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HOLOCENE HISTORY OF VEGETATION AND LANDSCAPE ON THE KÕPU PENINSULA, HIIUMAA ISLAND, ESTONIA

Lars-König KÖNIGSSON[a], Leili SAARSE[b], and Siim VESKI[a, b]

[a] Institute of Earth Sciences, Quaternary Geology, Norbyvägen 18B, S-75236 Uppsala, Sweden; e-mail: lars-konig.konigsson@natgeog.uu.se
[b] Institute of Geology at Tallinn Technical University, Estonia pst. 7, EE-0001 Tallinn, Estonia; e-mail: saarse@gi.ee, veski@gi.ee

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Abstract. The Kõivasoo area is partly covered by aeolian sands poor in nutrients. Sedimentation started here later than the immigration of *Alnus* and with *Tilia* as an important marker. The development of the area includes the time since the immigration of *Alnus* into Hiiumaa, but several hiatuses have been recorded. Kõivasoo is extremely poor in cultural landscape and therefore merely animal husbandry has been practised there with little agriculture. The curves for xerophytic-heliophytic plants and cultural plants are not very rich but some increase in hemerophilous plants can be seen (favoured by human activities). An increase in charcoal dust is seen in Late Boreal, two in Early Atlantic and Late Atlantic, and one in Early Sub-Boreal times. The charcoal maxima occur together with expansions of xerophytic-heliophytic plants and hemerophilous plants like *Artemisia*, Chenopodiaceae, Asteraceae tubuliflorae, *Pteridium*, and *Urtica*. Supposedly they all grew in settlements, pathways, or clearances connected with the Late Mesolithic sites which are now excavated east of the Kõivasoo Bog.

Key words: pollen analysis, cultural history, archaeological development, Mesolithic settlements, landnam phase.

INTRODUCTION

Large islands in the Baltic Sea off the Estonian and Swedish coasts have long attracted the interest of botanists, geographers, and geologists. All islands show marginal conditions for plants, animals, and culture, and the marginality is both edaphic and climatic.

The organic world is very special on the islands. Many of the local plants and animals are characterized as relict forms, when compared with the main distribution of the same species in arctic and subarctic environments, as well as in continental areas in the southeast of Europe or in the more oceanic regions in the southwest and west. Numerous questions about possible immigration routes within and across the Baltic basin have arisen and some of them have never been sufficiently explained.

Both the climatic and cultural development trends are better studied in edaphically marginal areas than in areas with a heavy cover of Quaternary deposits upon the bedrock. Marginal conditions characterize all these islands, however to a lesser or larger degree. Therefore the islands serve as valuable objects for the study of palaeoenvironmental changes.

A transect across the Baltic from the Danish island Funen via Öland and Gotland to Saaremaa and Hiiumaa, and farther to the Estonian mainland and east to Russia passes over several climatic zones, showing a west–east transition from more oceanic to more continental conditions. The palaeoenvironmental changes taking place along this profile during the Holocene might, because of the edaphic circumstances, describe the changing climatic conditions especially adequately, and we have assumed that even minor changes might have resulted in vegetation or environmental impacts quite promptly.

The present investigation of one bog-site on western Hiiumaa forms a part of a research along the profile actively studied since the middle of the 1960s and as a joint Estonian–Swedish project since 1971. Our aim is to apply detailed analysis techniques to material from the bog and to use new geological and archaeological information (Eltermann, 1993a, 1993b; Lõugas et al., 1995; Kriiska, 1995, 1996; Moora & Lõugas, 1995; Raukas & Ratas, 1995), palaeobotanical results, and accelerator mass spectrometer (AMS) ^{14}C dating as a basis for the reinterpretation of the results.

Hiiumaa Island (Dagö) is rather young in its present shape, though its highest parts emerged from the sea more than 10 000 BP according to the existing knowledge about land uplift. As we know, the only bog dating back to earlier ages is that of Kõivasoo on the Kõpu Peninsula (Fig. 1). It occupies a former lagoon basin and the possible time when it was isolated from the Baltic basin has long been debated (Kessel & Raukas, 1967; Sepp, 1974; Ratas, 1976; Sarv, 1981; Sarv et al., 1982; Raukas & Ratas, 1995).

The first pollen diagram from Kõivasoo was presented by Kents in 1939 (analysed by P. Thomson). It showed sedimentation of calcareous gyttja during the Late Boreal, succeeded by *Carex* peat growth in the Atlantic and onwards. Kessel elaborated a second pollen diagram which confirmed Kents's results (Kessel & Raukas, 1967). Both diagrams were made in the mode of these times and were based upon tree pollen taxa only.

Kessel also studied the mollusc fauna at Kõivasoo and used the results to calculate a chronology of the isolation of the bog from the Baltic. According to

Kents the Litorina Sea transgression limits reached 27.3 m a.s.l. on the Kõpu Peninsula. Thus, the Litorina Sea could have transgressed into the Kõivasoo basin (Kents, 1939). Kessel, who used also diatom analysis for her interpretation, did not accept this view. She suggested that the isolation occurred about 7000 BP (Kessel & Raukas, 1967).

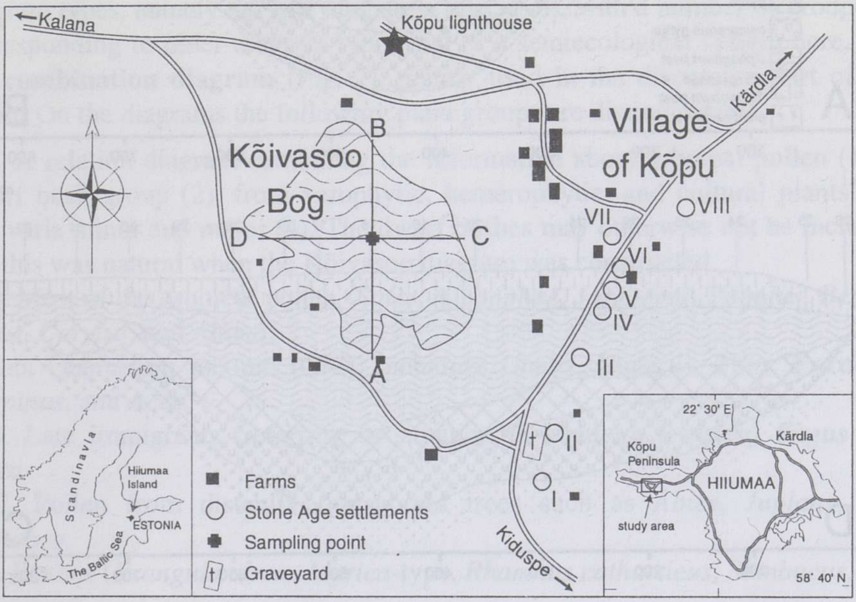

Fig. 1. The location of the Kõivasoo Bog, the Stone Age archaeological settlement sites, and the position of the investigated transects A–B and C–D.

