SOILS AND MORPHOLOGY OF CAROLINA BAYS, EASTERN SHORE, VIRGINIA

by

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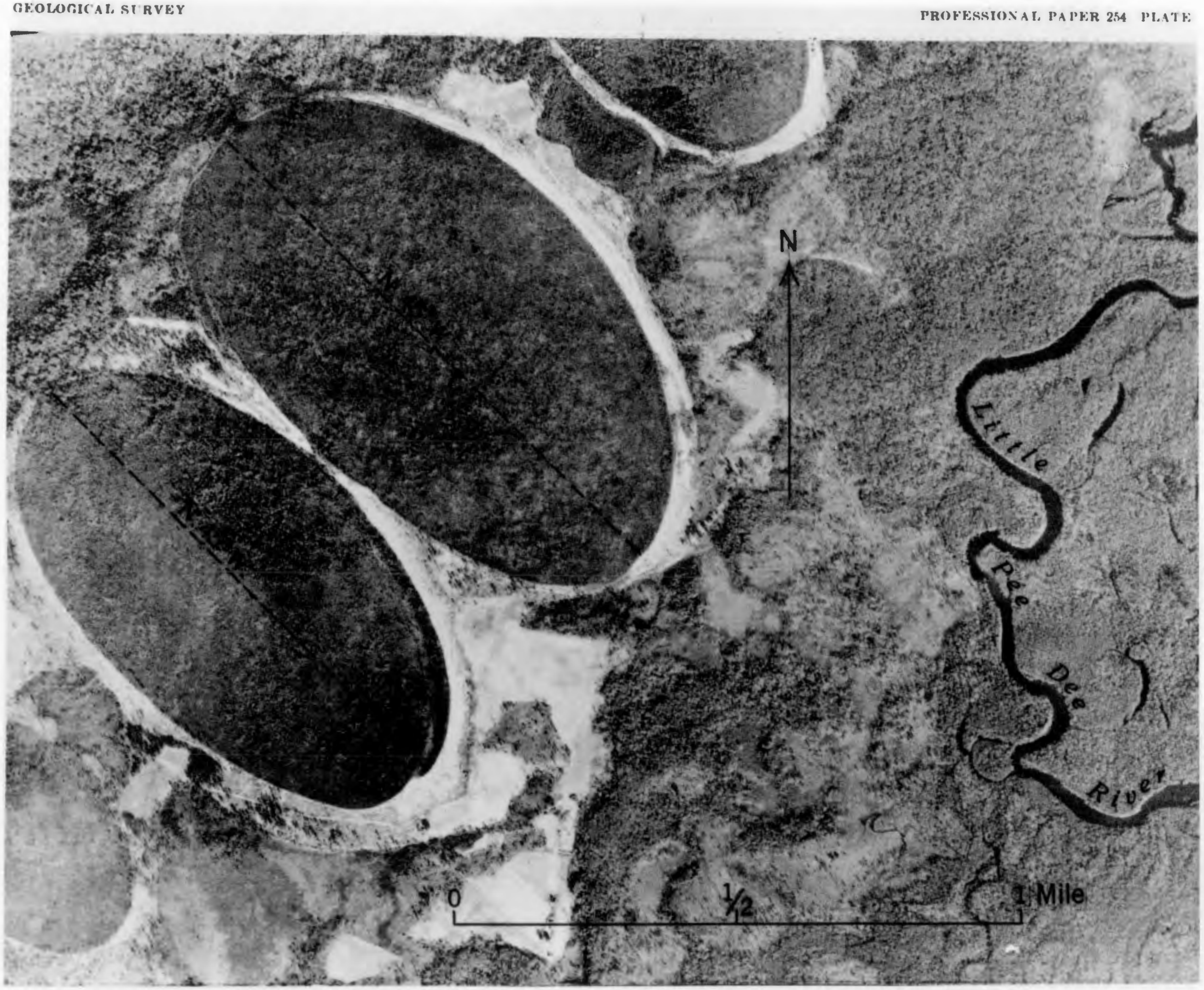


Fig. 1. Pee Dee Islands, Marion County, South Carolina (from Cooke 1954).

INTRODUCTION

Carolina bays are shallow elliptical depressions having parallel orientation which occur on the Atlantic Coastal Plain of the United States. Their unique features and apparent lack of relation to recognizable geologic processes have baffled scientists for many years. As a result, many unique hypotheses of origin have been proposed. It has only been in relatively recent times that similar landforms have been discovered and studied in other parts of the world. In spite of all the theories proposed and the evidence assembled, satisfactory explanations for the existence of some bay features are still lacking.

Previously, few studies have been directed at describing soil morphological and genetic relationships of Carolina bays. Although the Carolina bays on the Eastern Shore have been mentioned in a few reports, there have been no forthcoming studies describing bay morphology and their relationship to bays of other areas. Thom (1970) suggested the need for more bay data from areas previously not studied. Previous studies have not involved detailed investigation of bays in recent sedimentary environments.

The purposes of this study are primarily to:

1) Conduct an inventory of Carolina bays on the Eastern Shore of Virginia using remote sensing techniques.
2) Describe bay morphology and make comparisons with bays from other areas.
3) Describe morphology and mineralogy of Carolina bay soils and determine the genetic differences that are reflected therin.

4) Determine the relationship between Carolina bays and other local geomorphic features.

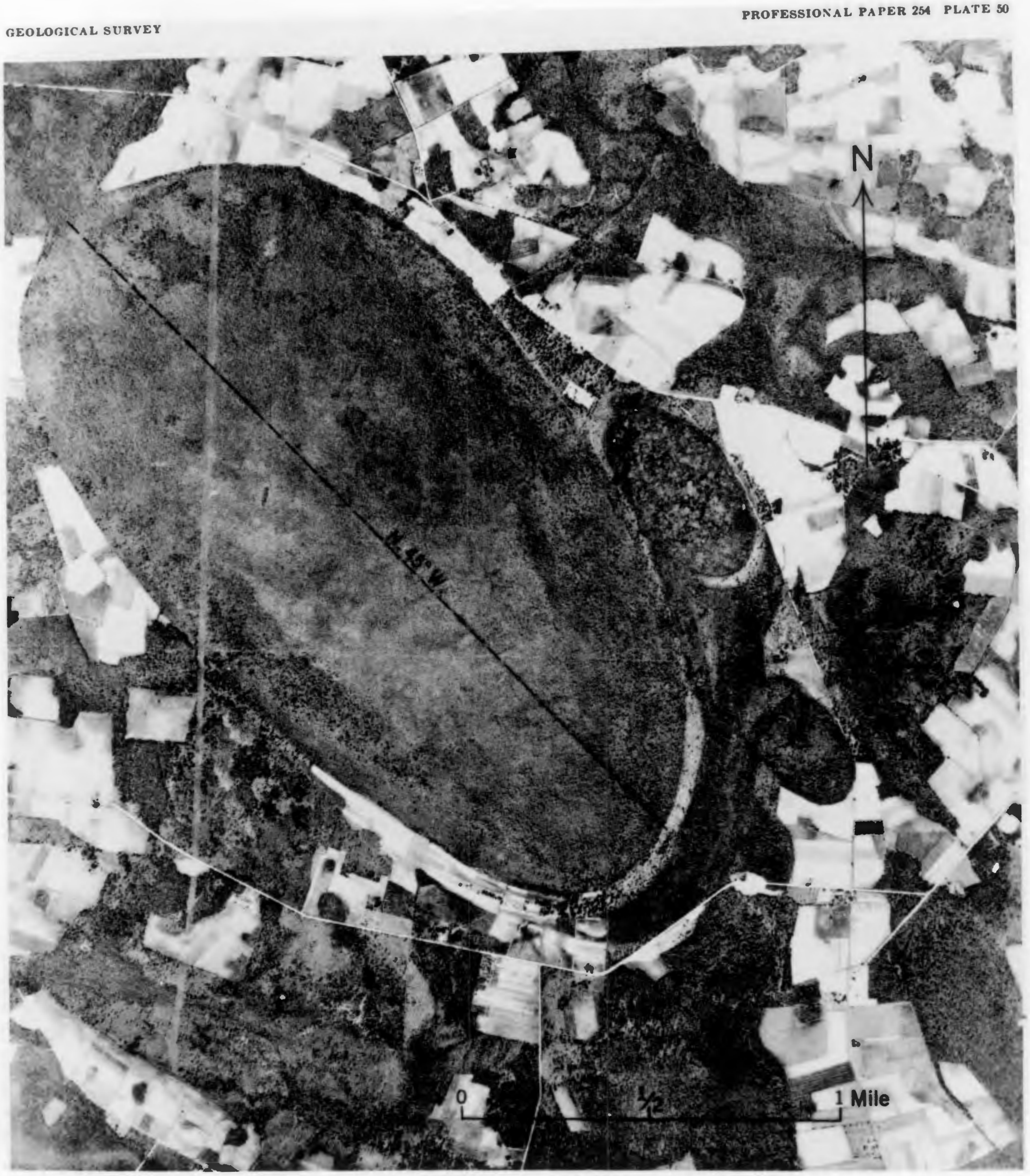


Fig. 2. Mill Bay, Florence County, South Carolina (from Cooke 1954).

REVIEW OF LITERATURE

Carolina bays (Figs. 1 and 2) are shallow ovate depressions located on the Atlantic Coastal Plain of the United States. These landforms are unique in that nearly all of them have a common long-axis orientation of northwest-southeast. Prouty (1952) reported they occur as far north as New Jersey and as far south as northeastern Florida, but the majority reportedly occur in South Carolina, North Carolina and Georgia. The term "Carolina bay" originated from Melton's and Schriever's (1933) discussion using aerial photographs. Thom (1970) reported the term bay originated from "bay" type of vegetation that is usually associated with these ovate depressions and other large less distinctive upland swamps (Pocosins) of the Coastal Plain.

Bay Morphology

Morphology of Carolina bays in the Carolinas has been discussed extensively in the literature. The most detailed reports have been given by Melton and Schriever (1933), Johnson (1942), Prouty (1952) and Thom (1970). The primary features involved in these discussions are orientation, ellipticity, rim development, form, and occurrence relative to other bays. These reports utilized aerial photography extensively to conduct surveys of the bays and to illustrate bay features.

The orientation of bays has been reported to be generally northwest-southeast. Johnson (1942) however, reported that bays in South Carolina and Georgia were more northerly oriented than those in North Carolina. Cooke (1954) reported similar results from descriptions of Carolina bays in Maryland, Virginia and North and South Carolina. Thom (1970) reported mean orientation to range from 300° to 317° among seven different geomorphic surfaces in Horry and Marion Counties, South Carolina.

The tendency for most of the large bays to be more elliptical than small bays has been reported (Melton and Schriever, 1933; Johnson, 1942; Prouty, 1952). Johnson (1942) also reported increasing ellipticity with increasing size of bays; however he suggested that correlation of size and ellipticity was poor. He reported the shape of bays differed among various locations. In the more southerly parts of the Coastal Plain the bays were more ovoid or "egg shaped" (Fig. 2) than in the more northerly regions (Fig. 1).

Most bays are encompassed by sloping, sandy, ridge-like rims (light areas bordering ovals Figs. 1 and 2). These rims usually border the oval depression in part, but a few bays have complete rims. Johnson (1942) reported that some bays lack sandy rims altogether. Prouty (1952), Melton and Schriever (1933) and McCarthy (1937) have emphasized the predominance of broad rims at the southeastern ends of many of the bays. According to the above authors rim relief ranges from a few feet to more than 15 feet. Bays having multiple rims have been reported by all of the above authors. Recently, Gamble _et al_ (1974) have revealed that many of the well developed southeastern rims are probably of secondary origin relative to the original bay depression.

Multiple bays and intersecting bays (Figs. 1 and 2) have been reported to be generally common in occurrence. The integrity of one of the bays is usually maintained.

The exact number of bays in the Coastal Plain is unknown. However, Prouty (1952) suggested there may be over one million bays existing. Most of the larger bays (2 or more miles in length) have been recognized, but there are many small bays (less than 500 ft.) that are relatively obscure on aerial photographs.

Relationship to Other Geomorphic Features

Reportedly Carolina bays are restricted to the unconsolidated sediments of the Coastal Plain. However they have not been determined to be related to any specific geologic process as they occur along with a wide variety of other geomorphic features. Early reports (Melton and Schriever 1933) show them to occur among ancient beach ridges in South Carolina. Other workers (Johnson, 1942; Prouty, 1952) reported bays on gentle valley slopes, interstream flatlands, older stream terraces and older portions of recent flood plains. Recently, Thom (1970) reported bays on seven geomorphic surfaces in Horry and Marion Counties, South Carolina. He recognized three basic bay types; fluvial terrace-contact bays, dune depression bays, and flat undissected interfluve bays. He also reported a perfect correlation with Carolina bays and "sandy" environments of deposition. There was a complete lack of bays in heavy textured environments. Carolina bays or similar features have been reported to occur on some high Coastal Plain undissected sand and gravel deposits (Taber, 1956; Johnson and Goodwin, 1967) and on recent salt marshes (Cooke, 1954; Pettry, 1973).

Theories of Origin

According to Prouty (1952), the earliest reports attributed bay formation to the action of springs rising to the surface of a sandy plain (Toumey 1848). Later, Glenn (1895) suggested formation by the building of sand bars across shallow coastal embayments by wind and waves. He also suggested they might have been formed as depressions enclosed by giant sand ripples.

Meteoric Theories

It appears that the widespread occurrence of the bays as well as common orientation and ellipticity was not fully realized until 1933 when aerial photos of the Coastal Plain became available. Melton's and Schriever's (1933) report using aerial photographs initiated a controversy that was to last for more than two decades. They proposed that the Carolina bays were formed by a shower of meteorites striking the soft unconsolidated sediments of the Coastal Plain. They emphasized the features of orientation, ellipticity, occurrence of rims and relationship to other landforms to support their hypothesis. Discussions supporting the meteorite hypothesis followed, using magnetometer surveys (McCarthy 1937) and bay morphological data from other areas of the Coastal Plain (Prouty 1935, 1952).

Terrestrial Theories

Opposition to the meteoric hypothesis mounted quickly. Cook (1933) proposed that the bays were formed by the segmentation of shallow marine lagoons by crescentic sand spits resulting from a dominant southeast wind. This theory has also been discussed by Robertson (1963) and Zenkovitch (1968). Cooke (1940, 1943, 1954) also proposed that the bays were formed by confined eddy currents generated by winds and waves which were oriented similarly to a precessing gyroscope. Johnson (1936) proposed that bay lakes were formed by solution, and shorelines were later modified by wind and wave action. Later, Johnson (1942) modified this theory to include activity of rising artesian springs and it is known as the complex artesian-solution-lacustrine-aeolian theory. He cited evidences of strike and dip of coastal plain sediments, the well sorted nature of sandy rims and the irregular or incomplete nature of many bays in support of his hypothesis. He also cited the work of Raisz (1934) which suggested that glacial ponds in Massachusetts were rounded by wind and wave action.

Legrand (1953) also favored solution activity in bay formation. He suggested that lateral movement of ground water in carbonate beds followed by slumping and vertical solution may have caused bay depressions.

Miscellaneous Theories

Grant (1945) suggested that bays might have been formed by schools of fish hovering over fresh water springs in the near shore zone. King and Maclean, (1970) suggested the possibility of upwelling gas as responsible for bay formation.

Recent Terrestrial Theories

Thom (1970) proposed that Carolina bays were formed by the expansion of shallow water bodies laterally under the influence of strong unidirectional winds from the southwest and other wind components. He also proposed that the original shallow water bodies could have been deflation hollows in dune fields, depressions on poorly drained interfluves or lake basins at the contact of fluvial terrace scarps. In support of this hypothesis he cited work by Price (1968) which suggested that Carolina bays are related to other oriented lakes such as those on the Alaskan Coastal Plain. The existence of these lakes was first reported by Black and Barksdale (1949). Livingstone (1954) proposed these lakes were oriented as a result of wave and current action generated by prevailing winds normal to the long axis. He and other workers (Rosenfeld and Hussey, 1958; Price 1963) also proposed these lakes might be related to the Carolina bays in origin. Carson and Hussey (1960, 1962) reported on the hydrodynamics and morphology of these lakes and they concluded that orientation resulted from expansion of shallow lakes normal to prevailing winds due to wave and current action. Their findings also accounted for more pronounced orientation with increasing size. However these Alaskan lakes lack the smooth outlines typical of many Carolina bays.

The early theories of Carolina bay origin have been subject to criticism at one time or another (Cooke, 1934, 1943; Johnson, 1942; Prouty, 1952; McCampbell, 1944; Melton, 1950; Schriever, 1951, 1955; Price, 1968; Thom, 1970). The controversy that occurred from the 1930's to the 1950's over the origin of the Carolina bays was stimulated by many popular articles which appeared during that period. Evidence presented by Johnson (1942) and Cooke (1943) and more recently by Price (1968) and Thom (1970) tends to reject the meteoric hypothesis. However, many questions still remain concerning the nature of origin of the Carolina bays. Thom (1970) has emphasized the limitations due to the relict nature of the bays. He also pointed out that most previous studies failed to consider the bays in the context of the geological history of a particular area.

Age of the Carolina Bays

Most early reports describe the Carolina bays as occurring on all of the "Pleistocene" Coastal Plain terraces (Melton and Schriever, 1933; Johnson, 1942; Prouty, 1952; Cooke, 1954). These reports generally indicate that the bays themselves are probably younger than the associated land surface since they often truncate associated landforms. More recent reports (Frey, 1950; Oaks and Coch, 1963; Daniels _et al_, 1971) suggest the higher coastal plain terraces (above 100 ft.) may actually be of Pleiocene or late Miocene age and that the higher terraces are probably non-marine in origin.

Examination of peat deposits in many of the bays has provided additional evidence of age based on pollen succession and C^{14} dates. Prouty (1952) cites the work of Buell (1946) which suggested an age of late Pliestocene for Jerome bay in Bladen County, North Carolina based on pollen succession. Frey (1950) obtained a C^{14} date of greater than 20,000 years for lower sediment layers of Singletary Lake in North Carolina. He estimated the lowest layers were between 40,000 and 100,000 years based on sedimentation rates. Thom (1970) cites Whitehead (1968) as reporting C^{14} dates of greater than 38,000 years for lower most sediments of some Bladen County, North Carolina bay lakes. Thom (1970) also reported a C^{14} age of 6630 ∓ 110 years for the oldest organic sediments of Pee Dee Island bay No. 2 in South Carolina. Most of the above reports suggest that bay formation was subsequent to deposition of associated surficial sediments.

Bay Stratigraphy and Sediments

Preston and Brown (1964) collected samples from power auger holes along the long axis of a Carolina bay in Sumpter County, South Carolina. The holes ranged in depth from 20 to 60 feet. They reported the underlying strata appeared to be in no way related to the existence of the bay. Thom (1970) used similar techniques to determine the stratigraphy of two bays in Horry County, South Carolina. The results also indicated that the underlying strata were not related to the presence of the bays.

Bay sediments have been analyzed in detail in some Bladen County, North Carolina bay lakes (Buell, 1946; Frey, 1949, 1950, 1951; Whitehead, 1965), in some Brunswick County, North Carolina bays (Wells, 1949; Wells and Boyce, 1953) and in Marion and Horry counties, South Carolina (Thom, 1970). In addition to organic sediments, these workers have described some inorganic silt that appears to have been deposited since the formation of the bays. Ingram _et al_ (1959) determined the clay mineralogy of the sediments from five bays in North Carolina. Two of the bays (lake bays) showed kaolinite, illite, and interlayered vermiculite, the remaining three showed kaolinite and interlayered vermiculite. They concluded that these sediments were blown in from surrounding deposits and were little altered since deposition.

Soils of the Bays

Some of the original soil surveys of the Coastal Plain (Perkins _et al_, 1925; Jurney _et al_, 1926; Latimer _et al_, 1928; Geib _et al_, 1931; Perkins _et al_, 1938) make brief reference to the existence and location of the Carolina bays, and they give general descriptions of the types of soil that occur on them. The term "Saucer-like depressions" is often used to refer to the bays. Generally, only a few of the largest bays were delineated on the soil maps. At least seven soil series were reported to be associated with the bays in the above mentioned soil surveys in North and South Carolina. Some of the rim soils described are the Norfolk (sand and loamy sand), St. Lucie (sand), and the Dunbar (sandy loam and fine sandy loam) series. Brief descriptions of these soils as described in the reports are presented in Table 1. The Dunbar soils occupy the low areas of the rims and the Norfolk and St. Lucie soils occupy the highest rim areas usually at the southeastern ends of many of the bays in these areas.

The soils of the depressional areas have been described in the surveys as belonging to the Leon (sand), Hyde (loam), Portsmouth (loam, sandy loam, fine sandy loam, fine sand) and Coxville (clay loam, fine sandy loam) series. Brief descriptions presented in the soil surveys are given in Table 2.

More detailed soils maps have been made of the Carolina bays in recent years in the soil survey of Scotland County, North Carolina (USDA, 1967). Each bay and component rims and depressions have been mapped in detail. This report shows that depression soils are mainly of the McColl, Coxville and Portsmouth series, and the rims are of the Lakeland, St. Lucie and Wagram series. This survey embraces a more modern system of soil classification (7th Approximation) and a more narrow concept of series definition. Descriptions of these soils are found in Tables 3 and 4.

Table 1. Soils on the rims of the Carolina bays from soil surveys (1925-1937).

Series	Depth	Color	Texture	Location
Norfolk sand	0-6"	Gray	Sandy loam to loamy sand	Dillon Co.
	6-10"	Light gray	Sand	
	10-36"	Light yellow to pale yellow	Sand	South Carolina
	36-72"	Pale yellow	Medium sand	
Norfolk loamy sand	0-9"	Yellowish-gray	Loamy sand	
	9-20"	Pale yellow	Sand	Cumberland Co.
	20-36"	Yellow	Clayey sand	North Carolina
	36"+	Yellow	Sandy clay	
St. Lucie sand	0-36"+	Light gray to nearly white	Loose sand	Cumberland Co. North Carolina
Dunbar sandy loam	0-8"	Gray	Loamy sand to sandy loam	Dillon Co.
	8-18"	Yellow to dull yellow	Heavy sandy loam	South Carolina
	18-36"	Yellow to dull yellow with bright red mottles appearing at 36"	Sandy clay	

Table 2. Soils in the depressions of the Carolina bays from soil surveys (1925-1937).

Series	Depth	Color	Texture	Location
Leon sand	0-3"	Light to dark gray	Sand	Cumberland Co.
	3-20"	Light gray, almost white	Loose sand	North Carolina
	20-30"	Dark brown, nearly black	Hardpan layer	
	30-40"	White	Sand	
Hyde loam	0-24"	Dark brown to black	Loam to silt loam	Brunswick Co.
	24-36"+	Brownish-gray to dingy brown	Sticky silty clay	North Carolina
Portsmouth fine sand	0-15"	Dark gray or black	Loamy fine sand	Brunswick Co.
	15-36"+	White, light gray or brown	Fine sand	North Carolina
Portsmouth loam	0-20"	Gray to black	Loam	Dillon Co.
	20-36"+	Brownish-gray to bluish-gray	Sticky silty clay to sandy clay	South Carolina
Coxville fine sandy loam	0-8"	Brownish-gray	Fine sandy loam	
	8-12"	Gray	Sandy loam	Williamsburg Co.
	12-20"	Gray, slightly mottled with yellow or brown	Clay loam	South Carolina
	20-40"	Gray, yellow and red mottled	Clay	

Table 3. Soil series descriptions of soils that occur on rims of Carolina bays in Scotland County, North Carolina, from 1967 Soil Survey.

Lakeland Series (Typic Quartzipsamments)

A_1 0 - 2 inches, dark-gray (10 YR 4/1) sand; single grain; loose; abundant woody roots; strongly acid; abrupt, wavy boundary. 2 to 4 inches thick.
C_1 2 - 20 inches, light yellowish-brown (10 YR 6/4) sand; single grain; loose; few to many woody roots; very strongly acid; gradual boundary. 15 to 30 inches thick.
C_2 20 - 44 inches, yellowish-brown (10 YR 5/6) sand; single grain; loose; few woody roots; very strongly acid; gradual boundary. 18 inches to several feet in thickness.
C_3 44 - 60 inches, very pale-brown (10 YR 8/4 to 10 YR 7/4) sand; single grain; loose; very strongly acid. Several feet in thickness.

St. Lucie Series (Typic Quartzipsamments)

A_1 0 - 3 inches, gray (N 5/0) sand; very thin layer of coarse white sand at the surface; single grain; loose; few fine and medium woody roots; very strongly acid; gradual boundary. 2 to 5 inches thick.
C_1 3 - 11 inches, light-gray (10 YR 7/1) coarse sand; single grain; loose; few woody roots; very strongly acid; gradual boundary. 6 to 12 inches thick.
C_2 11 - 50 inches +, white (N 8/0) coarse sand; single grain; loose; very strongly acid.

Wagram Series (Arenic Paledults)

A_p 0 - 8 inches, grayish-brown (10 YR 5/2) loamy sand; single grain; very friable; abrupt, smooth boundary. 6 to 10 inches thick.
A_2 8 - 24 inches, pale-brown (10 YR 6/3) loamy sand; single grain; loose; few thin horizontal bands; gradual wavy boundary. 14 to 20 inches thick.
B_1 24 - 27 inches, yellowish-brown (10 YR 5/6) sandy loam; weak, medium, subangular blocky structure; friable; some material from the A_2 horizon has penetrated this horizon; strongly acid; clear, wavy boundary. 2 to 6 inches thick.
B_{21t} 27 - 38 inches, yellowish-brown (10 YR 5/8) sandy clay loam; weak, medium, subangular blocky structure; friable; slightly sticky; very strongly acid; gradual, wavy boundary. 8 to 16 inches thick.

Table 3. (Continued).

Wagram Series (Cont.)

B_{22t} 38 - 52 inches, yellowish-brown (10 YR 5/8) sandy clay loam; common medium mottles of yellowish-red; weak, medium and coarse, subangular blocky structure; friable when moist, slightly sticky when wet; common grains of clear quartz, the size of coarse sand; very strongly acid; gradual wavy boundary. 10 to 18 inches thick.

B_3 52 - 75 inches, yellowish-brown (10 YR 5/6) sandy clay loam; weak, medium and coarse, subangular blocky structure; friable; few, medium, yellowish-red mottles and few, medium, pale-brown mottles; very strongly acid or strongly acid; gradual, irregular boundary. 20 to 30 inches thick.

C 75 - 82 inches, mottled yellowish-brown and gray sandy loam; structureless; lenses and pockets of sandy clay loam; some gray coarse sand; very strongly acid.

Table 4. Soil series descriptions of soils in the depressions of Carolina bays in Scotland County, North Carolina. From the soil Survey 1967.

McColl Series (Plinthic Ochraqults)

A_p 0 - 8 inches, very dark-gray (10 YR 3/1) loam; weak, medium granular structure; very friable; slightly sticky when wet; many fine roots; very strongly acid; clear, wavy boundary. 5 to 10 inches thick.

B_{21tg} 8 - 13 inches, gray (10 YR 6/1) clay; few, fine, distinct, brownish-yellow (10 YR 6/6) mottles; weak, medium subangular blocky structure; firm when moist, sticky when wet; slightly plastic; few root channels filled with dark gray material from the A_p horizon; very strongly acid; gradual boundary. 2 to 12 inches thick.

B_{22t} 13 - 30 inches, strong-brown (7.5 YR 5/8) sandy clay loam to sandy clay; many coarse prominent mottles of gray (10 YR 6/1); common, medium, distinct, mottles of yellowish-red (5 YR 5/6) and yellowish-brown (10 YR 5/8); weak, medium, subangular blocky structure; firm or friable when moist, sticky and slightly plastic when wet; gray color is in near verticle pattern; redder aggregates are brittle and firm; very strongly acid; gradual boundary. 15 to 30 inches thick.

B_{3g} 30 - 55 inches, light-gray (10 YR 7/1) sandy clay loam; common, medium, distinct, reddish-yellow (7.5 YR 6/6) mottles; weak, platy structure or massive; friable or firm when moist, slightly sticky and slightly plastic when wet; very strongly acid; gradual boundary.

C 55 - 66 inches, gray, yellow, and red loamy sand; loose; structureless; very strongly acid.

Coxville Series (Typic Ochraqults)

O_1 1 - 0 inches, dark-brown, partly decomposed organic material derived from hardwood leaves, pine needles, and twigs.

A_1 0 - 7 inches, very dark-gray (10 YR 3/1) loam; weak, fine, granular structure; very friable when dry, slightly sticky when wet; many medium and fine woody, roots; very strongly acid; abrupt, smooth boundary. 5 to 8 inches.

B_{21tg} 7 - 32 inches, gray (10 YR 6/1) clay; few, fine, distinct mottles of brownish-yellow (10 YR 6/8) and red (2.5 YR 4/8); weak, medium, angular blocky structure; firm; sticky and plastic when wet; patchy clay films; common, medium, woody roots; very strongly acid; gradual boundary. 25 to 36 inches thick.

Table 4. (Continued).

Coxville Series (Cont.)		
B_{3g}	32 -	48 inches, gray to light-gray (10 YR 6/1) sandy clay; few, fine, distinct, mottles of red (2.5 YR 4/8) and brownish-yellow (10 YR 6/8); weak, medium, subangular blocky structure; firm; very strongly acid; sticky and plastic when wet.
C_g	48 -	60 inches, light-gray (10 YR 7/1) sandy clay; common, medium, distinct mottles of red and strong brown; massive; firm; very strongly acid.
Portsmouth Series (Typic Umbraqults)		
A_1	0 -	10 inches, black (10 YR 2/1) loam; moderate, medium or coarse, granular, structure; very friable; many fine roots; very strongly acid; clear, wavy boundary. 8 to 20 inches thick.
B_{1g}	10 -	12 inches, dark-gray (10 YR 4/1) and gray (10 YR 5/1) sandy loam; friable; weak, medium, subangular blocky structure; many fine roots; very strongly acid; clear, wavy boundary. 2 to 6 inches thick.
B_{2tg}	12 -	28 inches, gray (10 YR 6/1) sandy clay loam to light sandy clay; weak, medium, subangular blocky structure; friable or firm; slightly sticky; few, fine roots; very strongly acid; gradual boundary. 12 to 30 inches thick.
B_{3g}	28 -	50 inches, gray (10 YR 6/1) sandy clay loam; few fine distinct mottles of brownish-yellow (10 YR 6/6); weak, medium, subangular blocky structure; friable; few fine roots; very strongly acid. 10 to 24 inches thick.
C_g	50 -	60 inches gray (10 YR 6/1) sandy loam; few medium, distinct mottles of strong brown and yellowish-brown; massive; friable; very strongly acid.

Soil Development and Soils Studies

In much of the bay literature (Melton and Schriever, 1933; Johnson, 1942; Prouty, 1952) the soils of the bays are mentioned quite often; however little is mentioned about the development of soils on the bays. Usually reference is made only to soil morphological features. Recently, Thom (1970) discussed soil development in comparing the ages of the bay rims with the ages of other geomorphic surfaces. He stressed, among other things, the fact that time is not the only soil forming factor.

Bryant and McCracken (1964) prepared a detailed soils map of a two and one-half square mile area containing many bays in Scotland County, North Carolina. They analyzed a total of thirty soil profiles taken from the rims and depressions of Carolina Bays. Their work suggested: a) that no radical differences existed between rim and depression soils, indicating that they had similar parent materials; b) that no lateral discontinuity was evident between rim and depression soils; c) that underlying strata appeared to be continuous beneath the bays; d) that interbay soils were interpreted to be of greater age than the bay soils; e) that discontinuities within the soil profiles within the bays might be accounted for by drainage, erosion and movement of subsurface waters.

Recently Gamble *et al* (1974) determined that southeastern rims were secondary in origin based on the existence of buried soils and morphological features of other bordering rim soils. They concluded that secondary origin of some sand rims could account for the occurrence of bays within bays, and for bays with multiple rims.

Remote Sensing and the Carolina Bays

Avery (1968) defines remote sensing as the detection, recognition or evaluation of objects by means of distant sensing or recording devices. These devices may include aerial cameras, radar systems or other devices that can detect energy emanating from an object. Remote sensing is a modern term which has arisen since the inception of devices capable of detecting electromagnetic energy outside of the visible spectrum usually at great distances. The recorded data is usually referred to as imagery which may include aerial photographs and digital printouts.

Remote sensing has played a significant role in the controversy concerning the origins of the Carolina bays. It was Melton's and Schriever's (1933) findings using aerial photographs of an area near Myrtle Beach, South Carolina that stimulated the initial discussion. Since that time, aerial photographs have played a vital role in illustrating bay features and provided morphometric data in studies of the bays. Johnson (1942) used photographs of various areas of the Coastal Plain in comparing morphological feature of bays. Prouty (1952) used aerial photos in conducting an extensive inventory of bays throughout most of the Coastal Plain. Thom (1970) conducted an extensive inventory of bays in Horry and Marion counties, South Carolina using aerial photographs.

Most of the above studies have utilized aerial photo-mosaics that were made for the U. S. Department of Agriculture. These photos have provided a means for direct observation and measurement of features for large numbers of bays. The primary features involved in the photo-interpretation of bays in the above studies are the light colored sandy rim soils which usually contrast sharply with the darker depression soils or the thickly vegetated depressions. The elliptical form and orientation also aid in delineating the bays.

MATERIALS AND METHODS

The Study Area

The Carolina bays which were the subject of this study are located in Accomac and Northampton Counties, Virginia. This area is usually referred to as the Eastern Shore of Virginia. The entire area consists of the lower part of the DelMarVa peninsula and is flanked on the west by the Chesapeake Bay and on the east and south by the Atlantic Ocean. About one-third of the area consists of marshland and the remaining two-thirds is referred to as the mainland. The entire area is devoted to intensive agriculture, mainly truck crops. A good description of the soils, agricultural practices, social and economic conditions prior to 1917 can be obtained from the only soil survey of the area (Stevens, 1920). More up-to-date general information can be obtained from recent data (Virginia Division of Planning, Accomac and Northampton counties, 1972).

Carolina Bays of the Area

Relatively little literature has been published concerning the Carolina bays on the Eastern Shore of Virginia. They were mentioned in the old soil survey (Stevens, 1920) but they were not called Carolina bays. The features were referred to as elliptical depressions. Cooke (1954) described recent bays, Half Moon Bay, and Island Bay in Accomac County as resulting from the action of tidal eddy currents. He did not refer to any other bays on the higher mainland portions of the area. Sinnott and Tibbitts (1968) referred to the Carolina bays and terrace scarps as being practically the only topographic features on the peninsula. Sinnott (1953) reported the existence of numerous bays along the peninsula and planned magnetometer and chemical studies of the soils as a test of Prouty's modified meteorite hypothesis.

Geology and Parent Material

The parent material for all of the soils of the area consists of Pleistocene to Recent marine and estuarine sediments (Sandford, 1913; Stevens, 1920; Wentworth, 1930; Sinnott and Tibbitts, 1968). These reports generally refer to marine terrace scarps and terraces as representing ancient shorelines and formational boundaries of subsequent sediments. Oaks and Coch (1963) using stratigraphic concepts have revealed a more complex nature of terrace formations than previously proposed. Their work has revealed the possibility of six submergent shorelines in nearby southeastern Virginia, since late Pliocene or early Pleistocene times. Their findings also reveal that present land surfaces at 5 ft. elevations may be of late Pleistocene (Sangamon) age and that surfaces higher than 45 ft. elevation may be as old as middle or early Pleistocene.

Sandford (1913), Sinnott and Tibbitts (1968) have reported on the ground water of the area. They reported the existence of flowing wells at low elevations but none having high volume flows. Also, none of the wells tapping only Pleistocene sediments were flowing. In other reports (Sinnott and Tibbitts, 1955, 1957) subsurface well logs and correlations are given. No limestone beds as such were reported in the underlying strata. The only comparable beds are those that contain large amounts of calcareous shells along with varying amounts of sand, silt, and clay.

Depths to the underlying Miocene sediments were reported to range from 50 to 100 feet. The total thickness of all the underlying sediments in the area has been recently estimated to vary between 4,500 and 8,000 feet (Johnson and Sweet, 1970).

