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THE FLORA AND FAUNA OF LATE PLEISTOCENE DEPOSITS ON THE COTENTIN PENINSULA, NORMANDY

By G. R. COOPE[1], J. H. DICKSON[2], R. L. JONES[3] and D. H. KEEN[3]

[1] *Department of Geological Sciences, University of Birmingham, Birmingham B*15 2*TT, U.K.*
[2] *Department of Botany, University of Glasgow, Glasgow G*12 8*QQ, U.K.*
[3] *Department of Geography, Coventry (Lanchester) Polytechnic, Coventry CV*1 5*FB, U.K.*

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[Plate 1; pullouts 1–3]

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The transition from late interglacial (temperate) to early glacial (cold) stage environments, involving not only climatic deterioration, but also a fall in sea level, has been rarely described. The Cotentin Peninsula, Normandy, lies beyond Pleistocene ice limits, and hence has less stratigraphic complexity than areas characterized by ice advances and retreats. Furthermore, it possesses a number of closely spaced coastal sites where late interglacial to early glacial organomineral sediments are present. These sediments overlie interglacial raised beach deposits, or more ancient wavecut rock platforms, and are succeeded by periglacial (head and loess) deposits.

These localities thus afforded an ideal opportunity for detailed multidisciplinary studies of sea level and terrestrial environmental change. Investigation of the geomorphology and stratigraphy was accompanied by palaeobotanical and palaeoentomological analysis of the organomineral deposits. The fossil evidence shows that as sea level fell from a height similar to the present day, the climate cooled from temperate to arctic, and that these changes were accompanied by major modifications in the flora and fauna.

Previous stratigraphic, pedological and palynological studies of the sites have been taken to imply multiple environmental changes, with ages ranging from Elsterian to Weichselian. The research described here, together with radiometric age determinations, implies that the raised beach and organomineral sediments were associated with a single marine regression between *ca.* 121 and 45 ka, that is, late in the Eemian Interglacial and early in the Weichselian Glacial stage.

These environmental changes are discussed with reference to those recorded at sites in France and Britain that probably date from the same period.

1. INTRODUCTION

This paper reports detailed investigations of environmental changes associated with the deteriorating climate and falling sea level which occurred at the end of a temperate (interglacial) and beginning of a cold (glacial) Pleistocene stage. These investigations have involved a multidisciplinary approach. Palaeobotanical (pollen, spore and macrofossil) and palaeoentomological analyses, with geomorphological, stratigraphic and radiometric dating evidence are integrated to provide a consolidated interpretation of the palaeoenvironments.

The study area, the Cotentin Peninsula, Lower Normandy (figure 1), is located south of Pleistocene ice limits. It possesses numerous coastal sites in close proximity, at which fossiliferous organomineral sediments overlie Pleistocene raised beaches and more ancient wave-cut rock

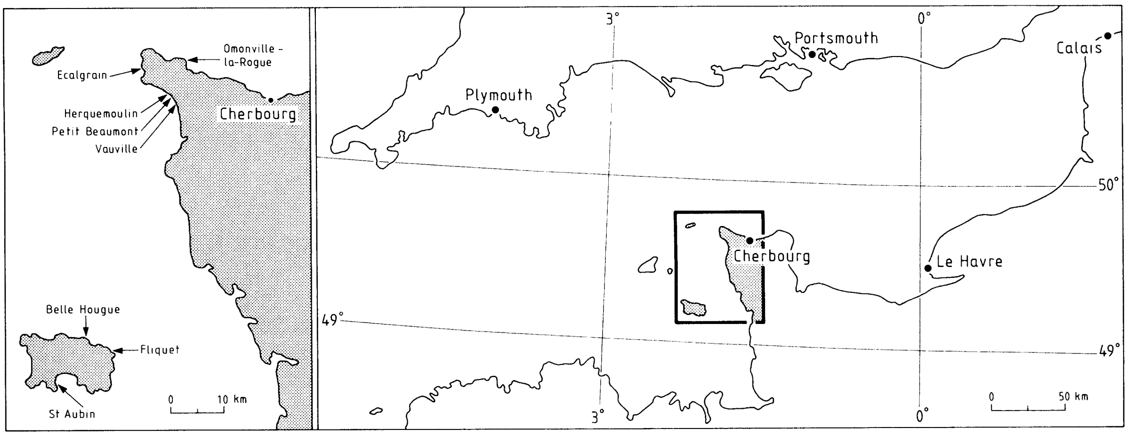


Figure 1. Location of the study area. Sites on the Cotentin Peninsula and Jersey on expanded map.

platforms. The fossiliferous sediments are overlain by, and occasionally intercalated with, periglacial head and loess. Thus ample opportunities existed for the detailed study of both sea-level and terrestrial environmental change, in a locality whose stratigraphy had not been affected by successive ice advances and retreats.

Stratigraphic detail for most of the area containing the nine sites examined in the present study has been provided by Watson & Watson (1970). They concluded that the sequences were of late Eemian and early Weichselian age. Environments of these times, especially the latter, are little-known in western Europe outside the Netherlands (Zagwijn 1961) and Denmark (Andersen 1965). Around the English Channel coasts, four previous studies have provided some insight into late Eemian and early Weichselian landscapes (West & Sparks 1960; Morzadec-Kerfourn 1974; Coope *et al.* 1980, 1985).

Earlier palaeontological investigations at the sites examined in this paper have been concerned solely with the pollen and spore flora. These investigations have either been outline, or have concentrated on a limited number of sites (Elhai 1962; Van Campo 1969; Coutard *et al.* 1979; Clet 1982). Only Clet (1983) has attempted a synthesis of palynological information. In none of this work is there agreement as to the ages of the sequences. Proposed chronologies range from Elsterian to Weichselian, with different ages sometimes assigned to the same deposits. Conflicting radiocarbon dates from the biogenic deposits have also hindered interpretation. Age ranges from *ca.* 13000 to 45000 years BP for material in similar stratigraphic positions, together with varying dates for a duplicate sample, have been obtained (Delibrias & Larsonneur 1966; Delibrias *et al.* 1969; Shotton *et al.* 1970; Shotton & Williams 1971). These radiometric dates are considered in relation to others, including a U-series determination, around the English Channel coasts. Their chronological implications are assessed in conjunction with the supporting geomorphic, stratigraphic and palaeontological data. From these considerations, a sequence of environmental change is proposed.

2. Analytical techniques

The geomorphology and stratigraphy of the sites were investigated by D.H.K., their pollen and spore content by R.L.J., plant macrofossils by J.H.D. and insects by G.R.C. Samples for palaeontological analysis were obtained from freshly cut open sections of unweathered material at the five localities. Single sites were examined at Omonville-la-Rogue, Vauville and Petit Beaumont; four sites at Herquemoulin and two at Ecalgrain. The pollen, plant macrofossil and insect samples were collected from the same profile, each bulk sample for macroremains incorporating one or more pollen samples (table 1). Additionally, use was made of biogenic material from exposures near the base of the head at Ecalgrain, collected in 1969 by Professor F. W. Shotton.

Table 1. Fossil pollen, plant macrofossil and insect sample location at each section and key to sample numbers

site	plant macrofossil and insect fossil sample number	incorporated fossil pollen sample levels: depths from top of stratigraphic units/m
Omonville-la-Rogue	OLR 2	0.06, 0.08
Ecalgrain A	EA 1	0.05
	EA 2	0.10, 0.15
	EA 3	0.20, 0.25
	EA 4	0.30, 0.35
	EA 5	0.40, 0.45 } duplicate
	EA 8	0.40, 0.45 } duplicate
Ecalgrain B	EB 1	0.00, 0.05 0.10, 0.15, 0.20, 0.25 0.30, 0.35, 0.40, 0.45 0.50
	EB 2	0.75, 0.80, 0.85, 0.90
Herquemoulin A	HA 1	0.00, 0.03, 0.06, 0.09 0.12, 0.15
Herquemoulin B	HB 1	0.00, 0.02, 0.04, 0.06
	HB 2	0.08, 0.10, 0.12
Herquemoulin C	HC 1	0.00, 0.20
	HC 2	0.25, 0.35
Herquemoulin D	HD 1	0.05, 0.20, 0.30
	HD 2	0.63, 0.68, 0.73, 0.78
	HD 3	0.83, 0.88, 0.93, 0.98
Petit Beaumont	PB 1	0.00, 0.02, 0.04, 0.06 0.08, 0.10, 0.12
	PB 2	0.14, 0.16, 0.18, 0.20 0.22, 0.24, 0.26
Vauville	V 1	0.00, 0.05
	V 2	0.10, 0.15, 0.20
	V 3	0.25, 0.30, 0.35
	V 4	0.40, 0.45

2.1. *Geomorphology and stratigraphy*

The Pleistocene stratigraphy of the Cotentin Peninsula is well displayed in modern coastal cliff sections, and also as isolated remnant patches in hollows in the ancient wave-cut platform forming the current foreshore. Where possible, stratigraphic units were measured directly, although the height and inaccessibility of some cliff sections means that certain thicknesses (of head in particular) are approximate. Sedimentary matrix colours were described with reference to a Japanese Standard Soil Colour Chart (Oyama & Takehara 1970). Clast sizes and shapes were measured and described when possible.

The sediment types encountered were head, detritus mud, clay mud and stony clay (the two last-named equivalent to the 'argile grise' of French geologists) (figure 2). The precise location of the foreshore remnants was mapped (figures 3, 5 and 9) and their relationships to the cliff sections determined where possible.

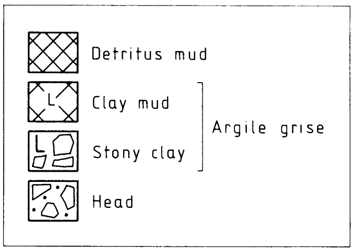


FIGURE 2. Sediment symbols used in the text.

In view of the site-specific nature of data collection, only the stratigraphy at the fossil sampling localities is reported in detail. More widespread stratigraphic sequences around the Cotentin Peninsula are presented by Watson & Watson (1970). The Pleistocene deposits of the Baie d'Ecalgrain have been sketched and described by Coutard *et al.* (1979).

2.2. *Pollen and spores*

Pollen and spores were extracted by standard techniques involving KOH digestion of organic samples and HF digestion of inorganic ones; the processes frequently being combined and accompanied by acetylation (Faegri & Iversen 1975; Jones & Cundill 1978). The preservation of pollen and spores was variable, with signs of oxidation and reworking of grains evident in the heads and clays. The pollen and spore content of many samples was relatively low. In view of this, a minimum of 300 grains and spores was used as the sum for percentage calculations. This total was achieved at all but a few levels. All values are expressed as percentages of total pollen and spores.

Apart from 'deteriorated' pollen (Lowe 1982), the major identification problem concerned triporate pollen resembling either *Betula*, *Corylus*, *Carpinus* or *Ostrya*. Most acute at Omonville-la-Rogue, this problem was partly resolved by the use of phase-contrast illumination with especial reference to pore and exine characteristics (Faegri & Iversen 1975). A number of three-pored, *Carpinus*-like grains were considered inseparable from those of *Ostrya*. Thus, a combined *Carpinus–Ostrya* curve is constructed on the pollen diagrams.

Nomenclature of vascular plants follows *Flora Europaea* (Halliday & Beadle 1983); that of mosses, Smith (1978). The scheme of describing (grouping and differentiating) pollen and spore taxa follows Birks (1973*a*). Pollen assemblage biozones are delimited by using the criteria of West (1970).

2.3. *Plant macrofossils*

Samples for macroscopic plant analysis were washed through coarse and fine sieves (500 and 150 μm mesh sizes), examined under a binocular microscope and the fruits, seeds and mosses identified by comparison with reference material (C. A. Dickson 1970; J. H. Dickson 1986). The number of taxa recovered was relatively small. The majority of plant material was in a poor state of preservation, a condition which hindered investigation. The results are presented in tabular form as absolute numbers.

2.4. *Insects*

Because of the readiness with which insect fossils are attacked by fungi, even while they are still embedded in their matrix, the exposure was cut back at least 0.60 m to reveal unweathered material. In spite of this precaution, some samples revealed only corroded remnants of the most robust species. For this reason, insect faunas are recorded for only a limited number of the samples. It is interesting to notice, however, that even in sites with no preserved insect fossils, there was adequate pollen to provide palynological spectra.

In the laboratory the samples were given the standard treatment for the recovery of insect remains (Coope 1986). The samples were disaggregated in water and washed over 300 μm sieves. The material retained on the sieves was mixed with paraffin (kerosene); the mixture was then put into a deep plastic bowl equipped with a spout, and enough cold water was added to give a good separation between the fraction that sank and that which floated. The latter fraction was then decanted into a sieve, where it was washed with detergent solution to remove any remnant oil, and then with alcohol to remove the water and the last traces of oil. This floating fraction consists largely of plant and animal debris in which arthropod remains, which absorb the oil, have been concentrated. The insect fragments were then matched against a comprehensive collection of modern specimens. No detectable differences were observed between the fossil and modern species.

In presenting the results, the species are listed in taxonomic order and the minimum number of individuals present in each sample is shown alongside each entry. Nomenclature of the Coleoptera follows that of the *Catalogus Coleopterorum Fennoscandiae et Daniae* (Lindroth 1960).

3. OMONVILLE-LA-ROGUE

3.1. *Geomorphology and stratigraphy*

This locality (49° 45′ N, 1° 45′ W) lies 1 km southeast of the harbour at Omonville-la-Rogue (figure 3). The bedrock, Cambrian quartzite, is well jointed and lithified and has contributed most of the coarse material of the local head. At the sample site, the stratigraphy described below was recorded.

6	Modern soil over dark brown (10YR 3/3) silty sand	0.75 m
5	Undifferentiated head composed of angular quartzite blocks up to 0.30 m long axis. The matrix becomes more loess-rich towards the top of the unit	5.50 m
4	Fine silty and granular head formed of quartzite fragments	3.00 m
3	Clay mud (argile grise). Brownish grey (10YR 5/1)	0.09 m
2	Detritus mud. Black (10YR 2/1)	0.09 m
1	Fine-grained raised beach gravel. Rolled fragments of quartzite, gneiss, and schist, with a few flints	0.50 m

At the base of the section is a wave-smoothed platform cut across the steeply dipping quartzite.

The individual units in this stratigraphy vary laterally in lithology and thickness. In particular, the raised beach sediment thins to *ca*. 0.30 m some 40 m NNE of the sample point. Here the fine gravel of the beach in the south of the bay is replaced by boulders up to 0.30 m long axis. On the north side of the bay, the beach deposits do not rest directly on a rock platform, but on a further layer of granular head up to 0.50 m thick.

At La Cormorandière, 500 m SE of the sample site (figure 3), the organic material above the raised beach is absent, but the beach itself rests upon a head. This head has a number of sub-rounded stones at its base, perhaps remnants of an even earlier marine horizon. At the base of this section is a wave-cut surface on heavily weathered, foliated granite. There is thus evidence of two discrete episodes of marine activity separated by an interval during which periglacial deposits were formed.

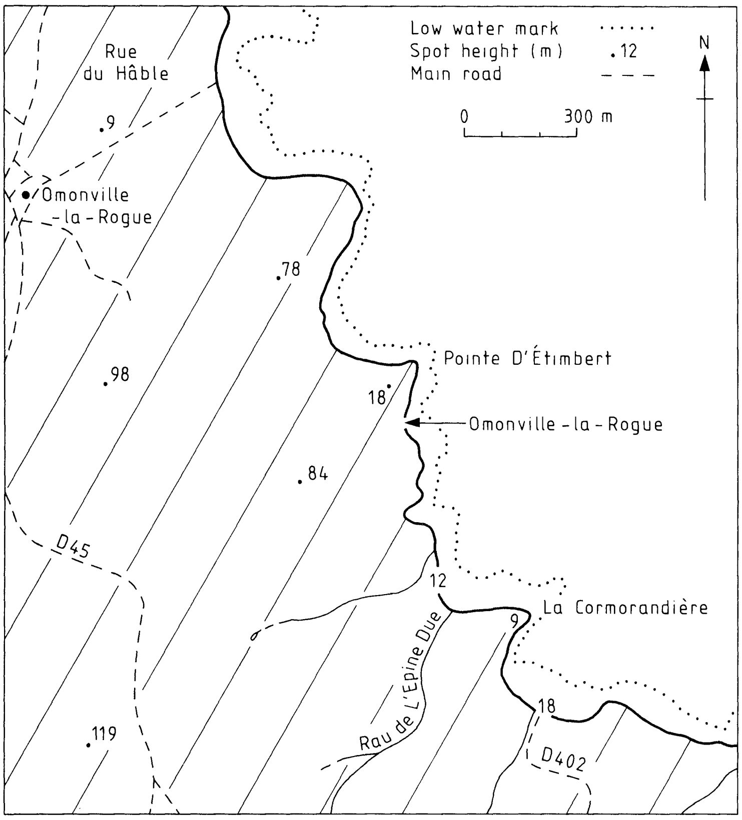


FIGURE 3. Omonville-la-Rogue: site plan.

3.2. *Floral and faunal analyses*

The detritus mud and clay mud overlying the raised beach and underlying the lower head (unit 4) were sampled. The pollen and spore assemblage biozone descriptions can be seen as captions to figure 4. No plant macrofossils were recovered from these sediments.

Substantial and sustained arboreal pollen values indicate that the time-period represented by all three biozones was one characterized by a woodland environment in the pollen catchment area of the site. During OLR-1 this woodland was mixed coniferous–deciduous and included *Pinus*, *Carpinus–Ostrya*, *Picea* and *Betula* as major constituents. *Abies* was present and there were isolated occurrences of *Quercus* and *Ulmus*. *Corylus* and *Ilex* were probably present in the woodland understorey. High Filicales values suggest an important fern component in the woodland field layer.

There were undoubtedly some open habitats at this time. A substantial amount of the Gramineae, Cyperaceae, Compositae, Cruciferae, Rosaceae and Rubiaceae pollen is likely to have been derived from local maritime and submaritime vegetation. This would have included cliff-top turf and dwarf-shrub heath communities. On an expanding coastal zone (as sea-level fell from its maximum denoted by the raised beach), salt- and/or brackish-water marsh, foreshore and sand-dune vegetation could also have developed.

As marine influence withdrew, biogenic material accumulated in one of a number of depressions on the raised beach platform. The detritus mud deposited first is devoid of plant macrofossils, but its pollen content reveals that open fresh water with *Nymphaea*, *Typha latifolia* and *Potamogeton* was present. Adjacent was a swamp–fen community where sedges and tall herbs (for example, *Lychnis* and *Filipendula*) could have grown, along with *Salix*.

