THE SUBMERGED FOREST AT BORTH AND YNYSLAS, CARDIGANSHIRE

DATA FOR THE STUDY OF POST-GLACIAL HISTORY. No. 1

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From the notes of F. N. Campbell James

(With Plate III and 5 figures in the text)

(For some years Mrs Campbell James worked in the Department of Botany, University College, Aberystwyth, on the problems of the submerged forest of the neighbouring coast. She had intended to submit her results in a thesis for a research degree, but her untimely death prevented this. The authors consider the results of her work worth recording, even though they are incomplete, in the expectation that they will fit into a larger scheme based on wider investigation of the post-glacial history of British forests and of the British coast-line.)

CONTENTS

Introduction

The submerged forest at Borth and Ynyslas lies on the shores of Cardigan Bay just to the south of the Dovey Estuary. The area with which this investigation is concerned stretches intermittently for about three miles along the shore. The sea and wind take such very heavy toll of the forest that its extinction is but a matter of time.

Physiography of the area

The submerged forest lies about half-way between high- and low-tide marks on the sands bordering the "Dovey Flats". The Dovey Flats, as will be seen from the map (Fig. 1), consist of low tracts of land lying between the River Dovey to the north and the low foothills and headland of Borth to the south. Just south of the Dovey they consist of sandy marshes with a typical salt-marsh flora, and they merge gradually into the 2000 acres of Borth Bog (Cors Fochno). This latter is a raised bog (Hochmoor), with typical oxyphilous communities.

The river Leri crosses the margin of the bog on the seaward side. Entering the area to the south it runs in a northerly direction in an artificial channel until it joins the Dovey, keeping parallel to the sea for the latter part of its course. To the west of the Leri is a line of shingle beach, or storm beach, on which the village of Borth is built.

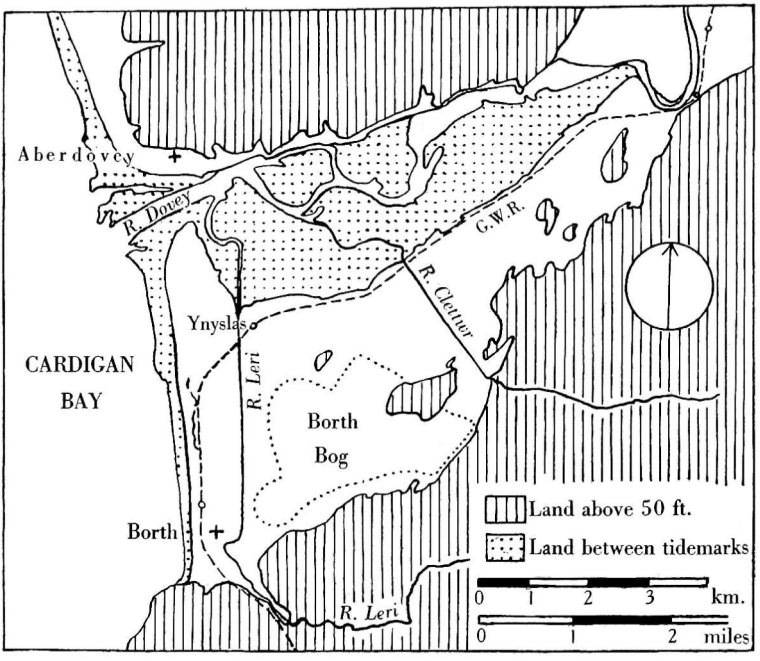

Fig. 1. Sketch-map of the area south of the Dovey Estuary, showing position of the submerged forest and of Borth Bog. Outcrops of the submerged forest occur between tide marks from Borth to Ynyslas.

To the north the beach is replaced by a line of sand dunes. There seems to be a constant drift of stones and sand toward the north (the prevailing wind is south-westerly) and this results in the formation of a bar across the mouth of the Dovey. Surrounding the whole area is a region of high ground. This consists of (1) the hills to the north, which rise steeply from the Dovey to the height of Cader Idris; (2) the foothills to the east, which run along the 50 ft. contour line and which mark the boundary of the post-Glacial deposits; (3) various "islands" of high ground on the edges and in the centre of the bog; (4) the headland to the south of Borth.

