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The quantity of benzyl bromide has therefore, much increased but the proportion *ortho-para* has kept fairly well unaltered.

For further particulars as to these researches VAN DER LAAN'S original dissertation should be consulted. An article by him on this subject will also appear, shortly, in the "Recueil".

Amsterdam, Sept. '05. Chemical Laboratory of the University.

**Geology.** — "*On fragments of rocks from the Ardennes found in the Diluvium of the Netherlands North of the Rhine.*" By Prof. A. WICHMANN.

(Communicated in the meeting of November 25, 1905).

Ever since the 18<sup>th</sup> Century, the attention of geologists has been drawn to the boulders scattered about our heathgrounds and in opposition to the various and oftentimes curious theories started to account for their presence there, A. VOSMAER then already expressed the opinion that they had been transported from elsewhere by "A Mighty Flood".<sup>1)</sup> A little later, A. BRUGMANS<sup>2)</sup> and after him S. J. BRUGMANS<sup>3)</sup> pointed to Scandinavia as the original home of these erratics; but this view, though shared by a few other scientists, was not generally adopted until after the publication of J. F. L. HAUSMANN'S treatise<sup>4)</sup>. It seemed then as if the only question still remaining to be solved, was in what way and by what road this transport had been affected. Little or no thought was given to the possibility that other countries might be also accountable for their origin.

It was not until 1844 that W. C. H. STARING, whilst investigating the nature of these boulders, discovered that at least those composed of sandstone and quartzite, were found as well in the Ardennes, in the districts of Berg and Mark, at the foot of the Harz Mountains

<sup>1)</sup> JOHANNES VAN LIER. Oudheidkundige brieven, bevattende eene verhandeling over de manier van Begraven, en over de Lijkbussen, Wapenen, Veld- en Eere-teekens der oude Germanen. Uitgegeven . . . door A. VOSMAER. 's-Gravenhage 1760, p. XV, 10, 11, 103.

<sup>2)</sup> Sermo publicus, de monumentis variarum mutatarum, quas Belgii foederati solum aliquando passum fuit. Verhandelingen ter nasporing van de Wetten en Gesteldheid onzes Vaderlands. I. Groningen 1773, p. 504, 508.

<sup>3)</sup> Lithologia Groningana. Groningae 1781. Preface p. 2, 3.

<sup>4)</sup> Verhandelingen over den oorsprong der Graniet en andere primitieve Rotsblokken, die over de vlakten der Nederlanden en van het Noordelijk Duitschland verspreid liggen. Natuurk. Verhandelingen der Hollandsche Maatsch. van Wetensch. XIX. Haarlem 1831, p. 341—349.

as in Scandinavia <sup>1)</sup>). It is to be noted that on his first geological map these diluvial beds are not marked out in separate divisions <sup>2)</sup>).

Two years later, however, his attention was arrested by the peculiarity that, while in Twente and in the Eastern part of Salland and probably over the whole extent of the Veluwe, the principal constituents of these erratics were quartzite, red or blackish jasper, near the Havelter hill, before Steenwijk when one comes from the side of Meppel, one suddenly finds the detritus to consist entirely of flints. He noticed the same phenomenon near Steenwijk, the Steenwijkerwold and even near Vollenhove <sup>3)</sup>). These facts led him to conclude that two distinct diluvial deposits had taken place, i. e. one of "siliceous material" transported from the Baltic and another "composed of quartz" derived from the Ardennes.

In 1854 STARING had modified his theories. To the siliceous formation he gave the name of "Scandinavian Diluvium", and the quartz, which he no longer regarded as derived from the Ardennes, received the appellation of "Diluvium of the Rhine", which also included the deposits between the Meuse and the Rhine; and the beds situated South of the river Lek received the name of Diluvium of the Meuse. He was careful to add however that: "it would be wrong to deduce from these appellations that Scandinavia alone was responsible for the diluvial formation in the North of Holland, and the Ardennes, or the mountains of what at present is known as the basin of the Meuse, for that of one of its Southern parts and the Rhine for that of the other." <sup>4)</sup>

Six years later STARING again proposed another division which he then considered decisive. Leaving the boundaries of the Scandinavian Diluvium and those of the Meuse unaltered, the limits of the diluvium of the Rhine were confined to those parts of the Netherlands lying between the Rhine and the Meuse. The formation North of the Rhine and South of the Vecht was indicated by the name of "mixed diluvium" <sup>5)</sup>, which therefore included the provinces of Overijssel, Guelders, Utrecht, and the district of the Gooi in North Holland. The characteristic feature of this diluvium is the presence of erratics from

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<sup>1)</sup> De Aardkunde en de Landbouw in Nederland. Zwolle 1844, p. 14.

<sup>2)</sup> Proef eener geologische kaart van de Nederlanden. Groningen 1844.

<sup>3)</sup> De Aardkunde van Salland en het Land van Vollenhove. Zwolle 1846, p. 8, 9, 53.

<sup>4)</sup> Het eiland Urk volgens den Hoogleraar HARTING en het Nederlandsche diluvium. Verhand. uitgegeven door de Commissie belast met het vervaardigen eener geologische kaart van Nederland. II. Haarlem 1854, p. 167 m. kaart.

<sup>5)</sup> De Bodem van Nederland. II. Haarlem 1860, p. 54—56. Pl. I.

Scandinavia, from Hanover, from the mountains along the banks of the Rhine and from the Ardennes; but STARING was unable accurately to define which erratics had been transported by the Rhine and which by the Meuse.

“By far the largest portion of the quartzites, sandstones, pudding-stones and slates, found in those parts of the diluvium, which are situated to the South of the Scandinavian drift, are derived from the Devonian strata of the Rhine and the Ardennes.”<sup>1)</sup> Neither did STARING succeed in proving that the erratics in the diluvium of the Meuse had originally come from the Ardennes. “The gravel and the flints of the Meuse are similar to those of the Veluwe, with the important difference, however, that no fragments of plutonic rocks are found among them.”<sup>2)</sup>

Although for the last ten years the erratics transported from the North of Europe have been the subject of much careful investigation, little interest has been bestowed on those derived from Southern parts. This neglect is due in a great measure to the very nature of those rocks. The first actual proof that detritus from the Ardennes has been carried North of the Rhine, was supplied by J. LORÉ when he discovered a *Rhynchonella Thurmanni* near Wageningen<sup>3)</sup>; but until now scarcely any further progress has been made in the study of this question.

The difficulty of tracing to their original home the boulders transported from the Ardennes, lies in the first place in the necessity of leaving out of consideration, fragments of those rocks which are represented both in the diluvium of the Rhine and in that of the Meuse, for it is impossible to determine the exact districts to which they originally belonged. In the second place, it is a well known fact that the greater part of the Ardennes is very poor in fossils, so that the chance of finding fossiliferous specimens among the diluvial erratics is almost nil; — and thirdly, some of the very characteristic rocks, e. g. the phyllites, are much too soft to offer adequate resistance to the accidents of transportation. However, as I hope to show in the following pages sufficient material from various formations

<sup>1)</sup> l. c. p. 97.

