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POLLEN ANALYSIS OF THE HORRY CLAY AND A SEASIDE PEAT DEPOSIT NEAR MYRTLE BEACH, S. C. *

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ABSTRACT. The Horry clay below the section described by Cooke is a freshwater deposit. Deposition of the middle portion of this formation was attended by climatic conditions evidently moister, and probably also warmer, than was either the top or bottom portion. The rapidly increasing percentage of pine towards the top seems to indicate, on the basis of North Carolina experience, progressive cooling, although the entire formation was laid down during an interglacial age. This has been assumed by others to be the early part of Sangamon time, followed by the deposition of the overlying marine Pamlico formation. Nearby at Myrtle Beach State Park there is a seaside peat deposit of uncertain stratigraphic relationship to the Horry clay, although presumably younger, that dates from a glacial age. The chief evidence for this is the high percentage of spruce among the tree pollens present in the salt marsh peat. It is believed the Myrtle Beach peat is more likely Wisconsin than Illinoian in age. There is no known unconformable relationship between the Horry clay and the Pamlico formation.

INTRODUCTION

AT two known localities in the Atlantic Coastal Plain a dark carbonaceous clay containing rooted cypress stumps occurs immediately beneath the marine Pamlico formation. The first such record was reported by Holmes (1885) for a site on the southwest bank of the Neuse River 10 miles below New Bern, N. C. At this location cypress stumps up to 8 feet in diameter are visible for several hundred yards along the river, and in one place where the bank has been eroded back they occur as much as 40 yards offshore projecting out of the water.

This site was subsequently revisited by Berry (1926) who identified the cypress as *Taxodium distichum*, by Mansfield (1928) who described the geological section exposed at this site and listed the marine shells of the overlying Pamlico formation and the diatoms of the clay itself, and finally by Richards (1936) who merely confirmed many of Mansfield's observations. At stations both upstream and downstream a mile or two from this site Mansfield noted that the Pamlico rested unconformably directly upon the underlying Pliocene

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deposits, and he concluded that the cypress-containing clay was laid down in a stream cut channel.

Shortly after the Intracoastal Waterway was constructed in the middle 1930's, Cooke (1937) found a similar section along the waterway near Myrtle Beach, S. C., which he described and named the Horry clay. This deposit is overlain by 18 feet of Pamlico formation, the lower 6 feet of which are loaded with marine fossils, principally molluscs. In the 3 feet of Horry clay exposed at this site 53 species of diatoms were identified, the majority of which are marine. This contrasted sharply with the Neuse River site, where 8 out of 10 species found are freshwater diatoms, the most abundant being *Nitzschia scalaris* (Mansfield, 1928). Yet in spite of the apparent environmental differences concerning their deposition, Cooke believed the two deposits were contemporaneous, and Richards (1950) concurred.

The most abundant diatom at the Myrtle Beach site is *Polymyxus coronalis*, a marine species now extinct along the Atlantic coast of North America but still living off the mouths of the Para and Amazon rivers. This and several other diatoms of present southern distribution suggested to Cooke that the Horry clay "was deposited under conditions at least as warm as, and most probably warmer, than those existing in the same region today." Cooke concluded, therefore, that the deposit could not have been laid down during a glacial age, but was probably laid down in the early part of the interglacial age that included Pamlico time. This is most likely the Sangamon, according to Flint (1947), although it is by no means proved.

Pollen analysis of Pleistocene carbonaceous sediments is a tool that geologists in this country have not utilized so widely as they might in helping them to draw conclusions. It was therefore of considerable interest to the author to be asked by Stephen Taber to analyze the pollen of the Horry clay for the light it might shed on the conditions of temperature, moisture, and salinity during the deposition of this formation.

MATERIALS

Eight samples in the present study are from the Horry clay at the Inland Waterway site near Myrtle Beach. The other 2 samples are from the peat deposits being eroded by

TABLE 1.

General description of samples from Myrtle Beach peat and Horry clay, arranged in stratigraphic sequence.

