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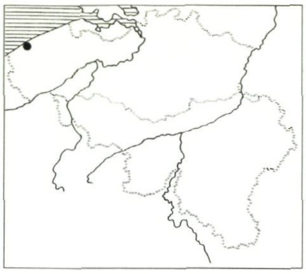

Petrology and Provenance of Unworked Stone from the Medieval Fishing-Village at Raversijde (mun. of Oostende, prov. of West Flanders)

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2 Pieters 1993 & 1994.

3 Verhulst 1964.

4 Choqueel 1950.

1 Introduction

Since the spring of 1992 a team of the Institute for the Archaeological Heritage (I.A.P.) conducted by the second author and working in close collaboration with the Provincial Government of West Flanders has been carrying out archaeological excavations at Raversijde[2]. The excavation site is partly located in the Provincial Domain of Raversijde and uncovers remains of a medieval fishing-village known in historical sources as *'Walraversijde'*[3].

Archaeological records of the sixties and seventies with regard to the present-day beach of Raversijde, made by E. and A. Cools-Mortier, suggest that the earliest human occupation at Walraversijde dates back to the 10th-12th century. At that time the village was situated on the former island Testerep, which faced the coastline and extended from Westende to Oostende. Testerep was separated from the mainland by the Groot Geleed, a creek that joined the river IJzer to the west.

During the 14th-15th centuries Testerep was repeatedly ravaged by high spring-tides and storms which badly damaged the former coastline. Many pieces of land, including parts of Walraversijde, disappeared with their settlements into the sea[4]. In these places the resident population had to move inland to save their lives and belongings. The construction of the 'Gravejansdyke' probably has to be situated in this context.

The archaeological finds fit in with these historic events. Coins recovered from the site of Walraversijde were mainly struck during the reign of John the Fearless (1405-1419) and his son and successor Philip the Good (1419-1467). They testify that the inhabitation of the inland area began with the building of the Gravejansdyke in the early 15th century. The area under study was left again towards the end of the 15th century. This may be linked up with the military troubles with Maximilian of Austria at that time in the Franc of Bruges.

About 50 ares of the inland part of the medieval settlement of Walraversijde have been unearthed thus far, revealing the ground-plan of fifteen houses and a variety of mobile archaeologica. The latter include pottery of both local and exotic origin, metal artefacts, vegetable remains, bone material, shells, pit-coal and other rock material, many of them being related to fishing activities (fish-hooks, weights for fishing-nets, piercers, etc.).

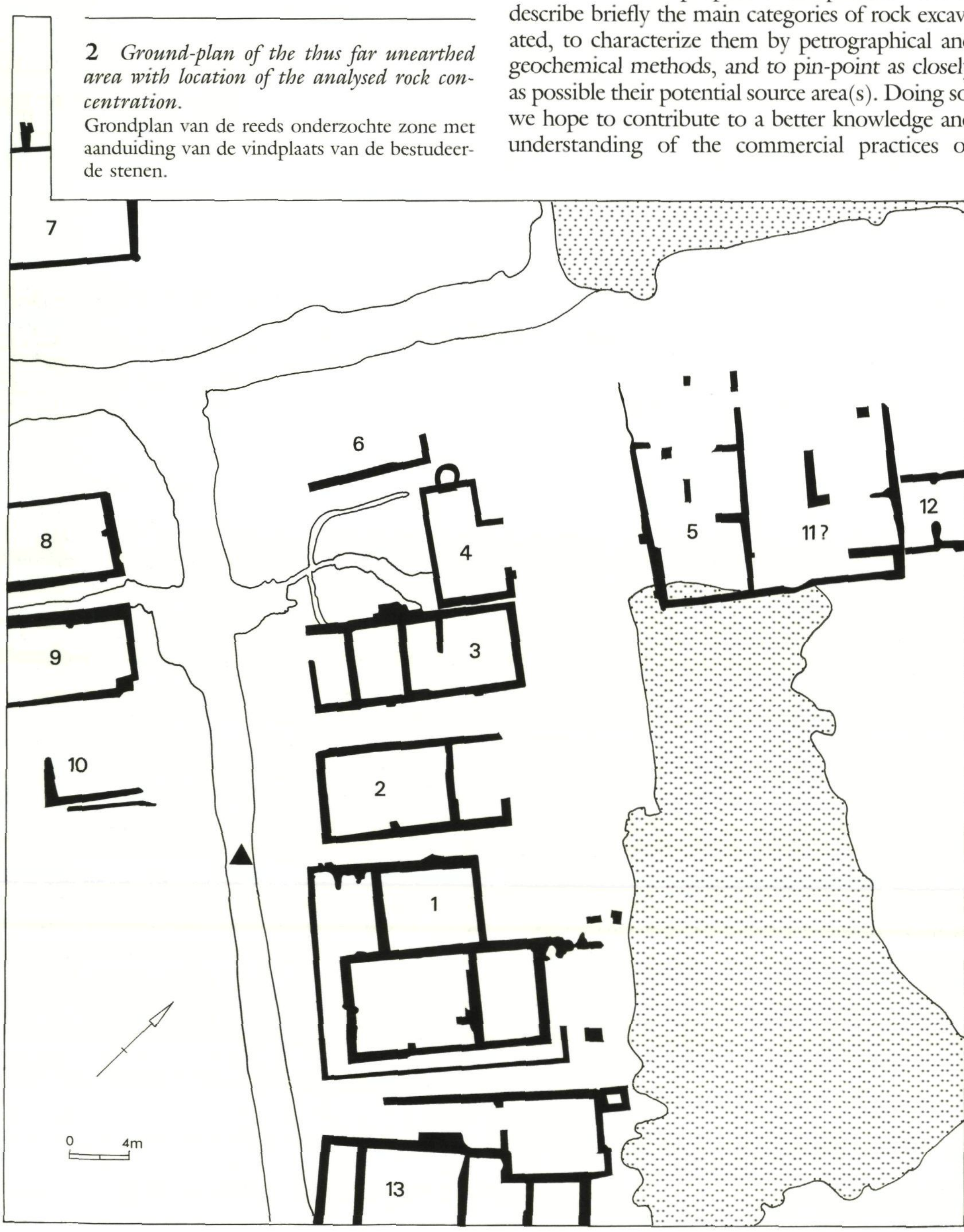
1 *The rock concentration uncovered in the ditch located between buildings 1 and 10.*
De concentratie stenen ontdekt in de grachtopvulling tussen de gebouwen 1 en 10.

As the application of techniques from the physical sciences to archaeological finds provides an independent means of unlocking information about man's past and our palaeoenvironment, it was decided by I.A.P. to call in the expertise of analytical scientists to investigate organic and anorganic materials assembled within the framework of the research programme presented above. This paper deals exclusively with data emerging from the petrologic study of rock samples found in the course of the second excavation campaign (April-October 1993).

2 Aims and scope of the study

The eighty-four stones examined were collected in the 3 to 4 metres wide ditch which parcels out the thus far unearthed part of the medieval dwelling site of Walraversijde into three 'dwelling islands'. They were recovered between building 1 and building 10, where they formed a unique rock concentration (fig. 1 en 2). The stones show no working traces and are thought to have been rounded by geological agents. The function of the finds still remains uncertain although it has been suggested[5] that they could have been used as ballast for ships by local fishermen.

It is the main purpose of the present work to describe briefly the main categories of rock excavated, to characterize them by petrographical and geochemical methods, and to pin-point as closely as possible their potential source area(s). Doing so, we hope to contribute to a better knowledge and understanding of the commercial practices or



2 *Ground-plan of the thus far unearthed area with location of the analysed rock concentration.*
Grondplan van de reeds onderzochte zone met aanduiding van de vindplaats van de bestudeerde stenen.