<sup>2)</sup> l. c. p. 96.

<sup>3)</sup> Contributions à la géologie des Pays-Bas. Archives Teyler (2) III. Haarlem 1887, p. 80.

Postscript: FERD. ROEMER has already mentioned silicified specimens of *Stephanoceras coronatum*, found in the boulders near Winterswijk, Guelders. (N. Jahrb. f. Min. 1854, p. 322, 323). These looked exactly like those occurring in the jurassic layers of Northern France. See also Cl. Schlüter in Zeitschr. d. D. geolog. Ges. XLIX. 1897, f. 486.

remains to prove that the erratics traceable to the Ardennes may claim a considerable share in the formation of the mixed diluvium <sup>1)</sup>.

*Cambrian system.* The principal part of the Ardennes is built up of layers belonging to the Cambrian system, which A. DUMONT originally sub-divided into three groups, namely Devillian, Revinian and Salmian <sup>2)</sup>. The Devillian and Revinian systems were afterwards united by J. GOSSELET, <sup>3)</sup> into one series, called the devillo-revinian, which consists of phyllites, alternating with bands of greyish black and dark bluish grey quartzites. These layers may be seen exposed principally near Revin and Deville, on the banks of the Meuse, near Rocroi and Stavelot, and also near Givonne, to the north of Sedan. <sup>4)</sup> These quartzites are often crossed in various directions by fine veins of quartz and — a distinctive feature by which they are easily recognized — they often contain small cubes of pyrite, which in some cases has been in a greater or lesser degree changed into hydroxyde of iron. Now and then specimens are found in which the original mineral has entirely disappeared, only the impression of the cubes being left. J. DE WINDT <sup>5)</sup> has given microscopical descriptions of these crystalline quartzites, but has omitted to mention one special characteristic in which they show great conformity with the phyllites. In reference to the latter, E. GEINITZ was the first to point out that the enclosed crystals of magnetite and pyrite are surrounded by a zone of quartz, thus forming elongated lenses. <sup>6)</sup> From the manner in which these minerals have grown together, as well as the chlorite, he was led to the conclusion that they were coeval. This theory has been refuted by A. RENARD. Although, with GEINITZ, he believes the magnetites and pyrites to have been formed at the same time as the mass of the rocks, he

<sup>1)</sup> In all probability this share will be found to be much larger than is thought at present, because a great many rocky fragments, among others quartzites and sandstones, are now ascribed to the diluvium of the Rhine although they are also present in that of the Meuse.

<sup>2)</sup> Mémoire sur les terrains Ardennais et Rhénan-Mémoires de l'Acad.-roy. de Belgique XX. Bruxelles 1847, p. 8

<sup>3)</sup> Esquisse géologique du nord de la France. Lille, 1880, p. 19.

<sup>4)</sup> It cannot be made out which of these localities have provided the boulders. They are represented in the accompanying map [as if they were coming from Revin, the chief locality.

<sup>5)</sup> Sur les relations lithologiques entre les roches considérées comme cambriennes des massifs de Rocroi, du Brabant et de Stavelot. Mém. cour. de l'Acad. roy. de Belgique LVI. Bruxelles 1898, p. 21, 68.

<sup>6)</sup> Der Phyllit von Rimognes in den Ardennen. TSCHERMAK's Mineralog. und Petrogr. Mitthlg. III. Wien. 1880, p. 533.

considers the zone of quartz surrounding these minerals to be of secondary origin, and that pressure on both sides had caused cavities which afterwards have been filled up with quartz.<sup>1)</sup> Some time before, A. DAUBRÉE had already furnished a description of transformed crystals of pyrites found near Rimognes.<sup>2)</sup> The studies of other kinds of rocks led to the same conclusion.<sup>3)</sup> An analysis of the pyritiferous quartzites of the Cambrian system affords still better proof of the secondary origin of this quartz, because in this case the rock itself is composed of this mineral. When examining specimens, it is easy to observe the sharp contrast between the two formations. The quartz which has formed itself around the pyrite, is clear and transparent, seldom contains enclosures, and is built up of fibres which stand perpendicular on the crystals of pyrite. The same structure is seen in the parts which form the veins. L. DE DORDOLOT, who has written on the same subject, is inclined to regard this quartz as chalcedony.<sup>4)</sup>

By the aid of this data it has not been difficult to prove that erratics of this kind have been widely dispersed, and it is very probable that in the course of time their presence will be signalized from many other places besides those we here indicate.

1. Province Utrecht: Railway cutting near Rhenen, on the river Lek, Darthuizer Berg, sandpit to the North of Rijsenburg, railway cutting at Maarn, the heath near the pyramid of Austerlitz, near Zeist, Heidebosch near the House ter Heide, between the stations de Bilt and Zeist, to the rear of Honderinge near de Bilt, Soester Berg.

2. Province of North-Holland: Hilversum and the sandy tract to the North of Larenberg.

3. Province of Guelders: Heath near Epe, Bennekom near Wageningen, Eerbeek near Dieren, at several places around Eibergen Boreulo, Groenlo and Hettenheuvel near Doetichen.

4. Province of Overijssel: Heriker Berg near Markelo.

<sup>1)</sup> Recherches sur la composition et la structure des phyllades ardennais. Bull. du Musée roy. d'hist. nat. de Belgique. II. Bruxelles 1883, p. 134—135.

<sup>2)</sup> Etudes synthétiques de géologie expérimentale. I. Paris 1879, p. 443.

<sup>3)</sup> H. LORETZ. Ueber Transversalschieferung und verwandte Erscheinungen im thüringischen Schiefergebirge. Jahrbuch der k. preuss. geolog. Landesanstalt für 1881. Berlin 1882, p. 283—289.

HANS REUSCH. Bömmelöen og Karmöen met omgivelser. Kristiania 1888, p. 69, 70.

ALFR. HARKER. On "Eyes" of Pyrites and other Minerals in Slate. Geolog. Magazine (3) VI. London 1889, p. 396, 397.

<sup>4)</sup> Quelques observations sur les cubes de pyrite des quartzites reviniens. Ann. Soc. géolog. de Belgique. XXXI. Liège 1903—04. Mém. p. 505.

It stands to reason that erratics of this type must be more plentiful still in the district South of the Rhine; in fact, similar quartzites have been found in the diluvium of the Meuse for a long time past. In the Province of Limburg they are looked upon as the most common kind of erratics. ALPH. ERENS came across one 3 M. high, 2.6 M. long and 0.6 M. broad <sup>1)</sup>. According to this author, they are also found in quantities in the Province of North Brabant, although they are not so large as those of Limburg. J. LORRÉ found rocks of this composition on the heaths at Mook and at Schaik, also in South Holland on the beach of Springer in Goedereede and near Rockanje in the island of Voorne.

