ABSTRACT

Title of Dissertation: THE ORIGIN AND PEDOGENIC HISTORY OF QUATERNARY SILTS ON THE DELMARVA PENINSULA IN MARYLAND

John S. Wah, Doctor of Philosophy, 2003

Dissertation directed by: Professor Martin C. Rabenhorst
Department of Natural Resource Sciences

Soils formed in Quaternary age silts are widespread on the Delmarva Peninsula in Maryland. The origin, mode of transportation and deposition, and age of the sediments in which these soils formed have long been debated and are important to understanding climate change and to investigations of the prehistory of the Delmarva. This study was undertaken in an effort to resolve the issue of the origin of parent sediments, to examine the pedogenic history of the soils, and to gain insight into the paleoclimate of the region. Thirty nine profiles were described and sampled in two north-south transects on the upland and the broad terrace along the Chesapeake Bay on Maryland's Eastern Shore. Laboratory analyses included determination of particle size distribution, determination of Zr, Ti, Ca, and K contents of coarse silts, mineralogical analysis, and the examination of

biogenic opal. The silty mantle overlying sands ranged in thickness from 150 cm to less than 50 cm, with considerable variation across the study area. Textures of this mantle were silt loam and silty clay loam with 53 to 94 percent clay-free silt and a mean clay-free particle size of 41 μm. The Zr content of the silts was uniform within profiles and across the study area while that of Ti, Ca, and K varied. Mineralogy of the silts was homogeneous across the study area. There were no features diagnostic of either fluvial/estuarine or eolian processes in the silt deposit. Minimal coarse fragments and no stratification were observed. Low chroma matrix colors of soils reflected modern drainage conditions rather than a reducing depositional environment. Pedological development argued for relatively young soils (< 30,000 years) and archaeological materials from surface horizons buried by the silts dated the onset of deposition to the end of the Pleistocene (approximately 10,500 ^{14}C years BP). The youthfulness of the silts precluded them from having been deposited during the Sangamon transgression, which occurred no more recently than 82,000 years BP, and proved unequivocally that the silts are loess. Buried paleosols were indicative of the landscape stability prior to loess deposition while phytoliths reflected a climate shift.

THE ORIGIN AND PEDOGENIC HISTORY OF QUATERNARY SILTS ON THE DELMARVA PENINSULA IN MARYLAND

by

John S. Wah

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2003

Advisory Committee:

Professor Martin C. Rabenhorst, Chair
Professor Emeritus Delvin S. Fanning
Professor Bruce R. James
Associate Professor Michael S. Kearney
Professor Richard A. Weismiller

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. Introduction

BACKGROUND

Soils formed in silts deposited during the latter stages of the Quaternary are widespread on the Delmarva Peninsula in Maryland. The origin, mode of transportation and deposition, and the timing of the deposition of these silty parent sediments have long been the subjects of disagreement. The manner in which sediments were deposited on the Delmarva is closely related to past climatic events. The silty sediments have been interpreted variously as having been deposited by fluvial/estuarine process during periods at which sea level was higher than present, by eolian processes during or at the end of the Pleistocene, or by some combination of fluvial/estuarine and eolian processes.

The age and origin of the silts is also of importance to investigations into the prehistory of the Delmarva. A fluvial/estuarine origin of the silts would restrict archaeological remains to the surface while the possibility of intact, stratified deposits exists of the silts are loess. The determination of the origin and mode of transportation of the silty sediments should also provide insight into the environment of the late Pleistocene. Soils formed in the silts should not only be useful in examining the origin of the deposit, but will likely also provide information regarding the paleoenvironment, landscape stability, and geomorphic responses to past climate changes.

The landforms and sediments that make up the Delmarva Peninsula in Maryland are a function of paleoclimatic fluctuations and their effects on glacial activity and sea level. The silty sediments in which soils have formed have been considered by some researchers to be part of the same deposit as the underlying sandy sediments and as such their deposition has been attributed to fluvial/estuarine processes and high sea stands related to interglacial or interstadial warm periods (Owens and Denny, 1979; Markewich et al., 1987). Alternatively, the parent materials of silty soils on the northern Delmarva had been identified as loess. Foss et al. (1978) suggested that the silty sediments south of their study area were also loess and that sediments were transported from glaciated regions in New York and Pennsylvania by an ancestral channel of the Susquehanna River during a period of low sea stand then subsequently moved by wind.

Early soil survey reports from Maryland counties on the Delmarva Peninsula described the silts as marine sediments (Snyder and Jester, 1926; Perkins and Hershberger, 1929; Winant and Bewley, 1930; Perkins and Winant, 1931). This view shifted, however, and the most recent reports from those counties listed these parent sediments as loess (White, 1982; Brewer et al., 1998), though no specific studies have addressed the issue of the origin of these materials south of northern Queen Anne's County.

THE STUDY AREA

The Delmarva Peninsula is situated within the Coastal Plain Province with landforms largely a function of past sea level. On the western side of the peninsula a broad, flat terrace with elevations less than six meters above sea level boarders the Chesapeake Bay between Kent County in the north and Somerset County in the south. This terrace was formed by the Sangamon high sea stand and has minimally incised

drainage networks. In some portions of the study area a pronounced scarp rises from the terrace to the earlier Pleistocene or Pliocene upland of the Delmarva, while in areas the shift to the east is more subtle. The topography on the upland is rolling with more deeply incised drainage and elevations less than 25 meters above sea level. Higher order rivers draining the upland and terrace to the Chesapeake Bay include the Sassafras and Chester rivers in the northern part of the peninsula, the Choptank River in the central portion, and the Nanticoke and Wicomico rivers in the south. Figure 1-1 shows the elevations of the terrace and upland and the larger rivers on the Delmarva Peninsula in Maryland. An annual average 1100 millimeters of precipitation distributed evenly throughout the year and an average annual temperature of 13.9 °C support a mixed hardwood vegetation dominated by Oak (*Quercus*) with Loblolly (*Pinus taeda*) and
Virginia Pine (*P. Virginius*) abundant in areas that have been cleared and abandoned. Shrubby species including greenbrier (*Smilax*), bayberry (*Myrica*), and sweet pepperbush azalea (*Clethra alnifolia*) are common, as are grasses (Brown and Brown, 1984; Brewer et al., 1998; Brown and Brown, 1999).

Soils formed in Quaternary age silts are present from Cecil County in the north to Somerset County in the south, from the Chesapeake Bay east to Caroline County and Delaware, over an area of approximately 5,000 square kilometers. On the terrace along the Bay, silts are prevalent and form a more continuous mantle, while on the more rolling topography of the upland their distribution is patchy and restricted to stable landscape positions (Figure 1-2). Soils formed in silts include the Matapeake, Nassawango, Mattapex, Othello, Keport, Elkton, Crosiadore, and Kentuck series (Brewer et al., 1998; Shields and Davis, 2001) .

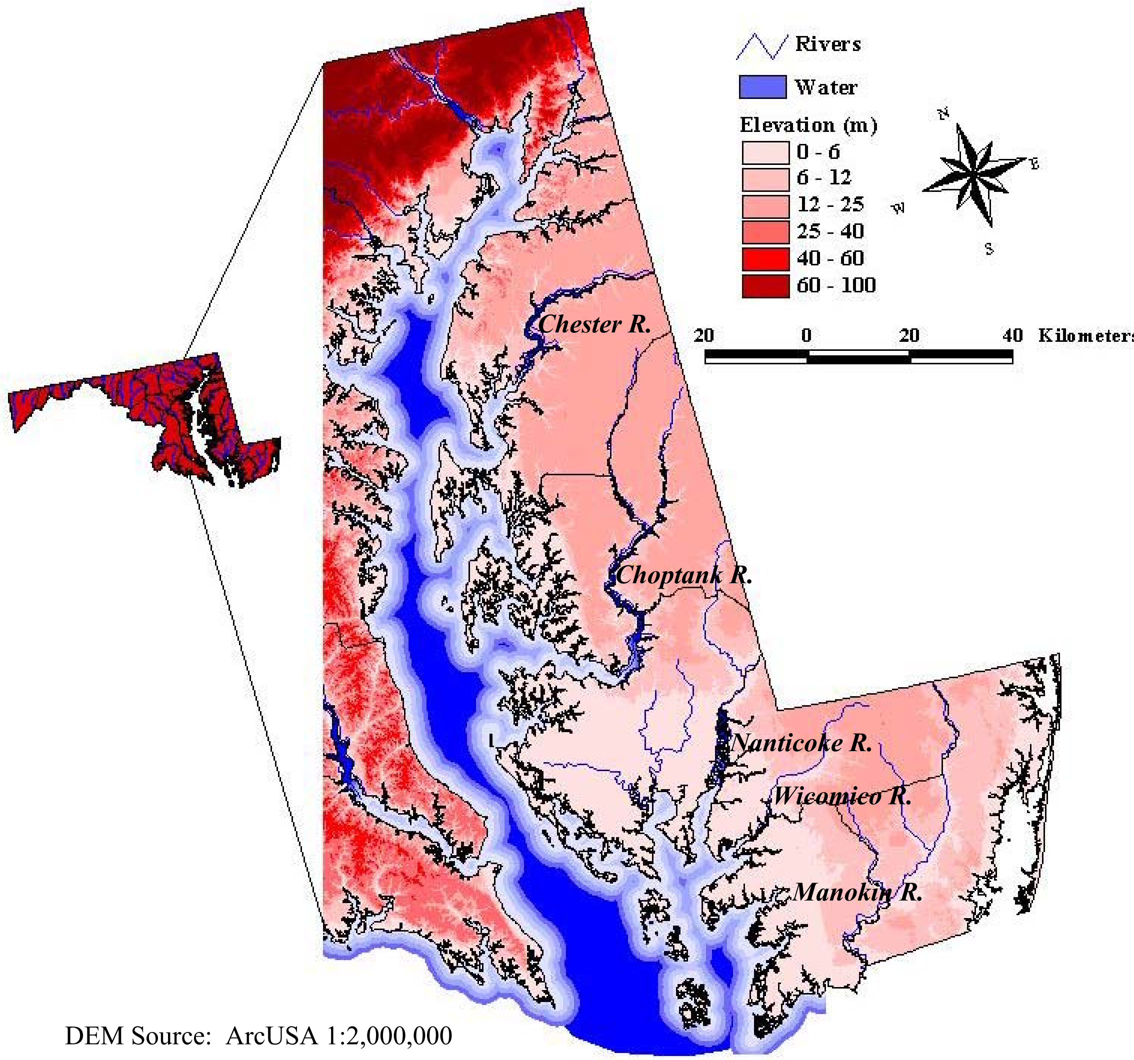


Figure 1-1. The Chesapeake Bay and Delmarva Peninsula in Maryland showing elevations and larger rivers.

