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DEFINITION OF THE REINBEKIAN/LANGENFELDIAN BOUNDARY AND SUBDIVISION OF YOUNGER NEOGENE STAGES IN DEEP AND SHALLOW ENVIRONMENT BY MEANS OF MOLLUSCS

by

Winfried Hinsch,
Geologisches Landesamt Schleswig-Holstein,
Kiel, F.R.G.

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In wells at Levensau (F.R.G., Schleswig-Holstein) near Kiel the Levensau substage is defined between the Lüneburg substage and the Reinbekian stage by an overlap range zone of mollusc species known before as Reinbekian or Langenfeldian index fossils, often divided by the Tostedt Member, without benthic record. The new substage could also be recognized at Hamburg-Georgswerder, Obspringen/Lower Rhine District, and in the Netherlands.

The Eidelstedt standard section can be emendated and subdivided by log correlation into four Syltian and two Gramian lithostratigraphic subunits. The Langenfeldian can be subdivided into four biostratigraphic units. These are a) Levensauian Substage with Reinbekian survivors, b) Lüneburgian Substage with *Ashtarotha*, c) Langenfeldian Substage of Serravallian age, d) Langenfeldian Substage of Tortonian age. The Levensauian/Lüneburgian boundary is correlated by logs and fauna in 160 wells in Schleswig-Holstein and statistically evaluated. An attempt is made to explain the sharp faunal break at the Levensauian/Lüneburgian boundary in shallow water.

Taxonomical notes refer to the gastropods *Hinia* (*Telasco*) *syltensis levensauensis* ssp. n. and to β-*Gemmula pluridenticulata*.

Dr W. Hinsch, Geologisches Landesamt Schleswig-Holstein, Mercatorstraße 7, 2300 Kiel, F.R.G.

Contents:

SAMENVATTING

Definitie van de grens Reinbekien/Langenfeldien en onderverdeling van jong-neogene tijdseenheden in diepe en ondiepe milieu's door middel van mollusken.

In boringen bij Levensau (Bondsrepubliek Duitsland, deelstaat Sleeswijk-Holstein) wordt de Levensau substage gedefinieerd, tussen de Lüneburg substage en het Reinbekien, door middel van een overlap range zone, gebaseerd op molluskensoorten die vroeger gebruikt werden als index-soorten voor het Reinbekien of het Langenfeldien. De zone is vaak in tweeën gedeeld door de Tostedt Member, waarin geen benthonische fossielen voorkomen. De nieuwe substage kon eveneens worden herkend in Hamburg-Georgswerder, in Obspringen (Nederrijngebied) en in Nederland.

De Eidelstedt standaardsectie kan nu worden aangepast en onderverdeeld met behulp van log-correlaties in vier Syltien en twee Gramien lithostratigrafische eenheden. Het Langenfeldien kan worden onderverdeeld in vier biostratigrafische eenheden. Dit zijn a) de Levensauian substage, met doorlopers vanuit het Reinbekien, b) de Lüneburgien substage met *Ashtarotha*, c) de Langenfeldien substage van Serravallien ouderdom, en d) de Langenfeldien substage van Tortonien ouderdom. De grens tussen het Levensauien en het Lüneburgien kon met logs en fauna worden gecorreleerd in 160 boringen in Sleeswijk-Holstein, alsmede statistisch worden geëvalueerd. Er wordt een poging gedaan om de plotselinge verandering in de ondiep-water fauna op de grens Levensauien/Lüneburgien te verklaren.

Systematische aantekeningen omvatten de beschrijving van *Hinia* (*Telasco*) *syltensis levensauensis* subsp. nov. en opmerkingen over β-*Gemmula pluridenticulata*.

GENERAL SITUATION

The stages of the Miocene in the North Sea Basin (Vierlandian, Hemmoorian, Reinbekian, Langenfeldian, Gramian and Syltian) are well-defined by molluscs used as index fossils, and their first appearances (FAD = first appearance datum) and last occurrences (LAD = last appearance datum). A summary of this biostratigraphy was given in Hinsch (1968c, d and f). The Reinbekian/Langenfeldian boundary seems to be well-defined by 40 Reinbekian and 8 Langenfeldian stage index fossils. Furthermore there is a maximum of 104 LAD's at the end of the Reinbekian and 39 FAD's at the beginning of the Langenfeldian. The sharpness of this stratigraphical boundary, however, could be effected by the paleogeographical situation. Near the Reinbekian/Langenfeldian boundary the Nordelbe Cycle reaches its maximum subsidence and in large parts of the North Sea Basin the fossiliferous beds are separated at this level by the anoxic deeper water facies of the Tostedt Member without fossil record.

Typical for the relation between verified Langenfeldian and Reinbekian, with the Tostedt biofacies in between, are the three wells specified in table 1. The synchronity of the events occurring

	Wursterheide			Uetersen			Eidelstedt		
	TK 25 Nordholz 2217			TK 25 Pinneberg 2324			TK 25 Niendorf 2325		
	depth	thickness	in %	depth	thickness	in %	depth	thickness	in %
verified Langenfeldian	168 - 256	88	73	13 - 80	67	50	145 - 236	91	49
Tostedt Mbr	256 - 282	26	22	80 - 125	45	33	236 - 269	33	18
verified Reinbekian	282 - 288.5	6.5	5	125 - 140	23	17	269 - 332	63	33
		120.5	100		135	100		187	100

Table 1. Relations between Langenfeldian, Tostedt Member and Reinbekian sediments in the wells Wursterheide, Uetersen and Eidelstedt-Nordgetränke.

between the two stages is therefore not established, but masked by the Tostedt Member biofacies. First hints for the presence of an intermediate stage between Reinbekian and Langenfeldian were a "Levensau Overlap Bereich" as mentioned by Hinsch (1986b: 3,5) and the Mol F 5 molluscan zone of Sliggers (1984). To fill this gap between Reinbekian and Langenfeldian in more marginal parts of the basin the biostratigraphy of the NW German sections of Levensau, Georgswerder and Obspringen will be dealt with.

ACKNOWLEDGEMENTS

I am grateful for cores and cuttings placed at my disposal for paleontological and stratigraphical research, from the Levensau well to Dr K. Stegman, Autobahnneubauamt, Neumünster, from the Georgswerder well to Dr G. Linke and Dr K. Wüstenhagen, Geologisches Landesamt, Hamburg, and from the Obspringen well to Dr H. Hager, Geologisches Landesamt Nordrhein-Westfalen, Krefeld.

The paleontological investigations and stratigraphical correlations were promoted by facilities and collections of the Geologisches Landesamt Schleswig-Holstein at Kiel.

The illustrations and tables were prepared by Mr H. Schneider (Geologisches Landesamt Schleswig-Holstein, Kiel) and the Rijksmuseum van Geologie en Mineralogie (Leiden).

LEVENSAU PROFILE

At the Kiel Canal near Kiel (map-sheet TK 25 Kiel 1626) five sections were cored for the construction of a new motorway bridge, that reached the Miocene clay below the Pleistocene cover. Three of these wells penetrated the Langenfeldian and ended in Reinbekian sediments. The wells are situated near the axis of the Felm Trough, between the salinary structures of Schinkel in the West and Honigsee-Schwedeneck in the East. A profile through these wells is given in fig. 1.

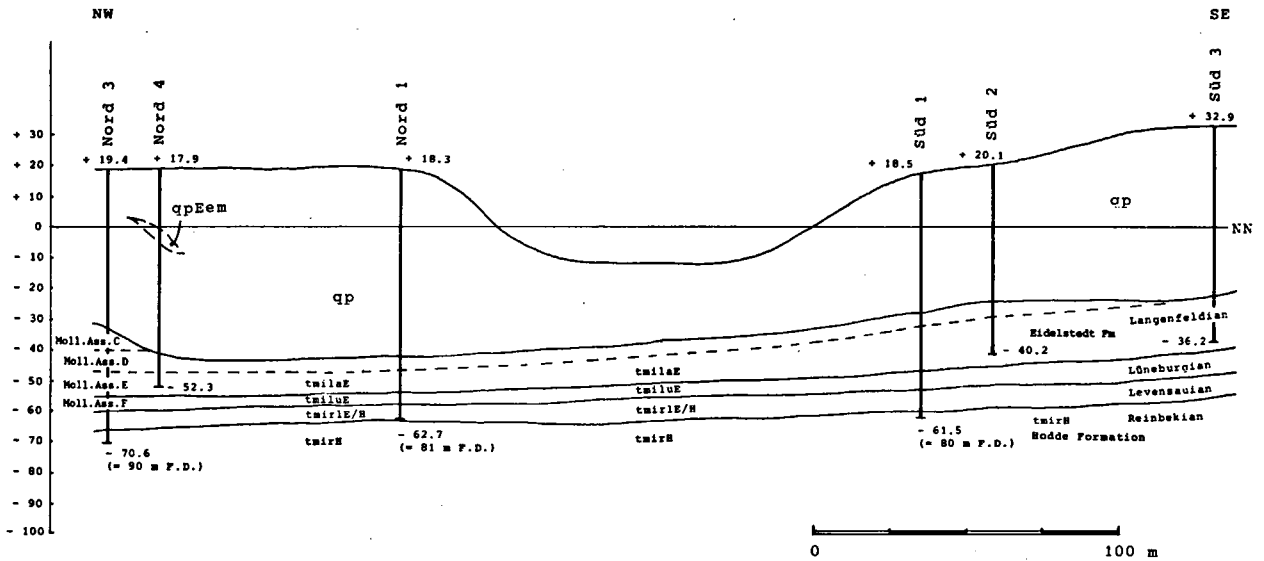


Fig. 1. Profile through six wells at the Kiel Canal near Kiel (map-sheet TK 25 Kiel 1626).