“Porphyroids.” But the most conclusive proofs that immense quantities of rocky fragments must have been transported from the Ardennes, are furnished by the so-called Porphyroids. This rocky formation is confined to the districts of Revin and Deville, where, more particularly in the neighbourhood of Laifour and Mairus, they form dikes from 0.1 to 20 M. wide, corresponding to the layers of the devillo-revinian group. At present only 17 places are known where this exceedingly characteristic formation <sup>2)</sup> may be encountered. Dispersed in a bluish gray or greyish groundmass, may be seen porphyritic crystals of bluish quartz and of feldspar. Owing to their peculiar position and their schistose structure, many geologists have classified these rocks among the series of crystalline schists, — whilst others have ascribed to them an eruptive origin. CH. DE LA VALLÉE POUSSIN and A. RENARD, who have given the most detailed description of these rocks, favoured the former view <sup>3)</sup>; BARROIS, DAUBRÉE, GOSSELET, VON LASAULX and others, on the contrary, justly considered them to be quartzporphyry, an opinion which A. RENARD also finally accepted.

Although these porphyroids can have but a minimum share in the formation of the Ardennes, they are frequently met with in diluvial deposits. In Belgium, G. DEWALQUE only noticed them near Liege <sup>4)</sup>, which proves that but little attention has been paid to them in that

<sup>1)</sup> Recherches sur les formations diluviennes du sud des Pays-Bas. Archives Teyler (2) III. 6<sup>ème</sup> partie. Haarlem 1891, p. 23.

<sup>2)</sup> J. GOSSELET. L'Ardenne. Paris 1888, p. 86.

<sup>3)</sup> Mémoire sur les caractères mineralogiques et stratigraphiques des roches dites plutoniennes de la Belgique. Mémoires cour. etc. de l'Acad. roy. de Belgique XL. Bruxelles 1876, p. 237—247 (also Zeitschr. d. D. geol. Ges. 1876, p. 750—769).

<sup>4)</sup> Prodrome d'une description géologique de la Belgique. Bruxelles et Liège 1868, p. 237.

country<sup>1)</sup>, for ALPH. ERENS mentions not less than 15 gravel-pits in the neighbourhood of Maastricht in which he found fragments of these rocks, one being 0.6 M. long and 0.5 M. thick. The most easterly place of deposit known at présent is Simpelveld<sup>2)</sup>. Not long ago, Mr. L. RUTTEN brought me several specimens dug up in the neighbourhood of Sittard. From observations of ERENS, it would appear that these erratics are scarce in the Province of North Brabant. He himself found a nice piece at Mook<sup>3)</sup>, and J. LORIE a fragment between Bladel and Postel.

North of the Rhine they have been discovered in the railway cuttings near Rhenen and also near Maarn (in the latter locality the fragment was over  $\frac{1}{3}$  M. in diameter), and on the Soester Berg, in the Province of Utrecht. Another piece was found near Eibergen, in Guelders and finally ERENS mentions having seen in the Geological Museum, at Leiden, a fragment found in Overijssel: unfortunately he does not state the exact spot at which it was found<sup>4)</sup>.

2. *Carboniferous system.* FERD. ROEMER has given a description of a few fragments of black carboniferous limestones containing *Productus striatus* Fisch. found in the Gooi, near Hilversum and sent to him for analysis by STARING. He came to the conclusion that they were derived from the carboniferous limestone of the district between Aix-la-Chapelle and Stolberg<sup>5)</sup>.

STARING on the contrary believed them to have been transported from Visé on the Meuse, in Belgium, and based his opinion on the similarity of their composition with the limestone found in that part and also on the almost total absence of this rock from Westphalia.<sup>6)</sup> Although fragments of carboniferous limestone from Ratingen, N.W. of Dusseldorf, might have found their way to the Netherlands, the fact that no traces of the said fossil have ever been observed in those rocks<sup>7)</sup>, evidently keeps them outside the discussion. It is true that in the district between Aix-la-Chapelle and Stolberg, the

<sup>1)</sup> J. LORIE e.g. found several fragments near Lancklaer on the Zuid-Willemscanal.

<sup>2)</sup> Note sur les roches cristallines recueillies dans les dépôts de transport dans la partie méridionale du Limbourg hollandais. Ann. de la Soc. géolog. de Belgique. XVI. 1888—89. Liège. Mém. p. 417—420.

<sup>3)</sup> Recherches sur les formations diluviennes du sud des Pays-Bas. Archives Teyler (2) III. 6<sup>ème</sup> partie. Haarlem 1891, p. 23, 33.

<sup>4)</sup> Recherches sur les formations diluviennes. I. c. p. 67.

<sup>5)</sup> Ueber Holländische Diluvial-Geschiebe. Neues Jahrb. f. Mineralogie. 1857, p. 389.

<sup>6)</sup> De Bodem van Nederland. II. Haarlem 1860, p. 96.

<sup>7)</sup> H. VON DECHEN. Erläuterungen zur geologischen Karte des Rheinlandes und der Provinz Westfalen. II. Bonn 1884, p. 216.



*Productus striatus* is occasionally met with <sup>1)</sup>, but, like many other fossils, it is extremely rare. <sup>2)</sup> The probability of one of these specimens having been transported to the Gooi becomes therefore nil. On the other hand, as STARING had already pointed out, they are very common at Visé in Belgium, consequently we are justified in concluding that the above mentioned fragments must be referred to that locality.

Other fossil mentioned by ROEMER is the *Goniatites sphaericus* Mart. (*Glyphioceras sphaericum*), a specimen of which had been found near IJolten, in Overijsel, and whose original birth-place he claims to have been the valley of the Roer. This fossil, however, is found both at Ratingen and Visé: nothing definite can therefore be said with regard to the place of its origin. I may here mention that in 1899, Dr. E. COLLINS brought me a fine specimen, well preserved and but little polished, which had been picked up in the gravel of a garden at Utrecht and was very probably brought from the Lek.

In the railway cutting near Maarn, to the East of Driebergen, I found in 1893 a block of crinoidal limestone weighing as much as 97 K.G. In that same cutting repeatedly were observed pieces of compact black limestone. In 1895, fragments of a very beautiful crinoidal limestone were found in the grounds of the villa Houderinge, near De Bilt, at a depth of about 1 M. Other pieces of black and next to these of grayish compact limestone were found in a railway cutting half way between the stations of De Bilt and Soest. On the whole, therefore, it cannot be said that rocks of this type are largely represented in the diluvial deposits under consideration. This is probably owing in a large measure to the sandy nature of the diluvium of those parts which allows the moisture of the atmosphere to penetrate to the limestone and gradually dissolve it. The same physical conditions are probably also responsible for the paucity of erratics of this description in the Provinces of North-Brabant and Limburg, and in the Campine. A. ERIENS found fragments of crinoidal limestone near Oudenbosch, <sup>3)</sup> É. DELVAUX of carboni-

<sup>1)</sup> H. VON DEGEN. l. c. p. 211.