Sarv repeated the pollen study of the Kõivasoo deposits, added macrofossil analysis to the methods used, and first applied ^{14}C analyses to the stratigraphy (Sarv, 1981; Sarv et al., 1982). The results showed that the lagoon probably separated from the Baltic basin already during the Late Boreal and at least 8200 BP (Sarv et al., 1982).

Based on fieldwork, we placed Kents's sampling spot tentatively close to the margin of the bog. It roughly coincides with core 5 in our profiles (Fig. 2). The sampling spot of Kessel and Raukas would lie close to our core 7, while Sarv's core has probably been taken near our cores 9 and 10. The position of the older cores has been decided on the basis of a correlation between the earlier reported stratigraphies and our profiles, and especially on the correlation with our depth figures of the contact between gyttja and calcareous gyttja (Fig. 2).

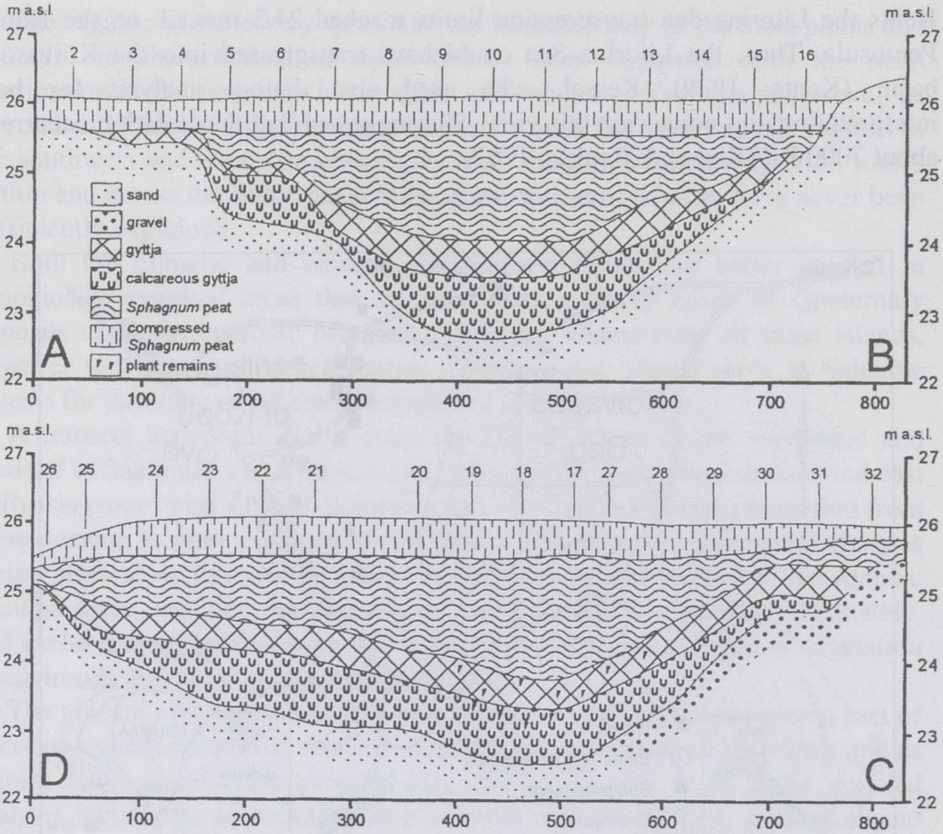

Fig. 2. Transects from the Kõivasoo Bog. For location see Fig. 1.

METHODS

Both the profiling and sampling were performed with a Belarus peat auger. Core 9, almost 3.5 m deep, was subsampled with an 1 cm interval. For geochemical investigations 2 cm thick samples were collected. These were dried at 105 °C for 48 hours, weighed, and kept in an oven at 500 °C for two hours, then weighed once more and heated at 825 °C. Finally the organic matter and carbonate contents were calculated (Fig. 3).

Pollen samples were prepared following standard methods. Samples containing minerogene particles were treated with HF according to Jørgensen (1963). Routine counting of the pollen grains was made at ×25 magnification, using ×10 oculars. Special determinations included phase contrast analysis at ×40 or ×100 magnification. No special measurements of larger grass pollen were made, nor were pore measurements practised. Pollen of *Hordeum*-type may then include barley, but might comprise millet pollen and some other large Gramineae as well. By all determinations the reference collection of the Department of Quaternary Geology at Uppsala University was used for comparison.

The pollen diagram was worked out mainly according to the ideas put forward by Königsson (Königsson, 1968; Königsson et al., 1995). Some of the ideas behind may be discussed and the decision of joining *Picea* and *Fagus* together in "the late immigrants" may well be debated. There are, further, two diagram types, namely the **full diagram** (Figs. 4–6), with a number of groupings corresponding to older diagram types and to a semiecological system here, and the **combination diagram** (Fig. 7), mainly used in the discussion part of the paper. On the diagrams the following plant groups are distinguished:

1–4. A relation diagram combining the information about arboreal pollen (1), a dwarf bush group (2), from xerophytic, hemerophytic, and cultural plants (3), and varia minor and major (4). The dwarf bushes may otherwise not be included but this was natural when the Kõivasoo diagram was constructed.

1 A. Most of the arboreal pollen (*Salix*, *Hippophaë*, *Juniperus*, *Populus*, *Betula*, *Pinus*, *Corylus*, and *Alnus*).

1 A:b. Quercetum mixtum (QM), including *Ulmus*, *Quercus*, *Tilia*, *Fraxinus*, *Carpinus*, and *Acer*.

1 B. Late immigrants (referring to situation in southern Sweden) *Fagus* and *Picea*.

1 C. Pollen from distantly transported trees such as *Abies*, *Juglans*, and *Castanea*.

1 E. Bushes (*Frangula alnus*, *Myrica*-type, *Rhamnus catharticus*, *Sambucus*, and *Viburnum*).

2. Dwarf bushes (*Calluna*, *Betula nana*, *Empetrum*-type, Ericaceae, *Vaccinium*-type). This group may include *Ephedra* too.

3 A:a and A:b. Xerophytic plants, minor and major. Since it has been important to follow the summary curve of the minor constituents and since the major constituents may dominate, we have chosen to divide these (and some further) curves in the one called "minor" and the one called "major".

3 B. Other terrestric plants.

3 C. Possibly cultivated plants (*Avena*-type, Cannabaceae, sometimes *Cannabis* and *Humulus* are distinguished, *Fagopyrum*-type, *Hordeum*-type, *Linum usitatissimum*, *Triticum*-type).