	Sample	Distance from top of Horry clay [1]	General description
Myrtle Beach peat	Upper peat	++	Brownish-black peat, with rounded quartz grains and pebbles up to 2-3 mm. diameter throughout.
	Lower peat	+	Brownish-black peat; much less sand than in previous sample.
Horry clay	Stump sample	–	Dark-gray silty-clay, very compact and smooth; small percentage of fine sand grains.
	39-1	1′3″	Fine textured black silt, compact, with large amount of amorphous organic matter; a few small marine (?) bivalves.
	39-2	2′9″-3′3″	Black, crumbly organic sediment, with occasional small twigs or bits of wood; almost no inorganic matter.
	39-3	3′6″-3′11″	Black, crumbly organic sediment; larger quantity of plant and wood fragments than in previous sample.
	39-4	3′11″-4′4″	Dark-gray silty-clay of irregular texture; some small sand grains and a few plant fragments.
	39-5	5′2″-5′9″	Medium-gray clay, fine and smooth, compact; only occasional plant fragments.
	39-6	7′1″-7′7″	Light- to medium-gray, fine sandy-clay; mottled in appearance from fibrous plant remains.
	39-7	7′7″-8′0″	Light to medium brownish-gray sand, coarser than above but with fair amount of clay as a binder; mottled appearance from organic fragments.

[1] The top of the Horry clay is 2′0″ above mean sea level. The upper peat sample is above, and the lower peat sample is below mean sea level.

the sea at Myrtle Beach State Park, 4½ miles from the Horry clay site. The peat deposits are presumably younger than the Horry clay.

Taber collected 7 samples from the Horry clay on November 14, 1949, with the aid of an earth auger. These samples are listed by field number in table 1. The other sample from the Horry clay was collected by the author on November 6, 1949, near the base of one of the cypress stumps at the same site. Its exact position in the section is not known, although on the basis of its pollen spectrum to be discussed later it is quite evidently younger than 39-1.

At Myrtle Beach State Park a sample of the peat exposed only at low spring tides was collected by the author on November 6. This sample is hereafter referred to as "lower peat".

It should be noted here that the Horry clay is considerably thicker than the 3 feet reported by Cooke. Taber was able to put the earth auger down 8 ft. 11 in. into the formation. In general the lowermost portion of the deposit consists of rather fine brownish-gray sand with organic fragments. Proceeding upwards the color gradually becomes darker, indicating an increasing percentage of organic matter, and at the same time the average particle size becomes smaller until in sample 39-2 there is virtually no inorganic matter. This trend in particle size indicates a progressive reduction in current and wave conditions, and perhaps also a reduction in amount of runoff from the nearby land. Enclosed basin sedimentation is indicated. Above sample 39-2 silt and clay again appear in quantity, and the organic content decreases.

The peat deposit at Myrtle Beach is almost entirely organic, except for occasional sand grains in the lower peat and more abundant wave-rounded sand grains and small stones in the upper peat. The material is a marsh deposit, rather than a basin deposit.

METHODS

A single method of preparing pollen slides cannot be employed for all types of deposits. Where pollen is abundant and not obscured by too much other material, it suffices merely to boil a small sample in 10% KOH to thoroughly deflocculate the particles. Where there is a preponderance of

TABLE 2.

Method of preparation of samples, and relative abundance of tree pollens in them.

	Sample	Method of preparation	Total tree pollens	Slide rows examined	Abundance factor	Condition of pollen
Myrtle Beach peat	Upper peat	KOH - acetolysis	65.5	59	1.1	well preserved
	Lower peat	KOH - acetolysis	55	44	1.3	well preserved
Horry clay	Stump sample	KOH - 3x bromoform	151	5	30.2	considerably fragmented
	39-1	KOH - 2x bromoform	81	21	3.9	poorly preserved, crumpled, fragmented
	39-2	KOH	155	15	10.3	mostly well preserved
	39-3	KOH - acetolysis	166	7	23.7	well preserved
	39-4	KOH - 2x bromoform	155	19	8.2	surface obscured, appears granular
	39-5	KOH - 2x bromoform	87	43	2.0	shrunken and crumpled, surface obscured
	39-6	KOH - 2x bromoform	95	43	2.2	somewhat better preserved
	39-7	KOH - 2x bromoform	103	22	4.7	ditto

fibrous plant material, as in peat deposits, it is advisable to concentrate the pollen by dissolving some of the plant material. This can be quite easily accomplished by means of the acetolysis method described by Erdtman (1943). Where the deposit is largely inorganic, it is necessary to get rid of as much of the extraneous material as possible to effect a concentration of the pollen grains. The author has best been able to accomplish this by flotation in bromoform according to a procedure already described (Frey, 1951). The manner of treatment of the individual samples is listed in table 2. From the final concentrated sample one or more slides were prepared by mixing a small amount of the concentrate with glycerine jelly containing gentian violet.