The surrounding islands already referred to, carry one of the roads round the bog, while one of the centre "islands" is known as Llwyn-y-garreg (the trees on the rock), and is extraordinarily interesting in that it shows how a rise of 5 ft. or so above the level of the bog enables an entirely different flora to flourish (see Yapp, 1911).

The submerged forest, which is frequently covered completely by sand, stretches intermittently along about two miles of coast. When fully exposed along its whole length (which seldom happens) it shows a flattened expanse of peat with many prostrate trees. To the south of Borth the peat abuts on rocks. The peat at the Borth end shows but few standing trunks, of which the majority are oaks.

It is probable that the hollows in the rocky base of the valley in which the bog is situated, are filled with boulder clay. Above this there appears to be a fairly continuous bed of "blue clay" or silt. This is found below all exposures of the forest which have been investigated, and it can be seen to run seaward. At very low tide it is seen to outcrop right on the sea edge. It is of unknown depth. To the south of Borth a boring 10 ft. below the peat of the surface, reached a hard mass and the borer brought up "boulder clay". One of the low-tide outcrops of clay at Ynyslas gave a clayey platform on which to bore and here, 8 ft. below the surface, the clay showed no change in composition and the borer refused to turn owing to the sticky nature of the clay. Deposits of an exactly similar nature occur below the bog whenever the depth of peat is not more than about 12–14 ft. The mechanical analysis of this clay or silt is shown below.

	Limits of diameter of particles (mm.)	Percentage
Fine gravel	3–1	Nil
Coarse sand	1–0·2	0·1
Fine sand	0·2–0·04	11·8
Silt	0·04–0·01	17·9
Fine silt	0·01–0·002	30·5
Clay	Below —0·002	20·6
Moisture	—	4·0
Loss on ignition	—	15·1

GENERAL STRATIGRAPHY OF THE SUBMERGED FOREST AREA

Both at Borth and at Ynyslas the general occurrence of the peat is similar. A layer of brown peat overlies the clay and merges gradually into it. The peat often consists of a mass of twigs and branches with or without bark, and is penetrated by roots; below, remains of *Phragmites* are abundant, and the upper surface is generally riddled with the holes of boring lamellibranchs. Trees are found abundantly with their stools and fallen trunks *in situ*, as is well shown in Plate III. *Pinus*,

Alnus, *Quercus* and *Betula* have been identified from the submerged forest at Borth, and four *Pinus* and three *Betula* (presumably seven separate trees) from the submerged forest at Ynyslas. The root systems of the larger trees are generally spread horizontally, though some also grow downwards. This is precisely the behaviour of trees growing in fen woods where the high-water table keeps all the tree roots (save alder) in the aerated surface layers of the peat.

The peat at Ynyslas is now usually 2 or 3 ft. thick; that at Borth is thicker.

(1) *The Ynyslas submerged forest sequence*

In November 1932 there was a good exposure of peat at Ynyslas,

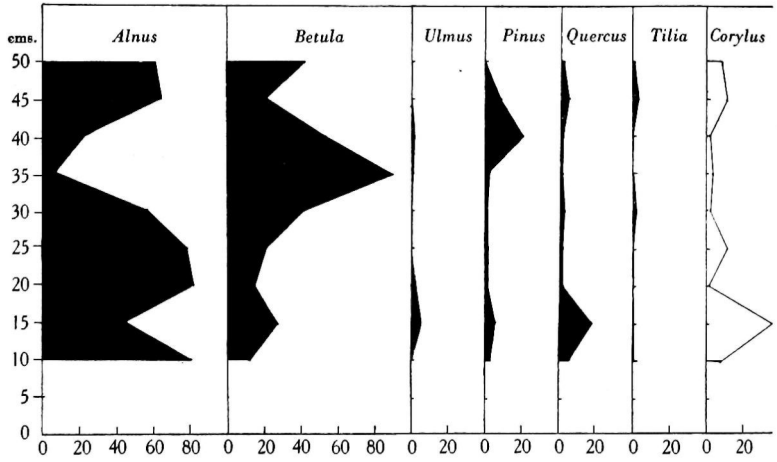

Fig. 2. Pollen analysis of profile in the submerged forest layer, Ynyslas. All pollen categories expressed as percentages of total tree pollen: this total excludes *Corylus*.

