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On the provenance of the Early-Pleistocene fluvial system in the southern Netherlands

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Abstract

Two series of Early Pleistocene fluvial deposits near Galder (southern Netherlands) are overlain by a series consisting of Weichselian aeolian and locally reworked aeolian deposits. Each of the three series is characterized by its own specific mineral association. Special attention is drawn to the origin of the upper fluvial unit which belongs to the 'Alphen Sands'. Mineralogical and petrographical analyses indicate a mainly southern ('pre-Scheldt') provenance of the sand fraction and a mixed southern and southeastern (Meuse) origin of the gravels. The Meuse transported gravel from the Ardennes and from the Cretaceous plateau between Liège and Maastricht.

Introduction

The Early Pleistocene deposits in the southern Netherlands have generally been assigned a fluvial origin. The lower part of these series consists of fine clayey and silty sediments (Doppert & Zonneveld 1955). The younger 'Alphen sands' are considerably coarser, occur in large gullies and have been deposited by a more energetic river (Vandenberghe & Krook 1981). The geomorphological and palaeo-hydrological evolution of these fluvial systems still poses many problems. Especially the relationship between the 'pre-Scheldt'-basin and the Meuse and Rhine system needs further clarification. The present report contributes to the fluviodynamic history of the Early Pleistocene rivers in the southern Netherlands and clarifies the provenance of their deposits.

Our investigation is based on the sedimentary sequence in an excavation near Galder (south of Breda: fig. 1). The stratigraphic position and the

Fig. 1. Location map.

palaeo-environmental reconstruction were studied by detailed sedimentological and sediment-petrographical analyses.

1. Lithostratigraphy and palaeo-environmental analysis of the deposits near Galder

The surface unit (I) consists of fine, horizontally laminated aeolian sands (figs. 2A and B). At the base a gravel bed of ca 15 cm thickness occurs corresponding with the Beuningen Gravel bed (Van der Hammen et al. 1967). Unit I dates from the end of the Weichselian Pleniglacial. In the underlying unit II poorly sorted, sandy beds (1 to 15 cm) alternate with humic, loamy beds. Frost cracks penetrate from the top. Very small gullies and small-scale current ripples are found. These deposits are interpreted as aeolian sediments which were redeposited by surface runoff. The lower boundary of unit II is formed by a discontinuous pebble horizon. It may be correlated with the lower pebble bed at the base of the Middle-Pleniglacial aeolian deposits in the southern Netherlands (Vandenberghe & Krook 1981; Vandenberghe 1983).

The fine subangular sands of unit III contain dispersed small pebbles and many silty beds. They show, as do units I and II, a mixed stable-unstable heavy mineral association (fig. 2B), which is typical of the Weichselian deposits in this region (Vandenberghe & Krook 1981). Unit III represents more or less reworked aeolian sediments of probably Early Weichselian age.

Unit IV (figs. 3A and B) strongly contrasts with the overlying deposits. It consists of white medium to coarse pure sands containing some conspiciously dark grains. These sediments occur in large, rather shallow gullies, often with gravel or coarse sand concentration at the base. The diameter of the pebbles is commonly a few cm, but considerably larger cobbles also occur. The sediments are generally quite heterogeneous and medium to ill-sorted. Dispersed pebbles are also found. In the lower gullies reworked clay pebbles, large pieces of wood and botanical macro-remains are observed. Large scale cross-bedding is the dominating structure indicating vertical accumulation as well as lateral

