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QUANTITATIVE DISTRIBUTION AND PALEOECOLOGY OF BENTHONIC FORAMINIFERA RECORDED FROM SOME EOCENE DEPOSITS IN BELGIUM

By

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Part I : Quantitative distribution of benthonic foraminifera in the Lede and Asse Formations (Eocene) at Zemst (Belgium).

1. Summary.

Quantitative countings of benthonic foraminifera, recorded from the Lede and Asse Formations, have resulted in distribution charts of the most frequently occurring taxa. These distribution charts show five different foraminiferal assemblages within the Lede Sands and two different assemblages within the Asse Formation, corresponding to the Wemmel Sands respectively the Asse Clay. Using some general information from studies on Recent foraminiferal assemblages, a paleoecological interpretation of the different associations is worked out.

2. Introduction.

In prospecting the construction of a new sealock on the canal Brussels-Rupel, near to Kapelle-op-den-Bos, but still on the territory of Zemst (locality map in fig. 1), a few wells have been made to explore the subsoil of the region. The geological interpretation of the profile, constructed on the base of these wells, is published by GULINCK (1971) (Fig. 2).
The Belgian Geological Survey delivered us samples from well n° 28 in order to study the benthonic foraminiferal assemblages in some striked Tertiary deposits.
In 1969, the upper part of these deposits could be sampled in a temporary outcrop, caused by the digging works of the sealock. The study of the benthonic foraminifera in this outcrop allows us to control the local validity of some results, obtained from the well samples.
The main aim of this study is to detail the vertical fluctuations in the distribution pattern of the benthonic foraminifera. Such fluctuations can be expected in the studied sections with distinctly changing sedimentological features. While observing some regular patterns within the vertical faunal distribution, we can try to work out a paleoecological interpretation, comparing our results with data from the literature on Recent assemblages.

3. Description of the studied sections.

a) Well n° 28 (Fig. 2)

The Belgian Geological Survey delivered us samples from the interval in well 28 between -36,5 m and -17 m beneath the mowing field.
In the interval -36,5 m and -36 m in the well, a very coarse heterogeneous quartz sand with nummulites has developed.

Between -36 m and -35,5 m, the sand is still heterogeneous, but less coarse. It is followed up by rather fine calcareous sand between -35,5 m and -34,5 m. A calcareous sandstone has developed between -34,5 m and -34 m.
The sediment is again distinctly coarser between 32,5 m and 32,3 m, and it is very rich in nummulites. In the rather heterogeneous calcareous and slightly glauconitic sand, developed between -32,3 m and -27,6 m, three sandy limestone beds, each 20 cm thick, have developed.
Between -27,6 m and -27,4 m, a fine calcareous sediment is slightly obdurated to a calcareous sandstone with nummulites. It is followed up by a coarser heterogeneous sand, rich in nummulites, developed between -27,4 m and -26 m. In the interval -26 m to -20,5 m, a silty calcareous sand is observed. It is generally glauconitic, but it becomes richer in glauconite in the upper part.
Between -20,5 m and -18,5 m a very sandy clay, extremely rich in coarse glauconite grains, has developed. Molluscs and nummulites are observed between -20 m and -19,5 m.
A sandy, slightly compact glauconitic clay occurs in the interval -18,5 m to -17 m.
The grainsize analysis of well n° 28 at Zemst is represented on figs. 2a and 2b. The suspention fraction smaller than 62μ is drafted on the right side. On the left side, the remaining detrital sediment coarser than 62μ is brought to 100% and the half-phi fractions are joined. In this way, the variable importance of the mixture of suspention fraction does not influence the characteristics of the transported sand. Four sedimentological environments can clearly be distinguished.

- Layer A (samples 1 - 6).

At the base, this layer is very coarse but rapidly it becomes a very fine sand with a mode around 100μ in samples 4, 5 and 6. Curve 5 shows the typical bimodality with a coarse bottom load, having a mode above 250μ.
The suspention fraction increases regularly. The environment is one of low energy but waves are still influencing the bottom.

- Layer B (samples 7 - 20).

This is characterized by an ill sorted sand, the sand-medium fluctuating around 170μ. Curve 16 shows a mixture of three sand populations, proving a strong diversity of energy with suspention material mostly washed away.
The energy is fluctuating : the mixture of a rapid succession of well sorted sands results in heterogeneous samples. It is a longshore undeep water environment.

- Layer C (samples 24 - 35).

This is a very homogeneous very fine sand, with an extraordinary fine mode around 80μ . The fraction under 62μ increases up to 25%. The sand is very well sorted and remains homogeneous over 6 m. The environment was one of low but rather constant energy.
Between B and C, a layer of coarse sand with only 20% below 250μ occurs (samples 22 and 23). The suspention fraction represents only 3%. It is a high energy level with strong currents and waves. It can not be the normal transition from B to C or from medium to low energy. It is considered as the high energy base of layer C, reworking the material of B.

- Layer D (samples 36 - 41).

The sand becomes much coarser againg. About 20% is coarser than 250µ and the mode is around 180µ. The sand is fairly well sorted and unimodal (curves 36 - 39). Towards the top, the suspention fraction increases to a heavy clay. The sand retains its same characteristics. The energy of transporting currents remains equal, but the sedimentation of suspention material increases. It can be explained by a diminishing wave activity in a deeper sea.

b) Outcrop (Fig. 3).

In order to construct the sea-lock, a pit was dug along the canal Brussels - Rupel. In this temporary outcrop, about 3,75 m of Tertiary deposits could be observed beneath a Quaternary alluvium of 15 m thickness.
The Tertiary deposits have been sampled every 0,25 m. The 15 samples are registered in the sample book of the Micropaleontological Laboratorium of the K.U.LEUVEN under the numbers B140 to B154.
In the lowermost 1,25 m of the pit, a silty homogeneous calcareous and more or less glauconitic sand was visible. Small clay lenses have been observed in the sand between 1,25 m and 1,5 m above the base of the pit. The silty sand contains nummulites. Higher up, between 1,5 m and 2,25 m, a sandy and very glauconitic clay, rich in molluscs and nummulites can be found. Nummulites still occur in the lower part of the less glauconitic, more compact clay between 2,25 m and 3,75 m above the base of the pit.

4. Lithostratigraphy.

a) Lede Formation

GULINCK (1971) recognized in well n° 28 the "Ledian" in the interval between -36,5 m and -27,6 m. A more detailed analysis however shows that the fine calcareous sand and calcareous sandstone from samples 20 and 21 can be included in the Lede Formation. The coarse heterogeneous sand from sample 23 between -26,5 m and -26 m in the well, corresponds to the basal gravel of the Wemmel transgression.
The basal gravel of the Lede Formation (KAASSCHIETER, 1961) contains coarse quartz grains and many reworked nummulites. Higher up, in samples 2 to 6 from well n° 28 at Zemst, a fine calcareous sand has developed. On top of this, a first sandy limestone bed occurs. This part of the section corresponds to the former "Laekénien s.s." of RUTOT (1878). A second pebble bed with nummulites is observed in sample 7. It corresponds to the reoccurrent basal gravel of the Lede transgression. Above this reoccurrent basal gravel, the Lede Sands consist of ill sorted calcareous sands. Three thin sandy limestone beds occur in the middle part of the Lede Sands.
In the upper part of these Sands, a very fine heteromorf sandlayer has developed. The fine sediment is partly obdurated to a calcareous sandstone (samples 20 and 21).

b) Asse Formation

The formal lithostratigraphic name "Asse Formation" is introduced by KAAS-SCHIETER (1961). Three members are distinguished : the Wemmel Sands, the Asse Clay and the Asse Sands.
In well n° 28 at Zemst, the Wemmel Sands and the Asse Clay are developed.

- Wemmel Sands Member (-27,1 m -20,5 m)

The coarse sediment from sample 22 corresponds to the basal gravel of the Wemmel transgression.
Between -26 m and -20,5 m in well n° 28, the Wemmel Sands consist of silty homogeneous, calcareous and glauconitic sands with nummulites.
In the temporary outcrop, the upper part of the Wemmel Sands could be observed (samples 1-6). It comprises a silty homogeneous calcareous and glauconific sand. Clay lenses are intercallated in the uppermost part of the Wemmel Sands.

- Asse Clay Member

The coarse glauconitic clayey sand with molluscs (Pecten corneus) and nummulites, developed between -20,5 m and -17 m in well n° 28, corresponds to the Asse Clay Member. In the temporary outcrop, this "Bande Noire" is about 1m thick (samples 7 to 9).
Above this glauconite rich layer, the sandy Asse Clay becomes more compact.
The Asse Clay Member is overlain by a Pleistocene deposit.

5. Quantitative distribution of the benthonic foraminifera. (Tables 1 and 2)

After treatment with H_2O_2, the sediment was sieved. Countings of 200 specimens per sample have been made in the sieve fractions larger than 125 micron. Altogether 97 species and subspecies were recognized. In tables 1 and 2, the frequencies of the taxa reaching 5% of the foraminiferal assemblage in one or more samples are indicated.

Well n° 28 at Zemst.

- Levels 1 - 21 (Lede Formation).

This interval is characterized by a number of species with distinct fluctuations in the quantitative distribution. Five different characteristic assemblages can be distinguished.

- Level 1.

The foraminiferal population in this sample is characterized by the dominant occurrence of broken Miliolacea and of Quinqueloculina carinata. It is typical for this assemblage that no other taxa are of significant importance.

- Levels 2 - 6.

The frequencies of the broken Miliolacea and of Quinqueloculina carinata decrease distinctly in favour of some other taxa such as Triloculina angularis, Cibicides tenellus tenellus, Reusella limbata, Bifarina selseyensis, Rotalia propingua and a few frequently occurring taxa as Textularia agglutinans and Globulina gravida gravida. Within this interval the frequency of Triloculina angularis decreases upwards, while those of Bifarina selseyensis and Rotalia propingua increase. Reussella limbata, Textularia agglutinans and Globulina gravida gravida occur more constantly. Remarkable is the fact that the frequency of Cibicides tenellus tenellus changes in an opposite way to that of the broken Miliolacea.

- Levels 7 - 10.

After the increase of the broken Miliolacea and of Quinqueloculina carinata in level 7, which is followed again by the increase of Triloculina angularis in the lower part of the interval, their frequencies in higher levels decrease. Remarkable is the fact that the limited occurrence of those taxa is compensated by other taxa than those in the samples 2 to 6. Instead of Cibicides tenellus tenellus, Bifarina selseyensis and Rotalia propingua, especially Globulina gibba gibba and Asterigerina bartoniana occur, and partly or less distinctly Reussella limbata, Textularia agglutinans, Globulina gravida gravida and Guttulina irregularis.

- Levels 11 - 19

In this interval the frequencies of broken Miliolacea and of Quinqueloculina carinata gradually increase. As in samples 2 - 6, the frequency of Cibicides tenellus tenellus, which becomes important again, changes in the opposite way to this of the Miliolacea. Another important fact is the distinct appearance of Spiroloculina tricarinata belgica.
A number of taxa as f.i. Reussella limbata, Bifarina selseyensis, Globulina gravida gravida, Globulina gibba gibba, Guttulina irregularis, Rotalia propingua and Asterigerina bartoniana occur fairly constantly, but less frequently than before.

- Levels 20 - 21.

In the fine heteromorf sand, developed at the top of the Lede Sands, a particular foraminiferal assemblage occurs. Some taxa, occurring in samples 11 to 19, still occur in nearly the same frequencies : Spiroloculina tricarinata belgica, Globulina gravida gravida and Asterigerina bartoniana. On the other hand, a renewal of the foraminiferal population is observed. Textularia agglutinans, Planulina burlingtonensis, Bolivina anglica and Nonion affine reappear.

- Levels 22 - 35 of well n° 28 and levels 1 - 6 of the outcrop. (Wemmel Sands Member).

In this interval a homogeneous assemblage of benthonic foraminifera is observed. It is characterized by the occurrence of Reussella limbata, Bifarina selseyensis, Textularia agglutinans, Planulina burlingtonensis, Bolivina anglica, Rotalia propingua, Asterigerina bartoniana, Cibicides tenellus crassus, Cibicides dutemplei and Nonion affine. However, the frequency of Asterigerina bartoniana strongly increases in sample 35.

- Levels 36 - 40 of well n° 28 and levels 7 - 15 of the outcrop (Asse Clay Member).

Asterigerina bartoniana and Cibicides dutemplei dominate the benthonic foraminiferal assemblage in the "Bande Noire". However, a renewal of the population is observed : Bolivina cookei, Loxostomum teretum and Cibicides pygmeus appear in the assemblage. This renewal is distinctly consolidated higher up. The frequency of Bolivina cookei increases and Trifarina wilcoxensis and Karreriella siphonella appear.
Some other taxa as Globulina gibba punctata, Spiroplectammina carinata deperdita, Cibicides lobatulus and less distinctly Globulina gibba gibba and Guttulina irregularis occur more frequently.

6. Paleoecological interpretation.

a) Introduction.

From studies on Recent benthonic foraminifera, we know that based on generic associations different biofacies can be distinguished. These associations are controlled by environmental features.
In studying fossil assemblages, problems arise concerning the validity of ecological criteria, known from studies on Recent assemblages. (WALTON, 1964) It could be possible that the adaptation to environmental circumstances changed through the geological time. It is considered however as unlikely that, during the Tertiary, generic distribution and mean population characters are significantly affected by changes in tolerance on specific levels.
In trying to explain the paleoecological factors determining the fluctuations in the associations of benthonic foraminifera in the studied sections, we consequently mainly used the distribution of the most frequently occuring genera in the population. Rarely occurring taxa are less important to explain the paleoecological circumstances, controlling the composition of the populations. Some species may occur in distinctly different environments, but preferably and thus more frequently in some of them (f.i. at a distinct depth). The depth distribution of some genera can slightly change from one area to another. Other changing ecological factors as f.i. temperature, salinity, turbidity, foot supply and kind of substrate can interfere with the depth at which a species preferably occurs.
Consequently, we can only try to indicate some trends in the depth distribution of the populations.

b) Paleoecological conclusions.

The distinct dominance of broken Miliolacea and of Quinqueloculina carinata in level 1 of the Lede Sands, reflects a typical near-shore or littoral facies (BANDY, 1964). Quinqueloculina especially dominates as euryhaline genus in this littoral facies, in which the salinity distinctly changes under the influence of run-off. In this turbulent environment, the thick walled miliolids are attached to coarse sand grains (PHLEGER, 1960).

It is typical for this biofacies that other smaller benthonic foraminifera survive with difficulty. This level marks the basal transgression layer of the Lede Formation.
The important enrichment of the foraminiferal assemblages in samples 2 - 6 reflects a changing environment. The more restricted occurrence of miliolids and the appearance of different other taxa indicate a deepening of the sea. In this slightly deeper sea Triloculina (Triloculina angularis), which is also euryhaline appears, but its frequency decreases upwards with increasing depth of the sea. Cibicides (Cibicides tenellus tenellus) becomes the dominant genus, but the faunal dominance is lower in this inner shelf zone than in the littoral environment observed below. The faunal variability however becomes larger in this inner shelf zone : Reussella, Bifarina and Rotalia occur. The new increase in miliolids in level 7 corresponds to the reoccurrence of the basal transgression layer. Again, Triloculina reaches its maximum frequency after the decrease of the miliolids. It disappears nearly completely with the new increasing depth of the sea. Asterigerina becomes the dominant genus in level 10, which indicates a more stable salinity in an inner to central shelf zone (BANDY, 1964). At this depth the faunal dominance is lower than before the reoccurrence of the basal transgression layer.
In this environment the morphological simple agglutinated Textularia occurs more frequently (BANDY, 1964).
The gradual increase of the miliolids in the interval 10- 19 reflects a regression of the sea. The distinct appearance on the euryhaline Spiroloculina also indicates a more distinctly changing salinity. In this inner shelf environment with ill sorted sediments, the frequencies of other genera as f.i. Asterigerina and Textularia decrease.
Cibicides, which dominates the foraminiferal population when the regression starts, is gradually superseded by the miliolids, with the decreasing depth of the sea. Remarkable is the renewal of the foraminiferal assemblages in the fine sediment, observed in samples 20 and 21. A mixture of the foraminiferal associations from the upper part of the Lede Sands and from the Wemmel Sands is observed. The definitive transgression of the Wemmel sea is indicated by the presence of a coarser sediment in level 22. The foraminiferal populations are remarkably constant in the interval 22 - 36. The diversity of the faunal association is distinctly higher than before.
Agglutinated and calcareous perforated foraminifera coexist. Textularia and Asterigerina occur again more frequently. Those revivals are due to a more silty sedimentation, with periodical turbidities, and to the more stable salinity in the inner to central shelf zone. In this central shelf zone the coarsely perforate planispiral Planulina (BANDY, 1964) occurs as well.
The presence of non-striated Bolivina (B. anglica) is another typical feature of the population at this depth (BANDY, 1964).
Agglutinated foraminifera with more complex morphological features such as Spiroplectammina and Karreriella (with siphonate aperture) occur preferably at greater depth in the sea (BANDY, 1964). Their frequencies increase in the Asse Clay. In the central to outer shelf zone Bolivina species with striate surface (BANDY, 1964), Trifarina and Loxostomum occur.

Part 2 : Quantitative distribution of benthonic foraminifera recorded from the Middle Eocene Brussels and Lede Formations at Haasrode and Nederokkerzeel (Belgium).

1. Summary.

Benthonic foraminifera are recorded from two sandpits. The first is situated at Haasrode, where the Brussels sands are outcropping ; the second is situated at Nederokkerzeel (locality map in fig. 1.).
In this second one, the Brussels Sands are overlain by the Lede Sands.
The quantitative distribution charts of the benthonic foraminifera recorded from the Brussels Sands at Haasrode show a homogeneous association.
At Nederokkerzeel, vertical fluctuations in the foraminiferal assemblages are observed. In the Lede Sands, a typical population of benthonic foraminifera occurs. A paleoecological interpretation of the different associations is worked out.

2. Description of the sections and lithostratigraphy.

a) Haasrode.

In this sandpit, two profiles have been sampled : H_1 and H_2, about 15 m apart (fig. 4). In both sections, a calcareous, slightly glauconitic yellow sand has developed. This fairly homogeneous sand shows a fine lamination. At different levels, sandstone beds are intercalated. Especially in profile H_2, the sand is clayey in the lower part of the section. Thin clay lenses have developed here. On top of profile H_1, a bed about 20 cm thick and rich in molluscs, occurs. The sands outcropping in this sandpit correspond to the Brussels Formation.

b) Nederokkerzeel.

In this sandpit, three different profiles have been sampled : N_1, N_2 and N_3 (fig. 5).
In the lowermost 4 m of N_1 and at the base of the N_2 and N_3 sections, a homogeneous, calcarous yellow sand has developed. This sand is rich in molluscs. Thin sandstone beds occur in the N_1 profile.
Higher up in the N_1 profile, a gully-like structure has developed.
This structure is filled up with a white sand which is especially rich in molluscs in the upper part.
This sand is about 2 m thick in the studied profile.
This part of the studied sections corresponds to the Brussels Formation.

Above the Brussels Sands, a coarse sandstone layer about 25 cm thick and rich in reworked nummulites and fish-teeth, has developed. It corresponds to the basal layer of the Lede transgression. Higher up, the Lede Sands are white in color and they contain scarse shell fragments.

3. Quantitative distribution of the benthonic foraminifera.

Countings of 200 specimens per sample have been made in sieve fractions = larger than 74 micron. The frequencies of taxa, representing at least 2% of the foraminiferal population in one or more samples, are indicated in tables 3-9.

a) Haasrode.

The Quantitative distribution charts of benthonic foraminifera recorded from the Brussels Sands at Haasrode, show a homogeneous assemblage in the studied profiles. The population is dominated by Cibicides, especially C. westi, C. tallahatensis and C. tenellus tenellus. Less frequently, but also constantly Elphidium laeve and Hanzawaia boueana occur.

b) Nederokkerzeel.

- Brussels Sands

The foraminiferal populations in the Brussels Sands at Nederokkerzeel show distinct fluctuations.
Within the Brussels Sands, the assemblages are dominated by Cibicides. However Elphidium laeve and Hanzawaia boueana also occur constantly but less frequently. Within the genus Cibicides C. tenellus tenellus dominates in samples N_1 1-14. Higher up its frequency decreases and C. tallahatensis increasingly dominates the population. C. tenellus tenellus however occurs again more frequently in the upper part of the Brussels Sands in profile N_1 (samples N_1 19-21).

- Lede Sands

A distinct enrichment of the foraminiferal assemblage is observed in the Lede Sands. Besides the appearance of f.i. Asterigerina, Bifarina selseyensis, Bolivina anglica, Reussella limbata, Reussella terquemi, Rotalia audouini and Textularia agglutinans, the revival of Miliolacea is especially important. Cibicides carinatus occurs more frequently, while other Cibicides species become less important in the foraminiferal assemblage.

4.Paleoecological conclusions.

The benthonic foraminiferal assemblages recorded from the Brussels Sands are characterized by a remarkably dominant occurrence of Cibicides.
At Haasrode, C. westi is the dominating species. In the lower part of the N_1 profile at Nederokkerzeel, C. tenellus tenellus dominates, while higher up, C. tallahatensis becomes more important. According to BANDY (1960), the dominant occurrence of Cibicides is characteristic of a central shelf zone, where hyaline calcareous foraminifera most frequently occur at moderate temperature and salinity. In the central shelf zone, the occurrence of Cibicides is favoured by the large amount of sea-weed and shells of molluscs to which Cibicides is attached.
The enrichment of the foraminiferal assemblages in the Lede Sands and especially the important occurrence of Miliolacea are explained by the littoral to inner shelf environment, marking the transgression on the Lede sea.

Part 3 : Quantitative distribution of the benthonic foraminifera recorded from the Lower Eocene Ieper Formation at Egem (Belgium).

1. Summary.

Quantitative countings have been made of the benthonic foraminifera recorded from the Flanders Clay and Mons-en-Pévèle Sands, outcropping in the Ampe clay- and sandpit at Egem. The vertical fluctuations in the quantitative distribution of the benthonic foraminifera reflect a gradual regression of the sea.

2. Description of the Ampe clay and sandpit at Egem (figs. 1 and 6).

In the lowermost part of this quarry, a compact plastic micaceous gray clay is visible over about 2,5 m. Above this clay, a bed very rich in nummulites occurs (sample A7). It is succeeded by alternating beds of micaceous silts and clays (samples A8 - A12). Shell fragments occur frequently above the first clay bed (sample A10).
Higher up, a fine grained micaceous and glauconitic silty sand with two beds rich in nummulites (samples A13 and A15) has developed (samples A13 - A18). Molluscs occur frequently higher up in this silty complex (sample A17).
On top of this complex a coarser sand layer with cross lamination and a bed very rich in molluscs occurs.
In the uppermost part of the section, a sandstone layer has developed.

3. Lithostratigraphy.

The compact micaceous gray clay in the lower part of the quarry corresponds to the Flanders Clay. The alternating beds of silts and clays are considered to be the gradual transition from the Flanders Clay to the Mons-en-Pévèle Sands. In the silty Mons-en-Pévèle Sands different beds with molluscs and nummulites occur.
These Mons-en-Pévèle Sands are covered in the Ampe clay-and sandpit by the Panisel Formation, the thickness of which is however very restricted here.

4. Quantitative distribution of the benthonic foraminifera in the Ampe clay and sandpit.

After treatement with H_2O_2, the sediment was sieved. Countings of 200 specimens per sample were made in the sieve fractions larger than 74 micron.

