THE STRATIGRAPHIC POSITION OF THE QUICK CLAY AT BEKKELAGET, OSLO

BY

ROLF W. FEYLING-HANSSEN

(University of Oslo)

With three text-figures and one plate.

A b s t r a c t: The foraminiferal content of two clay samples, one from the quick clay at Bekkelaget (sample nr. 1142) and one from the underlying deposit (sample nr. 1145), was examined for stratigraphic determination of the deposits. The quick clay appeared to be of Post-Glacial age (*Isocardia*-clay), whereas the underlying one was of Late-Glacial age.

Analyses.

A sample of the quick clay from Bekkelaget (5 km southeast of Oslo centre) was handed over to me by Curator H. ROSENDAHL for stratigraphic determination, as good megafossils were lacking. The clay had been pressed up to the surface, 6 m above sea level, by the landslide on October 7th, 1953, and was fluid.

The foraminiferal content of the clay sample was rich, and revealed at once the Post-Glacial character of the sediment. It is an *Isocardia*-clay deposited during the Post-Glacial warm period.

The mechanical analysis (50 g of the sample treated) gave the following result:

Grade fraction	Percentage
< 125.0 μ	99
« 74.0 «	97
« 45.3 «	94
« 35.3 «	92
« 26.9 «	89
« 17.9 «	86
« 9.4 «	74
« 6.8 «	66
« 4.9 «	57
« 2.5 «	42
« 1.1 «	28

Median diameter, $M = 3.7\,\mu$. Quartiles, $Q_3 = 9.8\,\mu$, $Q_1 = 0.8\,\mu$. Coefficient of sorting, $So = \sqrt{Q_3/Q_1} = 3.5$, *i. e.* normal sorting (TRASK 1932). Coefficient of quartile skewness, $Sk = Q_1Q_3/M^2 = 5.7$, *i. e.* the maximum sorting lies on the fine side of the median diameter (fig. 1, nr. 1142).

For micropaleontological investigation another part of the sample was placed, for some hours, in a solution of H_2O_2 and then sieved through a 0.1 mm sieve. Of the residuum three extraction trays were examined, from which 1000 specimens of Foraminifera were picked out. Additionally some ostracod valves were present, and also one tergum of a small specimen of the cirriped *Verruca stroemia* (O. F. MÜLLER 1776).

The foraminiferal analysis gave the following result:

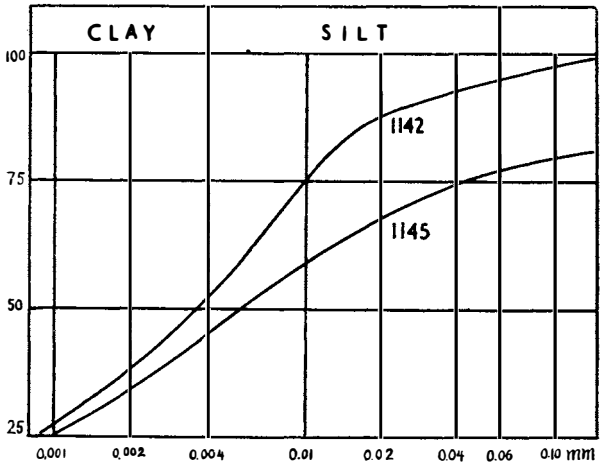


Fig. 1.
Cumulative-frequency curves of the quick clay (sample nr. 1142), and the underlying clay (sample nr. 1145), from Bekkelaget, Oslo.

Bekkelaget. Quick clay. Sample nr. 1142.

