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A NEOLITHIC SETTLEMENT ON THE DUTCH NORTH SEA COAST *c.* 3500 CAL BC

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15 Diatoms

Hein de Wolf
Piet Cleveringa

Diatom analysis of sediments made it possible to follow in detail the environmental changes that took place during the period of occupation, in particular the changes in salinity and tidal influence. The settlement lay between the saline and freshwater spheres of influence. In the course of time the freshwater conditions began to prevail. The presence of Hantzschia amphioxys *and* Navicula cincta *shows that humans and cattle had an impact on their environment. The only pit whose diatom content was analysed was found to have been humid, and to have been quickly filled with wind-blown sand. A selection of 22 potsherds shows that the pottery was made from local clays; in the case of one of the sherds this is not clear.*

15.1 Introduction

15.1.1 Research questions

The study of the diatoms (algae that secrete silicious skeletons) comprised three components.

The first aim was to find answers to specific questions relating to the sedimentary environment and the changes that took place in it. The composition of the remains of the diatom flora in samples provides information on hydrodynamic conditions, the palaeoenvironment, the sedimentation conditions, and in particular salinity.

Secondly, it was hoped that the diatoms would provide information to show whether the interpretation of the many pits dug at the site as 'unlined wells' is correct. The pits in question could for example also have been dug to obtain clay for the manufacture of pottery.

The latter option brings us to the third – archaeological – component of the study, which concerns the question whether the diatom composition of the clay used to make the pottery would enable us to determine whether all or some of the pottery was manufactured locally (or regionally) or elsewhere, *i.e.* outside the region. This question was inspired by the remarkable differences in the employed types of temper, which, besides indisputably local material (crushed shell), also include crushed quartz and other types of rock, incidentally even granite. Could the pottery tempered with the latter materials have been produced elsewhere?

The answer to the last question is of substantial importance in determining the exact function of the site, and in particular whether it was occupied on a year-round or a seasonal basis. Local pottery production is a strong argument in favour of a basic site function, implying the presence of entire households. That does however not automatically imply year-round occupation. Pottery manufacture is a typical summer activity (on account of the drying process), which may in the case of a more mobile community in principle have taken place at summer camps.

15.2 Data, materials

In consultation with the excavation supervisors two sampling points were selected for the purpose of determining the former environment. A point was selected on each side of the dune – the northwestern and southeastern – so as to be able to assess any differences in sedimentation conditions. The samples were taken as far away from the dune as possible, to ensure that they would provide the most reliable natural signal, beyond the direct anthropogenic influences. It was moreover ensured that both samples covered the entire excavation stratigraphy, from the deposits predating the period of occupation (Unit 26) to those postdating it (Units 2 and 1). Section D1 was taken on the southeastern side of the dune. The sample taken on the northwestern side was obtained from two sections to enable us to benefit from the optimum conditions of the separate units. Section D2 covers the lowermost units and section D3 the units dating from the end of the occupation period and the subsequent deposits (fig. 15.1).

Only one pit interpreted as an 'unlined well' was sampled. A pit (no. 12-314) lying relatively high up the dune slope was selected, as the questions concerning these features related most specifically to those areas. The bases of the primary and secondary fills of this pit were sampled.

The pottery analysis was carried out in two phases. The analysis started with a pilot study involving 12 sherds. The results of this study were so promising that it was decided to increase the number of sherds to 22. In view of the limited number of sherds concerned, the analysis focused on tracing any differences between phases 2a and 3, *i.e.* the beginning and end of occupation, and on any differences between the pottery tempered with shell fragments and that tempered with crushed quartz or other types of rock.

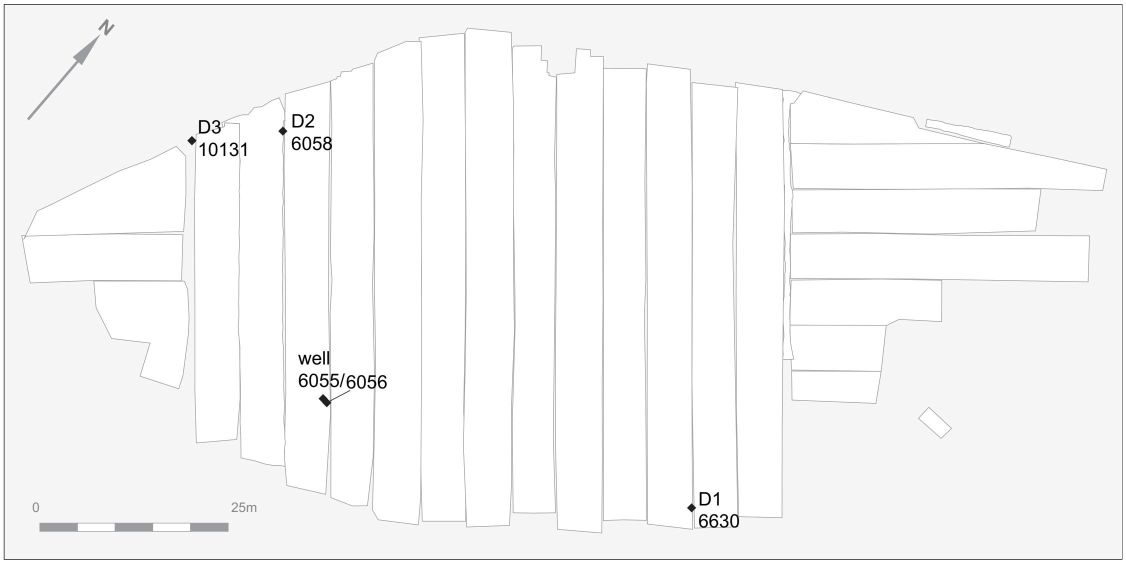

Figure 15.1 The sections analysed for diatoms.

15.3 Methods

The samples (weighing about 5 grams) from the sections and the pit fill were both prepared in the usual manner (Van der Werff 1955). The sherds were first thoroughly cleaned and mechanically crushed. The residue was treated and prepared in the same way as described above. The preparations were analysed with the aid of a Leitz Orthoplan microscope at 400 and 1000× magnification. Where possible, more than 100 diatoms were counted in a sample. A distinction was made between complete silicious skeletons and fragments. Besides information on transport, this distinction in the proportions of complete and fragmented diatoms would also provide insight into postsedimentary processes such as partial dissolution of diatoms in the sediment caused by the vegetation that developed on it, as diatoms (biogenic silica) serve as nutrients for grasses and herbs.

