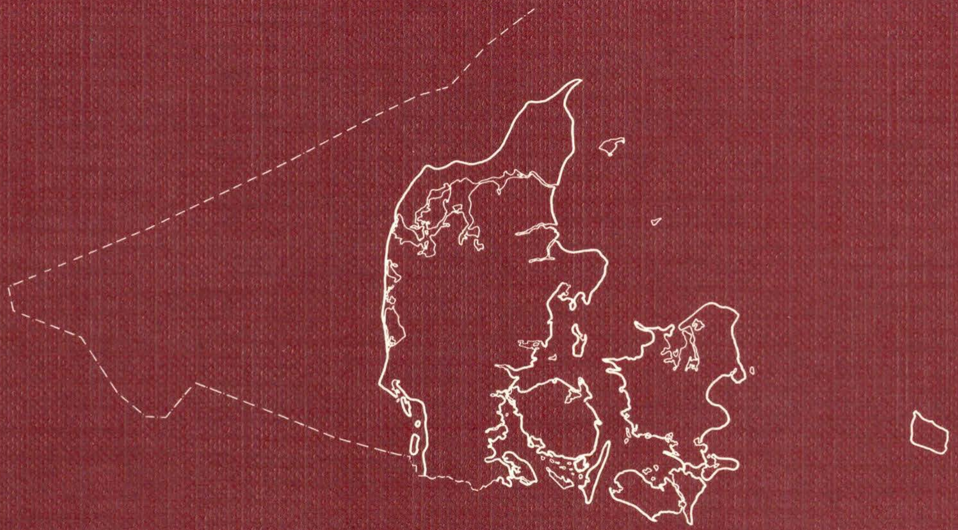
Danmarks Geologiske Undersøgelse
Geological Survey of Denmark . Yearbook 1976

Årbog 1976



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Local and regional vegetational development in eastern Denmark in the Holocene

Svend Th. Andersen

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Two pollen diagrams from two small hollows in Eldrup Forest, East Jutland show the Holocene vegetational development on high ground. Four vegetational phases, *Betula*-forest, *Corylus-Pinus-Populus-Betula*-forest, *Tilia-Quercus*-forest and *Fagus*-forest, are distinguished. There were noticeable human influences on the forest in Subboreal and early Subatlantic time. Similar features occur in regional pollen diagrams from eastern Denmark, which record both high-ground and low-ground vegetation. *Ulmus, Fraxinus* and *Alnus* occurred mainly on the low ground. Leaf-foddering was widespread in the early Subboreal and an agricultural expansion lasted from the middle Subboreal (2000 BC) until the middle Subatlantic (AD 500). Cultivation intensity was low or moderate AD 500–1600, where a new expansion occurred.

Regional and local pollen diagrams

The conventional regional pollen diagrams from the Holocene show a distorted picture of the vegetational development because the various components are variously represented in the pollen spectra. At the same time it is difficult to distinguish upland and lowland vegetation and the former processes on the various habitats. Corrected regional pollen diagrams from Denmark were shown by Iversen (1949 and later), Mikkelsen (1949), Troels-Smith (1960) and Jørgensen (1963) and from southernmost Sweden by Nilsson (1961, 1964), however, the relative pollen productivity of the trees were insufficiently known at that time. More satisfactory correction factors were determined in Andersen (1970).

Pollen diagrams from very small hollows of less than 20–30 m diameter have the advantage that they reflect mainly the forest within a very short distance and can show the former composition of single communities with a great clarity. In this manner it may be possible to distinguish the vegetational development on upland and lowland sites, which is confused in the regional pollen diagrams (Andersen 1973, 1975).

A pollen diagram from a small hollow in Eldrup Forest at Løvenholm in eastern Jutland was mentioned in Andersen (1973). The record there extended back to the early Atlantic. The vegetational sequence of the early Holocene is represented in another hollow within the same forest, and the entire Holocene development in the area is now known. The Holocene sequence from Eldrup Forest will be compared with the regional development.

Upland vegetational development in Eldrup Forest, East Jutland, in the Holocene

Sites

Eldrup Forest is an ancient deciduous woodland, which to-day is united with other woodlands into the extensive Løvenholm Forest in northern Djursland (Fig. 1). A part of Eldrup Forest is a protected research area. Its central part was fenced and mapped in detail (Fig. 2).

The forest is situated on a morainal ridge. The substrate is sandy till covered in some places by a thin sandy melt-water deposit. The soil is devoid of carbonates within the uppermost metres and is now podsol with a raw humus layer. The topography and the tree population are shown on Fig. 2. The area is on the northeast side of the ridge. The southeastern part has rather steep slopes and mostly *Fagus silvatica* forest, and the northwestern part is rather even with mixed *Fagus* and *Quercus petraea* stands.

The two hollows investigated are shown on Fig. 2. Site 1 is about 20 × 20 m. It is still a pool with about 1 m silty gyttja and 3.5 m late-glacial clay, which contains an Allerød gyttja layer. The pool was used by red deer for wallowing until the area was fenced, and the uppermost 70 cm of the deposit are disturbed and unsuitable for pollen analysis. Site 2 is 36 × 16 m and contains 90 cm peat and sandy gyttja. Below the deposit is till. The pollen diagram mentioned in Andersen (1973) is from this site. The sandy gyttja started being deposited in early Atlantic time. The 2 hollows were presumably formed by ground-collapse after the melting of buried ice masses.

Pollen diagrams

Pollen diagrams from the 2 sites in Eldrup Forest are shown on Fig. 3. The 2 hollows are so small that the tree canopy extends over them. Most of the tree pollen preserved in the deposits thus fell directly from the trees similar to the pollen found in the recent moss polsters examined by Andersen (1970). The curves for the trees show percentages of the tree pollen sum after correction

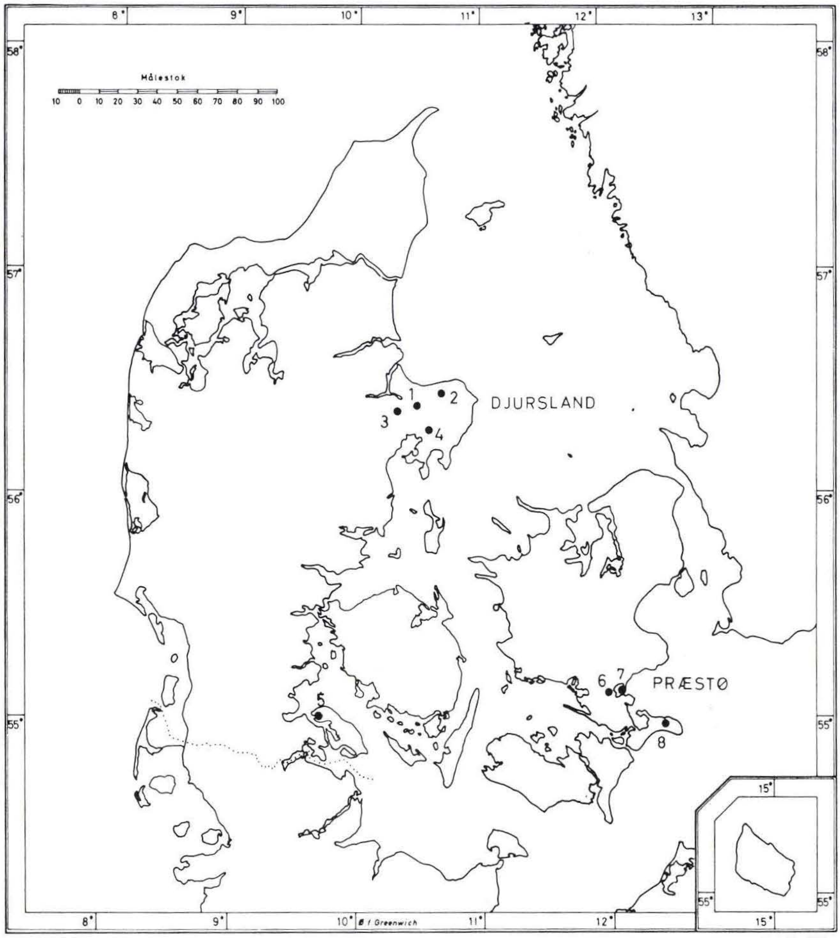

Fig. 1. Localities mentioned in the text. 1. Eldrup Forest. 2. Fuglsø Bog. 3. Dyrholmen. 4. Lake Korup. 5. Bundsø. 6. Lake Even. 7. Præstø Fjord. 8. Borre.

with the factors found for the moss polsters. The pollen productivity of *Populus* is unknown, however, it was necessary to consider this tree a high pollen producer, because otherwise it would have become dominant during the Boreal, a situation which is highly unlikely. *Ulmus, Fraxinus, Alnus, Carpinus* and *Picea* occur with frequencies less that 5%, and were not present near the hollows. The curves for the other trees can be supposed to show their areal frequencies near the hollows at various times rather faithfully except for *Corylus,* which is likely to be underrepresented due to low flowering intensity in the phases where it did not reach the tree canopy (Andersen 1970).

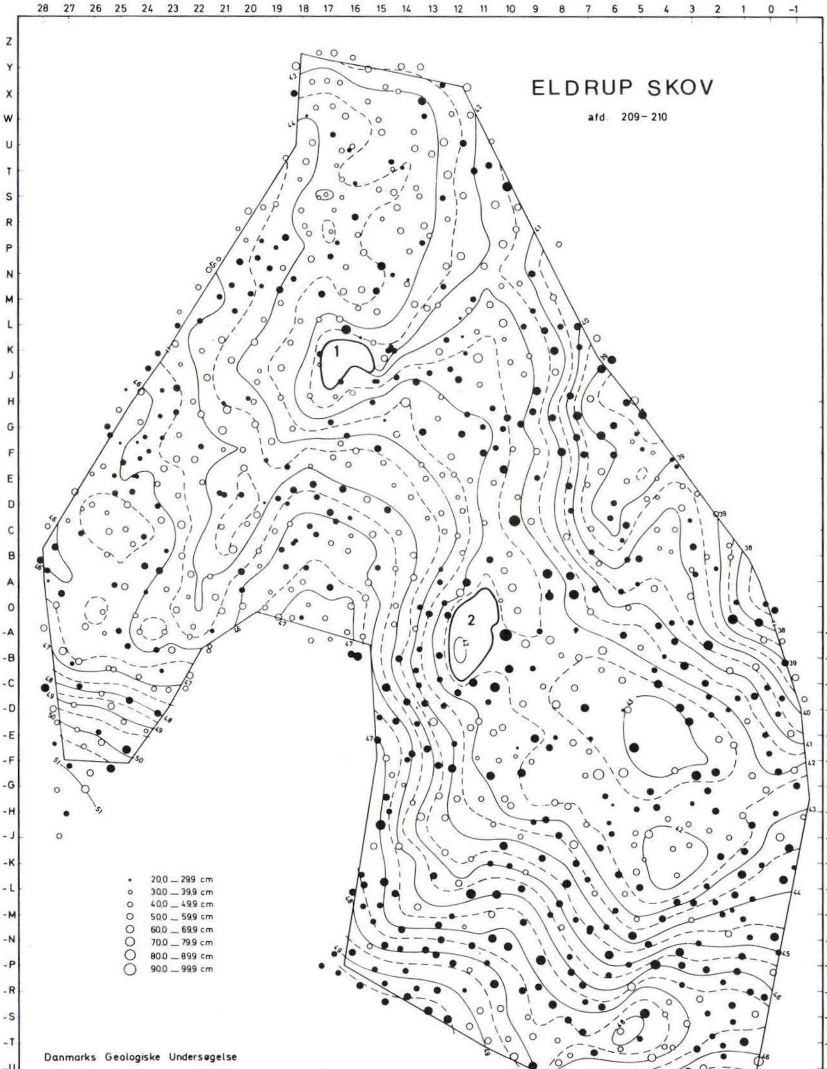

Fig. 2. The fenced research area in Eldrup Forest with the sites 1 and 2. Surface contour intervals 0.5 m. ● *Fagus silvatica*, ○ *Quercus petraea*.

A curve for open-land plants comprises *Juniperus*, *Calluna*, the dry-ground herbs, and the Poaceae. The curve shows percentages of the corrected tree pollen total and the open-land plants. In this manner the tree pollen productivity is equalized with that of *Fagus*. The pollen productivity of the anemophilous open-land plants is known to be high, and their frequen-

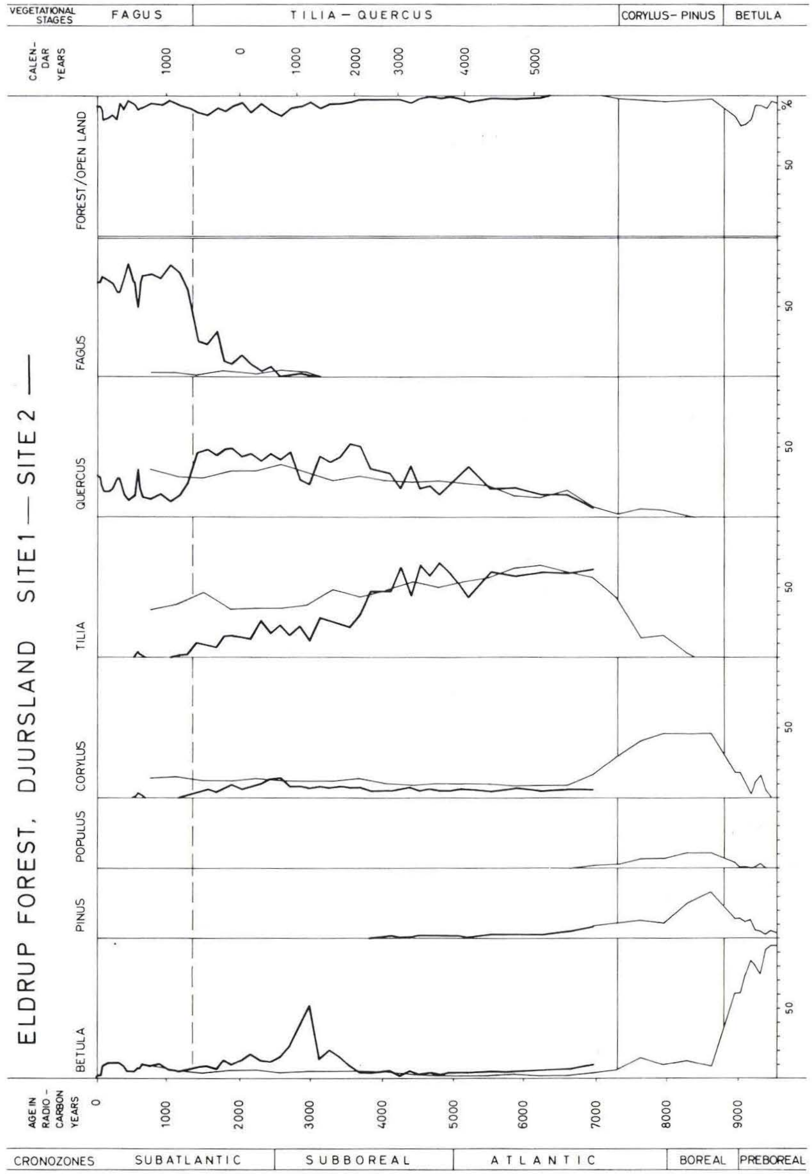

Fig. 3. Pollen diagrams from the sites 1 and 2 in Eldrup Forest. The tree pollen frequencies were corrected with the following factors, *Pinus, Betula Quercus, Populus, Corylus* × 0.25. *Fagus* × 1, *Tilia* × 2 (cp. text). Calendar years according to Clark (1975).

cies were divided by 4 in the lower parts of the pollen diagram (cp. Iversen 1969), where natural vegetation occurred. However, agricultural activities may have occurred from the late Atlantic, and as fields are more or less unproductive in pollen, the frequencies for the open-land plants were not changed in the upper part of the diagram.

Pollen preservation

Pollen grains with corrosion marks were frequent in the middle part of the section at site 1 and the lower part of the section at site 2. The frequencies of grains with corrosion marks differ somewhat in the various tree species, and the sequence of the trees arranged with increasing corrosion frequencies is nearly the same as found by Havinga (1967) and Andersen (1970).

Havinga (1974 and earlier) suggested that *Quercus* pollen in particular may have been removed in certain soils with the result that the *Quercus* pollen percentages are too low, and several authors have suggested that high *Tilia* pollen frequencies may be due to removal of other grains by corrosion (see Munaut 1967), a supposition that was contradicted by Munaut (l.c.).

In order to evaluate a possible distortion of the pollen spectra by differential corrosion, the pollen frequencies of *Quercus, Corylus* and *Tilia,* the most frequent trees in synchronous pollen spectra from 4 sites in Eldrup Forest, were compared. The sites are sites 1 and 2 mentioned above and 2 soil profiles near site 2 (Table 1).

The best correlations were obtained when the corrected pollen frequencies were compared with the frequencies of corroded grains. The pollen percentages calculated for highly corroded samples differ only slightly from the percentages calculated for weakly corroded samples (not more than –3% for *Quercus* and *Corylus,* +7% for *Tilia*). Such a corrosion-effect can hardly affect the interpretation of the pollen spectra.

Table 1. Correlation of pollen frequency (corrected) with the frequency of corroded grains at synchronous levels in Eldrup Forest (n = 20), and calculated pollen frequency at the lowest and the highest frequency of corroded grains (22 and 73%). r = correlation coefficient. b = regression coefficient.

	r	P	b	Calc. pollen frequency, %	Difference, %
Quercus	−.390	.09	−.077	(21.4)–(17.5)	(−3.9)
Corylus	−.419	.07	−.052	(12.1)–(9.4)	(−2.7)
Tilia	+.514	.01*	+.129	66.5 – 73.1	+6.6

Quercus, *Corylus* and *Tilia* are the most important trees in the levels in the pollen diagrams from Eldrup Forest with high corrosion. The other trees are so scarcely represented at these levels that a possible corrosion-effect must be negligible.

Time scale

The two pollen diagrams were synchronized on a common radiocarbon-age scale. The deposits themselves were not well suited for radiocarbon dating because the alkali-insoluble organic content is low, and because the alkali-soluble matter was avoided due to a possible infiltration of younger humic substances from above. There is 1 radiocarbon date from the sites themselves (wood of *Quercus* sp.); and 5 radiocarbon dates from a peat- and gyttja-section at Elsborg Bog 700 m southwest of the sites were used, whereas the ages of other levels were obtained from other sources (table 2 and 3). No levels below the 7000 BP level at site 2 could be fixed in time, and this part at site 2 was omitted. The calculated sedimentation rates in table 2 are almost constant except for the lowermost deposit at site 1, which has a very high mineral content, and the uppermost deposit at site 2, which is peat. Hence, the time scale may be approximately correct.

Table 2. Assumed ages of levels in the pollen diagrams from the 2 sites in Eldrup Forest and calculated sedimentation rates.

	Age in years		Sed. rates cm/100 years		
	^{14}C	Calendar	^{14}C	Calendar	Comment
Site 2					
Picea increase		1850		7.0	Historical date
Fagopyrum and *Centaurea cyanus*		12–1400		3.1	Mikkelsen 1954 (cp. text)
Fagus expansion	1500	450		.8	See Table 3
Quercus wood	5400	–4300		.7	–
Quercus increase	7000	–5800	.6	.6	–
Site 1					
Fagus continuous	3000	–1300			inferred from site 2
Ulmus decline	5200	–4000	.3	.2	See table 3
Quercus increase	7000	–5800	.3	.3	–
Tilia increase	8000		.3		–
Corylus expansion	9000		(.3)		inferred
Corylus increase	9400		(1.5)		See table 3

Table 3. Radiocarbon dates from eastern Denmark and South Sweden.

Event	Source		Radiocarbon years before 1950 T/2 = 5570	Calendar years (Clark 1975)
Cultivation expansion	Bahnson 1962	K-2092	970 ± 100	980
Cultivation phase	– –	K-2102	1490 ± 100	480
Fagus expansion	Nilsson 1964	St-979	1495 ± 85	470
– –	Elsborg Bog	K-2217	1520 ± 100	450
– –	– –	K-2393	<1680 ± 100	>310
Cultivation phase	Bahnson 1962	K-2099	>1790 ± 100	>220
		K-1355	<2550 ± 100	<– 800
Fagus increase and herb expansion	Nilsson 1964	St-1050	3360 ± 85	–1990
Cultivation phase	Bahnson 1962	K-2101	4110 ± 100	–2860
Ulmus decline	Elsborg Bog	K-2220	5160 ± 100	–4000
Quercus wood	Eldrup Forest, site 2	K-1421	5400 ± 120	–4330
Quercus increase	Elsborg Bog	K-2421	7100 ± 115	
Tilia increase	Fredskild 1975	K-2251	7970 ± 130	
– –	Nilsson 1964	St-1001	>7950 ± 85	
		St-1002	<8160 ± 110	
– –	Berglund 1966	St-1333	8140 ± 90	
Corylus expansion	Tauber 1966	K-1082	>8990 ± 140	
		K- 852	<9550 ± 140	
– –	Krog 1973	K- 926	9300 ± 150	
– –	Nilsson 1964	St- 800	9590 ± 160*	
– –	Berglund 1966	St-1679	9380 ± 120	

* calcareous deposit, probably too old.

Chronozones in accordance with Mangerud et al. (1974) are shown on the pollen diagram. Ages will be mentioned in radiocarbon years (before 1950) or in calendar years (corrected according to Clark 1975, cp. Mangerud et al. l.c.).

The Holocene vegetational development of Eldrup Forest

The vegetational development in Eldrup Forest is divided into vegetational stages according to tree dominance.

The curve for open-land plants has a small peak in the late Preboreal, otherwise it is rather low. It is difficult to say whether the open-land pollen at later times derived from small populations at the sites, from nearby clearings, or from sites further away. In any case, the tree cover must have been fairly continuous throughout the time spans represented.

Betula-stage. *Betula* was the only tree present in the early Preboreal, and we may presume that the area was covered by pure *Betula*-forest at that time. *Pinus* was at first very scarce and increased in the late Preboreal due to an initial spreading near the site at that time. *Corylus* began to increase somewhat earlier. *Corylus* thus immigrated to the site earlier than *Pinus*, however, the frequencies decreased again, and *Corylus* was again replaced by *Betula* and *Pinus*. the open-land plants (mainly *Juniperus, Empetrum,* Poaceae, *Artemisia, Rumex, Filipendula*) were rather scarce at first, indicating that the Preboreal *Betula*-forest was rather dense. The peak at the level of the *Corylus* minimum indicates a phase with a more open tree cover. The *Corylus*-decrease at the end of the Preboreal in Eldrup Forest presumably was a local event, due to some local cause. At that early time buried ice masses may still have persisted, and local landslides may have caused the *Corylus*-decrease and a disruption of the tree canopy.

Corylus-Pinus stage. *Corylus* dominated the forest in the Boreal and earliest Atlantic (50%). *Pinus* and *Populus* had maxima in the Boreal (30% and 10%), and *Betula* persisted with notable frequencies (10–15%). *Tilia* began to spread at the transition to the Atlantic.

Corylus expanded at the cost of *Betula* presumably because its shade prevented the germination of *Betula*-seeds. However, the upland *Corylus*-forest was not sufficiently dense to prevent the growth of scattered *Pinus, Betula* and *Populus*.

Tilia-Quercus stage. *Tilia* expanded in the early Atlantic, however, it appears that a considerable time, probably about 1000 years, elapsed before this tree became fully dominant. The *Tilia* increase was very irregular at site 2 (not shown here) where open-forest conditions are suggested, probably due to yet unstable soils particularly on the steep slopes (cp. Andersen 1973). *Quercus* pollen occurs from the Boreal-Atlantic transition but the tree may not have been present at that time. The *Quercus* frequencies increased at the time when *Tilia* obtained dominance, and *Betula, Pinus, Populus* and *Corylus* were suppressed to insignificant values. A similar *Quercus*-increase occurs in regional pollen diagrams from eastern Denmark.

Once established, the *Tilia*-forest remained stable for several thousand years. *Tilia* was dominant (about 60%), and *Quercus* was present (with 20–30%), whereas *Betula, Pinus* and *Corylus* were insignificant. *Corylus* may have formed an understorey in the forest. In that case it had a low pollen productivity, and its actual coverage would have been about 40% (calculated outside the tree cover).

The tree pollen curves at site 1 remain nearly constant throughout Atlantic, Subboreal and early and middle Subatlantic time except for a very slow decrease in *Tilia* and a tenacious increase in *Quercus*. This development may indicate a slowly proceeding soil depauperization unaffected by man through millenia.

At site 2 the *Tilia* and *Quercus* curves become unstable in the late Atlantic and the early Subboreal with repeated minima in *Tilia* and maxima for *Quercus*. This development was interpreted earlier (Andersen 1973) as an effect by man. Foddering with leaves particularly of *Ulmus* and also of *Tilia* in early Subboreal time was postulated by Fægri (1940), Troels-Smith (1954, 1955, 1960) and others. Leaf-foddering of tethered animals as described by Troels-Smith (l.c.) requires no fires and results only in a decreased flowering intensity in the pollarded trees, whereas slash-and-burn cultivation followed by pasture as demonstrated by Iversen (1941 and later) produces conspicuous maxima in the *Betula* and herb pollen curves. It is, however, difficult to prove definitely that the small minima in the *Tilia* curve at site 2 in the early Subboreal were due to pollarding.

Tilia decreased abruptly (to about 20%) at site 2 in the middle Subboreal and remained low throughout the late Subboreal and early Subatlantic. *Quercus* increased at the same time (to about 50%), and there are several more or less pronounced peaks on the *Betula* curve (up to 50%). There can be no doubt that these events signify a period with human activities around site 2. The peaks on the *Betula* curve can best be explained by repeated artificial forest fires, however, the curve for open-ground plants increases only slightly, and this pollen may have been transported from other sites. Human activities on Djursland were intensive at that time. Troels-Smith (1942) found a strong herb pollen expansion at Dyrholmen 10 km west of Eldrup Forest in the middle Subboreal, and there are indications of intensive agriculture at Fuglsø Bog 8 km west of Eldrup Forest in the middle Subboreal and the early Subatlantic (Bahnson 1972, cp. table 3). Eldrup Forest seems to have been a marginal area, where only restricted human activities occurred. It is possible that *Tilia* was pollarded for leaf-foddering and the *Betula*-maxima may suggest repeated slash-and-burn activity. By the latter method the cultivation phases may have been so short that cereal and weed pollen maxima are not reflected in the pollen spectra, each of which comprises about 50 years. It is fairly certain, at least, that the forest was exploited in a limited degree and cattle-grazing did not occur.

Secale pollen appeared in the early Subatlantic. The oldest finds of *Secale* grains at archaeological sites in Denmark are from shortly after the Birth of Christ. *Hordeum* was the main crop at that time and *Secale* was only an accidental weed until the Viking Age (Jessen 1951, Helbæk 1970). *Hordeum* pollen is extremely rare in the deposit in Eldrup Forest, and the presence of

Secale pollen must be due to its better dispersal capacity. However, it is not possible to say whether *Secale* occurred near site 2 or at some distant locality.

Fagus occurred with low percentages in the late Subboreal. The frequencies remained low at site 1, whereas *Fagus* at site 2 increased somewhat in the early Subatlantic (10–20%). *Fagus* thus was present at site 2 at that time but was apparently hampered by the human activities.

Fagus stage. *Fagus* continued to be rare at site 1 in the middle Subatlantic, whereas *Fagus* became dominant (80%) at site 2.

It is very remarkable that *Fagus* was unable to expand at site 1 although the tree was present in the vicinity. *Fagus* expanded at site 2 at the cost of *Betula*, *Corylus*, *Tilia* and *Quercus*, and it is clear that this change reflected abandonment of the human activities. Mor conditions and raw humus accumulation began at that time in soil profiles at site 2. The cessation of cultural influence thus caused a change from poor-mull to mor, the substrate became too poor for *Tilia* and *Corylus*, and *Quercus* was suppressed by shade from the dominating *Fagus*.

Fagus remained dominant at site 2 until to-day. 2 slight *Betula* and *Quercus* peaks suggest restricted human activities in the vicinity. A phase of intensive cultivation began at Fuglsø Bog at about AD 1000 (Bahnson 1972 and table 3). *Fagopyrum* and *Centaurea cyanus* pollen appear together with the first *Betula-Quercus* peak. Pollen of these plants occur commonly in the Middle Ages (Mikkelsen 1949, 1954). Hence it is likely that the *Betula-Quercus* peaks in the late Subatlantic reflect restricted human activities in the Middle Ages and somewhat later, probably in the 17th and 18th centuries. There are slight peaks on the curve for the open-land plants at the same time.

It is unfortunate that the youngest development at site 1 cannot be traced. Soil profiles in the vicinity of site 1 show traces of cultural influences in the Middle Ages, and since then *Fagus* dominated the forest there.

Eldrup Forest had a very unexpected recent history. In one area left unattended by man, the "Atlantic" *Tilia*-forest persisted probably until the early Middle Ages, whereas man destroyed the original *Tilia*-forest already in the middle Subboreal in the near vicinity, and the present *Fagus*-forest there was established in the middle Subatlantic.

Regional and local vegetational development in eastern Denmark in the Holocene

Holocene regional pollen diagrams from Denmark

There are very few regional pollen diagrams from Djursland which can be compared with the local sequences from Eldrup Forest.

The pollen diagram from Elsborg Bog not far from Eldrup Forest mentioned above has regional features, however, it contains several time gaps. *Ulmus, Alnus* and *Corylus* have higher frequencies than in Eldrup Forest showing that these trees were frequent on lowland habitats within the region. Iversen (1941) published a pollen diagram from Lake Korup 20 km southeast of Eldrup Forest, which extends from the late Boreal to the late Subboreal, and the pollen diagrams from Dyrholmen (Troels-Smith 1942) cover the Atlantic and the early and middle Subboreal. These pollen diagrams resemble other regional pollen diagrams from eastern Denmark and have higher *Ulmus, Alnus* and *Corylus* frequencies than Eldrup Forest.

There are several other pollen diagrams from eastern Denmark of regional significance, however, few of them extend for long time intervals, and especially the late Subboreal and the Subatlantic are badly represented. Only one pollen diagram extends for the entire Holocene, a pollen diagram from Lake Even near Præstø, published by Mikkelsen (1949). This pollen diagram has characteristic features common with the other regional pollen diagrams from eastern Denmark.

The few regional pollen diagrams from western Jutland show a somewhat different vegetational development (cp. Iversen 1967, 1973).

A re-calculated pollen diagram from Lake Even is shown on Fig. 4. together with the curves from Eldrup Forest.

Regional pollen assemblage zones

The pollen diagram from Lake Even can be subdivided into the conventional Danish pollen zones IV–IX for the Holocene. These 6 pollen zones were defined by changes in pollen curves of regional significance and can therefore be considered regional pollen assemblage zones (cp. Mangerud et al. 1974). It should be noticed that assemblage zones are defined by the fossil contents of the deposits. Hence they should refer to the fossil assemblages directly. It is accordingly to be preferred to define pollen assemblage zones by way of changes in the original pollen frequencies without correction.

The Holocene pollen zones IV–IX were originally defined by Jessen (1935), and were later re-defined at various points by various authors (see

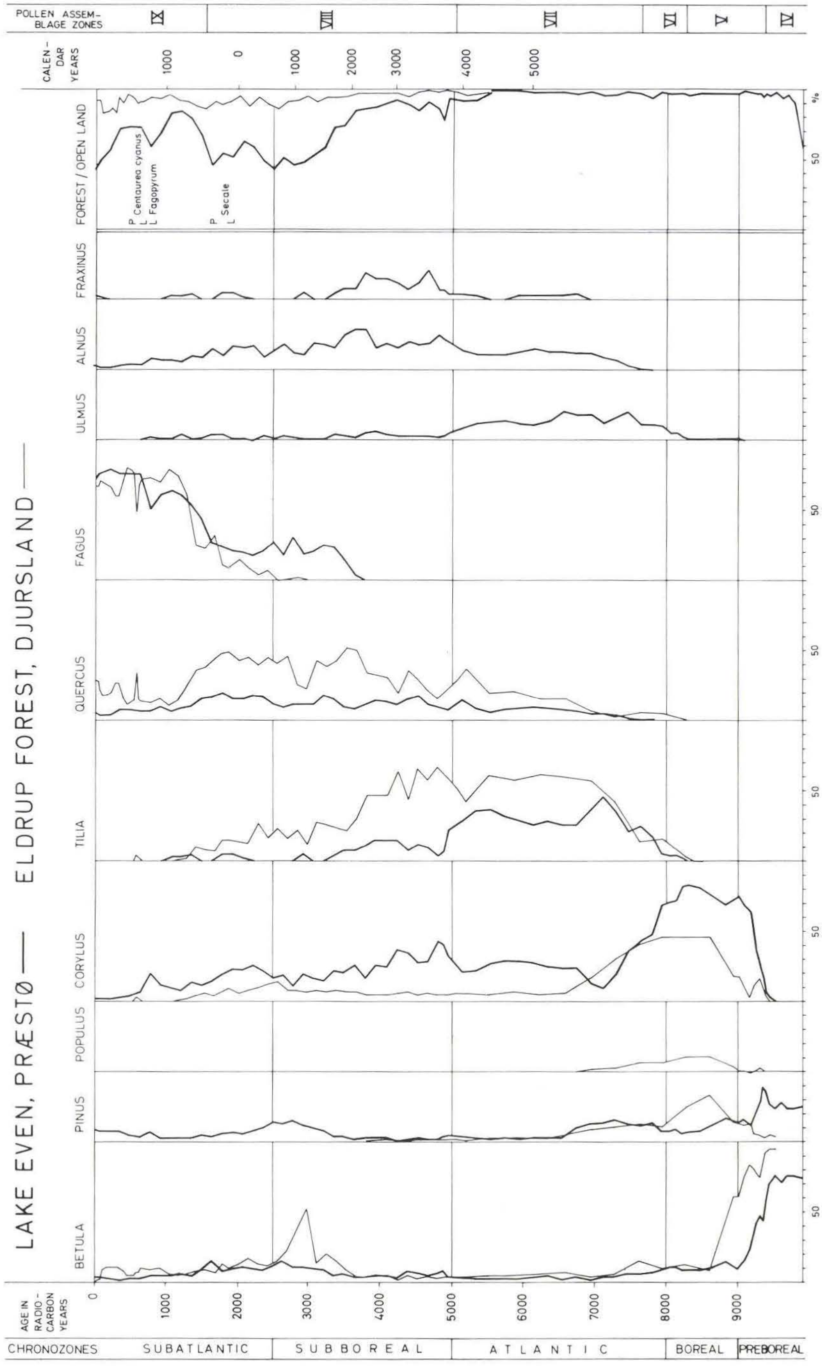

Fig. 4. Pollen diagrams from Eldrup Forest and Lake Even near Præstø (from Mikkelsen 1949). The tree pollen frequencies were corrected with the following factors, *Pinus, Betula, Quercus, Alnus, Corylus* × 0.25, *Ulmus* × 0.5, *Fagus* × 1, *Tilia, Fraxinus* × 2 (cp. text). Calendar years according to Clark (1975).

below). *Corylus* was not included in the pollen total by Jessen (l.c.) as done by Iversen (1949) and Jørgensen (1954, 1963), and Jessen's definitions must be changed accordingly. It may therefore be useful to re-summarize the definitions of the Danish Holocene regional pollen assemblage zones.

Herb pollen frequencies were not considered by Jessen and other authors at the definitions of pollen zone borders.

IV, *Betula-Pinus*. *Betula* dominant, *Pinus* increasing. The upper zone border at the *Corylus* expansion.

V, *Corylus-Pinus-Betula*. *Corylus* dominant, *Pinus* and *Betula* decreasing. Jørgensen (1954) placed the upper zone border at an increase in *Ulmus*, *Quercus* and *Tilia*.

VI, *Corylus-Quercus-Ulmus-Tilia-Alnus*. *Corylus* decreasing, *Quercus*, *Ulmus*, *Tilia* and *Alnus*, low, increasing. Jørgensen (1954) placed the upper zone border at a level where the "Quercetum mixtum" increase ceases (after the rise of the *Quercus* curve), whereas Iversen (1960) placed the upper border somewhat lower, at a level where the *Tilia* increase ceases.

VII, *Corylus-Alnus-Quercus-Ulmus-Tilia*. *Corylus* and *Alnus* are dominant, *Quercus* lower, and *Ulmus* and *Tilia* rather low. Jessen (1935) placed the upper zone border at a decrease in *Tilia*, and Iversen (1941) at a decrease in *Ulmus*. The *Ulmus* decrease may be somewhat earlier than the *Tilia* decrease.

VIII, *Corylus-Alnus-Quercus*. *Corylus*, *Alnus* and *Quercus* are dominant. In eastern Denmark *Fagus* attains a low frequency (Jessen 1935). Jessen placed the upper zone border at the expansion of *Fagus* in eastern Denmark, and the appearance of *Fagus* in western Jutland.

IX, *Fagus-Corylus-Quercus-Alnus*. *Fagus* dominant in eastern Denmark and less frequent in western Denmark (Jessen l.c.).

Chronozones according to Mangerud et al. (1974) and regional pollen assemblage zones are indicated on Fig. 4.

The regional pollen diagram

The tree pollen frequencies at Lake Even were corrected with the factors used for Eldrup Forest. Lake Even is about 300 m wide. Hence, the main part of the pollen deposited in the lake must have been transported from a wide distance, probably mainly by wind passing over the vegetation. Pollen transported in this manner may suffer losses due to filtration when the lower parts of the pollen cloud passes the top of the vegetation. Large pollen grains are more likely to be lost than small grains by such filtration, however, the differences are so small that they are unlikely to affect the composition of the pollen cloud greatly, except for very large pollen grains which may be retained differentially (Andersen 1974). The correction factors calculated within forests thus are likely to apply also in this case.

Mikkelsen (1949) showed a re-calculated average pollen diagram from Lake Even where the correction factors suggested by Iversen (1949) were used.

The herb pollen curve from Lake Even was calculated in the same way as in Eldrup Forest. The herb pollen frequency in the topmost sample, 60%, resembles fairly the areal distribution of cultivated land within 1–2 km from the site.

The pollen diagrams from Eldrup Forest and Lake Even were synchronized on a common time scale. There are no radiocarbon dates from Lake Even and it is therefore not possible to establish a certain time scale. Levels that can be fixed with reasonable accuracy (cp. table 3) are the *Corylus* expansion (9400 BP), the *Tilia* expansion (8000 BP), the *Quercus* increase (7000 BP), the *Ulmus* decline (about 5000 BP), and the *Picea* increase (19th century). These dates suggest sedimentation rates of 12 cm/100 years for the lower gyttja, 5 cm/100 years for the peat, and 14 or 12 cm/100 years for the upper gyttja. Hence, the original depth scale has hardly been changed except for the peat layer. On this time scale the first *Fagus*-increase falls at about 2000 BC. A similar *Fagus*-increase in South Sweden (SB1/SB2, Nilsson 1964) was dated at about 2000 BC (table 3). This date differs from the date suggested by Mikkelsen (1949, Subboreal-Subatlantic transition, 500 BC). The *Fagus* expansion falls at AD 500, and a similar Fagus expansion in South Sweden was dated at about AD 500 (table 3). This date conforms with Mikkelsen's opinion (l.c.). The time scale thus may be fairly accurate.

Regional and local vegetational development

Landscape development. The herb pollen curve is high at the bottom of the regional pollen diagram showing the transition from the Late Weichselian to the Holocene. The herb pollen curve is insignificant in the Preboreal, Boreal and Atlantic.

The herb pollen is about 10% in the early Subboreal with small peaks at 20 and 15%. Agricultural and pastoral activities at that time were apparently of restricted importance (cp. Mikkelsen 1949).

There is a strong expansion of the herb pollen in the regional pollen diagram in the middle Subboreal, and the frequencies remain around 50–60% until the middle Subatlantic except for a slight decrease in the earliest Subatlantic. There are similar expansions of the herb pollen frequencies in pollen diagrams from Præstø Fjord and Borre Bog on Møn (Mikkelsen l.c.) and in A. Andersen's pollen diagram from Bundsø, southeast Jutland (1954). Mikkelsen and A. Andersen (l.c.) dated these herb pollen expansions at the beginning of the Subatlantic, and Iversen (1967, 1973) was of a similar opinion mainly because they coincided with an increase in the *Fagus* pollen frequencies to values above 1%. In southeasternmost Sweden similar levels were placed by Nilsson in the middle Subboreal coincident with the first Fagus increase (1961, 1964; SB1/SB2, radiocarbon-dated at 2000 BC, table 3). Mikkelsen (l.c.) noticed several archaeological records from the early Iron Age in the Præstø area. However, Mikkelsen did not consider finds from the late Neolithic and the Bronze Age. There are many Bronze Age barrows in the vicinity of Lake Even (map in Brøndsted 1966). The strong increase in the herb pollen frequencies at Dyrholmen also occurs in the middle Subboreal corresponding to the appearance of the Single Grave culture, according to Troels-Smith (1942), and is contemporaneous with the human activities noticeable in Eldrup Forest and Fuglsø Bog on Djursland.

There seems accordingly to be good evidence for intensive agricultural activity from the middle Subboreal to the middle Subatlantic corresponding to the late Neolithic, the Bronze Age and the Pre-Roman and Roman Iron Age. The very low frequencies of cereal pollen noticed by Mikkelsen (1949) at Lake Even and by A. Andersen (1954) at Bundsø may suggest an ineffective agriculture with many weeds (cp. Jessen 1951, Helbæk 1970), and cattle grazing may have been extensive. *Secale* pollen was noticed by Mikkelsen (l.c.) at the end of this period, however, *Secale* was insignificant at that time.

The regional herb pollen curve drops to surprisingly low values (15%) in the middle Subatlantic. This age is in accordance with Mikkelsen's dating (l.c., AD 500). The area must have become almost totally covered by forest at that time. A similar decrease occurs in Mikkelsen's pollen diagram from Borre on Møn, and a decrease at Bundsø is of the same age as at Lake Even in Iversen's opinion (1967, 1973). The decrease in the herb pollen curve coincides with the decrease of the human activities on Djursland. The pollen diagrams from southeasternmost Sweden (Nilsson 1961, 1964) show a less pronounced decrease, however, a decrease can be traced further eastward in south Sweden (Berglund 1969, Königsson 1969).

The apparently very low population density in a wide area in the late Iron Age has been widely discussed (cp. Iversen 1967, 1973, Berglund 1969, Königsson 1969), however, it is difficult to find a plausible explanation.

The herb pollen curve in the regional pollen diagram remains remarkably low (20–30%) until modern time. There is an intermediate peak (40%) which Mikkelsen (l.c.) dated to the 13th century, a date which is in accordance with the present interpretation. The decrease after the 13th century was connected by Mikkelsen (l.c.) with the medieval agricultural crisis, an event which also is unexplained (Gissel 1969). There were also noticeable human activities on Djursland in the early and middle Medieval. The low level of the herb pollen curve in the Middle Ages may be due to a concentration of the population in villages surrounded by small permanent fields, whereas the uncultivated areas were forested and used for feeding of swine (cp. Gissel 1969).

A final expansion in the herb pollen curve at Lake Even (50–60%) began at about AD 1600 in the present interpretation, a date which is in accordance with A. Andersen's date for a final herb pollen expansion at Bundsø (1954). A smilar expansion also occurs in Mikkelsen's pollen diagram from Borre on Møn, and there was a noticeable increase in the human activities on Djursland at about the same time (17th century). Cereal pollen became common (10–15%) at Lake Even and at Bundsø indicating an agricultural technique, which was more effective than that of the Bronze Age-Iron Age.

It appears that the landscape was densely forest-covered in major parts of the Holocene. The agricultural activities were of varying significance, and were particularly intensive in the middle and late Subboreal and the early and late Subatlantic corresponding to the late Neolithic, the Bronze Age and the early Iron Age and modern time.

Forest development. The tree pollen curves in the corrected pollen diagram show percentages of the tree pollen sum. Hence they show the tree participation within the forests.

If compared with the original pollen diagram in Mikkelsen (1949) it can be seen that the trend of the curves and the level of some individual curves have changed considerably. *Tilia, Fagus* and *Fraxinus* have increased in importance, and others, especially *Quercus,* have become much lower. The recalculated pollen diagram also differs from the composite diagram for East Denmark presented by Iversen (1967, 1973).

Preboreal. Betula was dominant (75%) and *Pinus* occurred with about 25%. Hence *Pinus* immigrated to southern Denmark earlier than on Djursland, where it arrived later than *Corylus. Betula* and *Pinus* dominated all kinds of habitats in southern Denmark, and open-ground vegetation was scarce already at that time. *Populus* pollen had not been recognized at the time when the pollen diagram from Lake Even was worked out. It occurs with varying frequencies at other sites and in some cases shows a maximum of 10–20% in the earliest or middle Preboreal, or in the Boreal (Krog 1959, Jørgensen 1963, Fredskild 1975). There is a distinct *Pinus* maximum (40%) at Lake Even in the late Preboreal, and a similar peak can be distinguished in some other pollen diagrams from eastern Denmark. *Corylus* expanded rapidly in the late Preboreal and suppressed *Betula* and *Pinus*.