OLR-2 witnessed a continuing mixed woodland cover. However, *Carpinus–Ostrya* now diminished in importance and *Abies* increased. *Corylus* and *Ilex* were still present, probably as understorey shrubs. *Juniperus* immigrated and may have replaced Ericaceae as the understorey in more open woodland. The role of ferns in woodland composition was reduced and there is evidence of a more diverse herb flora including *Rumex acetosa*, *Thalictrum* and Saxifragaceae.

The combined presence of *Juniperus*, *Thalictrum*, Saxifragaceae, *Huperzia selago* and *Selaginella selaginoides* suggests that conditions became slightly cooler in OLR-2. A woodland vegetation in OLR-1, analogous to that of southern Scandinavia today, was superseded in OLR-2 by one more characteristic of higher boreal latitudes (save for *Abies* which now grows mainly in montane central and southern Europe, although there are lowland occurrences in Normandy and eastern Poland (Tutin *et al.* 1964)). There was an increased influx of inorganic material into the water body during OLR-2, the clay mud indicating a phase of accelerated mass movement, probably a consequence of the creation of disturbed soils. On the latter, *Artemisia* could have flourished. A sedge-dominated swamp continued to exist adjacent to the water body. Its herbaceous component, apparently undiminished, would have benefited from the inwash of fresh, base-rich sediment from surrounding slopes.

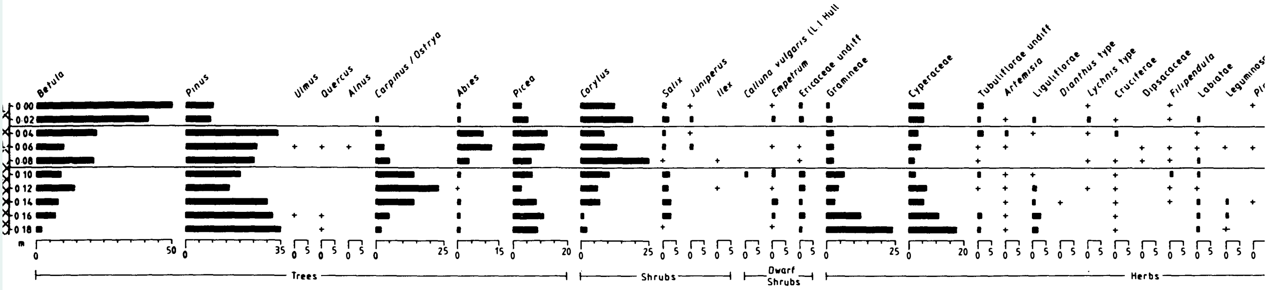
A further change in woodland composition took place in OLR-3. *Betula* now assumed dominance, *Corylus* increased in importance along with Ericaceae, and *Juniperus* continued its presence. The regional vegetation cover seems to have included open birch woodland with *Corylus*, *Juniperus*, Ericaceae, herbs and ferns. There were still local saline and freshwater communities, although the former are less well defined in the pollen record. Such a vegetational change must have been a response to a further cooling within a boreal climate. As the clay mud appears to pass conformably into head, a severe periglacial environment must soon have followed.

Insect remains were obtained only from sample OLR 2 (table 2), which includes pollen samples 0.06 and 0.08 m (table 1) within pollen assemblage biozone OLR-2 (figure 4, pullout 1).

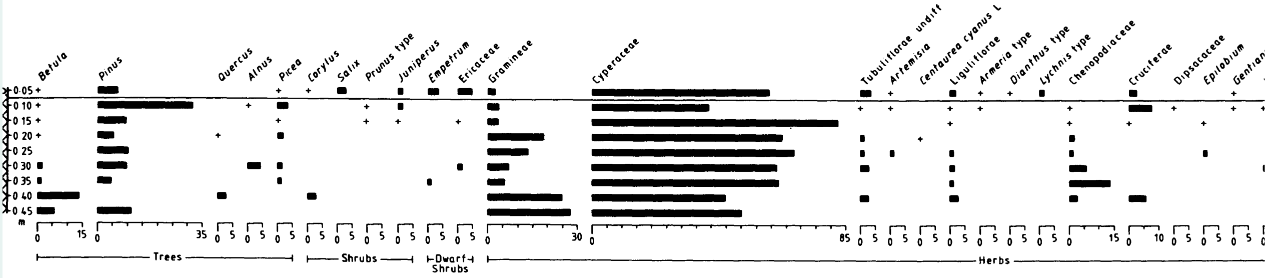
The small fauna is dominated by aquatic taxa. Only one species is represented by more than a single individual: *Ochthebius marinus*, which is usually found on salt-marshes. Only *Pycnoglypta lurida* has any climatic significance, being widespread in northern Europe but absent from lowland central Europe.

TABLE 2. OMONVILLE-LA-ROGUE (SAMPLE OLR 2): INSECT FAUNA

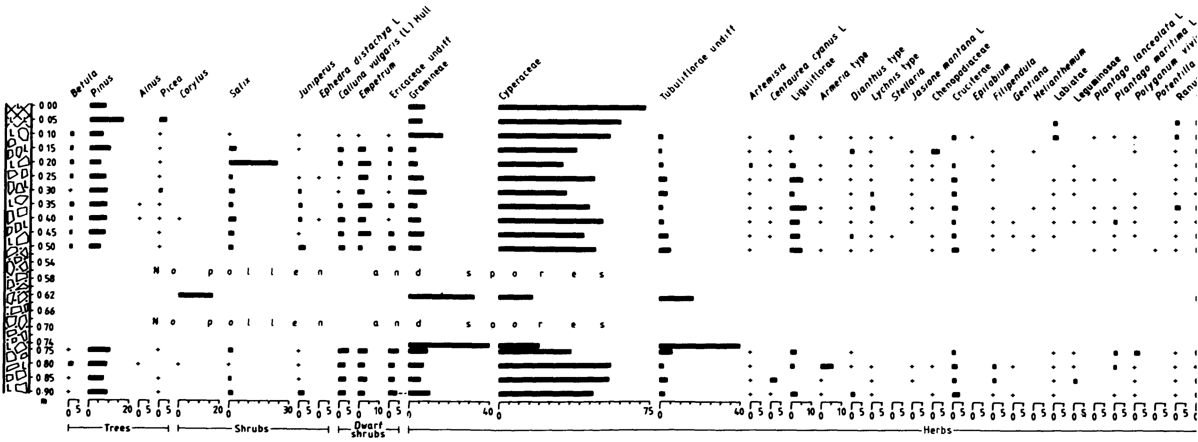
sample...	OLR 2
Dytiscidae	
Hydroporus sp.	1
Hydrophilidae	
Helophorus sp.	1
Hydrobius fuscipes (L.)	1
Hydraenidae	
Ochthebius marinus (Pk.)	2
Ochthebius minimus (F.)	1
Staphylinidae	
Olophrum fuscum (Grav.)	1
Pycnoglypta lurida Gyll.	1



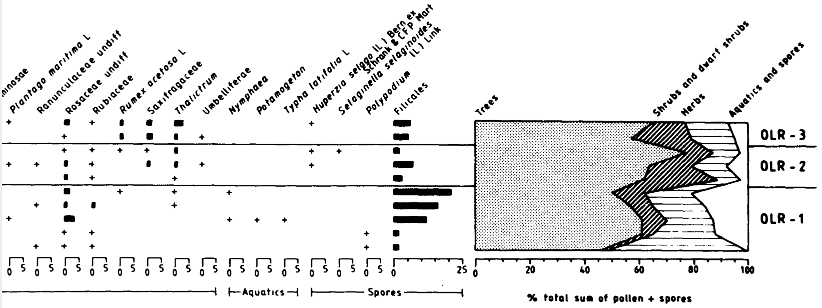
URE 4. Omonville-la-Rogue: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. OLR-1 *Pinus–Carpinus–O*
34%) with *Carpinus–Ostrya* (up to 23%); *Picea* (up to 16%); *Betula* (up to 14%); and *Abies*, *Ulmus* and *Quercus* occurring at values of 1% or
as are Compositae and Rosaceae. Gramineae and Cyperaceae values fall from 20–25% to 5%. *Nymphaea*, *Typha latifolia* and *Potamogeton* are
where *Carpinus–Ostrya* values fall from 15 to 5%. OLR-2 *Pinus–Betula–Picea–Abies*. Arboreal pollen accounts for 55–78%. *Pinus* is the maj
Carpinus 2–5%. *Ulmus*, *Quercus* and *Alnus* each are less than 1%. *Corylus* is up to 25%, *Salix* 2% or less. *Ilex* occurs in the lower part, *Junipe*
and Saxifragaceae are recorded. Filicales spores decline, while those of *Huperzia selago* and *Selaginella selaginoides* occur. The terminal bound
pollen is up to 60%, with *Betula ca.* 50%, *Pinus* 10%, *Picea* 5%, *Carpinus* and *Abies* 1%. *Corylus*, *Salix*, Ericales, Cyperaceae, Saxifragaceae



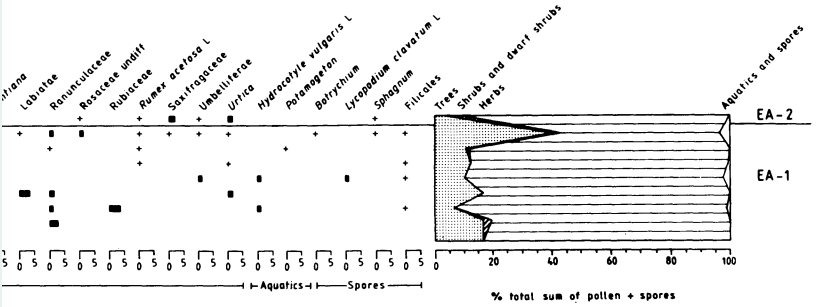
URE 6. Ecalgrain Site A: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. EA-1 Cyperaceae–Gramineae–
Gramineae, Chenopodiaceae, Compositae and Cruciferae also important. The arboreal component is mainly *Pinus*, with falling values of
Juniperus appears in the upper part. The terminal boundary is placed where arboreal values decline to 5%. EA-2 Cyperaceae–Ericales–*Pin*
and Cruciferae. Saxifragaceae values rise to 2%. *Juniperus* retains a minor representation but Ericales (*Empetrum* plus Ericaceae) expand to



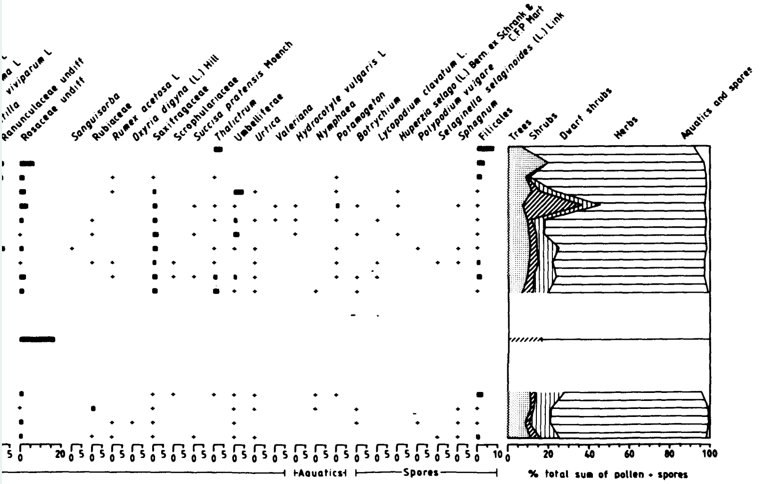
JRE 8. Ecalgrain Site B: pollen diagram and assemblage biozone. +, Under 1%; undiff., undifferentiated. Cyperaceae–Gramineae–Compo
are prominent, *Salix* and *Juniperus* consistently represented and *Ephedra distachya* recorded. There is a wide range of herbaceous taxa, notably
is the most consistent aquatic taxon, although *Nymphaea* occurs sporadically in the lower part of the assemblage. Filicales spores are continu
have scattered occurrences. The low arboreal values are made up mainly by *Pinus*, *Picea* and *Betula*. There are isolated records of *Alnus*.



-*Ostrya–Picea*. Arboreal pollen accounts for 50–60%. *Pinus* is the major contributor (up to
)r less. *Corylus* is under 10% and *Salix* 5%. Ericales (*Calluna*, *Empetrum*, Ericaceae) are 1–3%,
ıre recorded. Filicales spores are abundant, reaching 21%. The terminal boundary is placed
ıajor tree genus (25–35%), with *Betula* 10–22% and *Picea* 5–12%. *Abies* reaches 12% with
perus in the upper. Dwarf-shrub and herbaceous values are reduced but *Thalictrum* increases
ıdary is placed where *Abies* values fall from 8 to 1%. OLR-3 *Betula–Pinus–Picea*. Arboreal
e and *Thalictrum* values increase.



ɛ–*Pinus*–Chenopodiaceae. Herbs account for 80–85%. Cyperaceae dominate (40–82%) with
f *Betula*, sporadic *Picea* and isolated occurrences of *Quercus* and *Alnus*. *Corylus* is present and
inus. Herbs account for 90% and consist mainly of Cyperaceae, with subsidiary Compositae
.o 8%.



positae–Ericales. Non-arboreal pollen accounts for 85–90%, with shrubs 15–20%. Ericales
y Cyperaceae, Gramineae, Compositae, Cruciferae, Rosaceae and Saxifragaceae. *Potamogeton*
nuously recorded, and those of *Lycopodium clavatum*, *Huperzia selago* and *Selaginella selaginoides*

3.3. *Synthesis*

Pollen and spore evidence suggests that cool-temperate mixed woodland gradually diminished and was replaced by increasingly open vegetation of a more cold-tolerant nature. The stratigraphy supports the notion of climatic cooling. Pollen, spores and insects point to the presence of local maritime biota within a regional boreal environment.

4. ECALGRAIN

4.1. *The Bay and its deposits*

The Baie d'Ecalgrain (49° 44′ N, 1° 54′ W) lies 4.5 km south of the Cap de la Hague on the west-facing coast of the Cotentin (figure 1). The bay is cut in lightly metamorphosed Ordovician mudstones and sandstones. The cliffs in the centre of the bay are fashioned in head which attains *ca.* 20 m in thickness in a section cut by the Rivère du Moulin, and 30–35 m in both the north and south of the bay.

The sections in the bay are complex and variable. In the centre, a raised beach of fine gravel occurs, but north and south of the outfall of the Rivère du Moulin it is present as iron-cemented sandrock resting on a rock platform. Organomineral deposits overlying the beach are also of differing thicknesses and lithology, and upon detailed examination reveal a complex of detritus muds, clay muds and stony clays, with intercalated thin seams of head. The periglacial deposits, when traced laterally, differ slightly in composition and stratigraphy from those described by Coutard *et al.* (1979) at their principal section. However, their major divisions

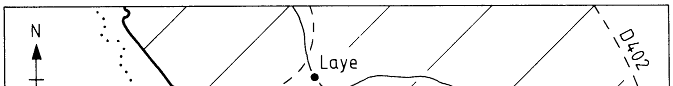


FIGURE 5. Ecalgrain: site plan.

(upper head; lower head) can generally be recognized, together with some loessic layers. Coutard *et al.* (1979) present a pollen diagram from a section where all stratigraphic units were visible. Current investigations were unable to locate such a site. However, a comparable sequence was seen in composite form, and two localities (Ecalgrain Site A on the foreshore, and Ecalgrain Site B in the backing cliff *ca.* 500 m to the south, figure 5) were studied.

4.2. *Site A*

4.2.1. *Geomorphology and stratigraphy*

The sediments consist of 0.43 m of brownish black (10YR 2/2) detritus mud overlain by 0.06 m of olive grey (5GY 5/1) stony clay. Orange (7.5YR 6/8) beach sand underlies the section, whose upper surface is exposed on the foreshore.

4.2.2. *Floral and faunal analyses*

Samples were obtained from the detritus mud and stony clay. The pollen and spore assemblage biozone descriptions can be seen as captions to figure 6. The plant macrofossils recovered are listed in table 3, with samples EA 8, EA 5 and EA 2 incorporating the pollen sample levels assigned to biozone EA-1, and sample EA 1 including the pollen sample levels of biozone EA-2 (table 1, figure 6).

TABLE 3. ECALGRAIN SITE A: PLANT MACROFOSSILS

samples (50 ml)...	EA 1	EA 2	EA 3	EA 5	EA 8
Atriplex seeds	—	—	—	3	6
Carex (biconvex) nutlets	—	1	12	9	32
Carex (trigonous) nutlets	7	50	—	—	—
Cirsium fruit	1	—	—	—	—
Eleocharis palustris (L.) Roemer and Schultes, fruits	—	—	—	—	2
Gramineae caryopsis	—	—	1	—	—
Hydrocotyle vulgaris L. fruits	—	1	—	5	7
Juncus acutifloris Ehrh. or *articulatus* L. seeds	—	—	—	—	6
Lythrum salicaria L. seed	—	1	—	—	—
Montia fontana L. seeds	—	—	—	4	22
Potentilla anserina L. fruits	—	—	—	—	2
Prunus spinosa L. fruitstone	—	—	—	—	1
Ranunculus sceleratus L. fruits	2	—	38	56	96
Sagina seed	—	—	—	—	1
Salix budscales	2	—	—	—	—
Sonchus asper (L.) Hill, fruit	—	—	—	1	—
Stellaria alsine Grimm, seeds	—	—	—	2	—
Zannichellia palustris L. fruits	—	—	—	—	1
mosses unident. fragments	—	—	2	8	11
fucoid algae fragments	—	—	—	50	1

Both pollen and spores and plant macrofossils indicate that open vegetation was dominant in the catchment area of the site during this timespan.

In pollen assemblage biozone EA-1 the herbaceous flora reflects the existence of a seemingly quite varied local vegetation. The locus of the site was initially a hollow in a sandy raised beach deposit where detritus mud accumulated. There appears to have been some open fresh water nearby, and a well developed marsh of both fresh and brackish or saline nature. However, falling values of Chenopodiaceae pollen may reflect the decreasing proximity of salt-marsh.

High Cyperaceae pollen values probably had their main provenance here: a sedge-dominated marsh is supported by numerous *Carex* nutlets. Considerable Gramineae pollen values (and a macrofossil caryopsis) suggest the local presence of grasses, and complementary pollen and macrofossils of *Hydrocotyle* and *Ranunculus* are also likely to have come from nearby wetland. A substantial amount of the *Potamogeton*, *Epilobium*, Labiatae, Compositae, Umbelliferae, Cruciferae and *Armeria* pollen was probably derived from local marshland vegetation, as were the macrofossils of *Juncus acutiflorus/articulatus*, *Eleocharis palustris*, *Montia fontana*, *Lythrum salicaria*, *Stellaria alsine*, *Zannichellia palustris*, *Atriplex*, *Potentilla anserina* and *Sonchus asper*.