[5] Pieters 1994, 293.

Table 1
The number (N) and percentages of all analysed stones from Raversijde according to rock type

Rock type	N	%
Igneous rocks	47	55.9 %
volcanic (28)		
hypabyssal (18)		
plutonic (1)		
Sedimentary rocks	33	39.3 %
rudaceous (1)		
arenaceous (16)		
calcareous (11)		
siliceous (5)		
Metamorphic rocks	4	4.8 %
metapelitic (2)		
meta-arenaceous (2)		
Total	84	100.0 %

trading activities of the inhabitants of the medieval fishing-community of Walraversijde.

3 Petrology

3.1 ANALYTICAL TECHNIQUES

The rock specimens available for the present study are complete or fragmented detrital clasts in the range of 1 to 20 cm that derive from pebble and cobble deposits. They show varying degrees of rounding. All were thin-sectioned and examined by transmitted light under the polarizing microscope. In addition to petrographic analysis, the whole-rock chemistry of a restricted number of specimens, selected on the basis of texture, size and weathering state, was determined using a Perkin-Elmer 2380 flame atomic absorption spectrophoto-to-meter (AAS). The method employed was developed by Van Hende (1976) and calibrated using international reference materials. Procedural details are beyond the scope of this work. Chemical analyses, CIPW norms and some useful petrochemical parameters (differentiation index DI, solidification index SI and anorthite content of the normative plagioclase) are given in table 2 and 3.

Samples numbers (from AR4965 to AR4989 and from AR5043 to AR5101) refer to the register of the Laboratory of Mineralogy, Petrology and Micropedology (LMPM) of the University of Gent, headed by Prof. Dr. G. Stoops, where the stones are presently stored and kept available for comparative analytical research.

3.2 PETROGRAPHIC AND CHEMICAL DATA

Thin-section analysis shows that the lithic material is of three main categories: igneous, sedimentary and metamorphic. As evidenced by table 1, some rock categories occur in great proportions, whereas others are very poorly represented.

Most samples of igneous origin appear very similar to each other in macroscopic features. They comprise basaltic and derivative volcanic rocks and their hypabyssal equivalents (dolerites). A grey to dark grey colour is highly characteristic and the material is massive, rather homogeneous and fine- to medium-grained depending on emplacement conditions (at or below the surface of the earth). Among the sedimentary rocks sandstones and limestones are widely distributed. Most commonly, the former have greenish grey or reddish to violet hues and display a complete gradation in particle size. The great majority of the limestone fragments are creamy, compact and very fine-grained. The third common type of sedimentary rock is chertified material. The rare metamorphic specimens forming part of the investigated collection are dissimilar as far as colour, grain size and fabric are concerned.

3.2.1 *Igneous rock types*

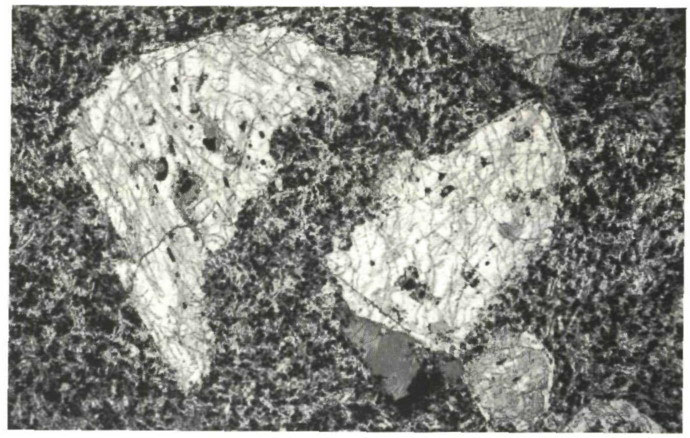
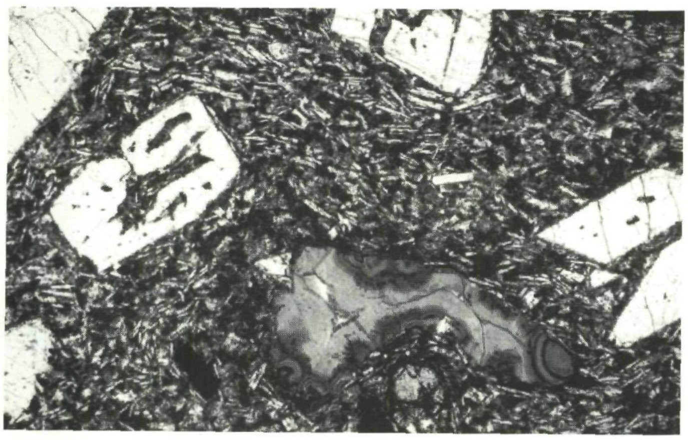
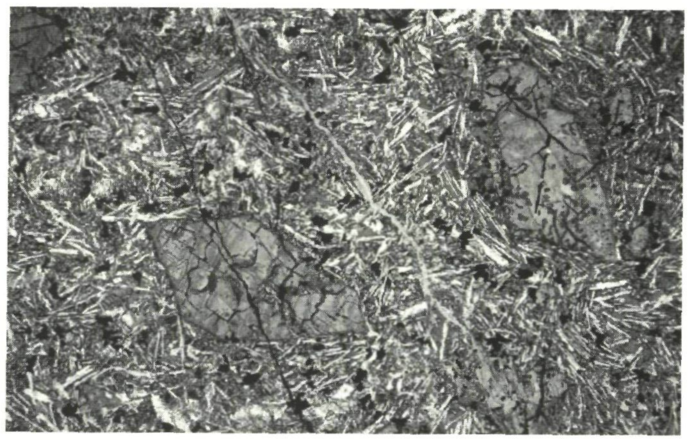
This major group is composed of twenty-eight pieces of lava, eighteen hypabyssal rock fragments (dyke rocks) and one specimen of intrusive origin.

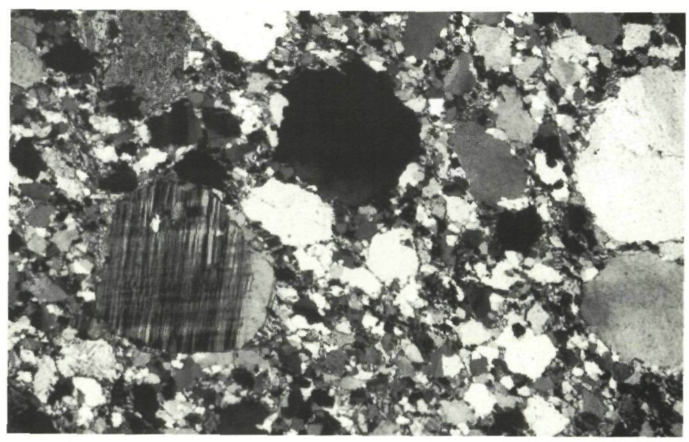
Volcanic rocks (fig. 3: a-d)

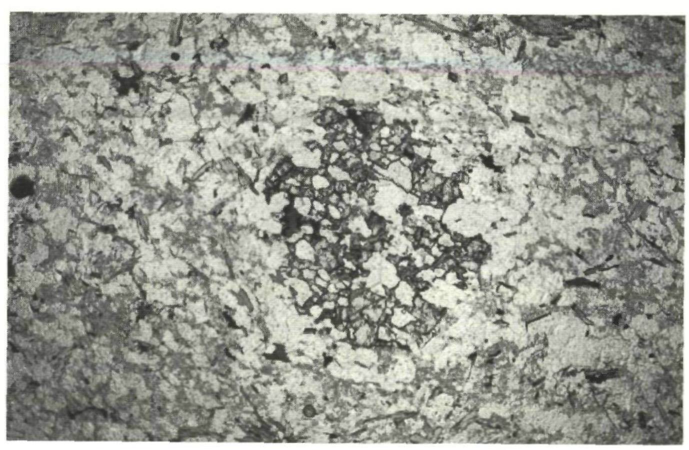
Twelve stones exhibit an aphantic texture. The remainder are either plagioclase phyric, olivine phyric or hornblende phyric. These three phenocryst-bearing variants are represented by seven, eight and one piece(s) of rock respectively.