Soils of the Eastern Shore

The soils of the area have been generally described in the Soil Survey of Accomac and Northampton counties (Stevens, 1920). Five soil series were recognized on the mainland based on general morphological features. These were further subdivided into thirteen soil types based on textural differences. Descriptions presented in the report are exhibited in Table 5.

Stevens (1920) suggested that the following general soil relationships existed on the Eastern Shore: a) the soils of the higher terrace (30-50 ft.) are mostly of the sandy loam type whereas those of the lower terraces were of the fine sandy loam types; b) weatherling and drainage appear to be the dominant soil-forming factors; c) most soils of the area are underlain by a relatively open porous substratum; and d) the soils occurring on low ridges surrounding saucer-like depressions (Carolina bays) are generally shallower than adjacent upland soils.

Land Use

The relative acreages of the different soil types are given in the Soil Survey. Agriculture (cropping and forestry) is the dominant land use. Reportedly, drainage is the dominant factor affecting the use of the land. Table 6 gives the acreage land use-break-down of the various soil types.

Remote Sensing

Table 5. Soils of the Eastern Shore of Virginia as described in the 1920 Soil Survey of Accomac and Northampton.

Sassafras sandy loam	0-12 inches, light-brown to brown, sandy loam
	12-36 inches, reddish-yellow to reddish-brown, heavy loam
	36+ inches, reddish-yellow to reddish-brown, loamy sand
Sassafras fine sandy loam	0-12 inches, grayish-brown or brown, fine sandy loam
	12-36 inches, yellowish-brown to reddish-brown, fine sandy clay loam
	36+ inches, yellowish-brown to reddish-brown, loamy fine sand
Keyport sandy loam	0-8 inches, grayish-brown, sandy loam
	8-15 inches, pale or grayish-yellow, faintly mottled, heavy sandy loam
	15-36 inches, yellow, reddish-brown and gray mottled, sandy clay loam
	36+ inches, grayish-yellow, loamy sand
Elkton sandy loam	0-8 inches, gray sandy loam
	8-15 inches, light-gray heavy sandy loam, sometimes mottled with rusty brown or yellow stains
	15-30 inches, mottled gray, yellow and rusty-brown heavy loam to plastic silty clay loam
	30+ inches, gray or yellowish-gray sticky sand
Elkton loam	0-10 inches, gray or brownish-gray loam
	10-36 inches, mottled, gray, yellow and rusty-brown heavy loam to plastic silty clay loam

Table 5. (Continued).

Elkton loam (Cont.)	36+ inches, gray or yellowish-gray, sticky, loamy sand saturated with water
Portsmouth sandy loam	0-15 inches, dark-gray to black sandy loam
	15-30 inches, gray sandy clay loam or sandy clay, mottled with yellow and rusty stains
	30+ inches, gray sticky sand, saturated with water
Portsmouth loam	0-15 inches, black spongy loam
	15-30 inches, gray, mottled with yellow, heavy loam to plastic silty clay loam
	30+ inches, gray loamy sand, wet and sticky
Norfolk fine sand	0-6 inches, gray or grayish-brown fine sand
	6-36+ inches, yellow fine sand

Table 6. Land use of various soil types from the Soil Survey of Accomac and Northampton Counties. 1920.

Soil Series	Type	Acres	Agriculture	Forestry
Sassafras	s.l.	100,672	80%	20%
	f.s.l.	62,144	80%	20%
	l.s.	3,072	50%	50%
	l.	512	100%	00%
Keyport	s.l.	24,576	60%	40%
	f.s.l.	14,912	60%	40%
	l.	1,728	50%	50%
Elkton	s.l.	22,464	30%	70%
	f.s.l.	18,048	25%	75%
	l.	29,120	25%	75%
Portsmouth	s.l.	768	30%	70%
	l.	4,096	10%	90%

Imagery - The imagery used in detecting the Carolina bays consists of color infrared (false color) photography of the Eastern Shore area made by the National Aeronautics and Space Administration. The film was exposed from a RC-130 aircraft at an altitude of 10,000 feet. A Wild RD-8 camera was used with a 6-inch focal length and a Wratten No. 12+2.2AV filter. The film was Kodak Aerochrome Infrared type 2443. The resulting transparencies were 9" x 9" and had an approximate scale of 1:20,000. This photography was part of NASA mission 181/174 covering the Eastern Shore of Virginia, Maryland and Delaware. The mission was flown on June 8, 1971.

Bay Inventory and Morphological Data

Field sheets - U.S.G.S. 7.5 minute topographic maps of the Eastern Shore were used as working maps and field sheets. An outline of each bay, and component rims and depressions was made by superimposing an image of the photograph onto the topographic map using a Kargl Reflecting Projector Model RP-T-45. Prominent features were matched to assure that features were transferred at the proper scale and alignment.

Bay morphological features - An inventory of all the detectable bays was made from photo interpretation of the imagery. The film was viewed using a Richards Light Table Model GFL-940. Length and width measurements of the bays as well as area measurements of the bay rims and depressions were made directly from the film transparencies. Area measurements were made using the dot grid method (80 dot grid). Bay orientation was determined from the field sheets. The scale of the transparencies was found to be variable; therefore the ratio between the topographic sheets and each photographic was determined and measurements were adjusted accordingly.

Field Work

Field reconniassance - A field survey of 45 bays was conducted between July 6, and July 20, 1973. The field sheets were used as guides for locating the bays. Bays were selected for observation according to their apparent degree of development. The best-developed bays were selected first. Soil characteristics of solum depth, color and texture were recorded for typical profiles of each bay rim and depression. Also, estimates of the amount of relief and variability of the rims along with descriptions of completeness and general morphology of the landforms were made.

Soil samples - Five bays, three small and two large, were selected at various elevations (0', 10', 20', 35', and 45') for detailed profile descriptions and sampling. One profile from each rim and depression was described and sampled. About one kilogram of soil was taken from each soil horizon. The samples were transferred to the laboratory at Virginia Polytechnic Institute and State University, air-dried, crushed with a wooden rolling pin, and the coarse fragments were separated by sieving. The coarse fragments were saved for later analysis.

Soil Chemical Analysis

Soil pH - Soil pH was determined in water using a 1:1 soil-water suspension with 25 ml of water and 25 g. of soil. The suspension was stirred and allowed to equilibrate for 30 minutes. The pH was then determined using a Beckman Model SS-2 pH meter.

Mineralogical Analyses

The mineralogy of the clay fraction (<2μ) and silt fraction (2-50μ) was determined using X-ray diffraction techniques. Differential thermal analysis (DTA) was also conducted of the clay fraction.

Separation of the Clay Fraction (-2 um)

Clay was separated from the soil using the method described by Jackson (1956), with modifications. Enough soil was taken to yield at least 1 g. of clay (usually 20-50 g.). The soil was placed in a 1,000 ml beaker and enough water was added to make a slurry. The pH was adjusted to 3.5 using N HCl. The soil was then centrifuged and the supernatant discarded to eliminate any flocculating salts. The soil was adjusted to pH 10 using N Na_2CO_3 and washed through a 270-mesh sieve to separate the sand from the silt and clay. Washing was facilitated by the use of water adjusted to pH 10 with N Na_2CO_3. The clay fraction was then separated from the silt by centrifuging the suspension at appropriate times and speeds using an International Model 2 centrifuge. The Na_2CO_3 pH 10 water was used to re-suspend the soil after each centrifuging period.

Magnesium saturation of clay samples - The clay fractions were washed into 100 ml centrifuge tubes and suspended using 0.2 N $MgCl_2$ solution. The suspension was centrifuged and the supernatant was discarded. This was repeated five times to saturate the samples. The samples were washed at least five times or until chloride free as determined using $AgNO_3$.

X-ray Diffraction

Preparation of slides - Ceramic slides of the Mg-saturated clay samples were prepared according to the method of Rich (1969). A known amount of the clay (250 mg.) was suspended in about 5 ml of distilled water and poured onto a wet unglazed ceramic tile placed in a suction device. The suspension was poured quickly and evenly to achieve a uniform thickness of clay on the slide. The slides were glycerol solvated by adding 5 ml of 20% glycerol solution and allowing it to pass through the slide. The slides were allowed to dry overnight in a dust free location.

Potassium saturated slides - K-saturated slides of the clay were made by treating the Mg-saturated slides with N KCl solution. After X-raying the Mg-saturated slides, they were placed in the suction apparatus and 1 ml portions of the N KCl were passed through the slide in five separate additions. This was followed by at least five washings with 1 ml portions of distilled water. The slides were allowed to dry overnight in a dust free location.

Silt slides - X-ray diffraction of the silt fraction (2 - 50μ) was accomplished using ceramic slides. The slides were prepared in the same manner as the Mg-saturated clay slides except that Mg-saturation was accomplished on the slides. The silt slides were not K-saturated.

Heat treatments - The Mg-saturated slides (silt and clay) were X-rayed at room temperature (25° C). The X-ray patterns of the K-saturated slides were obtained at room temperature, 110°, 300°, and 550° C. The slides were allowed to remain at each temperature level at least four hours before X-raying.

Instrumentation - A General Electric XRD-5 X-ray diffraction unit was used. Copper radiation was generated at 40 KV and 20 ma. and filtered through Nickel foil to isolate Ka radiation. The beam, soller and detector slits were 1.0°, MR and 0.2° respectively. A scanning rate of 2° 2θ per minute was used.

Differential Thermal Analysis

Sample preparation - The Mg-saturated clay fraction was dried in a desiccator, crushed to a powder in a mortar and diluted to a 1:3 ratio with Al_2O_3 powder. The sample was thoroughly mixed, then equilibrated in a desiccator over saturated $Mg(NO_3)_2$ in water, which maintained a relative humidity of 56%. The sample were equilibrated in the desiccator four days.

Instrumentation - A small portion of the equilibrated sample was transferred to the front hole of a four hole Inconel sample holder. The other three holes were filled with inert material (Al_2O_3 powder). The differential thermal analysis was made by heating the sample holder at the rate of 12.5° C per minute for 80 minutes. The temperatures of the sample and the inert material was recorded with Platinum/ 90% Platinum-10% Rhodium thermocouples, a DC amphlifier and a Leeds-Northrup X-Y recor recorder.

Particle Size Analysis

Pipette method - Particle size distribution was determined using the pipette method of Kilmer and Alexander as modified by Day (1965). The soil was thoroughly mixed and a 10 g. subsample was taken. If necessary, organic matter was removed with 10% H_2O_2. The sample was shaken overnight in a 250 ml solution containing a 10 ml of 5% Calgon.

The suspension was then washed through a 300-mesh sieve to separate the sand from the silt and clay. The sand was oven-dried at 105° C. The silt and clay suspension was washed into a 1-liter cylinder and the volume made up to 1,000 ml. and allowed to equilibrate to a constant temperature in a water bath. The suspension was stirred and 25 ml aliquots were taken from a depth of 5 cm. at the appropriate sedimentation times. The aliquots were oven-dried at 105° C in tared beakers, cooled in a desiccator and weighed on a Mettler Type H-15 balance. The sand fractions were separated by sieving and also weighed in a similar manner.

RESULTS AND DISCUSSION

Imagery Interpretation and Landform Morphology

A total of 163 landforms were observed in Accomac and Northampton counties using remote sensing data and field reconnaissance information. Most of these landforms have elliptical form and a parallel alignment of long axes, and therefore are considered to be Carolina bays. The location of each bay is graphically presented in Figures 3 and 4. Morphological properties, location descriptions, and landform type are given in Appendix I.

Some 41 landforms were examined in the field to acquire a general knowledge of soil and landform features for comparison with the imagery used in detection. The imagery used in this discussion (Figures 5, 6, and 7) serves to illustrate most of the features that were observed in the field. Topographic, soil, and vegetation differences were the main features used in describing the landforms. Exact comparisons of field and imagery conditions were not possible because the mission was flown in June, 1971 and the field reconnaissance was not made until July, 1973. It is felt, however, that most of the differences between field observations and imagery conditions could be accounted for by differences in crop growth and the location of crops. Crop differences relative to landforms in the field compared favorably with differences on the imagery. Many of the fields were bare at the time of reconnaissance and soil differences were easily observed. Where bays rims were well developed (greatest relief), the soil differences were the most dramatic, but in many cases they were usually marked by darker soils, higher in

Figure 3

Carolina Bays in Accomac County, Virginia

Figure 3 in Map Pocket

Figure 3. CAROLINA BAYS IN ACCOMAC COUNTY, VIRGINIA

SOIL MAP*

Poorly and somewhat poorly drained soils which represent depressional areas.

Es--Elkton sandy loam

Ks--Keyport sandy loam

Ps--Portsmouth sandy loam

* Courtesy USDA

Figure 4

Carolina Bays in Northampton County, Virginia

Figure 4 in Map Pocket

Figure 4. CAROLINA BAYS IN NORTHAMPTON COUNTY, VIRGINIA

SOIL MAP *

Poorly and somewhat poorly drained soils which represent depressional areas.

Ks--Keyport sandy loam

Es--Elkton sandy loam

Ps--Portsmouth sandy loam

* Courtesy USDA

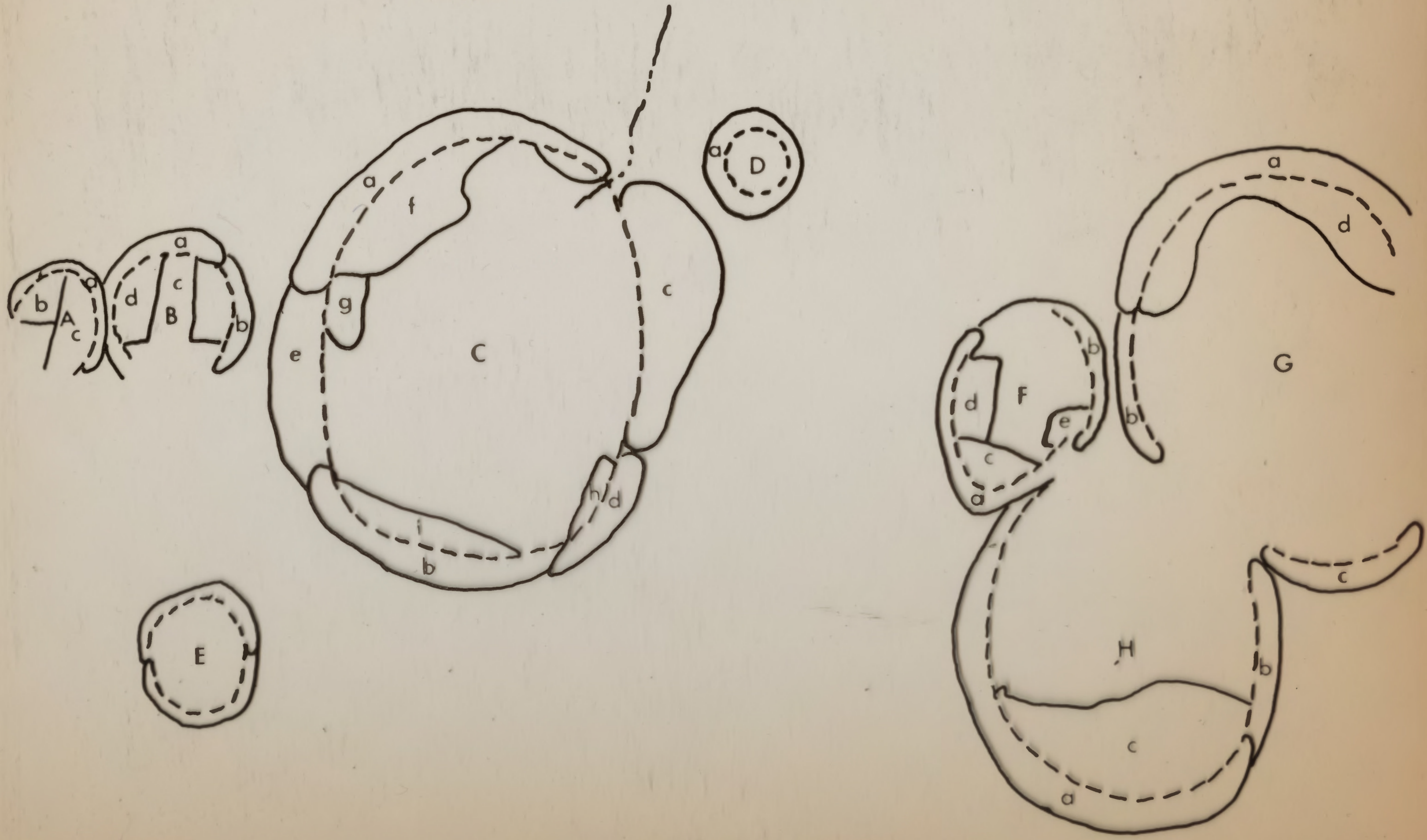
organic matter and moisture than the rim soils. Observations of crop differences on the imagery indicate that moisture conditions were probably similar at the time of field reconniassance.

The colors portrayed on the color infrared photographs used in this study are false colors, because a shift in apparent colors is achieved by the use of filters and film dyes as outlined by Heller (1970). Healthy green vegetation which has high infrared reflectance appears red on the photographs. Vegetation which is diseased or under moisture stress has reduced infrared reflectance and may appear green. Soils high in moisture have high energy absorbance and appear darker.

Carolina Bays near Nelsonia, Virginia

Figure 5 shows eight bays located near Nelsonia and Mappsville, Virginia (Bloxom quadrangle, 7.5 min. U.S.G.S. topographic sheet). The elevations of these bays range from 45 feet to greater than 50 feet. These bays have the characteristic elliptical form and parallel orientation, but differences can be seen which will be discussed later.

The rims of these bays are characterized by soils that are lighter in color and much drier than adjacent soils. The highest rim portions differ in relief from about 6 feet to more than 12 feet in places. The side slopes of these rims range from 5 to 15% either toward or away from the central depression. In bay Ca the highest rim gradually decreases toward the road west of Nelsonia. Some of these high rims (Aa, Ba, Fa, Ga) are particularly accentuated by lighter tones and lower density red colors which is characteristic of sparser vegetation and lower moisture status. The occurrence of these higher ridge-like rims does not appear


A
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b
c
B
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C
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Fig. 5. Bays near Nelsonia, Accomac County, Virginia.

Fig. 5. Bays near Nelsonia, Accomac County, Virginia.

to be related consistently to any particular quadrant in any one bay. However, they appear to be lacking in the northeastern quadrant.

The low rims are not ridge-like in nature. Some bay rims (Cb, Ce, Gc, Hb) consist of low ridges with 2-4% side slopes. Other rims (Bb, Cc, Eb, Fb, Gb) occur as borders of larger well-drained soil bodies that gradually slope towards the central depressions. The rim may be lacking altogether as shown between bays F, G and H (Figure 3).

Regardless of whether the rims are high or low, they are never simple discrete bodies. Rim height and slope vary about the border of the bay. The soils occurring on the rim of the bays vary in drainage from moderately well to excessively drained.

The central depressions of these bays studied near Nelsonia are comprised of poorly to somewhat poorly drained soils. Cleared depressions are evidenced photographically by lower reflectance due to higher moisture status and darker colors. The darker bay portions (Ab, Bc, Cg, Fd, Fe, Hc, E) indicate the nature of the soil and serve to contrast the much drier rims. The higher crop density and vigor as evidenced by denser red colors is also indicative of the higher moisture status of these depression soils. Other soil areas of bays (Cf, Ci and Gd) are not as strongly contrasting as other bare soil areas. The light colored bay portions usually represent moderately well drained soils or somewhat poorly drained soils with thick surface horizons. The wetter areas of these bays have remained largely in forest cover. In bays C, G, H and F, portions of the forested areas are curved and outline the wetter parts of the depressions. These wooded features help in delineating similar depressions in other areas. The bay depressions are generally flat in nature with the internal relief differing by 1-3 feet. Minor relief changes may be accompanied by marked soil changes.

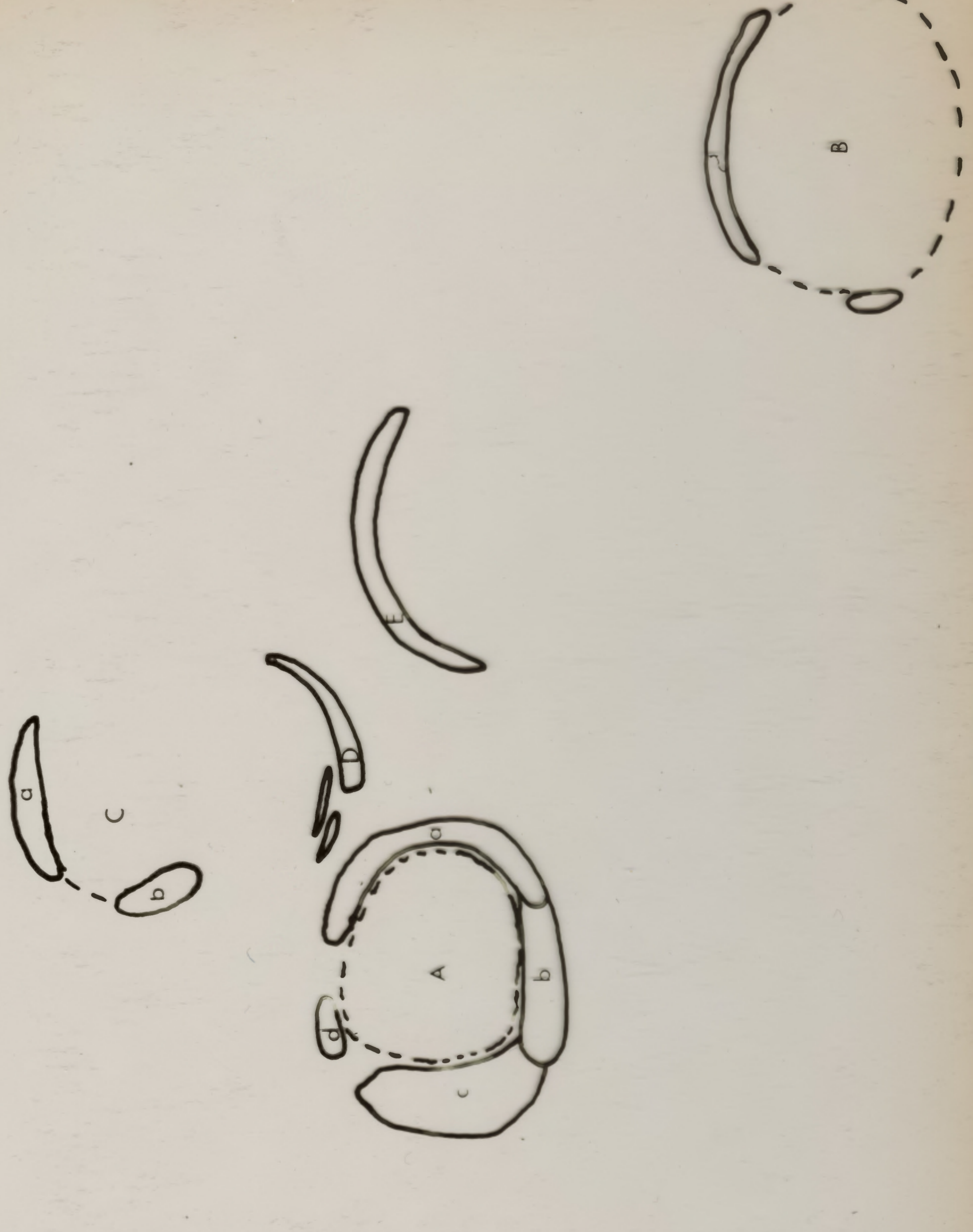
The bays shown in Figure 3 appear to have influenced the land use. Drainage appears to be the most influential factor affecting usage. Many poorly drained areas of the bays have been left to forest land. Generally, the better-drained areas have been cleared for crop land. The town of Nelsonia is located on the broad southwestern rim of bay C. Usually, the higher bay rims, especially as in bay Ca, have not been separated for a specific crop use despite being excessively drained.

Bays Near Guildfords Creek, Accomac County

Figure 6 shows Carolina bays and related features near Guildfords Creek in Accomac County (Parksley quadrangle, 7.5 min. U.S.F.S. topographic sheet). The highest elevations of these bays range from about 5 to 7 feet. A few miles to the south of this area lies Halfmoon Island which Cooke (1954) described. Guildfords Creek empties into Beasley Bay which is an extension of Chesapeake Bay.

Distinction is stressed between landforms that definitely appear to be Carolina bays (A, B) and those which appear to be related to the bays (C, D, E). The related features consist of semi-circular or semi-elliptical ridges which compare favorably in form with portions of Carolina bay rims.

The primary features used in delineating these bays via imagery evaluation are vegetation and tonal variations. The rims and ridges support a growth of pines and woody shrubs which have a higher infrared


B
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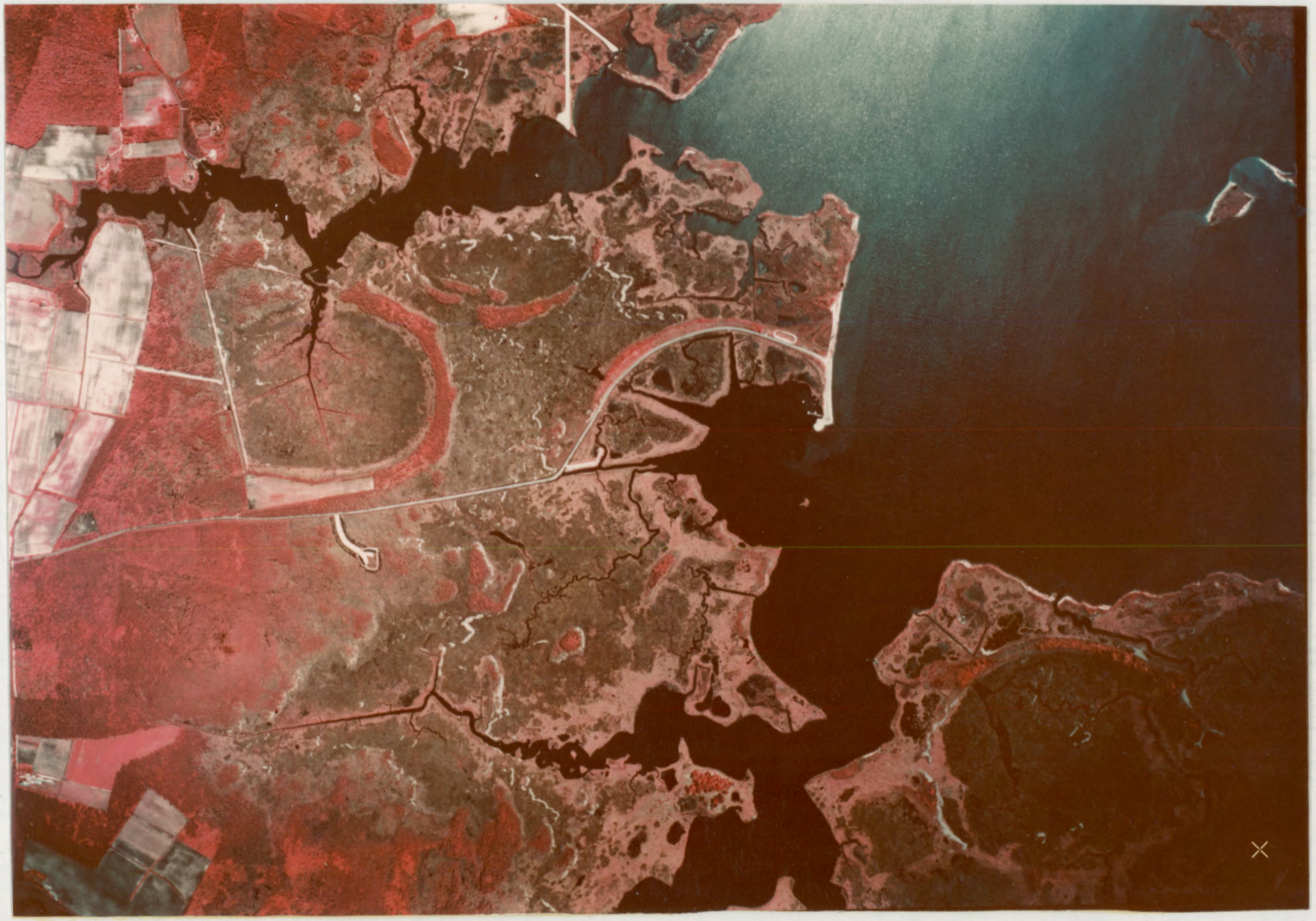


Fig. 6. Bays near Guildford Creek, Accomac County, Virginia.

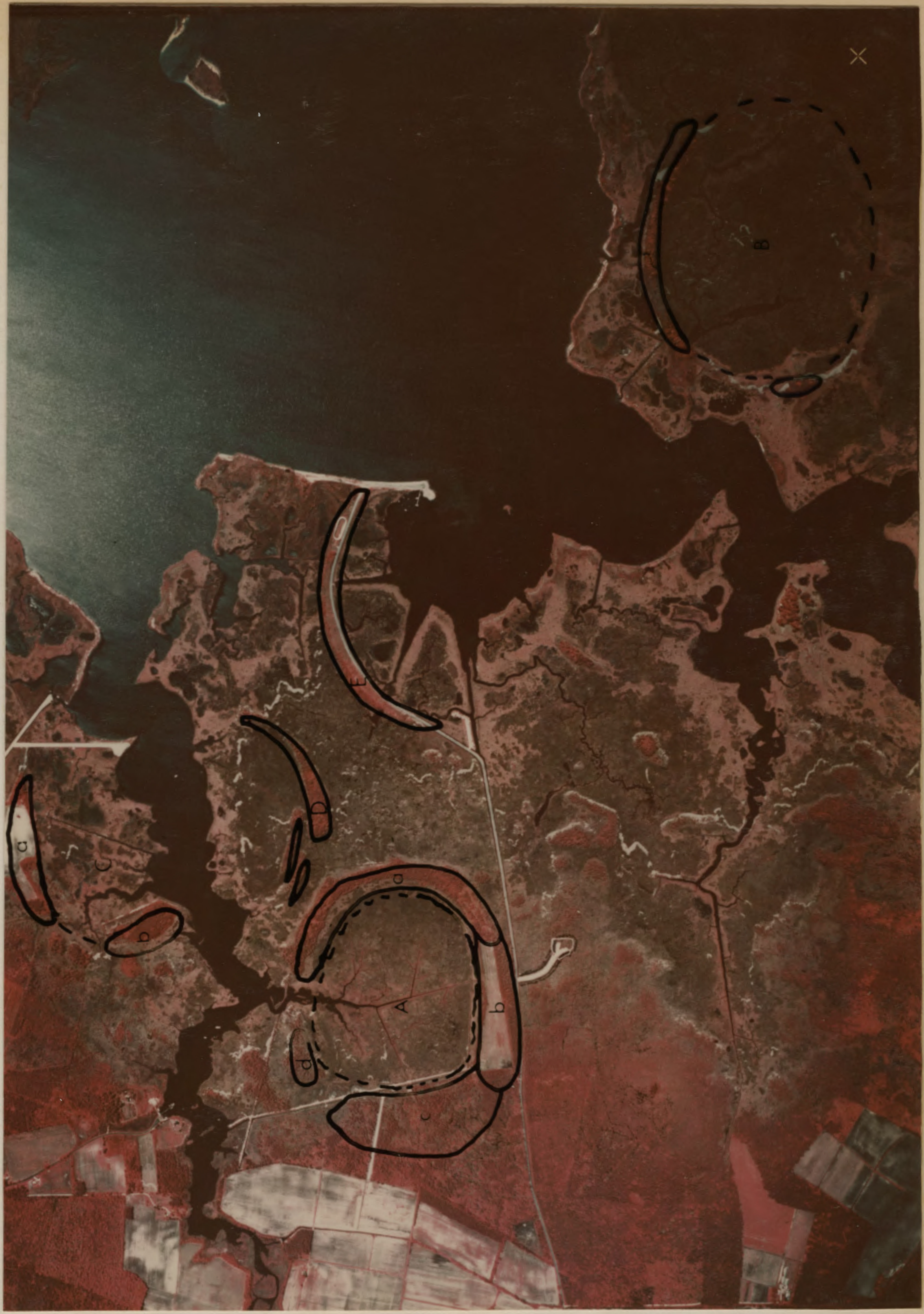


Fig. 6. Bays near Guildford Creek, Accomac County, Virginia.

reflectance compared to the surrounding marsh-land grasses and sedges. The wetter marsh grasses have a lower infrared reflectance, and they appear green on the imagery. Two bare soil areas (Ab, Ca) indicate the high reflectance of the rim soils.

The higher rims of these bays and ridges usually range in height from 3 to 7 feet. The relief is not prominent and the side-slopes are usually 1-3%. It is difficult to determine the exact elliptical or curved nature of these ridges in the field. They have the appearance of elongated islands on the marsh.

Bay A has two sections of low rim (Ab, Ac). Portion Ab is a low flat ridge with a maximum elevation of 3 to 4 feet. The soils are moderately well drained to somewhat poorly drained. The cleared field in this portion (Ab) was not under cultivation at the time of observation and it appeared that high tides may have flooded portions of this rim recently. Rim portion Ac actually does not constitute a raised rim as such. It is a low, poorly drained soil area and it is elevated 1 to 3 feet above the wetter marsh.

The central bay depressions, notably in A and B, consist of salt marsh. In bay A, a branch of Guildford Creek has dissected part of the marsh. Callahan (1972) reported that on color infrared photographs of salt marshes, the redder areas adjacent to tidal streams represent slightly higher areas of sediment accumulation. The green areas surrounding this redder area in the depression of bay A are probably slightly lower in elevation.

Rim development on these landforms is probably the most distinct feature. It appears that these ridges show the greatest development in the southern quadrant. Significant rim development is generally lacking in the north and east quadrants except for bay A.

Carolina bays in this area have to some extent served as land use resources. The fields in bays A and G have been under cultivation. The road follows the ridge of bay E to the spit at Guard Shore (Figure 6).

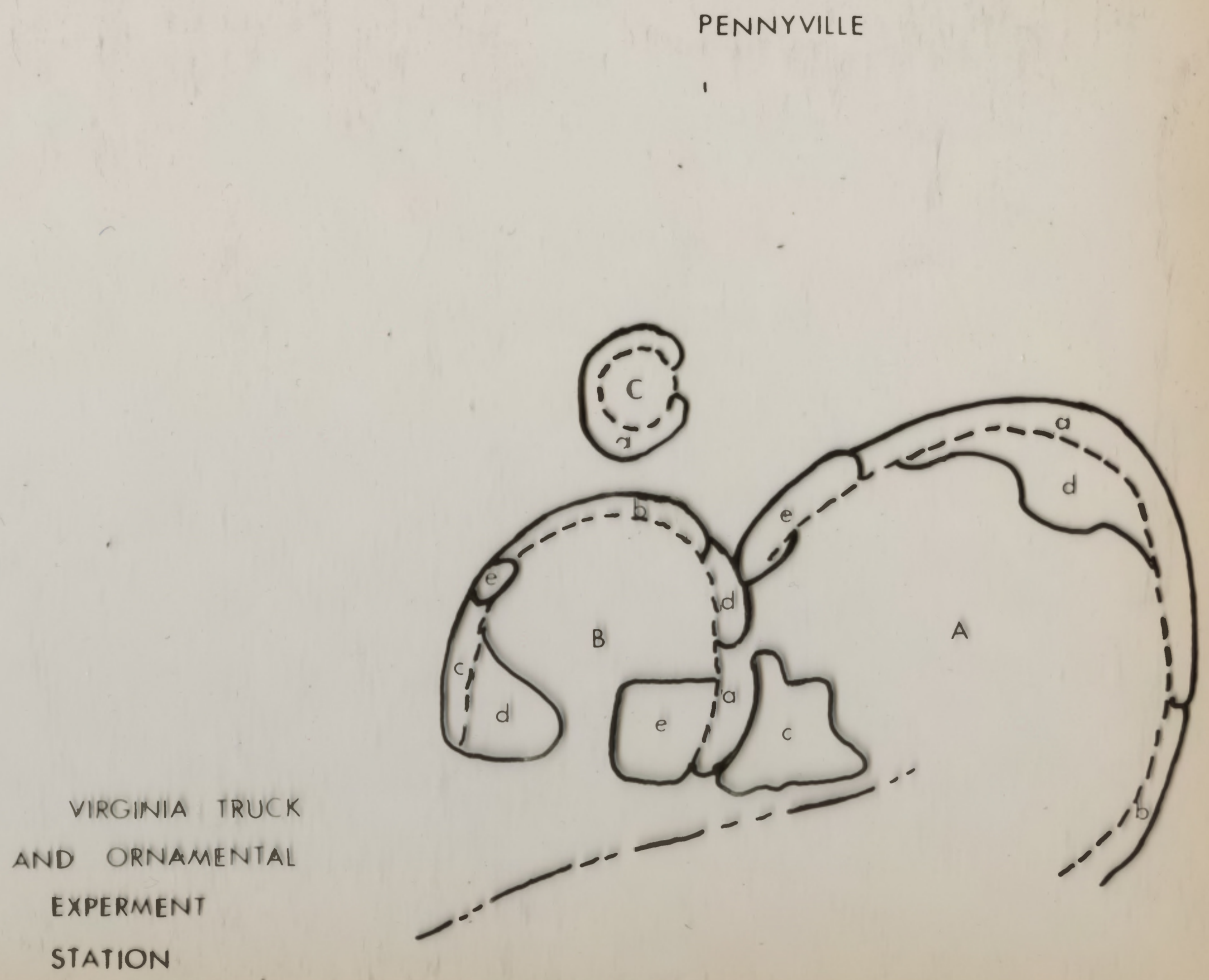
These landforms differ considerably in vegetation, relief and morphology from those described near Nelsonia. However, the landforms observed appear to be related to those at the higher elevations.