By means of the molluscan fauna the Miocene mica clay can be subdivided into the following units, listed here with the appropriate intervals:

Eidelstedt Formation with mollusc association C	(Langenfeldian substage)
Levensau Nord 3	52 - 58 m
Eidelstedt Formation with mollusc association D	(Langenfeldian substage)
Levensau Nord 3	58 - 65 m
Levensau Nord 4	59.3- 65 m
Levensau Nord 1	64 - 67 m
Levensau Süd 1	47 - 49 m
Levensau Süd 2	45 - 46 m
Eidelstedt Formation with mollusc association E	(Langenfeldian substage)
Levensau Nord 3	65 - 76 m
Levensau Nord 1	71 - 72 m
Levensau Süd 1	49 -60.5m
Eidelstedt Formation with Lüneburg substage (Ashtarotha Biozone, mollusc association D)	
Levensau Nord 3	76 - 79 m
Levensau Süd 1	64 -70.5 m
Eidelstedt Formation with Levensau substage	
Levensau Nord 3	79 - 84 m
Levensau Nord 1	75 - 81 m
Levensau Süd 1	74.5- 76 m
Hodde Formation of Reinbekian stage	
Levensau Nord 3	84 - 90 m
Levensau Süd 1	78.5- 80 m

The Miocene mollusc fauna of the Levensau sections comprises 24 bivalves, 4 scaphopods and 51 gastropods, together 79 mollusc species. This fauna is listed in table 2.

Location of the five cored sections:

Map-sheet TK 25 Kiel 1626

Levensau Nord 3	R ^{35}69 650	H ^{60}27 130	+	19.4 m NN
Levensau Nord 4	R ^{35}69 980	H ^{60}27 150	+	17.9 m NN
Levensau Nord 1	T ^{35}70 020	H ^{60}27 070	+	18.3 m NN
Levensau Süd 1	R ^{35}70 130	H ^{60}26 940	+	18.5 m NN
Levensau Süd 2	R ^{60}70 180	H ^{60}26 935	+	20.1 m NN

The youngest association C, representing the shallowest environment, was only found in Levensau Nord 3 with 3 bivalves, 2 scaphopods and 13 gastropods, together 18 mollusc species. It is an *Astarte*-clay facies, without *Cyclocardia*, but with *Lamellinucula georgiana, Astarte* (*Nicaniella*) *gleuei, Pagodula semperi, Hinia holsatica, Hinia* (*Telasco*) *syltensis* and *Aquilofusus luneburgensis*.

The mollusc association D of the Langenfeldian is the mica clay facies of normal water depth (approx. 50 m), with both *Astarte* and *Cyclocardia*, but without *Limopsis*. In the five sections a fauna of 10 bivalves, 3 scaphopods and 31 gastropods, together 44 mollusc species was encountered, comprising for example *Carinastarte vetula, Turritella tricarinata* and *Tubicauda spinicosta*.

The mollusc association E of the Langenfeldian is the *Limopsis*-biofacies of deeper water. At Levensau it has the greatest species diversity. It was found in three sections with 18 bivalves, 3 scaphopods and 39 gastropods, together 60 mollusc species.

Mollusc associations C, D and E belong to the Langenfeldian sensu stricto. The underlying Lüneburgian and Levensauian substages have a more restricted species diversity because they partly replace the anoxic Tostedt Member of the more central parts of the North Sea Basin. At Levensau, however, the benthic fauna is sufficiently rich to enable a stratigraphical subdivision.

The Lüneburgian (mollusc association F), characterized by the zone of *Astarte* (*Ashtarotha*) *anus*, was found in two sections with 5 bivalves, 1 scaphopod and 14 gastropods, together 20 mollusc species.

Below the Lüneburgian the Levensau substage, which has its type locality here, demonstrates an overlap range of index fossils known from the Langenfeldian (*Lamellinucula georgiana, Carinastarte vetula*) and Reinbekian (*Saccella westendorpi, Cyclocardia orbicularis, Fusiturris duchasteli*). A first representative of the *Hinia* (*Telasco*) *syltensis*-line is present with the new subspecies *H.* (*T.*) *syltensis levensauensis*, which is restricted to Levensauian and Lüneburgian.

The Reinbekian Hodde Formation, underlying the Levensauian deposits, was present in two sections with 6 bivalves, 1 scaphopod and 7 gastropods, together 14 mollusc species.

Fig. 2 gives the faunal distribution of the well Levensau Nord 3, the most complete section. Glauconite was found in the washing residues from 78 to 84 m (Lüneburgian and Levensauian). This is the first indication of a transgressive tendency, intensified towards the Honigsee structure, where also the Langenfeldian section has a glauconitic base. Successively the Levensauian and the Lüneburgian disappear towards the salt structure, where finally at Preetz the Langenfeldian substage is directly overlying Reinbekian or even Hemmoorian deposits.

Table 2.
Mollusc fauna of the Levensau well

	tmila Langenfeldian substage									tmilu Lüne-burgian		Levensauian			Rein-bekian	
Moll.Ass.	C	D					E			F		tmirl			tmir	
	N 3	N 3	N 4	N 1	S 1	S 2	N 3	N 1	S 1	N 3	S 1	N 3	N 1	S 1	N 3	S 1
Ditrupa sp.		x	x				x		x							
Lamellinucula georgiana (Semper)	x	x		x		x	x		x	x	x	x	x			
Saccella westendorpi (Nyst)												x			x	
Yoldiella pygmaea (von Münster)		x		x		x	x		x	x			x		x	
Yoldia glaberrima (von Münster)	x	x	x		x	x	x	x	x					x	x	
Anadara sp.		x														
Limopsis aurita (Brocchi)							x	x	x				x	x		
Pectunculina sp.				x												
Korobkovia sp.									x							
Peplum clavatum (Poli)							x									
Palliolum tigerinum (Müller)							x		x							
Astarte (A.) goldfussi Hinsch															x	
Astarte (Nicaniella) gleuei Wolleman	x	x	x		x	x	x		x							
Astarte (Nicaniella) radiata Nyst & Westendorp																x
Astarte (Carinastarte) vetula Philippi				x			x	x			x	x				
Astarte (Ashtarotha) anus Philippi										x	x					
Cyclocardia cf *tuberculata* (von Münster)		x	x	x	x	x	x	x		x	x					
Cyclocardia orbicularis (Sowerby)												x	x	x	x	
Spaniodontella nitida (Reuss)							x									
Thyasira hanseata (Kautsky)					x		x									
Parvicardium straeleni (Glibert)							x		x							
Abra sp.							x		x				x			
Hiatella sp.									x							
Varicorbula gibba (Olivi)									x							
Thracia sp.					x		x									
Pandora sp.							x									
Dentalium cf *"badense" = floratum* Zimmermann	x	x	x	x	x	x	x	x	x	x			x	x		
Dentalium cf *"dollfusi"* auct.												x			x	x
Siphonodentalium sp.	x	x	x		x		x		x							
Laevidentalium sp.		x					x		x							
Turritella tricarinata (Brocchi)		x	x	x	x	x	x		x							
Torculoidella sp.															x	x
Eulima glabra (da Costa)		x		x												
Balcis sp.							x									
Capulus hungaricus regularis (Wood)												x				
Xenophora sp.							x									
Aporrhais alata (von Eichwald)						x										
Euspira helicina (Brocchi)	x	x	x		x	x	x		x	x					x	
Semicassis miolaevigata (Sacco)		x					x									
Ficus conditus (Brongniart)		x														
Pagodula semperi (von Koenen)	x						x		x	x						
Murex (Tubicauda) spinicosta Bronn		x	x													
Lyrotyphis (Eotyphis) sejunctus (Semper)		x	x				x		x							
Amyclina facki (von Koenen)			x				x		x							
Hinia (Hinia) holsatica (Beyrich)	x	x	x		x	x	x		x		x				x	
Hinia (Telasco) syltensis syltensis (Beyrich)	x	x	x		x		x		x							
Hinia (T.) syltensis levensauensis n.ssp.										x		x				
Miohinia sp.						x										
Sipho gregarius distinctus (Beyrich)					x		x				x					
Aquilofusus luneburgensis (Philippi)	x	x	x	x		x	x		x							
Aquilofusus puggaardi (Beyrich)							x									
Pseudolatirus rothi (Beyrich)							x		x							
Sveltia lyrata (Brocchi)							x		x							
Calcarata calcarata (Brocchi)							x									
Babulonella fusiformis (Cantraine)	x	x				x	x		x							
Gemmula pluridenticulata (Kautsky)	x	x	x	x	x	x	x		x	x	x					
Gemmula zimmermanni (Philippi)							x		x	x			x		x	
Gemmula boreoturricula "annae" (H. & A.)		x	x		x		x									
Fusiturris duchasteli (Nyst)													x			
Fusiturris helena (Semper)		x														
Bathytoma jugleri (Philippi)		x		x		x	x	x	x	x					x	
Acamptogenotia straeleni Glibert							x	x			x					
Spirotropis modiola (Jan)	x	x	x						x							
Brachytoma obtusangula (Brocchi)	x	x	x		x	x	x		x	x						
Microdrillia serratula (Bellardi)		x					x									
Oenopota kochi (von Koenen)	x	x					x		x							
Neoguraleus tenella (Mayer)							x									
Glyphostoma luisae (Semper)	x	x	x			x	x		x							
Philbertia cordieri (Payraudeau)			x													
Conolithus antediluvianus (Bruguière)	x	x	x		x	x	x					x				
Leucotina nordmanni Sorgenfrei									x							
Megastomia conoidea (Brocchi)	x															
Mormula koeneniana (Sacco)		x					x		x	x						
Pyrgolampros pseudoterebralis (Sacco)									x							
Pyramidella plicosa Bronn							x		x							
Ringicula buccinea (Brocchi)		x	x		x	x	x		x							x
Cylichna subcylindrica (d'Orbigny)							x									
Cylichnina elongata (von Eichwald)							x									
Limacina valvatina (Reuss)				x	x										x	
Limacina gramensis (Rasmussen)							x		x		x					
Limacina sp.						x	x		x	x	x			x		

