CAROLINA BAYS IN RELATION TO THE NORTH CAROLINA COASTAL PLAIN[1]

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The Atlantic Coastal Plain is a region of many problems and of widely conflicting opinions concerning a number of these. Two of direct importance in the present discussion are the questions of marine overlap onto the Coastal Plain with the possible production of "terraces", and the Carolina bays which occur on these terraces.

COASTAL PLAIN TERRACES

The idea of the Atlantic Coastal Plain being arranged in a series of broad steplike terraces, possibly representing successive sea levels higher than the present, was first conceived in Maryland. In 1907 Johnson described in general terms five of these terraces in North Carolina, and in 1912 Clark *et al.* published a map of the North Carolina Coastal Plain showing six terraces, of which the uppermost one, the Lafayette, was believed to be Pliocene in age and the other five Pleistocene. Fig. 1 shows a somewhat simplified arrangement of these terraces taken from this map; to avoid confusion the many reentrants of lower terraces along the larger streams have been omitted. The five Pleistocene terraces decrease in elevation towards the coast. The limits of these as given by Clark *et al.* are: Coharie 235–160 ft.; Sunderland 150–110 ft.; Wicomico 100–50 ft.; Chowan 50–25 ft.; Pamlico 25–0 ft. Cooke (1935) proposed that the Pamlico terrace was formed during the Peorian interglacial subage, the Talbot (= Chowan) and Wicomico during the Sangamon age, and the Sunderland and Coharie terraces during the Yarmouth interglacial age. No evidence is given for these datings other than the assumptions that the terraces were formed during interglacial ages when the melting of the glaciers made the sea level higher than at present, and that the terraces are arranged in chronological order from the youngest nearest the coast to the oldest at the inner border of the Coastal Plain.

Flint (1940) reviewed critically the evidence for terraces and rejected most of it as inadequate and too conflicting. On the basis of field studies he was able to find and trace only two wave-cut scarps in North Carolina, which probably represent eustatic changes in sea level. The lower one or Suffolk scarp follows approximately the boundary between the Pamlico and Chowan terraces as given by Clark *et al.*; its toe lies at an altitude of 20–30 ft. above sea level. The upper or

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Surry scarp lies close to the inner boundary of the Wicomico terrace, although in some places it is 15 miles away from the boundary as shown by Clark *et al.* Its toe lies at an elevation of 90–100 ft. Flint states that there is no evidence in the Carolinas for any marine invasions higher than the Surry scarp. This, if generally accepted, would make untenable any theories regarding the Carolina bays as having arisen along the sea coast or in shallow marine locations, unless they are exceedingly old. Flint also states that the general concept of terraces in the sense

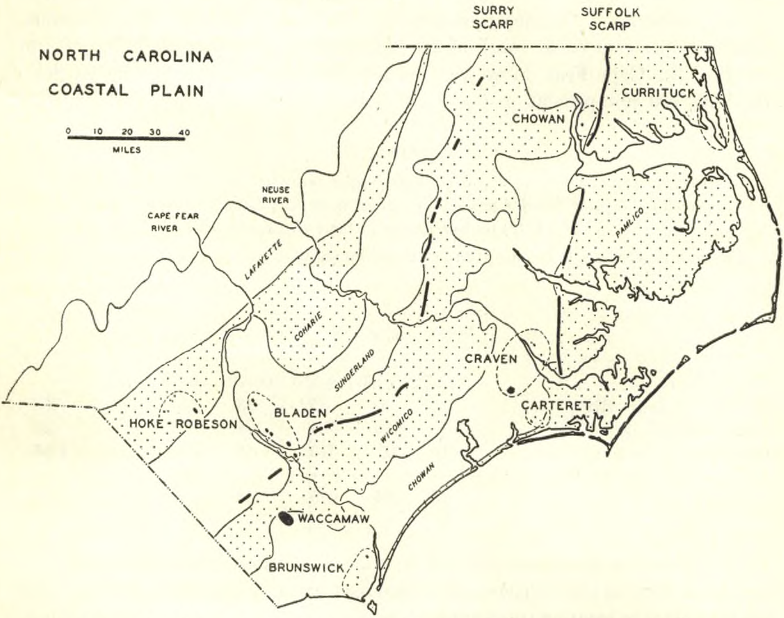

FIG. 1. Location of the Carolina bays sampled in 1949 in relation to Coastal Plain terraces and wave-cut scarps. The terraces are taken roughly from Clark *et al.* (1912) and the location of the scarps from Flint (1940).

of equilibrium phenomena resulting from various sea levels should probably be discarded, but in the present paper the original designations will be retained primarily as a convenience for designating general zones of elevation. The two scarps are shown in Fig. 1.

