along the planes of bedding	4-8 inches.
4. The so-called plant-bed passes into a browner stratum, more argillaceous, the darker colour being due chiefly to an admixture of finely disseminated carbonized vegetable fragments. Plant-remains occur also in it; and patches of lignite increase in frequency downwards. Total thickness of plant-layer and this bed	3 feet.
5. Lignite	1 foot.
6. Amygdaloidal basalt.	

The conglomerate is of irregular thickness, thinning out towards the S. W., whilst the finer sediments below increase slightly in

thickness in the same direction. Wherever a fine sediment occurs, even though in the conglomerate, plant-remains are present.

The plant-layer, which is mined and used as a flux, is of low specific gravity, and is not sufficiently rich in iron to be valuable for smelting. The following analysis of this rock is communicated by Dr. J. Apjohn.

Water	25.78
Silica with a little alumina	36.40
Peroxide of iron	9.12
Alumina and other oxides (by difference)	28.70
	<hr/> 100.00

Percentage of metallic iron..... 6.36

In a neighbouring pit on the N.E. side of the line of railway there is exhibited a similar section. The conglomerate-bed presents a maximum thickness of 10 feet, thinning away to the N.E., and with the underlying shales dipping in the contrary direction. The shales are about 6 feet thick and are underlain by lignite, which surmounts an amygdaloidal basalt.

2. *Relation of the Strata to the Basalts.*—The railway-cutting about a quarter of a mile to the N.E. of the ochre-pits presents a section (fig. 4), which enabled us to place the fore-mentioned sedimentary ores, shales, and lignite in juxtaposition with a subsequent basaltic flow (1).

Fig. 4.—Section in Ballypalidy Railway-cutting, north side.

A thin band of impure lignite (3), with or without a clay band below containing plant-remains, and always accompanied by an overlying stratum of clay (2), is seen in one place following the undulating line of the upper surface of a concretionary basalt (4), which latter is superimposed upon a ferruginous series of iron-ore and the underlying bole (5) and lithomarge (6). Elsewhere the basalt above the pisolitic iron has been eroded, and the lignite series rests upon the pisolitic iron-ore or inferior basalt.

The continuity of the lignite-band of these sections with that of the underlying plant-beds and conglomerates in the pits some little distance to the west, is not traceable step by step; but there is little doubt that the several portions visible are parts of one stratum.

3. *Origin of the Ore.*—The mode of occurrence of the conglomerate bed of iron-ore and the associated strata clearly demonstrates a sedimentary origin. The lignite has been derived from a plant-growth *in situ*, upon an eroded surface of basalt. The shaly beds have originated in the tranquil deposition of argillaceous and arenaceous materials mingled with some ferruginous matter, all derived from the degradation of basaltic rocks in the immediate vicinity. The presence of fragments of plants, chiefly leaves and small branches (for rarely do we find large pieces of wood), points to the growth of a terrestrial vegetation near the margins of a morass, or sheet of water, probably a lake. The finely laminated structure of the strata and the delicate nature of the parts of the plants preserved require a tranquil accumulation by aqueous agency.

The conglomerate-bed results from the degradation of the pisolitic iron-ore, of which it is chiefly reconstructed, and of the underlying ochres: it appears to have rapidly formed, and, so far as we know at present, brought to a close that period of rest in the volcanic activity during which these sedimentary beds had been accumulating.

The following analyses of the more spheroidal portion of the Ballapalidy ore indicate a close affinity with the pisolitic iron-ore of Tully, near Glenarm (see p. 159), and confirm our observations as to the source whence the ferruginous materials of the irregularly stratified beds at Ballapalidy have been derived.