Bays Near Pennyville, Accomac County

Figure 7 shows three bay landforms near Pennyville, in Accomac County (Exmore quadrangle U.S.G.S. 7.5 min. topographic sheet). The elevations of the uplands on this photograph range from 30 to 45 feet. The Virginia Truck and Ornamental Research Station is located about one mile to the south of the lower left of the photograph.

This imagery provides a good illustration of landforms (A and B) that resemble Carolina bays but do not constitute the complete elliptical form. They resemble half-bays, a condition that exists frequently in the study area. It appears that these bays may have been either partially formed or destroyed. It does not appear that the drainage has influenced these bays in a significant way.

The higher bay rim portions are similar in form to those discussed near Nelsonia. The heights range from 4 to 8 feet and the side-slopes from 4 to 10%. The slope is greater toward the central depression. The differential photographic reflectance of these rims results from the


PENNYVILLE
C
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VIRGINIA TRUCK
AND ORNAMENTAL
EXPERMENT
STATION

Fig. 7. Bays near Pennyville, Accomac County, Virginia

Fig. 7. Bays near Pennyville, Accomac County, Virginia

same factors affecting other rims, namely higher, drier and lighter colored soils.

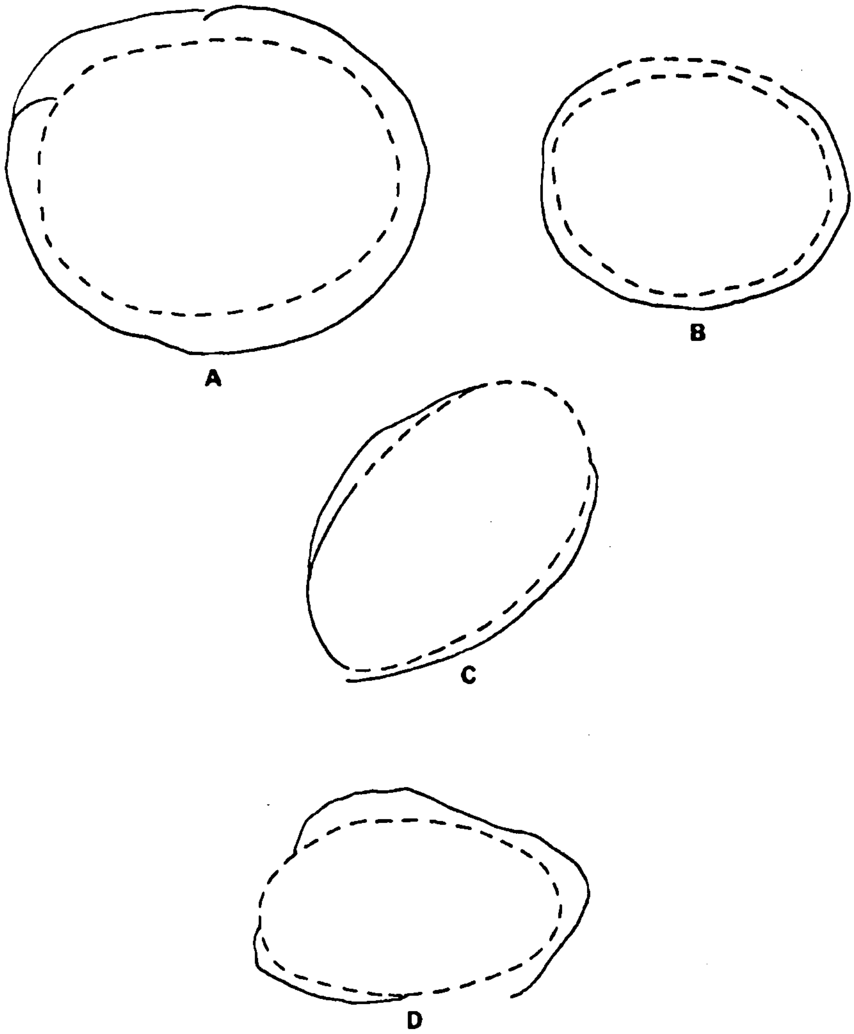
The distribution of these higher rims is mainly in the southwestern and northwestern quadrants. The lower rim areas have lower soil reflectance and slightly lower infrared reflectance from plants (as in Ae) than the higher rims as noted previously. Area Bd has a high infrared reflectance but this is related to the type of vegetation. The relief of these lower rims is about 2 to 4 feet with side slopes of 1 to 4%. Rim area Ab is lower and somewhat diffuse.

The large forrested areas of the depressions present a partial outline of these bays similar to the forest areas discussed in Figure 5. These areas are comprised mostly of poorly drained soils. The better drained soils (bay sections Ac, Ad, Bd, Be) have been cleared for agriculture. The higher moisture status and darker color of these basin soils presents a relatively sharp contrast from the well drained rims.

The small bay (C) differs considerably from the larger bays in morphology. The rim completely encircles the depression which is somewhat poorly to moderately well drained. The soil differences do not differ markedly from the soils of surrounding areas; however the landform is well developed. The rim is low but is easily delineated by drier and lighter colored soil conditions.

Ellipticity and Form

The most striking feature of Carolina bays is their elliptical form. The elliptical nature of the bays in the study area is generally illustrated in Figures 3, 4, 5, 6 and 7. A comparison of tracings of bay



A. Bay 228 near Nelsonia, Accomac County, Virginia.

B. Bay 28 SE of Cheriton, Northampton County, Virginia.

C. Bay near Bennettsville, South Carolina (from Anson, 1966).

D. Bay near Myrtle Beach, South Carolina (from Johnson, 1942).

Fig. 8. Some typical Carolina bay forms from the Eastern Shore area and other areas.

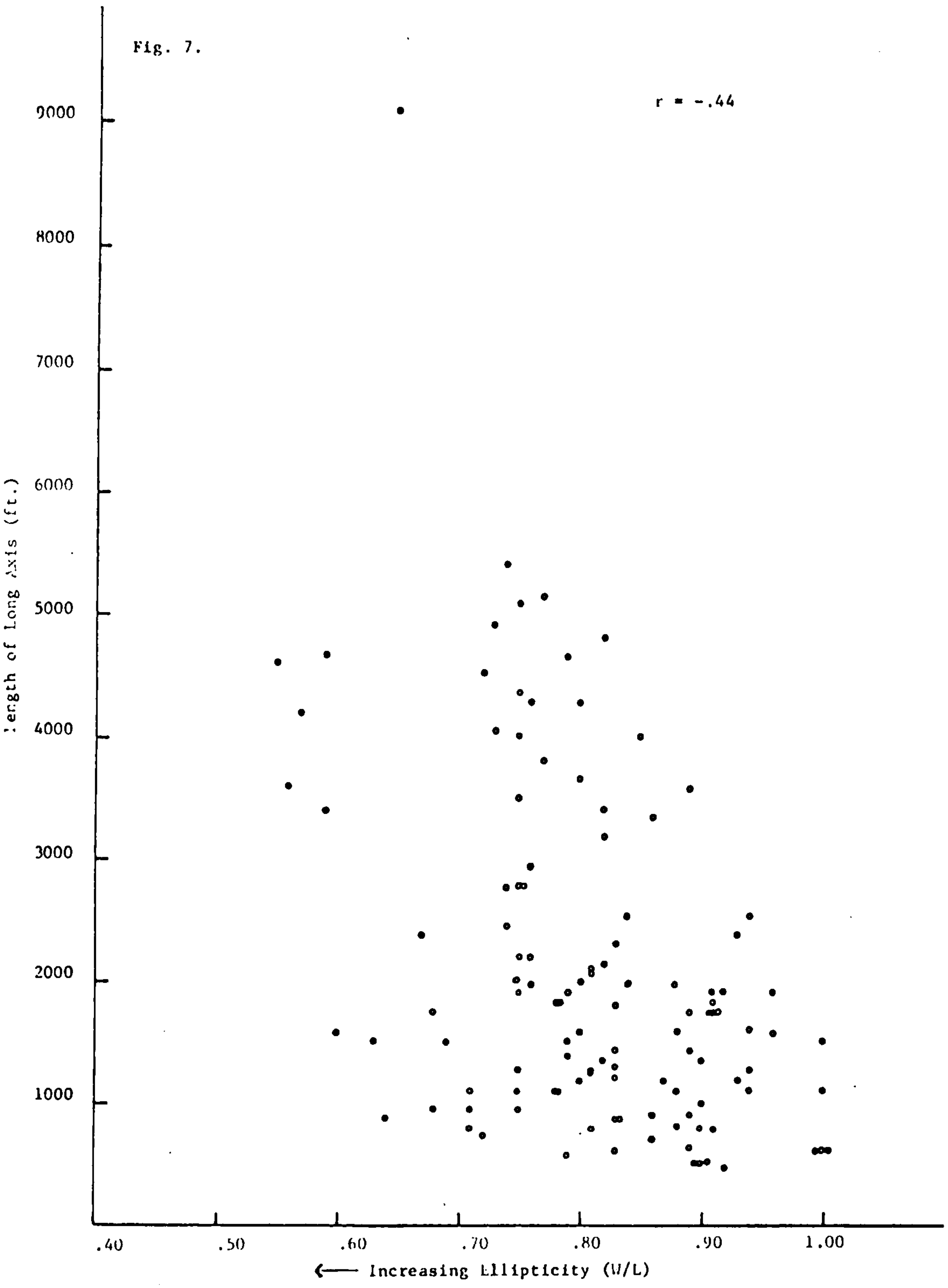


Fig. 9. Comparison of ellipticity (width/length) and length of long axis (size) of bays.

forms (Figure 8) suggests that these bays may differ in resemblances to forms reported from other areas. Few if any bays display the ovoid form as described by Johnson. Most bays appeared to be rounder and less elliptical. The average ellipticity (length/width) of 0.79 for all bays of this study is decidedly less than average values (0.59-0.73) reported by Thom (1970).

Ellipticity and bay size (length of long axis) were compared for all complete bays of this study (Figure 9). This data suggests increasing ellipticity with increasing size; however the correlation ($r = -0.44$) is poor. Melton and Schriever (1933) and Prouty (1952) have reported similar relationships for bays elsewhere. They did not determine correlation but their data suggested that correlation was also poor.

Observations in the field and on the imagery showed that relatively few bays exhibited the classical complete bay form. All gradations from semi-elliptical ridges to complete bays were observed. However the majority of bays were developed well enough so that ellipticity and orientation could be determined. These were termed complete in Table A, Appendix I. The discussions of Figure 6 and 7 also emphasize the nature of bay development in the study area. The bays of Figure 5 are some of the most well developed bays of the study area. Johnson (1942) reported that most bays from other areas were not completely developed and that many bays were in fact only vague resemblances of ellipses or semi-elliptical ridges bordering poorly drained areas.

Orientation

Parallel orientation is another striking feature of Carolina bays.

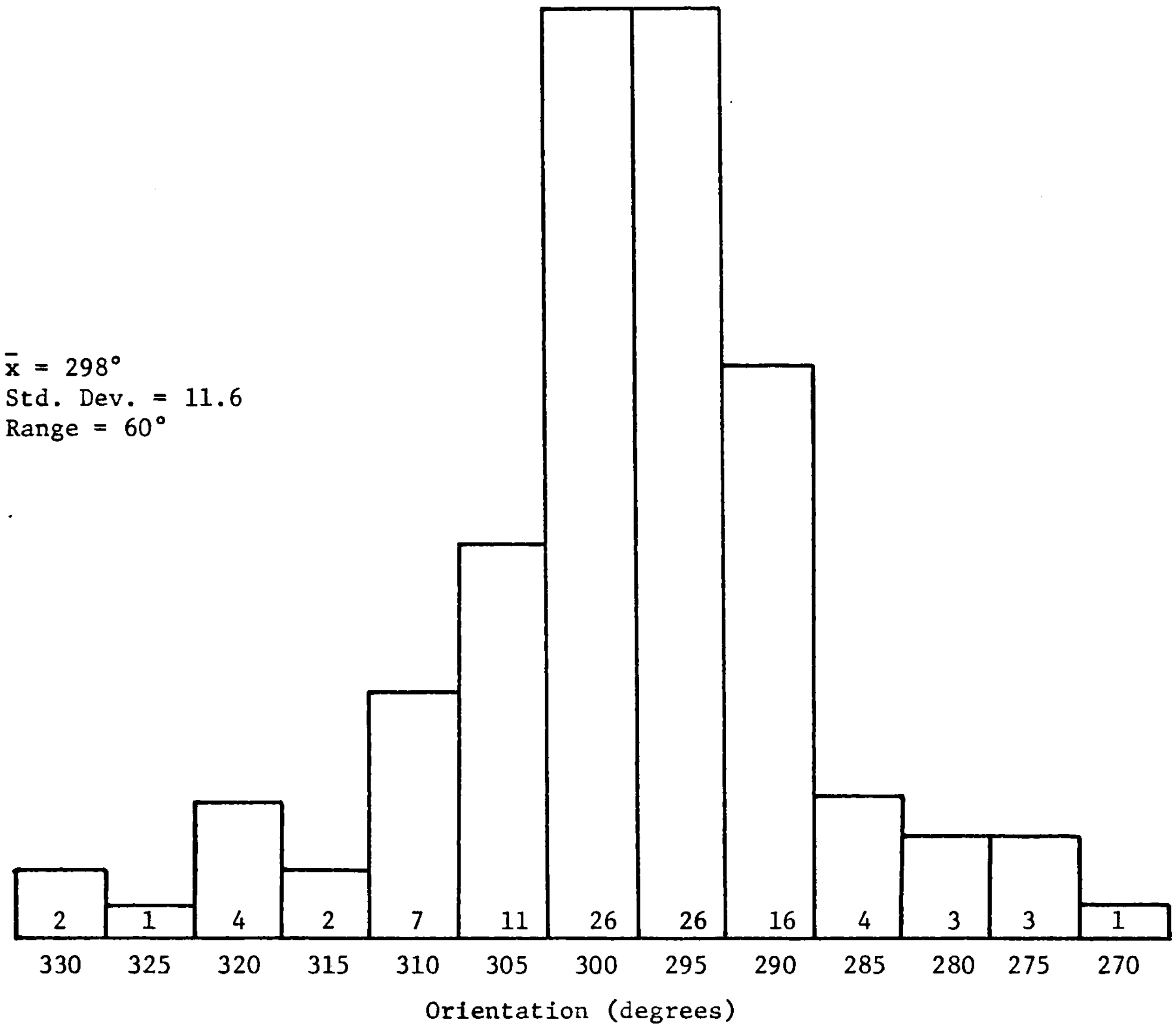


Fig. 10. Histogram showing the distribution of long axis orientation of Carolina Bays in Accomac and Northampton Counties, Virginia.

Orientation for bays of this study was determined (Figure 10; Table A, Appendix I). The average orientation of 298° is slightly more westerly than the 350° reported for bays in North Carolina (Johnson, 1942; Prouty 1952). Johnson (1942) reported that bays in the northern Coastal Plain were generally more westerly oriented than those of the southernmost Coastal Plain areas. Cooke (1954) also reported a similar trend; however his reported orientation of 307° for a few bays near Accomac and Northampton counties differs slightly from the mean of 298°.

Johnson (1942) attributed orientation of bays to artesian spring and solution activity as controlled by the strike and dip of underlying sediments. Detailed evidence is lacking in regard to the strike and dip of sediments underlying the Eastern Shore peninsula. Reports of the area west of the Chesapeake Bay (Spangler and Peterson, 1950) indicate that sediments in that area have a very gentle eastward dip. Other reports (Sinnott and Tibbitts, 1955, 1957) suggested that underlying sediments of the Eastern Shore differ from those in the Carolinas especially in the lack of limestone or marl beds. Other reports (Sinnott and Tibbitts, 1968; Sandford, 1912) do not indicate that any solution or significant artesian spring activity is presently occurring or has occurred in the study area.

Rim Development

In the field investigation it was observed that sandy ridge-like rims were well developed in at least one sector of every bay. However, few bays had rims encompassing the entire depression. Also rims did not appear to be consistently well developed in any one quadrant of all the

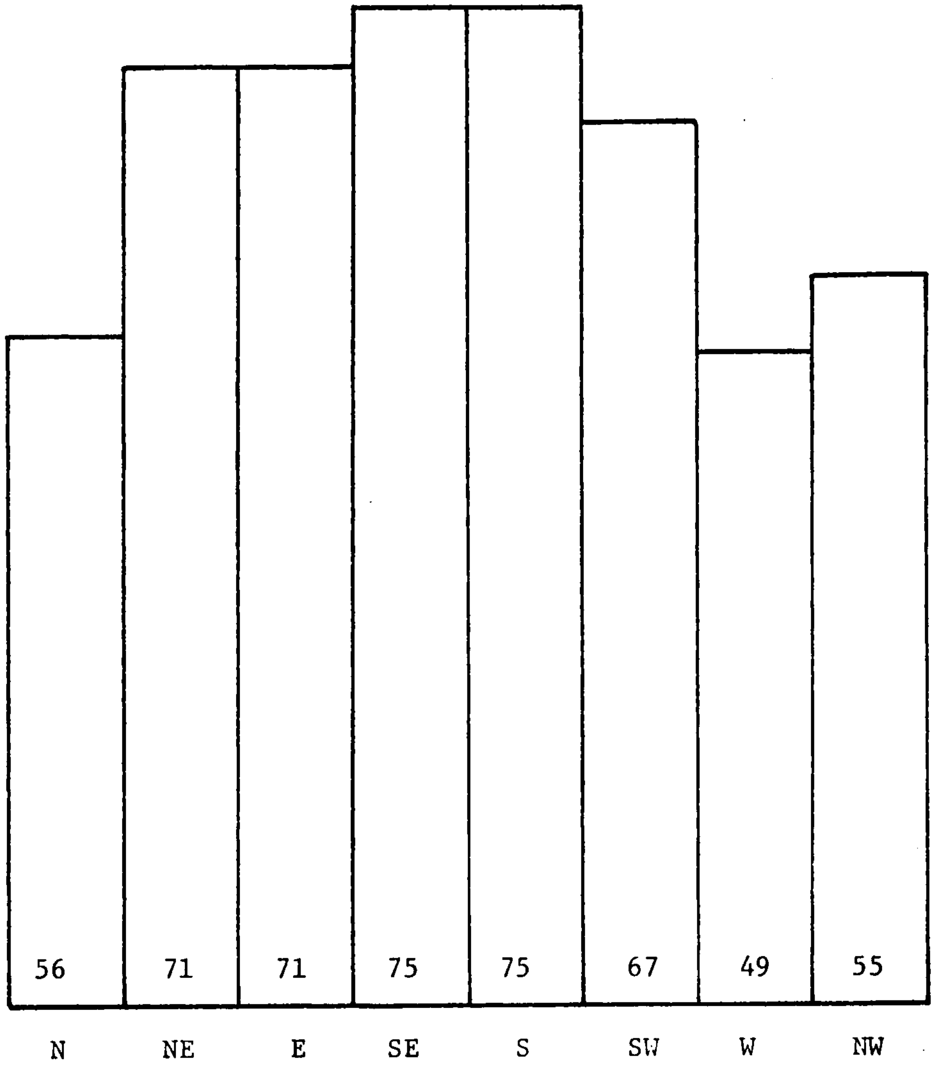


Fig. 11. The distribution of well developed sandy rims according to the number of occurrences at the eight cardinal and intercardinal compass points.

bays visited. In the photo interpretation, rim development was tabulated according to occurrence at points of the compass (Figure 11). There appears to be a tendency for greater rim development in southeastern quadrants. However, the relationship does not appear as strong as that suggested for bays in other areas (Prouty, 1952; Melton and Schriever, 1933; Odum, 1952). Johnson (1942) reported that bay rims were generally well developed in the southeastern quadrants but that well developed rims commonly occurred in other quadrants. It appears that rim development in this study area agrees with that reported by Johnson (1942). Gamble _et al_ (1974) reported that well developed southeastern rims of bays may be secondary in origin relative to the original bay depression.

Occurrence and Age of Carolina Bays on the Eastern Shore

The majority of Carolina bays on the Eastern Shore occur along the central backbone of the peninsula (Figures 3 and 4) at elevations above 30 ft. (Table A, Appendix I). These bays range in length from a maximum of 5400 ft. to a minimum of about 500 ft. The average length is about 2100 ft. For the most part these bays occur within Elkton, Keyport and Portsmouth soil areas (Figures 3 and 4) which are also distributed in a linear fashion along the peninsula. A few bays occur in the Sassafras soil areas but they are generally small.

The bays occurring at lower elevations are located in two groups. Those along a narrow peninsula south of Wachapreague (elevation 10 ft.) and those near Guildford Creek and Sandford (elevation 0-7 ft.).

The peninsula south of Wachapreague (Upshur's and Bradford's neck) is flanked on the west by the Machipongo River and its tidal flats, and on the east by the backbarrier lagoon and marshes. The maximum elevations

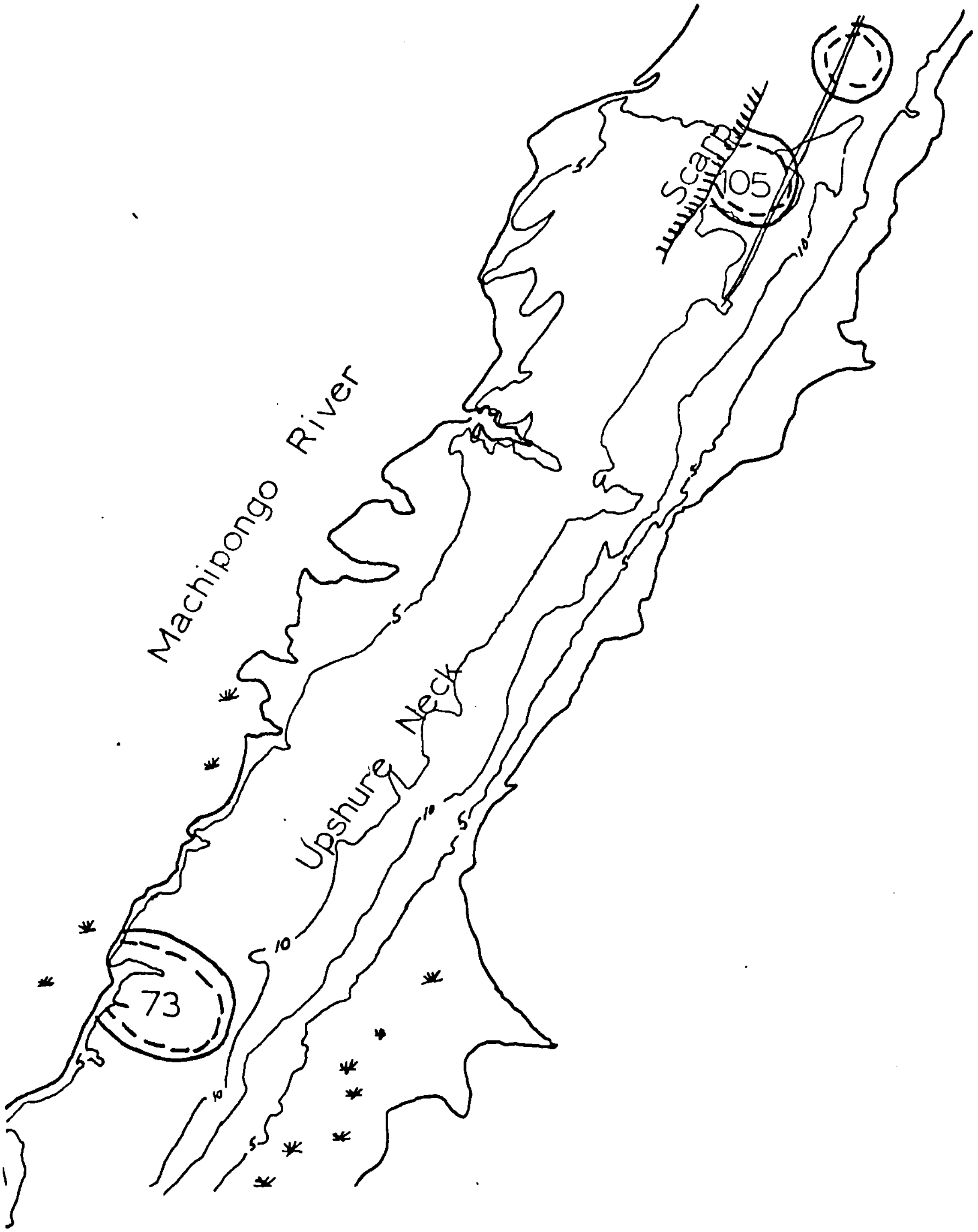


Fig. 12. Bays south of Quinby on Upshure Neck that have been truncated by a low scarp adjacent to the Machipongo River.

along this strip lie between 10 and 15 ft. The bays located there are small (average length 1000 ft.). There does not appear to be any remnants of larger bays on the peninsula itself.

Another important feature of this group of bays is the scarp facing the Machipongo River which truncates some of the bays (Figure 12). The relief of the scarp is about 5-6 ft. at bay 73 and the slope is nearly vertical but at bay 105 the slope is about 30%. At bay 73 the scarp is reflected by the topographic sheet contours. At bay 105 it is separated by the river shore by about 1/3 mile of low swampy forested land and is not shown by the contours. The linear nature and the location of this scarp at bay 105 suggest that it may have been formed by a higher stand of the Machipongo River. Oaks and Coch (1963) reported that stands of sea level 5 ft. higher than present probably occurred during late Pleistocene between the Sangamon interglacial and Wisconsin glacial epochs. They also report that pre-Recent sea levels were probably lower than the present and have been rising since the maximum emergence during the Wisconsin epoch.

The bays located between Guildford Creek and Sandford occur on the marsh near sea level. Maximum elevations of about 7 ft. occur on the rims of these bays. The bays of Figure 6 are included in this group. The average size of complete bays is about 4700 ft. with the maximum of 9100 ft. and minimum of 2300 ft. Many of the bays in this area are also poorly developed.

Callahan (1972) reported that salt marshes adjoining the Eastern Shore are recent in age, that they probably have been forming over the past

1000 years. The breaching of the rim of bay 199 (Bay A, Fig. 6) by Guildford Creek suggests that marsh formation has encroached on a pre-existing bay. This evidence and the general nature of surrounding environment suggests that these bays might be undergoing destruction presently. If such is the case, then the morphology of the surface on which the bays were constructed remains obscured by a blanket of Recent sediments.

Thom (1970) suggested that bays were formed in sandy poorly drained natural depressions. He also reported that bay size appears to be controlled by the size of these original depressions or size of associated landform. The occurrence of the majority of bays of this study in a linear pattern in conjunction with other larger poorly drained areas similarly distributed suggests a possible association. The restriction of bay size (max. of 5400 for bays on main peninsula; max. of 1000 ft. for bays on the peninsula south of Wachapreague) relative to associated land surface suggests the possibility of control over bay size by topography. This is further illustrated by the complete lack of large bays (over a 3 miles in length) as have been reported in other areas. The association of bays near Guildford Creek and Sandford with topography is obscure due to the effects of Recent sedimentation.

The truncation of bays by the scarp in Figure 12 shows that these bays are older than the scarp. A similar scarp was also observed on the western shore of the peninsula adjacent to bay 256 which suggests that it may be widely developed in the area. The existence of bays below the level of this scarp indicates a younger age.

Soils of the Carolina Bays, Eastern Shore

Field Investigation

Soil profile information from bay rims and depressions was obtained during the field survey of 41 Carolina bays. This survey was conducted of the bays which showed the most complete development during photo-inventory. Soil depth, color and textural information was obtained from hand-auger samples. Tabulated soil data from each bay examined are given in Table B, Appendix I. Of the 41 bays examined most occur above 25 feet in elevation. Only a few bays were examined at elevations near sea level, mainly due to the lack of well developed bays at this level. In this discussion more importance is placed on the soil characteristics of these lower lying bays than on the number of observations made or the number of bays present.

Soil texture - Table 8 shows a summary of subsurface textural relations of rims and depressions at different elevations. Generally, the depressions have heavier textures than the rims. However, the large number of sandy clay loam textures observed in both rim and depression soils indicates that textural differences are not sharply contrasting.

The B horizons of rim soils at elevations above 10 feet usually vary in texture from sandy loam to heavy sandy clay loam. There are isolated occurrences of rim soils that are considerably more loamy than surrounding soils due to an apparently higher silt content. There are also isolated areas of subsurface textures of light sandy loam to loamy sand. These areas are usually associated with rims that have dominantly sandy loam subsurface textures. The data from Table 7 also indicates that rims

Table 7. Numbers of B Horizons of Each Texture at Different Elevations from 41 Carolina Bay Rims and Depressions.

Elevation	Loamy Sand	Sandy Loam	Sandy Clay	Clay Loam	Clay
		RIMS			
30'-50'	-	7	17	-	-
20'	1	2	1	-	-
10'	-	1	3	-	-
0'- 5'	-	4	3	-	-
		DEPRESSIONS			
30'-50'	-	2	23	4	2
20'	-	3	1	-	-
10'	-	2	1	1	-
0'- 5'	-	-	1	2	1

below 10 feet elevation may be lighter in texture than rims of higher lying bays. Only three bays were examined at this low level and most of the profile descriptions were taken at Bay 199 (Bay A, Figure 4). The entire high rim of this bay has a light sandy loam to loamy sand subsurface texture. The lower rim portion of this bay (Ab, Figure 4) has a sandy loam to light sandy clay loam subsurface texture.

The dominant subsurface texture of the depressions above the 10 feet elevation is sandy clay loam. In small bay depressions the texture remains fairly uniform, but in larger bays there may be considerable differences in textures within the bay. A large bay (Bay 125) has subsurface textures in the depression ranging from heavy sand loam to loam, silty or clay loam. The larger bays may also have a few isolated areas of very light (sandy loam to loamy sand) subsurface textures which are usually associated with shallower solum depths.

Subsurface textures of bay depressions below the 10 feet elevation appear to be heavier than those of higher lying bays. Most of these areas were relatively inaccessible and the variability of the soils was not determined. The central depression of Bay 199 is flooded much of the time and it appears to be undergoing active sedimentation.

The surface texture relationship between rims and depressions generally follows a similar trend as the subsurface textures. The depressions usually have heavier surface textures which are associated with heavy subsurface textures. The same relationship occurs with lighter textures. There are a few isolated areas of rims where the surface soil consists of loose sand; however most surface soils have a considerable amount

Table 8. Solum Depths of Profiles from Rims and Depressions of 41 Bays at Different Elevations.

		Solum Depths (inches)		
	Elevation	20"-30"	30"-40"	40"-50"+
RIMS	30'+	4	14	5
	20'	-	2	2
	10'	3	1	-
	0-10'	6	-	-
DEPRESSIONS	30'+	4	21	7
	20'	-	2	2
	10'	3	1	-
	0-10'	2	2	-

of silt which imparts greater cohesiveness.

Solum depth - Solum depth data for rims and depressions at different elevations are shown in Table 8. In general, few solum depths greater than 50 inches were observed. These occurred in isolated locations. Also, few sola depths shallower than 18 inches were observed. The thinner sola usually occurred in depressions with high water tables and on some of the highest rims. The deeper, better developed rim soils usually occur on the low and flat rim areas. The thick sola on the high rims are usually associated with loamyer soil areas.

The data in Table 9 also show the low-lying bays (0-5 feet elevation) tend to have shallower solum depths than lying bays.

Soil Color - Distinct soil differences that were observed between rims and depressions are usually reflected by the surface colors. Most rim surface colors range from dark brown (10 YR 3/3) to dark yellowish-brown (10 YR 4/4) and grayish brown (2.5 Y 5/2). Depression soils generally have wetter and darker surface horizons. The colors range from black (10 YR 2/1) to dark gray (2.5 Y N4/). The colors and moisture relationships are also illustrated in the discussion of Figures 5 and 7.

Subsurface colors of rim soils range from reddish-brown (5 YR 4/4) to olive (5 Y 5/3). The colors of subsurface horizons of depression soils generally range from brownish-yellow (10 YR 6/6) to light olive-gray (5 Y 6/2). Table 9 shows the average values and chromas of different hues for subsurface horizons of rims and depressions. Generally darker, and yellower soil colors of depressions soils are indicative of the poorer drainage class.

Table 9. Average Munsell Colors of B_2t Horizons of Rims and Depressions at Various Elevations of 41 Carolina Bays.

Elev.	5 YR	7.5 YR	10 YR	2.5 Y	5 Y
			RIMS		
30'-50'	-	4.72/5.27	5.17/6.00	-	-
20'	4/4	5/6	5/7	-	-
10'	-	4.7/6	-	-	-
0'- 5'	-	-	4.8/5.2	-	5/3
			DEPRESSIONS		
30'-50'	-	-	5.66/3.66	4.91/3.50	6.12/2.50
20'	-	-	4.66/5.33	6/6	-
10'	-	-	6/1.5	5/2	-
0'- 5'	-	-	-	5/3	-

The data in Table 9 also show a trend toward lower values and chromas of bay soils at the lowest elevations.

Soil differences between low lying bays and those above 10 feet elevations are illustrated by the soil maps of the Appendix. The bay rims above 10 feet elevation (Bays 125, 163, 256, and 8) have well developed sola with subsurface colors of dark brown to brown (7.5 YR 4/4), or strong brown (7.5 YR 5/6). The textures are heavy sandy loam to sandy clay loam, and solum depths are usually greater than 30 inches. The lower lying bay (Bay 199) has subsurface colors of yellowish-brown (10 YR 5/4) to dark yellowish-brown (10 YR 4/4). The textures of the high rim are loamy sand to light sandy loam and solum depths are usually less than 30 inches.

<u>Other Soil Relationships</u> - The data (Tables B and C; Appendix I) shows that Carolina bay soils are generally sandy in nature. Even though the sola are sandy, they often sharply contrast with the substratum which in every case consists of loose sand. The generally sandy nature of all bay soils observed indicates that the bays on the Eastern Shore occur in sandy environments. Stevens (1920) reported that nearly all soils of the area were underlain by loose sand. Thom (1970) also observed that bays in Horry and Marion counties, South Carolina, occur in sandy environments.

The often sharply contrasting textures between B and C horizons (Table C, Appendix I) especially as influenced by silt content suggests that solum development may have been influenced by the deposition of silt concurrently with the upper layers of original sediments. The previous discussion on soil texture makes reference to rim soil areas that are loamier than most sandy rim soils. The abrupt decrease in silt between the B_{2t} and C_1 horizons of the depression profile from Bay 125 further illustrates this relationship.

