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Heavy minerals as a stratigraphical tool for the Eemian and Post-Eemian deposits in the lower Lys valley (Belgium)

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Abstract

The lithostratigraphic units in the Upper-Pleistocene Lys valley may be subdivided into two distinct populations, each with its own characteristic heavy mineral assemblage. The Eemian and Early Weichselian sediments, which belong to the Formations of Oostwinkel/Templeuve, Dendermonde and Oostakker, are characterized by a very high opaque grains and ubiquists content and by rather low proportions of epidote, garnet and hornblende. These sediments originate mainly from the erosion of the Eocene deposits in the studied area.

The overlying deposits, which make up the Formations of Oeselgem/Wevelgem, Eke, Gottem, St.-Baafs-Vijve and the youngest alluvial sediments, show a duplication in the number of garnets, epidotes and amphiboles and hence a considerable reduction in the amount of ubiquists. This heavy mineral association was influenced by an eolian supply from the north, in this case from the bottom of the then aerially exposed North Sea.

Introduction

In 1954 Gullentops introduced the analysis of heavy mineral distributions as an important technique in the study of the Quaternary stratigraphy of Belgium. Research since has been mainly focused on the loess belt of Central Belgium (Gullentops 1954, Juvigné 1978, 1985, Mees & Meijs 1984), on the eolian sediments in the Campine (De Ploey 1961) and on the recognition of ash layers derived from volcanic eruptions in the Eifel (e.g. Juvigné 1977, 1983, 1984).

Peeters (1943) and Tavernier (1947) carried out pioneering work in Flanders, following the work of Edelman (1933) on the Quaternary of the Netherlands. More recently, a preliminary analysis by Lootens (1977) revealed an evolution in the heavy mineral content of the different lithostratigraphic units in the Lys valley. The present paper considerably elaborates and refines the latter study, aiming to describe in more detail the mineralogic composition of the Quaternary sediments in that region and to evaluate in what manner this criterion can be used for stratigraphic purposes.

Regional setting, sampling and counting procedures

The Quaternary deposits in the embayment of the Flemish Valley south of Deinze in places attain a thickness of 25 m (De Moor & Lootens 1975). The identified local lithostratigraphic units have been correlated within the sediment group of the Flemish Valley as represented in Fig. 1. The bulk of

CHRONOSTRATIGRAPHY			LITHOSTRATIGRAPHY	LITHOLOGY	GENESIS
HOLOCENE			Youngest alluvium	Sandy loam and clay	Fluviatile
PLEISTOCENE	WEICHSELIAN	Late glacial	St.-Baafs-Vijve Formation	Sandy loam	Fluviatile
		Late Pleniglacial	Gottem Formation	Loamy coversand	Eolian
		Middle & Early Pleniglacial	Eke Formation	Sand	Fluvio-periglacial
			North : Oeselgem Formation South : Wevelgem Formation	Loam and sandy loam	Eolian and fluviatile
			Oostakker Formation	Loam and peaty loam	Fluvio-periglacial
		Early Glacial	Dendermonde Formation	Coarse sand and gravel	Fluvio-periglacial
	Eemian		Oostwinkel Formation with interdigitation of the Templeuve Formation	Loam with sandy lenses	Fluviatile and partially perimarine

Fig. 1. Integration of the local lithostratigraphic units within the sediment group of the Flemisch Valley. Based on Tavernier & De Moor 1974, De Moor & Heyse 1974, De Moor 1974, Tavernier & De Moor 1969, De Moor & Lootens 1975 and Lootens 1976.

the samples from the four most recent formations are from excavations, while the underlying units have mainly been sampled through drilling. The correlation between samples from different sites is based on lithostratigraphic criteria. Figure 2 marks the positions of the different sampling points, showing them to be situated more or less in the central part of the Lys valley to avoid the direct mineralogical influence of the underlying Tertiary sediments.

Heavy minerals were separated from the over-all sandfraction (50–500 μm) by the gravimetric method in bromoform. The minerals were mounted on glass slides and counted by the on-line method until a sum of 100 opaque and non-opaque minerals was attained. Thereupon only the transparent grains were recorded, again until 100 minerals were determined. Epidote, zoïsite and clinozoïsite are grouped in one and the same epidote class (Edelman & Doeglas 1938), including also saussurite with its numerous variations (Edelman, 1933); epidote, however, is the dominant mineral within this group. Alterite includes the unidentifiable chemically altered minerals.

Heavy mineral associations of the various lithostratigraphic units

On Fig. 3 the number of samples analysed from each lithostratigraphic unit is given in brackets and the mean percentages of the different mineralogical families are plotted graphically.