A total of 22 samples were taken from the sections, 16 of which were subjected to complete analysis and the other interim six samples to a quick scan to check whether the diatom data were in accordance with those of the preceding and/or succeeding analysed samples. This was done to prevent the risk of any transitions, hiatuses, *etc*. being overlooked.

Each of the identified types of diatoms has its own distinctive life conditions, which can be characterised with the aid of the environmental variables specified below. This classification system was set up several decades ago to group the abundant ecological data available on the species. The environmental variables are specified in different ways to enable them to be used by different disciplines. Classifications may vary from one discipline to another. A scientist measuring the quality of water will use diatom information in a different way than a researcher interested in the development of a coastal landscape.

In connection with the diatoms' great sensitivity to different environmental variables, the following classification system is used in practice and in diagrams:

salinity	marine	– polyhalobous
	brackish	– mesohalobous
	fresh	– oligohalobous halophilous
		– oligohalobous indifferent
		– halophobous
tidal influence	ampotixen – indifferent – pseudoampotiphil	
nutrients	eutrophic – mesotrophic – oligotrophic	
pH	acidophilous – indifferent – alkaliphilous	
life form	planktonic – tychoplanktonic – benthonic – epiphytic – aerophilous – euterrestrial	
temperature	cold – temperate – warm	
current	rheophilous – indifferent – limnophilous	

The most important differentiating factors in the case of the Schipluiden flora are salinity and life form, and the diatoms were therefore grouped as follows:

- salt – marine, allochthonous coastal
- brackish – estuarine (pools, wet/dry transitions, banks)
- fresh – fluviatile (pools and ditches, wet/dry transitions, banks)
- aerophilous – terrestrial

15.4 Explanation of terms

Some of the aforementioned classes will be explained below.

15.4.1 Allochthonous coastal species

Allochthonous coastal species are diatom species deriving from the North Sea coastal area. They are marine species, often with a planktonic (including tychoplanktonic) and partly also benthonic life form. In our study they comprised the following species:

Actinocyclus ehrenbergii
Actinoptychus splendens
Actinoptychus undulatus
Aulacodiscus argus
Biddulphia rhombus
Brockmanniella vanheurckii
Campylosira cymbelliformis
Cymatosira belgica
Melosira sulcata
Melosira westii
Nitzschia panduriformis
Odontella aurita
Podosira stelliger
Rhaphoneis amphiceros
Rhaphoneis surirella
Rhaphoneis minutissima
Thalassiosira decipiens
Thalassiosira eccentrica

They are transported by the tides and by waves, but sometimes – and only in the case of a storm – in small quantities also by the wind. As most coastal diatom species are highly silicious and their skeletons resistant to corrosion, they are found in almost all coast-related sediments. They are particularly common in sediments that are transported inland by tidal currents, wave action and sometimes the wind. Being strongly silicious, they are fairly insoluble. There is usually a good chance of their entire or partial preservation in sediments. But even if they are fragmented or corroded through solution they are readily identifiable thanks to their silicious skeletons.

15.4.2 Aerophilous species

Although diatoms are aquatic organisms, aerophilous diatoms require only little water to develop and bloom. Water adhering to sediment particles, more highly evolved plants and mosses, and interstitial water of sand granules and clay particles in soils is all they need.

Live aerophilous species are found in environments in which no, or only very little sedimentation takes place. Soil formation is the prevalent process. Fossilisation of aerophilous diatoms indicates that the diatoms were incorporated in sediments shortly after death, because diatoms rarely fossilise in soils as the vegetation dissolves their silica for absorption. So soils are usually devoid of diatoms. The most important aerophilous species in our study are:

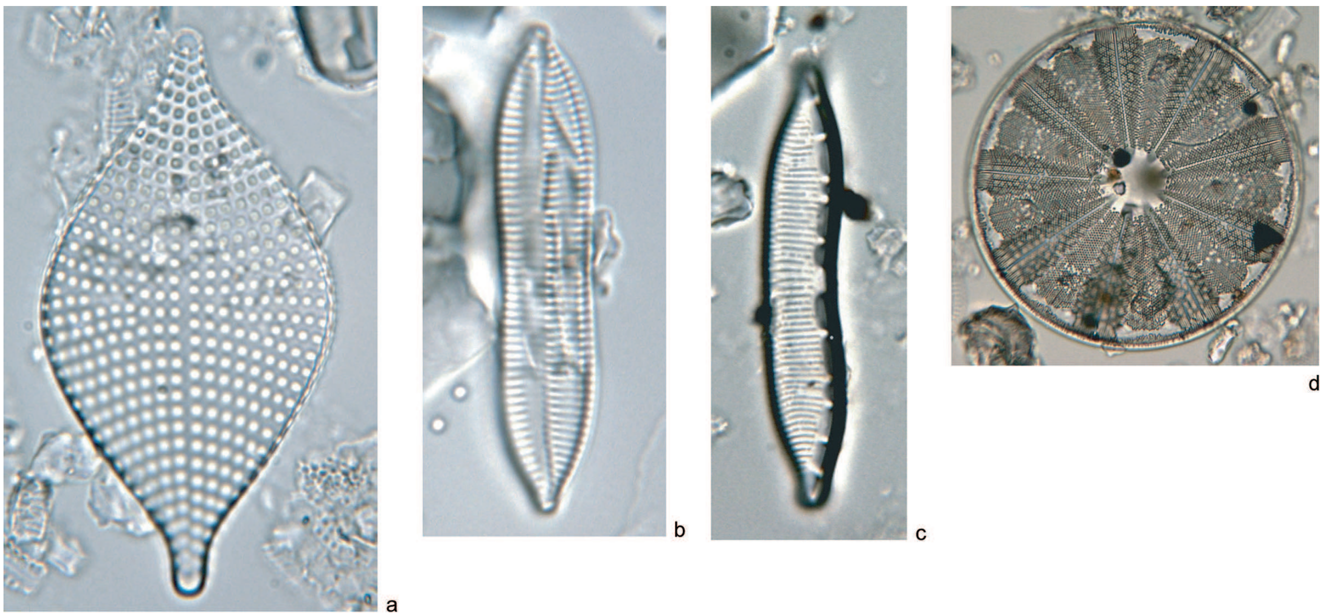

Figure 15.2 Some important diatom species, illustrating the great variety in forms. From left to right: *Rhaphoneis amphiceros*, (600×), *Nitzschia apiculata* (400×), *Hantzschia amphioxys* (400×) and *Actinoptychus splendens* (200×).