3 D:a and D:b. Hemerophilous plants, minor and major. Distinction according to Sterner (1938).

3 E. Terrestric spores.

4 A:a and A:b. Varia, minor and major.

5 A. Fen plants.

6 A. Aquatic plants.

7 A. Algae (*Pediastrum*, *Botryococcus*, Hystrix-Hystrichosphaeroid cysts).

8 A. Bryophyta.

9 A. Stomata.
10 A. Charcoal.
11 A. Destruction degree.
12 A. Pollen sum.
13 A. Diversity.

SITE DESCRIPTION

Kõivasoo is a small raised bog in the southern part of the Kõpu Peninsula (58°54’N, 22°12’E). It measures some 1120 × 875 m and has a modern vegetation cover with pine trees, *Sphagnum*-species, and heather dominating. Coastal formations and bluffs of some Baltic prestages surround it. To the north is Mägipe Hill with Tornimägi that reaches an elevation of 66.2 m a.s.l. Dune sands lying westwards reach 45.2 m a.s.l.

Geological setting and environmental conditions

The Kõpu area has an Ordovician substratum, mainly consisting of limestone. The overburden is characterized by glacial, glaciofluvial, marine, and aeolian deposits, the thickness of which amounts to some 82.7 m (Eltermann, 1993a). Mägipe Hill with Tornimägi is supposed to be of glacial, mostly erratic origin (Eltermann, 1993a, 1993b). The hill is surrounded by different beach formations of various Baltic prestages (Kents, 1939; Kessel & Raukas, 1967; Raukas & Ratas, 1995).

Ancylus Lake formations are located at levels between 30 and 45 m a.s.l., Litorina deposits at 15.5–27 m a.s.l. (Kents, 1939). New measurements of the terraces and bluffs have also shown levels of 30–40 m a.s.l. on the northern slope of the hill and 27–35 m a.s.l. on the southern slope (Eltermann, 1993b).

About 60% of the island is covered by pine, birch, and spruce woodlands, swampy thickets, and juniper shrubbery (Sepp, 1974; Saarse, 1994). Arable land makes up less than one-fourth of the territory and occurs in coastal areas and around villages. The flora is rich, with about 1000 species of higher plants and 50 rare species that are under protection (Sepp, 1974). Pine–spruce–birch forest and sandy heaths rich in lichens as *Cladonia* (Rebassoo, 1967) form *c*. 70% of the Kõpu Peninsula. The number of rare species, mainly Sub-Atlantic and Mediterranean ones (*Taxus baccata*, *Hedera helix*, etc.), is around 80.

At the beginning of historic times Hiiumaa was rather sparsely populated and used as the Saaremaa hinterland for hay making and timber cutting (Sepp, 1974; Ratas, 1976). According to Johansen (1951), Hiiumaa was permanently settled in the 13th century. However, the central part of the island stayed almost unsettled throughout the medieval period. By the 19th century, 13 estates and numerous farms owned and cultivated all suitable land. Forest cutting was very intense during the 16th–18th centuries, because the Kõpu lighthouse, Kärdla cloth mill, and building of Tallinn and Paldiski harbours needed timber. This caused a drastic decrease in the forest area and the migration of coastal dunes, especially on the Kõpu Peninsula (Tiismann, 1924). Owing to large-scale amelioration, the area of meadows and arable land has increased up to 30% during the last 40 years.

Archaeological remains

The village of Kõpuküla is rich in prehistoric monuments (Lõugas et al., 1995). The oldest finds are the Stone Age hearths on Ancylus and Litorina beach ridges, charcoal of which is dated to 6755±50 BP (Tln-2016) and 6640±60 BP (TA-2533) (Kriiska, 1996). More than 10 stone-cist graves have been identified, dating back to the Iron Age (Lõugas, 1981). One iron melting place and several stone heaps in the forest nearby have been excavated (Lõugas, 1981). They might derive from the Iron Age and mark an ancient field system.

RESULTS AND INTERPRETATION

Lithostratigraphy

We investigated the morphology and sediment stratigraphy of the Kõivasoo (Bog) Lagoon along two transects (Fig. 2). They show that the bottom topography of the bog is uneven, with terrace-like surfaces in the southern and eastern parts of the basin between the heights of 24–25 m a.s.l. The basal sediment is sand with plant remains in the deeper part of the basin and gravel on the slopes. It is covered by a calcareous unit, which on the lithological transects is shown as calcareous gyttja. Along the west–east transect (Fig. 2, D–C) the thickness of this unit is rather uniform, about 1 m, on the south–north transect (Fig. 2, A–B) the thickness varies, but does not exceed 0.90 m. Calcareous gyttja is covered by gyttja, which imprints the bottom topography of the basin with a total thickness of about 0.5 m. The lowermost gyttja unit is enriched with mollusc shells, the uppermost with plant detritus. Between them is an algae-gyttja bed. In Fig. 2 the lithology on the transects is simplified and different gyttja beds are indicated as one gyttja layer. The contact between the calcareous gyttja and gyttja is sharp and in some places paved with huge amounts of mollusc shells and thin sand lamina (Fig. 2, cores 17–19).

The lacustrine deposits are covered with peat, represented mostly by *Sphagnum* peat. A detailed description of the deposits is given below. The sediment composition is displayed in Fig. 3 and it shows one soil erosion period about 4400 years ago at the level of 125.5–126.5 cm.

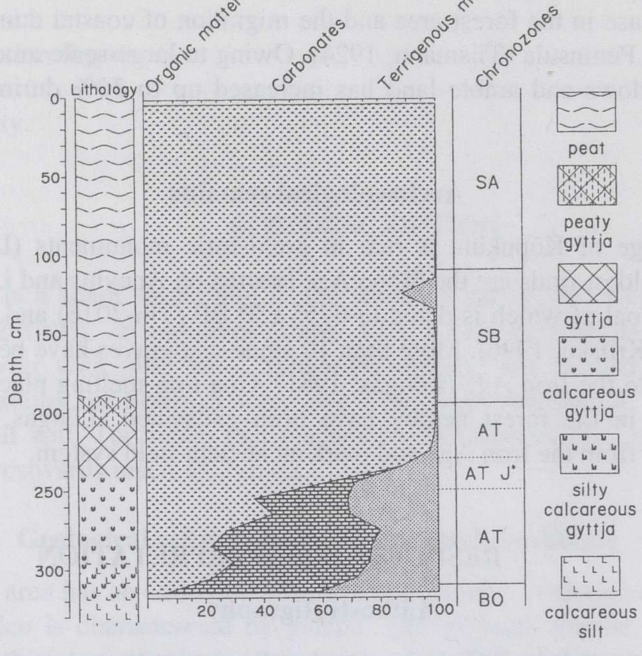

Fig. 3. Sediment composition of the Kõivasoo Bog (core 9).

Lithostratigraphy of the monolith

The monolith is described in the pollen diagram as a subdivision of peat underlain by gyttja, calcareous gyttja, downwards silty, and silt with some calcareous gyttja and mollusc remains (Figs. 1, 2, core 9). The general characterization of the deposits is given using the Troels-Smidt (1955) system. The lithology is simplified in Figs. 2–7.

