ON THE CORRELATION BETWEEN THE FLUVIAL DEPOSITS OF THE LOWER-RHINE AND THE LOWER-MEUSE IN THE NETHERLANDS AND THE GLACIAL PHENOMENA IN THE ALPS AND SCANDINAVIA

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INTRODUCTION.

When in April 1921 the 18th Congress of Physicians and Naturalists met at Utrecht, Prof. Dr. K. Oestreich, the president of the fourth section, provoked an ample discussion regarding one of the most important phenomena *i.e.* the presence of fluvial accumulation terraces and their connexion with glacial phenomena. Then the writer was charged to open this subject with regard to the Scandinavian ice-sheet that surely once covered our country.

As from English side trials have been made [1]) to parallelize the quaternary deposits present in the Netherlands with Alpine, North-German and English glacial phenomena, it did not appear superfluous to the writer, to repeat in a more detailed way the statements made by him at the Congress, with indication of the literature especially the Dutch one; at least as far as it relates to the subject.

The reason of the failure of Ch. Brooks' endeavour in 1919, referred to above, is, that he only knew the phenomena in the Netherlands from literature, which could not procure him sufficient information, to warrant such important conclusions. The knowledge the Dutch geologists possess about this question, is yet so fragmentary, that every endeavour to

set up a correlation must be rejected as being too premature, which will become obvious from the following considerations.

This also holds good for the Prussian geologists' endeavours, who in literature, repeatedly cited by Brooks, also mention our country. It is true, that some of them visited the Netherlands, but their knowledge obtained by a short stay and a cursory glance at the Dutch literature, was insufficient to infer from it the above mentioned correlation.

It is clear that all these endeavours must have a very unfavourable influence on the whole subject, if one pays attention to the fact that all publications concerning it, were made in languages far more widely read than ours. This fact caused a great number of inaccurate views about the Dutch soil which entered the world-literature and will not very soon disappear.

Let us come now to the point and first investigate how the generally existing opinions about the connexion of terraces and glacial phenomena have risen.

I. HISTORICAL REVIEW.

In 1884 appeared a treatise written by ALBRECHT PENCK 2) (who was then a 25 years old private-teacher in the University of Munich) which has had a great influence upon the opinion of the young geologists and naturalists.

The essential point of this treatise lies in the following words: „Die Accumulationsterrassen der deutschen Alpen sind geradezu das seitliche Aequivalent der Vereisung. Während sich die Gletscher entfalteten, schütteten die Flüsse ihre Täler mit Geröll zu. Zeitlich begann hier die Schotteranhäufung mit dem Eintritte der letzten Vergletscherung und deutlich lässt sich hier wahrnehmen, dass es die Wasser, welche den ehemaligen Gletscher entströmten, waren, die das Geröll anhäuften."

With these words PENCK pronounced the hypothesis, well known to all of us, that a chronological and genetic connexion must exist between the terraces in the immediate neighbourhood of the alpine glaciers and these glaciers themselves; that during the maximal extension of the phenomena of the glacial period, the rivers deposited sand and gravel, and that these deposits again were partly destroyed during the disappearance of the ice.

As this process, accumulation followed by erosion, was repeated several times, in the end the terraces extending along the rivers which have their origin in the Alps, were formed. How one has to imagine this connexion between terraces and

the phenomena of the glacial period was not formulated till after 7 years by LÉON DU PASQUIER 3) in the following words: „Die Schotter schliessen sich allmählich durch einen etwas steiler geneigten Uebergangskegel den Moränen an, und innerhalb der Uebergangskegel wird durch eine Blockfacies der Schotter der Uebergang beider Gebilde in einander angedeutet."

When PENCK in Bavaria, BRÜCKNER in the territory of the Salzach and L. DU PASQUIER in North-West-Switzerland had found next to a so-called „Niederterrassenschotter" (low-level valley gravel), a high-level valley gravel of which a connexion with moraines was probable, such connexion was finally considered to be a certainty, the latter coming to the great, general conclusion, that each „Schottersystem einer Vergletscherung", each erosion in these deposits an „Interglazialzeit entspricht".

Although PENCK in 1884 had drawn the attention to the fact, that „wie allgemein verbreitet auch die Talzuschüttung der Quartärzeit infolge gesteigerter Geschiebeführung der Flüsse war, **so ist doch keineswegs gesagt, dass eine jede Schotterterrasse ohne weiteres auf diesen Umstand zurück zu führen sei,"** DU PASQUIER did not hesitate to parallelize what he called „Hochterrasse des Rheines" at Wiesbaden and Cologne with the Alpine „Hochterrassenschotter", and this, because

a. „die Hochterrasse sich am Rhein über unser Gebiet hinaus fortsetzt" and

b. near Wiesbaden and Cologne also is covered with loess.

Referring to the deposits at Mosbach at the southern foot of the Taunus which then already aroused the interest of many naturalists, DU PASQUIER ends with the following words: „Aus der Aehnlichkeit der Terrassenausbildung und aus der Wechsellagerung der Mosbachersande mit glazialem Materiale der grossen (vorletzten) Vergletscherung, wie sie beim Hochterrassenschotter vorkommt, geht für mich mit **Wahrscheinlichkeit** hervor, dass beide Ablagerungen gleichaltrig sind."

As regards the „Wechsellagerung", it consisted according to DU PASQUIER in great angular erratic blocks, lying both in and under the sand, about which stones nothing has been reported, but that they must have been transported thither by flakes of river-ice. Because *Helix arbustorum*, as DU PASQUIER relates, was scarcely found in the sand-layers of Mosbach, after his opinion these layers could not be inter-glacial, but must be undoubtedly glacial. The possibility however was not excluded that the sand-deposits near Mosbach did not

descend from alpine glaciers, but from a local ice-sheet.

That, which was **supposed** by PENCK in 1884 concerning the Alps, and has been apprehended as **probable** for the Rhine by DU PASQUIER in 1891, was represented in 1904 with regard to our own country as a **manifestness,** for which a further proof need not be supplied. The discovery of some erratic blocks of large dimensions in a gravel pit near Venlo (*i.e.* clay-slate, quartzite, flint and basalt) caused the Dutch geologist E. DUBOIS to write, that these stones had been conducted by flakes of ice from the Upper-Rhine and Upper-Meuse; that therefore the Rhine diluvium was glacio-fluvial and chronologically aequivalent with the „Deckenschotter" of the „Middle-Rhine". Two years later this conclusion was extended, and then it was stated that the whole diluvium of the Rhine and the Meuse belongs to the first glacial period of the Alps and the oldest of the Scandinavian glacial periods. DUBOIS now goes one step farther and parallelizes the Alpine with the Scandinavian glacial periods; however he withholds us the proofs for this correlation. [4])

In the meantime PENCK had altered already in 1905 his opinions of 1884, *viz.* during his examination of the terraces of the Rhône near Villefranche. Then he wrote: „Wir müssen uns daher hüten, so wie wir es früher selbst getan haben, die Schotterterrassen im allgemeinen als Zeugen einer Eiszeit zu betrachten. In wie weit solche interglaziale Schotterterrassen ausserhalb der Gletschergebiete vorkommen, wird sich erst durch eine genaue Verfolgung der Flussterrassen an grossen Flüssen zeigen. An Donau und Rhein haben wir sie bis Wien und Basel nicht angetroffen; möglicherweise werden sie durch fossilreiche Ablagerungen repräsentiert, die weiter stromabwärts liegen und durch ihre Fauna sich als interglazial erweisen, wie z.B. die Sande von Mosbach." [5])

What strikes us in this acknowledgement, is, that the beds of Mosbach regarded by DU PASQUIER as being glacial, are considered by PENCK to be inter-glacial, which opinion offers the possibility, that at least one of the Rhine terraces is either wholly or partly inter-glacial.

The researches of O. AMPFERER regarding the terraces of the Inn-valley, and the theoretical remarks made by V. HILBER, induced PENCK's cooperator, A. BRÜCKNER, to write in 1909 that interglacial gravel deposits existed in the glaciated territory of the Alps, but, as to the terraces of the French and Belgian rivers, situated outside the territory of the former ice-sheet, this question wanted an independent solution. [6])

Although we observe a certain change as regards the

results of the latest researches, the criticisms on the theoretical opinions of PENCK and BRÜCKNER are only quite recent.

Here in the first place the word is with ALBERT HEIM, who, in his work „*Geologie der Schweiz*" reserves an ample space to the glacial and fluvio-glacial deposits. Where he treats the High-terrace of the Rhine (regarded by PENCK and BRÜCKNER as a deposit of the Riss-glacial period, by BROOKS as synchronical with the Mindel-glacial period) HEIM says: „Bei dem höher an die Gehänge hinaufreichenden Schotter, dem Hochterrassenschotter, konnte in unserem Lande (Switzerland) eine unmittelbare Abhängigkeit und Verknüpfung mit den Moränen nicht festgestellt werden. Im besonderen ist unter sicheren Hochterrassenschottern noch nirgends Moräne gefunden worden, und die darüberliegenden Moränen sind wesentlich jünger, indem sie Erosionsflächen des Hochterrassenschotters aufliegen. Echte Uebergangskegel aus Endmoränen horizontal in Hochterrassenschotter, d.h. sichere gleichzeitige Einlagerungen von Moräne im Hochterrassenschotter sind noch nie gefunden worden. Talaufwärts setzen die Hochterrassenschotter auch nicht an Moränen ab, vielmehr gehen sie im Gegensatz zur Niederterrasse noch bis in das Gebiet der letzten Vergletscherung, sogar stellenweise bis an den Ausgang der Alpentäler hinauf, und hören dann auf". And a little farther on he writes: „....Wenn nun nach der Auffassung von PENCK jede grosse Schotterbildung einem grossen Eisstande entspricht und Schotter und Moränen eiszeitliche gleichzeitige Facies darstellen (erstere vorherrschend ausserhalb, letztere nur innerhalb der betreffenden Vergletscherung gebildet), so müssen den vier Schotterterrassen entsprechend, vier Vergletscherungen statt gefunden haben.... So richtig dies in grossen Zügen und für die ältesten und jüngsten Vergletscherung ist, für die mittleren Eiszeiten fügen sich die Verhältnisse in der Schweiz diesem Schema nicht ohne weiteres. Die Natur ist immer komplizierter, als es unserem zur Schematisierung geneigten Geiste angenehm ist." And in the end he says: „....Somit scheint der Hochterrassenschotter eher das Produkt einer Interglazialzeit zu sein, wobei die Gletscherenden wenigstens bis in die Alpentäler zurückgewichen waren, und vielleicht ist seine Ablagerung nicht durch Ueberfülle von Gletscherschutt, sondern durch Gefällsverlust infolge eines Stillstandes in der Landeshebung oder einer Landessenkung bedingt". 7)

That which strikes us in these considerations of HEIM, is: *a.* that he ascribes to tectonic movements an influence upon formation of terraces and

b. that he considers the high terrace of the Rhine in Switzerland to be inter-glacial and moreover to be older than the largest ice-sheet (Mindel-glacial period) in Switzerland.

This bringing into prominence of what we might call „the tectonical moment", we also find in the treatises written by F. LEVY in 1915 and 1920, in those by A. ROTHPLETZ which appeared in 1917 and in those written by W. DEECKE in 1918.

In 1915 LEVY comes among other things to the result that the four different glacial deposits on the southern slopes of the Alps can be divided into two parts, an older and a younger one, between which lies a period of tectonical disturbances. [8])

In 1920 this geologist, in his study about the history of the Upper-Isar Valley, comes to the conclusion: „..... Gerade der Einfluss der tektonische Vorgänge darf nicht unterschätzt werden. Die dadurch bewirkte Steigerung des allgemeinen Talgefälles hat auch dort, wo keine Tieferlegung der Talsohle noch in der Inter-glazialzeit vorausging, während der folgenden Eiszeit, zu einer erheblichen Verstärkung des Gletscherschurfes geführt." [9])

The territory, northward of the one where LEVY worked, was treated in detail bij A. ROTHPLETZ in 1917. He assumes in the first place, that also in this territory we meet with far more tectonic disturbances than has been supposed by PENCK, who in 1880 began here his glacio-geological researches; secondly he thinks that the so-called „Deckenschotter" southward of Munich, is not fluvio-glacial, as PENCK supposed, but that it has been deposited during a temperate climate. PENCK's opinion was founded on the presence of mollusks in a loamy layer that, according to H. CLESSIN, showed an arctic character. A renewed and more thorough examination gave the opposite result. [10])

This case, from an historical Point of view, is most interesting, because we may learn from it that, if more fluvio-glacial deposits will be accurately examined, it will be possible that many of them shall lose their supposed fluvio-glacial character, which again will influence our theoretical views concerning the connexion of other river deposits, situated far outside the once ice-covered territory, and which are assumed to be correlative with the glacial period, on account of the conservation of the now adopted scheme, without the exact proof being furnished for it.