Hantzschia amphioxys
Navicula cincta
Navicula contenta
Navicula mutica
Nitzschia palea
Pinnularia borealis
Pinnularia lagerstedtii
Pinnularia subcapitata.

The aerophilous species *Hantzschia amphioxys* and *Navicula cincta* are also indicators of environments rich in nutrients, sometimes to the extent of having eutrophied, such as areas influenced by humans and cattle (Körber-Grohne 1967).

15.4.3 Brackish estuaries

The most important species in areas where fresh river water is exposed to saline seawater and the two mingle (estuaries) is *Cyclotella striata*. Only a few plankton species can live in such highly dynamic environments. Banks of estuaries, intertidal zones, and also areas of shallow water are moreover the habitats of brackish benthonic species, the most remarkable representative of which is *Nitzschia navicularis*. The two species occur combined only in brackish estuaries.

15.4.4 Brackish species

Lakes and pools in brackish environments whose waters freshen through rainfall have an unusual diatom association. They are occasionally flooded by seawater only at high (storm) tides and remain brackish through evaporation. Species characteristic of such environments are *e.g. Navicula pygmea, Nitzschia apiculata, Nitzschia hungarica, Rhopalodia musculus* and *Stauroneis gregori*.

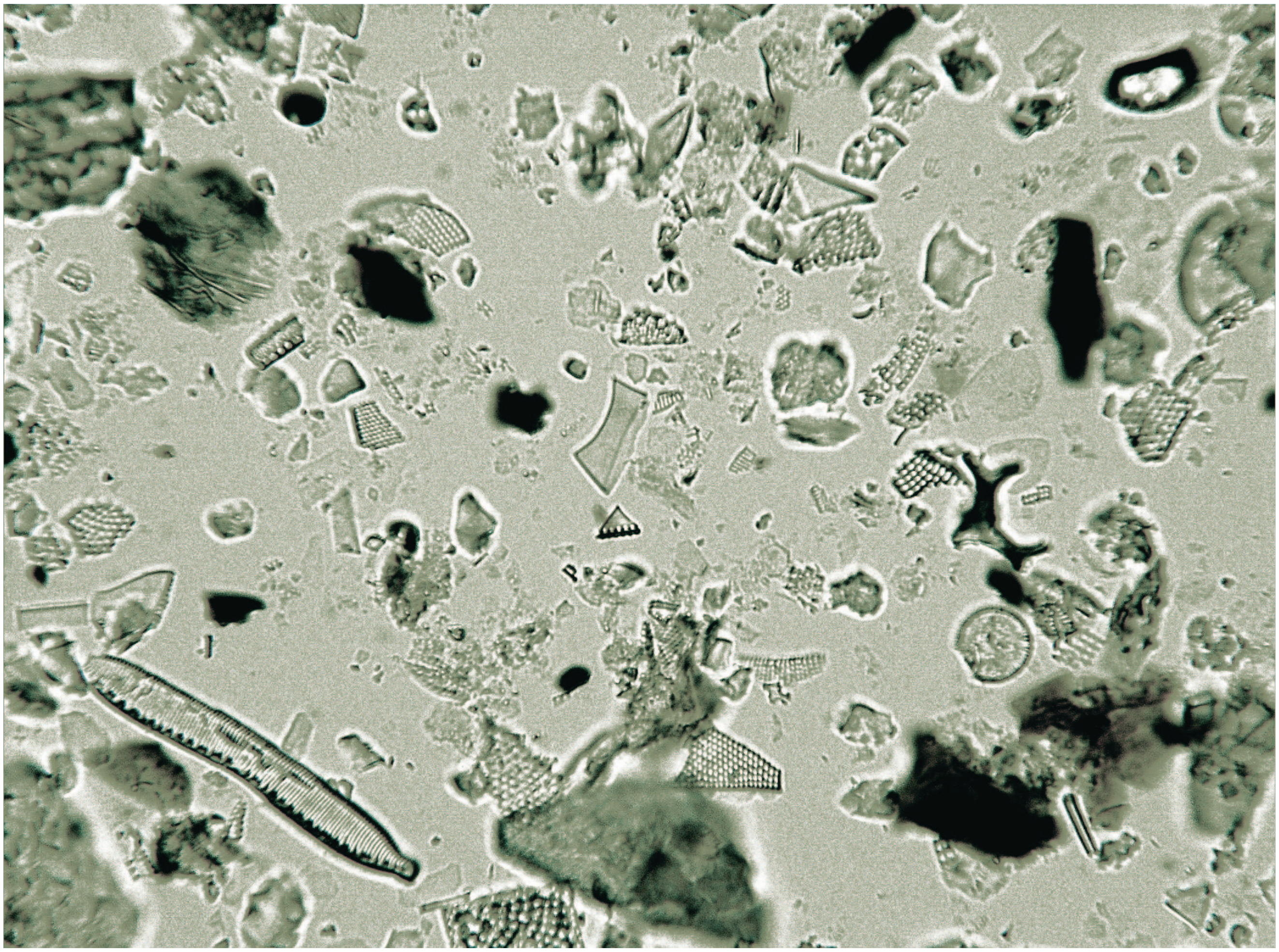

Figure 15.3 *Hantzschia amphioxys* (lower left corner) clearly stands out from the fragmented allochtonous diatoms that costitute the greater part of the assemblages. *Hantzschia amphioxys* is an indicator of a eutrophic environment affected by humans and cattle (magnification 1500×).

15.4.5 *Freshwater species*

Few freshwater species were encountered in the study. Most derived from river water and are species that can sometimes survive for some time under slightly more brackish conditions, such as *Cocconeis placentula*.

15.4.6 *Sample composition*

Diatoms are usually classified on the basis of succession and/or ecological criteria. However, not all species occurring in sediments can be classified according to such criteria. Vos set up a simpler classification system (Vos/De Wolf 1993) that provides insight into 'diatom worlds' on the basis of salinity and life form. This system works well in cases involving a succession of aquatic environments. At Schipluiden, however, aquatic conditions alternated with terrestrial ones, involving, among other processes, soil formation. Strict application of Vos' classification would have implied the loss of valuable diatom information.