The slides were examined for pollen and other microfossils at a magnification of 440 diameters. By means of a mechanical stage the slide was moved horizontally through the field of the microscope, and each pollen grain or spore was tabulated as encountered. The goal was to obtain 150 tree pollen grains from each level, according to standard procedure. In a number of instances, however, tree pollens were so scarce, even in the concentrated samples, that it would have required an excessive effort to comply with convention without commensurate increase in accuracy. This was particularly true in the two peat samples from Myrtle Beach State Park, and to a lesser extent in samples 39-5 and 39-6. The abundance factors listed in table 2 merely represent the average number of tree pollen grains found per horizontal traverse at high power and do not attempt to give the number of grains per unit volume or unit weight of sediment.

ANALYSIS OF HORRY CLAY

The overall results of the study are represented in table 3. As is customary in pollen analyses, each non-tree type of pollen or spore is expressed as a percentage of the total number of tree pollen grains found in the sample. The pollens and spores listed as "Unknowns" are either those that were clearly seen but not recognized by the author, or those that were so badly crumpled, fragmented, or obscured by granulations and internal clay particles that they were unrecognizable. For the most part these grains were not tricolpates, so that they would exert little or no effect on the percentage composition of the arboreal pollens. Only in samples 39-4 and 39-5 where the surface sculpturing was obscured and the pollen had a granular appearance, making tricolpate grains unidentifiable, is there any likelihood of an appreciable loss of tree pollens. These losses, however, are of a type that do not change the general interpretation of the results.

The tree pollen spectra in the Horry clay exhibit a progressive and orderly change from the lowest level to the uppermost. *Pinus* (pine), the most abundant tree pollen, comprises more than 90 per cent of the total tree pollens at either end of the section and only about 30 per cent in the middle. *Quercus* (oak), the next most abundant type, varies in a generally reciprocal manner, being least abundant at the top and bottom of the deposit and most abundant in the middle. Unfortunately for interpreting these changes, the species of oak and pine cannot be identified from their pollen grains, although attempts have been made by others (Cain, 1940) to identify pines on the basis of the size-frequency characteristics of fresh pollen of the various species. Such a wide variety of species of both pines and oaks with greatly differing ecological requirements occur in the Coastal Plain of the South Atlantic States that it is indeed lamentable more precise determinations cannot be made. However, other species and other pollen grains give clues as to the accompanying climatic conditions.

Excluding pine and oak which are present in all the samples, there is a greater diversity of the tree flora midway through the section than at either end. The types present in the middle of the deposit are such mesophytic types as *Nyssa* (tupelo), *Liquidambar* (sweetgum), *Fraxinus* (ash), *Ulmus* (elm), *Taxodium* (cypress), and *Salix* (willow). Climatic conditions were evidently moister, and probably also warmer, in the middle of the period than at both the beginning and end.

An increasing percentage of pine, like that in the upper half of the deposit, is probably an indication of cooling climate in the North Carolina-South Carolina region (Frey, 1951). If this cooling was antecedent to a glacial age, the climatic depression might have been sufficient to provide for the southward extension of *Picea* (spruce) and *Abies* (fir). Both of these types of pollens have been reported from Pleisto-

TABLE 3.

Pollen analysis of Horry clay and Myrtle Beach peat. All figures are expressed as percentages of total tree pollens.

	Myrtle Beach peat		Horry clay							
Pollen type	Upper peat	Lower peat	Stump sample	39-1	39-2	39-3	39-4	39-5	39-6	39-7
Pinus	36.7	58.2	95.6	81.5	79.3	30.7	53.5	52.9	79.0	93.2
Picea	42.0	3.6	0.3?							
Quercus	15.3	18.2	1.3	12.3	11.0	49.4	39.4	21.8	10.5	3.9
Carya	3.1	12.7	2.0	2.5		6.6	1.9	13.8	7.4	1.9
Liquidambar			0.7	1.2	1.9	6.0	2.6	3.4	1.1	
Nyssa	1.5	3.6		1.2	0.6	1.2		2.3	2.1	
Taxodium		3.6		1.2	5.2					
Betula	1.5				0.6		1.3			
Fraxinus					1.3	3.6				
Ulmus								2.3		1.0
Castanea							0.6			
Ostrya						2.4	0.6	2.3		
Salix								1.1		
Total tree pollens	65.5	55	151	81	155	166	155	87	95	103
Gramineae	1290	90.9		2.5	44.5	13.9	7.7	34.5	55.8	5.8
Compositae	146	43.6	0.7	2.5	3.2	0.6	7.7	14.9	24.2	1.9
Chenopodiaceae	1020	16.4	0.7	0.7			1.3			1.0
Cyperaceae	5.4			0.7	1.9		1.9		4.2	
Caryophyllaceae	10.8	12.7	0.7						2.1	
Aquatics										
Nuphar	20.6	7.3				1.2	0.6			
Nymphaea	5.4									
Myriophyllum	16.2					1.8		1.1		
Shrubs										
Ilex		3.6								
Rhus ?	20.6									
Myrica				0.7	1.3				1.1	
Corylus								1.1		
Ericaceae	5.4							2.3		
Alnus									1.1	
Pteridophytes										
Polypods	10.8	38.2						2.3	1.1	
Lycopods		5.5	0.7		0.6	3.6		3.4	5.3	1.0
Asplenium									3.2	
Isoetes ?		264								1.0
Sphagnum							0.6			
Unknowns	1000	287	3.3	70.4	59.3	100	100	264	94.8	28.1
Freshwater sponge spicules	—	—	—	+	+	+	+	+++	++	++

