[*Note*, June 29, 1866.—To the foregoing I may now add, that having subsequently examined an extensive series of specimens of Serpentinous Limestones from the "Fundamental Gneiss," sent to me by Dr. Gümbel, I find in some of them the precise parallel as to Microscopic appearances with the most characteristic forms of the Connemara *Eozoon*; whilst from these I can trace a continuous gradation, through a series of phases which appear due to subsequent metamorphism, to specimens whose characters seem purely mineral. Appearances of precisely the same character are presented by a series of specimens of the Serpentinous Limestones from the "Primitive Gneiss" of Scandinavia, kindly transmitted to me by Prof. Lovén.—In a communication I have received from Dr. Dawson, dated March 28th, he says:—"I have lately had my attention directed to a point of importance noticed in my paper on *Eozoon*, but since somewhat overlooked, *the occurrence of Eozoon preserved simply in Carbonate of Lime*, without any Serpentine or other foreign mineral, and showing the structure (that is of the canal-system, for I have not yet seen the fine tubulation) as perfectly, though not so prettily in the matter of colour, as the Serpentinous specimens. This fact alone, which was noticed in my original Paper, and which I have now verified, is of itself *a conclusive answer* to Professors King and Rowney's objections." "I may also say that a careful reexamination of the Chrysotile or fibrous Serpentine, with additional specimens, enables me to reaffirm, if possible with still greater confidence, its entire distinctness from any of the structures of the Canadian Eozoon."]

January 24, 1866.

James Mason, Esq., F.C.S., Brighton; William Nevill, Esq., of Langham Cottage, Godalming; and Henry T. L. von Uster, Esq., 3 Duke Street, Portland Place, W., were elected Fellows.

The following communication was read:—

On the KAINOZOIC FORMATIONS *of* BELGIUM. By R. A. C. GODWIN-AUSTEN, Esq., F.R.S., For. Sec. G.S.

CONTENTS.

I. Introduction.

The following notes relating to the Kainozoic or Tertiary* formations of Belgium were put together in the course of an interesting excursion through that country in the spring of 1865, in company with Mr. Hamilton, Mr. Prestwich, Captain D. Galton, Mr. W. W. Smyth, Mr. Busk, and Mr. Gwyn Jeffreys. Our route was from Harwich to Antwerp, Louvain, Hasselt, Maestricht, Liége (whence to Engis and Engihoul), Namur. Some of the party went into Brussels to see the collection in the Museum there; some to the Grotte de Han; in company with M. van Beneden I had the advantage of seeing, under the guidance of M. Malaise, the lower Palæozoic and fossiliferous rocks of Gembloux, which he considers to be of the age of the Lower Silurian series of Sir. R. Murchison.

From Dinant, where we were joined by the late Mr. H. Christy, we all visited, under the escort of MM. van Beneden, Dupont, and other Belgian geologists and antiquaries, the caves of Furfooz on the Lesse. An excursion in the neighbourhood of Mons, and a visit to the coast at Sangatte, near Calais, completed the trip.

Some of our party had been in Belgium before, even repeatedly. The points in its geology which on this occasion chiefly interested us were the Crag-formation of Antwerp and elsewhere, the Boldérien beds of M. Dumont, and the caves and recent researches at Furfooz.

To what extent the several members of our party may concur in the views here recorded is a point on which I will not venture to speculate; they are offered as my own exclusively; but I feel bound to acknowledge the great advantage I derived from visiting the district in company with so many experienced observers as naturalists and geologists; and we can all testify to the kind interest and assistance of the Belgian geologists, as also to that of the military authorities at Antwerp, for which last we were indebted to the exertions of Mr. J. Jones.

The cave-researches of Furfooz are under the superintendence of MM. van Beneden and Dupont; for this reason it would not be fitting that any comments should be made with respect to the views which were freely communicated to us, until such time as the final official report shall have been published. The question relating to some portion of the in-filling is so closely connected with that very complicated period to which the Löss, the Sables de Campine, and the Cailloux Ardennais belong, that a few short references are necessary.

II. Older Kainozoic or Crag Beds of Antwerp.

1. *General Remarks.*—By permission of the Belgian war department, we were enabled to examine at leisure the deep sections connected with the extensive military works in course of execution around Antwerp; in addition we received the cordial assistance of Captain Cocheteux and other Engineer officers.

The monograph of Mr. Searles Wood† had long since informed

* In this paper the author restricts the application of the terms Kainozoic and Tertiary to deposits of the age of the Faluns and of more recent date.—Edit.

† Palæontographical Soc. 1848–1850.

geologists how close an agreement existed between the marine fauna of the Suffolk Crag and that of Antwerp. At the same time it was evident from the work of M. Nyst * that there were many forms met with in one area which were apparently wanting in the other, and rendering it a matter of some interest in comparative geology that such a difference within such narrow limits should be accounted for; this difficulty has long been a point of special interest in Tertiary geology. The solution has been heretofore attempted by various applications of the percentage test, as by the proportion of recent forms to such as are unknown as living, or again by the proportion which a given parcel of shells might contain, either of Arctic or of more Southern forms. There has been so little agreement in the results thus arrived at that some fresh solution should be attempted. Percentage results, from their very nature, must ever be fluctuating; the process when first proposed seemed specious, inasmuch as it had the appearance of possessing arithmetical accuracy, but in reality it is the very reverse of this, in consequence of the uncertainty of all the elements of the calculation and of their negative character.

M. Dumont proposed a twofold division for the Tertiary or Kainozoic series of Antwerp, an upper or Scaldésien, a lower or Diestien. Sir Charles Lyell's account of the Antwerp Crag was prepared under disadvantageous circumstances. At that time a few detached excavations afforded the only attainable stratigraphical information, and hence it became necessary to give the fossils collected at each locality in separate lists, thus producing the impression that the Crag-formation there was both complicated and of considerable vertical thickness, but such is not the case.

At the time of our visit an examination of the Antwerp beds was extremely easy by means of two long artificial sections, one passing along the main ditch of the new "enceinte," 14,000 metres in length, the other along the ditch of the detached Forts, with a length of 17,000 metres; thus giving 31,000 metres of continuous section. These sections formed the subject of a short but very useful memoir by M. Dejardin, Capt. de Génie, one of the officers engaged on the work†.

In the excellent Memoir by Sir Charles Lyell‡, which has done so much to make English geologists acquainted with the relations of the various subdivisions of the Nummulitic and Tertiary formations of Belgium to those of this country, the Tertiary series is arranged as follows:—

§ 3. Antwerp Crag.

1. Yellow Crag = Upper Crag	Calloo, tab. ii. Steuvenberg, tab. iii.	Système Scaldésien, *Dum.*
2. Crag gris—Middle Crag—	tab. iv.	
3. Crag noir—Lower Crag—	tab. v.	

§ 4. Sands and Iron Sandstone of Diest—"Système Diestien" of *Dumont.*

§ 5. Bolderbèrg Sands— "Système Boldérien."

* Coquilles Tertiaires de la Belgique.

† Bull. de l'Acad. R. des Sc. de Belgique, t. xiii. p. 470.

‡ Quart. Journ. Geol. Soc. vol. viii. p. 277, 1852.

Of this arrangement it may be remarked that the "Crag noir" of the local Antwerp geologists is distinguished from and made superior to the *Système Diestien* of Dumont, whose *S. Diestien* at that place (see Map, small edition) is described as consisting of "sable glauconifère coquillier" *.

M. Nyst's latest subdivision of the Belgian Kainozoic series is as follows:—

1. Yellow Sands, Steuvenberg, Calloo.	Cyprina, Isocardia, Astarte.
2. Argillaceous Sands, Deurne.	Cetacean bones, Pecten, Cyprina, Astarte.
3. Grey Sands.	Pecten Gerardii, broken shells abundant.
4. Grey running Sand.	Bryozoa, shells scarce, same as 3.
5. Black Sands, Edeghem, Berchem, Fᵗ. Herenthals.	Includes *Pectunculus*-band.

In 1861 M. Nyst published a very interesting paper †, to which is appended a list of 146 species of fossil shells and four Zoophytes; of these, 58 had not been previously noticed as occurring in the Kainozoic beds of Belgium.

The object of this paper is to state the result of that particular enquiry which was of chief interest in connexion with the Antwerp sections, namely the Zoological value of the subdivisions of the crag beds there, and whether the proposed vertical order of arrangement was correct in fact. Mr. Lankester visited Antwerp in 1864, and a memoir communicated to this Society ‡ served to revive the interest of these questions.

