Bulletin de la Société belge de Géologie, T. 102 (1-2), 1993, pp. 203-213.
Bulletin van de Belgische Vereniging voor Geologie. Ed. 1994

MIDDLE EOCENE SEQUENCE STRATIGRAPHY IN THE BALEGEM QUARRY (WESTERN BELGIUM, SOUTHERN BIGHT NORTH SEA)

by

JACOBS Patric and SEVENS Erwin[1]

ABSTRACT

Application of sequence stratigraphy principles in a classic outcrop of a Middle Eocene shallow marine sediment series (Balegem, Western Belgium) allowed detailed sediment genesis reconstruction. The lowermost sequence consists of vertical and progradational aggradation of Vlierzele Member sands. Remnants of the missing Aalter Formation are included in the basis of the Lede Formation, forming a sequence with a mainly stepwise transgressive character as underlined by its stacked retrogradational pattern of several parasequences. The general occurrence of the calcareous sandstone layers document these higher order relative sea level fluctuations as iron sulfate reduction seems to be responsible for the carbonate precipitation in zones of mixing-fluid migrations. The uppermost sequence (basal part of the Maldegem Formation) consists of 2 stacked fining upward parasequences of transgressive and regressive but more distal character.

RESUME

L'application des principes de la stratigraphie séquentielle sur une série de sédiments marins de faible profondeur d'âge Eocène Moyen exposée dans un affleurement classique (Balegem, Belgique Occidentale), a permis de reconstruire en détail la génèse des sédiments. La séquence inférieure consiste d'aggradation verticale, puis progradationelle des sables du Membre de Vlierzele. Des éléments remaniés de la Formation d'Aalter (manquante) sont incorporés dans la base de la Formation de Lede, qui forme une séquence à charactère essentiellement transgressif mais périodique, comme prouve la succession verticale de diverses paraséquences. La présence générale des bancs de grès calcareux souligne les fluctuations relatives du niveau de la mer d'ordre supérieur, comme la réduction du sulphate de fer semble être responsable pour la précipitation du carbonate dans des zones de migration de fluides mixtes. La séquence supérieure (partie basale de la Formation de Maldegem) consiste de 2 séquences superposées à granuloclassement normal à charactère transgressif puis régressif, mais d'origine plus distale.

KEY WORDS

Southern Bight North Sea, Western Belgium, outcrop, Middle Eocene, sequence stratigraphy, systems tracts

MOTS CLES

Bordure méridionale de la Mer du Nord, Belgique Occidentale, Eocène Moyen, stratigraphie séquentielle, prismes de niveau marin

1. INTRODUCTION

Originally developed in seismics, sequence stratigraphy showed to be also applicable in outcrop and well studies as relative sea level changes govern sediment stratal patterns recognizable in the field. Depositional mechanisms determine lithofacies successions serving as a sediment genesis decodation tool in which sedi

[1] University of Gent, Renard Centre of Marine Geology, Stratigraphy Unit, Krijgslaan 281 - S8 - B-9000 Gent.