Most diatoms in coastal sediments represent a thanatocoenosis and not a biocoenosis. They comprise the silicious skeletons of (deceased) algae from different biological communities, varying from freshwater to entirely marine communities. The species from the 'open sea' – *i.e.* the planktonic, tychopelagic and benthonic species – are referred to as allochthonous coastal species. These species also occur both live and dead in estuaries and mud-flat areas. The exchange of seawater enables some allochthonous coastal diatoms to bloom in such environments, but they are also deposited in sediments in such areas as empty valves (diatom skeletons) transported there by the tides.

The allochthonous coastal species' preferred habitat may be the coast, but after their death they are incorporated in sediments and are in that form often transported, for example into estuaries.

15.5 Analysis

15.5.1 *Section D1* (fig. 15.4)

The stratification of the section (trench 20, north section, no. 6630)

0.00 – 0.03 m	Unit 1	peat/gyttja
0.03 – 0.13 m	Unit 2	clay, very humic, rooted and horizontally layered (disturbed)
0.13 – 0.20 m	Unit 11	sandy humic clay
0.20 – 0.29 m	Unit 18	humic clay, rooted
0.29 – 0.39 m	Unit 19	clay, slightly sandy, rooted
0.39 – 0.43 m	Unit 25	sand (aeolian?)
0.43 – 0.85 m	Unit 26	sandy humic clay (banded), rooted at the top

Diatom contents

Unit 26

The two samples (from 0.85 and 0.55 m) were found to be rich in diatoms. Allochthonous coastal species such as *Melosira sulcata, Rhaphoneis amphiceros* and *Rhaphoneis surirella* were frequently observed. Species such as *Cyclotella striata* and some freshwater species were found in lower percentages. The lowermost sample (0.85 m) included pyrite granules and faecal pellets containing freshwater diatoms.

The combination of marine allochthonous coastal species, the occurrence of *Cyclotella striata* – a plankton species characteristic of brackish estuaries – in percentages from 5 to 10, and the presence of freshwater species together points to estuarine sedimentation conditions. The freshwater species were most probably transported here by river water, because the water at the sampling point was brackish. Its salinity varied substantially, depending on the tides and the seasons. The presence of pyrite in the sample from 0.85 m moreover implies anoxic conditions at the time of sedimentation. When oxygen was introduced into the sediment in later times, the iron sulphide was converted into pyrite. The absence of pyrite in the 0.55 m sample implies that this area occasionally emerged from the water around this time already.

Units 26 and 19

The dominant species in these samples (from 0.45, 0.39 and 0.29 m) is *Nitzschia navicularis*, a benthonic species that is nowadays found in mud flats and estuaries. Other important species are *Nitzschia punctata, Nitzschia hungarica* and *Nitzschia sigma*. They are brackish species that nowadays live in coastal areas in isolated pools whose water is freshened through rainfall.

The section shows that the aquatic sedimentation in this area was for a short time interrupted by the deposition of a thin layer of aeolian sand, which extends to the foot of the dune (Unit 25). In fact there is a seamless transition between Units 26 and 19. This is confirmed by the diatom spectra. The changes evident in the samples from 0.39 and 0.29 m (Unit 19) are already observable in the sample from 0.45 m, from the top of Unit 26. The number of allochthonous coastal species in the uppermost sample is much smaller, but still points to an estuarine environment. The area emerged from the water at low tide, and water remaining in pools became fresh as a result of precipitation. The pools were flooded by seawater only at high (storm) tides. These observations all point to a succession associated with isolation from the sea.

Unit 11

The sample from 0.17 m had a low diatom content. The preparation was found to contain large quantities of fine organic matter that looked burnt. It also included very fine fragments of corroded diatoms. The most important species encountered are first of all the allochthonous coastal species

Cymatosira belgica and *Thalassiosira eccentrica* and secondly *Cyclotella striata* and *Cyclotella stylorum,* which are both brackish plankton species that are nowadays found in estuaries, although *Cyclotella stylorum* is extremely rare in our temperate climate. Two specimens of each species were found. In the third place there were also various freshwater diatoms: *Amphora ovalis, Navicula oblonga,* indet. *Pinnularia* fragments, and fragments of *Pinnularia maior*. They are benthonic species and epiphytes that live in *e.g.* ditches.

This sediment, which has the characteristics of a gyttja, was probably laid down in depressions in the landscape. Such depressions may from time to time have become quite warm, leading to an increase in salinity resulting in the formation of a favourable biotope for species such as *Cyclotella stylorum*, which is known from warmer climates. During precipitation the 'freshwater ditch flora' will then have flourished.

Unit 2

The lowermost sample (0.12 m) was rich in diatoms. It was found to contain many allochthonous coastal species, such as *Actinoptychus undulatus, Cymatosira belgica, Melosira westii, Melosira sulcata, Rhaphoneis amphiceros, Rhaphoneis surirella* and *Thalassiosira eccentrica*. *Achnanthes brevipes, Cyclotella striata, Diploneis elliptica* and *Rhopalodia musculus* moreover imply that the sediment was laid down in a shallow brackish, vegetated environment. The presence of *Hantzschia amphioxys* shows that this area periodically emerged from the water. The presence of the marine allochthonous coastal species and the fairly high percentages of *Cyclotella striata* indicate the influence of a nearby estuary – an environment in which sediment was during rare storm floods transported inland from the sea.

The uppermost sample (0.06 m) was also rich in diatoms. The dominant species are *Diploneis didyma* and *Nitzschia navicularis,* which are both characterised by a benthonic life form. They are nowadays found in mud flats and estuaries. Besides the usual allochthonous coastal species *Actinoptychus undulatus, Melosira westii, Melosira sulcata* and *Rhaphoneis amphiceros,* the sample also contained the brackish species *Diploneis elliptica* and *Nitzschia punctata*. The diatom spectrum points to a brackish estuarine environment. The area seems to have come under tidal influence again during the formation of this unit.

Unit 1

The sample from 0.01 m contained no diatoms, precluding interpretation. The diatom content was probably dissolved as result of soil formation and subsequent peat growth.

