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GEOLOGICAL HISTORY OF THE RIVER WESER (NORTHWEST GERMANY)

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RÉSUMÉ

L'origine de la Weser remonte jusqu'au début du Néogène. Préétablie par des linéaments tectoniques de direction vraisemblablement rhénane et hercynienne, la Weser s'est d'abord dirigée vers le nord puis vers le nord-ouest, soit en direction générale de la mer du Nord en retraite. Seule une vague reconstruction de ses cours successifs est possible. C'est seulement par la formation de la terrasse supérieure que commence le développement d'un escalier de terrasses en connexité étroite avec l'histoire des glaciations dans l'Allemagne du nord-ouest ainsi qu'avec des variations glacio-eustatiques du niveau de la mer. Le tout lié à des interférences continuelles entre mouvements orogéniques, d'une part, et variations de climat, d'autre part.

1. Present hydrography of the Weser

Today, the Weser River is formed at Hannoversch-Münden by the joining of the Fulda and Werra Rivers. Both streams drain Paleozoic to Mesozoic uplands extending from the Thüringer Wald to the Rheinisches Schiefergebirge. Including the Werra, the Weser is 727 km long, begins 700 m above sea level (at the Werra spring), and has a slope of 0.7 ‰ to the point where the Fulda joins. For the 434 km from this confluence to the river mouth, the slope is 0.45-0.15 ‰. Calculating from the source of the Fulda at 950 m above sea level, the Weser is 652 km long and the slope to the confluence with the Werra is 0,8 ‰. Before reaching Porta Westfalica, the Weser (upper Weser) is an antecedent upland river with unimportant tributaries. Of these, the most important is the Diemel (entering at the west bank). Average water flows are 114 m^3/sec at Hann.-Münden, 145 m^3/sec at Hameln, 170 m^3/sec at Minden, and 320 m^3/sec at Intschede (southwest of Bremen). Minimum and maximum flows are 41 m^3/sec and 800 m^3/sec at Hameln, 57 m^3/sec and 905 m^3/sec at Minden and 105 m^3/sec and 1 350 m^3/sec at Intschede. After the Porta, the Weser enters the Northwest German lowland and its banks and bed are formed only of unconsolidated Quaternary deposits. From a Rhenian flow direction (middle Weser), the Weser turns to a Hercynian flow direction (lower

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Weser) after being joined by the Aller, the most important tributary. At Bremen it reaches the tidal area. As a leisurely tidal river, the Weser reaches the North Sea today at Bremerhaven. There are two former river mouth channels, one which flowed west directly in front of Butjadingen. The other is the Alte Weser north of the present river.

The total drainage area of the Weser is 46 339 km^2. Precipitation is 600-850 mm/year of which about equal percentages are removed by evaporation, percolation, and runoff (about one-third of the precipitation for each).

2. The arrangement of the river system during the Tertiary

Geotectonically, the flow history of the Weser has been influenced by two large units.

a) In the south, the uplifted strips of upland blocks formed by Saxonian tectonics from Paleozoic and Mesozoic rocks.

b) The Northwest German basin, an old and continuously subsiding trough.

The first indication of the Weser drainage system followed the old trough which, at the time of the Middle to Late Oligocene Hessian Strait, became conspicuous as the paleogeographic connection between the Mainz basin and the Oligocene North Sea. A regression in this shallow marine strait can be recognized by the lithologic change to the estuarine deposits of the Upper Oligocene Kasseler Meeres-Sande and Brown Sands (in the Bramwald and Solling) (Murawski, 1953).

The fluviatile regime first appeared with the Brown Sands. River channels are not recognizeable; instead, there are vague detrital bodies trending northwestward away from the Saxonian orogen. The present-day drainage basin of the Fulda and Werra became nonmarine in the earliest Miocene. Locally, south-north trending bodies of river gravel can be found in the Miocene lignite sands. In the Kassel area (as well as at Steinberg near Hannoversch-Münden and in the Uslar basin) the gravel contains abundant flint pebbles in addition to the predominant pebbles of milky quartz and of cristalline pebbles derived from the Thüringer Wald. The flint was derived from Upper Cretaceous deposits in North Hessen (Huckriede, 1954; Lüttig, 1968).