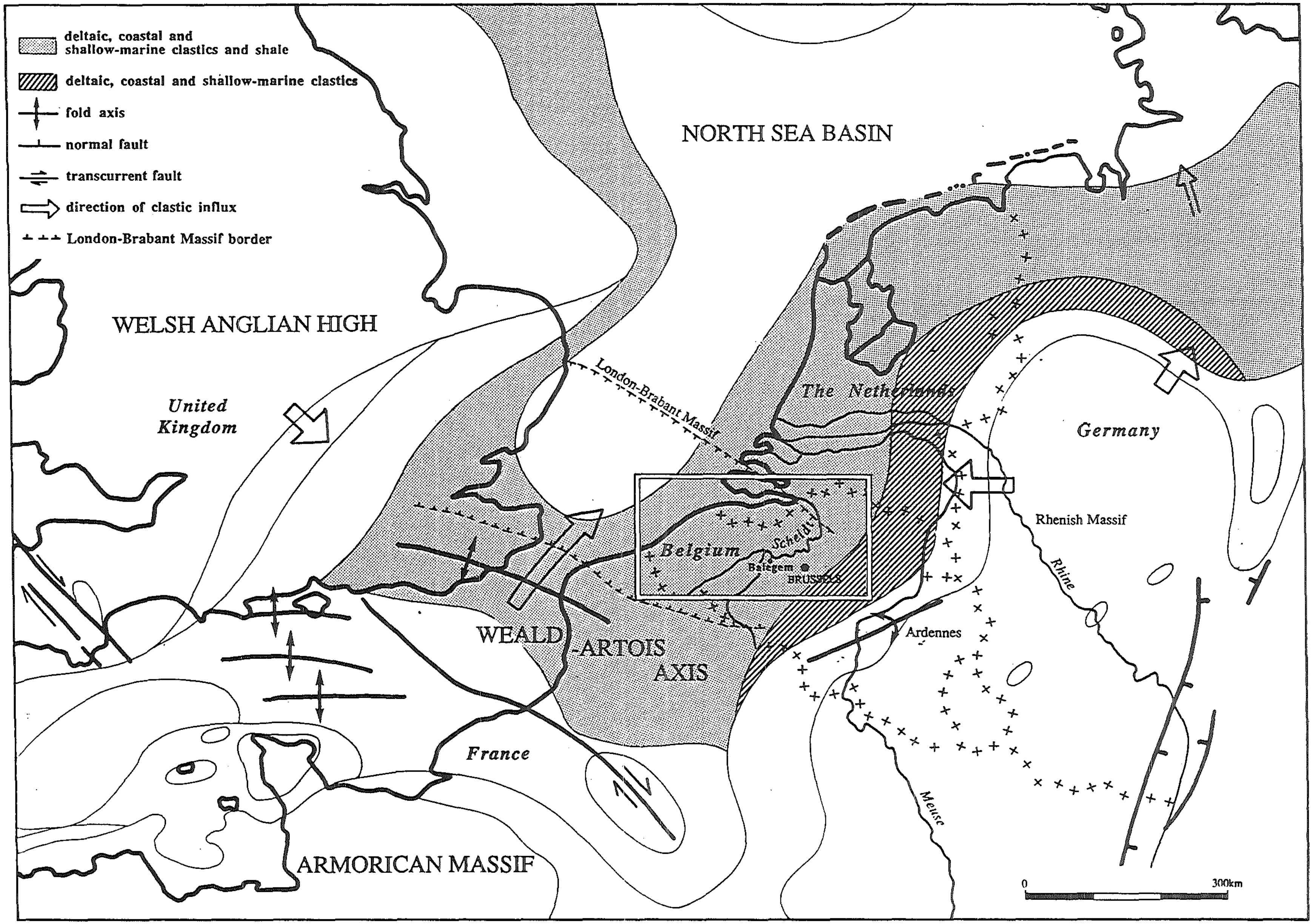


Figure 1. Situation of the Balegem sandpit in the Southern Bight of the North Sea (modified after Ziegler, 1982).

ment body characteristics in general and boundary conditions in particular play an important role. Relative sea level changes in shallow marine environments with a ramp margin setting generate copy book examples of sequence stratigraphy systems tracts patterns (Van Wagoner et al. 1990).

2. GENERAL SETTING

While the elongated deep-water Central (and Viking) Grabens act as sediment traps during the Late Palaeocene and Early Eocene, shallow marine siliciclastic sedimentation takes place in the southern margin of the North Sea Basin (Ziegler 1982), bordered by the Welsh-Anglian High, the Armorican and Rhenish Massifs, and the updoming Weald-Artois Axis, all prone to denudation (fig. 1).

In the shallow marine intracratonic Belgian Basin (Southern Bight of the North Sea) sedimentation high up on the shelf deposited a siliciclastic sediment series gently dipping (less than 1 %) to the NNE, ranging in age from Early Palaeocene to Late Pliocene. In an oversimplified way the Belgian Eocene (fig. 2, modified after Maréchal & Laga 1988) is characterized by a threefold division:

- an alternation of sandy and clayey sedimentation during Late Eocene times,
- a pronounced sandy sedimentation during Mid Eocene times,
- and a pronounced clayey sedimentation during Early Eocene times.

Jacobs *et al.* (1990) identified in total 11 sequences in an approximately 200 m composite Eocene section . In the lower and the upper portion, sequences tend to be longer favoured by the very low rates of distal sedimentation: in the lower portion nearly continuous clay decantation on the distal mud shelf builds up stacked parasequences of the Kortrijk Fm clays (formerly called Ypresian), while the alternation of sand and clay sedimentation of prodelta nature forms stacked sequences of the Maldegem Fm (formerly called Bartonian) in the upper portion. In the sandy middle portion of the section, characterized by prograding ebb tidal deltas and proximal sand barriers, lagoons, estuaries and tidal flats, the eustatic signal is much more pronounced as a result of the overall low relief palaeobathymetry of the Southern Bight, responsible for shorter (or partly incomplete) sequences.

3. BALEGEM SANDPIT

In Western Belgium, Middle Eocene sea level fluctuations are well documented in the Balegem sandpit (Province of East-Flanders, x = 110780, y = 178910, z = +72) (for location see fig. 1), where a section of approximately 17 m in the Vlierzele Member and the Lede and Maldegem Formations is exposed in what became an almost classic outcrop in Belgian Eocene geology (fig. 3). Tertiary sediments are covered by a Quaternary terrace with well rounded flint pebbles and some loess.

The Vlierzele Member (and the Brussel sands Formation) was the subject of a regional study of Houthuys (1990), comparing its depositional environment to the actual Flemish Banks in the North Sea. Fobe (1986) integrated the (Balegem) sandstone layers of the Lede Formation in a regional petrographical study of the Eocene sandstone layers of Low and Middle Belgium.

The Maldegem Formation was introduced by Jacobs (1975) in a regional lithostratigraphical study of Western Belgian Upper Eocene deposits.

The Balegem sandpit itself was already described by Mourlon in 1880 as part of a discussion on Eocene stratigraphy. Nolf (1974) gave a detailed description in his otolith biostratigraphy study. Occurring between Gent, Brussel and Ronse, the Lede Formation at Balegem belongs to the Meldert Facies (Fobe & Spiers 1992) characterized by a general fining upward grain size trend, storm-generated sedimentary structures and several internal erosion surfaces often associated with calcareous sandstone layers laterally persisting over tens of kilometres.

4. DESCRIPTION OF LITHO-UNITS

Detailed outcrop description with sedimentary facies analysis (grain size trends, sedimentary structures, boundary surfaces, fossil content,...) allows sediment genesis unraveling in relation to relative sea level changes for all sedimentary units present.

