Geology. — *"Cambrian Erratic-blocks at Hemelum in the South-west of Frisia."* By J. H. BONNEMA. (Communicated by Prof. J. W. MOLL).

To the East of Molkwerum, a railway-station between Leeuwarden and Stavoren, stretches a region that from a geological point of view is very remarkable; as was especially shown by the interesting researches of Dr. VAN CAPPELLE. [1])

The road first leads in a North-eastern direction to the village of Koudum, which is situated on elevated ground. As far as here the surface showed alluvial clay only; now we see for the first time diluvial formations. The outer part of this elevation consists of boulder-clay, whereas in two sand-pits it may be easily observed that preglacial layers form the inner part.

A little farther on, when the alluvial grounds are reached again, one comes to the Galama-dams. They are found on the Morra, according to the above-named author a bottommoraine-lake.

About a mile farther upward we again find diluvial soil, and on continuing our journey in the direction of Rijs we see, just before leaving Hemelumer-Oldephaert and Noordwolde, and entering the domain belonging to Gaasterland, in a meadow to the right of the road a large pit 8 metres deep. From this pit for some years boulder-clay has been dug in behalf of the brick-works of the Comp. "Gaasterland", at a short distance, on the other side of the road.

As far as I know, these are the only brick-works in the Northern part of the Netherlands, where bricks are made of boulder-clay.

The boulder-clay, which forms a bottom-moraine here and which must be found very deep in the earth, is coloured blue-grey. Only quite near the humus-layer it has become red-brown, under the influence

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1) VAN CAPPELLE, Les Escarpements du „Gaasterland" sur la côte meridionale de la Frise. Extrait du Bulletin de la Société Belge de géologie, de paléontologie et d'hydrologie 1889.

VAN CAPPELLE, Bijdrage tot de kennis van Frieslands bodem. II. Eenige mededeelingen betreffende de Gaasterlandsche kliffen. Tijdschrift v. h. Koninkl. Nederl. Aardrijksk. Genootschap. 1890.

VAN CAPPELLE, Bijdrage tot de kennis van Frieslands bodem. IV. Eenige mededeelingen over de diluviale heuvels in de gemeente Hemelumer-Oldephaert en Noordwolde. Tijdschr. v. h. Kon. Nederl. Aardrijksk. Genootschap. 1892.

VAN CAPPELLE, Bijdrage tot de kennis van Frieslands bodem. V. Karteering van 't diluvium van Gaasterland en Hemelumer-Oldephaert en Noordwolde. Tijdschr. v. h. Kon. Nederl. Aardrijksk. Genootschap. 1895.

VAN CAPPELLE, Diluvialstudien im Südwesten von Friesland. Verhandelingen der Koninkl. Akad. v. Wetensch. te Amsterdam. 1895.

of the weather. It contains comparatively few erratic-blocks. They often show very fine glacier-scratches and are mostly of average size.

During the time when this opportunity of gathering erratic-blocks has presented itself, I have several times visited, from Leeuwarden, this loam-pit. The result of these visits is that I brought home rather a large number of erratic-blocks (probably between 300 and 400).

The sedimentary ones are still here at present; after studying them I intend to present them to the Geological Institute at Groningen. The others, whose number is small compared with that of the sedimentary stones, have already been given to this Institute.

Though my collection is still small, it is large enough to confirm my opinion that our knowledge of our sedimentary erratic-blocks leaves much to be desired. I formed this opinion already after examining the erratic-blocks of Kloosterholt. [1])

In gathering erratic-blocks in the Gron. Hondsrug I had gradually come to the conclusion that our sedimentary ones almost exclusively originated from Silurian layers, and that the latter must have shown much resemblance to those of the Russian Baltic-sea provinces, perhaps are still to be found there. On getting acquainted with the erratic-blocks in the boulder-clay of Kloosterholt, however, I could not but see very soon that at any rate this rule does not hold good in all cases. In this place I often found pieces of older and younger formations, while corresponding stones occur as firm rocks in Sweden and Denmark. The very same phenomena, as I hope I shall indicate, are seen in the erratic-blocks of Hemelum. Besides Silurian formations, others, both older and younger, are numerously represented. At the same time all of them show almost exclusively a West-baltic character.

We should then see the remarkable phenomenon that at Groningen, which is situated between Kloosterholt and Rijs, erratic-blocks greatly differ from those of the two places mentioned.

Gradually, however, I am beginning to doubt whether my opinion about the character of the erratic-blocks in the Groningen Hondsrug should be the right one. In the years when I used to gather there, digging was almost entirely confined to the upper layers, so the chances are, that deeper parts contain other kinds of erratic-blocks.