In his treatise which appeared in 1918, W. DEECKE writes: „Die Untersuchung, welche uns ältere und jüngere Löss kund tun,

kehrt in Europa klar in dem Verhalten der Eisbedeckung wieder und diese selbst fällt zusammen mit sehr bedeutenden und ausgedehnten, das ganze Gebiet zwischen Alpen und Skandinavien umfassenden tektonischen Bewegungen. Dies gestattet mit einem gewissen Rechte, alle drei Erscheinungen ursächlich zu verbinden". [11])

Finally we must not forget, that the hypothesis, of the quaternary age of the alpine river-terraces was expressed by PENCK in the following words: „**Spärliche** Fossilfunde im ältesten Schotter des Eiszeitalters auf dem österreichischen Alpenvorlande vergewisserten uns vom pleistocänen Alter auch des ältesten Eiszeitgebildes der Alpen".

Whereas the climatologic hypothesis of the building of the terraces originated from Germany, there arose in the beginning of the twentieth century on French territory, the tectonic hypothesis, whose first defender was L. DE LAMOTHE. [12])

On the occasion of his investigations of the terraces of the Issel near Algiers, the Rhône near Valence, the Rhine near Basle and the Moselle in the Vosges, he discovered a remarkable conformity in the height of the different accumulation-terraces, which discovery induced him in 1901 to write that the formation of these terraces, in the above-mentioned places, was to be ascribed „à une succession de mouvements eustatiques, alternativement positifs et négatifs.... Ces mouvements alternatifs ont déterminé dans les vallées de phases successives d'érosion et de remblai, l'érosion correspondant au mouvement négatif, le remblai au mouvement positif."

As to the nature of these movements of the sealevel, the positive ones passed away very slowly, the negative ones on the contrary quicker, though never with shocks. Five years after this (in 1906), LAMOTHE's hypothesis found a warm support, on archaeological arguments, by M. BOULE [13]), and after that we see it slowly progress, only not everybody thought of the movements of the sea-level but the majority thought of movements of the earth-crust. Thus in 1908 J. CVYIC [14]), on the occasion of his investigations concerning the origin of the Iron Gates, came to the conclusion that a vertical uplift of the Rila-mountains and of the Thessalian Olympos, had caused an ice-covering of this territory, whereas for the rivers this elevation meant erosion and accumulation. Finally the terracing of the accumulation products would have been caused by climatic oscillations during the glacial period.

Exclusive oscillations of the sea-level we find as an hypothesis in K. WOLFF's [15]) publications on the origin of the terraces of

the Saale, and in L. SIEGERT's [16]) publications on the origin of the terraces of the Elbe, the Weser and the Lower-Rhine.

As for the terraces of the Lahn, an affluent of the Middle Rhine, J. AHLBURG writes: „Bezüglich der Lahnterrassen komme ich jedenfalls zu dem Schlusse, dass ein erkennbaren Zusammenhang des Terrassenphasen (Erosion und Aufschüttung) mit Klimaschwankungen der Diluvialzeit **nicht** besteht." [16a])

As regards South-East-France, I remember the considerations of W. KILIAN and M. GIGNOUX [17]), who combine glacier oscillations with oscillations of the sea-level in the territory of the estuary of the river terraces in Bas-Dauphiné, examined by them.

G. ZEIL, the last of the writers about the above-mentioned subject, argues in 1919 in a communication,, preceding a large study about movements of the earth's crust, that the mountains are reduced by the process of erosion, to which they are exposed, the bottom of the sea on the other hand is raised by the accumulation of the products of decay. The mountains are reduced, their average temperature increases, the ice-sheet diminishes or disappears quite; according to ZEIL, the interglacial period of the geologists commences, followed by the glacial period, which is characterised by a slow rising of the earth-crust combined with a sinking of the sea-level, by which the rivers deepened their beds from the estuary upward. [18])

To this historical account, which comprises a period of 35 years, we can add the following:

Fluvial accumulation-terraces of quaternary age we meet all over the earth, in the territories that once stood under the direct influence of the glaciers, which had developed on the higher mountain-slopes, as well as in those countries, which were situated far beyond them. Such a universal phenomenon calls logically for a universal explanation, and the question is, whether this explanation already can be given, and if it ever will be given. In my opinion our knowledge is only so far advanced at this moment, that we only can indicate some general points that are forced upon us when we take a general view of the whole literature. These general points are the following ones:

1. The territories that have been covered with ice during the quaternary period, were, owing to the heavy pressure of the ice, subject to vertical movements, namely to a sinking one of the continent during the ice-period and to a rising one after it. Already in 1882 Th. F. JAMIESON pointed out the possibility of

these movements; M. RUDZKI and R. VON KÖVESLEGITHY proved their consistency mathematically and in 1912 G. DE GEER made the probability credible. [19])

2. In addition to continental changes of level, we must also take into consideration the possibility of marine changes of level. The opinion that the quaternary ice-sheet at the poles had an influence on the sea-level, originated from J. CROLL (1875) and his idea was adopted by A. PENCK in 1882. The latter explained the influence of the ice-sheet as follows. He thinks that the ice-mass at both poles, estimated by him at a thickness of 1000 M. [1]), both raised the sea about 90 M. and caused a sinking of more than 100 M. by the formation of ice.

Because E. HERGESELL in 1887, E. v. DRYGALSKI in 1887 and R. S. WOODWARD in 1888, each independent of the others, proved by their mathematic calculations that the above-mentioned attraction is only important, when one has recourse to the supposition of a gigantic ice-cap of an enormous thickness, A. PENCK modified in 1890 his supposition in the following way: „Wenn sehr grosse Vergletscherungen von den Massen der diluvialen gleichzeitig auftreten, dann überwiegt überall der Betrag der Senkung durch Wasserentziehung jenen der Hebung durch Deformation und es steht allenthalben der Meeresspiegel tiefer als gegenwärtig, allerdings nahe den Vereisungen weniger als in den Antipodenpunkt derselben". And a few pages further on he writes: „Wenn während der Eiszeit gleichzeitig Nord-Europa, das nördliche Nord-Amerika und die antarktischen Gebiete vergletschert waren, so musste dem Ozeane eine beträchtliche Wassermasse entzogen sein und, eine Eismächtigkeit von 1000 M. angenommen, sein Spiegel 150 M. tiefer als heute liegen". [20])

In this connexion I remember that already E. VON DRYGALSKI in 1887 came to **the same amount**, however proceeding from the supposition that the ice at the poles had a thickness of 2000 M.; R. DALY, who in 1910 adopted PENCK's idea of 1890, calculated the amount of the maximal sinking for the tropical regions at about 30 fathoms (= 54 meter); G. MOLENGRAAFF in 1920 at least 70 M. [21])

3. An indirect consequence of the phenomena of the glacial period in the temperate regions had for the tropical regions probably the result of the appearance of a period, characterised by a larger rain-fall than the present (the pluvial

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[1]) 1 K.M. = 1000 M. 1 M. = 3 feet.

period). This greater rainfall occasioned in the Indian Archipelago:

a. a rise of the level of the lakes, *e.g.* Lake Toba in N. Sumatra;

b. an increase of the accumulative power of the rivers which enabled them to depose more gravel, which was the cause of the building up of the river terrace *e.g.* of the Wampoo in North-Sumatra;

c. a more effective weathering of the rocks by which, in my opinion, on the isle of Java, the red volcanic soil, often but incorrectly called laterite, was built.

4. Terraces may have been formed where mountains have been exposed to an ice-covering. However, we want to point out here, that the mechanism by which these forms can be caused, is not known as yet. Continental as well as marine level-changes or climate oscillations may have caused them, and to which of these three causes the preference must be given, will have to be stated at any rate separately. Here again time will have to teach us whether one of the hypotheses now formulated will prove to give a correct explanation, or, if perhaps these three causes are to be reduced to one common original cause.

II. THE STUDY OF THE TERRACES OF THE RHINE AND THE MEUSE IN GENERAL.

The question of the terraces as far as it relates to the Rhine and the Meuse, after the publications of PENCK, BRÜCKNER and DU PASQUIER, was tackled by several geologists and geographers, each in his own way. If we look over the treatises published till this day, to begin with the oldest document concerning the Upper-Rhine by G. STEINMANN (1898) and concerning the Lower-Rhine by L. LORIÉ (1902) and finishing up with the latest, F. JUNGBLUTH's work concerning the Rhine-terraces from Andernach to Bonn (1917), whereas for the Meuse-terraces the oldest treatise by X. STAINIER is dated 1903 and the latest by W. KLEIN (1914), it strikes us, however considerable the number of the researches may be, that our knowledge about the process and the formation of these terraces is still very uncertain and it strikes us too, how little right we have to parallelize the different parts of the terraces, or to establish a correlation of the terraces as a whole with the glacial phenomena in Switzerland and in the Vosges.

Moreover, we must observe that in the study of the terraces itself, the morphological method has been brought too much to the fore. However practical it may be to test barometrically the terraces, with regard to their upper as well as their lower surface, to determine their heights, we regret the lack in the different treatises the use of other methods, which being exactly and carefully applied can, in my opinion, considerably add to a right understanding of the formation of the accumulation-terraces.

In the first place the **geo-chemical** method must be considered, while special notice must be taken of the degree of decay of the terraces in general and of the state of decay of a similar kind of rock in the different places separately. It appears *e.g.* that the porphyroid of Mairus, originating from the French Ardennes, and very important as an indicating boulder for gravel-layers deposited by the Meuse, is strongly decomposed in the high-terrace of the Meuse near Keer, Houthem and Kelmond (See Map I) and is to be found quite unaltered in the immediate neighbourhood, in the middle-terrace of the Meuse near Smeermaas.

In the second place I want to draw the attention to the **palaeontological** method. It is true, that this method, as far as possible, is applied more frequently, but critical circumspection is missing when it ascribes a certain value to the fossils and fixes the age of the terraces and the nature of the climate in which the terraces were formed.

A third method, the **petrographical** one, by which is striven after an accurate investigation of the river gravels and a fixation of their origin, is far too seldom used. When studying the different writings with regard to this method, we feel very disappointed and OOSTINGH's monography about the Rhine-and Meuse-gravels gives us more than one proof for the neglect of said method [22])

About these terraces it is said that:

1. They are synchronous with the different ice-periods, known in the Alps and their mountainous surroundings.

2. The Alpine ice-periods being synchronous with the Scandinavian ones, the formation of the terraces is also synchronous with the formation of the different glacial deposits which the land-ice has brought us in the Netherlands.

In the following chapter we will discuss point 1, and give our attention to point 2 in chapter IV.

III. THE TERRACES OF THE LOWER-RHINE AND LOWER-MEUSE AND THEIR CONNEXION WITH THE ALPINE GLACIAL PERIODS.

No principle of stratigraphical geology has proved more fertile, in trying to fix the age of different layers, than that of correlation.

Before the study of organic remains was taken up seriously, the geologists had in the beginning of the 19th century drawn up the hypothesis, that conformity in petrographic composition of a group of layers A with a group of layers B would point out that the geological age of these groups had to be the same.

In fact two leading thoughts were implied in this hypothesis, namely that a positive correlation must exist between a definite group of layers (A) and the surroundings in which and the circumstances under which it arose, and 2ndly, that, if between this group A and another one (B), situated elsewhere, prevails a petrographic conformity, it therefrom proceeds, that group B has been formed under the same circumstances as A and that A and B have the same age.