During the Neogene, the uplift of southern Lower Saxony became more intense. Fault tectonics and basaltic volcanism formed the landscape, erosion was alternating with uplift. Neogene sedimentation was restricted essentially to basins produced by tectonism or salt movement and subrosion. Only in such deposits are locally biostratigraphically classifiable strata such as the lignite and Pliocene clays (Allershausen, Eichenberg, Fredelsloh; Chanda, 1962; Benda *et al.*, 1968; Benda and Lüttig, 1968) which are primarily correlative with strata of the so-called Rhenish Pollen assemblage. In most cases it is difficult to precisely stratigraphically classify the coarse-grained clastic sediments including the Neogene river gravel and sand. With some certainty it is possible to recognize Miocene, pre-basaltic sand and gravel in Uslar, Volpriehausen, and Witzenhausen areas. There is also a second unit with pebbles of Upper Miocene basalt which have been altered to bright red goethite-laterite by subtropical weathering (Lüttig, 1968). Flint and crystalline pebbles occur in the post-basaltic gravel in areal association with the Upper Pliocene Reuver-type clay in the Uslar Basin (Graul, 1885 ; Ebert, 1881). This

Miocene-Pliocene, fluviatile detritus does not show up morphostratigraphically in contrast with the younger gravel of the primitive Weser system.

A general depression existed north of an irregular boundary during the time of the uplift of the southern Lower Saxony upland. This boundary extended from the North Harz to the Wiehengebirge but was articulated by numerous domes and uplifts to the north (such as Elm, Asse, Salzgitter anticline, Hildesheimer Wald axis, Osterwald-Deister, and Nenndorf-Rehburg axis).

