Lithology of gravel deposits at the seabed East of the Westhinderbank

Michiel Dusar

for:

IWT-SBO project SeArch
Marnix Pieters, Maritiem en Onderwater Erfgoed
Agentschap Onroerend Erfgoed

Koninklijk Belgisch Instituut voor Natuurwetenschappen
Belgische Geologische Dienst
Jennerstraat 13
1000 Brussel

July 2014

contactpersoon: Michiel DUSAR
☎ ++32 (0)2 788.76.32
++32 (0)2 647.73.59
michiel.dusar@natuurwetenschappen.be

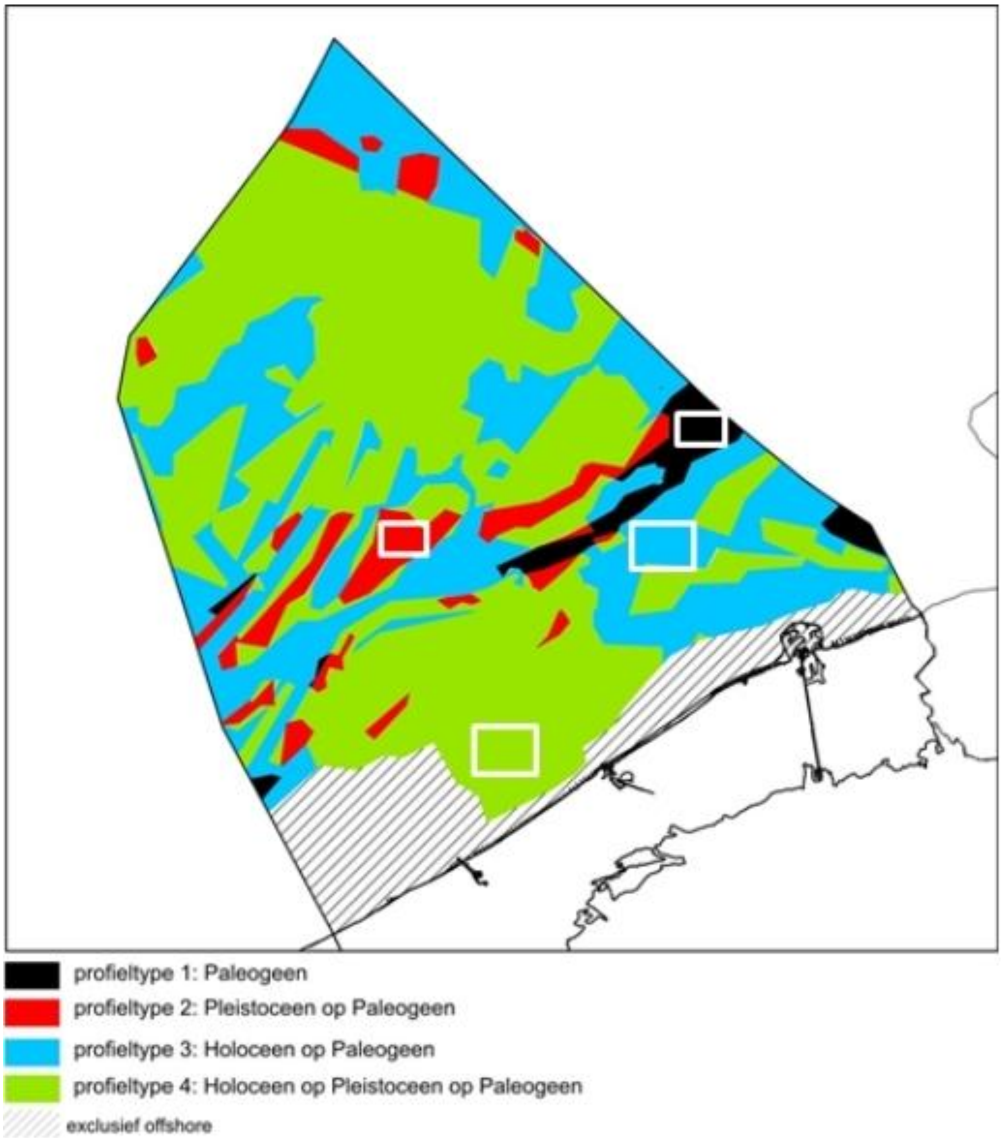
Lithology of gravel deposits at the seabed, East of the Westhinderbank