Boreal. *Corylus* was dominant (80%) in the Boreal in the regional diagram and *Betula* and *Pinus* occurred with about 10% each. *Pinus* had a maximum (30%) in Eldrup Forest at that time and *Populus* occurred with about 10% there. The Corylus-forest thus was rather open on the high ground, but *Corylus* must have occurred in pure stands on the moist sites.

Atlantic. *Tilia* began to expand in the early Atlantic. However, as at Eldrup Forest, the *Tilia* expansion in the regional diagram was slow and about 1000 years elapsed before *Tilia* attained maximum frequencies. Hence, the slow *Tilia* expansion is a general feature. This could be explained by a difficulty in penetrating into an already established climax forest (cp. Iversen 1960), however, the light-trees such as *Betula, Pinus* and *Populus* remained rather frequent during the *Tilia* expansion, a feature, which does not favour the idea of an impenetrable *Corylus*-forest. Hence edaphic conditions, probably unstable soils and landslides, may have hampered the establishment of a dense *Tilia*-forest. *Quercus* also increased at a very slow rate.

Ulmus and *Alnus* increased in the regional diagram in the early Atlantic, and the *Alnus* increase was in this case rather late. *Ulmus* and *Alnus* were apparently restricted mainly to the moist ground. It thus appears that *Tilia* and *Quercus* replaced the *Corylus-Betula-Pinus-Populus*-forest on high ground, whereas *Ulmus* and *Alnus* invaded *Corylus*-forest on low ground in the early Atlantic.

Tilia was dominant in Eldrup Forest together with *Quercus* in the middle and late Atlantic. The *Tilia* frequencies are lower (about 40%) in the regional pollen spectra than in Eldrup Forest (60%) because the regional pollen spectra comprise also the wet-ground vegetation. Iversen (1960) postulated that *Tilia* was a dominant tree on the high ground in Atlantic time. Later Berglund (1962), Munaut (1967), Iversen (1969) and Guillet (1970) found Tilia to be dominant in pollen spectra from bleached sand on dry sites in southern Sweden, Belgium, southern Denmark and eastern France. Hence, there is now scattered evidence that *Tilia* was the most important tree on high ground in a wide area, and the importance of *Quercus* in the Atlantic has been widely overestimated.

Ulmus and *Alnus* were apparently frequent on the low ground in the middle and late Atlantic, and *Fraxinus* occurred with low frequencies. The *Corylus* frequencies are rather high (about 30%) in the regional pollen spectra and *Corylus* apparently continued to be common on the low ground.

It thus appears that a stable vegetation with *Tilia-Quercus*-forest on the high ground and *Corylus-Ulmus-Alnus (-Fraxinus)*-forest on the low ground prevailed in the middle and late Atlantic.

Subboreal. Tilia and *Ulmus* decreased drastically near the end of the Atlantic and remained low during the Subboreal in the regional pollen diagram, and *Corylus, Quercus, Alnus* and *Fraxinus* increased. The *Tilia*-decrease was even more drastic than the *Ulmus*-decrease.

Troels-Smith (1954, 1960) explained the *Ulmus*-decrease by extensive use of elm-leaves for foddering, and Iversen (1941, 1949) explained transient minima in the *Quercus*- and *Tilia*-curves and maxima in the *Betula-, Corylus*- and herb-curves by burn-and slash cultivation and cattle-grazing. There are only faint traces of Iversen's landnam in the regional pollen diagram and the most important feature besides the *Ulmus*-decrease is the *Tilia*-decrease. In Eldrup Forest the *Tilia*-curve remains high in the early Subboreal, and there can be no doubt that the decimation of the *Tilia*-forest at Lake Even was due to human influence. As the low herb-pollen curve shows that agriculture and cattle-grazing were limited, it appears that foddering with *Ulmus*- and *Tilia*-leaves was the most important food-producing activity at that time. This method continued to be in use in Denmark in the Iron Age and the Middle Ages and was abandoned later (Steensberg 1943), whereas it has persisted until to-day in other places in Europe (see Troels-Smith 1960). *Quercus, Corylus, Alnus* and *Fraxinus* were apparently not exploited in the early Subboreal.

As mentioned above there was a very considerable expansion in the open land from the middle Subboreal at about 2000 BC and corresponding to the late Neolithic, the Broze Age, and the early Iron Age. The tree pollen curves from Eldrup Forest show that there were also human activities in the forest remnants on high ground. There were similar changes in the forests at Lake Even, i.e. decrease in *Tilia* and increase in *Quercus, Betula* and *Corylus*. The *Pinus*-frequencies increase at the same level. There was no *Pinus* on the high ground and it is likely that the *Pinus* pollen in the regional diagram was transported from south Sweden or north Germany (cp. Mikkelsen 1949). The *Alnus*-frequencies did not change in the middle Subboreal, and there was apparently only slight cultivation on the wet ground, whereas *Fraxinus* was affected noticeably (due to leaf-foddering?).

Fagus immigrated at Lake Even in the middle Subboreal, somewhat earlier than on Djursland, however, like in Eldrup Forest, *Fagus* did not expand presumably because of the human activities.

Subatlantic. As mentioned before the high human activity ceased in the middle Subatlantic (AD 500). *Fagus* expanded immediately at site 2 in Eldrup Forest. The forest spread all over the region at Lake Even and *Fagus* apparently colonized the abandoned fields whereas the other trees decreased in importance. *Fagus* thus became the dominant tree in eastern Denmark at about AD 500, and *Tilia* only persisted in small stands left unattended by man.

There was renewed human activity in the forest with a decrease in *Fagus* and peaks for *Corylus* (at Lake Even) and *Quercus* (in Eldrup Forest) in the Middle Ages (11th–13th century) corresponding to the increase in the cultivated area. Later, at the recession in cultivation in the 14th and 15th centuries, *Fagus* again expanded in the forest (to nearly 80%).

Expansions of the cultivated area thus were accompanied by increased human activity in the forest and reflected in a decrease in *Fagus*, and *Fagus* expanded at each recession in the cultural activities (cp. Iversen 1967, 1973).

The low-ground forest vanished in middle and late Subatlantic time.

Conclusion

The Holocene vegetational development in eastern Denmark is not yet known and understood in all details. Especially the upper Holocene is not known very well, and more exact datings of the events are needed. The evidence concealed in very small hollows may turn out new understanding of the vegetational differentiation and the changes which occurred on a variety of habitats. The considerations in the preceding chapters thus are based on evidence of yet limited significance.

Iversen (1960) considered the Atlantic *Tilia*-forest in Denmark a climax community, whereas the preceding forest types were considered seral communities by him. This opinion may be challenged because we cannot consider *Tilia* a climax tree at a time when it was not yet present. In the present author's opinion, we must consider the preboreal *Betula*-forest and the Boreal *Corylus*-forest, which persisted for about 1000 years each, as climax communities. Hence, the present evidence indicates that eastern Denmark had a sequence of four climax communities on high ground, *Betula-Pinus*-forest, *Corylus-Pinus-Betula-Populus*-forest, *Tilia-Quercus*-forest and *Fagus*-forest.

Tilia was pursued by man because of its foddering-quality, and the forest was also exploited in various other ways. *Tilia* did not expand again, when the human pressure ceased, and was replaced by *Fagus*. The *Fagus*-forest was exploited moderately by burning and grazing at various times.

The dominant trees on moist and wet ground were successively *Betula*, *Corylus* and *Corylus-Ulmus-Alnus-Fraxinus*. The low-ground forest was in the course of time strongly decimated by cultural influence starting with the exploitation of *Ulmus* in the early Neolithic.

Certain features in the cultural influence on the vegetation seem to be common for eastern Denmark. There was presumably scattered agriculture and pasture in the early Subboreal or early Neolithic, and foddering with *Tilia*- and *Ulmus*-leaves was extensive. A great agricultural expansion occurred from the middle Subboreal to the middle Subatlantic and comprised the late Neolithic, the Bronze Age and the early Iron Age (Pre-Roman and Roman), whereas there was a very distinctive recession in the middle Subatlantic (Migration Period). A slighter agricultural expansion occurred in the 11th–13th centuries and a new recession in the 13th–14th centuries. An agricultural expansion began in the 16th–17th centuries and lasted until the present day.

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Dansk sammendrag

En nærmere forståelse af den holocæne vegetationsudvikling vanskeliggøres dels fordi de forskellige træarter er uensartet repræsenteret i de konventionelle pollendiagrammer, dels fordi det ikke kan afgøres hvordan træarterne var fordelt på tør og fugtig jordbund. Disse vanskeligheder kan gøres mindre dels ved en korrektion af pollenspektrene, dels ved studiet af udviklingen omkring ganske små mosehuller, hvor kun vegetationen på en enkelt jordbundstype er afspejlet.

Den holocæne vegetationsudvikling på veldrænet jordbund vises af pollendiagrammer fra ganske små mosehuller i Eldrup Skov på Djursland. Der fandtes her en rækkefølge af birkeskov, hassel-fyrre-birke-aspeskov, linde-egeskov og bøgeskov. Ved det ene mosehul skete der ingen menneskelige indgreb før sen tid, og lindeskoven holdt sig uændret til henimod middelalderen, hvor den afløstes af bøgeskov efter kulturindgreb. Ved det andet mosehul ødelagdes lindeskoven ved afbrændinger og formentlig løvhøstning i Subborealtid og tidlig Subatlantisk tid. Disse indgreb ophørte omkring 500 e.kr., og området har været bøgeskov siden.

Vegetationsudviklingen på den høje jordbund er sammenlignet med et regionalt præget oprindelig af Mikkelsen (1949) udarbejdet pollendiagram, som er blevet korrigeret for uensartet pollenproduktion og delvis omdateret. Den regionale udvikling viser en ringe opdyrkning og græsning i tidlig Subborealtid og en stærk kulturaktivitet fra midt i Subborealtid til midt i Subatlantisk tid svarende til sen neolitisk tid, bronzealder og førromersk og romersk jernalder. Kulturaktiviteten var forholdsvis ringe og skoven fremherskende i sen jernalder og middelalder, dog med en vis opblomstring i 12.–13. århundrede. Der skete en stærk agerbrugsekspansion fra omkring 1600 til i dag.

Skovudviklingen på den høje jordbund lignede meget den der er beskrevet fra de lokalt prægede pollendiagrammer. Hassel og senere elm, ask og el har været almindelige på lav og fugtig jordbund. Elm og lind blev stærkt udnyttet til løvfodring af kvæg, som må have været en fremtrædende ernæringskilde i tidlig neolitisk tid. Bøgen indvandrede i Subborealtid og var fremherskende i skovene fra omkring 500 e.kr. da kulturpåvirkningen ophørte, indtil i dag.

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The Late Weichselian freshwater beds at Nørre Lyngby. C-14 dates and pollen diagram

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Krog, Harald: The Late Weichselian freshwater beds at Nørre Lyngby. C-14 dates and pollen diagram. *Danm. geol. Unders., Årbog 1976,* pp. 29–43. København, 1. marts 1978.

An additional layer sequence below the well known stratigraphical succession in the central part of the Late Weichselian freshwater basin at Nørre Lyngby, Jylland, has given rise to a new pollen diagram and a series of C-14 datings from the pollen profile and from the allochthonous peat layer in the southern part of the section. The stratigraphical position of the peat layer should be below the layers of the pollen profile. The C-14 dates from the peat layer span from late Bølling into early Allerød, and accordingly the layers in the pollen profile are younger than early Allerød. The C-14 dates from the pollen profile indicate that most of the dated material has been redeposited from the peat. The pollen diagram is divided in stages A, B and C. A and B are referred to the Allerød, C possibly to Younger Dryas. In Iversen's 1942 pollen diagram his zones Ic and II are correlated with B, and III with C in the present diagram.

The freshwater layers at Nørre Lyngby, near the northern tip of Jylland, have played an important role in the literature on Danish Quaternary geology during the last 100 years because of the finds made there. Already 1877 was found a lower jaw of European suslik, *Spermophilus rufescens,* and this find gave rise to the very much debated theory of a steppe period in Denmark after the last glaciation. Several other plant and animal remains have been found in the freshwater sediments, latest a cranium of desman, *Desmana moschata* (Bondesen & Lykke-Andersen 1976), but the bulk was found by an extensive investigation in 1913–14 which formed the main basis for a monographic work on the site (Jessen & Nordmann 1915). By this investigation was further found an arrowhead of flint which for several years represented the oldest geologically dated implement within the Danish-Scandinavian area. The 1915 paper (with a rather copious English summary) is still valid as a source to general information and description of the site, but the dating, as to which opinions have alternated during the years, was not satisfactorily solved until Johs. Iversen in 1942 (l.c.) based on a pollen diagram from the site definitely proved the freshwater series to be of Late Weichselian age.

In 1971 it was decided to collect material for entomological studies from Danish Late Weichselian sediments by a joint British–Danish operation initiated by Prof. F. W. Shotton and guided by Dr. Johs. Iversen. One of the sites studied was Nr. Lyngby which should be well suited for the purpose: an easily accessible cliff section of freshwater sediments with well dated and easily recognizable stratigraphical boundaries. By our visit in 1971 the lowermost part of the cliff section was exposed by means of a bulldozer, and the known sequence was supplemented by a stratigraphical succession not formerly known. Hence, it was necessary to prepare a new pollen diagram from the site in order to get a better idea of the chronology of this part of the section. The new pollen diagram and a series of C-14 dates from the site are presented in this paper.

The freshwater layers appear in the sea cliff as a section through a dish shaped basin filling situated in Late Weichselian marine sand and clay deposits. The first impression is that extent and appearance of the section has changed little since the description by Jessen & Nordmann (1915). The present extent is abt. 160 m compared to formerly abt. 180 m, and the general stratigraphical succession as described 1915 is still found. A marker horizon is a prominent layer of dark clay rich in mollusc shells. On top of this follows first a zone of alternate clay and sand layers and then several metres of pure sand. Below the clay layer the sequence consists mostly of sand. In the lateral southern part occurs only a thin layer of freshwater sand with one or occasionally two thin peat layers irregularly embedded, which corresponds with the 1915 description. In the central part a succession of dark bands in the sand appeared by the present investigation.

Fig. 1 shows the southern part of the present basin section in the sea cliff. The principal features of the stratigraphical succession in the lowermost part, i.e. from the clay downwards have been stressed, whereas details in the stratigraphical sequence above the clay have been neglected. In fig. 2 is seen a photograph from the left-hand part of the section in fig. 1.

Units a and b in fig. 1 are the sandy top series and the clay layer. The dark bands below the clay dip downwards towards the centre of the basin. They are divided naturally into 3 groups (c, d, and e in fig.'s 1 and 2). The uppermost group (c) dips and spreads fanshaped towards the basin centre, in the opposite direction it condensates and ultimately coalesces with the clay layer. The dark bands in this unit are very sandy -silty, partly rich in organic material, in the upper part occasionally with many twigs of *Salix,* in the lower part rich in fine-grained, partly peat-like, organic material. Shells of *Anodonta* are common in the upper part as they are in the clay layer above. The coalescence of this unit with the clay layer above has not been traced in detail but it may be noticed, that its uppermost part gradually changed to a

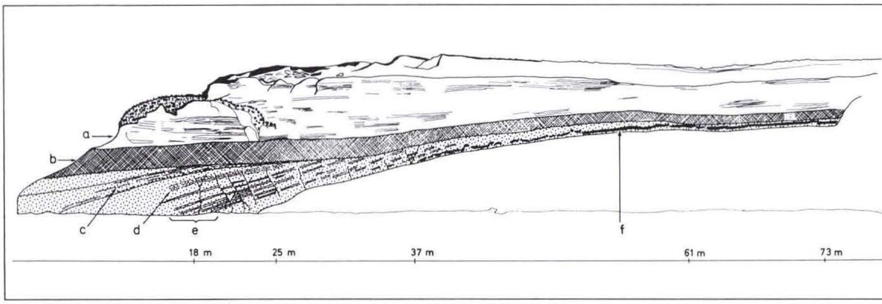

Fig. 1. Stratigraphical succession in the southern part of the basin section. Scale below marks distance in metres S of the basin centre. Horizontal and vertical scales are identical, but stratigraphic measures are not exact. For further explanation see text.

clay similar to that above it. Below group c and parallel with its lower border follows group d, a zone with a series of irregular thin and faint bands, stained dark by a small content of mainly fine-grained organic material. The layers are contorted and during the field investigation we thought their disturbance caused by cryoturbation or more probably by slumping down the slope of the basin. These layers were referred to as the "contorted zone". The lowermost group of dark bands, e, is a series of laminae of very silty clay, partly very thin. They are generally poor in organic material, but layers relatively rich in

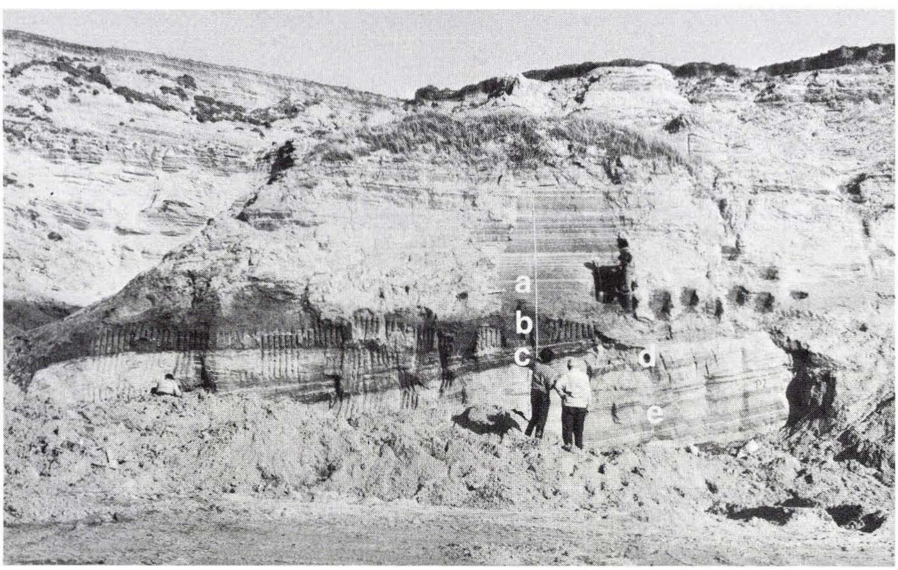

Fig. 2. Photograph from the central part of the basin, corresponding to the left-hand part of fig.1. The rule at the left one of the two standing persons marks the pollen profile at 18 m, "P 2" in the lower right-hand part of the section wall marks the pollen profile at 25 m.

coarse organic material occur occasionally. Small mollusc shells (*Pisidium* or *Sphaerium* sp.) occur only sparsely. Slidings and vertical dislocations occur increasingly towards the lateral parts. The lateral parts of d and e have been removed by erosion, and it can be seen in the profile that the clay layer (b) cuts the strata discordantly.

In the southern part of the profile was seen a peat band (f) in the freshwater sand immediately above the marine deposits. The stratigraphical boundaries were not traced between these two areas and this resulted in doubt as to the stratigraphical position of the peat layer compared to the succession in the central part of the basin section. During later visits to the site I have attempted to solve this problem. Fig. 3 shows the area at 73 m where samples from the peat layer and adjoining layers were taken in 1971. The rule (1 m high) is crossed by two black peat bands which are very irregular and only partly coherent. The lower band can only be seen in this part of the profile and only over very short distances, but the upper band can be traced towards the basin centre to abt. 37 m as indicated on fig. 1, in the lowermost part as very irregularly situated and not coherent layer fragments. The position of the peat stratigraphically is below the group of bands marked e, and accordingly the peat layer is the lowermost – and oldest – organic layer in the fresh-water series. Fig. 4 shows in more detail an area of the peat bands from where a series of pollen samples were taken, abt. 0.5 m to the left of the rule in fig. 3.

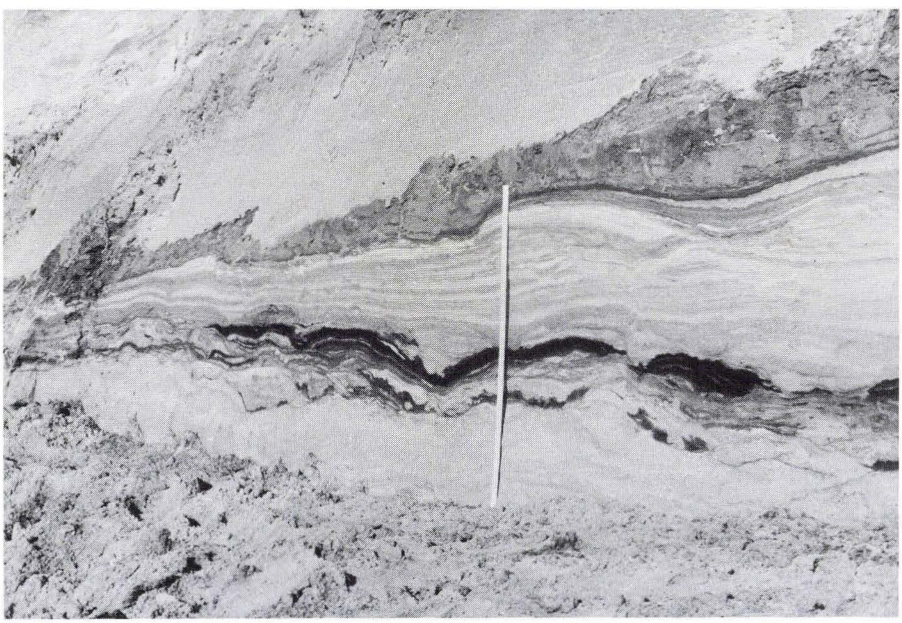

Fig. 3. Peat layers at abt. 73 m in the section.

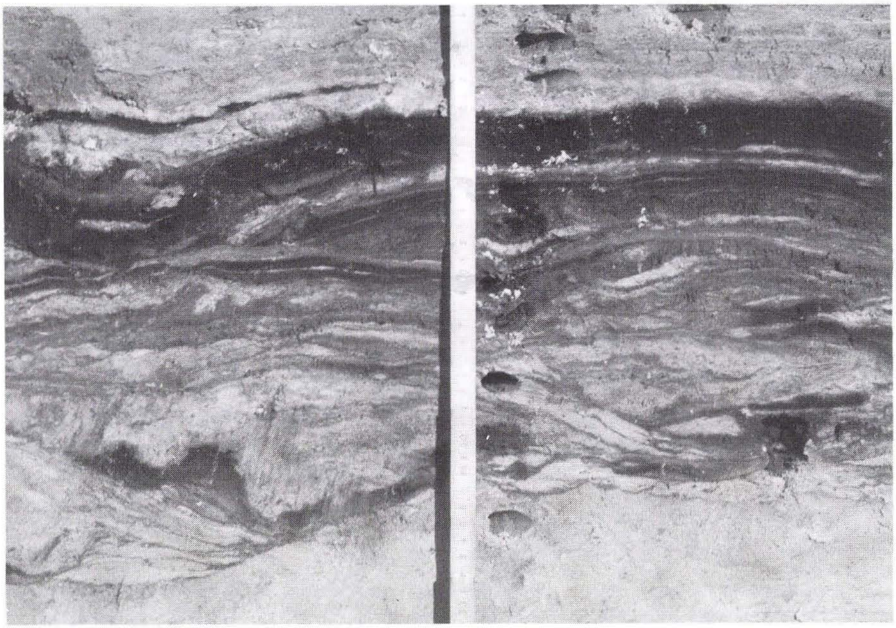

Fig. 4. Peat stratigraphy abt. 0.5 m to the left of the rule in fig. 3.

The confused layering seen on the photographs fig.'s 3 and 4 clearly indicates that the peat bands are allochthonous in this area.

C-14 datings

During the field investigation in 1971 both the British and Danish members collected material for C-14 dating and got a series of samples which were apparently fitted for the purpose. They were taken from different layers below the dark clay in the central part of the basin and from the peat layer at abt. 73 m. I have later made further samplings from the peat layer, at abt. 61 m where it looked undisturbed, and at abt. 37 m which was as far as the peat layer could be traced towards the basin centre. All datings are listed in table 1 and their position in the section is indicated on fig. 5. In the pollen diagram, fig. 7, are further shown those dates which come from or can be easily equated with the pollen profile. Those sampled some distance away but equated with the pollen profile are marked cp. in table 1. The list includes two of the British dates (BIRM 281 and 282) which are the only Bitish dates considered unaffected by hard-water error (Shotton 1972, Shotton and Williams 1973). K-962 and 963 are two formerly dated samples from the peat

Table 1. C-14 dates. Age calculations are based on a half-life for radiocarbon of 5570 years and dates are expressed in conventional C-14 years.

Number	Years B.P.	Material	Location
K-1989	11,810 ± 170	*Salix* branch	cp. diagram, 516–517 cm
K-1988	11,770 ± 120	twigs	cp. diagram, 516–517 cm
BIRM 281	11,330 ± 150	twigs	cp. diagram, 516–517 cm
K-1938	12,120 ± 140	twigs	diagram, 518–523 cm
K-1990	12,090 ± 180	twigs	diagram, 523–530 cm
K-1942	12,110 ± 130	twigs, mainly without bark	diagram, 722 cm
K-1943	12,010 ± 150	twigs, mainly with bark	diagram, 722 cm
K-2111	12,560 ± 130	lens of sedge peat	cp. diagram, 800 cm
K-2110	11,540 ± 130	sedge peat, unsieved, humates not extracted	peat layer, 37 m
K-2109	11,580 ± 170	sedge peat, sieved	peat layer, 37 m
K-2113	8,360 ± 130	sedge peat with twigs, sieve fraction 0.25–1 mm	peat layer, 61 m
K-2114	12,010 ± 120	same sample and sieve fraction as K-2113, humates not extracted	peat layer, 61 m
K-2112	12,370 ± 160	same sample as K-2113, fraction >1 mm	peat layer, 61 m
K-1941	11,560 ± 130	twigs, humates not extracted	peat layer, 73 m
K-1939	11,670 ± 140	*Salix* branch	73 m, same layer as K-1941
K-1940	11,830 ± 180	twigs	73 m, same layer as K-1941
BIRM 282	12,050 ± 160	twigs	peat layer, near 73 m
K-962	11,680 ± 140	moss sedge peat with twigs	uppermost part of upper peat layer, near 75 m
K-963	11,780 ± 180	peat with twigs	lowermost part of upper peat layer, near 75 m

layer (Tauber 1966). The samples collected 1971 and later were treated with KOH or NaOH for extraction of possible secondary content of humates except, for comparison purposes, 3 samples marked in the list. The twigs which constitute the main part of the dated material are supposed to be exclusively *Salix* spp. as several specimens examined were all determined to *Salix*. An exception was a small piece of *Picea* wood, found at 516–517 cm in the pollen profile, which macroscopically clearly differed from the *Salix* twigs.

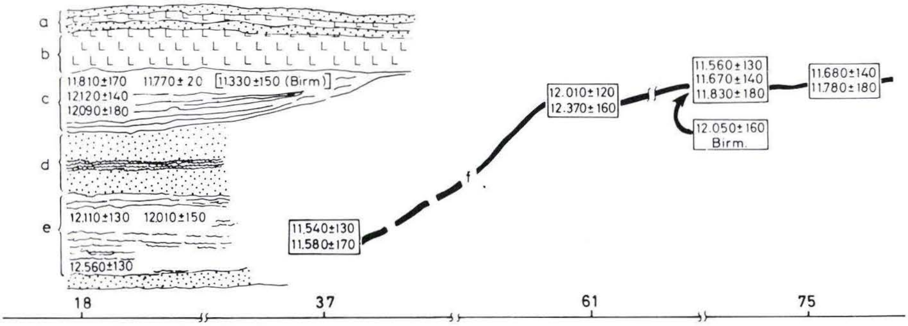

Fig. 5. Stratigraphic positions of the C-14 datings.

All samples except one are noncalcareous. K-2111, a lens of sedge peat from lowermost in the pollen profile, could not be sufficiently cleaned from the surrounding calcareous clay and the date 12,560 ± 130 may for this reason be too high. The date K-2113 is unexpectedly and unexplainably low (8,360 ± 130). It is one out of three from fractions of the same peat sample (at 61 m), but the fractioning does not explain the extremely low age which must be wrong. All other dates are considered reliable in the sense that they are supposed to give principally true radiocarbon ages of the samples dated.

The age variation within the dates from the peat layer is considerable. The peat is mostly or exclusively in a secondary position and may be composed by layer units of different origin which may explain the age variation. The spread of the dates from 12,370 ± 160 (K-2112) to 11,540 ± 130 (K-2110) covers the time span from the end of Bølling into early Allerød. Hence, all the layers above the peat, including the units a–e in the central part, must be younger than the early Allerød.

Within the pollen profile one date, BIRM 281, 11,330 ± 150 belongs to the middle Allerød. All the other dates are grouped rather close on both sides of 12,000 and do not conclusively show difference in age from top to bottom. The dates from the peat layer are not higher but show almost exactly the same variation. The only reasonable explanation of this identity in age of the two groups of samples is a common origin of the dated material, in other words, the material dated in the pollen profile has been redeposited to stratigraphically higher situated layers in the pollen profile.

Pollen analysis

Iversen's dating 1942 was based on a pollen diagram from a sample series covering the clay layer and the layers immediately above and below it. The

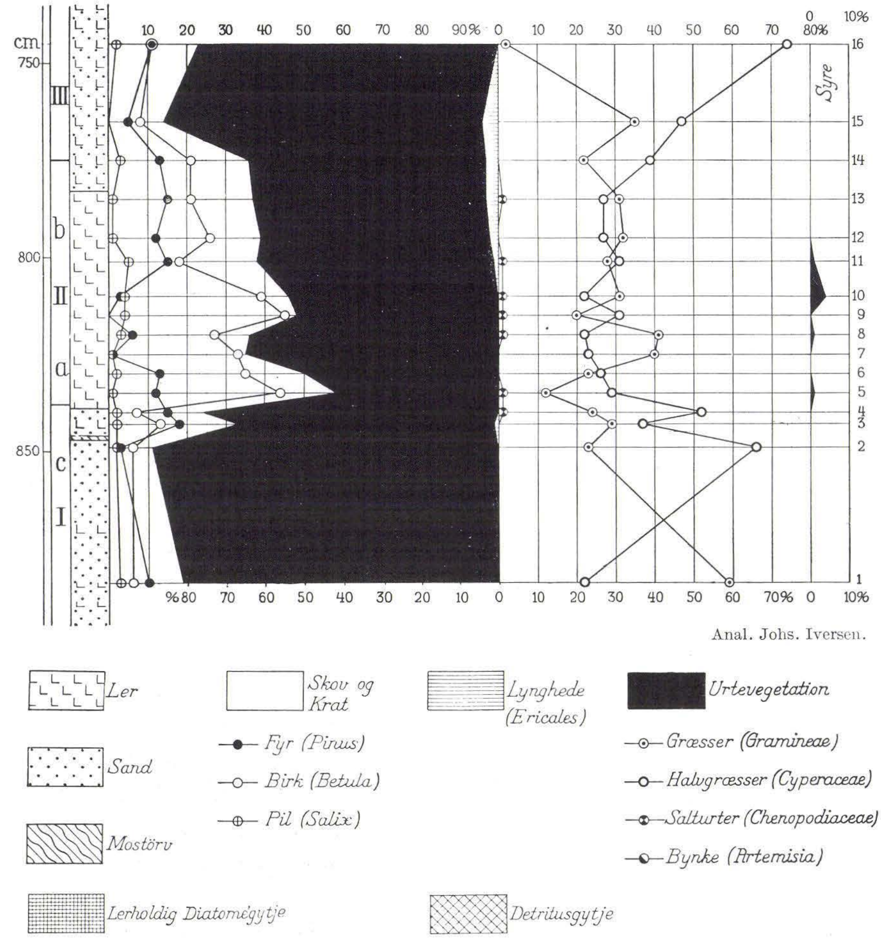

Fig. 6. Iversen's pollen diagram (1942) from Nr. Lyngby.
Syre = *Rumex* + *Oxyria*.

diagram is reproduced here in fig. 6. The series was taken "a little S of the basin centre – approximately where the peat layer stops" (Iversen 1942, p. 132, translated) which might be at 35–37 m in the present section (fig. 1). Iversen's description of the layer below the clay layer (57 cm of freshwater sand, in parts somewhat clayey and with peaty bands) also fits with this location. Iversen correlated the clay layer with pollen zone II, the sandy series above with zone III, and the sand below with zone I c.

It should be noticed that a peat layer is not indicated in Iversen's description of the lower sand, but in the lithological column of the pollen diagram a peat layer, 1 cm thick, is indicated 7–8 cm below the clay layer. Iversen equated this thin peat layer with the more or less coherent peat layer situated lowermost in the southern part of the section (f in fig. 1), and accordingly the peat layer was dated at the end of zone I c. This age conception was later corroborated by the two C-14 dates of samples from the peat layer (Tauber 1966), collected by me 1949.

The present pollen diagram (fig. 7) has been composed by two sample series, an upper one covering the layers marked a–d, and a lower one covering the bands marked e on fig. 1. The upper series is taken at 18 m and the lower series at 25 m on fig. 1. The limit between the two series is found at 640 cm on the pollen diagram and is indicated by not fully drawn curves.

The lithology of the composite series may be summarized as follows (a–d correspond to fig. 1). The 0-level is arbitrary.

Upper series, 18 m.

a	?–407 cm	Alternating layers of silty sand and silty clay.
b	407–505	Black silty clay, rich in gyttja, many molluscs (*Pisidium, Sphaerium, Anondonta*).
c_1	505–530	Clayey-silty-sandy bands rich in coarse organic material, partly with many twigs of *Salix*.
c_2	530–557	Bands of sandy-silty gyttja, with fragments of sedge peat.
	557–585	Sand.
d	585–631	Sand with irregular thin and faint gyttja bands.
	631–646	Sand.

Lower series, 25 m.

e	646–803	Sand with numerous, partly very thin, laminae of very silty clay, generally poor in organic material, but layers relatively rich in coarse organic material (moss, twigs) occur occasionally. Small mollusc shells (*Pisidium* or *Sphaerium*) occur very sparsely.
	803–?	Sand. Limit between fresh water and marine sand not determined.

A serious difficulty and possible source of error for the pollen analysis of this series of highly minerogenic sediments is the great content of rebedded pollen. A correction method was demonstrated earlier by Iversen (1936, 1938), and in his Nr. Lyngby paper (1942) the correction of all pollen spectra in his diagram is shown in detail. The method is based on the assumption that the percentual composition of rebedded pollen is constant throughout the series because the argillaceous sediments of the basin – and their original pollen content – have been washed in from well mixed sediments in the

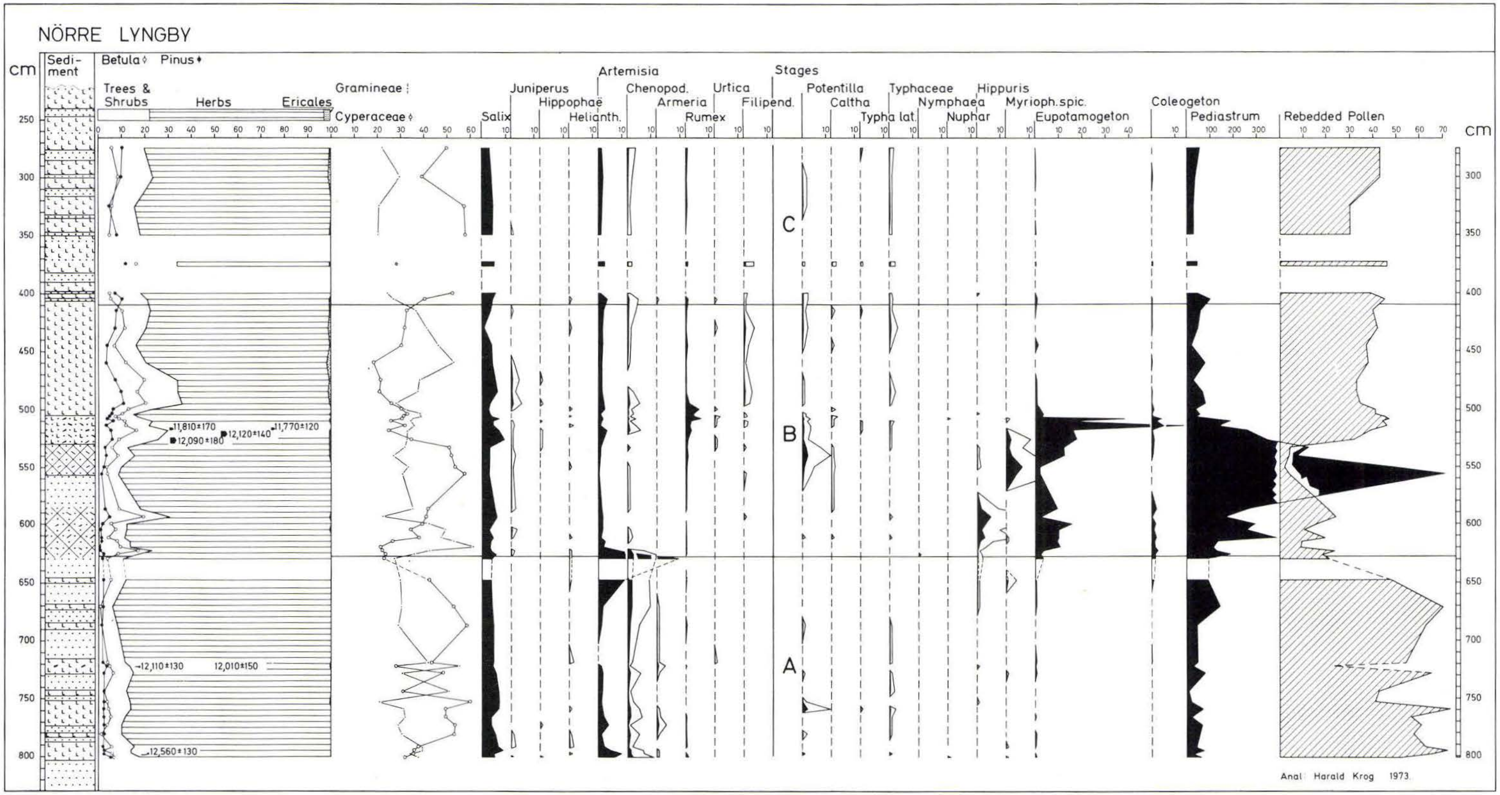

Fig. 7. Pollen diagram composed of sample series from 18 m and 25 m in fig. 1. Calculation basis is the total of tree pollen and non tree pollen exclusive aquatics, in a minimum of 500 per sample. All curves except the *Pediastrum* curve are drawn to the same scale, in addition some silhouettes representing low values, e.g. *Juniperus*, are drawn to a scale 5 × 1. The sediment symbols are in accordance with Troels-Smith (1955). C-14 datings (yr B.P.) of samples which fit into the stratigraphical sequence of the pollen profile are shown at appropriate levels in the diagram within the silhouette "Herbs".

surroundings (marine clay). If the percentage composition of pollen in the source sediments is known it should therefore be possible to subtract the rebedded, or secondary, part from the pollen spectra with mixed primary and secondary pollen.

I have used the method in the following way. As supposed source material was used a sample from "Late Glacial Yoldia clay" which is in part substratum for the freshwater beds and is widely distributed in the area. The pollen count of the sample was divided in two groups, A consisting of grains (1223) definitely pre-Late Weichselian in origin, and B in which the grains (357) might as well be of Late Weichselian age, including i.a. *Betula* and *Pinus*. In similar way the pollen spectrum of each diagram sample was divided in an A and a B group. From the B group was subtracted a fraction of supposed rebedded pollen grains, with the same composition as the B group from the Yoldia clay sample, and determined by the ratio between the A groups in the diagram sample and the Yoldia clay sample. The curve for rebedded pollen in the diagram (fig. 7) includes the A group and the part subtracted from the B group, and the percentage calculation for this curve is based on the sum of the A and the B groups.

For all diagram samples the percentage composition of pollen in the A group has been compared mutually and with the composition of the A group of the Yoldia clay, and in general there was found agreement, which confirms the assumption of constant percentage composition throughout the section, and which is a basic demand for the applicability of the method. A serious disagreement was found in only one case, at 722 cm, marked in the curve for rebedded pollen by a not fully drawn line. In this sample was found overrepresentation of *Alnus* which was normalized with the other samples before the subtraction calculation was made.

The correction method used cannot be exact in every detail but it is my conviction that it has worked satisfactorily so that pre-Late Weichselian pollen no longer influences the trend of the pollen curves or the interpretation of the diagram seriously.

A list of pollen grains omitted in the diagram is shown in table 2.

The pollen diagram has been divided into 3 stages, A, B and C. Important for the distinction is the *Betula* curve which is here a collective curve including more than one species. Morphologically distinguishable *Betula nana* grains were observed through the whole sequence, but percentage estimations were not attempted.

Within stage A the values of the *Betula* curve are extremely low, from 1 to 7%. Generally the values of the *Salix* curve surpass the *Betula* values slightly. The stage is fully dominated by NAP pollen, in particular by *Cyperaceae* and *Gramineae*. There is a distinct *Artemisia* maximum (34%) at the very end of the stage. An *Artemisia* maximum of this magnitude is not known from other Danish pollen diagrams. The trend of the *Chenopodiaceae* curve is similar to that of *Artemisia*. *Armeria* is relatively common in stage A and is almost restricted to this stage.

Compared with stage A stage B is characterized by higher *Betula* frequencies and by the occurrence of relatively thermophilous taxa such as *Juniperus, Urtica, Filipendula* and *Typha latifolia*. The beginning of stage B is placed at the first rise of the *Betula* curve and the decrease of *Artemisia*. The border is further marked by an increase of aquatics (*Hippuris, Potamogeton, Pediastrum*) and a decrease of rebedded pollen. The end of the stage is placed at the level where *Betula* again decreases to low values.

Stage C again has very low *Betula* frequencies (5–9%) and is fully dominated by NAP pollen. The sample at 375 cm seems out of place and has not been connected with the curves. I would fit better in stage B at abt. 495 cm.

The stages A and B in the present pollen diagram must belong to the Allerød, and it is possible that stage C belongs to the Younger Dryas. The low *Betula* curve in Allerød time may be due partly to local overrepresentation of herbs and partly to rebedded Late Weichselian pollen. It still appears that the vegetation in northern Jylland was more open than in southern Denmark. As mentioned above distinctly thermophilous elements are present in stage B in the present diagram, which may correspond to the upper *Betula* maximum in zone II in southern Denmark. The presence of *Hippophaë, Helianthemum* and *Dryas octopetala* (table 2) and the low *Empetrum* frequencies suggest that the soil had undergone no leaching.

Koenigia islandica is represented by one pollen grain from stage C (table 2). The species has not formerly been found in Danish Late Weichselian deposits (cp. Danielsen 1970).

One pollen grain of *Ambrosia* (table 2) must have been transported over a long distance from North America, and two grains of *Ephedra strobilacea* type (table 2) are considered to have a distant origin too, in accordance with the view held by Danielsen (1970).

The lower part of Iversen's pollen diagram (1942) referred by him to zone Ic belongs in the present interpretation to stage B. The present diagram can be correlated fairly exactly with Iversen's based on a peak of *Myriophyllum spicatum* (7%) in sample 2 (850 cm) in Iversen's diagram (Iversen 1942, Tabel IV), which occurs at 550 cm in the present diagram, and the two *Betula* maxima at 810–840 cm in Iversen's diagram, which correspond to the maxima at 470–520 cm in the present diagram. Iversen's zone boundary II/III is placed at the top of the dark clay and corresponds to the boundary B/C in the present diagram.

According to the above correlation the peat layer in Iversen's profile at 843

Table 2. List of pollen and spore types which are omitted in the pollen diagram.