4.1. Vlierzele Member

The grey-green glauconitic fine sands of the Vlierzele Member (Gent Formation) are characterized by decimetric megaripple low angle X-bedded sets with herringbone structures, reactivation planes and tidal bundles, and massive apparently structureless (storm influenced?) sets (pl. 1, photo 1). They document a roughly east-west orientated (tidally influenced) rapid valley infill (Houthuys 1990). On top intense bioturbation (*Callianassa*), coarser quartz grains, lignitic horizons and plant remains,... indicate rapid infill completion under less energetic shallowing and coarsening upward conditions, near to the coast, with a vegetation cover in the vicinity and few transport.

4.2. Lede Formation

An irregular and undulating but knife edge sharp surface forms the lower boundary of a decimetric

CHRONO	BIO	*LITHO*		
EPOCH	ZONES	**GROUPS**	*FORMATIONS*	Members
L. EOCENE M. EOCENE	NP 16 NP 15		*MALDEGEM*	Onderdijke Buisputten Zomergem Onderdale Ursel Asse Wemmel
M. EOCENE	NP 15	**ZENNE**	*LEDE*	
	NP 14		*BRUSSEL*	Chaumont-Gistoux/ Bois de la Houssière Neerijse/Diegem/ Archennes
	NP 14		*AALTER*	Oedelem Beernem
E. EOCENE	NP 14 NP 13	**IEPER**	*GENT*	Vlierzele Pittem Merelbeke
	NP 13		*TIELT*	Egem Kortemark
	NP 11-12		*KORTRIJK*	Aalbeke Moen Saint-Maur Mont-Héribu

Figure 2. Eocene chrono-, bio- and lithostratigraphy in Belgium (modified after Maréchal & Laga 1988).

heterogeneous package of grey-yellowish fine sands, calcareous, with well rounded calcareous sandstone pebbles, abundant *Nummulites variolarius* and at the base in broad but very shallow gullies (Pl. 1, photo 2) extreme shell grit concentrations of transported (convex up) large *Cardita planicosta* specimen, typical for the Aalter Fm sands. A second sharp boundary is underlined by a lag of small and large well rounded calcareous sandstone pebbles with shell grit and numerous shark and ray teeth.

In these 6 to 7 m thick massive grey-yellowish calcareous fine sands with very abundant *Nummulites variolarius* and dispersed small but robust shells, (in general 3) fossiliferous calcareous sandstone layers occur. Their very well cemented and denser center part transitions at top and bottom into sand via a poorly cemented crumbly and cavernous zone. Small shells and *Ditrupa* accumulations occur just beneath the second sandstone layer. The uppermost (third) sandstone layer is often laterally replaced by a layer of