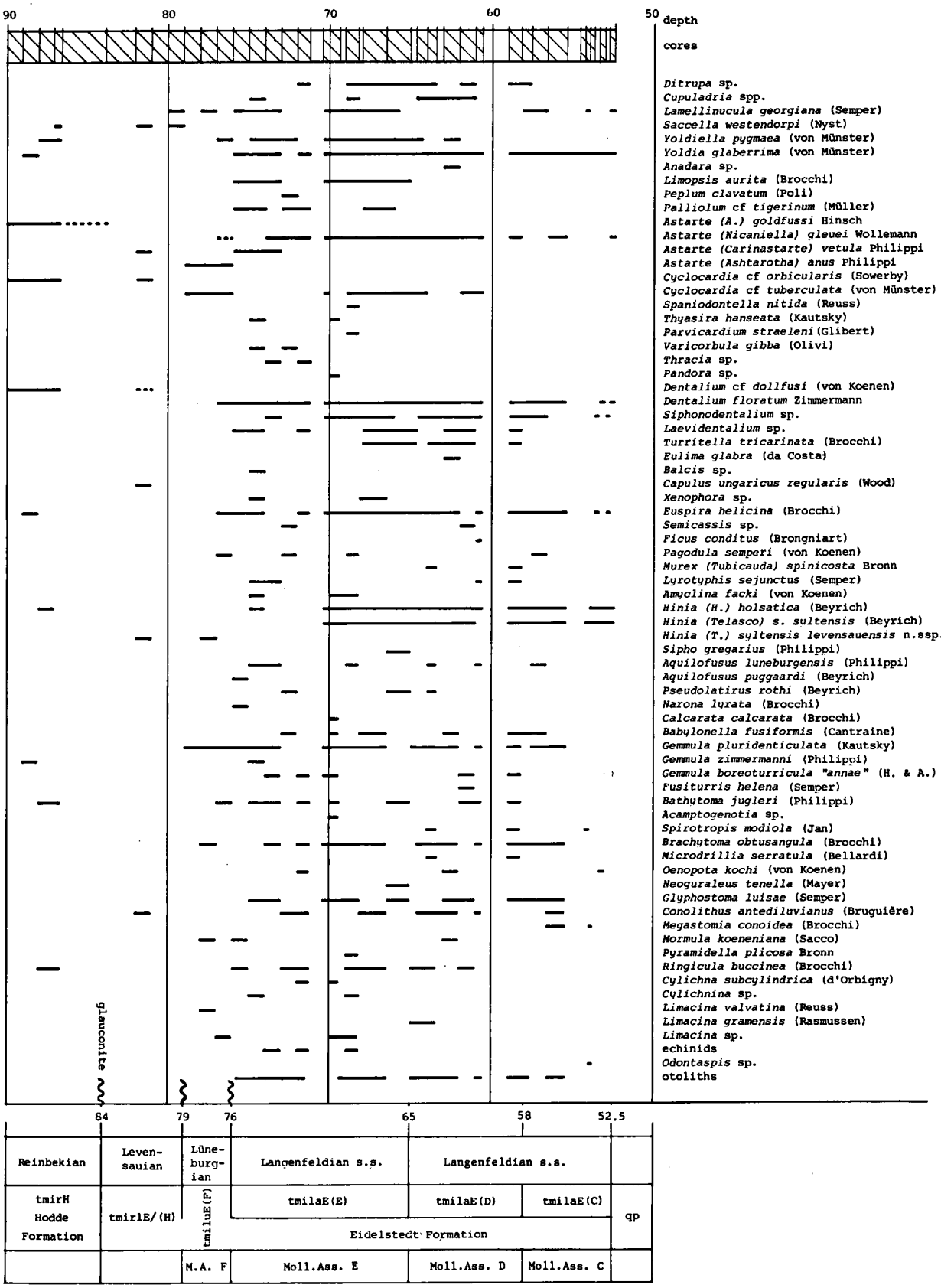


Fig. 2. Faunal distribution in the well Levensau Nord 3 (map-sheet TK 25 Kiel 1626).

PROFILE GEORGSWERDER

In the Hamburg Supertrough (Hinsch, 1986e) verified Reinbekian sediments are separated from Langenfeldian deposits by the Tostedt Member, without benthic record. At the rim of the Hamburg Supertrough, however, a section was cored at Georgswerder, Fiskalische Straße (map-sheet TK 25 Wandsbek 2426, R ^{35}68 095 H ^{59}31 939, + 1.3 m NN), in which Lüneburgian and Levensauian could be recognized. The mollusc fauna is less diverse, compared with Levensau, and in the section mica clay with benthic fauna is alternating with non-fossiliferous facies of the Tostedt Member. Nevertheless the fauna is still sufficient for a biostratigraphical subdivision. The Late Reinbekian and Early Langenfeldian faunas comprise 15 bivalves, 3 scaphopods and 10 gastropods, together 28 mollusc species. The section can be subdivided into five biostratigraphical units within the Langenfeldian and upper Reinbekian sediments:

Langenfeldian with mollusc association D	20.0-21.5 m
Langenfeldian with mollusc association E	21.5-29.0 m
Lüneburgian	29.0-34.0 m
Levensauian	34.0-40.0 m
Reinbekian, Hodde Formation	40.0-76.5 m

Table 3 shows the distribution of the mollusc species within these units.

	Langenfeldian		Lüne-	Leven-	late
	Moll. Ass.D	Moll. Ass.E	burgian	sauian	Rein- bekian
Nucula sp.					x
Lamellinucula georgiana (Semper)	x	x		x	
Yoldiella pygmaea (von Münster)		x			x
Yoldia glaberrima (von Münster)	x	x			x
Limopsis aurita (Brocchi)		x			x
Pectunculina lamellata (Lehmann)					x
Astarte (Ashtarotha) anus Philippi			x		
Astarte goldfussi Hinsch				x	
Astarte (Nicaniella) gleuei Wollemann	x	x			
Cyclocardia cf *tuberculata* (von Münster)	x	x	x		
Cyclocardia orbicularis (Sowerby)				x	x
Parvicardium straeleni (Glibert)		x			x
Ventricoloidea sp.					x
Thracia sp.					x
Cuspidaria cuspidata (Olivi)		x			
Dentalium floratum Zimmermann		x			
Dentalium cf "*dollfusi*" (von Koenen)				x	x
Laevidentalium sp.		x			x
Turritella tricarinata (Brocchi)	x	x			
Aporrhais alata (von Eichwald)					x
Euspira sp.		x			
Lyrotyphis sp.		x			
Hinia (Telasco) syltensis levensauensis n.ssp.				x	
Bathytoma sp.	x				
Ringicula sp.		x			
Limacina valvatina (Reuss)		x		x	x
Limacina gramensis (Rasmussen)		x			
Limacina sp.	x	x			

Table 3. Distribution of mollusc species in the borehole Georgswerder (Fiskalische Strasse).

The mollusc association D has 4 bivalves and 3 gastropods (together 7 mollusc species), among which *Astarte* (*Nicaniella*) and *Cyclocardia*. The most diverse fauna is again observed in the *Limopsis*-facies of mollusc association E with 7 bivalves, 1 scaphopod and 9 gastropods. The Lüneburgian is very poor in species, yielding only *Ashtarotha* and *Cyclocardia*. In the Levensauian 3 bivalves, 1 scaphopod and 2 gastropods were found. It shows the overlap of the Langenfeldian species *Lamellinucula georgiana* with the Reinbekian species *Astarte goldfussi, Cyclocardia orbicularis* and *Dentalium* cf *dollfusi*, and the occurrence of *Hinia* (*Telasco*) *syltensis levensauensis*. The Reinbekian Hodde Formation is interrupted by a Tostedt Member from 51.5-57.0 m and thus subdivided into an Upper and Lower Hodde Formation, yielding 9 bivalves, 1 scaphopod and 3 gastropods, together 13 mollusc species.

Underlying the Reinbekian Hodde Formation are more sandy, fossiliferous beds, of which no cored samples are available. They belong to the early Reinbekian Katzheide Member (76.5-82.0 m) and the Hemmoorian (late Oxlundian) *Lembulus*-Katzheide Member (82.0-88.0 m), together with 20 bivalves, 2 scaphopods and 23 gastropods = 45 mollusc species. In between the Katzheide and Trittau Members brachyhaline beds are present belonging to the Oxlundian Itzstedt Member, containing *Ervilia* and *Lentidium* (88.0-91.0 m), with 20 bivalves, 3 scaphopods and 17 gastropods.

In fig. 3 the distribution of the mollusc fauna near the Langenfeldian/Reinbekian boundary is given, together with the gamma-ray log for the complete marine Miocene section. It is possible to correlate this log to other cored sections in the harbour of Hamburg, as well as with the proposed neotype-section of the Langenfeldian, well Eidelstedt-Nordgetränke (Hinsch, 1986d: 368-369). This well was not cored, but drilled by air lifting. This profile needs some emendation, as a) some caving is not impossible, and b) the barren interval between Langenfeldian and Reinbekian has to be filled in by means of a section with verified (fossiliferous) Lüneburgian and Levensauian deposits.