2. *Système Scaldésien.*—In order that the position of the Kainozoic series about Antwerp may be understood, it must be borne in mind that from the North Citadel on the Scheldt, as far as Deurne (about half the extent of the "enceinte"), the level of the country is below that of the river at high-water, which now rises 4·50 metres; low-water being 0·15 metre above that at Ostend. At this, the north end of the section, where the Crag beds have been laid bare beneath polder mud, its upper surface is at about low-water level, and at nearly the same level are the beds so rich in shells, out of which the Docks have been excavated, from beneath peaty beds and polder mud. We collected largely from these shell-beds, or rather from the spoil-banks. The assemblage is that given by Sir Charles Lyell, tab. ii. and iii., and by M. Nyst, list 34, p. 601§.

North of Deurne the glacis has been formed out of the spoil from the main ditch, and shows that it has been excavated out of an extension of the same mass of sands, gravel, and broken shells, as above. South of Deurne the ground rises somewhat, and as the works were then in progress, good sections were to be seen from 4

* Tabl. des Terr. &c. de la Belgique.

† Notice sur un nouveau gîte de fossiles, se rapportant aux espèces faluniennes du Midi de l'Europe, découvert à Edeghem près d'Anvers. Bull de l'Acad. R. des Sc. de Belg. t. xiii. p. 29. See also Lyell's 'Elements,' 6th edit. p. 232.

‡ Quart. Journ. Geol. Soc. vol. xxi. p. 221, 1865.

§ Omalius, Abrégé de Géologie, 7ᵉ édit. 1862.

to 6 metres deep. The blocks left for measuring the work done show such sections as the following:—

a. Système Scaldésien...	Yellow sands, gravel and broken shells. Grey sands, numerous broken shells. Brown sands.
b. Système Diestien.....	Pale-green sands, shells few, not much broken. Dark-green sands, *Pectunculus*-band. Very dark compact beds.

The relative thicknesses vary much from place to place, the whole not being more than 12 feet thick, of which the upper brown and yellow sands form about 6 feet. In the Dock-sections these upper beds may have been somewhat thicker, but at no place do they probably exceed 8 feet.

The upper series (*a*) constituting the "*Système Scaldésien*" of M. Dumont, viewed as a marine accumulation, presents a very common condition of sea-bed, consisting of dead-shell gravel, mostly forming banks, and heaped up under inconsiderable depths of water. This is a good division of the series, inasmuch as it marks a change in the depth and moving power of the water at this particular spot, the result, doubtless, of a physical change of wider extent; the effect of which was the disturbance of previously formed sea-beds and their rearrangement. At the same time there was an outward distribution of the materials of a higher or sublittoral zone, as seen in the gravel.

The "Système Scaldésien," as exhibited at Antwerp in the form of "couches remaniés," very closely resembles both in the condition of its materials and fossils, the Red Crag beds of Suffolk; nor is there any reason why the physical change which caused the Red Crag to succeed the Bryozoan should not be referred to the same geological change which made the Scaldésien follow on the Diestien.

3. *Système Diestien.*—In the section given above, which is just such as is to be seen everywhere from the Porte de Tournhout to that of Malines, the Scaldésien beds, or yellow and grey coarse series, contain either fine pale-green, somewhat loose sands, or else dark-green, almost black, and compact sands; these are the Diestien beds of Dumont. With reference to condition of sea-bed, it is that form well known as deep-water sandy and muddy ooze, and was the deposit of tranquil depths.

Although the whole thickness of this lower series has not been cut through within the area of the fortifications, even in the section above referred to, which presents the deepest cuttings, yet it has been proved, as we were informed by the Engineer officers on the spot, that the Diestien beds extended only a few feet below the excavations for the main ditch, and that within the area as well as without, the dark-green Diestien beds overlie compact Rupellien clay.

A maximum thickness of about 4 metres may be assigned to the Diestien beds; generally they are less, and small as are the vertical

dimensions of the whole of the Crag series at Antwerp; there is no other place in Belgium where they are so thick—indeed, beds of the true Scaldésien, Crag-like type, occur only at that place: it is also the only spot where fossiliferous Diestien beds have been observed.

The Diestien beds of Antwerp represent a condition of sea-bed over which submarine life is abundantly developed, and that with a distinctive facies. Viewed in this way the sections from the Porte de Tournhout are exceedingly interesting, presenting a rich and varied fauna, of which a full enumeration has recently been given by M. Nyst (Bull. de l'Acad. Roy. des Sciences de Belg. 1861, sér. 2. t. xii. p. 20). One particular form, the *Pectunculus glycimeris*, numerically exceeds all others by 1000 to 1; it colonized this area of the Crag sea, attaining a large size, and forming banks which in places are not less than $2\frac{1}{2}$ feet in thickness. The Diestien was a true life-zone, and exceedingly prolific, and as such it is in striking contrast to the Scaldésien division, of which the whole of the assigned fauna is from dead and drifted shells: it may safely be asserted that of the shells met with in the Scaldésien beds not one lived where it is now found; this, from a natural-history point of view, is the real difference between the upper and lower Crag of Antwerp.

The area over which the Scaldésien shell-gravel and the fossiliferous Diestien ooze are to be seen together is even now so limited that much generalization would be hazardous. Traced from below upwards, the Antwerp sections show a gradual passage from very fine and dark muddy ooze into sandy ooze, and finally into fine pale-green clean sand; in this there is a clear indication of a slight increase in the moving power of the water: a slightly diminishing depth might cause such a change. The more sandy beds, where they remain, form the uppermost portion of the Diestien division, and contain but few shells.

The Scaldésien division overlies an eroded surface of the Diestien, and is found on every component portion of the series down to the lowest and most compact beds. The line of separation is always to be traced, and is mostly very distinct—it marks a sudden change of condition;—but as in the Diestien so in the Scaldésien series, the rearranged pale-green sands, brown sands with shells whole or broken, the dead-shell banks, and uppermost the thickest layer of gravel with pounded shells, indicate a progressive change and slow shallowing.

The bathymetrical conditions indicated by the Scaldésien and Diestien accumulations may be judged of by the guidance of the soundings over the English channel; the difference may have been as much as from 30 to 40 fathoms, or to such an extent must the crag-sea have shallowed about Antwerp from the time of the shell-bearing Diestien beds, their denudation, and the formation of the dead-shell sand and gravel bank. The *Pectunculus glycimeris*, the most abundant member of the fauna, ranges from 25 to 60, and, according to some, to 100 fathoms; but no part of the Diestien beds indicate a depth at which *Dentalia* become abundant and characteristic, such as 80 to 100 fathoms.

I received from Captain Cocheteux, a small but very interesting collection of fossils from the lowest Diestien beds in the neighbourhood of Fort 4, towards Edeghem (see list); but we did not visit the Edeghem brickfield-section above referred to as described by M. Nyst. From a recollection of what I saw in 1861, the Diestien beds exactly corresponded in colour and composition with those of the enceinte. The only place near Antwerp at which we saw the superposition of the Diestien Crag to the Rupellien clay was at Schelle.

4. *Schelle.*—The Crag-sea accumulations of the several localities to be noticed have been called Diestien, but they belong to very different submarine conditions from those of the base of the Antwerp Crag.

As at Edeghem, beds of Rupellien clay are worked extensively for bricks and tiles at Schelle. This Rupellien clay is an upper member of the Nummulitic series of Belgium, corresponding in age and condition with, and externally very like, our Barton clay of Hants.

The Rupellien clay is capped by sandy beds, which, towards their base, and particularly at the upper end of the section, become as dark as those about Antwerp, though they are not so thick. These sands are altogether about 3·5 metres thick. A very distinctly marked line separates these formations; at one place there is unconformity on an eroded surface, and throughout there is a line or band of flints, some large, remaining in place, together with Septariæ from the Rupellien clay; one of these measured more than a foot across. These Crag beds belong for the most part to the drift-sand sea zone.

At Schelle the upper surface of the Crag sand has been eroded, and at either end of the section the denudation has been carried down to the Rupellien clay. Schelle is 10 kilomètres south of Antwerp, and the great interest of the section, as of that of Edeghem, consists in the evidence it affords of the complete break of continuity between the Rupellien clay beds and the overlying Crag.

5. *Louvain.*—Louvain is between 4 and 5 myriamètres south-east of Antwerp. The remains of the Crag-sea beds occur only over the Belgian area in detached patches, and the interest of this locality consists in the evidence it affords of the great depth to which denudation of a date subsequent to the Crag period has been carried.

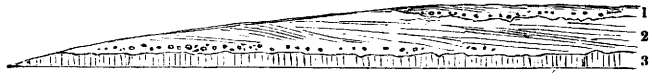
We were conducted to an interesting section on the side of a line of hill, on the road from Louvain to Pellenberg and Tirlemont, by M. Van Beneden, who had with him a diagram prepared by M. Dumont. The upper part of this section alone is referable to the Crag, the details are given in fig. 1.