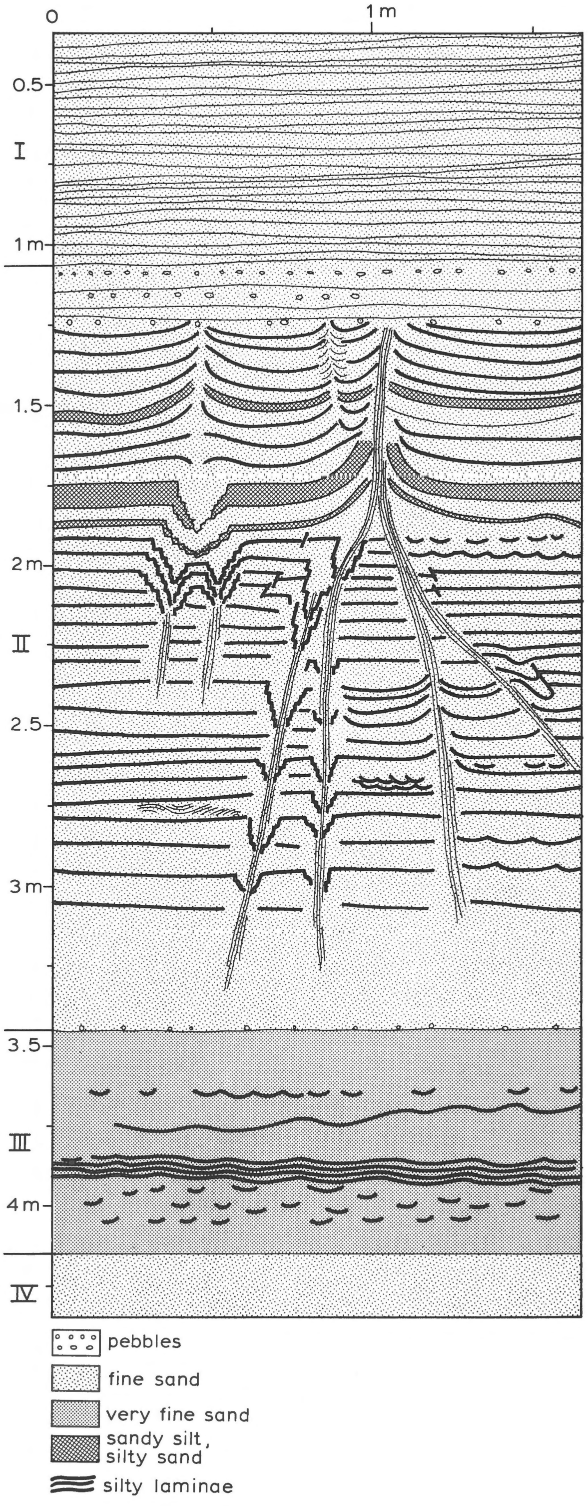


Fig. 2A. Upper part of the section at Galder.