DISTRIBUTION OF CAROLINA BAYS

A second disputed question, which is even less close to being settled than the first, concerns the origin and subsequent history of the very numerous elliptical basins—the Carolina bays—in the Coastal Plain. Theories concerning their origin are quite numerous and have been reviewed by Johnson (1942), but studies concerning the bays themselves have been altogether too few, so that at present there is no conclusive evidence compelling the acceptance of one or another of these theories.

On the basis of a map showing the distribution of all bays larger than 800 ft. compiled from aerial photographs by the late W. F. Prouty and the terrace map by Clark *et al.*, a count was made for each of the terraces in each of three transverse portions of the Coastal Plain (Table 1).

The bays are not distributed uniformly over the state, as was obvious previously from Fig. 2 of Johnson (1942) or from even a cursory examination of aerial photographs. Of the approximately 2000 large bays in North Carolina, almost 90 per cent occur south of the Neuse River, and more than 50 per cent south of the Cape Fear. Moreover, even in the areas of greatest concentration the bays are not present in equal abundance at all elevations. Omitting the

TABLE 1

Approximate number of Carolina bays greater than 800 ft. in diameter in the Coastal Plain of North Carolina, arranged according to the terraces of Clark et al. (1912) and according to three transverse belts

The counts were made in part from an unpublished map by W. F. Prouty.

REGION	TERRACE						TOTALS
	Lafayette	Coharie	Sunderland	Wicomico	Chowan	Pamlico	
Elevation, ft.	>235	235–160	150–110	100–50	50–25	25–0	
Va. line to Neuse River	13	40	45	33	43	30	204
Neuse R. to Cape Fear R.	2	188	185	178	74	4	631
Cape Fear R. to S. C. line	10	577	380	22	176	0	1165
Totals	25	805	610	233	293	34	2000

Lafayette terrace which has only a few, some of which are doubtful and most of which are close to the Coharie terrace and may actually be situated on the latter through error in locating the boundary between these two zones, there is roughly a decrease in number of bays with decreasing elevation. Thus the highest terrace, the Coharie, has the greatest number of bays and the Pamlico the least. Assuming that there is a concentric chronological arrangement of surficial Coastal Plain sediments corresponding to the terraces, one is tempted to speculate that the older a formation is the more bays it has. A corollary of this is that the bays are not necessarily all the same age.

PRESENT STUDY: METHODS

In an attempt to gather data concerning the comparative age and ontogeny of basins located at various elevations, a study of the sediments of the Carolina bays which was started on Singletary Lake in 1948 was extended to a number of diverse bays in 1949. Fig. 1 shows the bays and areas sampled in relation to the Coastal Plain terraces and the Surry and Suffolk scarps.

In each area studied several bays were sampled to provide a more nearly representative picture than could be obtained from just one bay and to give some idea of possible variation with respect to size. The bays were selected for their regularity of outline so that there would be no question as to their being bays, for the presence of standing water or at least saturated conditions to provide continuous deposition and some protection from burning, for their general accessibility, and for a range of size. With the aid of aerial photographs and a sighting compass (and a machete!) the bay was penetrated to its approximate center. Along the way "soundings" were taken at regular intervals by means of the $\frac{3}{8}$-inch steel rods of the Davis peat borer. The total depth to which the rods could be pushed and any pronounced variation in the configuration of the bottom was noted. If the density of vegetation permitted, soundings were taken in various directions from the center to determine if the place selected was in fact the deepest part of the bay that could be conveniently found. When the sampling station was finally decided on, samples of the bay sediments were collected with a Davis peat sampler at 6-inch intervals (or sometimes more frequently as the occasion demanded) from the surface of the bay down as far as the sampler could be pushed and pounded without damaging it unduly. No attempt was made by other means to penetrate the sand or clayey-sand below this level. Sometimes a Hiller-type sampler was used for very soft surface deposits. The samples were preserved in properly labelled plastic screw cap vials for subsequent laboratory analysis.

RESULTS

This report presents just a few of the more general results and a suggestion of what may be expected from a complete analysis of the cores.