Epidote, garnet and zircon are abundant (⩾10%); rutile, staurolite and tourmaline are common (5–10%); while grains like anatase, andalusite, brookite, hornblende, kyanite and sphene occur only occasionally (1–5%). Rare minerals (<1%) are actinolite, aegyrine, anthophylite, apatite, augite, chloritoïd, diopside, glaucophane, brown hornblende, hypersthene, pigeonite and sillimanite.

On the basis of the mean frequencies of the different heavy mineral groups, the lithostrati-

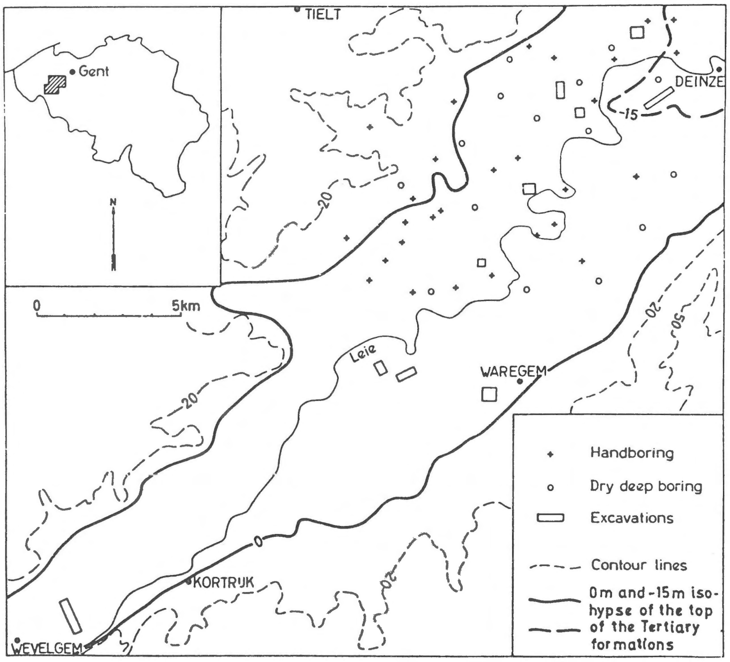

Fig. 2. Regional setting and positions of the sampling points.

graphic units are divided into two clusters.

The lower complex (the Formations of Oostwinkel/Templeuve, Dendermonde and Oostakker) is characterized by very many opaque grains (59–71%); an excess, 53–58%, of ubiquists (tourmaline, zircon, rutile, anatase, brookite and sphene), where zircon dominates tourmaline; a parametamorphic group, mostly staurolite, of 10–12%; garnets in a range of 12–15%; an epidote-group varying between 10 and 12%; few amphiboles (4–5%) and alterites (3–5%); and a negligible number of pyroxenes (1%). In spite of the contrasting granulometric composition of the three formations the difference between numbers of minerals of highly different shape (e.g. zircon and tourmaline) is small.

The upper complex (the Formations of Oeselgem/Wevelgem, Eke, Gottem, St.-Baafs-Vijve and the recent alluvial deposits) differs substantially in heavy mineral composition from the underlying deposits. The number of opaques and ubiquists is halved and varies between 30 and 39% and between 21 and 29%, respectively. The percentage of garnet and epidote increases sharply, varying respectively between 22 and 26% – except for the Gottem Formation – and between 20 and 30%. Also the number of amphiboles (8–13%) and alterites (4–9%) has been doubled. Only the parametamorphic group (8–9%) and the very rare pyroxene-group (1%) do not differ from the older units and are consequently not stratigraphically diagnostic.

The binomial structure of these Quaternary sediments can also be illustrated by the ratios of percentages of certain minerals or groups of minerals (Fig. 4). Although the values of the three mineralogical indices are quite different for the upper and the lower complex, it seems prematurely to use them as a differentiating factor between the two groups of sediments. Application of the chi-square test for the complete set of samples shows – at the 95% significance level – the existence of a heterogeneous population, which consists, however, of two homogeneous subpopulations.

Concerning the qualitative differences between the two lithostratigraphic complexes the presence must be noted of strikingly large and fresh specimens of zircon, kyanite, sphene, staurolite and tourmaline in the lower complex. In the upper complex, and mainly in the Oeselgem and Eke