1. Background information and location

Study carried out for IWT-SBO project SeArch (“Archaeological heritage in the North Sea: development of an efficient methodology and approach towards a sustainable management policy and legal framework in Belgium”)

Coordinator: Marnix Pieters, Hoofdadviseur Maritiem en Onderwater Erfgoed
Agentschap Onroerend Erfgoed

Sampling: RV Belgica cruise 2014/11
Zone S2 Gilson trawl sample dd 29/04/2014
Location : from 2°36,199 - 51°26,845 to 2°39,740 - 51°25,268 (WGS84)
Lambert 72 coordinates (central point): X : 29300 - Y : 237500



Location map of Gilson trawl samples. Zone S2 has exposed Pleistocene at the sea bottom (rectangle over profile type 2, red area).
Map provided by Agentschap Onroerend Erfgoed – Martitiem en Onderwater Erfgoed.

Ref: Fettweis, M. et al., 2014. Rv Belgica Cruise 2014/11 – Cruise Report. Operational Directorate Natural Environment, 9 p.
With thanks to Sven Van Haelst, Maritiem Erfgoedonderzoeker, Agentschap Onroerend Erfgoed, for additional data and specifications.

Cover illustration: the dredged rocks, photo provided by M. Pieters

2. Quantitative data on the gravel

	0-10 cm	10-20 cm	>20 cm	total
flint	321	69	3	393
granite	6	11	2	19
sedimentary	63	34	18	115
total	390	114	23	527

On board of RV Belgica, a total of 527 stones were inspected and classified according to general lithological composition and size (data supplied by S. Van Haelst).

Sample S2 consist of gravel. The pebble/cobble size seems to follow a lognormal distribution for flint, but larger sizes are overrepresented for the granitic and sedimentary rocks. This may imply a mixed sediment with different origins for the flint and non-flint components.

Flint (silex) represents nearly 75% of the total composition, is making up over 82% of the smallest size group but only 13% of the largest size group, as could be expected from the size distribution of flint nodules in the original chalk sediment outcropping along the Channel coast. The preponderance of flint is in line with the observations on the composition of the extracted sand and fine gravel, dredged for commercial purposes from the sand banks.
Flint is continuously transported from south to north through the Southern Bight of the North Sea. The preponderance of flint is thus what could be expected. However, the presence of 'allochtonous' sedimentary and magmatic rocks is remarkable and needs further explanation.

3. Report on collected stones, other than flint

<u>Introduction</u>
The descriptions are based on a macroscopic examination of 33 samples, which are chips hewn off the collected pebbles/cobbles/blocks. These are of limited dimensions (from 1 to 10 cm; large are >5 cm; medium 2-5 cm and small <2 cm), whereas the collected stones are up to 30 cm in diameter. The outside is generally colonized by bryozoans, sometimes also by serpulids, and often perforated by burrowing organisms.
All described rock fragments are incorporated (with own numbering) in the lithotheque of the Geological Survey of Belgium and registered under GeoDoc 999 – Noordzee n° 038. Based on a picture of the stone harvest, the number of dredged rocks is vastly greater than the number of samples, undermining the notion of representativeness of the cuttings. However, the rock chippings provided are assumed to be representative for the different lithologies encountered in the dredging sample (except flint). Possibly, the limestones are overrepresented among the collected samples, the sandstones which are supposed to make up the bulk of the material based on the photograph (on cover of the report) are probably underrepresented.
Confirmation of the lithological interpretations and their publication would require additional petrographic analysis based on thin sections.