numerous patches being visible, generally in depressions filled with water. One fallen tree (*Pinus*) was lying *in situ* with its apex pointing eastwards and its roots intact.

Three borings showed the clay at 47, 44 and 51 cm.: a complete section was dug and examined at the third of these borings and samples were taken for the pollen analysis recorded below.

Each pollen sample (2·5 cm.) was treated with 20 c.c. of 5 % KOH at 100° C. for 24 hr. The residue after straining through muslin was centrifuged and washed and then mounted in glycerine jelly. Three slides were made from each sample.

The results of analysis are given in Table I and Fig. 2. They are all expressed as percentages of the total tree pollen, but, owing to the

TABLE I. *Submerged Forest. Ynyslas.*

Depth (cm.)	Percentages of total tree pollen							No. of pollen grains in total of 200				Percentage of total pollen count of 200			Comments and notes on forms not included in total of 200
	Alnus	*Betula*	*Ulmus*	*Pinus*	*Quercus*	*Tilia*	*Corylus*	Tree total	M.	O.	M.+O.	% tree	% M.+O.	% M.	
50	56	42	—	—	2	—	8	72	40	88[a]	128	36	64	20	[a] 57 *Sphagnum* spores, 7 ericoid, 16 unknown
45	63	21	—	8	5	3	11	38	13	149[b]	162	19	81	7	[b] 66 *Sphagnum* spores, 55 ericoid, 24 unknown
40	23	53	1	21[c]	2	—	2	169	7	24	31	85	16	4	[c] *Pinus* maximum
35	7	90[d]	1	2	1	—	3	182	6	12	18	91	9	3	[d] Betula maximum
30	56	41	—	1	2	1	2	169	22	9	31	85	16	11	—
25	78[e]	21	—	1	1	—	11	152	22	26	48	76	24	11	[e] *Alnus* maximum
20	82[f]	15	5	1	1	—	1	151	34	15	49	76	25	17	[f] *Alnus* maximum
15	45	27	1	5	18	—	36	22	125[g]	53	178	11	89	63	[g] Monocot maximum
10	80[h]	12	—	2	5	—	9	127	42	31	73	64	37	21	[h] *Alnus* maximum
5	Grains too few to count. *Alnus* most prevalent, then *Corylus*. Occasional *Pinus*, *Betula*, *Quercus*, with few fern spores														
0	Clay base, horizontal rhizomes and erect axes of *Phragmites*. Little pollen but *Pinus* and *Corylus* could be distinguished														

M. = monocotyledonous pollen; O. = other pollen.

fact that 200 pollen grains *of all kinds* was made the total count for each sample, the samples vary much in respect of the number of tree pollens they include. It is at once apparent that the diagram shows broadly the lower half of the peat bed to have a dominance of alder pollen (10–30 cm.), followed by a phase of birch dominance (35 cm.),