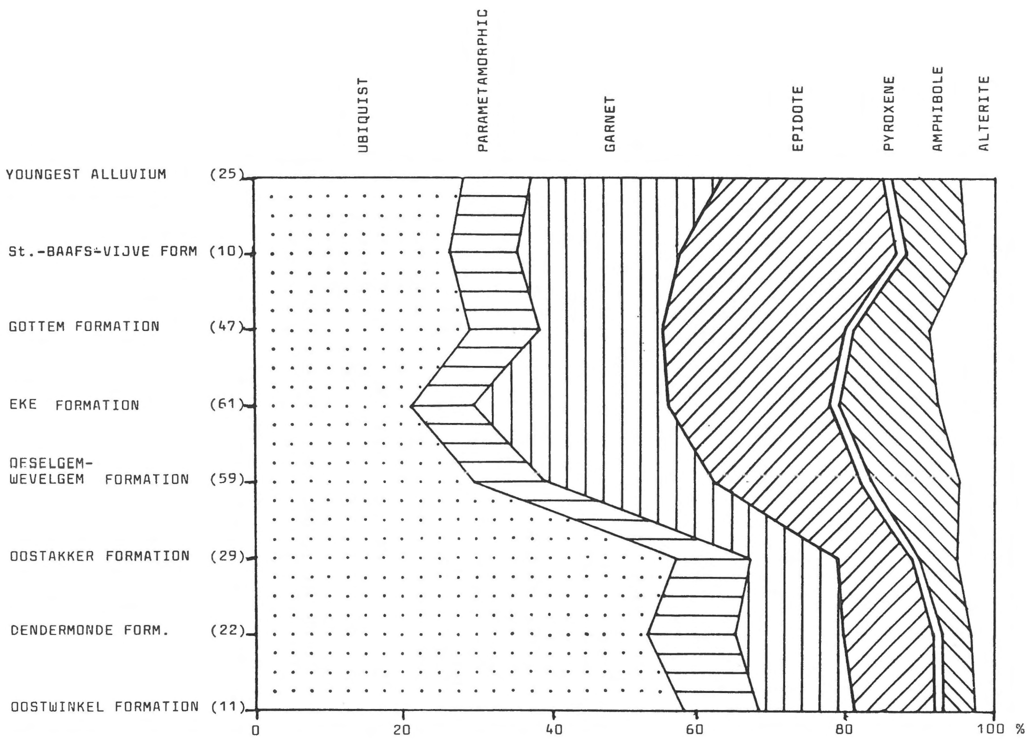

Fig. 3. Heavy-mineral diagram with indication of the number of samples analysed.

Formations, large specimens of green hornblende and large pink garnet are conspicuous. Apart from that every sample has both rounded and angular grains, proving that several generations of heavy minerals have been mixed. An attempt to distinguish different mineral types by their colour, shape or roundness gave results that are too uncertain for a quantitative approach. The very rare volcanic minerals (e.g. augite, enstatite), which are present in all the lithostratigraphic units, do not permit identification of distinct volcanic ash layers and hence correlation with dated eruptions (Juvigné 1977).

Provenance of the heavy minerals – discussion

As the Formations of *Oostwinkel/Templeuve, Dendermonde and Oostakker* consist mainly of fluviatile deposits, it is logic to compare their heavy mineral content with the composition of the eroded Tertiary sediments in the interfluves. The heavy mineral content of the Flanders Member (Ypres Formation), the most common deposit in the studied regio, is characterized by an abundance of ubiquists (mostly zircon) beside the presence of parametamorphic minerals, garnet and epidote; the amount of amphiboles and pyroxenes is negligible (Geets & De Breuck 1982) (Fig. 5). In view of the local paleomorphology, the preponderance of fluvial erosional and depositional processes – both in a quiet and in an agitated aquatic environment – during the first half of the Weichselian, and taking into account the similarity of their heavy mineral assemblage, the three oldest lithostratographic units seem to derive largely from the Tertiary sediments. The freshness of the most commonly occurring minerals favours this provenance. The absence of a high percentage of easily weatherable minerals may be a reflection of the age of the deposits but may also indicate a local origin of the sediments, whereby pedochemical weathering in the Eemian and possible older Quaternary soils caused a relative enrichment in ubiquists. Neither transport and

	a	b	c
Youngest alluvium	1.78	1.73	3.11
St.-Baafs-Vijve	1.56	1.57	2.89
Gottem	1.39	1.31	3.22
Eke	3.00	2.89	2.62
Oeselgem/Wevelgem	1.82	1.77	3.22
Oostakker	0.40	0.46	5.70
Dendermonde	0.50	0.56	4.42
Oostwinkel	0.42	0.45	5.80

Fig. 4. Mineralogical indices. After

(a) Juvigné 1978 $\frac{\% \text{ garnet} + \% \text{ gr. hornblende}}{\% \text{ zircon} + \% \text{ rutile}}$

(b) Mirsky 1961 $\frac{\% \text{ garnet}}{\% \text{ zircon}}$

(c) Parfenoff et al 1970 $\frac{\% \text{ ubiquist}}{\% \text{ parametamorphic}}$

	Lower complex (present study)	Flanders Member (Ypres Formation) (Geets & De Breuck 1982)	Upper complex (present study)	A-province (Edelman 1933)	H-province (Baak 1936)
Ubiquist	56	66	26	13	5
Parametamorphic	11	8	9	3	7
Garnet	13	16	20	31	30
Epidote	11	7	24	27	26
Pyroxene	1	+	1	1	3
Amphibole	4	+	10	24	14
Alterite	4	-	6	1	-

Fig. 5. Comparison of the main mineralogical groups of the lower and upper complex with the Tertiary deposits and the A- and H-provinces. (+ = <1 % ; – : not mentioned)

sedimentation, nor the nature and shape of the grains seem to have been selective. Nevertheless, the way in which these sediments have been sampled – e.i. by boring – hampers recognition of minor sedimentary structures which point to various hydraulic conditions that cause variations in heavy mineral content according to their difference in shape and/or density.