Mineral phases occurring in aphyric samples (AR 4966, AR5053, AR5054, AR5056, AR5058, AR 5068, AR5069, AR5071, AR5073, AR5074, AR 5075 and AR5076) include variable but appreciable quantities of plagioclase, opaque ore, clino-pyroxenes, olivine, chlorite and calcite, which occasionally are associated with traces of biotite, apatite and quartz. The texture is typically intergranular, though in 50% of the analysed specimens the feldspar laths show a distinctive fluxion (or trachytoidal) texture. Vesicles are uncommon, small-sized, and completely filled with calcite, euhedral quartz, opaques and/or chlorite minerals. In some sections intergranular and subophitic textures are seen side by side.

Plagioclase microlites are unaltered or partially replaced by various secondary minerals, the major decomposition products being veinlets and clots of calcite and albitic feldspar. Fresh clinopyroxene crystals are colourless, pale brown, purplish brown or deep lilac. Clinopyroxene pseudomorphs appear to be particularly widespread and essentially made up of minerals of the chlorite group. Opaque ores





3 *Thin sections of unworked stones from Raversijde under the polarizing microscope.*
Slijpplaatjes van de niet-bewerkte stenen uit Raversijde onder de polarisatiemicroscoop.

(a) Aphyric basaltic lava (sample AR5053). Essentially composed of sub-parallel plagioclase laths, olivine entirely altered to chloritic and/or iddingsite-like material, iron ore and interstitial titaniferous augite. Cross-polarized light. The longer side of the view measures 5 mm.
Afierische bazaltische lava (gesteente AR5053). Bestaat hoofdzakelijk uit plagioklaaslatten met nagenoeg evenwijdige rangschikking, olivijn dat volledig tot chloriet en/of iddingsiet is omgezet, ijzererts en interstitiële titaanaugiet.
Gekruiste nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(b) Plagioclase phyric basaltic lava (sample AR 4972). Phenocrysts of sericitized plagioclase feldspar in an intergranular matrix of plagioclase, augite, iron ore and interstitial chlorite. Plane-polarized light. The longer side of the view measures 5 mm.
Bazaltische lava met plagioklaasfenokristen (gesteente AR4972).
Fenokristen van gesericitiseerde plagioklaas in een intergranulaire grondmassa die uit plagioklaas, augiet, ijzererts en interstitieel ontwikkelde chloriet bestaat.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(c) Plagioclase phyric basaltic lava (sample AR5082). Phenocrysts of plagioclase and microphenocrysts of augite and iron ore in a groundmass of plagioclase, granular iron ore, chlorite and calcite. An amygdule with highly irregular outline filled with chlorite in the middle of the section. The cavity-filling chlorite displays a fibroradial pattern. Plane-polarized light. The longer side of the view measures 5 mm.
Bazaltische lava met plagioklaasfenokristen (gesteente AR5082).
Fenokristen van plagioklaas en mikrofenokristen van ertsmineralen en augiet in een grondmassa die uit plagioklaas, ijzerertskorrels, chloriet en calciet bestaat. Een onregelmatige holte is opgevuld met chloriet (in het midden van de foto). De chlorietvulling is waaiervormig ontwikkeld.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(d) Olivine phyric basaltic lava (sample AR5081). Phenocrysts of olivine, which are entirely altered to chloritic material, enclosed in a matrix of plagioclase, granular augite, iron ore and interstitial patches of chlorite. Plane-polarized light. The longer side of the view measures 5 mm.
Bazaltische lava met olivijnfenokristen (gesteente AR5081).
Olivijnfenokristen, die volledig tot chlorietmineralen zijn omgevormd, zijn opgenomen in een grondmassa die uit plagioklaas, augiet, ijzererts en interstitiële chloriet bestaat.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(e) Hypabyssal basaltic rock (sample AR5060). Composed of sericitized plagioclase, subophitic augite, iron ore, hornblende, biotite and chlorite. Plane-polarized light. The longer side of the view measures 5 mm.
Bazaltisch ganggesteente (gesteente AR5060).
Samengesteld uit gesericitiseerde plagioklaas, subophitische augiet, ijzererts, hoornblende, biotiet en chloriet.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(f) Subfeldspathic arenite (AR5090). Larger grains of quartz and microcline in an interlocking mosaic of quartz, white mica, microcline, iron oxide, calcite and a little plagioclase. Cross-polarized light. The longer side of the view measures 5 mm.
Subveldspathische areniet (gesteente AR5090).
Tamelijk grote kwarts- en mikroklienkorrels liggen vervat in een mozaïek van kwarts, witte glimmer, mikroklien, ijzererts, calciet en wat plagioklaas.
Gekruiste nicols. De lengte van de lange zijde van de opname bedraagt 5 mm.

(g) Quartz arenite with calcite cement (sample AR4986). Angular quartz grains firmly cemented with granular calcite. Plane-polarized light. The longer side of the view measures 1.25 mm.
Kwartsareniet met calcietcement (gesteente AR4986).
Hoekige kwartskorrels die aaneengekit zijn door korrelige calciet.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 1,25 mm.

(h) Porphyroblastic schist (sample AR4987). Skeletal garnet porphyroblasts embedded in an aggregate consisting chiefly of quartz grains and biotite flakes. Plane-polarized light. The longer side of the view measures 1.25 mm.
Porfieroblastische schist (gesteente AR4987).
Skeletvormig ontwikkelde granaatporfieroblast in een grondmassa die hoofdzakelijk uit kwartskorrels en biotietlamellen bestaat.
Evenwijdige nicols. De lengte van de lange zijde van de opname bedraagt 1,25 mm.

are typically granular, needle-like or dendritic. Petrographic evidence indicates that the primary mineral assemblage of various aphyric volcanic samples included olivine as a major constituent. However, relicts of unaltered olivine have been detected in none of the studied sections. Olivine replacements consist of an iddingsite-like material, calcite, chlorite, iron ores, serpentine minerals and/or saponites. They mimic the external crystal form of the replaced phase. Prisms of apatite were found only once (AR4966). Sparse minute biotite flakes are enclosed in three samples (AR5056, AR5068 and AR 5076). They display a moderate to strong pleochroism and a reddish orange maximum absorption colour.

Microscopically, the aphyric volcanic rock samples may be described as tholeiitic basalts (without olivine pseudomorphs in the groundmass) and alkali basalts (with Carich, more or less titaniferous augite and abundant altered olivine microlites in the mineral assemblage).