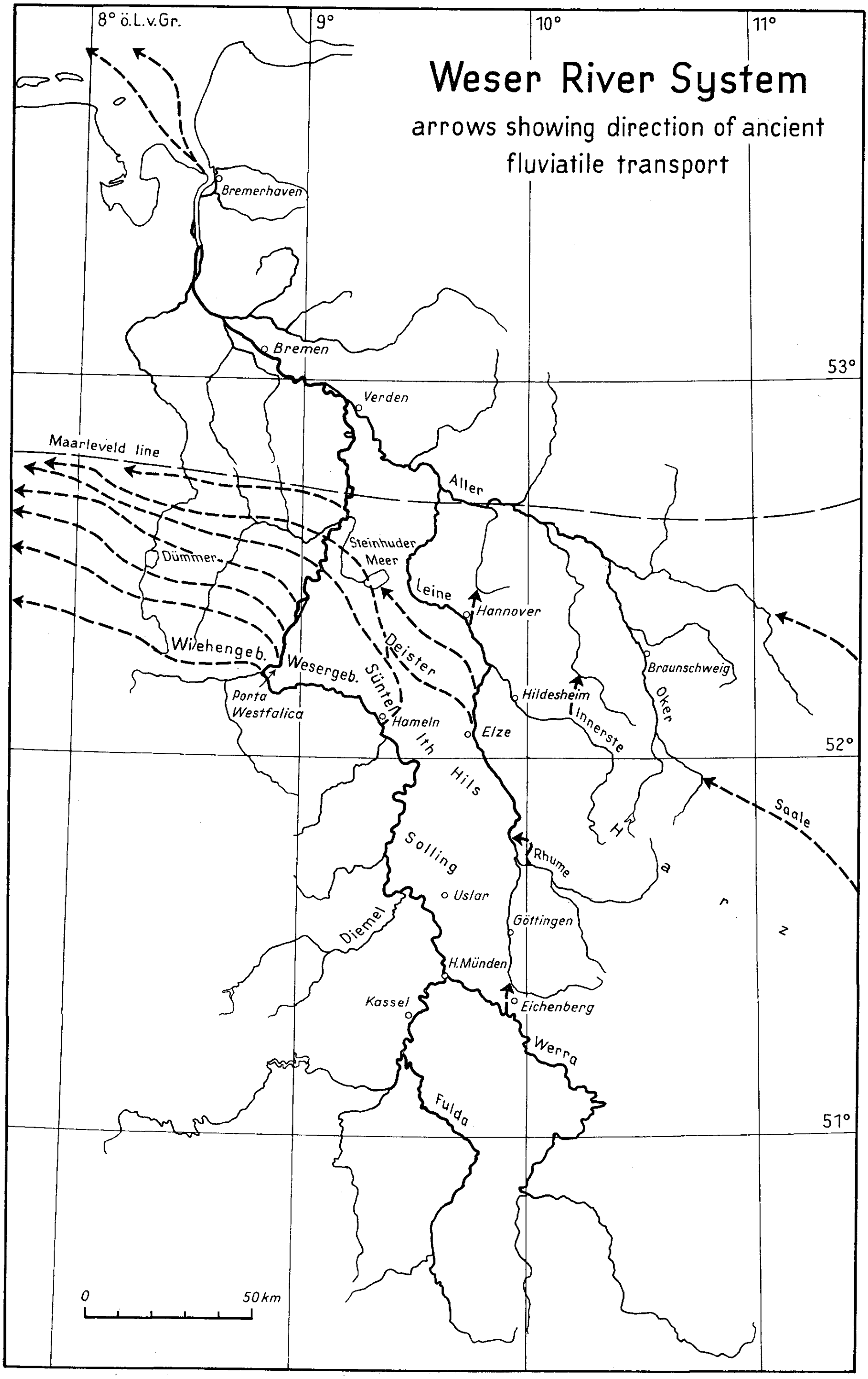
Essentially Hercynian trending rivers (in addition to the Rhenian trending primitive Weser) must have drained into the Miocene North Sea. At the time of its greatest expansion, this sea extended far into northwest Lower Saxony. The reconstruction of the Hercynian river system depends extensively upon pebble analyses of younger strata. Perhaps a primitive Saale River flowing west-northwest past the Lower Harz, after draining the Thuringian basin, played a role in this river system. In the Pliocene, the North Sea retreated to beyond its present coastline. How the Weser River reached the sea and its location at this time is not known. Fluviatile transport of Baltic, silicified limestone following the Baltic Sea trough is known from the area around Stettin (K. Richter, 1935) and numerous boreholes in the Lüneburg-Hamburg area. The material deposited is apparently related to the Sylt-type kaolin sand. Quartz pebbles of southern type are known from numerous places in the area between the Weser and Ems Rivers, but neither the middle nor upper courses of the rivers are known. Also the source cannot be reconstructed from pebble composition. Throughout the Northwest German lowland, migrating river systems appear to have followed the coast being formed by the negative sea-level changes. The history of the river after the Late Pliocene is better known.

3. Remnants of old Weser terraces and terrace bodies

Considered as "old" in this paper are the Upper Pliocene, Eo-Pleistocene (as defined by Lüttig, 1968), and Lower Pleistocene deposits and forms of the Weser River and its tributaries. Included are the commonly difficult to subdivide strata deposited between the Late Pliocene and the Holstein Interglacial (before the formation of the Middle terrace, that is, inclusive of the Upper terrace, *sensu lato*). During this time the rivers of northern and central Germany settled into more regular flow channels rather than migrating. The channels were not necessarily located where they are today (fig. 1). This is the case even for the Fulda and Werra Rivers. The porphyry pebbles from the Thüringer Wald and granite pebbles from Ruhla-Brotterode in the gravel at Steinberg near Hannoversch-Münden are clearly Werra material. The lower course of the stream is not known, however.

The location of the primitive Fulda River is not known for the period between the Late Pliocene and the Saale glaciation. That means the only reason to consider the flint gravels in the Uslarer basin as Fulda deposits is that the lack of pebbles of crystalline rock from the Thüringer Wald suggests that the Werra River was not involved.