The foraminifera were concentrated by the CCL_4 method in view of the fact that these samples were extremely poor in foraminifera.
The quantitative frequencies of the benthonic foraminifera are indicated in tables 10 and 11.
The distribution charts of the benthonic foraminifera, recorded from the Ampe quarry, show distinct fluctuations in the foraminiferal assemblages. Generally, three different associations can be distinguished.

a) Levels A1 - A3.

The foraminiferal populations of the Flanders Clay are remarkably dominated by Cibicididae. In sample A1, they even constitute 74% of the whole assemblage, especially with C. tenellus tenellus (20%), C. proprius (18%), C. lobatulus (10%), and less frequently, C. carinatus and C. westi.
Noniodidae are also well represented, especially with N. scaphum (6%) and N. affine (5%).
Higher up, the frequency of Cibicididae decreases (45% in sample A2, 42% in sample A3) in favour of Nonionidae (30% in sample 23% in sample A3).
The frequency of Polymorphinidae, especially with Guttulina irregularis, Globulina gibba gibba and Globulina gravida gravida, increases gradually to 20% in level A3.

b) Levels A7 - A11.

Cibicididae (about 45%) and Nonionidae (about 20%) still dominate the association. Cibicides westi however is recorded only from sample A10, while Cibicides carinatus disappears completely. The frequency of Cibicides lobatulus increases to about 23% in sample A10. Polymorphinidae, still important in sample A7, decrease distinctly higher up in this interval, while especially Bolivinidae, with B. anglica (19% in level A9), Buliminidae, with B. parisiensis (9% in sample A9) and Elphidiidea, with E. laeve (10% in sample A11) become more important.

c) Levels A13 - A17.

The frequencies of Cibicididae increase distinctly (65% in sample A15).
C. lobatulus gradually becomes more important in the foraminiferal assemblage, while C. proprius occurs less frequently. The Nonionidae also occur less frequently in favour of Elphidiidae in the lower part and Rotaliidae in the upper part of this interval.

5. Paleoecological conclusions.

According to PHLEGER (1960), the benthonic foraminiferal assemblage observed in samples A1 - A3 occurs typically in a central shelf zone, with moderate temperature and constant salinity. The increase in Buliminidae and Elphidiidae, observed in samples A7 - A11 can be explained by the shallowing of the water. The regression of the sea continues. This is indicated by the more frequent occurrence of Elphidiidae and Rotaliidae in the upper part of the Mons-en-Pévèle Sands.

Part 4 : Quantitative distribution of the benthonic foraminifera recorded from the Eocene Panisel Formation and Asse Formation at Zeebrugge (Belgium)

1. Summary.

This contribution deals with the quantitative distribution of benthonic foraminifera recorded from the Panisel Formation and the Asse Formation at Zeebrugge (locality map in fig. 1). Within the Panisel Formation, three different associations of benthonic foraminifera are recognized. The succeeding characteristic populations indicate a gradual regression of the sea. Within the Asse Formation they reflect a greater sea depht subsequently followed by a shallowing of the water.

2. Introduction.

In prospecting the construction of a new seaport at Zeebrugge, a few wells have been made to explore the subsoil (fig. 7). The Belgian Geological Survey provided us with samples from some of them in order to study the quantitative distribution of the benthonic foraminifera in the striked Tertiary deposits. Samples have been studied from wells n° 235 (B5), n° 237 (B8), n° 239 (B10) and n° 240 (B11).

3. Lithostratigraphy.

a) Panisel Formation.

The Panisel Formation was studied in well n° 235 (B5) and n° 237 (B8). In the lower part, silty clays rich in shell fragments have developed. The silty glauconitic sand higher up is less fossiliferous. The tickness of the observed sandstone beds varies (max. 1 m in well n° 235).

b) Asse Formation.

The Asse Formation is studied in wells n° 239 (B10) and n° 240 (B11). Two members of this formation can be distinguished : the Wemmel Sands Member and the Asse Clay Member.
At the base of the Wemmel Sands, a small gravel bed is developed. (B11). It contains black gravel pebbles and reworked nummulites. The Wemmel Sands consist of homogeneous calcareous glauconitic silty sands.

In the wells at Zeebrugge, the transition between the Wemmel Sands Member and the Asse Clay Member is very distinct due to the presence of the "Bande Noire" at the base of the Asse Clay (B10, B11). This "Bande Noire" is very rich in glauconite and contains a lot of nummulites and molluscs.
The Asse Clay itself is a greenish gray, glauconitic and less fossiliferous clay.

4. Quantitative distribution of the benthonic foraminifera.

After treatment with H_2O_2, the sediment was sieved. Countings of 200 specimens per sample were made in the sieve fractions larger than 74 micron.
The foraminifera were concentrated by the CCL_4 method in the samples of the Panisel Formation , this view of the fact that these samples are extremely poor in foraminifera.
The quantitative distributions of the benthonic foraminifera are given in tables 12 - 19.

a) Panisel Formation.

The quantitative distribution of the benthonic foraminifera in the Panisel Formation shows three distinctly different assemblages within this unit.

- Levels 19 - 20 from well n° 235 (B5).

This interval is characterized by a frequent occurrence of Polymorphinidae (32%), especially with Globulina gibba gibba and Guttulina irregularis. Nodosariidae (13%), especially with Lagena hexagona occur less frequently. Cibicididae (11% in level 19 and 36% in level 20), Anomalinidae (10%) especially with Hanzawaia producta and Discorbidae (11% in level 19) are also important.

- Levels 21 and 22 from well n° 235 (B5).

The foraminiferal population is characterized by important revivals of Textulariidae (T. agglutinans) and Eponididae (E. schreibersi), each representing 20% of the assemblage. Polymorphinidae, Anomalinidae and Discorbidae are insignificant or even completely absent.
Cibicides tenellus tenellus distinctly dominates within the Cibicides group. The occurrence of Nodosariidae remains constant.

- Level 23 from well n° 235 (B5).

Remarkable in this assemblage is the distinct appearance of Miliolidae (20%), with Quinqueloculina seminula and Q. impressa. Elphidiidae (18%), Rotaliidae (Ammonia beccarri, 15%), Textulariidae (7%), Nodosariidae (9%), Eponidae (5%) and Cibicididae occur less frequently. C. tenellus tenellus disappears completely.

b) Asse Formation.

- Levels 31 and 32 from well n° 239 (B10), and levels 38 - 41 from well n° 240 (B11) (Wemmel Sands Member).

In the Wemmel Sands Member, the foraminiferal population comprises especially Cibicididae, Bolivinidae, Uvigerinidae, Bagginidae, Discorbidae, Asterigerinidae, Eponididae and Nonionidae, without dominance of one or more of these groups. This population is consequently more diversified.

- Level 33 from well n° 239 (B10) and levels 42 - 43 from well n° 240 (B11) (Bande Noire).

Typical of the benthonic foraminiferal assemblage in the "Bande Noire" at the base of the Asse Clay Member is the fairly high frequency of Textulariidae (15 to 20%) and the occurrence of f.i. Uvigerinidae, Bolivinidae and Bagginidae.

- Levels 34 - 35 from well n° 239 (B10) and levels 44 - 46 from well n° 240 (B11).

The high frequencies of Bolivinidae and Uvigerinidae are especially important in this assemblage. Trifarina muralis, occurring in the Wemmel Sands and in the "Bande Noire" disappears and is replaced by Trifarina wilcoxensis.

- Levels 36 - 37 from well n° 239 (B10) and level 47 from well n° 240 (B11).

A renewal of the foraminiferal population is observed. Ammonia beccarii, Elphidium minutum and Cibicides westi appear. The frequencies of other taxa as f.i. Bolivina anglica, Cancris subconicus and Trifarina wilcoxensis decrease distinctly.

5. Paleoecological conclusions.

a) Panisel Formation.

According to BANDY (1960) and PHLEGER (1960), a benthonic foraminiferal population as observed in levels 19 and 20 from well n° 235 is characteristic of a central shelf zone. The revival of E. schreibersi in levels 21 and 22 reflects a regression of the sea. BANDY (1960) noted that this species preferably occurs at a depth of -50 m. The important occurrence of Textulariidae could be explained by periodical turbidities in this environment, where silty sediments accumulated. The distinct revivals of Miliolidae, Elphidiidae and Rotaliidae reflect a continuing regression of the sea (PHLEGER, 1960). In this more littoral environment Textulariidae, Nodosariidae, Eponididae and Cibicididae occur less frequently.

b) Asse Formation.

The presence of, in particular Bolivinidae, Uvigerinidae and Bagginidae in the Wemmel Sands, can be explained by the fact that these sands are deposited in a central shelf zone (PHLEGER, 1960).
In the "Bande Noire" Spiroplectammina deperdita as morphological more complex agglutinated species appears. This is due to the increasing depth of the sea. The increasing frequencies of Bolivinidae and Uvigerinidae in the Asse Clay are typical of a considerably deep sea. At this greater depth, Trifarina muralis is replaced by the competitive species T. wilcoxensis. The appearance of Ammonia beccarii and of Elphidium minutum however suggests a shallowing of the water. From this it may be concluded that the upper part of the Asse Clay Member in this locality has deposited in a less deep sea.

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Systematics.

Superfamily Lituolacea DE BLAINVILLE, 1825

Family Textulariidae EHRENBERG, 1838
Subfamily Spiroplectammininae CUSHMAN, 1927
Genus Spiroplectammina CUSHMAN, 1927
Spiroplectammina carinata deperdita CUSHMAN, 1927
+ 1846 Textularia deperdita d'Orbigny - d'ORBIGNY, p. 244, pl. 14, figs. 23 - 25.
v 1961 Spiroplectammina carinata (d'ORBIGNY) var. deperdita d'ORBIGNY - KAASSCHIETER, p. 140, pl. 1, fig. 19.
1974 Spiroplectammina deperdita (d'ORBIGNY) - MURRAY & WRIGHT, p. 121, pl. 1, figs. 4 - 5.

Remarks : As observed by KAASSCHIETER, the median ridge of our deperdita specimens varies from broad and granulated to narrow and smooth. Sp. carinata carinata (d'ORBIGNY, 1846), which differs from Sp. carinata deperdita by the dentate to spinose keeled periphery, has not been observed in our material.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Ieper Formation : Flanders Clay Member

Subfamily Textulariinae EHRENBERG, 1838
Genus Textularia DEFRANCE, 1824
Textularia agglutinans d'ORBIGNY, 1839
+ 1839 Textularia agglutinans d'Orbigny - d'ORBIGNY, p. 144, pl. 1, figs. 17, 18, 32, 33, 34
v 1961 Textularia agglutinans d'Orbigny - d'ORBIGNY, p. 144, pl. 1, figs. 14 - 16.
1974 Textularia agglutinans d'Orbigny - MURRAY & WRIGHT, p. 121, pl. 1, figs. 7 - 8.

Remarks : Besides typical specimens with elongated test, nearly horizontal sutures and slightly inflated chambers, smaller individuals with more compressed test and divergent sides occur.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation.
Panisel Formation.

Family Ataxophragmiidae SCHWAGER, 1877
Subfamily Globotextulariinae CUSHMAN, 1927
Genus Karreriella CUSHMAN, 1933
Karreriella siphonella (REUSS, 1851)
+ 1851 Gaudryina siphonella n. sp. - REUSS, p. 78, pl. 5, figs. 40 - 42.
v 1961 Karreriella siphonella (Reuss) - KAASSCHIETER, p. 143, figs. 21 - 23.

Remarks : Both chilostoma type (with more inflated chambers and coarser agglutinated wall) and siphonella type occur in our material.

Besides the conical microsferic form, the megalosferic form with rather parallel sides is also observed.
In the megalospheric form, the initial triserial part of the test is more restricted than in the microspheric form.

Occurrence : Asse Formation : Wemmel Sands Member and Asse Clay Member.

Superfamily Miliolacea EHRENBERG, 1839

Miliolacea undet. spp.

Remarks : A lot of broken Miliolacea individuals occur. They could not be determined as species. Mostly, they represent specimens of Quinqueloculina, but, though less frequently, also of Spiroloculina and Triloculina. In order to avoid a too subjective identification, these broken individuals are generally considered as "Miliolacea".

Occurrence : Asse Formation : Wemmel Sands Member
Lede Formation
Brussels Formation

Family Nubeculariidae JONES, 1875
Subfamily Spiroloculininae WIESLER, 1920
Genus Spiroloculina d'ORBIGNY, 1826
Spiroloculina canaliculata d'ORBIGNY, 1846
\+ 1846 Spiroloculina canaliculata d'Orbigny - d'ORBIGNY, p. 269, pl. 16, figs. 10 - 12
v 1961 Spiroloculina canaliculata d'Orbigny - KAASSCHIETER, p. 154, pl. 3, figs. 20 - 23.

Remarks : Some of our specimens resemble S. obscura CUSHMAN & TODD, 1944, with less distinct sutures and with chambers which increase more rapidly in size.

Occurrence : Lede Formation

Spiroloculina tricarinata belgica KAASSCHIETER, 1961
v + 1961 Spiroloculina tricarinata Terquem var. belgica, nov. var. KAASSCHIETER, p. 153, pl. 3, figs. 12 - 14

Remarks : Our specimens mostly have a well rounded periphery.

Occurrence : Asse Formation : Wemmel Sands Member
Lede Formation.

Spiroloculina tricarinata tricarinata TERQUEM, 1882
\+ 1882 Spiroloculina tricarinata Terq.(part) - TERQUEM, p. 158, pl. 16, figs. 19 - 20.
v 1961 Spiroloculina tricarinata Terquem - KAASSCHIETER, p. 153, pl. 3, fi figs. 9 - 11.

Remarks : Most of our specimens have three well developed peripheral keels. Transitional forms to Sp. tricarinata belgica KAASSCHIETER, 1961 with a rounded periphery occur as well.

Occurrence : Asse Formation : Wemmel Sands Member
Lede Formation.

Family Miliolidae EHRENBERG, 1839
Subfamily Quinqueloculininae CUSHMAN, 1947
Genus Quinqueloculina d'ORBIGNY, 1826
Quinqueloculina carinata d'ORBIGNY, 1850
+ 1850 Quiqueloculina carinata d'Orbigny - d'ORBIGNY, p. 410, fide ELLIS & MESSINA)
v 1961 Quinqueloculina carinata d'ORBIGNY - KAASSCHIETER, p. 147, pl. 2, figs. 9 - 11.
1974 Quinqueloculina carinata d'ORBIGNY - MURRAY & WRIGHT, p. 120, pl. 2, figs. 13 - 15.

Remarks : The cross section of the test of our specimens is more or less distinctly triangular, but we did not observe a clear transition to Q. lamarckiana d'ORBIGNY, 1839, which has very acute triangular cross-section.
Specimens with a more angular periphery resemble Q. ludwigi REUSS, 1866.

Occurrence : Asse Formation : Wemmel Sands Member
Lede Formation
Brussels Formation.

Quinqueloculina crassa d'ORBIGNY, 1850
+ 1850 Quinqueloculina crassa d'Orbigny - d'ORBIGNY, p. 409
v 1961 Quinqueloculina crassa d'ORBIGNY - KAASSCHIETER, p. 151, pl. 3, figs. 3a - c.
1970 Quinqueloculina crassa d'ORBIGNY - LE CALVEZ, p. 35, pl. 4, fig. 1

Remarks : Q. crassa differs from Q. grignonensis LE CALVEZ, 1947 because of the more subcircular test.

Occurrence : Lede Formation.

Quinqueloculina costata KARRER, 1867
+ 1867 Quinqueloculina costata Karrer - KARRER, p. 362, pl. 3, figs. 4a - c (fide ELLIS & MESSINA).
v 1961 Quinqueloculina costata KARRER - KAASSCHIETER, p. 150, pl. 2, figs. 17a - 18c.
1970 Quinqueloculina costata KARRER - LE CALVEZ, p. 34, pl. 3, figs. 7 - 8.
1974 Quinqueloculina costata KARRER - MURRAY & WRIGHT, pl. 3, figs. 1 - 3.

Remarks : In our specimens, the thickness and number of costae vary. Some specimens are difficult to distinguish from Q. juleana d'ORBIGNY, 1846

Occurrence : Lede Formation.

Quinqueloculina impressa REUSS, 1851
+ 1851 Quinqueloculina impressa Reuss - REUSS, p. 87, pl. 7, fig. 59
v 1961 Quinqueloculina impressa REUSS - KAASSCHIETER, p. 151, pl. 3, fig. 4a - 6c
1974 Quinqueloculina impressa Reuss - MURRAY & WRIGHT, pl. 3, figs. 7 - 9.

Remarks : In our specimens, the sutures are less deeply depressed. A few specimens have a triloculine appearance since one side shows only two chambers.

Occurrence : Panisel Formation.

Quinqueloculina juleana d'ORBIGNY, 1846
+ 1846 Quinqueloculina juleana d'Orbigny - d'ORBIGNY, p. 298, pl. 20, figs. 1 - 3.
v 1961 Quinqueloculina juleana d'ORBIGNY - KAASSCHIETER, p. 149, pl. 2, figs. 14a - 15c.
1970 Quinqueloculina juleana d'ORBIGNY - LE CALVEZ, p. 36
1974 Quinqueloculina juleana d'Orbigny - MURRAY & WRIGHT, pl. 3, figs. 10 - 12.

Remarks : The elongated tests have a well developed neck and an angular periphery.

Occurrence : Lede Formation.
Brussels Formation.

Quinqueloculina seminula (LINNE, 1758)
+ 1758 Serpula seminulum Linnaeus - LINNE, p. 736 (fide ELLIS & MESSINA)
v 1961 Quinqueloculina seminula (LINNE) - KAASSCHIETER, p. 147, pl. 2, figs. 5a - 6c.
1970 Quinqueloculina seminulum (LINNE) - LE CALVEZ, p. 40, figs. 6 - 7.
1974 Quinqueloculina seminulum (Linne) - MURRAY & WRIGHT, pl. 2, figs. 19 - 21.

Remarks : Some specimens are difficult to distinguish from Q. ludwigi REUSS, 1866, which has a more elongated test and a well developed neck. Other individuals with a more angular periphery resemble Q. carinata (d'ORBIGNY, 1850). Specimens with more elongated tests resemble Q. vulgaris CUSHMAN, 1929.

Occurrence : Lede Formation.
Brussels Formation
Panisel Formation.

Quinqueloculina ludwigi REUSS, 1866
+ 1866 Quinqueloculina ludwigi Reuss - Reuss, p. 126, pl. 1, figs. 12a - c.

v 1961 Quinqueloculina ludwigi REUSS - KAASSCHIETER, p. 148, pl. 2, figs. 7a - 8c.
1970 Quinqueloculina ludwigi REUSS - LE CALVEZ, p. 37, pl. 4, figs. 2 - 3.
1974 Quinqueloculina ludwigi Reuss - MURRAY & WRIGHT, pl. 3, figs. 13 - 15.

Remarks : Sometimes it is difficult to distinguish this species from Q.seminulum (LINNE, 1758) which normally has a more prolonged test and an apertural neck. Transition forms are found in our material.

Occurrence : Lede Formation
Brussels Formation.

Quinqueloculina striata d'ORBIGNY, 1843
1826 Quinqueloculina striata d'Orbigny - d'ORBIGNY, p. 301 (nom. nud.)
\+ 1843 Quinqueloculina striata d'Orbigny - GUERIN - MENEVILLE, p. 10, pl. 3, figs. 10a - b (fide ELLIS & MESSINA)
v 1961 Quinqueloculina striata d'ORBIGNY - KAASSCHIETER, p. 151, pl. 3, figs. 1a - 2c.
1970 Quinqueloculina striata d'ORBIGNY - LE CALVEZ, p. 41, pl. 3, fig. 5.

Remarks : As mentioned by KAASSCHIETER (1961) , this species differs from Q. costata KARRER, 1876 by its less elongated test with more and finer costae.
Only a few specimens of our material could be distinctly classified under this species.

Occurrence : Lede Formation

Genus Triloculina d'ORBIGNY, 1826
Triloculina angularis d'ORBIGNY, 1850
\+ 1850 Triloculina angularis d'Orbigny - d'ORBIGNY, p. 409
v 1961 Triloculina angularis d'ORBIGNY - KAASSCHIETER, p. 166, pl. 5, fig. 15.
1970 Triloculina angularis d'ORBIGNY - LE CALVEZ, p. 49, pl. 13, fig. 9.
1974 Triloculina angularis d'Orbigny - MURRAY & WRIGHT, pl. 4, figs. 4 - 5.

Remarks : Besides more typical specimens with slightly elongated tests, individuals, the width and length of which are equal in size occur.
We did not observe specimens with a more subangular cross-section as has T. trigonula (LAMARCK, 1804), instead of a triangular one, typical of T. angularis.
Specimens with a more rounded periphery resemble T. gibba d'ORBIGNY, 1846.

Occurrence : Lede Formation.

Triloculina gibba d'ORBIGNY, 1846
+ 1846 Triloculina gibba d'Orbigny - d'ORBIGNY, p. 274, pl. 16, figs. 22 - 24.
v 1961 Triloculina gibba d'ORBIGNY - KAASSCHIETER, p. 165, pl. 5, figs. 12a - 14c.
1970 Triloculina gibba d'ORBIGNY - LE CALVEZ, p. 49, pl. 8, figs. 3 - 4.

Remarks : Specimens with more inflated chambers resemble T. trigonula (LAMARCK, 1804).

Occurrence : Lede Formation.

Superfamily Nodosariacea EHRENBERG, 1838

Family Nodosariidae EHRENBERG, 1838

Subfamily Nodosariinae EHRENBERG, 1838

Genus Lagena WALKER & JACOB, 1798

Lagena hexagona (WILLIAMSON, 1848)

+ 1848 Entosolenia squamosa (Montagu) var. hexagona Williamson - Williamson, p. 20, pl. 2, fig. 23 (fide ELLIS & MESSINA).

1974 Lagena hexagona (Williamson) - MURRAY & WRIGHT, p. 119.

Remarks : The size of the hexagonal pattern of ribs varies in our specimens. A few specimens have a less distinct hexagonal pattern of ribs. They resemble L. squamosa (MONTAGU, 1803).

Occurrence : Brussels Formation
Panisel Formation
Ieper Formation : Mons-en-Pévèle Sands Member

Family Polymorphinidae d'ORBIGNY, 1839

Subfamily Polymorphininae d'ORBIGNY, 1839

Genus Globulina d'ORBIGNY, 1839

Globulina gibba gibba d'ORBIGNY, 1826

+ 1826 Globulina gibba Nob. - d'ORBIGNY, p. 266, Mod. n° 63.

1846 Globulina gibba d'Orbigny - d'ORBIGNY, p. 277

v 1961 Globulina gibba (d'ORBIGNY) - KAASSCHIETER, p. 183, pl. 7, figs. 6 - 7.

1970 Globulina gibba d'ORBIGNY - LE CALVEZ, p. 84, pl. 17, figs. 3 - 4.

1974 Globulina gibba (d'Orbigny) - MURRAY & WRIGHT, p. 118.

Remarks : The size of the central chamber varies in our material. This results in a variable outline of the test. Specimens with more compressed tests resemble G. inaequalis (REUSS, 1850).

Occurrence ; Asse Formation : Asse Clay Member, Wemmel Sands Member.
Lede Formation
Panisel Formation
Ieper Formation : Mons-en-Pévèle Sands Members Flanders Clay Member.