On an eroded surface of white and yellow marls, the equivalents of the Rupellien clays, according to Dumont, is first a line of chalk-flint shingle and gravel, surmounted by brown and ferruginous Diestien sands; these beds belong in a marked manner to the sea-zone of drifting sand. The uppermost portion of this capping to the hill consists of ferruginous sands distinctly bedded, occasionally diagonally, and below this is a line of waterworn flints on a scored sur-

face. The upper series is somewhat coarser than the lower, and indicates a local change, or disturbance of sea-bed; the whole of the crag accumulation at this place is sublittoral.

Along the valley of the Dyle denudation has removed all beds from the Crag down to the Bruxellien of Dumont, or Lower Nummulitic.

Fig. 1.—*Section showing Crag-sand and Shingle capping a hill east of Louvain.*



1. Flint shingle.
2. Very ferruginous sands, with flint shingle at the base.
3. White and yellow marl (Argile de Boom) underlain by Lower Rupellien sands.

6. *Berg.*—The furthest point to the E.S.E. of Antwerp, distant 7 myriamètres, at which we saw the rolled flints and yellow sands of the Crag-sea area, was at Berg; these gravel beds were pointed out to us as belonging to the base of the Campine sands, but the circumstance that the gravel is wholly composed of chalk flints is against such a supposition. These Crag beds, which indicate littoral conditions, overlie the uppermost portion of the Nummulitic series (Tongrien).

7. *Bolderberg.*—Our visit to this place was the most interesting point of the excursion: the locality had suggested to M. Dumont his "Système Boldérien;" as such it was adopted by Sir Charles Lyell (*ubi supra*, tab. 1. p. 270) as also by MM. d'Orbigny* and Beyrich†. The Boldérien formation or division has therefore a twofold interest:—1st, in respect of its distinctiveness or place as a marine sedimentary group, 2nd, as to its zoological value.

The section of the Bolderberg is well given by Sir Charles Lyell (*u. s.* p. 295), except that the position of the shingle-bed on an eroded uneven surface of the subjacent sandy strata is not represented in the woodcut. To whatever period the lower sands may belong, it is evident that they had become consolidated before the accumulation of the shingle. The shingle is wholly made up of chalk-flints, in which respect it agrees with the lines of gravel and shingle in the Louvain section (fig. 1), and also with that at Berg.

M. Dumont's systematic subdivisions were based on considerations of composition or mineral character; and in accordance with an assumed theory of geological change he considered that shingle-beds represented a break or division in a series of accumulations, and further, that the shingle- or gravel-beds were referable to the close

* Cours Elémentaire de Paléontologie, t. ii. p. 765.

† Ueber den Zusammenhang der Norddeutschen Tertiärbildungen, Abhandl. der k. Akad. der Wissensch. zu Berlin, Aus dem Jahre 1855, pp. 1 *et seq.*

of a geological period. In the case of the Bolderberg there was no difficulty in identifying the upper ferruginous sands with those of Diest, and overlying some older system, ending upwards in a shingle-bed.

So far as the "Système Boldérien" of M. Dumont is concerned, its geological value is dependent on this simple consideration,—Is the shingle-band connected with the sands below or the sands above? In nine cases out of 10 throughout the whole series of geological formations the shingle, gravel, and conglomerate beds form the base of each natural group of accumulations. In the case of the Bolderberg there is no ambiguity whatever, the break and unconformity, whatever it may be worth, occurs below, and from this line there is a progressive change upwards from sands with shingle to sands without; the whole mass of the upper ferruginous sands forming a continuous series, and differing from the capping to the hills about Louvain only in the circumstance of the fossils it contains. The lowest bed represents a littoral line; the higher sandy beds, the zone of drift-sand and of the Crag sea; the whole having been accumulated slowly as the area was being depressed or submerged.

Zoologically, the "Système Boldérien" has been represented as a true Miocene formation of the age of the Faluns of Touraine*, and this has constituted its palæontological interest. Sir Charles Lyell, with the assistance of MM. Nyst and Bosquet, gave a list of 47 species of fossil shells which presented this difficulty—that whereas the Faluns of Touraine do not contain a single form belonging to the Nummulitic formations, even those of its latest stage, but have a marine fauna, which so far as accurate identification has gone, is wholly Eastern Atlantic, the reputed Boldérien Miocene fauna has had assigned to it a mixed assemblage of North-Sea Crag shells, (recent species), and those of the Belgian equivalents of our Barton beds. It was this consideration probably which caused M. d'Orbigny to refer it to his "Sous-étage Tongrien"†; indeed, it is evident that it was the Bolderberg list which produced this double error.

We collected a considerable number of the fossils of this locality. They occurred, as stated by Sir Charles Lyell, in the pebble-beds and associated sands, they are for the most part broken and worn, and "resemble shells thrown on a sea-beach" (*u. s.* p. 296). The great preponderance of single valves and of fragments of *Pectunculus glycimeris*, and Crag forms of *Pecten*, *Venus*, &c., gives to the assemblage the aspect of the Scaldésien fauna; but with these are Diestien forms of *Lunulites*, *Flabellum*, and the little *Oliva flammulata*, all exceedingly well preserved. Even at first glance the fauna of the Bolderberg sands is to a very great extent identical with that of the Belgian Crag.

Sir Charles Lyell's list, when cleared of all species respecting which doubts were felt, leaves 23 forms. M. Nyst's more recent list also contains 47 species, but differing from the 47 given by Sir C. Lyell. Taking the first list, some of the identifications were erro-

* Quart. Journ. Geol. Soc. vol. viii. p. 279.
† Cours Elém. de Paléont. &c. t. 11. p. 764.

neous—*Corbula pisum*, *Cancellaria evulsa*, &c., have been recognized as such—some, it will be seen, are as yet peculiar, others have been described from imperfect or single specimens; eliminating these, the remainder are true Crag-shells and also recent species, so that the list no longer presents the admixture of Nummulitic and recent species as was once supposed.

The Boldérien fauna was considered to indicate a warmer climate than that of the Antwerp Crag (*u. s.* p. 297); but since the publication of Sir Charles Lyell's Memoir, the "Crag Noir," or "Système Diestien" has afforded all the forms of *Oliva*, *Conus*, *Ancillaria*, and *Cancellaria*, from which such conditions were inferred.

The Bolderberg is the only locality where the evidence of a Boldérien system, stage, or subdivision has been met with in Belgium. Of the newer formations of the Rhine valley, those of Grafenberg near Dusseldorf can alone, says Beyrich, be placed on the level of those of the Bolderberg; but he adds that it is very doubtful whether these do not rather belong to the older Sternberg beds or Tongrien; so that, both on purely geological as on zoological considerations, the Boldérien system may be removed from the general series of distinctive geological groups.

Since the above was written, I have met with the following passage by M. Nyst—the result of a comparison of the Edeghem shells with those of the Bolderberg:—"Ce qui nous fait penser que le système Boldérien n'est que la base du système Diestien de Dumont." It is true that the Bolderberg shells agree with those of Edeghem and Fort Herenthals; but inasmuch as the Bolderberg shells have been washed out of older beds, the Système Boldérien, as an accumulation, must necessarily be of *later* date in the Crag series, and not its base or oldest portion.

8. *General Results.*—The study of the Antwerp sections leads to the impression that the vertical dimensions of the whole of the Crag formation there are exceedingly small. From the highest ground (ligne culminante) down to the sea-level, the depth is only 9 metres, and within this is comprised the whole formation, including the Campine sands. As it happens in Suffolk*, so here, where the upper or Scaldésien Crag is thickest, the lower is thinnest; and where the Diestien is thickest, the upper is thinnest, or at times wholly wanting. If the Diestien beds be divided into upper sandy ooze and lower muddy ooze, the sections show that where the first has been removed and "remanié," the resulting Scaldésien beds take the form of "Crag gris;" and that where it has not, there are then yellowish, argillaceous, and gravelly sands. The real difference between the "Crag gris" and the "Crag jaune" of the Belgian geologists is, that the first contains a larger proportion of the "remanié fauna" of the Diestien beds; and although they may, as already stated, have been produced under slightly differing conditions, and in sequence, yet in the horizontal sections they replace one another, and have not an aggregate thickness of 4 metres. If, as

* In the Deben valley the Crag does not exceed 25 feet, and even in the Ipswich district it is of small amount.

was most probably the case, the Scaldésien accumulation was of the nature of a dead-shell sand and gravel-bank, like the "cordons littoraux" of the English Channel and North Sea, and so merely a local condition of sea-bed, the estimate for the thickness of the Crag must be still further reduced: the ordinary minute subdivisions of systematizing geologists are wholly inapplicable to such accumulations as these.