Foraminifera	Frequency	Percentage
Bulimina marginata D'ORBIGNY	581	58.1
Cassidulina laevigata D'ORBIGNY	160	16.0
Elphidium incertum (WILLIAMSON)	124	12.4
Elphidium clavatum CUSHMAN	41	4.1
Lagena elongata distoma PARKER and JONES	15	1.5
Nonion pompilioides (FICHTEL and MOLL)	12	1.2
Virgulina fusiformis (WILLIAMSON)	12	1.2
Streblus beccarii (LINNAEUS)	10	1.0
Cibicides pseudoungerianus (CUSHMAN)	9	0.9
Quinqueloculina seminulum (LINNAEUS)	8	0.8
Eponides exiguus (BRADY)	8	0.8
Elphidium cf. *selseyensis* HERON-ALLEN and EARLAND	5	0.5
Globobulimina turgida (BAILEY)	4	0.4
Triloculina trigonula (LAMARCK)	3	0.3
Nonionella turgida (WILLIAMSON)	2	0.2
Rheophax sp. (fragment)	1	0.1
Triloculina tricarinata D'ORBIGNY	1	0.1
Ophthalmidium inconstans (BRADY)	1	0.1
Lagena striata substriata (WILLIAMSON)	1	0.1
Uvigerina peregrina CUSHMAN	1	0.1
Cassidulina crassa D'ORBIGNY	1	0.1
	1000	100.0

The fauna thus contained 21 species, clearly dominated by *Bulimina marginata*. All of these species but one, were recorded from the *Isocardia*-clay of the Oslofjord area (FEYLING-HANSSEN 1954). *Triloculina tricarinata* D'ORBIGNY was not found there; it was originally described from the Red Sea (Cf. p. 189). There was a remarkably high frequency of *Cassidulina laevigata;* they were all carinated and most of them nearly opaque (Cf. pp. 193-194.).

The foraminiferal fauna of the quick clay from Bekkelaget indicates that the clay was deposited during the Post-Glacial warm period (Atlantic-Subboreal age) in fairly well ventilated water, at a depth of about 40—100 m (Cf. *i. a.* BARTENSTEIN 1938; BRAND 1941; HÖGLUND 1947, p. 295; VOORTHUYSEN 1949 and 1950).

Borings carried out by Norges Geotekniske Institutt (Civil engineer L. BJERRUM) revealed another clay sediment below the quick clay. A sample of this clay from core level 12.5 m was handed over to me by Dr. I. ROSENQVIST.

From the mechanical analysis (done by Norges Geotekniske Institutt) appeared: Median diameter, $M = 5.6\ \mu$; quartiles, $Q_3 = 45.0\ \mu$, $Q_1 = 1.0\ \mu$; coefficient of sorting, $So = 6.7$, *i. e.* poorly sorted; coefficient of quartile skewness, $Sk = 1.4$, *i. e.* the maximum sorting lies on the fine side of the median diameter (fig. 1, nr. 1145).

The foraminiferal content of the sample was poor. Examination of 12 extraction trays yielded only 302 specimens of Foraminifera. Additionally a few ostracod valves were present and also some fragments and juvenile valves of the pelecypod *Yoldiella lenticula* (MØLLER) (= *Portlandia lenticula* (MØLLER)).

The foraminiferal analysis gave the following result:

Bekkelaget. Clay, core level 12.5 m. Sample nr. 1145.

Foraminifera	Frequency	Percentage
Cassidulina laevigata D'ORBIGNY	72	23.8
Cassidulina crassa D'ORBIGNY	66	21.9
Elphidium clavatum CUSHMAN	36	11.9
Pullenia osloensis FEYLING-HANSSEN	34	11.3
Virgulina loeblichi sp. n.	32	10.4
Pyrgo cf. *simplex* (D'ORBIGNY)	16	5.3
Quinqueloculina stalkeri LOEBLICH and TAPPAN	13	4.3
Quinqueloculina seminulum (LINNAEUS)	6	2.0
Lagena striata striata (D'ORBIGNY)	5	1.7
Lenticulina sp.	5	1.7
Nonion labradoricum (DAWSON)	5	1.7
Pyrgo williamsoni (SILVESTRI)	3	1.0
Virgulina sp.	3	1.0
Lagena laevis (MONTAGU)	2	0.7
Quinqueloculina arctica CUSHMAN	1	0.3
Triloculina trihedra LOEBLICH and TAPPAN	1	0.3
Lagena elongata distoma PARKER and JONES	1	0.3
Elphidium incertum (WILLIAMSON)	1	0.3
	302	99.9

The fauna contained 18 species, dominated by *Cassidulina laevigata* (Cf. p. 193) and *Cassidulina crassa*. *Elphidium clavatum*, *Pullenia osloensis* (Cf. p. 194), and *Virgulina loeblichi* sp. n. were frequently represented.