<sup>2)</sup> C. DANTZ did not even come across a single specimen in the district of Aix-la-Chapelle. (Der Kohlenkalk in der Umgebung von Aachen. Zeitschr. d. D. geolog. Ges. XLV. Berlin 1893. p. 611).

<sup>3)</sup> L. G. DE KONINCK. Recherches sur les animaux fossiles. 1<sup>ère</sup> partie. Monographie des genres *Productus* et *Chonetes*. Liège 1847. p. 30.

<sup>4)</sup> Recherches sur les formations diluviennes l. c. p. 67.

ferous limestone in a gravel pit at Gelieren near Genck <sup>1)</sup> and J. LORIE at Smeermaes and Lancklaer, on the Zuid-Willems canal.

The original home of these various limestones cannot be determined with any certainty. However, as numerous layers of crinoidal limestone are present in the districts of Aix-la-Chapelle and Stolberg <sup>2)</sup> as well as in the valley of the Meuse, more especially near Dinant, it seems rational that we should in the first place look to these parts for their origin <sup>3)</sup>. In any case they must have been transported along the Meuse, for the district Aix-la-Chapelle—Stolberg is drained by the Geul, the Inde and the Worm, which all three flow into the Meuse.

Finally ROEMER gives in his treatise a description of fragments of phthanite, found near Ootmarsum, in Overijssel, which he thinks derived from the layers of culm on the lower Rhine. This conjecture is not inadmissible, but at the same time the fact must not be overlooked that this kind of rock is also plentiful in the valley of the Meuse.

*Jurassic System (Oxfordian).* In the foregoing pages mention has already been made of a piece of brownish yellow sandy clay, found by J. LORIE on the Wageninger hill (Guelders) in which was inbedded a perfect specimen of *Rhynchonella Thurmanni* Voltz, in every respect similar to the fossils of this species found at Vieil-Saint-Rémy, to the South-West of Mézières in the department of the Ardennes <sup>4)</sup>. This is the only fossil of this type discovered in our country, although in the diluvium of South Limbourg and Northern Belgium, jurassic

<sup>1)</sup> Les anciens dépôts de transport de la Meuse, appartenant à l'assise moséenne observés dans les ballastières de Gelieren près Genck en Campine. Ann. Soc. géol. de Belgique XIV. 1886—87. Liège 1887, Mém. p. 103.

Here again, as at Maarn, he ascribed their presence to an "accident".

<sup>2)</sup> J. BEISSEL. Ueber Struktur und Zusammensetzung des Kohlenkalks in der Umgebung von Aachen. Verhandl. naturh. Vereins Rheinl. u. Westf. XXXIX. Bonn 1882. Corresp. Bl. p. 92.

<sup>3)</sup> Ed. DUPONT. Notice sur les gîtes de fossiles du calcaire des bandes carbonifères de Flourens et de Dinant. Bull. Acad. roy. de Belgique (2) XII Bruxelles 1861 p. 293.

Ed. DUPONT. Essai d'une carte géologique des environs de Dinant l. c. (2) XX. 1865. p. 621, 622, 629.

Ed. DUPONT. Carte géologique des environs de Dinant. Bull. Soc. géol. de Fr. (2) XXIV. Paris 1866—67 p. 672, 673.

Ed. DUPONT et MICHEL MOURLON, Explication de la feuille de Dinant. Musée d'hist. nat. de Belgique. Service de la carte géolog. du Royaume. Bruxelles 1883, p. 9, 26, 33, 34, 53 et passim.

<sup>4)</sup> Contributions à la géologie des Pays-Bas. Archives Teyler (2) III. Haarlem 1887, p. 10.

fossils have been frequently met with. We find them already mentioned by J. T. BINKHORST VAN DEN BINKHORST <sup>1)</sup>.

FR. SEGHERS discovered a Rhynchonella and part of an Ammonites at Genck <sup>2)</sup>. Close to this place, at Gelieren, E. DELVAUX frequently came across remains of "calcaire à Chailles" <sup>3)</sup>. C. MALAISE gave a description of petrified Nerinea found at Rothem and an Isastraea at Jambes, near Namur <sup>4)</sup>. A. ERENS mentions a few other fossils <sup>5)</sup> and finally we have an account of a yellow oolite, discovered by E. VAN DEN BROECK among the erratics of the Meuse, and here we call attention to the peculiar siliceous oolites scattered about the plateau of the Meuse and which probably belong to the jurassic system <sup>6)</sup>. As yet no trace of similar oolites has been discovered North of the Rhine, but J. LORÉ noticed some in the borings of a well at Mariendaal, near Grave <sup>7)</sup>. A few weeks ago Mr. L. RUTTEN found a small pebble in the diluvium at Kollenberg, near Sittard.

*Tertiary system: (Eocene).* Very interesting are the accounts of the discovery of erratics comprising specimens of *Nummulina laevigata* Lam. FERD. ROEMER has given a description of a fragment of this kind derived from Holten, in Overijssel, but believed it to have only accidentally found its way among the erratics <sup>8)</sup>. STARING made mention of a couple of rounded-off pieces of hornstone, one of which had been found on the rising ground of Hellendoorn and the other on the Steenshul, near Oldebroek, and which he referred to the Alps? "If we did not know the place where these specimens were obtained, we should be rather inclined to think they came from a collection in which the objects had been confused and believe these rocks to

<sup>1)</sup> Esquisse géologique et paléontologique des couches crétacées du Limbourg. Maastricht 1859. p. 7.

<sup>2)</sup> Ann. de la Soc. malacolog. de Belgique X. Bruxelles 1875. Bull. p. XXXIV.

<sup>3)</sup> Les anciens dépôts de transport de la Meuse, appartenant à l'assise moséenne observés dans les ballastières de Gelieren près Genck en Campine. Bull. Soc. géolog. de Belgique XIV. 1886/87. Liège. 1887. Mém. p. 102.

<sup>4)</sup> Sur quelques fossiles du diluvium. Ann. Soc. malacolog. de Belgique X. Bruxelles 1875. Bull. p. IV.

<sup>5)</sup> Note sur les roches cristallines l. c. p. 413.

<sup>6)</sup> E. VAN DEN BROECK. Les cailloux oolithiques des graviers tertiaires des hauts plateaux de la Meuse. Bull. Soc. belge de Géologie III. Bruxelles 1890 p. 404—412.

X. STAINIER. Origine des cailloux oolithiques des couches à cailloux blancs du bassin de la Meuse. Ann. Soc. géolog. de Belgique XVIII. 1890—92, p. CV, 92.

E. VAN DEN BROECK. Coup d'œil synthétique sur l'Oligocène belge. Bull. Soc. belge de Géologie VII. Bruxelles 1893 p. 25, 266.

<sup>7)</sup> Beschrijving van cenige nieuwe grondboringen, Verhandel. K. Akademie v. W. 2de sectie. VI, N. 6. Amsterdam 1899, p. 33.

<sup>8)</sup> Ueber Holländische Diluvial-Geschiebe. Neues Jahrb. f. Min. 1857, p. 392.