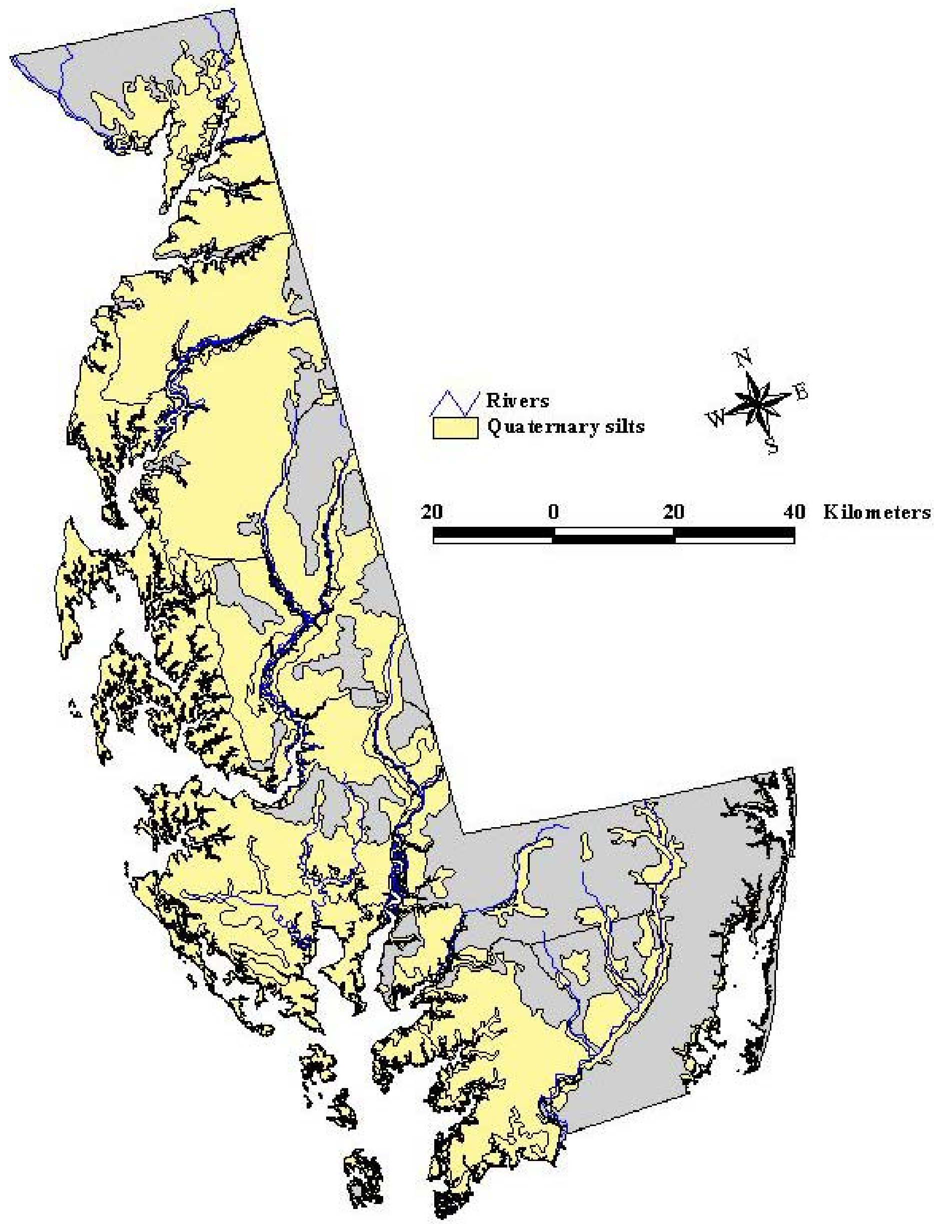


Figure 1-2. The distribution of Quaternary silts on the Delmarva Peninsula in Maryland. Mapping units of fine-silty soils were complied from the USDA-NRCS State Soil Geographic Database (STATSGO). Soil associations in STATASGO include dissimilar soils which, in this case, resulted in over-representation of the soils formed in silts.

OBJECTIVES

The objectives of this investigation are 1) to determine the mode of transportation of the silty sediments on the Delmarva Peninsula in Maryland and 2) to examine the paleoenvironmental and climatic conditions under which these sediments were deposited. The hypotheses tested were that 1) the silts on the Delmarva Peninsula were loess with a sediment source in the ancestral channel of the Susquehanna River, 2) they were fluvial/estuarine sediments deposited during a period of sea level higher than present, or 3) they were a combination of loess and fluvial/estuarine sediments.

Chapter 2. Review of Literature

INTRODUCTION

The landforms and sediments in which soils have formed on the Delmarva Peninsula are a function of the paleoclimate and its effect on glacial activity and sea level. During the Pleistocene, climatic fluctuations resulted in several episodes of glacial advance and retreat and concomitant fall and rise of relative sea level. During warm periods glacial retreat released water into the oceans causing increases in eustatic sea level while cold intervals resulted in sea levels falling as moisture was tied up in advancing glaciers. High sea stands cut terraces into existing landforms and deposited sediments during interglacials and interstadials. Drainage networks incised to maintain equilibrium and previously deposited sediments were exposed for reworking by fluvial and eolian process during glacial and stadial episodes and their accompanying low sea levels. Climate has played a further role in the deposition of sediments and development of soil both indirectly through its effect on vegetation and directly as a soil forming factor. Abundant vegetation under favorable climatic conditions stabilized sediments and soils on the landscape and decreased the likelihood of erosion and redeposition as well as influencing soil development while less favorable conditions and a dearth of vegetation increased that possibility.

PLEISTOCENE CLIMATE AND GLACIAL ACTIVITY

Beginning in the early twentieth century classical studies of climate change and glacial activity divided the Pleistocene into four major glacial/interglacial sequences. In North America these included, from oldest to youngest, the Nebraskan Glacial/Aftonian Interglacial, the Kansan Glacial/Yarmouth Interglacial, the Illinoian Glacial/Sangamon Interglacial, and the Wisconsin Glacial. These glacial stages were based on geomorphic features of maximum ice advance and did not account for less extensive expansions (Richmond and Fullerton, 1986; Smiley et al., 1991; Ehlers, 1996). This approach has been refined through more recent advances in the study of deep sea cores and of the oxygen-isotope record (Smiley et al., 1991; Bradley, 1999).

The ratio of ^{18}O to ^{16}O as a proxy for temperature has been used to identify ten glacial periods over the last million years (Smiley et al., 1991) and has been especially useful for examining climatic fluctuations since and including the Sangamon Interglacial approximately 125,000 years B.P. Oxygen isotope Stage 5 represents an interglacial period that began approximately 130,000 years B.P. and lasted until approximately 79,000 years B.P. This stage is divided into five substages (5e through 5a) which reflect temperature shifts within the interglacial, with the Sangamon Interglacial expressed during substage 5e, approximately 125,000 years B.P. (Richmond and Fullerton, 1986). Temperatures during the Sangamon Interglacial are estimated to have been two to three degrees Celsius higher than present (Smiley et al., 1991; Bradley, 1999). Warm temperatures have also been recognized for substages 5c and 5a, though temperatures were not as warm as at present (Toscano and York, 1992).

Oxygen-isotope stages 4 and 3 represent the early and middle Wisconsin to approximately 30,000 years B.P. (Richmond and Fullerton, 1986; Bradley, 1999). Temperatures during these periods did not approach those of the present (Bradley, 1999).

The late glacial maximum occurred during oxygen-isotope Stage 2, approximately 18,000 ^{14}C years B.P. Temperatures during this period are estimated to have been 4-5 °C cooler than present (Smiley et al., 1991) with glacial ice covering New York and reaching into northern Pennsylvania and New Jersey (Crowl and Sevon, 1980). Geomorphological evidence from Pennsylvania has indicated that glacial retreat may not have begun until as late as 15,000 ^{14}C yr B.P. (Crowl and Sevon, 1980).

Two events after the last glacial maximum are of particular interest, the Bølling /Allerød interstadial and the Younger Dryas stadial. The relatively warm temperatures of the Bølling/Allerød interstadial began approximately 12,500 ^{14}C years B.P. and ended abruptly with the onset of the Younger Dryas and, in some regions, glacial readvance (Ehlers, 1996; Bradley, 1999). The Younger Dryas cooling event lasted from approximately 11,000 ^{14}C years B.P. to 10,000 ^{14}C years B.P. with temperatures approximately 3-4 °C cooler than present. It was followed by renewed warming (Peteet et al., 1990; Alley et al., 1993; Peteet et al., 1993) with a drier climate through the beginning of the Holocene until approximately 8,000 ^{14}C years B.P. (Kneller and Peteet, 1993).

In addition to the oxygen-isotope records, terrestrial records, including pollen and macrofossils, have been useful records of climate change throughout the late Pleistocene especially the period after the last glacial maximum. Sangamon age sites in North America that have yielded pollen data that support the oxygen-isotope record with vegetation assemblages represented by the pollen indicating that the climate was similar to, though slightly warmer than, the modern climate. (Smiley et al., 1991). Pollen analysis from several sites in Nova Scotia has identified the Allerød/Younger Dryas climate oscillation (Mott et al., 1986) as has recent work from the eastern Great Lakes region (Yu and Wright, 2001). Abrupt climate changes at the onset of the Younger Dryas have been well documented in pollen assemblages, plant macrofossils, and fish remains (Peteet et al., 1990; Alley et al., 1993; Peteet et al., 1993; Shuman et al., 2002) which demonstrate the magnitude, extent, and duration of these temperature fluctuations.

PLEISTOCENE SEA LEVEL

Sea level is closely related to climate and glacial activity. Warm periods throughout the Pleistocene have resulted in glacial retreat and concomitant rise in relative sea level, while cold periods and glacial advance have caused sea levels to fall. Determining the relative level of the sea at any time in the past, however, is a complicated endeavor and one that has resulted in many disagreements and discrepancies in the literature. Relative sea level is dependent upon factors other than just the amount of water in the oceans at a given time. In glaciated areas and areas on the glacial margin, relative changes in sea level have largely been a function of both eustatic sea level and isostatic rebound or regional uplift associated with the removal of the weight of glacial ice (Dawson, 1992; Cronin, 1999). The determination of relative sea level is confounded by the fact that marine transgressions often destroy, through erosion, evidence of earlier, less high sea levels.

In the Mid-Atlantic region the last widely recognized high sea stand occurred during the Sangamon Interglacial, oxygen-isotope substage 5e, 125,000 years B.P. (Owens and Denny, 1979; Mixon, 1985; Toscano et al., 1989; Toscano and York, 1992; Gallup et al., 1994; Groot and Jordan, 1999). This high sea stand was likely between five and six meters above present (Toscano et al., 1989; Toscano and York, 1992; Groot and Jordan, 1999). Warm periods with relative sea levels near present have been recognized for substages of oxygen-isotope stage 5. Groot and Jordan (1999) have suggested a possible sea stand slightly higher than present at substage 5c or 5a, approximately 105,000 years B.P. or 82,000 years B.P., respectively. Toscano et al. (1989), however, indicated that sea levels were near present during stage 5c and seven meters below present during stage 5a, while Gallup et al. (1994) noted sea levels more than ten meters below present at those times.