The history of geology shows us that by and by the idea of correlation is going to be regarded as to be identical with the idea of synchrony. My opinion being that, in an argumentation for the identical age of deposits, lying geographically far apart, one has to separate the proofs pleading for the correlation, from the ones that must show the synchrony, we shall consider first:

A. The correlation between the different terraces and the Alpine ice-periods and then

B. The synchrony between these two groups of phenomena.

A. The arguments, supplied for a correlation of the terraces with the phenomena of the quaternary Ice-Period in Middle-Europe are:

I. In and on the high-terrace of the Meuse in South-Limburg and of the Lower-Rhine in Germany, big boulders are found, which cannot have been brought there by flowing water; so flakes of ice must have served as means of transport. These flakes of ice are said to originate from the Upper-Rhine and Upper-Meuse, where they only could have been formed in a so called ice-period. (See Plate Ia).

To meet this argument we shall make the following remarks.

1. As to the nature of the blocks, only being found in the oldest terraces of the Meuse and Rhine, they appear to be the well-known quartziferous sand-stone, problably originating from the Ardennes or the Eifel.

2. If, starting from the hypothesis of the sychronism of all pleistocene ice-sheets in Europe, we want to conclude that the Ardennes and the Eifel have had an ice-sheet, it will not do, to point out the presence of extraordinarily big stones north of this territory and probably originating from it, but we have to seek for the moraines and the morphological signs peculiar to all the mountains that once carried an ice-sheet. No proof is furnished till now for an ice-covered Ardennes. [23])

3. A transport of stones by flakes of ice need not be connected with an Ice-period; such transports are effected this very day. Thus W. DEECKE informs us that he observed, how, near Greifswald at the German East-Seacoast, stones, measuring about 1 M^3 were loosened from the bottom of the sea by ground-ice, during a N. E. storm, and pushed on over a wall of ice flakes with a height of more than 4 M. [24])

In 1907 the Finnish geologist J. LEIVISKA described similar facts at the coast of Gulf of Bothnia and in 1913 at the lake of Ulea, S. E. of Uleaborg (Finland). [25])

5. The situation of the great blocks on the tectonically disturbed oldest-terrace (See Plate I a and b), is not the original one and yet we must know this situation to be able to determine which transport can explain their presence on the spot.

6. The presence of these big stones at the base or on the gravel of the high-terrace, or on the older gravel of the principal terrace, does not prove, that they are of the same age as the high-terrace itself; as supposed by FLIEGEL in 1910, they may be the erosion-rests of a yet older quaternary or even tertiary deposit and the isolated erratic blocks, if lying on the high-terrace, may have been elevated by locally formed ground-ice.

7. Finally as regards the **so-called** glacier scratches (striae), WICHMANN already drew the attention (see reference 23) to the numerous communications concerning these stripes, resembling scratches, being found on the stones from the Ardennes. From his communications it became apparent that already different Belgian geologists were convinced that these stripes were **pseudo**-glacier scratches. From the territory of the Rhine H. BEHLEN mentions in 1904 glacier-scratches on sand- and lime-stones in the sandlayers of Mosbach near Wiesbaden, but these scratches could very well have been caused by the rubbing of stones against each other, as it has been seen in the case of cobble-stones, sliding down the mountain-slopes. [26])

II. An argument, about which seldom anything has been heard, is the presence of Alpine erratic blocks in the terraces

of the Lower-Rhine and of boulders of the Vosges in those of the Lower-Meuse; this argument however would have a relatively greater value for this correlation, if our knowledge of the petrographic composition of the terraces of the Rhine and the Meuse was not so very limited. [27])

B. With regards to the arguments, more or less clearly supplied in literature, in favour of a synchrony of the Lower-Rhine and -Meuse terraces, with the four Ice-Periods (Günz-, Mindel-, Riss-, and Würmperiod, distinguished by PENCK and BRÜCKNER), the following may be communicated:

I. The morphological argument: the continuation of the Dutch fluvial terraces of the Rhine to the glacial deposits of the pleistocene glaciers in Switzerland and those of the Meuse to the glacial deposits of the Vosges.

In consequence of the tectonical disturbances, to which the terraces in the Netherlands as well as in the Ardennes and the Eifel have been subject and the morphological interruptions, resulting from it, nothing proving this argument is to be seen on the field.

II. The palaeontological argument.

The terraces of the Lower-Rhine have brought in, till now, only little material, and moreover this little material has been adequately studied; the high-terrace of the Meuse (St. Petersberg) near Maastricht, delivered some material, the middle-terrace (near Smeermaas) delivered some more. In this period, however, the usefulness and value of the discoveries were not yet sufficiently appreciated; they only enriched our knowledge concerning the age of the terraces. Even RUTTEN's highly interesting endeavour [28]) to elaborate the material, dispersed in the different musea in the Netherlands, has not produced any certainty. Thus RUTTEN communicated that probably *Elephas trogontherii* is to be found in the high-terrace of the Meuse; on the contrary *Elephas primigenius* in the middle-terrace. According to H. F. OSBORN [29]), *E. primigenius* belongs to the „Mindel-Riss interglacial Epoch", and *E. primigenius* to the „Riss and the Würmglaciation". This opinion depended partly on PENCK's geological conceptions and partly on H. POHLIG's palaeontological researches.

If we compare them with the researches of W. SOERGEL [30]) concerning the importance of *E. antiquus* and *E. primigenius* for the classification of the German Pleistocene, we see that our knowledge concerning this point does not warrant our deducing from the presence of both kinds of elephants, anything about the nature and the character of the climate that must

have prevailed during the building of the terraces of the Meuse in the Netherlands. With regard to the terraces of the Lower-Rhine in Germany, G. FLIEGEL wrote: „Die Versuche das Diluvium am Niederrhein paläontologisch zu gliedern, haben bisher (1910) zu keinem befriedigenden Ergebnis geführt." [31]

III. The petrographical argument.

An argument especially pushed to the fore by the geologists working in the territories of the Rhine, is the presence of younger (= unaltered) loess and of older (= altered; weathered) löss, covered by younger unaltered loess.

According to G. STEINMANN'S first opinion (1893), loess was only to be found on the high-terrace, an opinion, afterwards changed by him so far, that decayed loess was to be found on the high-terrace and undecayed loess on the middle-one. To this statement he added in 1906 a second one, with regard to the terraces of the Lower-Rhine, *viz:* the lower-terrace has not any loess. Against this statement L. v. WERVEKE protested in 1906: In the Alsace younger loess is lying only on, what he calls, the lower-terrace, consequently the terrace of the Lower-Rhine, called by STEINMANN middle-terrace, must be called too lower-terrace. „.... Eine Mittelterrasse im Sinne STEINMANN'S besteht nicht. Die lössbedeckte Mittelterrasse am Nieder-Rhein entspricht der Schweizer Niederterrasse". [32]

These far-reaching conclusions depend on incomplete researches and it is inconsiderate to classify terraces after their comparative age, without a more extensive and better examination concerning the loess, than has been done till now. For the sake of the scheme, an ice-sheet has been supposed for each terrace, an interglacial- or glacial period for each loess-bed. With regard to the terraces of the Lower-Rhine W. WUNSTORF participates the opinion, that no loess is to be found on the lower-terrace, only younger löss on the middle terrace and older loess covered with younger on the high-terrace. [33]

I share the opinion of W. WUNSTORF and J. AHLBURG as regards the absence of loess on the lower-terrace of the Rhine and Meuse, likewise their conception that this lower-terrace is to be placed outside of the whole pleistocene and therefore ought to be reckoned among the holocene. As to the presence on the middle terrace of only younger loess WUNSTORF relies upon borings, whereas I examined in 1916 a large profile in a loess-pit on the middle-terrace of the Meuse near Smeermaas. Here I was able to show that under the younger loess lies an older layer strongly decayed. [34] (See Plate II a en b).

In 1918 E. ZIMMERMANN (the younger) found the same

phenomenon on the middle-terrace of the Rhine near Bonn. Now my opinion is that insufficient material led WUNSTORF to a wrong conclusion, but ZIMMERMAN tries to balance the contradiction between his profile researches and WUNSTORF's examinations made in one pit on the high-terrace and borings in the middle-terrace, by assuming that the older + the younger layer of loess near Bonn = the younger loess at the territory of WUNSTORF *viz.* the neighbourhood of München-Gladbach. [35])

This method of working is fatal because here again the theoretical connexion that always has been made between loess and terrace misled the writer.

If, finally, we look over the arguments that might plead for a synchrony of the terraces of the Lower Rhine and Lower Meuse with the Alpine ice-periods, our conclusion is that till now not one single proof can stand a sharp criticism.

The household word: what we want, are facts, must be our chief guide.

IV. THE CONNEXION BETWEEN THE TERRACES OF THE LOWER-RHINE AND THE LOWER-MEUSE WITH THE SCANDINAVIAN ICE-PERIOD PHENOMENA.

Starting from the supposition that the phenomena of the ice-period were synchronic all over Europe, and so every ice-period of the Alps may be said to have its analogon in an ice-covering of the North-German lowland, the geologists eagerly began to search how the scheme of the Four-Ice-Periods of PENCK and BRÜCKNER drawn up for the Alps, could be adapted to North-German situations. Though warnings against any inconsiderateness were not lacking, the geologists, especially in Germany, published several schemata, one contradicting the other.

Here again abiding by the distinction pointed out above, so that a difference must be made between correlation and synchrony, the attention, in connexion with synchrony must be drawn to the fact that a correlation between the deposits of the Scandinavian Ice-period and the fluvial terraces of the Lower-Rhine and the Lower-Meuse has never been proved and probably cannot be proved, because one gets caught in a labyrinth of auxiliary hypotheses.

As regards synchrony, my researches of late years have proved with certainty that the Scandinavian land-ice wa-

present at least **once** during the accumulation of an important part of the fluvial deposits of southern origin.

Giving here in concise form the facts published by me in 1920, I shall dwell longer on those I discovered near Ede in 1921 and which have not been described till now.

In 12 places I had already noticed that a distinctly glacial deposit (either boulder clay or glacial gravel) was mixed with southern erratic blocks, or was lying enclosed between layers of exclusively fluvial material of southern origin.

With regard to the phenomena near Ede, represented here after, we submit the following observations.

On the westerly slope of a plateau 16 kilometer long and 3 kilometer broad, rising up from the alluvial Rhine-valley with an escarpement of about 35 M., a factory was built near the railway-station of Ede on the line from Utrecht to Arnhem. In behalf of the water supply, three trenches were made, with a depth of 6-9 M. and a width of 6 M. At a right angle with these trenches some more, as large and as deep, but less long. (See the sketch; scale 1 : 3000).

The profiles brought to light by the cutting of these trenches have been photographed over their whole length and on the sketch the places where the photos were taken are indicated, as well as their orientation. (See plate III-XIV, with explanations). Summarizing the whole, we get the following sketches. (See the profile-drawings at the end).

Which conclusions can we draw from these observations?

1. The Scandinavian Inland-ice deposited near Ede its material into a depth of the terrain, which measured at least 10 M., taking count of the fact, that the terrain was levelled by digging about 5 M.

2. Before the Inland-ice was coming, the Rhine and the Meuse had already deposited layers of gravel and sand, which then **probably** were turned up by the pressure of the Inland-ice.

We can say with certainty, that this deposit is synchronic with the high-terrace of the Rhine and the Meuse situated in the southern part of the Netherlands and the Rhine-province. This deposit doesn't form on the Veluwe (See the map) a terrace but a vast plateau, consisting of heights and depths. These depths were filled up by the Inland-ice, that at the same time, according to the common view, turned up the layers at the bottom, across which it advanced and whereupon it, melting, deposited its material.

3. When the Inland-ice was lying near Ede, at its border a lake was formed, of which we do not know the extension and of

which the depth again must have been 10 M. In this lake settled the glacial sand and when this sand had filled the original lake almost entirely, the southern fresh water-streams came and deposited upon it loam, and later on sand and gravel. The mixed gravel (Scandinavian and southern erratic stones), to be found in the sand, proves that the edge of the ice was not far off.

These southern sand-and gravel-layers built in a yet unknown extensiveness the chain of hills, running from Wageningen to Lunteren and showing heights of 50 M. + O.D. [1]), consequently this chain of hills is **younger** than the terrain, measuring about 20 M. + O.D., near Ede, on which the Land-ice rested during the formation of these hills.