Bays are much more uniform when seen from the air than when seen from the ground. From the air they are all ellipses of varying size, oriented roughly parallel to one another in a general northwest-southeast direction. From the ground they are seen to have differing degrees of wetness and different plant communities. The latter are controlled by the prevailing moisture conditions, particularly the length of time each year that the soil is completely saturated with water, by the nature of the soil profile and by the frequency and severity of burning. Wells (1928) has designated the three main types of communities that occur in these wet depressions as swamp-forest, shrub-bog, and savanna-bog. Rockyhock Bay (Ch-3), a good example of a swamp-forest, consisted of a high canopy of large white cedars, sweet bays, and maples, with little shrub understory. More open swamp-forests, such as Cu-1, contained pocosin pines, black gum, maple, sweet gum, and holly, and in addition an understory of cane, ferns, small sweet bay, and abundant sphagnum. Still others had a rather thick shrub understory, with of course a more open canopy. The shrub-bog community, e.g. that of Cr-3 and Br-2, consists primarily of broadleaved evergreens, which in these instances were mainly waist-high to more than headhigh growths of gallberry (*Ilex*), pepperbush (*Clethra*), and titi (*Cyrilla*), frequently held together by bothersome cat briars (*Smilax laurifolia*), with many *Sphagnum*-filled pools below and scattered pocosin pines (*Pinus serotina*) projecting above this mass of vegetation. Other areas, such as extensive parts of Ca-1 and Ro-3, consisted primarily of grass and

TABLE 2

General geographic, morphometric, and edaphic characteristics of the Carolina bays of N. C. investigated in 1949

Lengths were measured without correction from USDA aerial photographs (scale approx. 1 in. = 1667 ft.), and altitudes were interpolated from U. S. Army Corps of Engineers maps, except for Waccamaw and Rennert which were obtained from N. C. Geol. and Econ. Surv. Bull. 27. Elevations of Singletary and Jones were reported previously by Frey (1949a). The elevation of RO-1 was interpolated from a nearby bench mark.

TERRACE	COUNTY	BAY	NAME	APPROX. ELEV.	LENGTH	DEPTH	SEQUENCE OF SEDIMENTS
				ft.	*yds.*	*ft.*	
Pamlico	Currituck	Cu-1		10	800	6.0	Thin organic, sandy clay, sand
		Cu-2		10	1060	6.0	Organic, clay, alternating sand and clay
		Cu-3		14	700	4.6	Organic, clay, alternating sand and clay
Chowan	Chowan	Ch-1		41	1030	5.0	Organic, brown sand
		Ch-3	Rockyhock Bay	18	1810	14.3	Organic, clay, organic, sand
	Craven	Cr-1			1150	10.0	Organic, clay, sand
		Cr-2			460	4.4	Organic, sand and clay, sand
		Cr-3			1040	5.8	Organic, sand
		Cr-4	Catfish Lake		3020	6.5	Organic, clay, sand
	Carteret	Ca-1			640	4.5	Organic, sand
		Ca-2			530	8.3	Organic with 2 sand lenses, clay, sand
		Ca-3			950	3.8+	Sandy organic
	Brunswick	Br-1		42	670	4.5	Organic, sand
		Br-2		48	630	4.2	Organic, sand
		Br-3		44	210	2.0	Sandy organic
		Br-4		52	480	4.3	Sandy organic
		Br-5	Funston Bay	45	1960	5.5+	Organic, clay, sand
		Br-6	Pumping Pond		440	16.0	Organic, sand
	Columbus	Wa-1	Lake Waccamaw	41	10820	14.7+	Organic, sandy clay, blue clay
Wicomico	Bladen	Si-25	Singletary Lake	63	3180	21.6	Organic, clay, organic, clay, organic, sand
Sunderland		J-1	Jones Lake	73	2590	17.7	Organic, clay
		Sa-1	Salters Lake		2660	18.4	Organic, clay, organic, sand
		LS-2	Little Singletary		3190	12.3	Organic, clay, organic, silt, sand
		Wh-1	White Lake		3740	12.4+	Organic, blue clay
		Bl-1			930	8.3	Organic, clay, sand
		Bl-2	Jerome Bay		2170	11.0	Organic, clay, sand
Coharie	Hoke	Ho-1			1040	3.5	Thin organic, clay, sandy clay
		Ho-2			740	3.0	Thin organic, clay, sandy clay
		Ho-3			940	5.4	Thin organic, clay
	Robeson	Ro-1		205	580	1.5+	Thin organic, sandy clay
		Ro-2			1020	2.5+	Thin organic, clay
		Ro-3	Rennert Bay	182	4580	7.6+	Organic, clay, sandy clay

ferns. Drier areas of some of the upland bays contained large holly and oaks. Evidence of fires was found in many of the bays.