Depth to water table was generally observed during the field investigation. In the poorly and somewhat poorly drained bay depressions the water table was usually within 50 inches of the surface. In a few bays it was within 18 inches especially in those bays at the lower elevations. Depth to water table in bay rims usually could not be determined as it was usually below the reach of the 60-inch hand auger except on rims of bays at low elevations.

Size Distribution of Rim and Depression Sand Fractions

During the field investigation it was observed that the sand of bay rims was consistently uniform from bay to bay. Soil profiles were sampled from five bays and particle size distribution of each horizon was determined. The shape of the histograms (Figures 13 and 14 suggests that the A, B and upper C horizons within these rim soils are related to each other. There also appears to be a similarity in histogram shape between rims of different bays. The most consistent feature of this similarity is the dominance of the medium sand fraction in these sands. It appears that the depression sands may be consistently finer in texture than those of rim sands. Folk (1965) reported that mean size of sediments in generally a function of size range of available materials and the amount of energy imparted to the sediment. The above size distribution data is in no way intended to be a statistical treatment, and cannot be

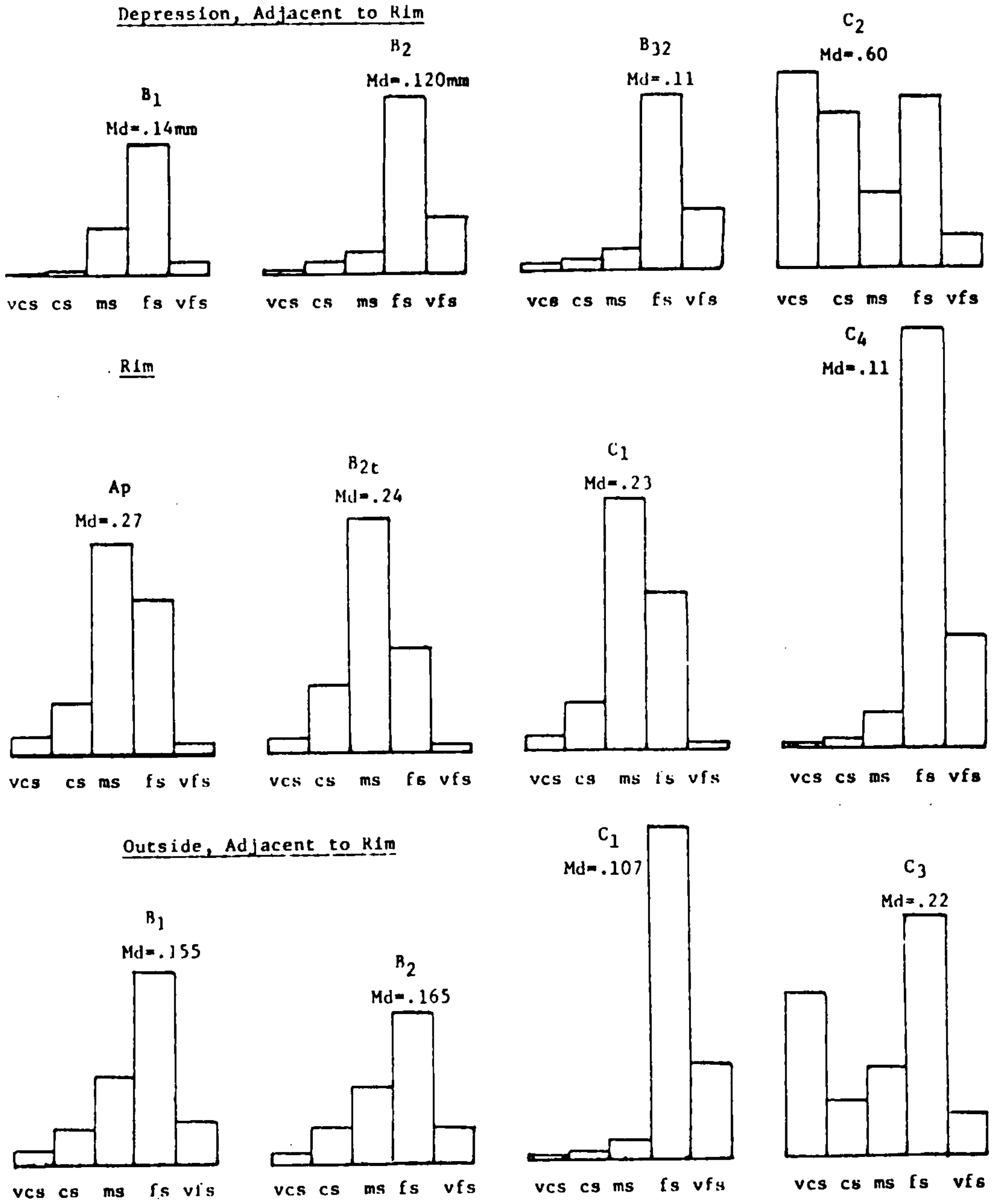


Fig. 13. Histograms showing particle size distributions of sand fractions from profiles of Bay 199.

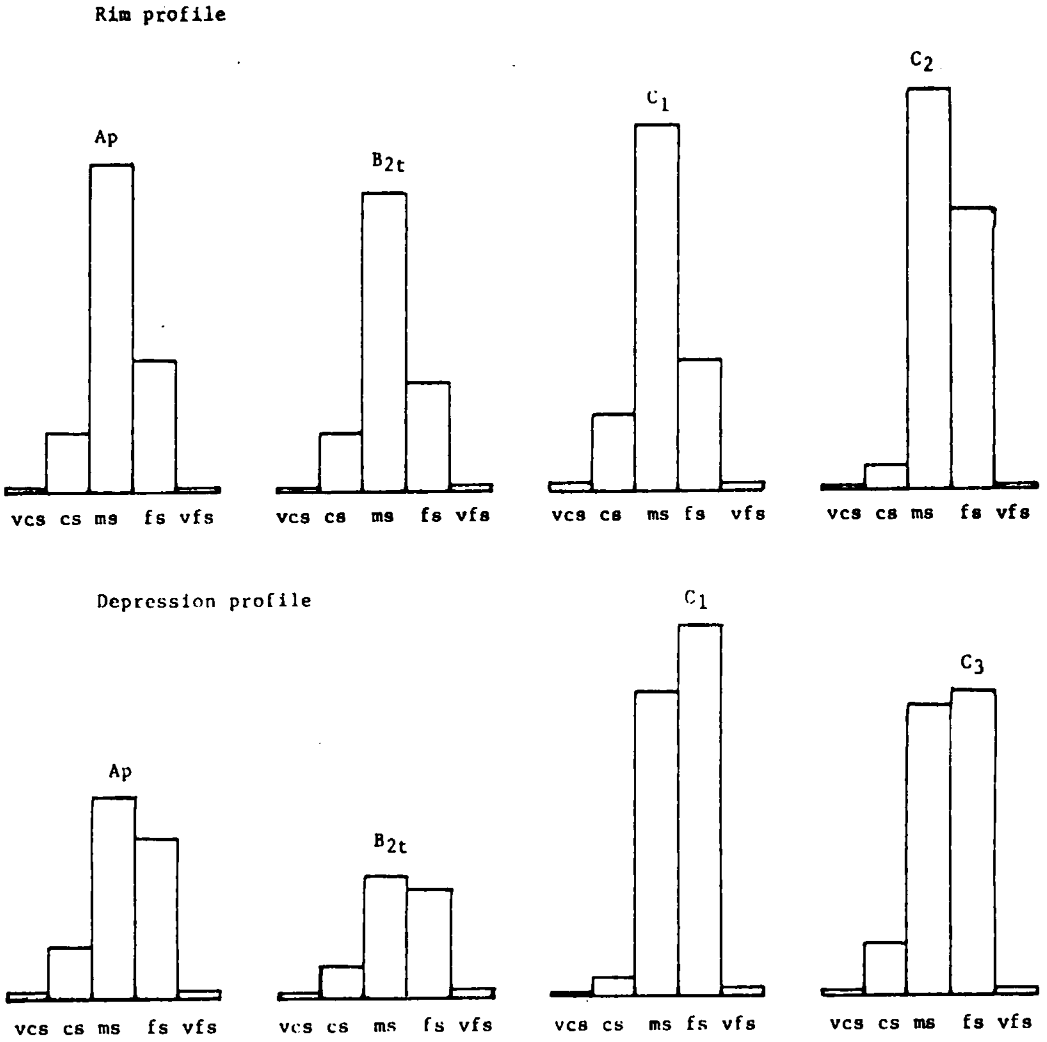


Fig. 14. Histograms showing particle size distribution of sand fractions from profiles of Bay 125.

conclusive. It merely suggests the possibility that bay rims were deposited by an agent of greater energy than sands of bay depressions and that bay rims be consistently better sorted. Johnson (1942) and Thom (1970) have recognized that bay rim sands in general are distinctively well sorted. These authors have suggested that bay rims have the nature of small sand dunes formed by the action of wind and waves at the edge of small shallow lakes that occupied natural depressions on the land surface.

The histograms of Figure 13 also show that the depressions profile and a profile sampled outside of the bay depression adjacent to the rim have similar characteristics. They are skewed toward the fine sand sizes and both have bimodal lower horizons. These profiles are in contrast to the rim profile which has the dominant medium sand. The lowermost rim horizon, however, is skewed toward the fine sand. It has a distribution which appears similar to C_1 horizons of adjacent profiles. The relationship between these horizons concurs with the suggestion by Bryant and McCrackan (1964) that no lateral discontinuities existed between bay rim and depression profiles.

Comparison with Carolina Bay Soils from Other Areas

The morphology of bay soils has been determined in other areas of the Coastal Plain (Tables 1, 2, 3, and 4). Figure 15 shows a comparison of rim soil profiles from Scotland County, North Carolina and this study area. This illustration shows considerably differences in rim soil morphology between different areas and within the same county (Scotland County). The Lakeland soil has little profile development whereas the

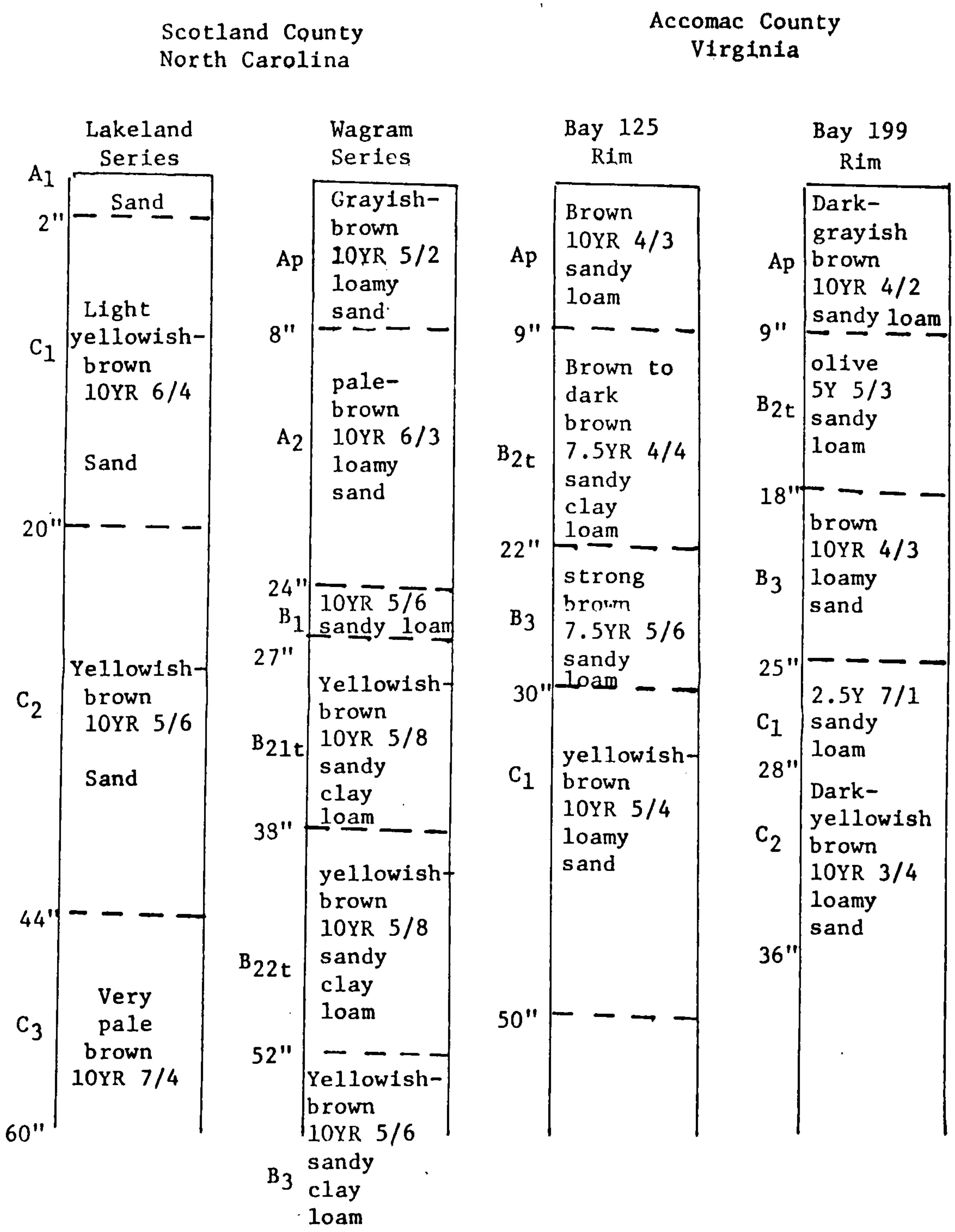


Fig. 15. Comparisons of soil profiles of the Eastern Shore Carolina bay rims and from bay rims of other areas.

Wagram soil has an extremely well developed soil profile. Gamble et al (1974) recently presented evidence that the sandy rim soils (similar to Lakeland) are of secondary origin relative to the associated bays in North Carolina. The contrast in rim profile morphology in this study relative to those in North Carolina suggests that rims of secondary origin may not be present. The rim profiles of this study area (Fig. 15) differ considerably from either of the Scotland County profiles and suggests differences in the function of the five soil forming factors (climate, organisms, time, parent materials, and topography). The Wagram soil is classified as a paleudult; whereas, a classification of hapudults for the rim soils in this study suggests different ages for the bay soils of different areas.

Mineralogy of Clay and Silt Fractions of Ten Selected Soil Profiles

Clay and silt mineralogy of 36 soil horizons from 10 sampled profile of Carolina bays (Bays 125, 8, 163, 256 and 199) was determined by X-ray diffraction and differential thermal analysis. The primary X-ray diffraction spacings and intensities for the <2μ fractions, and the 2-50μ fractions are given in Tables D, E, and F of Appendix I. Differential thermal patterns for the <2μ fraction are presented in Appendix II.

Clay and Silt Mineralogy of Bay Soils Above 10 ft. in Elevation

Clay Fraction (<2μ) - The X-ray diffraction patterns of rim and depression profiles for Bay 125 (Figures 16 and 17) are generally representative for this group of bay soils. The collapse of the 14 Å peak to spacings intermediate between 10 Å and 14 Å on heating of 300° and 500° (Table E, Appendix I) indicates the presence of interlayered vermiculite. The 7.12 Å peak (Mg-saturated, glycerol-solvated) which also persists at 300° (K-saturated) in the absence of a 14 Å peak indicates that kaolinite is present. The diagnostic endothermic peak at 500-520° on the DTA patterns (MacKenzie, 1957)(Figures 18 and 19) also indicates the presence of kaolinite. Interlayered vermiculite and kaolinite appear to be the dominant minerals of upper horizons. All X-ray peaks (Figures 16 and 17) show a decrease in intensity in peak intensity can be an indication of differences in the amounts of a particular mineral in the sample. He pointed out that this can be affected by factors such as particle size, chemical composition, presence of amorphous substances,

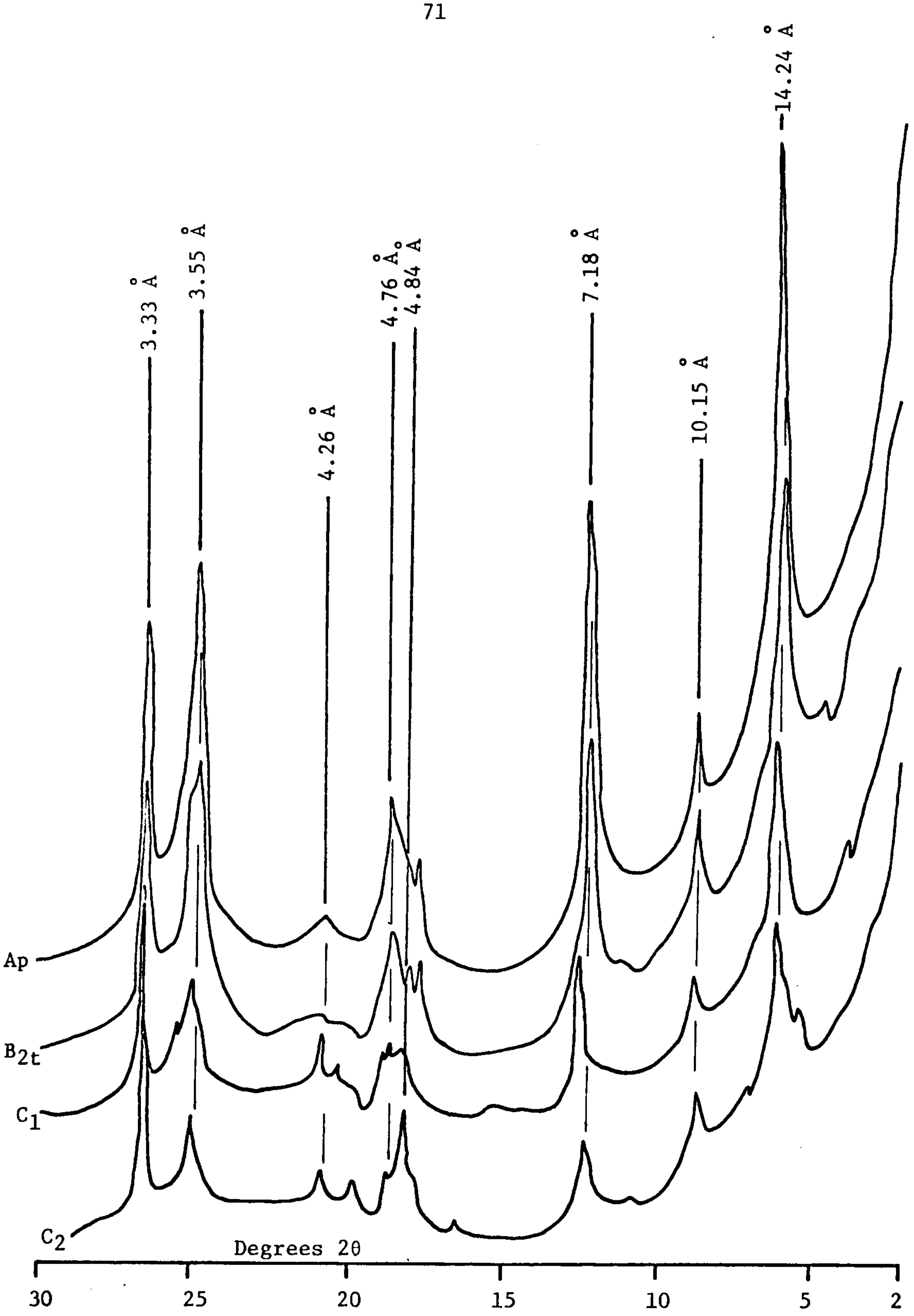


Fig. 16. X-ray diffraction patterns of <2μ fraction from the rim soil profile from Bay 125, Mg-saturated, glycerol solvated, 25° C.

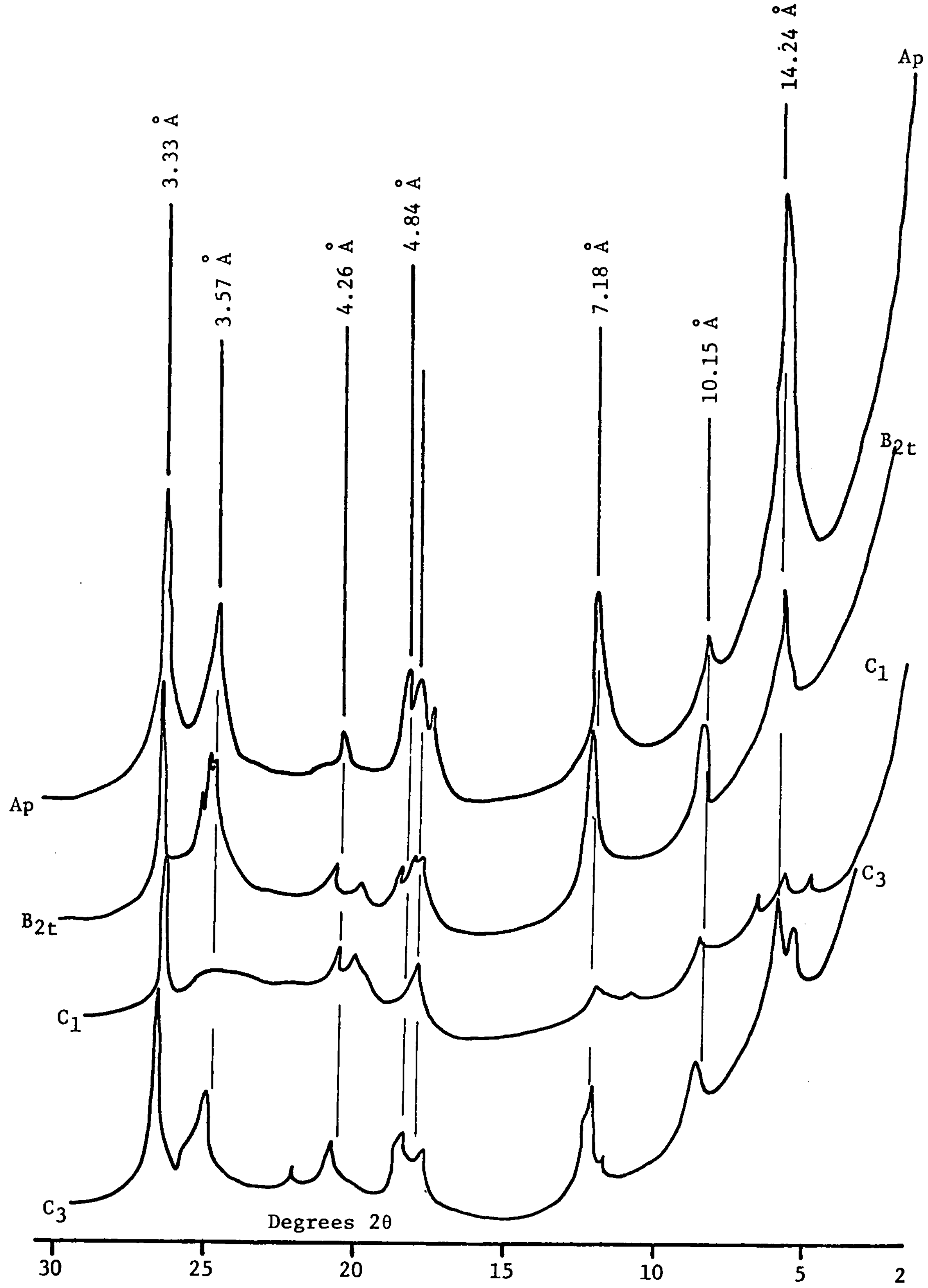


Fig. 17. X-ray Diffraction Patterns for <2μ fraction of the depression soil profile of Bay 125, Mg-saturated, glycerol solvated, 25° C.

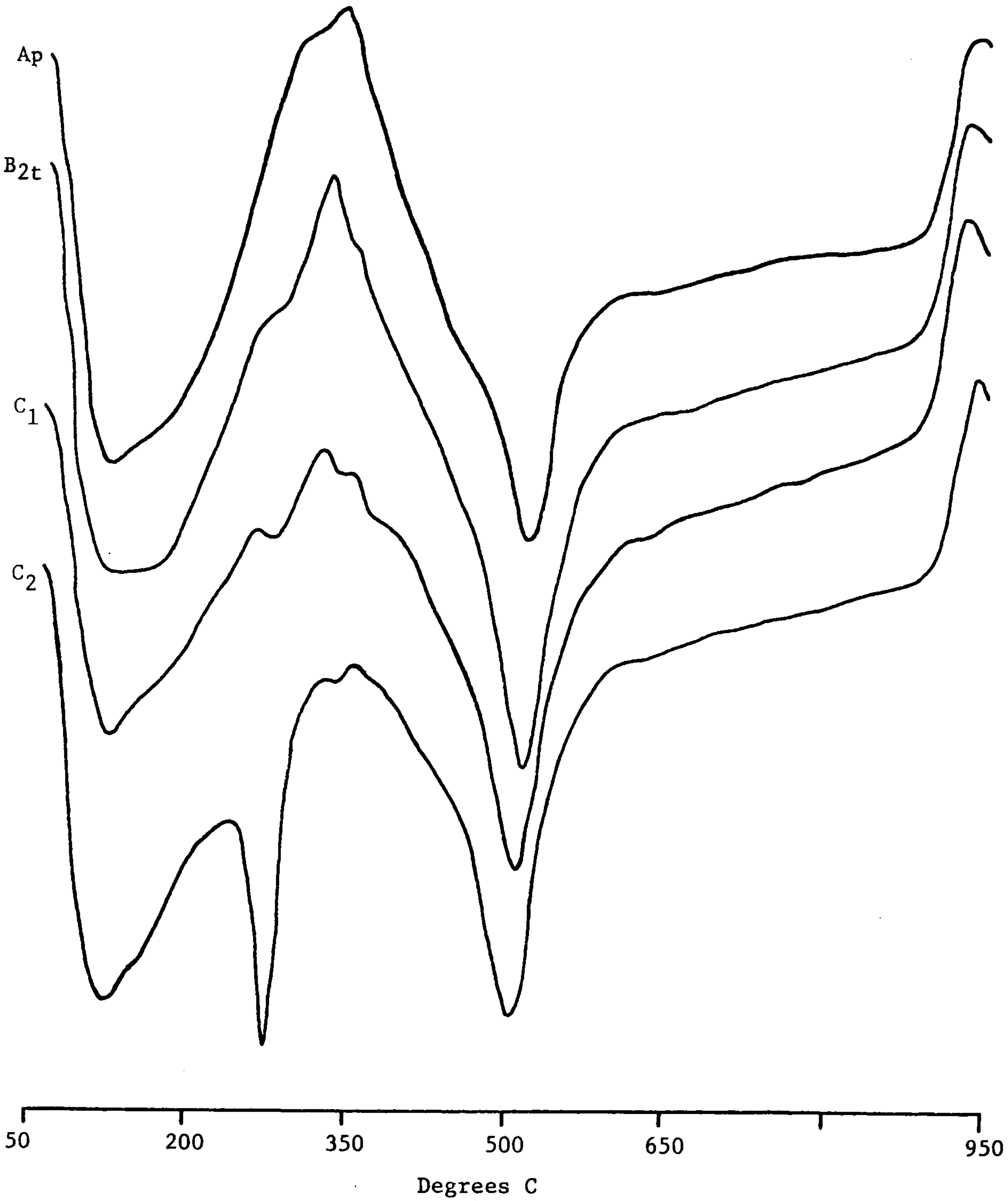


Fig. 18. Differential Thermal Analysis patterns for <2μ fractions from the rim profile from Bay 125, Mg-saturated, Equilibrated at 56% R.H.

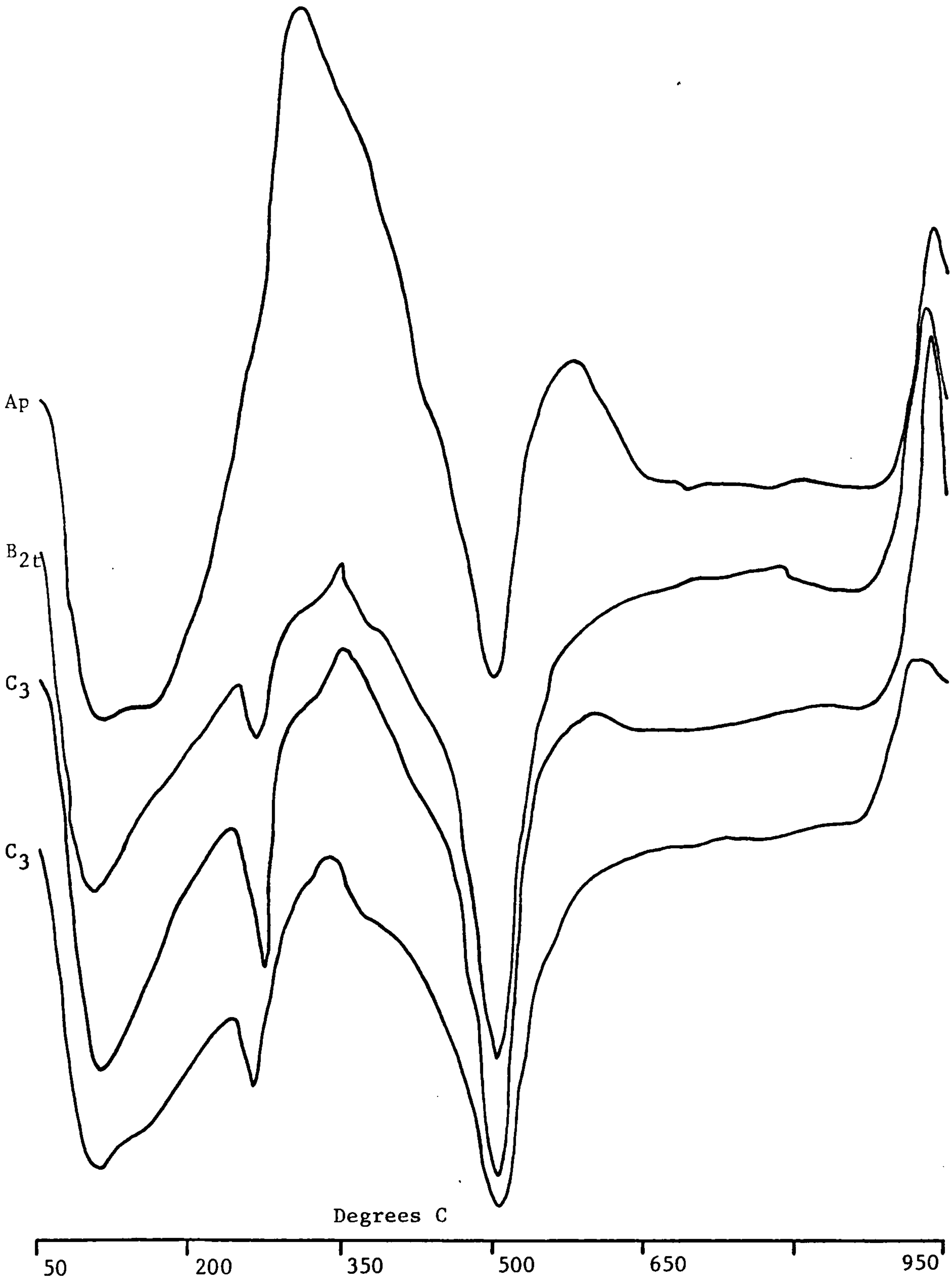


Fig. 19. Differential thermal analysis patterns for depression profile, <2μ fraction, Bay 125, Mg-saturated, equilibrated at 56% R. H.

crystal imperfections and orientation. In this study these factors are unknowns and the extent they may have affected the X-ray peaks was not determined. The persistence of the strong 510° DTA endothermic peaks in contrast to decreasing intensity of 7.12 Å X-ray peaks suggests that the X-ray patterns may be deceiving as to relative amount of kaolinite present in the clay fraction of the lower horizons. In Figure 13 the relative decrease in intensity of the 14 Å peak is greater than the relative decrease in intensity of the 7 Å peak with increasing depth. This suggests that interlayered vermiculite may be secondary in amounts relative to kaolinite in the lower horizons of some profiles. Rich (1967) reported that interlayered minerals are usually best developed in the surface horizons.

Illite or mica was detected in all horizons of these soils as indicated by the 10 Å peaks (Figures 16 and 17). The relative amounts appear to be small as indicated by the low intensity peaks. The 10 Å peak intensities of Figure 12 are the most pronounced of this group of soils.

Chlorite was detected mainly in the surface horizons as indicated by the persistence of the 14 Å peak in the 550° K-saturated treatment (Table E, Appendix). These peaks occur in only a few of the subsurface horizons. All Chlorite peaks are of relatively low intensity.

Gibbsite was detected in every profile of the bays occurring above the 10 ft. elevation as indicated by the X-ray diffraction peaks at 4.82-4.87 Å (Figures 16 and 17) and endothermic peaks at 265-285° on the DTA patterns (Figures 18 and 19). The characteristic endothermic peak of Gibbsite at 330-340° (MacKenzie, 1957) did not show up on the DTA patterns.

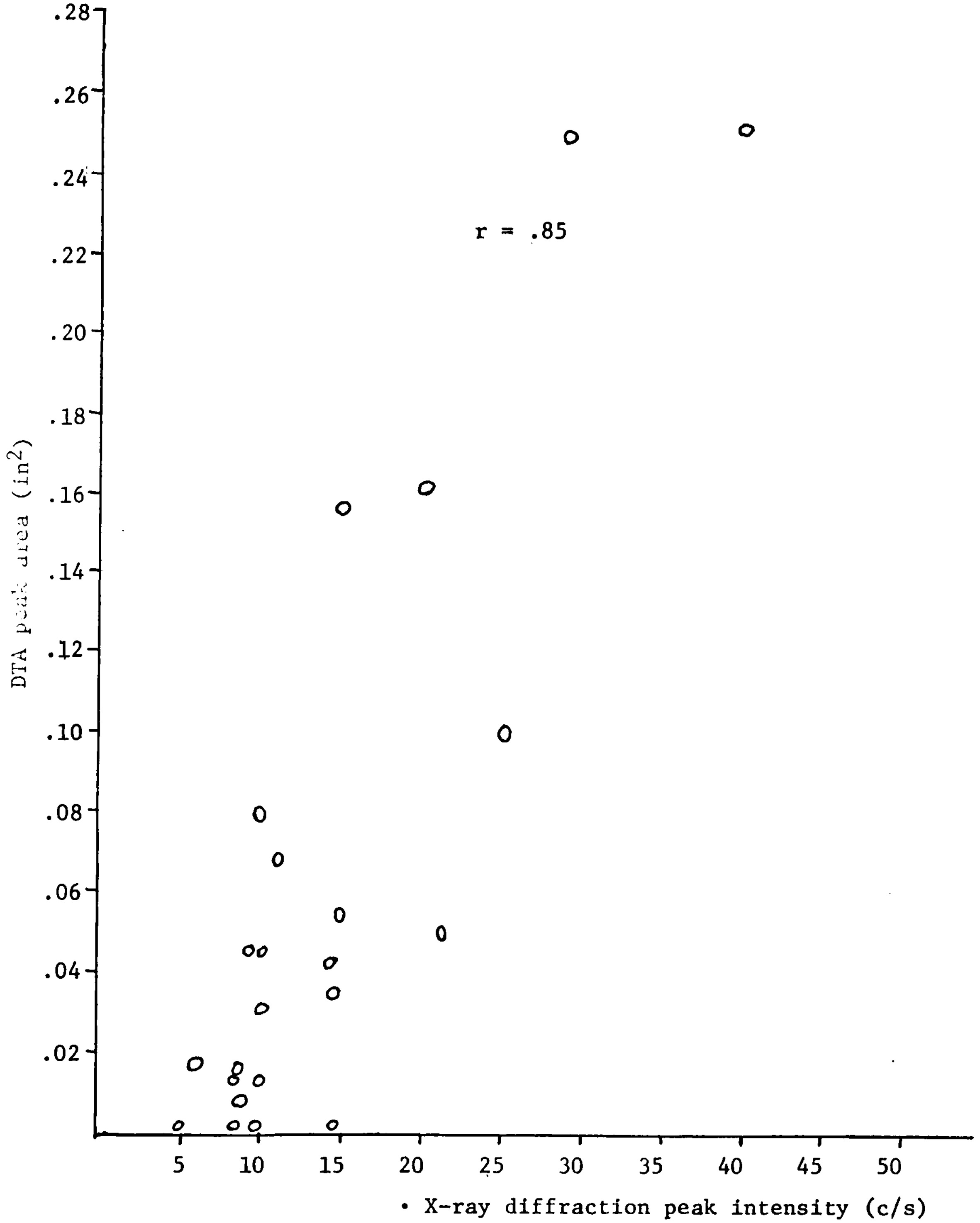


Fig. 20. The relation between 4.84 Å X-ray diffraction peak intensities and area under the 260-290° DTA peaks.