A few facts seem to indicate this. First of all: while a deep cave was being dug under the brewery called Barbarossa, at Helpman, big blocks of Saltholmlime with Terebratula lens Nilss made their

[1]) Van Calker. Ueber eine Sammlung von Geschieben von Kloosterholt. Zeitschr. d. Deutsch. Geol. Gesellsch. Jahrgang 1898 p. 234.

Bonnema, De sedimentaire zwerfblokken van Kloosterholt. Versl. v. d. Koninkl. Akad. van Wetensch. te Amsterdam 1898 pag. 448.

appearance. Some pieces of this material are still to be seen in the Geological Institute at Groningen.

Secondly: VAN CALKER [1]), — when the ramparts near one of the gates (Boteringepoort), which ramparts had certainly been made of the boulder-clay from the very deep ditches in that neighbourhood, were dug off, — found some erratic-blocks consisting of kinds of stone such as I never found afterward, and which do not occur in the Russian Baltic-Sea provinces, i.a. slate with graptolites, Faxe-lime and sandy glauconite lime-stone with Terebratula lens Nilss.

Deeper cuts made into the Hondsrug may afterwards give us an opportunity of learning whether my original opinion was entirely right, or is the true one only as far as the outer layers are concerned.

I should now like to tell something about the chief Cambrian pieces that are found in my collection. I am going to treat only of those stones whose age may be more or less precisely determined.

I. Lower-Cambrian Stones.

1. Scolithus-sandstone. Eleven stones consisting of this material are found in my collection. Nine of them are typical grey, quartziferous Scolithus-sandstone, showing a peculiar, fatty lustre on the side where they were broken off. No layers are visible as long as the stone is not changed by the influence of the weather. Only if this takes place, the layers become more or less visible. In one stone they are rather distinct and turn upward (perhaps downward) near the "scolithus." Two other stones, one of which is blue-grey, whilst the other moreover contains red parts, are clearly divided into layers and contain much finer tubes than are found in the typical stone. In the regions from which our erratic-blocks come, Scolithus-sandstone was first seen as firm rock in the isle of Runö near Oscarshamm, where according to TORELL [2]) it was discovered by Dr. HOLMSTRÖM. Afterwards it was also met with as such by NATHORST [3]), in the isle of Furon, not far from Runo.

I was wrong when, in treating of the Kloosterholt erratic-blocks, I told that Scolithus-sandstone as firm rock is found in Sweden, in the neighbourhood of Lund and Kalmar. The same mistake was

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[1]) VAN CALKER, Beitrage zur Kenntniss des Groninger Diluviums. Zeitsch. d. deutsch geol. Gesellsch. Jahrg. 1881 pag. 718 and 727.

[2]) TORELL, Petrificata Suecana formationis cambricae. Lunds Univ. Årsskrift. Tom. VI 1869 pag. 12.

[3]) NATHORST, Geol. Foreningens i Stockholm Förhandlingar 1879. Bd IV, pag. 293.

made by SCHROEDER VAN DER KOLK [1]) and by STEUSLOFF [2]). The latter and I probably came to make it unter the influence of what was told by ROEMER [3]) with regard to the origin of this kind of erratic-blocks. With SCHROEDER V. D. KOLK this is certainly the case, as appears from the note at the bottom of the page.

As to their being found at Hardeberga in the neighbourhood of Lund, ROEMER seems to have forgotten the fact that TORELL [4]), though he at first communicated that the Hardeberga sandstone contained worm-shaped bodies probably belonging to Scolithuslinearis Hall, afterwards makes mention of a new kind, viz. Scolithuserrans TORELL [5]). The latter are distinguished for being mostly curbed and running through the stone in various directions.

ROEMER'S information that TORELL describes Scolithuslinearis from an erratic-block found near Lund, and that according to NILSSON Scolithus-sandstone occurs near Calmar (as firm rock), must be attributed to an error. If my imperfect acquaintance with the Swedish language does not deceive me, TORELL [6]) writes that the place where the pictured stone (an erratic-block) was found, cannot be indicated for sure, but that NILSSON thinks he remembers that it was found near Calmar.