A. 344–318 cm: calcareous silt with shell fragments. At 340 cm clay layer. Bands and black spots, which might be FeS or heavy minerals as magnetite. Formula: *Ag* 3, *Lc* 1, (α+β)+. The core continued in underlying sand or silt.

B. 318–295 cm: banded grey calcareous gyttja with shades in olive green (algae remains), silty. At 300 and 314 cm tendencies of FeS spots or restricted bands. Upper *limes* indeterminable. Formula: *Lc* 4.

C. 295–291 cm: olive-grey, partly with black spots calcareous gyttja. Clear cyclotheme structure, but not in bands. Shell fragments. Upper *limes* ±1 mm.

D. 291–283 cm: light grey calcareous gyttja, almost without cyclothemes. Upper *limes* 1–5 mm. Formula: *Lc* 4.

E. 283–276 cm: yellowish grey calcareous gyttja with dark spots or points of FeS or organic. Upper *limes* ±1 mm. Formula: *Lc* 4, *Ag* (+).

F. 276–267 cm: light grey calcareous gyttja with some Characeae peat detritus in cyclothemic structure. Upper *limes* 1 mm–1 cm. Formula: *Lc* 4.

G. 267–256 cm: yellowish grey calcareous gyttja with darker bands, possibly with algae remains. Upper *limes* 1 mm–1 cm. Formula: *Lc* 4, *Ag*(+), Th^2++.
H. 256–246 cm: yellowish grey calcareous gyttja with obvious cyclotheme structures. Scattered plant and shell fragments, some silt. Upper *limes* unknown. Formula: *Lc* 4, *Ag* (+), Th^2 (+).
I. 246–240.5 cm: light grey calcareous gyttja with plant detritus, shells and shell fragments of *Pisidium* sp., *Bithynia* sp., *Limnaea ovata*. Small sand lenses, some *in situ* Characeae; they should be considered as thin peat fragments, sedentary grown. Upper *limes* ±1 mm. Formula: *Lc* 3, *Ag*++, α+β, (α+β)+.
J. 240.5–234.4 cm: greyish olive-brown homogeneous fine-grained gyttja, with small lenses of silt and plant detritus. Upper and lower *limes* ±1 mm. Formula: Ld^2 1, *Lc* 2, *Ag* 1, Th^2+.
K. 234.4–227 cm: olive-grey fine-grained gyttja with a 0.4 mm silt layer between 234–234.4 cm. Abundance of plant detritus. Both upper and lower *limes* ±1 mm. Formula: Ld^2 1, *Lc* 2+, *Ag*+ , Th^2++.
L. 227–211.5 cm: yellowish grey, quite homogeneous fine-grained gyttja, downward with silt and plant detritus. Upper *limes* ±1 cm. Formula: Ld^2 1, *Lc* 2, *Ag* 1, Th^2+.
M. 211.5–208 cm: pink-coloured algae gyttja with peat detritus in the uppermost part, homogeneously fine-grained, sandy. Upper *limes* ±1 mm. Formula Ld^2 3, *Ag* 1, Th^2+.
N. 208–201 cm: yellowish brown peat detritus and sand containing gyttja. Upper *limes* > 1 cm. Formula: Ld^2 2, Th^2 2, *Ag*+.
O. 201–197 cm: dark brown gyttja containing peat. Upper *limes* invisible. Formula: *Ld* 3, Th^3 1.
P. 197–190 cm: dark brown peat, probably with gyttja admixture. Contains *Eriophorum* stands. Upper *limes* >1 cm. Formula: Tb^3 1, Th^3 1–2, *Ld* 2, *Lc*+.
Q. 190–180 cm: yellowish brown *Sphagnum* peat. Contains a lot of other peat detritus and might have been formed in the telmatic zone just around the water level. Upper *limes* ±1 mm. Formula: Tb^2 1, Th^2 3.
R. 180–179 cm: blackish *Sphagnum* peat, decomposed or with charcoal. Upper *limes* quite sharp, ±1 mm. Formula: *Sh* 4?
S. 179–163 cm: lightly yellowish grey-brown heterogeneous *Sphagnum* peat with abundant peat detritus. Might be an admixture with a telmatic peat or limnic peat of *Phragmites* or *Typha* types. Upper *limes* >1 cm. Formula: Tb^3 3, Th^3 1.
T. 163–148 cm: brownish fine-grained *Sphagnum* peat with *Eriophorum* rests and some wood fragments. Upper *limes* >1 cm. Formula: Tb^3 3++, Th^1++.
U. 148–126.5 cm: brownish *Sphagnum* peat with *Eriophorum* rests and some wood fragments. Quite sharp upper *limes*, about ±1 mm. Formula: Tb^3 4, Th^1+, *Tl*+.
V. 126.5–125.5 cm: black layer, fine-grained, probably *Sphagnum* peat with sand and charcoal. Sharp upper *limes* <0.5 cm. Formula: *Sh* 4, Th^1+.
X. 125.5–98 cm: fine-grained greyish brown homogeneous *Sphagnum* peat with some *Eriophorum* stands. A few rootlets still penetrate the deposits down to this level. No visible upper *limes*. Formula: Tb^4 4, *Th*+.

Y. 98–77 cm: greyish compact homogeneous *Sphagnum* peat with occasional wood fragments. Formula: Tb^4 4, *Th*+, *Tl*+.
Z. 77–49 cm: dark brown to blackish brown homogeneous highly humified *Sphagnum* peat with few rootlets. No visible upper *limes*. Formula: Tb^4 4, Th^4+.
AA. 49–36 cm: slightly browned but still completely homogeneous, decomposed *Sphagnum* peat with remains of *Eriophorum* stands. Upper *limes* >1 cm. Formula: Tb^3 3, Th^3 1.
AB. 36–0 cm: dark brown to blackish brown highly humified *Sphagnum* peat with rootlets, especially in the uppermost part. Formula: Tb^3 3, Th^3 1.

Pollen analysis

Two parts, an upper with low tree pollen and a lower with considerably higher arboreal pollen values characterize the pollen diagram (Fig. 4). Pollen of Quercetum mixtum (QM) increases in the middle of the section. *Picea* pollen increases in the uppermost parts. *Pediastrum* and *Botryococcus* and some Hystrichosphaeroid cysts dominate in the lower section (Fig. 6), while the transition to the *Sphagnum* dominated peat shows an intermediate sedimentation of Cyperaceae, *Equisetum,* Gramineae, and Polypodiaceae together with pollen of fen plants and aquatics (Fig. 5).

Alnus ranges through the whole diagram while *Tilia* starts when the amount of QM increases. The *Tilia* limit is then present in the diagram, but the lower parts of it show low percentages as does QM as a whole. The pollen diversity increases upward and a number of culminations of the charcoal dust occur in the lower parts of the diagram.