15.5.2 Sections D2 and D3 (fig. 15.5)

The stratification of section D3 (trench 10, south section, no. 10,131)

0.00 – 0.22 m	Unit 0	clay containing many sand lenses
0.22 – 0.33 m	Unit 1	reed peat
0.33 – 0.44 m	Unit 2	humic clay (irregular transition to the underlying sand)
0.44 – 0.50 m	Unit 11	humic sand, rooted

The stratification of section D2 (trench 12, south section, no. 6058)

0.70 – 0.77 m	Unit 15	peat, sandy
0.77 – 0.84 m	Unit 17	sand, very humic (soil?), minerals (jarosite, siderite) at a depth of 0.77 m
0.84 – 1.20 m	Unit 26	clay with a sandy top (0.84 – 0.91 m), rooted

Diatom contents

Unit 26

The sample from 1.15 m was rich in diatoms, that from 0.95 m had a lower diatom content. Allochthonous coastal species were dominant, such as *Campylosira cymbelliformis, Cymatosira belgica, Melosira sulcata, Rhaphoneis amphiceros* and *Rhaphoneis surirella*. The brackish species *Cyclotella striata* is present in fairly high percentages. The aerophilous species *Hantzschia amphioxys, Navicula cincta* and *Navicula mutica* were found in low percentages.

The high *Cyclotella striata* values imply that the clay (with its sandy top) was laid down in the same estuarine environment as that in which the allochthonous coastal species were deposited. The aerophilous species *Hantzschia amphioxys, Navicula cincta* and *Navicula mutica* give more specific information about the environment. They show that the area emerged from the water for varying lengths of time several times a year. The numbers, preservation and species spectrum of the diatoms indicate regular deposition of sediments in an estuarine environment. This section reflects drier conditions in the area dominated by estuarine sediments than in the same Unit in section D1.

Unit 17

The sample from 0.81 m also included a few allochthonous coastal species, but more conspicuous are the aerophilous species *Hantzschia amphioxys, Navicula mutica, Navicula contenta, Nitzschia palea* and also *Amphora normannii, Nitzschia vitrea* and *Surirella minima*. *Navicula cincta* points to polluted conditions.

This sample represents a kind of transitional situation. It reflects a substantial decrease in sedimentation relative to Unit 26 (0.84 – 1.20 m). The annual floods referred to above had by this time become less prolonged.

Unit 15

This sample (0.73 m) contained fewer diatoms than the preceding sample. Besides the species encountered in the sample from Unit 17 it also contained *Navicula joubaudii, Nitzschia hantzschiana* and fragments of *Pinnularia borealis*. The latter are typically aerophilous species that are indicative of soil formation. But apparently some sedimentation was still taking place, because the diatoms would not have been preserved if they had not become incorporated in sediments shortly after death. Flooding, accompanied by sedimentation, occurred less often than during the time when Unit 17 was laid down, probably only a few times a year.

Unit 2

The sample from 0.40 m was rich in diatoms. Dominant are the allochthonous coastal species *Cymatosira belgica, Melosira sulcata, Rhaphoneis amphiceros, Rhaphoneis minutissima, Rhaphoneis surirella* and *Thalassiosira decipiens*. Other species encountered in the sample are the brackish *Cyclotella striata* and the freshwater *Melosira ambigua, Melosira granulata* and *Synedra ulna*. Entire valves of *Synedra ulna* were observed. The sample also contained many pyrite granules.

The combination of marine allochthonous coastal species, the occurrence of *Cyclotella striata* and the presence of freshwater species that were not transported, or transported only very little (entire *Synedra ulna* valves), implies that the sediment was laid down in the fresh part of an estuary. The pyrite in the sample was probably deposited under anoxic conditions, later followed by the introduction of oxygen.

Unit 0

The lowermost sample (0.15 m) was rich in diatoms. Dominant are allochthonous coastal species such as *Cymatosira belgica, Melosira sulcata, Rhaphoneis amphiceros, Rhaphoneis minutissima, Rhaphoneis surirella* and *Thalassiosira decipiens,* and also the freshwater species *Gomphonema angustatum* and *Gyrosigma eximium*. Other conspicuous species in the sample are *Cyclotella striata* (brackish) and *Meridion circulare* (freshwater).

The combination of marine allochthonous coastal species, the occurrence of *Cyclotella striata* and the presence of freshwater species such as *Gomphonema angustatum, Gyrosigma eximium* and *Meridion circulare* implies that the sediment was laid down in the fresher part of an estuary. The area emerged from the water at low tide and had by this time become less susceptible to marine ingression.

The uppermost sample (0.05 m) was also rich in diatoms. The sample contained many fragments. Dominant species are the allochthonous coastal species *Cymatosira belgica, Melosira sulcata, Rhaphoneis amphiceros, Rhaphoneis minutissima* and *Rhaphoneis surirella*. A few freshwater species were found, including *Cocconeis placentula* and *Synedra ulna*.

The combination of marine allochthonous coastal species and freshwater species implies that this sediment was formed within reach of the freshwater in the estuary. Sediments were supplied only during storm floods (as shown by the many fragments).

All three samples of section D3 contained *Actinoptychus splendens*. This is an allochthonous coastal species that has occurred in the North Sea basin only after the closing of the coast of the western Netherlands, following the development of an uninterrupted series of beach barriers and dunes (De Wolf /Denys 1993). The occurrence of this species in Unit 2 at Schipluiden is remarkable on account of the early date, around 4500 BP,

15.5.3 Samples from the fill of well 12-314 (nos. 6055 (bottom) and 6056 (top))

Two samples from the fill of one deep unlined well at the centre of the settlement site were analysed to obtain an impression of the local hydrological conditions. The preparations of these samples were not subjected to full analysis. A quick scan sufficed to provide a good impression of the composition of the diatom flora.

The dominant species in the lowermost sample, from the base of the pit fill (no. 6055), was the eutrophic, aerophilous species *Hantzschia amphioxys,* of which 8 complete (double) and 7 broken valves were found. A second important species was the likewise aerophilous *Navicula mutica*, which was represented by 4 complete (double) valves. The sample also contained a few fragments of marine (allochthonous) diatoms plus one valve each of *Cyclotella striata* (brackish) and *Pinnularia borealis* (aerobic).

Dominant in the uppermost sample, from halfway up the fill (no. 6056), was *Navicula mutica*, represented by 8 complete valves and 1 fragment. Other species encountered (all of which are aerophilous) are *Hantzschia amphioxys* (3 complete valves and 13 fragments), *Navicula cincta var. heufleri,* and also *Nitzschia hantzschiana, Navicula atomus, Stauroneis muriella* and *Pinnularia borealis*. The latter species were only sporadically observed. The sample also contained fragments of marine diatoms.