The sediments occurring within the bays constitute the main material for further work (Table 2). All the bays had a layer of organic matter (ooze, peat, or organic soil) at the surface. This varied in thickness from a few inches in most of the bays examined in the Hoke-Robeson region to a number of feet in most of the other regions. Below this was an inorganic layer consisting of sand in the shallower bays and clay or silt in the deeper bays. The clay (silt) usually rested upon sand except in a number of the Bladen County lakes (Salters, Little Singletary, Singletary) and Rockyhock Bay (Ch-3) where a second organic layer was interposed. In core Si-25 of Singletary Lake two such organic layers were found, making a total of 3 including the now accumulating surface sediment. With the equipment at hand it was not possible to push down into the sand. This is unfortunate, since it has been found in the more extensive studies on Singletary Lake in the summer of 1948 when with the aid of a Wilson sampler samples were obtained well into the sand, that stratified pollen indicating basin deposition occurs in the sand as well.

With the understanding that the depths of sediments here reported constitute only those that could be sampled with the Davis or Hiller devices and do not necessarily represent the total thickness of sediments, it is interesting to examine the relationship between size of bay and depth of sediments. Fig. 2 shows that in general as the size of the bay increases, the depth of the sediments also increases. With the exception of Rockyhock Bay, the seven deepest bays are the ones still containing enough water to be called lakes. Rockyhock Bay is interesting in that it is the only filled-in bay sampled which shows any of the morphometric characteristics of the bay lakes (Frey, 1949a); at the southeast end is a shallow sand terrace extending out from the present shore of the bay for a considerable distance and then dropping off rapidly to the depth sampled. This greater depth of the lake-containing bays suggests that a greater original depth as well as their greater size may help account for open water persisting in these particular localities.

Pumping Pond in Brunswick County does not have the shape of a bay and is probably not a Carolina Bay. It is representative of the numerous small ponds found along much of the immediate coastal region of North Carolina, and is included for comparison with the bays. Likewise Catfish Lake is not a bay. The bottom of Catfish Lake was very irregular, with many "hillocks" of peat projecting above the clay surface of the bottom. In between was a soupy accumulation of flocculent organic matter, and in addition there were many logs on the bottom. There is a strong possibility that Catfish Lake has been reformed relatively recently by the erosion and removal of deposits which obliterated the previously existing water area perhaps during the climatic optimum. Jerome Bay (Buell, 1946) is the only other bay in North Carolina previously reported upon. It is likewise included for comparison.

Scattered references occur in the literature relative to the depth of bays and the nature of the contained sediments. Glenn (1895), to whom credit must be given for first pointing out the bays and describing accurately some of their characteristics, noted that wells driven into bays showed a "dark fertile, compact clay, impervious to water" extending downward 15 to 25 ft. to the underlying water-containing sand. Johnson (1942) noted that Carolina bays may have a total depth up to 50 ft. below the general plain level. This, however, does not represent 50 ft. of sediments, since the floors of some of these crater-like depressions are themselves as much as 30 to 40 ft. below the surface of the surrounding plain. No such bays have been sampled by the author. On the basis of all existing information it is probably safe to conclude that the Carolina bays are

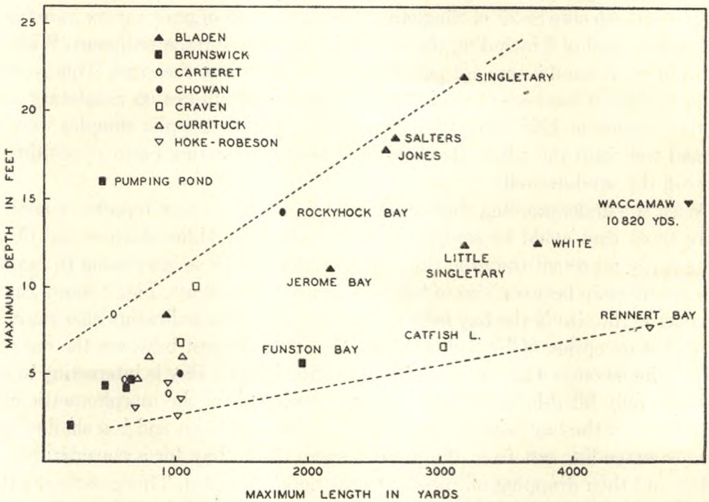

FIG. 2. Relationship between maximum length of the Carolina bays and maximum depth obtained with a $\frac{3}{8}$-inch steel rod. Pumping Pond and Catfish Lake are not bays. The data for Jerome Bay are from Buell (1946).

quite shallow, much more so in general than the ice block basins or glacial erosion basins of the northern part of the continent.