Pollen of dwarf bushes is abundant in the upper section especially *Calluna*, Ericaceae, and the *Vaccinium*-type. There are also signs of hiatuses in the curve for the dwarf bushes and two pronounced minimums in the *Calluna* curve which need attention.

As said above, *Alnus* is present in the whole diagram while *Tilia* starts well below the transition between the calcareous gyttja and gyttja (Fig. 4). According to Jørgensen (1954), the QM constituents may reach a certain level where the QM collective curves obtain an Atlantic "standard" and which is ultimately dropping together with the *Ulmus* decline. This level (Jørgensen's zone VII) marked as AT J^* in Figs. 4–7 is reached a little later and may indicate the start of "true" Atlantic conditions.

The first drop in the *Ulmus* curve appears well below the transition into the peat, before what has been judged to be the real *Ulmus* decline (Fig. 4). This may have had a similar background as suggested for the Pitkasoo Mire on Saaremaa (Saarse & Königsson, 1992), namely that there might have been an earlier drop in the QM curve because of an earlier land-use (combined with a slight rise in the *Pinus* curve). The final diminishing of *Ulmus* is then related to a later drop in the QM curve which happened already before the landnam phase *sensu stricto*. Apart from the mentioned increase in the *Pinus* curve, however, no other signs may be seen, neither in the *Juniperus* curve nor in the curves of xerophytic or hemerophilous plants.

Chronology

Two sets of radiocarbon dates have been obtained from the Kõivasoo Bog. Samples for the first set were taken by Sarv and Ilves (Sarv, 1981) about 50 m north from our main core (near our core 9–10, Fig. 2) and analysed at the ^{14}C-laboratory of the Institute of Zoology and Botany, Tartu (laboratory index TA in the table). The bulk organic matter or carbonate fraction was used for datings. The depth adjustment with our core is based on the correlation of the stratigraphical borders and the results of pollen analyses. The second set of samples for AMS dating was taken from our main monolith (core 9) and analysed at the Ångström Laboratory, Department of Ion Physics, Uppsala (laboratory index Ua in the table). At the depths of 36 and 140 cm a piece of wood was analysed, at 241 and 289.5 cm plant fragments were washed out and chemically pretreated using the normal acialkali-acid method (Königsson et al., 1995; Possnert, 1990). Wood as terrestrial material was a good object for dating, however, the date 2775±65 seems too old. The plant fragments washed out from the calcareous gyttja are more problematic in this respect, especially the date 8495±85 (Ua-12 070), which does not match with the pollen stratigraphy. Other dates, even the uppermost date 1060±60 BP, resulted from different radiocarbon techniques fit with the pollen stratigraphy, as the bog today is heavily drained and the uppermost peat is thus thought to have gone through oxidation and compression. This suggestion is also supported by the nonexisting *Secale* curve, confirming the changes in the upper part of the sediment column.

Results of radiocarbon dates from the Kõivasoo Bog

Depth, cm	Adjusted depth, cm	^{14}C age, BP	Laboratory No.	Material
Core 9				
36		2775±65	Ua-12073	Wood
140		4615±70	Ua-12072	Wood
245.5		6825±85	Ua-12071	Plant fragments
289.5		8495±85	Ua-12070	Plant fragments
Sarv, 1981				
0–10	0–10	1060±60	TA-523	Bulk organic
50–60	65–75	2440±60	TA-524	Bulk organic
100–110	110–120	4360±60	TA-525	Bulk organic
180–190	185–195	4860±70	TA-526	Bulk organic
200–210	215–225	6580±60	TA-527	Bulk organic
220–230	245–255	7440±60	TA-528	Carbonate fraction
230–240	260–270	7850±70	TA-529	Carbonate fraction
270–280	315–325	8190±90	TA-530	Carbonate fraction

DISCUSSION

Interpretation of pollen diagrams

There are two culminations in the **xerophytic plants**, one during the Late Boreal, the other during the Sub-Atlantic (Fig. 5). In the first case *Artemisia* and *Juniperus* (and *Populus*) dominate while *Artemisia* and some *Plantago lanceolata* dominate in the upper Sub-Atlantic part. Apart from *Artemisia* and *Juniperus*, only few other constituents are present. This might be expected as a large portion of the Kõpu Peninsula is covered with considerably thick aeolian material, till, and glaciolacustrine deposits, which is not a favourable environment for xerophytic plants. They may have grown in the nearshore zone of former Kõivasoo Lake.

This is unfortunately also the case with the (possibly) **cultivated plants** which are dominated by Gramineae >40 µm and with few pollen grains of the *Avena*-type and very few of the *Hordeum*-type. The *Avena* pollen is perhaps a more reliable cultural indicator as Gramineae >40 µm may very well include pollen from *Elymus* and *Glyceria* species too.

The two **hemerophilous** curves describe better the cultural pollen flora and the hemerophilous major group seems to include more useful information. Especially the curves for Gramineae and *Artemisia* contain such information and the amount of Gramineae pollen increases in connection with the interpreted Late Mesolithic human impact (just prior the elm decline).

The **terrestric spores** occur merely in the lower half of the diagram. This is especially true for *Lastrea dryopteris* which is the most common in the calcareous gyttja part and in the silt.

The **varia** pollen curves are abundant in two parts of the diagram in and along the transition between the gyttja and the peat, and especially in the lowermost parts of the peat. The part varia major shows particularly well the succession from the lake conditions to the peat. Another impressive succession is from the Polypodiaceae into a beginning reed formation (possibly *Phragmites*), followed by an increase in *Equisetum* spores (in two parts) and finally the appearance of Cyperaceae (*Carex*) pollen. In the peat proper the *Sphagnum* spores increase the share of the varia major sum. There are three pronounced maxima in the occurrence of spores.

The **fen plants** are merely present in the gyttja and there is also a succession seen as a change from the *Typha angustifolia/Sparganium*-type into a *Typha latifolia* and a *Menyanthes* phase, which can be described as a successive overgrowth situation.

The **aquatic plants** as well show a succession with *Potamogeton* species in the lake phase and *Nymphaea* in the gyttja, when the lake was certainly overgrowing.

The **algae** curves show interference between *Botryococcus* and *Pediastrum*. They act controversially in the way that *Botryococcus* dominates in the calcareous gyttja part while *Pediastrum* does so in the nutrient-rich lower (lagoon) silt and gyttja during the period of overgrowth.

The graph for **diversity** is quite low in the lower (Boreal) parts of the diagram but increases together with the immigration of *Tilia*. Diversity is intermediate during the Atlantic, which could be expected, but is still low during what has been interpreted as Sub-Boreal. It is especially high in the second half of the Sub-Atlantic (starting *c*. 70 cm below the peat surface).