In addition to the Sangamon high sea stand, Owens and Denny (1979) identified a period of marine/estuarine transgression four and a half meters above current sea level approximately 30,000 years B.P. based on ^{14}C dated terrestrial deposits. Based on the warm-temperate pollen assemblages and radiocarbon dates in excess of 40,000 years B.P. from this formation in other areas of the Delmarva Peninsula, these deposits have since been assigned to oxygen-isotope stage 5 (Mixon, 1985; Toscano and York, 1992) and consensus reached that there was no mid-Wisconsin high sea stand (Mixon, 1985; Toscano et al., 1989; Toscano and York, 1992; Groot and Jordan, 1999; T.M. Cronin, personal communication, 2002). Sea level was likely more than 40 meters below present between 30,000 and 40,000 years B.P. (T.M Cronin, personal communication, 2002).

During the last glacial maximum glaciers reached their farthest southern extent into northern Pennsylvania and New Jersey and sea levels fell to their lowest levels. The 18,000 ^{14}C years B.P. date used for this corresponds with oxygen-isotope stage 2, however, geomorphological evidence from eastern Pennsylvania has indicated that glacial retreat may not have begun until as late as 15,000 ^{14}C years B.P. (Crowl and Sevon, 1980). Fairbanks (1989) estimated that sea level at that time was 121 meters below present at tectonically stable Barbados. Estimates for the Mid-Atlantic have placed sea level at approximately 85 meters below present on the continental shelf (Dillon and Oldale, 1978) and 65 meters at the base of the Susquehanna River paleochannels in the modern Chesapeake Bay (Colman and Mixon, 1988).

Glacial retreat and sea level rise at the end of the Pleistocene are thought to have occurred in two major steps with a period of rapid sea level rise corresponding with the Bølling/Allerød interstadial, beginning ca. 12,500 ^{14}C yr B.P. and ending with the onset of the Younger Dryas Interstadial, ca. 11,000 ^{14}C yr B.P. A second episode of rapid sea level rise centered at 9,500 ^{14}C yr B.P. was followed by decreased rates throughout the Holocene (Fairbanks, 1989). Sea levels are estimated to have been between 26 meters (Kraft et al., 1987) and 30 meters (Colman et al., 2000) below present during the Younger Dryas, approximately 11,000 ^{14}C years B.P. Figure 2-1 shows oxygen-isotope stages and sea levels since the Sangamon Interglacial.

Time divisions	Age* (ka)	Oxygen-isotope stage*		Climatic event	Sea level (m)
Holocene		1		Younger Dryas	-22[a]
	11			Bølling/Allerød	-26[b] -30[c]
Late Wisconsin		2		Late glacial maximum	-120[g] -85[h]
					+4.5[e] -40[i]
	35				
Middle Wisconsin		3			
	65				
Early Wisconsin		4			
	75				
Early Wisconsin/ Late Sangamon		5	a		+?[a] -7[d] -15[f]
			b		OR
			c		+?[a] -15[f]
			d		
	120				
Sangamon Interglacial			e	Peak interglacial	+6[a,d,e,f]

*Richmond and Fullerton (1986) and Bradley (1999); [a]Groot and Jordan (1999); [b]Kraft et al. (1987); [c]Colman (2000); [d]Tuscano and York (1992); [e]Owens and Denny (1979); [f]Gallup et al. (1994); [g]Fairbanks (1989); [h]Dillon and Oldale (1978); [i]Cronin (personal communication, 2002)

Figure 2-1. Oxygen-isotope stages, climatic events, and relative sea levels in the Mid-Atlantic region during the Late Pleistocene.

LANDFORMS OF THE DELMARVA

Landforms on the Delmarva Peninsula are largely a function of past sea level. Early investigations into the genesis of the landforms reviewed by Owens and Denny (1979) focused on the marine-terrace concept according to which successive marine transgressions throughout the Quaternary cut terraces into the existing landscape and deposited sediments. In the early 20th century Shattuck identified four such terraces, the Talbot, Wicomico, Sunderland, and Lafayette, which were later modified by Cooke and used to correlate marine terraces and high sea stands along the Atlantic seaboard. Owens and Denny (1979) noted the broad acceptance of this concept despite a general lack of supporting evidence.

On the western side of the Delmarva, Owens and Denny (1979) recognized one broad flat terrace between one and six meters above sea level positioned between the Chesapeake Bay and a scarp rising to the east and an earlier Pleistocene and Pliocene upland 12 to 25 meters above sea level. They attributed this terrace to fluvial/estuarine processes related to a mid-Wisconsin high sea stand 30,000 years B.P. Mixon (1985) working on the southern Delmarva in Maryland and Virginia disagreed. Based on warm-temperate pollen assemblages and radiocarbon dates in excess of 40,000 years B.P. from this formation in other areas of the Delmarva Peninsula, he placed this terrace in the warm Sangamon interglacial, oxygen-isotope stage 5e, as did Toscano and York (1992). Groot and Jordan (1999) have tentatively identified a marine transgression higher than present during oxygen-isotope stage 5c or 5a that could have deposited sediments. The broad flat terrace along the Chesapeake Bay, then, is likely no younger than oxygen-isotope stage 5a, approximately 82,000 years B.P. and may well be from stage 5e, 125,000 years B.P.

In addition to terraces cut during marine transgressions, drainage networks responded to changes in sea level. Three paleochannels of the Susquehanna River have been identified. The oldest of the three, the Exmore incised during either oxygen-isotope stage 12 or stage 8, 450,000 or 250,000 years B.P., followed by a southward migration during the succeeding high sea stand. The Eastville paleochannel incised during stage 6, 150,000 years B.P. and like the Exmore continued to migrate to the south. The most recent Susquehanna River paleochannel, the Cape Charles, incised during the last glacial maximum, oxygen-isotope stage 2, approximately 18,000 ^{14}C years B.P. (Colman and Mixon, 1988) and carried meltwater and sediments from the glaciated areas of Pennsylvania and New York upon the late Pleistocene warming.

SEDIMENTS ON THE DELMARVA

Like the landforms, the sediments on the Delmarva are closely tied to sea level, glacial activity, and climate. The majority of the unconsolidated surficial deposits of the Delmarva have been deposited by marine transgressions during the Pliocene and Pleistocene (Owens and Denny, 1979; Mixon, 1985; Toscano and York, 1992; Groot and Jordan, 1999). The last episode of this deposition occurred either approximately 125,000 or 82,000 years B.P. with the recorrelation of the Kent Island Formation from the mid-Wisconsin to oxygen-isotope stage 5 (Owens and Denny, 1979; Mixon, 1985; Toscano and York, 1992).

In addition to coastal plain sediments deposited during high sea stands, there are eolian sands. The Parsonsburg Sand forms broad mantles of Sangamon age deposits reworked at the end of the Pleistocene ca. 30,000 to 13,000 ^{14}C years B.P. on the southern Delmarva (Denny et al., 1979) and sand dunes of similar age and origin present on the east side of the larger rivers in Maryland and Delaware (Denny and Owens, 1979). In at least one of these dunes Denny and Owens (1979) noted what appeared to be two separate episodes of sand deposition and speculated that the earlier sand dune may have been truncated and then covered by younger sediments.

Deposits of predominately silt sized particles are widespread on the Delmarva and mantle much of the upland and terrace along the Chesapeake Bay. These deposits were included in the fluvial/estuarine Kent Island formation of Owens and Denny (1979). Foss et al. (1978) found that these deposits on the northern Delmarva were wind transported or loess, while Markewich et al. (1987) concluded that while loess was likely present, its distribution was highly localized and did not form a widespread sheet.

Soil survey reports from Maryland counties on the Delmarva Peninsula have described the silty parent sediments in which soils have formed as marine sediments, possibly eolian silty coastal plain sediments, and loess. The earliest reports from Dorchester (Snyder and Jester, 1926), Talbot (Perkins and Hershberger, 1929), Queen Anne's (Perkins and Winant, 1931), and Kent (Winant and Bewley, 1930) counties remarked on the similarity of the silty soils in those counties to loessial soils elsewhere but concluded that the sediments on the Delmarva were of marine origin. Perkins and Hershberger (1929, p.18) concluded:

> The soil materials in the extensive forelands and necks are mainly silt deposits and resemble some of the loessial material in other parts of the United States. The silt deposit occurs also in many areas, especially in the flat stretches, in the uplands. Much of this material maintains the constructional form as it was laid down under the sea.

The 1959 Dorchester County report (Matthews,1959, p.62) described the parent material in which the Matapeake, Mattapex, Othello, and Portsmouth soils had formed as a "mantle of silts or loess, [which] probably was blown from glaciated areas to the north." More recent reports from Queen Anne's (Matthews and Reybold, 1966) and Somerset counties (Matthews and Hall, 1966, p. 81) referred to the same sediments as being of "possible eolian" origin. In the Talbot County update Matapeake, Mattapex, and Othello parent sediments were described as silty marine sediments (Reybold, 1970) while in Cecil County the Leonardtown Series was reported as having formed in silty coastal plain sediments (Andersen and Matthews, 1973). The most recent Kent and Dorchester County soil survey reports both listed the silty parent sediments as loess (White, 1982; (Brewer et al., 1998).

LOESS

Loess is wind transported silt and very fine sand sized particles. In North America its origin is a result of the mechanical grinding of rocks by glaciers and subsequent movement and deposition of that material by wind. During warm climatic periods outwash from retreating glaciers was carried downstream by abundant meltwater and deposited. In the ensuing cooler, drier periods during which less vegetation was present and water levels decreased, outwash deposits became exposed and the local source for wind transportation (Ruhe, 1983).

Loess deposits and soils formed in loess have unique characteristics that can be used for identification. Eolian sediments show sorting with distance from the source area as coarser particles fall out of suspension first resulting in deposits that become finer with distance. Likewise, deposits are thickest at the source and become increasingly thin with distance. Since loess is wind transported, deposits occur on landscapes at all elevations, and soils formed in loess are dominated by silt and very fine sand sized particles (Simonson, 1982; Ruhe, 1983; Pye, 1996). In relating loess to climate and glacial/interglacial cycles, each discrete deposit is representative of a relatively cold period in which conditions were suitable for loess accumulation and soils formed in the loess represent periods of interglacial or interstadial warm temperatures and landscape stability. The relative development of these soils is often related to the duration or intensity of the warm period (Ruhe, 1983; Norton et al., 1988).