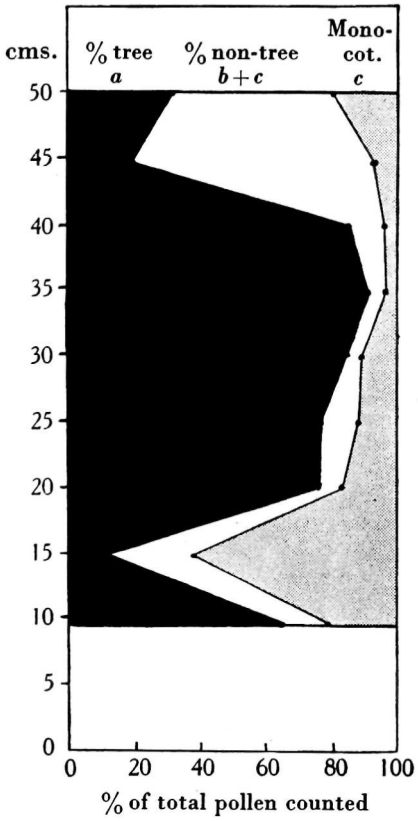

Fig. 3. Diagram of the Ynyslas profile shown in Fig. 2, expressing the relative proportions of tree pollen and of non-tree pollen of other categories.

then a small pine maximum (40 cm.), and lastly a return to high values for alder and birch. The basal clay contains foraminifera and is penetrated by *Phragmites* and the lower samples (especially at 15 cm.) show a very low ratio of tree pollen to non-tree pollen of monocotyledonous type. The peat from 20 to 40 cm., shows a very high ratio of tree pollen to other pollen (Fig. 3) which supports the idea that this was the horizon of the forest itself. The peat above 40 cm. shows

again a low tree pollen/non-tree pollen ratio, but the non-tree pollen here consists chiefly of *Sphagnum* spores or the pollen tetrads of Ericaceae. Microscopic remains of *Sphagnum* leaves are abundant and, together with *Calluna* twigs, show that acidic peat formed *in situ* over the forest peat.

The developmental sequence was apparently this:

(1) The formation of fen over the brackish-water basal clay, and the development of alkaline peat including *Phragmites*.

(2) The development of fen alder-woods on this peat—no doubt at first in patches and with a markedly wet reversion at 15 cm. In this reversion phase the tree pollen, wind-blown from the uplands, would play a greater part than in the succeeding phase of dense fenwood, and this would account for the relatively high values of oak, hazel and elm pollen. The monocotyledonous pollen from the fen itself quite swamps the total tree pollen under these conditions.

(3) Growth of the fenwoods *in situ*; at first alder, then birch and finally pine. This is in accord with the recognition of remains of these trees on the beach to-day.

(4) Development of *Sphagnum* peat (probably "raised bog") above the forest peat. Large raised bogs occur in the region at the present time (Tregaron Bog and Borth Bog).

It is to be noticed that the sequence of forest horizons, alder, birch, pine, and the corresponding tree-pollen maxima are well recognized on the Continent as a series occurring regularly at the transition from fenwoods to raised bog. It is well shown in the north-west German marshes (Brinkmann, 1934) and is recognizable also in the East-Anglian fens, where the subfossil pinewoods have been interpreted as having this status (Godwin *et al.* 1935).

In the view of the authors the pollen analyses do not yet permit of dating the forest except that it is clearly post-Boreal. Further knowledge of forest and bog development in Wales may however make these data of value. It may be noted in passing that Woodhead & Hodgson (1935) in the analysis of Snowdonian peats did not exclude the possibility of a post-Boreal pine maximum, and that Erdtman (1928) and Jessen (1934) have both recognized a secondary (sub-boreal) pine maximum in sites in different parts of the British Isles. It remains of course, for the present, an open question how far such pine maxima as occur are merely developmental phases of vegetation referable to any period, and how far they reflect by their prevalence, some specific climatic swing acting at the same time over a very large area.

There is no evidence in the pollen sequence of the submergence which brought the forest to its present position.