"have been picked up near Brussels <sup>1)</sup>". K. MARTIN <sup>2)</sup> and J. LORLÉ <sup>3)</sup> in fact assign them also to that locality; they forget, however, that no strata of nummulitic limestone are known to exist there <sup>4)</sup>. Their origin lies much farther South. In 1863 J. GOSSELET had already indicated the original source of these "silex à Nummulites", of which a few years later he published a description <sup>5)</sup>. They are dispersed in large quantities in the arrondissement of Avesnes, in the department du Nord, more especially in the environs of Trélon <sup>6)</sup> where, on account of their hardness, they are frequently used for the paving of roads.

Since then numerous fragments of this rock have also been found in Belgium, specially on the plateau situated between the Meuse and the Sambre, e. g. around Silenrieux, Sivry, Clermont, etc., as well as in parts lying further West <sup>7)</sup>.

The second question which we have to examine, is the period at which these rocky fragments from the Ardennes have been transported to districts at present situated North of the Rhine. The view expressed by STARING that this transport has taken place before the deposition of Scandinavian erratics, seems at present also satisfactorily established, for those carried by the Meuse. In the railway cuttings at Maarn and Rhenen, rocks of diverse origin lie together in friendly

<sup>1)</sup> De Bodem van Nederland. II. Haarlem 1860, p. 89.

<sup>2)</sup> Niederländische und Nordwestdeutsche Sedimentärgeschiebe. Leiden 1878, p. 37.

<sup>3)</sup> Les métamorphoses de l'Escaut et de la Meuse. Bull. Soc. belge de Géologie, IX. 1895 Bruxelles 1895—96, Mém. p. 60.

<sup>4)</sup> E. VAN DEN BROECK. A propos de l'origine des Nummulites laevigata du gravier de base du Laekénien. Bull. Soc. belge de Géologie. XVI. 1902. p. 580.

<sup>5)</sup> De l'extension des couches à Nummulites laevigata dans le nord de la France. Bull. Soc. géolog. de la France (3) II. 1873—74. Paris 1874, p. 51—58. See also Ann. Soc. géol. du Nord. I. 1870—74. Lille, p. 36.

<sup>6)</sup> Compte-rendu de l'excursion du 7 Septembre [1874] à Trélon l. c. p. 681. Leriche. L'Eocène des environs de Trélon. Ann. Soc. géol. du Nord. XXXII. Lille 1903. p. 179.

<sup>7)</sup> MICHEL MOURLON. Sur les amas de sable et les blocs de grès dissiminés à la surface des collines famenniennes dans l'Entre-Sambre-et-Meuse. Bull. Acad. roy. de Belgique (3) VII. Bruxelles 1884, p. 301—303.

A. RUTOT. Sur l'âge de grès de Fayat. Bull. Soc. belge de Géologie I, 1887, p. 47.

L. BAYET. Première note sur quelques dépôts tertiaires de l'Entre-Sambre-et-Meuse. Bull. Soc. belge de Géologie X, 1896. Bruxelles 1897—99 p. 139—140.

G. VELGE. De l'extension des sables éocènes laekéniens à travers la Hesbaye et la Haute Belgique. Ann. Soc. géolog. de Belgique, XXV, 1897—98. Liège, p. CLXV.

A. BRIART. Notice descriptive des terrains tertiaires et crétacés de l'Entre-Sambre-et-Meuse. Ann. Soc. géolog. de Belgique XV, 1887—88, p. 17.

juxtaposition and intermixture, which proves that they must have been carried together and at the same time to the place where they are found at present. From the shape of the front moraine, we conclude that the direction of the transport was from the North-East. The erratics nowadays found at the surface have been gradually denuded by the action of water and wind. It is therefore evident that originally these erratics were transported much farther to the North and East, than their present place of deposit, because they were seized by the advancing Baltic icestream and carried along together with the material of its moraine. We are therefore justified in fixing the period of the transport of the boulders from the Rhine and Meuse at the commencement of the epoch of maximum glaciation (Saxonian).

A far greater difficulty presents itself when we attempt to determine in what way this transport has taken place, for it can only have been effected by the agency of a river or a glacier. The hypothesis that all these boulders should have been carried along by the Meuse in its downward course, is scarcely admissible. Even leaving out of account the finding of rocky fragments from the Ardennes on the strands of Goedereede and Voorne — not to speak of Suffolk, in England — there remains a large tract of land 105 K.M. long stretching from Utrecht to Eibergen, over which these erratics are dispersed in the shape of a crescent. If carried by the Meuse, its mouths must have extended over a very large area. But a greater objection to this theory is that, in that case, they must have been transported across the Rhine (at present the IJssel) because rocks of this kind are found at places to the East of this river (Doetichem, Eibergen, Markelo). Finally, some of these blocks are so large that they could not possibly have been transported by a river. Besides, some of them present no marks of polish, which is another argument against their transport by running water.

For the better understanding of these objections we quote a few examples from the Province of Limburg and the Campine. A. ERENS found in the environs of Maastricht numerous large blocks of Cambrian quartzites; one of which was 3 M. high, 2,6 M. long and 0,6 M. in width, computed to weigh about 12400 K.G. <sup>1)</sup> More important still are the blocks of sandstone found in the diluvium of the Campine at Holsteen-Molenheide, near Zonhoven, in the neighbourhood of Hasselt, É. DELVAUX noticed blocks measuring from 4

<sup>1)</sup> Note sur les roches cristallines l. c. p. 412, 417. Mr. L. RUTTEN informed me that in the neighbourhood of Sittard similar boulders reach a diameter of  $\pm 3$  M.

to 36 M. cub, weighing from 10600 to 95400 K.G. <sup>1)</sup>. He believed them to belong to the landenian stage of the eocene system. His opinion, that they covered the plateau of the Ardennes (where CH. BARROIS was the first to discover similar masses <sup>2)</sup>, to a height of 672 M., has been much contested. E. VAN DEN BROECK classed these sandstones first among the triassic system <sup>3)</sup>, afterward referred them to the oligocene system <sup>4)</sup>, and finally suggested they might either be oligocene, miocene or pliocene, but certainly not eocene <sup>5)</sup>. G. DEWALQUE pronounced them to be miocene <sup>6)</sup>, whilst O. VAN ERTBORN sought their origin in the pliocene system <sup>7)</sup>, more especially in the diestian group <sup>8)</sup>, but was of opinion that they must be regarded as the remains of a "delta caillouteux" <sup>9)</sup>. M. MOURLON, on the contrary, held that they had been formed in the vicinity of their present place of deposit, by the fusion of the "sable de Moll" <sup>10)</sup>, an opinion which cannot be maintained, because similar blocks are present in the diluvium of Maastricht where no trace of this sand exists <sup>11)</sup>.