ANALYSIS OF SEDIMENTS

The sediments of a marshy or water-filled basin, if not disturbed or severely desiccated and oxidized during their history, preserve a chronological record of plant and animal remains. Long term changes in climate are recorded by changes in the percentage composition of tree pollens in the sediments. Buell (1945) working on Jerome Bay in Bladen County was the first to observe and record spruce pollen from surface sediments of North Carolina. This type of tree, found only in the clay at the bottom of the core, along with a small pine grain identified as *P. banksiana* on the basis of size-frequency distribution, suggests these lowermost sediments were contemporaneous with late Wisconsin time. More recently the author (Frey, 1949b) has analyzed core Si-25 containing the three organic layers. Although spruce is present in small percentages all the way to the bottom from where it first occurs in the upper part of the silt zone, there are definite ameliorations of climate associated with each of the two lower organic layers, as shown by increased percentages in oak, hickory, and even the occurrence of such pronounced mesophytic species as beech, chestnut, and hemlock. On the basis of these changes it was suggested that the sediments of Singletary Lake

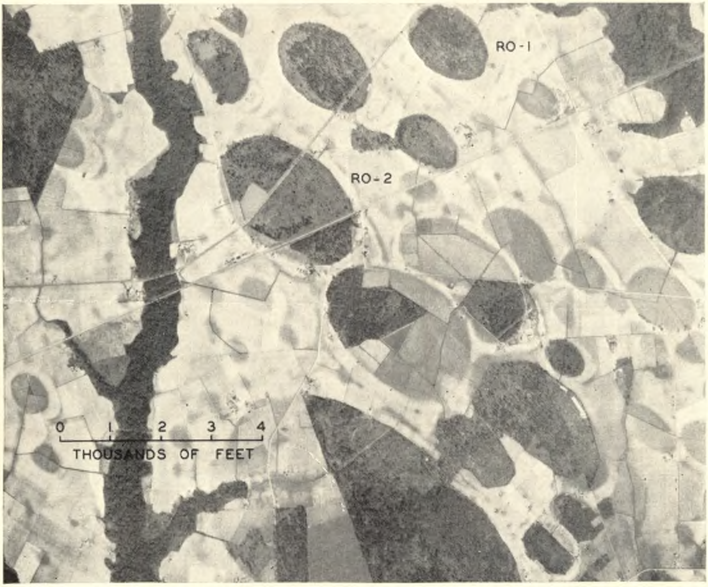

FIG. 3. Aerial photograph of a portion of Robeson County near Red Springs, showing the location of Ro-1 and Ro-2 and their relation to the surrounding surface features. The darker lines are drainage ditches. (USDA, Production and Marketing Administration.)

extend back into the Tazewell subage of the Wisconsin glacial age, making this record the longest continuous pollen record known from North America.

Certain regional differences are apparent in the bays which may be a reflection of differences in age. One of the most marked of these is that the bays on the Coharie terrace in particular are filled mainly with dark mineral soils having a relatively thin layer of organic matter on top. When these bays are cleared and drained they can be used quite successfully for agriculture. Fig. 3 is an aerial photograph of a portion of Robeson County near Red Springs taken on Feb. 20, 1938, showing the location of Ro-1 and Ro-2. The bays under cultivation can be readily distinguished by their darker color from the surrounding more sandy country.

Analysis of the cores collected from these and the other bays will enable the aging of their sediments and the working out of their histories. When means is obtained of sampling the sand deposits—at least the pollen bearing portions—it should then be possible to determine quite readily whether or not all the bays are the same age. In the meantime the more superficial sediments on hand will be valuable in helping determine the influence of glaciation on the southern United States and possibly of following the retreat and advance of vegetations with changing climatic conditions.

SUMMARY

Although Pleistocene marine influence has not been demonstrated in the Carolinas at elevations greater than 100 ft., the peat-filled Carolina bays are more numerous above this level than below. There is a general decrease in number of Carolina bays with decreasing elevation on the several Coastal Plain terraces. The depth of sediments down to impenetrable sand or sandy clay roughly increases with increasing size of the bay. Those bays still containing lakes are in general the deepest, suggesting that an original greater depth of the basins may have helped in the preservation of the water areas. In the two studies thus far on the pollen of bay sediments, spruce has been found in the inorganic layers below the superficial organic layer. In Singletary Lake two lower organic layers were associated with ameliorations in climate, although these were not intense enough nor of long enough duration to cause a disappearance of the spruce. The usefulness of pollen analysis in working out the age and ontogeny of these basins and of studying changes in vegetation during Wisconsin time is indicated.

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