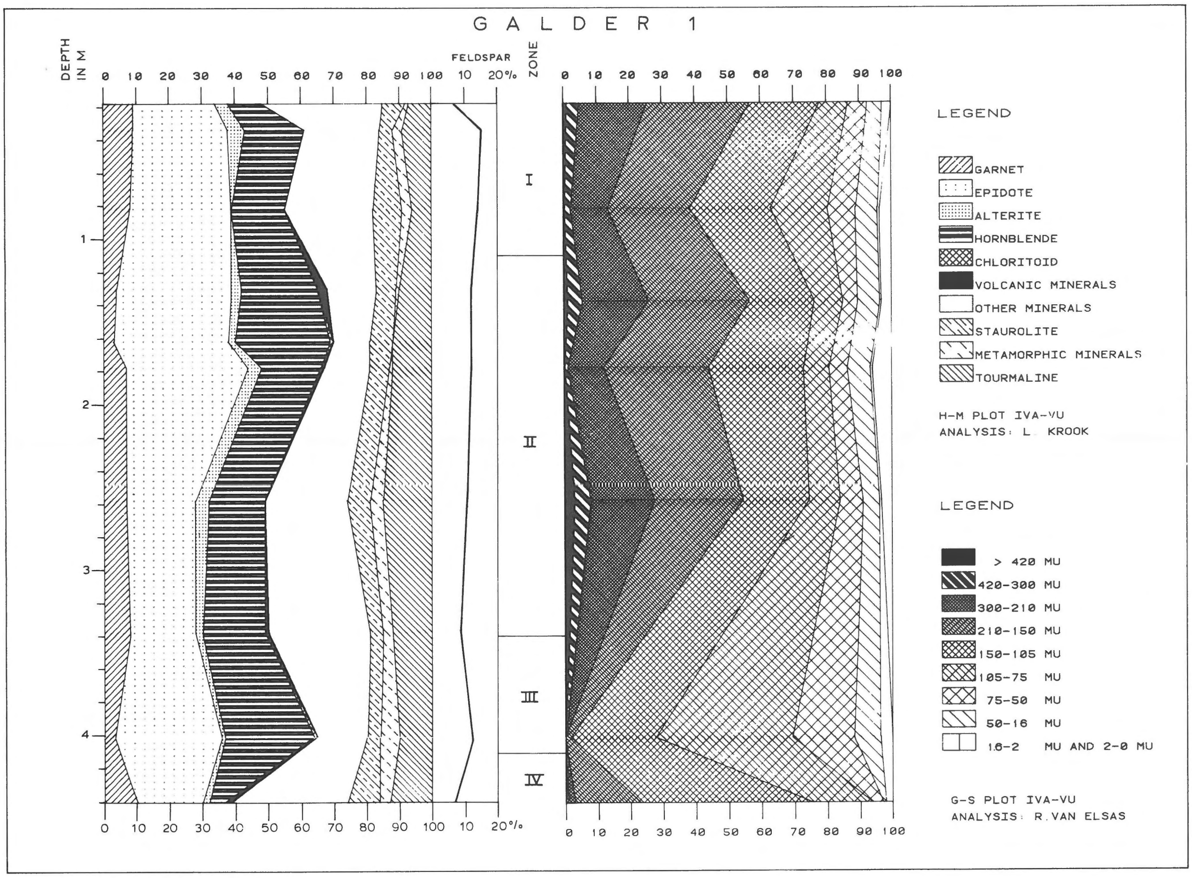


Fig. 2B. Heavy mineral analysis, feldspar content and grain size composition of the upper part of the section at Galder.

accretion. This points to quick infilling of the gullies after slight vertical erosion. The top sediments of the gullies are mostly fine-grained and in some cases ripple cross-lamination has been preserved by draped clayey silts. These features clearly result from gully displacement and sedimentation in a braided river system (Reineck & Singh 1973, p. 283, fig. 403). The heavy mineral association is characterized by very high percentages of stable minerals. The light fraction shows only about 4% feldspar, which strongly contrasts with the overlying and underlying deposits. All these characteristics are identical to the earlier described 'Alphen Sands' of pre-Cromerian and post-Eburonian age (Vandenberghe & Krook 1981). The basal gullies contain large amounts of macroscopical botanical remains. Particularly, the presence of megasporangia of *Azolla filliculoides* and *tegeliensis* should be mentioned. The latter indicates a Tiglian age, but all plant remains are thought to have been reworked from the underlying deposits. Consequently these fossils have no stratigraphical significance.

In the lowermost unit V fine sediments dominate: clay and silt layers dissected by clayey, very fine sandy gullies. The heavy mineral association approaches the more or less unstable character of the underlying, massive clay beds of the region which probably belong to the Tegelen Formation. Together with the peat lumps and pieces of wood found in the gullies, the mineral association points to considerable reworking of these clays by fluvial erosion.

In the next sections attention will be paid to unit IV in relation to its palaeo-environment, provenance and palaeo-geographical situation.

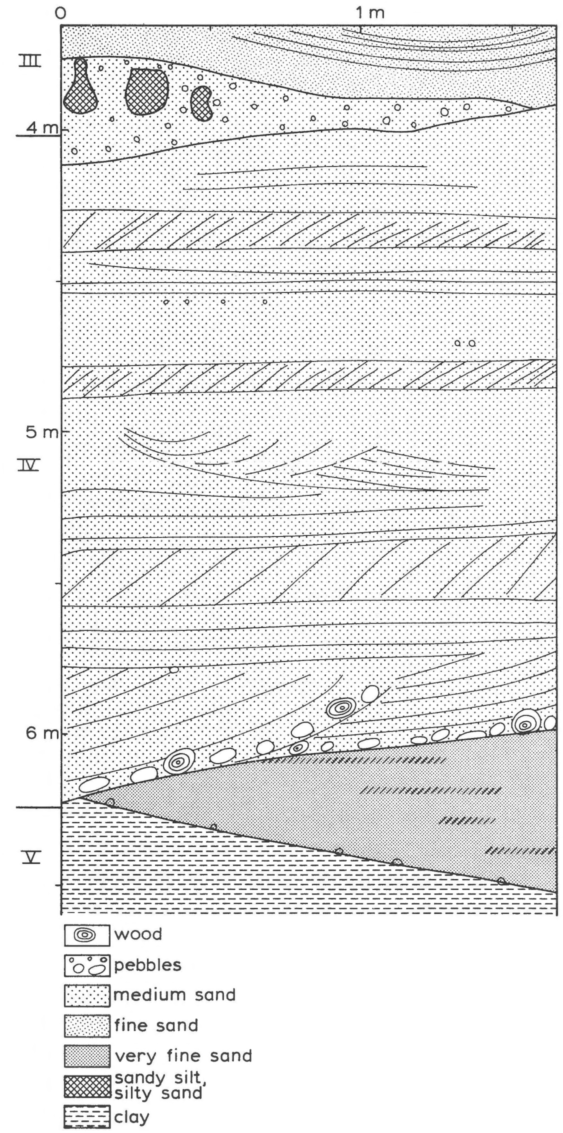


Fig. 3A. Lower part of the section at Galder.