The plagioclase phyric samples (AR4968, AR 4971, AR4972, AR5061, AR5062, AR5065 and AR5082) are moderately to strongly porphyritic with abundant large plagioclase phenocrysts and sparse olivine and magnetite microphenocrysts set in an intergranular matrix. The latter chiefly consists of plagioclase, iron ore, colourless to purplish brown clinopyroxene, olivine pseudomorphs with the characteristic lozenge-shaped outline, and chlorite minerals. Calcite, reddish brown biotite and sphene occur in minor proportions. Some rocks display a very low vesiculation. Void fillings enclose quartz, chlorites, calcite and hematite. The sizes of the plagioclase phenocrysts vary from 0.5 mm up to 7 mm. Some are very strongly corroded at their margins or crowded with minute glassy or opaque inclusions. Plagioclase is variously affected by alteration. The replacements include albite, sericite, and much more rarely calcite. Olivine phenocrysts and microphenocrysts (<0.5 mm) are converted into irregular aggregates of chlorite, calcite and quartz. Vein fillings are composed of quartz, chlorite and opaque ore. By lack of chemical data great difficulty is found to give a correct name to this second variety of volcanic rocks. It is likely however that they mainly derive from an alkalic magma series (mostly alkali olivine basalts) and that at least part of them might properly be referred to as hawaiite and/or mugearite.

The examined olivine phyric samples (AR4975, AR4977, AR5046, AR5051, AR5057, AR5064, AR5072 and AR5081) share the same general mineralogical and textural characteristics. They carry variable but usually important quantities of pseudomorphosed olivine phenocrysts and microphenocrysts, up to 4 mm in diameter, in an intergranular matrix of plagioclase, brown clinopyroxene, opaque ore, altered olivine, chlorite, brown glass and interstitial zeolites. Vesiculation is very low and vesicles are completely filled with secondary minerals. The chief mineral phase in the amygdules is chlorite, which may form fibroradial aggregates. In some samples the latter is associated with calcite. Except for AR4977, the primary olivine crystals are always completely replaced by alteration products and the large variety of olivine decomposition products (serpentine, calcite, chlorite, opaque ore) is a most striking feature of these rocks. In specimen AR 5051 the olivine phenocrysts form clusters giving to the rock a glomeroporphyritic texture.

In view of a more detailed characterization, four olivine phyric samples (AR4977, AR5051, AR5064 and AR5081) displaying variable degrees of alteration were analysed for their major element contents. The rock analyses, listed in order of increasing SiO_2 content, together with a calculation in terms of the standard compounds of the CIPW norm are given in table 2. The alkaline parentage of the analysed specimens, as evidenced by the petrographic data (in the first place the titaniferous lime-rich nature of the clinopyroxenes as suggested by their violet-purple colour and the widespread occurrence of olivine crystals in the groundmass) is also corrob-

Table 2

Major element contents and CIPW norms (in wt.%) of volcanic basaltic rocks from Raversijde (Anal. J. Van Hende). Oxide percentages were recalculated to 100 anhydrous before assigning within the norm and normative compositions are calculated assuming a uniform Fe_2O_3/FeO ratio of 0.15.

	AR5081	AR5051	AR4977	AR5064
SiO2	44.50	45.78	47.06	47.06
TiO2	1.99	1.89	2.04	2.09
Al2O3	14.02	13.53	13.94	13.91
Fe2O3	6.10	3.66	3.34	5.27
FeO	5.91	6.92	7.45	5.09
MnO	0.38	0.11	0.19	0.10
MgO	8.15	9.12	9.65	7.21
CaO	9.55	8.49	8.43	9.76
Na2O	1.93	1.60	3.01	2.14
K2O	1.06	1.21	1.42	0.95
P2O5	0.30	0.35	0.42	0.37
H2O+	3.62	4.75	2.25	3.19
H2O-	1.51	1.73	0.31	2.16
CIPW Norms				
or	6.68	7.74	8.68	6.01
ab	17.41	14.63	24.62	19.35
an	28.35	28.29	21.00	27.29
ne	-	-	0.92	-
di	16.68	12.15	15.94	17.99
hy	9.71	26.03	-	21.24
ol	13.47	3.79	21.27	0.45
mt	2.94	2.66	2.62	2.55
il	4.05	3.87	4.01	4.23
ap	0.77	0.91	1.01	0.94
DI	24	22	34	25
SI	35	41	39	35
Pl (An%)	62	66	46	59

orated by the major element composition of AR 4977, the only olivine phyric sample available for the present study enclosing a high proportion of fresh olivine and relatively few alteration products. An alkali olivine basalt composition for all olivine phyric specimens is therefore likely.

As compared to AR4977, the three other rock analyses presented in Table 2 are lower in MgO and total alkalis, but higher in total iron and CaO. 'Loss on ignition' values and Fe_2O_3/FeO ratios are also significantly higher for AR5051, AR5064 and AR5081. This is in perfect agreement with the microscopic observations which show that the latter are fairly rich in hydrated secondary minerals (chlorite, serpentine, zeolites, etc.) which replace partially or almost entirely the primary ferromagnesian compounds of the lava.

Sample AR5049 is pale grey in hand specimen, non-vesicular and hornblende phyric. Dispersed phenocrysts of hornblende (up to 5 mm in length), opaque minerals and severely altered feldspars are set in a fine-grained mesostasis composed of relicts of alkali feldspars, quartz, chloritized hornblende, opaque granules and pseudomorphs after clinopyroxene (?) associated with rare apatite and brown biotite. The phenocrystal hornblende, with tints from hazel-nut brown to almost colourless, is partially or completely transformed into chlorite, biotite and yellow epidote grains. The alkali feldspars are invariably strongly sericitized. The results of the petrographic analysis of AR5049 are consistent with a quartz trachytic composition.

Hypabyssal rocks (fig. 3: e)

From the textural point of view the analysed hypabyssal rock samples present a rather uniform appearance under the microscope. Their average grain size ranges from 0.8 to 1 mm in the fine-grained varieties and from 1.2 to 2.2 mm in those of medium size. There is a very large proportion of stones (at least 15 out of the 18 samples included in this group) composed of an interlacing network of plagioclase laths, stumpy colourless or very pale greenish clinopyroxene grains, ore minerals in skeletal or individualized forms, rare pseudomorphosed olivine and irregular quartz grains, enclosed ophitically by coarse plates of colourless to pale green clinopyroxene. In addition, intergrowths of quartz and plagioclase may also occur. Another minor constituent of some sections is interstitial reddish brown biotite. In several samples the pyroxene pseudomorphs are heavily stippled with minute subrounded sphene crystals. AR5050 is the most finegrained sample of the group and shows a prominent amygdaloidal texture. The larger amygdules are up to 5 mm across and filled by chlorite, calcite and quartz. Smaller ones only contain chlorite. Though the ophitic-textured specimens have suffered severely from albitization, sericitization, calcitization and/ or chloritization, many are thought to be tholeiitic dolerites in virtue of their primary mineralogy and texture.

The group of hypabyssal rocks also includes a small number of aphyric to moderately porphyritic, subophitic-textured samples with strongly resorbed phenocrystal plagioclase, up to 5 mm in length. They bear a close resemblance to some of the plagioclase phyric basaltic lavas described above. The clinopyroxene is usually pale brown to brown purplish and in some sections olivine is a major constituent of the mesostasis. These petrographical features are suggestive of an alkali olivine dolerite composition.