In the Northern part of the Netherlands erratic-blocks of Scolithus-sandstone are rather common. In Frisia were found, besides the stone treated of above, one in the Roode klif (Red Cliff) [7]), one in the Mirnsercliff [8]) and one at Warns (see number 3). Among the erratic-blocks of the Gron. Hondsrug [9]) only one piece was found up to this time, whereas I formerly described already two pieces from Kloosterholt [10]) and afterwards gathered more of them there. In the

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1) SCHROEDER VAN DER KOLK, Bijdrage tot de kennis der verspreiding onzer kristallijne zwervelingen. Dissertatie pag. 50.

2) STEUSLOFF, Sedimentärgeschiebe von Neubrandenburg. Archiv des Vereins der Freunde der Naturgeschichte in Mecklenburg. Jahrg. 45 pag. 162.

3) ROEMER, Lethaea erratica pag. 23.

4) TORELL, Bidrag till Sparagmitetagens geognosi och paleontologi. Lunds Univ. Årsskrift. Tom. IV. pag. 35.

5) TORELL, Petrif. Suec. format. cambric. pag. 12.

6) TORELL, Bid ag till Sparagmitetagens geogn. och paleontol. pag. 29.

7) VAN CAPPELLE, Bijdrage tot de kennis van Frieslands bodem. II pag. 12.

8) VAN CAPPELLE, Les Escarpements du „Gaasterland", pag. 236.

9) VAN CALKER, Ueber das Vorkommen cambrischer und untersilurischer Geschiebe bei Groningen. Zeitschr. d. deutsch. geol. Gesellsch. Bd XLIII pag. 793.

10) VAN CALKER, Ueber eine Sammlung von Geschieben von Kloosterholt, pag. 235. BONNEMA, De sedim. zwerfblokken van Kloosterholt, pag. 449.

province of Drente VAN CALKER [1]) mentions Buinen, Steenbergen and Zeegse as places where he came across these stones, whereas I myself found some at Odoorn.

2. Grey sandstone with interlaced coloured layers.

A small piece of quartziferous sandstone, 7 centimetres long, is almost entirely grey-coloured. Two systems of coloured layers, varying from red to violet, interlacing under angles of about 30 degrees, are also found. The layers of each system separately run parallel to each other. Surfaces of deposit do not occur and the size of the grains of sand is everywhere the same, so that it is impossible to examine which layer-system runs parallel to them.

This sandstone was made mention of for the first time by NATHORST [2]), who found erratic-blocks consisting of it in Jungfrun in the Kalmarsund. With DAMES [3]) he found the same kind of stone in Oeland, a few years after. Later on the latter writer [4]) could tell about this kind of erratic-block occurring in diluvial layers in the neighbourhood of Berlin.

As one of the pieces found there contains Scolithus-tubes, he could also draw the conclusion that their age is the same as that of the above mentioned Scolithus-sandstone. This conclusion is confirmed by means of a piece of Scolithus-sandstone that I found at Warns a short time ago. Through the grey piece of sandstone run on one side a few violet-coloured layers, which are intersecting the Scolithus-tubes under an angle of 60 degrees, while the latter always stand perpendicularly on the surfaces of deposit, which are not seen here.

That this stone also occurs in the Dutch diluvium, was already shown by VAN CALKER [5]); he proves that it is found in the erratic-blocks of the Gron. Hondsrug.

II. Mid-Cambrian Stones.

3. Limesandstone with Paradoxides-remains.

In my collection I have also a piece of grey, fine-grained sandstone with a large quantity of calcium-carbonate as binding-material.

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[1]) VAN CALKER, Ueber ein Vorkommen von Kantengeschieben und von Hyolithus- und Scolithus-Sandstein in Holland. Zeitschr. d. deutsch. geol. Gesellsch. Jahrg. 1890 pag. 583.

[2]) NATHORST, Geol. Foreningens i Stockholm Förhandlingar 1879. Bd IV pag. 293.

[3]) DAMES, Geol. Reisenotizen aus Schweden. Zeitschrift der deutsch. geol. Gesellschaft. Jahrg. 1881 pag. 417.

[4]) DAMES, Zeitschr. d. deutsch. geol. Gesellsch. Jahrg. 1890. Bd XLIII pag. 777.

[5]) VAN CALKER, Zeitschr. der deutsch. geol. Gesellsch. Jahrg. 1891. Bd XLIII pag. 793.

Through the stone run intersecting passages of the same mineral. Here and there are small grains of glauconite and pyrites-crystals. Besides many Paradoxides-fragments arranged in layers, my stone contains remains of horn-shelled Brachiopoda. The former are cream-coloured and do not allow of being further defined. Among the latter are easily found valves of Acrotele granulata Linn.