Jorgensen (1970) also reported low endothermic peaks (268°-272° C) for gibbsite in a peaty podzol soil. The absence of the 330-340° C peak for gibbsite may be due to the high organic matter content of some horizons which gives a broad exothermic peak in the region of 320-350° C which may be masking the primary gibbsite peak.

An attempt was made to correlate X-ray diffraction peak intensities of gibbsite (4.82-4.87 Å) with peak areas of 260-290° endothermic peaks of the DTA patterns (Figure 20). A positive correlation of 0.85 was obtained.

In bay profiles above 10 ft. elevation the 260-290° DTA endothermic peaks for gibbsite increased with an increase in depth from the B horizons downward (Eg. Figures 18 and 19). The presence of less gibbsite in the upper horizons suggests the "antigibbsite" effect (Jackson, 1962), which occurs in soils where 2:1 layer silicates are actively weathering. This may also be indicative of greater amounts of interlayered vermiculite in the surface horizons.

Quartz was detected in all horizons by the diagnostic 4.26 Å X-ray diffraction peak. The low intensity of most of these peaks (Table D, Appendix I) suggests relatively low quartz contents in the clay fractions. Jackson (1968) reports that the appearance of the 4.26 Å peak is indicative of amounts present greater than 10%.

Feldspars were detected in a few horizons as characterized by 3.18-3.24 Å spacings (Jackson, 1964). These peaks are of low intensity (Table D, Appendix I) which suggests relatively low amounts.

X-ray diffraction spacing of 25 Å and 21 Å were observed in samples from the B_{2t} and C_1 horizons when Mg-saturated and glycerol solvated from Bay 8. These spacings suggest regular interstratification of mica and vermiculite (Jackson, 1956) in these horizons.

Silt Mineralogy -- The silt fractions consists primarily of quartz with small amounts of feldspar, mica, kaolinite, and 14 Å minerals as evidenced by the relative intensities of X-ray diffraction spacings (Table F, Appendix I).

Mineralogy of Carolina Bay Soils Below 10 ft. Elevation

Clay fraction (<2μ) -- The rim soil profile from Bay 256 (10 ft. elevation) contains predominantly interlayered vermiculite and kaolinite with lesser amounts of illite, chlorite, gibbsite and quartz. The data (Figure 21) suggests that the clay minerals of this profile is similar to those above 10 ft.

The depression soil of Bay 256 is dominated by kaolinite and interlayered vermiculite in the upper (A_1 and B_2) horizons and by kaolinite and illite in the lower (C_1 and C_3) horizons. The strong 520-530° endothermic peaks (Appendix II) for these horizons indicate the predominance of kaolinite. Montmorillonite was also present in the A_1 and C_1 horizons. The 4.26 Å peak for quartz is relatively intense suggesting greater amounts than previously discussed. Relatively small amounts of interlayered vermiculite were detected in the lower horizons. Traces of gibbsite were also present as indicated by the small 4.87 Å peaks in the A_1 and C_1 horizons.

The dominant clay minerals of the rim profile of Bay 199 (3-5 ft. elevation) are interlayered vermiculite and kaolinite (Figure 22).

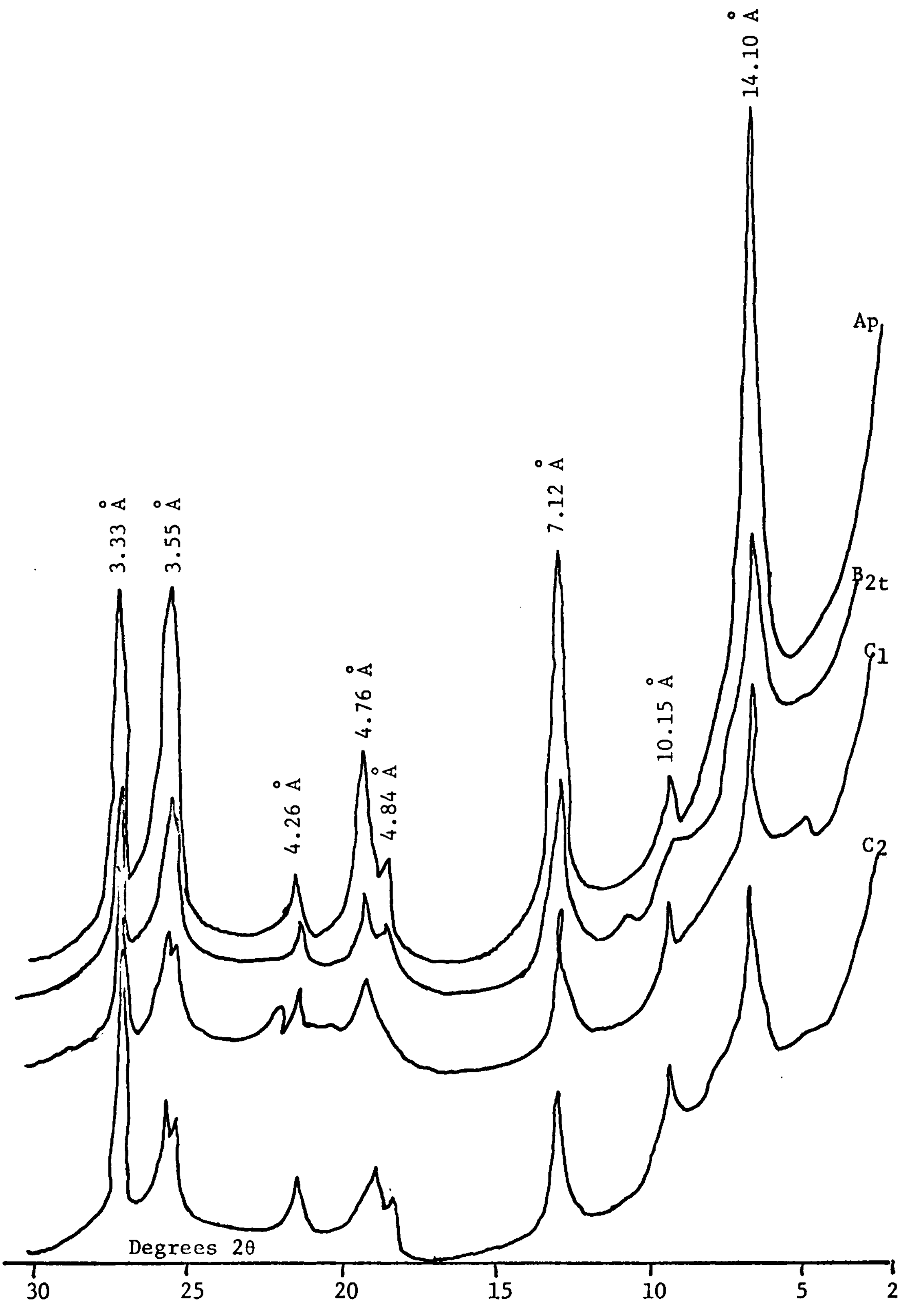


Fig. 21. X-ray diffractions patterns for <2μ fraction of rim profile from Bay 256, Mg-saturated, glycerol-saturated.

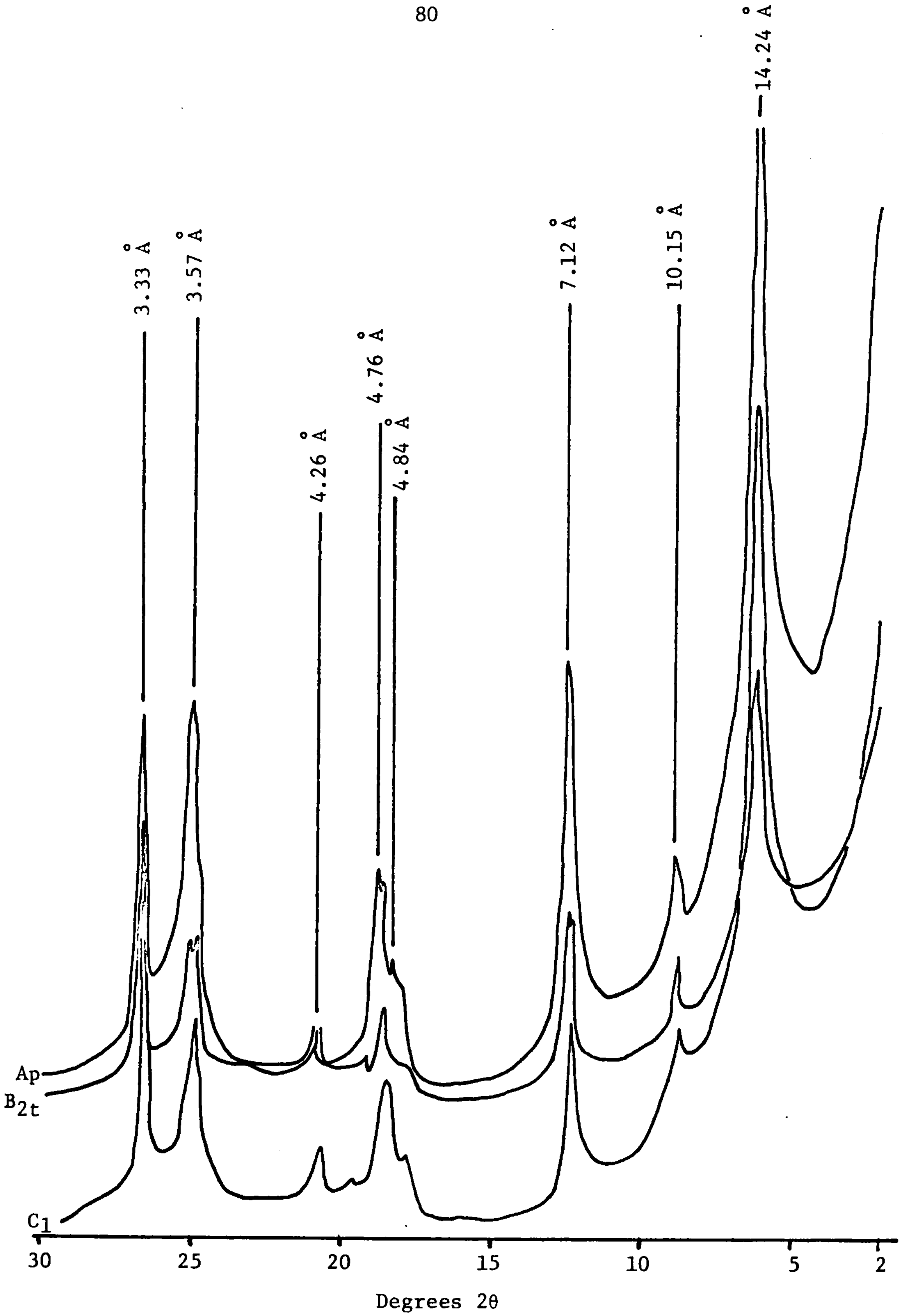


Fig. 22. X-ray diffraction patterns for the <2μ fraction of the rim soil of Bay 199, Mg-saturated, glycerol solvated, 25° C.

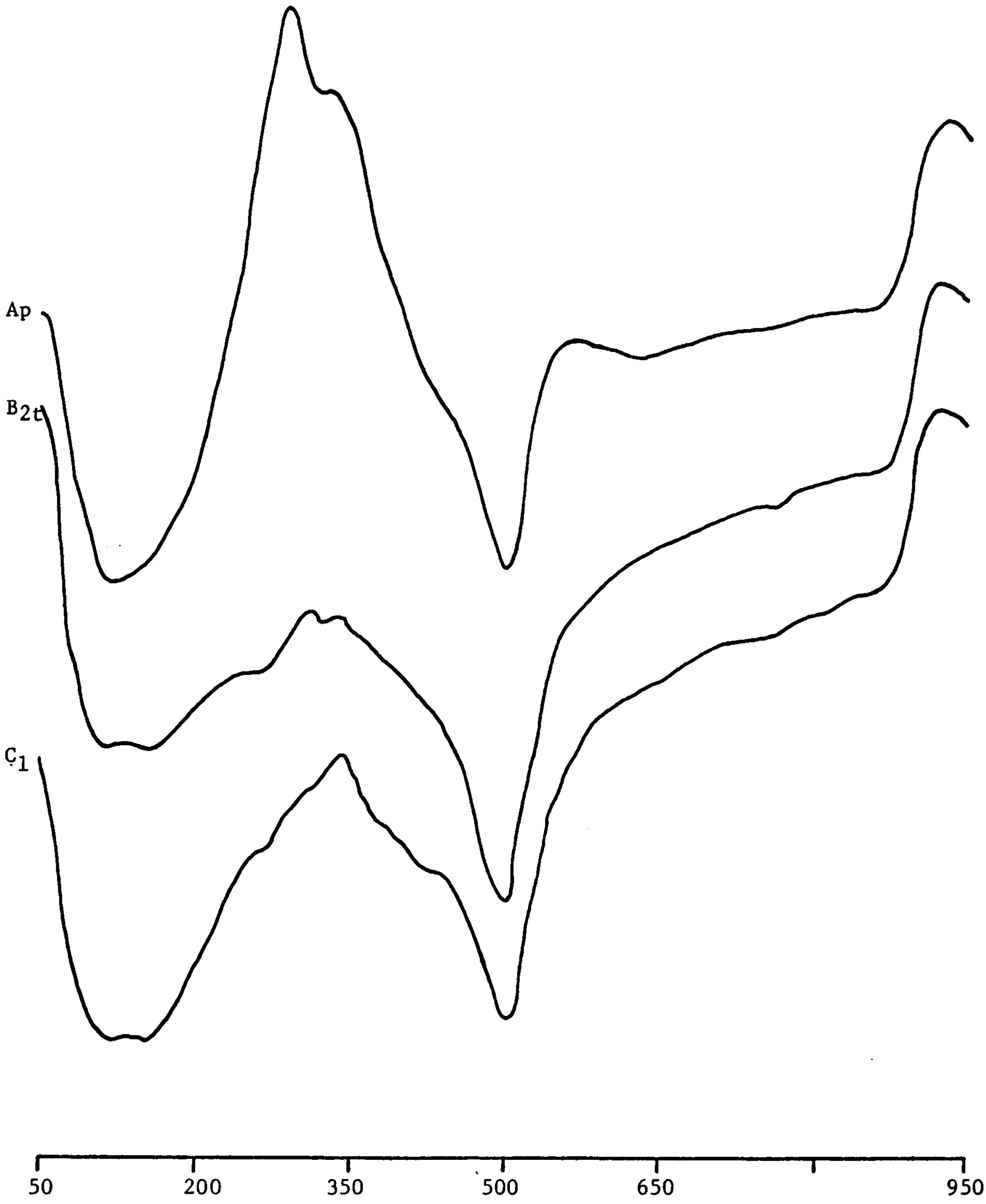


Fig. 23. Differential thermal analysis patterns for the <2μ fraction of the rim profile from Bay 199, Mg-saturated, equilibrated at 56% R.H.

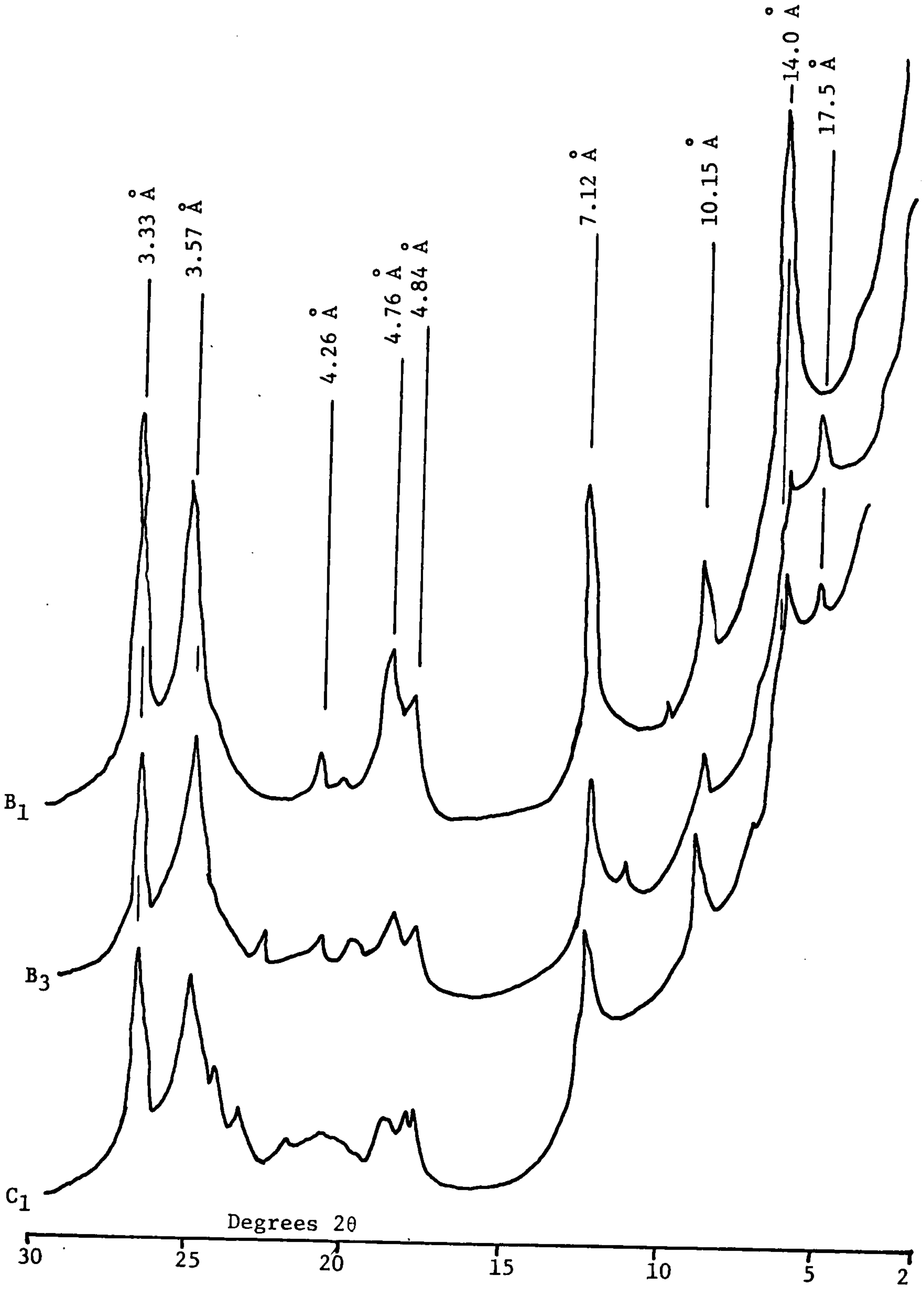


Fig. 24. X-ray diffraction patterns for the <2μ fraction of the depression profile of Bay 199, Mg-saturated, glycerol solvated, 25° C.

Chlorite is present in the B_{2t} and C_1 horizons in relatively small amounts but is absent in the surface horizons. Illite or mica and quartz are present in small amounts. Gibbsite is also present in relatively small amounts as characterized by the small endothermic reactions at 265° on the DTA patterns (Figure 23) and the 4.87 Å X-ray diffraction peaks. The 14 Å peaks of the C horizon of this profile appear more intense than those of the A horizon. This is in sharp contrast to the trend of decreasing intensity with depth that was observed in rim profiles of bays above 10 ft. in elevation.

The clay fraction of the soil profile of Bay 199 is dominated by kaolinite and interlayered vermiculite in the upper (B_1) horizon, kaolinite and montmorillonite in the B_3 horizon and by kaolinite, vermiculite and illite in the lower (C_1) horizon (Figure 24; Table E, Appendix I). Quartz is present in relatively small amounts in every horizon. The small 4.87 Å X-ray diffraction peak of the C_1 suggests the presence of traces of Gibbsite.

Silt fraction (2-50μ) -- The silt fractions of the bay soils below 10 ft. elevations are dominated by quartz as indicated by the relatively intense 4.26 Å peaks (Table F, Appendix I). Relatively small amounts of feldspars, kaolinite, mica and 14 Å minerals are also present in the silt fractions. Two horizons (A_1 and C_3 horizons, Bay 256) show conspicuous feldspar peaks (3.24 Å, 38 cps; 3.23 Å, 42 cps).

Clay and silt mineralogical data suggests that soils of Carolina bays 10 ft. or greater in elevation (including the rim of Bay 256) are dominated by interlayered vermiculite and kaolinite. They are also generally characterized by decreasing intensity of X-ray diffraction peaks with increasing depth in the profiles. Gibbsite is present in the subsurface horizons. The greatest amounts occur in the profiles above 20 ft. in elevation. The silt fraction (2-50μ) consists mainly of quartz. These bays are characterized morphologically (Appendix III) by well drained rim soils with colors of brown to reddish brown and well drained to somewhat poorly drained depression soils with colors of yellowish-brown and brownish-gray.

The rim profile of Bay 199 (3-5 ft. elevation) is dominated by kaolinite and interlayered vermiculite. The X-ray diffractions are of greater intensity in lower horizons in contrast to decreasing intensity of rim soils of higher occurring bays. This soil is moderately well to somewhat poorly drained with dark brown to olive colors in the B horizon.

The depression profiles of Bays 256 and 199 are dominated mainly by kaolinite, montmorillonite, illite and vermiculite. These soils are poorly to very poorly drained with colors of grayish-brown and dark gray in the B horizon.

SUMMARY AND CONCLUSIONS

A total of 163 landforms were identified in Accomac and Northampton Counties, Virginia, using remote sensing data provided by the National Aeronautics and Space Administration. Based on their morphology most of these landforms are considered to be Carolina bays. The primary features of soil and vegetation used in delineating these landforms on imagery compared favorably with characteristics observed in the field investigation. Bay depressions are delineated by semi-elliptical forested areas and soils which are wetter and darker than surrounding soil areas. Bay rims are characterized by drier and lighter soils than adjacent upland and depression soils which usually produce reduced vegetative growth. Vegetation which has high infrared reflectance is important in delineating bays on the salt marsh.

Bay features such as ellipticity, form, orientation and rim development were in general found to be similar to that reported from other areas. However there was a tendency for bays of this study to be more nearly round than other bays as evidenced by an average ellipticity 0.79. Average orientation also differed by being more westerly than the northernmost bays of North Carolina, which agrees with the trend that was suggested by Johnson (1942). A tendency for more well developed rims to occur in southeastern quadrants of bays was observed but the relationship did not appear as strong as that often reported in other areas. Degree of development of bay form was also observed. Forms were observed that ranged from complete oval bays to semi-elliptical ridges, which apparently agrees with the descriptions given by Johnson (1942).

Carolina bays were observed to occur mainly on the higher elevation along the backbone of the Eastern Shore peninsula. Small groups of bays occur on the peninsula south of Wachapreague and on the salt marsh between Guildford Creek and Sandford. Occurrence in groups shows a non-random distribution. Association of higher lying bays with poorly and somewhat poorly drained areas having a similar linear distribution suggests that a relationship between the two occurs. The restriction of bay size according to occurrence on land surface type suggests that size of land surface may have influenced bay size.

Truncation of bays near Wachapreague and Quinby by a low scarp suggests a probable age of late Sangamon for those bays. The occurrence of bays at elevations below the scarp definitely indicates that they are younger than higher lying bays.

Examination of soils from 41 Carolina bays showed that soils on rims of bays above 10 ft. in elevation had dominantly sandy clay loam textures, and strong brown colors in B horizons and solum depths ranging from 30 to 50 inches. In contrast rim soils of bays occurring below 10 ft. in elevation had yellowish-brown to grayish-brown colors and sandy loam to loamy sand textures in B horizons and solum depths less than 30 inches. Rim soils are generally well drained to moderately well drained.

Bay depression soils above 10 ft. differ from rim soils mainly by having slightly heavier textures, lighter or yellower colors. Drainage varies from well drained to very poorly drained. Depression soils below 10 ft. in elevation are poorly to very poorly drained with dark colors and heavier textures.

The substratum of bay soils was observed to be sandy in nature suggesting a sandy environment of bay formation as was observed elsewhere by Thom (1970).

Size distribution of sand fractions suggests that rim sediments were deposited by an agent of greater energy than depression sediments which also resulted in more consistent sorting patterns between rims of different bays than between depressions. Examination of profiles within and adjacent to bays suggested that underlying sediments were related.

Comparison of rim soils of the study area with those described in other areas suggest that bays of the study area are of younger age.

The dominant clay minerals of bay soils above 10 ft. in elevation consist of interlayered vermiculite and kaolinite. X-ray diffraction peak intensities decrease with increasing depth in the profile. The rim soil of bays below 10 ft. are also dominated by interlayered vermiculite and kaolinite but peak intensities increase with depth. Bay depression soils below 10 ft. in elevation have higher amounts of illite, vermiculite and montmorillonite.

The morphological and mineralogical data of soils indicate that Carolina bays occurring above 10 ft. in elevation are probably older than those below 10 ft. near sea level. The mineralogical data in itself is not absolutely conclusive because of the possible effects of drainage and influence by salts. However soil color and textural differences and the truncation of bays by a terrace scarp present strong evidence that bay formation has occurred in stages.

Definite conclusions that can be drawn from this study are that elliptical landforms on the Eastern Shore are Carolina bays and that there were at least two stages of bay formation. Other evidence strongly suggests that these bays were formed in shallow natural depressions during late Pleistocene and in more recent times. Bay rims were formed by a process that tended to sort sediments in a distinctive pattern. The process of bay formation also resulted in bays being more nearly round than in other areas.

It can also be concluded that infrared imagery is useful for delineation of landforms that are characterized by soil and vegetation differences.

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APPENDIX I

Table A. Location, elevation and morphological data for Carolina bays and similar landforms of the Eastern Shore, Virginia.

Bay	Location	U.S.G.S. 7.5 min. Topographic Sheet	Elev.	Orient.	Length	Width	Ellipt. L/W	Point of Best Rim Development*	Bay Type
1	Latimer Siding	Townsend	30'	305°	1747	1589	.91	1-2-3-4-5	Complete
2	Kiptopeake Beach	Townsend	30'	320°	3575	3178	.89	5-6-7-8-1	Complete
7	Devils Ditch	Townsend	35'	295°	5160	4050	.78	6-7-8-1	Complete
8	Townsend	Townsend	30'	300°	1000	900	.09	--	Complete
9	Townsend	Townsend	30'	290°	800	700	.88	--	Complete
9.5	Townsend	Townsend	30'	290°	1400	1100	.79	1-2-3-4-5-6	Complete
11	Cheapside	Townsend	35'	-	--	--	--	--	Ridge
12	Capeville	Townsend	30'	298°	3180	2620	.82	2-3-4-5-6	Complete
15	Cape Center	Townsend	33'	285°	5080	3810	.75	1-2-3-4-6-7-8	Complete
19	E. of Dalbys	Townsend	30'	300°	1990	1510	.76	1-2-3-4-5-6-8	Complete
20	E. of Dalbys	Townsend	30'	300°	1830	1670	.91	1-2-3-4-5-6-7-8	Complete
21	Plantation	Townsend	35'	290°	1600	1500	.94	1-2-3-4-5-6-7-8	Complete
23	Seaview	Cheriton	33'	295°	1910	1430	.75	1-2-3-4-5	Complete
25	Seaview	Cheriton	33'	295°	2060	1670	.81	1-2-3-5	Complete
27	Seaview	Cheriton	35'	295°	1510	1190	.79	1-2-3-4-5	Complete
28	Culls	Cheriton	35'	275°	4290	3420	.80	4-5-6-7-8	Complete
30	Chesapeake	Cheriton	40'	-	--	--	--	2-3-4-5	Half
31	Little Salisbury	Cheriton	40'	290°	3500	2620	.75	4-6-7-8	Complete
32	Simkins	Cheriton	35'	-	--	--	--	--	Ridge
33	Simkins	Cheriton	35'	320°	2540	2380	.94	4-5-6-7-8	Complete
24	E. of Stumptown	Cheriton	35'	275°	2380	1590	.67	--	Complete
35	Eastville Station	Cheriton	35'	290°	4050	2940	.73	1-2-3	Complete
36	Eastville	Cheriton	40'	-	--	--	--	2-3-4	Half
42	Machipongo	Franktown	40'	-	--	--	--	2-3-4-5	Half
43	E. of Treherneville	Franktown	33'	-	--	--	--	--	Ridge
46	W. of Birdsnest	Franktown	35'	325°	870	720	.83	--	Complete
46	W. of Bridsnest	Franktown	35'	295°	790	710	.90	--	Complete
47	N. of Birdsnest	Franktown	35'	-	--	--	--	--	Ridge
49	S. of Weirwood	Nassawadox	40'	-	--	--	--	--	Ridge
50	Wierwood	Nassawadox	35'	310°	4370	3260	.75	4-6-8	Complete
51	S. of Marionville	Nassawadox	30'	295°	1270	1030	.81	2-3-4-5-6	Complete
52	N.W. of Nassawadox	Nassawadox	40'	-	--	--	--	1-2-3-4-5	Half Bay
53	Hare Valley	Nassawadox	35'	-	--	--	--	--	Ridge
58	Hare Valley School	Exmore	40'	300°	4210	2383	.57	1-2	Complete
60	S.E. of TB Crossroads	Exmore	35'	300°	4530	3260	.72	2-3-4-5	Complete

Table A. (Continued).

Bay	Location	U.S.G.S. 7.5 min. Topographic Sheet	Elev.	Orient.	Length	Width	Ellipt. L/W	Point of Best Rim Development*	Bay Type
61	TB Crossroads	Exmore	40'	300°	4610	2450	.55	7-8-1	Complete
63	Hadlock	Exmore	40'	300°	4690	2780	.59	3-4-5-6	Complete
64	Epworth Church	Exmore	40'	300°	3654	2940	.80	3-4	Complete
66	N. of Exmore	Exmore	35'	310°	4000	3400	.85	5-6-8	Complete
67	Belle Haven	Exmore	35'	292°	3400	2800	.82	4-5-6	Complete
69	N.W. of Savage Town	Exmore	35'	295°	5400	4000	.74	1-2-5-7-8	Complete
70	Coal Kiln Crossing	Exmore	35'	295°	3600	2000	.56	1-2-3-8	Complete
73	Upshure Neck	Exmore	7'	295°	1830	1430	.78	3-4-5	Complete
74	Shields	Exmore	30'	-	--	--	--	5-6-7-8	Half
75	Coal Kiln Crossing	Exmore	35'	-	--	--	--	6-7-8	Ridge
76	S.E. of Painter	Exmore	35'	300°	500	450	.90	--	Complete
77	S.W. of Painter	Exmore	35'	295°	2060	1670	.81	3-4-5	Complete
78	1 mi. N.W. of Painter	Exmore	40'	295°	600	500	.83	--	Complete
79	1 mi. N.W. of Painter	Exmore	40'	295°	1400	1200	.86	2-3-4-5-6	Complete
80	1 mi. N.W. of Painter	Exmore	40'	-	--	--	--	5-6	Half
81	.75 mi. W. of Red Hill	Exmore	35'	-	--	--	--	2-3-4-5	Half
82	Central High School	Exmore	40'	-	600	600	1.00	--	Round
84	1 mi. S. of Pennyville	Exmore	35'	302°	--	--	--	2-6-7-8	Half
85	1 mi. S. of Pennyville	Exmore	35'	-	--	--	--	1-2-3-4-5-6-7-8	Com.Round
87	.75 mi. S.E. of Pennyville	Exmore	40'	320°	--	--	--	7-8-1	Half
89	2 mi. W. of Keller Rt. 619	Exmore	40'	285°	1600	1400	.88	2-3-5-6-8	Complete
92	2 mi. W.S.W. of Keller	Exmore	40'	280°	1900	1500	.79	1-2-6-7-8	Complete
94	2 mi. W.S.W. of Keller	Exmore	38'	305°	4800	3900	.82	1-2-4-5-6	Complete
95	2 mi. W.S.W. of Keller	Exmore	40'	300°	1800	1500	.83	1-2-3-4-5	Complete
105	1 mi. S. of Quinby	Wachapreague	10'	300°	1190	950	.80	3-4	Complete
106	.75 mi. S. of Quniby	Wachapreague	10'	-	790	720	.91	3-4-5	Rounded
107	.5 mi. N. of Quinby	Wachapreague	8'	-	--	--	--	--	Half
109	1.5 mi. N. of Quinby	Wachapreague	10'	-	--	--	--	--	Half
110	1.5 mi. N. of Quinby	Wachapreague	10'	-	--	--	--	--	Half
112	2.5 mi. S. of Wachapreague	Wachapreague	10'	-	--	--	--	--	Half
113	2.4 mi. S. of Wachapreague	Wachapreague	10'	300°	1510	950	.63	1-2-3-4-5	Complete
115	1.2 mi. S. of Wachapreague	Wachapreague	10'	295°	720	520	.72	2-3-4-5	Complete
116	.34 mi. S. of Wachapreague	Wachapreague	10'	300°	500	450	.90	--	Complete
117	.5 mi. S. of Wachapreague	Wachapreague	10'	300°	600	600	1.00	--	Complete
118	Wachapreague	Wachapreague	10'	295°	790	640	.81	2-3-4-5	Complete

Table A. (Continued).

Bay	Location	U.S.G.S. 7.5 min. Topographic Sheet	Elev.	Orient.	Length	Width	Ellipt. L/W	Point of Best Rim Development*	Bay Type
120	S.W. of Wachapreague	Wachapreague	10'	-	--	--	--	2-3-5-6	Half
121	N. of Wachapreague	Wachapreague	10'	-	--	--	--	--	Ridge
122	1 mi. S. of Melfa	Accomac	45'	295°	700	600	.86	1-2-3-4-5-6-8	Complete
123	S. of Melfa	Accomac	42'	290°	1200	1000	.83	1-2-3-6	Complete
124	Melfa	Accomac	45'	295°	2000	1600	.80	1-2-3-4-5-7-8	Complete
125	.5 mi. N.E. of Melfa	Accomac	50'	305°	2460	1830	.74	1-2-3-4-5-6-7-8	Complete
217	1 mi. N. of Melfa	Accomac	55'	-	--	--	--	--	Half
129	Rt. 13 N. of Melfa	Accomac	50'	300°	1200	1000	.83	1-3-4	Complete
130	2 mi. N.E. of Melfa	Accomac	50'	280°	3400	2000	.59	2-3-6-7	Complete
131	1.5 mi. S.S.W. of Onley	Accomac	45'	305°	4000	3000	.75	4-5-6-8	Complete
132	N.W. Rim of Bay 131	Accomac	45'	295°	2800	2100	.75	1-2-5-6-8	Complete
133	1.2 mi. S.E. of Locustville	Accomac	10'	-	--	--	--	2-3-4-5-6	Half
136	1.5 mi. S.E. of Onley	Accomac	40'	285°	2000	1500	.75	3-4-5	Complete
137	1.7 mi. E.S.E. of Onley	Accomac	40'	300°	1750	1590	.91	1-2-3-4-5-6-7	Complete
142	S.W. of Allentown	Accomac	45'	305°	2140	1750	.82	4-5-6-7-8	Complete
143	Allentown	Accomac	45'	300°	3340	2860	.86	4-5-8	Complete
145	E.S.E. of Tasley	Accomac	45'	305°	2200	1650	.75	2-3-4-5-6-7-8	Complete
146	Inside of 145	Accomac	45'	305°	950	650	.68	--	Complete
147	N.E. of 145	Accomac	45'	-	--	--	--	--	Ridge
148	Whispering Pines	Accomac	45'	-	--	--	--	--	Ridge
149	.75 mi. W. of Tasley	Accomac	40'	315°	1270	1190	.94	1-2-3-4-6-7-8	Complete
150	.75 mi. N.W. of Tasley	Accomac	33'	295°	1430	1270	.89	1-3-4-5-6-7-8	Complete
153	2 mi. E.N.E. of Accomac	Accomac	25'	310°	1430	1190	.83	1-2-6-7-8	Complete
154	1.5 mi. N. of Accomac	Accomac	45'	310°	500	450	.90	--	Complete
155	1 mi. N. of Accomac	Accomac	45'	-	1100	1100	1.00	--	Round
156	.6 mi. N.N.E. of Ticktown	Accomac	40'	330°	1270	950	.75	1-5-6-7-8	Complete
160	Joynes Neck	Accomac	20'	275°	1110	1030	.94	1-2-3-4-5-6	Complete
161	Joynes Neck	Accomac	20'	290°	1110	790	.71	1-2-3-4-5-7-8	Complete
162	Joynes Neck	Metomkin Inlet	20'	295°	1110	870	.78	1-2-3-4-5-6-7-8	Complete
163	Parker Neck	Parksley	20'	310°	870	560	.64	2-3-4-5-6	Complete
181		Parksley	40'	-	--	--	--	--	Ridge
182		Parksley	40'	-	--	--	--	--	Half
184	1 mi. S.S.E. of Parksley	Parksley	40'	-	--	--	--	--	Half
185	1 mi. S.S.E. of Parksley	Parksley	40'	-	--	--	--	--	Half
186	1.5 mi. S.E. of Parksley	Parksley	45'	320°	190	560	.71	1-2-7-8	Complete

Table A. (Continued).