The Pliocene "Höhenschotter" or elevated gravel unit of earlier authors is, in fact, only vaguely described. However, in the southern upland, it is possible to recognize a morphogenetic process which led to the development of the Upland-Quaternary type (Lüttig, 1960). The uplift of the uplands resulted in the older river deposits and forms being topographically higher than the younger features of the



8° ö.L.v.Gr.
9°
10°
11°
Weser River System
arrows showing direction of ancient fluviatile transport
Bremerhaven
Bremen
53°
Verden
Maarleveld line
Aller
Steinhuder Meer
Dümmer
Leine
Hannover
Wiehengeb.
Wesergeb.
Deister
Süntel
Braunschweig
Porta Westfalica
Hameln
Hildesheim
Innerste
Oker
Elze
52°
Ith
Hils
Saale
Solling
H
Rhume
a
r
z
Uslar
Diemel
Göttingen
H.Münden
Kassel
Eichenberg
Werra
Fulda
51°
0
50km

FIG. 1

river. The corresponding terraces are at the highest elevation above the present flood plain. This led to the progressive terracing known from many of the flood-plain areas. Upstream, the terraces merge with the valley floor. As has been described from the Harz Mountains, progressively younger terraces join the flood plain further and further downstream (Lüttig, 1955). Towards the basinal lowland, the elevation of the terraces above the valley floor decreases, commonly very rapidly.

There is an irregular boundary between upland and lowland which Quiring (1926) has described as a hinge between two tilted blocks. More properly, this is an area of structural strips in which tendencies towards both uplift and subsidence are irregularly combined. The terraces in this area and the river deposits to the north of it follow the normal geologic sequence with the oldest on the bottom and the youngest on the top (Lowland Quaternary type). It needs to be made clear that the overlap between the stratigraphically adjacent terraces in the respective river systems does not occur at the same point. For the Weser and Leine Rivers, for example, the Upper and Middle Terraces cross further south than do the Middle and Lower Terraces.

Pliocene elevated gravel and terrace remains are scattered at various places throughout the valleys of the Werra, Fulda, and upper Weser (Siegert, 1921; Grupe, 1937; Blanckenhorn, 1939). R. Herrmann (1950) has described a prominent old river bend in the area of Bodenwerder. This elevated gravel is between 90 and 170 m above the present valley floor.

In the area of the Aller and Leine Rivers, there are no unambiguous indications of the tributary streams to the north of the Weser River. It can be assumed that, at the time of formation of the Upper Terrace, the Werra River flowed through the pass of Eichenberg (south of Göttingen, H. L. Heck, 1928) and into the Leine Valley basin. Certainly the Werra was the precursor of the Leine which, at that time, was an unimportant tributary flowing from the east into the Werra.

The Late Pliocene precursor of the Weser north of the upland is completely unclear. Pebbles from the present source area of the Weser are present in gravel which occurs in a broad strip following Hercynian trends. This strip is located north of the Wiehengebirge and extends from the Minden and Nienburg area to the Netherlands and the present mouth of the Ems River. The deposits were known earlier as "pre-glacial", a name which has not yet been really improved upon. Since pebbles of granite and porphyry from the Thüringer Wald are present, one must be careful that these rocks are not related to an old Werra River. Material similar to the crystalline rocks of the Thüringer Wald (also Halle and Flechtinger Porphyries) is known from several places in the Braunschweig area (from unpublished drilling results to be reported on elsewhere). This material was deposited by an old Saale River which, along Hercynian trends, flowed westwards north of the Harz and emptied into the northern side of the Leine. Pebbles derived from southern sources are therefore known from a broad belt north of the uplands. The northern border of this belt is the Maarleveld line. The material is not adequate to attempt, as have Kurtz (1926, 1928) and Genieser (1962), a reconstruction of the river courses or make similar conclusions. This is primarily because the pebbles mostly have been retransported many times.