All identified species occur at present in Arctic and sub-Arctic waters. This indicates Late-Glacial age of the sediment. The comparatively large number of species suggests an age younger then that of the *Yoldia*-clay. The presence of *Pullenia osloensis* places the sediment somewhere within the range of the *Arca*-clay (FEYLING-HANSSEN 1954).

This underlying clay was also deposited in fairly well ventilated water.

Remarks on some of the species.

Triloculina tricarinata D'ORBIGNY 1826.

This species differs from *Triloculina trihedra* LOEBLICH and TAPPAN and *T. trigonula* (LAMARCK) in having distinctly concave, excavated sides, and acute angles. It was originally described from the Red Sea (D'ORBIGNY 1826, p. 299).

One specimen in the quick clay (Post-Glacial warm period, sample nr. 1142. It was unfortunately broken when I tried to mount it for photographing).

Pyrgo williamsoni (SILVESTRI 1923).

Plate 1, figs. 1—3.

LOEBLICH and TAPPAN 1953, p. 48, pl. 6, figs. 1—4.

Description (after LOEBLICH and TAPPEN 1953, p. 48): «Test oval in outline, inflated; chambers oval in outline, the last extending beyond the previous on all margins, the young specimens somewhat more elongate, the larger ones nearly circular; sutures distinct, depressed; wall calcareous, white, imperforate and vitreous in appearance, surface smooth; aperture ovate with a small, broad, and bifid tooth projecting from the inner and lower margin of the aperture, the tooth more strongly bifid in the older specimens».

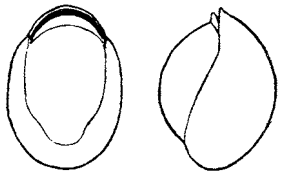
Remarks: Three specimens occurred in sample nr. 1145 (Late-Glacial). The largest one (Pl. 1, fig. 1) had a length of 0.45 mm, a

breadth of 0.30 mm, and a thickness of 0.27 mm. They were all oval in outline with a nearly circular aperture and spatulate tooth.

Pyrgo cf. *simplex* (D'ORBIGNY 1846).
Plate 1, figs. 4—6, text-fig. 2.

Goës 1894, p. 116, pl. 22, fig. 885.

Description: Test nearly circular in outline, much inflated; chamber development biloculine, the last chamber extending beyond the penultimate one on all margins; sutures distinct, depressed; wall calcareous, imperforate, surface smooth; aperture broad, curved, with a broad and thin tooth, or rather lip, projecting from the surface of the previous chamber, the lip lacking in many specimens, probably due to its fragility.



a b

Fig. 2. *Pyrgo* cf. *simplex* (D'ORBIGNY), a, front view, b, side view of a specimen from the Late-Glacial of Bekkelaget.

Remarks: 16 specimens were picked out from sample 1145 (Late-Glacial). The specimen of Pl. 1, fig. 5, which was a small one, measured: length 0.32 mm, breadth 0.22 mm, thickness 0.13 mm. Length of specimen of fig. 6, 0.35 mm, breadth 0.27 mm, thickness 0.26 mm.

Examination of specimens lacking the apertural lip, proved that it was usually preserved in the earlier developmental stages.

Lagena elongata distoma PARKER and JONES 1864.
Plate 1, fig. 7.

15 specimens were present in the quick clay, sample nr. 1142 (Post-Glacial), and one in the sample from the underlying clay (nr. 1145).