1- cream-beige very coarse-grained oolitic-bioclastic grainstone (oobiosparite).
The ooids are ca 1 mm, partly hollow (by dissolution of core layers); many bioclasts are added to the ooids: crinoids, surprisingly varied bryozoans and rare fragments of prismatic shells. The sediment may be bimodal with fine to medium grained bioclasts and/or small ooids in between the larger ones. Many bioclasts and broken ooids are altered with porous structure (probably due to early micritisation). All cemented by sparitic calcite. At the border of the pebble orange more recent weathering.
(large fragment)
Presumed stratigraphy: Jurassic

2- cream beige medium-coarse oolitic bioclastic grainstone (oobiosparite).
Bioclasts are hardly discernible by strong micritisation which also affects the internal structure of the ooids (creating secondary porosity). All cemented by sparitic calcite. Many burrows 1 mm wide from the surface of the pebble reach at least 2 cm deep towards the center of the pebble; macropores in the pebble probably connect to these burrows and may be covered with serpulids (sometimes it is difficult to say if they are fossil or recent)
(large fragment)
Presumed stratigraphy: Jurassic

3- cream beige coarse oolitic grainstone (oosparite).
The ooids are all hollow, often flattened and ≤1 mm in thickness (Savonnières-type). Many shell fragments are present within the mass of ooids; they are unsorted but oriented. The shell fragments are in fact calcite overgrowths or calcote replacements of the original dissolved aragonite. Other bioclasts such as crinoids are rare. The sparite cement does not fill the entire pore space and is probably a recrystallisation of an original more micritic cement. Thin orange-brown weathering crusts and irregular borings present.
(medium fragment)
Presumed stratigraphy: Jurassic

4- cream beige strongly micritised oolitic grainstone.
The ooids (≤1 mm) are full but strongly micritised. Overgrowths of dissolved small shell fragments are present. Cement is sparitic. The whole rock is locally affected by a pervasive micritisation (possibly under late diagenetic meteoric conditions).
(rather small fragment, embedded in medium-coarse quartz sand; grains not well rounded but with smooth pitted surface)
Presumed stratigraphy: Jurassic

5- beige to creamy yellow to greyish-white bioclastic grainstone (the colour gradation represents different grades of weathering)
The grains made of rounded bioclasts, possibly ooids are medium sized. Grains are micritised; cement is partly sparitic, partly micritised with rusty-orange speckles. Rounding and micritisation prevent macroscopic recognition of the components of the grains. In the greyish white core which is strongly cemented millimetric rusty-orange-stained mini-geodes with calcite cristals occur; submillimetric black cristals (magnetite?) follow biogenic contours (may be this represents a lithoclast)
(rather large fragment, strongly burrowed with both thin (ca 1 mm) deep burrows and surficial hollows made by boring mussels)
Presumed stratigraphy: Jurassic

6- light creamy grey arenitic sandstone

The quartz grains are homogeneous of composition and structure but very irregular in size, up to >1 mm, thus poorly sorted coarse, irregular in form with rounded angles. The matrix is quartz cement but mixed with whitish clay.
(medium size fragment with thin rusty brown crust)
Presumed stratigraphy: Upper Jurassic to Lower Cretaceous?

7- greyish purple fine to medium quartzitic sandstone
The sandstone is composed of rounded grains of varying grain sizes, predominantly fine but containing up to medium-coarse grains. The pervasive cement is siliceous and lighter coloured (purer) than the grains which are often dark coloured; it makes the rock tight with maximal density attainable by a rock with quartz composition. However the grain and cement distribution identifies this as a sedimentary rock.
(medium fragment, flat chip of a larger cobble)
Presumed stratigraphy: Paleozoic, pre-Carboniferous