Also unclear is whether the Pliocene river course reconstructed for the lower Emsland from the distribution of the Neermoor gravel belongs to the Weser or Ems River.

TABLE 1. — *Schematic diagram of Weser terraces*

Weichsel Glaciation			Lower Terrace (+3 m)
Eem Interglacial			Erosion, interglacial of Wallensen, Thöneböhn near Hameln, Honerdingen, etc.
Saale Glaciation	Warthe Stadial		In the lowland, locally "Talsand" terraces
	Gerdau Interstadial		Erosion
	Drenthe Stadial		Middle Terrace (+15 m)
Holstein Interglacial			Erosion, interglacials of Northeim, Wunstorf, Liebenau, Munster, etc.
Elster Glaciation			Upper Terrace *sensu lato* (+45 m and higher)
Cromer Complex			Thermomers of Bilshausen, Osterholz
Eo-Pleistocene			

The *Upper Terrace* is a much better known but stratigraphically not sufficiently delimited unit. Traces of it are known in the source river region and the areas of the upper Weser, Leine, Rhume, Oder, Söse, Innerste, and Oker Rivers. It is the oldest terrace in the Pleistocene terrace system. This system is summarized in figure 1.

It is necessary today to abandon the earlier, strict classification of the Upper Terrace (H. L. Heck, 1928; Grupe, 1910, 1913, 1922) as belonging to the early Elster Glaciation. The name "Upper Terrace" can only serve as a general term. This has been shown by both mapping and the recent refinement of Pleistocene stratigraphy such as the subdivision of the Cromer Complex and the Pleistocene prior to the Elster (Lüttig, Menke, and Schneekloth, 1967; Lüttig, 1968, R. G. West, 1968). In the future it will be possible to subdivide the Upper Terrace into stratigraphically well-described units in connection with the biostratigraphic study of the German Eo- and Lower Pleistocene.

In addition to the Upper Terrace remnants in the upper Weser area, Upper Terraces of the Leine-Aller system are particularly well recognized. The presence of the terrace in the Leine valley (on the basis of pebbles from the Thüringer Wald), the Göttingen area, and the Elze region is well documented (Lüttig, 1960). At that time the Leine flowed from Elze towards the west. Through time, flow changed from one channel to a second. One channel ran past the northern tip of the Ith mountains and emptied into the Weser which flowed northwards from Hameln and between the Süntel and Deister. The other channel ran through the pass of Springe and into the Weser at Bad Münder.

From here, the Weser flowed towards Steinhuder Lake and, upon reaching the Nienburg region, turned westward towards Holland. There, Weser material is known from the Enschede Formation, that is, in the Lower Pleistocene complex of Hattem (Lüttig and Maarleveld, 1961). The flow of the Weser northwards from Nienburg is considerably younger.

The Upper Terrace system is especially well preserved in the area of the Harz rivers. Here, a close relationship of the terrace to the glaciation of North Germany can be recognized.

4. The Elster Glaciation in the Weser area

Since the work of Soergel (1939, 1941) a relationship has been recognized between aggradation and eustatic changes of sea level during glaciation. This relationship suggests that the decimation of vegetation leads to periglacial erosion and solifluction causing extensive aggradation and terrace-building in the upper courses of streams. Glacial-climatic sea level changes cause incision of the lower course of the stream. Incision of the lower course of the Weser River is not so easily recognizable as in the case of the Thames (Zeuner, 1945, 1952*a*, *b*; Woldstedt, 1950). Investigations such as pebble analyses yield good information about the upper course, however. Especially along the Harz rivers it is possible to recognize the deposition of Upper Terrace bodies (*sensu stricto*) at the beginning of the Elster glaciation (Grupe, 1910, 1922; Spreitzer, 1931). At first, sediment was delivered from the highest and, initially, vegetationless drainage basins of the rivers. Just as in the Middle Terrace bodies, subsequent deposition was of more locally derived material. In the terraces at the boundary of the Harz Mountains it can be particularly well recognized that detritus derived from Paleozoic rocks is replaced stratigraphically upwards by more locally derived detritus from Mesozoic rocks.