EMENDATION OF EIDELSTEDT SECTION AND SUBDIVISION OF STAGES

The Eidelstedt section, changed by the results of the well Georgswerder (Fiskalische Straße) and correlated by gamma-ray log, should now run as follows (fig. 7):

0- 50	m	Pleistocene deposits	
----------		hiatus	
- 80.5	m	Oldesloe Formation, Pliocene	
-125	m	Syltian I-IV (Pinneberg Member, without fauna	
-145	m	Gramian I-II (Winnert Member to 130 m, Pinneberg Member to 145 m)	
-155	m	Pinneberg Member of Langenfeldian	Tortonian N 14
-162	m	mollusc association C Pinneberg/Eidelstedt	Tortonian N 14
-214	m	mollusc association D	Langenfeldian substage (Serravallian N 16 + ?N15)
-234	m	mollusc association E	(Eidelstedt Formation)
-252.5	m	Lüneburgian substage	Eidelstedt Formation
-252.5	m	Levensauian substage	Eidelstedt Formation
-323	m	Reinbekian Hodde Formation	
-332	m	Reinbekian Katzheide Member	
-340	m	equivalent of Oxlundian Itzstedt Member	
below		Trittau Formation (Oxlundian)	

The interpretation of the older parts of this section (Reinbekian to Eidelstedt Formation) was realized by means of correlation with the Georgswerder well. The younger parts (younger Langen-

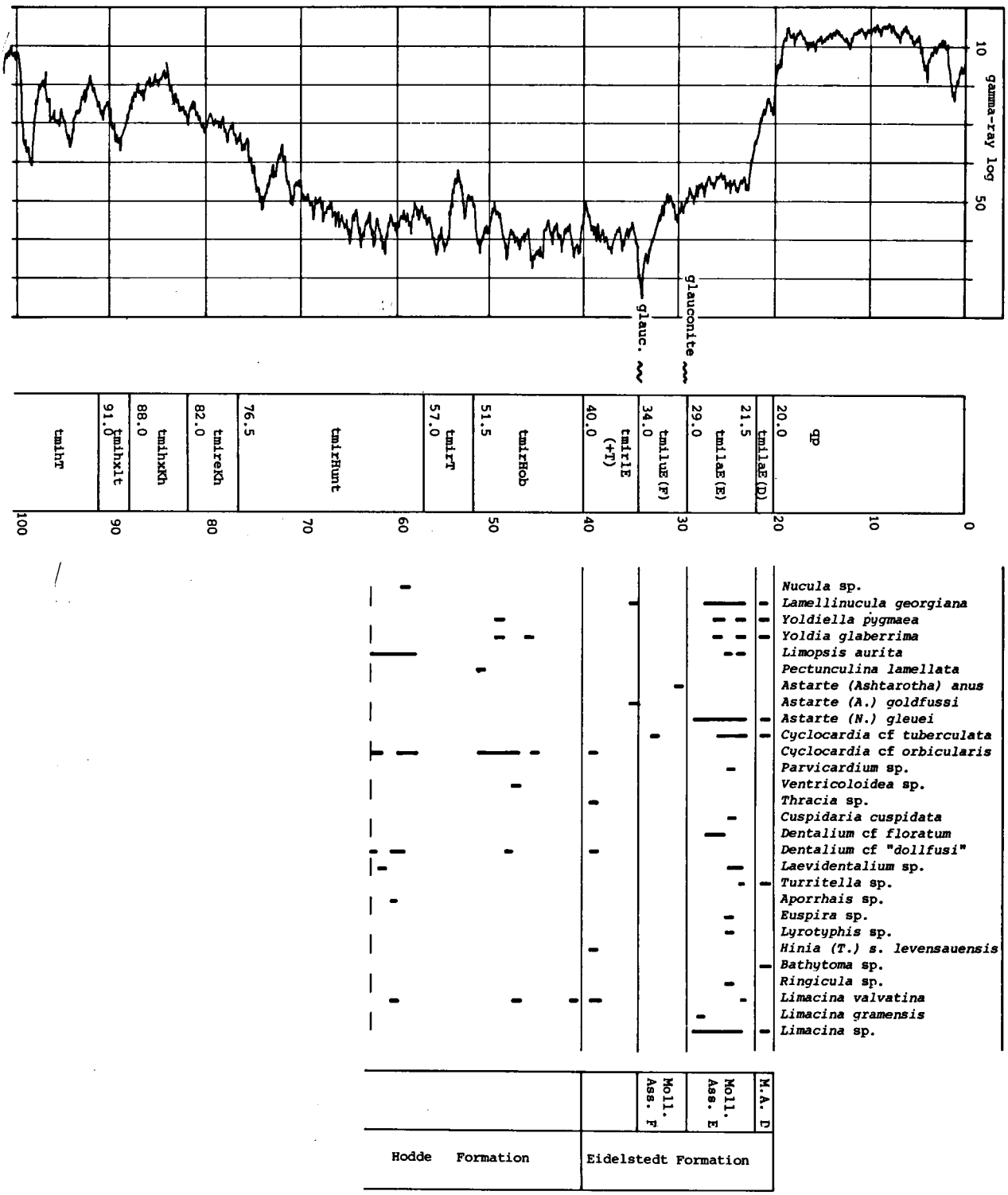


Fig. 3. Distribution of mollusc species in the Eidelstedt and Hodde formations of well Georgswerder, Fiskalische Straße (map-sheet TK 25 Wandsbek 2426).

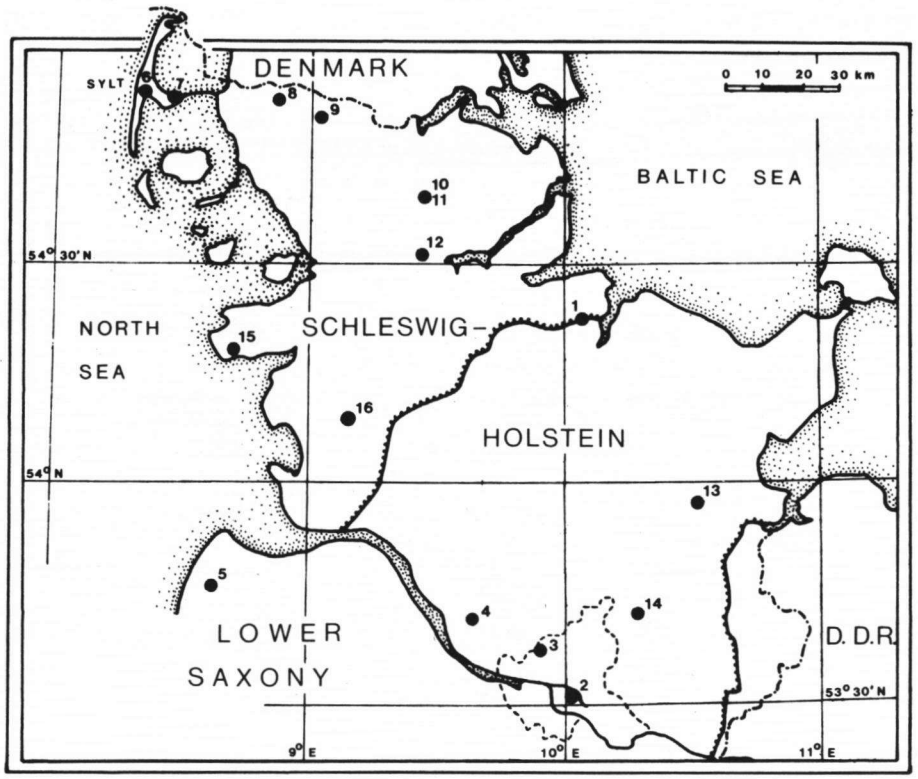


Fig. 4. Location of sections discussed in this paper.
1 = Levensau; 2 = Georgswerder; 3 = Eidelstedt; 4 = Uetersen; 5 = Wursterheide; 6 = Westerland; 7 = Morsum Cliff; 8 = Humptrup; 9 = Ladelund; 10 = Nordhöhe; 11 = Süderschmedeby; 12 = Norderschubyfeld; 13 = Rösing; 14 = Delingsdorf; 15 = Garding 1; 16 = Odderade.

feldian, Gramian, Syltian and Pliocene) can be correlated (fig. 4) with the wells Norderschubyfeld (map-sheet TK 25 Jübek 1422), Nordhöhe and Süderschmedeby (TK 25 Eggebek 1322), Ladelund (TK 25 Ladelund 1120), Humptrup (TK 25 Süderlügum 1119) and Westerland (TK 25 Rantum 1115).

The three younger stages of the Miocene may be subdivided in the following way:

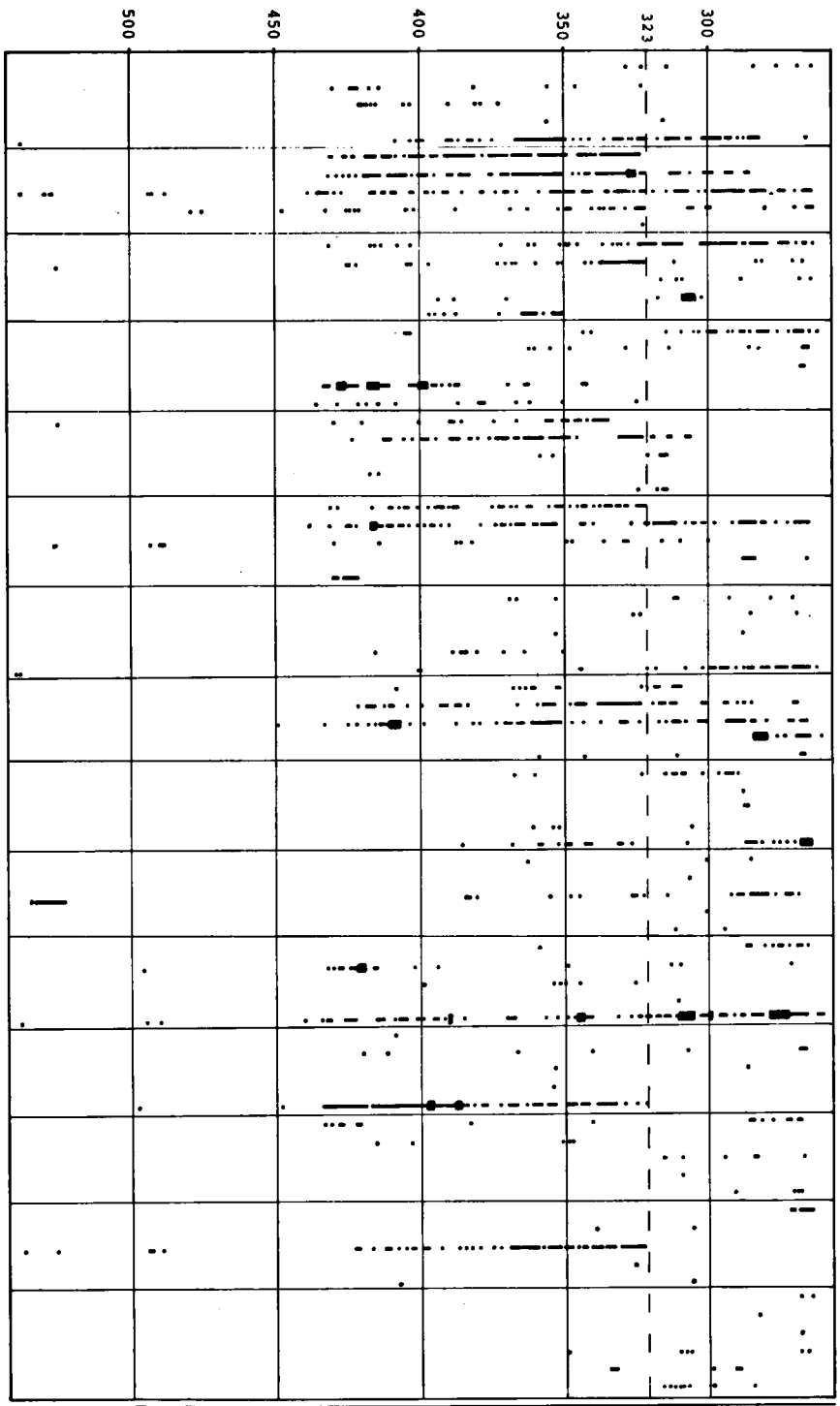
Syltian

A sufficient faunal content was only found on the Isle of Sylt, in Garding trough/Eiderstedt, at Odderade/Dithmarschen, Wursterheide and in the Netherlands. At Sylt (Morsum Cliff and Westerland) the Syltian can be subdivided into Upper Mica Sand = Syltian IV, Upper Mica Clay = Syltian III, Lower Mica Sand (with *Aporrhais* and *Ditrupa* beds) = Syltian II, and Lower Mica Clay = Syltian I.

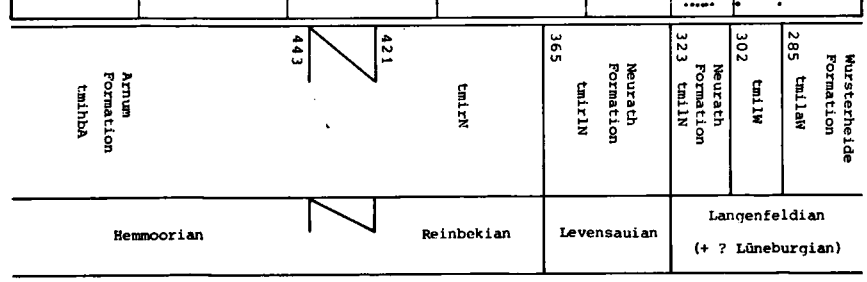
These units can be correlated via Norderschubyfeld to the Eidelstedt section, where the equivalents are:

80.5-	86 m	Syltian IV
86 -	93 m	Syltian III
93 -	111 m	Syltian II
111 -	125 m	Syltian I.

Fig. 5a



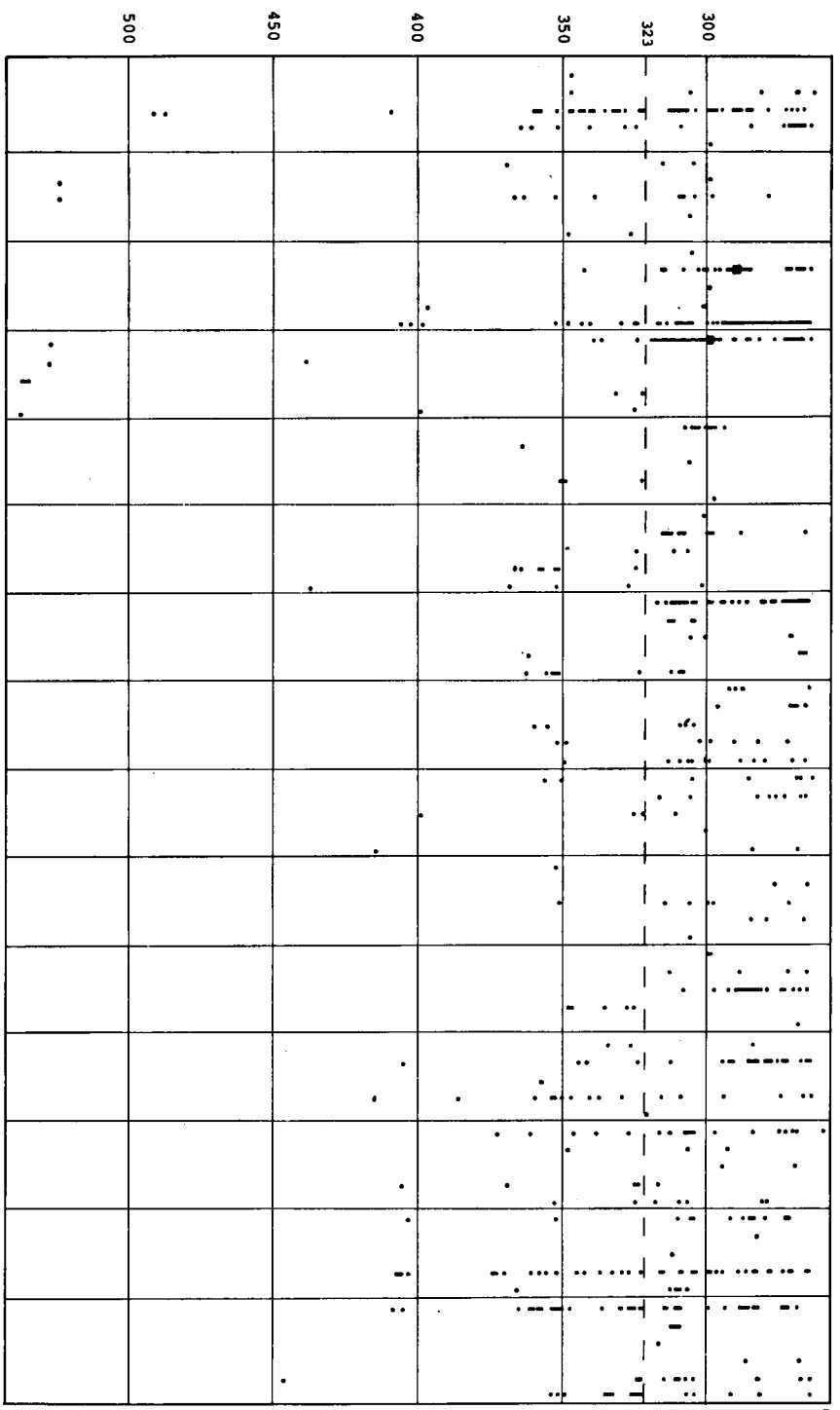
Leionucula laevigata (Sowerby)
Leionucula haesendoncki (Nyst)
Leionucula sp.
Nucula nucleus (Linné)
Lamellinucula georgiana (Semper)
Saccella westendorpi (Nyst)
Yoldiella pygmaea (von Münster)
Yoldia glaberrima (von Münster)
Anadara diluvii (Lamarck)
Bathyarca pectunculoides (Scacchi)
Glycymeris obovata baldii (Gl. & v.d.P.)
Pectunculina retifera (Semper)
Modiolula phaseolina (Philippi)
Pteria phalenacea (Lamarck)
Korobkovia woodi (Nyst)
Aequipecten seniensis (Lamarck)
Palliolum cf *lilli* (Pusch)
Ostrea sp.
Astarte goldfussi Hinsch
A. gracilis convexior Anderson
A. (Nicaniella) radiata Nyst & Westend.
A. (Nicaniella) waeli Glibert
A. (Ashtarotha(omalii peelensis Spaink
Digitaria beyschlagi (Kautsky)
Goodallia angulata (Lehmann)
Cyclocardia orbicularis (Sowerby)
Lucinoma borealis (Linné)
Gonimyrtea droueti (Nyst)
Loripinus fragilis (Philippi)
Lucinella sp.
Scacchia degrangei (Cossm. & Peyrot)
Lepton transversarium Cossmann
Properucina edlaueri (Kautsky)
Habecardium subturgidum (d'Orbigny)
Acanthocardia hanseata (Kautsky)
Parvicardium scabrum (Philippi)
Parvicardium straeleni (Glibert)
Spisula subtruncata (da Costa)
Ervilia pusilla (Philippi)
Moerella donacina (Linné)
Peronaea fallax (Lehmann
Donax sp.
Abra antwerpiensis Glibert
Abra berchemensis van der Mark
Spaniodontella nitida (Reuss)
Glossus sp.
Arctica sp.
Gouldia minima (Montagu)
Timoclea ovata (Pennant)
Dosinia sp.
Pitar rudis (Poli)
Ventricoloidea multilamella (Lamarck)
Cordiopsis sp.
Panope sp.
Varicorbula gibba (Olivi)
Sphenia pusilla (Sorgenfrei)
Thracia sp.
Pandora sp.
Cuspidaria cuspidata (Olivi)
Dentalium "dollfusi" auct.
Laevidentalium sp.
Ampullotrochus sp.
Circulus striatus (Philippi)
Circulus praecedens gliberti Janssen
Cingula inusitata (Beets)
Turritella tricarinata (Brocchi)
Torculoidella subangulata (Brocchi)
Haustator eryna (d'Orbigny)
Bittium spina (Hörnes)
Bittium tenuispina Sorgenfrei
Semibittium duvergieri (Cossm. & Peyr.)
Cerithiella sp.
Acirsa sp.
Spiniscala weversi (Nyst)
Balcis alba (da Costa)
Eulima glabra (da Costa)