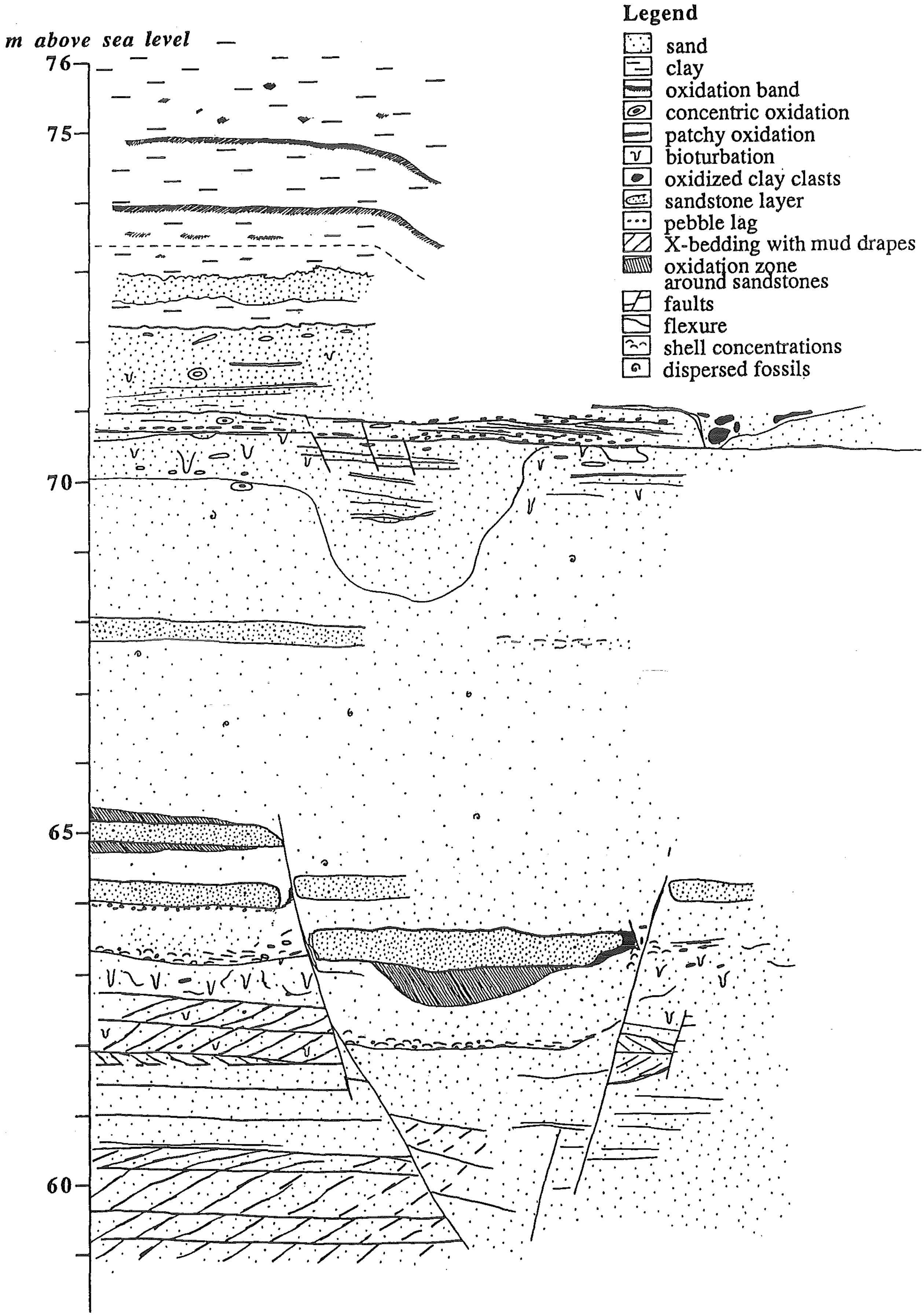


Figure 3. Balegem sandpit : schematic section.

coarse sand with shell fragments ((e.g. storm) event concentration of Kidwell 1991).On top of the Lede Formation locally 20 cm of white (leached) fine pure quartz sands and brown iron staining (oxidation) with clay infiltration might indicate soil formation conditions. Intense bioturbation of topzone is sometimes backfilled with glauconitic fine sand of overlying sediments. Clay migration due to post-depositional local irregular and deep decalcification (related to the structural deformation events?) revealed intense bioturbation and vague horizontal stratification, originally obscured by lime. Sometimes concentric oxidation occurs around plant roots.

Fault planes (see §5) acted as fluid conduits for agents dissolving *Cardita planicosta* specimen in the basal shell grit and calcareous sandstone layers in the Lede Fm basal portion as indicated by oxidized clay migration.

4.3. Maldegem Formation

4.3.1. Wemmel Member

A new sedimentation cycle starts with centimetric horizontally laminated, dark grey-green glauconitic fine sands with glauconite concentrations and intense fine bioturbation. The very sharp, slightly undulating lower boundary contains some fine clay clasts and large crab burrows at the base (Pl. 1, photo 3). Centimetric grey-green glauconitic fine sands with horizontal lamination underlined by mud drapes and fine but distinct clay laminae merge laterally into oxidized glauconite concentrations, in which small and large gullies occur filled in with large oxidized clay clasts. About a meter thick grey-green glauconitic fine sands display glauconite concentrations, fine clay laminae and concentric oxidations. The topzone is bioturbated and large burrows are backfilled with clay from the overlying sediments.

Both lower and upper boundaries are very well individualized and suggest a lithostratigraphic Wemmel Member age.

4.3.2. Asse and Ursel Members

A decimetric grey-yellow, slightly oxidized clay displays an irregular but sharp heavily burrowed lower boundary (Pl. 1, photo 6). It grades into a grey-green glauconitic sandy clay with bioturbations and glauconite concentrations, separated by a faint (bioturbated?) boundary from the overlying grey-blue slightly glauconitic massive clay with a patchy oxidation. A faint oxidation band marks the transition towards a grey-yellow slightly glauconitic massive clay with a slight overall oxidation. The overlying grey-blue slightly glauconitic massive clay is individualized by a lower distinct oxidation band and an upper one with a thin iron crust, forming the lower boundary of a grey-blue slightly massive clay with a patchy oxidation (Ursel Member).

5. STRUCTURAL DEFORMATIONS

In the upper portion of the section a flexure with a vertical throw of about 70 cm affected the Asse and Ursel Members (Pl. 1, photo 4), while the basal part of the Wemmel Member and the upper part of the Lede Formation display centimetric small scale faulting (Pl. 1, photo 5).

But the most eye-striking structural deformation affects the base of the Lede Formation and the top of the Vlierzele Member, where the lower sandstone layers and the basal shell grit with *Cardita planicosta* display a vertical throw of about 70 cm (Pl. 1, photo 7). These normal faults are probably related to Oligocene deformations as their orientation (N150°) matches the observed (Rupelian) east-west extension (Verschuren 1992, pers. comm.). It is not clear yet whether flexure, small scale faulting and extensional normal faults are related to the same tectonic event.

Fobe & Spiers (1992) infer oscillating tectonic movements of the Brabant Massif from thickness and facies variations in the Lede Formation, but do not provide any conclusive proof as their different lithofacies might as well have been generated by the interplay of sea level fluctuations, sediment supply and local topographic conditions.

6. SEQUENCE STRATIGRAPHIC INTERPRETATION

During relative sea level lowstand erosion of Highstand Systems Tracts (HST) deposits of older cycles took place in response of a sea level drop, forcing base level to fall with consequent valley incision. This unconformity (Sequence Boundary SB) is not reached by the excavation front in the Balegem quarry. As relative sea level starts to rise, the roughly east-west orientated incised valleys (Houthuys 1990) are gradually filled in with proximal marine clastics (Vlierzele Member glauconitic fine sands) poured into the basin by deltas backstepping on the shelf (Jacobs & Sevens 1990), fed by a proto Rhine-Meuse-Scheldt river drainage system with a southern sediment supply caused by constant hinterland uplift (Jacobs 1993, in press). Initial fluvial to tidal infill (Transgressive Systems Tracts TST) under an ebb dominated regime is rapid (no bioturbation) and massive (sediments dumped by storm events?). In early highstand times the infill is completed and sedimentation slows down by loss of accomodation space (bioturbation keeps up with sedimentation, beds coarsen and shallow up) due to (initially) vertical and (later) progradational aggradation. During latest highstand times (HST) (just before the next relative sea level drop) in the surrounding coastal plain under regressive (terrestrial) conditions an exhumation surface with a vegetation cover (lignite, plants,...) developes, the remains of which were transported into the basin by a less energetic short distance transport regime.