Primarily Grupe has clearly shown that northern material increases stratigraphically upwards in the pebble association of the Upper Terrace. For this reason he called this deposit the "mixed gravel." The mixed gravel indicates the approach from the northeast of the Elster ice. The ice initially reached the Harz mountains in the Quedlinburg-Harzburg area. The meltwater flowed into the river systems of the northwestern Harz. From there, the water of the first Elster advance (the Bornhäuser Stadial, Lüttig, 1952) flowed to the Gandersheim area and then to the north with the Leine. Finally, the ice extended past the northwestern Harz and overrode this drainage system. After a short recession, the ice of the Bockenemer Stadial advanced to the west and south, overrode large areas of the uplands of southern Lower Saxony, and blocked the Weser valley at Hameln and the Leine valley.

We must assume that the meltwater, if it did not flow northwestward under the ice, must have escaped south of the Wiehengebirge into the area of Osnabrück. From there it would have flowed towards Holland just as did the water of the Leine and Weser Rivers. The edge of the Elster ice cannot be precisely located west of and in the middle Weser area. At the most, the margin of the ice could have extended from Minden northwestwards into the Emden area. From Hameln eastwards to Saxony and Silesia, the moraines of the Elster Glaciation indicate the southernmost limit of the Pleistocene ice. However, the Saale (Drenthe) moraines mark the outermost ice margin west of Hameln.

The furthest ice advance of the Elster Glaciation reached the area of the upper and middle Weser but was only part of a complicated series of short-term advances and retreats. In no way was it representative of the total period of the Elster Glaciation. Considerable time was involved in the build-up and retreat of the Elster ice. The marginal deposits of these periods are to be found northeast of the Weser area.

5. Holstein Interglacial, Middle Terrace, and Saale Glacial

The above-mentioned interpretations demonstrated by drilling and mapping to be true for Elster Glaciation are also true for the Saale Glaciation.

During the retreat of the Elster ice, the upper Elster Lauenburger Clay was deposited in glacial depressions in the lower Weser area. At the same time, in the areas of the upper Weser and its tributaries, the valley floors were downcut to a level lower than that at present for the first time. The very deep erosion resulted in the Holstein Interglacial (following the Elster Glacial) being a warm period of special morphostratigraphic importance. The Holstein Interglacial (the "Great Interglacial") must be considered to have consisted of two warm periods (Erd, 1965; Lüttig, Menke and Schneekloth, 1967). Thermomer deposits of the Holstein Interglacial, such as the interglacials of Northeim (Heck, 1928; Chanda, 1962; Lüttig, 1954), Elze (Hoffmann 1927; Lüttig, 1953, 1955), Wunstorf (Sickenberg, 1951; von Rochow, 1952), and Liebenau (Lüttig, 1961), all accumulated at topographically low positions as a consequence of the erosion.

The glacial-climatic deposition which began at the beginning of the Saale Glaciation (Drenthe Stadium) resulted in a complex sequence which has been described as the "Vollgliederung" of the Drenthe Stadial (Lüttig, 1958). Clear to the upper courses of the rivers the complexities of this sequence reflected the individual expansion phases of the Drenthe ice and its climatic effects.

Initially, the so-called warm gravels accumulated. The name stems from the fact that numerous reworked faunal elements from the Holstein Interglacial have been incorporated in the lower gravel of the Middle Terrace bodies. Acheulian, Mousterian, and Aurignacian artifacts are included in the faunal elements (Barner, 1962; Lüttig, 1963; Lüttig and Schwabedissen, 1963). In the upper part of the terrace body, the cryomeric character of the gravel increases; this has become especially apparent through the work of K. Richter (1953, 1954) in the Leine area. Finally the Middle Terrace gravel was formed almost entirely from locally-derived cryomeric detritus. In detail, the Middle Terrace bodies were formed during a combination of cryomers and thermomers within the Drenthe Stadial (Lüttig, 1958, 1964; Garleff, 1966).