2. The Alphen Sands (unit IV)

1. The gravel association

Three samples have been analysed and the results are summarized in Fig. 4

a. Composition:
A strikingly high amount of total flint is present in every size class. Percentages range from nearly 40 to over 80. This group is composed of angular flint, flakes of cortex and well-rounded flint. Most of the flint, especially in the coarse fraction, is typical of the Upper Cretaceous limestones. It usually has a black or brown colour, but this may have been partly replaced by a whitish colour due to dehydration. There is also a kind of flint, however, of greyish colour, which bears no textural resemblance to the flint as normally found in the Upper Cretaceous chalk of Limburg. A study of thin slides of the flints showed that the 'grey flint', although still typically cryptocrystalline, appears to be slightly coarser than the typical Limburg Cretaceous flints. It is also 'dirty', being full of small opaque specks. Moreover, observation of a fresh surface shows that this flint is slightly porous. Remarkably, both kinds of flint are especially abundant in the finer fractions. The relative amount of rolled flint, however, increases with the pebble size.

Quartz percentages range from 10 to 40% with a preference for the coarser fractions. A conspicuously high content of the quartz is 'rest quartz', mostly dark transparant quartz derived from igneous rocks. Most of this quartz, especially in the fine fractions, is well rounded , which might have been the result of wave action on an abrasion coast.

The 'remainder' group consists of erosion-resistant sedimentary rock components as lydite, quartzite, Revinian quartzite, etc. It increases from 1 to 20% from the 3–5 mm class to the >23 mm class. The fractions coarser than 5 mm reveal the presence of crystalline components, mostly granite.

The composition of the gravel, especially of the finer fractions, shows some resemblance with the Sc (Scheldt)-gravel association of Zandstra (1969, 1978) due to both the high content of flint and rest quartz. The main difference is the nearly complete lack of weatherable gravel in the Alphen sands.

b. Source areas:
Sandstone and quartzites may have been derived from many Cambro-Silurian or Devonian formations. Granite, Revinian quartzite, Westphalian sandstones and shales and Visean crinoid limestones point to an Ardennes provenance and have