■ abundant

Well Obspringen
TK 50 Heinsberg
R 25 00 887
H 56 59 770
+ 47 m NN

Fig. 5b


500
450
400
350
323
300
Calyptraea chinensis (Linné)
Xenophora deshayesi (Michelotti)
Euspira helicina (Brocchi)
Neverita olla (des Serres)
Natica tigrina Defrance
Semicassis miolaevigata (Sacco)
Ficus simplex (Beyrich)
Ficus conditus (Brongniart)
Tubicauda spinicosta (Bronn)
Typhis pungens (Solander)
Lyrotyphis sejunctus (Semper)
Macrurella nassoides (Grateloup)
Amyclina facki (von Koenen)
Miohinia bocholtensis (Beyrich)
Uzita prysmatica (Brocchi)
Telasco holsatica (Beyrich)
Hinia sp.
Miohinia schlotheimi (Beyrich)
Tritonella serraticosta (Bronn)
Tritonella tenuistriata (Beyrich)
Tritonella woodwardi (Harmer)
Aquilofusus beyrichi (Nyst)
Bivetiella cancellata (Lamarck)
Sveltia varicosa (Brocchi)
Calcarata calcarata (Brocchi)
Ventrilia sp.
Babylonella fusiformis (Cantraine)
Acamptogenotia escheri (Mayer)
Gemmula stoffelsi (Nyst)
Gemmula boreoturricula (Kautsky)
Fusiturris helena (Semper)
Fusiturris aquensis (Grateloup)
Bathytoma jugleri (Philippi)
Crassispira borealis (Kautsky)
Brachytoma obtusangula (Brocchi)
Brachytoma pannoides (von Koenen)
Asthenotoma ravni Rasmussen
Asthenotoma pannus (de Basterot)
Mangelia miorugulosa Kautsky
Mangelia calais (Kautsky)
Oenopota kochi (von Koenen)
Neoguraleus tenella (Mayer)
Neoguraleus sorgenfreii (Nordsieck)
Neoguraleus plicatelloides (Nordsieck)
Glyphostoma simplex (Sorgenfrei)
Nannodiella hannoverana (Kautsky)
Pleurotomella mioweberi (Nordsieck)
Teretia anceps (von Eichwald)
Conolithus antediluvianus (Bruguière)
Conolithus dujardini (Deshayes)
Strioterebrum hoernesi (Beyrich)
Terebra sp.
Parthenina semireticulata (Sorgenfrei)
Parthenina cimbrica (Kautsky)
Kleinella nordmanni Sorgenfrei
Pyrgulina pygmaea (Grateloup)
Megastomia conoidea (Brocchi)
Odostomia sp.
Syrnola hoernesi (von Koenen)
Eulimella acicula (Nyst)
Pyramidella plicosa Bronn
Mormula koeneniana (Sacco)
Pyrgolampros undulatus (von Koenen)
Pyrgolampros pseudoterebralis (Sacco)
Turbonilla gastaldii auct.
Actaeon semistriatus (de Férussac)
Crenilabium terebelloides (Philippi)
Tornatina bellardii (von Koenen)
Ringicula buccinea (Brocchi)
Acteocina lajonkaireana okeni (Eichw.)
Cylichna subcylindrica (d'Orbigny)
Roxania utriculus (Brocchi)
Scaphander grateloupi (Michelotti)
Coelophysis truncatula (Bruguière)
Cylichnina elongata (von Eichwald)
Rhizorus acuminatus (Bruguière)
443
421
365
323
302
285
Arnum Formation
tmihbA
tmirN
Neurath Formation
tmirlN
Neurath Formation
tmilN
tmilW
Wursterheide Formation
tmilaW
Hemmoorian
Reinbekian
Levensauian
Langenfeldian
(+ ? Lüneburgian)
■ abundant
Well Obspringen
TK 50 Heinsberg
R 25 00 887
H 56 59 770
+ 47 m NN

Gramian

In the Westerland and Humptrup wells it could be proven that the Saed Member (Rasmussen, 1958), with *Tritonella slieswicia, Carinastarte reimersi* and *Gemmula pluridenticulata*, is of Gramian age, underlying the early Syltian (Syltian I). Therefore the Gramian can be subdivided into the upper, more sandy Saed Member and the lower mica clay of the Gram Formation. The correlated equivalents in the Eidelstedt section are:

- 132.5 m Saed Member equivalent (Winnert Member/Pinneberg Member)
- 145 m Gram Formation equivalent (Pinneberg Member)

Langenfeldian s. lat (= Langenfeldian s.s. + Lüneburgian + Levensauian)

The Langenfeldian can be subdivided biostratigraphically into four units (fig. 7):

— the uppermost Langenfeldian substage, with *Cardita laevicosta* (= Mol F 3 of Sliggers), with planktonic foraminifer zone N 16 (identified by Spiegler), therefore of Tortonian age (Mediterranean scale); lithostratigraphically indicated as Pinneberg Member in the eastern part of Schleswig-Holstein (145-162 m at Eidelstedt-Nordgetränke).
— Langenfeldian substage of Serravallian age (Mediterranean scale), with zone N 14 (+ ?15) (identified by Spiegler), usually mica clay of the Eidelstedt Formation (except along the southern coast, where a brachyhaline biofacies occurs in the Wursterheide Formation), with various mollusc associations, viz. (B), C: 162-214 m, and *Limopsis*-biofacies D: 214-234 m at Eidelstedt. This is the zone Mol F 4a in the Netherlands).
— Lüneburg substage (234-252.5 m, correlated with Tostedt Member at Eidelstedt) (probably zone Mol F 4b in the Netherlands).
— Levensau substage (252.5-262.5 m, correlated with Tostedt Member at Eidelstedt) (= zone Mol F 5 in the Netherlands).

OBSPRINGEN/LOWER RHINE DISTRICT

A facies development different from that in the central and eastern part of the basin is observed along the southern coast of the North Sea Basin. On the other hand similarities can be detected between Wursterheide (map-sheet TK 25 Nordholz 2217) (see Hinsch, 1986a) and the well Obspringen in the Lower Rhine District (TK 50 Heinsberg, R ^{35}00 887 H ^{56}59 770, + 47 m NN), as for example the start of brachyhaline Wursterheide Formation within the Langenfeldian, by fluviatile influences from the South. The Obspringen well was drilled with the air lift method.

The mollusc fauna in the near-shore facies of Obspringen is much more diverse than in the mica clays of Levensau and Georgswerder. Between 260 and 540 m 58 bivalves, 2 scaphopods and 90 gastropods, together 150 mollusc species were found at Obspringen. The distribution of these species in the section is given in fig. 5.

Fig. 5a and 5b (see p. 136 and 137). Distribution of mollusc species in the well Obspringen, Lower Rhine District (TK 50 Heinsberg).

The upper part of the Langenfeldian has a more or less brachyhaline facies with *Ervilia* from 260 to 285 m. Below the *Ervilia* horizon the Langenfeldian is only slightly brachyhaline to about 300 m depth, with *Acanthocardia* and some acmes of *Varicorbula*. These beds can be placed into the Wursterheide Formation. The lower part of the Langenfeldian, including the indistinguishable Lüneburgian, is developed in euhaline facies (Neurath Sands, Neurath Formation), containing e.g. *Lamellinucula georgiana, Ashtarotha omalii peelensis* and *Fusiturris helena*. A very sharp faunal break is observed at Obspringen at a depth of 323 m, which is the boundary between the Langenfeldian (+ Lüneburgian) and Levensauian. There is only one FAD (*Fusiturris helena*), but several LAD's of species, most of which were very common before, like *Leionucula haesendoncki, Saccella westendorpi, Astarte goldfussi, Haustator eryna* and *Gemmula stoffelsi*. Each of these forms was common between 323 and 365 m, where they occurred together with *Lamellinucula georgiana, Ashtarotha omalii peelensis* and *Hinia* (*Uzita*) *prysmatica*. For this reason the beds between 323 and 365 m were placed into the Levensauian, or zone Mol F 5 of Sliggers. Quite surprising is the survival of *Haustator eryna*, elsewhere disappearing at the end of the Oxlundian. Apparently the shallow water environment near the southern coast of the basin enabled this gastropod to survive until the end of the Levensauian/zone Mol F 5. The abrupt extinction datum at 323 m cannot be explained by lithological characteristics, there are no indications of a transgression. A special event must have caused the disappearance of the cited species that were common before. This might have been the assumed passage of the asteroid "Nemesis" 14 Ma ago, with its showers of meteorite dust (Whitmire & Jackson, 1984).

Below the Levensauian sediments of Reinbekian age are present to 420/440 m, overlying Hemmoorian limnic/terrestric deposits with some marine intercalations.

CORRELATION OF LEVENSAUIAN/LÜNEBURGIAN BOUNDARY

The extremely sharp boundary between the Levensauian and the Langenfeldian (+ Lüneburgian) allowed a correlation of early Lüneburgian and Levensauian sections of 160 wells in Schleswig-Holstein, of which logs were available.