From this it is evident that the Antwerp sections fully satisfy the inquiry as to relative age. The Scaldésien division there is younger than the Diestien, as it has been accumulated over it. So likewise the upper Scaldésien must be younger than the lower; but this is merely relative age in respect of rearrangement. The corresponding conditions on the English and Belgian areas of the Crag sea are the Red Crag and the Scaldésien; both are "remanié" accumulations. The difference which these present in respect of the marine fauna they contain, is not of much amount numerically, and, viewed in detail, it is just such as would arise from the different sources whence each was derived. The Red Crag was from the break up of a neighbouring Bryozoan sea-zone, the Scaldésien from Ooze depths. Any comparison of the fossil contents of the "Coralline Crag" and of the "Crag noir" must be subject to the consideration of differences which result from depth and condition of sea-bed. From the nature of the question, therefore, a percentage calculation for determining relative age is inapplicable with respect to the component parts of the English and Belgian Crag, or even of one part with another of the same series.

The fossils of the Système Diestien are proper to it; and from them may be inferred the condition of that part of the Crag sea for that particular time. The fossils of the Scaldésien beds are wholly extraneous to them, belonging to all regions of depth, and all periods of the Crag formation—from them no guidance in geological chronology can be derived.

III. Conditions of Crag-Sea Area.

By combining the results obtainable from the East Anglian and Belgian Crag beds, some general views may be deduced as to the Crag sea, both physical (1) and zoological (2).

1. *Physical Features.*—Along the lower courses of the Orwell and Deben, and thence towards Orford and Aldborough, the Crag beds occupy an old depression. The greatest extension which the sea had here was by Bentley, Ipswich, and Woodbridge. The Red Crag of these places being a true sub-littoral accumulation.

Corresponding beds, as to age, occur in two other old depressions, those of the Blyth and the Yare. At Yarmouth it may be inferred that there is a considerable thickness of Crag (Prestwich, Quart. Journ. Geol. Soc. vol. xvi. p. 449). Finally, a sea-bed of the same age is seen at Mundesley. In tracing the outline of the Crag sea, it may safely be made to include a rather wide area, about the lower courses of the Waveney, Yare, and Bure.

Rivers discharged at several places, bringing down the land and freshwater shells of the period into the Crag sea, of which forms the *Unio litoralis* and *Cyrena consobrina* are the best guides. On one side of this sea, the Grays beds represent the purely fluviatile or estuarine beds of the great tributary of the Thames valley; whilst the Norwich beds and those of Kelsey belong to the fluvio-marine facies, in connection with the streams or rivers of the Yare and Humber.

North of the East Anglian area the Crag sea is indicated at intervals, as at Bridlington and Stains (Aberdeenshire), and by its fossils over the bed of the North Sea.

In addition to the conditions here given, we have on the English side of the area the Coralline Crag, or Bryozoan facies of its sea-bed.

From near Maastricht the Crag beds extend beneath newer accumulations into Guelderland (Winterswyk, Rekken)*.

The shelly sands which in North Holland occur beneath the Dune-sand, Polder-, and Peaty-beds, are, undoubtedly, of the Crag Period, and the same sea-bed is met with in Segeberg, Lüneberg, and Sylt; but it does not extend eastwards into the Baltic area, and that depression owes its origin to a subsidence or depression of the great Scandinavian mass, the line of which, very probably, is that of the deep-sea soundings, and which accordingly has been taken (*vide* Map, fig. 2).

The Crag sea opened out northwards. On the extreme south its condition is indicated, first, by the great breadth of the sand-zone, extending the whole length of the axis of Artois, and the Ardennes chain; and next by the transport, along a line of coast, of the flint-gravel and shingle, which must necessarily have been derived from the English side of the area. As these materials occur from the basement bed to the uppermost, such a coast-line must have been continued during the whole of the Crag-sea period, as a limit on the South. Structurally, the limitation was dependent on the extension of the axis of Artois, and of our own Wealden elevation. The Sangatte section shows that this barrier was maintained until the close of the Glacial Period†.

At this time the Northern hemisphere presented a broad belt of circumpolar land, and these geographical arrangements influenced the character of the Crag-sea fauna.

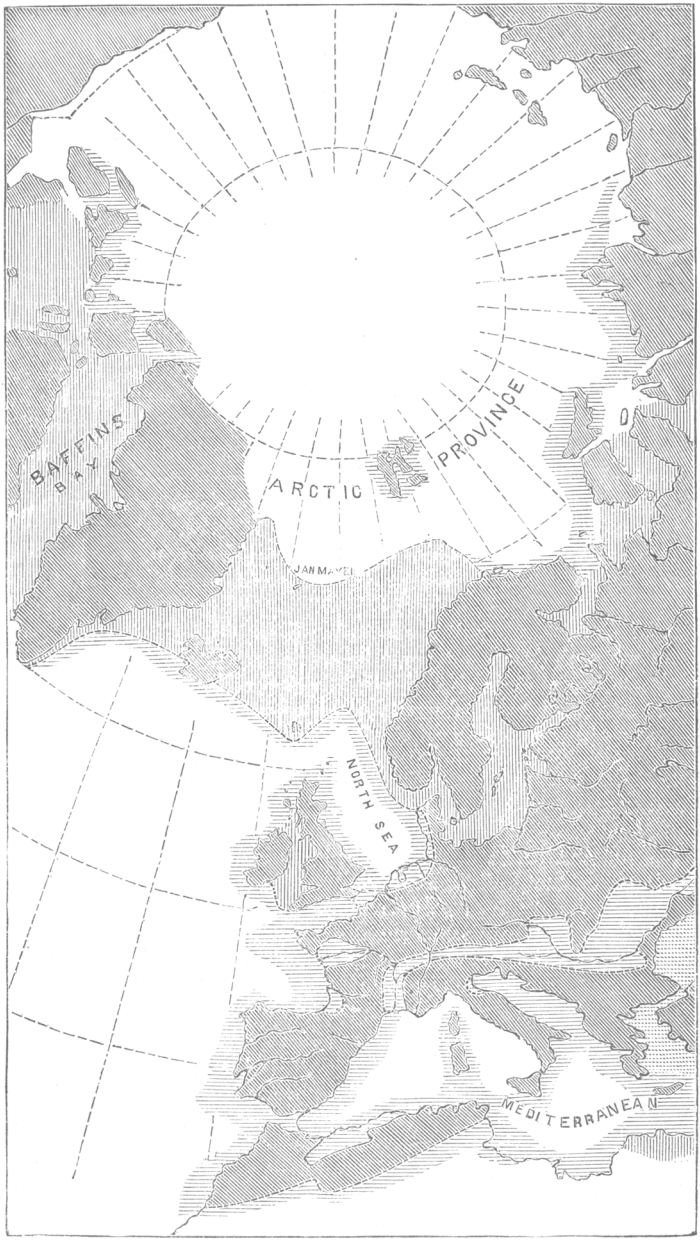
Such a communication as the present does not admit of a detailed analysis of the Crag-sea fauna in respect of its origin, though the materials are amply sufficient, but the subject may be alluded to, inasmuch as the peculiarities can alone be explained by reference to bygone geographical arrangements.

What these must have been is given in the accompanying small sketch-map, which shows why the Crag Molluscan fauna, which is wholly Atlantic, like that of the synchronous sea-beds of Selsey, the Cotentin, the Faluns of Touraine and Bordeaux, &c., should differ from these last to so great an extent. The Crag-sea area included the representatives of two distinct Atlantic provinces, the Boreal or

* Staring. Bodem van Nederland. vol. ii. p. 284.

† See Nat. Hist. of European Seas, p. 286, and Map II.

Fig. 2.—*Map showing the extent of the Crag-sea area.*



The vertical tint indicates ancient land.
The horizontal tint indicates ancient seas.
The inclined tint indicates present land that has not been submerged during the Crag period.

North Atlantic, both Eastern and Western, and the Southern or Lusitanian.

The greater extent of circumpolar land would exercise a great influence on the course of the North Atlantic Ocean-current, and the general temperature of its waters, from 55° to 65° N. lat., would have been much higher than at present. Under these conditions there would have been an extension eastward of the transatlantic littoral fauna, whilst at the same time the temperature would encourage a more northern range of Lusitanian forms.

The marine beds of the Tagus, of the Adour, of the Loire, and of the English Channel, which were indents from the Eastern Atlantic, have this common characteristic, that the fauna of each, so far as living species can guide us, is more southern than that of the corresponding coast at present; and this order of difference is progressive from south northwards, so that whilst the beds of the English Channel have Lusitanian relations, those of Touraine, and to a greater extent those of Bordeaux* and the places south connect themselves with the West African marine fauna.

2. *Zoological Features.*—The Crag fauna of the English area is incomplete, so also is that of Belgium; taken together, they form a completer marine fauna, representing a greater range of sea-zones.

Various comparisons have been made for percentage calculations between the shells of the "Crag jaune" and the "Crag gris," and again between those from the Scaldésien generally and the "Crag noir" or Diestien.