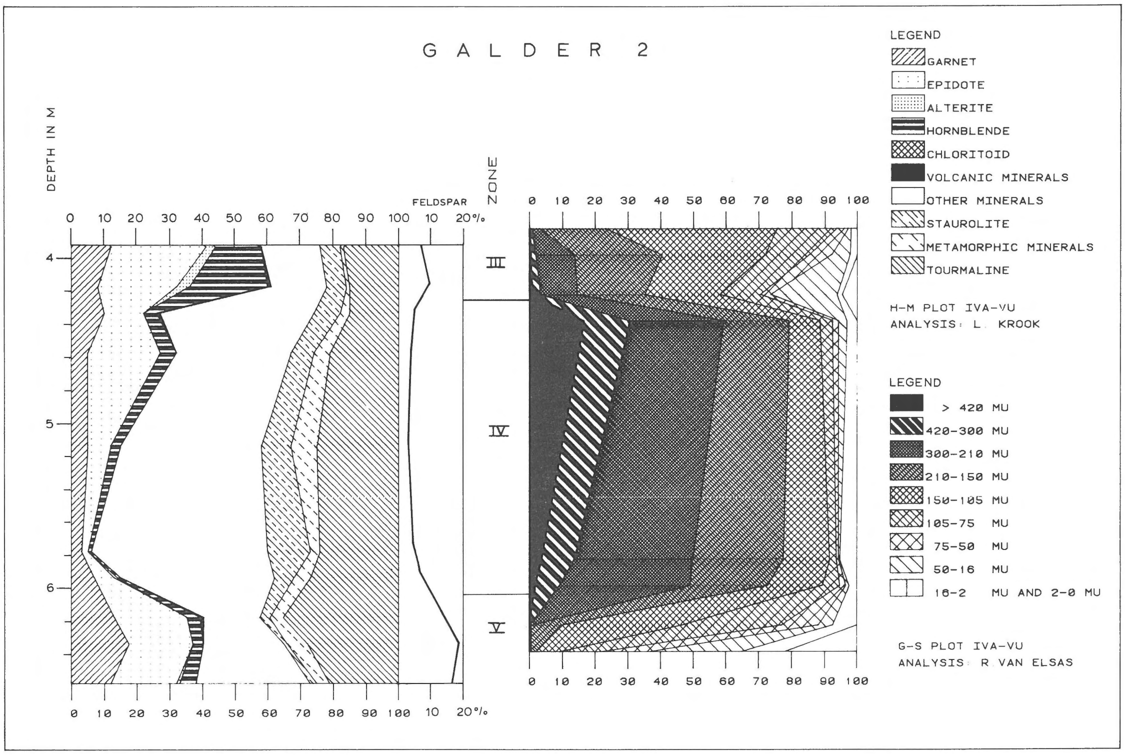


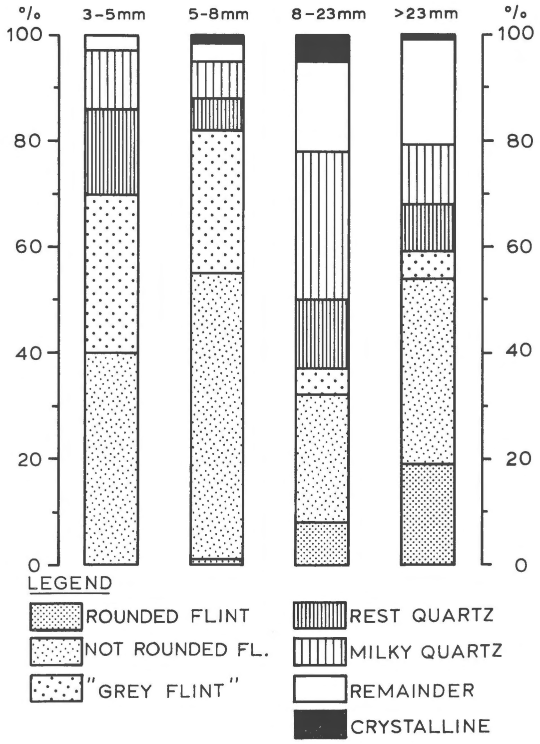
Fig. 3B. Heavy mineral analyses, feldspar content and grain size composition of the lower part of the section at Galder.

apparently been supplied by the Meuse (see also Van Straaten 1946). Several silicified oolithes have been counted as well. No pebbles have been found which would indicate a Rhine origin.

Rolled flint originates from the base gravels of Tertiary marine deposits in Central and northern Belgium. A fragment of Eocene silicified sandstone indicates a southern origin as well.

Angular flint is well known from the Cretaceous deposits outcropping in Belgian and Dutch Limburg. More specifically it occurs in the 'flint eluvium' ('vuursteeneluvium') which is the weathering product of the chalk (Felder 1975; 1983). As has been noted above, the provenance of the 'grey flint' is more difficult to trace. Flint of a similar type occurs, together with the well rounded rest quartz, in the base gravels of the Tertiary deposits in central and northern Belgium (see further below).

Fig. 4. Gravel composition of unit IV (Alphen Sands) as a function of the size class. →



c. Habitus:
Most of the gravel components, including lithologies other than flint, carry a brilliant burnish. A piece of burnished flint was subjected to SEM-analysis (scanning electron microscopy) only to reveal the very flat surface without any distinctive marks on it. Several 'Dreikanter' were observed. A brilliant burnish may by caused by wind action deflected at low angles across surfaces (Whitney & Splettstoesser 1982). Fluviatile bed load with organic debris as well may have a burnishing effect on gravel comparable to wind gloss. The latter is often only locally present and shows a wide range of intensity (Stapert 1976). Since the gravel was found in clearly fluviatile sediments, a burnish that is evenly distributed and that shows no grain impacts may be assumed to be of fluvial origin.