The early Lüneburgian, with conspicuous gamma-ray peaks, ranges in thickness from 0 m, at places where it was transgressively removed, to a maximum of 32 m (well Garding 1). The mean thickness is 4.9 m, most frequent is 4 m. The number of gamma-ray peaks is between 0 and 3, with following frequencies:

number of gamma-ray peaks	number of wells	percentage
0	1	0.7
1	30	18.8
2	97	60.5
3	32	20.0
	160	100.0

These countings are somewhat subjective, depending on the logs. The most striking peaks, exceeding the general gamma level, were observed in those cases where two peaks were observed. A good example is the log of well Delingsdorf Gh 46 (fig. 6).

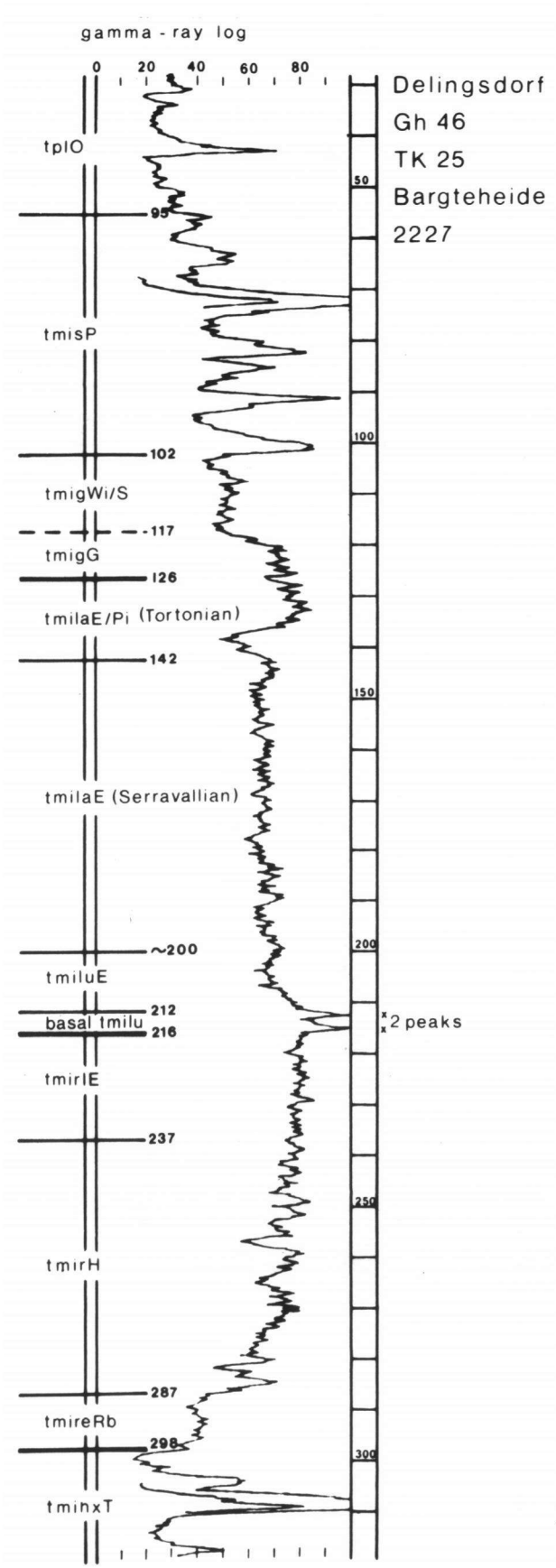


Fig. 6. Gamma-ray log of the well Delingsdorf Gh 46 (TK 25 Bargteheide 2227).

The overlap zone of the Levensauian has thicknesses ranging from 0 to 62 m (Garding 1). The mean thickness is 11.1 m, most frequent is a thickness of 5 m. Paleontological reports from these beds are available for 125 wells. A statistical review of the paleontological data for the Levensauian intervals, as correlated by means of the gamma-ray logs, supplied the following datings:

dating by means of fauna	number of wells	percentage	
Langenfeldian	55	44.0	caving possible
Lüneburgian	12	9.6	
only Tostedt Member	19	15.2	
Levensauian transgressively removed	10	8.0	
Reinbekian or Levensauian	29	23.2	
	125	100.0	

These data clearly demonstrate that the Levensau substage cannot be proved in those wells of which only cuttings are available. Cored sections are necessary to establish the presence of Levensauian deposits in marginal basin positions.

Among the 29 wells (23.2%) in Schleswig-Holstein, indicated above as "Reinbekian or Levensauian" the following species were present, indicating a Levensauian substage:

Saccella westendorpi	3 ×	Quickborn, Steinhorst, Dwerkaten
Pectunculina lamellata	3 ×	Klanxbüll, Vosshöhlen
Astarte goldfussi	5 ×	
Cyclocardia orbicularis	14 ×	
Dentalium cf *dollfusi*	9 ×	
Torculoidella subangulata	1 ×	
Miohinia cf *bocholtensis*	9 ×	
Hinia (Telasco) syltensis levensauensis	2 ×	(Rösing, Georgswerder)
Fusiturris duchasteli	4 ×	
Splendrillia selenkae	1 ×	(Schmachthagen)

The FAD of Langenfeldian index fossils is not synchronous with the disappearance of some warm water species of Reinbekian age. Therefore a Levensau substage has to be separated below the Lüneburgian for the overlap range of these species. Equivalents of the Levensau substage are the mollusc zone Mol F 5 of Sliggers (1985) and probably a part of the "Mecklenburg-Gühlitz-Stufe" of Staesche (1930). In the centre of the basin the presence of this substage is frequently masked, when it occurs as the Tostedt Member, without benthic record. Therefore it had to be discerned in more marginal parts of the basin.

The most abrupt upper boundary of the Levensauian/Mol F 5 was observed in the well Obspringen. No indication for a transgressive hiuatus was observed in this section and therefore the sudden disappearance of some species that were common before had to be explained by the asumption of a sudden deterioriation of climate, influencing also the bottom waters of shallow seas. A similar decrease of temperature (from intertropical to subtropical) in strata of Serravallian age in the Mediterranean area was postulated by Demarcq (1983), who explained it by the first glaciation of Antarctic. Another cause might be the passage of the asteroid "Nemesis", 13-14 Ma ago, with its showers of meteoritic dust reducing temperatures. The two peaks observed in the gamma-ray log of the basal Lüneburgian might be striking indicators for meteoritic dust (or glauconitic clay?).

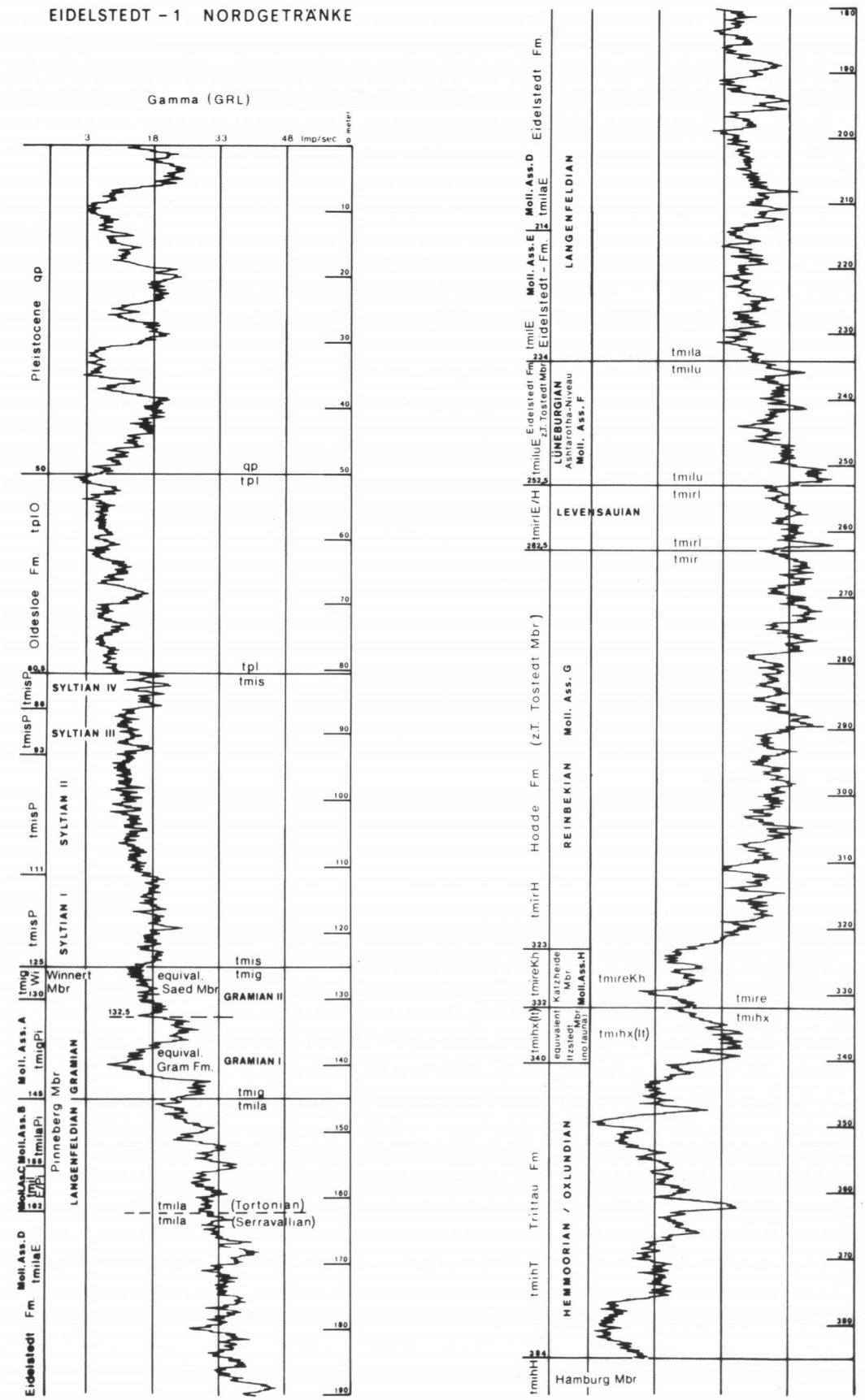


Fig. 7. Gamma-ray log of the well Eidelstedt 1, Nordgetränke (TK 25 Niendorf 2325).