About this stone I have up to this time nowhere found any information. It is probably of the same age with the layers of Paradoxides Tessini Brongn., or it is a little older than these are.

4. Gravel-stone with Paradoxides Tessini Brongn.

a. It is a piece of fine-grained, hard sand-stone, yellow-grey inside and light grey nearer the surface, whilst the surface itself is brown in some places. With a magnifying-glass some grains of glauconite and a few mica-scales may be distinguished in it.

With muriatic acid applied to it, there is no effervescence; consequently it does not contain calcium-carbonate. There are no layers.

The chief remnant occurring in this erratic-block is a mid-shell, a little more than 1 centimetre long, of a Paradoxides, which mid-shell is visible for the greater part. The cream-coloured shell is still almost entirely present. That this remnant originates from Paradoxides Tessini Brongn., could be easily determined by means of the description and the pictures which LINNARSSON [1]) gave us of this kind. Prof. MOBERG, to whom I had the honour of showing this erratic-block, when visiting Lund, thought my determination right.

The glabella increases in breadth towards the front; quite near the front it is broadest. The front-edge is rounded off. On each side the glabella has two side-furrows, which in the middle run into those of the other side, which is also the case with Paradoxides Oelandicus. Of smaller furrows, which according to LINNARSSON are sometimes found in the latter, nothing is to be seen here. The edge before the glabella is very narrow in the middle and broadens towards the ends. This is characteristic of Paradoxides Tessini, whilst with Paradoxides Oelandicus the breadth of the edge before the glabella is rather considerable, and remains about the same towards the sides.

We also find here a piece of a thorax-ring of a kind of Paradoxides, in which it may be seen that the pleurae first run straightway towards the outside and then turn to the back, forming an almost right angle. This also occurs with Paradoxides Tessini, whereas with Paradoxides Oelandicus this turning to the back takes place gradually.

[1]) LINNARSSON, Om Faunan i Kalken med Conocoryphe exsulans („Coronatus kalken"). Sveriges geologiska undersökning. Series C. N° 35 pag. 6. Scene I fig 1—4.

Finally are found in this erratic-block a few small valves of horn-shelled Brachiopoda, among which is one of Lingula or Lingulella.

b. Besides the piece treated of just now I found a piece of sandstone with Paradoxides-remains, which shows no effervescence when hydrochloric acid is applied to it, and which consequently is gravel-stone.

It is a flat piece, consisting of two parts of a different nature. One of them is formed by sandstone and does not present many layers. This sandstone greatly resembles the material of which consists the erratic-block treated of under *a*, but is a little bluish. Some small mica-scales and glauconite-grains are also present here. The other part shows many more layers and has a dark bluish-grey colour. Sometimes the layers are as thin as paper, so that the material becomes slate-like.

Just as in the other piece of stone, the Paradoxides-remains are cream-coloured here. They are, however, too fragmentary to enable us to draw the conclusion that they originate from Paradoxides Tessini. As up to this time, however, only sandstone with this kind of Paradoxides has been found in diluvial grounds, and the petrographical nature of one part of them bears a great resemblance to that of the previous piece, I think I may suppose this much, and I venture to range this erratic-block under this head.

I think that both pieces originate from a layer-complex of gravel-stone with Paradoxides Tessini-remains, which complex consisted both of slate-like blue-grey parts and of thicker light-coloured layers. The last-mentioned erratic-block may originate from the former, whereas the one treated of under *a* would be a piece of a thicker layer.

If my supposition is not false, it may be easily explained from the difference in firmness and the difference in fitness for being transported issuing from this, why in literature nothing is found about erratic-blocks that should bear resemblance to the last-mentioned piece, whilst two or three communications have been received about the finding of erratic-blocks that most probably are more like the piece treated of in the first place.

The first communication we got from ROEMER. [1]) It deals with a piece of gravel-stone that was found in a sand-pit of Nieder-Kunzendorf near Freiberg in Silesia. It seems to have been more exposed to the influence of the weather than the erratic-block found by me, the writer mentioned speaking of a ferrugious outer crust, while round my piece such a crust begins to form itself.

Probably I must also range among this kind a piece of sandstone

[1]) ROEMER, Zeitschr. der deutsch. geol. Gesellschaft. Bd 9. Jahrg. 1857 pag. 511.

with Paradoxides Tessini-remains that was found in the collection of Groningen erratic-blocks, given to the geological Institute at Lund by Mr. DE SITTER, L. L. D., then burgomaster of Groningen. It was described by LUNDGREN [1]). I am sorry that we do not learn whether it is gravel-stone or lime-sandstone. I wrote to Prof. MOBERG, director of the Institute mentioned above, in order to ask after this, but he could not give me any information concerning the piece just then. I think, however, that it is gravel-stone, LUNDGREN telling us that the colour is „gråhvit", while according to ROEMER [2]) lime-sandstone with Paradoxides Tessini is dark grey.