The sequence up to the upper Middle Terrace (about 15 m above the recent flood plain in the upper and middle river courses) can be correlated with the Rehburger Phase of the Drenthe Stadium. The corresponding moraines extend in a broad belt from the Braunschweig area into the Netherlands and can be everywhere correlated stratigraphically and areally with gravel deposited by the Weser and its tributaries (Spreitzer, 1931; Lüttig, 1958). The Middle Terrace was cut down to a lower level during a relatively long interval after the Rehburger Phase. The ground moraine of the furthest advance of the Hameln Phase (Lüttig, 1952, 1959) was deposited on this newly formed surface. The southermost end moraines occur near Freden in the Leine valley and near Hameln in the Weser valley.

A new advance, the Heisterberg Phase, followed another retreat. In the vicinity of the Rehburger ice margin, the ice of this advance pushed against the Middle Terrace remnants and the older Drenthe moraines. This formed the push-moraine which can be traced from Hannover into the Hoge Veluwe, Netherlands.

As yet unpublished drilling results have shown that immediately after the retreat of the ice, the Weser initially ran over Nienburg-Hoya and into the lower Aller valley. This may have been caused by glacial overdeepening (Woldstedt, 1956).

After long having flowed westwards, the middle Weser first joined the lower Weser during the late Drenthe Stadial. The course of the lower Weser River had already been formed by the Aller River by the beginning of the Drenthe Stadial. This is shown both by the low-lying Middle Terrace of the Aller west of Verden and by a Drenthe ground moraine lower than the geest near Verden-Bremen. This moraine drops down somewhat from the Verden geest into the Weser valley and rises again on the geest of Syke-Bassum. Due to its high position, the latter geest commonly led to ice pushing in the Drenthe Stadial.

The history of the Weser River and its tributaries is not represented by Gerdau Interstadial and Warthe Stadial terraces in the middle and upper Weser valley. The only record is a Warthe Stadial valley sand terrace present in the region of the northern tributaries to the Aller. This terrace can be morphostratigraphically correlated in part with Warthe Stadial sand deposits (Piesker, 1932; Woldstedt, 1950; Hövermann, 1956).

6. Eem Interglacial, Weichsel Glacial, and the Lower Terrace

The river bed in the upper and middle Weser River system was topographically lower after the retreat of the Drenthe and Warthe ice. However, in its lower course, the river had to adjust to a new flow direction and, during the transition to the Eem Interglacial, to another rise in sea level. Where present in the river valleys, the Eem Interglacial deposits are topographically relatively low. Examples are the clayeyhumous or calcareous sediments of Honerdingen (Selle, 1941; Woldstedt, Rein, and Selle, 1951), Lehringen (Selle, 1941), Liebenau (Lüttig, 1961), Vechelde, and Zweidorf (Woldstedt, 1950, Selle, 1954, 1957).

The ice of the Weichsel Glaciation did not reach the present or earlier drainage basin of the Weser River. However, the area was commonly subject to periglacial processes during the Weichsel Glaciation. Sequences of solifluction alluvium followed by flow-earth, reworked loess, and loess formed as a result.

The Weser and its tributaries had to contend with a considerable gravel load because of the intensive frost action. Choked by this detritus, the rivers deposited the 5 to 10 m thick (locally thicker) Lower Terraces. The upper surface of the terraces is usually 3 to 5 m above the present floodplain. A lower and upper Lower Terrace can be recognized locally (Mensching, 1950; Wortmann, 1962). There is no loess cover over the Lower Terrace. In contrast, the Middle Terrace carries the Younger Loess of the Weichsel Glaciation which overlies the Older Loess of the Saale Glaciation on the Upper Terrace. ^{14}C dating of the Lower Terrace shows that it is continuating to the late glacial whereas the Middle and Upper Terraces are restricted to the early glacial.

Except for an old course of the Leine north of Hannover (Lang, 1962), the courses of the Weser and its tributaries after the Eem Glaciation were the same as today.