The dominance of *Hantzschia amphioxys* in the lowermost sample points to an environment richer in nutrients (eutrophied) than that reflected by the uppermost sample, in which the dominant species *Navicula mutica* implies a shortage of phosphate and nitrate. Evidently an environment less rich in nutrients formed in the pit. The majority of the species point to alkaline conditions. Their dominance implies that the pit was often dry. As the pit was evidently no longer used, it filled up relatively quickly, ensuring the burial and preservation of the diatom flora contained in it. The differences in the composition of the diatom flora show that the pit did not become filled in one go. This is also evident from the (micro)stratification of the fill.

15.5.4 Pottery sherds

The diatom contents of the sherd samples were found to vary substantially, from less than six identifiable fragments (8×) to very high diatom contents (3×) of more than 100 identifications. The sample of one sherd (no. 3664) also contained phytolites from grasses. Together with the aero-philous diatoms, they show that the clay used for the pot concerned was obtained at the former ground surface. The phytolites may derive from grasses either directly or indirectly, for example via (cattle) manure.

The sherds could be grouped on the basis of the concentrations and the species spectra.

The first group consists of sherds that contained no diatoms, or at least too few to allow determination of the clay's sedimentary environment. This could be attributable to dissolution (soil formation) and/or specific sedimentation conditions – most probably a combination of the two factors, considering the development of the landscape as outlined above. This group 1 comprises eight sherds, which were tempered with crushed quartz (4×), shell (3×) or vegetable matter (1×). The majority of the sherds remarkably date from phase 3, but there are also some from phase 2a (table 15.1). One of the sherds of this group with low diatom contents (no. 256) did contain two fragments of freshwater diatoms – Pinnularia, one of which was Pinnularia maior. The pot concerned may have been produced non-locally.

The sherds of the second group are characterised by the presence of large quantities of aerophilous diatoms alongside brackish and allochthonous coastal species. This group comprises ten sherds, tempered with crushed quartz (5×, in one case combined with vegetable matter), stone (2×) and shell (3×). They date from all the occupation phases. Four sherds, finally, were attributed to a third group. They did contain (fairly) large quantities of diatoms, but no aerophilous species. The majority of the represented species are allochthonous coastal and brackish estuarine species: *Cyclotella striata* (planktonic), *Nitzschia navicularis* (benthotic) and *Navicula pygmea*. The succession that can be inferred from the three sample sections from the sections of the excavation trenches leads to the conclusion that these sherds are made of clay obtained from the deepest part of Unit 26. They date from phases 1 (2×), 2a and 3. Did the potters deliberately select this particular clay or was it coincidence that the same clay happened to be used each time?

15.6 Conclusions

15.6.1 Environmental changes

The changes in the diatom compositions of the analysed sediments clearly reflect the changes that took place in the sedimentary environment and the hydrological conditions throughout the period of occupation. The general trend was a decrease in flooding frequency, with regular high and low tides gradually giving way to more irregular floods during spring tides and storms. In the end, sediments were deposited over short periods of time only during severe storms. This development was accompanied by a gradual change towards freshwater conditions and the emergence of the clastic deposits from the water.

Prior to the period of occupation (Unit 40) the site was characterised by dynamic estuarine conditions with a strongly varying salinity. Pyrite indicates that sediments were laid down in an anoxic environment and that they later emerged from the water and became exposed to oxygen.

The diatom composition of the sediments of Unit 26 is likewise in accordance with an estuarine environment. In some sediments allochthonous coastal species are dominant, whereas in others freshwater species are well represented. The sediments also contain valves of marine and brackish diatoms. During high (spring and storm) tides the area was regularly raised by sedimentation. The surface was negotiable in calm periods. Water remaining in depressions (pools) became fresh as a result of precipitation and a brackish flora developed during phases 1 and 2a (Units 19 and 18). High tides were accompanied by the ingression of salt water, each time followed by a gradual return to freshwater conditions. Conditions varied from one area to another due to differences in altitude, susceptibility to marine ingression and evaporation of the seawater. In addition to this brackish diatom flora, Unit 17 – the peaty (chronological) equivalent of Unit 18 – contains an aerophilous component. Occasionally sedimentation occurred, but the surface also remained dry for long periods of time. This implies a landscape that was suitable for long-term occupation.

The concentration of allochthonous coastal, marine and brackish diatoms in the peat sediment of Unit 11 (phase 3) is even lower, with the main autochthonous diatoms being aerophilous species. Large amounts of black organic matter were also found in the preparations. Sedimentation had evidently decreased further since the formation of Units 17 and 18.

15.6.2 The new allochthonous coastal species Actinoptychus splendens

The general transformation of the diatom flora of Schipluiden illustrates the environmental changes that took place in this area in the centuries after around 5000 BP (3650 cal BC, see chapter 2) – the period in which the coastline began to expand. The area of Rijswijk, Schipluiden and Ypenburg gradually came to be closed off from the sea due to the formation of beach barriers and dunes, and this development was accompanied by a switch to freshwater conditions