While it is impossible to ascertain the precise floristic composition of the local plant communities, the ecological tolerances of certain taxa provide clues. Some are intolerant of saline or brackish water, for example, *Hydrocotyle vulgaris*, *Juncus acutiflorus/articulatus*, *Lythrum salicaria* and *Montia fontana*, but others are facultative halophytes. Certain *Carex* species, such as *C. distans*, some grasses, and ecotypes of *Eleocharis palustris* (Bell 1970) are salt-tolerant. *Zannichellia palustris* has a wide salinity tolerance (oligo-, meso- and polyhaline) according to Pals *et al.* (1980) and is a submerged aquatic growing at depths of up to 2 m (Haslam *et al.* 1975). *Atriplex* will grow in salt-marshes or on sea-shore shingle, and *Potentilla anserina* occurs in sand-dunes and estuaries (Bell 1970; Hulten 1971). *Sonchus asper* is also tolerant of saline soils (Lewin 1948), and *Armeria* is most frequently a coastal dweller on salt-marshes, pastures, rocks and cliffs (Clapham *et al.* 1962). *Ranunculus sceleratus* is frequently encountered in shallow, still or slow flowing brackish water, or on seasonally exposed mud (Haslam *et al.* 1975). Fucoid seaweeds (figure 7, plate 1) are obligates of intertidal saline habitats.

The pollen spectra also indicate that the regional plant cover during EA-1 was rather open. There seems to have been scrub and heath, including *Betula*, *Corylus*, *Prunus spinosa* and Ericales. This vegetation may have been analogous to that which is widespread about 55–60°N on northwest European coasts today. The dominant tree pollens, however, are those of *Pinus* and *Picea*, and it is possible that coniferous woodland existed in the area, perhaps localized and quite close to the site as a successional end-member of sand-dune communities (Clet-Pellerin 1983). There is little doubt that the coastal zone was extending at this time, as sea-level fell from the height of the raised beach. Sand-dune accumulation is occurring along this coast in suitable locations at present, and is likely to have been more widespread under conditions of falling sea-level. Alternatively, such pollens may have been the result of long-distance transport (to which they are susceptible), from boreal forest vegetation further afield. During pollen assemblage biozone EA-2 most of the local vegetational characteristics postulated for EA-1 seem to have persisted. Regionally, there was a more marked dwarf-shrub component. Higher values of herbaceous (notably Compositae and Saxifragaceae) pollens, together with a change in sedimentary facies to an increasingly stony clay, indicate the onset of colder climatic conditions in which mass movement accelerated.

Four samples yielded insect remains: EA 5, EA 4, EA 3 and EA 2. These incorporate pollen samples 0.10–0.45 m (table 1) and are equivalent in age to pollen assemblage biozone EA-1 (figure 6). No insect fossils were found in sample EA 1 (table 4).

The lowest two samples contained many fragments of *Cercyon depressus* which is a stenotopic species restricted to heaps of decomposing seaweed along the strand-line. In the lowest sample (EA 5) this is the only species present. *Trechus fulvus* lives under stones on rocky and sandy seashores near high-water mark (Lindroth 1974). *Coelostoma orbiculare* is a pond species, and *Chaetarthria seminulum* occurs at the margins of very muddy pools of fresh water with an

TABLE 4. ECALGRAIN SITE A: INSECT FAUNA

sample...	EA 2	EA 3	EA 4	EA 5
Carabidae				
Trechus fulvus Dej.	1	—	—	—
Pterostichus diligens (Sturm)	2	—	—	—
Pterostichus nigrita (Payk.)	—	—	1	—
Dytiscidae				
Agabus bipustulatus (L.)	1	—	—	—
Agabus sp.	—	—	1	—
Hydrophilidae				
Coelostoma orbiculare (F.)	1	1	2	—
Cercyon depressus (Steph.)	1	—	13	3
Chaetarthria seminulum (Hbst.)	5	—	—	—
Hydraenidae				
Limnebius truncatellus (Thunb.)	1	—	—	—
Staphylinidae				
Olophrum fuscum (Grav.)	1	—	—	—
Lesteva sp.	1	—	—	—
Anotylus rugosus (F.)	1	—	—	
Curculionidae				
Micrellus ericae (Gyll.)	1	—	1	

abundance of decaying vegetable matter (Balfour-Browne 1958). *Agabus bipustulatus* is a carnivorous water-beetle that lives in a great variety of aquatic habitats. The two species of *Pterostichus*, though in general eurytopic, occur together in acid bogs and, in this context, it is interesting to note that the only phytophagous species in this assemblage is the small weevil *Micrellus ericae* which feeds exclusively on species of *Calluna* and *Erica*.

This small insect assemblage provides little evidence of the climate under which the detritus mud accumulated, though *Cercyon depressus* and *Chaetarthria seminulum* are now absent from the northern parts of Fennoscandia. *Trechus fulvus* is a west European species that is very scarce in Scandinavia but reaches as far north as the Shetland and Faeroe Islands in the northwest. At most, therefore, the insects from Ecalgrain A suggest that the climate was not cold, and rather oceanic in nature.

4.2.3. *Synthesis*

Plant and insect evidence combine to provide a detailed insight into local environments during the timespan represented by the detritus mud. There was a mosaic of nearshore vegetation which included freshwater and saline marsh and probably sand-dunes, together with intertidal algal communities. The extraordinary lithology of sample EA 4, with its amorphous black texture, its abundant fucoid fragments, and the dominance of the marine littoral beetle *Cercyon depressus*, combine to indicate that the site at this time was actually located on the strand-line. Regionally, cool-temperate scrub and heath vegetation seems to have predominated. Later, the pollen and spore flora and insects suggest the emergence of a more cold-tolerant, largely heathland vegetation. Evidence of maritime and submaritime plant communities diminishes upwards. This seems to have been a result of a fall in sea-level, probably in response to climatic deterioration. This interpretation is supported by the clear diminution in the numbers of *Cercyon depressus* in the upper parts of the sequence. The uppermost sedimentary unit, a progressively more stony clay, reflects the onset of a periglacial environment associated with this deterioration (see below).

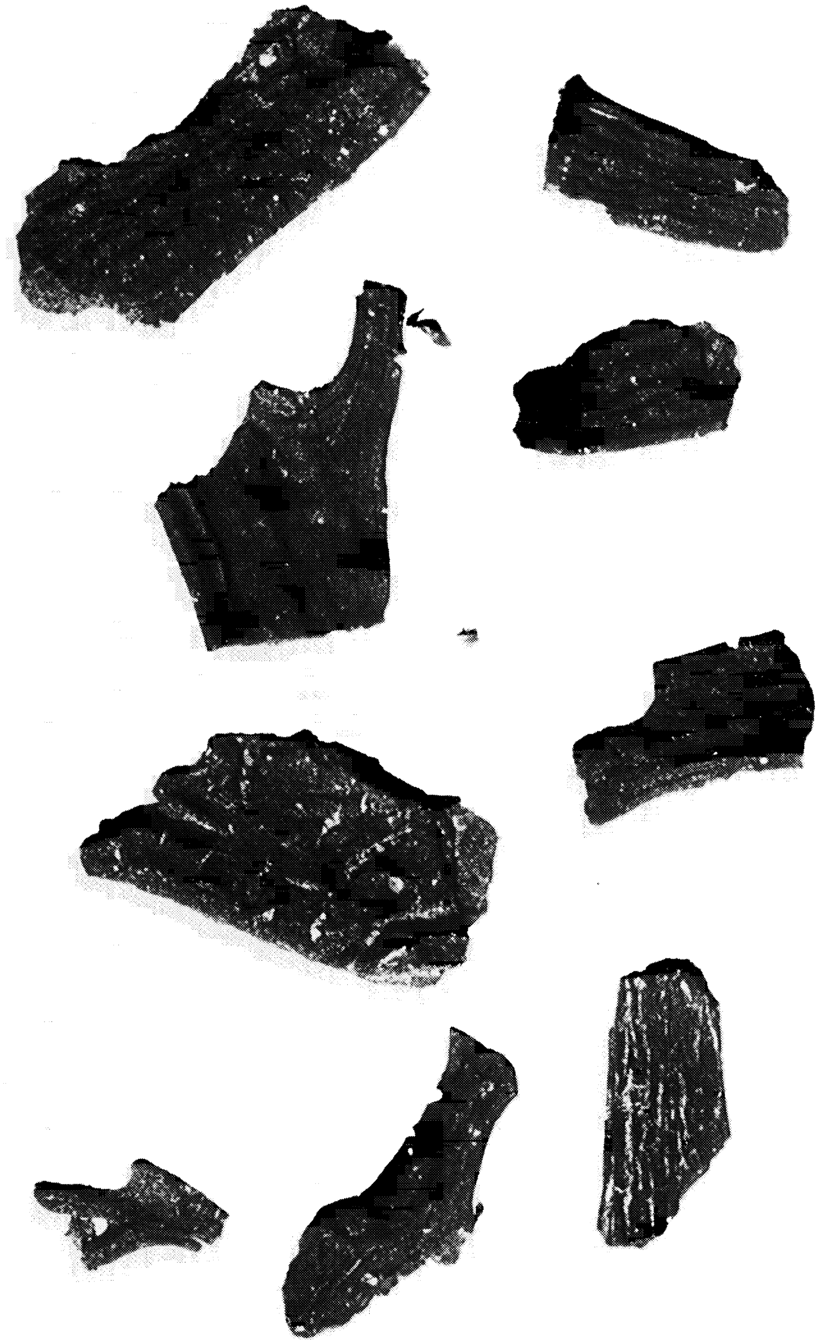


FIGURE 7. Fucoid seaweed remains from Ecalgrain Site A.

4.3. *Site B*

4.3.1. *Geomorphology and stratigraphy*

The sediments consist of 0.15 m of olive-grey (5GY 5/1) stony organic clay superseded by 0.25 m of head, followed by a further 0.42 m of olive-grey (5GY 5/1) stony organic clay and 0.8 m of bluish-grey (5BG 6/1) clay mud. Head deposits underlie and overlie the organic horizons.

4.3.2. *Floral and faunal analyses*

Samples were obtained from each stratigraphic unit between the main heads. The pollen and spore assemblage biozone descriptions can be seen as captions to figure 8.

The only sample to yield plant macro-remains was EB1, which includes pollen samples 0–0.50 m in the upper stony clay (table 1). From these, caryopses of Gramineae and *Salix* budscales were recovered.

The dominance of non-arboreal pollen denotes the existence of an open landscape during the timespan represented by the pollen and spore assemblage. The relatively small amounts of Chenopodiaceae, Cruciferae, *Armeria* and *Jasione montana* pollen may have been produced by continuing, but still more distant salt-marsh, foreshore, sand-dune and cliff-top vegetation that was once proximal to the Ecalgrain A site. However, in view of the regional vegetational implications of the pollen and spore flora (see below) these taxa could also have been members of inland, open plant communities, some of which may have been halophytic.

From time to time there was local open fresh water, where *Potamogeton* and, more infrequently, *Nymphaea* grew. A sedge-swamp containing a variety of other herbs, probably including *Lychnis* and *Thalictrum*, also appears to have been present nearby.

Regionally, birch–juniper scrub, dwarf-shrub heath and grassland seems to have occurred in the vegetation mosaic. The heath contained *Empetrum* and Ericaceae, the grassland, *Helianthemum*, *Polygonum viviparum*, Saxifragaceae and perhaps *Lycopodium*, *Huperzia*, *Selaginella*, *Armeria* and *Jasione*.

Ephedra distachya currently has a disjunct distribution. Its major area of occurrence is the Eurasian steppe; other localities include coastal dunes in western France, as far north as Brittany (Godwin 1975). Thus its fossil pollen could have originated from coastal dune or continental grassland vegetation, or both, in the Cotentin region, elements of both of which are suggested by other pollen and spore taxa. It should also be noted, however, that *Ephedra* pollen is capable of being transported long distances (Maher 1964), and may, like that of *Pinus* and *Picea*, have come from an extra-regional source.

Overall, the indications from the flora are of mixed boreal-arctic vegetation analogous to that found in northern Eurasia today (see, for example, Yurtsev 1972; Hansen & Johansen 1982).

Insect remains, almost entirely of Coleoptera, occur patchily in the organic clays and muds interbedded with the head deposits near the exposed base of the cliff. Samples for insect analysis were obtained from the upper organic stony clay and clay mud (EB 1), and the lower organic stony clay (EB 2) (table 1). In view of the paucity of insect fossils in the samples, an additional 2 kg of material from each layer, collected in 1969 by Professor F. W. Shotton and kindly made available, was used in the production of the fauna listed below (table 5).

In the faunal list, the species from each of these samples are shown separately but they do

Table 5. Ecalgrain Site B: insect fauna

sample...	EB 1	EB 2
Carabidae		
Notiophilus aquaticus (L.)	—	2
Notiophilus sp.	1	1
Elaphrus cupreus (Duft.)	1	1
Dyschirius globosus (Hbst.)	2	—
Patrobus assimilis Chaud.	—	2
Bembidion aeneum Germ.	2	—
Bembidion transparens Gebl.	—	2
Pterostichus diligens (Sturm)	—	2
Pterostichus melanarius (Ill.)	—	1
Agonum sp.	4	2
Hydrophilidae		
Cercyon melanocephalus L.	—	1
Hydrobius fuscipes (L.)	—	1
Staphylinidae		
Micropeplus fulvus Er.	1	—
Olophrum assimile (Pk.)	—	4
Olophrum fuscum (Grav.)	3	10
Arpedium brachypterum (Grav.) type	11	10
Pycnoglypta lurida Gyll	5	2
Boreaphilus henningianus Sahlb.	—	1
Acidota crenata (F.)	1	1
Lesteva sp.	1	—
Anotylus rugosus (F.)	1	—
Oxytelus laqueatus (Marsh.)	1	—
Stenus juno (Pk.)	3	—
Euaesthetus bipunctatus (Ljun.)	1	—
Euaesthetus laeviusculus Mannh.	3	—
Quedius sp.	—	2
Tachyporus sp.	—	1
Gymnusa variegata Kies.	—	1
Alaeocharinae *gen. et sp.*?	—	2
Scarabaeidae		
Aphodius sp.		
Byrrhidae		
Cytilus sericeus (Forst.)	1	—
Curculionidae		
Otiorhynchus arcticus (F.)	—	1
Otiorhynchus nodosus (Müll.)	1	—
Otiorhynchus proximus Stierl.	—	2
Otiorhynchus rugifrons (Gyll.)	2	1
Barynotus squamosus Germ.	—	1
Sitona sp.	3	—
Notaris acridulus (L.)	2	3
Notaris aethiops (F.)	12	6
Rhynchaenus foliorum (Müll.) or *flagellum* Er.	—	1

not differ significantly in their environmental implications and, in consequence, the fauna will be treated as a single assemblage.

In general this fauna presents a rather monotonous picture of an open landscape in which rich vegetation was confined to marshy areas, and sparse plant cover dominated the drier places. Thus, *Notiophilus aquaticus* is a predator of colembola in rather barren, dry places. *Dyschirius globosus* lives in rather varied habitats in damper, open country. *Otiorhynchus rugifrons* is a weevil that feeds on various small herbs, also in open country. Damper, more richly vegetated areas would have provided suitable habitats for *Elaphrus cupreus*, *Bembidion aeneum*, and *Bembidion transparens*. There is no evidence from the insect fauna of any open water, but the abundance of the weevil *Notaris aethiops* suggests a *Carex* swamp, and *Notaris acridulus* feeds chiefly on *Glyceria aquatica*. *Cytilus sericeus* feeds exclusively on moss. There are no tree-dependent species in this fauna. The very small weevil *Rhynchaenus foliorum/flagellum* feeds on *Salix*, but it is frequently found living on dwarf species, and does not imply the presence of tree willows. The great abundance of small staphylinid beetles, particularly *Olophrum fuscum* and *Arpedium brachypterum*, represents a suite of predatory species living chiefly on small soil arthropods and worms in decaying accumulations of plant debris in damp places. Such accumulations of rotting plant material could account for the presence of the single specimen of *Aphodius* which is most frequently found in dung, but which includes species that can make do with decomposing vegetation of similar texture.

This assemblage implies climatic conditions rather colder than those in Normandy at the present day. Such species as *Pycnoglypta lurida*, *Arpedium brachypterum*, and *Boreaphilus henningianus* are chiefly boreomontane at the present time. The weevil *Notaris aethiops* now has a similar geographical distribution, being found only at high altitude in France, i.e. le Puy-de-Dôme, at le Meyrand (1200 m) and Lac Chambon (880 m) (Hoffman 1958).

4.3.3. *Synthesis*

While the successions at sites A and B can nowhere be observed in superposition, there is a strong probability that the former are older than the latter, having been exhumed from beneath the head sequence. For example, the stony clay above the detritus mud on the foreshore is very similar to one in the base of the cliff behind the section. There is certainly an erosional hiatus between the two sections, but the plant and insect data suggest that this may not be prolonged. Had the period of erosion been at all protracted, the insect fossils at Ecalgrain A would have been more decomposed. Furthermore, a continued but reduced presence of maritime and submaritime vegetation is suggested at site B. This would have been a logical corollary of a continued fall in sea level as the environment became colder. At times, the climate was cold enough for periglaciation with slopewash, solifluction and head formation. The flora and fauna from the clays and muds suggest that the climate may have ameliorated between periglacial episodes indicated by the heads. Some of the thin head seams may have resulted from single, very short-lived geomorphological events.

5. Herquemoulin

5.1. *General context of the deposits*

The cliffs of Herquemoulin (49° 39′ N, 1° 54′ W) form the northernmost extent of the Anse de Vauville and lie 5 km southeast of Ecalgrain (figure 1). The solid formations in the area are Cambrian and Ordovician sandstones and shales, lightly metamorphosed and generally inclined south or south-southeast. The head on this part of the Cotentin ranges from 25 m thick at the Descente de Herquemoulin, to 35–45 m thick at many other localities. The Herquemoulin head, unlike that at Ecalgrain is relatively unstratified with no visible loessic bands. Only in the sides of the ravine at the Descente de Herquemoulin can a crude stratification be observed. Here, beds of alternating sandy and muddy gravel with individual units up to 0.20 m thick occur, the sequence inclined seaward at angles of up to 44° (Watson & Watson 1970).

The lower layers of the head are generally finer-grained than the bulk of the deposit, which contains boulders up to 0.70 m long axis. The cliff sections show basal fine-grained, organomineral sediments, but these vary considerably in occurrence and thickness. A raised beach is intermittently present below the head. This is probably the result of the encroachment of the head flows on to the abandoned shore zone, which currently is composed of both beach deposits and rock outcrops. Both these latter types of substrate would have been left behind by the falling sea level of post-raised beach time.

5.2 *Site A*

5.2.1. *Geomorphology and stratigraphy*

This is the most southerly site at the locality, occurring about 150 m north of the settlement of le Petit Beaumont (figure 9). It is a foreshore exposure which shows a rock platform cut in schist overlain by 0.15 m of brownish-black (5YR 2/1) detritus mud.