*Analyses of Brown Aluminous Hematite *.*

Seequoide of iron	35.91	.....	27.93
Protoxide of iron	6.57	.....	5.08
" of manganese	0.05	.....	tr.
Alumina	27.95	.....	34.57
Lime	0.60	.....	0.91
Magnesia	0.20	.....	0.62
Potash	0.49	.....	—
Silica	9.75	.....	9.87
Phosphoric acid .....	—	.....	tr.
Water	18.60	.....	19.36
Titanic acid .....	—	.....	3.51
	100.12		101.86

4. *Plant-remains of the Series.*—Though Mr. Baily's account of the plants found at Ballapalidy is the first published record of the occurrence of vegetable remains associated with the basalts of Antrim, yet their presence in these same beds was known as early as 1862, soon after the commencement of mining operations at that locality. The discovery we owe to Mr. Rowland Smeeth, a pupil of one of us; and it was made public in a course of geological lectures delivered at Belfast. The plants then obtained were few in number, *Pinus* and *Cupressites* being the only forms identified. But the priority of discovery of plants in the Antrim basalt we accord to Dr. J. Bryce, F.G.S., who, with an unaccountable diffidence, hesitated to make known his researches, though a favourable opportunity offered on the

* Percy, Metallurgy of Iron, p. 207.

occasion of the reading of the Duke of Argyll's paper on the "Leaf-beds of the Isle of Mull." The plant-remains were obtained on the shores of Lough Neagh, near Shane's Castle, and opposite Ram's Island, on the east shore of the Lough. These and other species additional to those enumerated by Mr. Baily from the Antrim basalt concur to fix the period of their growth on the horizon of the Upper Miocene, and to establish a contemporaneity with the flora of the Basalts of Mull.

Amongst the plant-remains from the ash-beds on the shore of Lough Neagh, collected by Dr. Bryce, we recognize *Platanus aceroides*, *Sequoia Langsdorfi*, species of *Juglans*, *Fagus*, *Laurus*, &c. And from the sedimentary ochreous beds at Ballypallidy we have collected the following unrecorded forms:—*Eucalyptus oceanica*, Ung., *Hakea*, sp., *Celastrus*, sp., *Daphnogene Kanii*, Heer?, *Graminites*, sp., &c.

V. ECONOMICS AND MINERAL STATISTICS.

The Antrim iron-ore, though of but recent introduction, has already attracted some attention among the iron-masters in England. Its freedom from deleterious substances, such as phosphorus and sulphur, and from any qualities injurious to the production of superior iron, commends it highly, while the presence of titaniferous acid in the pisolite-bed adds much to its value for the production of steel. But it is the high percentage of alumina that claims for this ore peculiar importance.

Mr. S. Evans, who has introduced much of this ore into England, informs us that its value as a flux is becoming more and more appreciated, and that the furnaces of Cumberland and Lancashire are now supplied with large quantities for mixing with the siliceous hæmatites of that district. The effect of combining these two ores in the furnace is to soften the slag and to produce what is called a "loose load," which allows the metal to pass through with facility, and at the same time acts as a protection to the inner casing of the furnace. But, in addition to these valuable properties, the alumina determines the separation of the silica from the hæmatite-ores, thereby producing from a given quantity a larger percentage of metallic iron than could otherwise be obtained.

The great difficulty hitherto has been to produce an iron free from silica for the Bessemer process of steel-iron making. The Cumberland ore has been found well adapted for producing this steel; but the contained silica has always been a drawback, injurious and difficult to remove. The great demand is for an iron free from silica; and since the Antrim ore has entered the market this desideratum has been accomplished: it contains little or nothing deleterious, and yet has within itself the essential properties for making a superior steel-iron, while the large excess of alumina acts as a purifier to the richer ferruginous ores, and has thus enabled the Cumberland and Lancashire furnaces to stand first in producing the most suitable iron for Bessemer's process.

It is not difficult to discern that other districts will soon learn the

value of this ore. The poorer kind, as lithomarge, may be used as a flux, while the richer bole and pisolite are made to yield a superior iron, suitable alike for steel- or machinery-purposes*.

The growing demand for this Antrim ore proves its utility; during the past year upwards of 50,000 tons were shipped to England from several ports along the Antrim coast. The mining has become a steady and increasing industry in the county.

VI. GENERAL CONCLUSIONS.

1. That during the period of volcanic activity in the N.E. of Ireland, there was a cessation of igneous eruption over certain areas, during which lacustrine deposits were formed, and a growth of terrestrial plants took place.

As to the extent of the lake, or of the land-surface, the data are incomplete to form any conclusions. The lignite in the Giant's-Causeway basalt, the leaf-beds of the Isle of Mull, and the bituminous deposits in other localities may be on the same horizon. However, it is perhaps more probable that these several land-accumulations may have been formed in isolated areas, though during the one period of rest in the volcanic forces.