Three questions still remain to be answered.

Given the fact that we get to know 2 elements in the neighbourhood of Ede, namely one **pre-glacial** deposit and one **„glacial"** deposit, the former built up by the Rhine and the Meuse, the latter by Inland-ice together with the same rivers, the question arises: **Where do we find these elements again in the Netherlands?**

A second question is: **With what terrace-deposit of the Lower-Rhine and Lower-Meuse is the „glacial" [2]) deposit of southern material near Ede to be parallelized?**

And at last there is the question: **Which is the relative age of the Scandinavian ice-sheet on the Veluwe?**

A. The answer to the first question is only to be given under a certain reserve, deep incisions failing about everywhere, but bearing in mind the geo-morphological aspect of the landscape, we must reckon among the older pre-glacial chains of hills, the ones, running from Arnhem to the village of Vierhouten, and to the younger „glacial" [2]) chains of hills, those running from Wageningen to Lunteren.

It is only in the first chain of hills we find for the first time a deep incision, near Arnhem of a depth of 13 M. and extending from 52 M. to 65 M. + O.D. (See plate XV and XVI).

When studying the composition of this chain, I observed the following:

I. Uncommonly strong disturbances in the situation of the layers from the deepest part almost to the top. Plate XVI gives an image of these disturbances in the lower part of the incision. **In my opinion, these disturbances are of a tectonic origin.**

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[1]) + O. D. = + A. P. (Dutch).

[2]) „Glacial" in the meaning of as old as the Scandinavian Land-ice, that deposited its material near Ede.

II. Only in the uppermost part, at about 5 M. below the surface, amidst southern gravel, some granites as big as a fist, were to be found; below it exclusively characteristic boulders originating from southern countries (porphyry and basalt from the Rhine, quartzite and porphyroid from Mairus, in the French Ardennes, *etc*). No other glacial deposits of erratic boulders from Scandinavian origin could be found and so I came to the same conclusion I made already in 1907, that this large chain of hills existed already, before the Inland-ice arrived at the Veluwe. Only the uppermost part is perhaps to be regarded as a deposit of that Land-ice, at least if we ascribe to one single piece of granite so much demonstrative power and overlook the granites to be found in the river-terraces of the southern Netherlands, originating from the South. [36])

The opinion of KEILHACK, that this range of hills from Arnhem to Vierhouten, might be a „Stau-moräne", is as incorrect as his notion, that the glacial landscape-forms in the North of the Veluwe, might be wind-forms. Here again the short visit, KEILHACK paid to the Netherlands in 1915, has led to a wrong insight and it is certainly not accidental, that KEILHACK in his essay regarding the Veluwe, nowhere mentioned, where he had been and which things he exactly observed. [37])

The big and high hill-chains with horizontal crest-line, which arise in the East of the Netherlands from Lochem to Ommen, belong, as I explained in 1910, [38]) to the same category of prae-glacial deposits as those of Arnhem, which is proved by the form and the composition. Showing at the surface the aspect of the Veluwe, we find in the large railway-incision of Nijverdal gravel-layers of southern origin, lifted up only in the centre [1]) and only in the upper most layer we sporadically find granite. When getting to the north of the river Vecht, we arrive at the province of Drente and there we find that all pre-glacial hill-chains have disappeared, because they have sunken away and lie hidden under a deposit, consisting of sharp quartz-sand of an unknown thickness, which at the surface has the same age as the boulder-clay, immediately lying upon it. I had a good opportunity to observe this phenomenon in 1914 and 1915, in a large sand-pit near the station

1) In my opinion, the uplifting of these layers [from the bottom to the top of about 20 M.] has not been caused by the moving Inland-ice, but by the folding of the earth-crust. But we have not yet got to the study of the deformations of sand-and gravel-layers by warping, folding and faulting.

of Vries-Zuidlaren. I'll describe here for the first time the profiles, going from the south to the north which I carefully examined.

The layers will be indicated in the following way:

A-sand = fluvial sand with exclusively southern stones and therefore from southern origin, deposited by the Rhine perhaps in cooperation with the Meuse.

Ba = boulder-clay = yellow boulder-clay (Scandinavian origin).

Bb = boulder-clay = red boulder-clay (Scandinavian origin).

C-sand = boulder-sand (Scandinavian origin).

The situation of the layers is **from bottom to top** the following one:

1. At the beginning of the sand-pit **A**-sand, thickness 3 M., at the upper-side covered with an undulated layer of brown-coloured debris of Scandinavian boulders, cemented by ferric-oxyde.
   On this **A**-sand rests **B**a, grey, with yellow spots, thickness 0.3 M. (about 1 foot), unconformably covered with **C**-sand, of a thickness of 0.75 M.
2. 28 M. farther to the North:
   A-sand, exclusively covered with **C**-sand with a thicknes of 1 M.
3. 11 M. farther to the North:
   A-sand, covered with **B**b, hard, dry and of a red colour, thickness 1.3 M., with undulating nether side; upon this layer rests unconformably **C**-sand.
4. 25 M. farther to the North:
   A-sand, covered with **C**-sand and on the boundary between both, small pieces of red boulder-clay.
5. 5 M. farther to the North:
   Exclusively **A**-sand with enclosed loam-bank; above this bank, the **A**-sand is grey — and below it yellow coloured. On the boundary between the loam and the grey sand, there is a thin layer of limonite concretions. Probably we have to do here with the influence of a lake, having existed, formerly or with the influence of a high ground-water level, at which border limonite was deposited.
6. 20 M. farther to the North:
   A-sand, yellow coloured, thickness 3 M. Upon this sand a layer of limonite concretions, thickness 0.05 M; thereupon **A**-sand, grey coloured, with little Scandinavian erratic boulders, thickness 0.5 M. Upon this **A**-sand, grey coloured with a thin layer of loam, of a thickness of 0.3 M. Upon this sand

red boulder-clay, thickness 0.2 M. and thereupon unconformably **C**-sand, 0.9 M.

7. 7 M. farther to the North:
   A-sand, yellow coloured, covered with a dark brown, hard and compact layer of limonite, running from the left top to the right bottom; upon this layer **A**-sand, grey coloured, with a lens of debris of Scandinavian boulders; upon this, red boulder-clay, with undulating netherside.
8. 11 M. farther to the North, the end of the sand-pit:
   A-sand, yellow coloured, with an uplifted bank of loam, all covered by a horizontal layer of limonite nodules; upon this layer **A**-sand, grey coloured, covered by red boulder-clay, thickness 0.1 M.; thereupon unconformably **C**-sand, thickness 1 M.
   On the boundary of the red boulder-clay and the yellow bouldersand, was lying a Scandinavian erratic boulder, horizontally broken into two pieces, the upper half lying at a distance of 2 M. from the lower half.

The opposite ridge of the pit, the one looking on the West, consists only of 2 deposits, namely grey coloured **A**-sand and thereupon **C**-sand, of a thickness of 1 M.

On the boundary between them there lies a thin layer of northern and southern stones, all polished by the wind.

From the above mentioned observations we may conclude, that here again *one* Scandinavian ice-sheet was synchronic with *one* southern deposit.

The yellow boulder-sand is an independent deposit building ridges, which according to their morphological aspect, must bear the name of terminal moraines. (See plate XVII and XVIII).

Finally I'll draw the attention to the fact, that I described in 1920 the results of an microscopical examination of a complete profile of boulder-clay near Zuidlaren (thickness: 1.7 M.) and at Miste near Winterswijk, (thickness: 1 M.) from which it appeared, that this boulder-clay had been deposited in two places, lying far asunder and under the united action of Scandinavian Land-ice and southern rivers. [39])

B. The answer to the second question, is not easy to be given. It is true, that one feels inclined to say: with the middle-terrace of the Lower-Rhine and the Lower-Meuse, but the persons speaking like this, do so under the influence of 2 hypotheses, *viz.*

1. the synchrony of a terrace with one Ice-period and
2. the Land-ice, having covered the Netherlands at least once, is synchronic with the Second Ice-period of North-Germany.

This last point, however, is a hypothesis too, for which the proof has never been furnished.

C. An answer to the last question cannot be given either. At present the current opinion is:

The Netherlands have known one Ice-period, which was synchronic with the Second North-German Ice-period.

In my opinion this conception will later on appear to be incorrect.

Already now voices arise in North-Germany, saying that the *First* Ice-period there is the principal one, the „Haupt-Eiszeit", and A. PENCK, writing about the above mentioned profiles near Ede, which I was able to show him in March 1921, says: „.....So muss man folgern, dass die diluvialen Ablagerungen zwischen Rhein und IJsel älter sind als die vorletzte Interglazialzeit Norddeutschlands". [40])

Now there is yet the question: Have the Netherlands known one or two Ice-periods? According to the above described profiles of Ede and Zuidlaren certainly **two,** in the opinion of the other Dutch geologists **one** period. [41]) What is said about this question in foreign countries, cannot be taken into consideration, the literature of the latest years not being known there. The answer to it we must leave to the future. Only an extensive and skilful research will be able to help us, but no presupposed theories.

Every foreign geologist, not fully acquainted with the phenomena of the field and the Dutch literature, who will notwithstanding endeavour to parallelize the Scandinavian ice-deposits in the Netherlands with the terraces in Middle-Europe and the phenomena of the Ice-period in the Alps and Scandinavia, will become aware of the fact, that his endeavour, as being immature, will be rejected. The time, for drawing up a parallelization, as BROOKS tried to do in 1919, has not yet arrived.

WAGENINGEN, November 1921.

REFERENCES

1) CH. E. P. BROOKS, The correlation of the quaternary deposits of the British isles with those of the continent of Europe. (From the Smithsonian Report for 1917, Washington 1919, p. 277-375),

2) A. PENCK, Zur Periodicität der Thalbildung (Verh. d. Gesellsch. f. Erdkunde zu Berlin, 1884, p. 39).

3) L. DU PASQUIER, Ueber die fluvioglacialen Ablagerungen der Nord-Schweiz. (Beiträge zur geologischen Karte der Schweiz, Lieferung 31, Bern, 1891, p. 28, 68, 124).

4) E. DUBOIS, On an aequivalent of the Cromer Forest-Bed in the Netherlands. (Proceedings Royal Academy of Sciences at Amsterdam, Meeting of Sept. 24, 1904. Vol. VII, p. 214).
E. DUBOIS, La pluralité des périodes glaciaires dan les dépôts pleistocènes et pliocènes des Pays-Bas (Archives du Musée Teyler, 2e Série, 2e partie, Haarlem, 1906 p. 163).

5) A. PENCK und E. BRÜCKNER, Die Alpen im Eiszeitalter, Bd. II, 1905, p. 669, „Interglaciale Schotterterrassen".

6) O. AMPFERER, Ueber die Entstehung der Inntal-terrassen. (Zeitschr. f. Gletscherkunde, Bd. III, 1908, p. 52).
V. HILBER, Gegenbemerkungen über Terrassen und mittelsteirische Wanderblöcke (Zeitschr. f. Gletscherkunde, Bd. IV, 1909, p. 71).
V. HILBER, Entstehung der quartären Schotterterrassen im Umkreise der Alpen. (Zeitschr. f. Gletscherkunde, Bd. IV, 1910, p. 304).
E. BRÜCKNER, Bemerkungen zu HILBER's „Entstehung der quartären Schotterterrassen im Umkreise der Alpen. (Zeitschr. f. Gletscherkunde, Bd. IV, 1910, p. 305).
O. AMPFERER, Ueber einige Grundfragen der Glazialgeologie. (Verhandelungen d. geol. Reichsanstalt in Wien, 1912, p. 237).

7) A. HEIM, Geologie der Schweiz, Bd. I, 1917, p. 270.

8) F. LEVY, Die eiszeitliche Vergletscherung der Südalpen zwischen Dora Riparia und Etsch. Eine prinzipielle stratigraphische Untersuchung (Zeitschr. f. Gletscherkunde, Bd. IX, 1915, p. 225).

9) E. LEVY, Diluviale Talgeschichte des Werdenfelser Landes und sein Nachbargebiete. (Ostalpine Formenstudien, Abt. I, Heft 1, 1920, p. 172 and 174).