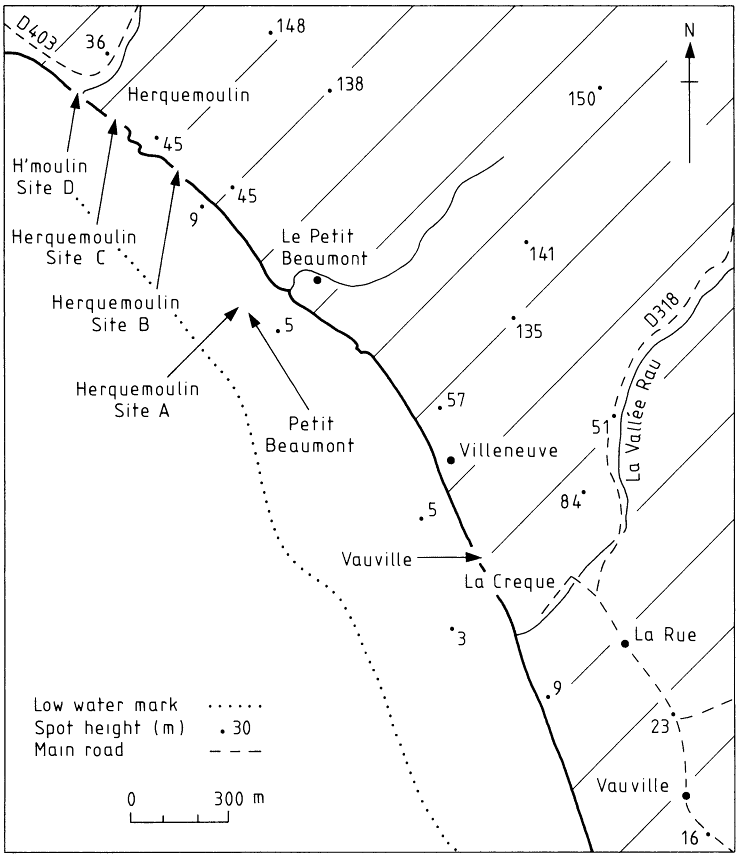


FIGURE 9. Herquemoulin-Petit Beaumont-Vauville: site plan.

5.2.2. *Floral and faunal analyses*

Samples were obtained from the detritus mud. The pollen and spore assemblage biozone descriptions can be seen as captions to figure 10.

Because the deposit was thin, only one sample (HA 1) was obtained for plant macrofossils and is thus equivalent to both pollen assemblage biozones (table 1, figure 10). Remains of 13 plant taxa were recovered, together with those of *Cenococcum geophilum* (table 6).

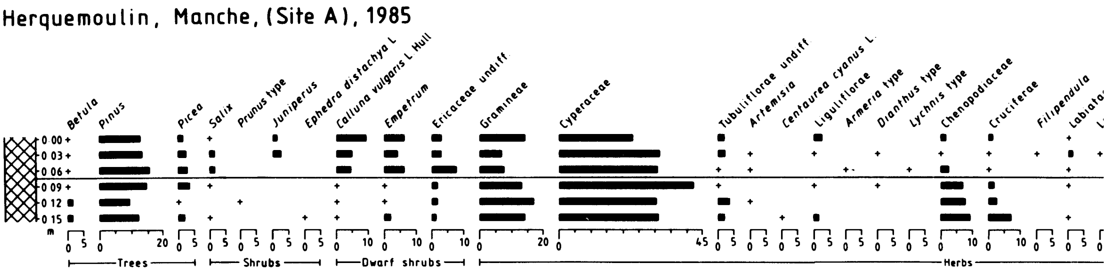


FIGURE 10. Herquemoulin Site A: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. HA Chenopodiaceae, Cruciferae and Compositae. Arboreal pollen is 12–18% and comprises *Pinus*, *Picea* and *Betula*. Shru and *Typha latifolia*. Filicales reach 15% and *Polypodium*, *Huperzia selago* and *Selaginella selaginoides* are recorded. Cyperaceae–Ericales–*Pinus*. Arboreal values are comparable to those of HA-1. Shrubs (especially dwarf-shrubs) accou Compositae and Saxifragaceae are also well represented. Filicales have values similar to those of HA-1.

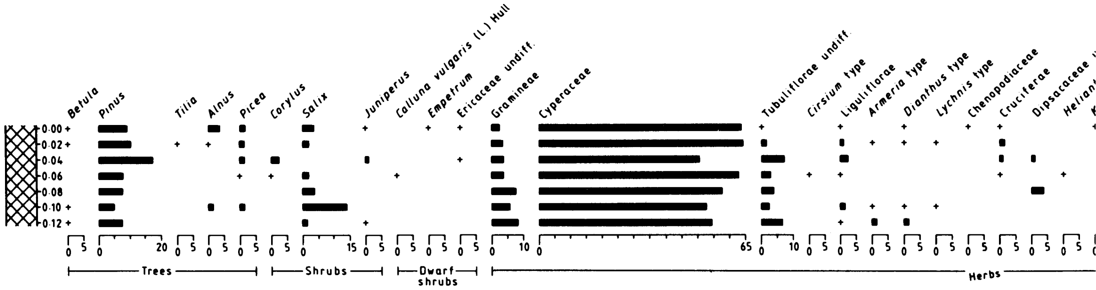


FIGURE 11. Herquemoulin Site B: pollen diagram and assemblage biozone. +, Under 1%; undiff., undifferentiated. Cyp especially Cyperaceae, Gramineae, Compositae, Rosaceae, Saxifragaceae and *Polygonum viviparum*. *Pinus* and *Picea* are t are low but *Potamogeton* is consistently present. Spores are less than 5% with *Huperzia selago*, *Polypodium* and *Pteridium*

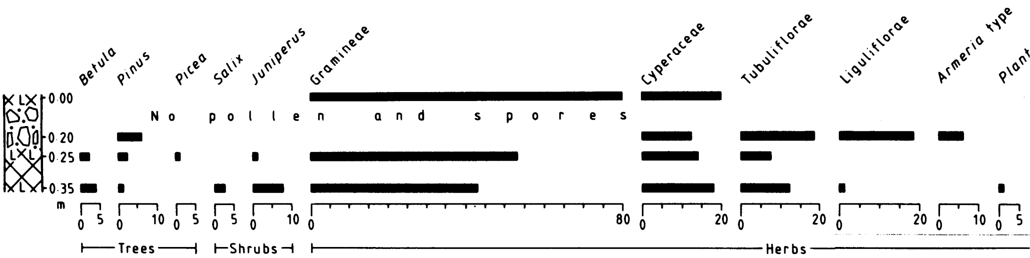
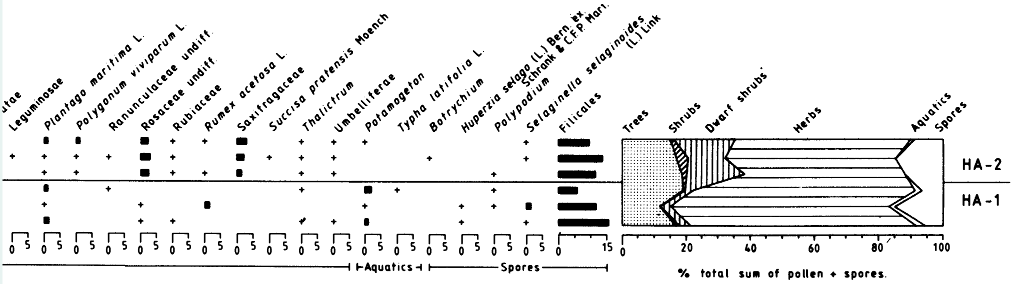
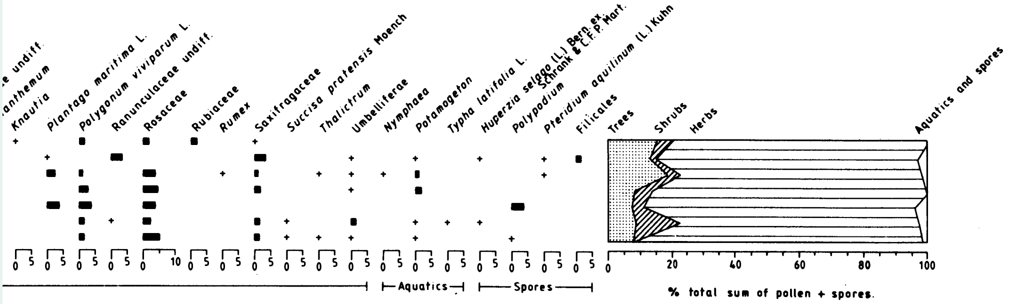


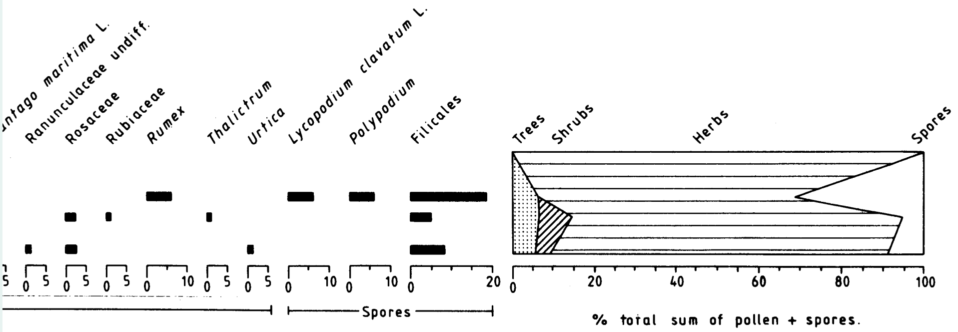
FIGURE 12. Herquemoulin Site C: pollen diagram and assemblage biozone. Undiff., undifferentiated. Gramineae–Cyperacea and Rosaceae, dominant. *Betula*, *Pinus*, *Picea*, *Salix* and *J*



A-1 Cyperaceae–Gramineae–*Pinus*–Chenopodiaceae. Herbs account for 60–70 %, notably Cyperaceae, Gramineae, ubs (*Salix*, *Ephedra distachya*, *Calluna*, Ericaceae and *Empetrum*) attain 5 %. Aquatics are represented by *Potamogeton*, d. The terminal boundary is placed where Gramineae, Chenopodiaceae and Cruciferae values fall. HA-2 ount for up to 20 %. *Juniperus* is present. Cyperaceae and Gramineae dominate the herbaceous taxa but Rosaceae,



peraceae–*Pinus*–Gramineae–Compositae. Non-arboreal values are up to 90 %, with herbaceous pollens dominant, the major tree taxa, and *Salix* the principal shrub. *Juniperus*, *Empetrum* and Ericaceae are recorded. Aquatic values *aquilinum* represented, as well as Filicales.



ae–Compositae. Non-arboreal values are 95 % or more, with herbs, especially Gramineae, Cyperaceae, Compositae *Juniperus* are the only trees and shrubs present.

Table 6. Herquemoulin Site A: plant macrofossils

sample (50 ml)...	HA 1
Carex (biconvex) nutlets	12
Carex (trigonous) nutlets	33
Cirsium fruit	1
Cruciferae seed	1
Potamogeton cf. coloratus Hornem., endocarps	3
Ranunculus subg. *Batrachium* fruit	1
Ranunculus sceleratus L. fruits	28
Rubus fruticosus agg. or *idaeus* L. fruitstone	1
Stellaria alsine Grimm, seed	1
Viola palustris L. seed	1
Viola seed	3
Mosses unident. fragments	2
Cenococcum geophilum Fr. sclerotia	5

The palaeobotanical data indicate that HA-1 and HA-2 are herb biozones. A substantial proportion of the flora of HA-1 can be referred to local vegetation. There appears to have been a mosaic of fresh and brackish or saltwater vegetation in close proximity. The high Cyperaceae pollen values and *Carex* macroremains must, in part, be associated with a freshwater marsh which surrounded open water. *Potamogeton*, *Typha latifolia*, *Ranunculus* (*Batrachium*), *Stellaria alsine* and *Viola palustris*, were present in this vegetation. *Ranunculus sceleratus* is tolerant of both fresh and brackish water, and may have existed in both habitats. Some sedges and grasses, together with Chenopodiaceae, Cruciferae, Compositae and *Plantago maritima*, are likely to have been members of local maritime and submaritime plant communities. The *Pinus* and *Picea* pollen curves may, as at Ecalgrain, reflect the presence of these trees on sand-dunes, or denote long-distance transport of the grains. Similarly, the pollen of *Ephedra distachya* may have come from plants growing on sand-dunes, in grassland or from an extraregional source (see above).

Notwithstanding the possible status of the conifers, trees seem to have played little part in the regional vegetation during HA-1. There may have been some *Betula* scrub with a ground flora in which ferns were prominent. Dwarf-shrub heath with *Calluna* and *Empetrum* occurred. *Ephedra distachya* was probably present in vegetation that included grasses, *Artemisia*, *Centaurea cyanus*, *Plantago maritima*, Rosaceae and Caryophyllaceae. Overall, there is little doubt that the environment was cool, with both maritime and continental elements.

HA-2 portrays the same type of local vegetation as HA-1. However, sharp falls in Chenopodiaceae and Cruciferae pollens suggest a reduced representation of maritime plant communities, probably as a result of their more distant location as sea-level dropped. There is also less evidence of open, fresh water. Regionally, the scrub vegetation now contained juniper and probably *Salix*, in addition to *Betula*, with ferns retaining their understorey role. A rise in dwarf-shrub pollens reflects an extension of heathland. Increased Saxifragaceae pollen values, accompanied by Compositae, *Polygonum viviparum*, *Rumex acetosa*, Rubiaceae, *Succisa pratensis*, *Botrychium* and *Selaginella selaginoides* indicates the spread of montane–arctic grassland. Some of the latter may have been steppe-like and contained halophytic communities including species of Chenopodiaceae and Cruciferae.

No identifiable insects were recovered from a sample of this profile.

5.2.3. *Synthesis*

The plant remains indicate open habitat vegetation, both locally and regionally throughout the timespan. There was freshwater marsh nearby, initially probably accompanied by brackish–saline plant communities. Regionally, grass-heath dominated, with perhaps some scrub. Overall, the environment was at best cool, with the severity of climate increasing as time progressed.

5.3. *Site B*

5.3.1. *Geomorphology and stratigraphy*

This is a cliff section, 300 m southeast of the Descente de Herquemoulin (figure 9), with the stratigraphy described below.

4	Very coarse rubble head with boulders in a loessic matrix	*ca.* 20.00 m
3	Dark reddish-brown (7.5R 3/2) shale head with wood fragments in the bottom 0.60 m	1.18 m
2	Dark bluish-grey (5BG 4/1) detritus mud with wood fragments	0.12 m
1	Blocky head resting on bedrock	0.34 m

5.3.2. *Floral and faunal analyses*

The detritus mud between the basal blocky head and the shale head was sampled. The pollen and spore assemblage biozone descriptions can be seen as the caption to figure 11.

Two samples were examined for plant macrofossils, HB 1 including pollen samples 0.0–0.06 m, and HB 2, including pollen samples 0.08–0.12 m (table 1, figure 1). Both contained fragments of *Salix* wood; HB 1 also yielded sclerotia of *Cenococcum geophilum*.

A hollow in the surface of the lowest head was the site of organic matter accumulation. *Nymphaea*, *Typha latifolia* and *Potamogeton* pollen indicates that from time to time, there must have been open, fresh water. A fringing swamp and fen including Cyperaceae, Umbelliferae, *Lychnis*, *Thalictrum*, *Salix*, and perhaps *Alnus*, occurred. Similar temporal relationships to those of Ecalgrain Sites A and B are proposed for Herquemoulin Sites A and B. Thus, with the possibility that their pollen may also have originated from interior habitats (see above), the values for Chenopodiaceae, Cruciferae, Compositae, *Armeria* and *Plantago maritima* at Herquemoulin B, are considered, at least in part, to reflect gradually diminishing coastal (salt-marsh, foreshore, sand-dune, cliff-top) elements in the vegetation mosaic.

The high shrub and herb pollen counts denote a predominantly open regional landscape. If *Pinus* and *Picea* were present locally, as suggested above, the remainder of the vegetation was a mixture of birch–juniper scrub with ferns, dwarf-shrub heath with Ericales, and an open sward including grasses, sedges, *Helianthemum*, *Polygonum viviparum*, Compositae, Rosaceae, Saxifragaceae, Chenopodiaceae and Cruciferae.

No recognizable insect fossils were found in these deposits.

5.3.3. *Synthesis*

The plant assemblage reflects an open local and regional vegetation of high boreal and low arctic type. Wood remains in the lower part of the head overlying the detritus mud may have been incorporated from up-slope during cold-climate mass movement. If so, they could be from vegetation that was overwhelmed by severe periglacial activity, or from reworked earlier sediments.

5.4. *Site C*

5.4.1. *Geomorphology and stratigraphy*

This is a cliff section 25 m south of the stream at the Descente de Herquemoulin (figure 9), where the deposits described below occur.

6	Angular head	*ca.* 30.00 m
5	Bluish-grey (5BG 6/1) clay mud	0.03 m
4	Shale head with some quartzite blocks up to 0.10 m long axis in a sandy matrix	0.20 m
3	Bluish-grey (5BG 6/1) clay mud	0.10 m
2	Sub-angular stones becoming more rounded with depth	0.45 m
1	Well-rounded quartzite pebbles and cobbles in an iron cement. Raised beach	0.30 m+

5.4.2. *Floral and faunal analyses*

The two layers of clay mud separated by a thin head (the tripartite stratigraphy above the raised beach and below the main head) were sampled. The pollen and spore assemblage biozone descriptions can be seen as the caption to figure 12. No plant macrofossils were found in these sediments.

Pollen and spore frequencies are low, and the range of taxa restricted. The pollen in the head is deteriorated.

In spite of these problems, certain vegetation types thought to have existed locally and regionally at Herquemoulin A and B appear to be represented. For example, fern-rich *Betula–Juniperus* scrub is suggested. There are no records of freshwater aquatic taxa to correlate with the clay muds. Some grass pollen, accompanied by, for example, that of *Armeria* and *Plantago maritima*, could reflect open coastal or interior vegetation.

No identifiable insects were recovered from these sediments.

5.4.3. *Synthesis*

The combined stratigraphic and pollen evidence indicates open vegetation of cool to cold aspect. The raised beach was presumably associated with temperate conditions, but then seems to have gained a colder component in the form of angular, unworn clasts. The thin head separating the clay muds was probably the result of a local catastrophic event, although the massive overlying head signifies major periglacial activity.