Globulina gibba punctata d'ORBIGNY, 1846

+ 1846 Globulina punctata d'ORBIGNY - d'ORBIGNY, p. 229, pl. 13, figs. 17 - 18.

1846 Globulina rugosa d'Orbigny - d'ORBIGNY, p. 229, pl. 13, figs. 19 - 20.

1846 Globulina tuberculata d'Orbigny - d'ORBIGNY, p. 230, pl. 13, figs. 21 - 22.

v 1961 Globulina gibba (d'ORBIGNY) var. punctata d'ORBIGNY - KAASSCHIETER, p. 183, pl. 8, figs. 8 - 9.

Remarks : The kind of punctation varies. Specimens with punstations arranged in longitudinal rows represent the rugosa-type.
Individuals with coarse punctations represent the tuberculata type of d'ORBIGNY.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Lede Formation.

Globulina gravida (TERQUEM, 1878).
+ 1878 Guttulina gravida Terq. - TERQUEM, p. 47, pl. 4, figs. 28 - 32.
v 1961 Globulina gravida (TERQUEM) - KAASSCHIETER, p. 184, pl. 8, fig. 11.
1970 Globulina gravida (Terquem) - LE CALVEZ, p. 87.
1974 Globulina gravida (Terquem) - MURRAY & WRIGHT, p. 119.

Remarks : Specimens with a more rounded basal part of the test and deep sutures resemble G. ampulla (JONES, 1882) p. 267.
Some specimens from the Wemmel Sands and from the Asse Clay show a very indistinct, fine striation. They are considered to be transitional forms between this species and G. lineata (KAASSCHIETER, 1961).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Lede Formation.
Panisel Formation
Ieper Formation : Flanders Clay Member

Genus Guttulina d'ORBIGNY, 1839.
Guttulina irregularis d'ORBIGNY, 1846.
+ 1846 Guttulina irregularis d'Orbigny - d'ORBIGNY, p. 226, pl. 13, figs. 9 - 10.
v 1961 Guttulina irregularis (d'ORBIGNY) - KAASSCHIETER, p. 181, pl. 8, fig. 23.
1970 Guttulina irregularis (d'ORBIGNY) - LE CALVEZ, p. 92, pl. 20, fig. 3.

Remarks : Some variation is observed in the lenght/width proportion of the test as well as in the size of the last chamber. Specimens with a slightly elongated test resemble G. bulloides REUSS, as figured by BATHIA, 1955, p. 676, pl. 67, fig. 28.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Lede Formation.
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Guttulina lactea (WALKER & JACOB, 1798).
+ 1798 Serpula lactea Walker & Jacob - WALKER & JACOB, p. 634, pl. 14, fig. 4.
v 1961 Guttulina lactea (WALKER & JACOB) - KAASSCHIETER, p. 182, pl. 8, fig. 5.
1970 Guttulina lactea (WALKER & JACOB) - LE CALVEZ, p. 93

Remarks : Small specimens with a less distinct elongate test are rather difficult to distinguish from G. problema.

Occurrence : Lede Formation
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Guttulina problema d'ORBIGNY, 1846.
1826 Polymorphina (Guttulina) problema d'Orbigny - d'ORBIGNY, p. 266 (nom. nud.)
+ 1846 Guttulina problema d'Orbigny - d'ORBIGNY, p. 224, pl. 12, figs. 26 - 28.
v 1961 Guttulina problema (d'Orbigny) - KAASSCHIETER, p. 181, pl. 7, figs. 30 - 32, pl. 8, fig. 1.
1970 Guttulina problema d'ORBIGNY - LE CALVEZ, p. 94, pl. 19, fig. 4.
1974 Guttulina problema d'Orbigny - MURRAY & WRIGHT, p. 129.

Remarks : This species resembles G. austriaca, but it should have more typical elongated chambers and the bases of the secondary chambers are less embracing.

Occurrence : Panisel Formation
Ieper Formation : Flanders clay Member, Mons-en-Pévèle Sands Member.

Genus Pyrulina d'ORBIGNY, 1839
Pyrulina thouini (d'ORBIGNY, 1826)
Polymorphina gutta d'Orbigny - d'ORBIGNY, p. 167, pl. 12, figs. 5 - 6.
v 1961 Pyrulina thouini (d'ORBIGNY) - KAASSCHIETER, p. 185, pl. 8, figs. 13, 14.
1970 Pyrulina thouini (d'ORBIGNY) - LE CALVEZ, p. 97,
1974 Pyrulina thouini (d'Orbigny) - MURRAY & WRIGHT, p. 120.

Remarks : Specimens with a less elongate test resemble P. cylindroides (ROEMER, 1839).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member

Family Glandulinidae REUSS, 1860
Subfamily Oolinae LOEBLICH & TAPPAN, 1961
Genus Fissurina REUSS, 1850
Fissurina marginata (WALKER & JACOB, 1784).
+ 1784 Serpula marginata Walker & Boys - WALKER & JACOB, p. 2, pl. 1, fig. 7 (fide ELLIS & MESSINA).
v 1961 Entosolenia marginata (Walker & Boys) - KAASSCHIETER, p. 180, pl. 7, fig. 28.
1974 Fissurina marginata (Walker & Boys) - MURRAY & WRIGHT, p. 118, pl. 6, fig. 5.

Remarks : The width of the peripheral keel varies.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Panisel Formation.

Superfamily Buliminacea

Family Bolivinitidae CUSHMAN, 1927
Genus Bolivina d'ORBIGNY, 1939
Bolivina anglica CUSHMAN, 1936
+ 1936 Bolivina anglica Cushman - CUSHMAN, p. 50, pl. 7, fig. 11.
v 1961 Bolivina anglica CUSHMAN - KAASSCHIETER, p. 194, pl. 9, figs. 18-19.
1970 Bolivina anglica CUSHMAN - LE CALVEZ, p. 111.

Remarks : In our specimens, the height of the chambers in the later part of the test varies.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Bolivina carinata TERQUEM, 1882.
+ 1882 Bolivina carinata TER. - TERQUEM, p. 148, pl. 15, figs. 19a-b.
v 1961 Bolivina carinata TERQUEM -KAASSCHIETER, p. 193, pl. 9, figs. 12-14.
1970 Bolivina carinata TERQUEM - LE CALVEZ, p. 111, pl. 22, fig. 3.

Remarks : The lenght width proportion of the test varies.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Panisel Formation
Ieper Formation : Flanders Clay Member

Bolivina cookei CUSHMAN, 1922
+ 1922 Bolivina cookei Cushman - CUSHMAN, p. 126, pl. 29, fig. 1.
v 1961 Bolivina cookei CUSHMAN - KAASSCHIETER, p. 195, pl. VIII, figs. 25-26.

Remarks : The costae vary from thin and restricted in the earlier part of the test, to very distinct along the whole test.

Occurrence : Asse Formation : Asse Clay Member.

Bolivina crenulata CUSHMAN, 1936
+ 1936 Bolivina crenulata Cushman, n. sp. - CUSHMAN, p. 50, pl. 7, fig. 13.
v 1961 Bolivina crenulata CUSHMAN - KAASSCHIETER, p. 194, pl. 9, figs 15a-17b.
1970 Bolivina crenulata CUSHMAN - LE CALVEZ, p. 119, pl. 22, fig. 8
1974 Bolivina crenulata Cushman - MURRAY & WRIGHT, pl. 6, fig. 12.

Remarks : The sutures become indistinct at the crenulate basal part of the chambers.

Occurrence : Lede Formation.

Family Buliminidae JONES, 1875
Subfamily Bulimininae JONES, 1875
Genus Bulimina d'ORBIGNY, 1826
Bulimina parisiensis KAASSCHIETER, 1961
v + 1961 Bulimina parisiensis nov. nom. - KAASSCHIETER, p. 190, pl. 8, figs. 19a-c, pl. 9, figs. 3a-4c.
1970 Bulimina parisiensis KAASSCHIETER - LE CALVEZ, p. 118, pl. 21, fig. 4.

Remarks : Some specimens with a smaller last chamber resemble B. candita (TERQUEM, 1882).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Panisel Formation
Ieper Formation.

Subfamily Pavonininae EIMER & FICKERT, 1899
Genus Reussella GALLOWAY, 1933
Reussella limbata (TERQUEM, 1882).
≠ 1882 Reussella limbata Terq. - TERQUEM, p. 105, pl. 11, fig. 12
v 1961 Reussella limbata Terquem - KAASSCHIETER, p. 192, pl. 8, figs. 20-21.

Remarks : Some of our specimens have a less angular peripheral border. Other individuals show a peripheral keel which is interrupted by spines at the lower part of the test.

Occurrence : Asse Formation : Wemmel Sands Member,
Lede Formation.

Reussella terquemi CUSHMAN, 1945
+ 1945 Reussella terquemi Cushman, n. sp. - CUSHMAN, p. 28, pl. 5, figs. 15-16.
v 1961 Reussella terquemi CUSHMAN - KAASSCHIETER, p. 192, pl. 9, fig. 11.
1970 Reussella terquemi CUSHMAN - LE CALVEZ, p. 121, pl. 24, fig. 7.
1974 Reussella terquemi Cushman - MURRAY & WRIGHT, p. 121.

Remarks : Only a few specimens have distinctly developed spines at the base of the chambers.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Ieper Formation : Flanders Clay Member

Family Uvigerinidae HAECKEL, 1894
Genus Uvigerina d'ORBIGNY, 1826
Uvigerina farinosa HANTKEN, 1875.
+ 1875 Uvigerina farinosa Hantken - HANTKEN, p. 62, pl. 7, fig. 6 (fide ELLIS & MESSINA).
v 1961 Uvigerina farinosa HANTKEN - KAASSCHIETER, p. 196, pl. 9, fig. 21.

Remarks : All our specimens have a triserial test.

Occurrence : Asse Formation : Wemmel Sands Member,
Asse Clay Member.

Genus Trifarina CUSHMAN, 1923

Trifarina abbreviata abbreviata (TERQUEM, 1882)

+ 1882 Uvigerina abbreviata Terquem - TERQUEM, p. 120, pl. 12, fig. 33.
1970 Uvigerinella abbreviata (TERQUEM) - LE CALVEZ, p. 124, pl. 26, fig. 4.
1974 Uvigerinella abbreviata (Terquem) - MURRAY & WRIGHT, p. 122, pl. 7, fig. 6.

Remarks : According to the systematics of LOEBLICH & TAPPAN, this taxon belongs to Trifarina.

Occurrence : Ieper Formation.

Trifarina muralis (TERQUEM, 1882)

+ 1882 Uvigerina muralis Terq. - TERQUEM, p. 119, pl. 12, figs. 26 - 29
v 1961 Angulogerina muralis (TERQUEM) - KAASSCHIETER, p. 199, pl. 10, figs. 3a - 4c.
1970 Angulogerina muralis (TERQUEM) - LE CALVEZ, p. 124, pl. 23, fig. 1.
1974 Uvigerina muralis Terquem - MURRAY & WRIGHT, pl. 7, fig. 3.

Remarks : The peripheral angles are slightly rounded. Specimens with more inflated chambers have a less distinct trigonal cross section.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation.
Ieper Formation : Flanders Clay Member

Trifarina wilcoxensis (CUSHMAN & PONTON, 1932).

+ 1932 Pseudouvigerina wilcoxensis Cushman & Ponton, n. sp. - CUSHMAN & PONTON, p. 66, pl. 8, fig. 18.
v 1961 Trifarina wilcoxensis (CUSHMAN & PONTON) - KAASSCHIETER, p. 199, pl. 10, figs. 6 - 7.
1970 Trifarina wilcoxensis (CUSHMAN & PONTON) - LE CALVEZ, p. 127, pl. 23, fig. 5
1974 Trifarina wilcoxensis (Cushman & Ponton) - MURRAY & WRIGHT, p. 122, pl. 7, fig. 5.

Remarks : Adult specimens become uniserial. The canaliculate periphery is well developed. The sutures are distinctly curved and the wall is coarsely perforated.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member,
Brussels Formation.
Panisel Formation.

Superfamily Discorbacea EHRENBERG, 1838

Family Discorbidae EHRENBERG, 1838

Subfamily Baggininae CUSHMAN, 1927

Genus Cancris DE MONTFORT, 1808

Cancris subconicus (TERQUEM, 1882).

\+ 1882 Rotalina subconicus Terq. - TERQUEM, p. 61, pl. 41, figs. 4 - 5

v 1961 Cancris subconicus (TERQUEM) - KAASSCHIETER, p. 213, pl. 12,

1970 Cancris subconicus (TERQUEM) - LE CALVEZ, p. 145, pl. 43, fig. 6.

1974 Cancris subconicus (Terquem) - MURRAY & WRIGHT, p. 117, pl. 9, figs. 12 - 14.

Remarks : Specimens with a less rounded periphery resemble C. auriculus (FICHTEL & MOLL, 1803).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Panisel Formation
Ieper Formation : Flanders Clay Member

Family Asterigerinidae d'ORBIGNY, 1839

Genus Asterigerina s'ORBIGNY, 1839

Asterigerina bartoniana (TEN DAM, 1944)

\+ 1944 Rotalia granulosa nov. spec. - TEN DAM, p. 121, pl. 4, fig. 2.

v 1961 Asterigerina bartoniana (TEN DAM) - KAASSCHIETER, p. 232, pl. 16, figs. 2 - 3.

Remarks : Our specimens show a variability in their morphological features as described by KAASSCHIETER (1961).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Lede Formation.

Asterigerina sp. cf. A. guerrai (BERMUDEZ, 1952).

\+ 1952 Asterigerina guerrai Bermudez - BERMUDEZ, p. 204, pl. 1, fig. 4.

v 1961 Asterigerina sp. cf. A. guerrai (BERMUDEZ) - KAASSCHIETER, p. 233, pl. 16, fig. 1.

1970 Asterigerina guerrai BERMUDEZ - LE CALVEZ, p. 152, pl. 31, fig. 2.

1974 Asterigerina cf. A. guerrai (Bermudez) - MURRAY & WRIGHT, p. 116.

Remarks : The secondary chamberlets are less distinct and the arched aperture extends more to the periphery than that of the typical specimens.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Panisel Formation
Ieper Formation : Flanders Clay Member

Asterigerina spp.

Remarks : Our specimens from the Brussels and Lede Formations differ from those decribed by KAASSCHIETER (1961) in the less convex dorsal side. They also have a higher subcircular aperture.

Other specimens from the Panisel and Asse Formations resemble A. spp. cf. A. glabra (BERMUDEZ, 1952).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Brussels Formation
Panisel Formation

Asterigerina tatumi HUSSEY, 1951
+ Asterigerina tatumi Hussey, n. sp. - HUSSEY, p. 19, pl. 3, figs. 1 - 3.

Remarks : Our specimens differ from those described by HUSSEY in the convexity of the test. As HUSSEY's specimens have a distinct biconvex test, those found in our material show a planiconvex to very slightly biconvex one. The ventral side is distinctly more convex than the dorsal.

Occurrence : Lede Formation
Brussels Formation.

Occurrence : Panisel Formation

Elphidium spp.

In the Panisel Formation specimens resembling Elphidium ungeri (REUSS, 1850) occur but they have a more angular periphery and shorter "retral processes".

Occurrence : Panisel Formation

? Elphidium ungeri (REUSS, 1850)
?+ 1850 Polystomella ungeri Reuss - REUSS, p. 369, pl. 48, fig. 2.
? 1939 Elphidium ungeri (Reuss) - CUSHMAN, p. 44, pl. 11, fig. 20.
? 1958 Elphidium ungeri (REUSS) - BATJES, p. 165, pl. 12, fig. 3.

Remarks : Our specimens have a more angular periphery and less developed retral processes.

Family Rotaliidae EHRENBERG, 1839
Subfamily Rotaliinae EHRENBERG, 1839
Genus Ammonia BRUNNICH, 1772
Ammonia beccarii CLINNAEUS, 1758)
\+ 1758 Nautilus beccarii Linnaeus - LINNAEUS, p. 710, pl. 1, figs. 1a - c (fide ELLIS & MESSINA).
1928 Rotalia beccarii (Linné) - CUSHMAN, p. 103, pl. 15, figs. 1 - 7.
1958 Rotalia beccarii (LINNE) - BATJES, p. 167, pl. 12, fig. 11.

Remarks : Our specimens resemble A. beccarii, but CUSHMAN (1928) noted that different subspecies might be considered in the fossil material.

Occurrence : Asse Formation : Asse Clay Member
Panisel Formation

Genus Rotalia LAMRCK, 1804
Rotalia audouini d'ORBIGNY, 1850
\+ 1850 Rotalia audouini d'Orbigny - d'ORBIGNY, p. 407 (fide ELLIS & MESSINA).
1882 Rotalia armata (d'Orbigny) - TERQUEM, p. 67, pl. 5, figs. 14 - 15.
1961 Rotalia audouini d'ORBIGNY - KAASSCHIETER, p. 241, pl. 16, figs 8 - 10.
1970 Pararotalia audouini (d'ORBIGNY) - LE CALVEZ, p. 162, pl. 34, fig. 8.
1974 Pararotalia audouini (d'Orbigny) - MURRAY & WRIGHT, p. 120, pl. 12, figs. 3, 4, 8.

Remarks : All transitional forms occur between typical R. audouini specimens and R. armata d'ORBIGNY, 1850.

Occurrence : Lede Formation
Ieper Formation.

Superfamily Rotaliacea EHRENBERG, 1839

Family Elphidiidae GALLOWAY, 1933
Subfamily Elphidiinae GALLOWAY, 1933
Genus Elphidium DE MONTFORT, 1808
Elphidium inflatum (REUSS, 1861)
?+ 1861 Polystomella inflata Reuss - REUSS, p. 358, pl. 1, fig. 10.
? 1939 Elphidium inflatum (Reuss) - CUSHMAN, p. 46, pl. 12, fig. 7.
? 1958 Elphidium inflatum (REUSS) - BATJES, p. 164, pl. 12, fig. 2.

Remarks : There is a good resemblance between our specimens and those figured by CUSHMAN, which however are recorded from the Miocene.

Occurrence : Panisel Formation.

Elphidium laeve (d'ORBIGNY, 1826)
+ 1820 Nonionina laevis d'Orbigny - d'ORBIGNY, p. 294 (fide ELLIS & MESSINA).
v 1961 Elphidium laeve (d'ORBIGNY) - KAASSCHIETER, p. 239, pl. 16, figs. 15 - 16.
1970 Elphidium laeve (d'ORBIGNY) - LE CALVEZ, p. 168, pl. 25, fig. 1.
1974 Elphidium laeve (d'Orbigny) MURRAY & WRIGHT, p. 120, pl. 13, figs. 9 - 13.

Remarks : Specimens with a less deeply incised area around the umbilicus are difficult to distinguish from E. subnodosum (MUNSTER, 1838).

Occurrence : Lede Formation
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Elphidium minutum (REUSS, 1863)
+ 1863 Polystomella minutum Reuss - REUSS, p. 478, pl. 4, fig. 6.
1970 Elphidium minutum (REUSS) - LE CALVEZ, p. 169, pl. 27, fig.
1974 Elphidium minutum (Reuss) - MURRAY & WRIGHT, p. 118

Occurrence : Asse Formation : Asse Clay Member
Panisel Formation : Aalter Sands Member.

Elpidium subnodosum (ROEMER, 1838)
+ 1838 Robulina subnodosa von Münster - ROEMER, p. 391, pl. 3, figs. 6a - b.
v 1961 Elphidium subnodosum (ROEMER) - KAASSCHIETER, p. 239, pl. 16, figs. 17 - 18.
1970 Elphidium subnodosum (MUNSTER) - LE CALVEZ, p. 170, pl. 25, fig. 7.

Remarks : Most of our individuals are rather small.

Rotalia propingua REUSS, 1856
\+ 1856 *Rotalia propingua* Reuss - REUSS, p. 241, pl. 4, fig. 53, (fide ELLIS & MESSINA)
v 1961 *Rotalia propingua* REUSS - KAASSCHIETER, p. 243, pl. 16, fig. 12.

Remarks : Our specimens show the same variability in the presence of an umbilical knob and in the more deeply incesed sutures around the umbilicus as described by KAASSCHIETER (1961).

Occurrence : Asse Formation : Asse Clay Member, Wemmel Sands Member.
Lede Formation.

Superfamily Globigerinacea CARPENTER, PARKER & JONES, 1862

Family Heterohelicidae CUSHMAN, 1927

Subfamily Heterohelicinae CUSHMAN, 1927

Genus Bifarina PARKER & JONES, 1872

Bifarina selseyensis (HERON - ALLEN & EARLAND, 1909)

+ 1909 Bigeneria selseyensis Heron - Allen & Earland - HERON - ALLEN & EARLAND, p. 330, pl. 15, figs. 15 - 17.

v 1961 Bifarina selseyensis (HERON - ALLEN & EARLAND) - KAASSCHIETER, p. 200, pl. 10, figs. 8a - 10b.

Remarks : Specimens with an uniserial final part of the test are not observed in our material.

Occurrence : Wemmel Formation
Lede Formation.

Superfamily Orbitoidacea SCHWAGER, 1876

Family Eponididae HOFKER, 1951

Genus Eponides DE MONTFORT, 1888

Eponides schreibersi (d'ORBIGNY, 1846)

+ 1846 Rotalia schreibersi d'Orbigny - d'ORBIGNY, p. 154, pl. 8, figs. 4 - 6.

v 1961 Eponides schreibersi d'ORBIGNY - KAASSCHIETER, p. 210, pl. 11, figs. 14 - 15.

1963 Eponides schreibersi d'ORBIGNY - KUMMERLE, p. 49, pl. 8, figs. 1a - c.

Remarks : The convexity of the ventral side varies slightly. The aperture extends more or less to the periphery.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Panisel Formation

Eponides spp.

In the Asse Formation, several small Eponides individuals occur. Their identification was impossible due to the small size of their tests.

Occurrence : Asse Formation : Asse Clay Member, Wemmel Sands Member

Family Cibicididae CUSHMAN, 1927

Subfamily Planulininae BERMUDEZ, 1952

Genus Planulina d'ORBIGNY, 1826

Planulina burlingtonensis (JENNINGS, 1936)

+ 1936 Cibicides burlingtonensis nov. sp. - JENNINGS, p. 39, pl. 5, fig. 5.

v 1961 Planulina burlingtonensis (JENNINGS) - KAASSCHIETER, p. 224 pl. 14, figs. 9 - 10.

Remarks : The ventral side is partly involute and the sutures are recurved. In some specimens, the aperture extends from the periphery to the umbilicus.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Subfamily Cibicidinae CUSHMAN, 1927

Genus Cibicides DE MONTFORT, 1808

Cibicides carinatus (TERQUEM, 1882)

+ 1882 Truncatulina carinata Terquem - TERQUEM, p. 94, pl. 10, figs. 1 - 2.

v 1961 Cibicides carinatus (TERQUEM) - KAASSCHIETER, p. 221, pl. 14, fig. 6.
1970 Cibicides carinatus (TERQUEM) - LE CALVEZ, p. 180, text-figs. 66 - 68.
1974 Cibicides carinatus (Terquem) - MURRAY & WRIGHT, p. 117, pl. 15, figs 4 - 6.

Remarks : Our species have a well developed peripheral keel.

Occurrence : Lede Formation
Brussels Formation
Ieper Formation : Flanders Clay Member

Cibicides dutemplei (d'ORBIGNY, 1846)
\+ 1846 Rotalia dutemplei d'Orbigny - d'ORBIGNY, p. 157, pl. 8, figs. 19 - 21.
v 1961 Cibicides dutemplei (d'ORBIGNY) - KAASSCHIETER, p. 218, pl. 12, fig. 15.