	phase	3	2a	2a	3	3	3	x	3	1	1	2a	2a	2a	2a	2a	2b	3	3	1	1	2a	3
	diatom group	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3
	find number	256	339	2022	2107	3407	7937	8479	7353	4738	4589	4493	6484	2127	987	2897	4431	3454	3664	4741	4589a	4489	5647
	Unit	10	18	17	11	11	10	20	11	19	19	18	18	18	18	17	16	10	11	19	19	18	10
	temper	qua	pl	shell	qua	qua	qua	shell	shell	pl, qua	shell	shell	sto	shell	qua	shell	qua	qua	sto	qua	qua	shell	grog
ecogroup		very poor	barren	barren	many small fragments indet	some probably marine fragments	poor	poor	barren					many small fragments indet.		some probably marine fragments						many small marine fragments	
1	Actinocyclus ehrenbergii									f	f		f-1	f					2f			2f	6f
1	Actinoptychus undulatus									2f-1			2f-1	2f-1	f	1	1			1		4f	f
1	Aulacodiscus argus									f	f		f	f								f	f
1	Campylosira cymbelliformis														1				1				
1	Coscinodiscus perforatus																		2f				3f
1	Cymatosira belgica									4f-8	1	f-2	3f-4	5f-13	5	3				f-1	3	1	f
1	Melosira sulcata				1					7	f	5	f	2f-13	2f-1		1		f-1	f-2	4	12	5f-5
1	Melosira westi									f-1	1	1	f-1	2f-6					1			3	f-2
1	Nitzschia panduriformis														1				1			f	
1	Podosira stelliger									f		f	2f	f	2f							4f	4f
1	Rhaphoneis amphiceros									2f			5f-2	f-1						2f-1		f	2f
1	Rhaphoneis surirella									2f	1		3f-1	2f-6	2f-2	2f	1						3f-1
1	Thalassiosira decipiens							1					2f		f-1			1	f			f	2f-3
1	Thalassiosira eccentrica									1										f-1			
4	Cyclotella striata				f					2	f	f-1	3f-1	2f-8	1					2	2	f-1	4f-2
4	Nitzschia navicularis				f					10f-6	2f-4	5f-8	21f-7	1	3f-1	f-2	f			5	6f-9	4f-1	25f-2
5	Navicula pygmea									1	f	f-7	1							3f-32	3f-6		
5	Nitzschia apiculata									f-1	1	2								5	2		
5	Nitzschia hungarica									5f-1	f	6f-12	3f							2f-8	3f-3		
5	Rhopalodia musculus											1				2							
5	Stauroneis gregori																			9			
2	Navicula contenta											2											
2	Navicula mutica									2						1		f-2					
2	Nitzschia palea												f		2f		9						
2	Pinnularia borealis																	f	f				
2	Pinnularia lagerstedtii																	1					
2	Pinnularia subcapitata															2							
3	Hantzschia amphioxys						1			4f-3		1	3f	2f		f-3	10f-3	5f-4	5f-2	2			
3	Navicula cincta									6f-4		2f-7	2f-8	3f-5	5f-7	2f-9	5f-9	f-3	1	2f-11			

Legend

1	allochtonous coastal species
4	estuarine brackish species
5	brackish species
2	aerophilous species
3	aerophilous species/ cattle

Table 15.1 Survey of the diatom identifications of pottery sherds. Only indicators for specific ecological condition are selected. They are classified in five main classes. The values refer to the number of complete (unbroken) diatom skeletons. Fragments are indicated with 'f'.

(chapter 14; Cleveringa 2000). Particularly reliable evidence of this change in coastal development is provided by the dates of shells that were found in an exposure near Rijswijk (Van der Valk *et al*. 1985, appendix).

The results of our diatom study confirm this development. An environment had developed in which the newly formed beach barriers were here and there raised further during severe storms. In drier periods the wind would blow up the sand, leading to the formation of low dunes. This ultimately resulted in an uninterrupted coastline. The further development of freshwater conditions and soil formation created an environment favourable for peat growth (Cleveringa *et al*. 1985). The onset of peat formation has been dated to around 4700 BP (3600 cal. BC, Van der Valk 1985).

Interesting in this context is the earliest occurrence of valves of the allochthonous coastal diatom *Actinoptychus splendens* (Unit 2, section D3, sample 0.40 m). This species was not found in the older samples, but neither was it observed in the samples from the same Unit 2 in section D1. From research elsewhere in the coastal area of the Netherlands and Flanders it is known that the occurrence of this diatom species in sediments implies an age of about 4500 BP. It would seem that the appearance of this species is associated with the closing of the coastline and the development of a new, favourable biotope in the North Sea. The flat, shallow coast with its distinct shoreface gradually became steeper. Via the estuaries of the main rivers the valves of this species were transported inland along with water from the North Sea. So sediments laid down around 4500 BP can be dated more precisely via *Actinoptychus splendens*. It would seem that this new species became increasingly important as the coast grew steeper.

15.6.3 The function of the 'well'

The diatoms encountered in the one sampled well are predominantly aerophilous. The pit was humid, but it was not permanently filled with water, because otherwise aerophilous diatoms would not have been able to develop there. The pit became filled with sediments blown in from its immediate surroundings. As our analysis was restricted to only one pit, little can be said about the general use of the pits concerned. Having been dug through the body of the dune down into the underlying sediments, the pits may also have served to obtain clay for the production of pottery.

15.6.4 Conclusions with respect to the manufacture of the pottery

Fourteen of the 22 examined sherds contained (more than) enough diatoms to allow a reliable characterisation of the employed clay. In terms of composition they correspond completely to the analysed samples of the clays bordering the dune, containing combinations of allochthonous coastal, brackish and aerophilous species that were also found in the clays. This leads to the conclusion that the pottery of this group was locally produced, using clay occurring at the surface. Aerophilous diatoms were significantly absent from some of the sherds (N=4). In those cases the pottery was probably produced from clay from an older layer or from a fresh sediment, untouched by humans or cattle.

The other examined sherds (N=8) contained very few or no diatoms. As the clay of three of these sherds was tempered with crushed shell, implying that the pottery was made in the coastal area, we assume that the absence of diatoms is attributable to dissolution due to soil formation or specific conditions in the deposition environment. Intriguing is one (quartz-tempered) sherd that was found to contain exclusively two freshwater diatom species. The pot in question may have been produced elsewhere.

There is no clear correlation between these groups and the employed temper. All three types of clay were tempered with crushed shell, even that of group 1 with a low diatom content. This is an extra argument for assuming that the latter pottery was also produced locally.

There is on the contrary a clear correlation between the distinguished types of clay and the occupation phases. The clay with a low diatom content (group 1) was used predominantly in phase 3 and that containing marine diatoms in phase 2a. Three of the four sherds from phase 1 contain no or only very few aerophilous diatoms, making it highly likely that the pots concerned were made from clay available at the surface. In phase 1 fresh, estuarine clay was used for the manufacture of pottery, in phase 2a clay formed under aerophilous conditions and in phase 3'old' clay, from which the diatoms had largely disappeared due to dissolution.