J. GOSSELET compares these rocks with the freshwater-quartzites of the diluvium of the Rhine and, with reason, thinks that they belong to the oligocene system <sup>12)</sup>. At all events it is universally admitted that the Ardennes have been covered by extensive layers of tertiary

<sup>1)</sup> Description sommaire des blocs colossaux de grès blanc cristallins provenant de l'étage landénien supérieur . . . . en différents points de la Campine limbourgeoise. Ann. Soc. géolog. de Belgique XIV. 1886—87. Liège 1887. Mém. p. 117—130.

<sup>2)</sup> Sur l'étendue du système tertiaire inférieur dans les Ardennes. Ann. Soc. géol. du Nord. VI. Lille 1879, p. 371.

<sup>3)</sup> Ann. Soc. roy. malacolog. de Belgique XVI. Bruxelles 1880. Bull. p. LXXIV.

<sup>4)</sup> Note préliminaire sur le niveau stratigraphique de la Belgique et de la région d'origine de certains des blocs de grès quartzeux de la Moyenne et de la Basse-Belgique. Bull. Soc. belge de Géologie IX. 1895. Bruxelles Proc. verb. p. 94—99.

<sup>5)</sup> Les grès erratiques du sud du Démer et dans la région de HEURCK. Bull. Soc. belge de Géologie XV. 1901. Bruxelles 1902. Proc. verb. p. 628.

<sup>6)</sup> Ann. Soc. géolog. de Belgique. XIV. 1886—87. Liège 1887. Bull. p. 18.

<sup>7)</sup> Le Quaternaire dans le sud de la Belgique. Bull. Soc. belge de Géologie. XV. 1901. Proc. verb. p. 662.

<sup>8)</sup> Quelques mots au sujet des divers niveaux gréseux du tertiaire supérieur dans le nord de la Belgique. l. c. p. 632.

<sup>9)</sup> Contribution à l'Étude des Étages rupélien, boldérien, diestien et poederlien, l. c. XVI. 1902. Mém. p. 65.

<sup>10)</sup> Compte rendu de l'excursion géologique en Campine les 23, 24 et 25 septembre. l. c. XIII. 1899. Mém. p. 205, 213, 214.

<sup>11)</sup> ALPH. ERENS. Note sur les roches cristallines l. c. Pl. XIII.

<sup>12)</sup> L'Ardenne. Paris 1888, p. 833.

system, as has been pointed out by M. LOHEST <sup>1)</sup>, X. STAINIER <sup>2)</sup>, J. CORNET <sup>3)</sup> and others.

Before stating our reasons for supposing the presence of a glacier in the Ardennes during the second glacial period, we are willing to admit that J. GOSSMERT, who of all geologists knew most of this mountain range, remarked in reference to this hypothesis: "on n'en trouve aucun indice sérieux" <sup>4)</sup>. Indeed we have but few indications in support of it. The first to draw attention to this question was FR. VAN HOREN, who at the time of the making of the railway line between Tirlemont and Jodoigne, found near Bost blocks of quartzites from the Ardennes which presented marks quite similar to the striae caused by glaciers. VAN HOREN, however, did not feel justified in drawing from this discovery the conclusion of the former existence of a glacier <sup>5)</sup>. A year later C. MALAISE observed similar marks on blocks of quartzites on the banks of the Grande Geete, close to the spot formerly occupied by the Abbey of Ramez-les-Jochelette, about 10 K.M. from Bost <sup>6)</sup>. G. DEWALQUE believed to have seen unmistakable striae on blocks of quartzites in the valley of the Amblève, near Stavelot, on the "Hohe Venn" <sup>7)</sup>. E. DELVAUX also noticed these horizontally parallel scratches, but believes them to have been produced by a "torrent entraînant et roulant pêle-mêle des sables et des cailloux." <sup>8)</sup>.

Finally, South of Stavelot, on the road to Somagne, G. DEWALQUE discovered giants' kettles formed by the agency of glaciers <sup>9)</sup>. It is regrettable to find that the more detailed study of this subject has been much impeded by the practice in Belgium of giving the name

<sup>1)</sup> Les dépôts tertiaires de la haute Belgique. Ann. Soc. géolog. de Belgique XV. Liège 1887—88 Mém. p. 59.

<sup>2)</sup> Le grès blanc de Maizeroul. Ann. Soc. géolog. de Belgique XVIII. Liège 1890—91. Mém. p. 61.

<sup>3)</sup> Etude sur l'Évolution des Rivières belges. Ann. Soc. géol. de Belgique XXXI. 1903—04. Mém. p. 317, 355.

<sup>4)</sup> L'Ardenne, p. 843.

<sup>5)</sup> Note sur quelques points relatifs à la géologie des environs de Tirlemont. Bull. Acad. roy. de Belgique (2) XXV. Bruxelles 1868, p. 645, 664; 1 Pl.

<sup>6)</sup> Roches usées avec cannelures de la vallée de la grande Geethe. l. c. (2) XXVII, 1879, p. 682—685.

<sup>7)</sup> Sur la présence de stries glaciaires dans la vallée de l'Amblève. Ann. Soc. géolog. de Belgique. XII. 1884—85. Liège. 1885. Bull. p. 157—158.

<sup>8)</sup> Note succincte sur l'excursion de la Société géologique à Spa, STAVELOT et LAMMERSDORF en août-septembre 1885. Ann. Soc. roy. malacol. de Belgique XX. Bruxelles 1885, Mém. p. 19.

<sup>9)</sup> Marmites de géants près de Stavelot. Ann. Soc. géol. de Belgique. XXV. 1897—98, p. CXXXVIII.

of pseudoglacial to all kinds of bosses and scratches which elsewhere would scarcely be so called, because they do not in the least resemble the striae of glaciers<sup>1)</sup>.

This absence of positive characteristics is however easily explained. Leaving alone the fact that as yet no thorough investigation of the subject has been made, the condition of the Ardennes themselves are very unfavorable to research. Its dense forests, fens and heaths make it difficult to reach the surface of the rocks, whose harder layers are only capable of preserving marks. The reason why so few traces are found on the sides of the valleys and on the plateau of the Meuse becomes plain, when we remember that during the period following the receding of the Northern glacier, the waters of the Meuse rose 200 M. above the level of the sea, and not only filled the whole valley but inundated the plateau of the Meuse and thus destroyed the traces left by the glacier.

Of this we find the clearest proofs in the terraces which have retained their boulders.<sup>2)</sup> Besides, exactly the same thing happened with the Rhine and its tributaries. The sand and small pebbles carried along by their waters must necessarily have almost entirely obliterated the marks of the glaciers left on the rocks<sup>3)</sup>.

Striae, however, are not the only evidences of the action of a

1) X. STAINIER. Stries pseudo-glaciaires en Belgique. Bull. Soc. belge de Géologie X. Bruxelles 1896. Pr. verb. p. 212—216.

E. VAN DEN BROECK. Contributions à l'étude des phénomènes d'altérations dont l'interprétation erronée pourrait faire croire à l'existence de stries glaciaires. l. c. XIII. 1899. Mém. p. 323—334. Pl. XX.