A high percentage of the flint components shows frost splitting. Part of them shows extremely fresh edges and has therefore not been subjected to transport of any importance after frost action. The others are characterized by burnish and a slight white patina on the frost-split surfaces and thus has suffered from surficial weathering after splitting.

The formation of 'Dreikanter', the presence of wind gloss on part of the pebble population and the obvious frost shattering phenomena point to a surficial position of, at least part of, the gravels. These gravels have been affected by frost weathering, probably in the temporarily abandoned beds of the braided river by which they are transported. As a result, the flint pebbles were split so that the number of fine flint clasts has been multiplied, while sandstone gravel, if originally present, would probably have disintegrated.

2. The sand fraction

It has been shown above that the heavy mineral association of the Alphen sands contains mainly stable minerals. These comprise zircon, tourmaline, metamorphic minerals, rutile and some anatase. The samples shown in the graph (figs. 2B and 3B) also contain some unstable minerals as epidote, garnet and hornblende, but a few others collected in the section are entirely stable. Minerals occurring in traces include brookite, topaz, green spinel and monazite. With regards to the provenance two fluvial systems may be considered, viz the early Pleistocene Meuse and an old S-N flowing fluvial system draining the Cenozoic deposits in Central Belgium.

As far as the first possibility is concerned, the heavy mineral association shows a significant difference with the sands found in the deposits of the Meuse as encountered in the river terraces in the province of Limburg (Zonneveld 1949) and in the Belgian Meuse terraces (Bustamente Santa Cruz 1974). Indeed, two of the most characteristic Meuse components, browngreen hornblende and 'turbid' chloritoid, are missing entirely.

A southern provenance, on the other hand, seems much more obvious. The deposits that were mainly eroded by the S-N flowing rivers should have been the Tertiary sediments of which the Middle Eocene 'Brussel Sands' play an important role. In these sands two main associations have been recorded, both extremely stable. One association consists mainly of tourmaline and metamorphic minerals (especially staurolite and andalusite) and only of small amounts of zircon and rutile. Pomerol (1961) found it in both the Brussel and the overlying Lede Sands at Vorst (near Brussels) and Krook (unpublished) in a quarry at Korbeek-Lo (east of Louvain). In the other association zircon and rutile predominate, followed by tourmaline and metamorphic minerals. Gullentops (1963) showed that the Brussel Sands in a quarry at Heverlee (SW of Louvain), have the following heavy mineral composition: garnet 5%, epidote 1–3%, rest (mainly zircon, some rutile) 33–62%, metamorphic minerals (including staurolite) 13–23% and tourmaline (17–38%). This is perfectly in accordance with the samples in figs. 2B and 3B. In the Brussel Sands south of the Sambre and the Meuse Geets (1984) found mainly zircon and metamorphic minerals in the lower fine part and mainly tourmaline and metamorphic minerals in the upper coarse sands.

It has been remarked above that the sands are conspicuous for their 'black' grains. From a microscopic study it appears that most of the grains are flint. When observed in an immersion fluid they turn out to be the 'grey flint', full of opaque 'dust'.

Chips of 'normal' Cretaceous flint were studied for comparision, but these are clear and transparent. From the proposed source of the main sand fraction it may be deduced that the 'grey flint' seems also to be derived from outcrops of Tertiary rocks in the south.

3. Paleogeographical evolution (Fig. 5)

As shown in the previous section, the Early Pleistocene sediments in the Galder area have been derived from 3 different sources: the Paleozoic rocks of the Condroz-Ardennes Massif, the flint eluvium on the chalk subsoil in Limburg and the Cenozoic marine deposits in central Belgium. It is an old idea that the initial hydrographic pattern in central- and northern Belgium has developed as a consequent network after the Oligocene (Lohest 1900), Miocene (Cornet 1904) or Pliocene transgressions (Briquet 1906) draining toward a coastline that ran generally W(SW)-E(NE). During the Early Quaternary the latest littoral proximity is represented by clays and sands deposited under tidal conditions in the northern Campine region (Dricot 1961). Regression of the sea by the general lowering of the North Sea Basin involved a more SW-NE trending coastline. The latter orientation, however, was modified by the more localised subsidence of the Central Graben and the Lower Rhine Embayment which developed into a wide bay (a.o. Zagwijn & Doppert 1978). Due to the slight uplift of the Brabant Massif during the Plio-Pleistocene the north-flowing rivers subsequently crossed the