In the more central and eastern part of the North Sea Basin the sharp boundary between Levensauian and Lüneburgian can also be explained by a transgressive tendency during the maximum of the Nordelbe Cycle subsidence. Especially sediments from deeper water show glauconitic clays. They were sometimes observed at the base of the Levensauian and frequently at the base of the Lüneburgian or of early Langenfeldian, causing hiatusses near the salinary structures, which form submarine ridges. Lüneburgian glauconitic clays were observed at Levensau and Geörgswerder.

TAXONOMIC NOTES

Description of a new subspecies

Hinia (Telasco) syltensis levensauensis subsp. nov.
Plate 1, figs 1-6

Diagnosis — A *Hinia* (*Telasco*) *syltensis* with two stronger subsutural spirals; the number of collabral ribs is smaller than in the nominal subspecies.

Locus typicus — Well Levensau Nord 3, 81-82 m (core).

Stratum typicum — Levensau substage in Lowest Eidelstedt Formation.

Holotype — Plate 1, fig. 2.

Type material — Well Levensau Nord 3, 77-78 m, Lüneburgian (1 specimen). 81-82 m, Levensauian (10 specimens) (Plate 1, figs 1-4). Well Georgswerder (Fiskalische Straße), 39.4 m, Levensauian (1 specimen). Well Rösing, 210-216 m, Levensauian (2 specimens) (Plate 1, fig. 5). 228-234 m (1 specimen, caving in tmir) (Plate 1, fig. 6).

Description — The protoconch of this subspecies is similar to that of the typical subspecies. The number of spirals (8 to 10) and the more threadlike than ribbonlike shape of the spirals, is equally similar to those of the nominal subspecies (Mostafawi, 1978), but two spirals, especially the last but one, below the suture are more accentuated than the others, thus forming more or less a shoulder, especially where crossing the collabral ribs. The number of ribs (12 to 15) is smaller than in *syltensis* s. str., and there is no tendency of dwindling in the collabral sculpture.

Discussion — This new subspecies comprises the earliest representatives of the *Hinia* (*Telasco*) *syltensis* lineage. *H. syltensis levensauensis* occurs during the Levensauian and Lüneburgian substages, whereas *H. syltensis syltensis* is present from early Langenfeldian until Syltian (compare Plate 1, fig. 7).

In the Levensau section three lineages of *Hinia* subgenera are represented:

— *Telasco lineage*

Hinia (*Telasco*) *syltensis levensauensis* (Plate 1, figs 1-6), present during Levensauian and Lüneburgian, replaced by *H.* (*T.*) *syltensis syltensis* (Plate 1, fig. 7) in the Langenfeldian substage.

— *Hinia* lineage

Hinia (*Hinia*) *holsatica* (Plate 1, fig. 8) is present in Reinbekian and Langenfeldian deposits.

— *Miohinia* lineage

After the acme-zone of *Hinia* (*Miohinia*) *bocholtensis* in the Reinbekian the rare and ultimate representative of *Miohinia* is *Hinia* (*Miohinia*) cf *pseudoturbinella* (Plate 1, fig. 9), see also Hinsch (1975, pl. 36, fig. 7), differing from typical *pseudoturbinella* Mostafawi, by the presence of more spirals (1 + 6 instead of 1 + 3).

New identification of Langenfeldian and Gramian β-*Gemmula*

Hinsch (1986) erroneously identified the *Gemmula*-species descendant from the Reinbekian *G. zimmermanni* (Philippi) as *G. badensis* (Hoernes). This younger form differs from *G. badensis, G. coronata* and *G. spiralis* by the shape of the spire and the presence of two strong spirals on the upper part of the canal.

This β-*Gemmula* of Langenfeldian and Gramian age, resembling also *G. rotata* (Brocchi), was described as *Gemmula pluridenticulata* (Kautsky, 1925). A specimen from the Levensau well is illustrated on Plate 1, fig. 10.

Kautsky (1925, p. 161, pl. 11, fig. 7) based his taxon on a single specimen from Hemmoor, which means that it is a derived specimen of younger Neogene age, just like several other species from this locality. *G. badensis* and *G. spiralis*, described by Kautsky and by A.W. Janssen (1984) are of Hemmoorian age.

EXPLANATION OF PLATE 1

Figs 1-6. *Hinia* (*Telasco*) *syltensis levensauensis* nov. subsp.
Figs 1-4. Four specimens from well Levensau Nord 3, depth 81-82 m (core); Levensau substage. Resp. specimens A and B and specimens C and F.
Fig. 5. Well Rösing I, depth 210-216 m (cuttings); Levensau substage.
Fig. 6. Well Rösing I, depth 228-234 m (cuttings); Levensau substage.

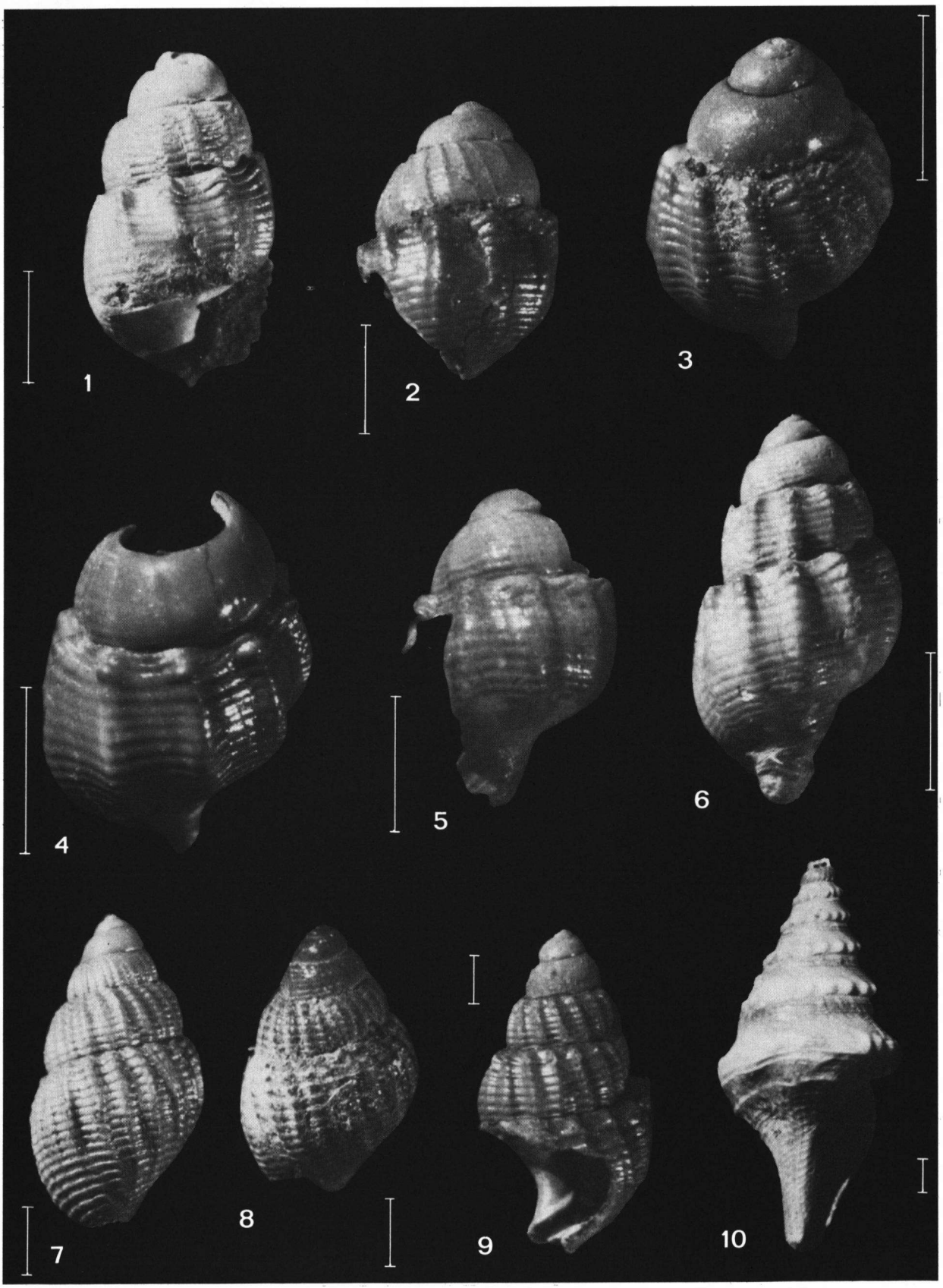
Fig. 7. *Hinia* (*Telasco*) *syltensis syltensis* (Beyrich)
Well Levensau Nord 3, depth 68-69 m (core); Langenfelde substage.

Fig. 8. *Hinia* (*Hinia*) *holsatica* (Beyrich)
Well Levensau Nord 3, depth 69.3-70 m (core); Langenfelde substage.

Fig. 9. *Hinia* (*Miohinia*) cf *pseudoturbinella* Mostafawi
Well Levensau Süd 2, depth 45.5-46 m (core); Langenfelde substage. Variety with 1 subsutural spiral and 6 (instead of 3 in the typical form) normal spirals.

Fig. 10. *Gemmula pluridenticulata* (Kautsky)
Well Levensau Süd 1, depth 53-54 m (core); Langenfeldian.

Bar length represents 1 mm.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