8- light bluish grey, brown weathering, fine grained slightly fossiliferous detrital sandy limestone. Impure limestone containing sand grains and rounded detrital bioclasts, with carbonate cement, leaving few macropores (probably at places originally rich in organic matter and/or pyrite). The broad (>1 cm) brown alteration zone around the pebble testifies of microporosity, not macroscopically observed. Some millimetric shell fragments are discernable.
(large but flattened fragment with few irregular borings)
Presumed stratigraphy: Upper Jurassic (Portlandian)

9- white-speckled bluish grey, brownish weathering detrital shelly limestone
Impure limestone containing few but coarse (1 mm) and very well rounded quartz grains, few greenish coloured ('verdis') broken rock fragments (>1 mm) derived from a basal conglomerate, rounded calcareous bioclasts and abundant shell fragments (millimetric to centrimetric in size) both thin-shelled and thick-shelled (>1 mm thick), making this rock a lumachelle. Fragments of thick-shelled prismatic shells are responsible for the white specks, clearly observable in the sample. Both sparitic and micritic cements, the latter more altered, causing more internal weathering.
(large but flattend fragment with many irregular burrowings)
Presumed stratigraphy: Upper Jurassic

10- dark grey strongly cemented siliceous sandstone
Very fine grained (grains hardly discernable of very fine sand to coarse silt size) siliceous (non-effervescent) quartzite with irregular whitish quartz veins; angular cleavage.
(small fragment)
Presumed stratigraphy: Upper Carboniferous Namurian ?

11- dark grey strongly cemented but altered siliceous sandstone
Fine to medium grained sandstone with siliceous cement (non-effervescent), completely cemented to a tight quartzitic rock, with irregular reddish brown (rusty) alteration zone, angular cleavage and large alteration zones stained by greenish-yellow clayey material (dickite?). The dickite (to be confirmed) is a typical alteration mineral in Carboniferous sandstones.
(large fragment of large cobble)
Presumed stratigraphy: Upper Carboniferous Namurian

12- grey silty sandstone
Fine-grained sandstone to siltstone with some clay matrix, and slightly shaly cleavage surface, covered by beige coloured clay film. Cementation by silica resulting in tight sandstone. No indication for carbonate (no efflorescence).
(medium flat fragment)

Presumed stratigraphy: Upper Carboniferous Namurian

13- light grey compact detrital limestone
Fine-grained limestone with grainstone texture, strongly cemented. Small (0.5 mm) pyrite cristals.
(large fragment with surfaces rounded by corrosion with a set of parallel striae caused by karren-type dissolution)
Presumed stratigraphy: Lower Carboniferous Dinantian

14- grey shaly sandstone
Fine to medium-grained sandstone in which the sand grains are embedded in a clayey matrix, resulting in a rather smooth cleavage, displaying fine lamination.
(small fragment)
Presumed stratigraphy: Upper Paleozoic Devonian ?

15- creamy silty chalk
Very hard very fine-grained detrital chalk. Because of its hardness it looks like silicified chalk but it shows efflorescence under acid attack; probably originated as a hardground.
(medium sized flattened chip, completely perforated by many small (ca 1 mm diameter) identical burrowings)
Presumed stratigraphy: Cretaceous

16- rosy granite
Fairly equally cristallised rather fine grained (<2 mm) granite with predominant orange-rose alkali-feldspar (?), rich in dark mineral (hornblende up to 3 mm but mainly small speckles difficult to identify). Quartz filling interstitial spaces is hardly visible.
(large fragment of cobble which could have reached at least 20 cm in diameter)
Presumed stratigraphy: magmatic intrusion

17- rose-red quartzitic sandstone
Very coarse grained sandstone of irregular grain size (up to >2 mm) and angular grains which are purple-reddish of colour, probably freshly derived from weathering of a granitic rock (with some but very perceptible colour variations, however, virtually all grains show this base colour, proving a single origin for the grains. The matrix is filled by much smaller grains (probably a bimodal function), some clay and silica cement. Cleavage of the rock results in an irregular surface and cristalline appearance (due to the large angular grains)
(large but flattened chip
Presumed stratigraphy: Paleozoic, close to a granite intrusion

18- rose-brown microconglomeratic quartzic sandstone
Very coarse grained sandstone with well rounded pitted quartz grains into granule grain size (up to 3 mm), embedded in a matrix of very fine grained (bimodal) quartz, orange-yellow to red-stained clays and silt.
(small fragment)
Presumed stratigraphy: ?