Remarks : Our specimens are planoconvex to slightly biconvex. There are 8 to 10 chambers in the last whorl. The wall is coarsely perforated. Sometimes however, it becomes difficult to distinguish this species from C. tenellus tenellus (REUSS, 1865), C. lobatulus (WALKER & JACOB, 1798) or C. propius acutimargo TEN DAM, 1944.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation

Cibicides lobatulus (WALKER & JACOB, 1798)
\+ 1798 Nautilus lobatulus Walker & Jacob - WALKER & JACOB, p. 642, pl. 14, fig. 36 (fide ELLIS & MESSINA)
v 1961 Cibicides lobatulus (WALKER & JACOB) - KAASSCHIETER, p. 221, pl. 114, fig. 5.
1970 Cibicides lobatulus (WALKER & JACOB) - LE CALVEZ, p. 181
1974 Cibicides lobatulus (Walker & Jacob) - MURRAY & WRIGHT, pl. 15, figs. 13 - 19.

Remarks : Our specimens have a lobate periphery and a flat dorsal side. The wall is coarsely perforated. Specimens from the Wemmel Sands and Asse Clay have a more pronounced convex umbilical side. Sometimes, it is difficult to distinguish our specimens from C. tenellus tenellus (REUSS, 1865) or C. carinatus (REUSS, 1882).

Occurrence : Asse Formation : Asse Clay Member, Wemmel Sands Member,
Lede Formation
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Cibicides mauricensis HOWE & ROBERTS, 1939
+ 1939 Cibicides mauricensis HOWE & ROBERTS - HOWE & ROBERTS, p. 87, pl. 13, figs. 4 - 5 (fide ELLIS & MESSINE).
v 1961 Cibicides sp. cf. C. mauricensis HOWE & ROBERTS - KAASSCHIETER, p. 223, pl. 14, fig. 8.
1970 Cibicides mauricensis HOWE & ROBERTS - LE CALVEZ, p. 182, pl. 40, figs. 4 - 6.
1974 Cibicides mauricensis Howe & Roberts - MURRAY & WRIGHT, p. 117, pl. 16, figs. 1 - 2.

Remarks : The convexity of the ventral side varies and the periphery is subangular to rounded. Some specimens lack the umbilical knob.

Occurrence : Lede Formation
Brussels Formation

Cibicides proprius proprius (BROTZEN, 1948)
+ 1948 Cibicidoides proprius Brotzen - BROTZEN, p. 78,
v 1961 Cibicides proprius (BROTZEN) - KAASSCHIETER, p. 202, pl. 13, figs. 9a - c.
1970 Cibicidoides proprius BROTZEN - LE CALVEZ, p. 200, pl. 41, figs. 1 - 2.
1974 Cibicidoides proprius Brotzen - MURRAY & WRIGHT, pl. 20, figs. 3, 5, 6.

Remarks : Sometimes, it becomes difficult to distinguish this species from C. proprius var. acutimargo (TEN DAM, 1944) which has a more rounded periphery and finer pores on the dorsal side.

Occurrence : Lede Formation
Brussels Formation

Cibicides proprius acutimargo (TEN DAM, 1944)
+ 1944 Cibicides cryptomphala (REUSS) var. acutimargo nov. var. TEN DAM, p. 133, pl. 5, fig. 4.
v 1961 Cibicides proprius (REUSS) var. acutimargo TEN DAM - KAASSCHIETER, p. 122, pl. 14, fig. 7.

Remarks : The test of adult specimens becomes lobate. Most of our specimens are biconvex. Specimens with slightly curved sutures are difficult to distinguish from C. proprius (BROTZEN, 1948).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Cibicides pygmeus (HANTKEN, 1875)
+ 1875 Pulvilina pygmea nov. spec. - HANTKEN, p. 78, pl. 10, fig. 8 (fide ELLIS & MESSINA).

v 1961 Cibicides pygmeus (HANTKEN) - KAASSCHIETER, p. 219, pl. 14, figs. 1a - c.
1974 Cibicides pygmeus (Hantken) - MURRAY & WRIGHT, pl. 16, figs. 6 - 8.

Remarks : This species is recognized by its rather trochospiral and rounded test. KAASSCHIETER (1961) observed juvenile specimens with an Eponides aperture (interiomarginal arc without internal tooth-plate). Our specimens show an interiomarginal opening with narrow lip.

Occurrence : Asse Formation : Asse Clay Member.
Lede Formation.

Cibicides tenellus crassus GROSSHEIDE & TRUNKO, 1965
+ 1965 Cibicides tenellus crassus n. subsp. - GROSSHEIDE & TRUNKO p. 151, pl. 14, fig. 7.

Remarks : The umbilical side of the planoconvex test shows 9 to 10 chambers. The wall is more coarsely perforated than that of C. tenellus tenellus (REUSS, 1865). However small specimens are difficult to distinguish from C. tenellus tenellus. As we could observe in the collection of KAASSCHIETER, C. tenellus crassus has been included in C. sp. cf. C. tenellus (REUSS) by this author.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.
Lede Formation.

Cibicides tallahatensis BANDY, 1949
+ 1949 Cibicides tallahatensis Bandy - BANDY, p. 110, pl. 20, figs. 5a - c.
1970 Cibicides tallahatensis BANDY - LE CALVEZ, p. 184, pl. 40, fig. 3.

Remarks : This species resembles C. westi, but differs from it because of the umbilical knob and the limbate dorsal sutures.

Occurrence : Lede Formation
Brussels Formation.

Cibicides tenellus tenellus (REUSS, 1865)
+ 1865 Truncatulina tenellus Reuss - REUSS, p. 477, pl. 5, fig. 6.
v 1961 Cibicides sp. cf. C. tenellus (REUSS) - KAASSCHIETER, p. 219, pl. 14, figs. 2a - c.
1974 Cibicides tenellus (Reuss) - MURRAY & WRIGHT, pl. 16, figs. 12 - 14.

Remarks : The umbilicus of C. tenellus tenellus is filled up with a glassy knob. The number of chambers in the last whorl varies from 9 to 13. The sutures become strongly recurved near the periphery. Some specimens have a more inflated last chamber. Variation is observed in the size of the umbilical knob, in the convexity of the test and in the rounding of the periphery.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Cibicides westi HOWE, 1939
+ 1939 Cibicides westi Howe - HOWE, p. 88, pl. 13, figs. 20 - 22 (fide ELLIS & MESSINA)
v 1961 Cibicides westi HOWE - KAASSCHIETER, p. 218, pl. 13, figs. 6a - 7c.
1970 Cibicides westi Howe - LE CALVEZ, p. 184, pl. 43, fig. 9.
1974 Cibicides westi Howe - MURRAY & WRIGHT, pl. 17, figs. 3 - 5.

Remarks : Our specimens lack the deep umbilical cavity as figured by HOWE (1939). C. westi resembles C. tallahatensis BANDY, 1949, but differs from it because of the more split-like aperture and the absence of an umbo.

Occurrence : Asse Formation : Asse Clay Member, Wemmel Sands Member
Lede Formation
Brussels Formation.
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Superfamily Cassidulinacea d'ORBIGNY, 1839

Family Loxostomidae LOEBLICH & TAPPAN, 1962
Genus Loxostomum EHRENBERG, 1854
Loxostomum teretum CUSHMAN, 1936
+ 1936 Loxostomum teretum Cushman - CUSHMAN, p. 60, pl. 8, fig. 14
v 1961 Loxostomum teretum Cushman - KAASSCHIETER, p. 195, pl. 9, fig. 20
1970 Loxostomum teretum CUSHMAN - LE CALVEZ, p. 132, pl. 24, figs. 2 - 3.

Remarks : Our specimens have a finely perforated wall and limbate sutures. Some individuals have a very elongated test.

Occurrence : Asse Formation : Asse Clay Member

Family Nonionodae SCHULZE, 1854
Subfamily Nonionidae SCHULZE, 1854
Genus Nonion DE MONTFORT, 1808
Nonion affine (REUSS, 1851)
+ 1851 Nonionina affinis m. - REUSS, p. 72, pl. 5, fig. 32
v 1961 Nonion affine (REUSS) - KAASSCHIETER, p. 203, pl. 9, figs. 3 - 4
1970 Nonion affine (Reuss) - LE CALVEZ, p. 190, pl. 27, fig. 2.

Remarks : Specimens of which the umbilicus is filled up with glassy material resemble N. chapopotensis (COLE, 1928). The convexity of the test varies.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation.
Brussels Formation
Panisel Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Nonion graniferum (TERQUEM, 1882)
+ 1882 Nonionina granifera, Terq. - TERQUEM, p. 42, pl. 2 figs. 8 - 9.
v 1961 Nonion graniferum (TERQUEM) - KAASSCHIETER, p. 204, pl. 10, figs. 15a - b.
1970 Nonion graniferum (Terquem) - LE CALVEZ, p. 192, pl. 26, fig. 5.
1974 Nonion graniferum (Terquem) - MURRAY & WRIGHT, p. 115, pl. 17, figs. 7 - 8.

Remarks : The granular material sometimes extends along the depressed sutures.

Occurrence : Lede Formation.

Nonion scaphum (FICHTEL & MOLL, 1798)
+ 1798 Nautilus scapha Fichtel & Moll - FICHTEL & MOLL, p. 105, pl. 19, figs. d - f (fide ELLIS & MESSINA)
1846 Nonionina communis d'Orbigny - d'ORBIGNY, p. 106, pl. 5, figs. 6 - 7.
v 1961 Nonion scaphum (Fichtel & Moll) - KAASSCHIETER, p. 204, pl. 10, figs. 14a - b, pl. 11, figs. 5a - b.
1970 Nonion commune (d'ORBIGNY) - LE CALVEZ, p. 191, pl. 27, fig. 5.

Remarks : Specimens of which the umbilicus is filled up with granular material, have not been observed in our material.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Genus Nonionella CUSHMAN, 1926

Nonionella spissa CUSHMAN, 1931

+ 1931 Nonionella hantkeni (CUSHMAN & APPLIN) var. spissa Cushman nov. var. - CUSHMAN, p. 58, pl. 7, fig. 13.
v 1961 Nonionella spissa CUSHMAN - KAASSCHIETER, p. 205, pl. 11, figs. 7 - 8.
1970 Nonionella cf. spissa CUSHMAN - LE CALVEZ, p. 194
1974 Nonionella spissa Cushman - MURRAY & WRIGHT, p. 120, pl. 18, figs. 6, 7, 9.

Remarks : Our specimens show a typical broad umbilical cavity.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Ieper Formation : Flanders Clay Member.

Nonionella wemmellensis KAASSCHIETER, 1961

v + 1961 Nonionella wemmellensis nov. sp. - KAASSCHIETER, p. 205, pl. 11, fig. 7
1970 Nonionella wemmellensis KAASSCHIETER - LE CALVEZ, p. 194, pl. 27, fig. 7.
1974 Nonionella cf. ? wemmellensis Kaasschieter - MURRAY & WRIGHT, pl. 18, figs. 10 - 11.

Remarks : The test is distinctly compressed and the lateral sides are parallel.

Occurrence : Asse Formation : Wemmel Sands Member,
Lede Formation

Family Alabaminidae HOFKER, 1951

Genus Alabamina TOULMIN, 1941

Alabámina obtusa BURROWS & HOLLAND, 1897

+ 1897 Pulvinulina exigua (Brady) var. obtusa BURROWS & HOLLAND - BURROWS & HOLLAND, p. 40, pl. 2, fig. 25 - 30
v 1961 Alabamina obtusa (BURROWS & HOLLAND) - KAASSCHIETER, p. 227, pl. 13, fig. 15.
1974 Alabamina obtusa (Burrows & Holland) - MURRAY & WRIGHT, p. 116, pl. 19, figs. 1 - 2.

Remarks : The convexity of the dorsal side varies and the periphery is more or less lobate. The apertural face of our specimens is distinctly declined.

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member.

Alabamina wolterstorffi (FRANKE, 1925)
+ 1925 Rotalia wolterstorffi Franke - FRANKE, p. 186, pl. 6, fig. 6b.
v 1961 Alabamina wolterstorffi (FRANKE) - KAASSCHIETER, p. 228, pl
pl. 14, fig. 13a - c.

Remarks : Besides typical specimens with rather acute periphery, individuals with a more rounded periphery occur. They can be considered as transitional forms to A. obtusa (BURROWS & HOLLAND, 1897).

Occurrence : Brussels Formation.

Genus Gyroidina d'ORBIGNY, 1826
Gyroidina octocamerata CUSHMAN & HANNA, 1927
+ 1927 Gyroidina soldanii d'Orbigny var. octocamerata Cushman & Hanna - CUSHMAN & HANNA, p. 223, pl. 14, figs. 6 - 18.
v 1961 Gyroidina octocamerata CUSHMAN and HANNA - KAASSCHIETER p. 212, pl. 13, figs. 2a - c.
1970 Gyroidina octocamerata CUSHMAN & HANNA - LE CALVEZ, p. 95, pl. 42, figs. 4 - 5.

Remarks : As mentioned by KAASSCHIETER (1961), this species differs from G. angustiumbilicata TEN DAM, 1944 in its more rounded periphery and its deeper umbilicus.
Our specimens show rather indistinct sutures.

Occurrence : Lede Formation
Brussels Formation

Family Anomalinidae CUSHMAN, 1927
Subfamily Anomalininae CUSHMAN, 1927
Genus Anomalina d'ORBIGNY, 1826
Anomalina acuta PLUMMER, 1926
+ 1926 Anomalina ammonoides (Reuss) var. acuta Plummer - PLUMMER, p. 149, pl. 10, fig. 2 (fide ELLIS & MESSINA)
v 1961 Anomalina acuta PLUMMER - KAASSCHIETER, p. 216, pl. 12, figs. 12 - 17, pl. 8, fig. 9.
1970 Anomalina acuta PLUMMER - LE CALVEZ, p. 197
1974 Anomalina acuta Plummer - MURRAY & WRIGHT, p. 116, pl. 19, figs. 3, 4, 7

Remarks : Our specimens typically have 10 to 15 chambers in the last whorl. Specimens with less chambers in the last whorl are known as A. acuta var. ypresiensis (BROTZEN, 1948).

Occurrence : Ieper Formation : Flanders Clay Member, Mons-en-Pévèle Sands Member.

Anomalina parvula GRZYBOWSKI, 1896
+ 1896 Anomalina parvula Grzybowski - GRZYBOWSKI, p. 302, pl. 11, fig. 6a - b. (fide ELLIS & MESSINA).
1970 Anomalina parvula GRZYBOWSKI - LE CALVEZ, p. 198, pl. 44, fig. 11.
1974 Anomalina parvula Grzybowski - MURRAY & WRIGHT, p. 116, pl. 13, figs. 14 - 15.

Occurrence : Lede Formation.

Genus Hanzawaia ASANO, 1944
Hanzawaia boueana d'ORBIGNY, 1882
+ 1882 Truncatulina boueana d'ORBIGNY - d'ORBIGNY, p. 169, pl. 9, figs. 24 - 26.
1958 Hanzawaia boueana (d'ORBIGNY) - BATJES, p. 154, pl. 8, fig. 5a - c.

Remarks : Our specimens have at least 9 chambers in the final whorl. The final chamber is more or less inflated.

Occurrence : Lede Formation
Brussels Formation

Hanzawaia producta (TERQUEM, 1882)
+ 1882 Truncatulina producta Terq. - TERQUEM, p. 92, pl. 9, figs. 20 - 21
v 1961 Hanzawaia producta (TERQUEM) - KAASSCHIETER, p. 266, pl. 12, fig. 13.
1970 Hanzawaia producta (TERQUEM) - LE CALVEZ, p. 210, pl. 44, fig fig. 3, 9.

Remarks : Most of our specimens have 6 to 8 chambers in the last whorl. Specimens with more chambers (9 to 10) in the last whorl and a smaller umbilicus belong to H. boueana (d'ORBIGNY, 1846).

Occurrence : Panisel Formation.

Family Ceratobuliminidae CUSHMAN, 1927
Subfamily Ceratobulimininae CUSHMAN, 1927
Genus Lamarckina BERTHELIN, 1881
Lamarckina cristellaroides, 1882
+ 1882 Rotalina cristellaroides Terq. - TERQUEM, p. 57, pl. 3, fig. 15a - c.
v 1961 Lamarckina cristellaroides (TERQUEM) - KAASSCHIETER, p. 231, pl. 15, fig. 34.
1970 Lamarckina cristellaroides (TERQUEM) - LE CALVEZ, p. 203, pl. 37, fig. 4.
1974 Lamarckina cristellaroides (Terquem) - MURRAY & WRIGHT, n° 14, p. 119.

Remarks : We did not find specimens with small spines on the dorsal side as recorded by KAASSCHIETER (1961).

Occurrence : Asse Formation : Wemmel Sands Member, Asse Clay Member
Lede Formation
Brussels Formation.

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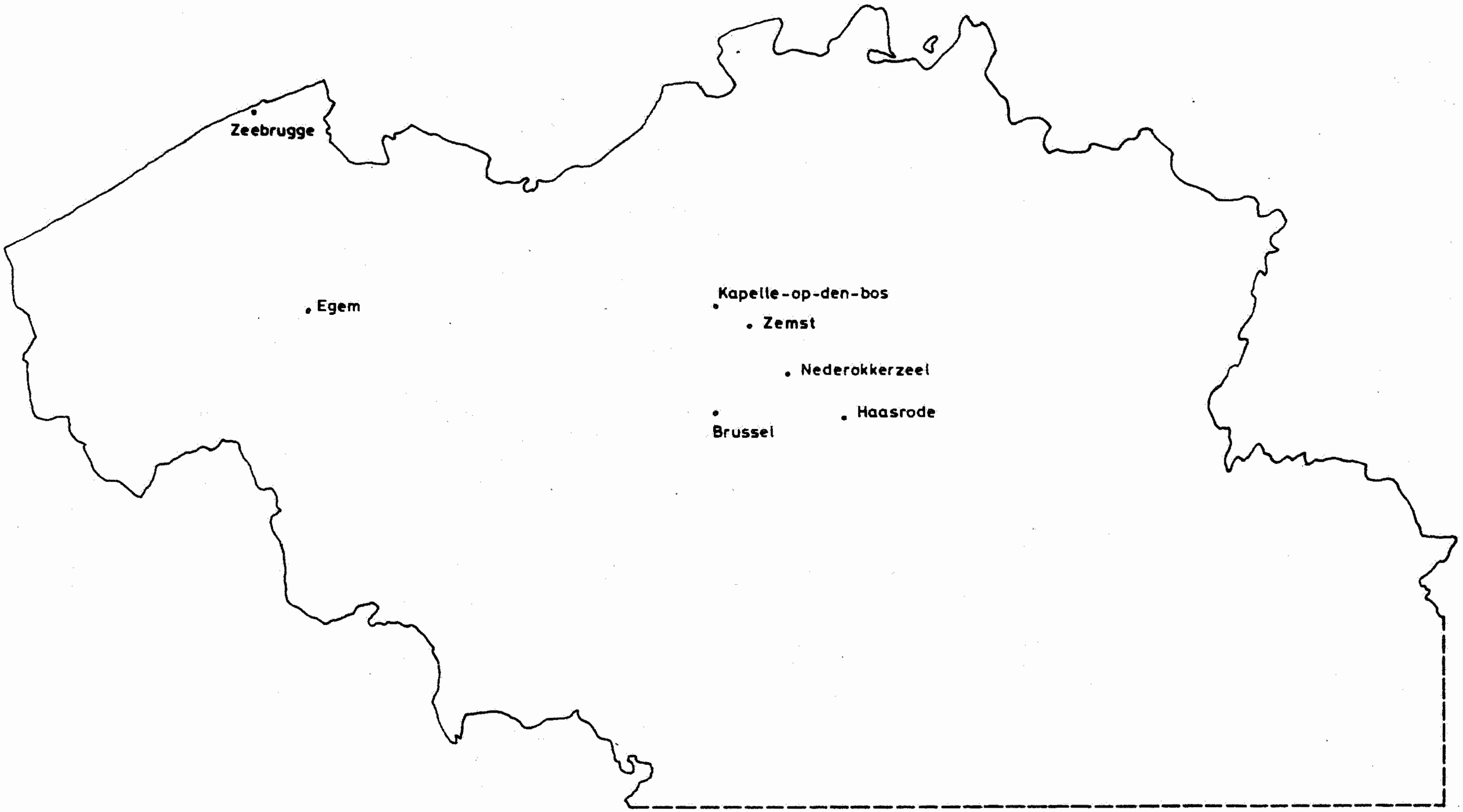


Fig 1 : Locality map.

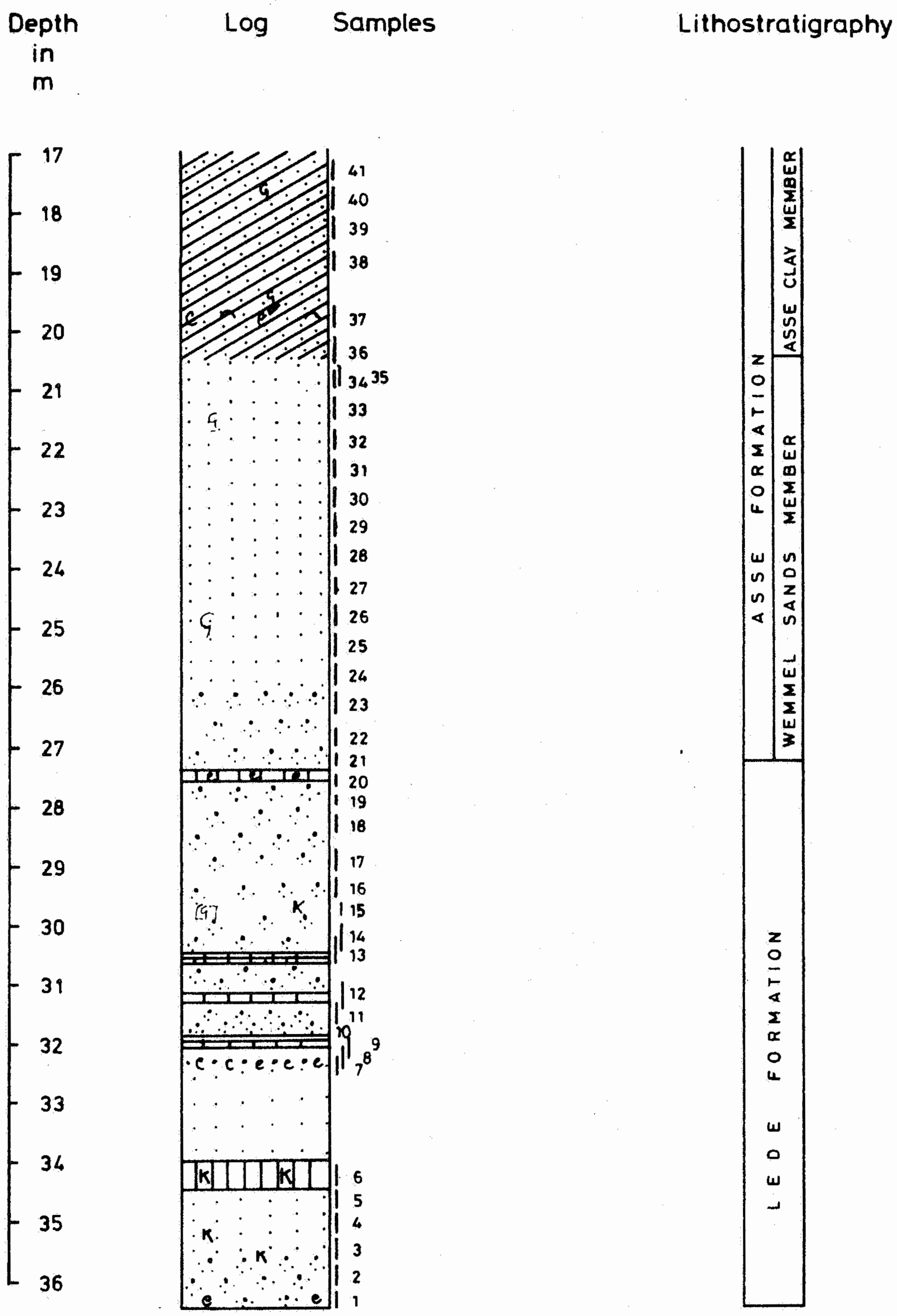


Fig. 2 : Description of well n° 28 at Zemst.