The **charcoal dust** curve is particularly interesting. There are usual high peaks in the lower parts of the stratigraphy. Four high peak areas are recorded. The first impressive peak appears in the Late Boreal. Two peaks occur in the Atlantic in connection with the *Tilia* immigration (both at the "tail" and together with the final rise according to Jørgensen, 1954), which would indicate the entrance of the true Atlantic conditions. The third peak is connected with what is interpreted as the elm decline. All these peaks occur together with an increase in some of the heliophilous-xerothermic curves like Gramineae >40 µm, Chenopodiaceae, *Artemisia*, Asteraceae tubuliflorae, *Pteridium*, and *Urtica* (which is nitrophilous). They all may be interpreted as favoured by man in connection with the establishing of temporary or periodical settlements, pathways, or clearances.

The stratigraphy and pollen diagram

The zonation of the pollen diagram has to be judged against different sedimentologic events, especially when comparing the limits between different strata. The limit between the gyttja and the peat is almost continuous (above 1 cm) but there are different strata within the peat and in the gyttja possessing sharp limits. The following layers have sharp upper limits: V – 125.5 cm, U – 126.5 cm, R – 179 cm, Q – 180 cm, M – 208 cm, K – 227 cm, J – 240.5 cm, E – 276 cm, and C – 291 cm.

The black and fine-grained layer with charcoal and sand between 125.5 and 126.5 cm has sharp upper and also rather sharp lower limitation. It was formed due to the human impact or because of the fires in the bog and the surrounding forest, which caused wind-blown sand to be carried into the bog. Hiatuses might be calculated to have formed there, both on its upper and lower borders and within the layer proper. This level is also a turning point in the peat increment. Upwards it decreased considerably. Another such layer has been observed between 179 and 180 cm below the peat surface. It was described in the field as either completely decomposed *Sphagnum* peat or a charcoal layer. Both limitations are sharp and the pollen curves suggest that there are hiatuses included in this layer.

The transition between the detritus gyttja and gyttja containing peat happens at 190 cm. The uppermost part is without silt, but at 208 cm is a very thin and well-defined minerogenic layer. This minerogenic layer might then be interpreted as a separate short sedimentological event or as representing extremely heavy rains or rainstorms or as a sign of temporary ingressive movements from the Baltic. Below the layer the transition continues with jelly algal gyttja. The silty part of the gyttja continues downwards to 267 cm where the silt disappears completely, but it reappears in the lowest parts.

According to radiocarbon dates calcareous gyttja possibly accumulated 8200–6800 BP, gyttja 6800–5300 BP, and peat started to deposit from 5300 BP onwards. These dates are tentative, as there are lags in the sediment profile of unknown duration.

The pollen diagram and the archaeological development

Eight Stone Age sites have been found lately and they all are situated along the eastern shore of the Kõivasoo embayment-lake-fen-peatbog (Kriiska, 1996; Fig. 1). The settlement history extends into the Late Mesolithic (Kriiska, 1995, 1996). It seems quite possible that the settlement history may date back into the Late Boreal and Atlantic times according to the results and interpretations of the Kõivasoo Bog site. All the mentioned events with heliophytic-xerophytic or nitrophilous plants accompanying the charcoal dust peaks in the Early and Mid-Atlantic can very well be interpreted as signals of land occupation during these periods. The archaeological excavations at Kõpu sites I and IV displayed a lot of finds and charcoal pieces from the fire-pits which at site IV dated to 6755±50 (Tln-2016) and 6640±60 BP (Tln-2533; Kriiska, 1996). The Kõpu VIII settlement site, also rich in artefacts, was obviously founded about 500 years later. The find material and radiocarbon dates suggest that the first inhabitants came to the Kõpu Peninsula already during the Late Mesolithic (site I; Kriiska, 1995). Obviously they were seal hunters, as the osteological material consists mostly of bones of ringed seal (Lõugas et al., 1995; Moora & Lõugas, 1995). Unfortunately the Stone Age habitation of the seal hunters at Kõpu falls into the period when the former lake at Kõivasoo began to overgrow, producing much local pollen and thus hampering the distribution and representation of pollen from dryer areas. This is especially true when talking about the nonlocal nonarboreal pollen and diversity. The discussed pre-elm decline in the *Ulmus* curve around 5000 BP could be of anthropogenic origin.

The development of the landscape on the Kõpu Peninsula

The wind-blown sands of the Kõpu Peninsula seem to have been a dominating part of the environment for a long time. It is likely that the sand started to accumulate quite early since no obvious sand horizons have been included in the Kõivasoo stratigraphy. There are, however, some minor sand layers included in the profile (unit V, 125.5–126.5 cm), and the lowermost silty part contains some sand and also shells and might have developed in a shore phase. The contact of calcareous gyttja and gyttja is sharp and paved by huge amounts of mollusc shells near the central part of the basin (around cores 17–19). This might indicate the lake-level rise and the changes in ecological conditions

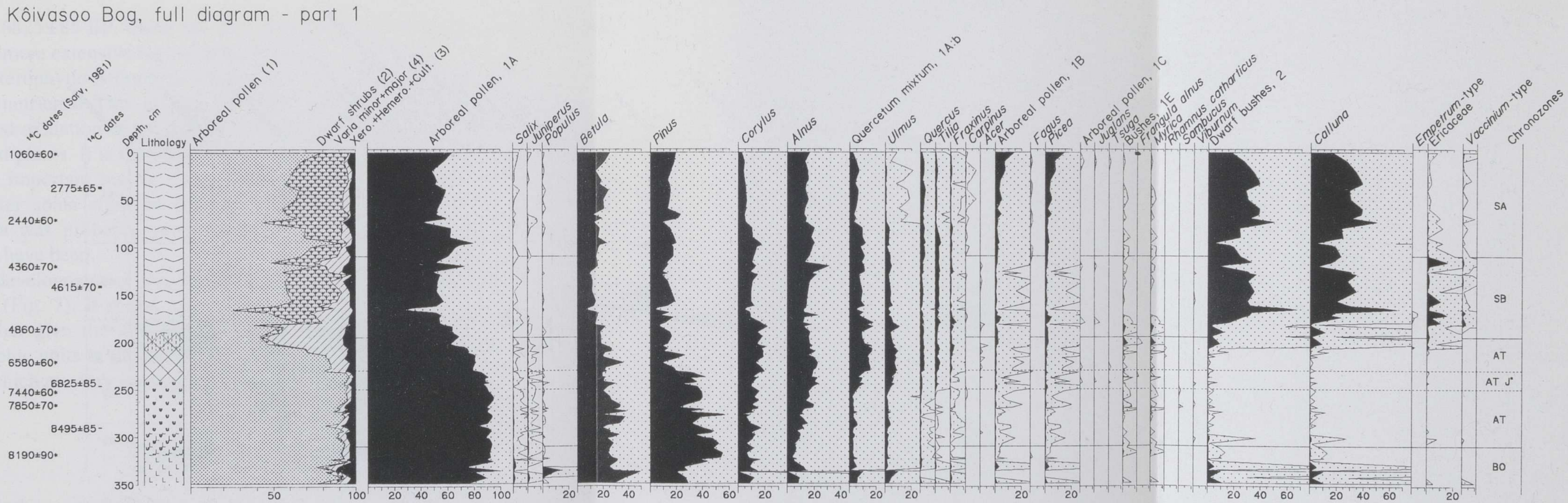

Fig. 4. Full pollen diagram of the Kõivasoo Bog (core 9). Part 1 – arboreal pollen and dwarf bushes. J* is the "true Atlantic" in the sense of Jørgensen, 1954. For legend see Fig. 3.