It will not be necessary here to reproduce the whole of M. Nyst's latest lists, given in the work of Omalius; for the first comparison the differences in the first two lists will suffice. It might be expected, from the extent to which the Diestien beds have been denuded, that the whole of their proper fauna should be met with in the Scaldésien beds which resulted from that change; it is so to a great extent, but it is also evident on the spot that it is mainly the stronger shells which have endured removal; besides this, in the Antwerp district, where alone true Scaldésien beds occur, the Diestien beds on which they lie have not been denuded quite so low as the second life-zone (Edeghem, Fort Herenthal), in which the deepest water assemblage is met with.

It would appear, so far as collections at present indicate, that of 143 species enumerated by M. Nyst, there are some in the "Crag jaune" which are scarce or wanting in the "Crag gris" (Tab. I.), and in the latter, some wanting in the other (Tab. II.); but the lists may be somewhat reduced by removing such species as are known only as Belgic at present. *Paludestrina? terebellata*, N.; *Turbinella internodula*, N.; *Eulima lævis*, N.; *Natica proxima* (a doubtful species); *Cancellaria minuta*, N. (un seul individu); *Pleurotoma turrifera? P. costata*; *P. histrix*; *P. Woodii*; *Murex tortuosus*, M. C.

* The boundary of the Crag sea is so traced on its eastern side as to include the Upper Kainozoic formations near Cassel, Luithorst, Freden, and Dichholtz; these are all in the latitude of the Belgian crag, and along the courses of the Weser and Lesse.

(a deformity of *M. erinaceus*); *Trophon striatum*; *Cerithium Woodwardii*, N.; leaving for Tab. I. 16 peculiar species.

Table I.

(*The species with an asterisk occur in the Edeghem zone.*)

Rissoa.		
vitrea, *Mont.*	Wt. Brit. to N. Spain, 4–40 faths.	Bryozoan Crag.
Turbo.		
*plicata, *Mont.*	Brit. and Lusit. 10–60 faths.	Bry. Cr. Subap.
Actæon.		
*Noæ, *M. C.* = A. tornatilis	Boreal and Lusit. 40 faths.	Bry. Cr.
Tornatella.		
conoidea, *Brc.* = T. plicata, *Mont.*; fide Alder, *Lovén.*		
Natica.		
Sowerbyi, *N.* = catenoides = nitida	Boreal and Lusit., litt., 40 faths.	Red Cr.
Trochus.		
papillosus, *Da C.* = similis, *M. C.*	Sth. Brit. to Lusit. litt., 50 faths.	Red Cr. *T. similis* in "Crag gris."
cinerarius, *L.*	Boreal to Sth. Brit. litt., 20 faths.	Red Cr.
Cancellaria.		
costellifera, *M. C.* = viridula	Greenland Eur. Boreal, 10–50 faths.	Bry. and Red Cr.
umbilicaris, *Brc.* = cancellata = similaris	Lusit., W. African, 4–25 faths.	
Pleurotoma.		
*turricula, *Brc.* non Bellatur.		Red Cr. It. Sic. (Bolderberg).
elegans, *Scac.* = attenuatum, *Mont.*	N. Lusit. to Mediterranean, 6–25 faths.	Touraine (*Pl. incrassata*, Dej.).
gracilis, *Scac.*	Brit. to Lusit., 8–30 faths.	
Trophon.		
scalariforme, *Gould* = clathratum, *L.* fide Lovén.	Boreal and Brit. litt. to 100 faths.	Red Cr.
tetragona, *M. C.* = capillus, L.	Boreal to N. Lusit., 5–10 faths.	Red Cr. (a deformed variety).
Cerithium.		
punctatum, *Woodw.*		Red Cr. Tour. Subap.
Nassa.		
prismatica, *Brc.*	Lusit., 20–40 faths.	Bry. and Red Cr. Tour. Subap.
Buccinum.		
crassum, *N.* = Dalei, *M. C.*	Boreal and Lusit., 81 faths.	Red Cr.
Patella.		
virginea, *Müll.*	Boreal to Lusit. litt., to 50 faths.	Red Crag.

In like manner the following may be deducted from the list of "Crag gris" shells:—*Scalaria Woodiana*, N.; *Turbinella similis*; *Cerithium sinistrorsum*; *Nassa flexuosa*; *N. crassilabra*; *N. contorta*; *Pileopsis militaris*, Mont. (a spurious West-India shell, F. and H. ii. p. 462); *Dentalium semiclausum*; leaving 16 peculiar species, viz.:—

Table II.

Pyramidella.		
læviuscula, *Sw.*		Bry. Cr. Tourain. fal. jaune. Bord.
Scalaria.		
clathratula	S. W. Brit. to Canaries, 10–80 faths.	Bry. Cr.
Actæon.		
*levidensis, *Sw.*=tornatilis, *L.*=Noæ, *M. C.*	Brit. to Spain, litt. to 40 faths.	Bry. and Red Cr. (in tab. i.).
Ringicula.		
*buccinea, *M. C.*=auriculata, *Mont.*	Lusit. 4–60 faths.	Bry. and Red Cr. Bord. Subap.
Trochus.		
similis, *M. C.*=papillosus	W. Brit. to Canaries	also in tab. i.
Kickxii, *N.*=Adansonii, *Payr.*	Lusit.	Bry. and Red Cr.
Robynsii, *N.*		
conulus, *L.*=zizyphinus, southern form of	Lusit. litt. to 40 faths.	Bry. Cr.
Margarita.		
? monilifera, *N.*=maculata, *Sw.*		Bry. Cr.
Pleurotoma.		
*intorta, *Brc.*		Red Cr. Dax. Subap. (Steuvenberg).
Trophon.		
alveolatum, *M. C.*		Bry. Cr. com. Red Cr.
antiquum, *Müll.*	Boreal to W. Lusit. and Med.	Cr. passim.
muricatum, *Mont.*	Brit. and Lusit. 12–50 faths.	Bry. and Red Cr.
Pyrula.		
*reticulata, *Lam.*		Br. and Red Cr. Tour. Subap.
Nassa.		
*granulata, *M. C.*, var. of incrassata	Boreal and Lusit. litt. to 50 faths.	Bry. and Red Cr.
Cassidaria.		
*bicarinata, *M. C.*=echinophora	Lusit. 6 faths.	Bry. and Red Cr., rare.
Pileopsis.		
obliquus, *Sw.*=ungaricus, var.	Brit. and Lusit. 15–30 faths.	
Dentalium.		
costatum=dentale, *Lin.*	Lusit. 2–30 faths.	Bry. and Red. Cr.

The Conchifera from the "Crag jaune" and "Crag gris" are the same; the differences are solely in respect of the gasteropods. The distribution in depth of the living analogues of the Crag conchifers will satisfactorily explain this; and the only other inferences which these tables suggest are, 1st, that the species generally indicate a greater depth of water, as their life-zone, than that of remanié Scaldésien beds in which they occur; and, 2nd, that these deeper zones of the Crag-sea had very decided southern or Lusitanian relations.

M. Nyst is of opinion that the marine fauna of the lower Diestien beds (Crag noir) is more nearly allied to that of the Faluns of Bordeaux, Piedmont, Sicily, and Austria, than that of the Scaldésien Crag. This view is hardly supported by a consideration of the 25 species of Conchifera which occur in the Edeghem and Fort Herenthal zone. As the product of the shallower-water sea-zones which contributed the Scaldésien fauna, shows decided southern relations, the deeper-water zones would necessarily show a like relation somewhat more strongly, from the more uniform conditions which obtain there. This is just what happens now. This impression as to the Falunien facies of the lower Crag is very likely to suggest itself, from the presence of corals such as *Stephanophyllia*, *Flabellum*, and the marked preponderance of such genera as *Cancellaria*, *Fusus*, *Pleurotoma*, *Conus*, many of which are so very like Barton and Rupellien species as to give an even older aspect to these beds. All the Diestien species are, however, distinct, and these resemblances are good illustrations of that system of representation which is to be observed in respect of the products of like conditions and zones of depth of every geological period.

M. Nyst's list of Edeghem shells may be reduced from 145 to 130 in respect of uncertainties; of these 47 are known as living. This gives a seemingly larger proportion of unknown to known forms than is the case with the Scaldésien Crag. The question which arises is, whether this difference is connected with relative age,—whether it is any proof that the Edeghem beds are of greater antiquity than the Scaldésien. Geologists have so considered it.

The 47 species above referred to are as follows,—L. signifying Lusitanian province, Br. British, B. Boreal.

Table III.