During Aalter Formation times, glauconitic fine to medium fine sands with typical *Cardita planicosta* specimen are deposited in the Balegem area with afterwards development of calcareous sandstone layers, probably in an environmental setting comparable to the one of the Oedelem Member (occurring some 40 km more northwest) (Jacobs *et al.* 1993, in press). After a new sea level drop, erosion with short distance transport collects *Cardita* specimen and sandstone pebbles in the base of broad and shallow gullies incised in the top of the Vlierzele Member sands. This lag-concentration (Kidwell 1991) is dominated by the least soluble and least transportable shells *(Cardita)*, densely packed, in poor condition (disarticulated, pitted), and marks an horizon of significant stratigraphic truncation, commonly formed in subaerial and shallow marine environments associated with initial transgression as the lag displays shell concentrations with mixed attributes.

As nearly the complete Aalter Fm sequence has been eroded during the succeeding lowstand, a complete sequence is missing in the study area, leaving the suggested transgressive backstepping (Fobe 1988) of the Oedelem Member (Aalter Fm) in the northwest, the Brussel Fm in the east and the Lede Fm in Late Middle Eocene times without definite proof. High resolution biostratigraphy is indeed still inconclusive about age dating of these juxtaposed sediment bodies.
The irregular but knife edge sharp lower boundary of the fluvial basal shell bed forms a (most probably) type 1 SB high on the shelf, although incision seemed too insignificant for tidal infill. The shell lag itself with reworked Vlierzele Member sands but containing *Nummulites variolarius*, might be considered as a late lowstand-early transgressive deposit (Lowstand Systems Tracts LST - Transgressive Systems Tracts TST), just before relative sea level starts to rise. The second pebble lag consisting of small and large sandstone pebbles, shark and ray teeth and shell grit, marks the definite onset of the Lede Fm sequence deposition, transgressing over a flat and low lying coastal plain (transgressive surface ts). The transgressive character of the Lede Fm sands (TST) is inferred from the faunal content (*Nummulites*) and its nature (small but robust fossil specimen like *Ditrupa* and *Homolaxis*), and the sedimentary structures (no apparent layering but a more massive character due to sediment dumping by storm events; bioturbation only at the top; a stepwise slight fining upward trend as coarser calcareous sandstone layers tend to occur in the basal portion).

The formation of the calcareous sandstone layers is triggered by influx of meteoric water pumped through the Lede Fm sands aquifer during relative sea level movements, the somewhat coarser sand layers with shell fragments acting as a conduit. The iron for the iron-calcite cement in the sandstones is most probably provided by the fine glauconite in the sands, its percentages being comparable with the ones in the calcareous sandstone layers, although pyrite may also be considered as a possible iron source (Fobe 1990). Stoessell (1992) discusses the effects of sulfate reduction on carbonate dissolution and precipitation in mixing-zone fluids, and concludes that major amounts of sulfate reduction enhance precipitation in all mixing-zone fluid compositions, occurring from the transformation of iron oxides to sulfides. Without oxidation of aqueous sulfide and with goethite transformation to iron sulfides (which presences are also mentioned by Fobe 1990), calcite dissolution is always less or precipitation is always more than without sulfate reduction. Furthermore, organic matter oxidation by reduction of iron oxides without the precipitation of metallic sulfides, will raise the pH and increase bicarbonate concentrations, promoting the precipitation of $CaCO_3$ (Froelich *et al.* 1979). As sea level rises in (most probably 3) pulses, higher order transgressive surfaces of stacked parasequences develope, characterized by slightly coarser sand and shell accumulations (lag deposits as fines are winnowed out) serving as preferential fluid conduits. The general occurrence of the 3 sandstone layers in Flanders therefore underlines the fluid migrations related to the 3 transgression pulses, the presence of the third sandstone layer being influenced by local sediment or topographic conditions. Consequently the iron transformation and migration can be considered as the driving mechanism for the advancement of the carbonate cementation front forming the sandstones, which was stopped the moment that the triggering effect of the oxidizing meteoric water supply was totally cut off after burial of the Lede Fm sands by younger Maldegem Formation clays acting as a seal.