10) A. ROTHPLETZ, Die Osterseen und der Isar-Vorlandgletscher. (Landeskundl. Forschungen d. geograph. Gesellschaft in München, Heft 24, 1917, p. 23, 31, 43, 68 and 128).

11) W. DEECKE, Kritische Studien zu Glazialfragen Deutschlands. (Zeitschr. f. Gletscherkunde, Bd. XI, 1918, p. 34).

12) L. DE LAMOTHE, Sur le rôle des oscillations eustatiques du niveau de base dans la formation des systèmes de terrasses de quelques vallées. (Compte rendu de l'Académie des Sciences, Paris, Tome 132, 1901, p. 1428).
L. DE LAMOTHE, Étude comparée des systèmes de terrasses des vallées de l'Isser, de la Moselle, du Rhin et du Rhône (Bulletin Soc. géol. de France, Série IV, Tome I, p. 97).

13) M. BOULE, Les Grottes de Grimaldi, résumés et conclusions des études géologiques. (L'Anthropologie, Tome XVII, 1906, p. 257).

14) J. CVYIC, Entwicklungsgeschichte des Eisernen Tores. (Petermans Mitteilungen, Ergänzungsheft No. 160, 1908, p. 44).

15) K. WOLFF, Die Terrassen des Saaletals und die Ursachen ihrer Entstehung. (Forschungen zur deutschen Landes- und Volkskunde, Bd. XVIII, Heft 2, 1909, p. 167).

16) L. SIEGERT, Zur Theorie der Talbildung. (Zeitschr. d. deutschen geol. Gesellsch. Monatsbericht No. 1, 1910, p. 1).

16a). J. AHLBURG, Über das Tertiär und das Diluvium im Flussgebiete der Lahn (Jahrbuch der preuss. geologischen Landesanstalt für 1915, Band XXXVI, Teil I, p. 269). A very interesting study with reference to the terraces of the Middle-Rhine in general and those of the Lahn particularly.

17) W. KILIAN et M. GIGNOUX, Les formations fluvio-glaciaires du Bas-Dauphiné. (Bulletin des services de la carte géologique de la France, Tome XXI, 1911, p. 74).

18) G. ZEIL, Corrélations entre les terrasses quaternaires, les récurrences glaciaires et les mouvements ascensionnels de l'écorce terrestre. (Comptes Rendus de l'Académie des Sciences, Tome 169, 1919, p. 1406).

19) TH. F. JAMIESON, On the cause of the depression and re-elevation of the Land during the glacial period. (Geological Magazine, 1882, p. 400).
M. P. RUDZKI, Deformationen der Erde während der Eiszeit. (Zeitschr. f. Gletscherkunde, Band I, 1906, p. 182).
R. v. KÖVESLITHY, Zur Erklärung d. alten Strandlinien. (Zeitschr. d. Ungarischen geol. Gesellsch. Band XXXII, 1902, p. 394).
G. DE GEER, Kontinentale Niveauveränderungen in Norden Europas. (Petermanns Mitteilungen, 1912, II, p. 121).

20) A. PENCK, Morphologie der Erdoberfläche, II, 1890, p. 531 and 660.

21) E. VON DRYGALSKI, Die Geoiddeformationen der Eiszeit. (Zeitschr. d. Gesellsch. f. Erdkunde zu Berlin, XXII, 1887, p. 169).
R. DALY, Pleistocene glaciation and the Coral reef problem. (American Journal of Science, 4th Series, Vol. XXX, p. 29).
G. MOLENGRAAFF and M. WEBER, On the relation between the pleistocene glacial period and the origin of the Sunda Sea. (Proceedings of the Royal Academy of Sciences. Amsterdam Vol. XXVIII, 1920, p. 497).

22) C. H. OOSTINGH, Contribution to the knowledge of erratic boulders of southern origin being found in the Netherlands and their neighbourhood. (Proceedings of the Agricultural University at Wageningen, XIX, 1921) [Dutch]. This monography contains 164 pages, 2 maps, 4 plates and an extensive bibliography.

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The only pamphlet, drawing our attention to the petrographic method in the investigation of river-terraces is: W. SOERGEL, Die Ursachen der diluvialen Aufschotterung und Erosion, Berlin, 1921. In this book the author gives us the following important remarks:

„.....Petrographische Schotteruntersuchungen können auch über die Ursachen einer Aufschotterung, über das Klima, in dem sie statt fand, und damit über die allgemeine Alterstellung im diluvialen System Aufschluss geben; sie können in diesem Zusammenhang zum Teil eine wichtige Stütze werden für den faunistischen Befund, zum Teil die Deutung dieses Befunds, die fast stets von rezenten, oft keineswegs hinreichend bekannten oder eindeutige Schlüsse gestatteten Verhältnissen ausgeht, korrigieren. Den Fragen nach der speziellen Alterstellung von Schottern mit interglazialer Fauna, nach den Vorgängen in unseren Flusstälern zur Postglazialzeit, die heute nur in grossen Zügen, nicht in den Eizelheiten erkennbar ist, kann mit Erfolg vor allem auf diesem Wege nachgegangen werden. Die nicht unbeträchtlichen Schwankungen, die in der petrographischen Zusammensetzung der einzelnen Kies- und Schotterlagen selbst eines Aufschlusses bestehen, machen zur Gewinning brauchbarer Daten natürlich die Untersuchung zahlreicher und nicht zu kleiner Proben notwendig. Ueberhaupt muss eine Methodik der Schotteruntersuchung und der Bewertung erst ausgearbeitet werden. Die einzelnen Schichten sind nach der Grösse ihrer Komponenten verschieden zu beurteilen. Dasselbe Gestein aus einem bestimmten Teil des Einzugsgebiet muss in Sanden oder feinen Kiesen in einem anderen Mengenverhältnis vertreten sein, als in gröberen Kiesen und Schottern. Hier spielt die Widerstandsfähigkeit des Gesteins gegen Abrollung und Zertrümmerung beim Verfrachtungsprozess eine entscheidende Rolle, eben so das spezifische Gewicht. Für Gesteine von gleichen physikalischen Eigenschaften bezüglich der Einwirkungen der fluviatilen Verfrachtung ist zur richtigen Bewertung ihrer prozentualen Beteiligung und der herrschenden Geröllgrössen die Länge des Wegs vom Anstehenden bis zur Ablagerungsstelle in Rücksicht zu ziehen. Die Geröllgrösse und damit das Mengenverhältnis, in dem ein Gestein in feineren und gröberen Kiesen beteiligt ist, hängt also von einer Summe verschiedenartiger Bedingungen ab. Für petrographische Schotteruntersuchungen genügt es daher nicht nur das Mengenverhältnis der einzelnen Gesteine nach Gewicht oder Volumen festzustellen; es muss der Grad der Härte oder Zähigkeit, das spezifische Gewicht, die Grösse der Gerölle, in jedem Falle die Entfernung vom Ursprungsort, das Massenverhältnis in feinen, mittelgroben und groben Kiesen vermittelt, es müssen alle diese Daten in ihrem gegenseitigen Abhängigkeitsverhältnis geprüft werden. An einem gut aufgeschlossenen diluvialen Kieslager eines Flusses, dessen Einzugsgebiet zu damaliger Zeit vollständig bekannt ist, wäre zunächst eine Methodik aufzustellen. **Hier öffnet sich der induktiven Forschung ein weites Arbeitsfeld,** aus dem der Diluvialgeologie der nicht vereist gewesenen Gebiete, deren diluvialen Bildungen die wichtigsten Dokumente zur Entwicklungsgeschichte des Menschen und der jüngeren Säugetiere und damit zu einer allgemeinen Entwicklungsgeschichte liefern, eine feste, der reinen Spekulation entrückte Grundlage erwachsen muss.

23) A. WICHMANN in his contribution: On fragments of rocks from the Ardennes found in the Diluvium of the Netherlands, north of the Rhine. (Proceedings Royal Academy of Sciences at Amsterdam, Meeting of Dec. 30, 1905, Vol. VIII, p. 518, with map) was the first one, who made the supposition of an ice-sheet in the Ardennes. To my opinion however, expressed in my book: „The soil of the Netherlands, Vol. II, The Quaternary Period," Amsterdam, 1920, p. 490 (Dutch), the Ardennes have known during the Glacial Period only an extreme weathering of the rocks by freezing and thawing, by which

process considerable talus have been formed. In the Ardennes we find back the **periglacial facies** of the Inland-ice.

24) W. DEECKE, Kritische Studien zur Glazialfragen Deutschlands. (Zeitschr. f. Gletscherkunde, Bd. XI, 1918, p. 52).

25) J. LEIVISKÄ, Ueber die Oberflächenbildungen Mittel-Ostbottniens. (Fennia, Tome 25, No. 2, Helsingfors 1907, p. 107). With a photograph of the blocks.
J. LEIVISKÄ, Ueber den See Oulujärvi und seine Uferformen. (Annales Academiae Scientiarum Fennicae, series A, Vol. III, Number 12. Helsingfors, 1913, p. 102).
See also the note of G. FORCHHAMMER, the Danish geologist, about the working of sea-ice in the Belt in: Bulletin de la Societé geologique de France, 2e Série, T. IV, 1847, p. 1181 and the communications on the working of the flakes of river-ice of J. PRESTWICH in: Philosophical Transactions, Vol. 154, 1864, p. 287.

26) H. BEHLEN, Glacialgeschrammte Steine in den Mosbacher Sanden. (Jahrb. d. Nassauischen Vereins f. Naturkunde, Jahrg. 57, Wiesbaden, 1904, p. 173).
He, who wishes to know all the causes by which scratches on cobblestones and pebbles can be formed, must consult:
A. BÖHM, Bekannte und neue Arten natürlicher Gesteinsglättung. (Mitteilungen d. geographischen Gesellschaft in Wien, Bd. 60, 1917, p. 335).

27) In the collections of my Museum at Wageningen, is only one fragment of rock, probably originated from the Vosges or the Black Forest among 45 well-determined rock-types of the Ardennes and the Eifel. It is a strongly-weathered pegmatite, found among a great number of erratic stones from the mountaineous territories of the Rhine. When considering the fact, that 1000 meter farther to the North-West a great number of Scandinavian boulders was lying, among which were different pieces of the well-known fresh and unweathered pegmatite from Sweden, I hold myself entitled to say, that this pegmatite, the first find of this kind, is of southern origin.

28) L. RUTTEN, Die diluvialen Säugetiere der Niederlande. Utrecht, 1909, p. 102.

29) H. F. OSBORN, The age of Mammals, London 1910, p. 379.

30) W. SOERGEL, Elephas trogontherii Pohl. und Elephas antiquus Falc., ihre Stammesgeschichte und ihre Bedeutung für die Gliederung des deutschen Diluviums. (Palaeontographica, Bd. LX, Stuttgart, 1912, p. 99).

31) W. WUNSTORF and G. FLIEGEL, Die Geologie des niederrheinischen Tieflandes. (Abhandlungen der preussischen geologischen Landesanstalt, Neue Folge, Heft 67, Berlin, 1910, p. 117).

32) L. v. WERVEKE, Löss auf der Niederterrasse. (Mitteilungen der geologischen Landes-anstalt von Elsass-Lotharingen, Vol. VII, 1909, p. 133).

33) W. WUNSTORF, Ueber Löss und Schotterlehm im niederrheinischen Tiefland. (Verhandlungen d. Naturhistorischen Vereins d. Rheinlandes und Westfalens, Vol. LIX, 1912, p. 334); J. AHLBURG, p. 363 of his treatise, mentioned in reference 16a.

34) J. v. BAREN, Older and younger löss in the Netherlands. (Journal of the Royal Dutch geographical Society, Vol. XXXIII, 1916, p. 201; with photographs, mineralogical and physico-chemical analyses).
J. v. BAREN, The soil of the Netherlands, Vol. II, Amsterdam, 1920, p. 652 (Both in Dutch).

35) E. ZIMMERMANN (II), Löss und Decksand am Südrande der Niederrheinischen Bucht. (Jahrb. d. preussischen geologischen Landesanstalt f. 1918, Vol. XXXIX, 1, p. 157).