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Section D1 (6630)

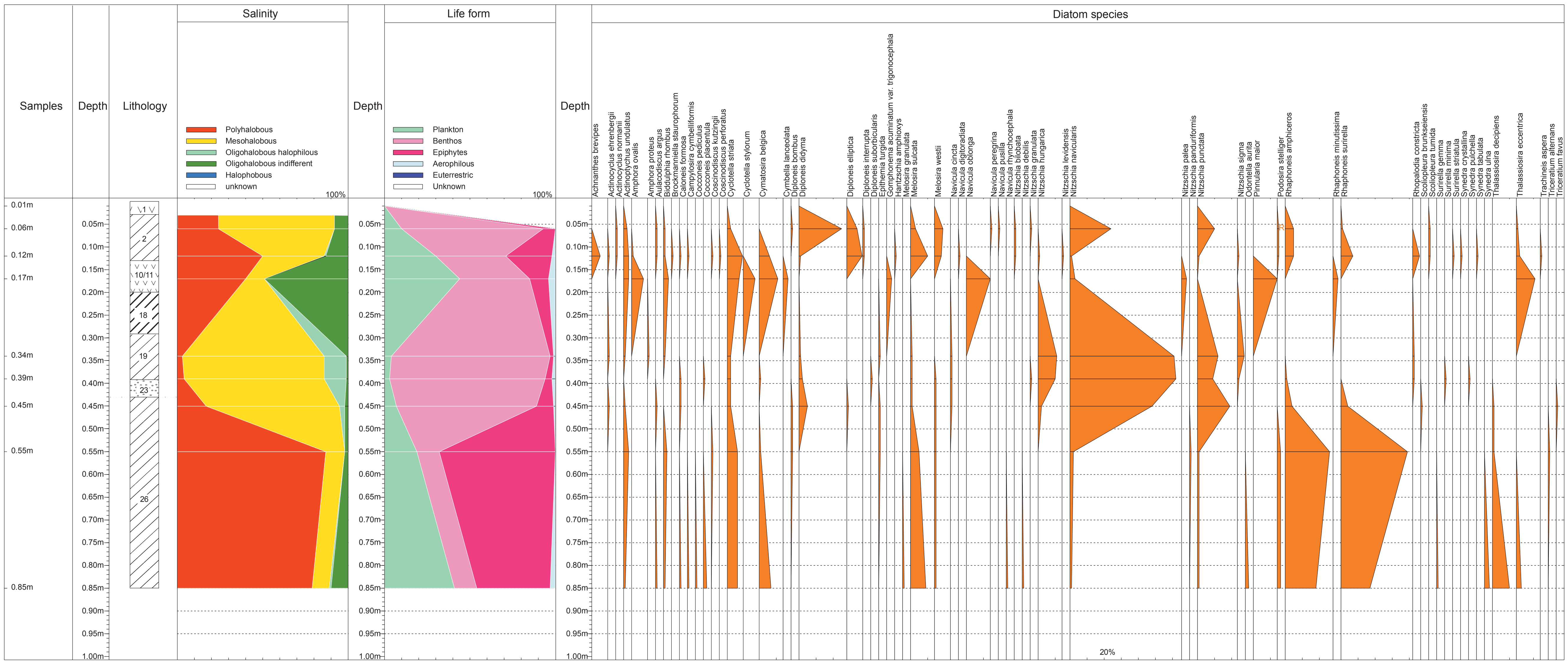

Figure 15.4 Diatom diagram D1, no. 6630.

Section D2 / D3 Combi (10131/6058)

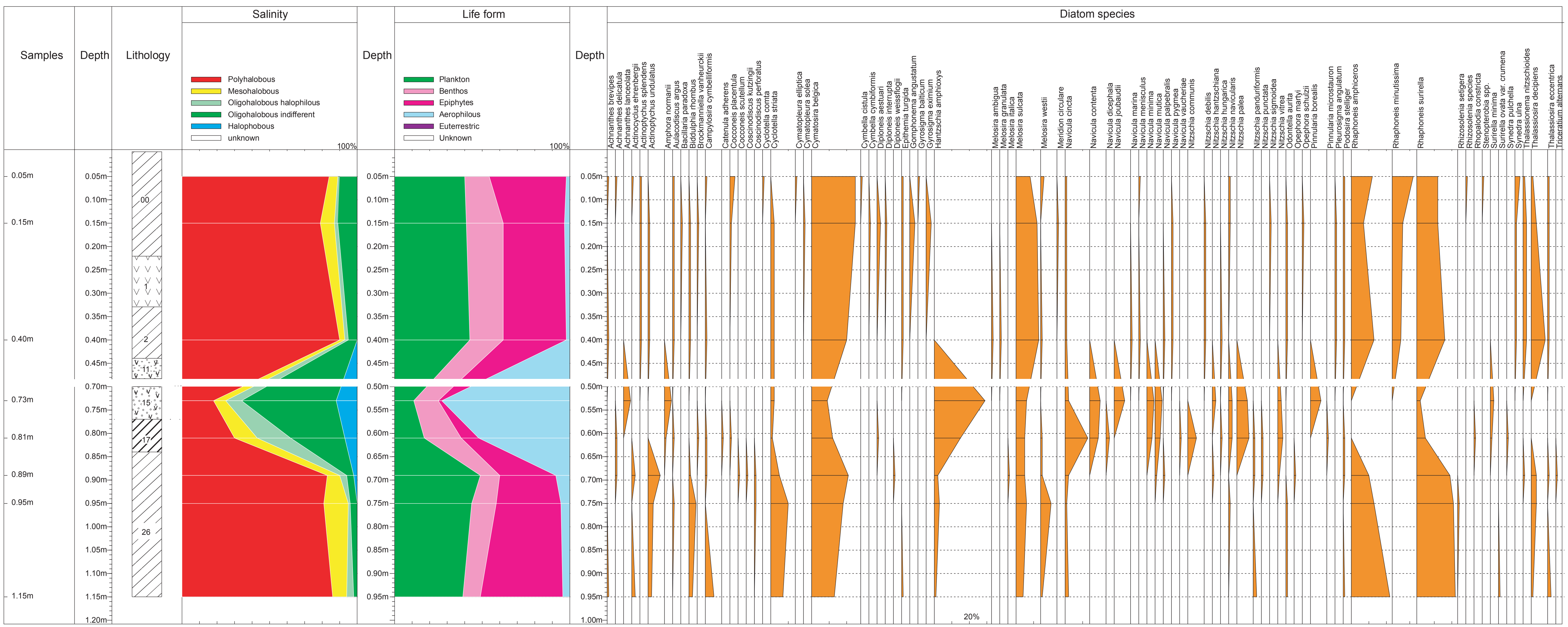

Figure 15.5 Combined diatom diagrams D2 (10,131) and D3 (6058).

Comment on the diagrams shown in figures 15.4 and 15.5.
The curves representing the individual diatom species have been arranged in alphabetical order. The main diagrams (salinity and life form) were obtained by adding up species with the same ecology. Details on the species are to be found in section 15.4. Lithology according to chapter 2.