Loess is common in the Midwestern United States and along the Mississippi River south of the glacial border with deposits ranging from Colorado in the west to Ohio in the east and from Minnesota to Louisiana (Frye et al., 1962; Ruhe, 1983; Norton et al., 1988; Leigh and Knox, 1994). Three main loess deposits have been recognized, though dates vary and numerous different names have been applied to them, locally. The oldest of the three, the Loveland loess, was deposited during the Illinoian glacial, likely oxygen-isotope stage 6, approximately 135,000 years B.P. A strongly developed soil formed in the Loveland loess during the subsequent Sangamon interglacial (Norton et al., 1988). The Roxana silt or Farmdale loess was likely deposited during the middle Wisconsin with dates from underlying materials ranging from 25,000 to 33,000 years B.P. (Ruhe, 1983; Norton et al., 1988; Leigh and Knox, 1994). The paleosol formed in this deposit was less well developed than both the Sangamon soil formed in the Loveland loess and the modern soil indicating a short and/or relatively mild stadial warming (Norton et al., 1988). The youngest of the three widely recognized loess deposits and the most widespread, the Peoria loess, is of late Wisconsin age. Radiocarbon dates indicate that it was likely emplaced between ca. 22,000 years and 16,000 ^{14}C years B.P. (Ruhe, 1983; Norton et al., 1988; Leigh and Knox, 1994). Another less widely distributed or less widely recognized loess deposit, the Bignell loess, is likely late Pleistocene/Holocene in age. In Nebraska and Kansas, ^{14}C dates from the paleosol underlying this deposit place it after 9,000 years B.P. (Ruhe, 1983). A similar loess in Colorado is thought to have been emplaced between 11,000 ^{14}C years and 9,000 ^{14}C years B.P. and possibly be related to the Younger Dryas cold episode (Muhs et al., 1999).

Loess has been identified in the Mid-Atlantic region. In southeastern Pennsylvania, silty soils in Bucks and Montgomery counties were determined to have formed in loess likely derived from materials transported by the Delaware and Schuylkill rivers (Carey et al., 1976). Soils in adjacent areas in New Jersey were also described as loess (Tedrow and MacClintock, 1953). Simonson (1982) noted the presence of loess in Delaware, Maryland, and northeastern Virginia. Silty soils on the uplands and the broad flat terrace along the Chesapeake Bay on the northern Delmarva Peninsula in Cecil, Kent, and Queen Anne's counties were identified as loess based on the physical properties of the soils and deposits (Foss et al., 1978). The ancestral channels of the Susquehanna River were thought to have been the source of the sediments which were later transported by wind across the Delmarva. The surface horizon of a paleosol buried by this loess yielded a date of approximately 10,520 ^{14}C years B.P. (Foss et al., 1978). Darmody and Foss (1982) noted a loess mantle covering truncated paleosols formed in residuum in the Piedmont of Maryland. Soils formed in the loess had physical and morphological properties similar to those of the loessial soils from the northern Delmarva and a stone line at the discontinuity. Similarly, Rabenhorst et al. (1982) identified silty eolian additions to soils formed in serpentinite residuum on the Maryland Piedmont. On the Coastal Plain west of the Chesapeake Bay in southern Maryland, soils formed in a silt mantle thought to be loess overlie well developed paleosols (Wright, 1972). Recently, a loess cap overlying a stone line was identified near Occoquan in the Piedmont Province of northern Virginia with a thermoluminesence date of approximately 13.8 B.P. (Feldman et al., 2000).

PALEOSOLS

There is some debate as to the exact definition of paleosols, however, in general, paleosols are soils formed in a landscape or under climatic conditions other than those in which the modern soil has formed (Yaalon, 1983; Bronger and Catt, 1989). Paleosols may be buried by younger sediments or buried and exhumed by erosion of the younger sediments. They may be truncated by erosion or they may be intact, subaerial, and undergoing continued pedogenesis in which case they are often referred to as relict soils (Yaalon, 1983; Bronger and Catt 1989). Paleosols reflect the conditions under which they formed and are, therefore, good indicators of past climates and landscapes (Yaalon, 1983; Bronger and Heinkele, 1989). In the Midwestern United States, well developed soils formed in the Loveland loess and subsequently buried reflect the warm temperatures and extended weathering during the Sangamon interglacial stage (Norton et al., 1988). Additionally, widespread paleosols that are morphologically distinct and identifiable, such as the Sangamon soil, can be used as stratigraphic markers to develop spatial and temporal frameworks over broad areas (Olson, 1989).

BIOGENIC OPAL

Biogenic opal (opal-A) is a silica polymorph ($SiO_2 \cdot nH_2O$) that is found in soils and which, through distinct morphological properties, can be traced to the plant or animal by which it was formed. Spicules (needle-like support structures produced by sponges), diatoms (silica cell walls of unicellular algae), and phytoliths (silica bodies secreted by plants), persist in most soil environments. Biogenic opal has a specific gravity that ranges from 1.5 to 2.3 which is a function of the particle structure, H_2O content, and chemical inclusions (Drees et al., 1989). Color is dependent upon the amount of chemical inclusions and ranges from dark brown to colorless. Opal-A is generally isotropic with a refractive index between 1.41 and 1.47 (Wilding and Drees, 1968, 1971; Klein and Hurlbut, 1993; Drees et al., 1989). The size and shape of biogenic opal directly reflect the organism from which it came. Preservation in soils is related to the size and density of the opal particles and pH, temperature, and soluble silica concentrations of the soil. Increased stability of opal-A may also be related to iron and aluminum on the silica surface (Drees et al., 1989).

The presence, absence, and relative abundance of certain types of biogenic opal in soils have been used to identify lithologic discontinuities, buried surface horizons, and to assess the uniformity of parent materials (Wilding and Drees, 1968, 1971; Verma and Rust, 1969; Drees et al., 1989), to determine the origin/mode of transportation of sediments (Jones and Beavers,1963; Wilding and Drees, 1971), and to draw conclusions about vegetation (Wilding and Drees, 1968, 1971; Verma and Rust, 1968; Waltman and Ciolkosz, 1995) and past environmental conditions (Blecker et al., 1997; Barboni et al., 1999)

Sponge Spicules

Sponge spicules are opaline support structures produced by both fresh- and saltwater sponges. They range in size to >300 μm. Freshwater sponge spicules commonly found in soil are smooth, needle-like bodies distinguishable from elongated phytoliths by an axial canal (Jones and Beavers, 1963). Sponge spicules in primary deposits are generally evenly distributed and indicative of relatively shallow and calm aquatic environments. As with any small particles, spicules are susceptible to erosion, transportation, and redeposition. Jones and Beavers (1963) in Illinois and Wilding and Drees (1968, 1971) in Ohio identified freshwater sponge spicules in the silt fractions of soils from upland interfluve positions and concluded from their presence as well as their fragmented nature that they were transported with other loessial material from local fluvial source areas. In the Illinois study Jones and Beavers (1963) observed a trend of decreasing spicule content with distance away from the source area while Wilding and

Drees (1971) noted the potential usefulness of sponge spicules for examining the uniformity of loessial parent materials.

Diatoms

Diatoms are opaline cell walls of unicellular organisms that are present in most marine and freshwater environments. Centric diatoms display radial symmetry and are generally less than 25 µm in diameter while pennate diatoms are bilaterally symmetrical and vary in size up to 100 µm in length. Either type can be present in fresh or salt water, however, concentric diatoms tend to be more common in salt water environments and pennate in fresh (California Academy of Sciences, 2002). The morphology of diatoms varies widely and their environmental niche specificity makes them excellent indicators of climatic, environmental, and sea level changes (Cooper, 1999; Denys and De Wolf, 1999; Stoermer and Smol, 1999). Bratton et al. (2002) indicated that sediments of the Chesapeake Bay were composed of between five and ten percent biogenic silica, the majority of which came from diatoms. Like spicules, diatoms are subject to transportation and redeposition and so their presence and distribution in soil can reflect either the aquatic environment in which they were initially deposited or a secondary depositional environment.

Phytoliths

Phytoliths are silica plant secretions that are of the size and shape of the cell in which they have formed. Those from fundamental and bulliform cells from grass epidermis range in size from 15 to >100 μm while silica bodies from more specialized short cells tend to be less than 20 μm (Bonnett, 1972; (Piperno, 1988). While the larger phytoliths are common among grasses, the less than 20 μm silica bodies are morphologically distinct and allow the differentiation of grasses to the subfamily (Twiss et al., 1969) and, in some cases, lower taxonomic levels (Piperno, 1988). Phytoliths from deciduous trees tend to be fragile cell wall linings distinct from grass phytoliths with the majority being less than 20 μm in size (Wilding and Drees, 1971).

Classification systems for phytoliths are based on the morphological properties of the silica bodies. Some systems relate the size and shape of the opal to particular plants at some taxonomic level while others favor the assignment of classes based on the functional cellular origins of the phytoliths. Combinations of the taxonomic and functional approaches to phytolith classification are often most useful (Twiss et al., 1969; Piperno, 1988; Mulholland and Rapp, 1992).

Through the cyclical growth and decay of plants, phytoliths accumulate on the surface and in the shallow subsurface of soils which has proven useful to pedological, paleoecological, and paleoclimatic studies in many ways. Since phytolith contents are highest in surface horizons of soil and decrease with depth they are ideal indicators of buried surface horizons, especially when organic matter in the buried surface has been oxidized and other morphological indicators lost, and of lithologic discontinuities. Jones and Beavers (1964), Wilding and Drees (1968, 1971), and Verma and Rust (1969) all observed high phytolith contents in surface horizons decreasing with depth with those of Wilding and Drees (1971) ranging from 0.1 to 0.3% in surface horizons and less than 0.03% below 50 cm. Verma and Rust (1969) observed a similar decrease in phytolith content with depth with the exception of areas in which relatively thin loess blanketed a second parent material. In those cases, phytolith content increased at the discontinuity indicating the possible existence of a buried surface.

The ability to attribute phytoliths preserved in soils to particular subfamilies of plants has increased the ability of pedological investigations to draw conclusions regarding past vegetative and paleoenvironmental conditions. Phytoliths from C_3 grasses are, generally, morphologically distinct from those from C_4 grasses (Twiss, 1992) as are those of grasses from trees (Wilding and Drees, 1968, 1971; Geis, 1973) allowing phytolith assemblages to represent vegetation which in turn serves as a proxy for climate. Several researchers have used phytolith analysis as a part of pedological investigations. In the U.S. Midwest phytoliths have been used to examine soils formed in prairie areas to determine not only the type of vegetation that has occupied the landscape and contributed to soil formation but also how long the conditions represented by that vegetation endured (Wilding and Drees, 1968, 1971; Verma and Rust, 1968; Waltman and Ciolkosz, 1995). Wilding and Drees (1968, 1971) found significantly lower phytolith contents in soils of the Ohio Prairie Peninsula compared to similar Illinois soils and concluded the Ohio soils had been forming under prairie conditions for a relatively short period of time, on the order of 200 to 400 years, while most of their development had taken place under forest. Verma and Rust (1969) determined that the soils from southeastern Minnesota developed predominately under bluestem prairie with a brief period of forest cover or forest-prairie mix indicated by the presence of phytoliths from oak, hickory, and ironwood. Waltman and Ciolkosz (1995) determined from the phytolith content of soils in prairie areas of northwestern Pennsylvania that the mollic epipedons present had formed in an estimated 2,000 to 6,000 years.