Bay	Location	U.S.G.S. 7.5 min. Topographic Sheet	Elev.	Orient.	Length	Width	Ellipt. L/W	Point of Best Rim Development*	Bay Type
187	1.5 mi. S.E. of Parksley	Parksley	45'	-	--	--	--	--	Ridge
188	1.5 mi. S.E. of Parksley	Parksley	45'	-	1190	1110	.93	2-3	Round
189	.75 E.S.E. of Parksley	Parksley	40'	295°	3810	2940	.77	3-4-5-6-7-8	Complete
190	.5 mi. S.E. of Parksley	Parksley	45'	300°	480	440	.92	1-2-3-4-5-6	Complete
191	.5 mi. S.E. of Parksley	Parksley	45'	300°	560	440	.79	1-2-3-4-5-6-7-8	Complete
199	1 mi. W. of Winterville	Parksley	0'	295°	2300	1900	.83	1-2-6-7-8	Complete
206	Old Tree Island	Parksley	0'	310°	2800	2100	.75	5-6-7	Complete
213	1.2 mi. E.S.E. of Centerville	Bloxom	20'	-	1900	1830	.96	1-2-3-4	Round
216	S. of Rue	Bloxom	45'	300°	1910	1750	.92	1-2-3	Complete
217	.5 mi. N.W. of Rue	Bloxom	50'	290°	870	720	.83	2-3-4	Complete
218	.5 mi. N.W. of Rue	Bloxom	46'	270°	1110	870	.78	--	Complete
219	.5 mi. N.W. of Rue	Bloxom	45'	310°	1590	950	.60	1-2-7-8	Complete
221	Gargatha	Bloxom	45'	280°	2380	2220	.93	4-5-6	Complete
222	.5 mi. N.W. of Gargatha	Bloxom	50'	290°	630	560	.89	1-2-3-4-5-6-7-8	Complete
223	.5 mi. N.W. of Gargatha	Bloxom	50'	300°	1190	1030	.87	1-7-8	Complete
224	.7 mi, S.E. of Nelsonia	Bloxom	45'	290°	1350	1110	.82	1-6-7-8	Complete
225	.5 mi. S.S.W. of Nelsonia	Bloxom	50'	295°	1270	1030	.81	1-6-7-8	Complete
226	S.S.W. of Nelsonia	Bloxom	50'	-	1580	1510	.96	4-5-6-6	Round
228	N.E. of Nelsonia	Bloxom	50'	305°	5160	3970	.77	2-3-6-7	Complete
229	1.3 mi. N. of Nelsonia	Bloxom	45'	-	--	--	--	1-2-3-4-5-6-7-8	Round
230	1 mi. S.W. of Mappsville	Bloxom	50'	315°	2200	1670	.76	3-4-5-6-7	Complete
231	1 mi. S. of Mappsville	Bloxom	43'	290°	4290	3260	.76	4-5-6	Complete
233	Mappsville	Bloxom	50'	-	--	--	--	--	Half
234	W. of Mappsville	Bloxom	50'	290°	4920	3570	.73	6-7-8	Complete
235	N. of Mappsville	Bloxom	50	295°	1980	1670	.84	2-3-4-5	Complete
241	1.5 mi. SSE of Temperanceville	Bloxom	45'	295°	2780	2065	.74	6	Complete
244	Messongo Creek	Saxis	5'	-	--	--	--	--	Ridge
245	Messongo Creek	Saxis	5'	-	--	--	--	--	Ridge
246	1.5 mi. SE of Marsh Market	Saxis	5'	-	--	--	--	--	Ridge
247	1.5 mi. SE of Marsh Market	Saxis	5'	-	--	--	--	--	Ridge
249	.5 mi SE of Messongo	Saxis	5'	-	--	--	--	--	Ridge
250	Sandford	Saxis	5'	290°	9100	5900	.65	1-5-6-8	Complete
255	.5 mi. N. of Jenkins Bridge	Hallwood	10'	-	---	--	--	--	Ridge
256	.5 mi. W. of Miona	Hallwood	15'	-	1500	1500	1.00	1-3-4-5-6-7-8	Round
258	1 mi. S. of Temperanceville	Hallwood	45'	-	--	--	--	--	Ridge

Table A. (Continued).

Bay	Location	U.S.G.S. 7.5 min. Topographic Sheet	Elev.	Orient.	Length	Width	Ellipt. L/W	Point of Best Rim Development*	Bay Type
260	SE of Temperanceville	Hallwood	40'	330°	1500	1030	.69	4-5-6	Complete
262	N.W. of Temperanceville	Hallwood	45'	-	--	--	—	--	Ridge
265	1.2 mi. N. of Temperanceville	Hallwood	45'	307°	950	670	.71	2-3-4-5-6-7-8	Complete
266	Jerusalem Church	Hallwood	40'	-	--	--	--	2-3-4	Half
267	12. mi. N.W. of Atlantic	Hallwood	40'	-	--	--	--	2-3-4-5	Half
268	1 mi. N.W. of Atlantic	Hallwood	40'	305°	1980	1750	.88	2-3-5-6-7-8	Complete
270	S.S.E. of Atlantic	Hallwood	40'	-	--	--	--	--	Ridge
271	E. of Atlantic	Hallwood	40'	-	--	--	--	1-2-3-4-5	Half
273	W.N.W. of Atlantic	Hallwood	40'	285°	2540	2140	.84	1-5-6-7-8	Complete
274	S.W. of Bay 273	Hallwood	40'	305°	2940	2220	.76	2-4-7-8	Complete
276	.6 mi. S. of Johnsons Corner	Hallwood	40'	295°	950	710	.75	4-5-6	Complete
277	N. of Bay 276	Hallwood	40'	-	600	600	1.00	--	Round
278	.5 mi. SSW of Johnsons Corner	Hallwood	30'	-	--	—	--	--	Ridge
279	.75 mi. ENE of Johns Corner	Hallwood	40'	297°	1830	1430	.78	--	Complete
281	.3 mi. W. of Friendship Church	Hallwood	40'	-	--	--	--	--	Half
282	1 mi. S.E. of Nash Corner	Hallwood	45'	297°	1750	1590	.91	1-2-3-8	Complete
283	S.E. of Bay 282	Hallwood	45'	290°	1100	830	.75	1-2-3-4-5-6-7-8	Complete
284	1 mi. ESE of Nash Corner	Hallwood	40'	295°	1350	1220	.90	1-2-3-4-8	Complete
286	.3 mi WNW of Chincoteague Church	Hallwood	25'	-	--	--	--	--	Ridge
287	.75 mi. SSW of Wallops Station	Chincoteague W.	40'	300°	1590	1270	.80	2-3-4-5-6	Complete
285	.7 mi. E. of New Church	Hallwood	30'	-	--	--	--	--	Ridge
135	S.E. of Onley	Accomac	50'	300°	1750	1200	.68	2-3-4-5	Complete
44	--	Franktown	35'	290°	900	800	.89	--	Complete

* Rim development signified by occurrence at cardinal and intercardinal points of the compass. 1 = North; 2 = Northeast; 3 = East; 4 = Southeast; 5 = South; 6 = Southwest; 7 = West; and 8 = Northwest.

Table B. Soil profile data from the field investigation of 41 Carolina Bays.

			Rim						Depression					
Bay	Elev.	Relief	Solum Depth	B_t Depth	Sur. Tex.	B_t Tex.	Sur. Color	B_t Color	Solum Depth	B_t Depth	Sur. Tex.	B_t Tex.	Sur. Color	B_t Color
1	30'	8'	--	--	--	--	--	--	45"	35"	sl	scl	--	5Y 6/3
2	30'	12'	--	--	--	--	--	--	35"	22"	ls	sl	--	2.5Y 6/4
9.5	30'	8'	--	--	--	--	--	--	45"	30"	ls	scl	--	2.5Y 6/4
7	35'	12'	--	--	--	--	--	--	36"	22"	ls	scl	--	5Y 6/2
8	30'	8'	50"	40"	ls	scl	10YR 4/3	7.5YR 4/4	47"	27"	sl	scl	10YR 4/2	10YR 5/8
12	30'	10'	50"	--	ls	sl	--	--	38"	32"	sl	scl	--	10YR 6/6
19	30'	10'	--	--	--	--	--	--	36"	26"	ls	sl	--	5Y 6/3
20	30'	8'	--	--	ls	sl	--	--	37"	30"	l	cl	--	2.5Y 6/2
23	33'	10'	--	--	--	--	--	--	38"	30"	sl	scl	--	10YR 5/4
25	33'	--	30"	20"	ls	scl	--	7.5YR 5/6	36"	26"	sl	scl	--	5Y 6/3
27	35'	10'	35"	18"	sl	scl	--	7.5YR 5/6	30"	22"	ls	scl	--	2.5Y 6/4
28	35'	8'	--	--	--	--	--	--	30"	22"	--	--	--	10YR 7/3
50	35'	10'	--	--	--	--	--	--	36"	28"	sl	scl	--	2.5Y 6/3
51	30'	10'	36"	20"	ls	scl	--	7.5YR 5/6	36"	20"	l	cl	10YR 3/1	2.5Y 6/2
122	45'	9'	32"	24"	ls	scl	10YR 3/3	10YR 5/8	40"	20"	sl	scl	10YR 3/2	2.5Y 5/4
123	42'	11'	34"	27"	ls	scl	10YR 4/3	7.5YR 5/6	36"	20"	sl	scl	10YR 3/2	5Y 6/2
124	45'	15'	33"	22"	sl	scl	10YR 3/3	10YR 5/6	33"	21"	sl	scl	10YR 4/2	--
125	50'	12'	31"	26"	ls	sl	10YR 4/3	10YR 5/6	40"	28"	sl	scl	10YR 3/1	2.5Y 6/2
137	40'	15'	18"	16"	ls	sl	10YR 3/3	10YR 5/6	49"	40"	sl	scl	10YR 4/2	10YR 5/1
234	50'	10'	36"	--	ls	scl	--	--	30"	22"	sl	scl	10YR 3/1	5Y 6/2
235	50'	8'	24"	14"	ls	sl	10YR 4/3	7.5YR 5/6	30"	22"	sl	scl	10YR 3/1	5Y 6/2
267	40'	4'	35"	24"	sl	scl	10YR 5/3	10YR 5/8	--	--	--	--	--	--
268	40'	4'	35"	24"	sl	scl	10YR 5/3	10YR 5/8	32"	22"	sl	scl	10YR 6/2	2.5Y 6/4
273	40'	4'	28"	20"	sl	scl	10YR 5/3	10YR 5/8	28"	20"	l	scl	10YR 2/1	10YR 5/1
274	40'	4'	40"	32"	sl	scl	10YR 6/2	10YR 5/6	42"	38"	l	scl	10YR 3/3	10YR 7/1
281	40'	3'	35"	24"	ls	sl	2.5Y 5/2	10YR 6/4	32"	22"	sl	scl	2.5Y N/4	2.5Y N/6
282	45'	6'	42"	36"	sl	scl	10YR 5/4	10YR 5/8	17"	11"	l	cl	10YR 4/1	10YR 6/1
283	45'	5'	42"	25"	sl	scl	10YR 5/3	7.5YR 5/6	29"	23"	l	c	10YR 5/1	2.5Y N/6
284	40'	4'	33"	22"	sl	scl	10YR 5/4	10YR 6/6	38"	31"	l	cl	10YR 6/2	2.5Y 6/1
287	40'	10'	--	--	--	--	--	--	38"	26"	sl	scl	10YR 4/3	10YR 5/6

Table B. (Continued).

			Rim						Depression					
Bay	Elev.	Relief	Solum Depth	B_t Depth	Sur. Tex.	B_t Tex.	Sur. Color	B_t Color	Solum Depth	B_t Depth	Sur. Tex.	B_t Tex.	Sur. Color	B_t Color
286	25'	4'	33"	25"	sl	sl	10YR 4/2	10YR 5/6	31"	25"	l	c	10YR 2/1	10YR 6/1
Avg. (Above 25 ft.)			35"	24"					35"	25"				
157	20'	8'	50"	43"	ls	sl	10YR 4/3	7.5YR 5/6	46"	33"	sl	sl	10YR 4/3	10YR 5/6
160	20'	9'	60"	53"	ls	ls	10YR 5/4	10YR 5/8	35"	16"	ls	sl	10YR 3/2	2.5Y 6/6
162	20'	10'	31"	22"	ls	sl	10YR 4/3	10YR 5/6	39"	29"	ls	sl	10YR 3/3	10YR 5/6
163	20'	8'	30"	20"	sl	scl	10YR 4/3	5YR 4/4	40"	30"	sl	scl	10YR 4/2	10YR 4/4
Avg. (20 ft.)			43"	35"					40"	27"				
256	10'	15'	22"	13"	ls	scl	10YR 5/4	7.5YR 5/6	23"	8"	sl	sl	10YR 4/4	10YR 5/2
256	--	--	36"	28"	sl	scl	--	7.5YR 5/8	16"	5"	sl	sl	10YR 2/2	2.5Y 5/2
115	10'	--	28"	21"	sl	scl	10YR 4/4	7.5YR 4/4						
118	10'	5'	--	--	--	--	--	--	24"	16"	sl	scl	10YR 5/1	N 5/0
133	10'	12'	24"	14"	ls	sl	10YR 4/3	7.5YR 5/6	31"	22"	sl	cl	10YR 4/2	10 YR 7/1
Avg. (10 ft.)			27"	19"					24"	13"				
257	5-8'	4'	30"	21"	sl	scl	10YR 5/3	10YR 5/8	33"	23"	l	cl	10YR 3/2	2.5Y 5/4
199	0-5'	5'	28"	16"	sl	scl	10YR 4/2	10YR 5/4	28"	18"	sl	cl	10YR 3/3	2.5Y 5/4
199	--	--	25"	16"	sl	sl	10YR 4/2	5Y 5/3	--	--	--	--	--	--
199	--	--	26"	18"	ls	sl	10YR 5/2	10YR 5/4	36"	30"	sl	scl	2.5Y 5/2	2.5Y 5/2
199	--	--	28"	18"	ls	sl	2.5Y 5/4	10YR 4/4	--	--	--	--	--	--
250	5-8'	7'	21"	10"	sl	scl	10YR 5/3	10YR 5/6	29"	18"	sl	c	10YR 2/2	2.5Y 5/2
Avg. (5 ft.)			26"	17"					31"	22"				

Table C. Particle size distribution of soils as determined by the pipette method

Bay	Horiz.	Depth	Very Coarse Sand 2-1	Coarse Sand 1-.05	Medium Sand .5-.25	Fine Sand .25-.10	Very Fine Sand .10-.05	Coarse Silt .05-.02	Medium Silt .02-.005	Fine Silt .005-.002	Clay <.002
8	Ap	0-10"	.51	11.73	45.44	14.67	.75	9.86	8.43	2.77	5.86
Rim	B_2t	10-30"	.53	9.76	38.98	14.66	.60	8.24	9.48	3.51	14.34
	C_1	30-50"	.66	13.54	50.43	24.18	.99	2.06	1.97	1.21	4.95
	C_2	50-74"	1.61	15.51	57.15	21.77	.34	.13	.13	.13	3.23
	C_3	74-86"	.23	12.37	68.65	16.96	.12	167	.04	.08	.88
8	Ap	0-11"	1.09	8.16	36.54	16.94	.90	10.11	12.32	5.74	8.20
Depression	A_2	11-21"	.61	8.26	37.07	19.75	1.06	10.79	9.83	3.46	9.18
	B_1t	21-27"	.95	6.60	32.94	18.06	.87	8.51	10.49	3.89	17.74
	B_2t	27-38"	1.33	5.22	29.44	16.99	.85	10.37	9.18	3.89	22.75
	B_3	38-47"	1.49	5.85	31.94	21.03	1.00	7.65	8.03	3.02	19.98
	C_1	47-72"	.02	3.05	54.37	36.96	.76	.61	.08	.24	.93
	C_2	72-82"	.68	10.19	59.18	25.79	.46	0.00	0.00	0.00	3.69
125	Ap	0-9"	.33	8.02	45.63	18.71	.61	8.73	8.39	3.69	5.90
Rim	B_2t	9-22"	.21	8.21	41.20	14.63	.31	5.98	10.28	4.31	14.92
	C_1	30-50"	1.13	10.37	49.97	18.75	.13	7.14	6.05	2.61	3.85
	C_2	50"+	.30	2.70	55.23	38.17	.08	.98	.88	.16	1.49
125	Ap	0-12"	.49	7.31	28.39	22.75	1.22	14.45	13.61	3.64	8.12
Depression	B_2t	18-34"	.22	4.31	17.70	15.19	.72	15.80	24.86	4.96	16.22
	C_1	40-65"	.02	2.64	42.74	51.06	1.16	1.23	.16	.00	1.04
	C_2	65-72"	.14	7.23	40.85	42.26	1.10	2.65	1.69	.24	3.85
163	Ap	0-10"	1.09	9.80	28.54	17.39	.54	7.94	15.68	8.67	10.33
Depression	B_1	10-21"	1.64	13.33	41.32	19.62	.49	5.35	7.21	3.46	7.57
	$B_{21}t$	21-28"	1.32	11.39	35.06	18.99	.46	6.67	9.98	3.47	12.65
	$B_{22}t$	28-37"	1.10	11.08	34.25	17.97	.44	6.62	9.75	3.82	14.98

Table C. (Continued).

Bay	Horiz.	Depth	Very Coarse Sand 2-1	Coarse Sand 1-.05	Medium Sand .5-.25	Fine Sand .25-.10	Very Fine Sand .10-.05	Coarse Silt .05-.02	Medium Silt .02-.005	Fine Silt .005-.002	Clay <.002
163 Depression (cont.)	B_3	27-44"	2.25	14.46	42.26	19.82	.53	2.54	5.26	1.38	11.53
	C_1	44-58"	21.12	29.76	27.91	8.08	.06	.29	.16	.04	2.57
	C_2	58"+	1.16	6.81	53.23	36.46	.34	.00	.39	.00	1.60
163 Rim	Ap	0-8"	.22	5.29	38.12	33.55	1.08	6.79	6.99	2.49	5.47
	B_2t	8-16"	.08	3.35	28.44	27.34	.71	6.54	10.60	4.40	18.51
	B_{31}	16-25"	.02	3.90	36.49	36.99	.79	3.08	3.72	1.94	13.06
	B_{32}	25-37"	.06	3.18	38.76	46.08	1.28	.34	1.58	.93	7.80
	C_1	37-54"	.07	5.50	47.92	41.52	1.54	.23	.20	.04	2.97
	C_2	54-66"	1.18	8.91	49.27	37.41	.83	.30	.20	.20	1.24
	C_3	66-79"	.10	4.24	42.47	49.04	1.25	.10	.10	.13	2.58
	C_4	79-100"+	.68	7.47	56.69	32.85	1.69	.05	.00	.00	.56
199 Rim	Ap	0-9"	2.45	8.88	30.95	22.85	1.53	11.47	11.69	3.87	6.29
	B_2t	9-18"	2.04	9.44	34.31	15.42	.98	6.38	14.38	6.08	10.96
	B_3	18-25"	1.34	9.19	48.67	24.31	.90	.69	3.39	1.01	10.49
	C_1	25-28"	2.39	7.36	36.79	22.59	1.51	5.10	10.12	4.26	9.88
	C_2	28-36"	5.53	13.29	45.34	24.39	.91	.64	.73	.20	8.97
	C_3	36-65"	6.82	14.63	30.03	28.71	4.07	2.57	3.01	1.41	8.75
	C_4	65-90"+	.31	.64	4.94	61.75	16.88	5.76	2.50	1.21	6.00
199 Depression	A_2	6-15"	.51	1.58	6.91	19.59	1.92	11.06	23.09	10.35	24.99
	B_2	15-27"	.75	2.24	5.24	32.83	4.18	10.97	16.90	7.01	19.88
	B_3	27-40"	.77	1.98	3.90	28.50	4.06	9.48	17.05	6.88	27.37
	C_1	40-56"	1.04	1.72	2.90	25.70	8.36	14.77	18.73	5.80	20.98
	C_2	50-56"	9.24	12.19	11.10	41.10	6.71	3.89	5.44	2.30	8.02
	C_3	56-60"	28.82	22.61	10.83	24.97	4.30	1.37	2.45	.92	3.73
256 Rim	Ap	0-12"	.56	6.62	31.93	33.14	2.19	7.78	8.39	3.09	6.31
	B_2t	12-20"	.39	6.32	34.05	34.49	2.24	4.23	4.32	1.90	12.04

Table C. (Continued).

Bay	Horiz.	Depth	Very Coarse Sand 2-1	Coarse Sand 1-.05	Medium Sand .5-.25	Fine Sand .25-.10	Very Fine Sand .10-.05	Coarse Silt .05-.02	Medium Silt .02-.005	Fine Silt .005-.002	Clay <.002
265 Rim (cont.)	B_3	20-30"	1.36	8.11	49.78	23.32	1.15	7.27	2.69	.72	5.58
	C_1	30-42"	.57	9.35	40.92	39.69	1.45	2.08	1.96	1.08	2.89
	C_2	42-78"	.97	10.82	48.19	33.19	1.44	.81	1.20	.24	3.13
	C_3	78"+	4.97	22.20	43.84	22.53	.88	.20	2.16	.24	2.97
256 Depression	A_1	0-8"	1.19	6.13	23.66	30.10	2.24	9.00	11.09	6.32	10.27
	A_2	8-14"	4.44	7.74	23.97	35.85	2.88	5.75	8.27	4.32	6.78
	B_1	14-20"	13.18	13.55	19.88	40.56	3.25	3.15	3.77	1.00	1.68
	B_2	20-26"	5.49	7.42	23.07	42.14	3.15	4.84	6.96	2.82	4.10
	C_1	26-32"	10.86	5.39	7.23	41.21	11.23	4.35	4.50	3.37	11.85
	C_2	32-56"	2.57	4.89	7.40	57.16	5.06	2.70	3.40	2.43	14.37
	C_3	56"+	.30	1.39	8.18	53.17	4.95	6.32	5.73	3.79	15.14

Table D. X-ray diffraction data for the < 2μ fraction of Carolina Bay soils Mg-saturated, glycerol solvated.

Bay	Horizon	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s
125	A_p	14.24	189	10.15	42	7.18	145	-	-	4.26	10	-	-
Rim	B_{2t}	14.48	104	10.15	42	7.18	94	4.89	10	-	-	-	-
	C_1	14.47	75	10.04	21	7.07	48	4.87	10	4.26	23	-	-
	C_2	14.47	56	10.15	25	7.18	25	4.84	40	4.26	17	-	-
Depression	A_p	14.24	146	10.15	23	7.18	67	4.84	27	4.26	12	-	-
125	B_{2t}	14.47	48	10.04	33	7.13	58	4.84	25	4.26	15	3.20	8
	C_1	14.71	17	10.04	17	7.13	15	4.84	23	4.26	21	-	-
	C_3	14.47	50	10.15	23	7.18	40	4.84	10	4.26	17	-	-
8	A_p	14.24	190	10.27	14	7.15	70	-	-	4.26	12	-	-
Rim	B_{2t}	14.24	80	10.04	10	7.18	25	4.82	18	4.26	11	-	-
	C_1	14.47	85	10.15	10	7.13	20	4.89	14	4.26	15	3.24	10
Depression	A_p	14.47	262	10.27	17	7.19	95	4.89	20	4.26	17	3.25	12
8	B_{2t}	14.47	50	10.15	25	7.18	35	4.87	20	4.26	10	-	-
	C_1	14.96	16	10.77	10	7.13	14	-	-	4.26	10	-	-
163	A_p	14.47	125	10.15	5	7.18	45	-	-	4.26	10	-	-
Rim	B_{2t}	14.24	180	10.04	20	7.19	80	4.85	20	4.26	12	-	-
	C_1	14.47	30	-	-	7.18	12	4.87	38	4.26	15	-	-
	C_2	14.96	27	-	-	7.19	7	-	-	4.26	22	3.26	7
Depression	A_p	14.24	125	10.30	16	7.20	44	4.89	10	4.28	15	-	-
163	B_{2t}	14.47	53	10.27	15	7.18	38	4.82	17	4.26	10	3.20	10
	C_1	14.24	55	-	-	7.18	30	4.81	28	4.26	17	3.24	10
	C_2	14.47	30	-	-	7.18	22	4.84	25	4.24	10	3.24	10
256	A_p	-	-	14.01	239	9.93	29	7.07	127	-	-	4.26	25
Rim	B_{2t}	-	-	14.01	83	10.04	15	7.07	62	4.90	15	4.26	15
	C_1	19.61	19	14.24	67	9.93	17	7.07	46	4.87	12	4.26	19
	C_3	20.06	15	14.01	73	9.93	35	7.01	50	4.82	27	4.26	23
Depression	A_1	16.66	37	14.24	210	10.04	27	7.13	118	4.87	10	4.22	29
256	B_2	-	-	14.24	110	10.15	21	7.13	75	4.81	10	4.24	44
	C_1	-	-	14.24	67	9.93	81	7.13	141	4.84	31	4.22	14
	C_3	18.78	21	14.96	15	9.93	104	7.07	104	-	-	4.26	12
199	A_p	14.01	279	9.93	33	7.01	129	4.84	15	4.26	19	-	-
Rim	B_{2t}	14.01	71	10.04	25	7.13	58	4.84	10	4.26	19	-	-
	C_1	14.01	212	10.04	23	7.07	62	4.90	10	4.26	21	-	-

Table D. (Continued).

Bay	Horizon	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s	d, Å	I, c/s
Depression 199	B_1	-	-	14.72	144	10.15	46	7.18	96	-	-	4.26	21
	B_3	17.66	25	14.72	20	10.15	20	7.18	45	-	-	4.26	10
	C_1	17.66	20	14.24	35	9.93	42	7.13	56	4.87	15	4.26	12

Table E. X-ray Diffraction data for the <2μ fraction of Carolina bay soils, K-saturated.

						K-saturated									
		25° C						300° C				550° C			
Bay	Horiz.	d,Å	I,c/s	dÅ	d,Å	d,Å	dÅ	dÅ	dÅ	dÅ	I,c/s	d,Å	I,c/s	dÅ	dÅ
125 Rim	Ap	14.01	95	--	10.04	7.13	13.18	--	10.09	7.13	50	13.59	25	10.64	10.15
	B_{2t}	13.80	35	--	10.04	7.13	14.01	12.80	9.93	7.13	50	13.59	15	--	10.15
	C_1	14.01	30	12.99	10.04	7.01	--	--	10.27	7.13	20	14.01	10	11.18	10.15
	C_2	14.01	30	11.04	10.04	7.07	14.01	12.62	10.15	7.13	25	13.80	20	--	10.04
125 Depression	Ap	14.01	230	--	10.04	7.13	--	12.44	10.04	7.13	85	--	--	11.32	10.39
	B_{2t}	14.01	30	--	10.04	7.13	15.22	13.18	10.04	7.13	65	14.24	13	--	10.15
	C_1	15.22	12	13.18	--	7.82	15.49	--	--	7.13	23	--	--	--	--
	C_3	13.79	32	--	10.04	7.13	--	--	9.92	7.13	20	--	--	11.04	10.15
8 Rim	Ap	14.01	310	11.18	10.04	7.01	12.98	10.77	10.15	7.13	80	14.24	30	11.32	10.15
	B_{2t}	14.01	70	--	10.27	7.13	13.38	11.77	10.04	7.13	47	14.24	12	11.04	10.15
	C_1	13.79	80	--	10.15	7.13	--	12.80	10.04	7.07	33	15.22	15	13.58	10.77
8 Depression	Ap	14.01	310	--	10.04	7.13	--	12.80	10.15	7.07	85	13.80	30	11.32	10.15
	B_{2t}	14.01	55	10.15	9.81	7.13	13.79	11.93	10.04	7.13	55	--	--	10.90	10.15
	C_1	14.24	15	--	10.04	--	--	--	--	7.24	20	--	--	--	10.04
163 Rim	Ap	14.24	200	11.32	10.15	7.18	12.99	10.77	10.04	7.07	70	14.02	35	12.70	10.27
	B_{2t}	14.24	75	13.80	10.15	7.18	12.80	--	10.15	7.07	38	20.53	10	11.32	10.20
	C_1	14.24	15	--	--	--	14.24	--	--	7.07	7	15.22	7	--	--
	C_4	14.24	10	--	--	--	--	--	--	--	--	--	--	--	--
163 Depression	Ap	14.24	205	10.60	10.20	7.13	13.00	--	10.3	7.13	60	14.20	35	11.50	10.50
	B_{2t}	14.01	50	--	10.04	7.07	13.58	--	10.15	7.01	30	15.22	10	11.18	10.04
	C_1	14.24	25	--	9.81	7.13	14.71	--	10.15	7.07	15	15.76	8	--	10.27
	C_2	14.01	15	--	9.87	7.07	14.47	--	9.81	7.07	7	--	--	--	--
256 Rim	Ap	14.01	145	--	--	7.01	12.80	12.27	10.04	7.07	90	13.80	27	11.18	10.15
	B_{2t}	14.01	47	--	10.04	7.13	13.18	--	10.04	7.07	40	15.22	12	10.77	10.04
	C_1	14.01	40	--	10.15	7.13	14.01	12.80	10.04	7.13	50	13.80	25	--	10.15
	C_3	14.01	63	--	10.04	7.07	16.66	13.38	9.93	7.01	55	13.80	36	--	10.04

Table E. (Continued).

		K-saturated													
		25° C					300° C					550° C			
Bay	Horiz.	d,Å	I,c/s	dÅ	d,Å	d,Å	dÅ	dÅ	dÅ	dÅ	I,c/s	d,Å	I,c/s	dÅ	dÅ
256 Depression	A_1	14.01	150	--	10.15	7.13	13.58	12.80	10.04	7.13	170	--	--	10.90	10.04
	B_2	14.01	165	11.77	10.04	7.13	--	12.50	10.04	7.13	110	--	--	10.52	10.14
	C_1	14.24	55	13.18	10.04	7.18	--	--	10.04	7.18	240	--	--	--	10.04
	C_3	--	--	9.93	6.31	6.13	--	--	8.83	6.13	115	14.24	15	--	10.15
199 Rim	Ap	14.01	85	--	10.04	7.13	--	11.44	9.81	7.07	145	--	--	10.77	10.04
	B_{2t}	14.01	130	--	10.04	7.07	13.18	12.26	10.04	7.13	105	13.80	38	10.90	10.15
	C_1	14.01	350+	10.04	7.62	7.13	--	12.27	10.04	7.13	100	13.59	37	11.18	10.04
199 Depression	B_1	14.24	210	--	10.04	7.18	12.27	11.62	10.04	7.18	155	--	--	11.04	10.15
	B_3	13.18	40	12.44	9.93	7.13	--	--	9.93	7.13	73	--	--	--	10.15
	C_1	--	--	--	9.93	7.13	14.01	--	9.87	7.13	63	--	--	--	10.04

Table F. X-ray diffraction spacings and intensities of (2-50μ) fractions from soils of Carolina bays (Mg-saturated-glycerol solvated).

Bay	Horiz.	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s
125	Ap	15.76	12	14.01	29	9.93	35	7.01	19	4.25	148	3.19	19
Rim	B_{2t}	15.49	15	14.24	25	10.04	31	7.07	19	4.26	100	3.25	23
	C_1	--	--	14.47	21	9.93	17	7.01	10	4.24	98	3.24	
	C_2	16.05	17	14.24	40	10.04	35	7.13	35	4.24	83	3.24	15
125	Ap	15.49	12	14.24	17	10.04	10	7.01	8	4.24	129	3.24	23
Depression	B_{2t}	15.49	15	14.01	19	9.81	19	7.01	8	4.24	129	3.24	12
	C_1	15.76	15	14.24	12	9.70	8	--	--	4.22	54	3.18	31
	C_3	15.22	21	14.47	17	--	--	--	--	4.24	116	3.22	19
8	Ap	--	--	14.71	12	9.92	10	--		4.22	131	3.22	8
Rim	B_{2t}	--	--	14.24	23	10.04	19	7.07	15	4.26	139	3.25	25
	C_1	15.49	21	14.01	17	--	--	--	--	4.26	131	3.24	23
8	Ap	--	--	14.01	29	10.04	15	7.01	12	4.23	98	3.17	17
Depression	B_{2t}	15.22	12	14.02	15	10.04	21	7.01	12	4.22	87	3.24	10
	C_1									4.22	17	3.22	6
163	Ap	19.91	8	14.47	15	10.04	12	7.01	8	4.22	119	3.21	15
Rim	B_{2t}	--	--	14.24	27	10.04	21	7.07	15	4.24	123	3.17	19
	C_1	--	--	14.01	17	10.27	6	--	--	4.24	50	3.16	17
	C_4	--	--	14.97	17	9.92	10	--	--	4.22	48	3.18	33
163	Ap	--	--	14.24	13	9.9	10	7.01	7	4.26	57	3.18	12
Depression	B_{2t}	--	--	14.01	17	9.92	19	7.01	15	4.24	110	3.21	18
	C_1	--	--	14.01	37	10.04	17	7.07	19	4.24	64	3.19	10
	C_2	15.76	4	14.24	6	9.4	8	--	--	4.24	77	3.19	10
256	Ap	--	--	14.24	17	10.04	23	7.07	21	4.26	104	3.21	17
Rim	B_{2t}	15.49	15	14.01	19	10.04	19	7.07	19	4.23	81	3.23	12
	C_3	--	--	14.24	29	10.04	25	--	--	4.22	85	3.16	25

Table F. (Continued).