36) J. v. BAREN, The morphology of the diluvium westward of the IJsel. (Journal of the Royal Dutch geographical Society, Vol. XXIV, 1907, p. 129, with plates and map; Dutch).

37) K. KEILHACK, Das glaziale Diluvium der mittleren Niederlande. (Jahrbuch d. preussischen geologischen Landesanstalt f. 1915, Vol. XXXVI, 1, p. 458, with map).

38) J. v. BAREN, The morphology of the Diluvium eastward of the IJsel. (Journal of the Royal Dutch geographical Society, Vol. XXVII, 1910, p. 893. With plates and map; Dutch).

39) J. v. BAREN, The soil of the Netherlands, p. 556-562. (Dutch).

40) A. PENCK, Das Alter des Diluviums zwischen Rhein und IJsel. (Journal of the Royal Dutch geographical Society, Vol. XXXVIII, 1921, p. 554).

41) All the arguments pro and con the hypothesis of a repeated ice-covering of the Netherlands, I discussed in detail in my Dutch book „The soil of the Netherlands", p. 589-608.

EXPLANATION OF THE PLATES.

PLATE Ia. A block of white quartz-sandstone, often named lignite-sandstone („Braunkohlensandstein"), found by the author in May 1921 naer Gulpen, situated in the oldest gravel-accumulations of the Meuse. (See map I). The dimensions are: Length 2.35 M., breadth 1.40 M., height 0.95 M. In the Netherlands we find these blocks, which are often gigantic, in several places. (Gulpen, Maastricht, Heerlen, Winterswijk, Arnhem, Wageningen, a.s.o.).

PLATE Ib. shows the numerous disturbances, to be seen in every gravel-pit, as well in the fluvial accumulations southward of the Rhine as in the ones northward of the Rhine. Boths photographs were taken in May 1921, in a gravel-pit near Gulpen by Mr. J. MEERTENS.

Every geologist judging, that the disturbances southward of the Rhine are of tectonic origin, the dislocations inside the area of the Inland-ice, northward of the Rhine, are said to be of glacial origin. Nobody however, supposes the possibility, that these disturbances too can have a tectonic origin.

PLATE IIa. Loess- and gravelpit in the middle-terrace of the Meuse near Smeermaas.

PLATE IIb. A wall of the pit of plate IIa.
a. Younger loess, decalcified; thickness 0.90 M.
b. Younger loess, undecayed; amount of lime 12 %; thickness 3.65 M.
c. Older, decayed loess; thickness 1 M.
d. Fine, loamy sand with gravel; thickness 1.4 M.
e. Coarse gravel of the middle-terrace.
(Plate IIa and IIb have been taken by Mr. L. v. VUUREN, May 1921).

PLATE III and IV. The whole wall consists, from top to bottom, of fluvial material, deposited there by the Rhine and the Meuse with mutual cooperation, as appears from its petrographic composition. The original situation of the layers of gravel and sand have been strongly disturbed.

PLATE V. The greater part of this picture is occupied by disturbed layers of fluvial sand and gravel.
At the left side, at the top, the beginning of a glacial deposit is to be seen, consisting of Scandinavian erratic boulders, lying in a small layer of sand, on the right side already being levelled by digging.

PLATE VI. In the middle and on the right side the strongly disturbed, grey coloured fluvial layers of southern origin (a); thereupon, unconformably, a deposit of fine sand, horizontally stratified, with Scandinavian erratic boulders (b).
The structure of these layers clearly points to a deposit in a lake (glacio-lacustrine).

The inclination of the glacial sand-beds is 2°—5°; that of the tilted fluvial layers 15°—30°. The sand has a yellow colour and is limeless; at its basis lies a layer of northern erratic boulders, the ground-moraine of the Scandinavian Land-ice (c). The thickness of this glacio-lacustrine layer amount (under the bar at the left of the picture) to 1.70—2.30 M. The direction is W—E, that of the horizontal sand-beds, almost at right angles to the first, is N.E—S.W.

In the higher part, now quite being levelled by digging, I examined the presence of the following Scandinavian boulders: granite in different varieties, pegmatite, diorite, gabbro, quartz-porphyry, basalt, diabase, folded gneiss, conglomerate-gneiss and mica-schist. Next to it I found stones, of which cannot be said for sure, that they are not of northern origin and therefore a southern origin is not to be rejected without further ado, namely: quartzite, sandstone, conglomerate, lydite and flint, whereas I found at the same time slates, decidedly being of southern origin.

PLATE VII, VIII and IX. These plates show the continuation of the layers a, b and c from N.E.—S.W. Bx consisted of Scandinavian boulders and stones of southern origin.

PLATE X. The continution of layers a, b and c from W.—E. The dotted line shows, how the ground-moraine of the Land-ice disappeared in an easterly direction. On the occasion of a boring near the skirt of the wood (at the right side) the ground-moraine was found lying 14 M. below the surface. Bx = gravel and sand with Scandinavian and southern stones. Regarding the signification of d and e, see the explanation of plate XIII.

On the back-ground the railway from Ede (at the left) to Arnhem.

PLATE XI. The layers at the edge of plate X (at the left). The layers strike W. (left) to E. (right).

a = Sand and gravel of southern origin.
c = Groundmoraine.
b = Glacio-lacustrine deposit.
bx = Mixed gravel (Scandinavian and southern boulders).

PLATE XII. The whole wall, running from W. (left) to E (right), is occupied by the glacio-lacustrine layer (b), but close to the right, a yellow-brown spotted limeless clay-bed (d) has been deposited on it, the thickness increasing towards the East to 1.30 M. Upon nearer examination, it was verified, that this clay did not contain any stone of northern origin but consisted only of colourless grains of quartz, so the clay must be fluvial one. At the right side the terrain is rising towards the skirt of the wood, which is caused by the presence of the layers d and e to be seen on plate XIII.

PLATE XIII. On this plate we see from bottom to top the following three layers:

I. The glacio-lacustrine layer (b), thickness 5 M., the base of it, the ground-moraine (c) has sunk into the depth.
II. the fluvial clay-bed (d), here of a thickness of 1.3 M.
III. A sand-bed (e), bleached at the top, horizontally stratified and enclosing little gravel-layers, which are consisting of some distinctly rolled Scandinavian erratic boulders and a great many pebbles of southern origin, transported by the Rhine and the Meuse.

PLATE XIV. A trench, made some M. farther to the south, in W-E direction (this means from the factory to the skirt of the wood), showed in its depth of 10 M. and over the whole length, that the soil consisted

of sand with some little gravel-layers, in which the following stones were found: quartz, quartzite, lydite, sandstone, flint, Nahe-porphyry and only very few pieces of granite. The situation of the layers is perfectly horizontal; in the middle again a limeless clay-bed is to be seen, the southern continuation of the one, showed on plate XIII (layer d).

The complex of layers of plate XIV, is to be continued to the skirt of the wood on the back-ground, where layer e is slowly increasing and is rising to a great height; gravel-pits show the presence of some granite-pebbles between southern stones. The supposition is not to be declined that *in this case* the granites are too of southern origin.

PLATE XV. This plate shows the deep incision, with a depth of 13 M., north of Arnhem, looking from south to north.

The walls consist of layers of fluvial material, disturbed from bottom to top.

Only in the uppermost part I found twice a granite. After KEILHACK's opinion **37**) the whole plateau (height 50—110 M. above O. D.) is a terminal moraine. A. PENCK, the well-known glaciologist of Berlin, however held a quite different opinion. The reason of it is, that while KEILHACK had not seen any incisions in the terminal moraine from Arnhem to Vierhouten, I was able to show PENCK the incision, represented on this plate. After he had seen the great sections, he wrote as follows: **40**)

„Darum halte ich es für unrichtig, wenn KEILHACK bei Arnheim Endmoränen angiebt. Die dortigen Hügel bestehen lediglich aus zusammengestaute Rheindiluvium. Sie haben *nicht* Moränenform, sondern tragen das charakterische Mittelrelief, welches durch die Erosionswirkungen des rinnenden Wassers gebildet wird".

I myself came already to the same opinion, long before the above-mentioned incision was opened and expressed this in 1907. **36**)

PLATE XVI shows part of the right wall of the incision (at the bottom) and demonstrates the great disturbances of the fluvial layers. After my opinion we have to do here with a tectonic phenomenon and not with disturbances, caused bij the pressure of the inland-ice, which according to the general opinion was lying upon this plateau. I think, that this plateau is an upheaved block, perhaps a little folded, but at any rate lifted up.

The answer to this very difficult question, however, can only be given in the future.

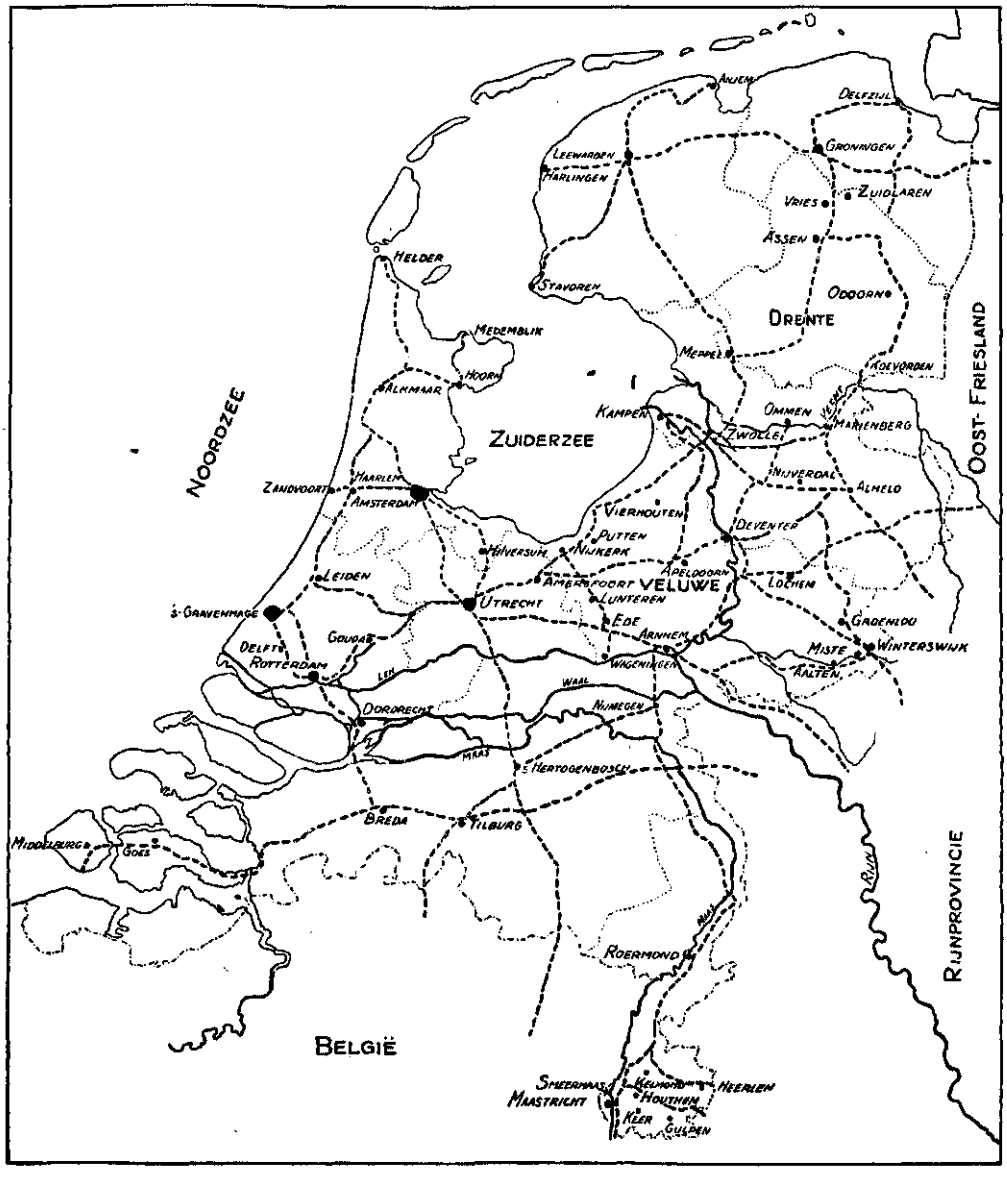
PLATE XVII represents the glacial landscape near Odoorn (Drente). This landscape consists of terminal moraines, built of yellow, limeless sand with Scandinavian boulders at the bottom.