Chemnitzia similis, *Forbes*. L.
Pyramidella plicosa, *Bronn*. L.
Odostomia plicata, *Broc*. B. & S. L. 10–70 f.
Actæon tornatilis, *Lin*. B.–L., 3–60 f.
Ringicula buccinea. L., 4–60 f.
Natica millepunctata, *Lin*. L. litt.–40 f.
—— Josephinea = Olla. L., 8–12 f.
Cypræa pyrum, *Gm*. L., uncertain.
—— Europæa, *Mont*. B. & L., litt.–20 f.
Oliva flammulata. West Afr.
Mitra fusiformis, *Broc*. L.
Aporrhais pes-pelecani, *Lin*. B.-L., 100 f.
Pleurotoma intorta, *Broc*.
Nassa incrassata, *Müll*. B.–L., litt.–50 f.
Cassis Saburon. L.–W. Africa. 8– ?.
Calyptræa sinensis, *Lin*. S. Br.–L., litt.–10 f.
Crepidula unguiformis. L.
Emarginula fissura, *Lin*.
Dentalium entalis, *Lin*. L., 2–200 f.

TABLE III. (*continued*).

Bulla lignaria, *Lin.* B.–L., litt.–40 f.
—— cylindracea, *Brug.* B.–S.L., litt. –90.
—— acuminata, *Brug.*
—— conuloidea, *Wood.*
—— utricula, *Broc.*
Vaginella depressa. Lusit. latitudes.
Spirialis rostralis. ,,
Pholas papyracea. S. Br., litt.–20 f.
Solen ensis, *Lin.* B.–L., litt.
—— strigillatus. L., litt.–10 f.
Saxicava arctica. Litt.–160 f.
—— rugosa. Br. & L., 6–20 f.
—— fragilis.
Syndosmya prismatica. B.–L., 3–100 f.
Leda pygmæa, *Phil.* E. & W. B., L., 25–50 f.
Venus rudis, *Poli.* L.
Venus chione, *Lin.* S. Br. & L., litt. 40 f.
Corbula gibba, *Oliv.* B.–L., 5–30 f.
Cyprina Islandica. B. & Br., 5–80 f.
Mya ferruginosa. N. Br., L., 3–80 f.
Axinus sinuosus. B.–L., 8–80 f.
Lucina borealis. B.–L., litt.–80 f.
Pectunculus glycimeris. 10–50–100 f.
Modiola marmorata, *Forbes.* B.–L., litt.–40 f.
Pecten tigrinus. B.–L., 10–100 f.
—— Sowerbyi.
—— pusio. Litt.–90 f.
Anomia ephippium. B.–L., litt.–160 f.

It is evident from the foregoing list that the Edeghem fauna is referable generally to a much deeper bed than the Scaldésien. This consideration by itself shuts out such comparisons as have been made; things so unlike as the assemblages of fossil shells from very different ranges and conditions of sea-bed can only be compared for the purpose of obtaining a knowledge of what those depths were. Our acquaintance with the distribution of marine species over deep-sea beds is as yet imperfect, but we know that it has its peculiar facies; and geologists have not sufficiently regarded this, hence much erroneous generalization. It is well observed by Mr. J. G. Jeffreys*: "It is obvious that negative evidence of the occurrence of any species (and especially of those which inhabit deep water) in any given area of sea is inadmissible; and naturalists do not differ from logicians or lawyers in rejecting such evidence." The peculiar forms of the "Crag Noir" could not possibly occur in Scaldésien beds, in respect of their conditions of existence, though they should have been inhabitants of the same sea at the same time. The occupation of the North Sea area by the true Crag fauna was not of lengthened duration, nor does the fauna itself indicate that change in time which is so clearly to be traced in the accumulations of long periods, whether Palæozoic, Secondary, or Nummulitic. The Crag is not a formation, but merely a single stage in the Kainozoic series.

3. *Denudation.*—The extent to which portions of the rock-formations have been removed, and the character of the surface denudations, are amongst the most interesting of the geological phenomena of Belgium. Such is the denudation which occurred antecedently to the Cretaceous series, and again before the Nummulitic. For the present I would call attention to that which followed the completion of the Crag-sea beds, because the evidence is very striking, and has a bearing on some views recently put forward by English geologists, to the effect that there is evidence of continuity and unbroken marine conditions, from the Suffolk Crag upwards into the Boulder-formation.

* Ann. and Mag. Nat. Hist. ser. 2. vol. xvii. p. 168.

Abundant illustration might be derived from our own East Anglian area to controvert this view, and prove that a great break and a long interval of time intervened between the Crag beds and the Boulder series, during which the North Sea was a terrestial area. The Belgian evidence bears most on the length of the interval or the lapse of time.

Over the whole of the broad area of the Scaldésien, Diestien, and Boldérien systems of the map of Dumont the formations are severally at present represented only by isolated masses or patches: away from Antwerp, and as the country rises southwards, these occur as the cappings of hills, or ridges. These sandy strata, which perhaps may have admitted of easy denudation, must, from their composition, have extended from place to place; and what now remains is not a thousandth part of what once was. In the case of the valley of the Dyle, by Louvain, the denudation has extended down to the Bruxellian beds of the Nummulitic series to a depth of 100 feet; and the completeness with which all the materials have been removed is well seen in the slope of the hills, as also on the level, along the railway cutting. The denudation about the Bolderberg is of nearly like amount as at Louvain.

In these cases, as in that of Schelle, the löss and Campine sands were spread out after the denudation of the Crag-sea beds; and as these belong to the later portion of the glacial period, the denudation of the country must be referred to some intermediate stage *.

4. *Variation in Depth.*—The movements of elevation and depression of the water-level which the North-Sea area experienced during the Crag period, are very simple, and so far are in harmony with the apparent short duration of that period.

The chalk flints, and the Septarian blocks derived from the subjacent Rupellien beds, which also occur elsewhere at the base of the Diestien system (Edeghem) are the remains of shallower water conditions than such as followed, or are proofs of depression.

Both on our own Suffolk area, as on that of Belgium, the change indicated from the Red Crag to the Bryozoan, and from the Scaldésien to the Diestien, was of diminished depth, or is evidence of elevation. Its subsequent emergence was in the same direction.

The earliest condition of the Crag-sea area here indicated is supported by a study of the list of shells given by Mr. Nyst, as obtained from the gravel bed at the base of the Diestien system at Edeghem †.

The Faluns of Touraine have experienced an amount of denudation such as is presented by the Belgian Crag. M. d'Orbigny has made this remark with respect to the first-named formation, that removal to so great an extent should have happened to synchronous accumu-

* Considered with reference to a line of section from Fort 2. towards the North citadel, the whole of the Crag series has been planed off from N.E. to S.W., so that lower beds come to the surface; and this has happened twice:—1. during the Crag period, when by diminution of depth the deeper sea-bed was denuded, and covered up by the Scaldésien; 2. when its general surface was eroded and removed.

† Bull. de l'Acad. Roy. de Sciences de Belg. sér. 2, vol. xiii. p. 29.

lations, though somewhat distant, is curious as a coincidence, but in both cases it perhaps may be explained by the inconsiderable thickness, as also the loose materials, of the two formations.

IV. Newer Kainozoic.

1. *Cailloux Ardennais.*—In the sections about Antwerp we seldom failed to detect the thin line of quartz pebbles, to which the Belgian geologists have called attention, as underlying the Campine sands. They were here very small, few in number, but perfectly rounded; they have been derived from the quartz veins of Palæozoic rocks. These are the *Cailloux Ardennais* of M. Omalius, and came originally from that ridge or axis. As compared with other places to the north and east they have evidently at Antwerp reached their extreme limit of dispersion*.

In the section at Schelle the quartz pebbles serve to separate the Campine sand from the older sandy accumulation; but for these the line might easily escape detection, so closely do the surface-sands resemble the Crag sands beneath. At this place it is evident that Campine sand has been spread over the country since the denudation of the Crag, as at either end of the section it rests on the surface of the Rupellien clay, and in this position the quartz pebbles are mixed up with the chalk-flints which originally occurred at the base of the Crag, and still remain *en place*.

About Hasselt the quartz pebbles occur in great abundance and of large size; with them are chalk-flints, somewhat less water-worn. Towards Maestricht the quartz gravel, as seen in the railway banks, underlies a considerable thickness of argillaceous sand; the accumulation increases in thickness as it approaches the line of the valley of the Meuse, ending abruptly at a considerable elevation above the present level of that river, which has deepened its course out of these gravel beds.

From Hasselt towards the Bolderberg the plain presents a continuous spread of siliceous sands, overlying coarse quartz shingle with flints. These sands and gravels end off at the base of the Bolderberg ridge.

Quartz pebbles, beneath löss, occur in the high ground above Liege on the north, as also north of Namur, both on the surface of the Carboniferous limestone, beneath the löss, as also in the wide fissures of those rocks. Wherever patches of Nummulitic sands occur (Bruxelles beds), the quartz shingle separates the older sands from the löss.