Stages	A	B	B	C
Stratigraphic units	e	d	b + c	a
Total number of pollen grains counted after deduction of secondary pollen	9367	5927	13055	4028
Asteraceae, sect. *Liguliflorae*	28	88	80	40
– , sect. *Tubuliflorae*	36	27	128	25
Astragalus alpinus	3	1	2	–
Caryophyllaceae	40	8	83	18
Chamaenerion angustifolium	–	–	1	–
Cruciferae	4	–	9	–
Dryas octopetala	17	14	9	2
Epilobium	1	–	1	1
Galium	7	12	23	3
Koenigia islandica	–	–	–	1
Labiatae	–	2	1	–
Leguminosae	–	2	1	1
Liliaceae	1	–	1	–
Menyanthes trifoliata	–	–	1	–
Parnassia palustris	6	18	8	2
Plantago maritima	5	6	9	–
– *media*	6	5	2	1
Polygonum aviculare	1	3	2	1
– *Bistorta/viviparum*	4	1	4	1
Ranunculaceae	10	13	18	4
cf. *Rubus chamaemorus*	7	2	–	1
Sanguisorba officinalis	–	–	1	–
Saxifraga aizoides	–	–	2	–
– cf. *hirculus*	–	–	1	–
– *oppositifolia* type	3	–	2	1
Scrophulariaceae	1	1	1	–
Sedum	1	–	–	1
Swertia	1	2	1	1
Thalictrum	50	16	36	13
Tofieldia	7	8	2	1
Umbelliferae	16	19	25	17
Valeriana	–	1	–	1
Botrychium	9	4	18	6
Equisetum	30	162	95	8
Gymnocarpium dryopteris	17	2	5	4
Huperzia selago	3	–	1	–
Lycopodium alpinum type	6	1	8	3
– *annotinum*	5	2	8	6
– *clavatum* type	1	–	1	1
Selaginella selaginoides	11	5	67	14
Ambrosia	–	–	1	–
Ephedra strobilacea type	2	–	–	–

cm clearly corresponds to the layer 530–557 cm in the present profile. It cannot be correlated with the peat layer f in fig. 1, as done by Iversen, and the peat f must be older than any layers represented in the two pollen diagrams. Further pollen analytical investigation showed that the layers just above the peat at 73–75 m in fig. 1 might be correlated with the level 500–550 cm in the pollen diagram fig. 7 (layer c in fig. 1), which means that a time gap exists between the peat and the layers above it. The pollen spectra from the peat were normally strongly dominated by *Cyperaceae*, like those shown by Iversen (1942, Tabel IV), and gave no basis for stratigraphic or climatic correlation. Nowhere else in the section I have found a place which looked more promising for pollen dating of the peat layer.

Acknowledgements. Jens Stockmarr was very helpful during the excavations and has made several wood determinations. The C-14 samples were measured at the Carbon-14 Dating Laboratory of the Geological Survey and the National Museum under the supervision of *Henrik Tauber*. My sincere thanks are due to both of them.

Dansk sammendrag

Det blev i 1971 konstateret, at de kendte senglaciale ferskvandslag ved Nørre Lyngby i Vendsyssel omfatter en hidtil ukendt lagserie nederst i den centrale del af bassinet. Dette forhold gav anledning til udarbejdelsen af et nyt pollendiagram og til en række C-14 dateringer, som fremlægges her. Den nye lagserie forekommer under lerlaget b og omfatter lagene c, d og e, se fig. 1 og 2. Det fra bassinets sydlige del velkendte allochtone tørvelag, f i fig. 1, samt fig. 3 og 4, kan følges mod bassinets midte til et sted markeret v. 37 m i fig. 1, og det fremgår at lagets stratigrafiske beliggenhed, hvis det fortsatte til bassinets midte, måtte blive nederst i lagserien, under e. C-14 dateringerne fra tørvelaget, fig. 5, table 1, grupperer sig omkring 12.000 før 1950 og omfatter et tidsinterval fra slutningen af Bølling over Ældre Dryas ind i tidlig Allerød. Følgelig er lagserien i bassinets centrale del, som er omfattet af pollendiagrammet fig. 7, yngre end begyndelsen af Allerød. C-14 dateringerne fra pollenprofilet, fig. 7, fig. 5, table 1, viser næsten samme tidsmæssige spredning som dateringerne fra tørvelaget, og det må antages, at det meste af det daterede materiale er omlejret fra tørvelaget, således at disse dateringer ikke kan støtte den pollenanalytiske datering.

Pollendiagrammet er delt i afsnittene A, B og C, af hvilke A og B henregnes til Allerød, C antagelig til Yngre Dryas. Iversens pollendiagram fra 1942, her vist i fig. 6, kan korreleres med det nye diagram, således at Iversens zoner Ic og II svarer til B, og III til C i det nye diagram. Den tynde tørvestribe ved ca. 843 cm i Iversens diagram, som af Iversen blev antaget for at være identisk med tørvelaget f i fig. 1, kan med fuld sikkerhed korreleres med laget 530–557 cm i det nye diagram.

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The age of the introduction of *Plantago lanceolata* to the Shetland Islands

Jóhannes Jóhansen

Jóhansen, Jóhannes: The age of the introduction of *Plantago lanceolata* to the Shetland Islands. *Danm. geol. Unders., Årbog 1976,* pp. 45–48, pl. 1. København, 1. marts 1978.

Three radiocarbon datings corresponding to a previously published diagram from the Shetland Islands are presented. The recorded depths correspond closely to the depths in the published diagram, so the dates can be transferred directly to that diagram. It is concluded that *Plantago lanceolata* was local and that its appearance dates the immigration of man to the Shetland Islands at 3400 BC.

In 1975 I published a pollen diagram from a peat bog on the Shetland Islands (Jóhansen 1975), reproduced as plate 1. The diagram was the result of a visit to the islands in 1970. Because a Hiller sampler was used for most part of the profile no radiocarbon datings were possible. Only the lowermost one metre which was taken with a Livingstone corer gave material for datings. As better equipment for peat sampling – a modified Jousey sampler (Tolonen 1967) – became available I found it worth making a new visit to the locality. Of special interest to me was the horizon where the *Plantago lanceolata* curve became continuous because I supposed it to indicate the first human settlement in the islands. In February 1976 I had an opportunity to do supplementary work and the uppermost three metres were sampled. It was checked by pollen analysis that the levels of the two corings corresponded. Hence, the dates listed below could be correlated with the previously published diagram.

The radiocarbon datings

Three samples were chosen for dating. Ages are given in C-14 years bp (T ½ = 5568) and in calibrated calendar years (Damon et al. 1972).

K-2704. Material: humus matter extracted from peat. Depth: 5–10 cm. Age: 520 ± 70 bp. Calibrated age: 1510 ± 75 AD. Thus the last 500 years are lacking in the profile, no doubt because of peat digging.

K-2705. Material: peat. Depth: 202–210 cm. Age: 4680 ± 95 bp. Calibrated age: 3410 ± 130 BC. This horizon marks the beginning of the continous *Plantago lanceolata* curve and is discussed below.

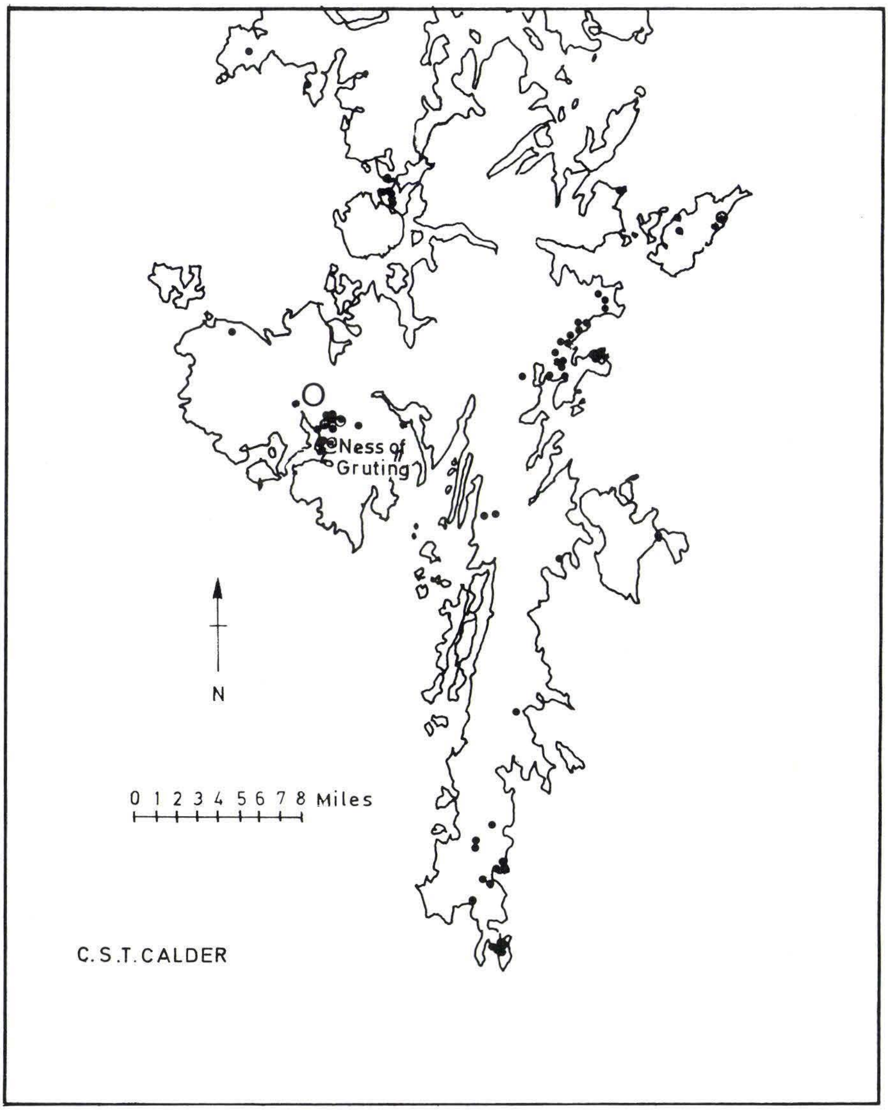

Fig. 1. Distribution map of Neolithic houses in Shetland (Calder 1964). The circle shows the position of my sampling site. Reproduced with the permission of Thomas Nelson and Sons, Ltd., London.

K-2706. Material: peat. Depth: 292–300 cm. Age: 7850 ± 120 bp. This horizon marks the transition to the Atlantic. The *Corylus* maximum noticed below this level, see plate 1, thus falls in the Boreal.

The *Plantago lanceolata* curve

As already mentioned the main purpose of my second trip to Shetland was to collect material for dating of the horizon where the *P. lanceolata* curve becomes continuous with steadily increasing percentages.

The question naturally arises whether the *Plantago lanceolata* pollen grains have been transported from outside Shetland. Four pollen grains found scattered below the continuous *Plantago* curve are clearly long distance transported. The plant has been growing in Scotland and Isle of Skye in Late Weichselian and Flandrian times (Birks 1973, Godwin 1975). The pollen grains appearing at the depth of 206 cm and upwards can not be regarded far distance transported. This can be seen by comparing the *Plantago* curve with the curves of the trees, the pollen grains of which are certainly long distance transported. These curves are falling at the same time as the *Plantago* curve is rising. The *Plantago* pollen source thus must be local.

The next question is: did the plant immigrate spontaneously by the natural agents: wind, birds, sea currents or was it introduced by man? The first possibility can of course not quite be ruled out, but judging from archaeological evidence the second explanation is the most likely one.

Archaeological evidence

Chambered tombs and long mounds in Scotland were built in the 4th millenium BC (Henshall 1974). Passage graves are very numerous in Scotland, the Hebrides and Orkney (about 300, Henshall l.c.). This shows that a population spread over not only the Scottish mainland but also on the mentioned islands at Neolithic times. Calder (1964) has mapped the distribution in Shetland of houses which he considers Neolithic, fig. 1. A group of them are concentrated in an area close to my sampling site. From Shetland I do only know about one C-14 dating related to human settlement apart from my own. It is from Ness of Gruting (fig. 1) where a barley cache has been dated to about 2000 BC (Henshall l.c.), but this date does of course not say anything about the *first* colonization.

It should be borne in mind, as pointed out by for instance V. G. Childe (1964) that the Orkney Islands are clearly visible from the Scottish mainland. From those islands you can see Fair Isle and from Fair Isle Sumburgh Head of Shetland can be seen. This will make a step by step immigration almost inevitable. From the Shetland Islands and northwards no land can be seen and the Faroe Islands were not colonized at this time.

Conclusion

In this study I have exclusively used the curve of *Plantago lanceolata* as an indicator of man's arrival to the Shetland Islands. A decline of *Salix* and rise of *Calluna* may point at land clearings. In light of the archaeological evidence I feel confident that the *Plantago* curve really is a consequence of human activity and unlike buildings and tombs it gives us the *time* of immigration: about 3400 BC.

Acknowledgements. The radiocarbon datings were carried out by H. Tauber at the C-14 Laboratory of the Geological Survey and the National Museum.

Dansk sammendrag

Tre C-14 dateringer af et tidligere publiceret pollendiagram fra Shetlandsøerne (her reproduceret som plate 1) præsenteres. Dybderne i den boring, der gav materiale til dateringerne er de samme som i det publicerede diagram, så de kan overføres direkte til diagrammet. Det konkluderes, at *Plantago lanceolata* er lokal og at den daterer de første menneskers bosættelse på Shetlandsøerne til omkring 3400 f.Kr.

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Den prækvartære overflade ved Juelsminde, Danmark

Jens Stockmarr

Stockmarr, Jens: Den prækvartære overflade ved Juelsminde, Danmark. *Danm. geol. Unders., Årbog 1976*, pp. 49–52, pl. 1. København, 1. marts 1978.

A "geological basisdatamap" superposed by contourlines of the pre-Quaternary (Tertiary) surface relief has been produced (plate 1), in connection with a hydrogeological mapping in eastern Jutland.

Two elongated, probably structural, depressions, perpendicular to each other, in the pre-Quaternary surface are discussed.

Furthermore, a probably glacial dislocated plate of Tertiary sediments inclining to ENE is discussed.

I 1975–76 blev der ved Danmarks geologiske Undersøgelse udført en hydrogeologisk kortlægning af Juelsminde kommune med henblik på planlægningen af den fremtidige vandforsyningsstruktur i kommunen (Stockmarr, 1976). I den forbindelse blev der blandt andet fremstillet et »geologisk basisdatakort« og et »kort over den prækvartære overflade«.

Det geologiske basisdatakort indeholder størstedelen af de oplysninger fra området, som forefindes i Danmarks geologiske Undersøgelses borearkiv. Cirkeldiagrammerne er fremstillet i overensstemmelse med den af Andersen (1973) angivne metode. Der sondres mellem boringer, der er beskrevet af brøndborere, og boringer, der desforuden er beskrevet af geologer ved Danmarks geologiske Undersøgelse. Farvelægningen af cirkeldiagrammerne repræsenterer den geologiske tolkning af jordlagenes alder og beskaffenhed. De tekniske og hydrologiske oplysninger er meddelt af brøndborere.

Kortet over den prækvartære overflade er et temakort fremstillet ud fra oplysningerne på det geologiske basisdatakort. Den prækvartære overflades højdeforhold er udtrykt ved et kurvebillede. Da det fremkomne kurvebillede er baseret på et forholdsvis lille antal observationspunkter, må det fortolkes med forsigtighed.

På det foreliggende kortudsnit (plate 1) er det geologiske basisdatakort og kurveplanen fra kortet over den prækvartære overflade sammenstillet.

De prækvartære aflejringer består hovedsagelig af eocæn Søvindmergel og plastisk ler og oligocæn-miocæn glimmerler og -silt. Undergrænsen for de eocæne aflejringer kendes ikke, men på grundlag af seismiske undersøgelser må tykkelsen dog anslås til 100–150 m. De oligocæne og miocæne aflejringer er sjældent tykkere end ca. 20 m. Den prækvartære overflade har et markant relief. Den ligger højst i SV (op til kote +60), mens den ligger dybere end kote −35 lige nord for Juelsminde by.

De kvartære aflejringer består hovedsagelig af moræneler og smeltevandssand og -ler. Hvor den prækvartære overflade ligger højt, er det kvartære dække kun tyndt. I den øvrige del af området fordeler de kvartære bjergarter sig således, at smeltevandsaflejringerne er mest udbredt i den nordlige og sydlige del af kortudsnittet adskilt af et bælte med tykke lag af moræneler.

Geofysiske målinger udenfor området indicerer en forkastningsbetinget struktur med retningen VNV–ØSØ (Horsens og Vejle fjorde), mens strukturer med retningen NNØ–SSV kun er indiceret ved det lange dalstrøg i terrænoverfladen, der kan følges over ca. 100 km. fra nordvest for Haderslev til syd for Århus. At der i det sidste tilfælde er tale om en brudstruktur, underbygges muligvis ved et højere indhold af mineralvand i grundvandet i denne zone.

Ved den foreliggende kortlægning i området har det vist sig, at den prækvartære overflade er langt mere kompliceret, end hidtil antaget. Det karakteristiske, som ikke tidligere har været kortlagt på grund af den manglende 3-dimensionale fremstillingsform, er forekomsten af en langstrakt depression (kaldet As-Dalen) med samme retning som Vejle og Horsens fjorde, samt forekomsten af større dislocerede flager af tertiært materiale i de kvartære aflejringer, hvoraf én (kaldet Klejs flagen) skal behandles nærmere. Både dalens og flagernes udstrækning er ikke nærmere kendt og til en vis grad udtryk for fortolkninger.

As-Dalen

De dybeste dele af dalen i den prækvartære overflade er kun påvist gennem et mindre antal boringer: DGU arkiv nr. 117.33c, 37, 40, 137, 139, 237, 241 samt boringerne omkring Palsgård (bl.a. nr. 117.59a og 115) og på As Hoved (nr. 117.255 og 256). Kun ved de sidstnævnte 4 boringer er kvartæret gennemboret. Dalens udstrækning mod VNV er på kortudsnittet angivet som afsluttet. Dette er muligvis ikke tilfældet, men der foreligger ikke oplysninger fra dybere boringer før ca. 10 km længere mod vest ved Løsning, hvor kvartæret ikke er gennemboret ved kote ÷38. Dette kan eventuelt indicere et videre forløb af dalen.

Det har ikke været muligt at erkende dalen i de seismiske data fra et profil, der har næsten samme forløb som kortudsnittets vestlige begrænsning, bl.a. fordi de seismiske undersøgelser var udført med henblik på olieefterforskning i dybtliggende aflejringer. Dalens længderetning er parallel med Horsens-sænkningens forkastningslinier, hvilket tyder på, at dalen er at tektonisk oprindelse, evt. senere videre udformet ved erosion. Dalen er i kvartærtiden, såvidt det hidtil er oplyst, næsten udelukkende opfyldt med finsandet moræneler. Dog viser boringerne ved Palsgård tilstedeværelsen af dybtliggende sandlag. Det er i dag ikke muligt udfra områdets morfologi at erkende dalens tilstedeværelse.

I den nordøstlige del af kortudsnittet ses en mindre dal, der løber mod NNØ ud over kortkanten. Denne dal er i dag en ådal, men er også eftervist i én boring i Glud nord for kortudsnittet, hvor den prækvartære overflade ligger i kote ÷13, dækket af moræneler. Dalens udstrækning og oprindelse er usikker, men beliggenheden passer ind i det tidligere omtalte ca. 100 km lange dalstrøg, og vandanalyser ved Glud indicerer tilmed en opstrømning af mineralvand (Stockmarr, 1976).

Klejs Flagen

I et område omkring Klejs (midt i kortudsnittet), beliggende over den dybe del af As Dalen, er der i 5 boringer truffet tertiære aflejringer. Overfladen af de tertiære aflejringer hælder stærkt mod ØNØ fra kote +95 til kote +17. Overfladen af aflejringerne er altså beliggende op til mere end 100 m højere end den fortolkede prækvartære overflade i dalen, hvorfor de prækvartære og muligvis en del af de kvartære aflejringer kan tolkes som glacialt dislocerede. Også i området sydøst for den angivne flage kendes tertiært ler fra bunden af vanderosionskløfter (Madsen, 1900), hvorfor flagens udstrækning må formodes at være større end vist på kortudsnittet. Flagens rumlige orientering indicerer en dislocation fra nordøst.

I kortets nordlige del er angivet tilstedeværelse af 3 andre flager af prækvartært materiale i kvartæret, hvoraf den største er gennemboret, og her er de dybereliggende, formentlig faststående, prækvartære aflejringer nået.

Desuden viser de ret almindeligt forekommende mindre dislocerede flager af prækvartært materiale i kystklinter (Madsen, 1900), at flager er hyppigt forekommende i området.

I foråret 1978 vil Klejs Flagen blive søgt gennemboret, for at verificere hypotesen om flagens eksistens, samt eventuelt at kunne følge omkringliggende jordlags fortsættelse ind under flagen. Boringen vil blive fortsat, indtil den prækvartære overflade i As-Dalens bund er nået.

Litteratur

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Dalmanitina beds (late Ordovician) on Bornholm

Valdemar Poulsen

Poulsen, Valdemar: *Dalmanitina* beds (late Ordovician) on Bornholm. *Danm. geol. Unders., Årbog 1976,* pp. 53–87, pl. 1–4. København, 1. marts 1978.

A new well drilled through the Silurian in the southern part of Bornholm has revealed the presence of the regressive late Ordovician *Dalmanitina* beds. The pre-Silurian well section is described, and the Ashgillian fauna is described and discussed. The well cuttings from the *Tretaspis* Shale have yielded *Lonchodomas portlocki, Microparia speciosa, Tretaspis granulata, Uhakiella* sp., *Paterula* cf. *portlocki, Sowerbyella?* cf. *restricta,* and echinoderm fragments. The *Dalmanitina* beds, hitherto believed to be absent in the sequence on Bornholm, contain *Dalmanitina mucronata, Illaenus angustifrons depressus,* indeterminate proetids known from equivalent beds in Poland, *Primitiella tenera, Holopea?* cf. *mobergi, Michelinoceras?* sp., *Conularia* sp., *Lepidocoleus suecicus, Sowerbyella?* cf. *restricta,* and echinoderm fragments.

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The Cambro-Silurian beds in the southern part of Bornholm are preserved in a mosaic of fault blocks, and are mostly hidden under a Quaternary cover. Truncated fragments of the sequence are primarily exposed along a few major rivulets, and the Ordovician-Silurian transition is not exposed anywhere on the island. However, the possibility of the complete transition being present under the Quaternary cover has not been excluded (Poulsen 1969).

In 1973 the Sømarken waterworks drilled a new well at Bavnegård (map, fig. 1), and this passed through the basal Silurian and the Upper Ashgillian (Upper Harjuan) *Dalmanitina* beds, stopping in beds of supposed Middle Cambrian age. The well has the DGU File No. 248.39.

The sparse material of chips from the well was delivered to the Geological Survey of Denmark, and the material from the *Dalmanitina* sequence was kindly placed at the author's disposal by the Director of the Geological Survey, Dr. Ole Berthelsen.

Most of the photographic work has been taken care of by Mr. Jan Aagaard, Institute of Historical Geology and Palaeontology, University of Copenhagen.

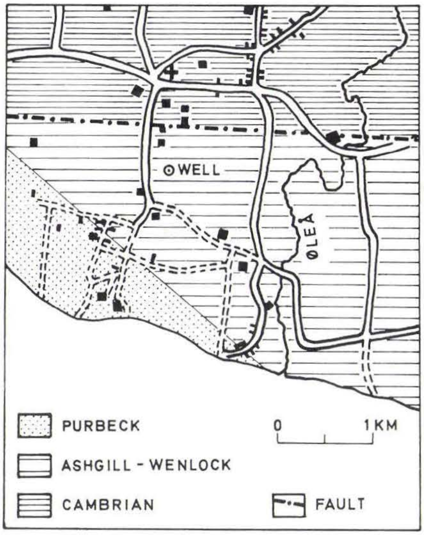

Fig. 1. Sketch-map showing the location of the new well at Bavnegård and the geology around the rivulet Øleå in the southern part of Bornholm. The Upper Ordovician *Tretaspis* Shale just south of the fault at Øleå, the *Dalmanitina* beds and the basal Silurian at the site of the well suggest that the complete Ordovician-Silurian transition may be found in a wide east-west stretch south of the fault.

The material described and figured here is in the collections of the Geological Museum of the University of Copenhagen, filed as MGUH nos. 13992–14032.

The well section

The available material consists of well cuttings collected at infrequent intervals and, accordingly, estimates of the thickness of the individual divisions are inaccurate due to "gaps" and contamination from material falling down the hole. A tentative compilation of the lithology and stratigraphy of the well section is shown in fig. 2.

The drilling penetrated to a depth of 98.5 m below ground level, stopping in quartz sand or calcarinate sandstone. The rounded or subangular quartz grains are from 0.5–1.5 mm in diameter and are mixed with glauconite grains (0.2–1.0 mm in diameter). A content of bentonite and black shale fragments is regarded as contamination.

The basal part is overlain by a thick sequence of black alum shale which contains fusiform pyrite pseudomorphs after barytes at some levels, whereas stinkstone occurs at other levels. The alum shale in the well section corresponds very well to the known exposures on Bornholm with regard to lithology and thickness and, consequently, the alum shale from the well is here regarded as ranging from uppermost Middle Cambrian into the Tremadocian.

The 2 m (?) thick sequence of quartz sand or sandstone at the bottom of the

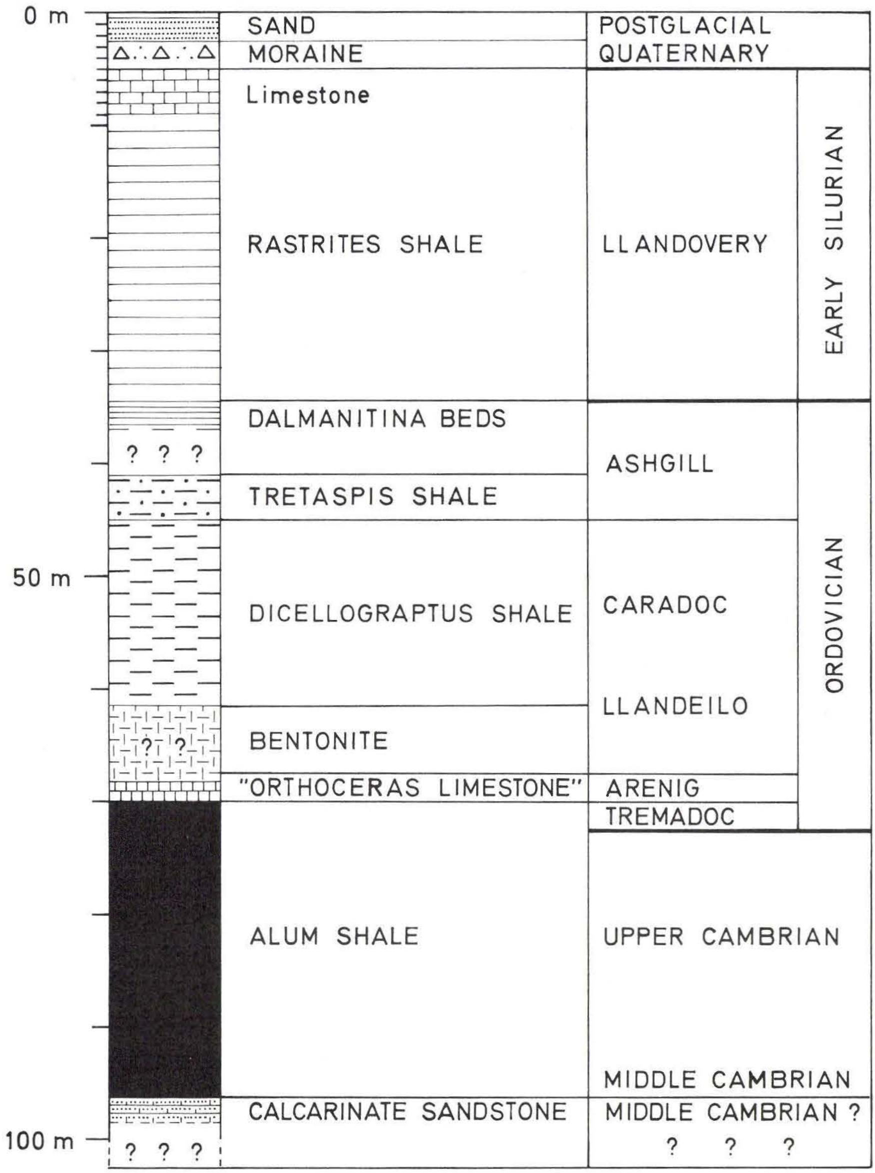

Fig. 2. Tentative lithology and stratigraphy of the section at the new well at Bavnegård, 1250 m west of the rivulet Øleå. Only a limited number of ditch samples has been available, and contamination from material falling down the hole prevents accurate thickness estimates of the divisions. Thus, the bentonite bed is probably much thinner, as the "*Orthoceras* limestone" may be expected to be about 5 m thick as in all known exposures in neighbouring fault blocks.

well may partly belong to the Middle Cambrian, and partly to the Lower Cambrian. The content of glauconite suggests a possible correlation with the Middle Cambrian "*exsulans* limestone" or Kalby Clay, both of which contain a fair to high amount of glauconite (Poulsen 1966, p. 119). These units, however, will probably be less than 30 cm thick, and the lowermost part of the well section may therefore correspond to the upper part of the Lower Cambrian Rispebjerg Sandstone – provided that the glauconite at the very bottom is contamination originating from the immediately overlying beds of assumed Middle Cambrian age.

The "*Orthoceras* limestone" in the well section is about 2 m thick, unless the overlying interval with bentonite is exaggerated due to contamination. Judging from the well cuttings the bentonite beds should be more than 5 m thick – a quite unrealistic figure. Based on the results of Bergström & Nilsson (1974) the bentonite most likely belongs in the lower part of the *Diplograptus multidens* Zone, and the thickness of the series with bentonite beds from this level at Vasagård (at the rivulet Læså) is about 1.65 m. It is, therefore, concluded that the "*Orthoceras* limestone" probably is about 5 m thick as in the known exposures on Bornholm, and that the overlying bentonite sequence is less than 2 m thick.

The homogeneous "*Orthoceras* limestone" is of a light to medium grey colour, recrystallized, transected by calcite veins which are 1–1.5 mm wide. The limestone contains a few inarticulate brachiopods and trilobite fragments (including a styginid pygidium), all poorly preserved. The absence of phosphorite pebbles indicates a possible correlation with part of the Komstad Limestone (Poulsen 1965, p. 53).

The overlying bentonite with subordinate (?) beds of shale is of a greyish-white to faint green colour, indurated, and with a notable content of biotite as small dark-brown scales.

The greyish-black *Dicellograptus* Shale has yielded a few fossils which are to be described by Merete Bjerreskov (in prep.).

The *Tretaspis* Shale, which probably is about 3–4 m thick, is greyish-black, not highly fissile. The few fossils found in this part of the sequence are described below.

A gap in the sampling of the well cuttings prevents and accurate estimate of the thickness of the overlying *Dalmanitina* beds which may be from 2–6 m thick. The beds comprise light-grey indurated shales that are poorly fissile. Some levels are highly fossiliferous. The fauna is described below.

The basal part of the Llandoverian *Rastrites* Shale constitutes the top of the Palaeozoic sequence in the well section. The graptolites from this part have been described by Bjerreskov (1975). The Quaternary and postglacial cover is about 5 m thick.

The Ordovician-Silurian transition in Sweden and on Bornholm

The change in lithology and fauna demonstrated by the Scanian *Dalmanitina* beds has complicated the stratigraphical discussion on the Ordovician-Silurian boundary in the Scanian and Baltic region. Troedsson (1918) regarded the *Dalmanitina* beds as the transgressive basal Silurian and placed the Ordovician-Silurian boundary between the zones of *Staurocephalus clavifrons* and *Dalmanitina olini*. This choice of boundary finds a possible support in the widespread break between the *Tretaspis* Series and the *Dalmanitina* beds (Henningsmoen in Wærn et al. 1948, p. 427).

The *Dalmanitina* beds have more recently been considered to represent the regressive top of the Ordovician. Wærn (in Wærn et al. 1948, pp. 461–462) showed that the *Dalmanitina* beds in the Kullatorp core (Kinnekulle in Västergötland) are followed by mudstones from the *Glyptograptus persculptus* Zone (basal Llandovery). Jones (1949) compared the Kullatorp section with the British sections and suggested that the Ordovician-Silurian boundary should be drawn above the *Dalmanitina* beds. This point of view has been supported by all subsequent authors.

Jaanusson (1956, p. 391), who also presented an excellent summary of previous discussions on the Ordovician-Silurian boundary in Balto-Scandia, did not exclude the possibility that the upper part of the *Dalmanitina* beds at Kullatorp (developed as calcarinate sandstone) may belong to the basal Silurian. At present the entire sequence of *Dalmanitina* beds is referred to the Upper Ordovician. Jaanusson (1963, p. 132) introduced the Tommarp Stage to include the *Dalmanitina* beds in Sweden and Poland.

None of the exposures on Bornholm show the Ordovician-Silurian transition, and the existence of a hiatus at this level has been suggested (Poulsen 1966, p. 130), as the Cambro-Silurian sequence on Bornholm is demonstrably known to be incomplete as a result of uplifts. The breaks and change in facies in Sweden towards the close of the Ordovician lend credibility to the idea of a hiatus at this level on Bornholm. However, the possibility of the complete transition being present under the Quaternary cover has not been entirely excluded, as the structural setting immediately south of the fault at the rivulet Øleå (see map, fig. 1) leaves space for a complete sequence with a thickness comparable to that of the Scanian succession (Poulsen 1969, p. 350).

The new well shows the presence of 2–6 m *Dalmanitina* beds developed as light-grey shale, and, in view of the occurrence of *Tretaspis* Shale at Øleå south of the fault (map, fig. 1) and the general dip of the sequence towards the south, the *Dalmanitina* beds may be expected to be distributed along a wide east-west stretch south of the fault.

The *Tretaspis* Shale

In Danish usage the *Tretaspis* Shale comprises the zones of *Eodindymene pulchra* and *Staurocephalus clavifrons* (see Poulsen 1966, p. 129) and this concept in an agreement with Olin (1906). The species found in the interval from 41–45 m below ground level suggest a provenance from the *Eodindymene pulchra* Zone. *Lonchodomas portlocki, Tretaspis granulata,* and *Microparia speciosa* are known from both zones, whereas *Paterula* cf. *portlocki* apparently would indicate the *E. pulchra* Zone – unless the top of the subjacent *Pleurograptus linearis* Zone may be found within this part of the section.

Species from the *Tretaspis* Shale

Lonchodomas portlocki (Barrande, 1846)
Pl. 1, figs. 1–2

Material. – A single, somewhat crushed fragment of cephalon, and a fragment of a frontal glabellar spine.

Description. – The "reniform" cephalic fragment is 8 by 3 mm. The most conspicuous feature is the rather evenly distributed, shallow or moderately impressed pits in the test. The distance between the pits varies from 0.15–0.3 mm. The fragment of the frontal glabellar spine is 2 mm long and about 0.5 mm wide, hardly tapering. The spine is distinctly quadri-carinate, with a concave, diamond-shaped cross-section which shows a circular outline of the section through the central cavity.

Remarks. – The state of preservation of the cephalic fragment makes an assignment of this alone to genus unreliable. The ornamentation of pits is not unlike the ornamentation see in some illaenids, and there is thus some resemblance to "*Illaenus*" cf. *angelini* figured by Kielan (1959, pl. 14, figs. 7–9). On the other hand, the find of a frontal glabellar spine with the regular cross-section typical of *Lonchodomas portlocki* suggests that the cephalon may be assigned to the same species which is distinguished by the ornament of closely situated pits (Kielan 1959, p. 170).

Microparia speciosa Hawle & Chorda, 1847
Pl. 1, fig. 3

Material. – A single specimen showing posterior two-thirds of glabella with three adjoining thoracic segments.

Description. – The preserved two-thirds of the glabella is cracked due to flattening and, accordingly, the outline is somewhat distorted. The posterior glabellar margin is straight, transverse. The three contiguous thoracic segments are slender, with a rapidly tapering rhachis. The extremely wide axial rings are delimited by moderately impressed dorsal furrows. The relief of the dorsal furrows is uneven, as moderately deep pits are situated in the furrows opposite the posterior pleural bands. The short (tr.) pleurae are divided into narrow anterior and wide posterior pleural bands by strongly oblique pleural furrows which run from the dorsal furrow half-way through the pleurae. The distal part of the pleurae appears to be almost truncate, as the pleural spines are very short and directed obliquely backwards.

Remarks. – *Microparia speciosa* has previously been collected by the author from Risebæk at the south coast, and from Øleå south of the fault at Billegravgård.

Tretaspis granulata (Wahlenberg, 1818)
Pl. 1, figs. 4–5

Material. – Fragment of proximal part of genal roll prolongation, two marginal fragments of lower lamellae.

Description. – The fragment of the triangular genal roll prolongation measures 5 × 4 × 3.5 mm and includes the postero-lateral part of the fringe. The distribution pattern and morphology of the pits may be considered diagnostic of the species. The gently convex genal roll is densely covered with round pits which are of a uniform size; there are 6–8 pits on a transverse line, level with the assumed position of the posterior cephalic margin, and about 12 pits in the proximal row parallel to the marginal suture on the inside of the prolongation. There is a gentle transition from the genal roll to the brim in which two rows of pits are seen; the proximal row contains round pits like the ones in the genal roll, whereas the marginal row consists of radially elongated pits which are somewhat wider than the pits on the genal roll.

A small, postero-lateral part of the lower lamella is exposed, showing a single marginal row of elongate tubercles, a well-defined girder, and more weakly developed tubercles on the inner part of the lower lamella close to the girder.

The two marginal fragments of lower lamellae show elongate tubercles identical to those described above.

Remarks. – Kielan (1959, pp. 173–174) discussed the arrangement of pits on the tretaspid fringe and was able to demonstrate a considerable variation in *Tretaspis granulata*. She came to the conclusion that the subspecies *T. granulata granulata* and *T. granulata bucklandi* (Barrande), which were recognized by Størmer (1930), both fell within the variation of *T. granulata*, and the subspecies were abandoned.

The arrangements of pits in the fragment of the genal roll prolongation strongly resembles that of *T. granulata* in Kielan's plate 33, fig. 1 (1959).

Uhakiella sp.
Pl. 1, figs. 6–8; text-fig. 3

Material. – Seven incompletely preserved specimens, of which two are external moulds (two right valves) and five are internal moulds (two left valves and three right valves). Measurements of the specimens are presented in text-fig. 3.

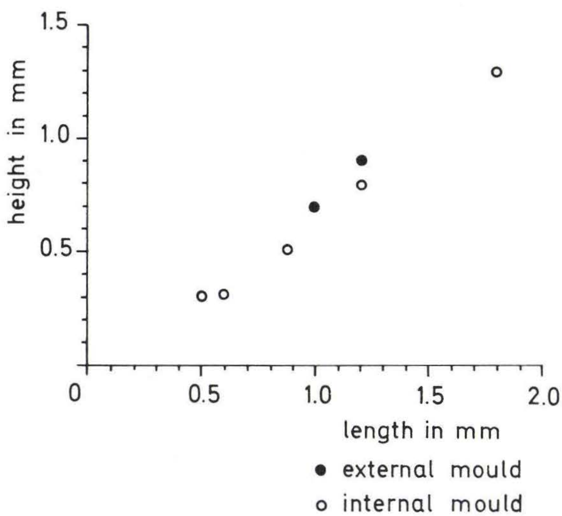

Fig. 3. Measurements of seven tecnomorphic single valves of *Uhakiella* sp. from the *Tretaspis* Shale in the new well section.

Description. – The valves, probably all tecnomorphs, appear to be almost amplete in outline, but may be more postplete, as the free border is not fully preserved. The sulcus is moderately impressed, and the lobation is indistinct. No velar structures seem to be developed. The surface of the test in the larger specimens shows a moderately coarse granulation.

Remarks. – *Uhakiella magnifica*, which was erected by Sarv (1959), is known from the Nabala, Vormsi, and Pirgu Stages in Estonia – corresponding to the zones of *Pleurograptus linearis, Dicellograptus complanatus,* and *Dicellograptus anceps.* The Estonian species is fairly large and has coarsely granulated valves. The form from Bornholm has a much less prominent granulation and cannot be conspecific with the Estonian species. The poor material does not permit the establishment of a new species, especially in view of the known range of variation within *Uhakiella.*

Paterula cf. *portlocki* (Geinitz, 1852)
Pl. 1, fig. 9

Material. – A single dorsal (?) valve, flattened and slightly distorted.

Description. – The thin-shelled dorsal (?) valve is slightly distorted due to flattening and now measures 0.5 mm in length and 0.3 mm in width. The outline is probably slightly ovate, and the original relief presumably very low. The apex is situated 0.14 mm from the posterior end and is surrounded by concentric growth-lines which are distinct all the way to the depressed marginal border.

Remarks. – Species of *Paterula* may be difficult to distinguish, and the extremely small size of the single valve at hand makes an assignment more difficult still. Henningsmoen (in Wærn et al. 1948, pp. 393–395) discussed the vertical distribution of *Paterula* cf. *portlocki* which occurs throughout the black shale of the *Pleurograptus linearis – Climacograptus styloideus* Zone in Västergötland, but not above this level. On Bornholm *Paterula portlocki* is seen at many levels in the entire sequence of *Dicellograptus* Shale. It is not possible to verify that the small specimen at hand does come from the *Tretaspis* Shale, as the mixed well cuttings from the interval 41–45 m below ground level may span the boundary between the zones of *Pleurograptus linearis* and *Eodindymene pulchra* – or the specimen may belong to a different species.

Sowerbyella? cf. *restricta* (Hadding, 1913)
Pl. 1, fig. 10

Material. – A single incomplete and immature pedicle valve.

Description. – The gently convex pedicle valve has a subsemicircular outline with the maximum width at the hinge; the valve is about 2.4 mm long and more than 4.7 mm wide. The umbonal region is not prominent, scarcely protruding above the level of the hinge line. The cardinal angle is about 70°. Impersistent rugae are developed at infrequent intervals, and the valve is further ornamented with radiating costae and costellae in an almost multicostellate pattern. The surface of the test is incompletely preserved, but it is evident that the costae and costellae are of almost equal strength; the median costa appears to be raised slightly above the other ribs. There are most likely about 10 costae, separated by 3–5 (?) first order costellae, some of which are branching distally.

Internal structures are not known.

Remarks. – An assignment to *Sowerbyella* cannot be confirmed until the internal structures are known. Radially arranged pits or pseudopunctae are seen between the ribs as a result of surface damage, and the valve corresponds in this respect also to *Sowerbyella? restricta,* originally described as *Leptaena sericea* var. *restricta* by Hadding (1913, p. 62). This form was described from the *Nemagraptus gracilis* Zone and immediately overlying beds in Scania, and Henningsmoen (in Wærn et al. 1948, p. 396) recorded the species *restricta* from the Upper Ordovician *Tretaspis* Shale in Västergötland. *Sowerbyella?* cf. *restricta* is also found in the well cuttings from the *Dalmanitina* beds – see later.

Thus, it is very likely that the species persisted into the *Dalmanitina* beds. *S.? restricta* may be closely related to *S. sericea* which is known from the Scanian *Dalmanitina* beds (Troedsson 1918, p. 38).

The single specimen also shows a considerable resemblance to some Lower and Middle Ordovician species of *Sowerbyella* (subgenera *Sowerbyella* and *Viruella*) described from Estonia by Öpik (1930) and Rõõmusoks (1959), but Upper Ordovician species are not too well known, and the state of preservation prevents an assignment to species.

Echinoderm fragments
Pl. 1, fig. 11

Material. – A few indeterminate echinoderm fragments have been found. They appear as massive cylindrical stem ossicles broken along rhombohedral cleavage planes typical of calcite. The figured stem fragment measures about 2 mm in diameter.

The *Dalmanitina* beds

Well cuttings from the interval 34.5–34.6 m below ground level show the presence of a light-grey, indurated, and poorly fissile shale which may be referred to the *Dalmanitina* beds on account of the contained fossils. The following species have been identified: *Dalmanitina mucronata, Illaenus angustifrons depressus,* indeterminate proetids known from equivalent beds in Poland, *Primitiella tenera, Holopea?* cf. *mobergi, Michelinoceras?* sp., *Conularia* sp., *Lepidocoleus suecicus,* and *Sowerbyella?* cf. *restricta*. The fauna contains more forms than listed here, including ostracods and echinoderms, but the state of preservation and the coquina-like concentration of small fragments prevent determination of the majority of fragments.

A gap in the sampling og well cuttings makes an accurate estimate of the thickness of the *Dalmanitina* sequence impossible, but the evidence from fossiliferous levels below and above the critical interval suggests that the *Dalmanitina* beds are 2–6 m thick. The well cuttings show that the fossils tend to be concentrated at certain levels. The larger specimens are inevitably broken into small fragments which are mixed with more intact small, or juvenile specimens in a pseudocoquina, and this may indicate reworking in a high energy, shallow water environment.

The *Dalmanitina* beds in Scania have been divided into three zones – in ascending order: The *Dalmanitina olini* Zone, the *Dalmanitina mucronata* Zone, and the *Brongniartella platynota* Zone (see discussion in Regnéll 1960, pp. 24–25). However, the *Dalmanitina olini* Zone has not been recognized in other parts of Sweden, or in Bohemia (Kielan 1959, p. 26). The assemblage from Bornholm appears to be inconclusive and in the present paper the *Dalmanitina* beds on Bornholm are regarded as a single unit.

The regressive termination of the Ordovician created a variety of environments, and the vertical distribution of the *Dalmanitina* species, and probably other groups as well, may have been facies controlled, as suggested by Troedsson (1918, pp. 70–71) and later Temple (1952, p. 27). In a few cases *Dalmanitina olini* and *D. mucronata* have been found on the same bedding plane, believed to be the junction between the two zones (see Troedsson 1935). In the discussion of the geographical distribution of Upper Ashgillian trilobites Kielan (1959, p. 26) treated both zones together, and any emphasis on the zonation should probably be avoided until the true vertical range of a large number of species in this sequence is better known.