PLATE XVIII. A vertical section of the above-mentioned terminal moraine.

1 = sand, deposited by the wind in historical times.
2 = ancient soil-surface.
3 = bleached sand (Dutch: schierzand; German: Bleichsand).
4 = hardpan (Dutch: zandoer; German: Ortstein).
5 = glacial sand with Scandinavian boulders at the bottom.

TOPOGRAPHICAL MAP OF THE NETHERLANDS

(Scale 1 : 1325000)



Rivers.

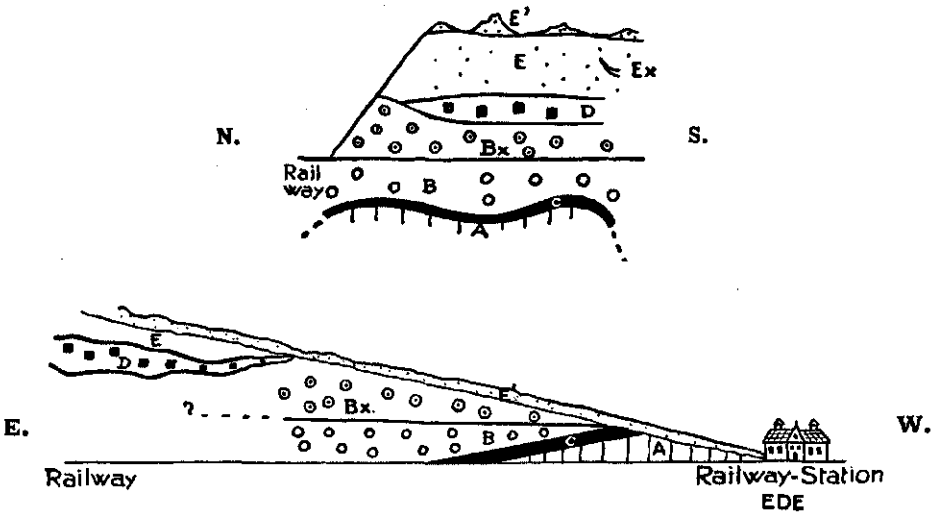
Frontiers between the countries.

Frontiers between the provinces.

Railways.

SCHEMATICAL SECTIONS THROUGH THE NEIGHBOURHOOD OF EDE,

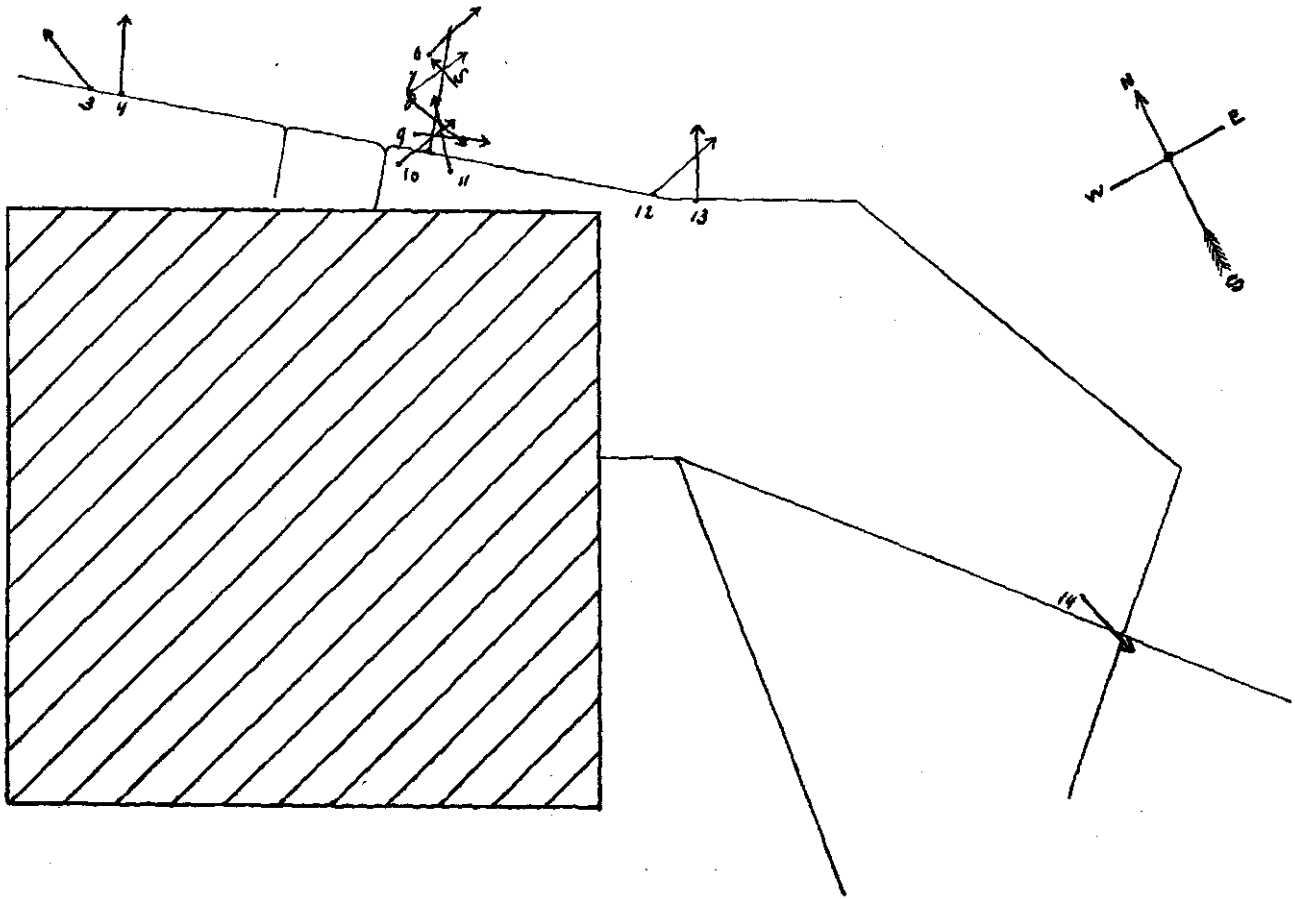
SHOWING THE MUTUAL CONNEXION BETWEEN THE SCANDINAVIAN INLAND-ICE AND THE FLUVIAL DEPOSITS OF THE LOWER-RHINE AND LOWER-MEUSE ON THAT PLACE.



A = Disturbed layers consisting of fluvial material of southern origin.
C = Ground-moraine of the Scandinavian Inland-ice.
B = Glacio-lacustrine layers deposited bij the Inland-ice into a lake, formed along the border of the Ice.
Bx = Sand-layer with enclosed gravel-beds, composed of Scandinavian boulders (some ones striated and abraded by glacial wear) and fluvial stones of southern origin.
D = Fluvial loam.
E = Fluvial sand with some little stones of southern origin and on one plot a strongly decayed tusk of ELEPHAS (Ex).
E' = Windblown-sand.

PLAN OF THE FACTORY NEAR EDE.

(Scale 1 : 3000).



The straight lines represent the trenches dug out; the arrows indicate the places from which the photographs have been taken; the numbers correspond with the numbers of the plates.

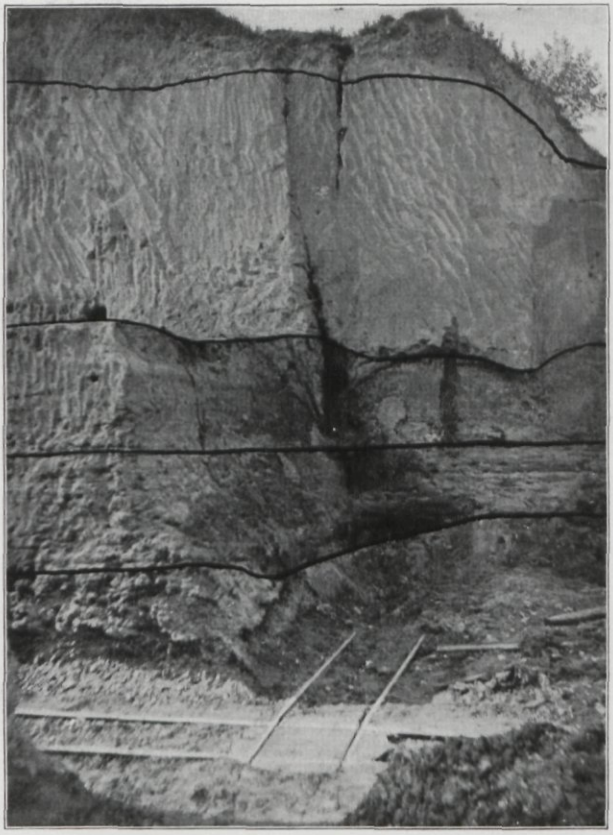
The railway Ede—Arnhem (left to right) lies 250 M. northward of the trenches.

PLATE I*a*

PLATE I*b*

PLATE II*a*

PLATE II*b*



a

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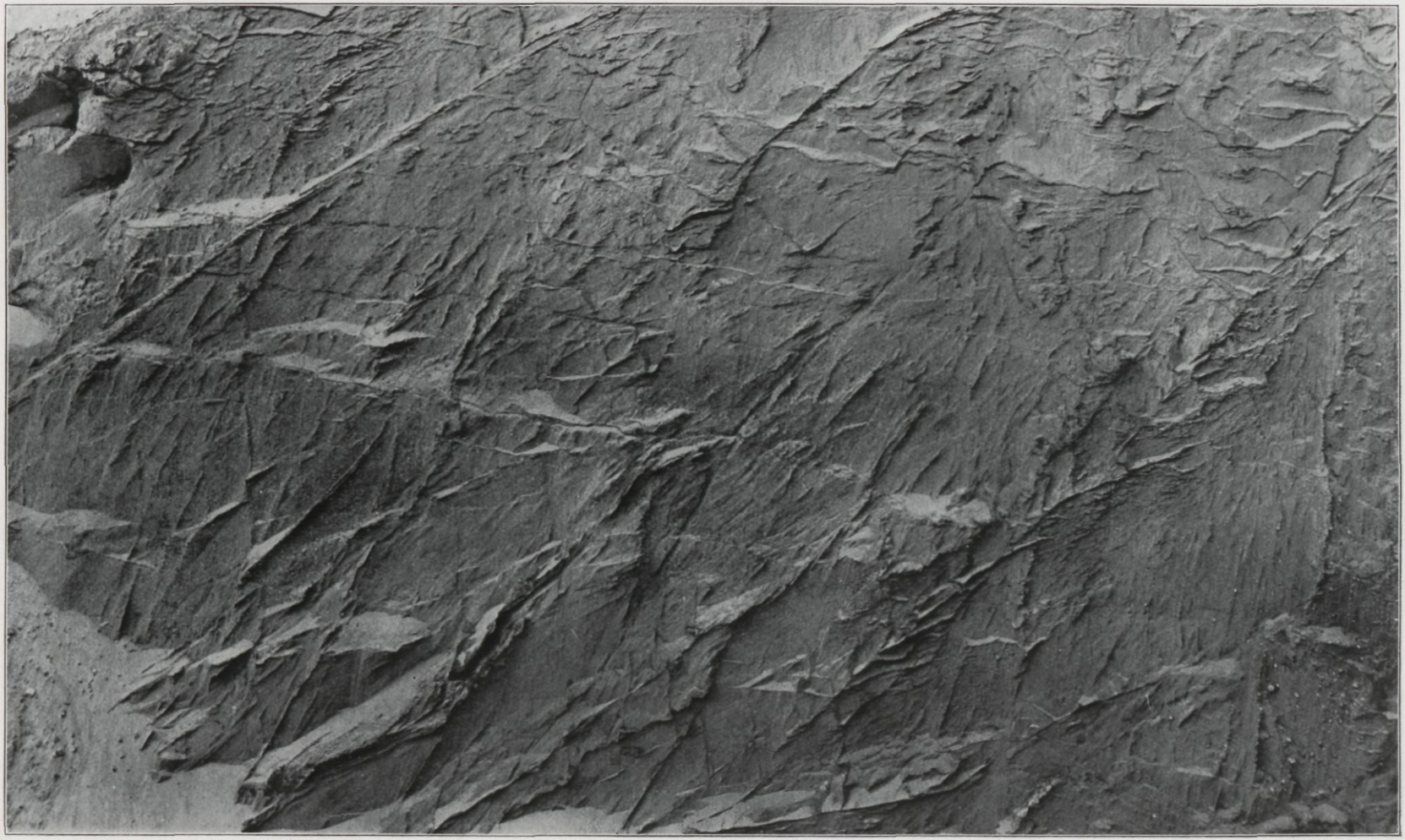
c