The substantially different mineral composition of the upper complex indicates another provenance of these deposits. Therefore, a comparison was made with the heavy mineral content of previously investigated sediment-petrological provinces of the Holocene and Pleistocene deposits in Belgium and the Netherlands (Fig. 5). The composition of the upper complex is similar to the assemblage of the A-province of Edelman (1933) but contains fewer amphiboles. The agreement is better with the H-group of Baak (1936) – including nevertheless more saussurite, not separately counted in the present study – or with the A-group of Baak. In the latter case, however, the percentage of amphiboles is higher than in the samples actually studied. Nevertheless, the upper complex contains significantly more ubiquists than the original A- and H-provinces. For Tavernier (1947) the Quaternary sediments in the Lys valley belong to the above-mentioned H-group. This association, which occurs in the Southern North Sea, is a mixture of sediments with a northern (Fenno-Scandinavian) glacial origin and of fluvial sediments from the Rhine; it dates from the Riss glaciation.

Comparisons between our results and the conclusions of Crommelin (1964) are difficult, considering his use of a fractionated analysis (150–210μm). He concluded that the Young Pleistocene coversands in the Netherlands are of mainly local origin. Vandenberghe & Krook (1981), using the 50–420μm sand fraction, described a heavy-mineral association for the Eemian and Weichselian deposits at Alphen (southern Netherlands) that consists for 50 to 60% of epidote, hornblende, garnet and alterite. This value approximates the composition of our upper complex. In their opinion, this part of the heavy-mineral suite was transported by NW-winds and originates from sands supplied by the Rhine. Mixing took place with local stable minerals.

This means that, beginning with the Formation of Oeselgem, the Pleistocene and Holocene deposits in the Lys valley reflect the influence of an eolian supply from the north. These sediments may originate from the bottom of the then dry North Sea, where deposits are found which belong to the A- and H-associations of Baak. This provenance is in agreement with the sediment-genetic interpretation previously advanced (De Moor & Lootens 1975). The allochthonous sands were mixed with the underlying Quaternary deposits and contaminated by Tertiary outcrops, that were locally eroded even during the Pleni-Weichselian (De Moor 1974).

It is premature to advance an explanation for the minor variations within the upper complex because of the influence of local circumstances. Small variations may also be caused by correlating samples which have been subjected to selective pedochemical weathering (Bateman & Catt 1985).

Conclusion

This study of the heavy-mineral content of the lithostratigraphic units in the Upper Pleistocene Lys valley reveals the presence of two sedimentary complexes each with a distinct heavy-mineral association. De Ploey (1961) found a similar structure and differentiation based on heavy minerals for the eolian sands in the Campine.

The mineralogic suite of the Eemian deposits and the Early Weichselian sediments belonging to the Dendermonde and Oostakker Formations is similar to the heavy mineral content of the Eocene deposits. During the first, rather humid part of the Weichselian, erosion was dominant in the surrounding interfluves. In consequence, the fluvial deposits reflect their provenance from the Tertiary deposits. During the second half of the Pleni-Weichselian, a dryer climate resulted in an allochthonous, eolian supply from the north. The heavy minerals of those sediments, that were mixed with pre-existing local deposits and were later reworked, indicate partly an origin from the bottom of the North Sea. The presence of the Tertiary substratum at shallow depths in the interfluves causes a permanent mixture and results in a less homogeneous composition of the heavy mineral suite within the upper complex.

The mineralogic index of Juvigné (Fig. 4), which he, Juvigné (1978, 1985), used to distinguish Weichselian loesses (values from 0.56 to 4.1) from pre-Weichselian ones (values lower than 0.6) is not suitable here. Juvigné's technique of separation and his granulometric fraction are very different from the ones I used. Because of the possible influence of the Tertiary substratum the mineralogical index should be handled with caution. Nevertheless, the presence of an Eemian deposit containing *Corbicula fluminalis* and *Cardium edule* (De Moor & Lootens 1975) at the base of the Quaternary sequence proves a Weichselian or post Weichselian age for all the overlying lithostratigraphic units.

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