Species from the *Dalmanitina* beds.

Dalmanitina mucronata (Brongniart, 1822)
Pl. 2, figs. 1–4

Material. – Two incomplete free cheeks, an almost complete pygidium, numerous small thoracic fragments.

Description. – A free cheek, in which the anterior portion in front of the eye is concealed (by a *Sowerbyella*), has dimensions suggesting a cephalon with a length about 10 mm and posterior width (excluding spines) about 15 mm. The genal field slopes gently down from the fairly large eye and is coarsely ornamented with low, anastomosing ridges. The wide lateral border, which is delimited from the genal field by a wide and shallow border furrow, is gently convex and raised. The posterior branch of the facial suture is gently convex forward, turnings backwards at a good distance from the posterior end of the eye to cut the lateral margin at an angle of about 15° and at a level somewhat posterior to the eye. The lateral border is completely covered with equally sized granules, whereas identical granules occur more scattered in the genal field.

The almost complete pygidium is rounded triangular in outline and measures 5 mm i length (exclusive of the posterior spine which is broken off), 8 mm in width at anterior margin, and the width of the rhachis anteriorly is 2.3 mm. The rhachis, which is well elevated above the pleural fields, tapers moderately in posterior direction. Eleven axial rings are present, including the highly elevated terminal piece that most likely projected as a stout posterior spine. The transverse ring furrows are wide and well impressed all the way across the rhachis, although they become progressively more shallow towards the posterior end of rhachis. The dorsal furrows are narrow, deeply impressed. The pleural fields contain eight pleurae, of which the anterior are almost at right angles to the rhachis, whereas the succeeding pleurae leave the axial furrows at progressively smaller angles, so that the last pleura is parallel to the sagittal axis. The wide and deep pleural furrows, which join the dorsal furrows and terminate at the pygidial border without becoming shallower, run almost parallel to the pleurae which are divided into anterior and posterior pleural bands of almost equal width (sag.). The interpleural furrows are narrow and moderately impressed throughout, elevated above the level of the pleural furrows. The flat and fairly narrow pygidial border forms an abrupt termination of the pleural extremities, as the border furrow is narrow and indistinctly defined. The antero-lateral corners of the pygidium are depressed to form moderately large articulating facets. The pygidial border is completely covered with fine, equal sized granules, and similar granules occur more scattered on the rhachis and in the pleural fields, including the furrows.

A number of small thoracic fragments probably belong to this species, as the pleural furrow structure and granulation pattern are exactly as seen in the pygidial pleurae described above. One of the fragments (pl. 2, fig. 4), representing the abaxial extremity of a posterior pleural band, shows an obliquely backward-directed, rapidly tapering, and fairly short pleural spine.

Remarks. – In a revision of *Dalmanitina mucronata* and allies Temple (1952) erected *Dalmanitina olini*, including herein the specimens of *Phacops eucentra* Angelin figured by Olin (1906). Angelin's figure from 1851 of *Phacops eucentra* was considered unsatisfactory for identification; the pygidium is identical to that of *D. mucronata* and Temple concluded that the cephalon is aberrant. Accordingly, Angelin's species was included in *Dalmanitina mucronata*. *Phacops pulchellus* Linnarsson, 1869 was also considered to be a synonym of *D. mucronata*. Kielan (1959) claimed *Dalmanites kiaeri* Troedsson, 1918 to be a junior synonym of *D. mucronata*.

Thus it appears that *Dalmanitina mucronata* and *D. olini* so far are the only species of that genus known from the Upper Ordovician in Balto-Scandia. Distinction of the two species has been discussed at length by Troedsson (1918) and Temple (1952), and the pygidium described above perfectly fits *Dalmanitina mucronata* in all diagnostic respects, e.g. number of axial rings and pleurae, impression depth of pleural and interpleural furrows, and equal width of anterior and posterior pleural bands. The distinctly forward convex posterior branch of the facial suture in the free cheek, corresponding to long eye lobes, is also strongly suggestive of *Dalmanitina mucronata*, although the course of the facial suture may show a considerable intraspecific variation.

Dalmanitina mucronata has a considerable vertical distribution, ranging from the *Staurocephalus clavifrons* Zone in the Upper Ordovician into the Llandovery, but the "*mucronata* type" is almost completely suppressed in the time interval corresponding to the lower part of the *Dalmanitina* beds, in which *Dalmanitina olini* is predominant. *D. mucronata* came back in force in the upper part of the *Dalmanitina* beds and persisted into the Silurian. The distribution of the two species may have been facies controlled, as suggested by Troedsson (1918) and Temple (1952), and facies may also have affected the ostracods.

The *Tretaspis* Shale on Bornholm includes at least a part of the *Staurocephalus clavifrons* Zone, but *Dalmanitina* has never been found in any of the outcrops, and *Dalmanitina mucronata* is here considered to indicate the upper part of the *Dalmanitina* beds, especially in view of the immediately overlying shale sequence with graptolites from the basal Llandovery.

Illaenus angustifrons depressus Holm, 1886
Pl. 2, figs. 5–6

Material. – Two cranidia, one of which is an internal mould with preserved original relief, whereas the other is flattened and partly crushed, but with parts of the test preserved. One pygidium.

Description. – The outline of the cephalon is probably almost semicircular. The convexity of the cranidium is low to moderate sagittally and transversely. The glabella is flatly arched transversely, and the curvature of the lateral parts continues into the adjoining parts of the fixigenae; the glabella is expanded forward, with a slight lateral constriction and depression at posterior one-third line across glabella. No glabellar tubercle appears to be present. The dorsal furrows run slightly inward-forward from the posterior margin to the constriction and are well-impressed along this stretch; anterior to the constriction the dorsal furrows diverge strongly, following an evenly curved course almost to the anterior cephalic margin, and this part of the dorsal furrows is ill-defined. The internal mould shows a short (tr.), simple, convex occipital ring, gently accentuated by a shallow occipital furrow which is effaced mesially. The other cranidium, which has parts of the test preserved, shows no trace of the occipital structures. The fixigenae are moderately convex and downsloping in anterior, lateral, and posterior directions, with no indications of an anterior or posterior border furrow. The eye lobes are situated on the posterior one-third line across glabella, opposite the glabellar constriction; the diminutive, strongly curved palpebral lobes are only set off by a slight flattening in the curvature of the fixigenae. The posterior branches of facial suture run almost straight back to the posterior margin; the fixigenal margins are not intact in front of the eye lobes, but the anterior branches of facial suture appear to diverge slightly at first, then running straight, or curving slightly inward-forward towards the anterior cephalic margin. The internal mould as well as the outer surface of the test are adorned with scattered, relatively coarse granules; terrace lines do not seem to be developed, or, if originally fine, are not preserved.

The pygidium, an internal mould with patches of the test preserved, is about twice as wide as long, oval in outline, gently convex both ways, and with inclined articulating facets. The rhachis is less than half the pygidial length and between one-third and one-fourth the pygidial width at anterior margin, strongly tapering, with little relief and almost level with the pleural regions. Traces of ring furrows and dorsal furrows are seen anteriorly. The pleural regions are moderately convex, evenly downsloping to the lateral and posterior margins, without traces of segmentation. The course of the inner margin of the doublure is imprinted on the dorsal side of the pygidium as a result of a slight flattening. The doublure is fairly narrow and of equal width throughout. Faint traces of backward-curving terrace lines are preserved on the surface of the test, and apart from these lines the surface is marked by scattered, fairly coarse granules, similar to those on the cranidium – although they appear to be slightly finer on the pygidium.

Dimensions. – The cranidia are 2.8 and 2.6 mm long (dorsal projection) and both measure 3.2 mm in width. The pygidium is 3.6 mm long and 6 mm wide (slightly in front of midline across rhachis); the rhachis is about 1.6 mm wide at anterior margin.

Remarks. – The gross morphology of the cranidia and the pygidium fits well with an *Illaenus* of the *Parillaenus* group (Jaanusson 1954), and the pygidial doublure is especially characteristic, being of equal width throughout.

Illaenus angustifrons depressus was erected by Holm (1886) as var. *depressa* to include Estonian specimens of *I. angustifrons* characterized by smaller size, lower convexity, and a more narrow glabella and rhachis. The variety was the only *Illaenus* reported from the Estonian Borkholm beds, corresponding to the Porkuni Substage (F_2) which again is equivalent to the *Dalmanitina* beds. A single cranidium from the subjacent Lyckholm beds (Pirgu Substage) was also referred too the new variety. *Illaenus angustifrons depressus* was also recorded from Quaternary erratics in northern Germany. In a modern sense Holm's variety should be regarded as a subspecies.

Whittington (1965, p. 387) noted that the granulation on the illaenid test in some cases is restricted to the inner surface, corresponding to pits on the internal moulds, and at the same time the outer surface of the test may be pitted. The granulation in the specimens described above is seen both on the outer surface and on the internal mould, most likely corresponding to congruent pits on the inner surface.

Proetid genus et species indet. a (= Trilobites sp. Kielan, 1959)
Pl. 2, figs. 7–8; ? pl. 4, fig. 1

Material. – External mould of cranidial fragment, ? free cheek fragment in ventral view, ? Juvenile cranidium.

Description. – The cranidial fragment is about 6 mm long and comprises the left side of the glabella, frontal area, occipital region, anterior and palpebral area of fixigenae. The moderately convex glabella is strongly tapering forward from a wide base, resulting in a subtriangular outline, acutely rounded anteriorly, outlined by a deeply impressed dorsal furrow. The occipital furrow is very deep and wide, probably joining the dorsal furrow, delimiting a moderately sized occipital ring which appears to get narrow towards the dorsal furrow. The convex preglabellar field occupies slightly more than half of the frontal area, bordered by a gently curved, wide and deep border furrow with dimensions much like the occipital furrow. The evenly curved anterior border is narrow (sag.), convex and upturned. The lateral glabellar furrows are very indistinct; one short pair, situated slightly behind the palpebral lobe and separated from the dorsal furrow, converges backwards without reaching the middle portion of glabella. The round and markedly raised, small palpebral lobe is situated rather close to the dorsal furrow, slightly in front of midline across glabella. A short and wide (sag.), ill-defined eye ridge runs inward-forwards from the palpebral lobe. The palpebral area of fixigena is almost restricted to the palpebral lobe itself,unless the cranidium has suffered a slight transverse compression. The convex anterior and posterior areas of fixigena slope down from the palpebral lobe. Anterior section of the facial suture runs in an almost straight line forwards to the anterior cephalic margin, only gently influenced by the curvature of anterior area of fixigena; posterior section of the facial suture, which is only preserved anteriorly, runs obliquely backwards when leaving the palpebral lobe. The entire surface of the cranidium, including occipital furrow and anterior border furrow, is densely covered by granules of the same size.

The ventrally exposed free cheek fragment shows a gently curved lateral margin and a fairly wide doublure with up to 9 discontinuous, marked terrace lines which are parallel to the cephalic margin. The genal field is gently convex, and is ornamented with a granulation similar to that of the cranidium, although the granulation becomes finer in abaxial direction.

Remarks. – The cranidium, although incomplete, shows sufficient diagnostic features to be safely considered conspecific with Trilobites sp. described by Kielan (1959, pp. 178–179; pl. 3, figs. 4–5; pl. 21, fig. 3). The free cheek fragment, described above, is confidently referred to the same species on account of the characteristic granulation which has not been encountered in association with other trilobite species in the material from Bornholm. The granulate meraspid cranidium (pl. 4, fig. 1) is tentatively assigned to the same species.

Kielan (1959, p. 179) discussed the possible relationships of the indeterminate trilobite which was regarded as a late descendant of Cambrian olenids. The gross morphology of the cranidium and doublure of the free cheek, provided that they belong together, strongly suggests a proetid affinity. Kielan's material originated from the *Dalmanitina mucronata* Zone in the

Bardo syncline, where the species occurs in association with other proetids that also are identified in the well cuttings from Bornholm (see below).

Proetid genus et species indet. b (? = "*Proetus*" spp. a & b Kielan, 1959)
Pl. 3, figs. 1–7; pl. 2, fig. 5

Material. – Five cranidial fragments and four incomplete pygidia, probably all belonging to the same species.

Description. – All the cranidial fragments show the glabellar region and adjoining portion of the fixigenae and frontal area; the length of the cranidia varies from 3 to 6 mm. The prominent glabella tapers forward from a wide base, evenly rounded anteriorly, outlined by narrow, but deeply impressed dorsal furrows and preglabellar furrow. The occipital ring is simple and flat, slightly expanded mesially, and delimited by a narrow, moderately impressed occipital furrow which runs transversely across glabella, then turning slightly forward, not quite reaching the dorsal furrows. The lateral glabellar furrows appear to be present as wide and shallow impressions, but all the available cranidia are somewhat flattened and cracked, so the precise nature and number of furrows cannot be observed. The original proportions of the frontal area are obscured by distortion in all specimens; the preglabellar field appears to be strongly convex, and one specimen shows an upturned anterior border. The fixigenae are mostly not preserved, with the exception that the proximal part of posterior area of fixigenae is seen in two cranidia; the posterior border is flat and simple, bordered by a narrow and moderately impressed border furrow which is situated slightly posterior to the occipital furrow. The cranidial surface anterior to the occipital furrow is ornamented with fine, raised, anastomosing lines in a Bertillon pattern, elongate concentric around the midpoint of the occipital furrow, whereas the line pattern on the occipital ring is concentric around the midpoint of posterior margin of the cephalon. Apart from the line pattern the glabella possesses an ornament of scattered small granules.

The pygidia measure from about 1.5 to 3 mm in length, and from 3 to 5 mm in width at anterior margin. The pygidial outline is transversely semielliptical, as the maximum width is at the level of the second axial ring. The prominent rhachis, which anteriorly occupies about one-third of the pygidial width, is well elevated above the pleural fields, tapering fairly rapidly to an evenly rounded terminal piece, so that the rhachis only covers about three-fourths of the pygidial length. There are 6 distinct axial rings including the terminal piece which is slightly wider (sag.) than the preceding rings and with a faint restriction, suggesting the presence of an additional axial ring. The transverse ring furrows are wide throughout, moderately impressed anteriorly and becoming progressively more shallow in posterior direction. The prominent articulating half ring is crescentic and bordered by a transverse furrow which is deeper than the anterior ring furrows. The dorsal furrows appear to be deep and wide. The pleural regions are constituted by five wide pleural ribs which curve outward-backward. The pleural furrows are wide and deeply impressed almost all the way to the pygidial margin, whereas the narrow interpleural furrows are almost effaced. The wide doublure, exposed in one specimen, is marked by distinct, scattered terrace lines (about 12 lines in 1 mm). The pygidial surface is finely granulate, and a fine transverse striation is preserved on the rhachis in one specimen.

Remarks. – The cranidia and pygidia are believed to be conspecific, as they appear to match in type, size, ornamentation, and frequency. The pygidia are not likely to belong to the coarsely granulated form described above. The cranidia show great resemblance to "*Proetus*" sp. a in all preserved details, and the pygidia resemble "*Proetus*" sp. b, both of which were described by Kielan (1959, pp. 181–182) from the *Dalmanitina mucronata* Zone in the Zalesie section in the Bardo syncline. The Zalesie cranidia differ, however, in having more distinct lateral glabellar furrows, an occipital node, and the line ornament in a Bertillon pattern is more strongly developed. On the other hand, these differences may be related to the difference in size, the Polish specimens being slightly larger.

Kielan's "*Proetus*" sp. b, only represented by pygidia, was described as having 3–4 pleural ribs, but the figured specimen (Kielan 1959, pl. 21, fig. 2) appears to have 5 pleural ribs, of which the posterior one, admittedly, is only faintly indicated. The material from Bornholm is poor, but the author, nevertheless, feels convinced that the pygidia and cranidia belong together and that they correspond to Kielan's "*Proetus*" spp. a and b which probably represent a single species.

Primitiella tenera (Linnarsson, 1869)
Pl. 3, figs. 8–10; text-fig. 4

Material. – Seven carapaces and one left valve. Measurements are presented in text-fig. 4.

Description. – The valves are non-sulcate, similar, strongly biconvex, about twice as long as high, and slightly postplete in outline, although the height is almost constant along the nearly straight ventral margin, resulting in an almost subrectangular outline. The hinge is somewhat more than two-thirds

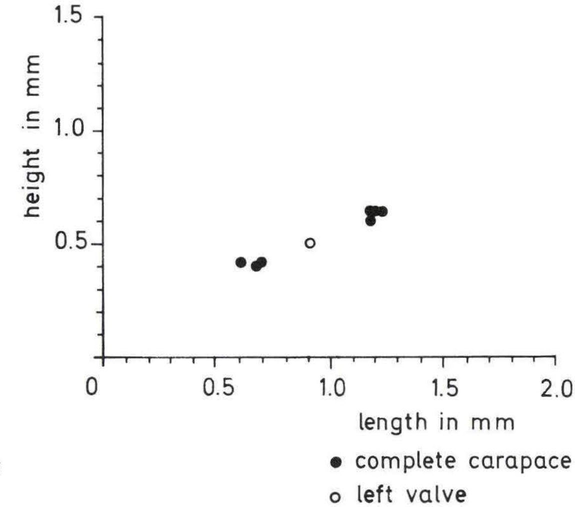

Fig. 4. Measurements of four specimens of *Primitiella tenera* (Linnarsson) from the *Dalmanitina* beds in the new well section.

of the valve length, and the hinge line is straight. The dorsal margin, which is slightly concave, curves regularly into anterior and posterior margins. A depressed zone along the free margin, if present originally, is not preserved. The surface of the tests appears to be smooth.

Remarks. – *Primitiella* tenera is characterized by the strong convexity and the length:height ratio, and the material from Bornholm perfectly matches Linnarsson's diagnosis. The specimens have preserved the original convexity, and there are indications of lobes and furrows, as described by Troedsson (1918, p. 47) in flattened valves. Apart from that, all known specimens of this species appear to be identical, and the dimorphism suggested by Kay (1940, p. 262) in his redescription of the type species *Primitiella constricta* Ulrich, 1894 may not be present after all.

Primitiella tenera occurs throughout the *Dalmanitina* beds in Scania, but it is furthermore reported to be common in the *Staurocephalus clavifrons* Zone in the upper part of the *Tretaspis* Shale, and Linnarsson's material from Västergötland also originated from the *Tretaspis* Shale. The "*Dalmanitina* bed age" for the specimens from Bornholm is based on the associated fauna.

Holopea? cf. *mobergi* Troedsson, 1918
Pl. 4, figs. 1–2

Material. – Six slightly flattened and distorted internal moulds of the shell. The height varies from about 1 mm to 3.5 mm, and the maximum width from 0.9 to 3.2 mm.

Description. – The turbiniform shell is moderately high spired, with 4–5 rounded whorls and deeply impressed sutures. The height of each whorl is about 1.5 times the height of the preceding one. The cross-section of the whorls is almost circular. The apical angle varies from 60°–70°, probably affected by the imperfect state of preservation. The apertural and umbilical regions are not exposed. No traces of surface ornamentation are preserved.

Remarks. – The material is in agreement with Troedsson's species in all respects apart from a distinct difference in size. The specimens from Bornholm are about one-third the size of *Holopea? mobergi* specimens from Scania. It appears very likely that the small specimens represent juvenile stages of *H.? mobergi*.

Troedsson (1918, p. 42) stated that *Holopea? mobergi* is one of the most common species in the *Dalmanitina* beds and makes its first appearance in the *Staurocephalus clavifrons* Zone.

The assignment to the genus *Holopea* may be questioned, but the state of preservation of Troedsson's original material and of that described above does not permit a revision at genus level.

Michelinoceras? sp.
Pl. 4, figs. 3–4

Material. – Four somewhat flattened phragmocone fragments, and a few external moulds of small fragments.

Description. – The best preserved phragmocone fragment is 12 mm long and has an original anterior diameter of about 3 mm. The slight expansion of the phragmocone suggests an apical angle about 4° and a phragmocone length about 40 mm (at the stage where the living chamber had a diameter of about 3 mm). The long, slender orthocone is probably originally circular in cross-section and has fairly short camerae, as the average distance between the septa is only 1.3 mm (slightly closer towards the apical end). The septa are simple, with a convavity which is about half the cameral length, and with simple sutures at right angles to the sagittal axis of the conch. The siphuncle is stenosiphonate, central, circular in cross-section, and with straight, cylindrical septal necks which are 0.6 mm in diameter. Small transverse ridges or lirae of equal strength occur on the surface of the conch in a number of 6–10 in 1 mm, and the position of the suture is marked by a slight irregularity that, however, may be an effect of the flattening.

Remarks. – A number of Ordovician orthoceratids originally assigned to *Orthoceras* were moved to the new genus *Michelinoceras* by Foerste (1932), and this practice was followed by Sweet (1964), who realized that not all of the included species could be regarded as related. The taxonomic difficulties are self-evident in cases where the material, as here, is imperfectly preserved. *Michelinoceras* supposedly is characterized by long camerae and by absence of depressions or grooves at the middle part of the body chamber (Foerste 1932, pp. 7–72). The body chamber is not preserved in the material from Bornholm, and the phragmocones are only tentatively referred to *Michelinoceras,* especially since the camerae are fairly short. However, the septal spacing may be expected to be closer in the vicinity of the apex.

Conularia sp.
Pl. 4, fig. 5

Material. – A single fragment of an internal mould, about 5 mm long and 3 mm wide.

Description. – The outline of the conularid is not preserved, but the the ornamentation is typical of members of the group Cancellatae (Holm 1893). More strongly developed transverse ribs alternate with fainter ribs, and the spacing of the transverse ribs is about 15–20 ribs per 5 mm. Faint and short longitudinal ribs (6–8 per 1 mm) are seen in the bands or furrows between the transverse ribs, and the longitudinal ribs in one band are aligned with the space between the longitudinal ribs in adjoining bands. Nodes are developed where the longitudinal ribs join the transverse ribs which in fact appear as strings of very closely situated nodes, due to the interspaced longitudinal ribs.

Remarks. – The composite structure of the ornamentation resulting in the formation of nodes or short spines permits an assignment to the group Cancellatae, established by Holm (1893, p. 135). This group contains many species and ranges from the Ordovician into the Carboniferous. The ornamentation does not show much variation within the cancellate conularids, and the species are mostly separated on the basis of differences in gross morphology and the shape of the cross-section.

Conularia cancellata Sandberger, 1847, known from Bohemia and England, and widespread in Balto-Scandia, spans the Ordovician-Silurian transition. Lindström described the species from the Silurian of Gotland, and it has been reported from the Estonian Upper Ordovician Lyckholm beds (Pirgu Substage), from Quaternary erratics in Sweden of Upper Ordovician limestone, and from the *Dalmanitina* beds in Östergötland. A single specimen has been found in the Ashgillian Stage 5a at Oslo.

However, the ornamentation of the specimen from Bornholm appears to differ significantly from that of *Conularia cancellata* in that the transverse ribs alternate in strength, and it may represent a new species.

Lepidocoleus suecicus Moberg, 1914
Pl. 4, figs. 6–7

Material. – Five isolated, incompletely preserved plates, three of which are external moulds.

Description. – One specimen (external mould, pl. 4, fig. 7), showing part of the rounded triangular outline, is about 4.9 mm long (measured from apex to base) and considerably more than 4 mm wide (the full width is not preserved). The rounded triangular plate has a slightly overturned apex. The entire surface is covered with fine, homogeneous, and sinuous growth-lines (about 8 lines in 1 mm) which are concave towards the apex, parallel to posterior margin, and joining lateral margins at an angle of about 80°. The other specimens show an identical pattern of growth-lines.

Remarks. – The growth-lines present the most characteristic feature and are much more closely spaced than in *Plumulites*. Furthermore, the plates of *Plumulites* appear to be more elongate.

Lepidocoleus suecicus was described by Moberg (1914a) from the "Black *Tretaspis* Shale" (now Fjäcka Shale, *Pleurograptus linearis* Zone) in Dalarne and Östergötland, by Henningsmoen (in Wærn et al. 1948, p. 420) from the same level in Västergötland, and Moberg (1914b) reported the species from Scania in samples of marly shale containing also *Dalmanitina olini* (= "*Phacops eucentra*", see discussion on *Dalmanitina mucronata*). The samples were believed to represent the transition from the *Tretaspis* Series to the *Dalmanitina* beds. The species is reported to be common in the *Staurocephalus clavifrons* Zone, and Troedsson (1918, p. 46) has found a few plates in the upper part of the *Dalmanitina* beds in Scania.

Regnéll (1945, pp. 47–49) discussed the machaeridians, and after a restudy of the material described by Moberg (1914a and b) concluded that the Swedish species failed to show the rhombohedral cleavage typical of the single-crystal calcite forming the echinoderm skeletal units. Bengtson (1977, pp. 27–36) has recently analysed the ultrastructure of lepidocoleid plates which are composed of an outer layer of dense calcite and an inner laminated layer. The structures indicate a growth by secretion of internal growth layers from an epithelium, and this pattern does not appear to be compatible with the mesodermal endoskeleton of echinoderms. Bengtson (1977, pp. 36–37) also discussed a possible mitrosagophoran affinity that was suggested previously (Bengtson 1970, pp. 383–390).

The material from Bornholm is too poor to yield any information with regard to the systematic position of the machaeridians.

Sowerbyella? cf. *restricta* (Hadding, 1913)
Pl. 4, fig. 8; pl. 2, fig. 1

Material. – Four isolated pedicle valves and a number of small valve fragments.

Description. – The four pedicle valves evidently represent a small species with a valve width at the hinge line from 5.2.–5.5 mm, and a length from 3.5–3.6 mm. The outline of the valve is close to being semicircular, the cardinal angle being about 85°. The hinge line is almost straight, as the tiny umbonal region only protrudes slightly above the level of the hinge line. The valve is gently convex, sloping evenly down in all directions from the centre of the valve. The surface of the valve is ornamented with distinct costae and costellae which are rounded in cross-section. Five prominent costae around the median part of the shell arise at the protegulal node and are all the way raised above the other ribs, whereas the radial ornament appears less differentiated on the postero-lateral parts of the valve, since the costae and costellae here are of equal strength. The spaces between neighbouring major costae are occupied by first order costellae, of which two originate about one-fourth the distance from the umbo to the anterior margin, and externally a third costella starts at about half this distance. Second order costellae are formed by branching or intercalation slightly anterior to the middle part of the valve, and further branching is indicated in the vicinity of the anterior and lateral margin. Five of the second order costellae are more prominent that the remaining four.

The valve is further adorned with faint concentric lines which also cross the ribs, thereby giving these a slightly beaded appearance.

The brachial valve and the internal structures are not known.

Remarks. – The valve exterior appears to have a general sowerbyellid morphology with the small size and the rib ornament as the most distinctive features. Hadding (1913, p. 62) discussed *Sowerbyella? restricta* (= *Leptaena sericea* var. *restricta*), and he noted the five prominent costae which result in some resemblance to *Sowerbyella quinquecostata*. The costellae in this species, however, are very faintly developed (see Jones 1928, p. 466).

The form from the *Dalmanitina* beds on Bornholm matches the earlier descriptions of *S.? restricta* with regard to size and costal morphology. The main difference is in the number of costellae; Hadding mentioned the presence of about five costellae between the costae, and Henningsmoen (in Wærn et al. 1948, p. 396) found the same number in the specimens from the *Tretaspis* Shale in the Kullatorp core (Västergötland). Furthermore, the same number is probably present in the single valve from the *Tretaspis* Shale in the new well at Bavnegård (described above). Five of the second order costellae formed by branching or intercalation in the form from the *Dalmanitina* beds on Bornholm are more prominent, and they are believed to represent the five costellae mentioned by Hadding and Henningsmoen. Less prominent costellae may be affected by the state of preservation, or the total number of costellae may have increased through time. Jones (1928, p. 407) discussed the evolution of the genus *Sowerbyella* through the Ordovician into the Silurian, and found a characteristic trend in the surface ornamentation which became increasingly differentiated at higher levels.

The scarce material from Bornholm does not permit the establishment of a new species, and the author prefers to regard the form as a late representative of the species *restricta* with a slightly more advanced differentiation of the rib ornament.

Hyolithids

The well cuttings contain a few flattened and broken fragments of hyolithids which are impossible to identify.

Echinoderm fragments

A few indeterminate massive stem fragments, which are a few mm long, are seen, all showing the typical calcite cleavage.

Dansk sammendrag

En nyere dansk vandværksboring ved Bavnegård, DGU arkivnr. 248.39, viser overgangen Ordovicium-Silur. Boreprofilet viser, at *Dalmanitina* lag i en mægtighed af 2–6 meter optræder mellem *Tretaspis*-skifer fra øvre Ordovicium og *Rastrites*-skifer fra ældste Silur. De strukturelle forhold (se kort, tekst-fig. 1) antyder, at *Dalmanitina* lagene, som hidtil ikke har været påvist på Bornholm, kan have en betydelig udstrækning øst-vest i forkastningsblokken ved Øleå, syd for Søndre Landevej.

Boringen er udført som en skylleboring, og den ufuldstændige prøvetagning tillader ikke præcise mægtighedsangivelser for den gennemborede lagserie, hvis nederste del kan svare til den nedre kambriske Rispebjerg Sandsten. Lagserien op til og med *Dalmanitina* lagene beskrives, og faunaen, blandt andet indeholdende trilobiter, ostracoder og brachiopoder, fra *Tretaspis*-skiferen og *Dalmanitina* lagene beskrives. Materialet er fragmenteret i betydelig grad, hvorfor mange slægts- eller artsbestemmelser er noget usikre. Alligevel viser faunaen en tydelig forskel mellem *Tretaspis*-skiferen og *Dalmanitina* lagene, hvoraf sidstnævnte synes at vise god overensstemmelse med de tilsvarende dannelser i Skåne.

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Plate 1. Species from the *Tretaspis* Shale

Figs. 1–2. *Lonchodomas portlocki* (Barrande, 1846)

1: Crushed cephalic fragment (MGUH no. 13992). × 6.

2: Fragment of frontal glabellar spine (MGUH no. 13993). × 6.

Fig. 3. *Microparia speciosa* Hawle & Chorda, 1847

3: Glabella with three adjoining thoracic segments (MGUH no. 13994). × 6.

Figs. 4–5. *Tretaspis granulata* (Wahlenberg, 1818)

4: Fragment of genal roll prolongation (MGUH no. 13995). × 6.

5: Marginal fragment of lower lamella (MGUH no. 13996). × 6.

Fig. 6–8. *Uhakiella* sp.

6: Left valve, tecnomorph (MGUH no. 13997). × 15.

7: Right valve, technomorph (MGUH no. 13998), 'Photographic replica'. × 15.

8: Right valve, tecnomorph (MGUH no. 13999). × 15.

Fig. 9. *Paterula* cf. *portlocki* (Geinitz, 1852)

9: Flattened dorsal (?) valve (MGUH no. 14000). × 15.

Fig. 10. *Sowerbyella?* cf. *restricta* (Hadding, 1913)

10: Immature pedicle valve (MGUH no. 14001). × 6.

Fig. 11. Echinoderm fragment

11: Fragment of stem ossicle (MGUH no. 14002). × 6.

All figured specimens are whitened with antimony. The photographs are not retouched. 'Photographic replica' (fig. 7) of specimen in ventral view is an optical illusion, produced by the light coming from the lower right corner.

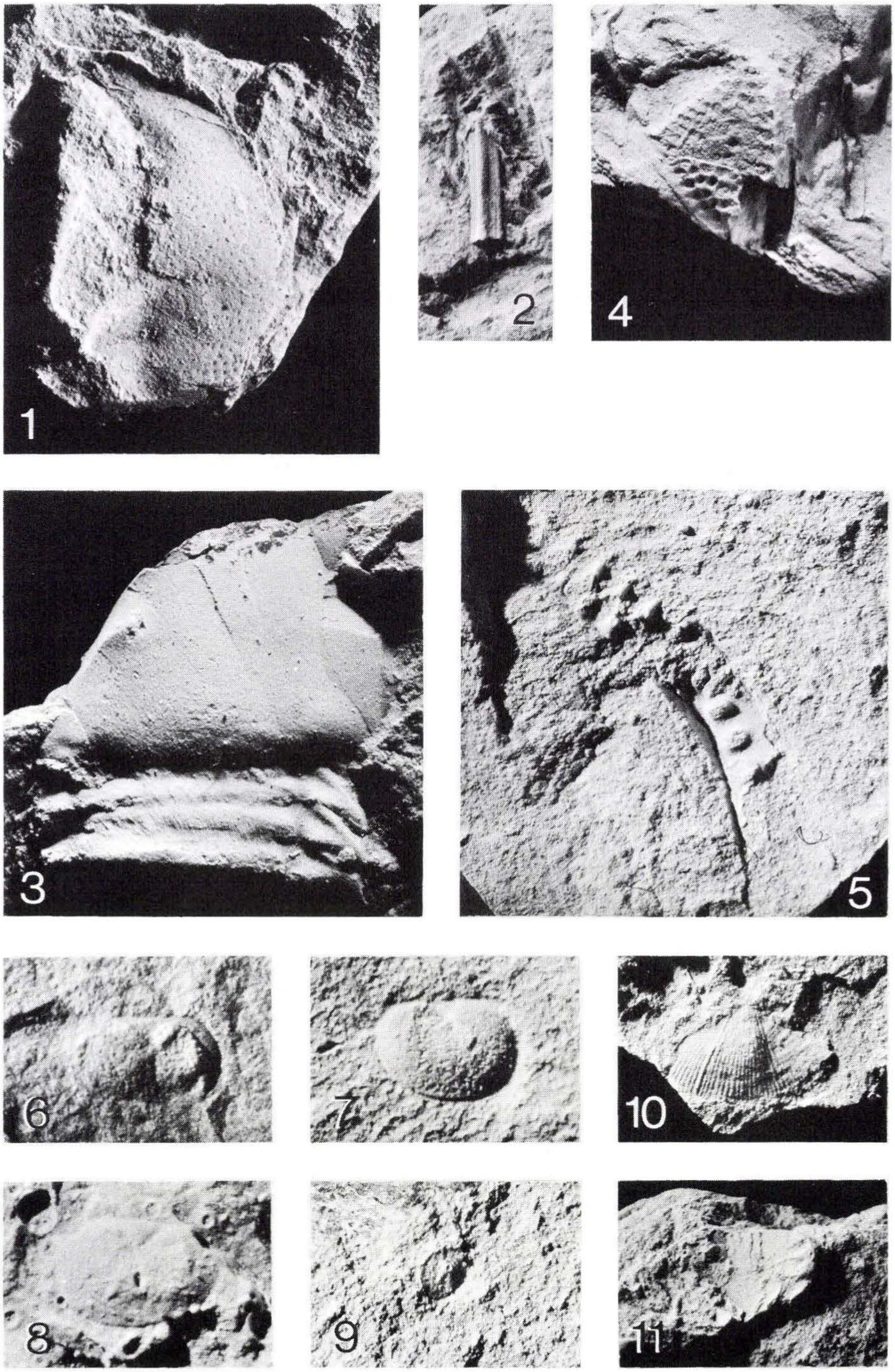

Plate 2. Species from the *Dalmanitina* beds.

Figs. 1–4. *Dalmanitina mucronata (Brongniart, 1822)*

1: Almost complete free cheek (MGUH no. 14003) anteriorly concealed by *Sowerbyella?* cf. *restricta* (MGUH no. 14032). × 6.

2: Fairly complete pygidium (MGUH no. 14004). × 6.

3: Fragment of free cheek (MGUH no. 14005). × 6.

4: Pleural fragment with preserved spine (MGUH no. 14006). × 6.

Figs. 5–6. *Illaenus angustifrons depressus* Holm, 1886

5: Pygidium, partly as internal mould (MGUH no. 14007). Below pygidium of proetid sp. indet. b (MGUH no. 14021). × 6.

6: Internal mould of cranidium (MGUH no. 14008). × 6.

Figs. 7–8. Proetid genus et species indet. a (= Trilobites sp. Kielan, 1959)

7: Cranidial fragment (MGUH no. 14009). 'Photographic replica'. × 6.

8: Free cheek fragment in ventral view (MGUH no. 14010). × 6.

All figured specimens are whitened with antimony. The photographs are not retouched. 'Photographic replica' (fig. 7) of specimen in ventral view is an optical illusion, produced by the light coming from the lower right corner.

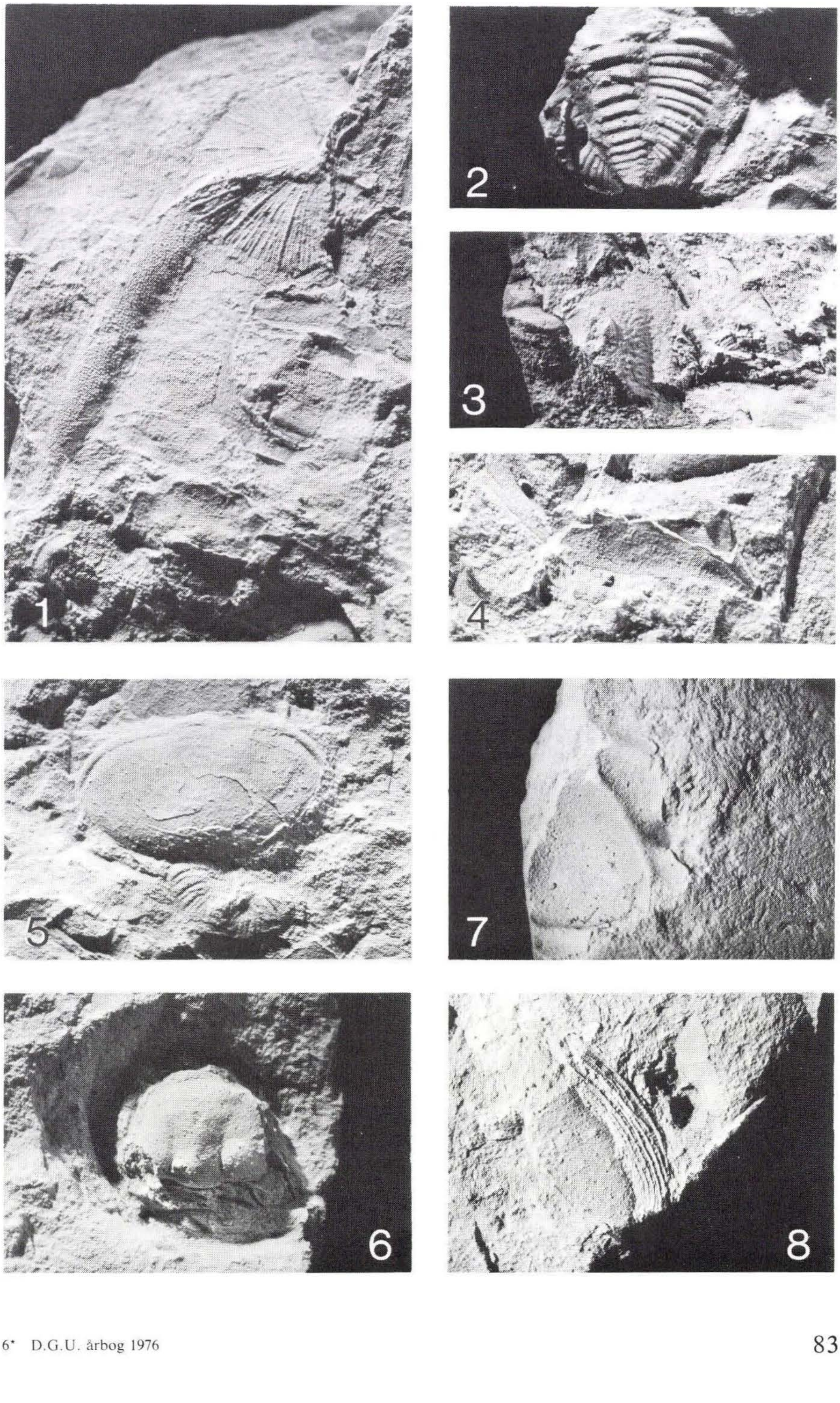
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Plate 3. Species from the *Dalmanitina* beds

Figs. 1–7. Proetid genus et species indet. b (? = "*Proetus*" spp. a & b Kielan, 1959)

1: Cranidial fragment (MGUH no. 14011). × 6.

2: Cranidial fragment (MGUH no. 14012). × 6.

3: Cranidial fragment (MGUH no. 14013). × 6.

4: Cranidial fragment (MGUH no. 14014). × 6.

5: Left side of pygidium (MGUH no. 14014). × 6.

5: Left side of pygidium (MGUH no. 14015) showing part of the doublure with terrace lines. × 6.

6: Pygidial fragment (MGUH no. 14016). 'Photographic replica'. × 6.

7: Slightly broken pygidium (MGUH no. 14017). × 6.

Figs. 8–10. *Primitiella tenera* (Linnarsson, 1869)

8: Carapace in left lateral view (MGUH no. 14018). × 15.

9: Carapace in right lateral view (MGUH no. 14019). × 15.

10: Carapace in ventral view (MGUH no. 14020). × 15.

All figured specimens are whitened with antimony. The photographs are not retouched. 'Photographic replica' (fig. 6) is an optical illusion, produced by the light coming from the lower right corner.

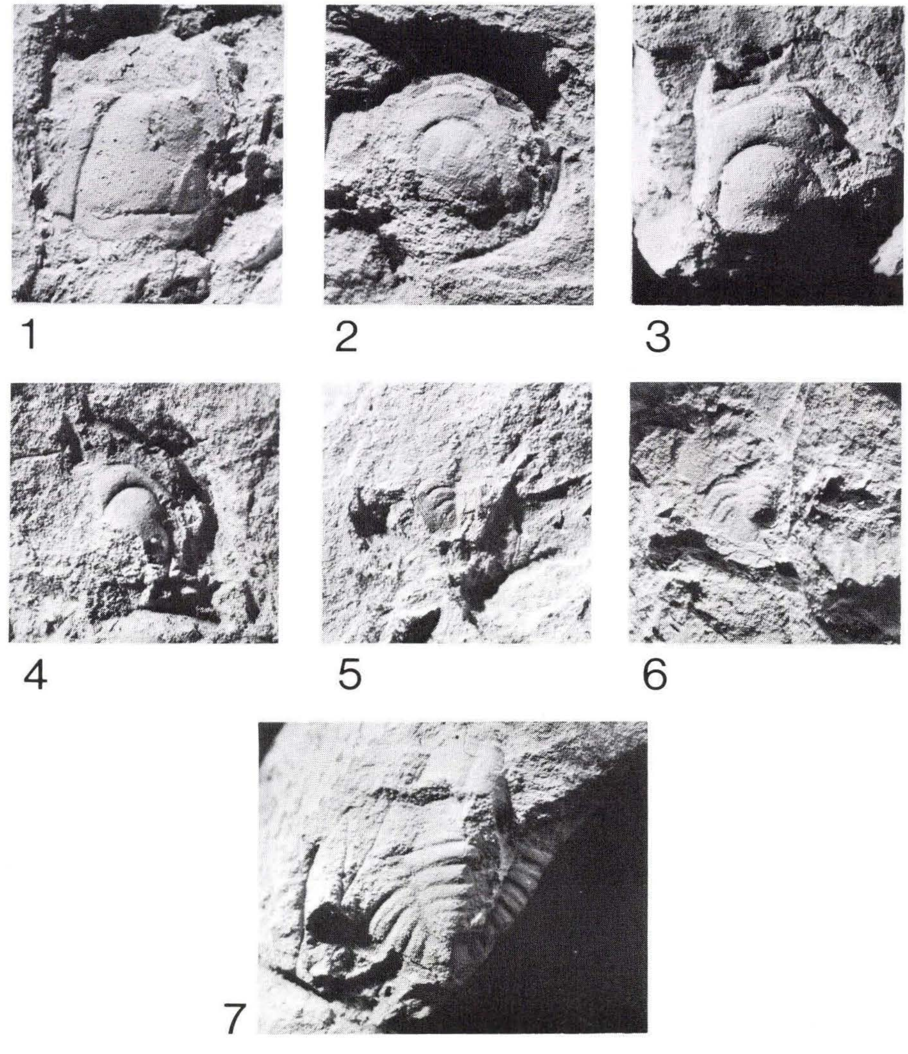
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Plate 4. Species from the *Dalmanitina* beds

Figs. 1–2. *Holopea?* cf. *mobergi* Troedsson, 1918

1: Internal mould of juvenile shell (MGUH no. 14022). Above a meraspid cranidium of ? proetid species indet. a (MGUH no. 14023). × 15.

2: Internal mould of juvenile shell (MGUH no. 14024). × 15.

Figs. 3–4. *Michelinoceras?* sp.

3: Phragmocone fragment (MGUH no. 14025). × 6.

4: Fragments of two different phragmocones (MGUH nos. 14026 (left) and 14027). × 6.

Fig. 5. *Conularia* sp.

5: Fragment of internal mould (MGUH no. 14028). × 6.