d

e


FIRMA C. DE RUITER
AMSTERDAM

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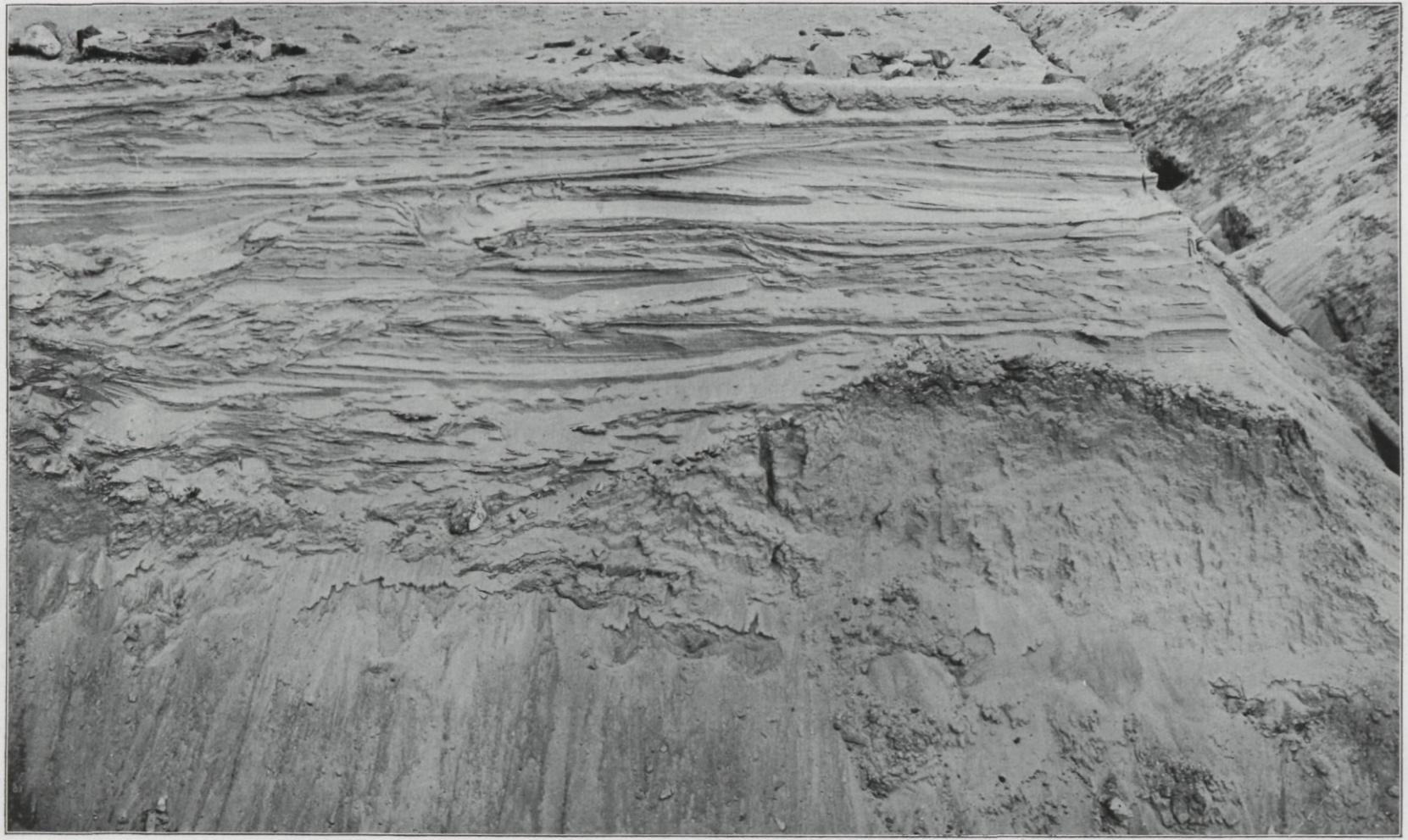
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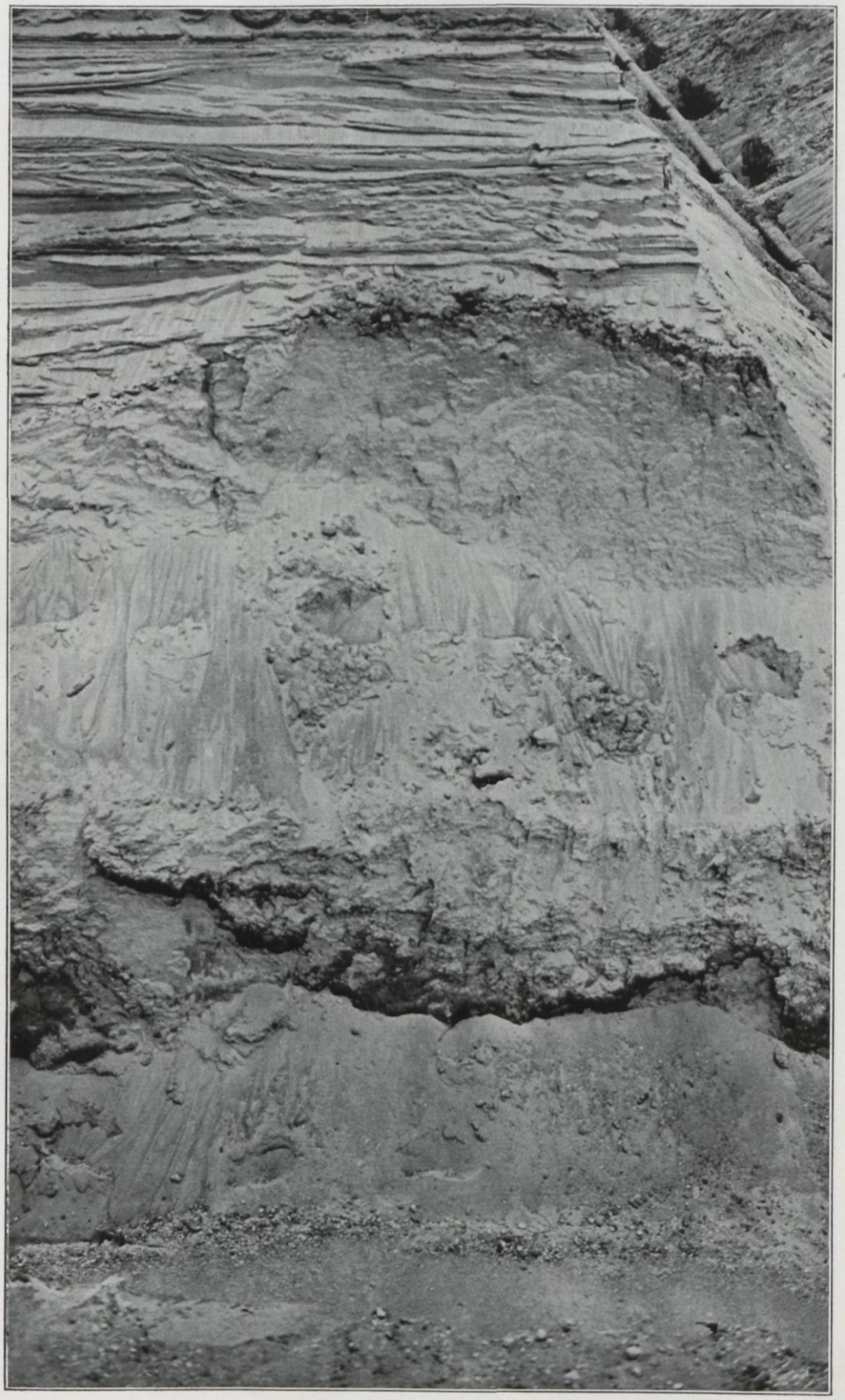
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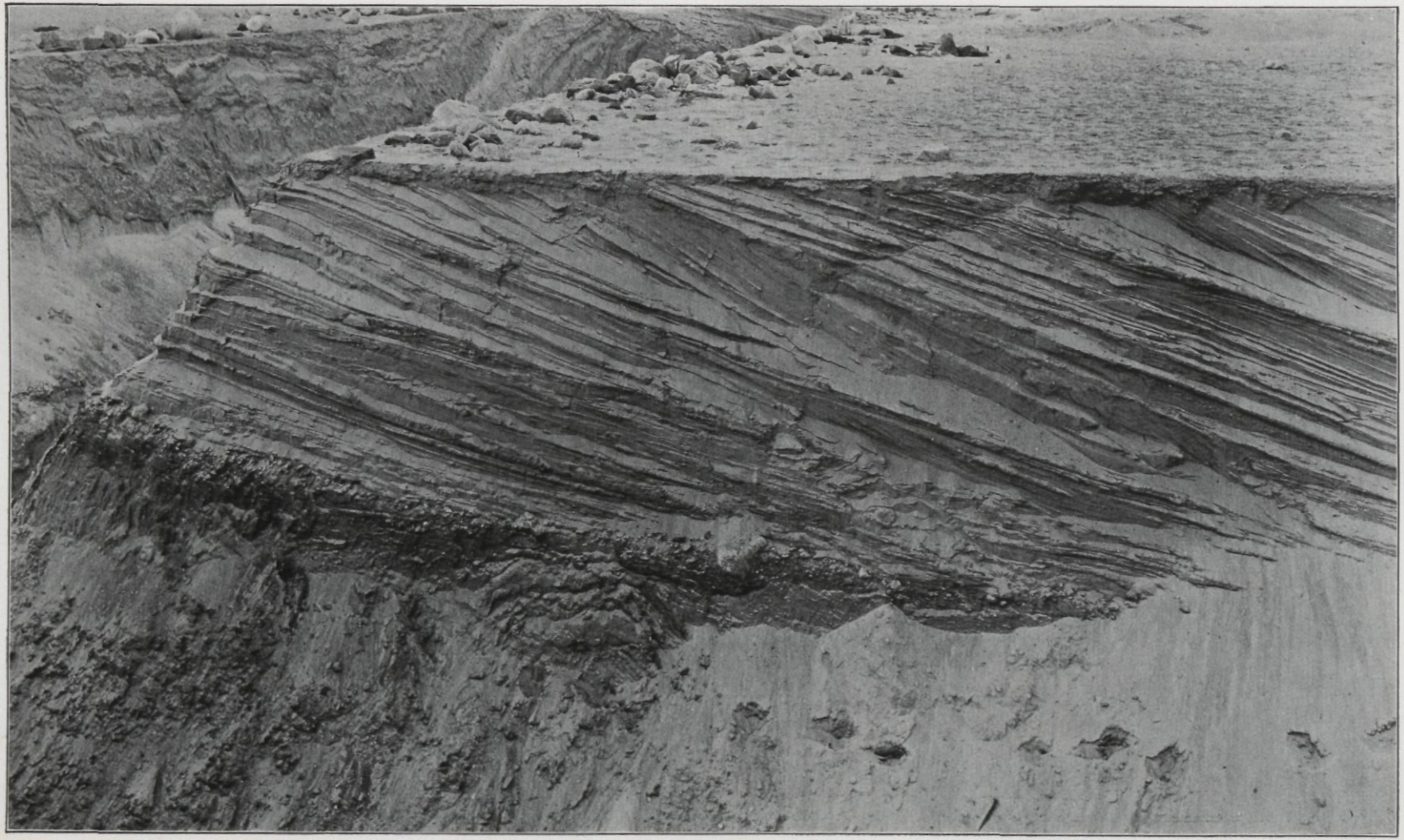


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