In addition to drawing conclusions about vegetation and climatic conditions that influenced the modern soil, the examination of phytoliths in pedological investigations of surface horizons and paleosols isolated from further phytolith additions by burial allows investigators to gain insight into past vegetative assemblages and the paleoclimate that they represent. Blecker et al. (1997) identified early and middle Holocene paleosols in alluvial soils in Colorado and based on the presence of Panicoid phytoliths concluded that the early and middle Holocene had a more favorable climate for grass production with warm conditions and more available soil moisture than the present. Pleistocene and Holocene sediment samples from the Middle Awash Valley in Ethiopia were collected and the phytoliths from those samples examined by Barboni et al. (1999) to study the paleoclimate and environment of the region. They found the Pleistocene phytoliths were predominately those of C_4 Panicoideae subfamily indicating a grass vegetation with a limited woody plant component and a warm, humid climate while those from the Holocene were C_4 Chloridoideae grasses adapted to warm dry climate.

Chapter 3. Morphological and Physical Characteristics of Quaternary Silts and Associated Soils

INTRODUCTION

Soils formed in silts deposited during the latter stages of the Quaternary are widespread on the Delmarva Peninsula in Maryland. The origin and mode of transportation and deposition of the silty parent sediments are closely related to environmental factors and past climatic events. There is no consensus among researchers, however, as to what event or events were responsible for the silts. The silty sediments on the Delmarva are frequently considered to be part of the same deposit as the underlying sands and as such are thought to have been deposited by fluvial/estuarine processes during a period of marine transgression (Owens and Denny, 1979; Markewich et al., 1987). Sea levels were last higher than present approximately 82,000 years B.P. or 125,000 years B.P. (Toscano et al., 1989; Groot and Jordan, 1999). Alternatively, the silts have been identified as eolian sediments deposited at the end of the Pleistocene. Foss et al. (1978) determined that the silts on the upland in northern portion of the Delmarva were loess, based on the physical properties of the soils formed in the silts and of the silt deposit, itself. No specific studies have addressed the origin of these materials south of northern Queen Anne's County.

Morphology and physical properties of soils can be used to examine the nature of the parent sediments and the pedogenic history of the soils. They can, similarly, be employed to evaluate the continuity of a deposit and determine whether parent materials are of comparable age and origin and likely of the same depositional event or if there were multiple, distinct deposits representing more than one event and possibly more than one mode of transportation and deposition. An estimated age of the soils can be determined based on soil development (Birkeland, 1984; Foss and Segovia, 1984).

The objectives of this study were to determine the origin of the silty sediments on the Delmarva through the examination of morphological and physical properties of soils formed in those sediments. The hypotheses tested were that 1) the silts on the Delmarva Peninsula are loess with a sediment source in the ancestral channel of the Susquehanna River, 2) they are fluvial/estuarine sediments deposited during a period of sea level higher than present, and 3) if multiple, distinct silts deposits were present, that they were deposited by a combination of eolian and fluvial/estuarine processes.

MATERIALS AND METHODS

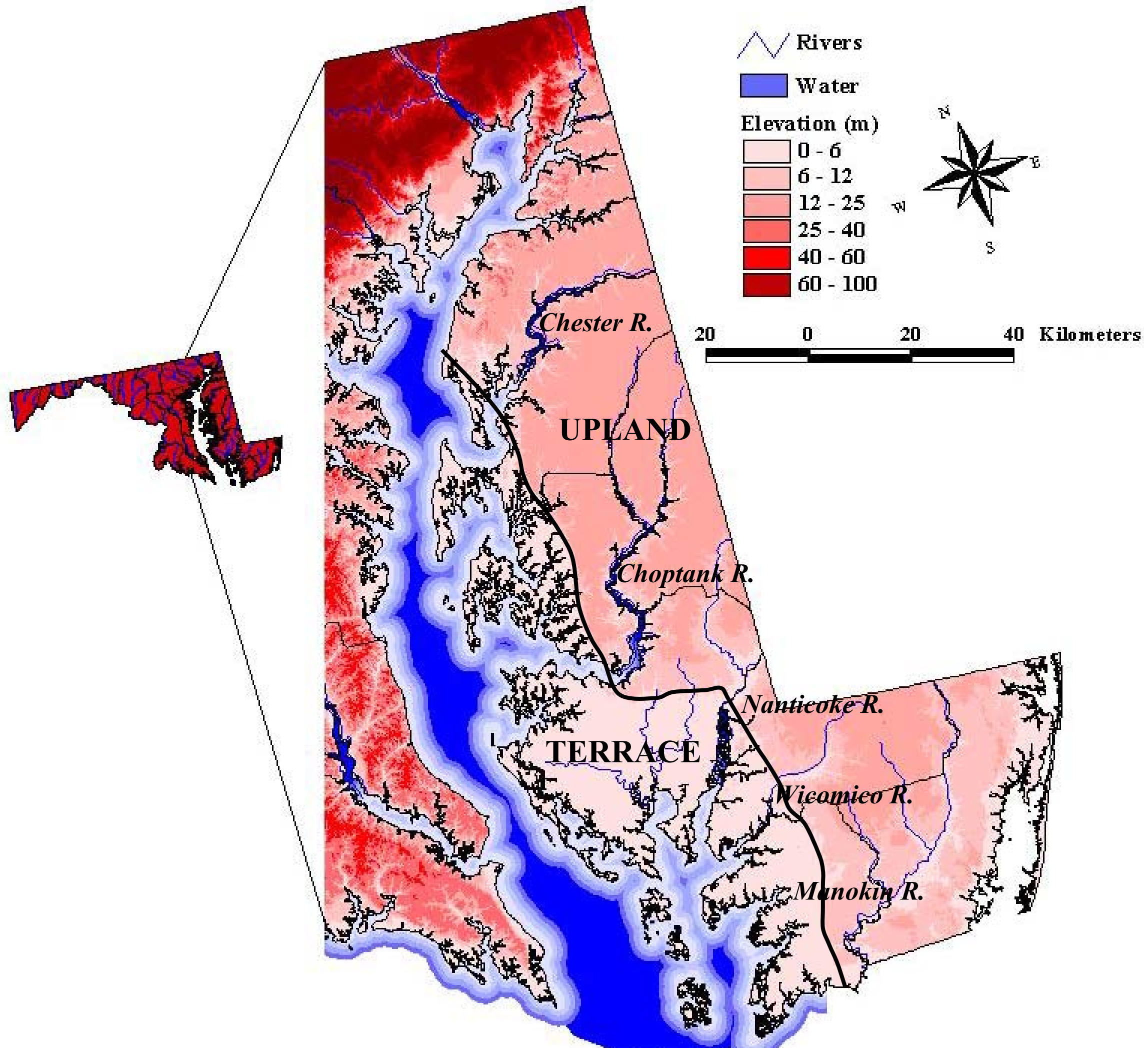
The Study Area

The Delmarva Peninsula is situated within the Coastal Plain Province with landforms largely a function of past sea level. On the western side of the peninsula a broad, flat terrace with elevations less than six meters above sea level boarders the Chesapeake Bay between Kent County in the north and Somerset County in the south. To the east a pronounced scarp rises to the earlier Pleistocene or Pliocene upland of the Delmarva with elevations generally between 12 and 25 meters above sea level. The topography on the upland is rolling with more deeply incised drainage. Higher order rivers draining the upland and terrace to the Chesapeake Bay include the Sassafras and Chester rivers in the northern part of the peninsula, the Choptank River in the central portion, and the Nanticoke and Wicomico rivers in the south. Figure 3-1 shows the elevations of the terrace and upland and the larger rivers on the Delmarva Peninsula in Maryland.

Soils formed in Quaternary age silts are present from Cecil County in the north to Somerset County in the south, from the Chesapeake Bay east to Caroline County and Delaware, over an area of approximately 5,000 square kilometers (Figure 3-2). On the terrace along the Bay, silts are prevalent and form a more continuous mantle, while on the more rolling topography of the upland their distribution is patchy and restricted to stable landscape positions.

Site Selection and Sampling

Deposit thinning and fining with distance from the source area are characteristics frequently used to identify eolian sediments (Ruhe, 1969; Simonson, 1982; Ruhe, 1983). At the Missouri River Valley in Iowa the loess deposit was over 17.5 meters thick and thinned to slightly less than two and a half meters 275 kilometers to the east (Ruhe, 1969). In contrast, the loess deposit on the northern Delmarva was less than 150 centimeters thick at the Chesapeake Bay and thinned to less than 50 centimeters within 30 kilometers (Foss et al., 1978). In the thick loess deposits of the Midwest natural



DEM Source: ArcUSA 1:2,000,000

Figure 3-1. The Chesapeake Bay and Delmarva Peninsula in Maryland. The low terrace (0-6 m above sea level), the upland (> 6 m above sea level), and the larger rivers are labeled.

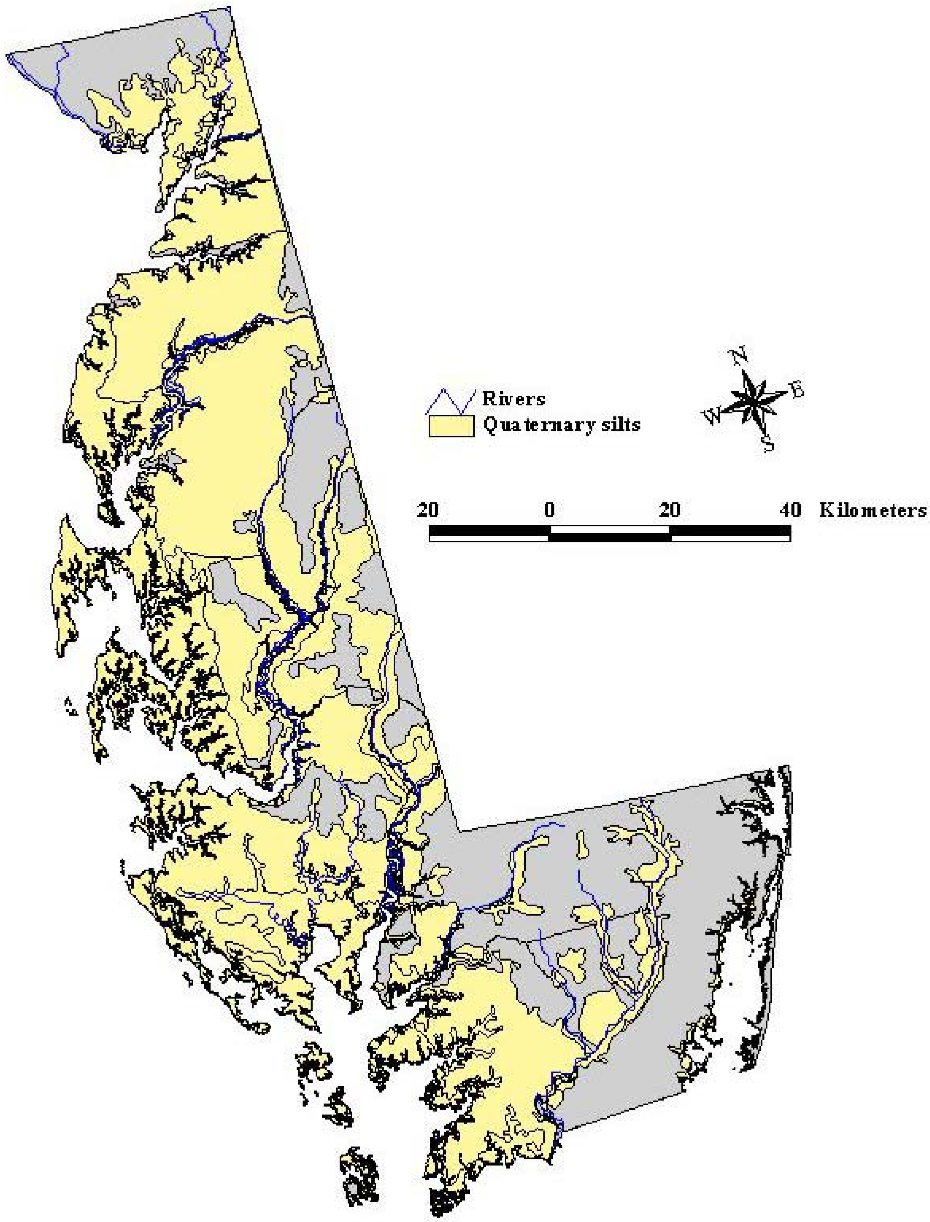


Figure 3-2. The distribution of Quaternary silts on the Delmarva Peninsula in Maryland. Mapping units of fine-silty soils were complied from the USDA-NRCS State Soil Geographic Database (STATSGO). Soil associations in STATASGO include dissimilar soils which, in this case, resulted in over-representation of the soils formed in silts.