Bay	Horiz.	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s	d,Å	I,c/s
256 Depression	A_1	15.22	17	--	--	10.04	8	7.18	8	4.26	110	3.24	46
	B_2	--	--	14.96	12	10.04	10	7.07	8	4.24	94	3.24	14
	C_1	15.22	15	14.47	19	10.04	23	7.13	19	4.24	69	3.23	48
199 Rim	Ap	--	--	14.71	17	10.04	10	7.13	8	4.24	125	3.18	19
	B_{2t}	15.22	19	14.24	27	10.04	17	7.07	12	4.26	96	3.24	15
	C_1	--	--	14.47	23	10.04	12	--	--	4.22	108	3.22	12
199 Depression	B_1	15.22	19	--	--	10.04	15	--	--	4.26	108	3.19	19
	B_3	15.22	23	--	--	10.04	15	--	--	4.24	94	3.17	25
	C_1	--	--	14.71	17	10.04	21	--	--	4.24	104	3.24	33

APPENDIX II

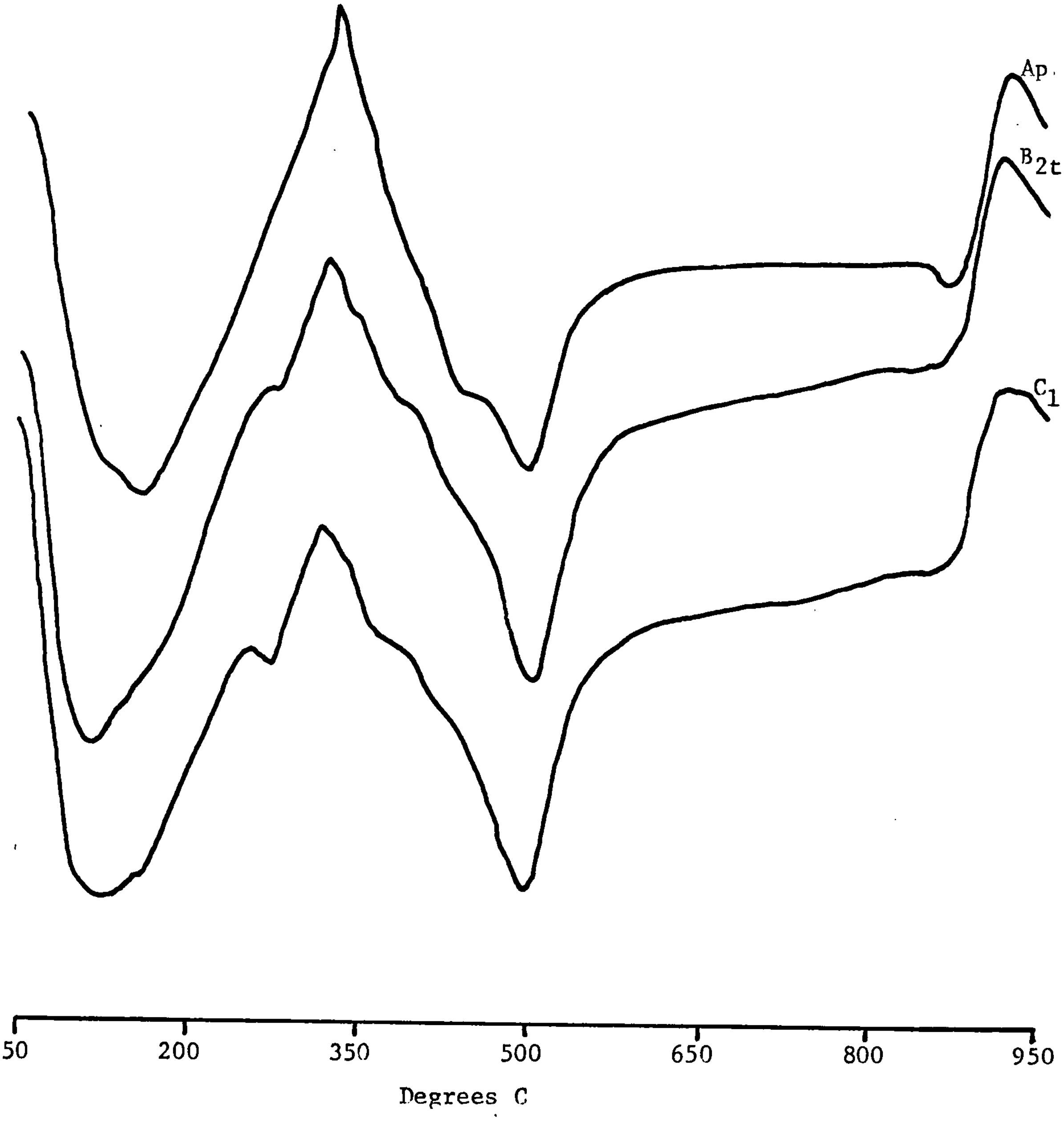

Fig. 25. Differential thermal analysis patterns for the <2μ fraction of the rim soil profile from bay 8, Mg-saturated, equilibrated at 56% R.H.

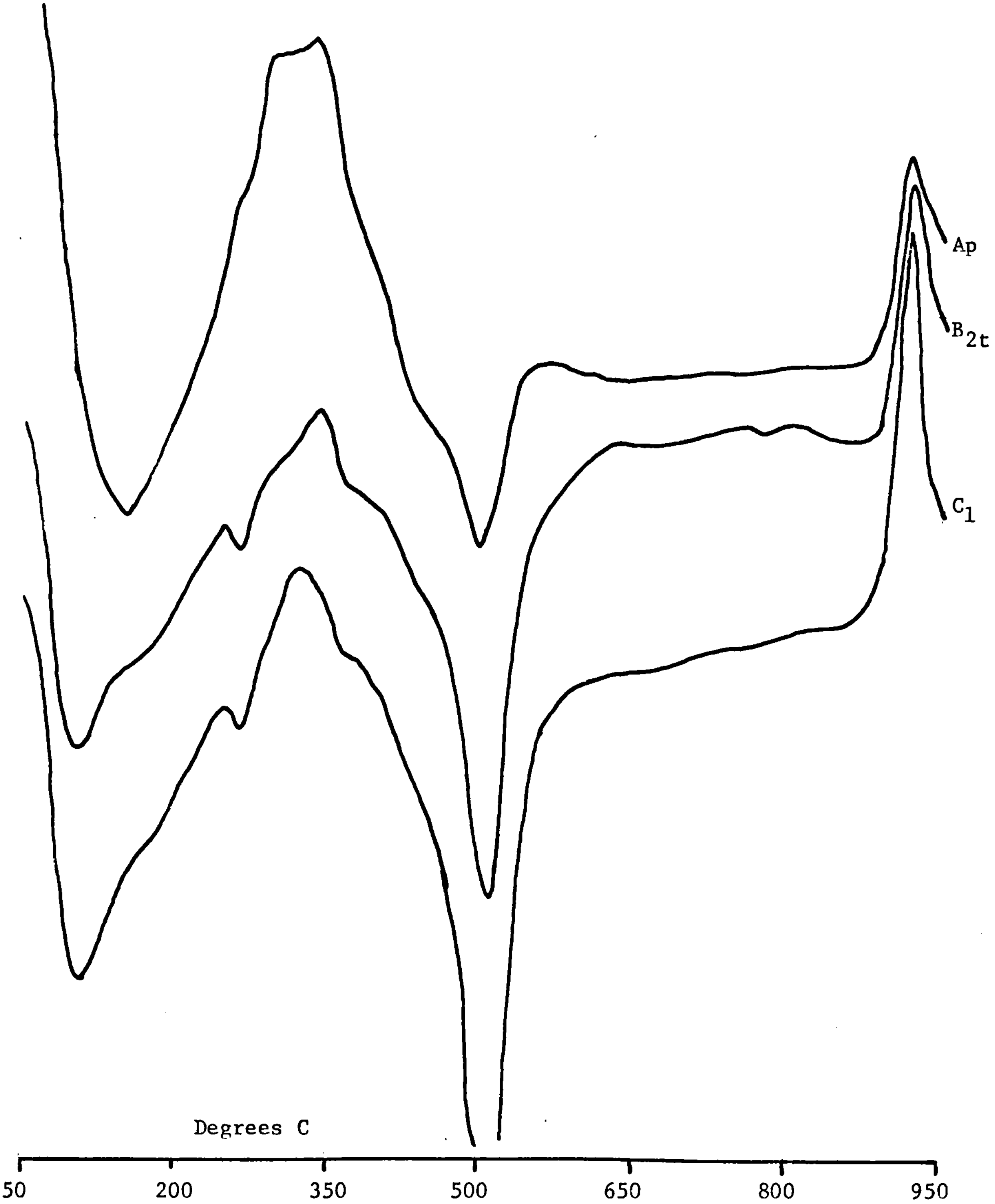

Fig. 26. Differential thermal analysis patterns for the <2μ fraction of the depression soil profile from bay 8, Mg-saturated, equilibrated, equilibrated at 56% R.H.

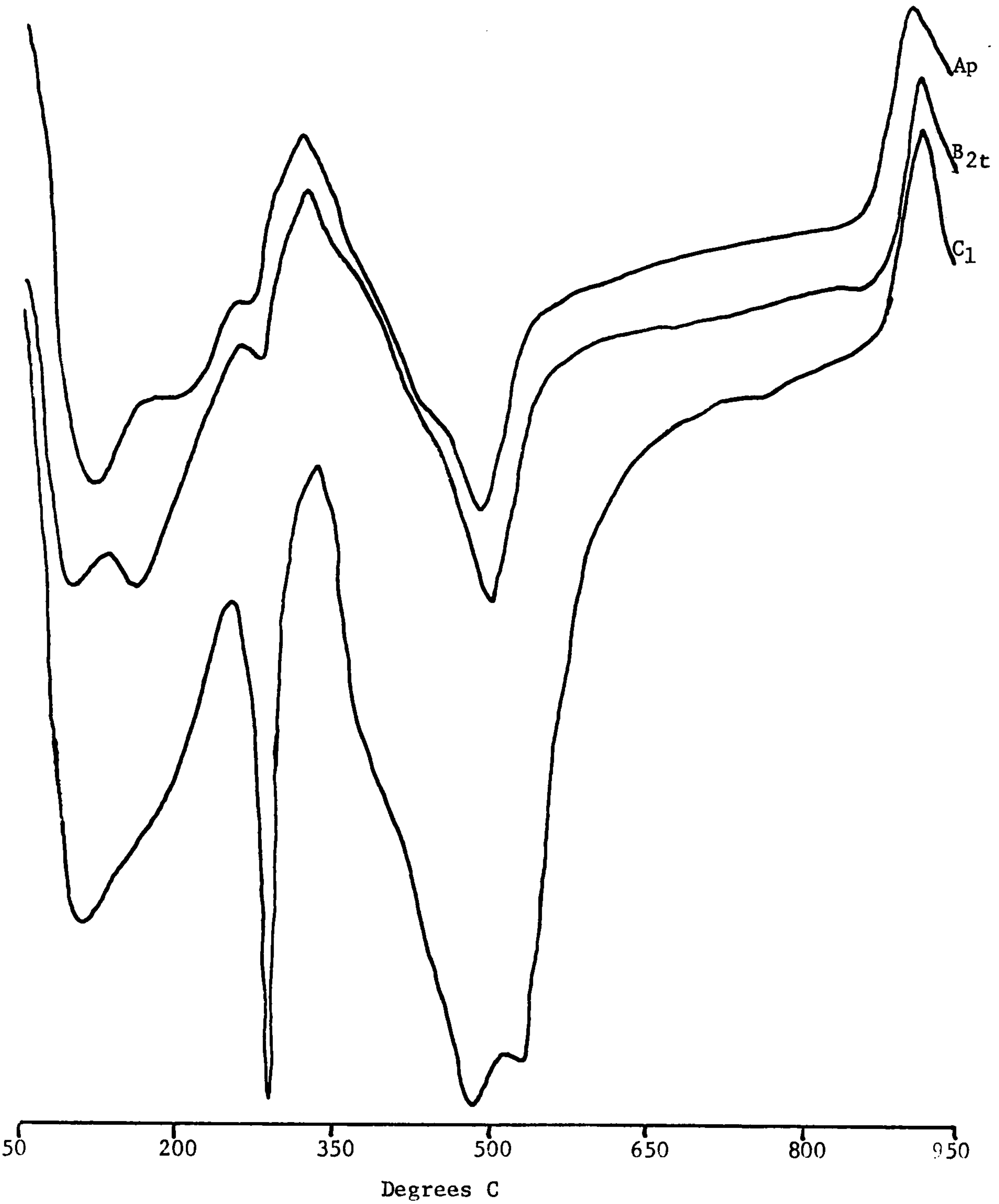

Fig. 27. Differential thermal analysis patterns for the <2μ fraction of the rim soil profile from bay 163, Mg-saturated, equilibrated at 56% R.H.

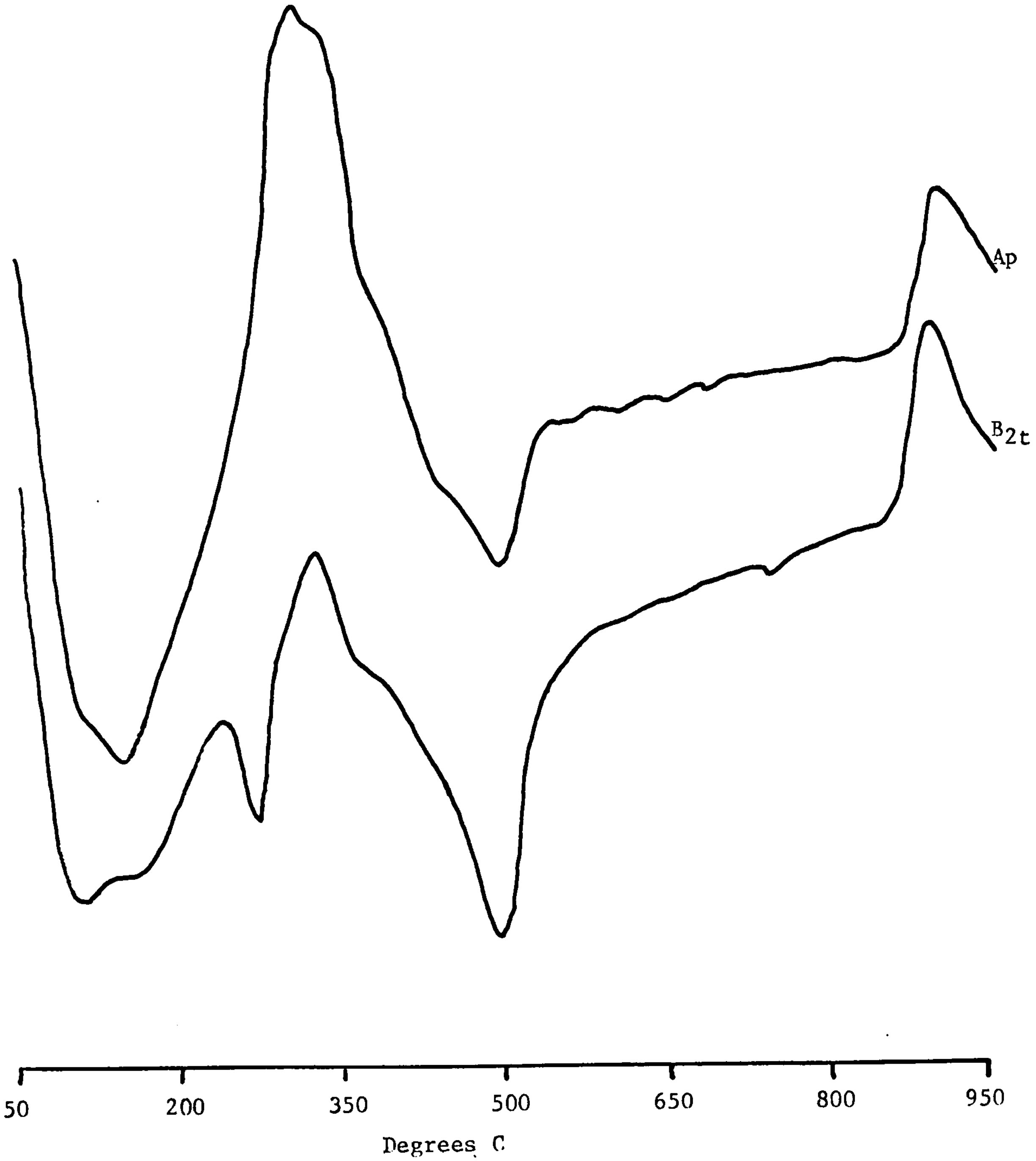

Fig. 28. Differential thermal analysis patterns for the Ap and B_{2t} horizons of the depression soil profile from bay 163, Mg-saturated, equilibrated at 56% R.H.

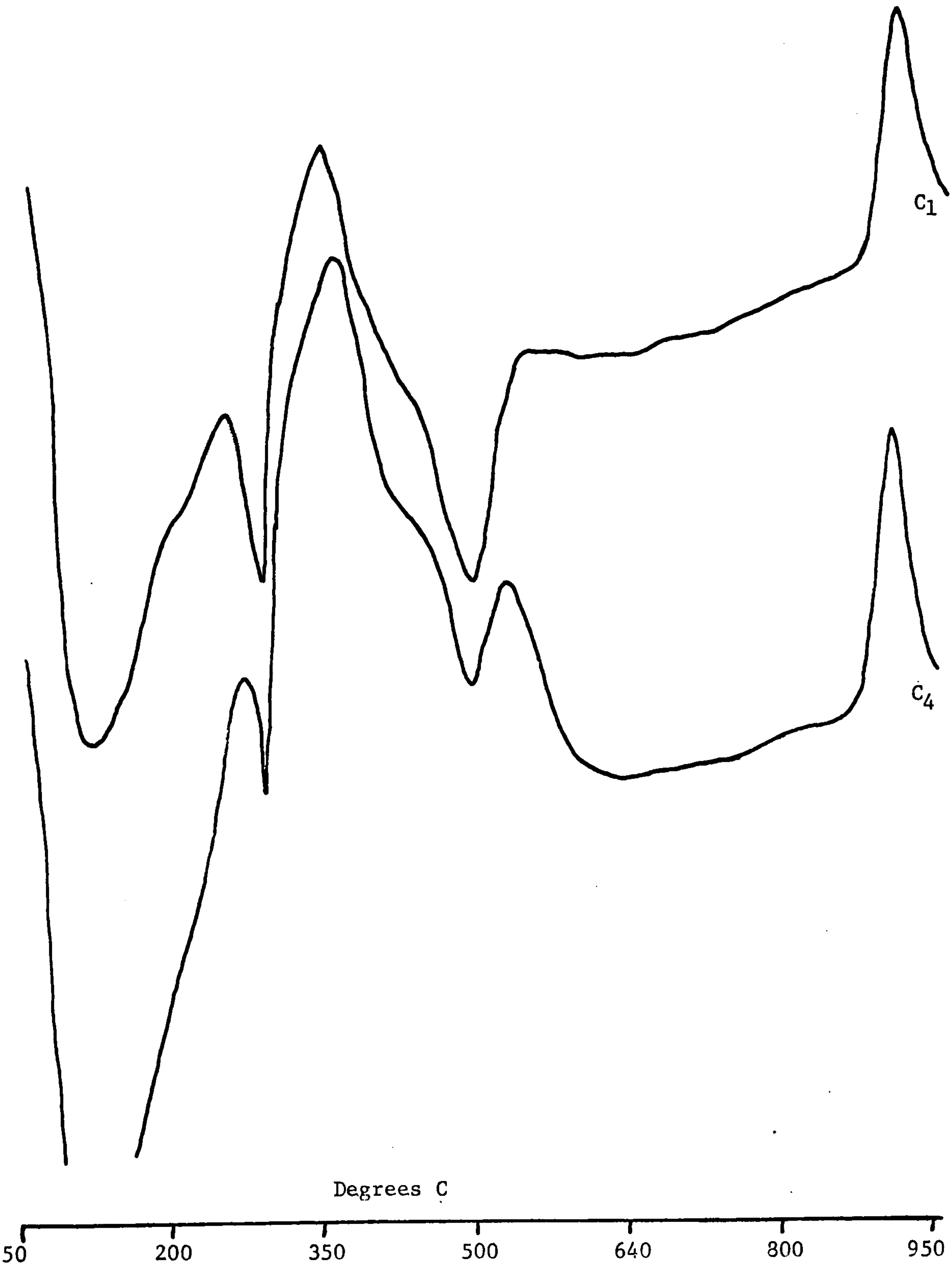

Fig. 29. Differential thermal analysis patterns for the C_1 and C_4 horizons of the depression soil profile from bay 163, Mg-saturated, equilibrated at 56% R.H.

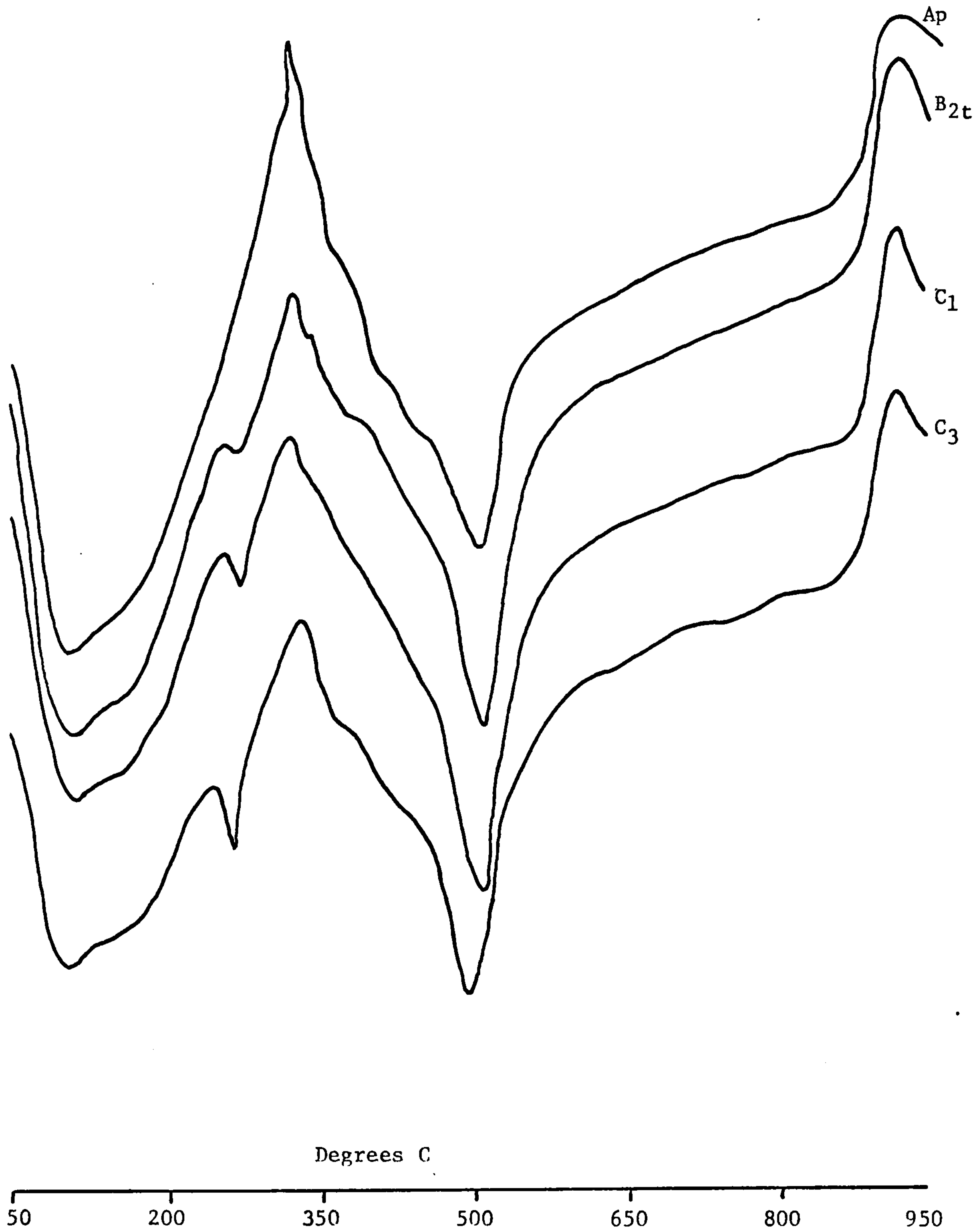

Fig. 30. Differential thermal analysis patterns of the rim soil profile from bay 256, Mg-saturated, equilibrated at 56% R.H.

Fig. 31. Differential thermal analysis patterns for the A_1 and B_2 horizons of the depression soil profile from bay 256, Mg-saturated, equilibrated at 56% R.H.

Fig. 32. Differential thermal analysis patterns for the C_1 and C_3 horizons of the depression soil profile from bay 256, Mg-saturated, equilibrated at 56% R.H.

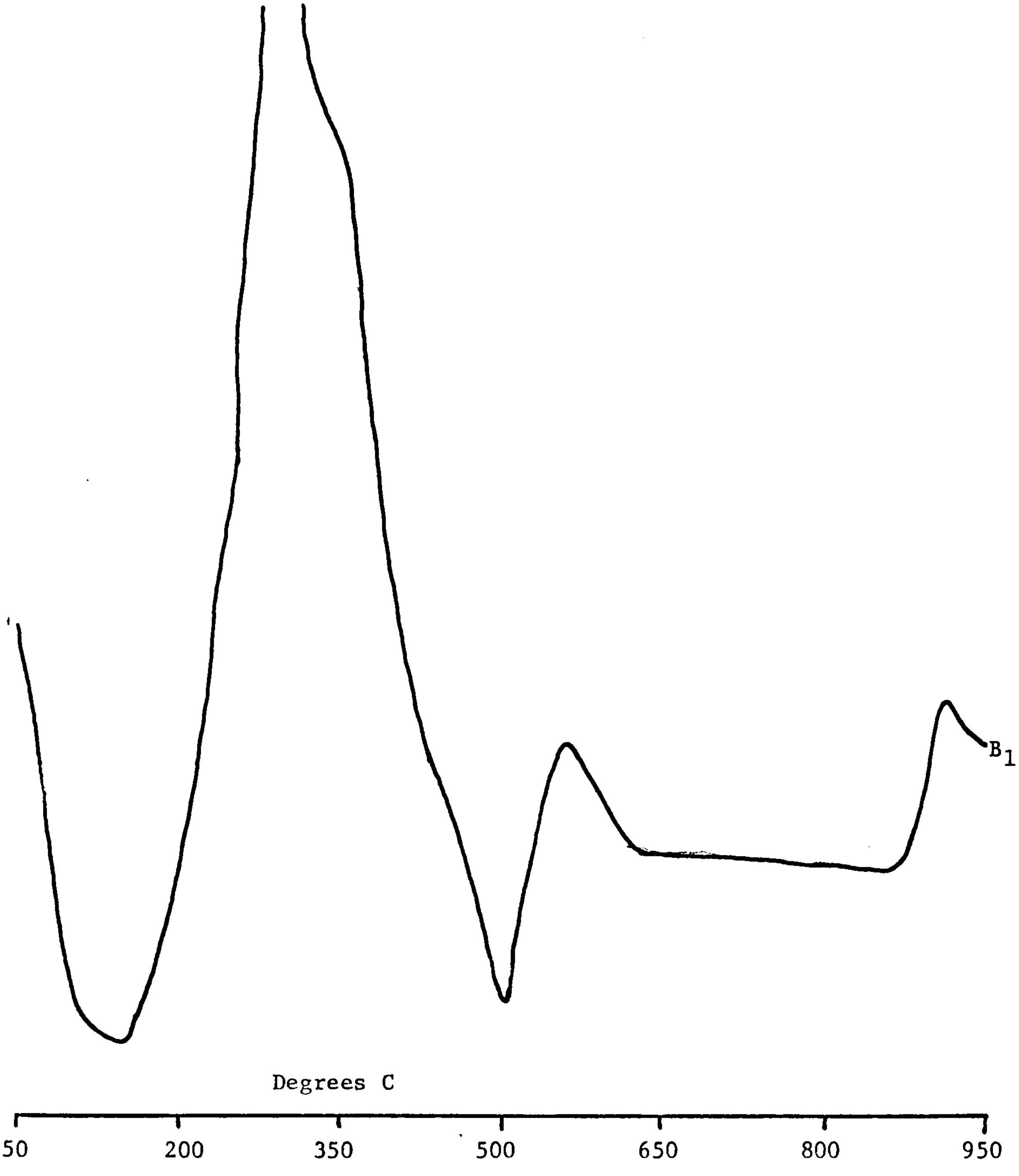

Fig. 33. Differential thermal analysis patterns for the B_1 horizon of the depression soil profile from bay 199, Mg-saturated, equilibrated at 56% R.H.

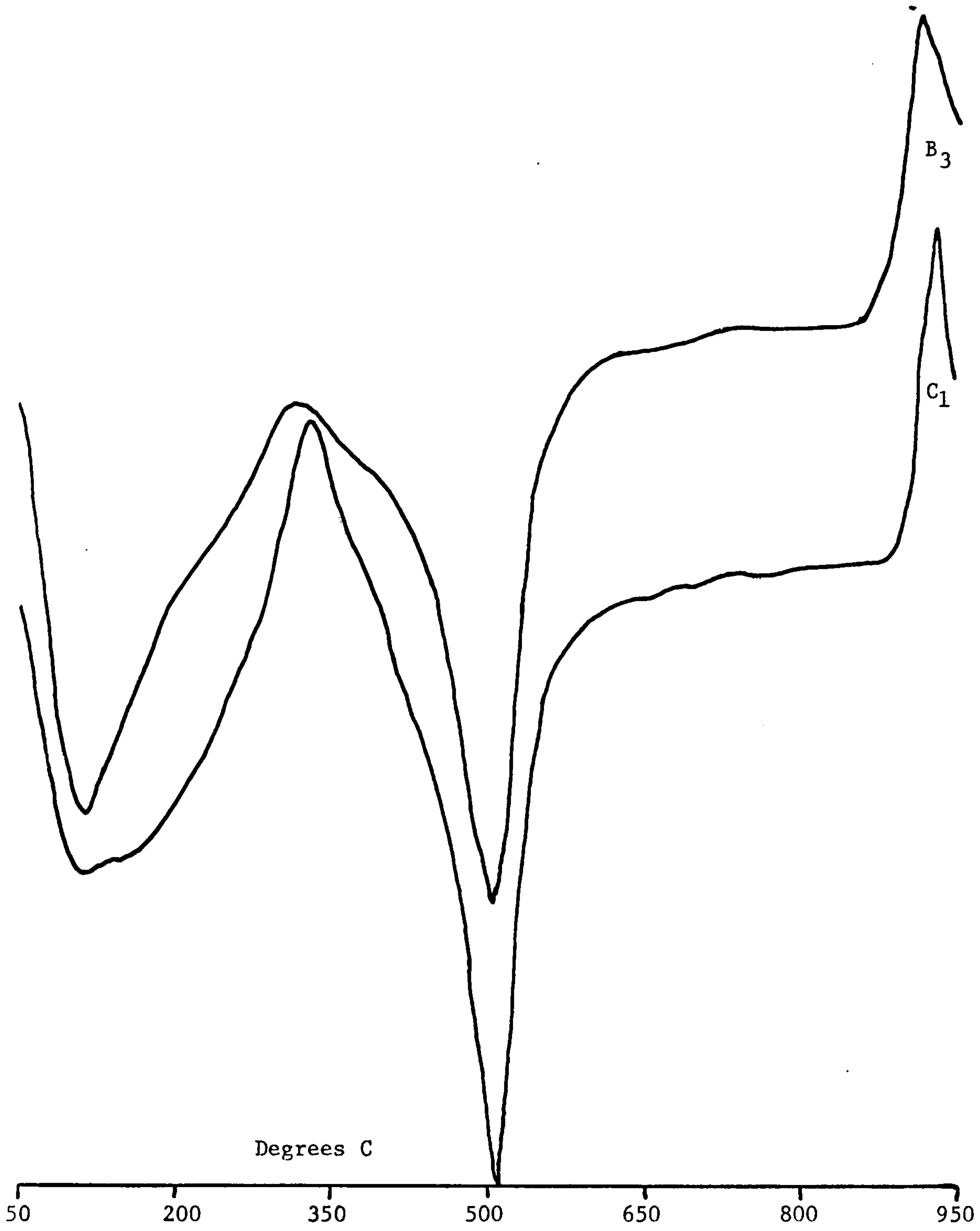

Fig. 34. Differential thermal patterns for the B_3 and C_1 horizons of the depression soil profile from bay 199, Mg-saturated, equilibrated at 56% R.H.

APPENDIX III

SOIL PROFILE DESCRIPTION (Bay 125)

Location -.5 miles Northeast of Melfa

Elevation - 45-50 ft.

Relief - 8-10 ft.

Rim Profile

Ap 0 - 92 inches, brown to dark brown (10 YR 4/3) sandy loam; weak fine granular structure; friable when moist, non-sticky when wet; str strongly acid; abrupt, smooth boundary.

B_2t 9 - 22 inches, brown to dark brown (7.5 YR 4/4) light sandy clay loam; weak, fine, subangular blocky structure; friable when moist, slightly sticky when wet; few fine roots; strongly acid; gradual, smooth boundary.

B_3 22 - 30 inches, reddish brown (5 YR 4/4) to strong brown (7.5 YR 5/6) sandy loam; structureless massive; very friable when moist, non-sticky when wet; strongly acid; gradual smooth boundary.

C_1 30 - 50 inches, yellowish-brown (10 YR 5/4) loamy sand; structureless, single grain; very friable, nonsticky; acid; gradual diffuse boundary.

C_2 - 50 inches+,

Depression Profile

Ap 0 - 12 inches, very dark gray (10 YR 3/1) sandy loam; weak, fine, granular structure; very friable when moist, nonsticky when wet; common fine roots; strongly acid; clear, smooth boundary.

B_1t 12 - 18 inches, light brownish-gray (2.5 Y 6/2) sandy loam; few medium, distinct, yellowish-brown (10 YR 5/6) mottles; weak, fine, subangular blocky structure; friable when moist, slightly sticky when wet; few fine roots; strongly acid; clear smooth boundary.

B_2t 18 - 34 inches, light brownish-gray (2.5 YR6/2) sandy clay loam; co common, medium, distinct mottles of yellowish-brown (10 YR 5/8); roots; very strongly acid; clear smooth boundary.

B_3 34 - 40 inches, light olive gray (5 Y 6/2) loamy sand; common, structure; very friable moist, nonsticky wet; few fine roots; strongly acid; gradual smooth boundary.

C_1 40 - 66 inches, pale yellow (2.5 Y 7/4) sand; single grain structure; strongly acid; gradual smooth boundary.

C_2 66 - 72 inches.

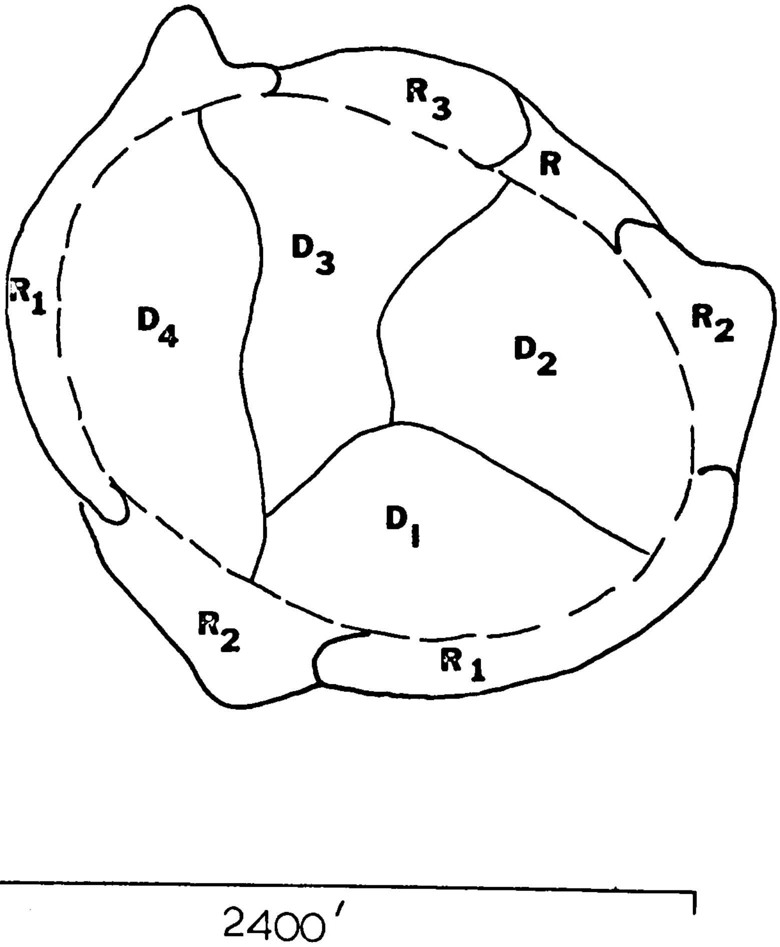

Fig. 35. Soil map of Bay 125 located 1/2 mile northeast of Melfa, Accomac County, Virginia.