Figs. 6–7. *Lepidocoleus suecicus* Moberg, 1914

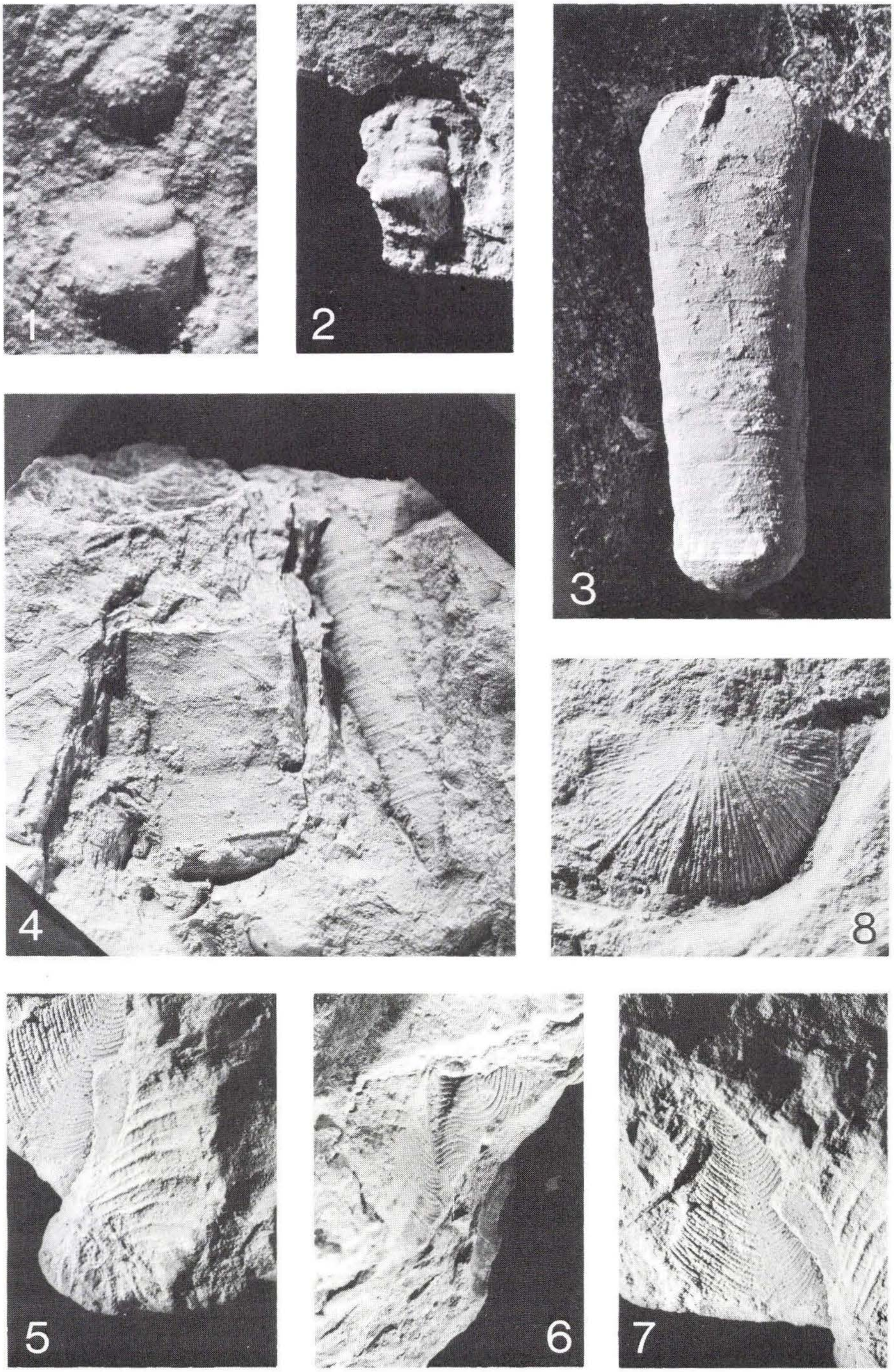
6: Plate fragment (MGUH no. 14029). × 6.

7: Plate fragment, external mould (MGUH no. 14030). × 6.

Fig. 8. *Sowerbyella?* cf. *restricta* (Hadding, 1913)

8: Pedicle valve (MGUH no. 14031). × 6.

All figured specimens are whitened with antimony. The photographs are not retouched.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Sedimentological and microprobe studies of the lime tufas at Åstrup, Zealand

Arne Villumsen and Bent Grelk

Villumsen, Arne and Grelk, Bent: Sedimentological and microprobe studies of the lime tufas at Åstrup, Zealand. *Danm. geol. Unders., Årbog 1976,* pp. 89–114. København, 1. marts 1978.

The formation of lime tufa, containing bands of iron and manganese, has been studied. The weathering of glacial sediments in the study-area occurs at a relatively high pH level and low Eh values, leading to a removal of calcium, manganese and iron, which are transported in solution until a decrease of CO_2 pressure and increase of Eh occur. This happens typically around springs on the flanks and in the bottom of the investigated valley. The texture and mineralogy of the lime tufa seems to be determined by the physical and chemical environment of formation. Electron microprobe studies of a well-oxidized lime tufa containing thin zones of iron and manganese have shown that the zones are well-defined. The zones presumably represent different geochemical situations in the local weathering environment. The formation of the thin iron zones seems to have involved a replacement of the manganese and calcium zones, while the manganese zones were apparently formed without replacement. The lime tufa formation in the investigated area has occurred throughout the postglacial epoch at least, and formation still continues. The maximal thickness of lime tufa in the area is approximately 8 metres.

The climatic conditions in Denmark are favourable to weathering processes. As the lithological and mineralogical compositions of glacigene deposits are influenced to a certain extent by the substratum, most of the glacial sediments in Denmark were originally rich in calcium carbonate because on its way from Norway and Sweden towards Denmark the ice passed over Prequaternary lime deposits (Sorgenfrei and Berthelsen 1954). During the various glaciations the older Quaternary sediments have been reworked several times. It is thus believed that the glacial sediments in Denmark originally were of roughly the same composition throughout the country although it is possible that only a minor content of lime was present in the glacigene deposits in Western Jutland. Today the superficial deposits in Western Jutland are deeply weathered, in contrast to the rest of Denmark. The main reason for this geochemical difference is presumably that weathering processes have occurred in Western Jutland during a substantially longer period than in the remaining part of Denmark, since Western Jutland was free of ice during most of the Weichselian glaciation. In addition, hydrological differences (for example greater precipitation in Western Jutland) and differences in the permeability of the superficial sediments between the two parts of Denmark have increased the geochemical differences. Today the result of these processes is that across Denmark different stages of chemical weathering can be studied. In the eastern parts where lime is still present in the soil, weathering occurs at a high pH level, and precipitation of chemical carbonate sediments (lime tufa etc.) is common, while in Western Jutland the weathering takes place at a lower pH level, allowing manganese and iron to be dissolved and reprecipitated (for example as bog iron ore). – The above-mentioned regional differences are only valid as a wide generalization from which many exceptions could be mentioned, but they are presented here in order to place the investigation reported below in a broader framework.

The present paper deals with the weathering processes and chemical precipitations leading to the formation of lime tufa etc., which represents the initial stage of weathering of glacial deposits containing calcium carbonate.

Description of localities

The area investigated is a valley situated on Zealand between the cities of Roskilde and Holbæk (fig. 1). The glacial sediments in the area surrounding the valley are built up of clayey till, which is normally rich in calcium carbonate. Sandier till deposits are found locally in the surrounding area. The valley was probably formed by extramarginal meltwater erosion after the Weichselian glaciation (Nielsen 1967). No contributions can be given at present to the discussion of the origin of the valley. During the late- and postglacial epoch, sedimentation of calcareous and peaty freshwater and terrestrial sediments took place in the valley. Marine postglacial sediments (Littorina deposits) are present in the valley a few hundred metres north of the investigated area (Rørdam and Milthers 1900).

On both sides and in the bottom of the valley lime tufas are present, often of relatively great thickness. A great number of springs are still active in the valley, and at different levels on the valley sides recent formation of lime tufa containing iron and manganese can be studied. The paper describes the different sedimentary facies and the genesis of these calcareous deposits. Special emphasis is directed to the description of the microzonation of iron, manganese and calcium within the lime tufa. Elberling (1870) described the zonation of the lime tufa which very often contains red, black and white bands, and related these to iron hydroxide, manganese dioxide and calcium carbonate respectively. The lime tufas have earlier been mined and used for building material, agricultural purposes and as asphalt filler (Nielsen 1965).

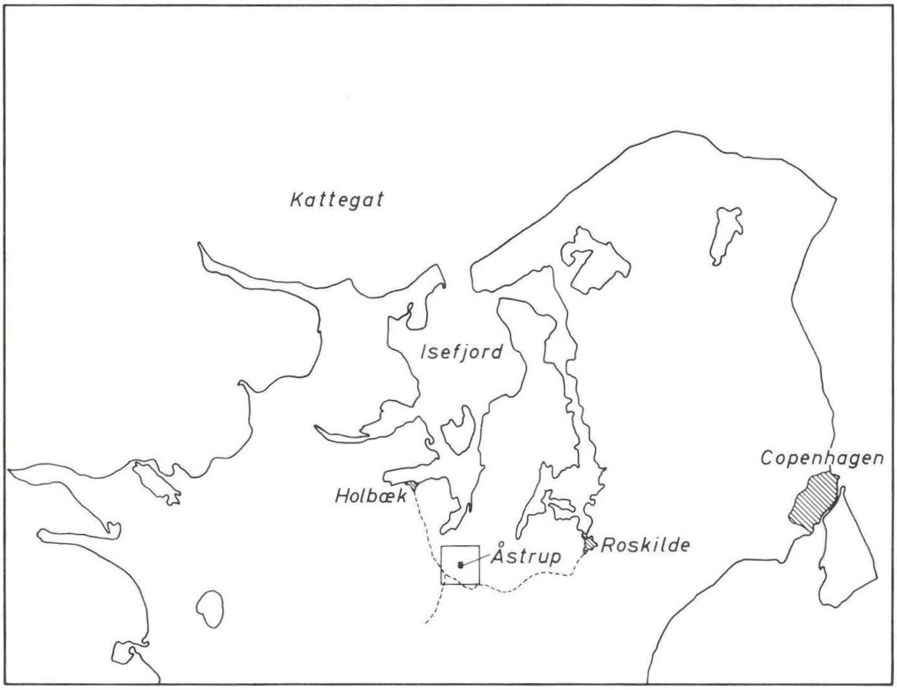

Fig. 1. Location map. The dashed line indicates a railway.

Today the mining has practically ceased, but an open profile is still present in the area (at Louiselund, see figs. 2 and 6).

Methods

In the field, surface mapping and depth mapping (using a Hiller-type corer) of a minor area (fig. 2) were carried out as a supplement to the earlier systematic mapping (Rørdam and Milthers 1900). A few borings were carried out through the thickest deposits of lime tufas to obtain samples for laboratory work (dating etc.). Finally, a survey of the profile at Louiselund was carried out. In the laboratory, X-ray diffractometry (Philips PW 1012, Cu-K_{α} radiation) of bulk samples representing 3 different sedimentary environments in the area (see p. 97) was used for preliminary mineral identification. Polish preparations of a selected sample were made. This sample is a well-oxidized lime tufa of sintered appearance, where thin white, red and black zones were visible, possibly representing zones rich in calcium, iron and manganese. The zones

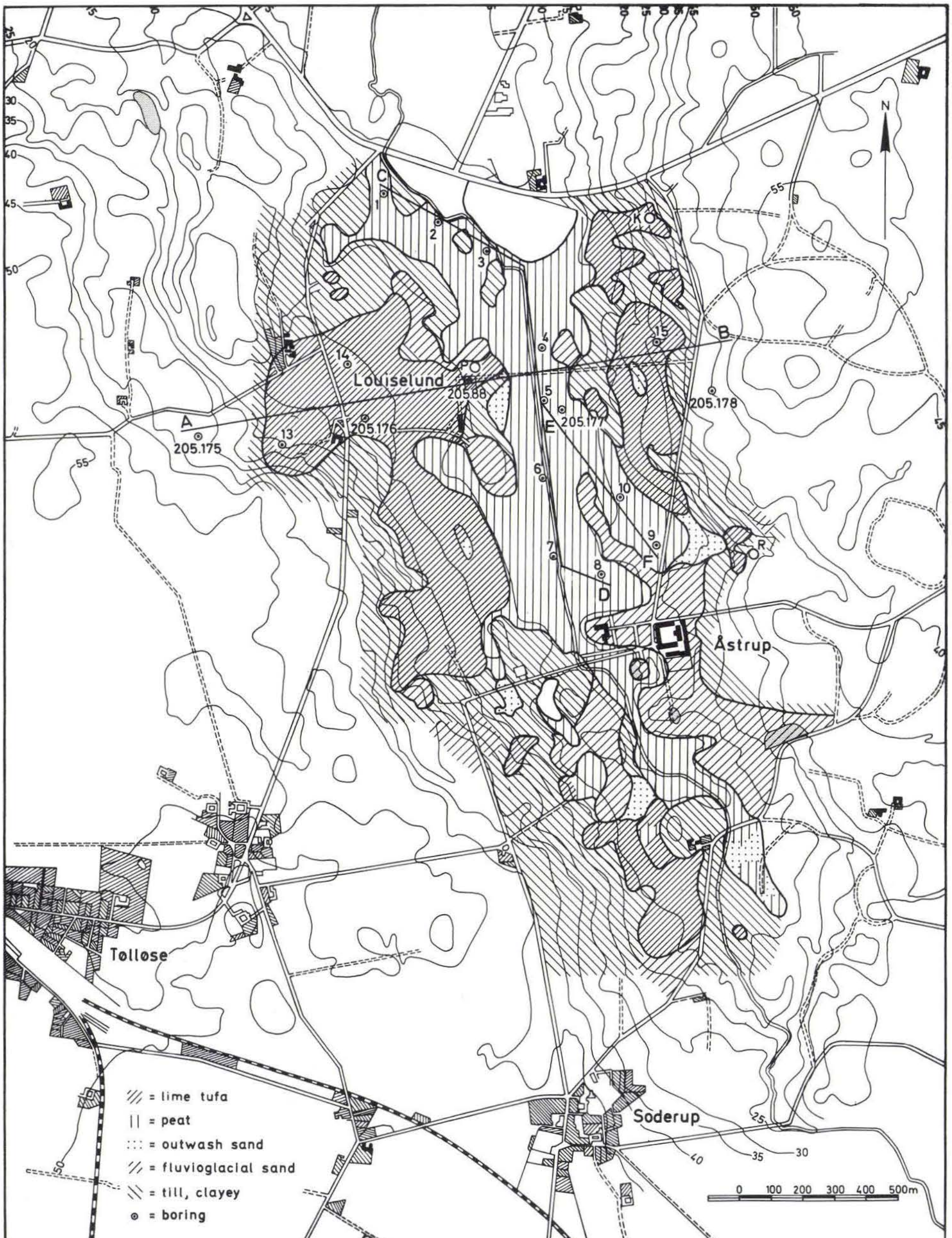

Fig. 2. Lithology and topography of the investigated area (height in m a.s.l.). The lime tufas are found on the flanks and in the bottom of the valley. The cross sections A–B, C–D and E–F are shown in figs. 3, 4 and 5, respectively. The letters K, P and R indicate localities where samples were taken for X-ray diffraction studies.

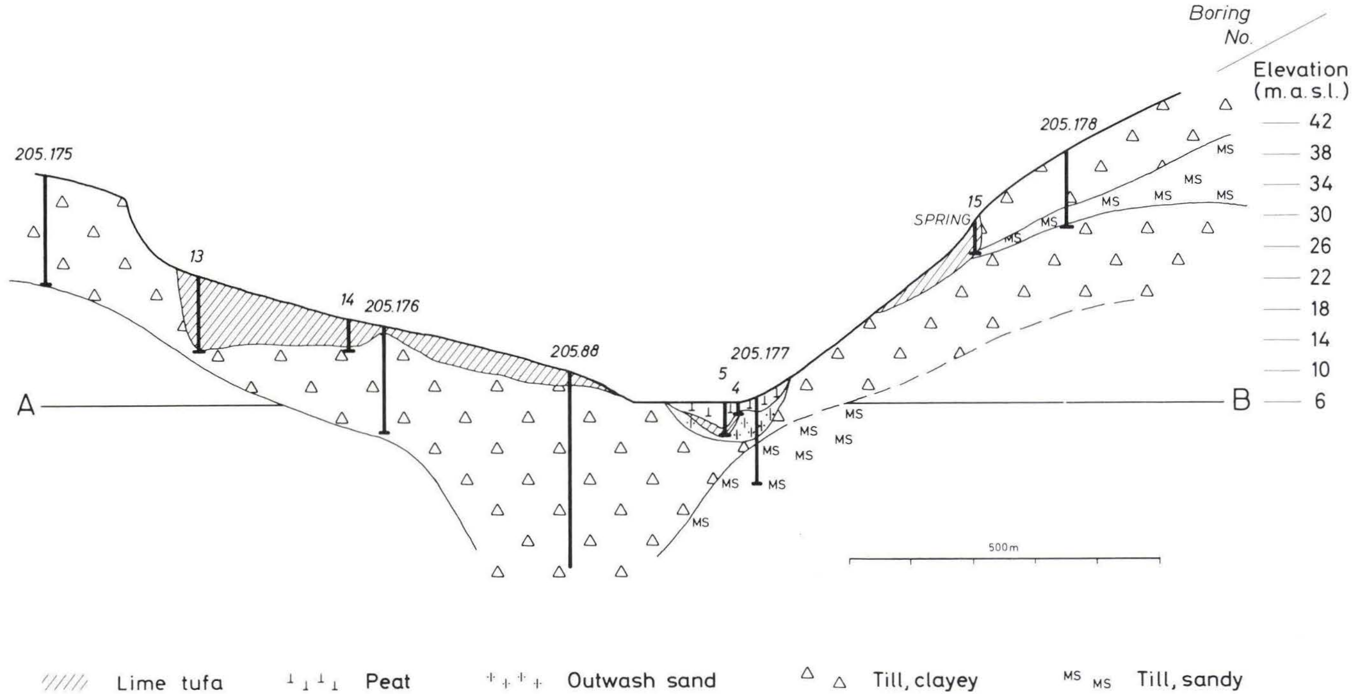

Fig. 3. Section A–B (locality, see fig. 2) across the valley illustrating the thickness of the lime tufa and the lithology of the Quaternary sediments.

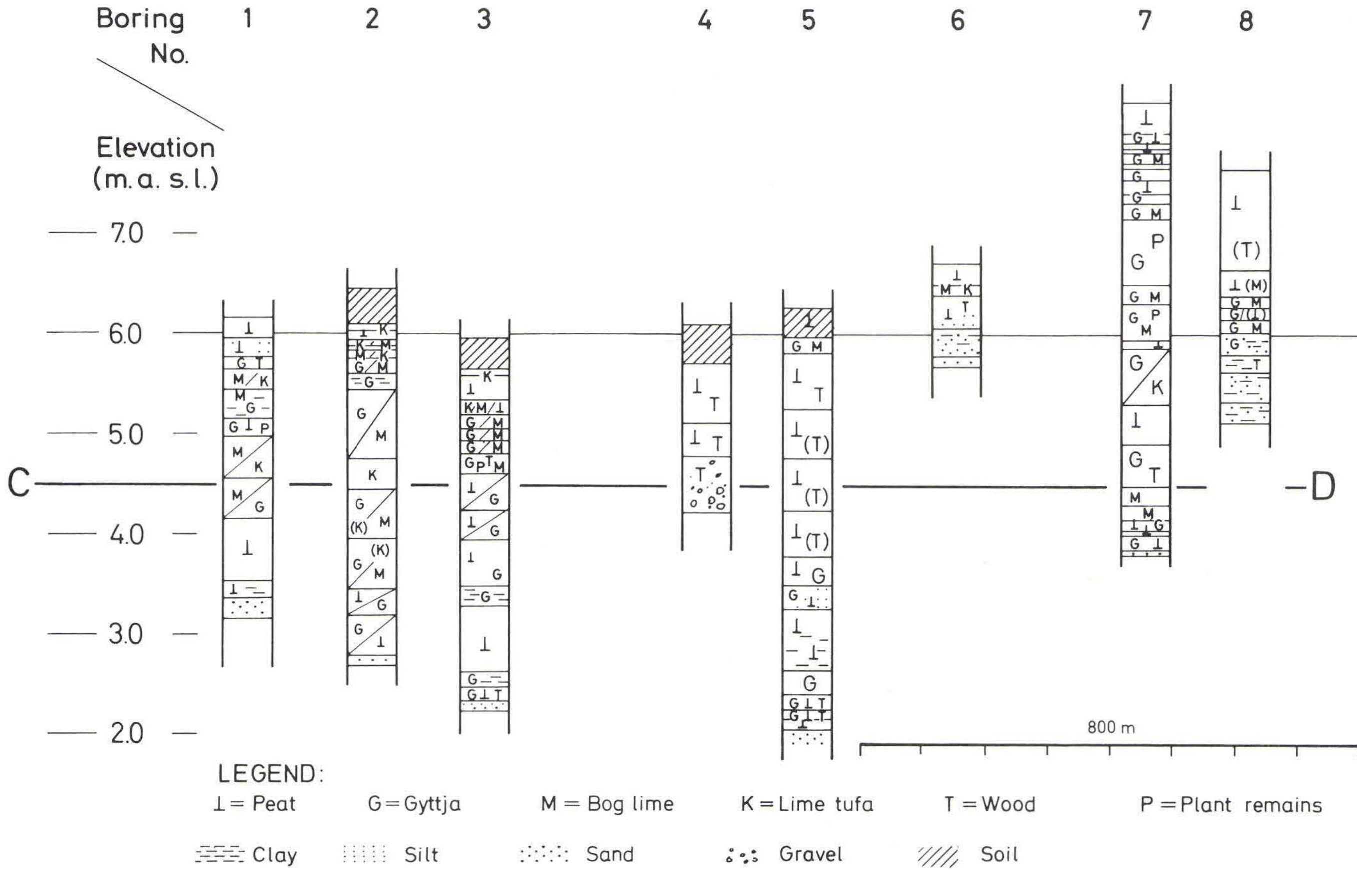

Fig. 4. Profile C–D (locality, see fig. 2). The figure gives an impression of the sedimentary facies through the valley.

were examined by ore microscopy in order to select suitable areas for electron microprobe analyses. No X-ray-diffractometry study was carried out on this sample. Two areas (A and B), which were taken to be representative for the zonation within the sample, are shown on the photographs (figs. 7 and 16; taken by ore microscope). Before the microprobe analysis the sample was coated with carbon. The microprobe analysis was carried out using an Applied Research Laboratory microprobe (type EMX), and element-distribution pictures of Ca, Mn and Fe were taken. Figs. 10, 11 and 12 show the element-distribution pictures for part of area A. Analogously, an electron picture (sample-current picture) was taken. This picture shows the atomic number variation in the surface. Very often the sample-current picture resembles the light-optical picture. Fig. 9 is a sample-current picture showing part of area A. Finally, a quantitative microprobe analysis across the zonation in area A and B was carried out. Wollastonite, manganite and hematite were used as standards. 17 measurements were taken in area A, and 8 measurements in area B. The localization of the measuring points can be seen in figs. 15 and 17. The microprobe quantitative data were corrected for the background level (based on countings on a wave length close to the used lines of analyses). As the standards used here do not differ essentially from the samples investigated, no further corrections of the data seem to be necessary (Sweatman and Long 1969; Nielsen 1971; Keil 1973). The data shown in tables 2 and 3 thus have a relative uncertainty of ±5%. Finally, a few analyses were made of water from different springs in the area.

Results

Widespread occurrences of lime tufas have been found at different levels on the flanks and in the bottom of the valley (see fig. 2). The lime tufas on the flanks of the valley form fans with their origin in a spring. Often the different fans overlap. In a number of cases the springs are still active, and small stalactites up to a length of 10 cm are sometimes seen in the brooks. The typical lime tufas found on the flanks are hard, friable and stalk-like and have a sintered appearance. Colour bandings (white – red – black, corresponding to calcium, iron and manganese zones) are often seen in profiles as well as in borings through the deposits. The different colour zones are normally only a few centimetres in thickness, and often the zones are much thinner. Thin peat and bog lime layers were found in and below the lime tufa by some of the borings on the flanks of the valley. The total thickness of the lime tufa situated on the flanks of the valley amounts in places to more than 8 metres (see fig. 3). By pollen analyses (kindly communicated by Bent Åby, the Geological

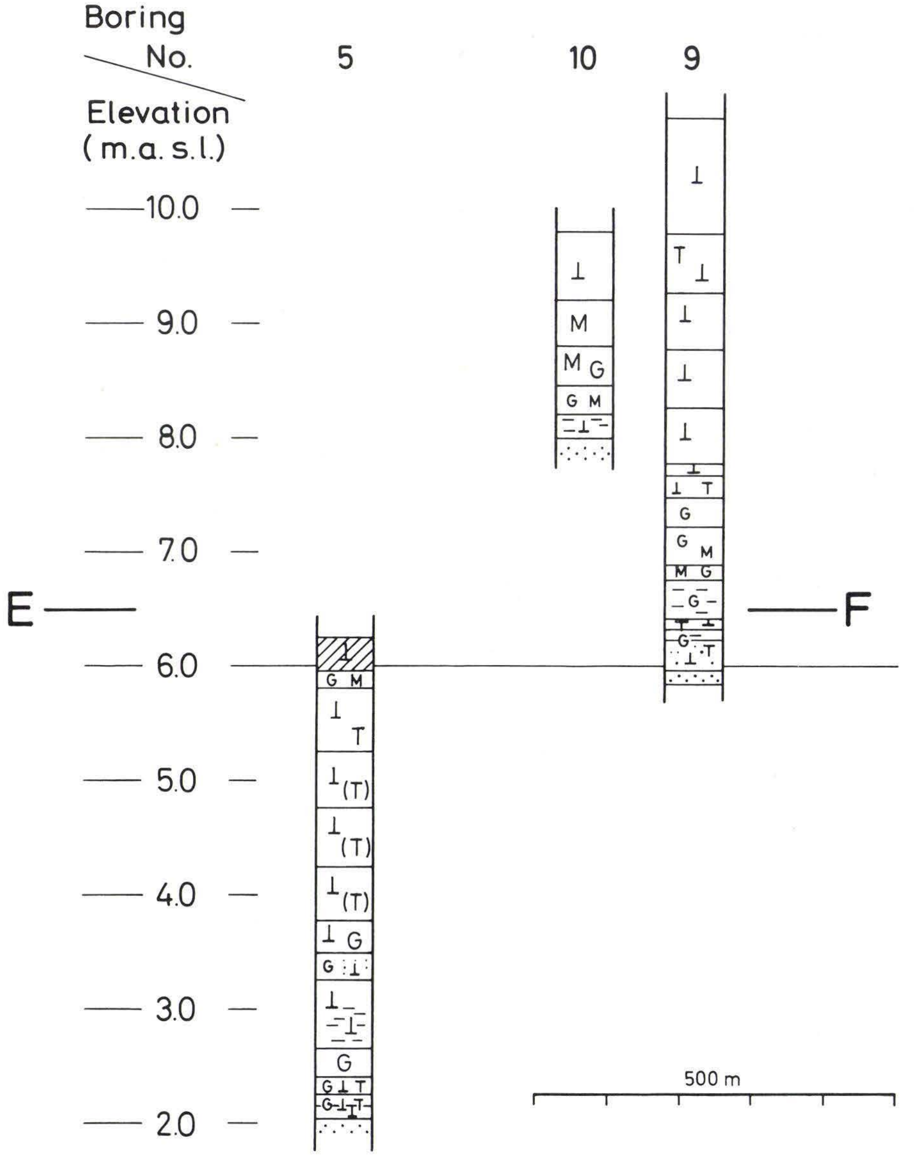

Fig. 5. Profile E–F (locality, see fig. 2). Legend see fig. 4.

Survey of Denmark) the age of layers rich in organic matter just below the lime tufa could be fixed to the pre-boreal period. Where the valley flanks are almost horizontal, the lime tufa sometimes forms small hills a few metres high, indicating the presence of subsurface spring activity. The general

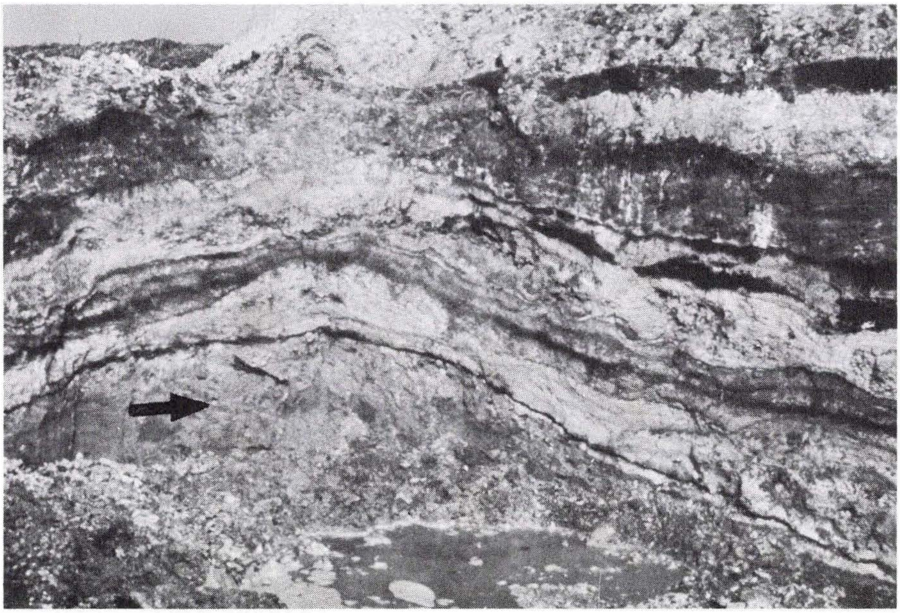

Fig. 6. Photo showing part of the open pit profile at Louiselund (see fig. 2). Note the many thin bands in the profile wall, which mostly represent zones of $CaCO_3$, $Fe(OH)_3$, and MnO_2. The height of the profile is ca. 2 m. The arrow indicates the underlying till.

impression is that the most iron-rich sediments are found nearest to the recent spring or to the top of the fan deposits.

In the bottom of the valley, freshwater lake sediments very rich in calcium carbonate (bog lime) are found below a relatively thin peat layer (see figs. 3, 4 and 5). The bog lime is puttylike in texture and often of a clear white colour. Besides the bog lime, white-grey to dark-grey gyttja is found locally. The maximal thickness of these freshwater sediments is a few metres. In the area around Louiselund (see fig. 2) lime tufa of the same type as is found on the flanks of the valley is present (see fig. 6). Below the lime tufa at Louiselund a layer of iron carbonates more than 0.5 m in thickness was found. No laboratory study of the iron carbonates was performed.

The mineralogical composition of 14 samples, representing 3 major sedimentary environments within the area, is shown in table 1. The description of these samples is given below: –

Recent spring, locality K (fig. 2).
K1: Earthy lime from boring close to spring (depth: 1 m).
K2: Calcareous deposit in the brook at about 10 m downstream.
K3: Iron-rich sediment from spring.

Fig. 7. Ore microscope photo (2 × 3 mm) of area A. On the edges of the figure the *Ca zone* (dark grey to black) is seen. Close to this zone the grey-white *Mn zone* is visible. In the middle the Fe zone (light grey), containing many cracks, is present. The cracks may have been caused either by dehydration of the limonite or during the preparation of the sample. The dark wedge running from the upper right corner of the picture towards the centre is a larger cavity (the zones are shown in fig. 8).

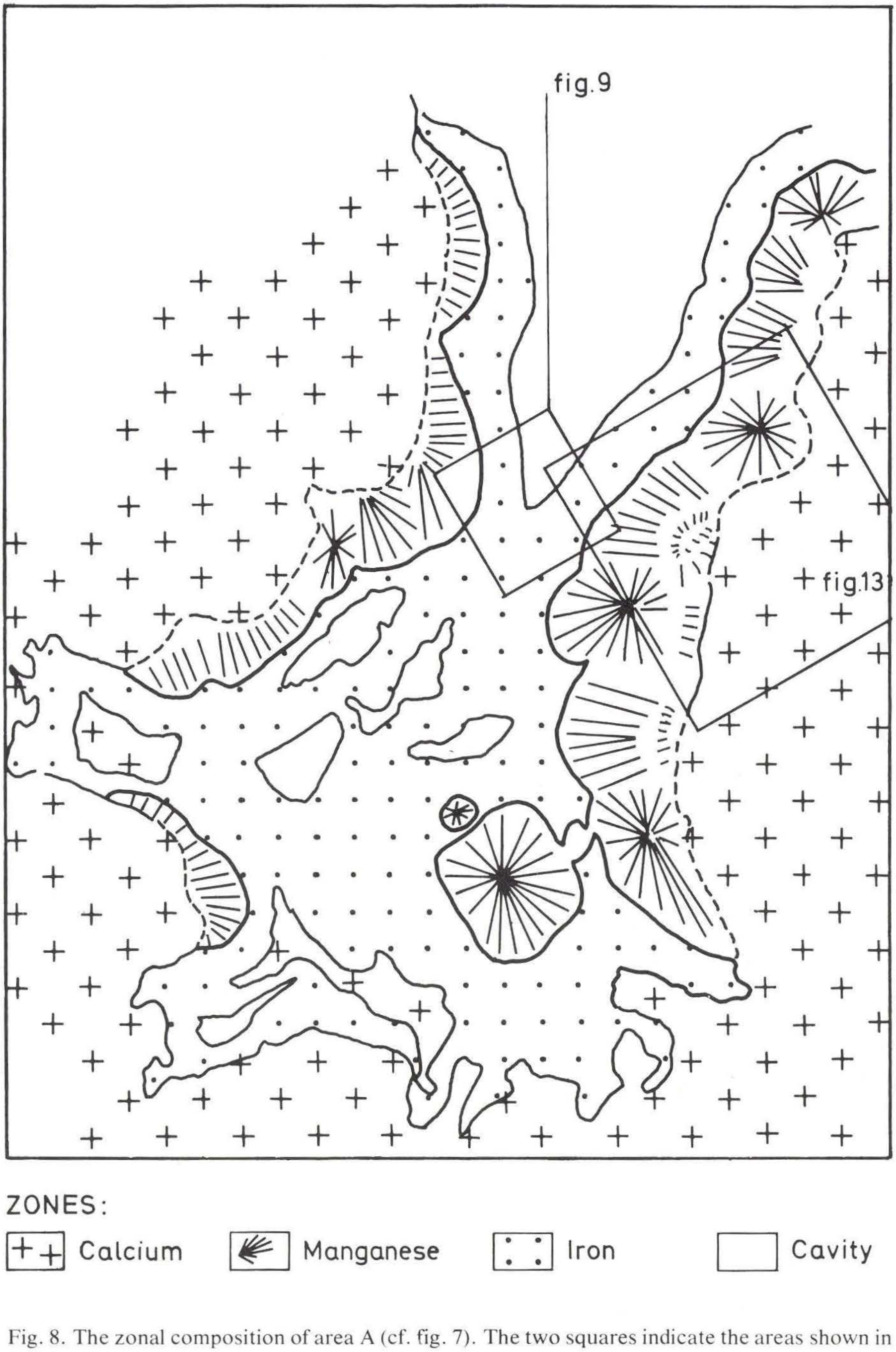

Fig. 8. The zonal composition of area A (cf. fig. 7). The two squares indicate the areas shown in fig. 9 and 13.

Open pit profile at Louiselund, locality P (figs. 2 and 6).
P1: Limonite horizon (50 to 70 cm below the surface).
P2: Lime zone with substantial limonite deposits (70 to 100 cm below surface).
P3: Compact iron-rich horizon (ca. 100 to 110 cm below the surface).
P4: Lime zone with limonite bands (ca. 130 cm below surface).
P5: Lime zone with organic matter and a few bands rich in iron (ca. 160 cm).
P6: Lime zone with less organic matter than P5 (180 cm).
P7: Lime zone with a few limonite bands (200 cm).
P8: Till (220 cm).

Drain, locality R (fig. 2).
R1: Limonite horizon about 20 cm in thickness 0.5 m below the surface.
R2: Band rich in manganese, about 1 cm wide, just below R1.
R3: Zone of almost pure lime underneath R2.

The thin colour bandings (white – red – black) which were studied by microprobe showed 3 well-defined zones in both areas studied (figs. 7, 8, 16, 17, 18, and 19). The calcium zone contained 40% Ca, the iron zone 46–51% Fe, the manganese zone 45–51% Mn. Besides Ca, Fe and Mn the concentration of Al, Si and Mg in the zones was measured by the microprobe. The contents were slightly above the detection limit and below 0.5% in all zones. The microprobe analytical data for Ca, Fe and Mn are shown in tables 2 and 3. The calculated theoretical mineral content for calcium carbonate, pyrolusite and goethite are also shown.

Chemical analyses of water from springs in the area generally show pH values of 6.9 to 7.9. The alkalinity is normally between 5.0 and 5.5 meq./1, and the Ca^{2+} content is rather constant at 100 ppm. The iron content is 1–2 ppm, manganese slightly lower (approximately 1 ppm). Most of the water does not contain NO_3^- (nitrate), but locally a certain NO_3^- content is present. The NO_3^- content might indicate variations in Eh, important for the transportation of iron and manganese (see later).

Discussion

The formation of lime tufa is based on the fact that in pure water only a very small amount of calcium carbonate ($CaCO_3$) can be dissolved, while in water containing carbon dioxide (CO_2) a much greater quantity of dissolved calcium bicarbonate ($Ca(HCO_3)_2$) can be present.

In the atmosphere 0.03 vol. % CO_2 is present, but in the soil the CO_2 concentration can be at least 10 times as high, due to the biological break-

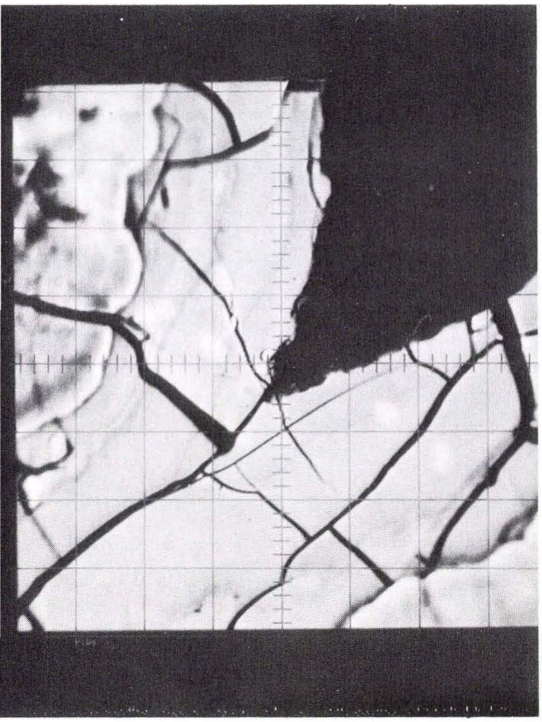

Fig. 9. Sample-current picture (× 200, corresponding to 360 × 360 μm), showing parts of the manganese and iron zones from area A. In fig. 8 the position of fig. 9 is indicated. The black wedge is the cavity; the rims in the upper left corner and in the lower right corner are the manganese zones. Between these is the iron zone (taken at 15 kV, 50 nA).

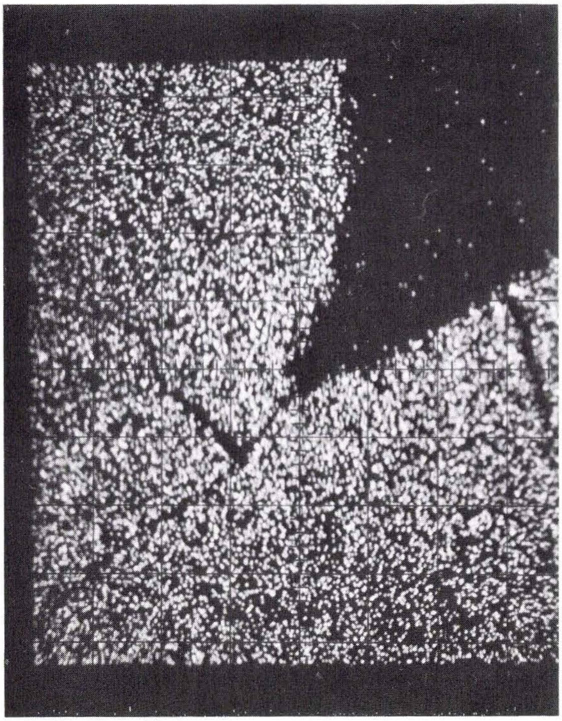

Fig. 10. Electron beam scanning picture (360 × 360 μm), showing the Ca distribution within the same part of area as shown in fig. 9. The picture was taken by recording the backscattered electrons and the KαX-ray radiation of Ca (15 kV; 50 nA). The light intensity corresponds to the element's concentration.

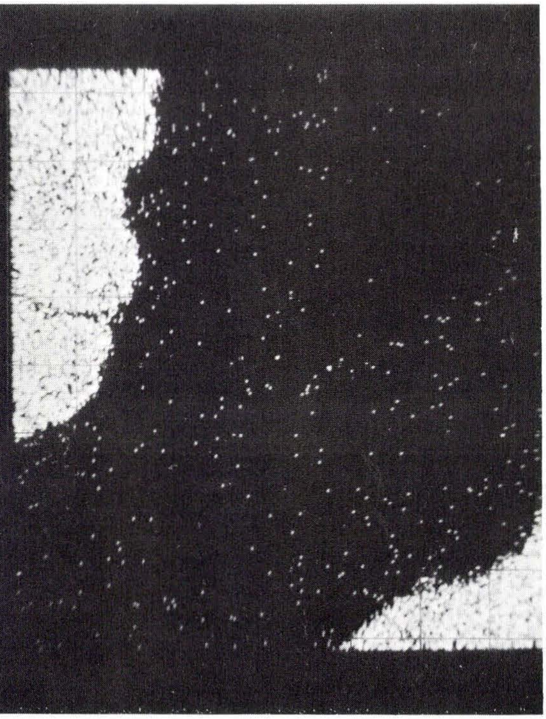

Fig. 11. Electron beam scanning picture showing the Mn distribution (analogous to fig. 10).

Fig. 12. Electron beam scanning picture showing the Fe distribution (analogous to figs. 10 and 11).

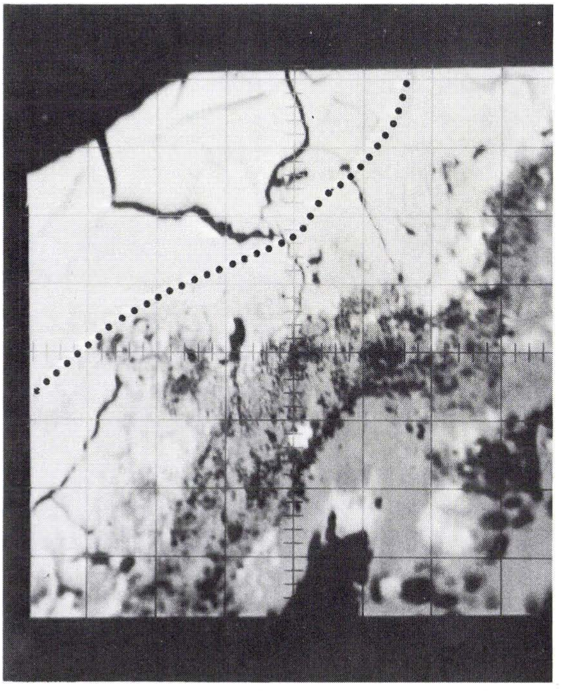

Fig. 13. Sample current picture (× 100, corresponding to 720 × 720 µm), showing part of area A (see fig. 8 for location). The diagonal from the upper left to the lower right corner crosses the following zones: cavity (black), the iron zone with cracks (white), the manganese zone (Fe/Mn-boundary marked by dotted line), the calcium zone (cloudy grey). Due to the extreme enlargement the sizes and colours of the different zones are somewhat distorted.

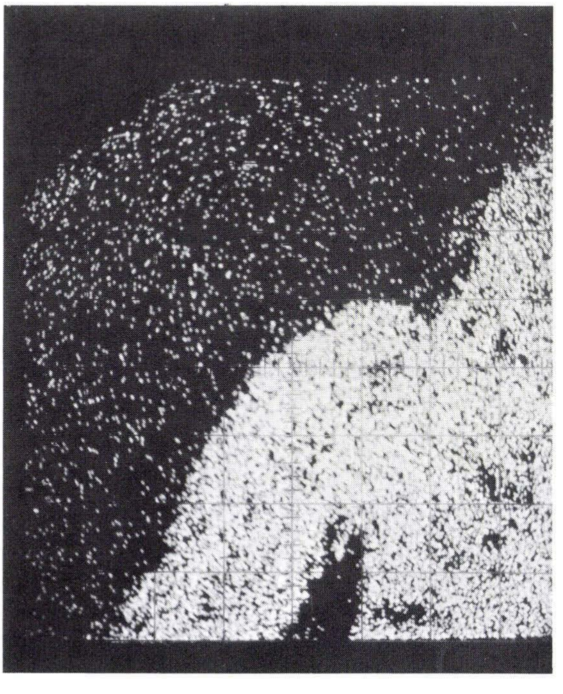

Fig. 14. Electron beam scanning picture showing the Ca distribution of the area described in fig. 13. Analogous to fig. 10.

down of organic matter and the respiration of plant roots. Sometimes the soil air contains up to 1 vol. % CO_2 (Christensen 1962 and 1966). In the area here studied there is also the possibility of a CO_2 supply caused by oxidation of CH_4 (methane) from deeperlying reduced groundwater reservoirs in the area.