5.5. *Site D*

5.5.1. *Geomorphology and stratigraphy*

This is a cliff section 20 m north of the stream at the Descente de Herquemoulin (figure 9), whose stratigraphy is

5	Crudely stratified rubble head	*ca.* 30.00 m
4	Grey (5Y 4/1) stony clay	0.35 m
3	Angular head with a dark reddish-brown (2.5YR 3/2) silty matrix	0.33 m
2	Olive-black (7.5Y 3/1) stony clay	0.37 m
1	Iron-stained, lightly rolled sandstone and shale gravel. Raised beach	0.22 m

5.5.2. *Floral and faunal analyses*

The two stony clays and intervening thin head above the raised beach and below the main head were sampled. The pollen and spore assemblage biozone is described in the legend to figure 13. Six taxa of plant macrofossils were found in samples HD 2 and HD 3, which incorporate the pollen samples 0.63–0.98 m (tables 1 and 7; figure 13).

The percentages of pollen and spores denote the existence of an open landscape throughout this period. Regionally, some *Betula–Juniperus* scrub with ferns may have been present. Dwarf-shrub heath seems to have been quite widespread, along with herbaceous vegetation including *Artemisia*, *Centaurea cyanus*, *Epilobium*, *Helianthemum*, *Polygonum viviparum*, *Rumex acetosa*, Saxifragaceae, *Botrychium*, *Lycopodium*, *Huperzia* and *Selaginella*. If sea-level continued to fall during the deposition of the assumed younger (cliff) organomineral sediments here as at Ecalgrain (see above), Chenopodiaceae, Cruciferae, *Armeria* and *Plantago maritima* pollen may have come from increasingly distant maritime and submaritime plant communities. However, as noted previously, these taxa could also have been members of interior vegetation that included open and halophytic components. The low values of *Pinus* and *Picea* pollen may indicate its long-distance transport.

TABLE 7. HERQUEMOULIN SITE D: PLANT MACROFOSSILS

sample...	HD 2	HD 3
Carex nutlet	—	1
Luzula seeds	1	3
Potentilla palustris (L.) Scop. fruits	3	1
Salix budscales	3	7
Viola seeds	1	1
Cenococcum geophilum Fr. sclerotia	44	38

Such a pollen and spore flora seems to have closest affinity with contemporary high-latitude vegetation mosaics including tundra and steppe (Hadač 1963; Yurtsev 1982).

The fossiliferous deposits accumulated in a series of hollows on a former beach surface. Here, open fresh water with *Myriophyllum*, *Typha* and *Potamogeton* existed from time to time. There appears to have been some freshwater marsh and fen, where *Carex*, *Luzula*, *Potentilla palustris*, *Viola*, *Caltha*, *Lychnis*, *Filipendula* and *Thalictrum* grew, probably also *Salix* and *Alnus*. *Cenococcum geophilum* forms mycorrhiza with numerous angiosperms and gymnosperms (Trappe 1964). Sclerotia formation seems to be most effective in dry environments. Van Geel (1976) suggested that it may occur in raised bogs only under relatively dry conditions. This might support the notion from stratigraphic and other palaeobotanical evidence of a cold, dry climate.

Three bulk samples that included the series of pollen samples were analysed for insect remains (table 1, figure 13). The fauna was similar in each and they are presented as a single list (HD 1–3) (table 8).

Somewhat surprisingly, named insect remains were obtained from this locality only, the other Herquemoulin sites producing heavily corroded, unrecognizable specimens from the samples investigated. The faunal assemblage has fewer species, but in general is similar to that from Ecalgrain Site B. However, the numbers of individuals of certain environmentally important species are relatively higher. This fauna is indicative of a rather barren landscape with patchy vegetation and, in contrast to Ecalgrain B, with limited *Carex* swamp. The only aquatic beetles are *Helophorus aquaticus* and *Hydrobius fuscipes*, but both can live in very small puddles, and do

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TABLE 8. HERQUEMOULIN SITE D: INSECT FAUNA

sample...	HD 1–3
Carabidae	
Patrobus assimilis Chaud	1
Patrobus septentrionis (Dej.)	1
Bembidion sp.	1
Agonum exaratum Mann.	2
Hydrophilidae	
Helophorus aquaticus (L.) type	2
Cercyon sp.	1
Hydrobius fuscipes (L.)	1
Staphylinidae	
Olophrum assimile (Pk.)	9
Olophrum fuscum (Grav.)	28
Arpedium brachypterum (Grav.) type	10
Pycnoglypta lurida Gyll	9
Boreaphilus henningianus Sahlb.	3
Acidota crenata (F.)	1
Stenus spp.	8
Quedius sp.	1
Alaeocharinae gen. et sp.?	4
Byrrhidae	
Simplocaria semistriata (F.)	1
Chrysomelidae	
Plateumaris sp.	1
Curculionidae	
Otiorhynchus proximus Stierl.	1
Otiorhynchus rugifrons (Gyll.)	2

essarily suggest open water in quantity. The sole plant-feeding Coleoptera are *Simplocaria semistriata* which eats moss, and the two weevils *Otiorhynchus rugifrons* and *Otiorhynchus proximus* which eat a wide range of low-growing plant species. The list of small staphylinid beetles of the leaf-litter fauna is reduced compared with Ecalgrain B, but the number of individuals, particularly of *Olophrum fuscum*, remains high.

The climatic implications of this faunal assemblage are of considerable interest. *Agonum exaratum*, here the most abundant carabid, is one of the most cold-adapted species of this genus, barely occurring below the forest limit at present (Lindroth 1966). Its nearest occurrence to Normandy is on the east of the Kola Peninsula in arctic Russia. Similarly, the currently northern staphylinid species *Boreaphilis henningianus* is relatively common. *Otiorhynchus proximus* is now a mountain species of the eastern Alps and Carpathians (Moseley 1982). Thus, although this fauna has no precise modern analogue, its composition, with high boreal and alpine taxa, implies that the climate must have been similar to that of the tundra of the present day.

5.5.3. *Synthesis*

The stratigraphic and fossil evidence points to an episode characterized by cold, open conditions. Scrub, shrub heath and herb-rich sward assumed importance, the latter perhaps containing some halophytes. The climate may have been dry as well as cold. Such conditions pertain in tundra and high-latitude steppe today (Borisov 1965; Yurtsev 1982). Evidence from the insects also indicates arctic-montane and probably continental climatic conditions, with one species (*Agonum exaratum*) which lives almost exclusively above the treeline, and the rest are well able to thrive under such conditions. The stony clays and head denote that cold-climate rock fracture and mass movement was of considerable importance at this time.

6. PETIT BEAUMONT

6.1. *Geomorphology and stratigraphy*

The cliffs at Herquemoulin continue southeastwards towards Vauville, where the head is buried by blown sand (see below) (figure 1). At Petit Beaumont (49° 41′ N, 1° 51′ W), 0.9 km southeast of the Descente de Herquemoulin, patches of organomineral deposits are found in hollows in a shore platform cut in the same mudstones as at Herquemoulin (figure 9). A section 30 m from the base of the head cliff and 15 m south of the stream at le Petit Beaumont showed the deposits described below.

2	Bluish-grey (5BG 6/1) clay mud	0.12 m
1	Brownish-black (5YR 2/1) detritus mud	0.18 m

It is probable that a continuous expanse of these deposits existed around mid-tide level (0m NGF) before recent marine action cut into and buried parts of the deposit. The compacted nature of the muds, and the condition of the plant fragments (see below), together with the presence of a large number of angular boulders scattered over the outcrops, leaves little doubt that the organomineral material has been exhumed from beneath a cover of head. The only recorded exposure of organomineral material overlain by head is in the ravine at Petit Beaumont (Clet *et al.* 1982).

The head of Petit Beaumont has been investigated by Clet *et al.* (1982), who suggest a similar stratigraphic sequence to that at Ecalgrain. A thick lower head is covered by a thin lower loess, the latter affected by strong palaeosol development. A thin upper head and upper loess complete the sequence. The head here is around 30 m thick overall.

6.2. *Floral and faunal analyses*

The detritus mud and clay mud were sampled. The pollen and spore assemblage biozone descriptions can be seen in the legend to figure 14. Two samples yielded plant macrofossils (table 9), PB 1, including pollen samples 0.0–0.12 m, and PB 2 including pollen samples 0.14–0.26 m (table 1, figure 14).

The high sedge component in the plant record is most likely to have been associated with a local marsh environment. Hollows in the rock platform contained open, fresh water, where *Nuphar*, *Nymphaea* and more frequently, *Potamogeton* were able to exist. *Callitriche* and *Hydrocotyle* must have grown on a muddy substrate near to the water. The probable marsh herbs, *Lycopus*, *Lychnis*, *Gentiana*, *Thalictrum*, *Potentilla palustris* and *Viola palustris* were present, and there is evidence of rich-fen conditions from the mosses *Campylium stellatum* and *Cratoneuron filicinum*. However, the presence also of *Drepanocladus fluitans*, *Sphagnum* and *Scheuchzeria palustris* denotes that patches of acid bog occurred locally. *Betula*, *Salix* and *Alnus* were also likely members of the swamp-fen community.

The very low tree pollen values indicate a lack of forest at this time. The pine and spruce pollen was either extraregional or could have come from local expanses of conifers on sandy soils (see above). Some scrub with birch, juniper and ferns may have existed. Heathland with a variety of dwarf shrubs is indicated. *Rubus chamaemorus*, *Huperzia* and *Lycopodium clavatum* may also have grown here, supporting the notion of montane–arctic plant communities. Such vegetation is also indicated by the herbaceous pollen record, with saxifrages, Rosaceae, *Rumex acetosa*, *Linum catharticum*, *Helianthemum*, *Polygonum viviparum*, *Selaginella selaginoides* and *Botrychium*,

Table 9. Petit Beaumont: plant macrofossils

samples (50 ml)...	PB 1	PB 2
Carex (biconvex) nutlets	33	4
Carex (trigonous) nutlets	3	2
Potentilla palustris (L.) Scop. fruits	4	—
Salix budscales	3	6
Viola palustris L. seeds	3	—
Campylium stellatum (Hedw.) J. Lange & C. Jens, stems and leaves	13	28
Cratoneuron filicinum (Hedw.) Spruce, stems and leaves	16	2
Drepanocladus fluitans (Hedw.) Warnst, stems and leaves	1	—
Mosses unident. fragments	26	6
Cenococcum geophilum Fr. sclerotia	3	1

together with grasses and sedges, appearing to have contributed to a mosaic of tundra and steppe. *Artemisia*, *Succisa pratensis* and *Urtica* would also be consonant with these conditions, growing upon disturbed soils.

Here, as at Ecalgrain and Herquemoulin, maritime and submaritime environments could be reflected by *Armeria*, *Jasione montana*, *Glaux maritima* and *Plantago maritima*, as well as by chenopods and crucifers. It is worth noting, however, that while a coastal location is most likely for these taxa in Western Europe today, they would also be able to exist as members of tundra or steppe vegetation.

Remains of Coleoptera were recovered from both samples PB 1 and PB 2 (table 1, figure 14), but since there is so little difference between the two assemblages, they will be treated here as if they belonged to a single community. Altogether, 29 taxa of Coleoptera were obtained, of which 20 have been named to species (table 10). Although this number is small, nevertheless there are a relatively large number of species represented by several individuals, suggesting that the fossil assemblage is not merely a small sample of an originally diverse fauna, but an indication of the specific impoverishment of the fauna of the time.

The insect fauna suggests that the local environment must have been very monotonous, with much open country and most of the vegetation in marshy swamps. Thus the ground beetles *Diacheila arctica*, *Patrobus septentrionis*, *Bembidion aeneum*, *Bembidion guttula* and *Agonum exaratum* are species that live chiefly in soft marshy ground overgrown with *Carex* and moss. *Patrobus assimilis* is less hygrophilous than *P. septentrionis* and usually occurs on rather dry, gravelly or peaty soil (Lindroth 1974). *Helophorus grandis* lives in pools of standing water that may be little more than puddles. The weevil *Notaris aethiops* suggests the presence of various Cyperaceae or similar plants, and *Otiorhynchus nodosus*, though polyphagous, is also frequently a bog species.

Otiorhynchus arcticus is likewise polyphagous, feeding on a wide variety of low plants in open and rather drier places than *O. nodosus*. The moderately large weevil *Cryptorhynchus lapathi* has larvae that excavate galleries in wood, chiefly of *Salix* or *Betula*, and is too large to be satisfied with dwarf willows. The suite of small staphylinid beetles, by far the most numerous component of this assemblage, live among leaf or moss litter in damp places, where they are predators on small arthropods and worms. *Aphodius* and *Colobopterus* are usually dung beetles but accumulated rotten vegetation, if of a similar consistency, can provide alternative habitats.

There can be no doubt that this fauna indicates very cold conditions. Four species are highlighted because they appear, from their present-day distributions, to be adapted to very low temperatures.

Table 10. Petit Beaumont: insect fauna

sample…	PB 1	PB 2
Carabidae		
Diacheila arctica Gyll.	1	1
Patrobus assimilis Chaud.	1	—
Patrobus septentrionis (Dej.)	2	2
Bembidion aeneum Germ.	1	—
Bembidion guttula (F.)	1	2
Agonum exaratum Mann.	3	?
Hydrophilidae		
Helophorus glacialis Villa.	—	1
Helophorus grandis Ill.	1	3
Hydraenidae		
Ochthebius sp.	—	1
Staphylinidae		
Olophrum fuscum (Grav.)	9	7
Arpedium brachypterum (Grav.) type	18	8
Pycnoglypta lurida Gyll.	10	8
Boreaphilus nordenskioeldi Makl	3	1
Acidota crenata (F.)	1	1
Stenus spp.	4	2
Philonthus sp.	2	—
Quedius sp.	1	1
Gymnusa variegata Kies.	1	—
Alaeocharinae *gen. et sp.?*	7	8
Scarabaeidae		
Colobopterus fossor (L.)	1	—
Aphodius sp.	2	1
Byrrhidae		
Simplecaria semistriata (F.)	1	?
Cytilus sericeus (Forst.)	1	—
Coccinellidae		
Coccinella sp.	1	—
Chrysomelidae		
Chrysolina sp.	1	—
Curculionidae		
Otiorhynchus arcticus (F.)	1	—
Otiorhynchus nodosus (Müll.)	1	1
Cryptorhynchus lapathi (L.)	1	—
Notaris aethiops (F.)	2	—

(i) *Diacheila arctica* has a circumpolar distribution at high latitudes, reaching as far west as northern Fennoscandia, where it occurs only north of the Arctic Circle. It also occurs in the mountains of central Asia. Its southern limit extends into the northern fringes of the boreal coniferous forest.

(ii) *Agonum exaratum* is also a circumpolar species in the arctic, with its nearest locality on the extreme east of the Kola Peninsula (represented by a single specimen). This is the most pronouncedly arctic species of *Agonum*, barely occurring below the forest limit (Lindroth 1966).

(iii) *Helophorus glacialis* is chiefly a European species that is found principally at the margins of melting snow patches, and in the streams that issue from them. It is confined to high latitude, and high altitude in central and southern Europe.

(iv) *Boreaphilus nordenskioeldi* is circumpolar in its geographical range, in the far north extending west to the Kanin Peninsula in arctic Russia. In North America, it reaches into the northern edge of the boreal forest.

Since these species only occur sporadically below the timber limit today, their presence

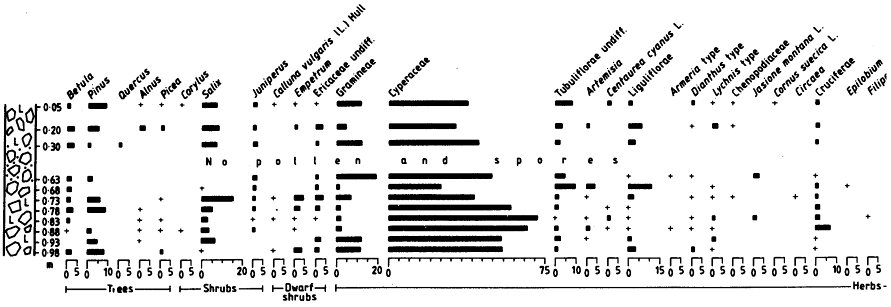


FIGURE 13. Herquemoulin Site D: pollen diagram and assemblage biozone. +, under 1 %; undiff., undifferentiated. Gramineae, Compositae, Rosaceae, Cruciferae and Saxifragaceae. Shrubs account for 5–20 % with *Salix*, *Junip* at low values. Aquatics are represented by *Myriophyllum alterniflorum*, *Typha latifolia* and *Potamogeton*. Among sp

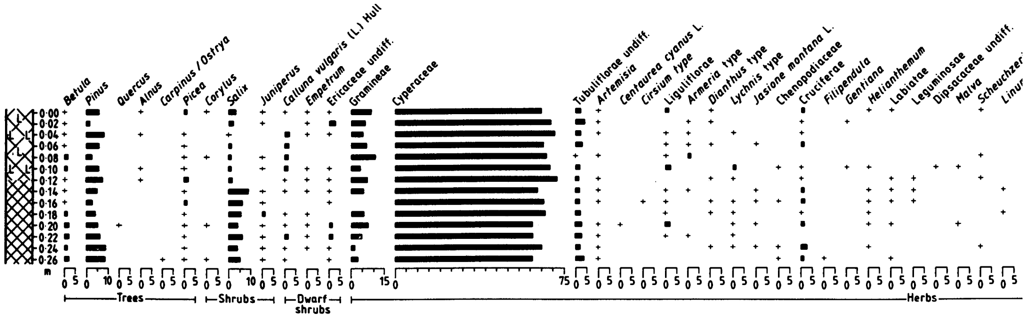


FIGURE 14. Petit Beaumont: pollen diagram and assemblage biozone. +, under 1 %; undiff., undifferentiated. Cyp and Gramineae, *Salix*, Compositae and Rosaceae also well-represented. Saxifragaceae, Cruciferae and *Plantag* (12 % or less throughout) consists mainly of *Pinus*, *Betula* and *Picea*.