One subophitic-textured rock (AR4984) and five ophitic-textured samples (AR4978, AR5045, AR5059, AR5063 and AR5070) were analysed chemically. The results are given in table 3. The plagioclase phyric rock AR4984 (table 3, column 1) is characterized by a relative high content of Al_2O_3, TiO_2 and alkalis coupled with relatively low MgO. It differs markedly from the other samples which reveal a remarkable uniformity in the bulk composition (table 3, columns 2 to 6). Unlike the

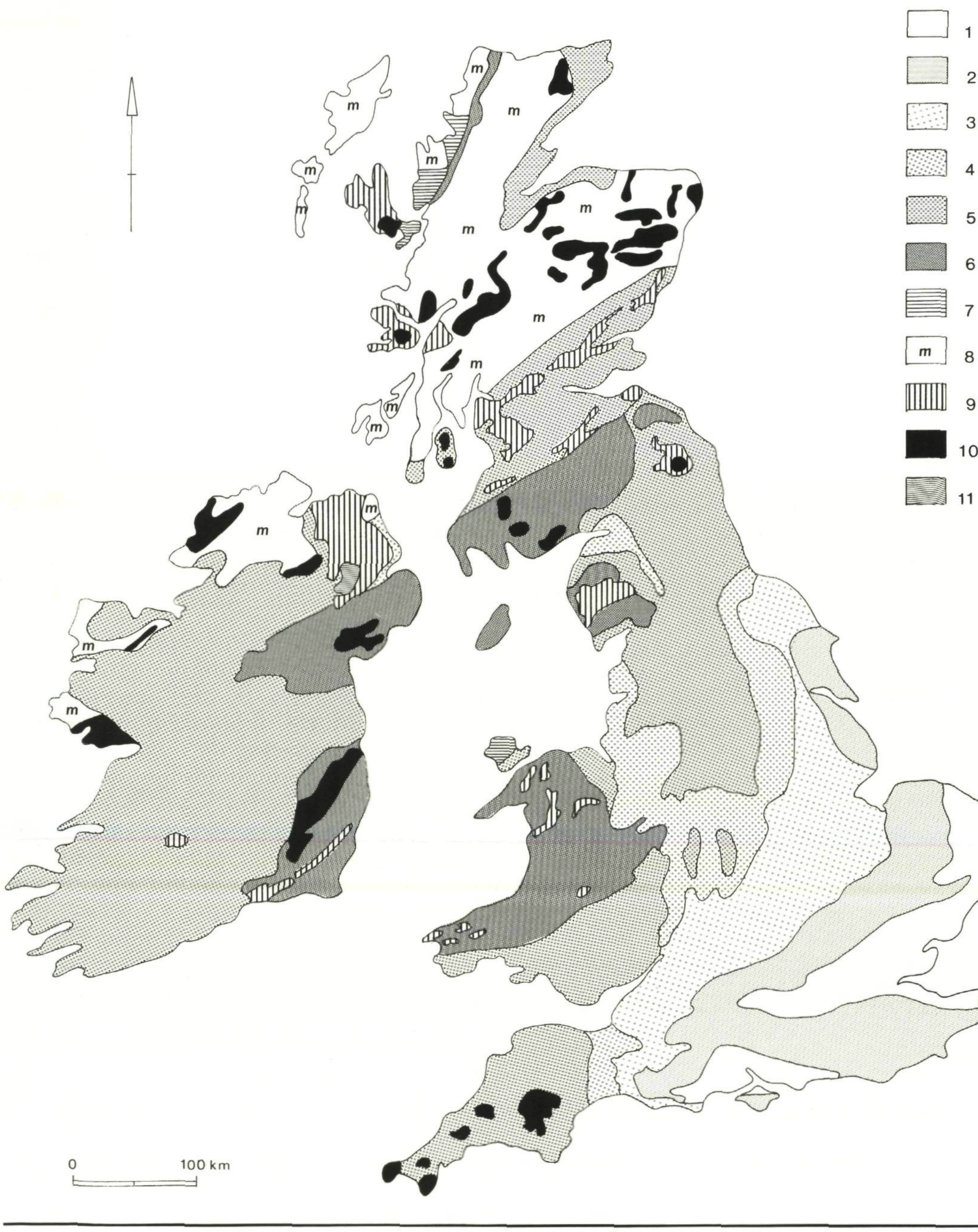
Table 3
Major element contents and CIPW norms (in wt.%) of hypabyssal basaltic rocks from Raversijde (Anal. J. Van Hende). Oxide percentages were recalculated to 100 anhydrous before assigning within the norm and normative compositions are calculated assuming a uniform Fe_2O_3/FeO ratio of 0.15.

	AR4984	AR5059	AR5063	AR5045	AR4978	AR5070
SiO2	45.78	49.20	49.63	50.05	50.91	50.92
TiO2	3.22	2.68	2.88	2.33	2.38	2.48
Al2O3	16.29	13.57	13.64	13.65	13.72	13.30
Fe2O3	7.52	6.86	9.01	4.52	3.17	4.70
FeO	6.42	6.31	4.48	7.54	9.06	7.74
MnO	0.19	0.22	0.24	0.18	0.17	0.18
MgO	3.97	5.85	5.01	4.73	5.36	4.94
CaO	6.87	7.17	6.88	9.25	6.14	6.32
Na2O	3.62	2.94	3.38	2.35	3.08	3.20
K2O	1.42	1.58	1.18	0.53	1.13	1.91
P2O5	0.53	0.37	0.42	0.32	0.28	0.28
H2O+	2.62	2.18	2.28	2.81	3.16	2.44
H2O-	0.95	0.83	0.50	0.88	0.98	0.74
CIPW Norms						
q	-	-	0.96	6.73	4.22	1.71
or	8.79	9.69	7.29	3.28	7.01	11.80
ab	32.15	25.80	29.79	20.92	27.32	28.27
an	25.18	19.95	19.30	26.40	21.28	17.05
di	6.14	12.18	11.31	16.45	7.44	11.62
hy	2.27	22.38	21.51	17.87	24.30	20.97
ol	14.48	0.76	-	-	-	-
mt	3.36	3.13	3.17	2.94	3.03	3.03
il	6.42	5.28	5.69	4.66	4.75	4.92
ap	1.31	0.91	1.04	0.81	0.67	0.67
DI	41	35	38	31	39	42
SI	17	25	22	24	25	22
Pl (An%)	44	44	39	56	44	38

other tholeiitic dolerites examined, AR5045 has a fairly high CaO content. This reflects the presence of considerable calcite in interstices and cavity fillings in the rock.

Plutonic rocks

As stated previously, this group is of little importance, one sample only (AR5048) having been identified. In thin section it consists of phenocrystal plagioclase, brown hornblende and colourless clinopyroxene in a dense matrix rich in plagioclase, orthoclase, chlorite, iron ore and actinolite. Minor constituents include apatite, sphene, epidote (pistacite) and quartz. Euhedral plagioclase phenocrysts are fairly abundant, partially saussuritized and up to 8 mm long. Hornblende phenocrysts are much smaller, less common and either euhedral or corroded. Partial replacement of hornblende by chlorite is unusual. Augite phenocrysts occur in very small quantity and are marginally converted into uralite. We suspect that the primary mineral assemblage of the rock contained biotite as a major phase but the mineral is now thoroughly altered into a mixture of chlorite, epidote and sphene. AR5048 is termed a diorite porphyry, because of its porphyritic texture and mineralogy.



4 *Schematic geological map of the British Isles.*
Schematische geologische kaart van de Britse Eilanden.

1. *Pliocene, Oligocene and Eocene.*
   Plioceen, Oligoceen en Eoceen.
2. *Cretaceous.*
   Krijt.
3. *Jurassic.*
   Jura.
4. *Triassic.*
   Trias.
5. *Permian, Carboniferous and Devonian.*
   Perm, Carboon en Devoon.
6. *Silurian, Ordovician and Cambrian.*
   Siluur, Ordovicium en Cambrium.
7. *Torridonian, etc.*
   Torridoniaan, enz.
8. *Schists and gneisses.*
   Schisten en gneissen.
9. *Volcanic rocks: basalts, etc.*
   Vulkanische gesteenten: bazalten, enz.
10. *Intrusive rocks: granites, etc.*
    Dieptegesteenten: granieten, enz.
11. *Lough Neagh.*
    Het Neagh-meer.