19- light greenish grey polymict quartzitic sandstone
Very coarse to microconglomeratic densely stacked sandstone with siliceous cement giving a quartzite texture. The Grains are of different size, colour, translucency (for the quartz), and composition (including grey microquartzite.
(large but flattened fragment)
Presumed stratigraphy: Upper Carboniferous Namurian Millstone grit

20- light greenish-cream-coloured arkose
Very coarse grained to granule (max grain size 2-3 mm) detrital rock composed of angular feldspar, generally rounded quartz, hollow covered by rusty crust of probably dissolved pyritic of Fe-Mg rich unstable minerals, embedded in a clayey-silty matrix. Pressure solution has resulted in a shaly cleavage, giving the rock a laminated appearance.
(medium size fragment of possible smaller pebble - this rock does not look stongly resistant to weathering)
Presumed stratigraphy: basal Devonian arkose or Millstone grit (?), containing weathering products from magmatic intrusion.

21- Grey impure sandstone
Medium-grained micaceous sandstone (mica flakes not concentrated on bedding planes but embedded in the sand); sand grains are probably of different composition, and surrounded by clayey matrix and silica cementation.
(rather small-sized fragment of probably small pebble)
Presumed stratigraphy: Devonian sandstone

22- Grey shaly sandstone
Probably very fine to silty sandstone with shaly matrix and shale drapings, developing into slickenside (which suggests that this rock fragment has undergone orogenesis).
(rather small fragment of probably small cobble of about the same size)
Presumed stratigraphy: Devonian sandstone

23-grey sandy shale
Strongly sandy to silty shale with fine cleavage lamination, as a result of tectonic loading and compaction. Within this matrix occurrence of large milky quartz grains and lenses (deforming the laminated structure) up to 0.4 cm in thickness and 3 cm in length; the quartz inclusions are parallel oriented but not laying in the same plan. They rather look like exsolution features rather than sedimentary structures and thus originate from an area where the shale is intruded by quartz veins (synorogenic or early diagenetic, sample too small to allow macroscopic distinction).
(large flat fragment; impressions of barnacles on smooth cleavage surface indicates that this rock is not very hard – nevertheless it must be sufficient resistant to survive gravel transport because it cannot be of local origin)
Presumed stratigraphy: Devonian shale

24- grey sandy shale
Strongly silty to sandy shale with millimetric repetition of granulometric cycles, from fine silty to fine sandy. This results in a set of fine line of intersection appearing on the surfaces of the pebble.
(very large flat fragment, may represent the bulk of the original pebble)
Presumed stratigraphy: Devonian shale

25- grey silty shale
More homogeneous silty shale with dispersed very fine muscovite flakes, displaying shaly cleavage (all cleavage is non metamorphic)
(rather large flat fragment, probably representing the entire pebble)
Presumed stratigraphy: Devonian shale

26- very pale grey quartzarenitic slightly glauconiferous carbonatic sandstone
Medium-grained spherical but rather angular quartz grains are surrounded by whitish clay film and cemented by carbonate cement; black glauconite grains make up at most a few %; they are the same size as the quartz but irregularly distributed, probably following bioturbation patterns. The resulting sandstone has a clear sedimentary texture but is rich in quartz. Brittle cleavage.