During latest highstand times and succeeding relative sea level drop, the top of the Lede Fm sands most have formed an exhumation surface as indicated by bioturbations, concentric oxidations (around ghost plant roots), leaching of top sands and consequent clay illuviation below (rudimental soil formation). This drop was followed by a new relative sea level rise depositing (dark) grey-green glauconitic fine sands with intense but fine bioturbations. The knife edge sharp lower boundary with large burrows forms the SB and at the same time the ts of a fining upward first TST-parasequence (grain size trend, small and large gullies with oxidized clay clasts, merging glauconite rich laminae and presence of *Nummulites wemmelensis* recorded in Oedelem outside the study area). These transgressive Wemmel Member sands (base of the Maldegem Fm) with bioturbations, glauconite concentrations and horizontal lamination underlined by mud drapes and fine clay laminae, are characterized by low sedimentation rates. On top the irregular but sharp and heavily burrowed boundary stands as a candidate for the maximum flooding surface mfs as from hereon clay sedimentation starts. But the system floods back as a new grey-green glauconitic sandy clay (Asse Member) with bioturbations and glauconite concentrations (the so-called "bande noire" of previous authors) is deposited, developing at its base the ts of a new parasequence. This glauconitic marker bed formed during a period of reduced sedimentation rate, characterizes the onset of the Asse Member transgression as the glauconite gradually fines up and decreases towards the top. The faint (bioturbated?) boundary at its top represents the mfs of a second fining upward TST-parasequence as clay sedimentation in the basin definitely becomes prominent, depositing a massive grey clay (Ursel Member) by loss of sand and glauconite as a Highstand Systems Tracts HST.

7. CONCLUSIONS

A Middle Eocene outcrop in Balegem (Southern Bight of the North Sea) displays 3 sequences deposited in a shallow marine environment high up on the shelf. Sedimentary facies analysis (grain size trends, sedimentary structures, boundary surfaces, fossil content,...) enable unraveling of sediment genesis in relation to sea level changes. The lower sequence (Vlierzele Member sands) documents a proximal incised (fluvial and tidal) valley infill during rising relative sea level (TST) until early and late highstand times. The second unit (Lede Formation sands) constitutes a complete sequence (LST-TST-HST) of (storm influenced?) event deposits, but also provides evidence for former deposition and erosion of a (complete?) sequence. The upper sequence (Maldegem Formation) is formed by 2 stacked (TST-HST) parasequences of a more distal prodelta sedimentation.

Stratal patterns and vertical lithofacies distributions are characteristic for a sedimentation on a ramp margin position high up on the shelf with a low relief topography but without shelf break. Eustatic sea level fluctuations imprint a distinct signal recognizable in sediments even of metric thickness. In general transgressive and highstand deposits are developed; lowstand sediments are only represented by lag deposits at the base of incised valley infills. Fluid flows related to sea level fluctuations seem to favour carbonate precipitation governed by depositional characteristics.

All sequences in the Balegem quarry have been affected by a Late Tertiary relaxation event, reflecting distant and late Alpine tectonics probably connected to the opening of the North Atlantic. However it is not clear whether or not oscillating movements of the Brabant Massif played a role in the facies succession of the Middle Eocene. The interplay of eustatic sea level fluctuations, sediment supply and local topographic conditions provides a sufficient framework to explane all vertical lithofacies distributions, although locally a tectonic overprinting might not be ruled out.

ACKNOWLEDGEMENTS

This paper benefited greatly from discussions in the field with Jan Hardenbol (Exxon Production Research Co., Houston, Texas, USA) during an excursion guided by the first author at the occasion of the RCNPS-RCNNS meeting in Gent, september 1991.

REFERENCES

FOBE, B., 1986 - Petrografisch onderzoek van de coherente gesteenten van het Eoceen in Laag- en Midden-België. Ph. D. Thesis, University of Gent, 215 p. + 138 p.

FOBE, B., 1988 - De steenbanken van het Midden-Eoceen uit de boring van Kallo: lithologie en stratigrafische interpretatie. *Bull. Belg. Ver. Geol.*, **97**: 25-28.

FOBE, B., 1990 - Onderzoek van bruine banden in de Formatie van Lede, ontstaan door in situ-verwering van Balegemse steen. *Natuurwet. Tijdschr.*, **72**: 136-142.

FOBE, B. & SPIERS, V., 1992 - Sedimentology and facies distribution of the Lede Formation (Eocene) in Belgium and Northern France. *Contr. Tert. Quatern. Geol.*, **29**: 9-20.

FROELICH, P.N., KLINKHAMMER, G.P., BENDER, M.L., LUEDTKE, N.A., HEATH, G.R., CULLEN, D., DAUPHIN, P., HAMMOND, D., HARTMAN, B. & MAYNARD, V., 1979 - Early oxidation of organic matter in pelagic sediments of the eastern equatorial Atlantic: suboxic diagenesis. *Geochimica et Cosmochimica Acta*, **43**: 1075-1090.

HOUTHUYS, R., 1990 - Vergelijkende studie van de afzettingsstruktuur van getijdenzanden uit het Eoceen en van de huidige Vlaamse Banken. *Aardkund. Meded.*, **5**, 137 p.

JACOBS, P., 1975 - Bijdrage tot de litostratigrafie van het Boven-Eoceen en het Onder-Oligoceen in noordwest België. Ph. D. Thesis, University of Gent, 182 p.

JACOBS, P., 1993 (in press) - Western Belgian Eocene sediment supply determined through heavy-mineral distributions. *Geol. & Mijnb.*

JACOBS, P. & SEVENS, E., 1990 - Eo-Oligocene siliciclastic sedimentation in northwestern Belgium. *Abstracts 13th Int. Sediment. Congress*, 244, Nottingham.

JACOBS, P., SEVENS, E., DE BATIST, M. & HENRIET, J.P., 1990 - Grain size-, facies- and sequence analysis of West Belgian Eocene continental shelf deposits. *Zbl. Geol. Paläont. Teil I*, **8**: 931-955.