(After the archives of the Belgian Geological Survey)

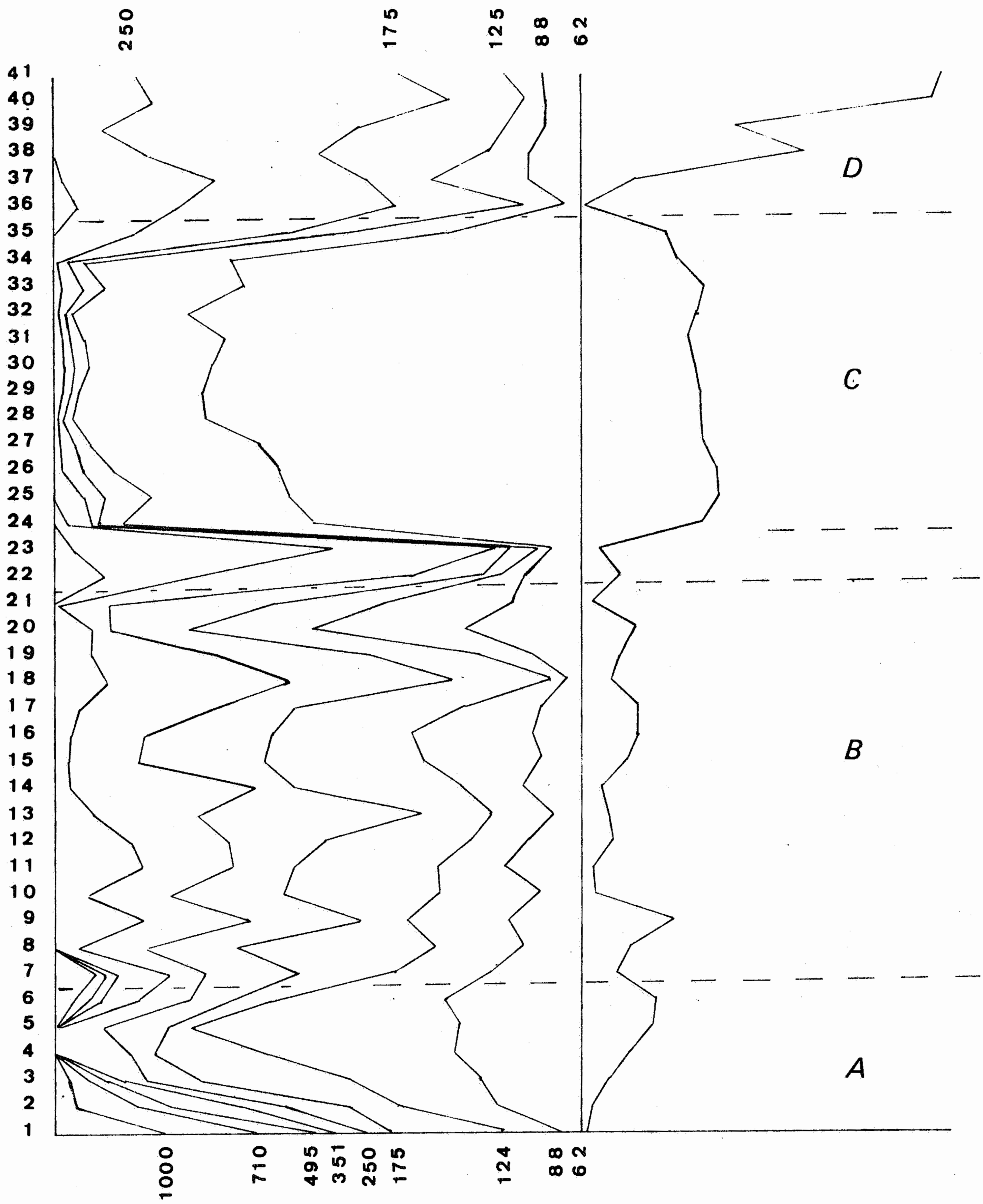


Fig 2a : Grainsize analysis of the samples from well n° 28 at Zemst.

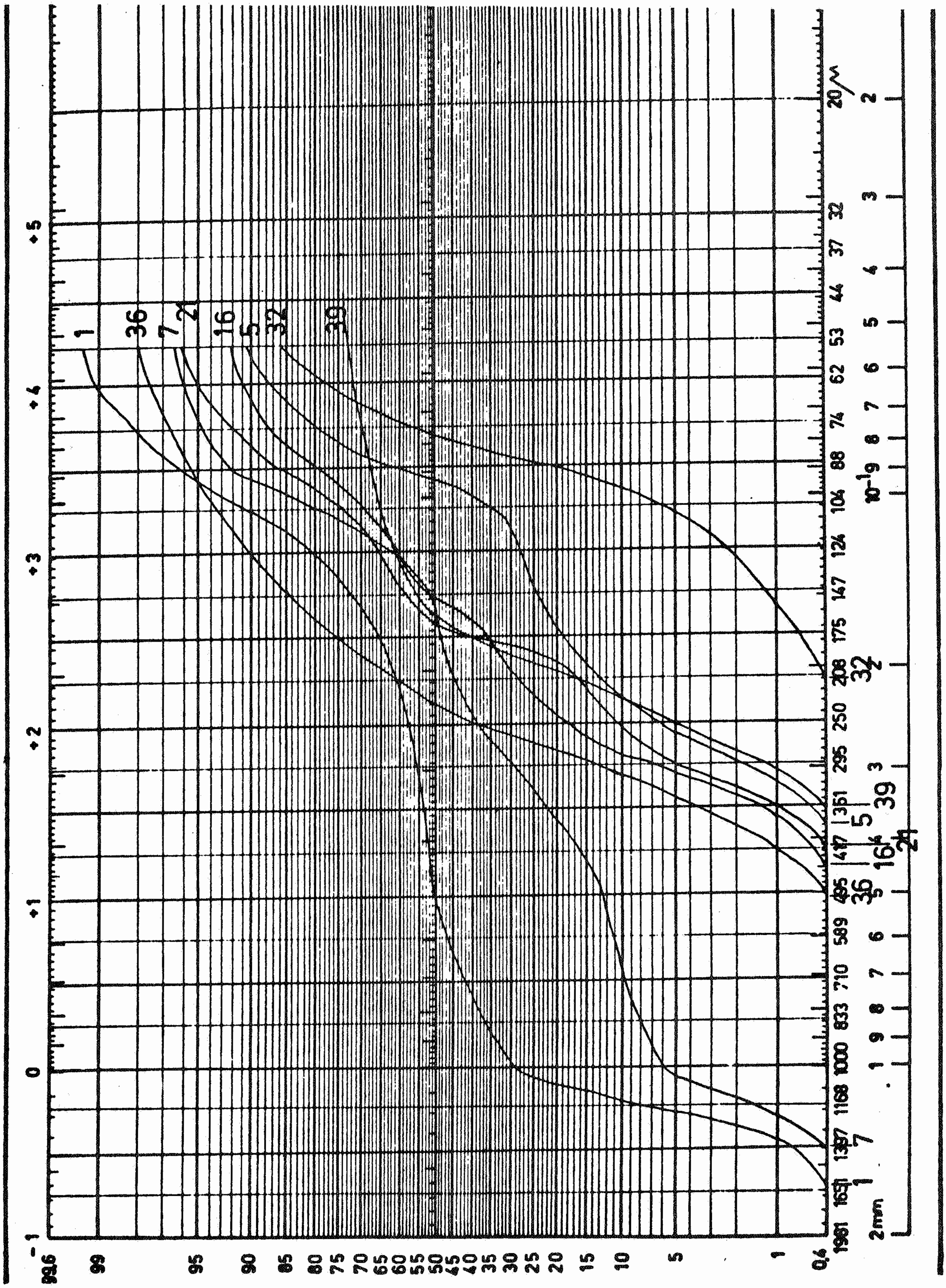


Fig 2b : Grainsize analysis of some selected samples from well n° 28 at Zemst.

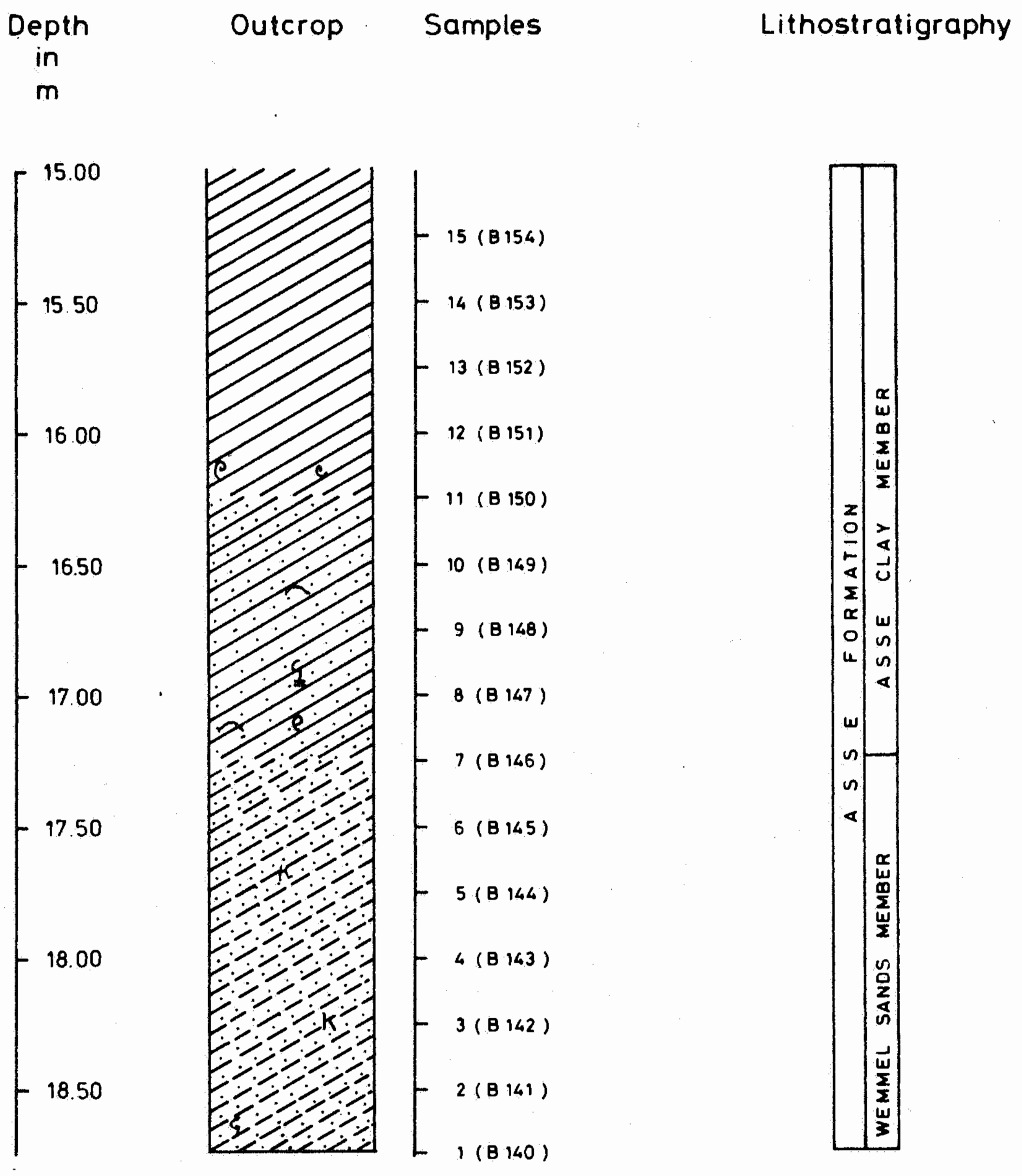


Fig. 3 : Temporary outcrop at Zemst.

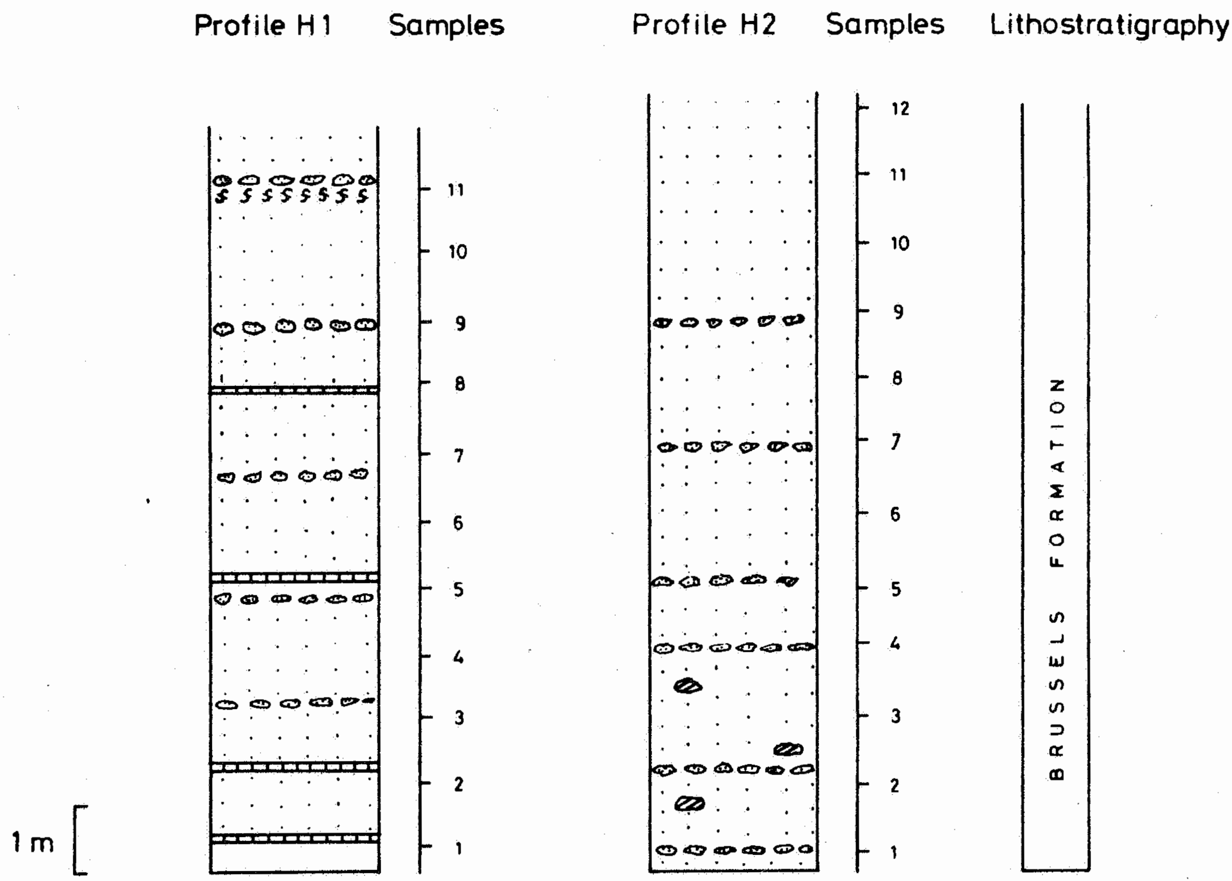


Fig. 4 : Studied profiles in the quarry at Haasrode.

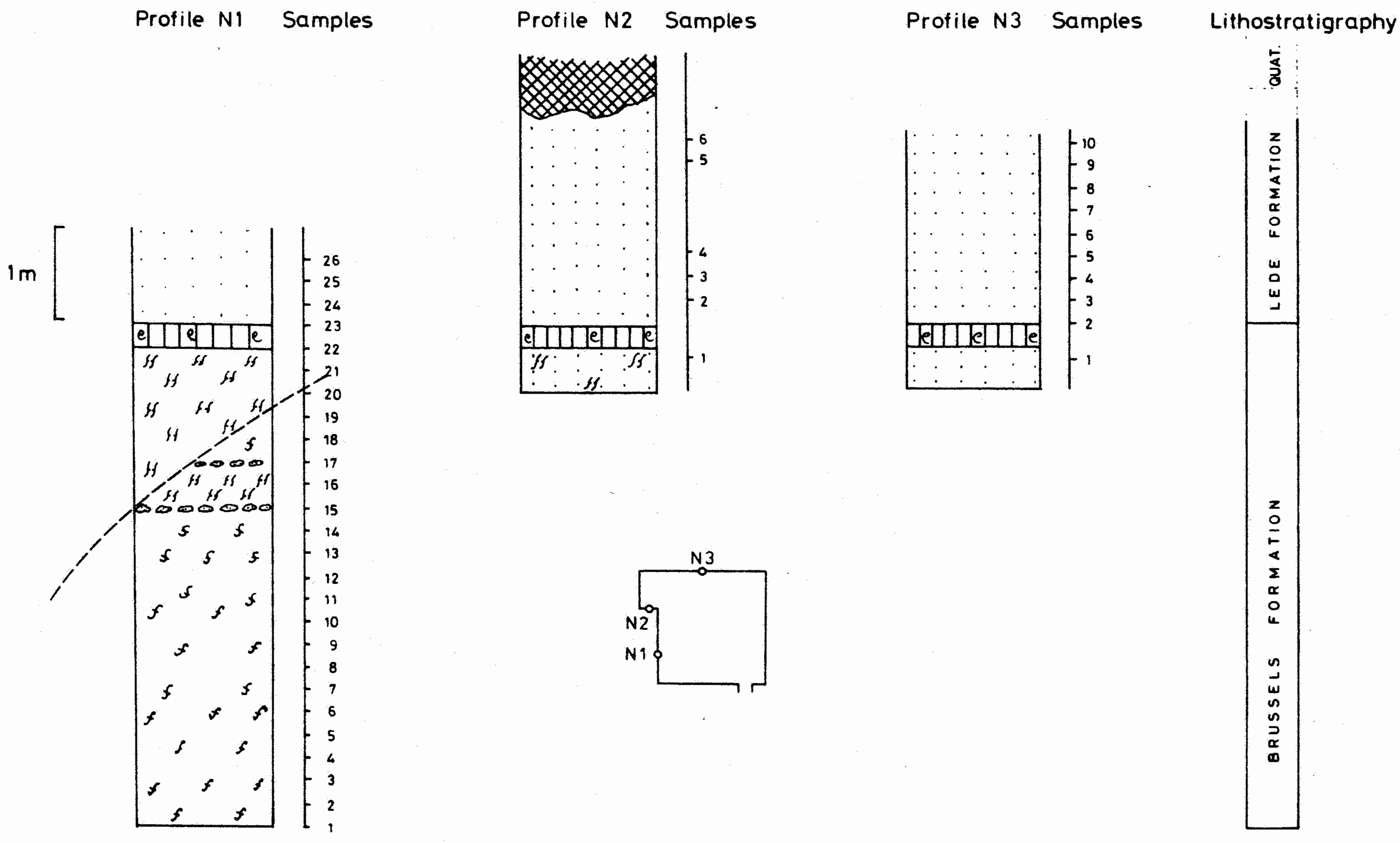


Fig 5 : Studied profiles in the quarry at Nederokkerzeel.

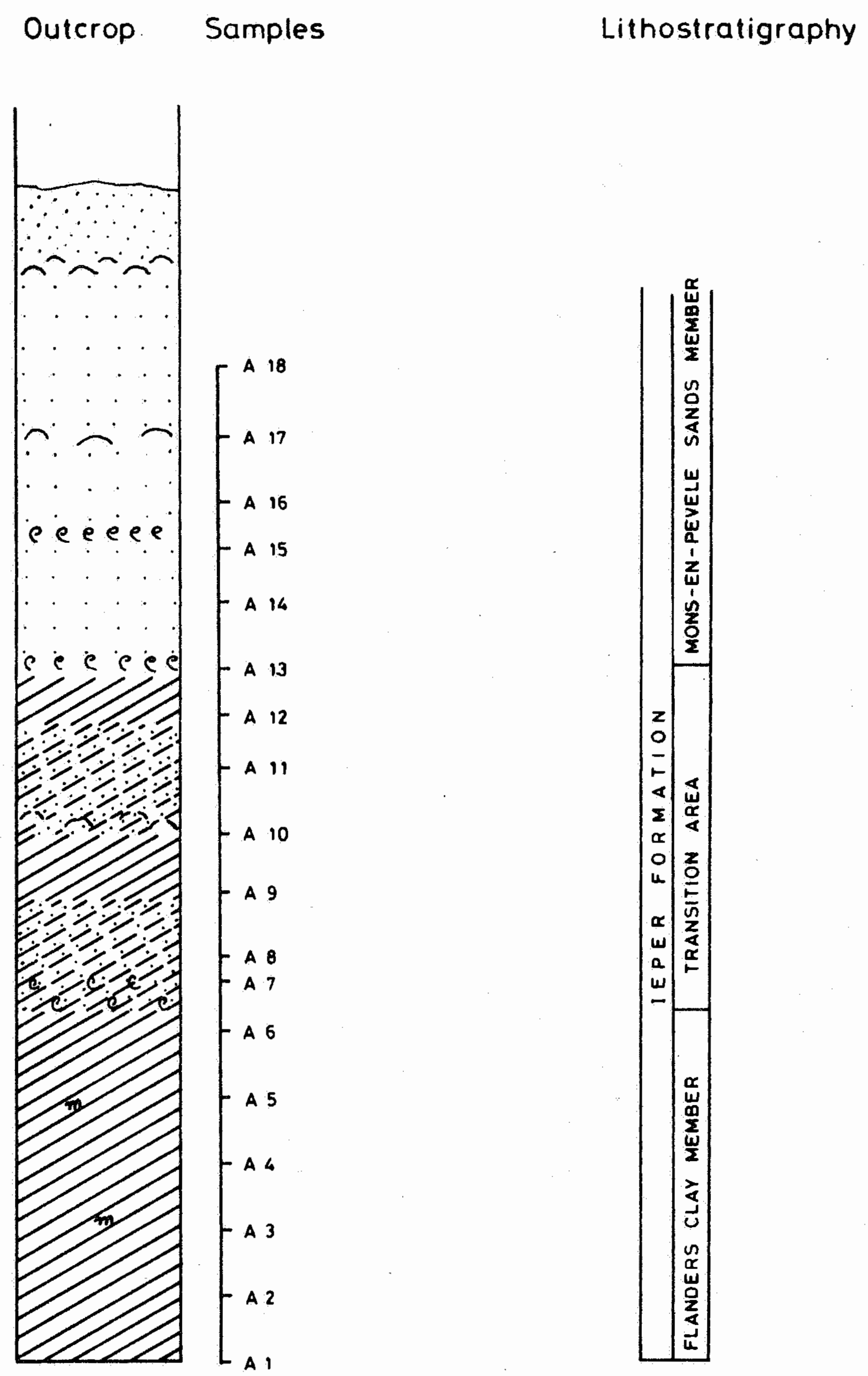


Fig. 6 : Lithological description of the Ampe quarry.