(large fragment with deep hollows of boring mussels and vague perforations – some rusty brown staining parallel to the surface but sometimes deeply penetrating)
Presumed stratigraphy: Upper Jurassic (Portlandian)

27- pale grey more rusty stained quartzarenitic sandstone
Fine grained sandstone of homogeneous grain size but differential cementation: locally more carbonate matrix (strong efflorescence) prevent strong siliceous cementation, at other places silica cement gives quartzitic glassy appearance. Notable absence of glauconite. There is one larger particle (3 by 1 mm) of black vegetal fossil, probably pyrite rich.
(medium sized very flat chip with deep hollows and perforations; the weathering and staining is due to both micro porosity enhanced by carbonate dissolution).
Presumed stratigraphy: Upper Jurassic (Portlandian)

28- red granite
Very coarse cristallised granite, composed of rose alkali feldspar, milky white quartz (quartz cristals ca 0.5 cm) and biotite.
(small fragment; the small size of the chips prevents estimation of the feldspar cristal size)
Presumed stratigraphy: magmatic intrusion

29- whitish glauconitic sandstone
Very porous sandstone composed of coarse (up to 1 mm) angular milky quartz grains and perfectly rounded to lobed dark green glauconite, making up about 20% of the grains. The quartz grains are surrounded by a slightly carbonatic clayey matrix which is largely dissolved or washed out, leaving high porosity. By superficial appearance this sandstone looks like a calcarenite from the base of a chalk sequence.
(very small chip)
Presumed stratigraphy: Cretaceous to Jurassic

30- pale grey quartzarenitic sandstone
Medium to coarse translucent quartz, desnely packed and cemented by sparitic carbonate cement (strongly efflorescent), with some black weathered glauconite grains, the same size or even larger than the quartz (around 1%).
(very small chip affected by large hollows by boring mussels)
Presumed stratigraphy: Upper Jurassic (Portlandian)

31- pale reddish grey heterolithic sandstone
Sandstone with poorly sorted grains, mostly rather angular and very coarse (2 mm) quartz with the habitus of cristal prisms; large muscovite books deformed in between the quartz grains; some black ferromagnesian minerals; large volume of rosy-whitish non-carbonatic clayey but gritty matrix, probably composed of in-situ weathered feldspars: arkose located very close to granitic rocks, but with strong post-deposition weathering
(very small chip)
Presumed stratigraphy: Devonian (?) arkose, containing weathering products from magmatic intrusion.

32- rosy microgranite
Very small cristallised (ca 1 mm) probably magmatic rock, rich in quartz (the best cristals), in a matrix dominated by alkali-feldspar with some ferromagnesian minerals
(very small chip)
Presumed stratigraphy: magmatic intrusion.

33- pale to whitish beach sandstone

Composed of well rounded quartz grains, averaging 1 mm but ranging from ≤0;5 to >1 mm, seldom 2 mm and well rounded but lobed glauconite, both green and black, of the same size. The grains are matrix supported and embedded in a white probably clayey matrix which is not carbonated. However, carbonate particles occur.
(very small chip)
Presumed stratigraphy: Cretaceous to Jurassic

4. Interpretation

Different rock lithologies are admixed in the trawl sample, basically consisting of two groups, flint, which comes from the Channel and is the normal gravel component in this part of the Southern Bight of the North Sea, and 'allochtonous' non-flint, already recognised during the sampling operation as consisting of 'granites' (cristalline rocks) and 'other' (sedimentary/metamorphic rocks).

The non-flint part can be grouped as follows, according to their tentative stratigraphic age:
Jurassic limestones, Jurassic calcareous sandstones, possibly Cretaceous chalk-like sandstones, Upper Carboniferous sandstones, Millstone grit polymict sandstones, Dinantian limestone, Devonian sandstones, Devonian shales, granites and arkoses.
It is assumed that the selection of samples is sufficiently representative of the different lithologies and granulometric classes.