3.2.2 *Sedimentary rock types*

The thirty-three sedimentary rock samples have been divided into four main groups: rudites, sandstones, carbonate rocks and siliceous rocks. The microscopical properties of at least one representative sample of each group are summarized below.

Rudaceous rocks

AR4988 is the coarse-grained equivalent of a feldspathic arenite. It is composed of a chaotic assemblage of scattered subrounded and rounded quartz, K-feldspar and quartzite grains of granule size (from 2 to 4 mm across) set in a dominant matrix of quartz, K-feldspars (including intergrowths of quartz and feldspar), sodic plagioclase, flaky detrital micas (brown biotite being much more common than muscovite), opaques and accessory zircon. The K-feldspar clasts are usually subrounded, perthitic and perfectly fresh, whereas sodic plagioclase grains are subangular, twinned according to the albite law and occasionally sericitized. The coarser quartz grains are either monocrystalline, with undulatory extinction, or polycrystalline, with sutured crystals or individuals forming polygonized mosaics.

Sandstones (fig. 3: f-g)

Within this group of closely related rocks several varieties could be distinguished using the amount of interstitial argillaceous matrix (<30 μ fraction) and the mineralogical composition of the framework grains (quartz, feldspar and lithic or rock fragments) as primary discriminators for classification[6]. Relying on these two criteria the analysed sandstones from Raversijde comprise the following varieties: quartzites (AR4973, AR5084 and AR5087), quartz arenites with calcite cement (AR4970, AR 4986 and AR5083), subfeldspathic and feldspathic arenites (AR4969, AR5078, AR5079 and AR 5090), sublithic and lithic arenites (AR4980, AR 5080 and AR5085), quartz wackes (AR4967 and AR4976) and feldspathic wackes (AR5052).

On a freshly fractured surface the colour of the quartzites is a very pale grey to weakly yellowish with occasionally some irregular orange patches. These rocks are microscopically almost identical and consist of a tightly interlocking mosaic of very well-sorted quartz crystals 0.12 to 0.2 mm across. In order of decreasing abundance the accessory minerals include opaque compounds, muscovite flakes, plagioclase, microcline and zircon.

The analysed calcite-cemented quartz arenites are pale grey or yellowish brown in hand specimen depending on calcite content. AR4986 has a framework of relatively well-sorted but irregularly shaped monocrystalline quartz grains, with an average size of about 0.25 mm, cemented by microcrystalline calcite. Minor framework minerals comprise microcline, plagioclase feldspar, muscovite, iron ore, tourmaline, staurolite, colourless garnet and exceptionally lithic fragments (muscovite-bearing granite, myrmekite, chert, phyllitic-looking aggregates). The calcite content of AR4970 is distinctly lower than in the foregoing rock sample although the mineralogies of the framework grains of both are indistinguishable. The framework of AR5086, the third rock belonging to the group of quartz arenites with calcite cement, offers a rich suite of heavy minerals, including essentially zircon, colourless garnet, clinozoisite, epidote, sphene, rutile, tourmaline and apatite.

As stated above AR4969, AR5078, AR5079 and AR5090 are rather immature sandstone varieties and are interpreted as subfeldspathic and feldspathic arenites. The presence of hematite in the interstitial matrix imparts to some of these rocks (AR5079, AR5090) an intense deep reddish colour. Hematite-bearing varieties are relatively coarse-grained and may carry lithic fragments or abundant large broken microcline crystals. The lithic grains embedded in AR5079 predominantly derive from altered microcrystalline basaltic rocks. The dominant feldspar in AR5090 is perfectly fresh microcline up to 1.5 mm across. The colour of the other feldspar-rich arenites is greenish (AR4969) or yellowish grey (AR5078). AR4969 is a poorly sorted subfeldspathic variety with subangular framework grains of intermediate size. The latter consist essentially of quartz and albite-twinned plagioclase and are set in an interstitial matrix rich in fibrous chlorite. This phyllitic mineral is accompanied with detrital distorted, bent and frayed muscovite flakes, opaque iron ore, zircon, sericite, and more sporadically with calcite.

Sample AR4980 is a coarse-grained reddish volcaniclastic rock[7]. The lithoclasts were produced by weathering and mechanical erosion of igneous, sedimentary and metamorphic rocks. They consist overwhelmingly of a mixture of aphyric trachytoidal-textured volcanic fragments in combination with porphyritic rocks of basic, intermediate and more felsic composition, intermediate types being largely predominant. Many lava fragments are partially or completely replaced by carbonate minerals. We note also a significant proportion of nonvolcanic particles, including granite, chert, quartzite, micaschist, and a nonfossiliferous type of carbonate rock.

The rock fragments that are scattered throughout the sublithic arenite AR5085 mainly derive from granitic and metamorphic sources. Detrital micas (both muscovite and brown biotite) are fairly abundant and, isolated in the matrix, we have noted a large garnet porphyroblast with S-shaped trails of quartz inclusions. AR5080 is a transitional rock type displaying well-rounded grains of quartz cemented by either interfering syntaxial quartz overgrowths in optical continuity or carbonate minerals.

AR4967 and AR4976 are two pale grey quartz wackes containing a sand-size fraction that is made up predominantly of quartz grains of variable shape, up to 2.5 mm across. Most of the quartz grains

6 Classification elaborated by Dott 1964 and modified by Pettijohn *et al.* 1987.

7 According to the definition given by Fisher 1961 and Fisher 1966.

display undulatory extinction. Other detrital particles are rare and composed of muscovite, plagioclase, perthite, chlorite, iron ore, tourmaline, zircon and rutile. Lithoclasts are very uncommon. Some derive from micaceous calc-schist deposits. The matrix of both samples consists of a microcrystalline to fine-grained intergrowth of chlorite, sericite, quartz and more occasionally carbonate minerals.

The only member of the group of the feldspathic wackes is AR5052. It is grey, very poorly sorted, with detrital grains up to 5 mm across, consisting dominantly of quartz with undulatory extinction. Feldspar grains comprise both sodic plagioclase and K-feldspars. Plagioclase is typically twinned and in some instances altered to sericite. Minor detrital elements include micas (mostly muscovite flakes), opaque substances and rare zircon. The matrix is built by an aggregate of quartz, sericite and chlorite.

Carbonate rocks

Three types have been recognized: calcilutites (AR4981, AR4983, AR4985, AR5086, AR5092, AR5093, AR5096, AR5097 and AR5098), biocalcarenites (AR5099) and dolostone (AR5067).

The calcilutites listed above are petrographically similar and creamy in hand specimen. They consist of a cryptocrystalline groundmass of micrite in which occur randomly scattered globular tests of pelagic (?) micro-organisms with internal microsparite filling, angular silt-sized grains of detrital quartz and some opaque substances, including pyrite. Mica flakes are very rare. The non-carbonate constituents are volumetrically unimportant. In one sample (AR4983) the detrital quartz fraction reaches 10 to 20 % of the rock volume whereas in another (AR4985) the micro-organisms build about a third of the rock mass.

The analysed biocalcarenite AR5099 is yellowish white to creamy and distinctly bedded. The abundant bioclasts, displaying a vast spectrum of shapes and sizes (up to 2.5 mm across), are set in an interstitial sparite cement. They are entirely composed of carbonate minerals. There is no admixture of detrital quartz grains.

AR5067 is a very dark brown, finely crystalline dolostone consisting of rounded silt-sized dolomite particles enclosing rare detrital quartz grains of the silt-size fraction, minute thin muscovite flakes, opaque constituents and shell debris.