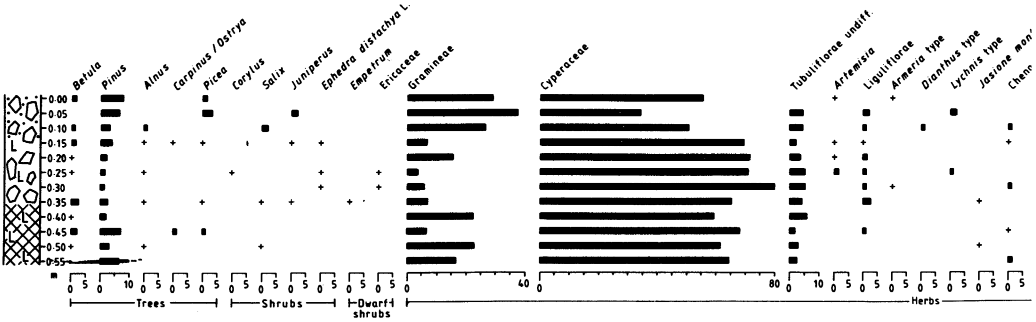
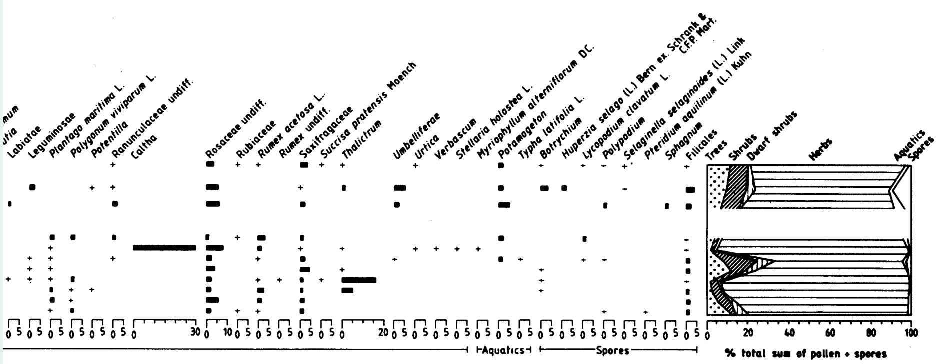
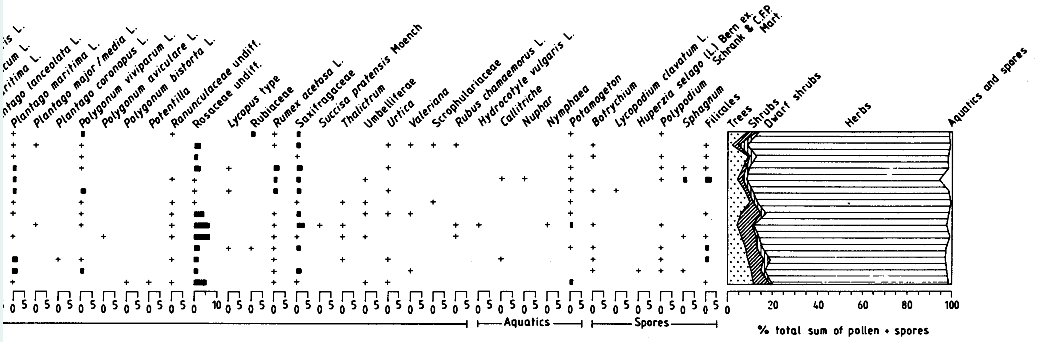


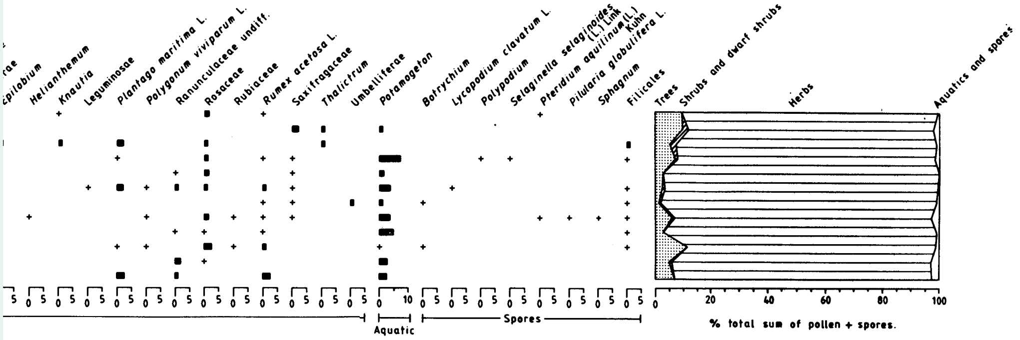
FIGURE 15. Vauville: pollen diagram and assemblage biozone. +, under 1 %; undiff., undifferentiated. Cyperaceae- are poorly represented, with *Salix* and *Juniperus* occurring sporadically at 2 % or less. *Ephedra distachya*, *Empetrum* a Rosaceae, *Rumex acetosa* and Saxifragaceae. *Potamogeton* is the main aquatic (up to 9 %). *Selaginella selaginoides* c



eraceae–Gramineae–Compositae. Non-arboreal values are up to 90 % with herbs most frequent, especially Cyperaceae,
Empetrum and Ericaceae present. *Pinus* and *Betula* are the most important tree taxa. *Picea* and *Alnus* occur sporadically
s, *Lycopodium clavatum*, *Huperzia selago* and *Selaginella selaginoides* are recorded.



ceae–Gramineae–*Pinus*–*Salix*. Non-arboreal values range from 85–95 %, with Cyperaceae accounting for up to 72 %,
aritima occur frequently at 2–3 %, and *Juniperus* at less than 1 %. Dwarf shrubs account for up to 5 %. Tree pollen



mineae–*Pinus*–Compositae. Arboreal values are under 10 %, with *Pinus*, *Betula* and *Picea* the major tree types. Shrubs
ricaceae are recorded infrequently. The major herbaceous taxa are Cyperaceae, Gramineae, Compositae, Cruciferae,
s near the top of the sequence. *Pilularia globulifera* is recorded.

together in this assemblage is strongly suggestive that the climate was equivalent to that above the tree line. This is conventionally recognized as coinciding approximately with the 10 °C mean July isotherm. Only one species does not today live in such cold conditions; *Bembidion guttula* has its most northern localities in the *Betula* zone on the south coast of the Kola Peninsula. There is thus a suggestion that, though mean July temperatures were close to 10 °C, they were probably not much colder than this. Mean January temperatures were probably not above −12 °C, and may have been considerably lower. These values imply a considerably greater degree of climatic continentality at this time, compared with Normandy at the present day.

6.3. *Synthesis*

The overall inference from the Petit Beaumont stratigraphy and fossil assemblages is that tundra and steppe environments prevailed. The clay mud indicates a change in the sedimentation régime at the site. Periglacial slopewash is the most likely explanation for the high mineral content of the topmost sediment. Freeze–thaw activity and disturbed soils would have provided the impetus for this sedimentation. The enhanced base-status of the sediment as a result of periglacial weathering probably contributed to the development of local rich-fen vegetation indicated by some plant macrofossils.

7. VAUVILLE

7.1. *Geomorphology and stratigraphy*

Vauville (49° 38′ N, 1° 50′ W) lies at the southeast of the extensive coastal section which contains Herquemoulin and Petit Beaumont (figure 1). The general setting is slopes cut in Ordovician shales and sandstones, backed by cliffs of head up to 30 m high (figure 9). At a point 250 m northwest of where the D318E1 road reaches the coast, the section described below was observed.

4	Coarse rubble head with loessic bands up to 0.50 m thick	*ca.* 25.00 m
3	Yellowish-brown (10YR 5/8) finely-bedded loessic head	1.14 m
2	Brown (7.5YR 4/4) clay mud	0.21 m
1	Olive-black (5Y 3/2) stony clay with large cobbles at base	0.20 m+

The base of the section is obscured by slumping but solid outcrops occur at the same elevation *ca.* 30 m northwest of the locality. As elsewhere in the vicinity, the Vauville head has a complex stratigraphy. There are loess-poor and -rich layers, regarded by Clet *et al.* (1982) as similar to the four-fold sequence at Ecalgrain.

7.2. *Floral and faunal analyses*

The stony clay and overlying clay mud were sampled. The pollen and spore assemblage biozone is described in the legend to figure 14. Samples V1, V2, V3 and V4 incorporating pollen samples 0–0.45 m (table 1, figure 14) yielded plant remains (table 11).

The pollen and spore record indicates a herb biozone. The site initially included a small freshwater body in a hollow on the rock platform. Aquatic flora was scarce, although *Potamogeton* had a more or less continuous presence, perhaps in a muddy substrate along with *Pilularia globulifera*. *Carex* swamp, with *Lychnis*, *Thalictrum*, *Epilobium*, *Selaginella*, *Salix* and *Alnus* was also likely. The macrofossil and microfossil records of *Selaginella selaginoides* late in the sequence may

TABLE 11. VAUVILLE: PLANT MACROFOSSILS

sample...	V1 (4 ml)	V2 (8 ml)	V3 (15 ml)	V4 (13 ml)
Selaginella selaginoides (L.) Link, megaspores	7	1	—	—
Carex nutlets	—	—	3	3

be indicative of local base-rich conditions, as it often inhabits flushes of this kind. It also reflects cold conditions; its European range is chiefly arctic-alpine (Jalas & Suominen 1972).

Regionally, grassland, heath and scrub woodland seems to have existed. There are high Gramineae pollen values that, together with Saxifragaceae, Rosaceae, *Rumex acetosa*, *Artemisia*, *Helianthemum*, *Botrychium*, *Ephedra distachya*, *Betula*, *Juniperus* and Ericales can be referred to such a vegetation mosaic. Pollen of Chenopodiaceae, Cruciferae, *Armeria*, *Jasione montana* and *Plantago maritima*, may have been derived from maritime and submaritime vegetation or that of interior, possibly saline, habitats.

Only samples V3 and V4 (table 1, figure 15) yielded insect remains. These were scarce, consisting of *Otiorhynchus nodosus* (V3) and *Notaris aethiops* (V4). Both species are predominantly wetland dwellers. They could have existed in *Carex* swamp developed in a boreoarctic environment.

7.3. *Synthesis*

The stratigraphic and palaeontological data from Vauville are consistent with a landscape dominated by open-habitat plants and insects. Many of the biota have affinity with high latitudes or altitudes, or both, where mass movement of the type represented in the sediments at the site occurs today.

8. DISCUSSION

8.1. *Sea level*

Geomorphological and stratigraphic evidence of former marine conditions is present at Omonville-la-Rogue, Ecalgrain Site A and Herquemoulin Sites C and D. Here, the lowest organic clays and muds rest on raised marine deposits, either beach gravel (Omonville, Herquemoulin) or sand (Ecalgrain). While the possibility of lacunae in the sedimentary sequences cannot be excluded, they appear conformable and thus allow the inference that sea-level was close to that of the present shortly before the initial accumulation of fossiliferous organomineral material. The stratigraphic record is supported by plant and insect remains from the localities. Some pollen records (of Chenopodiaceae, Cruciferae, *Plantago maritima* and *Armeria*, for instance), may point to the proximity of maritime and submaritime vegetation, although the potential roles of such taxa in open, interior plant communities (see above) must be borne in mind. Macroremains of *Atriplex*, *Potentilla anserina*, *Eleocharis palustris*, *Ranunculus sceleratus* and *Zannichellia palustris*, together with fucoid seaweeds, support the interpretation of intertidal and near-shore vegetation tolerant of saline or brackish conditions around Ecalgrain. *Ochthebius marinus*, recovered from Omonville, is largely a salt-marsh insect, while *Cercyon depressus*, recorded from Ecalgrain A, is an obligate species of decaying seaweed, and macroscopic remains of fucoid algae occurred at the same level. *Trechus fulvus*, also recorded from Ecalgrain A, is a current inhabitant of sea-shores. There is thus secure palaeontological evidence for the location of the palaeostrandline at this particular time. There is also substantial sedimentary, plant and insect evidence for the local presence of freshwater marsh, notably around Ecalgrain and Herquemoulin. Indeed, some of these localities may have been part of the ecotone between the lagoonal–tidal flat-barrier dune–shingle ridge, near-shore, and perimarine, coastal zones (Hageman 1969).

The Ecalgrain B, Herquemoulin A and B, Petit Beaumont and Vauville sites rest either on head, or the local solid formation. While the rock platform underlying the foreshore sites of Herquemoulin A and Petit Beaumont appears to be wave-cut, there are few sedimentological indicators of former marine conditions in this group of sites. Rounded cobbles at the base of the stony clay at Vauville are likely to be the product of marine processes, but no clear evidence of a beach is visible. However, the palaeobotanical record of these five sites is more informative, and indicates the previous existence of a mosaic of saline–brackish and freshwater marsh communities in the vicinity.

The clear evidence at the base of Ecalgrain A of a marine shoreline is followed by a gradual diminution of maritime taxa in that section. At Herquemoulin A, the plant record suggests a similar situation. At both Ecalgrain B and Herquemoulin (sites B, C and D) continued low frequencies of plants and animals that currently inhabit maritime and submaritime localities provide evidence of marine regression. There is no evidence to support more than one episode of falling sea level.

At Petit Beaumont, the fossiliferous deposit is in a similar stratigraphic position to that at Herquemoulin A (indeed, only 100 m separates the two sites). The pollen spectrum is, however, quite different. Plant taxa which may be indicative of saline conditions are maintained at a low level throughout the sequence. In this case the salinity may have originated from inland tundra or steppe environments, rather than be due to marine influence. The insect fauna of Petit Beaumont is decidedly arctic and continental, with two species which today reach no nearer to Normandy than northern Russia.

Interpretation of the sequence of sea-level movements is hindered by the isolation of outcrops, a lack of superposition among some sedimentary units, and equivocal interpretations than can be placed on the occurrence of halophytic floras. Clet-Pellerin (1983) proposed two phases of marine regression, invoking evidence from intrahead palaeosols as an adjunct to chronology (see below). In the present study altimetric, stratigraphic and fossil data combine to provide evidence for only one period of marine regression.

8.2. *Biogeography and climate*

The fossil record provides important evidence concerning biogeographical and climatic changes in the area. High values of tree and tall shrub pollen at Omonville-la-Rogue indicate a temperate coniferous–deciduous forest of humid–continental type similar to that found in southern Sweden today (Sjörs 1965). The only tree genus not now native to that area, *Abies*, mainly inhabits montane central and southern Europe, but also forms lowland forest in Normandy and eastern Poland (Tutin *et al.* 1964). The forest became more open as time progressed (pollen assemblage biozones OLR-2 and OLR-3), when higher boreal–montane plants entered the vegetation mosaic. The end of the Omonville sequence suggests that there was open birch woodland in the area. Similar vegetation changes have been widely documented from late- and post-temperate interglacial zones in northwest Europe (Turner and West 1968).

The palaeobotanical records from Ecalgrain A and Herquemoulin A appear to have a high local pollen content (Jacobson & Bradshaw 1981). These floras indicate a cool temperate local and regional environment, where oceanic influence is detectable. Similar plant and insect communities occur today in the maritime regions of northwest European coasts between *ca.* 60–65° latitude. Mean July temperatures may have been near to those of present day Normandy and at most could only have been 2–3 °C cooler.

The Ecalgrain B and Herquemoulin B, C and D sites have fossil assemblages indicative of local marsh, with drier scrub, heath and herbaceous communities nearby. Their nearest contemporary analogues appear to be in localities such as the Kola and Chukotskiy Peninsulas in northern Russia. The insects from Herquemoulin D possibly reflect the most harsh environment in this group: a tundra landscape where mass movement was in progress. Petit Beaumont (and possibly the upper part of the Vauville sequence, although the fossil record from this site is not as definitive) possess evidence of the harshest environment. Many plant and insect remains from Petit Beaumont are characteristic of the high arctic tundra today: herb-rich vegetation, with areas of bare soil and damp, peaty hollows. The insect assemblage suggests a climatic régime in which mean July temperatures were not higher than 10 °C, and winter means were around −12 °C. These values are 7 °C less than current mean summer, and 17 °C less than current mean winter temperatures in Normandy.

The problem of finding modern analogues for inferred former vegetation types is well known. It seems to be particularly acute in cold, open environments. Treeless landscapes in high latitudes derive their arboreal pollen, mainly *Pinus*, by means of long-distance transport. Gramineae and Cyperaceae are significant components of the vegetation and pollen floras, in which dwarf birch, *Salix*, *Artemisia*, *Rumex* and Ericaceae also assume importance (Birks 1973 *b*). Detailed floristic and palynological studies in subarctic and arctic environments (see, for example, Fredskild 1961, 1967; Lichti-Federovich & Ritchie 1968; Birks 1973 *b*; Nichols 1974; Ritchie & Cwynar 1982; Lamb 1984) have provided insight into the types of plant communities that may have existed in such localities.

8.3. *Correlation*

Few integrated accounts have yet been published of the geomorphology, stratigraphy and fossil assemblages from such a high density of sites over a relatively small area around the English Channel coast. However, a number of other localities around the Golfe Norman–Breton appear to share elements of the environmental sequence encountered on the Cotentin Peninsula.

Nearest, and showing the closest floral and faunal similarity are Fliquet (Coope *et al.* 1980) and St Aubin (Coope *et al.* 1985) on Jersey, some 60 km south southwest (figure 1). The pollen from biozone F-1 at Fliquet shows up to a 40% tree component (of total pollen and spores), mainly *Pinus* and *Betula*. The assemblage of insects from biozone f-1 suggests cool-temperate conditions akin to southern Fennoscandia today. Similar boreal vegetation, where mixed, rather open woodland was present, is also represented in the upper pollen assemblage biozones at Omonville-la-Rogue, although the *Abies* and *Carpinus–Ostrya* pollens at the latter were not encountered at Fliquet or St Aubin. Possible reasons for floristic variations, including the absence of certain taxa in otherwise apparently similar palaeoenvironments, have been explored by Coope *et al.* (1985). The insect fauna from biozone f-1 at Fliquet is similar to that recovered from a sample corresponding to pollen assemblage biozone OLR-2. The upper biozones at Fliquet (floral F-2 and faunal f-2), together with a single pollen and insect biozone at St Aubin, are indicative of a colder environment. Forest was lacking at this time (arboreal pollen amounts to less than 10% of total pollen and spores), the pollen spectra being indicative of a mainly herbaceous plant cover, although scattered tree and shrub growth may have occurred. The insects from faunal zone f-2 at Fliquet suggest that the climate was close to that acceptable for tree growth, and hints at increased continentality. At St Aubin, the insect assemblage is similar, but reflects increased cold. The projected July mean associated with f-2 was about 12 °C; at St Aubin this had fallen to 10 °C or less, and an arctic, tundra-like landscape must have characterized Jersey at this time.

These boreomontane–arctic communities are comparable with those represented at Ecalgrain (site B), Herquemoulin (sites B, C and D), Vauville and Petit Beaumont. Most affinity seems to occur between the latter site and St Aubin. For example, these are the only localities from which the high arctic carabid beetle, *Agonum exaratum* has so far been found as a Pleistocene fossil. Indeed, as Coope *et al.* (1985) conclude, it is likely that many of these deposits were laid down on an extensive coastal plain under a cold climatic regime, when sea-level was substantially below that of the present day, and the Channel Isles were linked to the Normandy coast by a wide expanse of tundra.