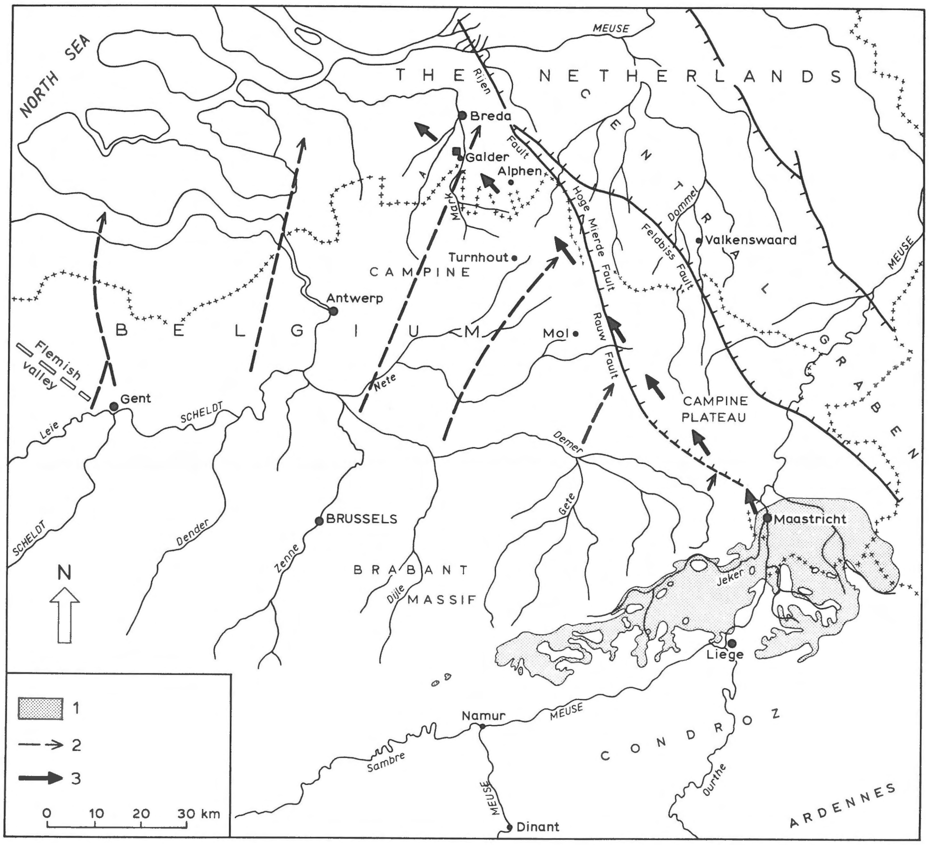


Fig. 5. Palaeogeographical map of the fluvial system at the time of deposition of the Alphen Sands. 1 = Cretaceous deposits outcropping or covered only by Late Quaternary sediments; 2 = Early Pleistocene course of rivers of the present Scheldt system; (partly after Tavernier & De Moor, 1974); 3 = late Early Pleistocene course of the Meuse.

outcroping Cenozoic deposits. The various layers of these deposits have different resistances against erosion. More specifically the thick Lower Pleistocene Campine clays are more resistant than the southerly outcropping Mio-Pliocene glauconitic fine sands (De Ploey 1961).

On the other hand, the opening of the Strait of Dover in the Middle Pleistocene (Paepe & Sommé 1975) considerably shortened the distance to the erosion base of the rivers. This caused renewed erosion which took place mainly under periglacial conditions and during periods of low sea level. Consequently the N-directed river drainage became secondary to the W-flowing rivers (Vandenberghe & De Smedt 1979). This resulted in the development of the Flemish Valley (Tavernier & De Moor 1974). Thus sands and gravels which were derived from Tertiary deposits in central Belgium have been transported by the originally consequent rivers of the Scheldt basin. At Galder these sediments are characterized by the stable heavy mineral association of the sands, the few silicified Tertiary sandstones, the rolled flint pebbles and probably the 'grey flint' both in the gravel and sand fraction. Such an origin for part of the flint from what are now considered Early Pleistocene deposits in the southwestern Netherlands was proposed already a long time ago (Van der Lugt 1928). Up to now, remnants of the original, consequent rivers have been found only sporadically and in a reworked state (Zandstra 1969; Zagwijn et al. 1971).