The figured specimen is that from the underlying clay. Its length was 1.40 mm, breadth 0.14 mm. It was more elongate than the Post-Glacial specimens.

Lagena laevis (MONTAGU 1803).
Plate 1, fig. 8.

Two specimens were present in sample nr. 1145 (Late-Glacial). Length of specimen of fig. 8, 0.49 mm, thickness 0.19 mm.

Lagena striata striata (D'ORBIGNY 1839).
Plate 1, figs. 9, 10.

Five specimens were present in the Late-Glacial sample. Length of specimen of fig. 9, 0.37 mm, thickness 0.17 mm; length of specimen of fig. 10, 0.38 mm, thickness 0.15 mm.

Lenticulina species.
Plate 1, figs. 11—13.

Description: Test almost semicircular in outline, moderately compressed, periphery subacute to rounded; chambers 4—5, increasing rapidly in height as added; sutures distinct, slightly depressed; wall hyaline, surface smooth; aperture radiate, at the dorsal angle.

Length of specimen of fig. 11, 0.30 mm, breadth 0.19 mm, thickness 0.11 mm; length of specimen of fig. 12, 0.24, mm, breadth 0.18 mm, thickness 0.11 mm; length of specimen of fig. 13, 0.27 mm, breadth 0.19 mm, thickness 0.12 mm.

Remarks: Five small specimens occurred in the sample of the underlying clay. They were most probably juveniles.

Virgulina loeblichi new species.
Plate 1, figs. 14—18, text-fig. 3.

Bulimina exilis BRADY—LOEBLICH and TAPPAN 1953, p. 110, pl. 20, figs. 4, 5.

Virgulina cf. *davisi* CHAPMAN and PARR—FEYLING-HANSSEN 1954, p. 132, pl. 1, figs. 12 a, b.

Description: Test elongate, 3—4 times as long as broad, biserial throughout both in microspheric and megalospheric form, very seldom triserial in the earliest stages, twisted, tapering towards the sometimes slightly apiculate initial end, no spines; chambers about 10, inflated, elongate, increasing rather rapidly in size as added; sutures distinct,

depressed; wall calcareous, very finely and densely perforate, more or less translucent, surface smooth; aperture large, broad, but elongate.

Length of holotype, fig. 14, 0.54 mm, breadth 0.18 mm. Length of paratype of fig. 15, 0.55 mm, breadth 0.15 mm; length of paratype of fig. 16, 0.54 mm, breadth 0.16 mm; length of paratype of fig. 17, 0.47 mm, breadth 0.15 mm; length of paratype of fig. 18 (microspheric form), 0.48 mm, breadth 0.16 mm.

Holotype: Paleontological museum, Oslo, Fo. 1145 A.

Type stratum and locality: Arca-clay of the Late-Glacial from Bekkelaget, Oslo, 12.5 m below surface.

Derivation of name: This species is named in honour of ALFRED R. LOEBLICH, JR., U. S. National Museum.

Occurrence: 32 specimens were picked out from the sample of *Arca*-clay from Bekkelaget. It was present in several samples of Late-Glacial age, viz. *Yoldia*-clay and *Arca*-clay, from the Oslofjord area, frequently in the *Arca*-clay (FEYLING-HANSSEN 1954, recorded as *Virgulina* cf. *davisi*).

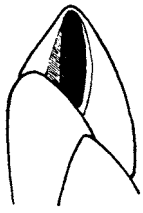


Fig. 3. *Virgulina loeblichi* sp.n. Apertural view of a specimen from the *Yoldia*-clay of Jomfruland (sample nr. 1017).

Its main recent distribution is probably arctic (LOEBLICH and TAPPAN 1953, p. 110).

Remarks: Only in a very few specimens I have observed a triserial arrangement in the very earliest portion of the test, the others were biserial throughout. Most of them were rather strongly twisted. Many of the megalospheric specimens were broadest towards the middle of the test, whereas the microspheric forms tapered more regularly, being broadest at the apertural end.