At Dinant, in the Condroz, the quartz shingle occurs everywhere over the surface on the high ground; and lastly we met it in the fissures which have been enlarged into the caves of Furfooz.

These caves occur in a mass of Carboniferous limestone overlooking the river Lesse, a tributary of the Meuse, and taking its rise in the high ground of the Ardennes, near St. Hubert.

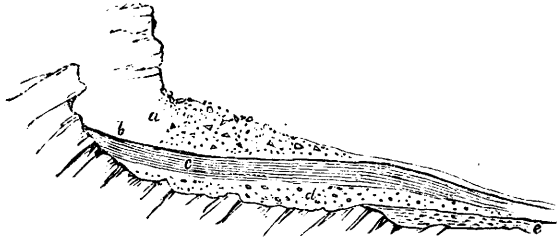
* I did not notice any quartz pebbles on the summit of the hill east of Louvain.

In the first cave, which is established on a line of fracture of the limestone, enlarged by the passage of water, the general order of the accumulation which occupies the lower portion, is as follows (as traced for me in my note-book by M. Dupont; a layer of "argile smectique" of M. Dupont, next to the limestone rock, is merely the product of the decomposition of the impure limestone):—

1. A thick accumulation of limestone talus, from the face of the cliff.
2. Loamy sand.
3. Rounded quartz pebbles.

Beds 2 and 3 extend back into the cave, sloping upwards.

Fig. 3.—*Section of the deposits at the entrance of the Furfooz Cave.*



a. Angular débris—Argile à blocs anguleux.
b. Stalagmite.
c. Sandy Clay. *Bear* and *Reindeer*.
d. Shingle—Cailloux Ardennais.
e. Fluviatile sands. *Beaver*, &c.

In the second cave, which is lower in the cliff, there is outside, an accumulation of debris, beneath which, and passing into the cave, are

1. Sandy and marly beds, in which are a few angular blocks, such as may have fallen from above whilst the bed was forming. Lines of successive accumulation.
2. Bed of quartz pebbles, in layers, sloping outwards.
3. Sands, bedded, like river sand; remains of beaver.

The upper level of the pebbles in the second cave* is wholly below that of the pebbles of the first cave; this circumstance entirely disconnects the shingle from any alluvial action of the Lesse. Even were the two accumulations at the same level, and had they been lodged in these caverns by a river flowing down the valley at a very high level, the arrangement of the pebbles would probably have been the reverse of what it is.

The materials of beds 1 and 2 seem to have been introduced from above; and the only portion of the accumulation which has the character of a fluviatile deposit is the sandy bed No. 3. Numerous specimens of the shingle are scattered over the upper platform of the

* Ten metres above the level of the river.

limestone mass in which these caves occur, and show that the dispersion of the pebbles belongs to some broader agency than river-action; whilst bed No. 3, with the remains of beaver, indicates that antecedently to these conditions the valley of the Lesse was much in the same state then as it is at present, or a line of river-drainage.

Bed No. 1 of the caves may be referred to the period of the löss, and

Bed No. 2 to the *Cailloux Ardennais*, which here consist of large coarse shingle.

There are no remains of any shingle banks at high levels along the northern slopes of the Ardennes, which have been produced at any Secondary, Nummulitic, or Tertiary period. Nor has the Palæozoic series of Belgium been the source of any shingle met with in the Nummulitic series of that country, the pebble beds in which are wholly of chalk-flints. At low levels, as in the Tournay district, there are great accumulations of quartz shingle at the base of the Cretaceous series (Tourtia); but this is the direction in which the *Cailloux Ardennais* are not met with. These Ardennais pebbles, which have been distributed at a definite stage of the Glacial Period, could not have been formed then, inasmuch as the region whence they have been derived was not submerged, and the only other source which suggests itself is that remarkable shingle bank which underlies the Devonian series of Belgium, in the Condroz, from Pepinster to Nassogne and Couvin, along the Ardennes, namely, the "Poudingue de Burnot" of Dumont.

2. *Glacial Drift.*—Detrital beds are in places interposed between the Campine sands and the Crag-formation. We were conducted by Captain Cocheteux to an interesting section exhibited in the outer ditch of Fort No. 4. The beds consisted of loose sands, loamy sand, ending with somewhat coarse sands; at the base were pebbles of white and black flint, and occasionally flint flakes (naturally formed); there were also small white quartz pebbles; with these were bones of Cetaceans, sharks' teeth, Crag shells, and other spoil from older Tertiary formations. All this material may be called local, such as might have been derived from beds at no great distance; but there were also many large ragged unworn chalk-flints; these occurred for the most part in the upper portion of the accumulation.

The Scaldésien beds were much reduced in thickness at this spot, so that the Campine sands and underlying detritus lay partly on green Diestien beds; these last were also much eroded, and blocks of the more tenacious portions had been cut out and caught up in the detritus; the whole surface was scored out, in one case to a considerable depth.

This accumulation in all its circumstances was very like some of the lower drift-beds of Suffolk; and enough was to be seen at this place to warrant a reference to that stage of the East Anglian marine drift-beds, which are represented by the sandy gravel-beds below or beyond the margin of the Boulder-clay.

Rocks of Scandinavian origin have not been met with beneath the Campine sands of this part, or indeed of any part of Belgium, nor

did any occur to us. The transport of northern detritus southwards, both over our own area and that of northern Europe, took place during the later Glacial period, and does not appear to have extended to this part of Belgium.

3. *Campine Sand.—Sables de la Campine.*—In every section which we saw about Antwerp, there was to be observed at the surface a very uniform layer, which has been referred by the Belgian geologists to that very remarkable sandy formation covering so large a district on the confines of Belgium and Holland, the Campine, or Kempenland, whence the "Sable Campinien" of Dumont.

About the city of Antwerp this accumulation seems to be thickest where the ground is highest, as outside the Malines Gate, in the direction of the roads to Schelle and Boom by Fort No. 7. The cuttings going on in this direction, beyond the "Enceinte," show good sections, six feet and upwards in thickness, of fine sand; though where the soil is moist, the beds have much the appearance, and even character, of some of the buff-coloured Löss of Brabant.

It is noticed by Dejardin that the limited area on which the city of Antwerp stands is bare of this formation: "Cette ville a dû former une île dans la mer Campinienne."

No fossil remains of any kind have ever been met with in this accumulation.

These sandy beds extend from Antwerp over the Campine, and thence into North Holland; they form for the most part a barren tract, which the Belgian Government has striven hard to bring into cultivation, with only partial success, owing to the extreme lightness of the sands, which are easily blown about, and are constantly shifting.

The superficial sands of Hasselt, towards the Bolderberg and Beverloo, belong to the Campine formation.

The manner in which this covering of sand follows the rise of the country from north southwards, overlapping all older formations, and its inconsiderable thickness compared with its great superficial extent, forbid the supposition of accumulation by water, or of a "Mer Campinienne." On the other hand, the aspect and uniform composition of these sands, the manner in which, when dry, they are lifted about by the wind, suggest that they have originated as Dune-sand, which has travelled inland from the coast-line of some former condition of the North Sea.

The age of the "Campine Sands" has often been discussed. They are now* very generally referred by Belgian geologists to the "Système Diluvien."

Though the true Campine sand has never been found to contain animal remains of any kind; it *overlies* a surface with *Elephas primigenius*. It is certainly older than the Polder-mud deposits, and

* M. Omalius, on the consideration that at Antwerp the Campine sands conform to the Crag, is disposed to refer them to that formation. The Antwerp sections show very clearly that those sands have been spread out since the general surface of the Crag sea-beds has been extensively denuded; occasional conformity is a mere accident.

their equivalents, the peat-growths. However, there may still be a great range between these extreme periods.

In like manner the Löss *overlies* the gravel beds in which the fragmentary remains of the great Pachyderm fauna occur.

Both the Campine sands and the Löss are subsequent accumulations to the Ardennes quartz pebbles; but the occurrence of these pebbles at the base of both does not necessarily connect them with either, but it suggests that these two accumulations must be nearly of the same age; and such, it seems, was M. Dumont's latest view.

The presence of quartz pebbles in the detrital beds at Fort 4 supplies another link to the chronology.

To what extent the surface of Belgium was submerged during the Glacial Period cannot easily be determined, owing to the thick coverings of subsequent date. Antwerp probably marks very nearly its marginal line; and this agrees very well with the range of the true "Boulder Formation" with northern rocks extending from Arnheim to Groningen and into Hanover. If the fine sands (Zand diluvium) which in North Holland form the overlying portions of the Boulder-formation, be connected with the Campine sands of South Holland and Belgium, they present a line parallel with that of the Boulder-coast; and then, as all their characters would indicate, they might be the blown sands from the marginal beds of that period, and of that stage of it when the Northern Hemisphere began to re-emerge—a process which took place from south to north.