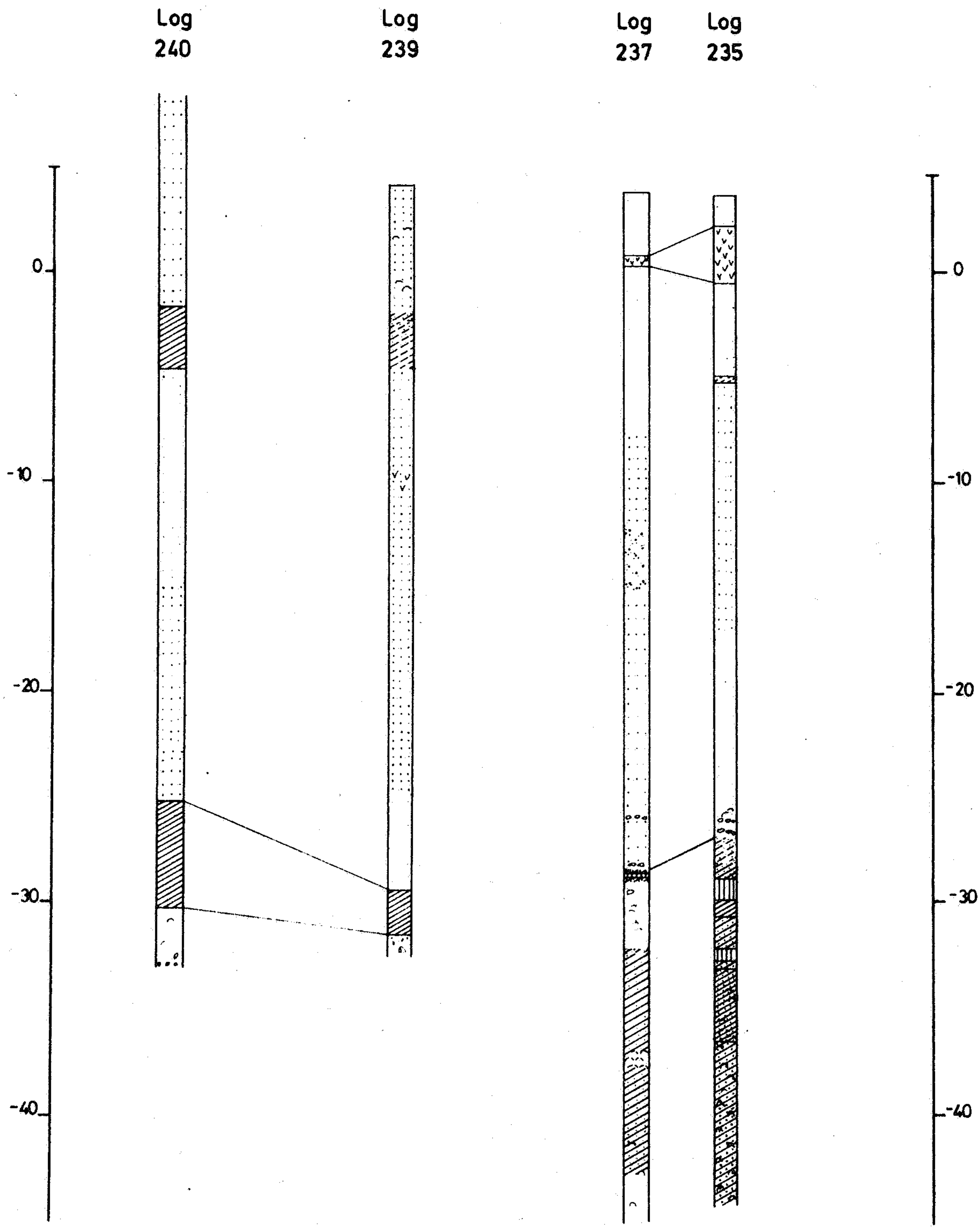


Fig 7 : Lithological description of the wells at Zeebrugge.

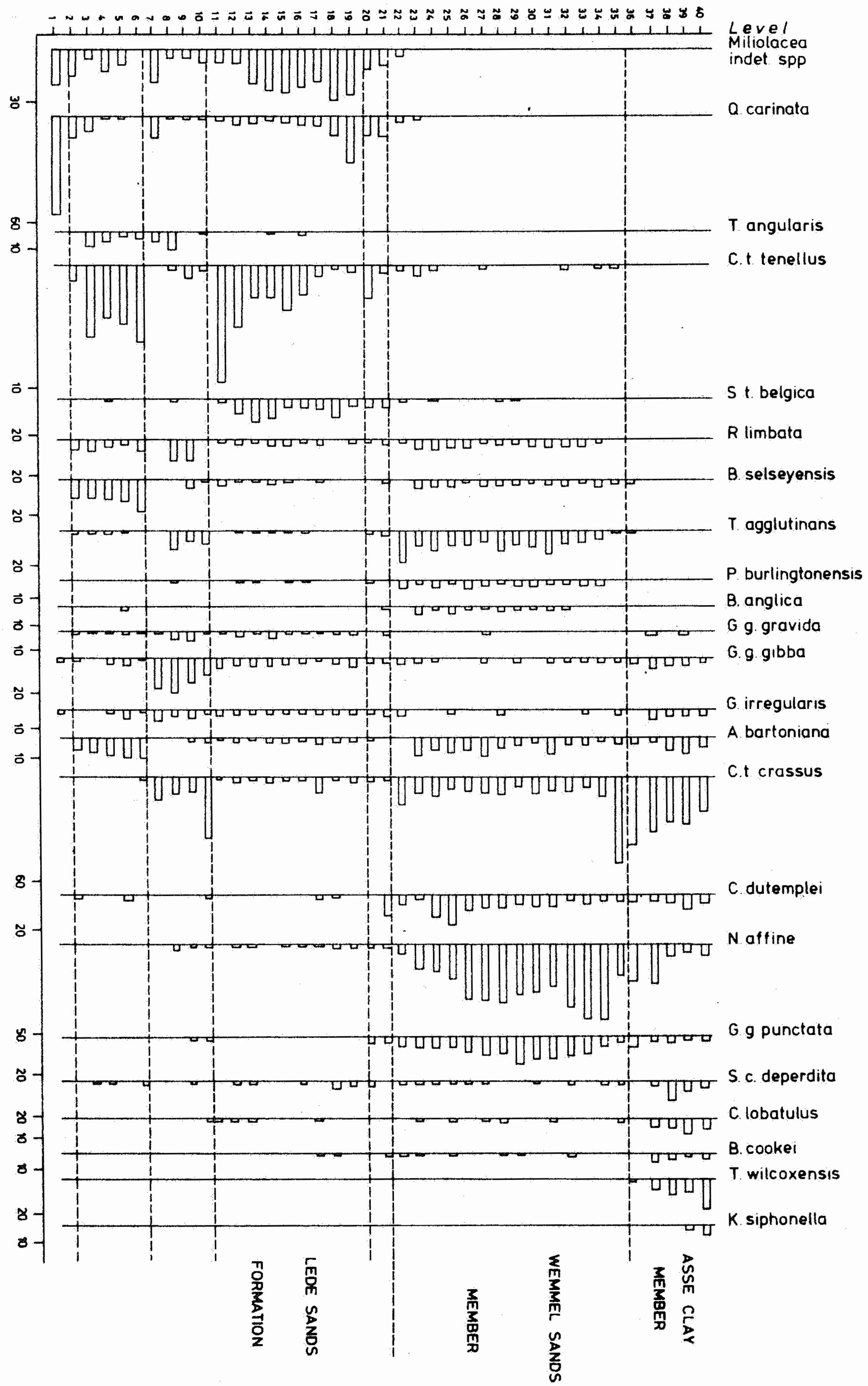


TABLE 1 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN WELL n° 28 AT ZEMST

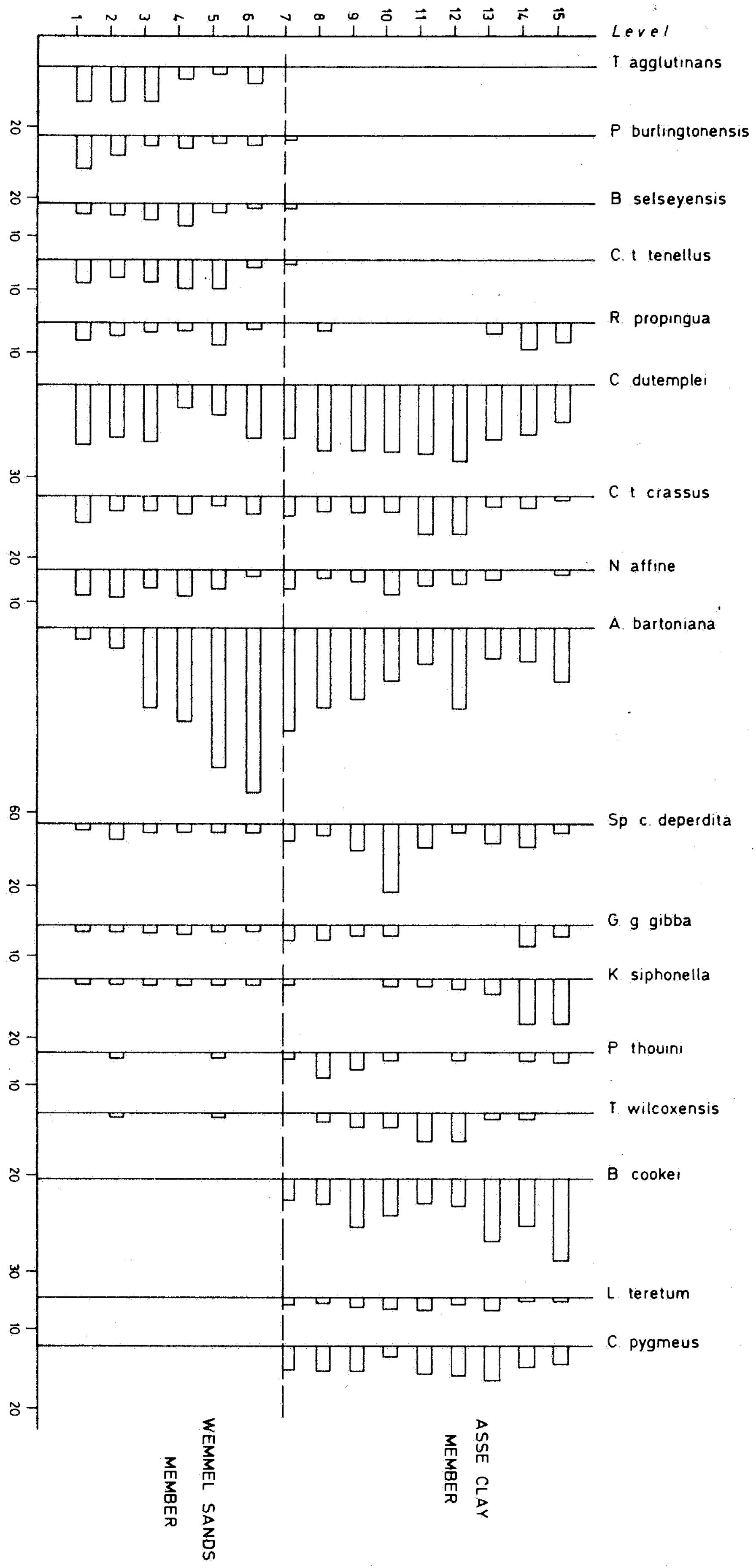


TABLE 2 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN THE TEMPORARY OUTCROP AT ZEMST.

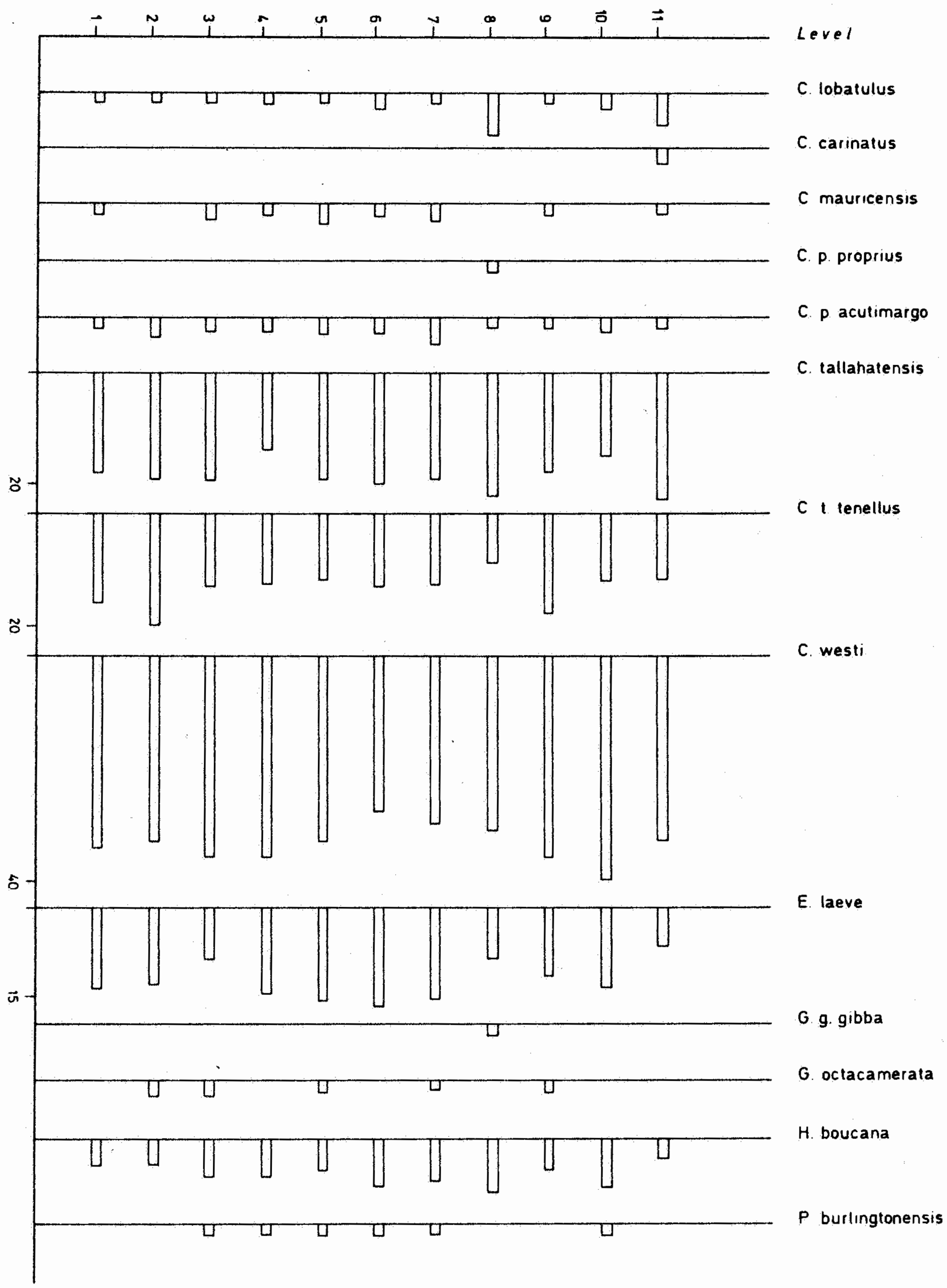


TABLE 3 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN PROFILE H1.

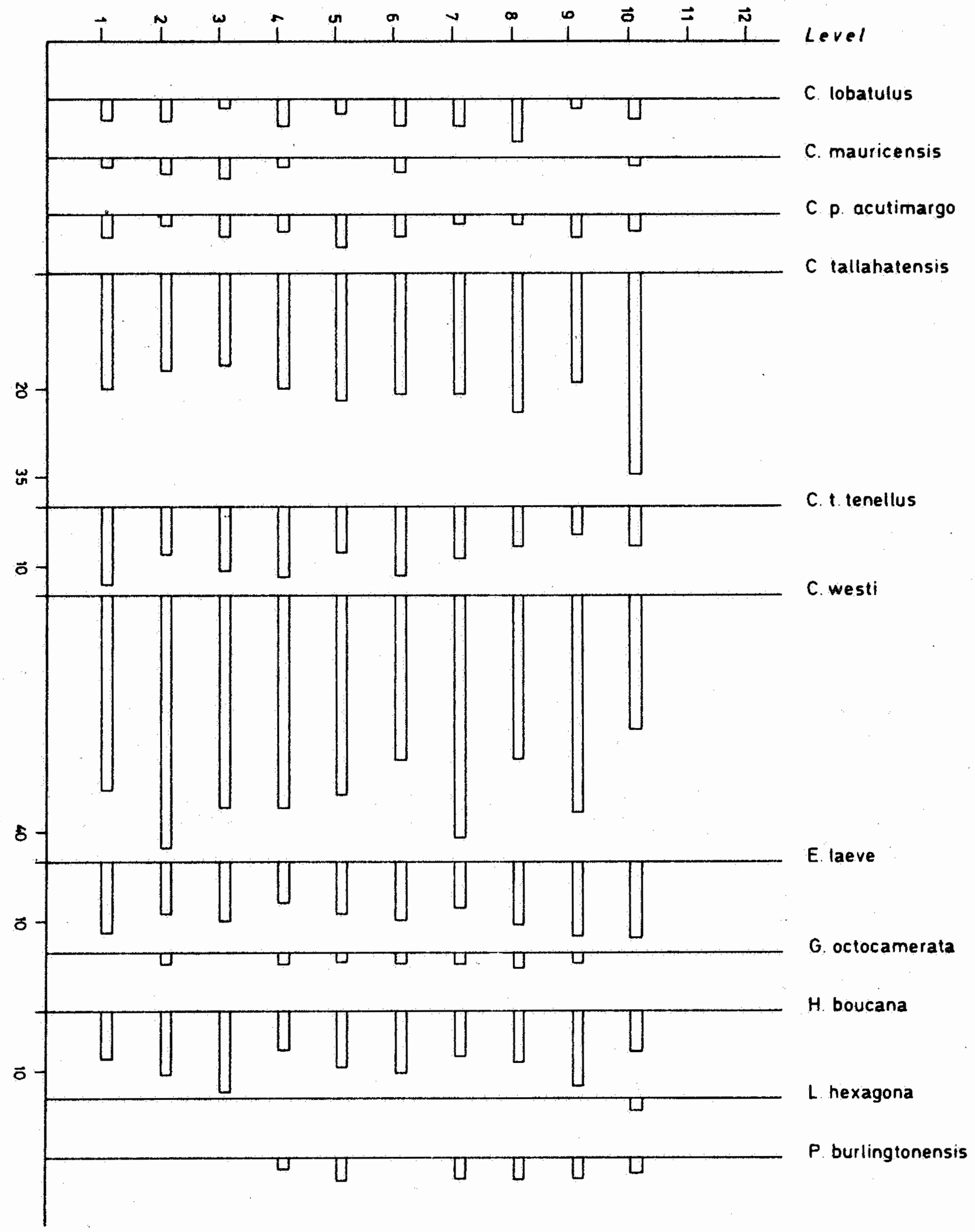


TABLE 4 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN PROFILE H2.