(2) *The Borth bog sequence*

The closeness of the present bog at Borth to the submerged forest suggested comparison of the pollen sequence in both, and in August 1933 a boring was made in Borth Bog through 4 metres of peat to the underlying clay. The samples for pollen analyses were prepared as follows: 0·1 c.c. of the sample was heated with 5 c.c. of 5% KOH for 3 or 4 hr. at 100° C., the test-tube was filled with water, and the sample left to stand overnight. Next day the settled residue was

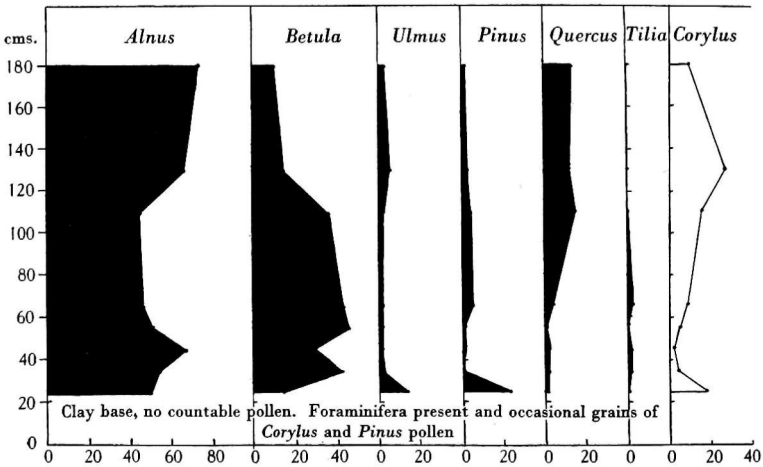

Fig. 4. Pollen analysis of profile in Borth Bog. All the pollen categories expressed as percentages of total tree pollen: this total excludes *Corylus*. The profile does not extend to the present bog-surface: the top 220 cm. were too poor in pollen to count.

shaken up with fresh water, and again left to stand. By a pipette the fine upper material was removed from the solid matter in the bottom of the test-tube;[1] this was spread on a slide and the water partly driven off by heating the slide on an asbestos plate. One or two drops of safranin jelly were mixed with the residue and a coverslip was added.

The results of analyses are shown in Table II and in Fig. 4. It should be noticed that only the lower half of the bog section is

[1] This method of preparation may involve errors due to the differential settling of the pollen.

TABLE II. *Borth Bog section*

Depth (cm.)	Percentages of total tree pollen							No. of pollen grains in total of 200				Percentage of total pollen count of 200			Comments and notes on forms not included in total of 200
	Alnus	*Betula*	*Ulmus*	*Pinus*	*Quercus*	*Tilia*	*Corylus*	Tree total	M.	O.	M.+O.	% tree	% M.+O.	% M.	
400–180	Tree pollen diminishes. Replaced by ferns, *Sphagnum* and moss spores, ericaceous pollen and monocots. *Myrica* leaves in upper layers.														
180	74[b]	10	3	—	13	—	10	31	38	131[a]	169	16	85	19	[a] 24 *Myrica*, 65 unknown. [b] *Alnus* maximum
160	Only tree pollen was found with a few ericaceous tetrads. Too little to count. [Omitted from graph]														
130	66	15	5	2	12	—	27	41	6	153[c]	159	20	80	3	[c] 65 *Sphagnum* spores. 53 *Myrica*
110	44	35	2	4	15	—	14	48	19	133[d]	152	24	76	10	[d] 107 *Sphagnum* spores
65	46	42	1	5	4	2	8	114	55	31	86	57	43	28	—
55	51	45[e]	1	1	1	—	5	142	36	22	58	71	29	18	[e] *Betula* maximum
45	67[f]	28	1	1	2	1	2	140	46	14	60	70	30	23	[f] *Alnus* maximum
35	54	41	2	—	2	1	4	129	47	24	71	64	36	24	—
25	50	14	14	23	—	—	18	22	157[g]	21	178	11	89	79	[g] Monocot, maximum. Mostly *Molinia* type
0– 25	Clay base, no countable pollen. Foraminifera present and occasional grains of *Corylus* and *Pinus*														

M. = monocotyledonous pollen; O. = other pollen.

represented, the upper samples containing too little pollen to count.