At 25°C and 1 atm., water can dissolve ca. its own volume of CO_2, corresponding to ca. 0.2 weight % CO_2. Most of the CO_2 is present as gas *dissolved* in the water, while a minor part *reacts* with the water leading to the formation of H_2CO_3 (carbonic acid), which again dissociates:

$$H_2CO_3 \rightleftarrows H^+ + HCO_3^-$$
$$HCO_3^- \rightleftarrows H^+ + CO_3^{2-}$$

In equilibrium with the CO_2 content in the atmosphere (0.03 vol. % CO_2) the water will theoretically have a pH of 5.7. At 1 vol. % CO_2 the pH will be 4.95, and in water saturated by CO_2 the pH will be 3.95 (Christensen 1962 and 1966). In practice these pH values will first be attained when all the buffer capacity of the minerals is neutralized. The low pH values will cause a solution of the mineral content, normally starting with the more soluble carbonates:

$$CaCO_3 + H_2CO_3 \rightleftarrows Ca^{2+} + 2\,HCO_3^-$$

i.e. water with a high content of CO_2 will dissolve $CaCO_3$, which will be tansported as Ca^{2+} and HCO_3^- until the CO_2 pressure decreases. The water analyses indicate that this reaction is dominant since equivalent concentrations of Ca^{2+} and HCO_3^- are found. When the $CaCO_3$ has been removed from the soil, the pH will drop to a lower value, and for example manganese and iron minerals can be brought into solution.

The effect of the CO_2 is therefore that Ca^{2+} and HCO_3^- will be released from the soil, and at low Eh values Mn^{2+} and Fe^{2+} are also brought into solution. These ions will be transported by the water until the CO_2 pressure decreases and the Eh increases. Typical areas where this happens are the origins of springs or in subsurface cavities. When the CO_2 pressure decreases, the pH will increase, and Ca^{2+} will at first precipitate as $CaCO_3$. Afterwards iron and manganese will precipitate, mainly due to the increase of redox potential, but also partly due to the increase of pH, since the oxidation rate of $Fe^{2+} \rightarrow Fe^{3+}$ increases at higher pH (Stumm and Lee 1960). Iron will be sedimented first, followed by manganese. One reason for this is that during the precipitation process manganese will oxidize iron due to its higher oxidation potential (Christensen 1961).

Water analyses performed on samples taken some distance from the origin of the springs still show a supersaturation of $CaCO_3$ (kindly communicated by Dieke Postma, the Geological Survey of Denmark). The concentrations of iron and manganese also seem to exceed the equilibrium values (Hem 1970).

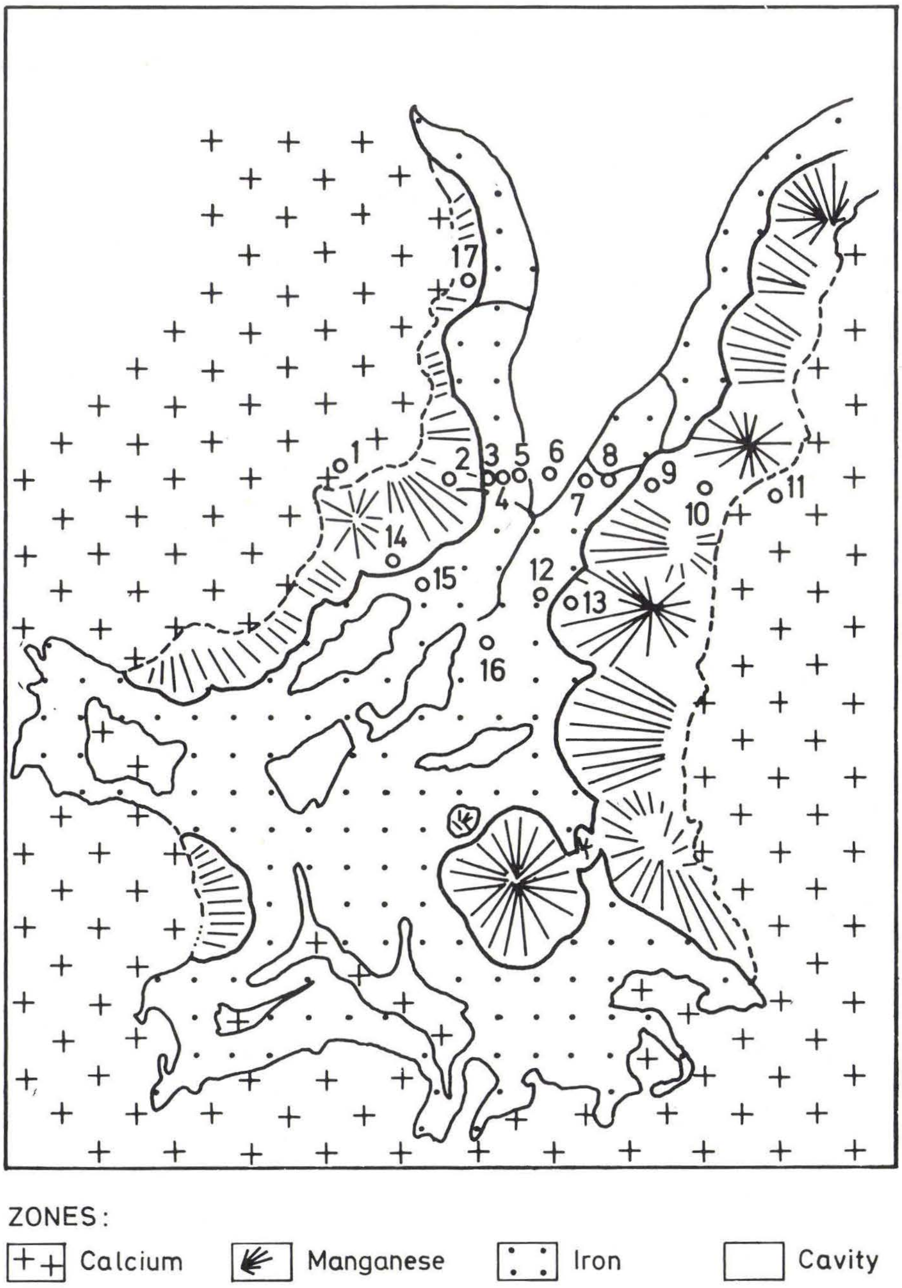

Fig. 15. Location of points of analyses for the microprobe investigation of area A (compare with figs. 7 and 8). Analytical data are shown in table 2.

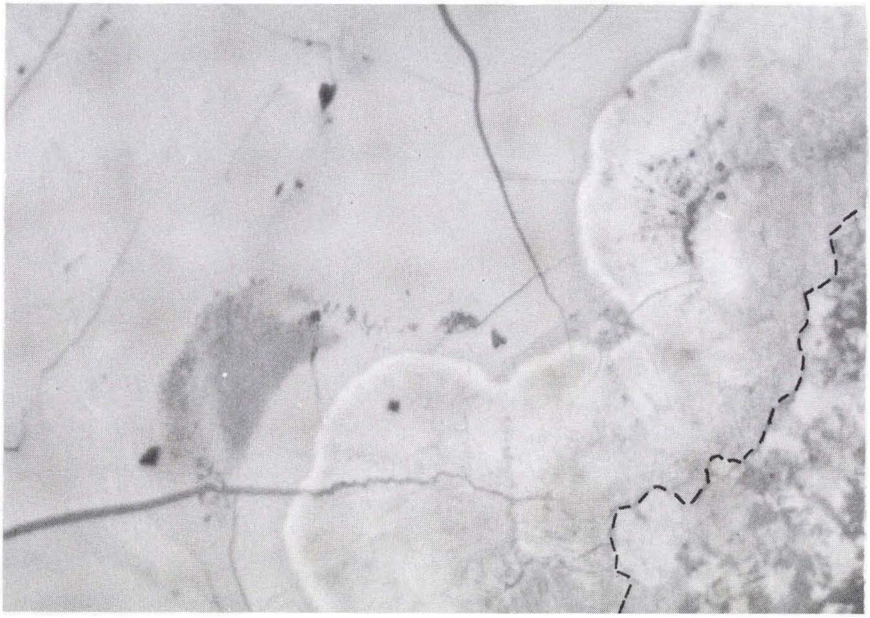

Fig. 16. Ore-microscope photo (300 × 450 μm) of area B. From left to right are seen the zones rich in iron, manganese and calcium, respectively (boundary between the two lastmentioned is marked by dot-and-dash line).

Different sediment types

Field observations in the investigated valley give the impression that the decrease in CO_2 pressure will lead to different sediment types, depending on the environment in which the sediment is laid down. On the flanks of the valley, where the springs open directly into the atmosphere, a stalk-like and sintered appearance of the chemical sediment is normal, but in the bottom of the valley, which was a lake when the lime sedimentation took place, a more puttylike sediment is found. It is thought that the difference between the terrestrial and the limnic environment influences the escape of CO_2 from the sediment, and this may explain the different textural types. The different minerals found in respectively the stalk-like and the puttylike lime sediments seem to reflect the redox potential at the time of formation, i.e. on the flanks of the valley manganese and iron with the highest oxidation levels (manganese +4 and +3 and iron +3) are found as the minerals pyrolusite, manganite and goethite, while in the bottom of the valley reduced mineral species of iron (e.g. iron carbonates) are found. Manganese carbonates have not been found. Normally the lime tufa contains alternating layers, a few

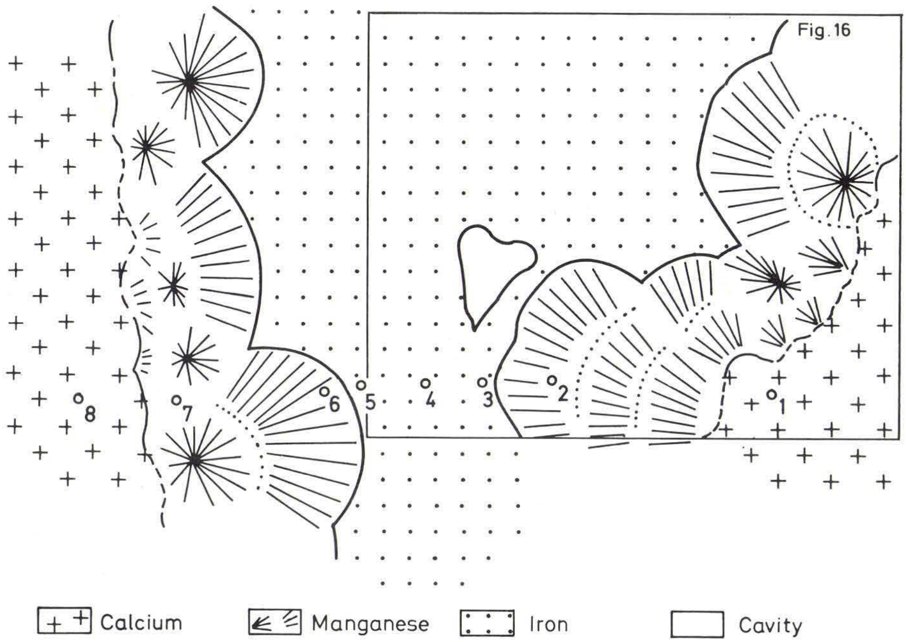

Fig. 17. The zonal composition of area B (fig. 16) and location for points of microprobe analyses. The analytical data are shown in table 3.

centimetres in thickness, rich in calcium, manganese and iron, which are believed to represent differences in the water chemistry in the local source area, i.e. layers rich in iron might reflect weathering at a slightly lower pH level than the layers rich in manganese (Hem 1970). Water rich in nitrate (NO_3^-), which is found locally, will not be able to transport iron and manganese in the reduced state (Hem 1970). This oxidized water type (still high in pH), originating at shallow depths in the area, accordingly cannot be responsible for the zones rich in iron and manganese in the lime tufa. A seasonal rhythm in the NO_3^- content of the water (corresponding to a change in Eh) cannot be excluded, and therefore it is possible that the alternating Ca, Mn and Fe zones to a certain extent could be related to changes in the NO_3^- content of the water.

The precipitation around a recent spring

Many of the springs still active at the flanks of the valley give a good impression of the course of precipitation. The findings are in accordance with the theoretical requirements for the precipitation of calcium, iron and man-

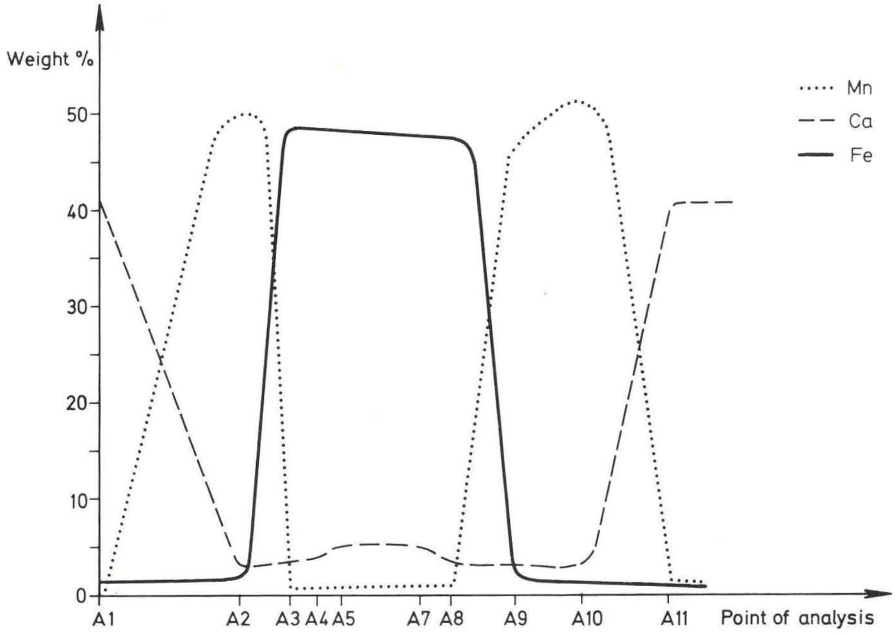

Fig. 18. Ca, Mn and Fe distribution (area A) determined by microprobe analyses of points A1 – A11.

ganese. Around the origin of the spring calcium carbonate and iron hydroxide are found. Often the decrease in the CO_2 pressure will lead to a spontaneous precipitation of calcium carbonate just at the origin of the spring, but in a number of cases calcium carbonate also precipitates around twigs, leaves etc. in the brook a few metres downstream (cf. Nordmann 1944). Water samples taken some distance downstream show a supersaturation of calcium carbonate as mentioned above. The iron is normally found very close to the origin of the spring, indicating that the oxidation process combined with the pH rise leads to a spontaneous precipitation of limonite here. Manganese minerals have seldom been found in the recent springs, and it is believed that the manganese is transported further downstream.

The microzonation

The zonation of calcium, iron and manganese was studied in detail by microprobe, and a very clear separation between the different zones can be observed (see figs. 18 and 19). The series of zones in the two sections studied include a calcium zone followed by a manganese zone, and this is again followed by an iron zone. The different zones can be seen in figs. 7, 8, 16 and 17. The

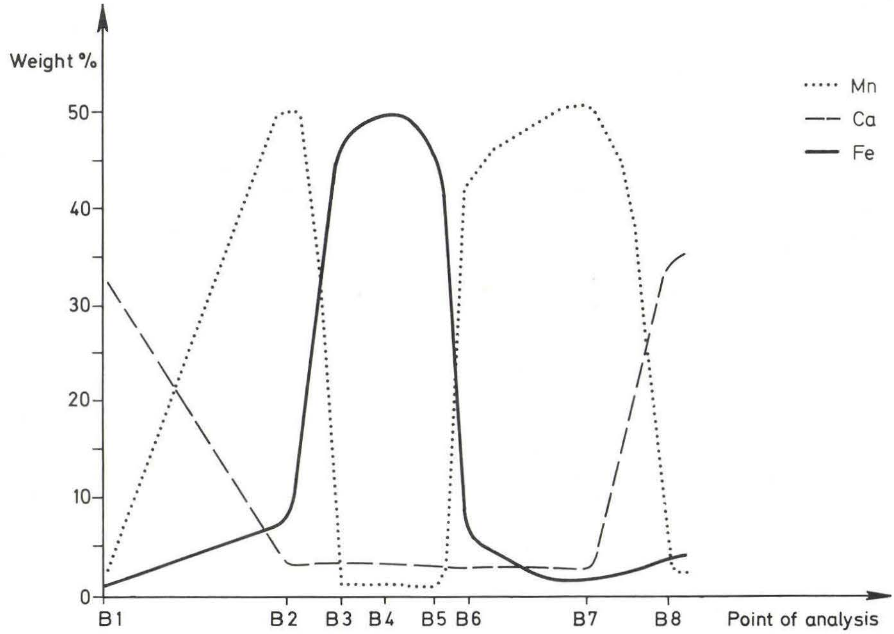

Fig. 19. Ca, Mn and Fe distribution (area B) determined by microprobe analyses of points B1-B8.

explanation of this finding, which at first does not seem to be in accordance with what was found in the recent springs, is as follows. Starting with the calcium zone it must be concluded that a CO_2 pressure decrease will lead to the calcium carbonate precipitation, but if the manganese and iron zones precipitated almost synchronously it should be expected that the iron zone would be situated closest to the calcium zone. The zonation visible in figs. 7, 8, 16 and 17 indicates a change in the chemical composition of the water, which might be the result of geochemical as well as hydrological changes. We believe that the manganese zone corresponds to precipitation from water very rich in manganese compared to the iron content of the water, and that the iron zone was formed afterwards by precipitation from water which has a higher content of iron (but in which the manganese content might still have been quite high). The microzonation of area A (figs. 7 and 8) might possibly elucidate the question whether the formation of the manganese and iron zones involved replacement. In figs. 7 and 8 it can be seen that the manganese zone is only present in the upper half of the photo. The contact between the calcium and the manganese zone is rather smooth, and within the manganese zone a tendency towards subzonataion can be seen. The manganese precipitation seems to have started around small nuclei on or near the calcium zone.

We therefore believe that the formation of the manganese zone occurred without corrosion of the original $CaCO_3$ zone, and that the precipitation of Mn occurred as rhythmical coatings radiating from the Ca zone. In the lower half of figs. 7 and 8 the manganese zone is almost absent, and the contact between the Ca zone and the Fe zone is filled with hollows, presumably due to corrosion of the Ca zone. This may be an indication of a synchronous dissolution of $CaCO_3$ by iron hydroxide, occurring when the iron zone was formed. This replacement may have included an original manganese zone in this area as well as replacement in the Ca zone.

The microprobe analyses indicate that a certain amount of calcium is present in the manganese zone as well as in the iron zone, and that a certain amount of manganese is found in the iron zone and vice versa (see figs. 18 and 19). The calculated mineralogical composition of the microzones investigated, based on microprobe data, shows that the calcium zone is almost exclusively built up of calcite, while the manganese and iron zones seem to contain more manganese and iron minerals. The calculated mineral compositions are shown in tables 2 and 3, and it is seen that the total calculated mineral content for the manganese and iron zones is sometimes rather low when the assumption is made that manganese is only present as MnO_2 (pyrolusite), and iron is only present as goethite ($FeO(OH)$). The most reasonable explanation for this is that the zones contain a variable amount of water, combined with the minerals. It should be mentioned that the sample investigated by microprobe is especially well oxidized, and therefore possibly contains less water than other samples from the lime tufa in the area. The X-ray-diffractometry study (cf. table 1) did not include the sample investigated by microprobe.

The age of the lime tufa

By pollen analysis of layers of peaty bog lime situated below some of the thickest lime tufa deposits found in the valley (borings Nos. 13 and 15, see fig. 2) an impression of the age of the lime tufa was obtained. In a sample of bog lime containing fresh-water gastropods from boring No. 13, the pollen dating indicates a boreal age (ca. 8,000 to 9,000 B.P.). In boring No. 15, one sample of bog lime and one of clayey peat have a preboreal to boreal age (ca. 9,000 B.P.). In boring No. 13 the thickness of the overlying lime tufa (which was not a homogeneous deposit through the profile) is around 8 metres, and in boring No. 15 almost 4 metres. The hydrological conditions responsible for the spring activity in the valley are believed to have persisted more or less unchanged throughout the postglacial epoch. Thus formation of lime tufa seems to have occurred without noteworthy interruptions during postglacial time. Observations in the recent springs show that formation still goes on. It is possible that lime-tufa formation started even earlier at other localities within the area. The thickness of the lime tufa in the two borings and generally in the valley gives no indication of the age of the lime tufa.

Conclusions

From the investigation reported here, no corrections can be given to the general theories for the formation of lime tufa, i.e. solution of calcium carbonate and iron and manganese from the source rock, and precipitation due to CO_2 escapement and oxidation processes. The precipitation of the different chemical sediments is believed to be dependent on the physical environment where the precipitation occurs. Thus a stalk-like sediment type is found when the precipitation occurs in contact with the atmosphere, and a puttylike appearance is found when the precipitation occurs in a lake bottom. The chemical environment (pH and Eh) determines the mineral type as the oxidized minerals are found in deposits laid down in contact with the atmosphere, and reduced mineral species are found when the redox potential is low. The lime tufa normally contains bands rich in manganese and iron, which are believed to represent differences in the local geochemical and hydrological source areas. The microzonation investigated shows that the calcium, the manganese and the iron zones normally are clearly separated. Replacement of Ca and eventually Mn by Fe seems to have occurred, but no signs of replacement of Ca by Mn were found. Formation of lime tufa seems to have started at the beginning of the postglacial epoch, and formation still goes on in the valley.

Acknowledgements. The authors gratefully acknowledge state geologist *Werner Christensen* (DGU) for calling our attention to the lime tufa deposit at Åstrup and for many inspiring discussions.

We have been assisted throughout the microprobe investigations by civil engineer *Anna Simonsen* and mag. scient. *Hans Kr. Schønwandt*, the Technical University of Denmark (DtH). Professor *Hans Pauly* and mag.scient. *Birger Larsen* (DtH) are thanked for valuable discussions. Technical help and advice concerning the preparation and the running of the microprobe have been given us by Mr. *Ib Nielsen* and civil engineer *R. Norback Nielsen* (DtH). The wollastonite, manganite and hematite standards were prepared and kindly placed at our disposal by mag.scient. *John Engell*. The pollen analytical dating was performed by cand.scient. *Bent Aaby* (DGU). The manuscript was typed by Miss *Vibeke Bøgh*, and the drawings produced by Miss *Kirsten Andersen*, Miss *Inge Martin-Legéne*, Mrs. *Eva Melskens*, and Mrs. *Helle Zetterwall*. In addition many unnamed colleagues at DGU and DtH are kindly acknowledged for valuable help and discussions.

Table 1. Mineralogical composition based on X-ray diffractometry. (×) = weak reflections; × = strong reflections. For description of the samples see p. 97. The sampling localities are shown in fig. 2 (marked by K, P and R).

Mineral \ Sample No.	K1	K2	K3	P1	P2	P3	P4	P5	P6	P7	P8	R1	R2	R3
Calcite	×	×	(×)	×	×	×	×	×	×	×	×	×	×	×
Goethite			(×)	×	(×)	×						×		
Manganite													(×)	
Quartz	×			×	×	×	×	×	×	×	×	×	(×)	×
Clay minerals											×			

Table 2. Results of quantitative microprobe analyses of the Ca, Mn and Fe zones of area A shown in figs. 7 and 8 and the calculated mineral content. The location of the points of analyses are indicated in fig. 15 (data for points A6 and A8 are excluded from the table because they are located in cracks and cavities (cf. fig. 15)).

Point of analysis	Found			Calculated			
	Ca %	Mn %	Fe %	$CaCO_3$ %	MnO_2 %	FeO(OH) %	Sum %
A1	40.5	0.2	0.4	101.3	0.3	0.6	102%
A2	3.0	50.0	1.5	7.5	80.1	2.4	90%
A3	3.8	0.5	48.8	9.5	0.8	77.0	87%
A4	4.0	0.4	48.8	10.0	0.6	77.0	88%
A5	5.1	0.7	47.0	12.8	1.1	74.6	88%
A7	5.0	0.3	47.1	12.5	0.5	74.8	88%
A9	3.0	46.2	3.0	7.5	74.0	4.8	86%
A10	3.0	51.1	0.5	7.5	81.8	0.8	90%
A11	40.0	1.1	0.5	100.0	1.8	0.8	103%
A12	3.8	0.5	50.8	9.5	0.8	80.6	91%
A13	3.0	51.3	2.0	7.5	82.1	3.2	93%
A14	3.0	50.0	2.0	7.5	80.1	3.2	91%
A15	3.3	0.6	47.0	8.3	1.0	74.6	84%
A16	3.8	0.1	50.7	9.5	0.2	80.4	90%
A17	3.0	51.4	2.0	7.5	82.5	3.2	93%

Table 3.
Results of quantitative microprobe analyses of the Ca, Mn and Fe zones shown in figs. 16 and 17, and the calculated mineral content. The points of analyses are indicated in fig. 17.

Point of		Found		Calculated			
analysis	Ca%	Mn %	Fe %	$CaCO_3$ %	MnO_2 %	FeO(OH) %	Sum %
B1	33.5	1.5	1.0	83.8	2.4	1.6	88%
B2	3.0	50.6	7.1	7.5	81.0	11.3	100%
B3	3.8	0.8	47.8	9.5	1.2	75.8	87%
B4	3.4	0.8	49.7	8.5	1.2	78.8	89%
B5	2.9	0.6	45.9	7.2	1.0	72.3	91%
B6	3.0	42.5	5.8	7.5	68.0	9.2	85%
B7	3.0	50.8	1.9	7.5	81.3	3.0	92%
B8	34.6	3.7	3.9	86.5	5.9	6.2	99%

Table 4. Average composition (based on microprobe analyses) of the Ca, Mn and Fe zones shown in fig. 7 (area A) and fig. 16 (area B).

	Ca zone	Mn zone	Fe zone
Area A			
Ca %	40	3	4
Fe %	<1	2	48
Mn %	<1	50	<1
Mg %	<1	<1	<1
Area B			
Ca %	34	3	3
Fe %	1	6	48
Mn %	2	48	1
Mg %	<1	<1	<1

Dansk sammendrag

De klimatiske forhold i Danmark er gunstige for forvitringsprocesser. Man kan groft set regne med, at de glaciale kvartære aflejringer overalt i Danmark oprindelig har haft et højt indhold af kalciumkarbonat, fordi de forskellige isfremstød fra såvel Norge som Sverige har måttet passere prækvartære kalkaflejringer (jfr. Sorgenfrei og Berthelsen 1954). I dag er den del af Jylland, der ikke var isdækket under Weichsel-glaciationen, i modsætning til den øvrige del af Danmark relativt dybt forvitret. Dette skyldes hovedsagelig, at forvitringsprocesserne inden for dette område har haft længere tid til rådighed. Denne geokemiske forskel afspejles bl.a. ved, at der i det vestlige Jylland typisk foregår en kemisk udfældning af jern- og manganrige sedimenter (f.eks. myremalm), mens der i de østligere egne dannes kildekalk.

Kildekalkforekomsten ved Åstrup på Sjælland repræsenterer således et initialstadium i den kemiske forvitring, som foregår ved et forholdsvis højt pH-niveau.

Kildekalken dannes ved, at kuldioxydholdigt og reduceret vand opløser kalk samt jern- og manganforbindelser fra de øverste jordlag, hvorfra de transporteres, indtil CO_2-trykket falder (pH stiger), og redoxpotentialet stiger. Dette foregår i og omkring de mange kildevæld, der findes i det undersøgte område. Kildekalkens tekstur ser ud til at være afhængig af den måde, hvorpå kuldioxyden undviger. Sker CO_2-undvigelsen direkte til atmosfæren, bliver kildekalken stænglet og sintret, mens der dannes en kitagtig søkalk, når CO_2-indholdet forsvinder under et vist vanddække. Kildekalkens mineralselskab er præget af pH og Eh i aflejringsmiljøet. Således forekommer jern- og manganoxyder og hydroxyder ved det højere Eh-niveau, der er fremherskende i det terrestriske miljø på dalsiderne, mens der lokalt er påvist jernkarbonat i dele af dalbunden, som på dannelsestidspunktet var sødækket og antagelig anaerobt. Mikrosondeundersøgelser af en stærkt oxideret kildekalkprøve, hvor tynde jern- og manganzoner var synlige, har vist, at de forskellige zoner er velafgrænsede. Zonerne tænkes at repræsentere forskellige geokemiske forhold i det lokale forvitringsmiljø. Det ser ud til, at afsættelsen af manganrige zoner på en oprindelig kalciumkarbonat-overflade har fundet sted, uden at mangan har replaceret kalcium, mens der i forbindelse med en senere dannelse af en jernzone på manganoverfladen tilsyneladende har fundet en replacering sted, omfattende såvel mangan som kalcium. Kildekalkdannelsen, der stadig foregår omkring kilder i området, startede ca. på overgangen mellem sen- og postglacialtiden. Den maksimale tykkelse, der er påvist i området, er ca. 8 meter.

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Oversigt over geologiske forskningsprojekter i Danmark og Færøerne

Henning Sørensen og Peter B. Konradi

Sørensen, Henning og Konradi, Peter B.: Oversigt over geologiske forskningsprojekter i Danmark og Færøerne. *Danm. geol. Unders., Årbog 1976*, pp. 115–119, København, 1. marts 1978.

In order to facilitate the exchange of information about geological field and laboratory investigations in Denmark and the Faroe Islands the Geological Survey of Denmark has distributed a questionary about geological research projects in Denmark. On the basis of the information of the questionaries contacts can be established between scientists working in related fields and regions.

The answers are grouped into 17 subject groups, and illustrated on a survey map.

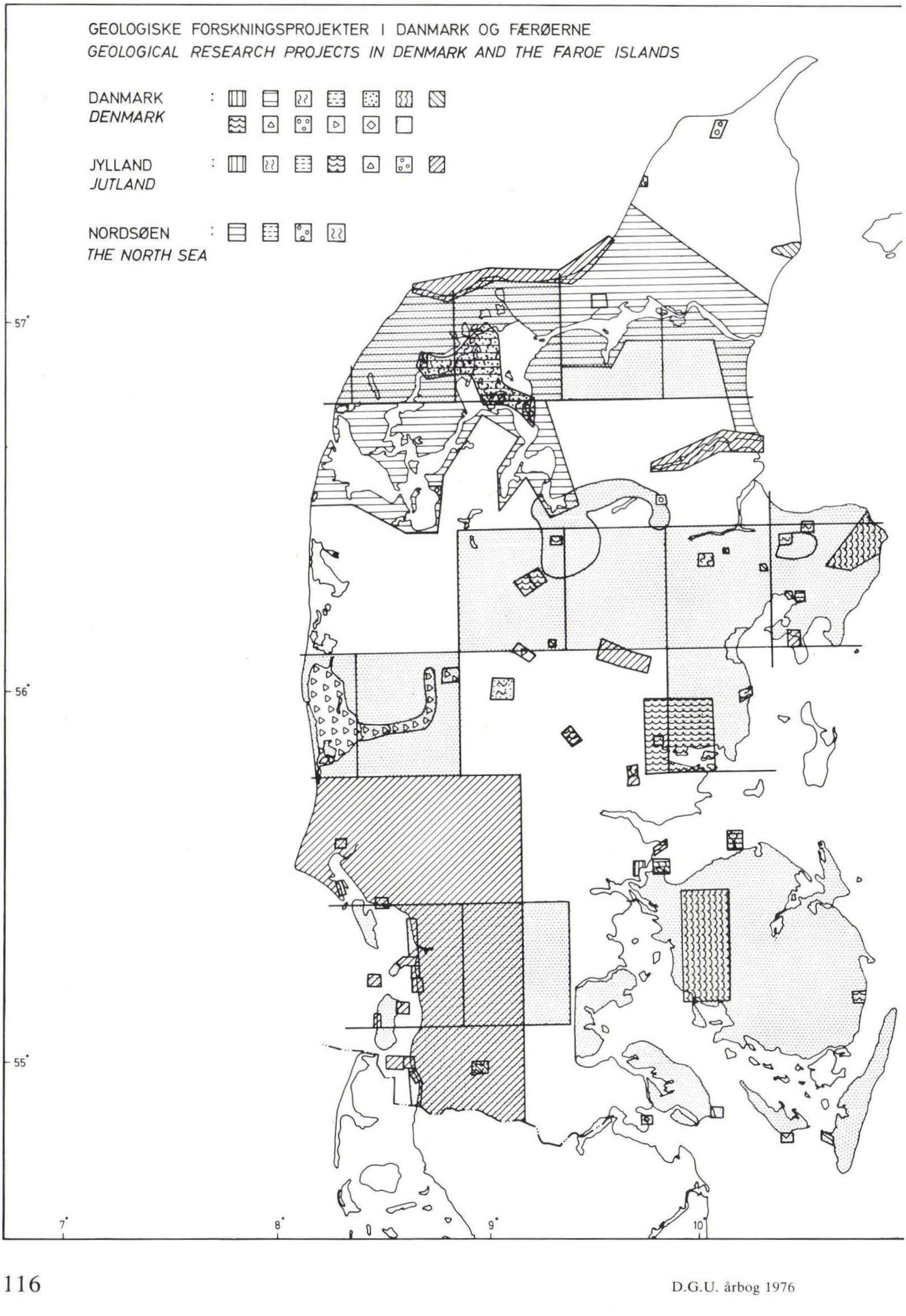
Danmarks Geologiske Undersøgelse får jævnligt henvendelser fra uden- og indenlandske kolleger vedrørende muligheden for at udføre geologisk feltarbejde i Danmark. Der modtages ligeledes forespørgsler fra kolleger, som søger kontakt med danske forskere inden for deres eget forskningsområde, herunder om der i Danmark forskes inden for bestemte problemkredse.

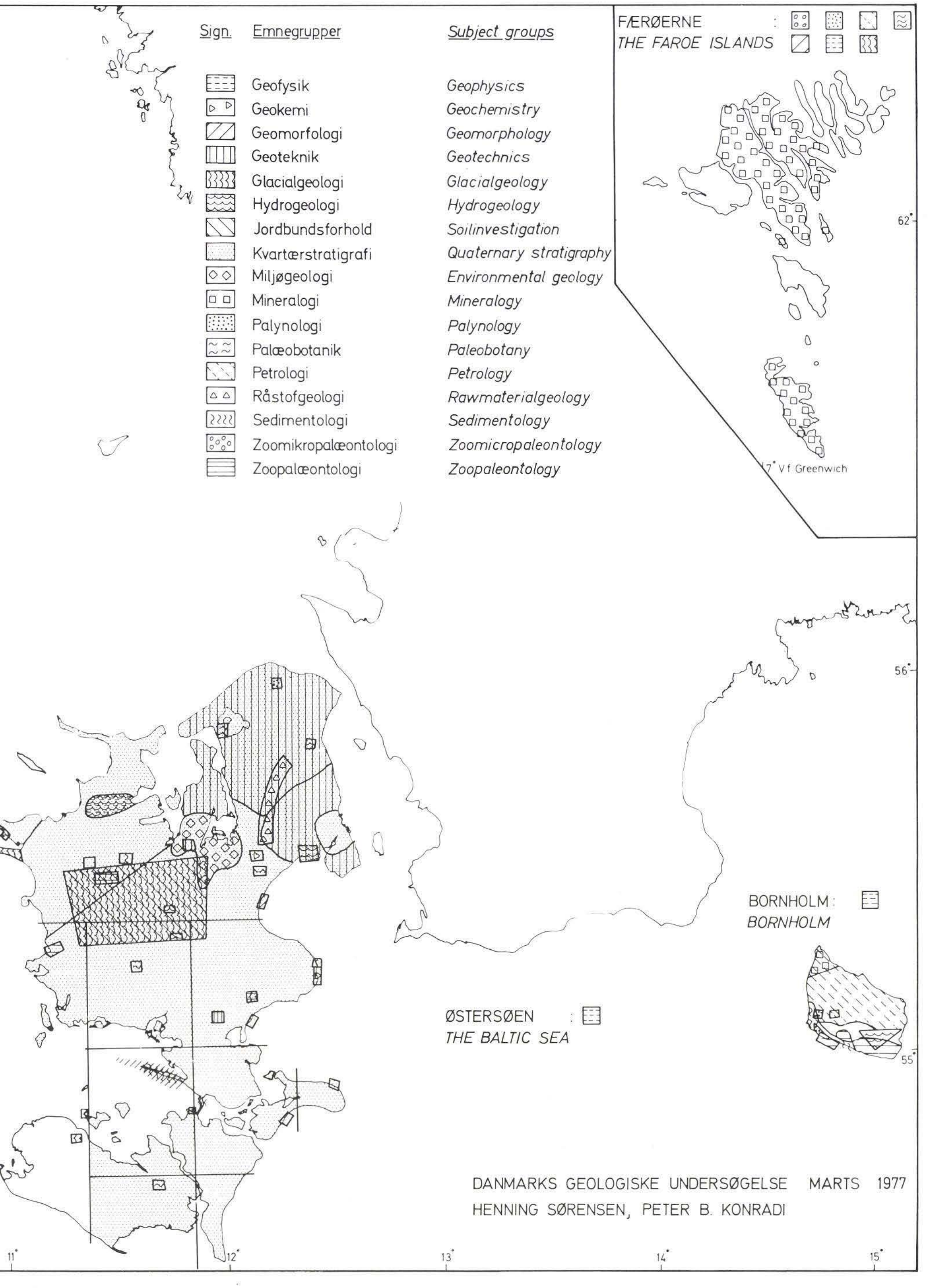
Den geologiske forskningsaktivitet rundt om i landet har nu nået et omfang, som vanskeliggør et samlet overblik. Således har det vist sig vanskeligt at besvare henvendelser og forespørgsler på tilfredsstillende måde, ligesom det ikke altid har været muligt at undgå unødig dublering af undersøgelser.

DGU har derfor taget initiativ til løbende at registrere de igangværende forskningsprojekter gennem udsendelse af spørgeskemaer og opbygning af et register herover. DGU vil således kunne besvare forespørgsler fra inden- og udenlandske forskere vedrørende feltarbejder i Danmark og Færøerne, og vil være i stand til at formidle de nødvendige kontakter. Det er vort håb derigennem at kunne bidrage til en udbygning af samarbejdet mellem fagfæller og en øget udveksling af ideer.

Spørgeskemaer blev udsendt i foråret 1976, og der er indtil 1. marts 1977 indkommet 196 besvarelser fra 117 personer, institutioner eller firmaer. Feltarbejderne fordeler sig på 164 lokaliteter, såvel lokale som regionale.

Feltarbejderne omfatter så mange emner, at det af praktiske grunde er fundet nødvendigt at gruppere dem i følgende 17 emnegrupper:


GEOLOGISKE FORSKNINGSPROJEKTER I DANMARK OG FÆRØERNE
GEOLOGICAL RESEARCH PROJECTS IN DENMARK AND THE FAROE ISLANDS
DANMARK
DENMARK
JYLLAND
JUTLAND
NORDSØEN
THE NORTH SEA
57°
56°
55°
7°
8°
9°
10


Sign.
Emnegrupper
Subject groups
Geofysik
Geophysics
Geokemi
Geochemistry
Geomorfologi
Geomorphology
Geoteknik
Geotechnics
Glacialgeologi
Glacialgeology
Hydrogeologi
Hydrogeology
Jordbundsforhold
Soilinvestigation
Kvartærstratigrafi
Quaternary stratigraphy
Miljøgeologi
Environmental geology
Mineralogi
Mineralogy
Palynologi
Palynology
Palæobotanik
Paleobotany
Petrologi
Petrology
Råstofgeologi
Rawmaterialgeology
Sedimentologi
Sedimentology
Zoomikropalæontologi
Zoomicropaleontology
Zoopalæontologi
Zoopaleontology
FÆRØERNE
THE FAROE ISLANDS
62°
7° V f Greenwich
56°
BORNHOLM
BORNHOLM
ØSTERSØEN
THE BALTIC SEA
55°
DANMARKS GEOLOGISKE UNDERSØGELSE MARTS 1977
HENNING SØRENSEN, PETER B. KONRADI
11°
12°
13°
14°
15°

Geofysik,	Som bl.a. indeholder geoelektrik, geotermik, magnetisme, seismik
Geokemi	
Geomorfologi,	som indeholder såvel undersøgelser af recente processer som tolkning af glaciale former
Geoteknik	
Glacialgeologi	
Hydrogeologi	
Jordbundsforhold	
Kvartærstratigrafi,	som bl.a. indeholder overfladekartering, morænestratigrafi, ledeblokanalyser, interglaciale aflejringer
Miljøgeologi,	som omfatter fredning og fysisk planlægning
Mineralogi	
Palynologi	
Palæobotanik	
Petrologi	
Råstofgeologi,	såvel på landjorden som på søterritoriet
Sedimentologi,	som indbefatter lithologi
Zoomikropalæontologi	
Zoopalæontologi	

På oversigtskortet er områderne for forskningsprojekterne indtegnet, ligesom forskningsemnerne er angivet. Emner som omfatter hele Danmark, såvel land- som havområder, Jylland, Nordsøen eller Færøerne er dog angivet separat.

Det indsamlede materiale formodes endnu ikke at være komplet. Vi håber i et senere nummer af Årbogen at kunne give en mere dybgående beskrivelse af den geologiske forskningsaktivitet i Danmark og Færøerne, end det er gjort i denne notits.

Registret udarbejdes af Almengeologisk afdeling på DGU, hvortil forespørgsler og bidrag til registret bedes rettet. Spørgeskemaer vil ligeledes kunne rekvireres her. DGU vil rutinemæssigt udsende spørgeskemaer hvert forår.

English summary

Geological research projects in Denmark and the Faroe Islands. In order to facilitate the exchange of information about geological field and laboratory investigations carried out in Denmark and the Faroe Islands the Geological Survey of Denmark has undertaken to distribute a questionary to all involved in geological research in Denmark. The information collected by means of the

questionary is filed in such a way that contacts can be established between scientists working in related fields and regions so that unnecessary duplicate work may be avoided and so that exchange of ideas and collaboration may be enhanced.

The first questionaries were sent out in 1976, and by the first of March 1977, 196 answers were received from 117 persons, institutions or firms. Projects are carried out in 164 areas, both local and regional.

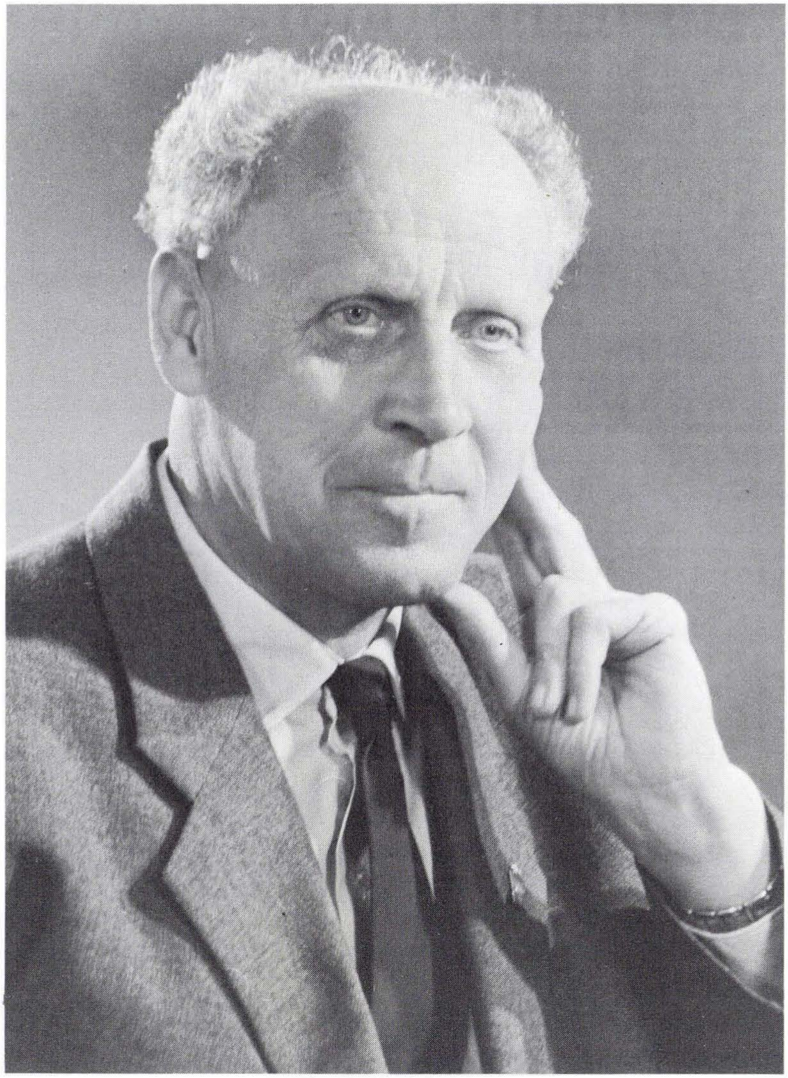
The research projects comprises so many subjects, that for practical reasons, it has been necessary to group them into the following 17 subject groups:

Geophysics	
Geochemistry	
Geomorphology,	including recent formations and interpretation of glacial forms
Geotechnics	
Glacial geology	
Hydrogeology	
Soil investigations	
Quaternary stratigrafi,	including mapping, till-stratigraphy, indicator boulder analysis, interglacial deposits
Environmental geology,	including nature conservation and physical planning
Mineralogy	
Palynology	
Paleobotanics	
Petrology	
Raw material geology,	both on land and on sea floor
Sedimentology,	including lithology
Zoomicropaleontology	
Zoopaleontology	

A survey of the projects is given on the map, where the areas of the projects are marked as well as the subject of the research project. Projects including the whole of Denmark, Jutland, the North Sea or the Faroe Islands are listed separately.