G. SIMOENS. Sur une roche présentant des stries pseudo-glaciaires en Condroz. l. c. Pr. verb. p. 222—223.

2) É. DUPONT et M. MOURLON. Explication de la feuille de Dinant. Bruxelles 1883, p. 100.

A. RUTOT. Résultats de quelques explorations dans le Quaternaire de la Meuse. Bull. Soc. belge de Géologie. XIV. Bruxelles 1900. Pr. verb. p. 259, 260.

X. STAINIER. Le cours de la Meuse depuis l'ère tertiaire l. c. VIII. 1894 Mém. p. 84. Pl. VII.

E. VAN DEN BROECK. Coup d'oeil synthétique sur l'Oligocène belge et les observations sur le Tongrien supérieur du Brabant l. c. VII. 1893, p. 255, 256, 266.

E. VAN DEN BROECK. Exposé sommaire des observations et découvertes stratigraphiques et paléontologiques faites dans les dépôts marins et fluvio-marins du Limbourg pendant les années 1880—81. Ann. Soc. roy. malacolog. de Belgique XVI, Bruxelles 1881 Bull. p. CXXV—CXLII.

3) It might be suggested that the transport of these boulders had taken place by means of ice-floes, but Mr. LOHST has demonstrated in the most positive manner that these ice-masses are incapable of effecting a notable removal. He comes to the conclusion that among the present climatic conditions no explanation can be



glacier and one might reasonably expect to find in the valleys some remains of the wall of moraines. That this is not the case may be accounted for by the supposition that the great Baltic ice-stream has travelled farther south and in its course also destroyed these evidences. As there exists a great diversity of opinion with respect to this forward movement of the ice-stream, it seems necessary here to state what is known of the dispersion of Scandinavian erratics in the Provinces of Limburg and North-Brabant and the Campine.

As long ago as 1778, J. A. DE LUC mentions the discovery of blocks of granite between Postel and Alfen, and also near Lommel and Helchteren<sup>1)</sup>. Subsequently, J. J. D'OMALIUS D'HALLOY drew attention to the numerous blocks of granite and other fragments of "primordial" rocks found on the heath of the Campine. "La quantité de ces blocs doit être été immense; car quoiqu'on fasse un grand usage pour paver les rues, ainsi que pour faire des jetées le long de la mer et des rivières, on en voit beaucoup dans les bruyères".<sup>2)</sup> And ENGELSPACH—LARIVIÈRE adds the information that some of these blocks of granite measured several M. cub.<sup>3)</sup> Somewhat later again, J. G. S. VAN BREDA mentioned the finding of two pebbles of granite in the subsoil of Maastricht, very justly remarking that these rocks must be regarded of later date than those transported from the Ardennes<sup>4)</sup>. At that time he already spoke of blocks of granite found at Oudenbosch, in North-Brabant<sup>5)</sup>. STARING expressed the opinion that these erratics had been brought there by "some accidental means or other"<sup>6)</sup>, although a short time before NORBERT DE WAEL had recorded the finding, at Weelde, 10 K.M. to the NNE. of Turnhout and also at Poppel,

found for the transport of the blocks of quartzites from the Ardennes. (Sur le transport et le déplacement des cailloux volumineux de l'Amblève. Ann. Soc. géol. de Belgique. XVIII. Liège 1890—91. Bull. p. CVII—CIX).

<sup>1)</sup> Lettres physiques et morales sur l'histoire de la terre et de l'homme. IV. Paris et La Haye 1779, p. 54, 57.

<sup>2)</sup> Mémoires pour servir à la description géologique des Pays-Bas, de la Flandre et de quelques contrées voisines. Namur. 1828, p. 204, 205.

<sup>3)</sup> Considérations sur les blocs erratiques et roches primordiales Bruxelles. 1829 (fide P. COGELS. Ann. Soc. roy. malacolog. de Belgique. XVI. 1881, Bull. p. LIV).

<sup>4)</sup> Natuurk. Verhandel. van de Holl. Maatsch. v. Wetensch. XIX. Haarlem 1831, p. 390.

<sup>5)</sup> The biggest one originally weighed  $\pm 5300$  K.G. (V. BECKER). Het zwerfblok van Oudenbosch en zijne omgeving. Studiën op Godsdienstig, Wetensch. en Letterk. Gebied. XXX. Utrecht. 1888, p. 25).

<sup>6)</sup> De bodem van Nederland II. Haarlem 1860, p. 78.

half-way between the last-named place and Tilburg, of erratics one of which weighed 200 K.G. <sup>1)</sup>). G. DELWAQUE then again mentioned two pebbles of granite found in the neighbourhood of Maastricht <sup>2)</sup>). It is only during the last ten years that a deeper interest has been taken in the study of this subject, with the result that the presence of erratics of Northern origin has been ascertained in several places, as we gather from the writings of C. BAMPS, V. BECKER, E. VAN DEN BROECK, P. COGELS, F. DELVAUX, G. DEWALQUE, A. ERENS, O. VAN ERTBORN, J. LORIÉ, A. VARD and CH. DE LA VALLÉE—POUSSIN.

Another fact worthy of notice is the presence, at these very places, of boulders derived from the district of the Rhine. The first indications of such finds, by G. DEWALQUE, are rather questionable. They were fragments of rocks from the lava of Niedermendig, near Andernach, frequently met with in the valley of the Amblève, but were believed to have been fragments of mill-stones, formerly used at Stavelot and Malmedy. Subsequently É. DELVAUX found a few pieces of lava and pumice stone in the diluvium of the Campine <sup>3)</sup>); but it was A. ERENS who discovered and described a great number of rocks derived from the Rhine district, composed of lava from Niedermendig, pumice stone and Taunus-quartzite <sup>4)</sup>). These were followed at a later period by trachyte from the Drachenfels, basalt and hornblende-andesite from the Siebengebirge, and melaphyre and agate from the basin of the Nahe <sup>5)</sup>). The discovery of these fragments in the North of Limburg admits of no other interpretation than that these rocks must have been carried South, simultaneously with the detritus from Scandinavia.

It cannot be denied that fewer erratics from Scandinavian rocks are found South of the Rhine than North of it. We give the following reasons in explanation of this fact: 1<sup>st</sup>. During the progress of the Baltic icestream in a South-Western direction, the Scandinavian drift must already have lost a certain portion of its material by the mixture of the debris of its own moraine with that of other sources; 2<sup>nd</sup>. It must have suffered further loss by mixing with the moraine

<sup>1)</sup> Bull. Soc. paléontolog. Bruxelles p. 36. (Séance du 5 Septembre 1858).