Siliceous rocks

In hand specimen the chert samples encountered at Raversijde (AR4989, AR5088, AR5089, AR5094 and AR5100) display either pale brown or very pale grey to dark grey hues with a mottled appearance. They primarily consist of granular and fibrocrystalline aggregates of chalcedony and microcrystalline quartz with patches occupied by siliceous sponge spicules and diagenetically silicified foraminifers and shell bioclasts. Imperfectly silicified tests are found but appear to be extremely rare. Very fine carbonaceous matter is randomly distributed throughout some sections. As the samples contain originally calcareous fossil forms they are obviously of secondary replacement origin (probably chertified chalk and chertified calcarenite).

3.2.3 *Metamorphic rock types* (fig. 3: h)

Only four samples were available for petrographical analysis. AR4965 is a low-grade pelitic schist. The typical assemblage of this pale green schistose rock is chlorite-muscovite-quartz, with albite, opaques, calcite, and both tourmaline and zircon as accessory minerals. AR4982 is a white metaquartzitic rock consisting of a granoblastic-polygonal aggregate of quartz combined with subordinate (chloritized) red-brown biotite, muscovite, microcline, albite, opaques, apatite and zircon. The plagioclases show incipient sericitization whereas microcline is always unaltered. Biotite may carry minute needle-like rutile crystals ('sagenite').

AR4987 is another pelitic schist. It contains sparse small garnet porphyroblasts, crowded with quartz inclusions, in an assemblage of quartz, untwinned but sericitized albite, (strongly chloritized) red-brown biotite, muscovite, with apatite and zircon as the commonest accessories. Some biotite crystals are also sagenite-bearing. AR5047, finally, is a poorly sorted subfeldspathic arenite of low metamorphic grade. The principal constituents of the rock are quartz and less frequently twinned albite and K-feldspars. The foliation is marked by thin bands of chlorite, muscovite and (rare) brown biotite. Accessory minerals include calcite, zircon, apatite and sphene.

4 Provenance

As the analysed stones probably derive from a gravel deposit which was built mainly or partly by pebble- and cobble-sized clasts, a distinction has to be made between the source of the raw materials of the clasts and that of the gravel.

4.1 RAW MATERIALS OF THE CLASTS

4.1.1 *Igneous rocks*

Alkalic and tholeiitic basalts and their coarse-grained equivalents (dolerites) are by far the commonest igneous rock types amongst the archaeological finds available for the present study. They are associated with some weakly to moderately evolved lavas (hawaiites, mugearites), a rare siliceous differentiate (quartz trachyte) and a subvolcanic hornblende diorite porphyry which from the petrologic and genetic point of view may be intimately related to the basaltic samples. As all examined igneous rock samples were subjected to intense mineralogical changes it is unlikely in our opinion that they derive from a Quaternary volcanic province.

It is well known that basalt is the most wide-spread volcanic rock type on earth and forms in diverse crustal settings. Representatives of the contrasting alkalic and tholeiitic magma series are found world-wide. In continental terrains, rocks of both suites are generally associated in a hot spot environment or in zones of tectonic tension and rifting (continental rift volcanism). Extensive volcanic provinces of Precambrian or Phanerozoic age which are built by rocks having now here alkalic, now there tholeiitic affinities are fairly uncommon in Western Europe and completely lacking in Belgium and most of the adjoining countries.

It is nevertheless true that there are two areas within relatively close geographical proximity to the Belgian coast that are typified by alkaline and tholeiitic extrusives and intrusives (dykes, sills and larger intrusive bodies). Both are located in the British Isles (fig. 4: 5). The first area extends from the Midland Valley of Scotland to Northern England. Here lavas were poured out in great prof-

5 *The British Isles, with indication of the localities and regions mentioned in the present study.*
De Britse Eilanden met aanduiding van de in de tekst vermelde plaats- en streeknamen.

usion during different periods of the Palaeozoic Era and their emplacement was accompanied with intrusion of vast amounts of igneous material (dolerites). The second district corresponds to the British Tertiary Volcanic Province[8] (BTVP). It is restricted mainly to the Inner Hebrides (from Skye to Mull), Arran, the adjacent Scottish mainland (the peninsula of Ardnamurchan) and North-east Ireland, though extensive north-westerly linear swarms of dykes belonging to various stages of this igneous period extend to North Wales and the English Midlands. As the absolute age of the paroxysmal magmatic phase is quite different for both areas it is not surprising that the Palaeozoic rocks of the Midland Valley of Scotland and Northern England tend to be much more altered than those exposed within the BTVP. The latter are known to date from early Tertiary times (Palaeocene and early Eocene).

4.1.2 *Sedimentary rocks*

A reliable determination of possible geological sources of sedimentary rocks is often problematic as many of these rocks have commonplace mineralogies and textural features. This also applies to the sedimentary material recovered from Raversijde. As we have already mentioned, all rudaceous, arenaceous, calcareous and siliceous rock samples investigated in the framework of the present project are composed essentially of ubiquitous constituents, show little or no diagnostic skeletal grains and represent rarely clear-cut or exclusive depositional environments.

The finding that the thirty-three analysed sedimentary rocks display very mixed lithologies – at least six different classes of sandstones and three classes of limestones have been recognized microscopically – is nevertheless a most interesting feature that allows meaningful speculation.

With regard to the seventeen rudaceous and arenaceous rocks identified, it was clearly established that the greater part of them are not only mineralogically, but also texturally immature, as shown by the abundance of feldspar grains of highly variable type and weathering state, the rather coarse-grained texture with usually poorly rounded and badly sorted clasts, and the frequent presence of an interstitial detrital matrix. The sandstone fragments furthermore display an extraordinary lithological variety expressing derivation from predominantly igneous (both volcanic and subvolcanic), but also metamorphic and sedimentary terrains. All these features argue for an origin outside Belgium.

For want of a good knowledge of the sedimentary petrography of the sandstone sequences cropping out in countries adjacent to Belgium, the most likely and nearest source of the studied sandstone samples from Raversijde seems to be the Lower (Cambrian, Ordovician, Silurian) and Upper Palaeozoic (Devonian, Carboniferous and Permian) formations of North, North-West or South-West England, Wales, the Midland Valley and Southern Uplands of Scotland (fig. 4: 5), or, although less probably, Brittany, in France.

As far as the cherts and the samples of calcilutite and biocalcarenite are concerned there is plentiful evidence for an origin in the London Basin or Paris Basin. The chertified limestone probably comes from the Cretaceous chalk, whereas the calcilutites and the biocalcarenite are thought to derive from Jurassic deposits. The source of the dolostone is much less obvious but a provenance in the rock sequences that yielded the sandstones is certainly conceivable.

4.1.3 *Metamorphic rocks*

Without exception all examined metamorphic rocks (schistose grit, metaquartzite and chlorite-muscovite schist) are of sedimentary origin and result from low-grade regional metamorphic processes. Similar rocks are e.g. extensively exposed in the Precambrian districts situated north of the Midland Valley of Scotland (including the Grampian Highlands) (fig. 4: 5) and less frequently in Brittany.

4.2 THE GRAVEL

The isolated occurrence of the finds within the site of Raversijde and the morphological characteristics of the individual clasts suggest in our opinion that the stones were brought collectively to the settlement after having been picked up in a shoreline environment. In such a sedimentary context, controlled by the dynamics of waves, tides and currents, clastic particles of any size coming from different geological sources mix and finally settle after having been abraded and transported by sea currents.

As the various rock types identified amongst the clastic particles of the gravel occur in great quantities in the area extending from the Grampian Highlands of Scotland to the English Midlands, and in the knowledge that sea currents in this part of the North Sea move their load by preference in direction of the Channel, it appears that the north-eastern or eastern coast of England is the most likely and nearest geological source of the stones under investigation. In the hypothetical case that the clasts originate from different localities or derive in part from a continental alluvial environment, some of the stones (especially cherts and limestone fragments) may also have been collected quite near Raversijde. It is well known e.g. that chert is a major constituent of alluvial deposits and also occurs at different levels within the Tertiary and Cretaceous rock sequences cropping out in Belgium and northern France.