The returned questionaries hold so much informations, that we intend to provide a more detailed survey of the geological research activities in Denmark and the Faroe Islands in a later issue of the Årbog.

Contributions to the index of geological research projects and inquiries should be adressed to Almengeologisk afdeling, D.G.U., where questionaries can be asked for.



Sigurd Hansen.

Sigurd Hansen

1900–1973. – Mere end 50 års geologisk virke for DGU

Arne Vagn Nielsen

Nielsen, Arne Vagn: Sigurd Hansen. 1900–1973. – Mere end 50 års geologisk virke for DGU. *Danm. geol. Unders., Årbog 1976*, pp. 120–138. København, 1. marts 1978.

Sigurd Hansen. 1900–1973. – More than 50 years geological work. A brief review of Sigurd Hansen's life and activities in Danish geology.

Statsgeolog, dr. phil. Sigurd Hansen døde pludselig den 19. oktober 1973, 73 år gammel. Lige til den sidste dag havde Sigurd Hansen været aktiv og taget del i det geologiske arbejde på Danmarks Geologiske Undersøgelse. Mere end 50 års arbejde i dansk geologi's tjeneste blev ved hans død brat afsluttet.

Sigurd Hansen var født den 4. september 1900 i Sejstrup nord for Ribe som søn af gårdejer Hans Nielsen Hansen og Hustru Maren Margrethe, født Lambertsen. Han blev matematisk student fra Ribe Katedralskole sommeren 1918 og påbegyndte straks efter det naturvidenskabelige studium ved Københavns Universitet. I årene 1922–25 var Sigurd Hansen alumne på Valkendorfs Kollegium, og beretninger fra den tid fortæller lidt om de forhold, hvorunder den unge student måtte kæmpe sig gennem studietiden.

Allerede tidligt var Sigurd Hansens interesse for geologien blevet vakt, og fra 1920 deltog han som sommerassistent i DGU's karteringsarbejde, i studieårene bl.a. på kortbladene Fredericia (1920), Ribe (1921), Tønder og Blåvandshuk (1923) under Axel Jessens og V. Nordmanns ledelse. Sommeren 1924 deltog Sigurd Hansen i geologiske undersøgelser på Island.

Det var under kartering på Tønder-bladet sommeren 1923, at Sigurd Hansen opdagede den interglaciale mose i Emmerlev Klint nordvest for Højer – hvorom V. Nordmann gav meddelelse i Geologisk Forening den 31. januar 1925.

Embedseksamen – cand. mag. i naturhistorie og geografi, med geologi som hovedfag og speciale i istidsgeologi – opnåede Sigurd Hansen med første karakter og udmærkelse i januar 1925.

Fra september 1925 til maj 1926 var Sigurd Hansen i Stockholm for videregående kvartærgeologiske studier, først og fremmest hos professor Gerard De Geer på Geokronologiska Institutet ved Stockholms Högskola, et studieophold, som fik afgørende betydning for hans videnskabelige løbebane. Her

Studenterne I. P. Andersen, Sigurd Hansen og A. Rosenkrantz på ekskursion i Nordsjælland, april 1921.

lærte han De Geers varvkronologiske system, som han overførte til de specielle danske afsmeltningsforhold.

De Geer havde omkring århundredskiftet opstillet en tidsskala over den sen- og postglaciale afsmeltning af indlandsisen fra NØ-Skåne i syd til Jämtland-Ångermannland i nord på basis af varv. I årene 1918–26 havde De Geer offentliggjort sine resultater af en varvkronologi for SV-Skåne og Danmark, som havde vakt ret betydelig modsigelse hos danske geologer.

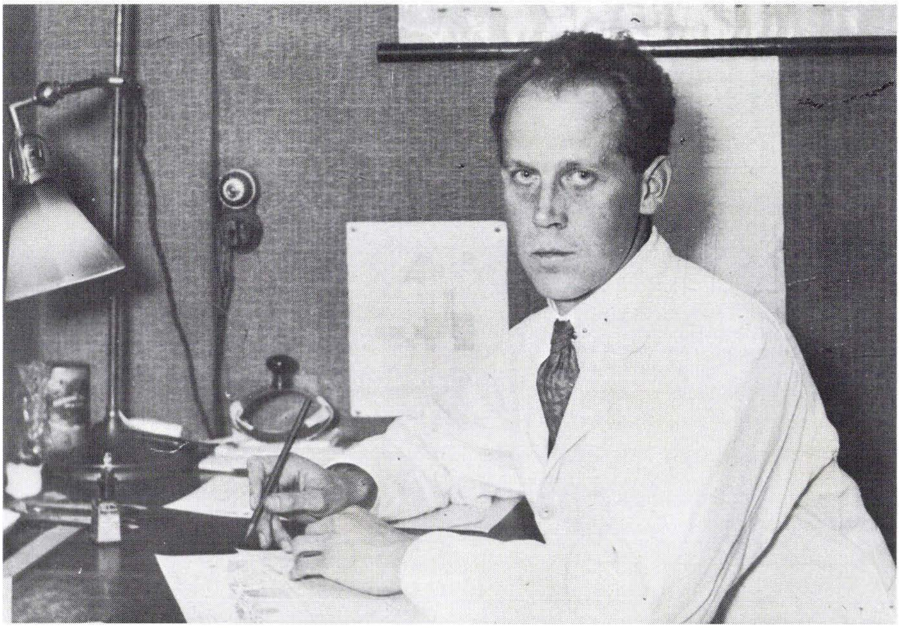
Om sin afrejse til Stockholm skriver Sigurd Hansen i dagbogsnotater for 3. september 1925 bl.a.:
»Forlod saa Fædrelandet i Eftermiddag med Damperen fra Havnegade Kl. 3 efter en travl Formiddag med pakning etc. Allerede Kl. 9.15 mødte jeg på D.G.U. for at tale med Dr. Madsen, der gav mig Introduktionsskrivelser med til De Geer og Gavelin samt stillede mig Assistentplads ved D.G.U. i Udsigt ved min Hjemkomst. Altsaa af to grunde en betydningsfuld Dag for mig . . .«

Om betydningen af studieopholdet i Stockholm og mødet med De Geer har Sigurd Hansen selv givet udtryk for i indledningen til sin disputats (1940) . . .
»En ganske særlig Tak maa rettes til min oprindelige Læremester, Professor Gerard De Geer i Stockholm. Min Interesse for Hovedproblemerne i nærværende Afhandling blev vakt under et Studieophold ved Stockholms Högskolas Geokronologiska Institut i Vinteren 1925–26. Den daglige berøring med en af den moderne Glacialgeologis Grundlæggere, som derved blev mig beskaaret, har hos mig efterladt ikke alene en Række af de skønneste Minder, men ogsaa en dyb Respekt for hans videnskabelige Ildhu og det enorme Arbejde, der ligger bag hans Udarbejdelse af den svenske Tidsskala og den glacialgeologiske Detailundersøgelse af Stockholm-Egnen. At jeg ved mine mere indgaaende Undersøgelser af Varvforekomster i Danmark og SV-Skåne har maattet kassere de fleste af De Geers Maalinger indenfor dette omraade, svækker på ingen Maade den Agtelse og Beundring, jeg fortsat nærer for Varvmaalingsmetodens og den senkvartære Geokronologis Fader.«

Gennem mange år arbejdede Sigurd Hansen med varvproblemerne i Danmark – et videnskabeligt forskningsarbejde af stor betydning for kvartærgeologien, for hvilket han allerede i 1929 fik Universitetets guldmedalje og senere i 1940 den filosofiske doktorgrad for den store monografi over »Varvighed i danske og skaanske senglaciale Aflejringer«.

Efter sin hjemkomst fra Stockholm blev Sigurd Hansen honorarlønnet assistent (pr. 1.4. 1926) ved DGU, der dengang havde til huse i Gammel Mønt. Allerede samme sommer optog han, som assistent for Axel Jessen på kortbladet Sønderborg, den ret omfattende undersøgelse og kortlægning af issøaflejringerne på nordsiden af Flensborg Fjord.

I 1927 udskrev Københavns Universitet følgende prisopgave i geologi: »En Undersøgelse af det »varvige« Ler, som den af De Geer for Sveriges Ved-



Den unge videnskabelige assistent Sigurd Hansen ved arbejdsbordet på DGU i Gammel Mønt, 1930.

kommende gennemførte, er hidtil ikke i større Udstrækning forsøgt i Danmark. Der ønskes derfor en Undersøgelse af danske senglaciale Leraflejringer, for om muligt at paavise Tilstedeværelsen af lignende Aarsvarv som de svenske og at forsøge en Udformning af »geokronologisk« Tidsregning for Danmarks Vedkommende eventuelt i Tilknytning til den svenske.«

Ved indleveringsfristens udløb i januar 1929 var der indkommet to besvarelser, den ene forfattet af Sigurd Hansen og den anden af S. A. Andersen. De havde begge først og fremmest taget spørgsmålet om tydning og opfattelse af de danske varv op til behandling, og selv om de måtte arbejde uafhængigt af hinanden (p.gr.a. opgaven), kom de dog i første omgang til samme principielle resultat, og de blev begge belønnet med Universitetets guldmedalje.

De fremsatte synspunkter – som iøvrigt hurtigt fandt tilslutning blandt danske geologer – gik ud på, at De Geers og Antevs varvmålinger i Danmark måtte forkastes, da de målte enheder ikke var ægte årsvarv, men underafdelinger af sådanne (s.k. »døgnvarv«), der registrerede mindre ændringer i vandbevægelsen, forårsaget af forskellige mere eller mindre lokale klimatiske ændringer (storm, regn, tø, højtryk, nedbør etc.).

Om Sigurd Hansens afhandling under mærket: Non sans cause (131 maskinskrevne sider, 44 diagrammer, 44 fotografier, 2 profiler og 3 kort) skrev

O. B. Bøggild og Poul Harder bl.a. i deres indstilling: »Forf. har øjensynlig lagt Vægt paa en streng kritisk Vurdering af Forholdene, saa der kan ikke være nogen Tvivl om, at de som sikre betegnede Aarsvarv virkelig fortjener denne betegnelse. Opgavens første Del maa derfor siges at være løst fuldt tilfredsstillende. Men paa den anden Side har den valgte Arbejdsmaade bevirket, at Resultatet rent kvantitativt set ikke er tilstrækkeligt til derpaa at basere en »geokronologisk« Tidsregning . . .« hvilket dog ikke lægges forfatteren til last bl.a. med begrundelse i »de danske Varvs særlige Beskaffenhed og Mægtighed i Forbindelse med de store afstande mellem Findestederne«, og da »tilmed Afhandlingen er særdeles vel skreven og i det hele taget fremtræder i en meget smuk, afrundet og gennemarbejdet Form, mener vi, at den bør tilkendes Prisen«. Sigurd Hansen modtog den ved Universitetets årsfest i november 1929.

Varvproblemerne og diskussionen herom var nu for alvor kommet ind i dansk kvartærgeologi, hvilket bl.a. fremgår af et 8 sider langt mødereferat fra den 25. november 1929 i DGF. På mødet talte S. A. Andersen om »De sjællandske Varv« og Sigurd Hansen om »Egernsund Issøen med Bemærkninger om Varvigheden i Danmark« – og mødet fortsatte den 2. december med meddelelser fra hr. J. Akselsson om »Nogle islandske Varvprofiler«, hvorefter fulgte en lang og bevæget debat foredragsholderne og tilhørerne imellem. Af referatet fremgår også den forskel i arbejdsmetode og tolkning, som altid skilte de to førende varvforskere herhjemme, Sigurd Hansen og S. A. Andersen, og som så meget andet ofte førte til heftige debatter.

Mens S. A. Andersen snart kastede sig over andre studier, fortsatte Sigurd Hansen endnu i mange år med at indsamle og bearbejde varvmateriale fra hele Danmark. I 1932 foretog Sigurd Hansen undersøgelser af »De glaciale Aarsvarv i Skåne« og publicerede året efter en foreløbig meddelelse herom, hvilket omgående affødte et modsvar fra De Geer.

I 1935 anfører Ernst Antevs – De Geers elev og mangeårige medarbejder – dog: ». . . During a visit in Copenhagen in January, 1933, the writer had opportunity to study Andersen's and Hansen's clay collections and agreed with their distinction between short-term layer-pairs and varves. The layer-pairs of the clay types nos 2 and 3 were, before 1921, incorrectly measured as varves by Gerard De Geer and the writer; and some of the incorrect measurements have been published by De Geer.« Hermed begyndte Sigurd Hansens og de danske synspunkter også at finde forståelse »hinsidan«.

I 1940 publiceredes så hans mange varvundersøgelser i disputatsen om »Varvighed i danske og skånske senglaciale Aflejringer – med særlig hensyntagen til Egernsund Issøsystem«. En omfattende beskrivelse og redegørelse af mere end 120 danske og 35 skånske lokaliteter med 115 varvdiagrammer, tillige med en udførlig kvartærgeologisk, historisk udredning af varvproblematikken og opstilling af klare varvdefinitioner og typebeskrivelser gjorde disputatsen til et hovedværk i dansk kvartærgeologi og tillige et værk af international karat.

I en omtale af Sigurd Hansens disputats skrev Ernst Antevs i The Journal of Geology, September 1940:

». . . Dr. Hansen is to be complimented on the conclusion of the difficult and time consuming study of the Scano-Danian clays. He and Andersen seem to have discovered the true natures of their different stratifications, and Hansen has logically applied the principles found to a great many clay deposits and has synthesized the findings. When the conditions of formation of these clays become better known through further physical and chemical laboratory tests, they should, together with Hansen's wealth of data, give new important suggestions on the climate and the mode of ice waning in this exceptionally interesting zone . . .«

Selvom det blev varvstudierne, der bragte Sigurd Hansen de største videnskabelige resultater, var Sigurd Hansen en all round kvartærgeolog, der gennem årene beskæftigede sig med mange forskellige geologiske opgaver.

I 1927 udkom Danmarks første »bygeologi«: Grundundersøgelser i Kolding – hvori Sigurd Hansen som ung assistent har beskrevet de geologiske forhold og de af J. O. Brandorff samlede boreresultater.

1930 publiceredes en oversigt over iagttagelser fra april samme år: »Om Forekomsten af Glacialflager af paleocæn Mergel på Sjælland« – og i 1934 sammen med N. Fabritius Buchwald en afhandling »Om Fund af Tøndersvamp fra Postglacialtiden i Danmark«.

I 1942 kom som resultat af en specialundersøgelse beretningen om »En isskuret Brolægning fra Egnen NØ for Odense«, i 1948 som foredragsreferat »En lössaflejring i NV-Jylland«, og i 1960 publiceredes sammen med H. Ødum: »Lerblokke som bundsediment i danske farvande«.

Herudover har Sigurd Hansen skrevet forskellige afhandlinger og artikler af mere populær art, bl.a. var han i mange år en trofast bidragyder til Naturhistorisk Tidende.

I sommeren 1929 deltog Sigurd Hansen sammen med bl.a. A. Rosenkrantz, Chr. Poulsen og Noe Nygaard i Lauge Koch's store Østgrønlandsekspedition, og sommeren 1930 var han igen i Grønland denne gang på en selvstændig ekspedition til Vestgrønland, der først og fremmest omfattede undersøgelser af gletscherisens bevægelsesmekanik i den store Frederikshåb Isblink.

Et par udpluk fra Sigurd Hansens udførlige dagbøger giver et lille indtryk af datidens ekspeditionsliv og ikke mindst af Sigurd Hansens omhyggelige og detaljerede dagbogsføring.

Søndag den 15. juni 1929.

Afsejling med »Godthaab« fra Trangraven Kl. 10.06 i udmærket Solskinsvejr. Mange Bekendte mødt op, . . . V.K. fulgte med til Helsingør, mellem Middelgrunden og Trekroner sejlede vi 3–4 gange i Ring for at faa rettet Kompasser. Kompasmanden og Direktør . . . forlod derefter Skibet i

Alfred Rosenkrantz, Sigurd Hansen og Chr. Poulsen i polar-antræk ombord på S/S Godthaab, Øst-Grønland, 1929.

Direktørens Lystbaad, der havde fulgt os. Frokost i Messen med Damerne. Tæt uden for Helsingørs Havn kom Lodsbaaden paa Siden af os og tog alle Gæsterne samt Lodsen ombord. Det sidste jeg saa af V.K. var den røde Hat, da hun hoppede i Land inde i Havnen (gennem den store 20 × Kikkert paa Kommandobroen). Op forbi Kullen med Medvind og rolig Sø. Mod Aften dog Regnbyge. Tidlig til Køjs, da jeg var meget søvntrængende.

Torsdag den 1. August.
Madsen og jeg stod op ivrigt diskuterende om Klokken var 2–3 som han mente, eller 7–8, som jeg troede; det var stille, men skyet, saa vi ikke kunde blive klare over, hvor Solen stod. Vi havde dog knapt faaet spist vor Morgen-Havregrød med Æbler, før Noe, Ros. og Poulsen dukkede op over den store Basalt-ur eller -delta umiddelbart Vest for Lejren. De var Aftenen forud gaaet fra Skibet og havde i Nattens Løb faaet et godt Udbytte af Fossiler fra Ammonitniveauet bag Nordmændenes Hus. De medbragte bl. andet mit Ur og en stegt Gaas. Klokken viste sig at være henved 4, saa Madsen havde altsaa nærmest Ret med Hensyn til Klokkeslettet. De nyankomne fik nu selvfølgelig ogsaa Mad, hvorefter Noe og jeg pakkede Nattens Udbytte i Kasse (nu i alt 7 Kasser fra denne Lejr) medens Ros. og P. gav sig til at se lidt nøjere paa Posidonomya Laget og Paleoniscus-Niveauet i Stranden Øst for lejren. Vejret blev efterhaanden meget fint, mildt og stille. Elegante hvide Skyer laa som en Bræmme langs Clavering Øens Bjergsider og særlig smukt paa Jordannill's og Granta Point. Ogsaa omkring den mørke Basalt (til 1200 m) over vore Hoveder var der svøbt Taageskyer. Vi ventede Motorbaaden, der skulde flytte Lejren hen til Kysten ud for Finsch-Øerne ved 10-Tiden, og i Mellemtiden gik jeg med Haglbøssen en lille Tur til Fjælds i Konglomeratvæggene, dels for at kikke efter Ammonitniveauet, dels for at se efter de to Harer, som optraadte heroppe i Gaar, da Madsen og jeg var der. Jeg var nok oppe i et par

Hundrede m Højde. Jeg saa Harerne, men kom dem ikke på Skudhold. Det er lystigt at se de smaa vævre Dyr staa fuldt oprejst paa Bagføddernes Tæer, spejdende omkring. Noe roede en Tur paa Bugten. Ved 10–11 Tiden kom 2 Motorbaade, Koch og Førstemester for at tage de fyldte Kasser tilbage til Skibet. Styrmand Hansen og Matros Jensen (fra Egernsund) for at bringe os til vor nye Lejrplads. Hurtig Nedpakning. Paa Sejlturen udmærket Lejlighed til at studere den ejendommelig Sydkyst af Bugten med de bløde Sedimenter (Skifre, Konglomerater, Ler etc.) af forskellig Farve nederst og de mørke effusive Basaltdækker øverst. Grænsen mellem dem ligger vist almindeligvis mellem 500 og 800 m over Havet. Nærmere Finsch-Øerne kommer der et Par Forkastninger, der medfører yngre Lags Optræden. De store Basaltterrasser ligger her længere inde i Landet (med store Gletschere!), medens man i Kysten væsentlig kun ser intrusive Basaltterrasser og -gange. Det store Delta ud for Finsch-Øerne er vokset saa langt ud, at der kun er en smal Passage mellem det og den inderste Finsch-Ø, hvilken ejendommelig nok ikke som de andre i Ø-Gruppen er opbygget af gamle krystallinske Dannelser, men af Sediment (rødt Konglomerat?). Maaske kan man her faa Overlejringen at se. Vi slog Lejr noget Øst for Deltaet ved en Basalt-Delta-Ur med snavset Vand i Hovedstrømmen, men rent Vand i et Par smaa side-Løb i Delta-Uren.

Lavede Kaffe til Styrmanden og Matrosen. Kølig Blæst, graat, Regn over Clavering m.m. Snart dryppede det ogsaa her. Klimaet her: Yderkyst-Klima. Ret megen Drivis meget Drivtømmer.

2 Rævefælder tilhørende Nordmændene (de har en Fangsthytte noget vestligere). Gjorde Lejren i Orden. Da det begyndte at regne ret kraftigt, maatte alting bringes ind i Teltet og en planlagt mindre Tur opgives. Vi trænger ogsaa til Søvn og Hvil. Oksekødssuppe og Blodbudding. Teltet holder godt for Vind og Regn. Soveposer ved 20-Tiden.

Lørdag den 14. September.
Stille Vejr, noget graat, ikke fuldstændigt sigtbart. Grønland kunde vi ikke se i Dag. Isen er ret tynd vistnok kun et Aar gammel og delt i overvejende smaa Flager. Vi arbejdede os langsom fremad næsten hele Dagen, i alt 7–8 Kvartmil.

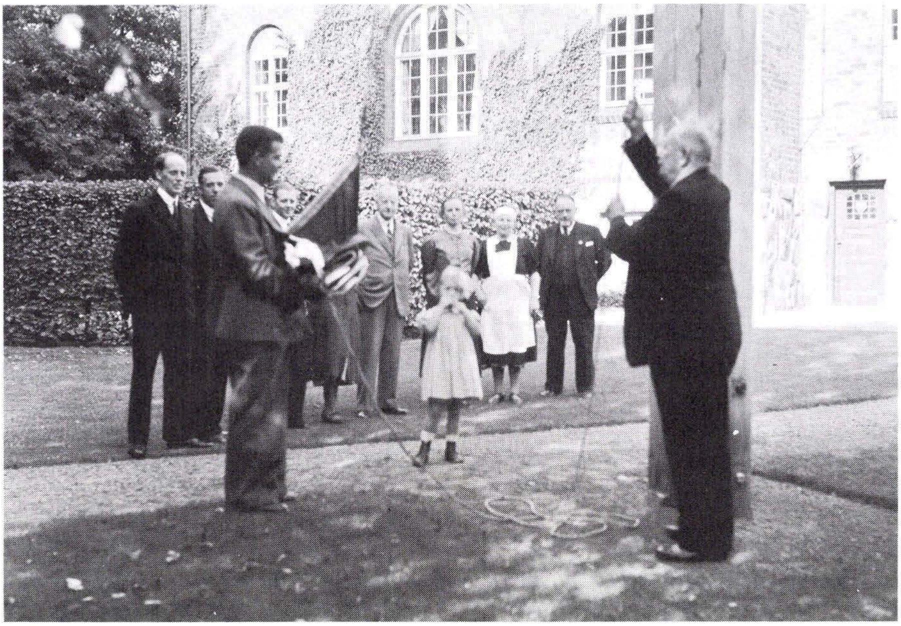
Skruen gik paa Is et Par Gange i Formiddagens Løb. 15–18 havde jeg Vagt i Maskinen sammen med Mester. En Falk blev skudt og overgivet Noe til Udstopning. Medens vi har ligget her i den tætte Is, har vi set 6–7 Falke, maaske er de paa Vej til Island? Isankeret blev sat 8.30–9 Tiden. Ros. Poul. Noe og T. spiller som sædvanlig Bridge.

Torsdag den 26. Sept.
Kongens Fødselsdag. Fin Sejlads-Dag. Svag Vind fra SV og V. Vi ændrede fra Morgenstunden Kurs til Ø, og venter at kunne se Skagens Fyr efter Midnat. Har endnu ikke set Norge. Næsten ingen Dyreliv og først om Aftenen saa vi andre Sejlere.

Vi ryddede op i Lastrummet forude. Man begynder at telegrafere hjem: Vi kommer Lørdag.

Lørdag den 28. Sept.
Da vi vaagnede ved 6.30 Tiden laa vi til Ankers ud for Rungsted. Dis lidet sigtbart, saa vi saa kun et lille Stykke af Kysten. Storvask og Gøren i Orden over alt. Koch i Land for at hente Fruen. De ankom ved 8-Tiden. Stille varmt Vejr, da vi i Formiddagens Løb sejlede ind til og ind i Havnen. Lagde til ved Grønlandske Handel Kl. 11.20.

Stor Modtagelse.



Flaghejsning ved DGU's nye domicil Det gamle Rådhus i Charlottenlund, 26. sept. 1938. H. Ødum med flaget, pens. rådhusbetjent Christensen med flaglinen, fra venstre: Sigurd Hansen, Werner Christensen, A. Noe Nygaard, A. Jessen, frk. A. Galle, fru L. Stephan og J. C. Kallestrup.

I 1931 fulgte udnævnelsen til afdelingsgeolog, og i 1938 – samtidig med at DGU flyttede til sit nye domicil på det Gamle Rådhus i Charlottenlund – udnævntes Sigurd Hansen til Statsgeolog.

En væsentlig del af Sigurd Hansens arbejdsindsats på DGU kom til at ligge inden for den kvartærgeologiske kortlægning – karteringen.

Efter mange års kartering på forskellige sydjyske kortblade overtog Sigurd Hansen selv Tønder- og Tinglev-bladene, og de forelå færdigkarterede i begyndelsen af 1940'erne. Herefter fortsatte karteringen på Sjælland med Korsør-bladet og tilgrænsende dele af Sorø-bladet.

Som elev af Axel Jessen videreførte og udbyggede Sigurd Hansen de principper og metoder, der var grundlaget for DGU's kartering, og han viderebragte dem til de mange karteringsassistenter, han gennem årene oplærte i karteringens kunst rundt om i landet på de kortblade, hvor kortlægningen nu foregik.

Kortbladet Korsør bærer nok prisen som det område i Danmark, hvor flest geologer – fra de årgange, hvor kartering indgik som et led i uddannelsen ved

DGU – har arbejdet. Mere end 25 unge geologer har i årene 1942–1965 i kortere eller længere perioder været udstationeret på Korsør-bladet, og man mindes endnu de gode, gamle karteringstider.

Som forløber for en samlet geologisk beskrivelse forelå i 1965 det geologiske og glacial-morfologiske kort til kortbladet Tinglev færdigtrykt – desværre de hidtil eneste resultater af de kortlægningsarbejder, Sigurd Hansen ledede. Men tilbage i DGU's arkiver ligger nu et meget stort og værdifuldt materiale i form af kort og dagbøger til belysning af de geologiske forhold i de egne, hvor Sigurd Hansen havde sit virke.

Udover den egentlige DGU-kartering har Sigurd Hansen også forestået mere specialpræget eller specielt ønsket kortlægning. Allerede sommeren 1929 udførte Sigurd Hansen en kartering af Vejlby Sogn ved Århus, publiceret i Ragnar Knudsen: Vejlby-Risskov gennem Tiderne. (1955).

I årene 1941–44 gennemførtes en geologisk kortlægning af NV-Jylland (omfattende væsentlige dele af kortbladene Lemvig, Struer, Husby og Holstebro) til brug for Therkel Mathiassens: Studier over Vest-Jyllands Oldtidsbebyggelse – publiceret 1948 med geologisk tekst og kort (1:100.000).

I 1950'erne udførtes under ledelse af Sigurd Hansen, som var DGU's repræsentant i Arbejdsudvalget for Nordsjællands Naturpark, en nykartering (1:10.000) af Naturparken mellem Farum og Slangerup, (publiceret 1965).

I årene lige efter krigen (1946–47) ledede Sigurd Hansen ved Åbenrå de af Københavns Universitet afholdte geologiske kurser for studerende i naturhistorie og geografi, og senere forestod han DGU's karteringskurser for sommerassistenter. Men også ex cathedra fik Sigurd Hansen lejlighed til at viderebringe sin geologiske viden og erfaring. Fra 1963–1969 var han lektor ved Københavns Universitet og gav her en lang række, ofte meget detaillerede og omfattende, men altid særdeles velforberedte forelæsninger over kvartærgeologi i almindelighed og Danmarks i særdeleshed.

En samlet oversigt over Danmarks Kvartærgeologi (The Quaternary of Denmark) forelå i 1965 fra Sigurd Hansen's side i The Geologic Systems – The Quaternary, og i 1973 kom en geologisk oversigt over De danske øer – som indledning i E. Aner og K. Kersten: Die Funde der älteren Bronzezeit des nordischen Kreises in Dänemark, Schleswig-Holstein und Niedersachsen, Bd. I. Hermed afsluttedes Sigurd Hansens geologiske publikationer.

Om sit syn på videnskabelige kvaliteter og de krav, der må stilles til geologisk forskning i særdeleshed, gav Sigurd Hansen bl.a. udtryk for, da han i 1960 var officiel opponent ved en kvartærgeologisk disputats ved Oslo Universitet. I hans publicerede indlæg hedder det bl.a.: . . .
»Jeg personligt kan dårligt forestille mig en kvartærgeologisk doktordisputats, der ikke omfatter og hviler på feltarbejder af passende omfang . . .
. . . Men for at erhverve doktorgraden er en vel gennemført undersøgelse i felten med gode resultater ikke tilstrækkelig. Resultaterne skal også kunne fremsættes i skrift eller tryk; de

Sigurd Hansen og boremester Spang Nielsen ved marskvandboring, sommeren 1955.

videnskabelige konklusioner, der kan drages af materialet – men heller ikke flere end dem, der med forsvarlighed kan drages – skal kritisk belyses af forfatteren selv. Men heller ikke det er nok; hvis materialet er ret lille og kun dækker et meget specielt og begrænset felt, kan evnen til at drage videnskabelige konklusioner måske nok demonstreres, men vi i Danmark forlanger også, at doktoranden demonstrerer evner til at indordne sine resultater i en større helhed, og at han kan foretage denne indordning i en pædagogisk forsvarlig form, altsammen ud fra den betragtning, at graden Dr. phil. ikke alene skal garantere for doktorandens evne til videnskabelig behandling af problemerne, men også giver ham jus docendi ved det pågældende universitet. Vi ser derfor helst, at disputatsafhandlingen i nogen grad har præg af en monografi, der viser, at doktorandens specielle forskningsresultater af ham selv kan indordnes i en noget større sammenhæng, og at såvel selve forskningsresultatet som dets indordning i den større sammenhæng kan fremsættes på en pædagogisk forsvarlig måde, altså egnet til at indgå f.eks. i en forelæsningsserie over emneområder i lidt udvidet ramme for hovedfagsstuderende ved universitetet . . .

En gang imellem har jeg følt savnet af lidt mere videnskabelig fantasi. Det er jo denne fantasi, der skal bringe os videnskabelige fremskridt og resultater; men naturligvis skal den holdes under kontrol. Ikke mindst er det opponentens opgave ved doktordisputatser at påse, at denne kontrol ikke svigter . . .«

Allerede 1919 blev Sigurd Hansen medlem af Dansk Geologisk Forening – (medlem nr. 618, livsvarigt medlem fra 10/10 1929). Han var medlem af DGF's bestyrelse 1927–39 og 1943–59, formand 1943–44 og kasserer alle de øvrige år. Da Sigurd Hansen på DGF's generalforsamling i januar 1960 ikke ønskede genvalg, kunne dirigenten med rette takke ham »for 29 års samvittighedsfuldt arbejde i foreningens bestyrelse, ikke mindst som mangeårig nidkær og forbilledlig kasserer«. Efter sin afgang var Sigurd Hansen til sin død revisor for foreningen.

Sigurd Hansen var tillige et meget aktivt medlem af DGF – han deltog trofast i møderne og havde ofte væsentlige diskussionsindlæg. En helt særlig foreningsindsats gjorde Sigurd Hansen som ekskursionsleder, hvor hans store og alsidige geologiske viden om og indleven i landskabernes og de geologiske formationers tilblivelse og udviklingshistorie gjorde ham til en meget afholdt og benyttet ekskursionsfører.

Der er grund til her at nævne de to sidste, store sommerekskursioner Sigurd Hansen arrangerede og ledede for DGF – og hvorom der foreligger udførlige ekskursionsberetninger. Ekskursionen til Syd-Sjælland, Vest-Møn, Falster og Lolland i juni 1960 og Ekskursionen til Sønderjylland i august 1965.

Sigurd Hansen på Nordiske Geolog-ekskursion 1951.

Den første (1960) – der var en slags generalprøve på sommerens senere, store syddanske ekskursion i forbindelse med den internationale Geologkongres i København – er et eksempel på Sigurd Hansens evne til selv fra et geologisk lidet kendt område at samle de spredte iagttagelser til en helhed, endog af international interesse.

Sønderjyllands-ekskursionen i 1965 blev Sigurd Hansens sidste, store demonstration af de landskaber, som han et langt liv igennem havde beskæftiget sig med. Fra øst til vest blev landsdelen gennemgået med en begejstring og glæde, som var karakteristisk for Sigurd Hansen, når han virkelig følte sig

Sigurd Hansen ovenfor Emmerlev Klint på DGU's sommerekskursion 1965.

hjemme i landskabet og kendt med alle detaljerne – såvel i problemstillingerne som i løsningen af dem.

Desværre blev hans ekskursionsguide (1960) og ekskursionsberetning (1966) de eneste publicerede beretninger om hans opfattelse af den sønderjyske landsdels geologi – den landsdel han havde viet så meget af sin geologiske arbejdsindsats, og hvor han havde nået de største videnskabelige resultater.

Hans øvrige ekskursions-beretninger omfatter geologiske ture til Herning-egnen 1938, Nordsjælland 1942, Mogenstrup Aas, Aamosen og Odsherred 1944, Lillerød-Veksø 1945, Nordslesvig 1947, Slagelse-Korsør-egnen 1950, Nordjylland (Nordisk Geologmøde) 1951, Allerød-Farum-Ganløse Eged 1952.

Fagfolk såvel som amatører nød under Sigurd Hansens geologiske ekskursioner godt af hans store erfaring og fortælleglæde.

Det var den samme meddelelses- og oplæringsglæde, man kunne opleve som ung – og næsten uvidende – geologassistent, når man var på tur med Sigurd Hansen rundt om i landet. Ofte fulgte også en ekstra omvej for yderligere demonstration eller indsamling af geologiske oplysninger, men også et stop på vejen for at lægge blomster ved mindestenen for studiekammeraten, der faldt for tyskernes håndlangere under krigen.

Som ung assistent hos Sigurd Hansen lærtes også, at videnskabsmandens første pligt er at tvivle – således forstået, at en sag, et geologisk spørgsmål først var klarlagt og besvaret, når alle muligheder var gennemgået, alle argumenter overvejet. Derfor blev Sigurd Hansens publikationsliste måske også så forholdsvis kort, men indholdsrig – fordi intet blev skrevet uden store overvejelser og meget grundige forberedelser. Dette kom også til udtryk, når sager forelagdes eller diskuteredes med Sigurd Hansen, så følte man sig ofte som i en boksering – altid med læremesteren Sigurd Hansen i modsatte ringhjørne. Hans diskussioner kunne grænse til uovervindelig påståelighed – hans meninger og opfattelser var svære at rokke.

Flid og sparsommelighed, som han lærte i barndomshjemmet og i studieårene, fulgt op med en pligtopfyldelse, der til tider oversteg tidens norm, giver meget af baggrunden for tjenestemanden Sigurd Hansen.

Hans tilværelse og geologiske virke var på sin vis præget af meget faste rammer og regler – f.eks. blev man ikke uden videre dus med Sigurd Hansen. Man skulle virkelig have kendt hinanden, arbejdet sammen, ja helst boet sammen i længere tid. Derfor føltes det også som en stor ære og glæde at blive dus med Sigurd Hansen, for det var et ærligt og velment håndslag, man dermed fik.

Som ældste statsgeolog var Sigurd Hansen gennem flere, ofte længere perioder fungerende direktør under Hilmar Ødums fravær, dels under besættelsen 1943–45 samt senere frem til 1963 under Ødums sygeorlov.

Sigurd Hansen ved sit 50 års jubilæum på DGU den 1. juni 1970.

Sigurd Hansen repræsenterede gennem årene DGU og dansk kvartærgeologi i talrige udvalg og kommissioner og har herunder leveret mange værdifulde geologiske udtalelser og vurderinger – bl.a. kan nævnes INQUA (Commission for the Quaternary Map of Europe), Komiteen for Kulstof-14 laboratoriet, Landbrugsministeriets udvalg angående mulighederne for sikring af bebyggelsen i marsken i Tønder og Ribe Amter, De danske Vade- og Marskundersøgelser bl.a. med henblik på ferskvandsforsyning, Det kgl. danske geografiske Selskabs Råd. Ligesom han også i mange år stod på broen, når det gode skib »Biologen« gennemførte DGU's submarine undersøgelser i indre danske farvande.

Til alle sine arbejder og hverv førte Sigurd Hansen meget omhyggelig dagbog, som ud over at indholde geologiske data også giver værdifulde bidrag til mere end 50 års geologisk udvikling og historie på DGU og i Danmark.

Den første juni 1970 fejredes på DGU Sigurd Hansens 50 års jubilæum, hvor venner og medarbejdere hyldede ham. Tre måneder senere trådte han tilbage ved 70 års dagen. Han fortsatte dog med at komme på DGU og arbejdede videre med sine mange geologiske notater og kort – men pludselig en tidlig morgen i oktober 1973 døde Sigurd Hansen. På DGU spredtes meddelelsen hurtigt og blev af mange mødt med et næsten ængstende – jamen, hvad nu! Som altid, når pladsen bliver tom efter en dygtig og travl mand, meldte spørgsmålene sig; men da var det uigenkaldeligt for sent.

Sigurd Hansens indsamlinger, registreringer og bearbejdelser af geologiske iagttagelser, hans erkendelser og konklusioner vil længe blive husket og benyttet i DGU's arbejde; hans administration og repræsentation i såvel faglige spørgsmål som i tjenstlige anliggender vil også fremover stå som eksempel til efterfølgelse. I hele sit arbejde var Sigurd Hansen altid den tjenstvillige og pligtopfyldende kollega i geologiens og DGU's tjeneste.

Hans navn og arbejde vil længe blive husket af mange.

Fortegnelse over Sigurd Hansens publikationer på grundlag af hans egne notater

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1929: Egernsund Issøen, med Bemærkninger om Varvigheden i Danmark. – Meddr dansk geol. Foren., 7, pp. 363–370. (Foredragsref.).

1930: Anmeldelse af Paul Woldstedt: Das Eiszeitalter. Grundlinien einer Geologie des Diluvium's. – Naturens Verden, pp. 324–437.

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1932: Nyere Opfattelser af Bevægelsesmekanikken for Gletscheris belyste ved egne Iagttagelser på Frederikshåb Isblink i Grønland. – Naturens Verden, pp. 357–376.

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1934: Sammen med N. Fabritius Buchwald: Om fund af Tøndersvamp (Polyporus fomentarius (L.) Fr.) fra Postglacialtiden i Danmark. (English summary). – Danm. geol. Unders., IV. række, bd. 2, 11, 20 p.

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– Anmeldelse af V. Hintze: Møens Klints Geologi. – Naturhist. Tidende, pp. 157–158.

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1940: Varvighed i danske og skaanske senglaciale Aflejringer. Med særlig Hensyntagen til Egernsund Issøsystemet. (English summary). – Danm. geol. Unders., II. række, 63, 478 p. + atlas. (Disputats).

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- Anmeldelse af: V. Milthers. Beskrivelse til Geologisk Kort over Danmark. Kortbladet Brande. – Naturhist. Tidende, pp. 77–78.

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Sidste nedisnings maksimums-udbredelse i Syd- og Midtjylland

Sigurd Hansen

Hansen, Sigurd: Sidste nedisnings maksimums-udbredelse i Syd- og Midtjylland. *Danm. geol. Unders., Årbog 1976*, pp. 139–152. København, 1. marts 1978.

Trykt efter Sigurd Hansens manuskript til foredrag i Kvartærgeologisk Klub i København den 9. februar 1970 og i DGF i Århus den 10. februar 1971 – med enkelte redaktionelle rettelser ved Arne Vagn Nielsen.

The maximum extension of the last glaciation in South and Central-Jutland. Printed after Sigurd Hansen's manuscript to lectures in 1970/71 – with a few verbal alterations by Arne Vagn Nielsen.

Angående dette emne tror jeg, det vil være rimeligt at se lidt historisk på sagen, og så plejer man jo at starte med Forchhammer, men det skal vi nu ikke gøre i denne forbindelse. Forchhammer var som bekendt geologisk diktator i Danmark og absolut modstander af istidsteorien, så først efter hans død i 1865 blev det muligt i officielle geologiske kredse at operere med tanken om isbedækninger af landet. Også Charles Lyell's drivisteori fra 1830 afvistes af Forchhammer. Forchammers efterfølger som geologi-professor i København J. F. Johnstrup havde derimod sluttet sig til istidsteorien, men først efter at hans mægtige velynder – Conferentzraaden – var død, kunne han på tryk offentligt udtale sig for denne teori, bl.a. forklarede han allerede i 1872–73 Møns Klint's opståen ved sidetryk af en indlandsismasse. Det første tilløb til det nu så betydningsfulde begreb: Hovedopholdslinien ned gennem Midt- og Sydjylland, kan derfor føres ca. 95 år tilbage, da Johnstrup i 1875 på sit »Geognostiske Oversigtkort over Danmark og Skåne« (Landmandsmøde i Viborg) angav en »Grændse for mere sluttede Partier af Rullestensler«. På baggrund af en rejse i Grønland året forud tolkede han den sandede og stenede højderyg ned gennem den midterste og sydlige del af den jydske halvø som »en sådan uhyre stor, uregelmæssig Endemoræne«. Den nævnte linie, han tegnede på sit kort, skulle altså afgrænse denne stenede midtzone fra hovedpartierne af »Rullestensleret« i Øst- og NV-Jylland. Denne linie skulle ikke direkte markere Hedesletternes østrand og ligger derfor også mellem Viborg-egnen og Vejle-egnen noget østligere, end vi nu tegner hovedopholdslinien. Desuden slår linien et slag op i Himmerlands temmeligt sandede områder, som man ikke genfinder på de nyere glacialmorfologiske kort, men mest bemærkelsesværdigt er det, at Johnstrup lader linien bøje ned mod Holstebro og syd om Lemvig ud til Bovbjerg ved Vesterhavet. Hermed var i grove træk faktisk Hovedopholdslinien indført i litteraturen og »Johnstrup fortjener at mindes som første danske geolog, der på istidsteoriens grundlag søgte at tyde jydske landskabsformer i deres forskelligartethed og deres afhængighed af israndens længere stilstand i visse perioder af afsmeltningstiden«. (Citat Garboe, 1961 p. 338).

Hedesletternes geologiske fader: Enrico Mylius Dalgas gav Johnstrup sin fulde tilslutning, medens han som bekendt i de fleste herhenhørende spørgsmål var temmelig uenig med Forchhammer. De fleste accepterede dog ikke Johnstrups liniens NV-jydske del og drejningen ud til Bovbjærg, og dette kom mest grelt frem i, at selveste Gerard De Geer 1896 i »Skandinaviens geografiska utveckling efter istiden« brugte de pommerske randmoræner og Johnstrups linie (indtil Randers-egnen) til at afgrænse sin store »baltiske istunge« som han selv sagde til mig »rakte for langt ud« – og lod hele Småland være isfri under sidste nedisning!