variation in deposit thickness of 50 centimeters at any location along a transect normal to the source area would not greatly affect the relationship between deposit thickness with distance from the source. In the thin loess on the northern Delmarva, however, such a variation would equal at least a third of the total thickness of the deposit and would greatly decrease the correlation between deposit thickness and distance from the source area. Foss et al. (1978) used the relationship between deposit thickness and distance from the source, among other things, to demonstrate that the silts present on the northern Delmarva were loess. Their correlation coefficients for deposit thickness and distance form Chesapeake ranged from -0.16 to -0.96, however, and they noted considerable variability in deposit thickness.

Given the modest thickness of the silt deposit (< 150 cm), its limited distribution on the southern Delmarva, and the variation encountered by Foss et al. (1978) it was decided that the use of classical methods for identifying loess involving deposit thinning and fining with distance from assumed source areas should not be relied upon heavily for examining the origins of the silts on the Delmarva. Instead, sites were selected to determine whether the silts spread across the Delmarva were of one deposit or whether there were separate, discrete silt deposits. If the silt deposit on the Delmarva was homogeneous, then it could be concluded that all of the silts were deposited at the same time and that they were an extension of the northern Delmarva loess. If, however, it was determined that more than one silt deposit was present, then age and mode of transportation of the discrete silt deposits would need to be determined separately. Therefore, rather than examine soils in several east-west transects from the Chesapeake, two north-south transects, one on the terrace and the other on the upland including the area on the northern peninsula identified by Foss et al. (1978) as loess, were sampled to test the spatial homogeneity of the deposit.

In addition to examining spatial homogeneity, soils were examined for morphological features indicative of a fluvial/estuarine depositional environment or of processes other than eolian transportation. Such features include coarse fragments, preserved stratification, abundant marine fossils, and evidence of past sulfidic conditions common in low energy estuarine environments, such as jarosite and pyrite.

The last marine transgression with sea levels higher than present is generally accepted to have occurred either 82,000 years B.P. or 125,000 years B.P. (Toscano and York, 1992; Groot and Jordan, 1999). If silts on the Delmarva were emplaced after the last marine transgression or at elevations higher than those reached by the sea at that time, then they were necessarily deposited by processes other than those associated with high sea levels. The degree of pedogenic development of soils formed in the silts in the Delmarva was examined to establish a relative age for the soil/silt deposit with regard to the timing of high sea stands.

The lines of investigation were employed to discern 1) whether the silts on the Delmarva were either all of the same depositional event or if there were multiple, discrete silt deposits on the Delmarva, 2) the presence or absence of features diagnostic of fluvial/estuarine deposition, and 3) the relative age of the soil/sediments and their relationship to past climatic events.

Sites were located in broad flat areas, as far removed as possible from topographic breaks and with slopes less than two percent, to minimize the likelihood of past erosion. In total, 39 sites were selected which included several areas of interest in addition to the two transects previously described (Figure 3-3). Soils were described and sampled in backhoe pits, at bank cuts, and through auger borings to a depth that included a lithologic discontinuity, generally between one and two meters. At each site soil morphological properties were described in accordance with the Soil Survey Manual (Soil Survey Staff, 1993) and the Handbook for Describing and Sampling Soils (Schoenberger et al., 1998) and samples taken from each horizon for laboratory analysis. Special emphasis was placed on the examination of profiles for morphological features possibly diagnostic of deposition by fluvial/estuarine process, including abundant coarse fragments, preserved stratification in the less weathered horizons, the presence of marine fossils, and evidence of past sulfidic conditions.

Laboratory Analysis

In the laboratory samples were dried, crushed, and passed through a number 10 (2 mm) sieve. The less than two millimeter fraction was used for physical characterization of the soil. Particle size distribution was determined by the pipette method (Gee and Bauder, 1986) with the silts divided into coarse (20-50 μm) and fine (2-20 μm) fractions for all samples. Weighted average particle size distributions for the soils formed in the silts were calculated by multiplying the weight percent of a given size fraction for a soil horizon by the thickness of that horizon, then dividing the sum of weighted size fractions from the horizons in the pedon by the lower depth of the pedon. In examining the particle size distribution of the silt deposit, weighted averages were generally calculated to a depth that excluded the mixing zone with underlying materials. Particle size

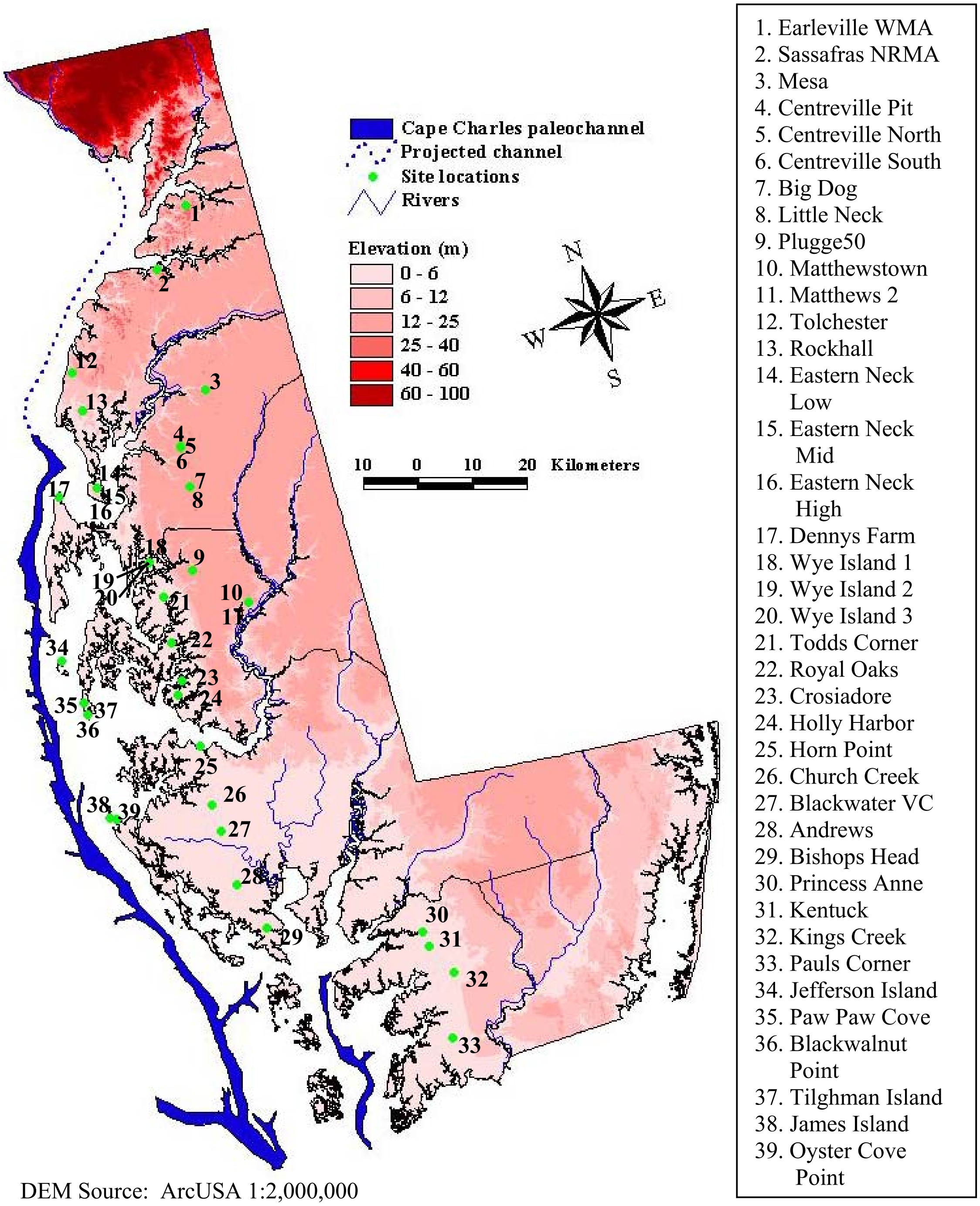


Figure 3-3. Site locations included in this study. Sites one through 11 were on the north-south transect on the upland. Sites 12 through 33 were on the north-south transect on the terrace. Sites 34 through 39 were located at places of interest.

statistics, including clay free mean and median particle size, were calculated in phi based on cumulative frequency (Reineck and Singh, 1980; Prothero and Schwab, 1996). Sorting was calculated in millimeters (Trask, 1932) (rather than phi) and divided into four classes. Soils with a sorting coefficient of 1.0 to 1.5 were considered to be excellent, 1.5 to 2.5 well, 2.5 to 4.0 moderately well, and > 4.0 poorly sorted (Carey et al., 1976). Surface interpolation maps of silt deposit thickness and particle size sorting across the study area were created by universal kriging in ArcView (Oliver and Webster, 1990).