This species shows affinities to *Virgulina nodosa* R. E. and K. C. STEWART (1930, p. 64, pl. 8, figs. 4a—c) from the Late Tertiary of California and Mexico (Cf. CUSHMAN 1937, p. 22, pl. 3, figs. 24a—c), from which it differs in the broader aperture (Cf. text-fig. 3) and in the more elongate chambers.

It has also much in common with *Virgulina complanata* EGGER (1893, p. 292, pl. 8, figs. 91, 92) from Western Australia (Cf. CUSHMAN 1937, p. 26, pl. 4, figs. 13—17), from which the present species differs in being smaller, less compressed, twisted throughout, and having more inflated chambers.

Virgulina loeblichi sp. n. has probably also been recorded as *Virgulina schreibersiana* CZJZEK 1847.

Virgulina species.
Plate 1, figs. 23, 24.

Description: Test elongate with nearly parallel sides, lowest part tapering towards the initial end, biserial, slightly compressed, periphery rounded, earlier part of the test slightly, if at all, twisted; chambers about 9, elongate; sutures quite distinct, depressed; wall calcareous, thin, finely perforate, translucent to hyaline, surface smooth; aperture large, at the end of the last formed chamber, tending to become terminal.

Length of specimen of fig. 23, 0.45 mm, breadth 0.13 mm; length of specimen of fig. 24, 0.45 mm, breadth 0.12 mm.

Remark: 3 specimens were present in the sample of Late-Glacial clay from Bekkelaget.

Cassidulina crassa D'ORBIGNY 1839.
Plate 1, figs. 19, 20.

66 specimens were picked out from the Late-Glacial clay sample (nr. 1145).

Length of specimen of fig. 19, 0.28 mm, thickness 0.16 mm; length of specimen of fig. 20, 0.29 mm, thickness 0.16 mm.

Only a single specimen of this species occurred in the sample from the overlying quick clay from the Post-Glacial warm period.

Cassidulina laevigata D'ORBIGNY 1826.
Plate 1, figs. 21—22 and 25—32.

The specimens from the Late-Glacial, *Arca*-clay, (figs. 27—32) are closely related to *Cassidulina teretis* TAPPAN 1951. They have a peripheral keel and translucent wall. They are also slightly evolute so that an umbonal boss occurs, «through which may be seen the earlier whorls...» (LOEBLICH and TAPPAN 1953, p. 121). But that condition is usually to be found only on one side of the test; on the opposite side the chambers extend more or less completely over the central portion.

Such specimens were found also in *Yoldia*-clay from the Oslofjord area (FEYLING-HANSSEN 1954, pl. 2, figs 2a—b). In samples of *Yoldia*-clay there also occurred specimens of *C. norcrossi* CUSHMAN, 1933.

Length of specimen of fig. 27, 0.29 mm, thickness 0.11 mm; length of specimen of fig. 28, 0.31 mm, thickness 0.12 mm; length of specimen of fig. 29, 0.35 mm, thickness 0.15 mm; length of specimen of fig. 30, 0.28 mm, thickness 0.12 mm; length of specimen of fig. 31, 0.30 mm, thickness 0.13 mm; length of specimen of fig. 32, 0.38 mm, thickness 0.14 mm.

In the overlying quick clay, of Post-Glacial age, the specimens of *C. laevigata* were still lenticular with a peripheral keel, but most of them were nearly opaque with very indistinct sutures (figs. 25—26); some were partly translucent (figs. 21—22). The chambers usually extended over the central portion on both sides of the test.

Length of specimen of fig. 21, 0.34 mm, thickness, 0.16 mm; length of specimen of fig. 22, 0.30 mm, thickness, 0.14 mm; length of specimen of fig. 25, 0.42 mm, thickness 0.19 mm; length of specimen of fig. 26, 0.35 mm, thickness 0.14 mm.

The specimens here referred to *C. laevigata* were frequent in the lower, Late-Glacial, clay as well as in the overlying quick clay, of Post-Glacial age.