8 Durant 1989.

5 Archaeological implications

From the foregoing can be concluded that the north-eastern or eastern coast of England is the most likely and nearest source of the stones under investigation. They probably arrived at Raversijde in the course of the 15th century, although an earlier arrival cannot be excluded.

The first observation must be that a combined archaeological/petrological study has independently from historical sources demonstrated a late medieval, probably a 15th century, link between the north-eastern/eastern coast of England and Walraversijde.

That lots of natural stones turn up in the context of a medieval fishing-village can be explained by the need for such materials as ballast for ships. Indeed, even small ships carry important amounts of ballast to improve the stability of the vessel[9].

But besides the use as ballast for ships, stones can also be used as construction material. At Raversijde e.g. natural stones have been used as path-flooring. Some 16th century records from the municipality of Ostend, a small town 5 km to the north-east of Raversijde, mention e.g. several Flemish fishermen, a.o. Vincent Verdieux from Walraversijde, being paid for bringing in natural stones (so-called '*zyncsteenen*') for the construction or repair of the Ostend harbour-infrastructure[10]. In the case of Vincent Verdieux, the stones, according to the historical source, came from England. It is indeed much easier to bring in such heavy loads by sea rather than over land.

It is however unlikely that the local fishermen went to the north-eastern or eastern coast of England just looking for natural stones. Besides, natural stones are not at all mentioned as commercial products in a historical study on the commercial and political relations between Burgundy and England in the middle of the 15th century[11].

On the other hand, it is known from historical data that Flemish fishermen, in the context of the herring-fishery, regularly called at ports on the eastern coast of the British Isles[12] from the 13th century onwards. Especially the ports of Newcastle upon Tyne, Scarborough, Filey, Great Yarmouth and Whitby are mentioned[13] (fig. 5). At the end of the 15th century the Flemish herring-fleet consisted probably of about 150 ships[14]. That the fishing-village of Walraversijde was quite important can be deduced from the number of safe-conducts for the English herring fishing-waters that the king of England delivered in 1443. From the 82 safe-conducts delivered to Flemish fishermen, 13 were destined to fishermen from Walraversijde[15].

The Flemish fishermen also participated in the pit-coal trade which in late medieval times was centred in Newcastle upon Tyne[16] (fig. 5). In the voyage back from the herring fishing-waters, after having sold the fish in English ports[17], pit-coal was shipped to Flanders.

The stones examined in this study probably arrived at Raversijde just because the Flemish fishermen regularly came to their area of origin for other reasons. As it is unlikely that natural stones were integrated in the commercial network in the area of origin, they are highly valuable in tracing ancient commercial routes. The commercial network is in late medieval times already rather complicated and doesn't allow a simple rectilinear relationship between the find spot and the area of origin[18].

Apart from this assemblage of natural stones, the site of Raversijde also delivered some scarce other finds of English origin: an isolated 14th century coin, a few fragments of querns in Purbeck Marble and of course numerous fragments of pit-coal.

It is hoped that future petrologic research on rocks excavated at Raversijde will provide additional information about the patterns of medieval contact and trade.

SAMENVATTING

Petrologie en herkomst van onbewerkte stenen uit het middeleeuws vissersdorp te Raversijde (Stad Oostende, prov. West-Vlaanderen)

Op het terrein van het verlaten middeleeuws vissersdorp te Raversijde (stad Oostende) werd in de 15de-eeuwse grachtvulling tussen de gebouwen 1 en 10 een concentratie natuursteen aangetroffen (fig. 1: 2). Het betrof 84 door natuurlijke processen afgeronde stenen zonder enig spoor van menselijke bewerking. De aanwezigheid van een dergelijke concentratie stenen in een steenarme regio als de Polders zette aan tot een nauwgezet petrologisch onderzoek. Op deze manier was het mogelijk om de vondsten mineralogisch, petrografisch en soms chemisch te karakteriseren en hun herkomstgebied nader te omschrijven.

Het geanalyseerde gesteentemateriaal bestaat uit 47 magmatische, 33 sedimentaire en 4 metamorfe gesteenten (fig. 3). De aard van heel wat vondsten sluit een herkomst in België en de meeste van de ons omringende landen uit. Daar de stenen waarschijnlijk afkomstig zijn uit een grindpakket dient tevens een onderscheid gemaakt te worden tussen het herkomstgebied van de grondstoffen en dat van de afgeronde stenen.

Wat de herkomst van de magmatische steensoorten betreft komen twee gebieden, beide op de Britse Eilanden gelegen, in aanmerking. Het eerste gebied strekt zich uit van de slenk van de Schotse laaglanden (de zgn. 'Midland Valley') tot Noord-Engeland (fig. 4: 5). Het tweede valt samen met de 'Britse Tertiaire Vulkanische Provincie (BTVP)'. Deze laatste treft men aan op sommige eilanden

9 Reinders *et al.* 1986, 27.
10 Vlietinck 1897, 47.
11 Thielemans 1966.
12 Coornaert 1976, 76; Asaert 1980.
13 Degryse 1972, 141; Degryse 1983, 164; Degryse 1994.
14 Asaert 1980, 134.
15 Degryse 1972, 145.
16 Degryse 1983, 157.
17 Asaert 1980, 132.
18 Hillewaert 1988; Verhaeghe 1992.

van de Binnen-Hebriden (o.m. op Skye en Mull), aan de westkust van Schotland (vooral in de buurt van het schiereiland Ardnamurchan), in Ulster en het noordoosten van de Ierse republiek.

Gezien de weinig specifieke mineralogische en texturele kenmerken van de onderzochte sedimentaire steensoorten is het onmogelijk om hun preciese herkomst te achterhalen. Het valt echter op dat ze ook in de randgebieden van beide hogergenoemde vulkanische provincies ontsloten zijn. Ook de vier beschikbare metamorfe gesteenten hebben weinig exclusieve kenmerken maar een herkomst in Noord-Schotland, meer in het bijzonder in de *Grampians*, behoort hoe dan ook tot de mogelijkheden.

Het geïsoleerd voorkomen van de onderzochte stenenconcentratie enerzijds en de morfologische kenmerken van de individuele stenen anderzijds suggereren dat deze ter hoogte van een stenige kustlijn zijn verzameld. Aangezien de bestudeerde steensoorten massaal voorkomen in een zone die zich uitstrekt van de Schotse *Grampians* tot de Engelse *Midlands* en de stromingen in de Noordzee hun lading vooral in de richting van het Kanaal verplaatsen, is de oostkust of noordoostkust van Engeland het meest voor de hand liggende herkomstgebied van de verzameling stenen die het voorwerp uitmaken van deze studie.

Uit deze gecombineerde archeologisch-petrologische studie kan het bestaan van een laatmiddeleeuws, eventueel zelfs een 15de-eeuws, contact tussen Raversijde en de oostkust van de Britse Eilanden worden afgeleid. Dat natuurstenen opduiken in een vissersdorp is te verklaren door een gebruik van dit materiaal als scheepsbalast. Anderzijds kan ook niet worden uitgesloten dat de stenen in een steenarme regio als de Polders als handelswaar werden beschouwd. Een Oostends 16de-eeuws document levert hiervan een voorbeeld.

Het feit dat dergelijke stenen waarschijnlijk niet als handelswaar werden beschouwd in hun gebied van herkomst, verhoogt hun waarde voor het opsporen en in kaart brengen van vroegere handelsroutes.

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