Two pollen sequences from further south in the Golfe Norman–Breton, described by Morzadec-Kerfourn (1974), also bear comparison with those from the Cotentin. At Kerguillé (Finisterre) (figure 16), the basal pollen assemblage biozone (KE-1) is developed in an 'argile grise' resting on raised beach pebbles. *Pinus* dominates the assemblage, and there are small amounts of *Carpinus*, *Picea*, *Corylus* and *Betula*. Non-arboreal pollen values are around 20 % of the total sum. At Kerguillé, a thin head separates the above argile grise from a higher one. The pollen assemblage from the latter (pollen assemblage biozone KE-2) resembles that of Ecalgrain (site B) and infers a cold, but not arctic environment. Tree pollen values are around 15 % of total, and there are substantial amounts of Gramineae, Ericaceae, Compositae and Caryophyllaceae. At Port-Lazo (Côtes-du-Nord) (figure 16), argile grise occurs within head. The pollen record indicates falling (*ca.* 30–10 % of total) tree and shrub (*Betula*, *Pinus*, *Picea*, *Alnus*, *Salix*) values, a substantial representation of Gramineae and Compositae, and a rising curve for Ericaceae. Morzadec-Kerfourn suggests that this pollen assemblage denotes the presence of steppe–tundra. There seems to have been little difference between the vegetation around Port-Lazo, the Cotentin and Jersey. If, as seems likely, the environments were

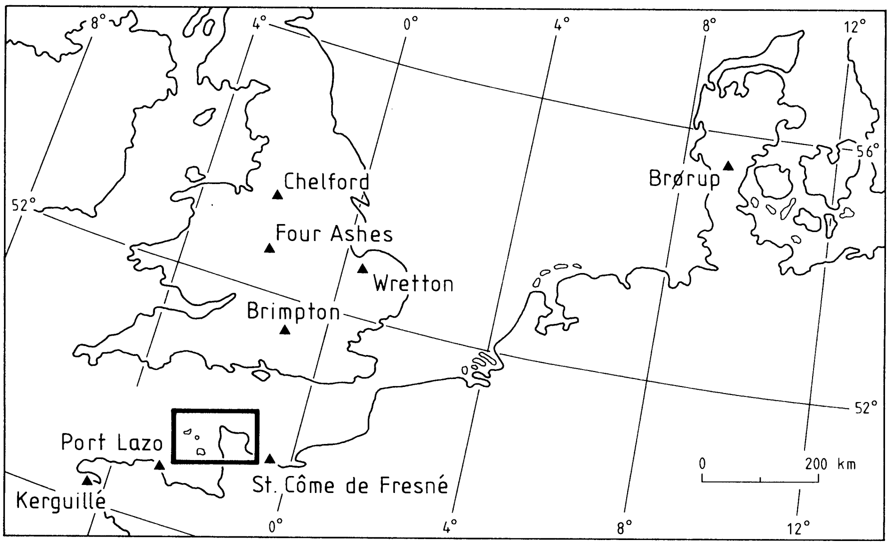


FIGURE 16. Location of extra-Cotentin Peninsula sites referred to in the text. The study area and Channel islands are enclosed within the rectangle.

contemporaneous, it may be that sea level was low enough to have also encompassed this part of the Golfe Norman–Breton in the extensive spread of herb-rich tundra, that appears to have united the Channel Islands and Normandy. The pollen and spore records also hint at a steppic element in the flora. Such plants would probably have occupied inland localities where base-saturated and saline soils existed.

A site at St Côme de Fresné (Calvados) in the Baie de Seine (figure 16), was described by West and Sparks (1960). The sediments, plants and Mollusca from this locality are equated with a regional cold, steppe-like environment. The basal sediments are estuarine and their tree pollens consist only of *Pinus* and *Betula*. High values of Chenopodiaceae at this juncture are equated with nearby salt-marsh vegetation. Higher in the sequence, *Pinus* and *Betula* are joined by *Quercus*, *Alnus* and *Picea*. Here trees account for only about 30% of total pollen. Chenopodiaceae pollen disappears at this point, but Cyperaceae, Gramineae, Compositae, Cruciferae and Umbelliferae are well represented. Such palynological changes may reflect both a withdrawal of the sea (estuarine sediments are succeeded by those of freshwater), and a climatic deterioration. The best analogy between St Côme and the Cotentin sites is probably found at Omonville. Both record declining mixed forest and increasing open habitat vegetation, accompanying a withdrawal of the sea. However, comparisons are hindered by the different local environments: an estuarine locality with dunes around St Côme, and a cliffed coast at Omonville. The St Côme estuarine sediments may, by virtue of their consistently high *Pinus* values, reflect the selective accumulation, and hence over-representation, of this taxon in such environments (Traverse & Ginsberg 1966). However, continuing similar high values of pine pollen in the overlying freshwater sediments might infer local or regional coniferous woodland, or indicate a persistent (now aerial) long-distance transport component in the assemblage.

There are no comparable coastal sites in England that demonstrate the replacement of the type of mixed forest portrayed on the Cotentin (at Omonville-la-Rogue), by more open, less thermophilous vegetation. Neither is there any published information regarding coastal cool–cold fossil assemblages similar to those described from the Golfe Norman–Breton. Certain localities (some 300–400 km distant) in interior England, reflect cool-temperate, often forested periods considered to be of (early Devensian) interstadial rank. However, detailed examination of plant and insect remains from, for example, Chelford, Cheshire (Simpson & West 1958; Coope 1959; Moseley 1982); Four Ashes, Staffordshire (Morgan 1973); Wretton, Norfolk (West *et al.* 1974) and Brimpton, Berkshire (Bryant *et al.* 1984) (figure 16), reveals very few similarities to the fossil flora and fauna of the Cotentin.

8.4. *Dating and chronology*

From the stratigraphic and fossil evidence, a general environmental sequence, involving a single episode of falling sea level and cooling climate, subsequent to a maximum interglacial stand of the ocean, is proposed. Clet-Pellerin (1983) believed that two phases of marine regression could be identified around the Cotentin Peninsula. On palaeobotanical evidence, she places an inferred regression at Les Ilets (Omonville-la-Rogue), at the end (Zone E6) of the Eemian Interglacial (Zagwijn 1961; Woillard 1978). The same interglacial is indicated by current investigations at Omonville, where the succession of vegetation, in sediments post-dating a raised beach some 8–10 m above current sea level, has affinities with late (Zones g, h, i; E5 and E6) Eemian sequences in the Netherlands (Zagwijn 1961; 1983) and Denmark (Anderson 1965, reviewed by Phillips (1974). West & Sparks (1960) assigned deposits at St Côme de

Fresné, and Morzadec-Kerfourn (1974) at Kerguillé, to a late Eemian context. Clet-Pellerin (1983) referred other sites in the Baie d'Ecalgrain and at Herquemoulin to a broadly similar context at the end of a pre-Eemian interglacial, either within the Saalian, or in Holsteinian time. To support such a chronology, she advanced evidence from the study of proposed interglacial palaeosol horizons which overlie the fossiliferous organomineral sediments in the Ecalgrain–Herquemoulin cliff sections (see also Clet *et al.* 1982). Thus, the fossiliferous organomineral deposits near the base of the cliffs are referred to an earlier interglacial, with an interhead palaeosol providing evidence of a later temperate period of the same magnitude.

Intensive observations of the cliff stratigraphy in the Ecalgrain–Herquemoulin area during the investigations reported here, revealed soil-like horizons within the head. However, nowhere were these seen in superposition over organomineral sediments. It thus seems prudent to point out that a chronology resting on such evidence must, at best, be tenuous. Clet *et al.* (1982) have admitted that the use of palaeosols in this context is of most validity in loess, such as that of Upper Normandy. Their extrapolation to the Lower Normandy coast, some 200 km to the west, and in a different sedimentological context, would appear to be precarious. Furthermore, insect evidence from England indicates at least one mid-Weichselian temperate episode during which, the climate was at least as warm as that of the present and is likely to have resulted in pedogenesis (Coope & Angus 1975). Such an event could have left incipient palaeosols in the head deposits of the Cotentin.

Evidence from two sites presented here may point towards a single episode of marine regression that occurred in late- and immediately post-Eemian time. At Omonville-la-Rogue, in the centre of the bay (figure 3), the fossiliferous sediments and underlying raised beach rest on a granular quartzite head. At other localities to the southeast of the sampled section (notably La Cormorandière, figure 3), a similar stratigraphy, but lacking organic horizons, can be observed. These occurrences indicate that marine and overlying freshwater sediments were deposited on extant shore zones composed of head from an earlier periglacial phase. The most parsimonious explanation of this sequence seems to involve a marine level representing the last interglacial, underlain by a head deposited in an earlier cold stage. The biogenic and inorganic sediments overlying the marine deposits could then be referred to late interglacial (Eemian) or succeeding early glacial (Weichselian) time. Similar reasoning for analogous stratigraphic contexts in the Channel Islands has been used to erect a chronology for their raised beaches (Keen 1978).

At Petit Beaumont, the organomineral mud on the foreshore is well within present tidal limits, and, moreover, faces west, the direction of maximum wave approach. It is thus unlikely that such unlithified material could survive two phases of high sea level (during the last and current interglacials), and thereby date from a cool-temperate or cold stage before these. The plant and insect fossils are not of Holocene character, and it is much more feasible to infer that these (and similar) fragile sediments have only been affected by one high sea-level, that is, during the present interglacial. As such, they can only be appropriately placed sometime within the climatic deterioration following the Eemian Interglacial thermal optimum, and during the commencement of the Weichselian Glacial stage. A similar timescale has been proposed for the deposition of foreshore deposits (whose fossils denote analogous palaeoenvironments), at Fliquet and St Aubin, Jersey (Coope *et al.* 1980; 1985).

Although it is perhaps premature to use insects as stratigraphical indicators, one species of beetle has the makings of a good index fossil. *Otiorhynchus proximus* is a weevil currently found in the eastern Alps and Carpathians. It occurred at Ecalgrain B, and so far has only been found in northwestern Europe as an early Weichselian interstadial fossil from Chelford (Moseley 1982), Elsing, Norfolk (G. R. Coope, unpublished), and Stenberget in southern Sweden (Moseley 1982).

During the past 20 years, a series of radiocarbon dates have been obtained from sites around the Cotentin Peninsula (table 12). Critical evaluation of these has led to the conclusion that all finite ones are unreliable (Morzadec-Kerfourn 1974; Coope *et al.* 1980). For instance, the Ecalgrain assays were carried out on duplicate material by different laboratories. At best, this suite of dates provides a minimum age for the deposits.

The age of the raised beach at *ca.* 8–10 m above NGF around the Cotentin is problematical. On Jersey, a beach at the same altitude, and with similar stratigraphic relationships, has been dated to 121000+14000 or −12000 years BP by uranium–thorium disequilibrium methods (Keen *et al.* 1981).

TABLE 12. RADIOCARBON DATES FROM COTENTIN PENINSULA SITES

site and sample number	laboratory number	date	references
Ecalgrain (EB 2)	Gif-368	12600 ± 400	Delibrias & Larsonneur (1966); Delibrias *et al.* (1969)
Ecalgrain (EB 2)	Birm-183	over 37000	Shotton & Williams (1971)
Ecalgrain (EB 2)	Birm-211	over 44500	Shotton & Williams (1971)
Herquemoulin (shore) (Site A?)	Gif-370	15020 ± 400	Delibrias & Larsonneur (1966); Delibrias *et al.* (1969)
Herquemoulin (foreshore) (Site A?)	Birm-169	28070 + 1650 − 1370	Shotton *et al.*, (1970)
Vauville (strand)	Gif-369	21940 ± 1500	Delibrias & Larsonneur (1966); Delibrias *et al.* (1969)
Fliquet (F-I; f-1)	Birm-955	over 25 500	Coope *et al.* (1980)

If the raised beach around the Cotentin is equivalent to that on Jersey, then the sediments above the former may provide evidence for continuous environmental change, involving a marine regression and climatic deterioration in late interglacial–early glacial time. The U-series data provides a maximum age for beach deposition. In conjunction with the oldest radio carbon assay, this places subsequent organomineral sedimentation between *ca.* 120000 and 45000 years BP. This period included the climatic deterioration at the end of the Eemian Interglacial around 115000 years BP, according to McIntyre & Ruddiman (1972). Although the length of time represented by the Cotentin sequence is unknown, there is an increasing body of evidence for rapid climatic deterioration in the late Pleistocene (see, for example, Coope 1975; Woillard 1978). Sudden change at the end of the Eemian Interglacial in Lower Normandy could have led to the accretion of the cool–cold climate Cotentin deposits in a relatively short time: probably in a few thousand years.

If there are erosional lacunae in the Cotentin sequence, and it is not continuous, an alternative explanation is available for the cool to cold climate sequence. The sediments may be recording the environments of one or more early Weichselian interstadials. Such a status is also possible for the Fliquet and St Aubin sites on Jersey. This situation was postulated by Morzadec-Kerfourn (1974) for Port-Lazo, whose deposits were equated with those of the

Brørup Interstadial in Denmark and Holland on the basis of similar pollen spectra. While such long-distance comparison, correlation and synchroneity is possible, it is considered here to be unnecessarily elaborate.

9. Conclusion

Nine sites on the Cotentin Peninsula have yielded geomorphological, stratigraphic and fossil evidence which allows the inference of a single period of falling sea level and deteriorating climate. The environmental changes involved the transition from a cool-temperate mixed forest landscape with a sea level close to that of the present, through high boreal and low arctic conditions when scrub and heath communities existed. Eventually, high arctic tundra and steppe became widespread, the former occupying much of an extensive coastal plain created by a greatly lowered sea level. The most likely time for these events seems to have been at the conclusion of the Eemian Interglacial and the commencement of the Weichselian Glacial. Radiocarbon assays have been shown to be unreliable at these sites. However, deposition of the dated material must have occurred before 45000 years BP. U-series dates on the raised beach on Jersey suggest that this sedimentation took place after 120000 years BP. If the climatic deterioration was swift and began *ca.* 115000 years BP, the sediments may have formed during a subsequent relatively short interval.

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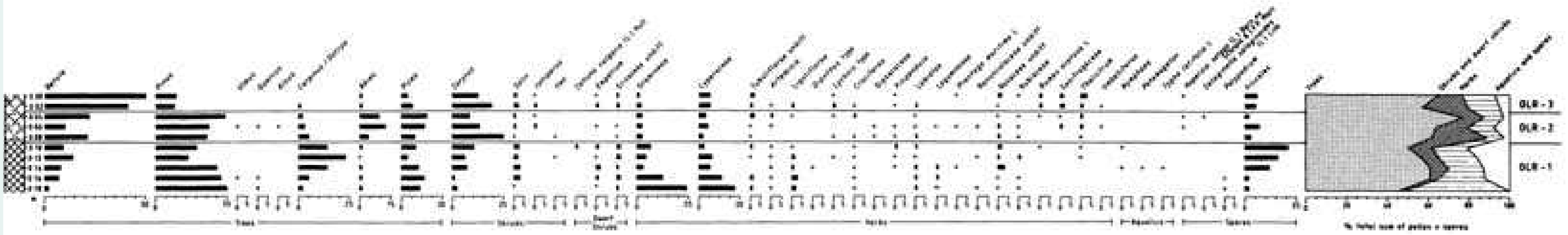
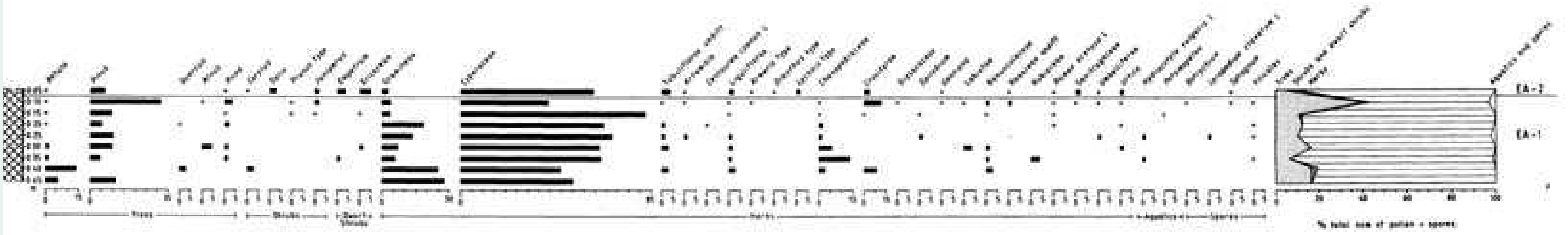
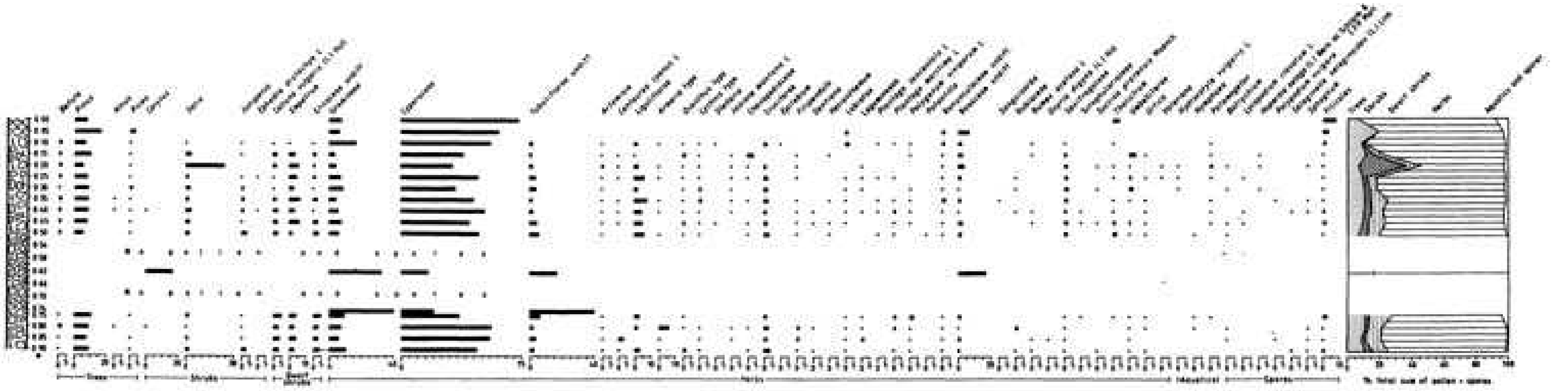


IGURE 4. Omonville-la-Rogue: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. OLR-1 *Pinus–Carpinus–Ostrya–Picea*. Arboreal pollen accounts for 50–60%. *Pinus* is the major contributor (up to 34%) with *Carpinus–Ostrya* (up to 23%); *Picea* (up to 16%); *Betula* (up to 14%); and *Abies*, *Ulmus* and *Quercus* occurring at values of 1% or less. *Corylus* is under 10% and *Salix* 5%. Ericales (*Calluna*, *Empetrum*, Ericaceae) are 1–3%, as are Compositae and Rosaceae. Gramineae and Cyperaceae values fall from 20–25% to 5%. *Nymphaea*, *Typha latifolia* and *Potamogeton* are recorded. Filicales spores are abundant, reaching 21%. The terminal boundary is placed where *Carpinus–Ostrya* values fall from 15 to 5%. OLR-2 *Pinus–Betula–Picea–Abies*. Arboreal pollen accounts for 55–78%. *Pinus* is the major tree genus (25–35%), with *Betula* 10–22% and *Picea* 5–12%. *Abies* reaches 12% with *Carpinus* 2–5%. *Ulmus*, *Quercus* and *Alnus* each are less than 1%. *Corylus* is up to 25%, *Salix* 2% or less. *Ilex* occurs in the lower part, *Juniperus* in the upper. Dwarf-shrub and herbaceous values are reduced but *Thalictrum* increases and Saxifragaceae are recorded. Filicales spores decline, while those of *Huperzia selago* and *Selaginella selaginoides* occur. The terminal boundary is placed where *Abies* values fall from 8 to 1%. OLR-3 *Betula–Pinus–Picea*. Arboreal pollen is up to 60%, with *Betula ca.* 50%, *Pinus* 10%, *Picea* 5%, *Carpinus* and *Abies* 1%. *Corylus*, *Salix*, Ericales, Cyperaceae, Saxifragaceae and *Thalictrum* values increase.