Først på dette senere tidspunkt – i firserne og halvfemserne – var man nået frem til en klar forestilling om, at der i begrebet »Istiden« indgik i hvert fald mindst 2 helt selvstændige nedisninger. Johnstrup selv vægrede sig længst muligt mod at tro derpå – først da opstod problemet om denne »Hovedopholdslinies« forhold til begrebet: Sidste isdækkes yderste israndsstilling eller dets maximale udbredelse. Hamburg-geologen C. Gottsche kom allerede i 1897 (Die Endmoränen und das marine Diluvium Schleswig-Holsteins, s. 56) ind på denne problemstilling: Ob die Blockpachungen im Westen der Halbinsel Reste der wirklichen Endmoränen darstellen, also die aüsserste Grenze der Eisrandes während des Höhepunktes der zweiten Vereisung bezeichnen, oder ob sie nur durch Ausläufer des Inlandeises veranlasst sind, welche den Eisrand um eine Anzahl von Kilometern nach Westen überschritten wird sich erst durch weitere Untersuchungen feststellen lassen«. Man skulle næsten tro at Ødum – før han foretog sin lille undersøgelse i 1926–27 netop havde læst disse linier – men jeg har ikke spurgt ham derom! Som bekendt lægger Gottsche iøvrigt hovedvægten på kortlægning af blokpakninger (og morænegrus), hvilke han betragter som afgørende kendemærker for endemoræner og dermed for vigtige israndstillinger. Hans linie gennem Holsten og Sønderjylland svarer endnu bedre end Johnstrups linie i Nørre-Jylland til vort nuværende begreb »Hovedopholdslinien«, selv om han ikke bruger udtrykket. Det var altså de Pommerske randmoræner + Gottsches blokpaknings-endemoræner + Johnstrups linie, der var grundlaget for De Geer's »forkerte« baltiske istunge, der jo efter vor nuværende mening gjorde de sønderjyske randmoræner synkrone med Ra-linierne og de mellemsvenske randmoræner, altså efter vort nuværende syn en absurd sammenstilling!

Ved dette lille historiske tilbageblik ser vi, hvorledes forestillingerne om liniens eller bæltets store betydning i glacialmorfologisk henseende opstod og efterhånden udvikledes.

Det var dog først i de to meget vigtige afhandlinger fra 1903 og 1907, at N. V. Ussing (som jo var Johnstrups efterfølger i professorstillingen) fastslog, at bæltet – eller snarere dets vestrand – markerer »Israndens Hovedstagnationslinie i Jylland«, for hvilken han indfører benævnelsen »Hovedopholdslinien«. Ussing er altså ophavsmand til selve navnet, selv om jeg også benyttede betegnelsen i den lille historiske indledning. Ussing beskæftigede sig med NV-, Midt-, Central- og Øst-Jylland. Hovedopholdslinien gennem Syd-Jylland (syd for Vejle-Grindsted) angives dog på kortet fra 1907 ned til Aabenraa-egnen og er efter Ussings mening en fortsættelse af det, De Geer og andre dengang kaldte »det nordtyske, baltiske endemorænestrøg« gennem Mecklenburg, Holsten og Slesvig, følgende »den baltiske Højderyg« – og hvis forløb var nærmere lokaliseret af Gottsche.

Ussing understreger stærkt, at det drejer sig om en stagnationslinie for isranden af det sidste isdække (Weichsel-Würm) uden at sige noget om, hvor langt han tænkte sig dette isdække udbredt mod vest og syd. Til sin død i 1911 (kun 47 år gammel) mente han, at de af Nikolaj Hartz i årene omkring århundredskiftet undersøgte jorddækkede interglaciale moser i Brørup-egnen, beliggende på bakkeøerne var dækkede af »fluvioglacialt« sand og morænesand, ligesom også Hartz selv mente, medens Axel Jessen allerede i 1905 (p. 86 ff.) hævdede, at dæklagene over disse moser ikke var af glacigen oprindelse. Som bekendt har eftertiden jo givet Axel Jessen ret over for Ussing og Hartz. Den meget kendte tyske glacialgeolog Paul Woldstedt behandlede i sin disputats 1913 »Beiträge zur Morphologie von Nordschleswig« området helt ud fra Ussings synspunkter, ganske uden at tage stilling til spørgsmålet om sidste nedisnings ydergrænse. En anden – og mere direkte – elev af Ussing, nemlig Poul Harder, der i min studentertid forelæste over glacialgeologi ved Københavns Universitet, indtog samme standpunkt. Det kan også nævnes, at to tyske geologer, Struck (1909) og Gagel (1910) regnede den sønderjydske Kridt-moræne, der har så stor udbredelse syd for Kongeåen helt ud til Højer-Ballum og ned i det vestlige Midtslesvig (Ladelund), for afsat af sidste nedisning.

Bortset fra Axel Jessen (1905), mente man (Hartz, Ussing, Harder, Woldstedt, Gagel o.s.v.) indtil 1ste verdenskrig (D.G.U. III. rk. nr. 2, Harders tredie udgave), at sidste nedisnings ydergrænse lå helt ude i Nordsøen, evt. i Esbjerg-Ribe-egnen. Tilsvarende opfattelser havde sydpå C. Gagel (1915), der nævner en linie mellem Föhr og Sild, samt J. Stoller (1918), der lader sidste nedisning række ud på Lüneburger Heide. Samtidig har dog W. Wolff (1915) påpeget den morfologiske landskabsgrænse for Hamburg-egnen som beliggende ved Ahrensburg mellem Hamburg og Lübeck, medens der nærmere Hamburg (Winterhude) findes interglaciale tørveaflejringer med tilsvarende dæklag som Brørup-mosernes.

Den afgørende ændring i anskuelserne fremkom herhjemme i 1918 (Brørup-Mosernes Lejringsforhold). Axel Jessen, Victor Madsen, V. Milthers og V. Nordmann undersøgte i krigsårene dæklagene over moserne og slog fast, at det ikke drejede sig om glacigene dannelser, men derimod om periglacialt betonede dæklag, solifluktionslag, søsand og eventuelt flyvesand. – I parentes bør det måske her indføjes, at der jo også i Øst-Jylland findes adskillige forekomster af interglaciale tørve- og andre ferskvandsaflejringer, som er forstyrrede af istryk, eller dækkede af glacigene eller glaciofluviale dannelser (Kollund, Ejstrup, Egtved, Hollerup o.s.v.), som er nærmere behandlet af Knud Jessen i 1928 i den store bibel, som han selv kaldte Milthers's og hans behandling af interglacialet.

Hermed var efter min mening det vigtigste kriterium kommet ind i diskussionen om sidste nedisnings maksimaludbredelse i Jylland, nemlig moserne!

Det næstvigtigste må være landskabsmorfologien, og sidst kommer efter min mening almene kvartærstratigrafiske forhold og eventuelle specifikke ledeblokforhold. – – – Disse sidste kriterier brugte V. Milthers (1925, Kortbladet Bække) til sit forsøg for egnen nord for Kongeåen, idet han dog efter min mening lægger for stor vægt på ledeblokke, nemlig den skånske basalt (tertiær), og en enkel mose med et noget tvivlsomt dæklag og mangel på de specifikke interglaciale planterester og for lidt vægt på det alment glacialmorfologiske.

Apropos det glacialmorfologiske foretog S. A. Andersen i sommeren 1924 en lille undersøgelse for at finde »Grænsen for sidste Nedisning i Sønder-Jylland«, idet han lagde vægt på de morfologiske forhold, f.eks. huller efter dødisklumperne i de store hedesletters østlige dele, derudover naturligvis randmoræner og terrænforskelle (østjydsk ungglacialt, småkuperet terræn kontra bakkeøernes afglattede former med små hældningsgradienter og mangel på aflukkede, afløbsløse huller). Jeg ledsagede ham en enkelt dag – og skønt det nu snart er 47 år siden, husker jeg, at vi standsede ved et bestemt jordfaldshul i Tinglev hedeslette ved Perbøl og var enige om, at hertil var isdækket i hvert fald nået. I efteråret 1924 holdt S. A. Andersen et lille foredrag i D.G.F. om iagttagelserne; der er desværre ikke noget trykt referat af foredraget; kun nogle bemærkninger i diskussionen af V. Milthers om, at man ikke kunne lægge en nedisningsgrænse ned midt igennem det af ham (publiceret 1925 og 1929) påpegede strøg med talrige skånske basalter blandt ledeblokkene i markstensdyngerne. Dette strøg mente han at have påvist fra Give-egnen i nord ned til Hovslund (NV for Aabenraa) i syd med betragtelig bredde i Ø-V. Dette område måtte efter V. Milthers's mening danne en helhed og dets overflade høre til ét og samme nedisningsområde, hvorfor han afviste S. A. Andersens liniedragning, der for øvrigt aldrig er blevet publiceret, men så vidt jeg husker, næppe afveg meget fra den hidtidig anvendte »Hovedopholdslinies forløb« (altså efter Ussing, Woldstedt og Gottsche).

Et par år efter meddelte Hilmar Ødum (1927) nogle »Bemærkninger om Vestgrænsen for den sidste Nedisning i Nordslesvig«, efter at han i de forudgående somre havde karteret egnen vest for og omkring Gram-Fole. Ødum mente at finde morfologiske argumenter for ydergrænsen vest om Foldingbro, Lintrup, Hygum og Fole ned til Endrupskov, kun 12 km SØ for Ribe; herfra lod han den formentlige nedisningsgrænse løbe i SØ-lig retning over Tislund, Galsted til Stenhøj (86 m) ved Hovslund. Ødum mente dog, at isfremstødet ud til den nævnte linie kun har været af kort varighed. Gram og Rødding »bakkeøer«, som vi vilde kalde dem (Woldstedt: præbaltiske Plateauer), har efter Ødums daværende opfattelse bevaret det i forvejen tilstedeværende terræns bakkeø-præg (med de udjævnede, storladne »gamle« former), dog med mere moræneler og lidt mere urolig terrænkarakter. Endvidere lagde han vægt på formentlige »jordfaldshuller« (efter dødis) NV for Hygum, ved Fole og Tislund; men han indrømmede, at der intet spor var af randmoræner langs den angivne linie. Ganske kort nævner han Milther's angivelse af de skånske basalters udbredelse øst for linien. Men nogen detailleret sporing af disse helt frem netop til Ødums linie foreligger der vistnok ikke noget om, ej heller om mangel på eller om ringe optræden vest for denne linie. Basaltblokke forekommer dog f.eks. ved Emmerlev Klev NV for Tønder, men vel næppe i så store tal, som i det af Milthers fremhævede område.

Ødums fremstilling fra 1927 af denne del af sidste nedisnings ydergrænse blev på basis af de to – autoriteter, kan vi vel godt kalde Milthers og Ødum – bestemmende for næsten alle kortfremstillinger i de næste 40 år, således Victor Madsen (1928) i Oversigt over Danmarks Geologi; Geologisk Kort over Sønderjylland (Axel Jessen, 1935); V. Milthers selv (1948); Axel Schou (1949) i Atlas over Danmark dog med modifikation for bakkeøerne. Også i nyeste tid er linien kopieret og brugt af de allerfleste forfattere (Hansen og Nielsen, 1960). A. Dücker, ekskursionskort 1965, i de sidstnævnte dog som hypotetisk, kortvarigt Würm-Weichsel fremstød. Et af de få kort uden den Ødumske bue på linien er kortet, som Keld Milthers og jeg udfærdigede i 1954 til »Geologi og Vandboring« (Sorgenfrei og Berthelsen, 1954, fig. 15).

Ingen har mig bekendt opponeret offentligt eller privat mod denne dragning af linien; jeg selv personlig har dog altid været skeptisk, og det gav jeg allerede i sommeren 1933 udtryk for i en intern karteringsrapport. Som ung afdelingsgeolog blev jeg under Dr. Nordmann's ledelse sat til at kartere bæltet nærmest syd for Kongeåen fra Kalvslund-Lintrup i vest til Skodborg-Vamdrup-egnen i øst. Jeg vil gerne citere en side af rapporten.

»Ved diskussionen om den sidste nedisnings vestgrænse må man naturligvis betragte Vestgrænsen (ved Birkegaard og Langager) for det østjydsk prægede landskab i Skodborg Sogn som en minimumsgrænse. Bag denne ligger jo også de typiske jordfaldshuller ved Skudstrup og åsen i hedesletten ved Lundgaard SØ for Vejen. Afgørende iagttagelser som f.eks. af interglaciale moser med kun flydejordsbedækning, der kunne give en maximumsgrænse, har jeg desværre ikke fundet ved kortlægningen. Dog vil det være værd at tage den store kridtmorænes optræden og udbredelse i øjesyn ved diskussionen om dette emne. Indtil videre må man vel betragte det som sandsynligt, at kridtmorænen mellem Kalvslund og Skudstrup er sammenhørende i oprindelse og alder med kridtmorænen længere mod SV ved Fjersted, Klaabygaard og Hviding. Den må i så fald på grund af dens optræden såvel i dette sydvestlige område som omkring Kalvslund og Baungaard regnes for at være aflejret af den næstsidste nedisnings is. Det vil sige, at på det her omhandlede stykke bakkeø bliver de dannelser, vi så kan henføre til sidste nedisning, alene de underordnede sandaflejringer, der dækker kridtmorænen i Skodborg Sogn. Sandaflejringerne omkring Langetved-Københoved-Heden kunne også tænkes henført dertil, men de har lige som hele landskabet et væsentligt andet præg. Vil man imidlertid som V. Milthers og H. Ødum henlægge nedisningsgrænsen til Foldingbro-Hygum-Fole egnen, skulle bakkeøen mellem Rødding-Foldingbro vejen mod vest og Københoved-Skrave mod øst have været overskredet af en isbedækning, der faktisk ikke havde aflejret andet end nogle basaltblokke, hvilket synes lidet troligt«. (Dagbog, august 1933).

Siden mit karteringsarbejde syd for Kongeåen 1933 har jeg stadig været i tvivl om rigtigheden af den Ødum-Milthers'ske linie gennem det nordlige Nordslesvig. – På refererende oversigtskort har jeg dog følt mig forpligtet til at angive linien (f.eks. den internationale ekskursion 1960) som markerende en hypotetisk kortvarig yderstilling for Würm-isbedækningen.

Disse synspunkter drøftede jeg af og til med dr. Ødum, og i sommeren 1967 – netop 40 år efter hans fremlæggelse af linien i D.G.F. – tog vi en ekskursion sammen gennem området og lagde en plan for boringer i flere af de lavninger, han havde opfattet som »dødishuller«, fremkomne ved isklumper, efterladte af den kortvarige, teoretiske Würm-isdækning. Ved udførelse af sådanne boringer skulle problemet kunne løses, hvis vi i dem kunne finde interglaciale tørvelag med non-glacigene dæklag – og sådanne dæklag er vi efterhånden blevet ret vel fortrolige med, især Sv. Th. Andersen og jeg (f.eks. fra Emmerlev Klev og gode lange profiler på Agerskov Nørremark).

Med D.G.U.'s boremester J. Spang Nielsen foretog jeg derefter i september 1967 tre boringer i lavninger, dr. Ødum og jeg havde udvalgt os som typiske, to NV for Hygum og een syd for landevejen mellem Rødding og

Grønnebæk (ved Jels). Jeg bør måske bemærke, at det da er meget muligt, at hullerne i landskabet virkelig er »dødishuller« – men i så fald dannet i slutningen af Riss-(Saale) nedisningen.

Det vestligste borehul (i bredden af en lille dam) gav 3 m dæklag (postglacialt dynd og grusblandet sand, tydet som periglacialt) over ¾ m interglacial tørv og gytje, hvilende på smeltevandsaflejringer (Riss-Saale), som vi borede i til 20,4 m. To prøver (3¼ og 3½ m dybde) blev pollenbestemt at dr. Sv. Th. Andersen til interglacial zone 3 og 4 (egezone og hasselzone).

Det andet borehul, kun ½ km mod øst, gav også 3 m dæklag (intet postglacial, men sand med podsoludvikling øverst og nedad meget få sten, utvivlsomt af periglacial oprindelse) og derunder 1¼–1½ m interglacial tørv og gytje, der med en prøve (3.0–3.2 m) efter Sv. Th. Andersen pegede på zone 3 (egezone). Disse to moser NV for Hygum ligger på et ret fladt terræn 20–22 m o.h. Underkanten af de interglaciale lag i det vestligste borehul ligger ca. 6 m under denne flade (måske en lille hedeslette fra Riss-isen?).

Den sidste og østligste boring blev placeret ca. 2 km øst for Rødding i en ret stor våd lavning, terrænkote ca. 60 m. Den gav kun ca. 2 m dæklag (¾ m postglacialt gytje og tørv over ca. 1¼ m middelgroft sand, nederst med indtil ægstore sten og klumper af moræneler). De interglaciale lag bestod af 55 cm sort, kornet tørv over 20 cm leret tørv, i alt ¾ m over en stenfri, fed leraflejring på godt 3 m tykkelse, der formentlig er en tidlig interglacial nedskylslerserie, så der i alt bliver tale om op til 4 m interglaciale dannelser. En prøve af tørven (dybde 2.42 m) blev pollenbestemt til den interglaciale zone 3 (egezone). Ved 6.1 m nåedes den store kridtmoræne, der med et indlejret gruslag fortsatte til boringens slutdybde: 10,9 m.

En fjerde lokalitet beliggende mellem Rødding by og skoven Sommerlyst tæt syd derfor fik jeg klaring på i sommeren 1969; på et byggemodnet areal fandt jeg tørv i en lille interglacial mose, opgravet ved kloakarbejderne og dækket af 4½ m skarpt dæksand, medens hele marken iøvrigt består af kridtrig Riss-(Saale) morænemergel. Der er en ret stor mergelgrav, der vidner om tidligere udnyttelse af denne mergel. I jordoverfladen er der ingen synlig sænkning over denne lille mose. sådan som det normalt kan ses, men mosen er formentlig kun omkring en snes meter i tværmål. På en hjembragt prøve har Sv. Th. Andersen pollenbestemt tørvens stratigrafiske alder til zone 6 (Picea-Gran-zone).

Da dæklagene over disse fire interglaciale moser absolut ikke er glacigene af oprindelse, må vores maximumsgrænse for sidste nedisnings udbredelse forskydes østpå, og fra Rødding Østermark-boringen er østpå faktisk kun omkring 3 km til en linie – som set ud fra detailtopografien giver en god morfologisk grænselinie mod det typiske, ungglaciale, småkuperede terræn og det blokrige strøg, som allerede Gottsche antydede for denne egn: Hovedopholdslinien = Grønnebæk – Haraldsholm – Langager – Sundbøl Gd. (tæt vest om Skodborg By) – Skodborghus (Kongeåen) op til Vejen Stationsby. Denne linie krydser altså Kongeå-hedesletten uden særlige spor, idet hedeslette-opbygningen vedvarede væsentligt længere (også under den næstfølgende israndstilling, Ødis-Hjarup). At yderlinien for isudbredelsen ikke kan trækkes væsentligt længere tilbage mod øst har vi argumenter for i jordfaldshullerne i Kongeå-sletten omkring Skudstrup og i den lille ås, der ved Lundgård, 2 km SØ for Vejen Stationsby, stikker op gennem hedesletten, og ligesåvel som Jels-søernes tunneldal længere i syd altsammen må tilskrives Würm-isen.

Ud fra det kriterium, som jeg anser for det vigtigste i diskussionen, nemlig de interglaciale moser uden glacigene dæklag og disses placering i landskabet, suppleret med det næstvigtigste kriterium, det rent landskabsmorfologiske, må vor konklusion blive, at vi fremtidig må tegne ydergrænsen for sidste nedisning over Vejen – Skodborg – Grønnebæk – vest om Jels by – Stursbøl Plantage – Jegerup – Skrydstrup – Over Jerstal – Stenhøj (86 m) ved Hovslund og herfra videre langs Hærvejen, der løber lige ovenfor Tinglev Hedeslettes proximalskrænt til Rødekro (altså ganske nær de ældre linier). Problemerne om de tertiære basaltledeblokke, hvis forekomst blandt markstenene i et bestemt område i meget stort antal blev brugt af V. Milthers til fastlæggelse af den diskuterede ydergrænse – er kun for området nord for Kongeåen (Bækkebladet) af V. Milthers publiceret med nærmere oplysninger om blokkenes talrighed. Jeg har hidtil ladet denne side af problemkomplekset ligge og betragter indtil videre ledeblokkriteriet som mindre vigtig end de andre nævnte.

Jeg behøver vel ikke at tilføje, at dr. Ødum er fuldstændig enig med mig i de her fremholdte konklusioner af min lille undersøgelse, som han jo selv var med til at planlægge; han fortæller mig, at han – om ikke før – så ved sine studier over flintkonglomeraternes udbredelse i Midt- og Vest-Jylland selv kom i tvivl om sin linies rigtighed (Ødum, 1968).

Dette var altså resultaterne af den lille undersøgelse for området syd for Kongeåen, d.v.s. specielt Rødding Bakkeøen, men det kan jo være rimeligt at forfølge problemet videre sydpå. Den næste bakkeø mod syd er Gram-Nustrup Bakkeø, som Ødum ikke behandler nærmere, men blot landskabsmæssigt sammenstiller med Rødding Bakkeøen. Han omtaler således ingen jordfaldshuller fra denne langstrakte bakkeø, og der er mig bekendt heller ikke påvist jorddækkede moser herpå. Det vil imidlertid for en ung kvartærgeolog være en udmærket opgave – blot udrustet med et Wennbergbor – at gennemsøge de allerøstligste dele af de to bakkeøer – der jo begge omfatter betydelige partier af moræneler (som jo erfaringsmæssigt giver størst chance for disse småmosers forekomst). Ved konstatering af flere af dem vil man kunne bidrage til en endnu mere eksakt dragning af den omdiskuterede linie. Formodentlig vil den lille Billund-dal, der fra Vojens-egnen ekstramarginalt førte smeltevand op til Gram Å-sletten, altså i NV-lig retning mod Øster Lindet, ligge tæt op mod linien. Over Gels Å-flodsletten forløber linien tæt vest om Over Jerstal inden den mellem Hjarup Mose og Strandelhjørn går op på NØ-siden af den største af de nordslesvigske bakkeøer nemlig Toftlund-Skærbæk bakkeøen, der fra Hovslund Station (Stenhøj, 86 m) strækker sig helt ud til vestkysten ved Astrup (hvor dens moræneler og sand brugtes til Rømødæmningen). Denne bakkeø har mere det normale bakkeø-præg end de to omtalte, men den rummer også et ret stort antal af de jorddækkede interglaciale moser, især mod SØ omkring Agerskov og Rangstrup, hvor vi i årene under og efter krigen har påvist 6–7 stykker, de fleste af helt normal udvikling. Også her vil en energisk eftersøgning sikkert kunde bringe de grønne pletter endnu nærmere ind mod den morfologiske linie i øst – (der er nu 5–7 km mellem de østligste af de kendte moser og linien).

Det nordøstligste hjørne af Tinglev Hedeslette med de pragtfulde randmoræner ved Øster Løgum, Hovslund og Rovbjerg er absolut det flotteste parti af »Hovedopholdslinien« i Sønderjylland; foruden randmorænerne er her den meget tydelige proximalskrænt (iskontakt-aftryk) af hedesletten, som her er repræsenteret af en forholdsvis mindre (og lokal) aflejringskegle med toppunkt omkring 60 m (det finere materiale i denne smukke kegle er sandsynligvis afsat af en supraglacial vandstrøm – og er bagefter gennemskåret af en ekstramarginal lille erosionsdal). Forneden under proximalskrænten kunne man tidligere i små grusgrave iagttage en »begravet« blok-randmoræne. Den ældgamle Hærvej og stam-jærnbanen følger begge kanten af hedesletten ned til Rødekro. Dette pragtfulde stykke »Hovedopholdslinie« anses også af alle for at være maximalgrænsen for sidste nedisning. Bagved linien ligger Genner åsen og en smuk lille kamesbakke, hvis overflade (52 m) flugter med hedeslettens overflade, tæt nord for Rødekro.

Ved Rødekro befinder man sig på det meget store, flade kegletoppunkt (44 m), og vest for byen fandtes de meget store grusgrave, hvor hedeslettegruset for en stor del består af hoved/fodstore rullede blokke, medens der 9 km ude i den meget jævne og regelmæssige hedeslette ligger en fremtrædende, men lille og typisk bakkeø (Riss-Saale). Ret tæt syd for Rødekro bliver der imidlertid tvivl om, hvorvidt Hovedopholdslinie og yderste isudbredelse nu længere følges!

Den egentlige Hovedopholdslinie (og hedeslettens østrand) har fra Rise utvivlsomt retning mod Torp (ved Røllum), men linien og en del af hedesletten er på et relativt sent tidspunkt bleven overrendt af en istunge, der fra Aabenraa Fjord skød sig ind på hedesletten omtrent til det sted, hvor nu Bolderslev jernbanestation ligger, øjensynligt uden at beskadige den allerede afsatte hedeslettes dannelser på anden måde end ved at overdække dem med et dække af 1–10 m fedt moræneler, hvad der også må siges at være en noget ualmindelig foreteelse. Morænen indeholder tilmed store mængder marine Eem-mollusker, tydeligvis opskrabede af istungen fra bunden af Aabenraa Fjord, hvor der altså på dette tidspunkt var en eroderende istunge og ikke nogen tunneldalsfunktion med store smeltevandsmængder – hedesletten var jo også færdigaflejret!

Ser vi på Tinglev Hedeslette som en helhed, adskiller de østlige (men ikke nordøstlige) og sydøstlige dele sig i en række henseender fra de centrale, nordlige og vestlige dele – mere normale og regelmæssige afsnit. De nævnte østlige dele har 1.) et meget uroligere relief med 2.) grusvægge 2–6 m høje 3.) lavninger mellem disse 4.) nogle steder typiske jordfaldshuller (»Sölle«) og 5. adskillige store brede sænkninger (6–10 m dybde), f.eks. Tinglev Sø og Ulvemose – og endelig 6.) det fluviatile mønster: uregelmæssige, flade og fligede moselavninger med helt tilfældige vandløbsforbindelser mellem disse – helt uden noget veludviklet dalmønster, og man ser egentlig intet spor af normal fluviatil erosion fra sen- eller postglacial tid. I de centrale dele af hedesletten er der ingen grus-strømrygge eller jordfaldshuller, men et smukt udviklet, erosivt bestemt dalmønster med dale, der målbevidst stiler mod Tønder Marsken.

P. Woldstedt omtaler i 1913 disse forhold i den østlige del af hedesletten, men opfatter dem som vidnesbyrd om en slags udjævnede randmoræner. Ud fra dette morfologiske mønster har jeg søgt at tolke landskabet som betinget af et temmelig tyndt dødissystem, afsat af et forbigående fremstød af en istunge – ældre end den først omtalte fra Aabenraa Fjord, men alligevel så relativt ung, at hedesletten i hovedsagen var afsat. Denne istunge må altså være ældre end hovedopholdslinien inde i øst (Rise – Røllum – Kliplev – Kidskelund), i modsætning til den først omtalte istunge. Det formodede dødisdække blev så overstrømmet af et netværk af supraglaciale småfloder, der skar sig render i dødisfladen og derefter fyldte disse små flodlejer med smeltevandsgrus og -sand. Det svage punkt i min teori er, at der intet steds er påvist nogetsomhelst morænemateriale (glacigent) afsat af denne istunge. Derimod er det lykkedes at påvise eksistensen af dødis, gennem et Allerød-muldprofil i Tinglev Sø, hvor dødisens tykkelse åbenbart var så stor, at den ifølge pollenprofilet holdt sig helt til Boreal tid (7000 år f.Chr.), altså vel i mindst 3–4000 år. Denne påvisning skete ved boringer, som Johs. Iversen og jeg foretog i 1940 i forbindelse med en større undersøgelse af søkalkaflejringerne i dette ejendommelige søbassin, hvis forhold blev ret grundigt oplyste gennem foretagelse af mere end 100 boringer (dog kun et ringere antal med Hiller-bor). De af Iversen i et par af disse boringer udtagne pollenprøver er analyserede af Alfred Andersen og publicerede i 1954, og disse pollendiagrammer viser, at sedimentationen – bortset fra Allerød-mulden, der dannedes oven på isen, hvor der voksede Pinus! – først kunne begynde i Boreal tid ved overgangen fra Birke-fyrretid til Hassel-fyrretid for ca. 9000 år siden. Fra disse borepunkter ud til den morfologiske grænse, som jeg havde trukket på det omtalte grundlag af overfladeforholdene, er der kun en afstand på 2 km. Selve den af mig trukne grænse i hedesletten ligger 24–28 m o. havfladen; bunden af sedimentserien i Tinglev Sø ligger 12 m o.h. – en depression i en hedeslette på 14 m dybde kan man jo ikke acceptere uden en specifik forklaring. Den trukne grænse i hedesletten viser intet spor af randmoræner – ikke en gang enkelte store sten eller blokke – og er i sig selv yderst lidt synlig i terrænet. Alligevel er der efter mit skøn en tydelig forskel mellem de østlige dele af hedesletten, der blev aflejret oven på dødisrester (flade – pladeformede?) og de vestlige og nordlige dele uden sådanne spor. Har der været en istunge fremme over disse områder på et eller andet tidligere stadium af Würm-Weichsel (forud for Hovedopholdsliniens tid), burde der i dybere niveau under hedeslettelagserierne eller dele af dem kunne findes glacigene lag (moræneler), men de skulle altså ligge i højere niveau end Riss-Saale's store Kridtmoræne.

Dette problem har vi efterforsket bl.a. i adskillige boringer ved Tinglev Vandværk (1933, 1938 og sidst i 1968), men helt uden held trods meget omhyggelig prøvetagning, og endda vi alle tre gange havde et interglacialt niveau som sikker begrænsning nedadtil, de to første gange marint Eem, men sidste gang kun ferskvandsinterglacial.

Naturligvis bør man også holde øjnene åbne for eventuelle helt nye tolkningsforsøg, men genfrysning af smeltevand i helt store, flerårige »aflejringskegler« har man dog vist ingen antydninger af ved recente indlandsdækker og »pingo-fænomener« kan dog vist heller ikke yde os brugelige synspunkter!

Hertil har mine egne betragtninger kun drejet sig om landet omkring Kongeåen og syd derfor. For det nørrejydske område ville jeg også fremkomme med nogle bemærkninger. For hele midtstykket mellem Vejen og Silkeborg har jeg intet nærmere personligt erfaringsgrundlag. Skal vi tegne landsdels- eller oversigtskort, må vi for dette parti indtil videre bruge de af V. Milthers givne linier i beskrivelserne til kortbladene Bække og Brande; dog vil jeg for min part også fremtidig – som Keld Milthers og jeg gjorde i 1954 på Danmarkskortet til Geologi og Vandboring – undlade at afbilde tungen nord for Brørup, der af V. Milthers baseredes på den tvivlsomme mose i Brørup Mergelselskabs Grav og på de skånske basalters hyppighed – og dette sidste indicium har vi jo fra Rødding Bakkeø fået en vis mistillid til. Fra Vejen stationsby vil jeg trække vor ydergrænselinie over Hundsbæk Plantage ved Læborg og derfra følge V. Milthers over Vorbasse-Ringgive-Brande-Paarup. På denne lange strækning er der ikke mig bekendt fundet interglaciale moser med periglaciale dæklag, som kunne forskyde – eller fastlåse – maximaludbredelseslinien, der her altså efter V. Milthers – ligger noget vestligere end den mest udprægede landskabsgrænse.

V. Milthers har jo imidlertid været ret ene om at fastlægge linierne her, så det kunne jo nok være nyttigt, at unge og friske øjne beskæftigede sig med hans liniedragninger, eventuelt fandt nogle flere interglaciale moser, der jo stadig væk må anses for det bedste kriterium.

Går man nord for linien Herning – Paarup – Silkeborg altså til egnen med Karup Hedeslette og Storå-området, melder problemerne og modsatte anskuelser sig igen. For Ussing var det intet problem, da han mere eller mindre stiltiende regnede med, at også Skovbjerg Bakkeø havde været omfattet af sidste isbedækning; men efter Victor Madsens behandling af denne bakkeø's morfologi (navnet tunneldal defineret her) har gennemgående alle anset denne bakkeø for uberørt af sidste nedisning på anden måde end ved smeltevandserosion af randene og så naturligvis de periglaciale virkninger. Ellers synes man almindeligvis at have tænkt sig, at den Ussingske »Hovedopholdslinie« også så nogenlunde var ydergrænsen for sidste nedisning, (Overs. o. Danmarks Geologi, 1928).

Et distinkt forslag til en ændring af denne almene opfattelse fremkom 1935 fra Keld Milthers som »en begravet Randmoræne under Karup Hedeslette« nemlig omkring Feldborg, hvor han mener, der under hedeslettens lag er antydninger af en randmoræne, der kunne tænkes at være jævnaldrende med det ældre stadium, hvor Sønderhede (samtidig med Kronhede og Klosterhede) dannedes endnu før afsætningen af den egentlige Karup Hedeslette kunne påbegyndes, idet dette område endnu var isdækket. Jeg personlig har i 1935 karteret Grove Sogn midt på Karup-sletten og fandt da i grusgrave i dalen ved Gindeskov Bæk ligeledes hedesletteaflejringernes underlag: en slags stenet moræne af norsk præg og ret stærkt forvitret, så jeg opfatter dette underlag for at høre til Riss (Saale) og konkluderede, at Würm-isen selv næppe havde været ude over dette punkt – altså i modsætning til Keld Milthers, der i 1942 (disputatsen) genfremstillede sin linie, trukket oppe fra Sevel-hjørnet af Sønderhede skråt mod SØ over Feldborg ned til NV-spidsen af Bording Bakkeøen.

I 1948 giver V. Milthers imidlertid på sit morfologiske kort den overraskende linieføring for ydergrænsen, hvormed han tilkendegiver, at han nu mener, at den nordøstlige del af Skovbjerg Bakkeø var dækket af Würm-isen. Han motiverer dette nye synspunkt dels med betragtninger over reliefforhold og vandløbsforhold, dels med tilstedeværelsen af de to søer, Sunds Sø ude på hedesletten og Gjødstrup Sø, der ligger mellem Herning By og salthorsten ved Nøvling, men han synes i teksten dog selv at være tvivlende. V. Milthers liniedragning synes ikke at have fået tilslutning fra nogen sider, heller ikke fra hans søn (Keld Milthers). Da Keld og jeg i 1954 lagde navn til det kvartær-morfologiske kort i »Geologi og Vandboring« brugte vi kun Ussings linie, og på A. V. Nielsens og mit kort fra 1960 (intern. kongres) satte vi Keld Milthers linie over Feldborg på (ligesom Ødums linie i Sønderjylland), endskønt jeg havde mine tvivl om begge liniestykker. Til løsning af problemet her på Karup-sletten og Skovbjerg Bakkeø vil jeg foreslå en nøjere eftersøgning af interglaciale moser på den nordøstlige del af bakkeøen, nye fund ville jo kunne vise, om Milthers senior skulle have ret.

Angående den Ø-V-gående del af den Ussingske linie fra Hagebro eller Sevel til Vesterhavet har der næppe været fremsat andre meninger, end at denne linie med dens smukke istunger og randmoræner skulle repræsentere såvel »Hovedopholdslinie« som ydergrænse. Mellem Trans og Fjaltring findes der syd for Dybå's udmunding i Vesterhavet en klint, hvor man næsten på meter kan bestemme grænsen Riss/Würm, medens hele Bovbjerg Klinten N derfor så afgjort viser snit gennem lag fra sidste nedisning.

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GEOLOGISK BASISDATAKORT

med kurver for den prækvartære overflade fra

JUELSMINDE KOMMUNE

....

SIGNATURFORKLARING

• Boringens beliggenhed

Koternes position i cirkelringene (m)

DGU ark.lb.nr. (821)
Bor. udførelsesår (1968)

Filterintervaller (a,b)
Filterdiametre (2",4")

Terræn (kote +22)
Borediameter (14")
Laggrænser (+7, −11)

Grundvandsspejl (a,b; kote +12, +3)
Evt. pejleår (1971)

Jordlagssymboler

Ydelse (m³/h/m sænkn)
DGU – prøvebeskrivelse foreligger

B Brønd
DG Smeltevandsgrus
DI Smeltevandssilt
DL Smeltevandsler
DS Smeltevandssand
DV Vekslende smeltevandsaflejringer
FI Postglacial ferskvandssilt
FL Postglacialt ferskvandsler
FS Postglacialt ferskvandssand
G Grus, grus og sten
GI Glimmersilt
GP Gytje
GL Glimmerler
GS Glimmersand
HL Postglacialt saltvandsler
HP Postglacial saltvandsgytje
HS Postglacialt saltvandssand
I Silt
KS Kvartssand
L Ler, mergel
LL Lillebæltler, plastisk ler
ML Moræneler
MS Morænesand
OL Oligocænt ler
Q Sandsten
S Sand
SL Søvindmergel
T Tørv
TI Senglacial ferskvandssilt
TL Senglacialt ferskvandsler
TS Senglacialt ferskvandssand
U Ler og sand, Ler og sten
V Vekslende små lag
X Ubekendte lag

GEOLOGISK TOLKNING

Postglaciale ferskvandsaflejringer
Postglacialt saltvandssand
Postglacialt saltvandsler
Postglacial saltvandsgytje
Senglaciale ferskvandsaflejringer
Smeltevandsler
Smeltevandssilt
Smeltevandssand
Smeltevandsgrus
Moræneler
Morænesand
Glimmersand, Kvartssand, Sandsten — Miocæn
Glimmerler, Glimmersilt — Oligocæn
Søvindmergel, Lillebæltler, plastisk ler — Eocæn

−10 / ±0 Prækvartærets overflade (kote)

Prækvartære flager i kvartæret

1:50.000

2000 1000 0 1 2km

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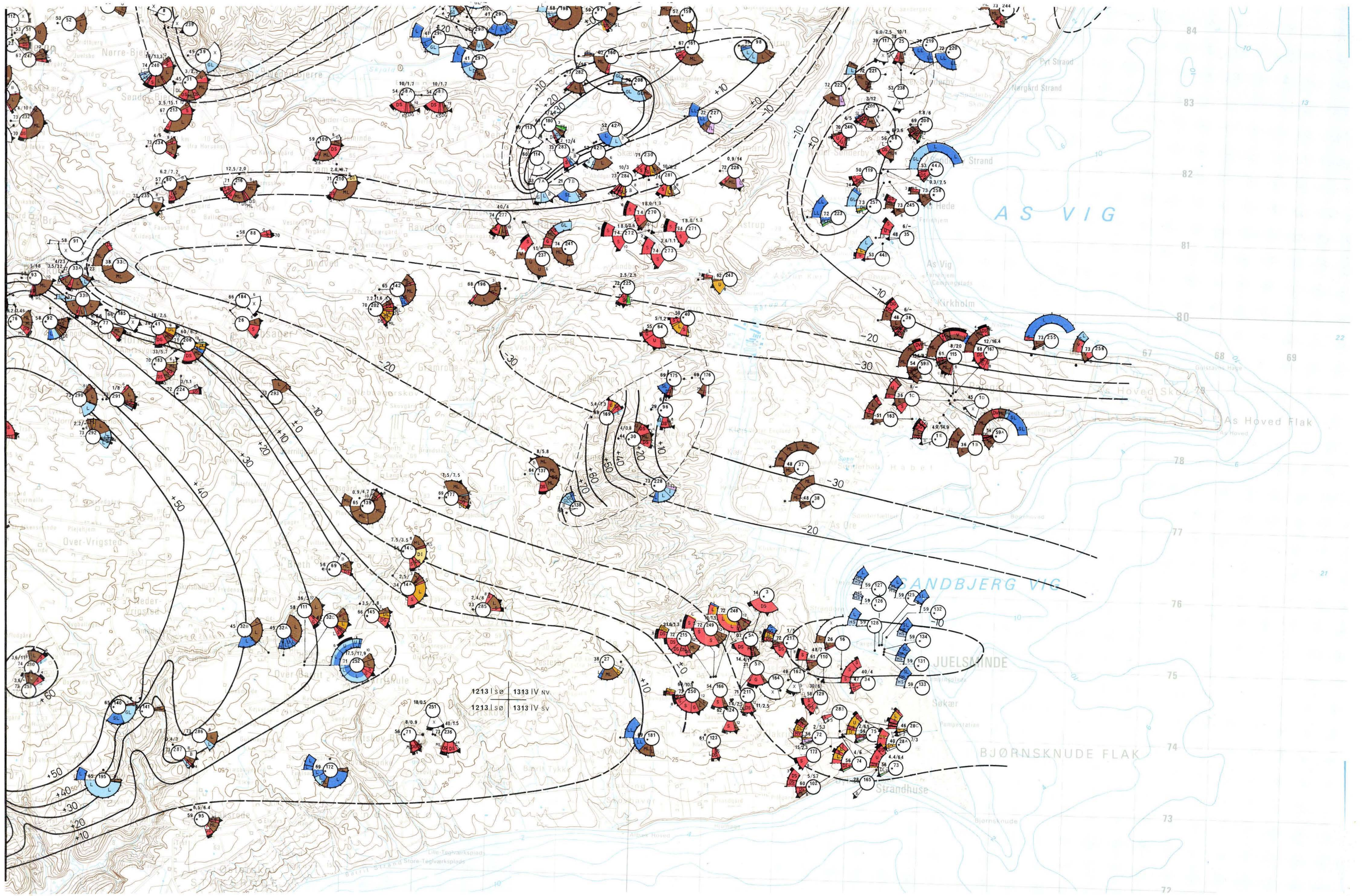
Danmarks Geologiske Undersøgelse

Jens Stockmarr, 1977



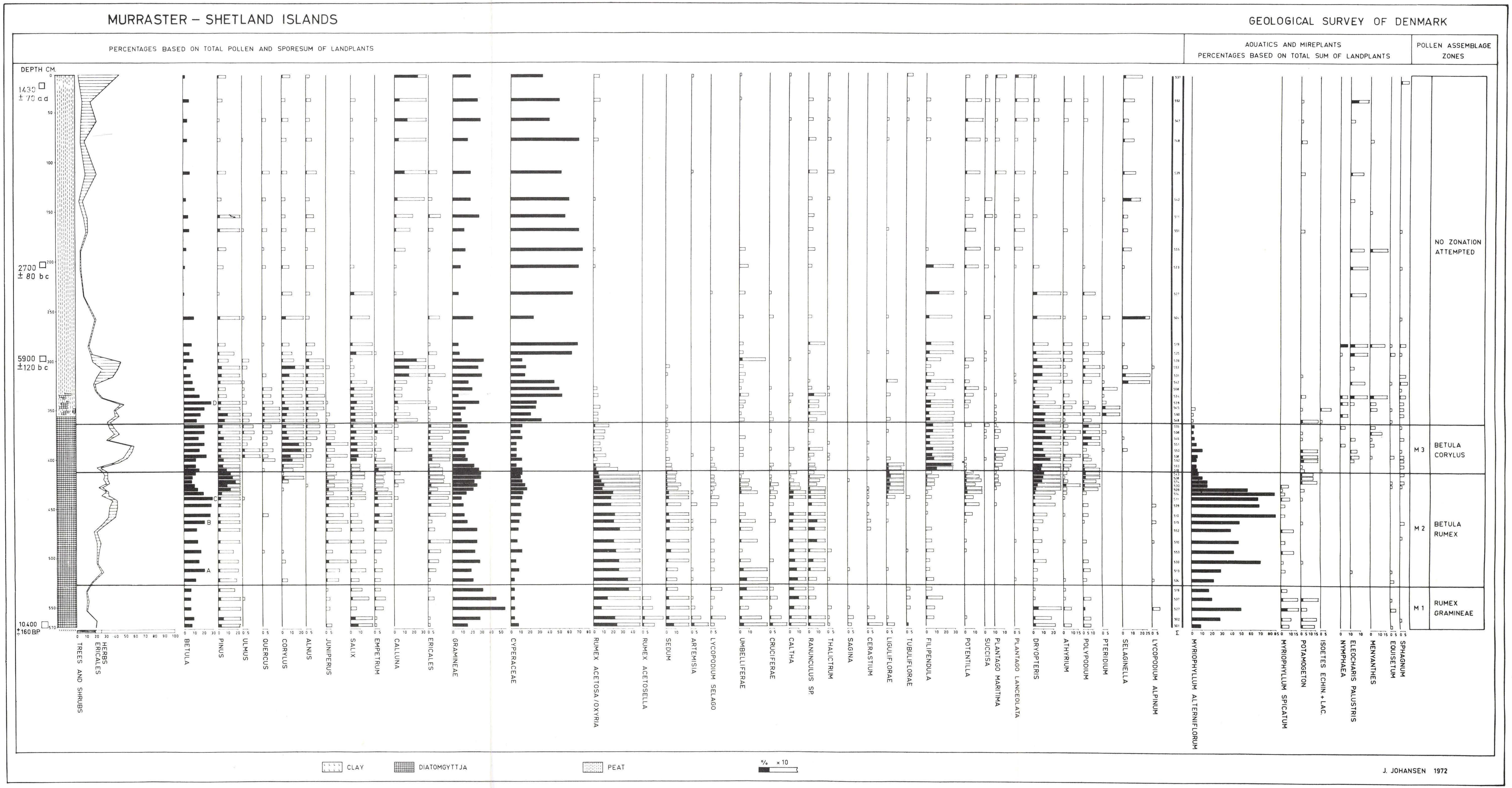


Plate 1. Pollen diagram from Murraster, Shetland Islands, (from Jóhansen 1975), with the new radiocarbon datings.