The composition of the non-flint pebbles/cobbles is remarkably diverse, suggesting fluvioglacial transport, which assumes a northern origin, different from the origin of the flint. The size distribution and slightly rounded character suggests a fluvial transport mode, at least in the final stage leading to the present character of the deposit.
An anthropogenic deposit (e.g. ballast of a boat) seems excluded because of the ill sorting and the presence of unsuitable rock types (e.g. porous oolitic limestones or angular Carboniferous sandstones). Moreover, ballast stones of ships plying the North Sea consisted of rounded cobbles of magmatic rocks of Scandinavian origin, as found recently in the former Damme harbour area (information Roland Dreesen, GSB).
There is no supply of local stones, the 'Paniselian veldsteen' (pierre volante, grès panisélien), a glauconiferous quartzarenite of Tertiary (Paleogene) age.

All rocks encountered are erosion products from geological systems outcropping either in the area of glacial erosion or in the North Sea drainage basin. The predominance of sedimentary rocks excludes a Scandinavian origin, such as encountered in the glacial tills of the Netherlands and Germany, which are predominantly composed of magmatic to metamorphic rocks. As these rocks come from different geological environments, at least their upstream transport route must have been different. Nevertheless it is probable that they all come from connected drainage systems. It is thus important to locate the area where all rock types might be outcropping in close proximity.
Some rock types are more appropriate for determining their stratigraphic origin and potential provenances; these encompass the Carboniferous and especially the Jurassic rocks.

<u>The Jurassic rocks</u>
Weakly consolidated limestones normally do not form part of river gravels. This observation suggests that if they are encountered in a gravel deposit, erosion must have been mechanical, suggesting either a glacial erosive phase prior to final transport by a river, or coastal cliff erosion and marine transport (which is less aggressive towards limestones). These hypotheses should also apply to the Jurassic limestones.
Jurassic oolitic limestones are well known from the Boulonnais in northern France, Champagne-Lorraine in the Meuse drainage basin in NE France and from southern England (Dorset coast) and the

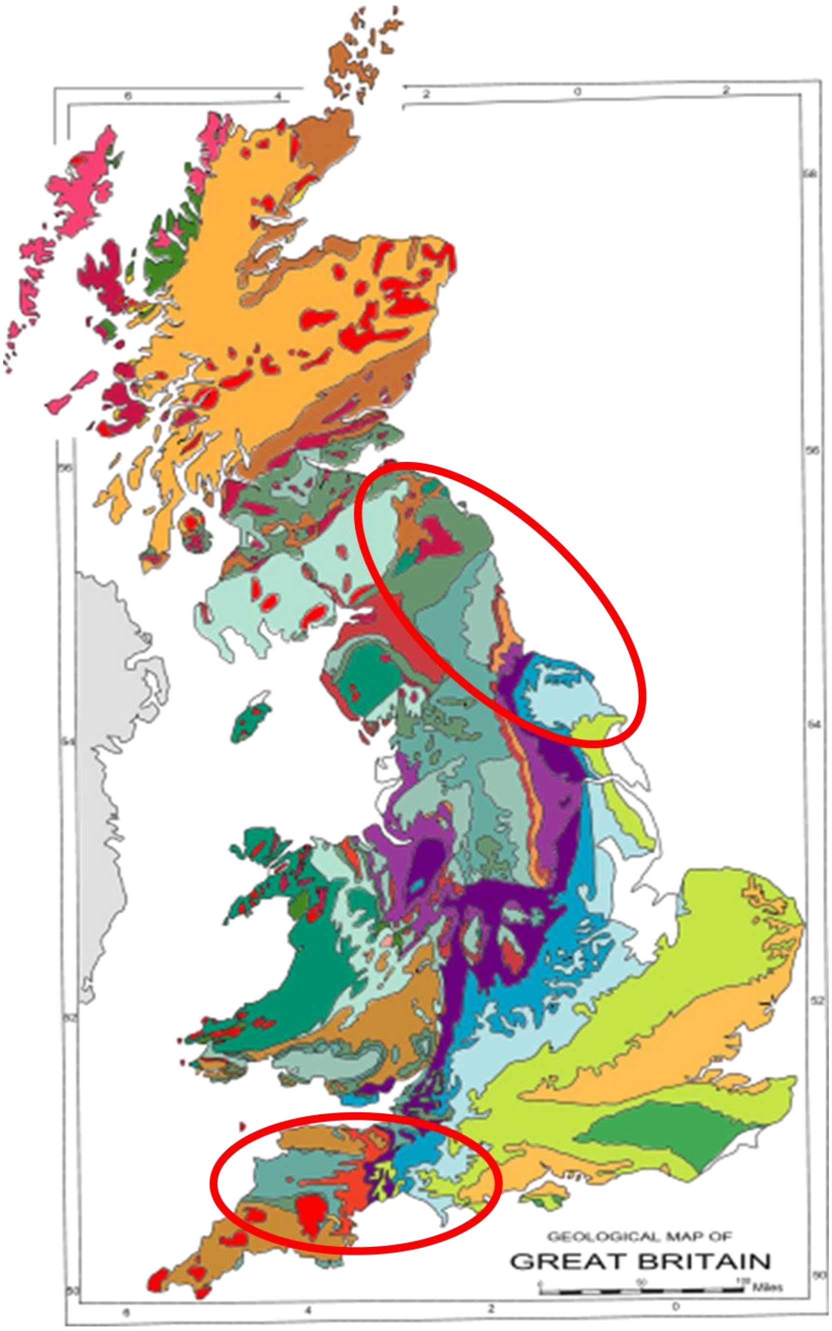
southern border of the English Midlands (Cotswolds) reaching the North Sea coast neat Whitby (Yorkshire).