7. The Weser River during the Holocene

At the end of and after the Weichsel Glaciation, the river channel was downcut, reaching in some places the bottom of the Lower Terrace. The post-glacially rising sea-level reached the coast of Lower Saxony by Atlantic time and resulted in a lessening of erosion in the lower river course. This increase of sedimentation over erosion gradually moved upstream to the middle and upper stream valleys. As a consequence, the sedimentation of the first sand and gravel of the high flood loam cycle of the Weser area began. In contrast with the climato-eustatic origin of this first high flood loam, one to three younger loam complexes resulted from human settling and clearing activities (Mensching, 1950, 1951). In the middle Weser area, the three identifiable high flood loams (Lüttig, 1960; Strautz, 1962) are inserted into one another; upstream, the spacing above the floodplain becomes the same.

The same circumstances prevail in the middle Leine area while along the Oker River the three loams are bedded into one another. The three high flood loams of the Weser, the

Stolzenauer Markloher Estorfer	levels (Lüttig, 1960),

are approximately time-equivalent to the high flood loams of the Leine River, the

Schulenburger
Mariemburg-
Elzer } levels (Lüttig, 1960).

This is nevertheless not true for all river systems as Dreschoff's (unpublished dissertation, Braunschweig, 1974) study of the Oker River has shown.

The flood plains of the eastern and/or northern banks of the Aller, the Leine below Hannover, and the Weser below Minden are accompanied by inland dunes. The location of the dunes has been determined by the prevailing wind direction and they formed primarily as a result of the lowering of humidity in post-Atlantic time. Today the dunes are mostly stable.

8. The Weser today

Man has left his mark on the banks of the Weser since Paleolithic times. By means of dams, the river has been made navigable as far upstream as Hann.-Münden. Flood danger has been controlled through retention basins. Present-day dangers to the river and the human environment are mostly anthropogene. The Weser today has an abnormally high salt content as the result of carrying mining waste-water from the Thüringian-Hessian potash area (Lüttig and Fricke, 1967). The introduction of halophilic fish has reduced much of the resultant damage and we have adjusted to the damage to the quality of the groundwater near the river banks. To avoid further damage and keep the Weser healthy will be our duty in the future.

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DISCUSSION

F. AHNERT *has two questions:*

1. *First, does the field of multiple channels between the Wiehengebirge and the Maarleveld-line represent a* progressive *northward shift, or has the channel shifted back and forth?*

2. *Second, is the preglacial (tertiary) change from a migrating to a fixed channel position accompanied by a change in the properties of the bank materials, just as modern channels that migrate easily tend to have non-cohesive bank materials, while fixed channels tend to have banks made up of cohesive materials?*

G. LÜTTIG answers:

1. On the map showing the westward channels N of the Wiehengebirge I have given a somewhat schematic figure. We know two Holsteinian channels North of the Porta Westfalica, and the younger channels are to be put stratigraphically into the series of Drenthe phases and intervals.

2. There is not enough knowledge in this moment to answer this question correctly.

A. THIADENS. — 1. *How far to the West have you been able to follow the westward channels of the Weser north of the Porta Westfalica?*

2. *How is the pollution of the Weser compared to the Rhine?*

G. LÜTTIG answers:

1. Only some 20-30 km West of the middle Weser; due to lack of drillholes and geophysical research we could not trace these channels to the Ems valley.

2. The pollution of the Weser with respect to potassium is much higher than that of the Rhine. In the last 3-4 years the pollution limits introduced for the chlorium-ion-content officially by the "Kaliabwasser-Kommission" have never been determined due to higher concentrations found in the control stations.

B. D'OLIER. — *Would Dr. Lüttig comment on the possibility of a steady sea-level rise during the Holocene or was it a fluctuating one?*

G. LÜTTIG answers:

Omitting the fact than there are different interpretations followed in our area I would say that the curve rises quickly in the early Holocene and is getting flatter after the postglacial climatic optimum. If compaction of the unconsolidated strata or sea-level fluctuation causes some smaller changes is unknown.