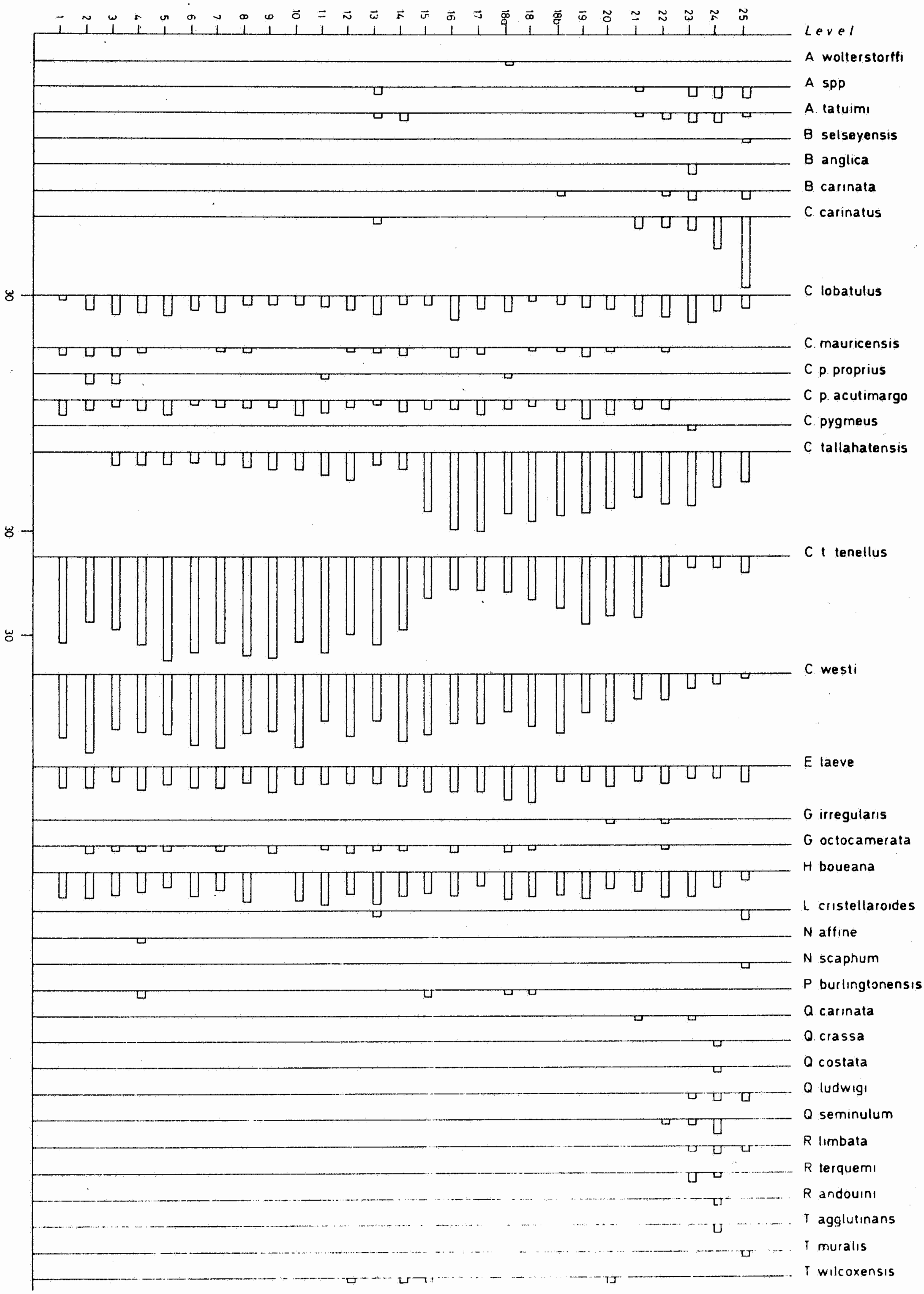


TABLE 5 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN PROFILE N1

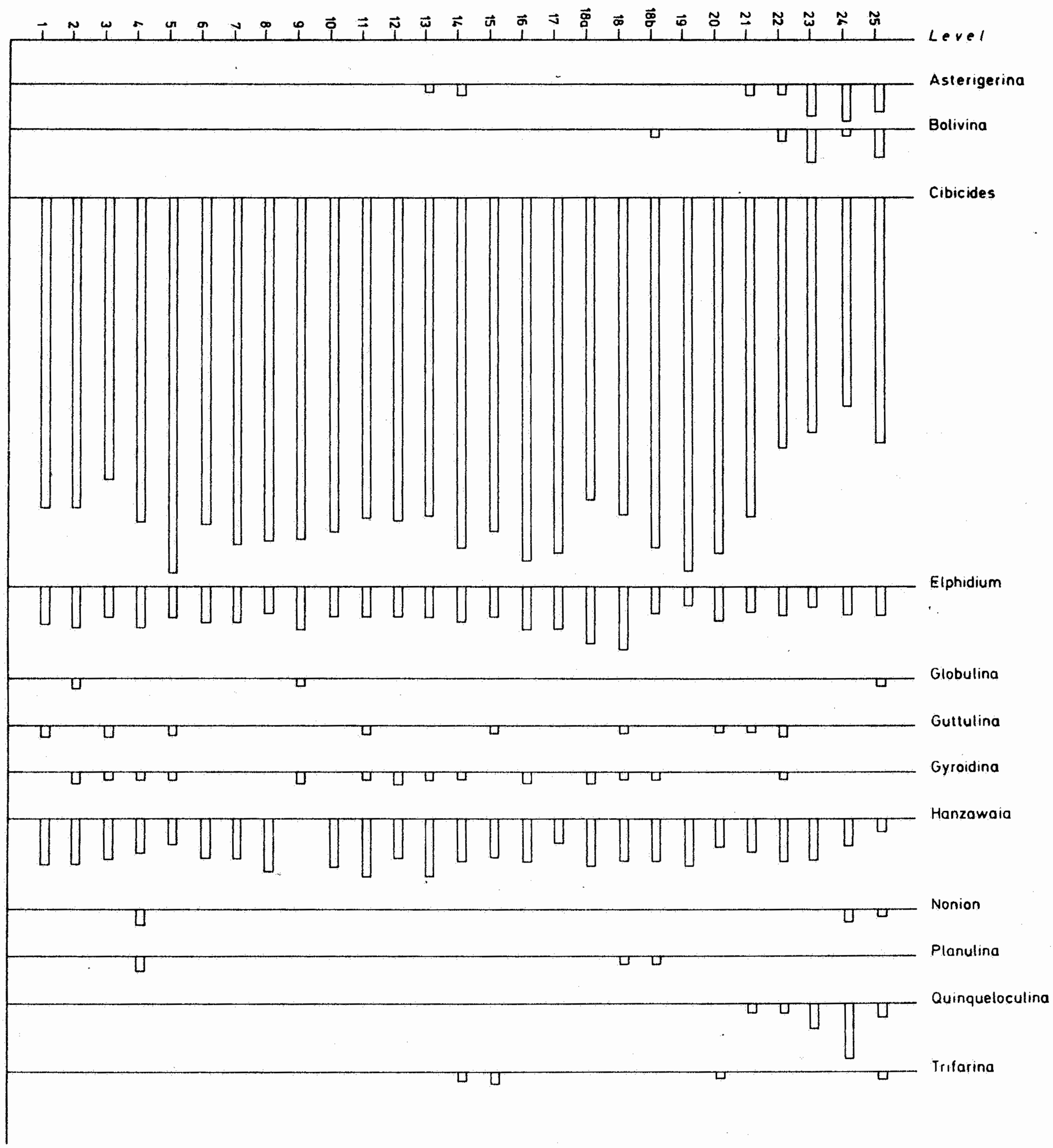


TABLE 6 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN PROFILE N_1

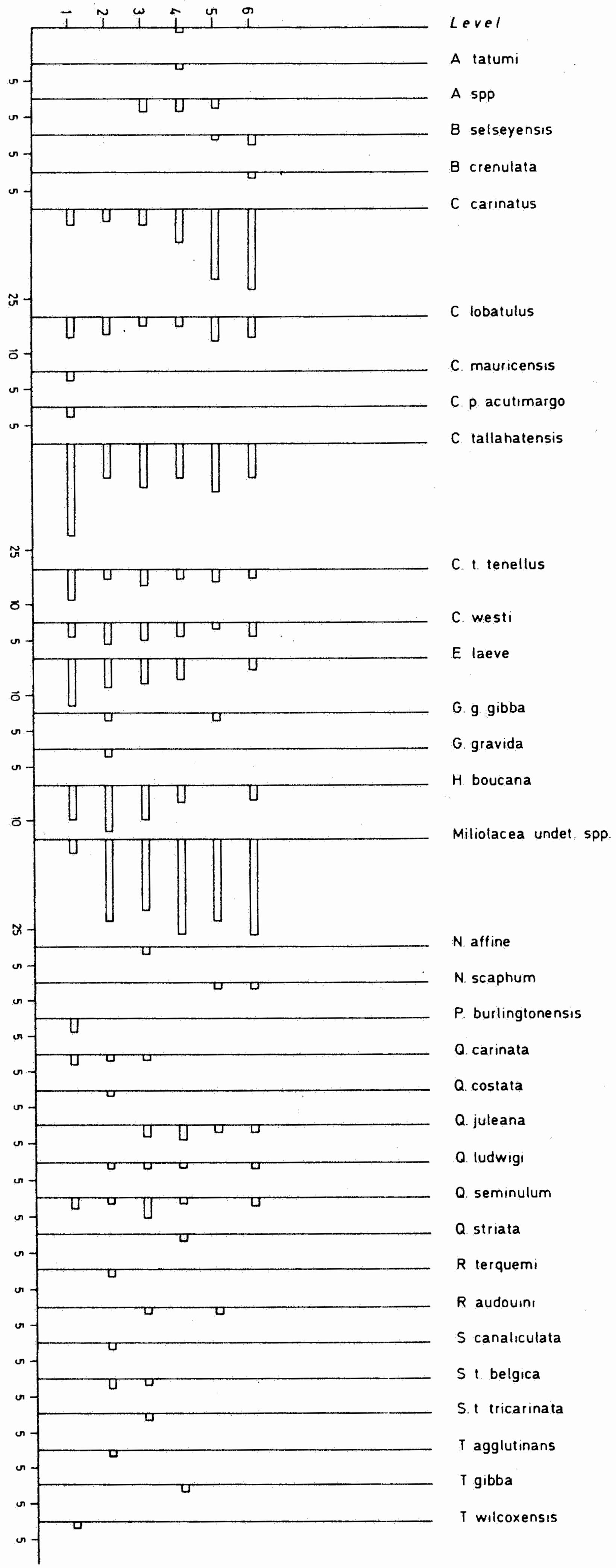


TABLE 7 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN PROFILE N2.

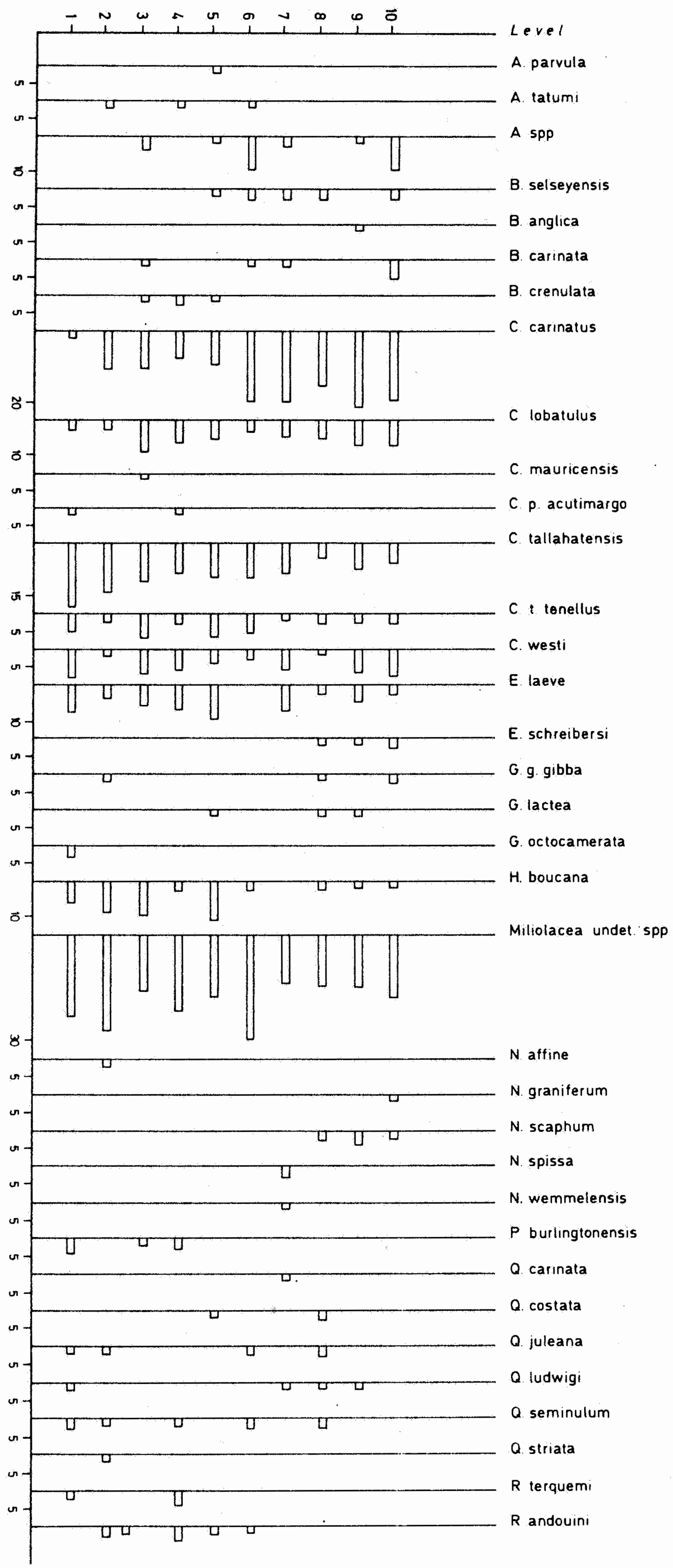


TABLE 8 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN PROFILE N3.

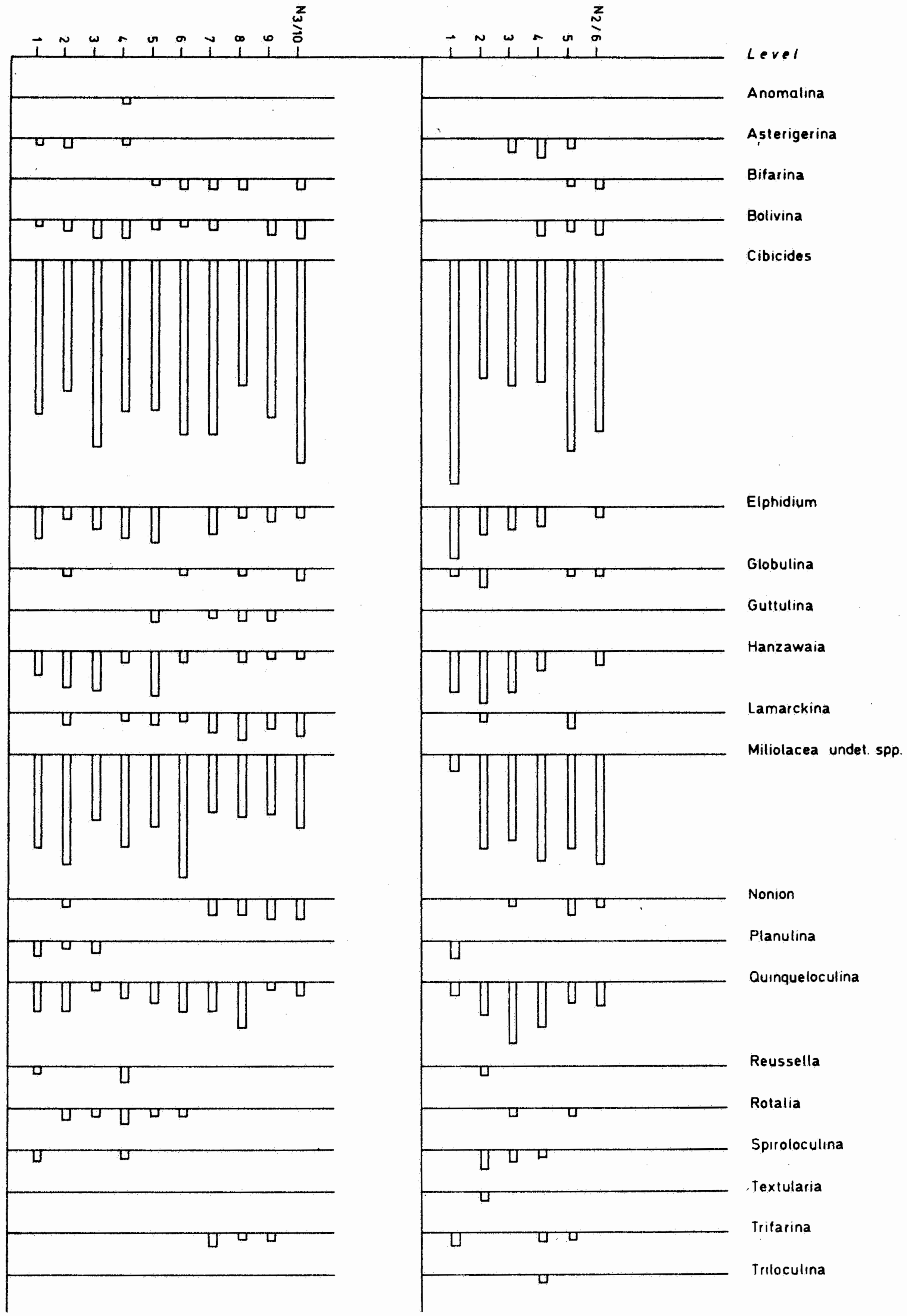


TABLE 9 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN PROFILES N_2 AND N_3.

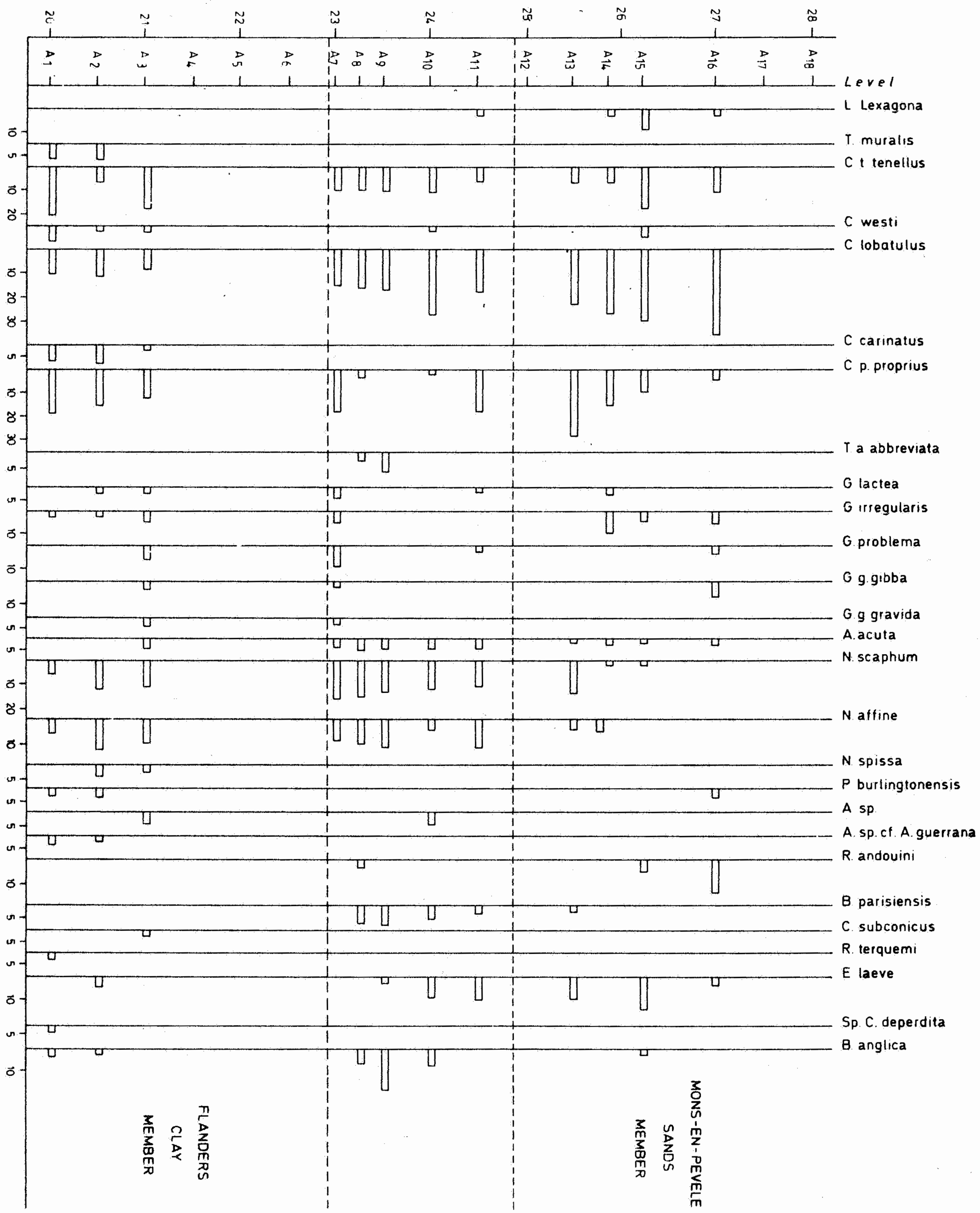


TABLE 10 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN THE AMPE QUARRY.

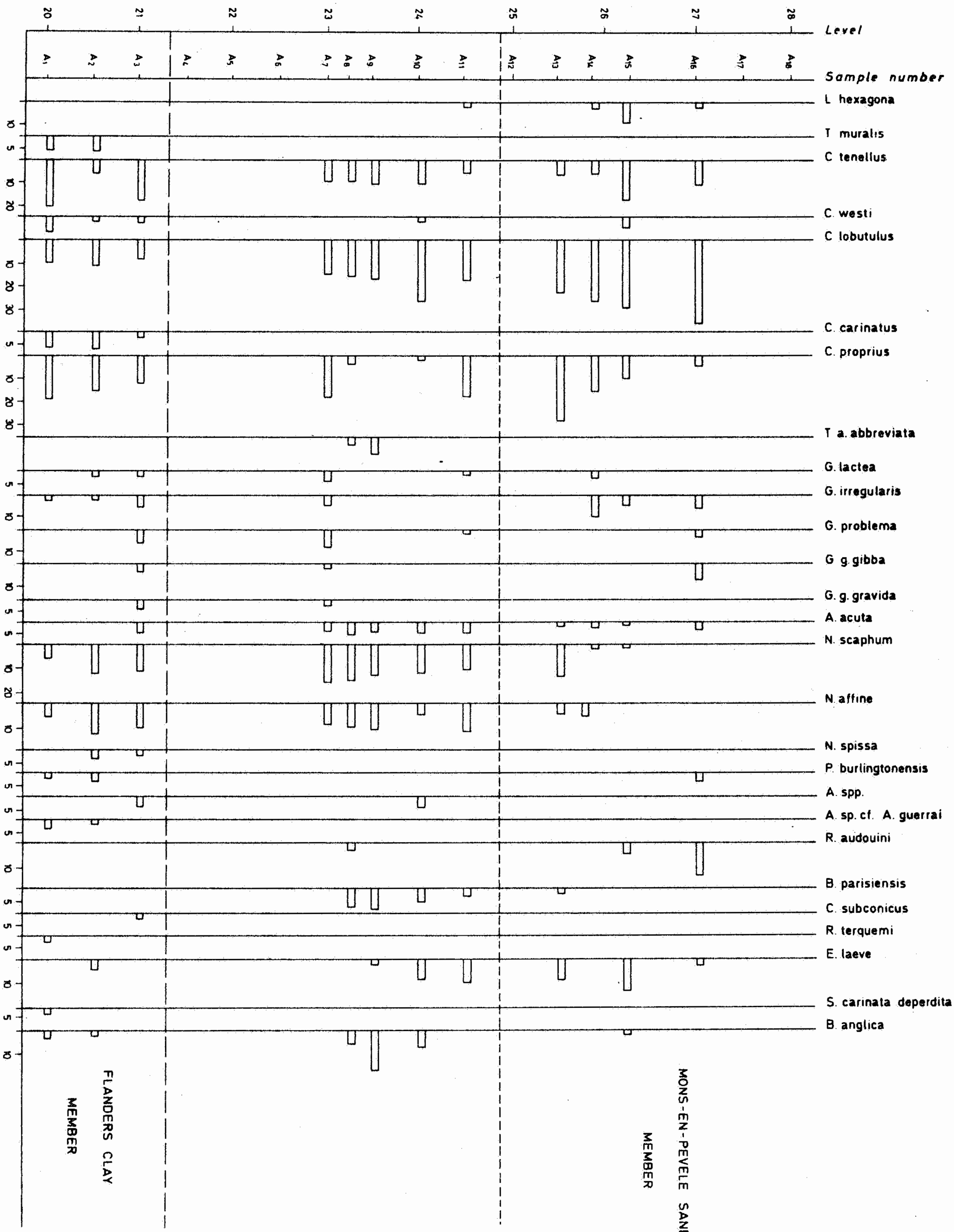
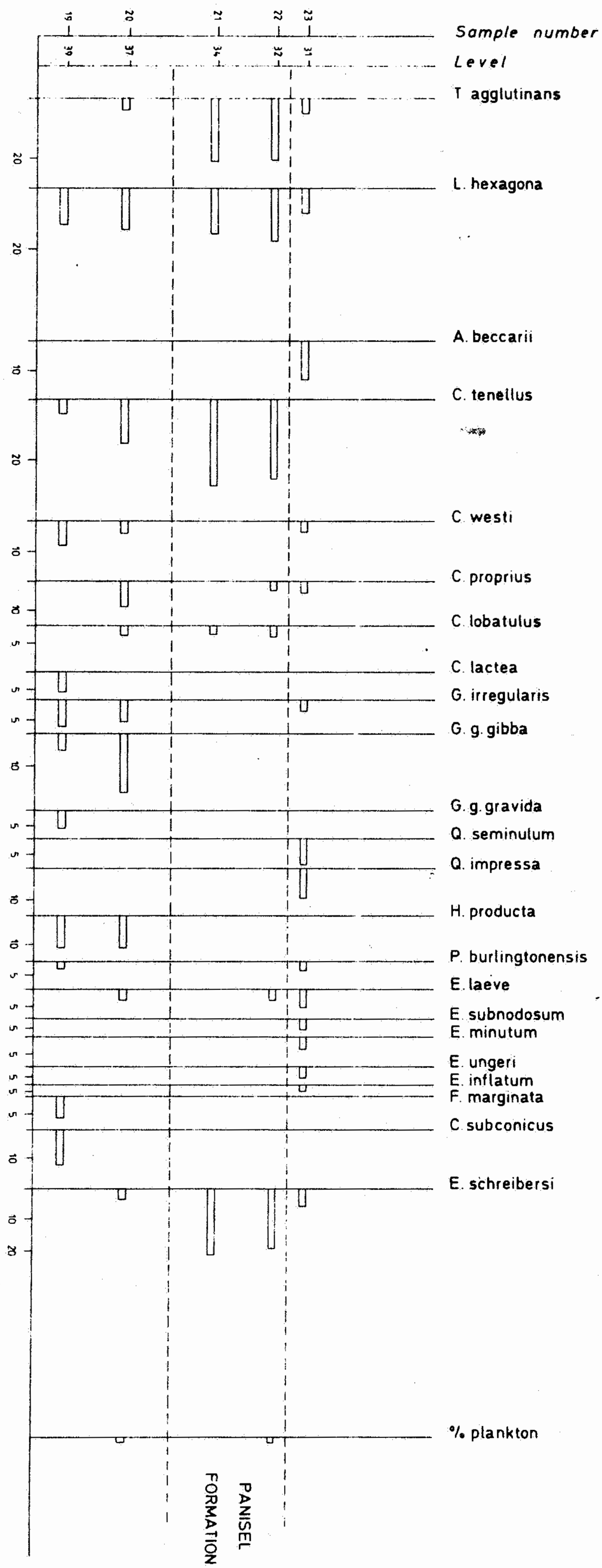


TABLE 11: QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN THE AMPE QUARRY AT EGEM.