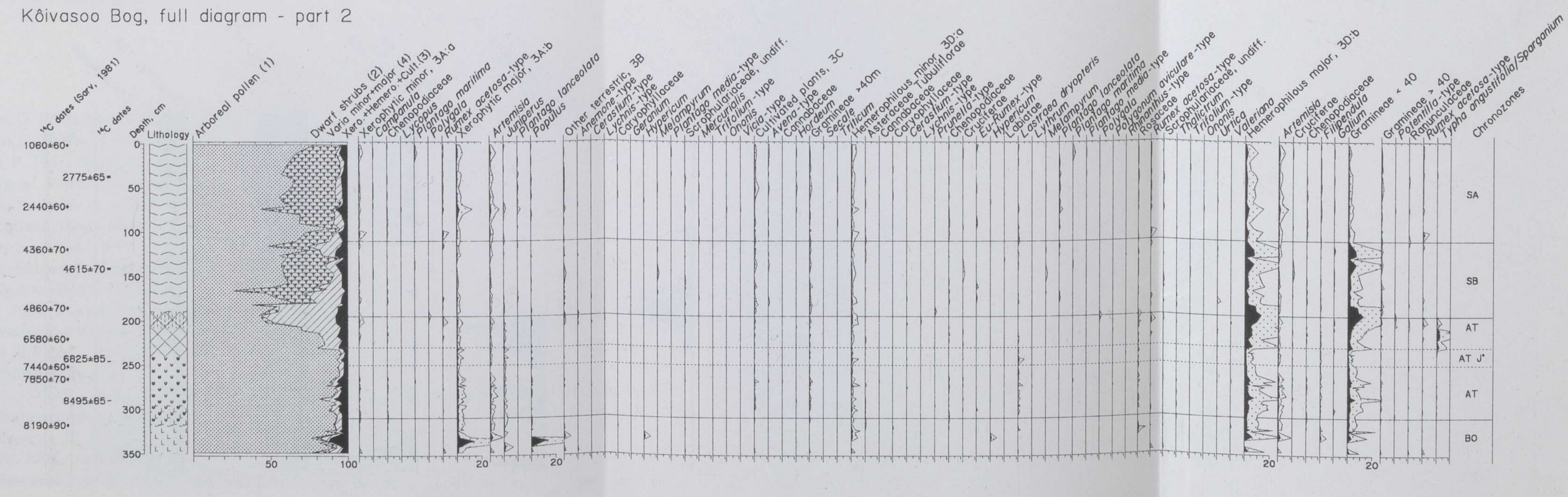

Fig. 5. Full pollen diagram of the Kõivasoo Bog (core 9). Part 2 – terrestrial nonarboreal pollen. For legend see Fig. 3.

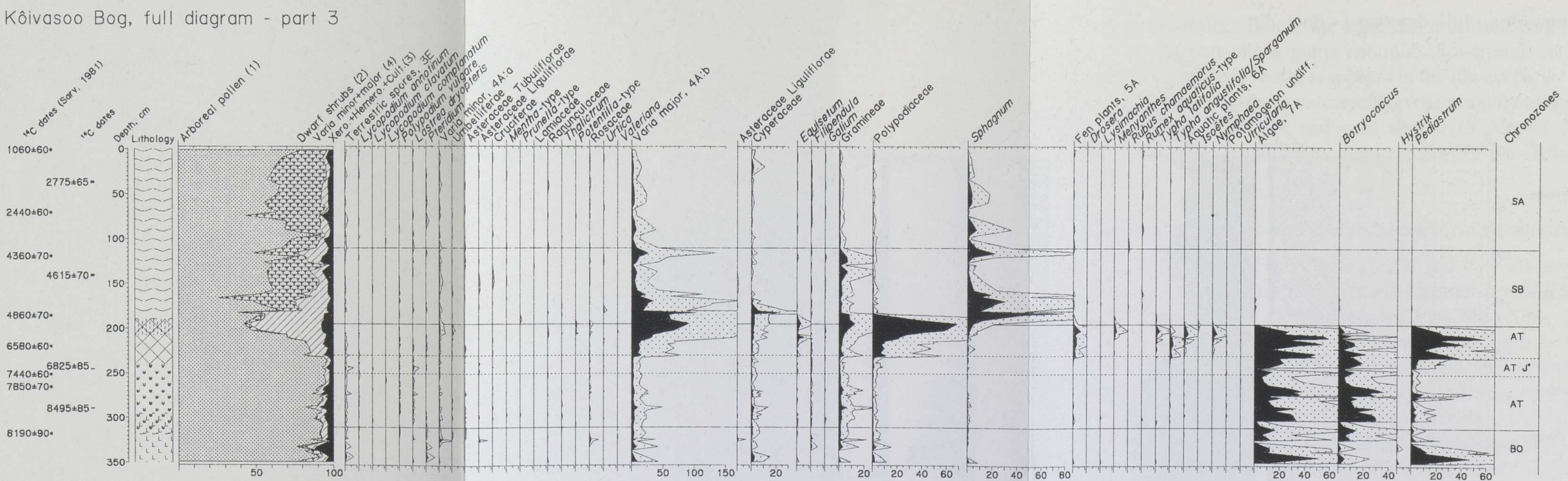

Fig. 6. Full pollen diagram of the Kõivasoo Bog (core 9). Part 3 – varia, fen plants, aquatics, and algae. For legend see Fig. 3.