Soil Mapping Unit Descriptions

Bay 125

D_1 0 - 6 inches, dark grayish-brown (10 YR 4/2) loamy sand.
6 - 14 inches, light olive-brown (2.5 Y 5/4) sandy loam.
14 - 26 inches, yellowish-brown (10 YR 5/6) heavy sandy loam with common large distinct mottles of light olive-brown (2.5 Y 5/4).
26 - 32 inches, yellowish-brown (10 YR 5/6) sandy loam.
32 inches, yellow (10 YR 7/8) sand.

Range in Characteristics--Solum depth ranges from 30 to 40 inches. Textures of the B horizons range from heavy sandy loam to sandy clay loam and colors range from yellowish-brown to yellow.

D_2 0 - 8 inches, dark grayish-brown (10 YR 4/2) sandy loam.
8 - 12 inches, grayish-brown (2.5 Y 5/2) heavy sandy loam.
12 - 36 inches, light olive-brown (2.5 Y 5/6) heavy sandy clay loam to silt loam with mottles of brownish-yellow (10 YR 6/6).
36 - 45 inches, light olive-brown (2.5 Y 5/6) sandy loam with mottles of light gray (2.5 Y 7/2) and brownish-yellow (10 YR 5/6).
45 inches, pale yellow (2.5 Y 7.4) loamy sand.

Range in Characteristics--Solum depth ranges from 40 to 50 inches. Textures of the B horizons range from heavy sandy clay loam to light clay loam and colors range from light olive-brown to brownish-yellow.

D_3 0 - 8 inches, dark grayish-brown (2.5 Y 4/2) sandy loam.
8 - 12 inches, pale olive (5 Y 6/3) sandy loam.
12 - 26 inches, olive (5 Y 5/3) sandy clay loam with mottles of pale olive (5 Y 6/3).
26 - 40 inches, light-gray (5 Y 6/1) sandy loam.
40 inches, pale olive (5 Y 6/4) loamy sand.

Range in Characteristics--Solum depth ranges from 30 to 40 inches. Textures of the B horizons range from heavy sandy loam to sandy clay loam and colors range from olive to light gray.

D_4 0 - 12 inches, very dark-gray (10 YR 3/1) fine sandy loam.
12 - 18 inches, gray (5 Y 5/1) heavy fine sandy loam to light sandy clay loam.
18 - 30 inches, olive (5 Y 5/3) loam to silty clay loam.
30 - 45 inches, light olive-gray (5 Y 6/2) sandy loam.

Range in Characteristics--Solum depth ranges from 25 to 45 inches. Textures of the B horizons range from heavy sandy clay loam to light clay loam and colors range from light-gray to olive.

Soil Mapping Unit Descriptions

Bay 125

R_1 0 - 9 inches, brown to dark-brown (19 YR 4/3) sandy loam.
9 - 22 inches, brown to dark brown (7.5 YR 4/4) light sandy clay loam.
22 - 30 inches, reddish-brown (5 YR 4/4) to strong brown (7.5 YR 5/6) sandy loam.
30 - 50 inches, yellowish-brown (10 YR 5/4) loamy sand.

Range in Characteristics--Solum depth ranges from 25 to 35 inches. Textures of the B horizons range from heavy sandy loam to sandy clay loam and colors range from reddish-brown to strong brown.

R_2 0 - 10 inches, brown to dark brown (10 YR 4/3) loamy sand.
10 - 21 inches, brownish-yellow (10 YR 6/6) sandy loam.
21 - 32 inches, yellow (10 YR 7/6) sandy loam.
32 - 45 inches, yellow (10 YR 7/6) sand.

Range in Characteristics--Solum depth ranges from 40 to 50 inches. Textures of the B horizons range from sandy loam to heavy loamy sand and colors range from brownish-yellow to yellow.

R_3 0 - 9 inches, brown to dark brown (10 YR 4/3) sandy loam.
9 - 15 inches, dark yellowish-brown (10 YR 4/4) sandy loam.
15 - 32 inches, strong brown (7.5 YR 5/6) sandy clay loam.
32 - 40 inches, strong brown (7.5 YR 5/8) sandy loam.
40 inches, brownish-yellow (10 YR 6/6) loamy sand.

Range in Characteristics--Solum depth ranges from 30 to 40 inches. Textures of the B horizons range from heavy sandy loam to heavy loam and colors range from strong brown to yellowish-brown.

R_4 0 - 12 inches, grayish-brown (10 YR 5/2) aand to loamy sand.
12 - 18 inches, light yellowish-brown (10 YR 6/4) sandy loam.
18 - 30 inches, olive yellow (5 Y 6/6) sandy loam to sandy clay loam.
30 - 40 inches, yellow (5 Y 7/6) loamy sand.

Range in Characteristics--Solum depth ranges from 30 to 40 inches. Textures of the B horizons range from sandy loam to sandy clay loam and colors range from olive yellow to yellow.

SOIL PROFILE DESCRIPTION (Bay 8)

Location - .25 mi. N. of Townsend

Elevation - 30 feet

Relief - 8 feet

Rim Profile

Ap 0 - 10 inches, dark yellowish-brown (10 YR 4/4) sandy loam; weak, fine, granular structure; moist friable, non-sticky and non-plastic when wet; very strongly acid; common fine roots; abrupt smooth boundary.

B_2t 10 - 30 inches, brown to dark brown (7.5 YR 4/4) sandy clay loam; weak, fine subangular blocky structure; moist friable, slightly sticky, slightly plastic when wet; common fine roots; diffuse smooth boundary.

C_1 30 - 50 inches, strong brown (7.5 YR 5/8) loamy sand; structureless single grain; moist loose, non-sticky and non-plastic wet; few fine roots; diffuse smooth boundary.

C_2 50 - 74 inches, brownish-yellow (10 YR 6/8) loamy sand; many coarse distinct mottles of dark yellowish-brown (10 YR 3/4); single grain structure; moist loose with brittle 10 YR 3/4 mottles; gradual wavy boundary.

C_3 74 - 86 inches, dark yellowish-brown (10 YR 4/4) sand; single grain structure.

Depression Profile

Ap 0 - 11 inches, dark grayish-brown (10 YR 4/2) sandy loam; weak, fine, granular structure; moist very friable, non-sticky and non-plastic; many fine roots; very strongly acid; abrupt, smooth boundary.

A_2 11 - 21 inches, brown (10 YR 5/3) sandy loam; weak, fine, granular structure; moist very friable, non-sticky and non-plastic; common, large roots; very strongly acid; clear smooth boundary.

B_1t 21 - 27 inches, yellowish-brown (10 YR 5/6) sandy clay loam; moderate, fine, subangular blocky structure; moist friable, slightly sticky and slightly plastic; few, large roots; very strongly acid; clear, smooth boundary.

B_2t 27 - 38 inches, yellowish-brown (10 YR 5/8) sandy clay loam; moderate, fine, subangular blocky structure; moist friable firm, slightly sticky and slightly plastic; few large roots; very strongly acid; clear, smooth boundary.

B_3t 38 - 47 inches, yellowish-brown (10 YR 5/8) heavy sandy loam; weak fine, subangular blocky structure; moist friable, sticky and slightly plastic when wet; few large roots; very strongly acid; gradual, smooth boundary.

C_1 47 - 72 inches, brownish-yellow (10 YR 6/8) sand; with few mottles of pale brown (10 YR 6/3); single grain; loose; very strongly acid; clear smooth boundary.

C_2 - 72 inches, brownish-yellow (10 YR 5/8) sand; single grain; loose; many mottles of grayish-brown (10 YR 5/2).

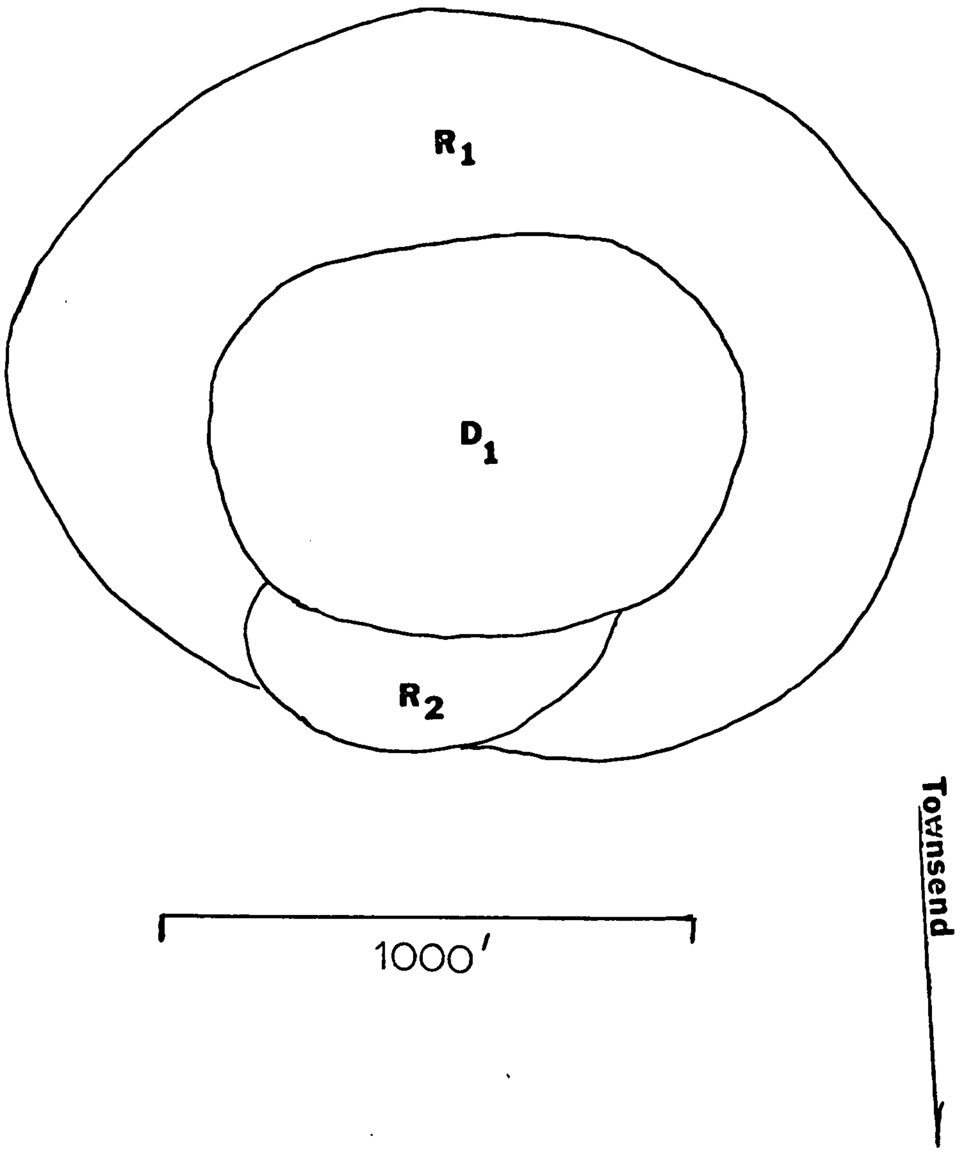

Fig. 38. Soil map of Bay 8 1/4 mile north of Townsend, Northampton County, Virginia.

Mapping Unit Descriptions

Bay 8

R_1 0 - 10 inches, brown to dark-brown (10 YR 4/3) sandy loam.
10 - 16 inches, strong brown (7.5 YR 5/6) sandy loam.
16 - 32 inches, strong brown (7.5 YR 5/6) sandy clay loam.
32 - 44 inches, strong brown (7.5 YR 5/6) to reddish brown (7.5 YR 6/6) sandy loam.
44 inches, reddish brown (7.5 YR 6/6).

Range in Characteristics--Solum depth ranges from 38 to 44 inches. Textures of the B horizons range from sandy clay loam to loam and colors range from brown to reddish yellow.

R_2 0 - 8 inches, brown to dark brown (10 YR 4/3) fine sandy loam.
8 - 15 inches brown (7.5 YR 4/4) to strong brown (7.5 YR 5/6) light sandy clay loam.
15 - 36 inches, brown (7.5 YR 4/4) to strong brown (7.5 YR 5/6) loam.
36 - 50 inches, strong brown (7.5 YR 5/6) to reddish yellow (7.5 YR 6/6) sandy clay loam.
50 inches, reddish-yellow (7.5 YR 6/6) loamy sand.

Range in Characteristics--Solum depth ranges from 45 to 55 inches. Textures of the B horizons range from sandy clay loam to silty clay loam and colors range from strong brown to reddish yellow.

D_1 0 - 11 inches, dark grayish-brown (10 YR 4/2) sandy loam.
11 - 21 inches, brown (10 YR 5/3) sandy loam.
21 - 27 inches, yellowish-brown (10 YR 5/3) sandy loam.
21 - 27 inches, yellowish-brown (10 YR 5/6) sandy clay loam.
27 - 38 inches, yellowish-brown (10 YR 5/8) sandy clay loam.
38 - 47 inches, yellowish-brown (10 YR 5/8) heavy sandy loam.
47 - 82 inches, brownish-yellow (10 YR 6/8) sand.

Range in Characteristics--Solum depth ranges from 35 to 50 inches. Textures of the B horizons range from sandy clay loam to heavy sandy clay loam and colors from yellowish-brown to yellow.

SOIL PROFILE DESCRIPTION (Bay 163)

Location - Parker Neck

Elevation - 20 ft.

Relief - 8 ft.

Rim Profile

Ap 0 - 8 inches, brown to dark-brown (10 YR 4/3) sandy loam; structureless, massive; moist friable to slightly brittle, non-sticky and non-plastic; many fine roots; very strongly acid; abrupt smooth boundary.

B_2t 8 - 16 inches, brown (7.5 YR 4/4) to reddish-brown (5 YR 4/4) sandy clay loam; structureless, massive; moist friable to slightly firm, slightly sticky and non-plastic; few fine roots; very strongly acid; clear smooth boundary.

B_{31} 16 - 25 inches, reddish-brown (5 YR 4/4) sandy loam; structureless, massive; very friable, non-sticky and non-plastic; few fine roots; strongly acid; gradual smooth boundary.

B_{32} 25 - 37 inches, strong brown (7.5 YR 5/6) sand; structureless, single grain; loose; few fine roots; strongly acid.

C_1 37 - 54 inches, brownish-yellow (10 YR 6/6) sand; with large nodules or concretions of dark yellowish-brown (10 YR 3/4); single grain; loose; clear boundary.

C_2 54 - 66 inches, light yellowish-brown (2.5 Y 6/4) sand; single grain; loose; clear boundary.

C_3 66 - 79 inches, light yellowish-brown (2.5 Y 6/4) sand; single grain; loose; clear boundary.

C_4 79 - 100 inches, pale yellow (5 Y 7/3) sand; with dark grayish-brown (10 YR 4/2) layer at 100 inches.

Depression Profile

Ap 0 - 10 inches, dark grayish-brown (10 YR 4/2) sandy loam; weak, fine, granular structure; moist friable to slightly firm, slightly sticky and non-plastic; common fine roots; extremely acid; abrupt smooth boundary.

B_1 10 - 21 inches, dark yellowish-brown (10 YR 4/4) sandy loam to loamy sand; massive structure; moist friable, non-sticky and non-plastic; common fine roots; extremely acid; gradual, smooth boundary.

$B_{21}t$ 21 - 28 inches, yellowish-brown (10 YR 5/4) sandy loam; massive structure; moist friable, slightly sticky, non-plastic; few fine roots; extremely acid; gradual smooth boundary.

$B_{22}t$ 28 - 37 inches, dark yellowish-brown (10 YR 4/4) sandy clay loam; massive structure; moist friable, slightly sticky, non-plastic; few fine roots; extremely acid; clear smooth boundary.

B_3 37 - 44 inches, strong brown (7.5 YR 5/6) loamy sand, massive structure, friable, non-sticky; very strongly acid; clear smooth boundary.

C_1 44 - 58 inches, yellowish-brown (10 YR 5/4) medium to coarse sand; single grain; loose.

C_2 58 - inches, fine sand.

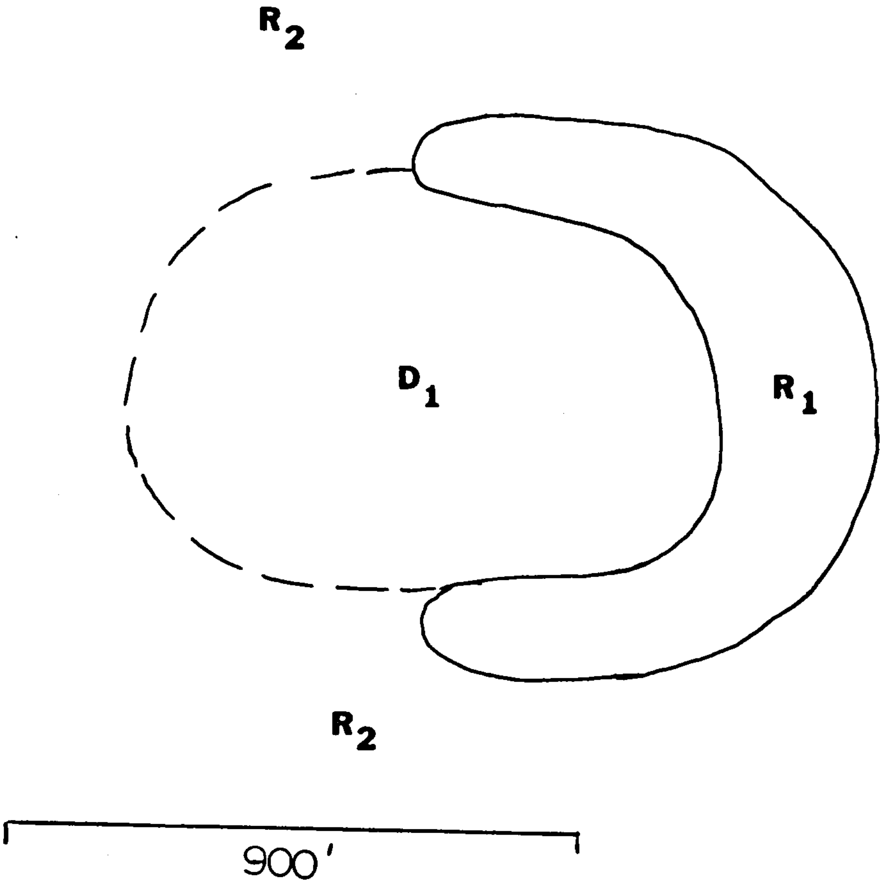

Fig. 36. Soils map of Bay 163 located 1 mile southeast of Centerville in Accomac County, Virginia.

Soil Mapping Unit Descriptions

Bay 163

R_1 0 - 8 inches, brown to dark brown (10 YR 4/3) sandy loam.
8 - 16 inches, brown (7.5 YR 4/4) to reddish-brown (5 YR 4/4) sandy clay loam.
16 - 25 inches, reddish-brown (5 YR 4/4) sandy loam.
25 - 37 inches, strong brown (7.5 YR 5/6) loamy sand.

Range in Characteristics--Solum depth ranges from 24 to 30 inches. Textures of the B horizons range from sandy loam to sandy clay loam. Colors of B horizons range from brown to reddish-brown.

R_2 0 - 8 inches, brown to dark brown (10 YR 4/3) sandy loam.
8 - 26 inches, strong brown (10 YR 5/6) sandy clay loam.
26 - 36 inches, strong brown (10 YR 5/8) sandy loam to loamy sand.
36 inches, yellowish-brown (10 YR 5/8) sand.

Range in Characteristics--Solum depth ranges from 32 to 40 inches. Textures of B horizons range from heavy sandy loam to sandy clay loam and colors range from brown to strong brown.

D_1 0 - 10 inches, dark grayish-brown (10 YR 4/2) sandy loam.
10 - 21 inches, dark yellowish-brown (10 YR 4/4) sandy loam.
21 - 37 inches, yellowish-brown (10 YR 5/4) sandy loam to sandy clay loam.
37 - 44 inches, strong brown (7.5 YR 5/6) loamy sand.

Range in Characteristics--Solum depth ranges from 40 to 45 inches. Textures of the B horizons range from sandy loam to sandy clay loam and colors range from brown to strong brown.

SOIL PROFILE DESCRIPTION (Bay 256)

Location - .5 mile West of Miona

Elevation - 10-15 ft.

Relief - 8-15 ft.

Rim Profile

Ap 0 - 12 inches, yellowish-brown (10 YR 5/4) loamy sand; massive structure; moist firm to friable, nonsticky and nonplastic; very strongly acid; clear smooth boundary.

B_2t 12 - 20 inches, strong brown (7.5 YR 5/6) sandy loam; massive structure; friable, nonsticky and nonplastic; extremely acid; clear smooth boundary.

B_3 20 - 30 inches, yellowish-brown (10 YR 5/8) loamy sand; with few fine faint mottles of white (10 YR 8/2); single grain; very friable; very strongly acid; gradual smooth boundary.

C_1 30 - 42 inches, brownish-yellow (10 YR 6/8) loamy sand; with common fine distinct mottles of very pale brown (10 YR 7/4); single grain; very friable; very strongly acid; gradual smooth boundary.

C_2 42 - 78 inches, yellow (10 YR 7/6) to very pale brown (10 YR 7/3) sand; single grain; loose; very strongly acid; clear smooth boundary.

C_3 78 inches+, very pale brown (10 YR 7/4) sand; single grain; loose; very strongly acid.

Depression Profile

A_1 0 - 8 inches,tblack (10 YR 2/1) fine sandy loam; weak, fine, granular structure; moist friable, non-sticky and non-plastic; few large roots; extremely acid; gradual smooth boundary.

A_2 8 - 14 inches, very dark gray (10 YR 3/1) to very dark grayish-brown (10 YR 3/2) sandy loam; weak, fine, granular structure; moist friable, medium to fine roots; extremely acid; clear smooth boundary.

B_2 14 - 20 inches, grayish-brown (2.5 Y 5/2) sandy loam; massive structure; friable, slightly sticky and nonplastic; few, medium to fine roots; extremely acid; abrupt smooth boundary.

B_3 20 - 26 inches, light gray (2.5 Y N7/) loamy sand; massive structure; nonsticky; very strongly acid; clear, smooth boundary.

C_1 26 - 32 inches, light gray to gray (5 Y 6/1) loamy sand, with many, medium, large mottles of pale olive (5 Y 6/3); massive structure; nonsticky; very strongly acid; gradual boundary.

C_2 32 - 56 inches, light gray (2.5 N6/) loamy sand; with common nonsticky; very strongly acid; gradual boundary.

C_3 56 inches +, light brownish-gray (2.5 Y 6/2) sandy loam to light clay loam; massive structure; strongly acid.

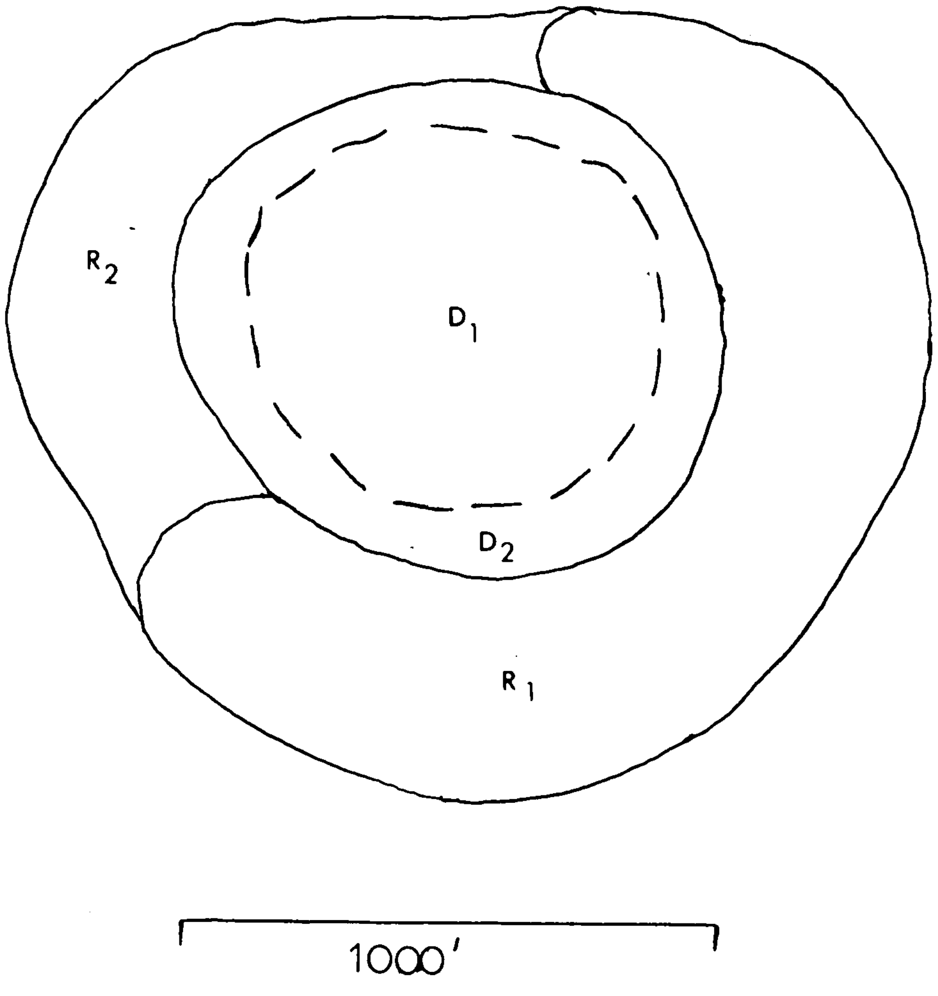

Fig. 37. Soil map of Bay 256 located 1/2 mile west of Miona, Northwestern Accomac County, Virginia.

Soil Mapping Unit Descriptions

Bay 256

R_1 0 - 12 inches, yellowish-brown (10 YR 5/4) loamy sand.
12 - 20 inches, strong brown (7.5 YR 5/6) sandy loam.
20 - 30 inches, yellowish-brown (10 YR 5/8) loamy sand.
30 - 42 inches, brownish-yellow (10 YR 6/8) loamy sand.
42 inches, yellow (10 YR 7/6) sand.

Range in Characteristics--Solum depth ranges from 26 to 34 inches. Textures of the B horizons range from sandy loam to light loamy sand and colors range from strong brown to brownish-yellow.

R_2 0 - 10 inches, brown to dark brown (10 YR 4/3) sandy loam.
10 - 22 inches, brown to dark brown (7.5 YR 4/4) sandy clay loam.
22 - 30 inches, brown to dark brown (7.5 YR 4/4) heavy sandy clay loam.
30 - 40 inches, yellowish-brown (10 YR 5/4) sandy loam.

Range in Characteristics--Solum depth ranges from 30 to 40 inches. Textures of B horizons range from heavy sandy loam to heavy sandy clay loam and colors range from brown to strong brown.

D_1 0 - 10 inches, brown (10 YR 5/3) loamy sand.
10 - 18 inches, yellowish-brown (10 YR 5/4) sandy loam.
18 - 30 inches, dark yellowish-brown (10 YR 4/4) sandy clay loam.
30 - 45 inches, yellowish-brown (10 YR 5/8) sandy loam.

Range in Characteristics--Solum depth ranges from 30 to 45 inches. Textures of the B horizons range from sandy loam to sandy clay loam. Colors of B horizons range from dark yellowish-brown to strong brown.

D_2 0 - 8 inches, black (10 YR 2/1) sandy loam.
8 - 14 inches, very dark gray (10 YR 3/1) sandy loam.
14 - 20 inches, grayish-brown (2.5 Y 5/2) sandy loam.
20 - 26 inches, gray (N5/) loamy aand.
26 - 32 inches, gray to light gray (N6/) loamy sand.
32 - 56 inches, light gray (N7/) loamy sand.

Range in Characteristics--Depth to stratified material ranges from 25 to 35 inches. Textures of B horizons range from sandy loam to loamy sand and colors range from gray to brownish-gray.

SOIL PROFILE DESCRIPTION (Bay 199)

Location - 1 mile West of Winterville

Elevation - 5 ft.

Relief - 5 ft.

Rim Profile

Ap 0 - 9 inches, dark grayish-brown (10 YR 4/2) sandy loam; weak, fine granular structure; moist friable or slightly firm; wet, slightly sticky and slightly plastic; very strongly acid; clear smooth boundary.

B_2t 9 - 18 inches, olive (5 Y 5/3) heavy sandy loam; structureless, massive; moist frim, slightly sticky and slightly plastic; few fine roots; strongly acid; gradual smooth boundary.

B_3 18 - 25 inches, brown to dark-brown (10 YR 4/3) loamy sand; structureless, massive; moist very friable, non-sticky and non-plastic; few fine roots; strongly acid; gradual smooth boundary.

C_1 25 - 28 inches, light gray (2.5 Y 7/2) to light yellowish-brown (10 YR 6/4) sandy loam; structurelss, massive; moist friable to slightly firm, non-sticky and non-plastic; strongly acid; clear, smooth boundary.

C_2 28 - 36 inches, dark grayish-brown (10 YR 4/2), dark yellowish-brown (10 YR 3/4) and yellowish-brown (10 YR 5/4) loamy sand; structureless single grain; very friable; strongly acid.

C_3 36 - 65 inches, loamy sand.

C_4 65 - 90+ inches, loamy sand to sandy loam.

Depression Profile

A_1 0 - 6 inches, dark gray (5 Y 4/1) fibrous mucky peat; many coarse roots; weakly acid; clear wavy boundary.

B_1 6 - 15 inches, dark gray (5 Y 4/1) silty muck; structureless, massive; sticky when wet; near neutral reaction; gradual boundary.

B_2 15 - 27 inches, dark gray (2.5 Y N4/) silty clay loam; structureless massive; sticky and plastic when wet; near neutral reaction; gradual boundary.

B_{31} 27 - 40 inches, dark gray (2.5 Y N4/) sandy clay loam; structureless, massive, sticky and plastic when wet; weakly acid; gradual goundary.

B_{32} 40 - 50 inches, gray (2.5 Y N5/) sandy loam.

C_1 50 - 56 inches, light gray (2.5 Y N7/) sandy loam.

C_2 56 - 60+ inches, light gray (2.5 Y 7/2) loamy sand; many coarse fragments.

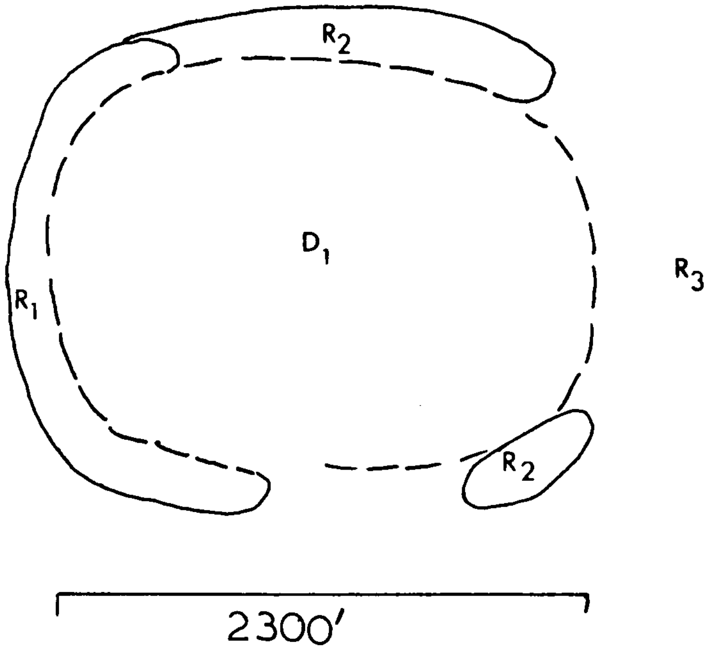

Fig. 39. Soil map of Bay 199 located 1 mile west of Winterville near Guildford Creek, Accomac County, Virginia.

Mapping Unit Descriptions

Bay 199

R_1 0 - 6 inches, light olive brown (2.5 Y 5/4) loamy sand.
6 - 15 inches, yellowish-brown (10 YR 5/4) loamy sand.
15 - 28 inches, dark yellowish-brown (10 YR 4/4) light sandy loam.
28 - 38 inches, yellowish brown (10 YR 5/4) loamy sand.

Range in Characteristics--Solum depth ranges from 25 inches to 32 inches. Textures of the B horizons range from sandy loam to loamy sand and colors range from yellowish-brown to dark yellowish-brown.

R_2 0 - 12 inches, very dark gray (10 YR 3/1) sandy loam.
12 - 16 inches, yellowish-brown (10 YR 5/8) sandy loam, with common medium distinct mottles of light brownish-gray (2.5 Y 6/2).
16 - 22 inches, brown (10 YR 5/3) sandy loam to light sandy clay loam with gray (2.5 Y N/5) mottles.
22 - 30 inches, light olive brown (2.5 Y 5/4) to gray (5 Y 5/1) sandy loam.
30 inches, loamy runny sand.

Range in Characteristics--Solum depth varies from 28 to 32 inches. Textures of the B horizons range from sandy loam to sandy clay loam and colors range from yellowish-brown to light olive gray.

R_3 0 - 6 inches, grayish-brown (2.5 Y 5/2) sandy loam.
6 - 12 inches, grayish-brown (2.5 Y 5/2) heavy sandy loam.
12 - 28 inches, grayish-brown (2.5 Y 5/2) sandy clay loam with common medium distinct mottles of olive yellow (2.5 Y 6/6).
28 - 36 inches, gray (5 Y 5/1) sandy loam.
36 inches, olive (5 Y 5/3) loamy sand with very dark grayish-brown organic stains.

Range in Characteristics--Solum depth ranges from 22 to 36 inches. Textures of the B horizons range from heavy sandy loam to heavy sandy clay loam and colors range from light olive brown to light olive gray.

D_1 0 - 6 inches, black (5 Y 2/1) silty fibrous peat with few coarse fragments.
6 - 12 inches, very dark gray (2.5 Y N3/) sandy clay loam.
12 - 28 inches, very dark gray (2.5 Y N3/) loam to silty clay loam.
28 - 40 inches, dark gray (5 Y 4/1) sand.

Mapping Unit Descriptions

Bay 199 (cont.)

40 - 54 inches, light gray (2.5 Y N6/) sand.

Range in Characteristics--Solum depth ranges from 28 to 50 inches. Textures of the B horizons range from heavy sandy clay loam to silty clay loam.

SOILS AND MORPHOLOGY OF CAROLINA BAYS ON THE EASTERN SHORE OF VIRGINIA

Abstract

by

Daniel John Bliley

Carolina bay landforms were studied on the Eastern Shore of Virginia using aerial infrared imagery provided by the National Aeronautics and Space Administration. Bays were delineated mainly by contrasting soil and vegetation which was enhanced on the imagery and further verified by field investigations.

Typical bay morphology was found in general to be similar to descriptions from other areas. However it was observed that many bays in the study area were more nearly round, and had a more westerly orientation. Consistent strongly developed southeastern rims were not observed as have been reported from other areas.

Bays were determined to be non-randomly distributed within the study area. The majority occur along the central backbone of the peninsula in a generally linear fashion and are apparently associated with larger less distinct depressions. The restriction of bay size by associated land surface may be evidenced by a number of small bays occurring on the narrow peninsula south of Wachapreague and the lack of large bays (over 2 miles in length) in the study area.

Truncation of bays above elevations of 7 ft. by a Pleistocene scarp

indicated that they were older than bays occurring at lower elevations near sea level. Examination of bay soils below the scarp also suggested a younger age than those above the scarp as evidenced by lighter textures, thinner solum depths and paler colors. Clay mineralogical determinations also revealed that soils of bays below the scarp were less weathered as evidenced by less gibbsite and greater amounts of weatherable minerals in subsurface horizons.

All soils examined had sandy subsurface horizons indicating a sandy environment of bay formation. Size distribution of sandy fractions revealed that differential sorting probably occurred between bay rims and depressions.