TABLE 12 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN WELL n° 5 AT ZEEBRUGGE.



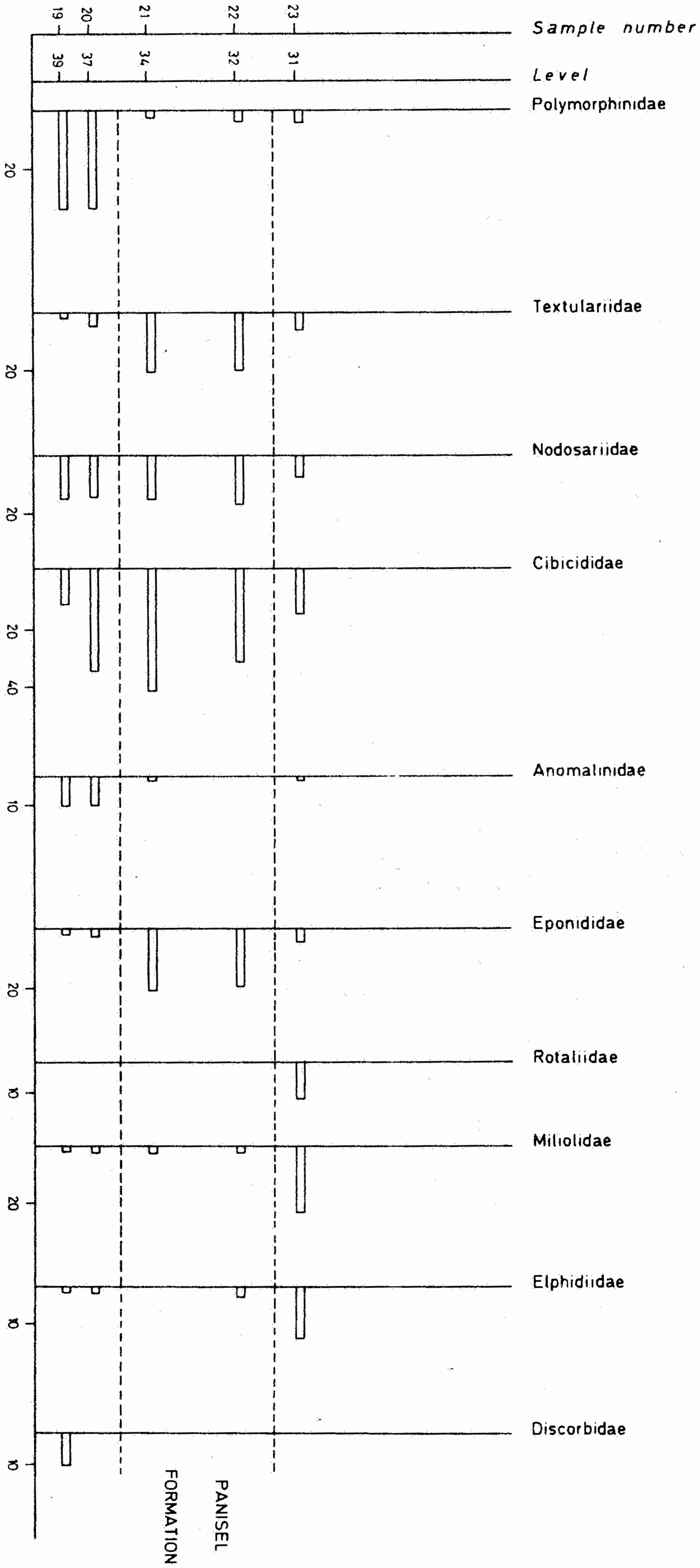


TABLE 13 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN WELL n° 5 AT ZEEBRUGGE.

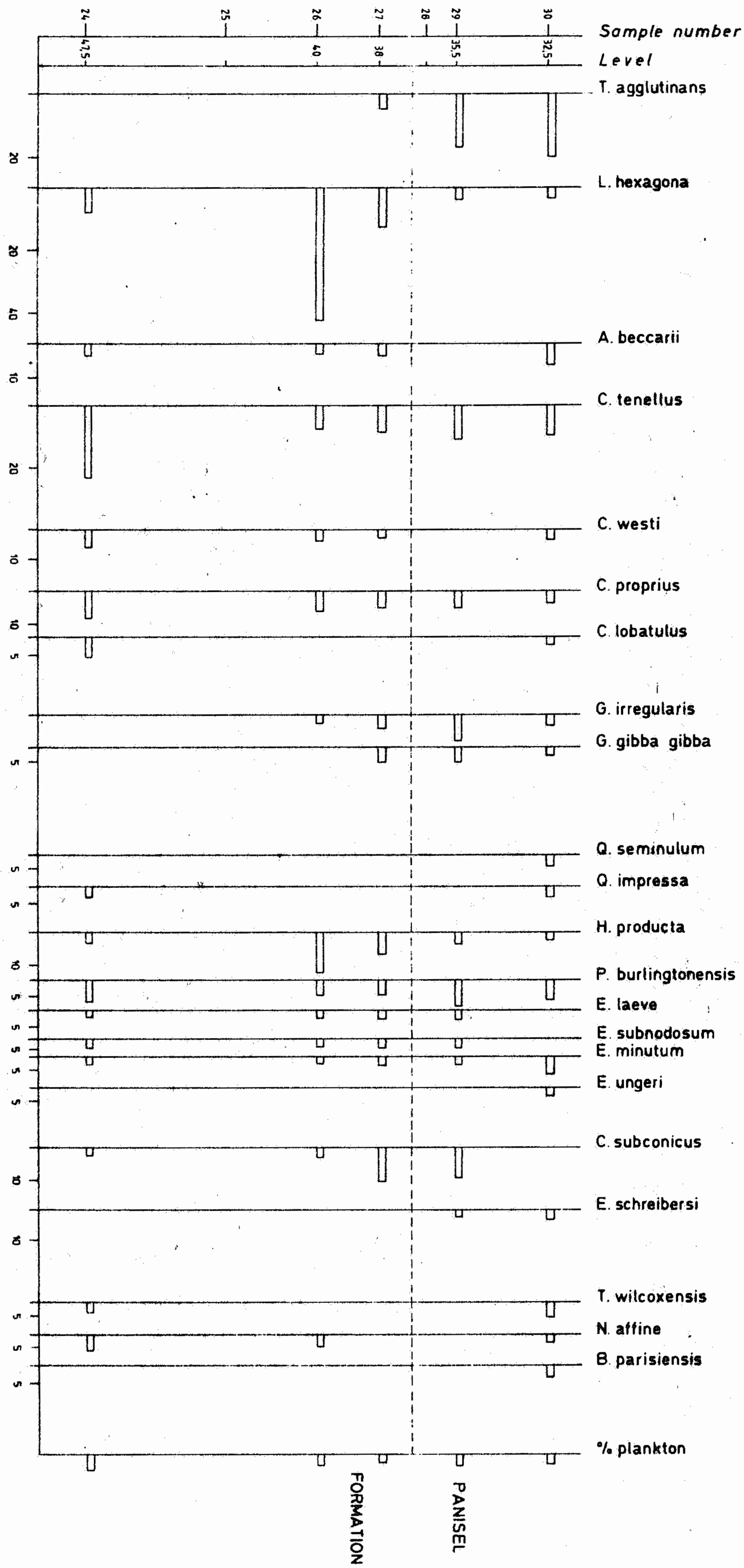


TABLE 14 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN WELL n° 8 AT ZEEBRUGGE.

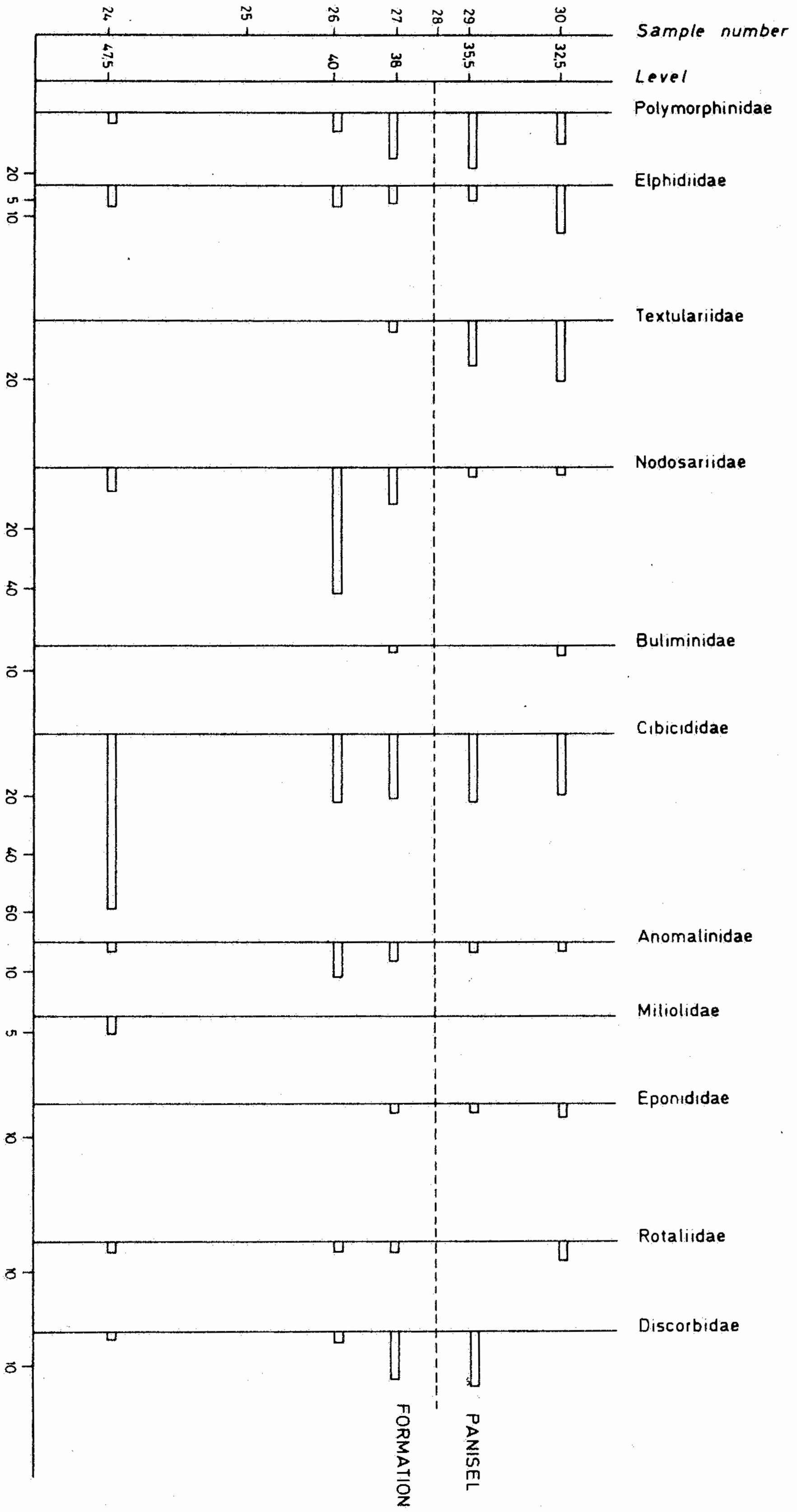


TABLE 15 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN WELL n° 8 AT ZEEBRUGGE.

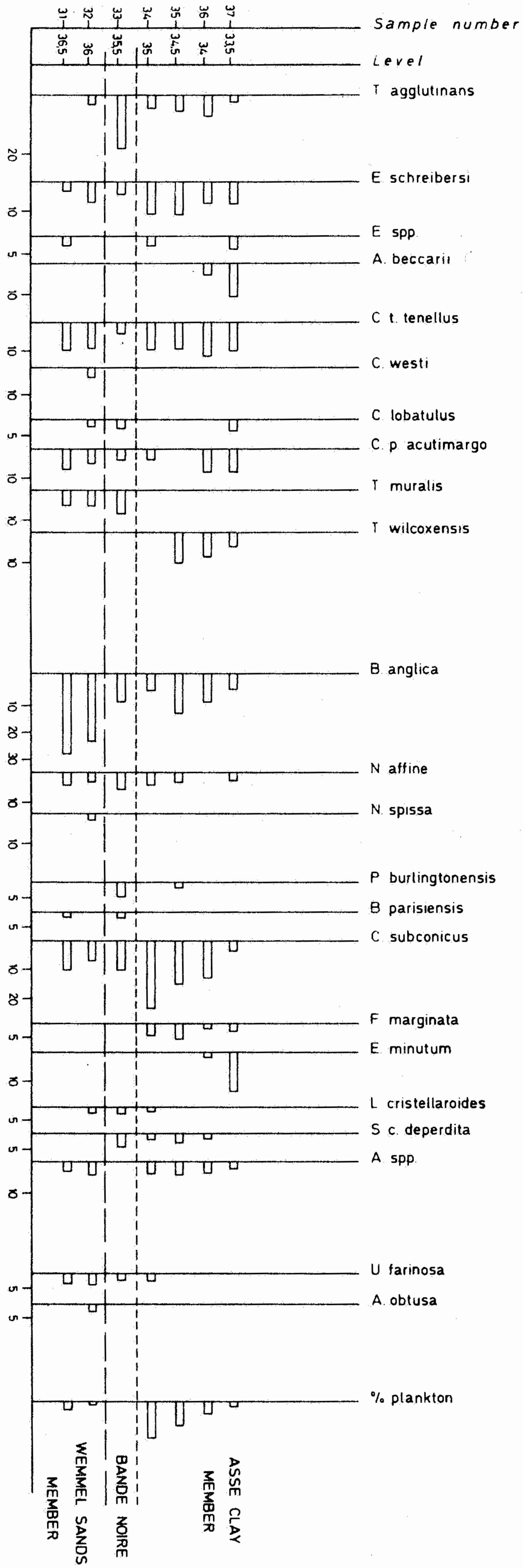


TABLE 16 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN WELL nº 10 AT ZEEBRUGGE.

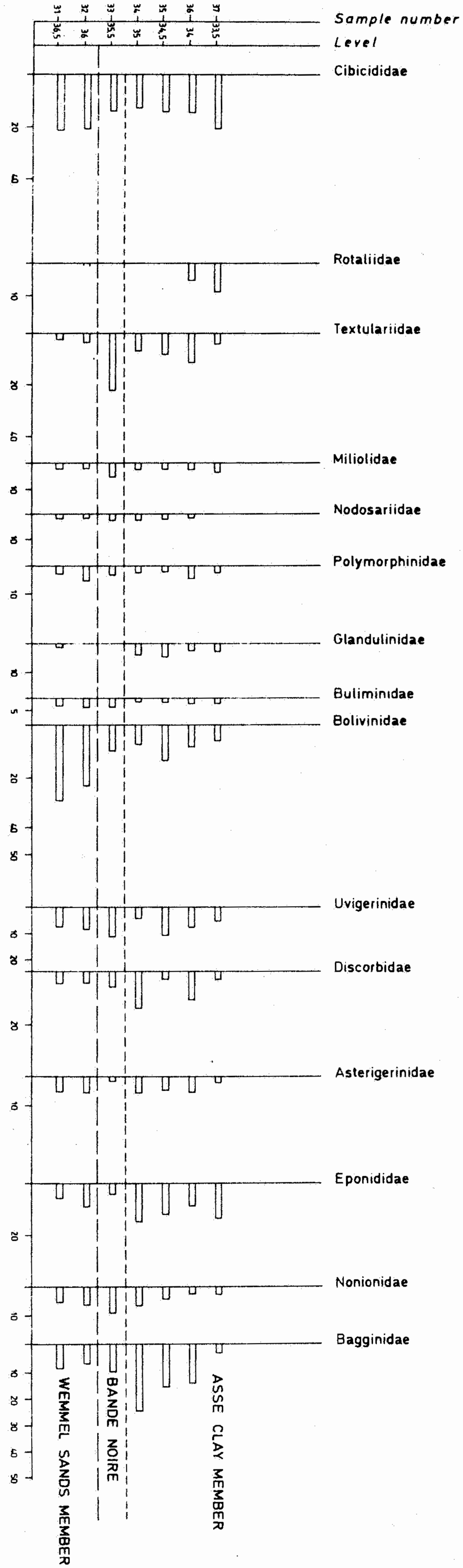
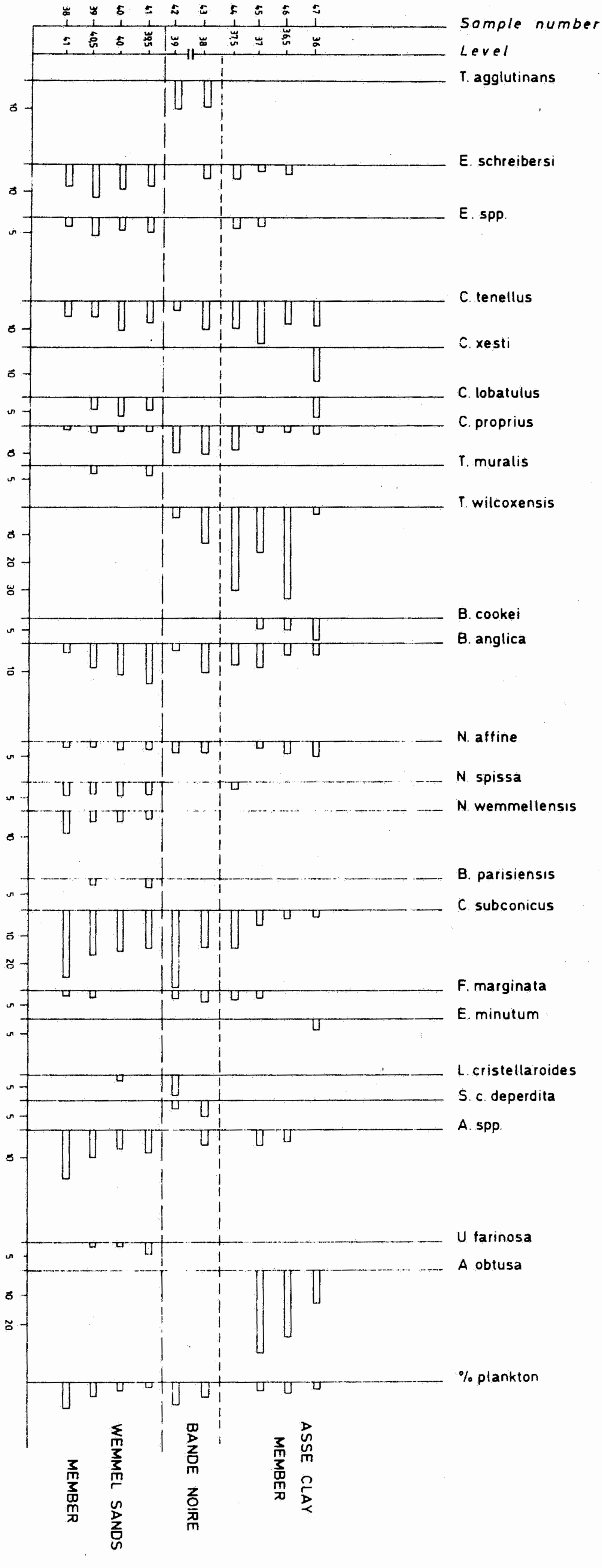


TABLE 17 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN WELL n° 10 AT ZEEBRUGGE.

TABLE 18 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERA IN WELL n° 11 AT ZEEBRUGGE



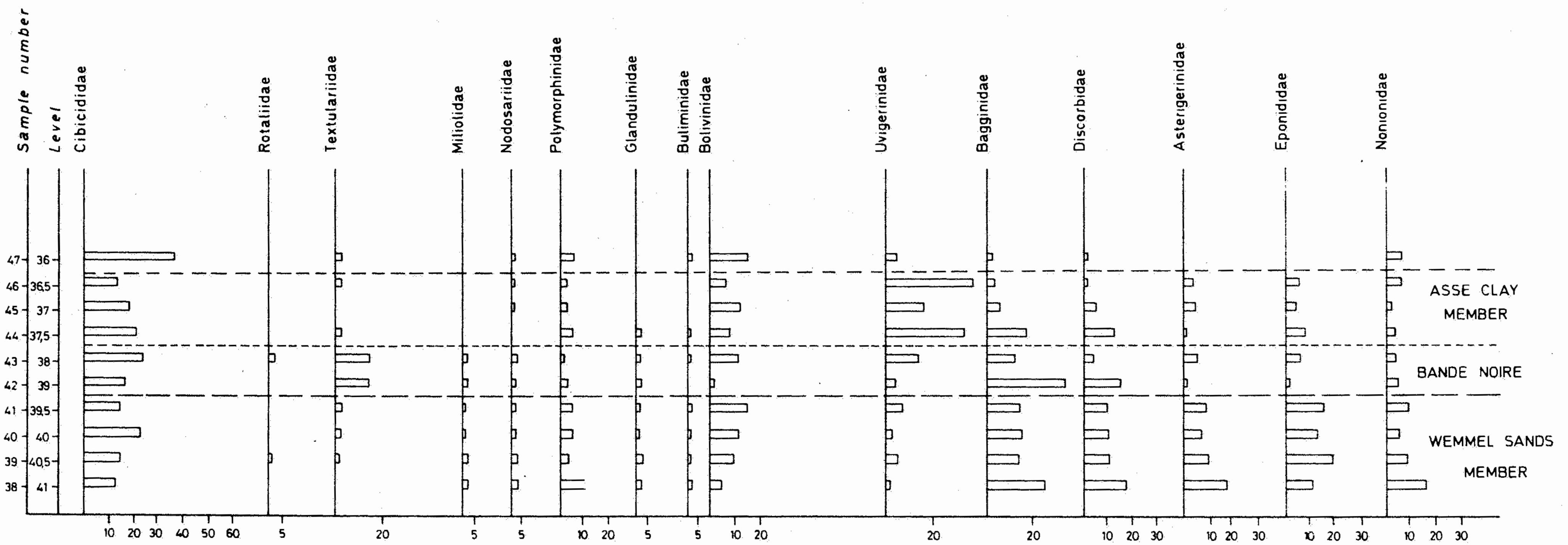


TABLE 19 : QUANTITATIVE DISTRIBUTION OF BENTHONIC FORAMINIFERAL GENERA IN WELL n° 11 AT ZEEBRUGGE.