Pullenia osloensis FEYLING-HANSSEN 1954, new name.
Plate 1, figs. 33—35.

Pullenia quinqueloba minuta FEYLING-HANSSEN 1954, p. 133, pl. 2, fig. 3a, b.

34 specimens were picked out from the sample of the lower, Post-Glacial, clay from Bekkelaget.

Length of the specimen of figs. 34 and 35, 0.19 mm, thickness 0.13 mm.

Remarks: This species has been given the new name *P. osloensis*, after its type locality, because *P. quinqueloba minuta* was preoccupied by *P. minuta* CUSHMAN 1936 (Contr. Cushman Lab. Foram. Research, vol. 12, p. 77, pl. 13, fig. 7) for an Upper Cretaceous form of Texas (kindly pointed out by Prof. Dr. HANS E. THALMANN of Stanford University). It has been raised to specific rank because further

examination of *Pullenia*-bearing material proved its distinct difference from other species of the genus.

Nonion labradoricum (DAWSON 1860).

Five specimens were present in the Late-Glacial clay. They were small for the species.

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Manuscript received February 17, 1954.

PLATE 1.

Figs. 1—3. *Pyrgo williamsoni* (SILVESTRI) ..... p. 189
1, Front view of largest specimen (nr. 1145 b), 2, 3, Front view and side view of another specimen (nr. 1145 b); both from the Late-Glacial of Bekkelaget, Oslo.

Figs. 4—6. *Pyrgo* cf. *simplex* (D'ORBIGNY) ..... p. 190
5, Front view showing the broad apertural lip, 4, 6, Side view, three different specimens (nr. 1145 c) from the Late-Glacial of Bekkelaget.

Fig. 7. *Lagena elongata distoma* PARKER and JONES ..... p. 190
Specimen (1145 d) from the Late-Glacial of Bekkelaget.

Fig. 8. *Lagena laevis* (MONTAGU) ..... p. 191
Specimen (nr. 1145 e) from the Late-Glacial of Bekkelaget.

Figs. 9, 10. *Lagena striata striata* (D'ORBIGNY) ..... p. 191
Two specimens (nr. 1145 f) from the Late-Glacial of Bekkelaget.

Figs. 11—13. *Lenticulina* species ..... p. 191
Side view of three different specimens (nr. 1145 g) from the Late-Glacial of Bekkelaget.

Figs. 14—18. *Virgulina loeblichi* new species ..... p. 191
14, Side view, showing the aperture, of holotype (nr. 1145 A). 15—18, Side view of paratypes (nr. 1145 h). 14—17, Megalospheric forms, 18, Microspheric form. All from the Late-Glacial of Bekkelaget.

Figs. 19, 20. *Cassidulina crassa* D'ORBIGNY ..... p. 193
19, Dorsal view, 20, ventral view, of two specimens (nr. 1145 k) from the Late-Glacial of Bekkelaget.