RESULTS AND DISCUSSION

Field Morphology

Characteristics of the Silt Deposit

The silt deposit on the Delmarva Peninsula was present over an area of approximately 5,000 square kilometers. It was relatively thin, less than one and a half meters thick in most places, and did not form a continuous mantle. Figure 3-4 shows the interpolated surface map of silt deposit thickness across the study area. The thickest deposit was observed at Dennys Farm (site 17), where the silts were 158 centimeters thick to the contact with underlying sands, which to some extent belied a trend of decreasing deposit thickness from north to south. In general the silt deposit was thicker in the northern portion of the study area and decreased to the south with the thinnest

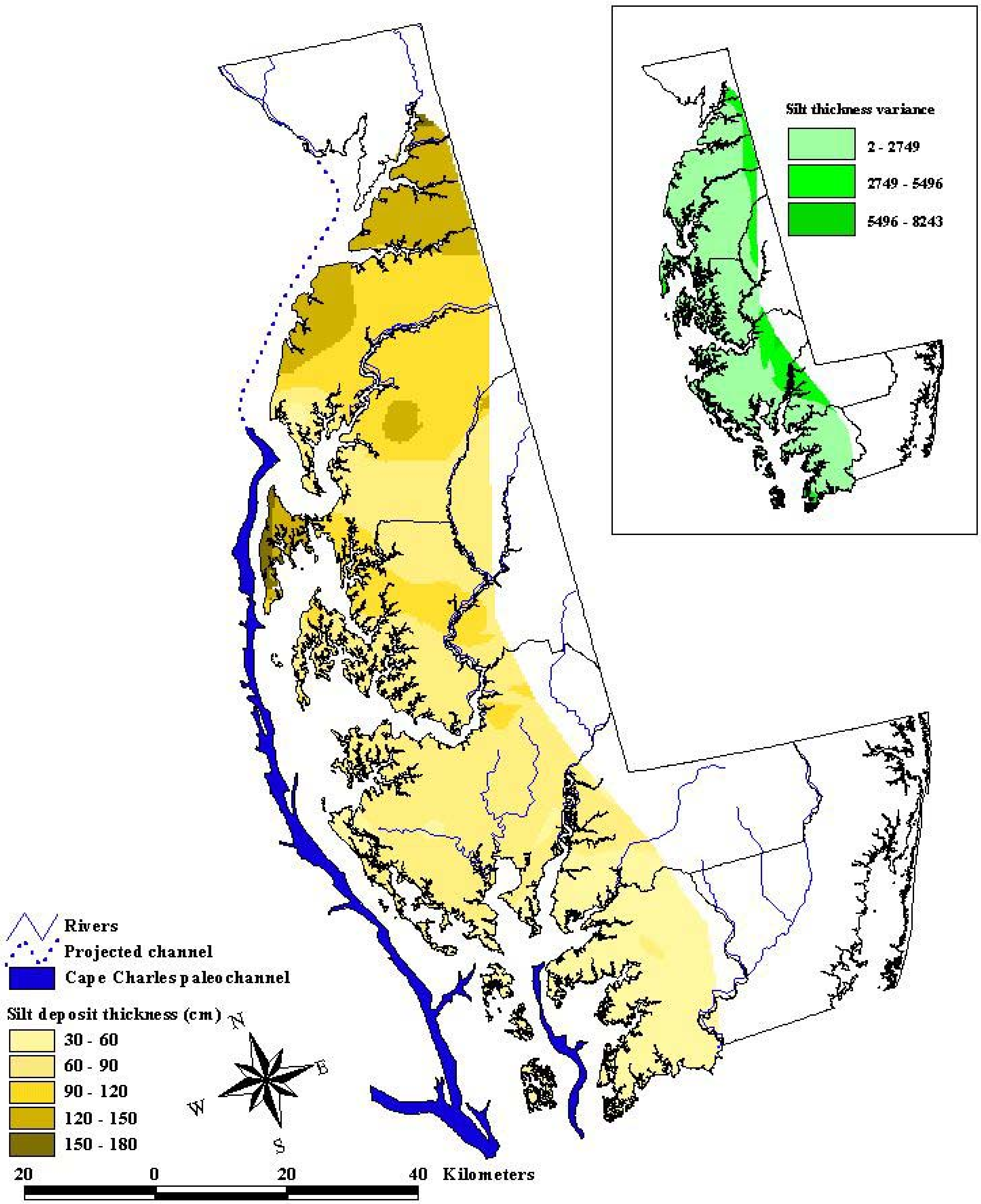


Figure 3-4. Interpolated surface map showing silt deposit thickness across the study area. The deposit was generally thicker in the north than in the south, however, there was considerable local variation. The inset map shows the variance for the interpolated data.

deposits observed at the southernmost sites. The silts in Somerset County were 43, 60, 61,and 46 centimeters thick at Pauls Corner (site 33), Kings Creek (site 32), Kentuck (site 31), and Princess Anne (site 30), respectively. There was, however, considerable local variation in deposit thickness. At Rockhall (site13) in the northern portion of the study area, the silts were only 53 centimeters thick while at the adjacent site, Tolchester (site12) eight kilometers to the north, they were 132 centimeters. At Paw Paw Cove (site 35) the silts were 53 centimeters thick while two kilometers to the south they were 86 centimeters thick at Blackwalnut Point (site 36). Similarly, at three sites within a hundred meters of each other, Wye Island 1 (site18), Wye Island 2 (site 19), and Wye Island 3 (site 20), the silt deposit was 80, 110, and 103 centimeters thick. The mean deposit thickness over the study area was 85 centimeters.

Though not a central focus of this investigation, the relationship between deposit thickness and distance from the sediment source has frequently been used to identify silts as loess. With the ancestral channel of the Susquehanna River, the Cape Charles paleochannel (Colman and Mixon, 1988), as the sediment source, this relationship was examined for the silts on the Delmarva. Table 3-1 shows the thickness of the silt deposit and distance from the Cape Charles paleochannel for all sites. The silt deposit was thickest at Dennys Farm (site 17), less than four kilometers from the paleochannel, and thinnest at Pauls Corner (site 33), more than 39 kilometers from the channel. There was, however, considerable variation across the study area. At Paw Paw Cove (site 35) and Oyster Cove Point (site 39), both of which were located within ten kilometers of the paleochannel, silts were 54 and 53 centimeters thick, respectively, while at Royal Oaks (site 22) 25 kilometers from the channel silts were 76 centimeters thick and at

Table 3-1. Silt deposit thickness and distance from the ancestral channel of the Susquehanna River of sites described and sampled.

Site	Distance from channel (km)	Silt thickness (cm)	Site	Distance from channel (km)	Silt thickness (cm)
Earleville WMA (site 1)	11	130	Todds Corner (site 21)	24	110
Sassafras NRMA (site 2)	12	115	Royal Oaks (site 22)	25	76
Mesa (site 3)	31	115	Crosidore (site 23)	25	71
Centreville North (site 4)	26	132	Holly Harbor (site 24)	25	80
Centreville Pit (site 5)	26	137	Horn Point (site 25)	26	78
Centreville South (site 6)	26	114	Church Creek (site 26)	22	89
Big Dog (site 7)	27	67	Black Water VC (site 27)	20	55
Little Neck (site 8)	27	60	Andrews (site 28)	16	74
Plugge50 (site 9)	30	80	Bishops Head (site 29)	16	60
Matthewstown (site 10)	39	109	Princess Anne (site 30)	40	46
Matthews 2 (site 11)	39	90	Kentuck (site 31)	41	61
Tolchester (site 12)	5	132	Kings Creek (site 32)	43	60
Rock Hall (site 13)	10	53	Pauls Corner (site 33)	39	43
Eastern Neck Low (site 14)	9	65	Paw Paw Cove (site 35)	7	54
Eastern Neck Mid (site 15)	9	72	Blackwalnut Point (site 36)	7	86
Eastern Neck High (site 16)	9	69	Tilghman Island (site 37)	7	105
Dennys Farm (site 17)	4	158	James Island (site 38)	8	79
Wye Island 1 (site 18)	23	80	Oyster Cove Point (site 39)	9	53
Wye Island 2 (site 19)	23	110	Wye Island 3 (site 20)	23	103

Matthewstown (site 10) 39 kilometers from the channel they were 109 centimeters. Across the study area silt deposit thickness exhibited a weak thinning trend with increasing distance from the assumed source area. The correlation coefficient was -0.20 ($P < 0.01$). Figure 3-5 shows the relationship between distance from the source area and deposit thickness for all sites.

The variability in silt deposit thickness and the weak correlation between deposit thickness with distance from the paleochannel do not favor the hypothesis that these are wind transported sediments. They do not, however, prove that the sediments are the result of fluvial estuarine processes. It is possible that movement of sediments following initial deposition has occurred. It is not possible, however, to determine how much of the local disparity in silt deposit thickness reflects the primary deposition of sediments and how much, if any, might be related to redeposition.

Soils Formed in the Silts

Soils formed in the silts were morphologically similar across the study area. Table 3-2 shows an abbreviated profile description from Sassafras NRMA (site 2) which was an upland site in the northern portion of the study area. The argillic horizon at Sassafras NRMA had silt loam texture with the maximum expression of the argillic horizon in the Bt2 horizon which occurred from 53 to 80 centimeters below the soil surface and had 24 percent clay. Moist colors of the argillic horizons had hues of 10YR. Pedogenic processes in the silt deposit, such as the translocation of clay and iron oxides, tended to extend through the silts and into the underlying sands, 'welding' the two parent

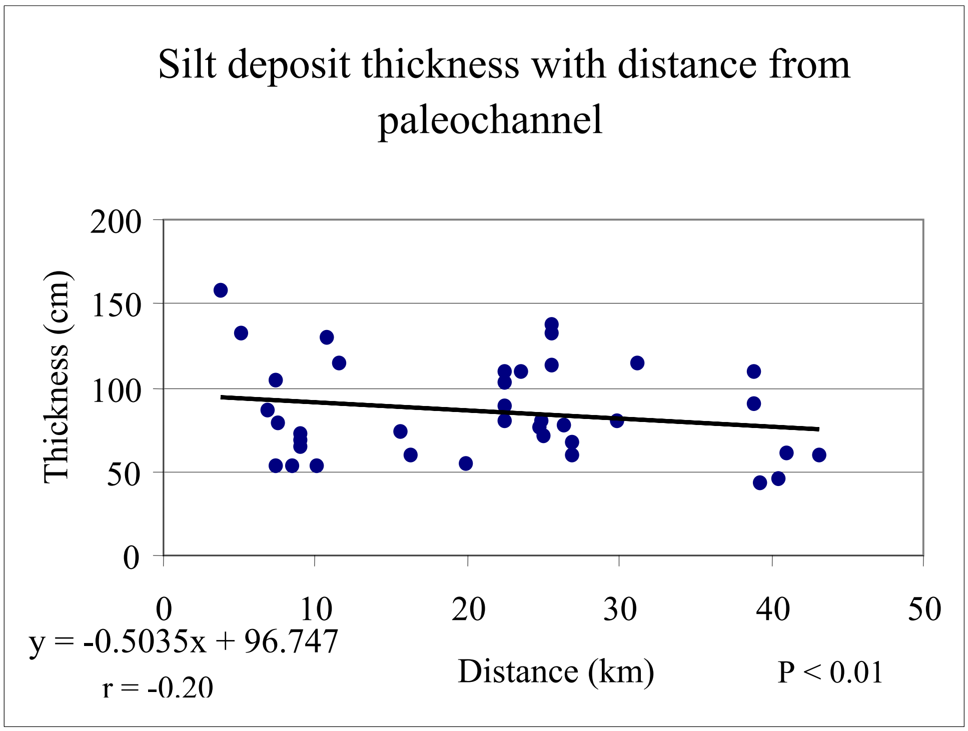


Figure 3-5. Silt deposit thickness versus distance from the ancestral channel of the Susquehanna River for all sites described and sampled. The correlation coefficient was -0.20.