Gravels from the Ardennes (second source area) have been transported by the Meuse. In Early Quaternary times this river already followed the W-E directed trunk from Namur towards Liège, from where a northern course has been taken after the Tiglian (Pissart 1974; Zagwijn 1974; Zonneveld 1974). North of Maastricht the northward flowing river Meuse crosses the southern faults of the Central Graben (Fig. 5). The lowered blocks in this graben are slightly tilted to the northwest. Consequently rivers show a clear tendency to northwesterly stream deviations when crossing the southern boundary of the Central Graben (Vandenberghe 1982). This may be observed for instance at the upstream branches of the Dommel river where it reaches the Feldbiss SW of Valkenswaard (Fig. 5) and at the Meuse where it crosses the Rijen–Hoge Mierde–Rauw–Fault zone (location after resp. Pattijn 1963; Vandenberghe 1982; Gullentops & Paulissen, unpubl.).

Meuse deposits of that time occur from Maastricht in a northwestern direction. They are limited to the SW by a line stretching from Maastricht to Mol, approximately corresponding to the Rauw Fault zone. SE of Mol the direction of the Rauw–Rijen Fault zone changes from approximately SE-NW to approximately SSW-NNE and north of this area the Meuse river has traversed the latter fault zone towards the west. The Meuse deposits in this area are intermingled with deposits of N-flowing rivers subsequently from east to west.

The relatively high amounts of angular, black or brown flint are characteristic for the gravel association. For their presence at Galder several hypotheses may be proposed. The most probable possibility for us is that the flint has been transported by the Meuse river from the Cretaceous layers outcropping in the Meuse valley between Liège and Maastricht (third source area). Upstream from Liège there are but few Cretaceous deposits in the Meuse valley, while downstream from Maastricht they are covered by Tertiary formations. The supply of flint by the Cretaceous deposits to the Meuse gravel association may be estimated from the flint percentages of the Campine Plateau gravels north of Maastricht. They amount to 10–13% (Paulissen 1973) and similar percentages have been found by Van Straaten (1946). This contrasts strongly with the higher percentages found at the Galder (Fig. 4). However, the Campine Plateau gravels are considerably younger (Cromerian or Elsterian) than the fluvial deposits at Galder (Early Pleistocene). This fact has striking geomorphological implications. Indeed, it is widely known that at the end of the Pliocene and the beginning of the Pleistocene the Meuse river transported especially plateau sand and gravel as residues from Tertiary weathering, while during the Quaternary the Meuse river incised deeper and deeper, thus progressively eroding the unweathered subsoil. Plateau gravels in the Ardennes-Condroz Massif consisted mainly of quartz, but on the Cretaceous plateau a thick 'flint eluvium' was present. This may explain the high amounts of unsplit (coarse) flint in the Early Pleistocene fluvial deposits and the low amounts during Middle Pleistocene times when the flint eluvium had largely been cleaned off.

Otherwise, flint could have been provided from the same Cretaceous plateau by the N-flowing rivers of the eastern originally consequent system (e.g. Gete, Demer river). However, there is no indication that the upstream parts of these rivers occupied large areas of this Cretaceous plateau at that time. Thus only the Late Tertiary flint eluvium on the Cretaceous plateau south of Maastricht may have acted as source area for the high amounts of non well-rounded, dark coloured flint in the fluvial deposits at Galder in Early Pleistocene times.

Conclusions

The Alphen Sands (Early Pleistocene) in the southern Netherlands have a mainly Central Belgian origin. The sediments consist of sands and gravels derived from the southern Tertiary deposits. On the other hand relatively large amounts of rather angular Cretaceous flint and Ardennes gravel occur which have probably been provided by the Meuse. It appears that the greater part of the sand and fine gravel fraction have been supplied by a northward flowing 'pre-Scheldt' system whereas the Meuse has deposited mainly coarse gravels. The typical gravel association at Galder is mainly composed of flint and quartz. Small amounts of quartzite and a few crystalline fragments occur in the coarse fractions. The Alphen Sands themselves have been deposited by a braided river during a cold period. The fluvial deposits at Galder are covered by sediments which have been locally reworked by wind action and overland flow. They show distinct differences in structure, grain size texture and mineralogical association in comparison with the Alphen Sands.

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