cene deposits in North Carolina (Buell, 1945; Frey, 1951) and South Carolina (Cain, 1944). The *Picea* in the sample around the cypress stumps is a doubtful record, because only a single half-grain of somewhat uncertain identity was found on the entire slide.

Taxodium pollen was found only in the two uppermost samples collected by Taber and not at all in the sample collected by the author from around the base of the cypress stumps. The pollen of cypress and swamp whitecedar is thin walled and apparently not so readily preserved as that of some of the other trees (Lewis and Cooke, 1927). It is consequently of interest that any recognizable cypress pollen was found, because of the great age of these sediments.

Carya (hickory) is present in all the samples except 39-2. There is quite a pronounced maximum of this tree type in the lower part of the deposit prior to the oak maximum. This is the same sequence observed by Frey (1951) in the pollen succession at Singletary Lake, N. C., during the most recent "postglacial" period. In this instance the hickory maximum was one stage in increasing dryness, culminating in the oak maximum, along with substantial percentages of grasses and composites. The shift from hickory to oak in the Horry clay seems not to represent similar changes in moisture conditions because of the contemporaneous occurrence of mesophytic types.

Pollen of three genera of freshwater aquatics (*Nuphar*, *Nymphaea*, and *Myriophyllum*) were found in small numbers in the middle portion of the deposit somewhat below the organic maximum. Moreover, monaxon flesh spicules of freshwater sponges were present in all samples except the uppermost, with a definite maximum in the three lowest samples. These two groups of fossil remains indicate freshwater basin deposition in the lower half of the section. Conditions of salinity in the upper half are obscure on the basis of the present material, although the decrease in abundance of sponge spicules may reflect either an absence of open water or an increase in salinity.

The pollen of grasses and composites is quite abundant in samples 39-2, 39-5, and 39-6. In the two latter samples there is also a representation of shrubs and pteridophytes. The overall interpretation of such conditions is that the surrounding land areas were only sparsely wooded, being covered rather with various herbs, shrubs, and ferns growing under fairly moist conditions edaphically and climatically.

ANALYSIS OF MYRTLE BEACH PEAT

The exact relationship of the seaside peat at Myrtle Beach State Park to the Horry clay is not known, although it is presumably younger. Very likely there was a considerable interval of time between the deposition of these two formations.

The presence of *Picea* pollen in both samples indicates the peat was laid down during a glacial period. There is little likelihood that spruce persisted in bogs during interglacial periods in this region, because Frey (1951) has shown that the spruce present in North Carolina in Wisconsin time disappeared rapidly and completely soon after the climate began to amelioriate after the Mankato maximum. Cain (1944) had already reported spruce (and fir) pollen from South Carolina in a number of buried soils. They, like the Myrtle Beach peat, are of uncertain age. The marked increase in percentage of spruce pollen in the upper peat may indicate that deposition began early in a glacial age and that climatic conditions became increasingly severe. In light of the Singletary Lake pollen diagrams (Frey, 1951) it is surprising to see the broadleaf trees so well represented during a glacial age.

Of equal interest to the occurrence of spruce pollen is the abundance of grasses, chenopods, and composites, especially in the upper peat. Such large percentages of chenopod and grass pollen in a coastal location can only mean that the peat was formed under salt marsh conditions. However, it is also apparent that there must have been some freshwater conditions as well, either alternating with brackish conditions or occurring simultaneously in separate basins. The species of aquatic plants are quite well represented with respect to the trees, and the mesophytic *Taxodium* and *Nyssa* are also present.