JACOBS, P., STEURBAUT, E. & NOLF, D., 1993 (in press) - The Aalter Formation. *Contr. Tert. Quatern. Geol.*

KIDWELL, S.M., 1991 - The Stratigraphy of Shell Concentrations. *In* : Taphonomy : Releasing the Data Locked in the Fossil Record, *Topics Geobiol.*, **9**. (Allison, P.A. & Briggs, D.E.G., Eds), 211-290, Plenum Press, New York.

MARECHAL, R. & LAGA, P., 1988 - Voorstel lithostratigrafische indeling van het Paleogeen. Nationale Commissies voor Stratigrafie, Commissie: Tertiair, *Belgische Geologische Dienst*, 208 p.

MOURLON, M., 1880 - Géologie de la Belgique. Tome **I**, 317 p. F. Hayez, Bruxelles.

NOLF, D., 1974 - De Teleosteï-Otolieten uit het Eoceen van het Belgisch Bekken - Reconstructie van de Fauna en Biostratigrafische Toepassing. Ph. D. Thesis, University of Gent, 173 p.

STOESSEL, R., 1992 - Effects of sulfate reduction on $CaCO_3$ dissolution and precipitation in mixing-zone fluids. *J. Sedim. Petrol.*, **62**: 873-880.

VAN WAGONER, J.C., MITCHUM, R.M., CAMPION, K.M. & RAHMANIAN, V.D., 1990 - Siliciclastic Sequence Stratigraphy in Well Logs, Cores, and Outcrops: Concepts for High-Resolution Correlation of Time and Facies. *AAPG Methods in Exploration Series*, **7**, 55 p.

ZIEGLER, P., 1982 - Geological Atlas of Western and Central Europe. Shell Internationale Petroleum Maatschappij B.V., 130 p. & encl., Elsevier, Amsterdam.

Manuscript received on 17.08.92 and accepted for publication on 15.10.1992.

PLATE 1

Photo 1 - Balegem sandpit : rapid valley infill by tidally influenced megaripple low angle X-bedded sands (Vlierzele Member).

Photo 2 - Balegem sandpit : broad gullies in the base of the Lede Formation sands with shell grit concentrations of *Cardita planicosta*, typical for the Aalter Formation sands.

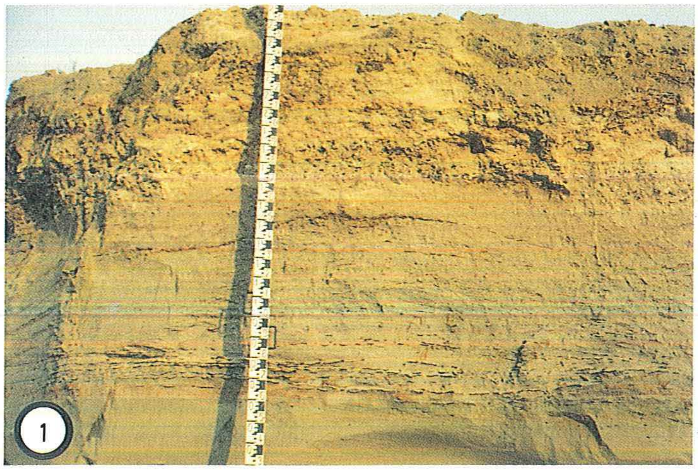
Photo 3 - Balegem sandpit : clay clasts and crab burrows forming the transgressive surface of the Wemmel Member sands on the Lede Formation sands.

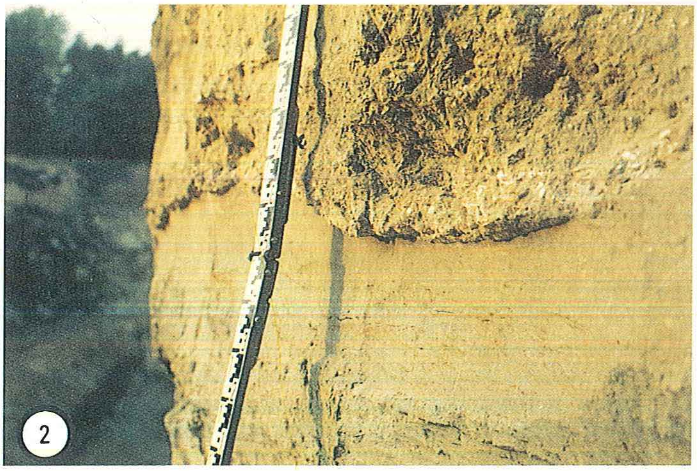
Photo 4 - Balegem sandpit : flexure with a vertical throw of 70 cm affecting the Asse and Ursel Member clays.

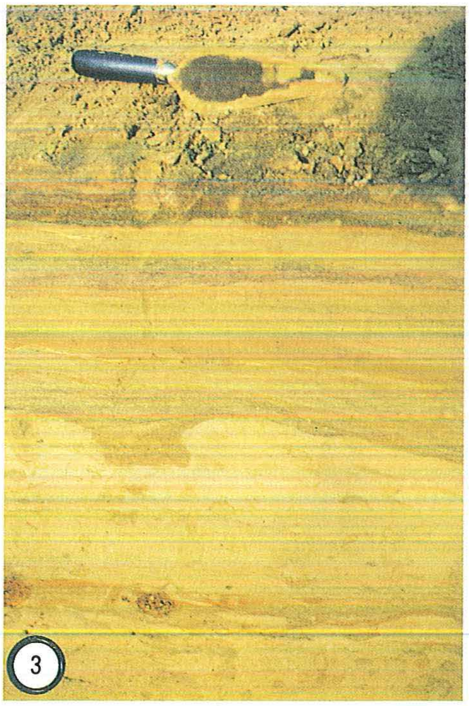
Photo 5 - Balegem sandpit : centimetric small scale faulting affecting the boundary between the Wemmel Member and the Lede Formation sands.