While in the previous case it has not yet been with certainty determined which kind of sandstone one has to deal with, REMELÉ [3]) has announced another gravel-stone with Paradoxides-remains having been found. This erratic-block differs from the piece I described under *a* in the fossils being coloured brown by manganite-superoxide. However, I think this of little importance, as it may be just as well a consequence of infiltration that occurred in diluvial grounds or even before that time.

Gravel-stone with Paradoxides Tessini has up to this time not been met with as firm rock. Probably it occurs as such, or did so in former times, in the neighbourhood of Oeland; for on the Western coast of this isle is found, in several places, lime-sandstone with the same kind of trilobites.

III. Upper-Cambrian Stones.

5. Alum-slate with Agnostus pisiformis L. var. socialis Tullb.

One time I was so fortunate as to find a piece of black slate, in which are scattered the grey head- and tailshields, preserved in relief, of a kind of Agnostus. They have a length and a breadth of 3 millimetres at most.

The head-shields are moderately vaulted. The dorsal furrows meet in front, and a tongue-shaped glabella is bounded by them. At the front-part of the glabella is on each side a lateral furrow. The two lateral furrows run into each other and in this way cut off a small part in front. At the foot of the glabella two small lobes are separated from the rest by means of two lateral furrows slanting backward. The central, largest part of the glabella shows

[1]) LUNDGREN, Geologiska Föreningens i Stockholm Förhandlingar. 1874. II N° 2 pag. 44.

[2]) ROEMER, Lethaea erratica, pag. 29.

[3]) REMELÉ, Zeitschr. der deutsch. geol. Gesellschaft. Bd 35. Jahrg. 1883 pag. 871.

in the midst a wedge-shaped elevation. The cheeks are in front separated by a furrow running from the front of the glabella to the edge-furrow.

The tail-shields are much more vaulted. This is especially the case with the rhachis, which broadens towards the back and stretches nearly as far as the edge. Consequently, the lateral parts of the pygidium, which are already narrow, become even more so towards the back part. They are not separated by a furrow, as it is the case with those of the head-shields. The pygidia have at the back-edge on either side a little cog pointing backward. The rhachis of the pygidia is clearly divided into three parts. The back-part is the largest by far and is particularly swollen. The lateral furrows of one side do not meet those of the other, as they are separated by a wedge-shaped elevation passing on from the second part to the first and ending towards the back in a blunt point slanting upward.

From the properties mentioned it may be easily seen why this kind of Agnostus was described by TULLBERG [1]) as Agnostus pisiformis L. var. socialis. Pictures of it have been given by BRÖGGER [2]) and POMPECKI [3]).

Up to this time this erratic-block is the only piece of alum-slate with Agnostus pisiformis L. var. socialis that was found in our diluvial grounds. In Germany they also seem to be very rare. Only GOTTSCHE [4]) mentions such a piece from SCHULAU. This one also contains, however, remains of Olenus truncatus Brünn. As firm rock such alum-slate with this variety of trilobites occurs in Sweden (Oeland and Bornholm included), in different places, as I learned from Prof. MOBERG, to whom I showed a piece of the erratic-block.

Microbiology. — *"Accumulation experiments with denitrifying bacteria"*. By G. VAN ITERSON JR. (Communicated by Prof. M. W. BEIJERINCK).

The great signification of the denitrifying bacteria for the circulation of nitrogen in organic life and the important biochemisms to which they give rise, make the study of these organisms very attractive.

[1]) TULLBERG, Om Agnostus-arterna i de Kambriska aflagringarne vid Andrarum. Sveriges geologiska Undersökning. Ser. C. N° 42 pag. 25.

[2]) BRÖGGER, Die Silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker. Pag. 56. Taf. 1. fig. 10 a b c.

[3]) POMPECKI, Die Trilobiten-Fauna der Ost- und Westpreussischen Diluvialgeschiebe. Beiträge zur Naturkunde Preussens herausgegeben von der Physikalisch Oekonomischen Gesellschaft zu Königsberg. Pag. 15, Taf. IV, fig. 24 a b.

[4]) GOTTSCHE, Die Sedimentär-Geschiebe der Provinz Schleswig-Holstein, pag. 11.