An origin from NE France can be excluded for two reasons:
- carbonate rocks are not represented in the Meuse or Rhine river gravels (the latter via the Moselle), hence it cannot be expected that they occur downstream of the main Meuse and Rhine terraces;
- Portlandian sandstones do not occur there.

An origin from northern France (Boulonais) seems unlikely, despite the shortest distance to the sampling site, although Portlandian sandstones (Grès de la Crèche or Grès de Baincthun building stone) and lumachelles and Bathonian oolitic limestones (Calcaires de Marquise – Rinxent) are well known, because the coarse-grained 'cornbrash' facies is of very limited extent in the Boulonnais and unlikely to yield stable rocks that could survive rough transport conditions. Moreover, the oolitic limestones are not exposed at the coast. Nevertheless it cannot be excluded that some Portlandian sandstones might have migrated along the coast from the Cap Gris Nez area, together with the flints.

An origin from the south England coast could be envisaged provided that erosion and transport occurred under marine conditions. However, this seems to be incompatible with a fluvioglacial origin for the non-flint components in the gravel and would also imply a common provenance for flint and non-flint, which probably would result in a much greater quantity of flint.
Therefore a more northern origin (Yorkshire – southern Scotland) is preferred according to the current transport model.

Millstone grit
Coarse grained sandstones and polymict microconglomerates are well known from the Namurian (Middle Carboniferous) and crop out as part of the Andenne Formation along the Meuse valley between Namur and Liège (BE) and as Millstone Grit along the Midlands dorsal range, especially in Yorkshire (UK). Although these conglomeratic sandstones are known to occur in the Meuse river gravels, a Belgian origin is unlikely because the British outcrops, hence their erosion potential is vastly greater. Moreover, a Yorkshire origin is compatible with the assumed Midlands origin for the Jurassic rocks.



Offical geological map of Great Britain (© British Geological Survey).
The outcrop area of the Jurassic oolitic limestones is in light blue, the Millstone Grit is steel blue, and the granites in red. Based on stratigraphical interpretation of the gravel possible provenance areas for the non-flint component are indicated by red circles: the Yorkshire and southeast Scotland coastline (most likely) and the Dorset – Cornwall coastline (unlikely).

5. Conclusion

The lithological variety of the trawl sample is exceptional and indicates a complex transport model. The provenance of the non-flint gravel elements is likely to be found in NE England, SE Scotland.

Michiel Dusar
Geological Survey of Belgium
18.7.2014