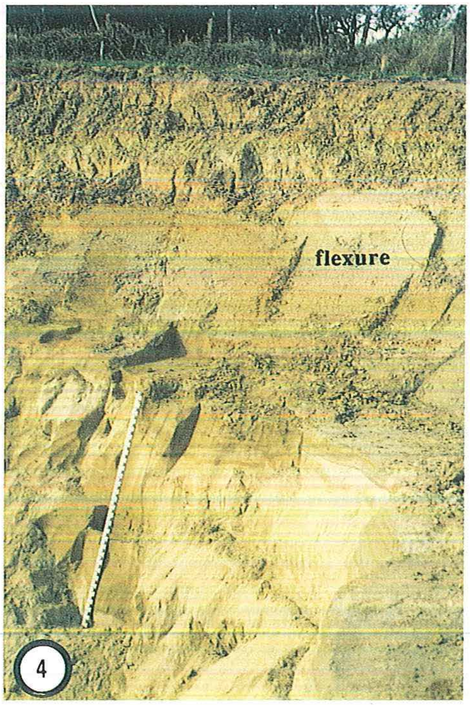
Photo 6 - Balegem sandpit : transgressive surface of the Asse Member clay parasequence on the Wemmel Member sands parasequence

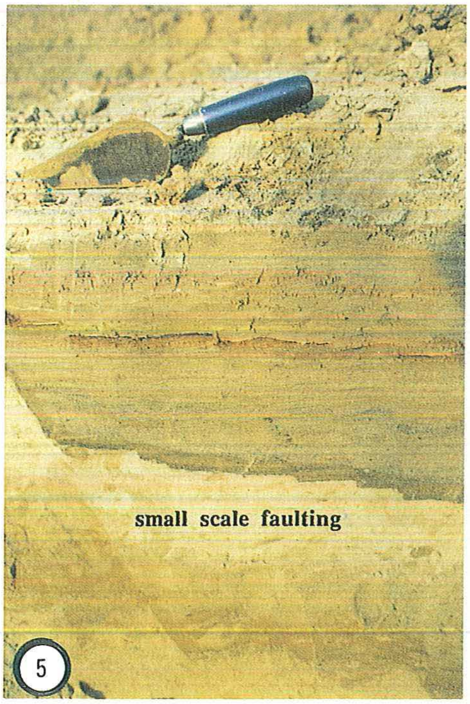
Photo 7 - Balegem sandpit: extensional normal faults with a vertical throw of 70 cm affecting the base of the Lede Formation sands and the top of the Vlierzele Member sands

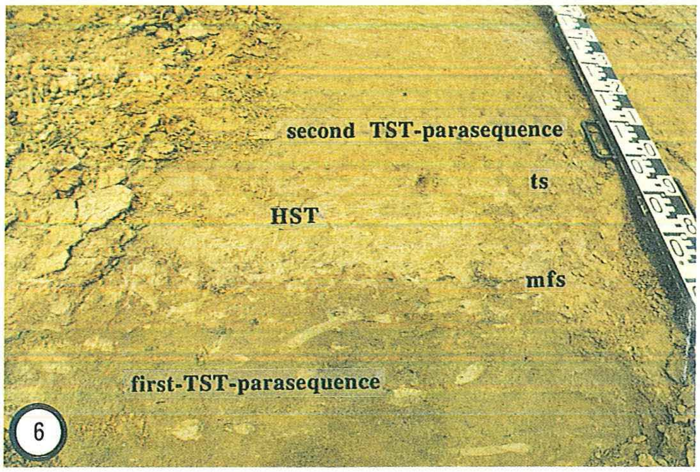

1

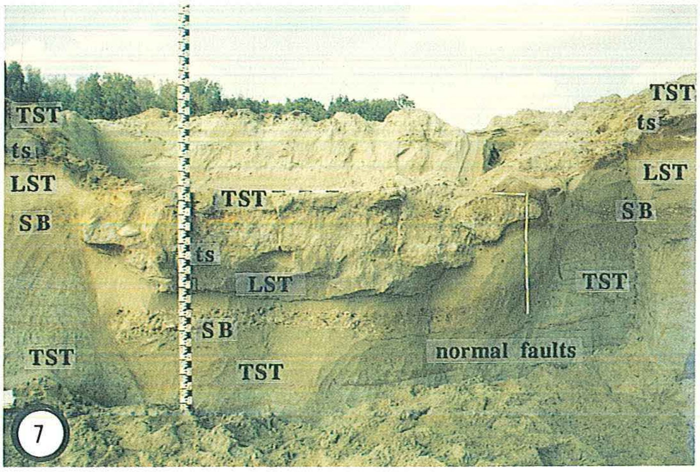

2


3


flexure
4


small scale faulting
5


second TST-parasequence
ts
HST
mfs
first-TST-parasequence
6


TST
ts
LST
SB
TST
ts
LST
SB
TST
TST
ts
LST
SB
TST
TST
normal faults
7