2. The preceding remarks imply that there were at least two periods of volcanic activity, the plant-beds or lignite marking an unconformability of an upper basaltic series to a lower. The plants being of Upper-Miocene age enables us to assign a position in the scale of geological time to the superior basalts. What may be the age of the inferior series, is a question that can only be approximately answered. That it is newer than the White Limestone (Upper Chalk) and older than the upper Miocene, is apparent.

3. The older basaltic series has undergone metamorphic changes in the composition of some of its interstratified lavas. The boles and ochres, which are decomposed basalts, are probably connected with subaqueous igneous flows, whilst the pisolitic iron-ore band, which is a metamorphosed *bole*, indicates subaerial action, and that during the period of emergence the bole was subjected to further metamorphism by heated superimposed basalt.

DISCUSSION.

Mr. D. FORBES was not prepared to admit some of the theoretical conclusions of the authors, and objected to calling in metamorphism to account for all that was hard to be understood. He could not recognize the division of beds so similar in character into two classes. He wished to know, assuming that the iron-ore merely resulted from the decomposition of the basalt, what became of all the silica and alumina which constituted three-fourths of the mass. The origin of the pisolitic ores was in fact organic. In Sweden certain lakes were regularly dredged each year for the pisolitic ore still in

* It would be of great importance to the prosperity of the north of Ireland if the ore could be smelted at home. Furnaces might easily be erected near the mines for the reduction of the richer pisolite; limestone is abundant; and coal can be procured easily and cheaply from Scotland.

course of formation by means of confervoid algæ. He therefore regarded the whole of these beds as in a certain sense sedimentary, and though due to organic agency, yet still deriving their original mineral matter indirectly from the basalt. The basalt contained a considerable amount both of phosphorus and sulphur; and if the ores had been derived directly from the basalt, both these substances would have been present in them. This was an argument against any direct metamorphism. The presence of vanadium afforded additional reason for regarding these ores as formed in the same manner as bog-iron and similar ores.

Sir CHARLES LYELL had observed in the basalts of Madeira red ochreous bands which represented old land-surfaces, in one of which Mr. Hartung and he had discovered a leaf-bed containing vegetation of much the same character as that of the island at the present day. Near Catania, in a recent lava-stream, he had seen the junction of the lava with the soil of the ancient gardens; and in character the soil now under the lava resembled the red beds of Madeira.

Mr. W. W. SMYTH was on the whole inclined to admit the power of metamorphism to produce such changes as had been here effected. He commented on the advantages of employing this Irish ore for admixture with hæmatitic ore, on account of the abundance of alumina present. Possibly there had been some difference in the chemical character of the different flows of basalt.

Mr. EVANS suggested that the Ballypalidy beds might be the littoral deposits of a lake in which the pisolitic ores of the other parts of Antrim were deposited further from the shore, and subsequently buried under a basaltic flow.

Mr. ETHERIDGE inquired whether the pisolitic ore had been subjected to microscopic examination, with a view of finding traces of organic forms, such as *Gaillonella*.

Mr. TATE, in reply, defended his views as to metamorphic action. He thought the uniformity in thickness and character of the pisolitic ore band over so large an area showed that it could not be a lacustrine deposit. He had not as yet discovered any diatoms in the spheroids.

2. Notes on the STRUCTURE of SIGILLARIA.

By Principal DAWSON, F.R.S., F.G.S., Montreal.

[The publication of this paper is deferred.]

(Abstract.)

In this paper the author criticised the statements of Mr. Carruthers on the structure of *Sigillaria* (see Q. J. G. S. xxv. p. 248). He remarked that *Sigillaria*, as evidenced by his specimens, is not coniferous, that the coniferous trunks found in the coal-formation of Nova Scotia do not present discigerous tissue of the same type as that of *Sigillaria*, that no conifer has a slender woody axis surrounded by an enormously thick bark, that *Calamodendron* was probably a Gymnosperm and allied to *Sigillaria*, that, although *Stigmara* may not always show medullary rays, the distinct sepa-