4. *Löss.*—During our visit we came upon good illustrations of the superficial layer known in Belgium as the "Limon de Hisbaye."

It occurs at considerable elevations to the north of the Sambre and Meuse, along the line from Liege to Namur and north of Charleroi; but it does not rise to corresponding elevations on the south of those rivers, on which side, though of great thickness, it is at low levels. During the excursion of 1852 we saw a thick accumulation, with *Succinea oblonga* and *Pupæ*, at Audregnies; and this year I saw good sections of it, both above Namur and about Gembloux. From Liege westwards the Löss may generally be separated from any beds it may overlie by the presence of a seam of quartz pebbles.

The land-shells cited above are not commonly met with, but they increase in frequency towards the line of the Ardennes. The Löss in its arrangement, when in great masses, shows that it has been deposited by water. The "Sable de Campine" and the "Limon de Hisbaye" form, as was long since said by M. Omalius, the "manteau de la Belgique." The two accumulations have never been noticed to overlap, they rather pass into one another, along a line from west to east, the sands being to the north and the fresh-water Löss to the south. The opinion of M. Dumont, that they were somewhat synchronous, has been alluded to.

5. *Polder Mud.*—The Polders, or brackish-water mud-flats of the low coast of Belgium and Holland reach up on either side of the Scheldt as far as Antwerp. This is the most recent sedimentary formation we saw, consisting of blue mud, as may be seen in the

banks of the Scheldt and on the slopes of the broad ditch of the north citadel, where it is full of small shells of the common *Cardium* and *Scrobicularia*; land and fresh-water shells also occur. The whole district of Zeeland, as the name implies, is of this sea mud. The "argile d'Ostende" is of the same age, with the same shells. Along the whole of this coast the Polder-mud passes below the present sea-level, as may be seen occasionally off the Ostend coast at low water, where the compact mud resists the action of the sea. The composition of the Ostend Polders differs a little from that of those to the north, in the large proportion of calcareous matter, which has probably been derived from the waste of the chalk. The Zeeklei of the North Holland coast is also Polder.

The Polder formation indicates a change of level, or of relative elevation of the land, of small amount, but of remarkable uniformity, from Ostend to the coast of Hanover; it also corresponds with alluvial accumulations and mud flats to be met with in suitable situations about our own coasts, whether of the English, Irish, or German Seas.

The Dunes, or great sand hills, along the coast south-west of Ostende, as well as those of North Holland, have all been accumulated on the Polder mud, and since the change of level.

The Polder mud differs from the accumulations of the present coast-line of Belgium and Holland, which consist of fine siliceous sands, and must have been deposited in brackish water lagoons, into which the rivers discharged, and which were separated from the open sea by sand-banks.

6. *Terrestrial Surface.*—From specimens in the Antwerp Museum it would appear that when a breach is made in the Polder mud, a terrestrial surface with large trees is exposed. The like was met with in the excavations for the new docks, consisting of rich peat. This old land-surface is to be seen at low water, beneath the Polder mud. In like manner it underlies the Zeeklei of Holland; and much, probably, of the surface of peat or old fen of Belgium and Holland (Hooge Veenen), above the level of the Polders, is merely an upward and inland extension of the same surface of plant-growth.

In the Antwerp collection are some Mammalian remains, which were obtained at West Capellen, the extreme seaward point of the Island of Walcheren, when the sea had made a breach there. Mr. Busk recognized the perfect lower jaw, tibia, and other bones of a young *Elephas primigenius*, also two teeth of *Rhinoceros tichorhinus*.

Belgium for the most part belonged to that particular zone which was a limit to the area of the last great north circumpolar depression; and its superficial geological phenomena belong to the subaerial agencies of the glacial period; such are the "Cailloux Ardennais" and the Löss, as well as the Sables de Campine.

At some time antecedently to that of greatest submersion, the line of Artois, and of the Ardennes (like our own Wealden), had been placed at a much greater elevation than at present, with respect to Brabant and the Hesbaye; the position of the Löss shows this. The surface may have been brought to its present levels partly by de-

pression of the line of the axis of the country, partly by the elevation of the district north of it (Brabant and Hesbaye); but had the valley of the Meuse existed as it is now, at the time of the dispersion of the Ardennes pebbles, or of the accumulation of the Löss, it must necessarily have been choked by them; but the very reverse is the case, and that valley (which is a line of fracture) may be safely pointed out as the line of one of the changes of relative level which have happened since the later Glacial Period.

Should the supposition be correct as to the source of the Ardennais pebbles, the disintegration of the surface by which the pebbles of the "Poudingue de Burnot" were set free along the slopes of the Ardennes, must be referred to the period of greatest elevation, of cold, and great river-courses; the larger and coarser accumulations connected with the line of the Meuse from Liege having been brought down by the Ourte and the Amblève. The quartz pebbles of the line of the Meuse having come from the upper sources of the Lesse, are of less size, inasmuch as the streams are smaller.

In like manner the Löss was the deposit of the turbid waters which, at the break up of every winter, periodically accumulated over the low area (now part of Brabant and the Hesbaye) between the slopes of the Condroz and the Dune sands from the coast.

Viewed in this light, the Belgian area seems to offer some very interesting illustrations of the varying conditions of the last great Glacial Period.

7. *Sangatte Beach.*—Before leaving the geological phenomena belonging to this period, I would briefly call attention to a few points connected with the section of the coast from Sangatte,—a section of very great interest, relative to which Mr. Prestwich has recently given a second paper, and which we visited together.

At the base of a vertical cliff of chalk there is a coarse shingle beach, and a little in advance of it are horizontal sands, with a few flint pebbles; these are of marine origin, and the section corresponds with that at the base of the subaerial beds at Rottingdean and Brighton.

Above the marine sand and shingle is a black band, occasionally very strongly marked, the evidence of an old terrestrial surface. The level of the old coast-line was very little above the present, but subsequently there must have been a rise, to what extent cannot here be determined; but the subsequent accumulations all indicate subaerial conditions.

Above all are blown sands; next below these, near Sangatte, is an angular débris of flints, with blocks of ferruginous sandstone, following the coast-line; layers of Löss succeed, with occasional flints, also land shells. The thickness of the beds of sandy Löss and of loam (as of the angular materials) increases in the direction of the chalk hills, and at last the mass passes by alternations from earthy Löss to chalky marl, and seams of chalk nodules; these become a chalk rubble; and angular blocks of chalk of considerable size, have been accumulated against and at the foot of the old cliff, and above the marine beds.

All these materials have been swept off the northern slopes of the chalk hills. The thickness of the accumulation is remarkable, as also is the distance to which the materials have been carried forward; and may serve as a measure doth of the duration and intensity of the Glacial Period.

The great plain of flint shingle which may be observed about Calais, and extending inland, belongs to the same level as that at the base of the old cliff, and is probably of the same age. The beds of chalk-marl which underlie the peat in the direction of St. Omer are also of the age of the Löss of the Sangatte section; and the details of that section may be assumed with respect to the base of the chalk range on the north, so far at least as the shingle extends.

The character of the subaerial glaciation of the south slopes of the Ardennes and axis of Artois is the same throughout; and if the phenomena are on a broader scale when they are in connexion with the higher parts of the range, the history of the period is perhaps more completely indicated in the Sangatte section.

February 7, 1866.

Thomas Belt, Esq., Prince of Wales Mine, Dolgelly; Thomas John Bewick, Esq., Haydon Bridge; Thomas Forster Brown, Esq., H.M. Deputy Gaveller of the Forest of Dean, Coleford; John F. Campbell, Esq., of Islay, Neddry Lodge, Kensington; William Cory, Esq., 4 Gordon Place, W.; Anastasius Gowdas, M.D., Athens; William Frederick Cowell Stepney, Esq., 9 Bolton Street, Piccadilly, W.; and John Young, M.D., Geological Survey of Great Britain, Jermyn-street, S.W., were elected Fellows.

The following communications were read:—

1. *On the* Formation *of* Lake-basins *in* New Zealand.

By W. T. Locke-Travers, Esq.

[In a letter to Sir Charles Lyell, Bart., F.R.S., F.G.S.]

In consequence of reading a notice in the 6th volume of the 'Intellectual Observer,' p. 461, of what I presume to have been a communication from Dr. Haast to the Geological Society, in reference to the formation of lake-basins in this country, and of my inability to subscribe to the views of Dr. Haast, I venture to submit my reasons for dissenting from them.

My observations have been chiefly directed to the great mountain-system named by me the "Spencer Mountains," which occupies the centre of the block of country constituting the Provinces of Nelson and Marlborough, in the Middle Island. The highest point of the range is Mount Franklin, estimated at 10,000 feet, whilst around it are several lower peaks, averaging from 7000 to 8000 feet.

A number of the largest rivers in the northern part of the island