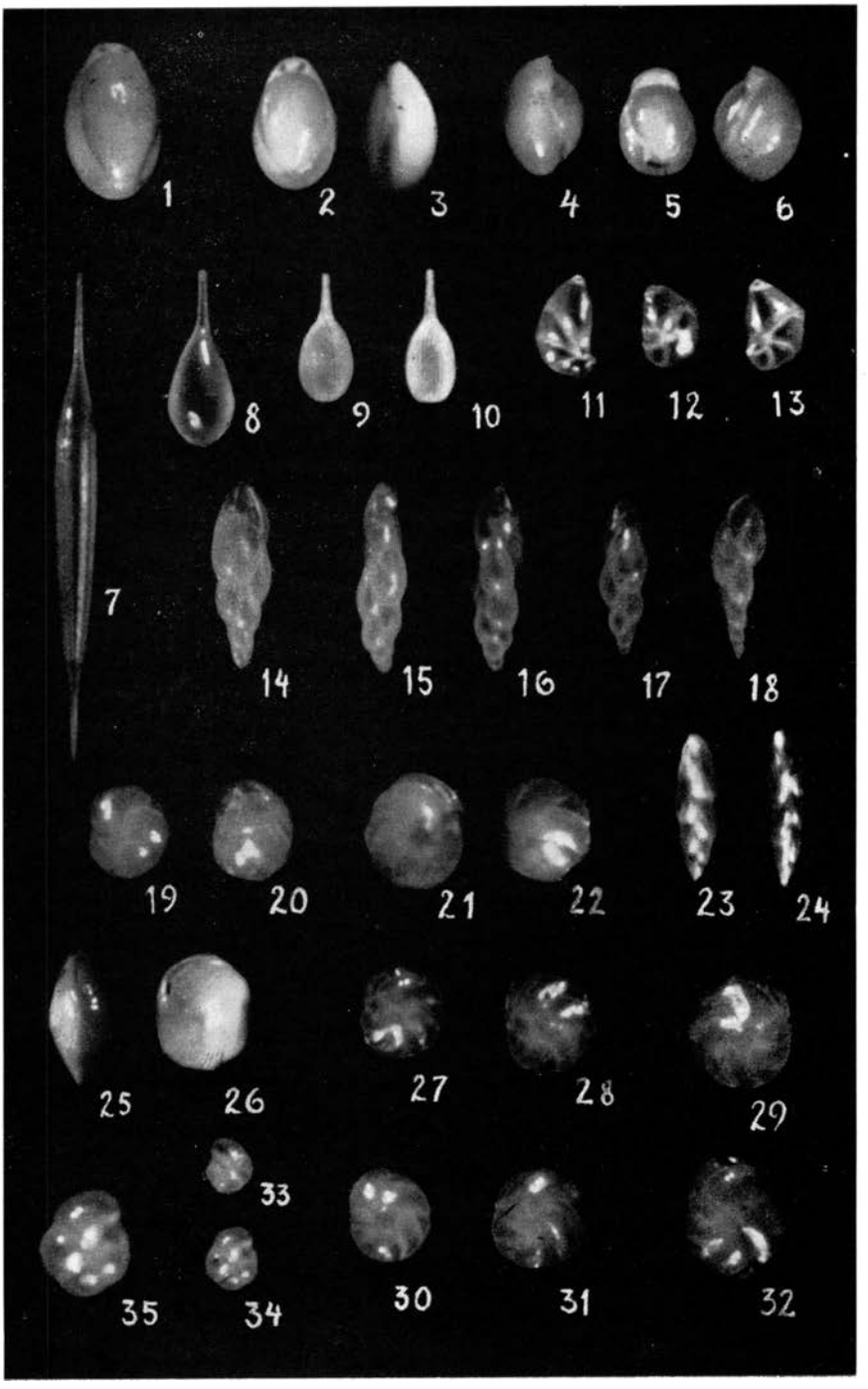
Figs. 21, 22, 25—32. *Cassidulina laevigata* D'ORBIGNY ..... p. 193
21, 22. Semitranslucent specimens from the quick clay of Post-Glacial age, ventral and dorsal view. 25, 26. Two opaque specimens (nr. 1142 b) from the Post-Glacial quick clay from Bekkelaget, peripheral and ventral view. 27—32, Translucent specimens (nr. 1145 m) from the underlying Late-Glacial clay.

Figs. 23, 24. *Virgulina* species ..... p. 193
Side view of two specimens (nr. 1145 n) from the Late-Glacial of Bekkelaget.

Figs. 33—35. *Pullenia osloensis* FEYLING-HANSSEN ..... p. 194
33, 34, Side view of two specimens (nr. 1145 p) from the Late-Glacial of Bekkelaget, lobulate forms. 35, The same as 34 in double magnification.

Figs. 1 — 34 × 45. Fig. 35 × 90.

The photographs for the plate were prepared by the Faculty photographer, Miss BERGLIOT MAURITZ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