IGURE 6. Ecalgrain Site A: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. EA-1 Cyperaceae–Gramineae–*Pinus*–Chenopodiaceae. Herbs account for 80–85%. Cyperaceae dominate (40–82%) with Gramineae, Chenopodiaceae, Compositae and Cruciferae also important. The arboreal component is mainly *Pinus*, with falling values of *Betula*, sporadic *Picea* and isolated occurrences of *Quercus* and *Alnus*. *Corylus* is present and *Juniperus* appears in the upper part. The terminal boundary is placed where arboreal values decline to 5%. EA-2 Cyperaceae–Ericales–*Pinus*. Herbs account for 90% and consist mainly of Cyperaceae, with subsidiary Compositae and Cruciferae. Saxifragaceae values rise to 2%. *Juniperus* retains a minor representation but Ericales (*Empetrum* plus Ericaceae) expand to 8%.



IGURE 8. Ecalgrain Site B: pollen diagram and assemblage biozone. +, Under 1%; undiff., undifferentiated. Cyperaceae–Gramineae–Compositae–Ericales. Non-arboreal pollen accounts for 85–90%, with shrubs 15–20%. Ericales are prominent, *Salix* and *Juniperus* consistently represented and *Ephedra distachya* recorded. There is a wide range of herbaceous taxa, notably Cyperaceae, Gramineae, Compositae, Cruciferae, Rosaceae and Saxifragaceae. *Potamogeton* is the most consistent aquatic taxon, although *Nymphaea* occurs sporadically in the lower part of the assemblage. Filicales spores are continuously recorded, and those of *Lycopodium clavatum*, *Huperzia selago* and *Selaginella selaginoides* have scattered occurrences. The low arboreal values are made up mainly by *Pinus*, *Picea* and *Betula*. There are isolated records of *Alnus*.

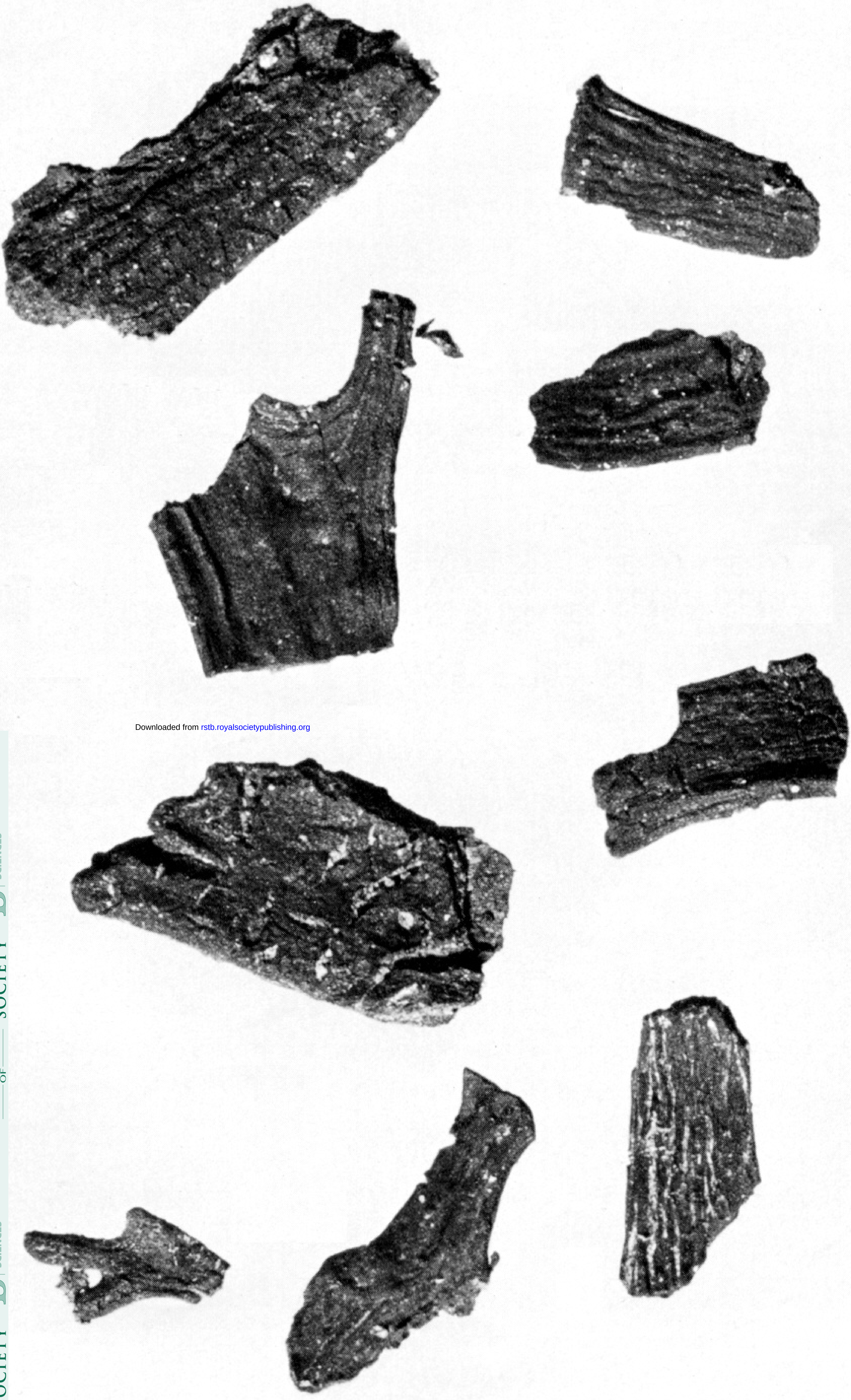


FIGURE 7. Fucoid seaweed remains from Ecalgrain Site A.

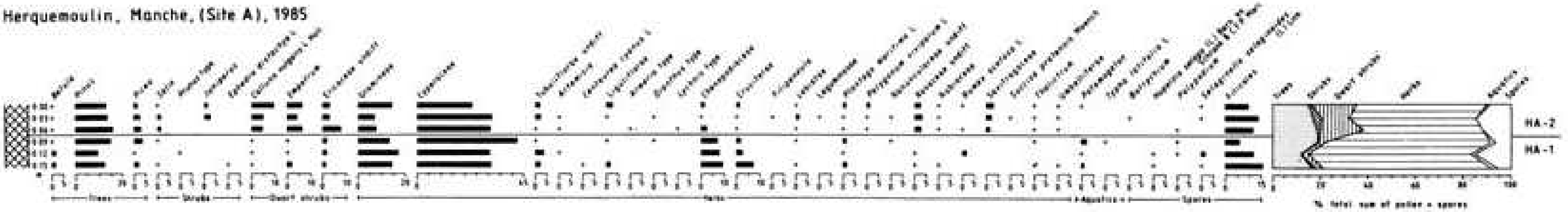


Figure 10. Herquemoulin Site A: pollen diagram and assemblage biozones. +, Under 1%; undiff., undifferentiated. HA-1 Cyperaceae–Gramineae–*Pinus*–Chenopodiaceae. Herbs account for 60–70%, notably Cyperaceae, Gramineae, Chenopodiaceae, Cruciferae and Compositae. Arboreal pollen is 12–18%, and comprises *Pinus*, *Picea* and *Betula*. Shrubs (*Salix*, *Ephedra distachya*, *Calluna*, Ericaceae and *Empetrum*) attain 5%. Aquatics are represented by *Potamogeton*, and *Typha latifolia*. Filicales reach 15% and *Polypodium*, *Huperzia selago* and *Selaginella selaginoides* are recorded. The terminal boundary is placed where Gramineae, Chenopodiaceae and Cruciferae values fall. HA-2 Cyperaceae–Ericales–*Pinus*. Arboreal values are comparable to those of HA-1. Shrubs (especially dwarf-shrubs) account for up to 20%. *Juniperus* is present. Cyperaceae and Gramineae dominate the herbaceous taxa but Rosaceae, Compositae and Saxifragaceae are also well represented. Filicales have values similar to those of HA-1.

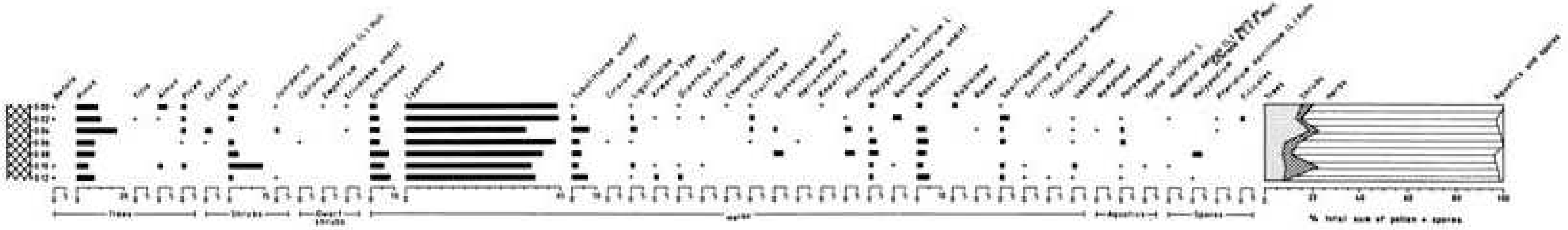


Figure 11. Herquemoulin Site B: pollen diagram and assemblage biozone. +, Under 1%; undiff., undifferentiated. Cyperaceae–*Pinus*–Gramineae–Compositae. Non-arboreal values are up to 90%, with herbaceous pollens dominant, especially Cyperaceae, Gramineae, Compositae, Rosaceae, Saxifragaceae and *Polygonum viviparum*. *Pinus* and *Picea* are the major tree taxa, and *Salix* the principal shrub. *Juniperus*, *Empetrum* and Ericaceae are recorded. Aquatic values are low but *Potamogeton* is consistently present. Spores are less than 5% with *Huperzia selago*, *Polypodium* and *Pteridium aquilinum* represented, as well as Filicales.

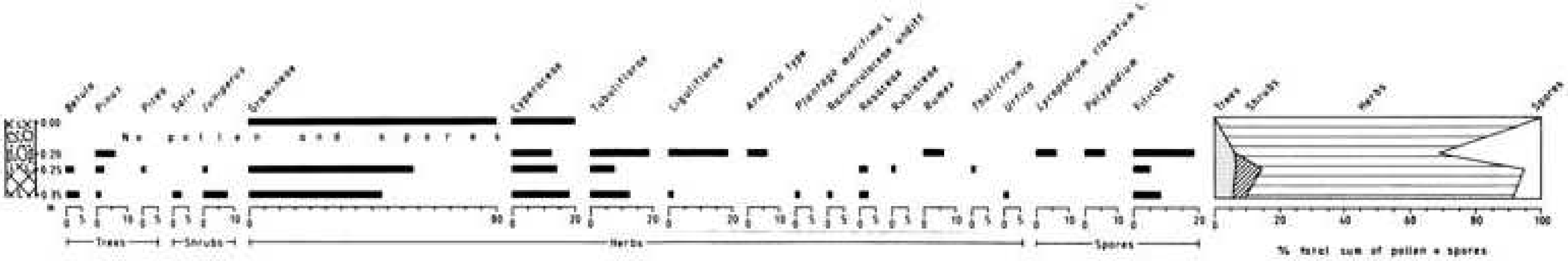


Figure 12. Herquemoulin Site C: pollen diagram and assemblage biozone. Undiff., undifferentiated. Gramineae–Cyperaceae–Compositae. Non-arboreal values are 95% or more, with herbs, especially Gramineae, Cyperaceae, Compositae and Rosaceae, dominant. *Betula*, *Pinus*, *Picea*, *Salix* and *Juniperus* are the only trees and shrubs present.

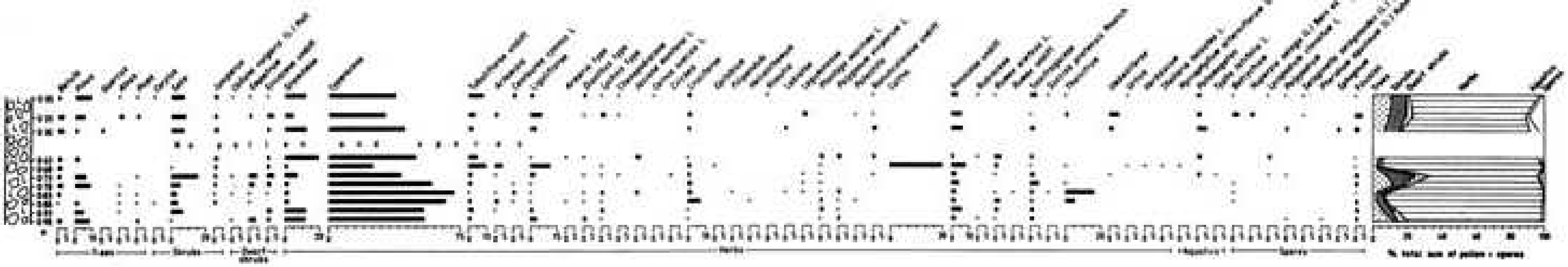


Figure 13. Herquemoulin Site D: pollen diagram and assemblage biozone. +, under 1%; undiff., undifferentiated. Cyperaceae–Gramineae–Compositae. Non-arboreal values are up to 90% with herbs most frequent, especially Cyperaceae, Gramineae, Compositae, Rosaceae, Cruciferae and Saxifragaceae. Shrubs account for 5–20% with *Salix*, *Juniperus*, *Empetrum* and Ericaceae present. *Pinus* and *Betula* are the most important tree taxa. *Picea* and *Alnus* occur sporadically at low values. Aquatics are represented by *Myriophyllum alterniflorum*, *Typha latifolia* and *Potamogeton*. Among spores, *Lycopodium clavatum*, *Huperzia selago* and *Selaginella selaginoides* are recorded.

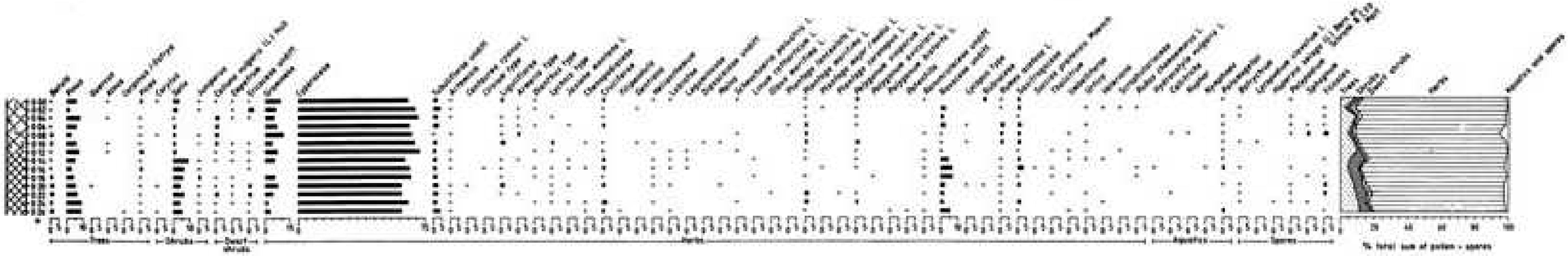


Figure 14. Petit Beaumont: pollen diagram and assemblage biozone. +, under 1%; undiff., undifferentiated. Cyperaceae–Gramineae–*Pinus*–*Salix*. Non-arboreal values range from 85–95%, with Cyperaceae accounting for up to 72%, and Gramineae, *Salix*, Compositae and Rosaceae also well-represented. Saxifragaceae, Cruciferae and *Plantago maritima* occur frequently at 2–3%, and *Juniperus* at less than 1%. Dwarf shrubs account for up to 5%. Tree pollen (12% or less throughout) consists mainly of *Pinus*, *Betula* and *Picea*.

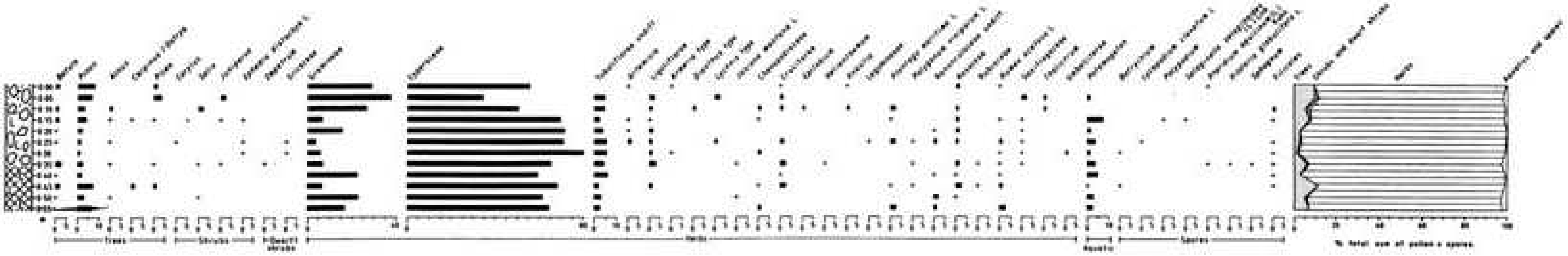


Figure 15. Vauville: pollen diagram and assemblage biozone. +, under 1%; undiff., undifferentiated. Cyperaceae–Gramineae–*Pinus*–Compositae. Arboreal values are under 10%, with *Pinus*, *Betula* and *Picea* the major tree types. Shrubs are poorly represented, with *Salix* and *Juniperus* occurring sporadically at 2% or less. *Ephedra distachya*, *Empetrum* and Ericaceae are recorded infrequently. The major herbaceous taxa are Cyperaceae, Gramineae, Compositae, Cruciferae, Rosaceae, *Rumex acetosa* and Saxifragaceae. *Potamogeton* is the main aquatic (up to 9%). *Selaginella selaginoides* occurs near the top of the sequence. *Pilularia globulifera* is recorded.