Very few tricolpate grains are included in the large number of unknowns in the upper peat sample. The types present are mainly smooth, acolpate grains of 3 sizes: a) the smallest might be moss spores; b) the medium-sized grains are about the size of *Juniperus*, and quite a number are monocolpate;

and c) the largest often have thick walls. Most of the grains tabulated as grass pollen were large, thin walled, with a prominent pore.

DISCUSSION

Spruce pollen in sediments of the South Atlantic coastal region is taken to indicate glacial time. Conversely, an absence of spruce pollen is taken to indicate interglacial time, and not merely a local recession of the glacier during Wisconsin time. Evidence for this generalization is the detailed pollen analysis of the sediments in Singletary Lake, N. C. (Frey, 1951), known by the radiocarbon method to extend through at least two of the interglacial sub-ages of Wisconsin time. Yet the climatic amelioration associated with these minor retreats of the ice was not sufficient in degree nor of long enough duration to completely eliminate spruce from the region, as indicated by the occurrence of its pollen in the sediments.

The prevailing opinion (Flint, 1947) is that the marine Pamlico formation was laid down during the mild Sangamon interglacial age, when the sea was approximately 25 feet higher than at present. Cooke (1937) considered the Horry clay to have been deposited during the early part of this interglacial age. According to this time relationship, one would expect to find indications of a warming climate in the pollen record of the Horry clay.

The climate was mild at this time but mainly in the middle of the section. Toward the top there was a deterioration of climate, as indicated by a progressive decline in broadleaf trees, particularly mesophytic types, and a progressive increase in pines. This evidence is contrary to the finding of polythermal marine diatoms in the upper part of the section, but these latter necessarily stem from marine environments, not terrestrial, and they may have been introduced by currents from more favorable localities. No unequivocal spruce pollen was found in the Horry clay samples.

The finding of spruce pollen in the Myrtle Beach peat indicates deposition during a glacial age. Along the Middle and South Atlantic coast of the United States there are quite a number of known peat deposits being eroded by the sea, sometimes at a depth up to 10 feet below mean low water.

Possibly all of these may date from the same glacial age as the Myrtle Beach peat. The peat at the Boylston Street fishweir, however, is not homologous, because its age is only about 5700 years (Flint and Deevey, 1951).

The radiocarbon age of the cypress stumps in the Horry clay is greater than 20,000 years (sample No. 105). This is taken by Flint and Deevey (1951) to indicate that the Pamlico formation does in fact date from the Sangamon interglacial age, because the only time since then that the sea level could have been higher than at present was during the thermal maximum, perhaps 7,000 years ago. Their reasoning obviously is based on the assumption that the Horry clay and the Pamlico formation both date from Sangamon time.

The stratigraphic relationship of the Myrtle Beach peat to the Pamlico formation and to the Horry clay is critical for interpreting the age of the latter. If the Horry clay is stratigraphically inferior to the peat, and hence chronologically older, then it would very likely date from Yarmouth time. But if the Horry clay and Pamlico formation were laid down in different interglacial ages, one would expect an erosional unconformity between them. Mansfield (1928) though there might be such an unconformity at the Neuse River site, but Cooke (1937) did not mention any unconformable relationship at the Inland Waterway site. Taber (correspondence) looked for an unconformity at the latter site but was unable to discover any. Hence, the stratigraphic evidence does not favor the interpretation that the Horry clay and Pamlico formation derive from different interglacial ages.

A more reasonable explanation might be that the Myrtle Beach peat, and similar deposits of the Atlantic Coast, were laid down in Wisconsin time, along the eroding edge of the Pamlico. In this case the peats are younger than the Pamlico, and there would be no mental compulsion to seek an unconformity between the Horry clay and Pamlico.

Cooke's interpretation of the conditions under which the Horry clay was formed was based entirely on the upper three feet of the deposit, which on the basis of the diatoms is entirely marine, except for the presence of the cypress stumps. He was unaware of the earlier freshwater portion of the formation. His assumption that the upper part of the clay possibly represents a salt marsh deposit is not compatible with the results of the present study, in that there is a general lack of grasses and chenopods indicative of such deposits.

Granted on the basis of evidence other than pollen that the upper part of the clay was laid down under salt water conditions (although not salt marsh conditions), there still must have been at least one rather prolonged freshwater period to permit the cypress trees to become established and grow in such abundance. As to the cause of the sudden death of these cypresses, Cooke believed it was a reinvasion of salt water, and that the deposits laid down eventually buried most of the stumps still in their upright position. What the actual sequence of events was might be discovered by a pollen and diatom analysis of samples collected at intervals of no more than several centimeters.

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