It is at once clear that the results from the present bog broadly resemble those from the Ynyslas submerged forest (Fig. 5). The clay base contains foraminifera. The lowest peat sample (24 cm.) shows a low tree/non-tree pollen ratio, and the non-tree pollen is mono-

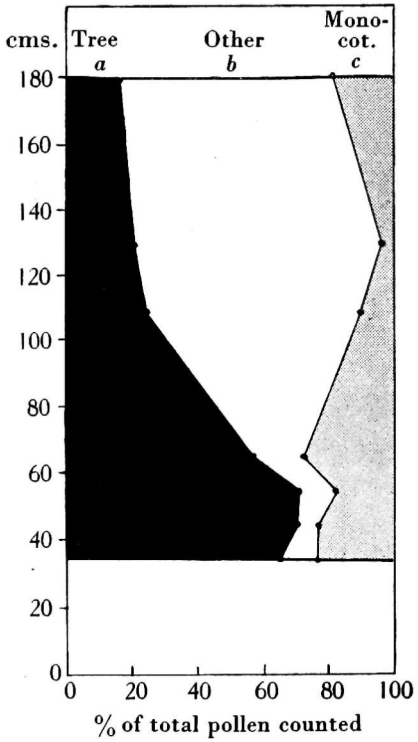

Fig. 5. Diagram of the Borth Bog profile shown in Fig. 4, expressing the relative proportions of tree pollen and of non-tree pollen of other categories.

cotyledonous. This suggests prevalent fenland, with the distant tree pollen component well marked (elm, pine, oak and hazel). The next four samples (34–54 cm.) show high tree/non-tree pollen ratios, and marked preponderance of alder and birch in the tree pollen. As at Ynyslas the alder maximum precedes that of birch and probably here also represents local fenwoods. It is not clear that here there was any local development of pinewoods. The three upper samples (100–180 cm.) show a fall to low tree/non-tree pollen ratios, and this

corresponds with the entry of *Sphagnum* spores and *Myrica* pollen in great amount. Taken with the diminishing tree pollen of the uncounted samples (180 to the bog surface) and their richness in *Sphagnum* spores, tetrads of Ericaceae, and leaves of *Myrica*, it seems clear that 100 cm. marks roughly the transition level of the bog from fenwoods to raised bog.

Conclusions

If this interpretation is correct, Borth Bog and the submerged peat at Ynyslas underwent a strikingly parallel development. This is not, of course, to say that the development was synchronous in the two cases. As to that, the evidence is lacking, though the higher pine values at the base of the Borth Bog suggest a somewhat later date than the base of Ynyslas peat, which apparently formed before pine was frequent, although it grew on the spot some time afterwards. Probably of more value as an index is the relation between the curves of *Ulmus* and *Tilia* pollen. Neither is a tree of bog or fens, and they therefore reflect in their behaviour changes in *regional* and not local conditions. It seems likely that late (Sub-Atlantic) diagrams in Britain are characterized by disappearance of *Tilia* or its subordination to *Ulmus*, in contrast with a former relative abundance. If this is so the upper part of the Borth bog diagram is definitely later than any part of the Ynyslas profile, and possibly marks the beginning of the Sub-Atlantic period.

It is, of course, particularly striking that there is no trace in the Borth bog series of the submergence which brought the coastal forest below sea-level. It should be remembered, however, that there are no records of peat composition or of pollen for the top 2 metres of the section, and it is also possible that the fen peat surrounding the present *Sphagnum* bog at Borth is the index to the submergence, and that this fen peat might be found to overlie *Sphagnum* peat. This problem would repay careful investigation.

The long developmental sequence shown by the submerged forest peat argues a long period of freedom from the marine influence under which the basal clay was deposited. Thus after the great submergence of the Boreal period, during which the North Sea was created, there must have been a considerable period before subsidence affected the sites now described. The term submergence is used here throughout, without any attempt to distinguish the eustatic and isostatic components of the movements of land and sea-level.

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EXPLANATION OF PLATE III

The submerged forest at Ynyslas, showing tree-stumps *in situ*, and exposures of peat partly covered with sand. View looking north towards the Dovey Estuary. Photo by Mr Challinor, May 1923.

GODWIN AND NEWTON—SUBMERGED FOREST, CARDIGANSHIRE