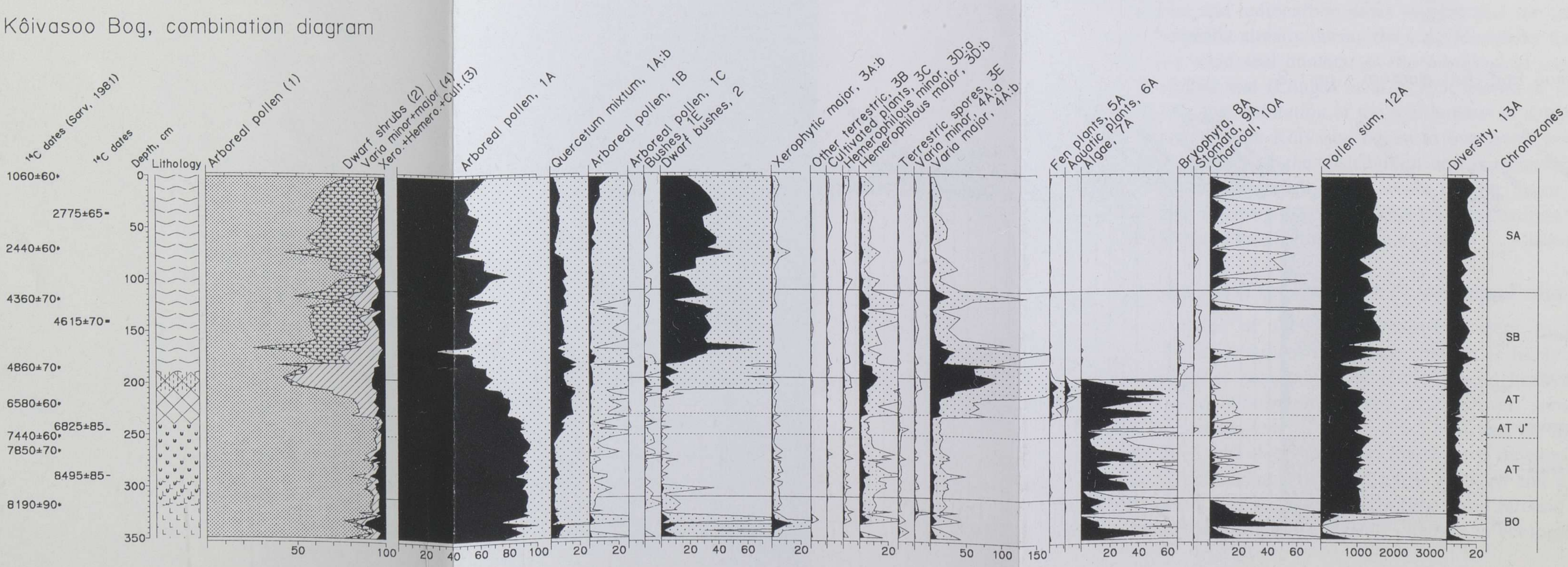

Fig. 7. Combination diagram of the Kõivasoo Bog (core 9). For legend see Fig. 3.

dated to 6825±85 BP. There are also several hiatuses identified, some of which can hide more extensive lags of sedimentation.

The xerophytic-heliophytic curves are low, since the sand layers are very poor in nutrients. This is also probably one of the reasons, apart from the mentioned oxidation of the peat surface, for such a modest representation of the cultivated plants. It is therefore likely that hunting-fishing-gathering culture was the most important way to survive during long times, at least during the Stone Age. Later some signs of pastoral economies can be traced, but the Kõpu Peninsula was probably never cultivated in the same way as other parts of Hiiumaa have been.

The development of the Kõivasoo area is summarized in the combination diagram (Fig. 7). It shows most of the appearances, especially the tree pollen curves that give the chronological order. We have also introduced different stratigraphic units in the lithostratigraphic column, and particularly the thin peat layers, which are very important for the interpretation of diagram.

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KÕPU POOLSAARE TAIMESTIKU JA MAASTIKU ARENG HOLOTSEENIS, HIIUMAA, EESTI

Lars-König KÖNIGSSON, Leili SAARSE ja Siim VESKI

Kõpu poolsaarel asuva Kõivasoo kohta tehti uus, detailne õietolmudiagramm, mis näitab, et holotseeni setete akumulatsioon algas siin pisut pärast lepa levikut ja samaaegselt pärna levikuga. Setete lasuvust illustreerivatel läbilõigetel joonistub välja terrassitaoline pind Kõivasoo ida- ja lõunaosas 24–25 m kõrgusel, mis jääb madalamale Litoriinamere kõrgeimast tasemest selles piirkonnas. Setteprofiili kirjeldus on väga detailne ja järgib Troels-Smidti soovitatut. Kuigi Kõpu poolsaare pinnakatte ülaosas valdavad peamiselt liivakad setted, on Kõivasoo setteprofiilis liivaseid kihte suhteliselt vähe. Liivasem ja süttsisaldav kiht 125,5–126,5 cm sügavusel on tekkinud umbes 4400 aastat tagasi ja langeb

hästi kokku puusöekõvera järsu tõusuga, tähistades seega kas inimtegevuse ulatuse kiiret laienemist või tõenäolisemalt metsa ja raba põlengut. Selle tagajärjel tekkinud tuiskliiv on kandunud ka soosetetesse.

Õietolmuanalüüsi tulemused on esitatud täieliku ja kombineeritud diagrammi kujul. Kultuurmaastikku iseloomustavaid liike on suhteliselt vähe. Väga kõnekas on puusöekõver, mis esmakordselt tõuseb hilisboreaalis. Tal on rida väiksemaid tippe atlantikumis, üks markantne tipp subboreaali alguses ning teine selle lõpul. Subatlantikumis on söe kõver praktiliselt pidev, kuid väga varieeruv. Söe maksimum langeb kokku selliste taimede õietolmu hulga suurenemisega nagu Chenopodiaceae, Asteraceae tubuliflorae, *Pteridium* ja *Urtica*, mis võisid kasvada mesoliitikumi asulakohtades või nende lähistel.

РАЗВИТИЕ РАСТИТЕЛЬНОСТИ И ЛАНДШАФТА НА ПОЛУОСТРОВЕ КЫПУ В ГОЛОЦЕНЕ, ОСТРОВ СААРЕМАА, ЭСТОНИЯ

Ларс-Кёниг КЁНИГССОН, Лейли СААРСЕ и Сийм ВЕСКИ

Новая палинологическая диаграмма болотных отложений Кыйвасоо показывает, что накопление здесь голоценовых отложений началось одновременно с иммиграцией ольхи и распространением липы. На геологических профилях вырисовываются террасовидные поверхности на абсолютных отметках 24–25 м ниже ур. м., несколько ниже наивысшего уровня Литоринового моря в этом месте. Детальное описание колонки (№ 9) основывается на рекомендациях Троелс-Смидта. Несмотря на преобладание в верхних слоях полуострова Кыпу песчаных отложений, песчанистые прослойки в профиле Кыйвасоо довольно редки. Один наиболее заметный песчанистый слой с древесным углем в торфе на глубине 125,5–126,5 см сформировался примерно 4400 лет т. н. и хорошо совпадает с приростом кривой угля на палинологической диаграмме, указывая тем самым на то, что лес и болото горели. Оголившиеся в результате пожара пески переносились ветром и оседали на болоте.

Результаты спорово-пыльцевого анализа представлены в виде полной и комбинированной диаграмм. Пыльцы, характеризующей хозяйственную деятельность человека, сравнительно мало. Зато кривая древесного угля весьма выразительна, ее четкие пики приходятся на суббореал и субатлантику. Максимальные содержания угля совпадают с ростом пыльцы ряда антропогенных индикаторов, которые могли расти вблизи мезолитических стоянок. Археологические раскопки последних продолжаются.