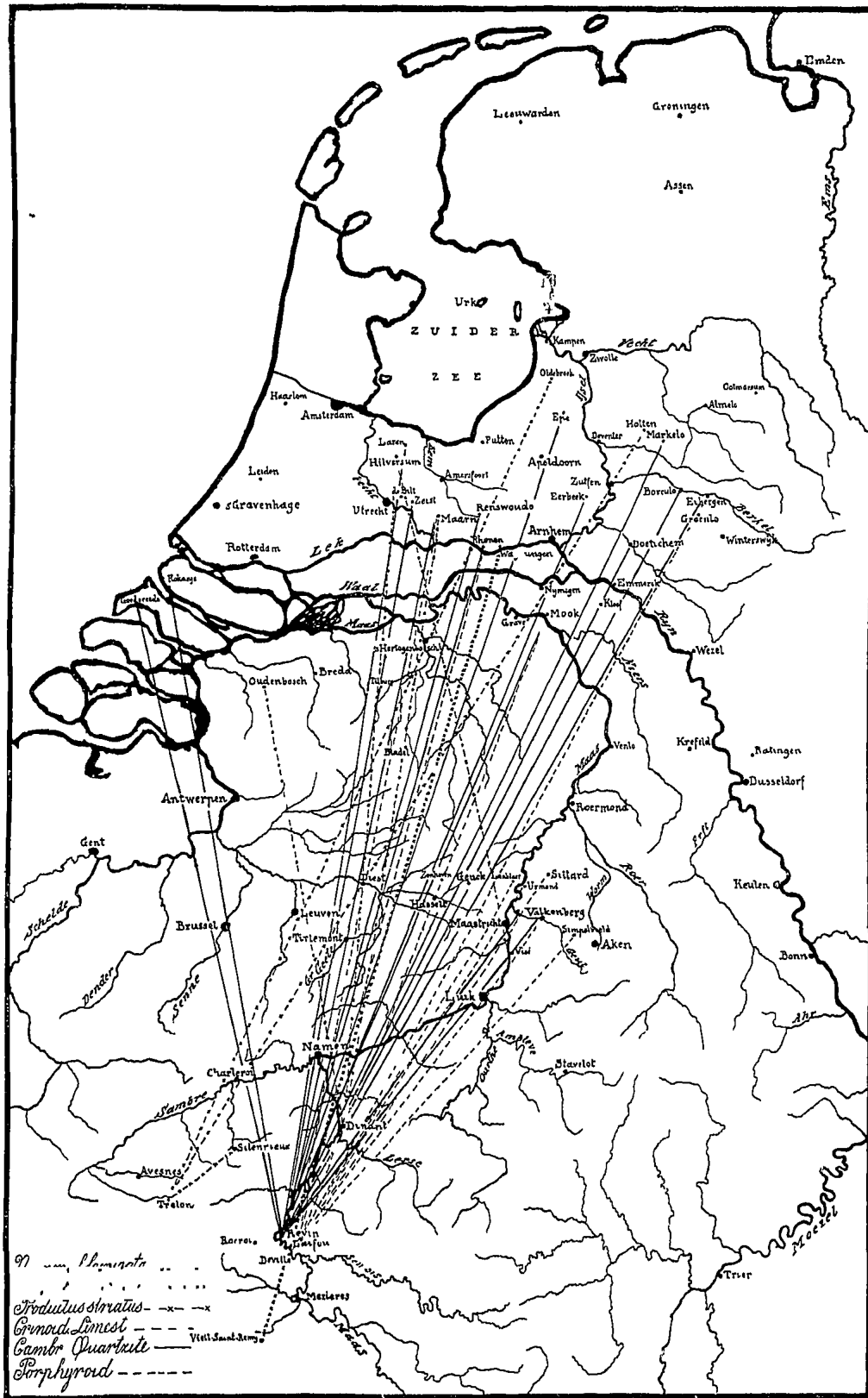
<sup>2)</sup> Prodrôme d'une description géologique de la Belgique. Bruxelles et Liège. 1868, p. 237.

<sup>3)</sup> Les anciens dépôts de transport de la Meuse. Ann. Soc. géol. de Belgique XIV. 1886—87. Mém. p. 102.

<sup>4)</sup> Note sur les roches cristallines... Ann. Soc. géol. de Belgique XVI. 1888—89. Mém. p. 414, 439—441, 444.

<sup>5)</sup> Recherches sur les formations diluviennes du sud des Pays-Bas. Archives Teyler (2) III. 6<sup>ème</sup> partie. Haarlem 1891. Tableaux synoptiques I—V.

A. WICHMANN. "On fragments of rocks from the Ardennes found in the Diluvium of the Netherlands North of the Rhine."



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débris of the glacier from the Ardennes; 3<sup>rd</sup>. The melting process commenced soon after reaching its Southern limit. It was only during its receding course that the Baltic ice-stream remained for some time stationary, and in this period of inaction was formed the front moraine extending from the South coast of the Zuiderzee to Grebbe and further as shown by J. LORÉ<sup>1)</sup>, over Nimeguen to Crefeld. The glacierformations, at present situated South of the Rhine, were afterwards, i. e., during the inter-glacial period, exposed to the turbulent waters of the Meuse, which, as has been stated above, rose 200 M. above the level of the sea, at least between Namur and Dinant, — proof of which is afforded by the high terrace. Although this terrace slopes down towards the North, near Nimeguen, it still reaches a height of between 50 and 100 M. + A.P.<sup>2)</sup>. Owing to this action of the Meuse, the erratics found in North-Brabant and Limburg are generally smaller and more polished than those of the diluvial deposits North of the Rhine. And lastly, a great portion of the glacier formation has got hidden from view by the large alluvial tract of the Rhine delta, which has been formed after the breach of this river at Nimeguen and subsequent alterations of the level by dislocations.

Anyhow, it is entirely out of the question to admit that in the beginning of the quaternary period the Meuse had its outlet into the sea, a little North of Maastricht and formed there an estuary, — a theory put forwards by M. MOURLON<sup>3)</sup> and A. RUTOT<sup>4)</sup>. As J. LORÉ justly observes, not a single indication exists of the sea having extended so far inland.

1) J. LORÉ. Le Rhin et le glacier scandinave quaternaire. Bull. Soc. belge de Géologie XVI. 1902. Mém. p. 129—153. N. VIII.

2) l. c. p. 131. The high terrace of the valley of the Meuse is generally considered of pliocene formation, but the presence of Scandinavian erratics in places situated farther North, e. g. Mook, Nimeguen, etc., proves that it must have been formed after the receding of the Baltic ice-stream.

3) Les mers quaternaires en Belgique. Bull. Acad. roy. de Belgique (3) XXXII. Bruxelles 1896 p. 671—711. La faune marine du quaternaire moséen révélée par les sondages de STRYBEEK (Meerle) et de WORTEL, près de HOOGSTRAETEN en Campine. l. c. (3) XXXIII. 1897, p. 776—782.

4) Les origines du quaternaire de la Belgique. Bull. Soc. belge de Géologie. XI. Bruxelles 1897, p. 117.

5) De hoogvenen en de gedaantewisseling der Maas in Noord-Brabant en Limburg. Verhandel. K. Akad. van W. Tweede Sectie III. No. 7. Amsterdam 1894, p. 10.