Table 3-2. Abbreviated profile description for Sassafras NRMA (site 2).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Consist.**
Ap	0-33	2.5Y4/4	--	SiL	vfr
Bt1	33-53	10YR5/6	--	SiL	fr
Bt2	53-80	10YR5/8	--	SiL	fr
Bt3	80-115	10YR5/6	f1f 7.5YR5/8 c1d 10YR7/3	SiL	fr
2Bt4	115-140	10YR5/6	f1d 7.5YR4/6 c1d 10YR6/3	L	vfr

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Fieldbook for Describing and Sampling Soils (Schoenberger et al., 1998)
**Moist samples

materials. Also apparent at the base of the silt deposit was a zone of mixing of the silts with the underlying sands. The total thickness of the argillic horizon at Sassafras NRMA (site 2), including that extending into the underlying sands, was slightly over a meter. Plugge50 (site 9), like Sassafras NRMA (site 2), was an upland site and had similar morphological features (Table 3-3), with a silt loam argillic horizon, the maximum expression of the argillic between 21 and 46 centimeters with 26 percent clay, and welding with the underlying sands. The total thickness of the argillic horizon at Plugge50 (site 9) was slightly under one meter.

Soils formed on the terraces were similar to each other and also were very much like those of the upland. Todds Corner (site 21) (Table 3-4) had a 70 centimeter thick argillic horizon with silt loam and silty clay loam textures and the maximum expression of the argillic horizon between 40 and 52 centimeters below the soil surface. Clay content in the argillic horizon was 30 percent. Moist colors in the Bt horizons had 10YR hues. The solum extended to a depth of 110 centimeters. Silty clay loam textures in argillic horizons were common in the soils on the terrace and, as on the upland, pedogenic process frequently extended into underlying materials. See appendix A for narrative descriptions for all sites included in this study.

In addition to the brightly colored well and moderately well drained soils with high chroma matrix colors, poorly drained soils were also common in the study area. Wye Island 1 (site 18) had gray (<2 chroma) matrix colors in every horizon below the surface horizon. Low chroma colors resulting from the reduction and depletion of iron from sediments have often been attributed to deposition of the sediments in a reducing environment, generally under water (Reineck and Singh, 1980). Iron reduction and gray

Table 3-3. Abbreviated profile description for Plugge50 (site 9).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Consist.**
Ap	0-21	2.5Y5/4	--	SiL	fr
Bt1	21-46	10YR5/8	--	SiL	fr
Bt2	46-71	10YR5/8	--	SiL	fr
Bt3	71-88	10YR5/6	--	L	fr
2Bt4	88-110	10YR5/6	--	SL	fr
2BC	110-120	10YR6/6	--	SL	vfr

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Fieldbook for Describing and Sampling Soils (Schoenberger et al., 1998)
**Moist samples

Table 3-4. Abbreviated profile description for Todds Corner (site 21).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Consist.**
A	0-6	10YR4/1	--	SiL	fr
E	6-14	2.5Y6/3	--	SiL	fr
BE	14-40	10YR6/4	c2f 10YR5/6 c2f 2.5Y6/2	SiL	fr
Bt1	40-52	10YR5/6	c2f 10YR5/8 f2d 7.5YR4/6 c2f 2.5Y6/1	SiCL	fr
Bt2	52-74	10YR6/6	c2d 10YR5/8 m2d 2.5Y7/1	SiL	fr
Btg1	74-98	2.5Y6/2	c2d 7.5YR5/6 c1f 2.5Y6/1	SiL	fr
Btg2	98-110	2.5Y6/1	f1f 10YR6/6 c2f 2.5Y5/1	SiL	fr
2Ab	110-130	2.5Y4/1	f1f 10YR5/6 f1f 2.5Y6/2	L	fr
2BC	130-140	10YR4/3	f2f 10YR6/4	FSL	vfr

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Fieldbook for Describing and Sampling Soils (Schoenberger et al., 1998)
**Moist samples

colors may, however, be a function of the landscape position occupied by the soil and hydrology (Richardson and Daniels, 1993).   At Wye Island 2 (site 19), 70 meters south of, and at the same elevation as Wye Island 1 (site 18), the matrix colors of the Bt1 and Bt2 horizons were 2.5Y5/6 and 2.5Y5/4, respectively. Sites with high chroma colors in the subsoil juxtaposed with sites with low chroma matrix colors clearly indicate that gray soil colors across the study area reflect modern drainage conditions rather than depositional environment.

Estimated Age from Soil Development

Morphological properties of a soil can be compared to those of other soils of known ages to examine the pedogenic development and gain an estimated age of the soil in question. Soil properties related to the translocation and accumulation of clay and iron oxides such as development of cambic or argillic horizons, increases in clay content of argillic horizons, increased solum thickness, and increased reddening of argillic horizons are frequently examined as indicators of relative soil development and age (Foss and Segovia, 1984; Dorronsoro and Alonso, 1994). It need be noted that when estimating the relative age of a soil by comparison, pedogenesis and morphological features of soils from different regions, soils formed in different parent materials, and soils formed during periods with different climatic conditions, have been influenced to some extent by soil forming factors other than time.

Across the Delmarva, soils displayed similar morphological properties and pedogenic development. Argillic horizons with textures of silt loam, silty clay loam, or loam with high fine and very fine sand contents had developed at all sites examined. Maximum clay content of the argillic horizons ranged from 16 to 37 percent, with the average maximum clay content of 26 percent for all sites. Solum thickness ranged from 53 to 158 centimeters, with an average solum thickness of 92 centimeters for all sites. Hues of the argillic horizons at the well- and moderately well drained sites were predominately 10YR with a few 7.5YR hues.

Soils formed in well dated sediments with textures similar to the silty Delmarva sediments are widespread and have been studied extensively in the Midwestern U.S. Soils developed from between 25,000 to 12,000 years B.P. to the present in the Peoria loess of Wisconsin and Illinois had clay contents of approximately 22 percent in the argillic horizons, 10YR hues in the argillics, and sola that were typically 150 centimeters thick (Leigh and Knox, 1994). Soils at these same sites formed in the Loveland loess between approximately 125,000 years B.P. and 50,000 years B.P. had argillic horizons with 30 to 40 percent clay, 7.5YR and 10YR hues, and sola that extended between one and a half and two meters deep. Norton et al. (1988) noted in two studies in Indiana and Ohio that soils formed in the Peoria loess, which was less than 22,000 years old, had maximum clay contents in the argillic horizons of 23 and 27 percent, respectively. In the same studies soils developed in the Loveland loess from the Sangamon Interglacial (ca.125,000 years B.P.) to the onset of deposition of the Farmdale or Roxana loess (ca. 33,000 years B.P.) had argillic horizons with more than 40 percent clay. The Midwestern sites are generally at higher latitudes than Maryland with climate slightly cooler and drier than that of the Delmarva Peninsula. Rates of pedogenesis are comparable, however, the warmer, wetter environment of the Delmarva might slightly favor weathering and the development of soil morphological features.

In a dated chronosequence in the Savannah River valley in Georgia, Foss and Segovia (1984) noted the progressive development of soil morphologic features with age. Argillic horizons formed within 4,000 to 6,000 years. Hues of the argillic horizons progressed from 10YR to 7.5YR in approximately 8,000 years, to 5YR in 10,300 to 30,000 years, and to 2.5YR in 100,000 years. Solum thickness increased from between 80 to 100 centimeters in 8,000 year old soils to between 100 to 150 centimeters in 10,300 year old soils, and to between 100 to 200 centimeters in 30,000 year old soils. In soils over 100,000 years old solum thickness was between 150 and 250 centimeters. Similarly, soils dating to the end of the Pleistocene in a northern Georgia chronosequence had developed argillic horizons with 25 to 35 percent clay and 10YR hues. Solum thickness was 90 centimeters. On older, higher terraces clay content of the argillic horizons increased to 40 to 52 percent and hues of reddened to 2.5YR (Leigh, 1996). Temperatures in Georgia are slightly higher than those in the Mid-Atlantic region and would tend to favor pedogenic processes. The result being that soils of the same age might show slightly stronger morphological development in Georgia than on the Delmarva Peninsula in Maryland.

In the Mid-Atlantic, soils formed in unconsolidated, coastal plain sediments on high altitude, stable landforms which were estimated to be several hundred thousand years old, had strongly expressed morphological features. Clay contents in the maximum expression of the argillic horizon averaged 41 percent. Colors in the argillics had 2.5YR hues. Solum thickness of more than three meters was common in these soils (Wright, 1972).

In comparison with the above examples the soils formed in silty sediments on the Delmarva showed moderate development. The clay contents of the argillic horizons and sola thicknesses were comparable to those of the soils formed in the Peoria loess as opposed to those formed in the Loveland loess in the Midwestern U.S. The Delmarva soils were also similar to those dating to the end of the Pleistocene or beginning of the Holocene in Georgia. In time the Delmarva soils would likely develop the strongly expressed morphological features similar to those of the soils of southern Maryland (Wright, 1972), however, based on their morphology the Delmarva soils appeared to be relatively young soils.

Coarse Fragments and Evidence of Fluvial/Estuarine Deposition

Coarse fragments (> 2 mm) were sparse in the soils formed in silts. Kings Creek (site 32) had the greatest coarse fragment content of all of the sites with 1.6 percent present in the BEg horizon. No other site had more than 1 percent coarse fragments in any horizon of the silty soil and most had none. Those coarse fragments present were rounded quartz gravel, generally less than two centimeters in diameter. The abundance of coarse fragments increased in the underlying materials and at sites such as Wye Island 1 (site 18), Tolchester (site 12), and Eastern Neck High (site 16) elevated coarse fragment concentrations at the contact between the silts and underlying sands seemed indicative of an erosional event preceding the deposition of the silts. No stratification, marine macrofossils, or evidence of past sulfidic conditions were observed in any of the profiles. The general lack of coarse fragments and the absence of features indicative of a fluvial/estuarine setting, however, neither confirm a possible eolian nor deny a fluvial/estuarine origin of the sediments.

Laboratory Physical Characterization

Characteristics of the Silt Deposit

Particle size distribution reflected both the nature of the parent sediments in which these soils formed as well as pedogenic process which had occurred. To lessen the influence of pedogenesis on the evaluation of physical characteristics of the silt deposit particle size statistics were calculated on a clay-free basis. By so doing soil horizons better reflected the initial state of the silt deposit for particle size separates larger than two micrometers. Table 3-5 shows the clay-free, weighted average particle size distribution and mean particle size for each of the pedons. Sassafras NRMA (site 2) was typical of the deposit in the study area with 89% silt sized particles (clay free basis) in a weighted average of the horizons in the pedon. The highest silt content was 96% at Holly Harbor (site24) while the lowest was 48% at Eastern Neck Low (site 14). The combined very fine sand and silt content at Eastern Neck Low (site 14) was 80%, however. Mean silt content across the study area was 83% and very fine sands and silts comprised an average of 91% of the sediments in the silty deposit. Very coarse, coarse, and medium

Table 3-5. Clay-free weighted average particle size distribution, mean, median, and sorting of sediments in the silt deposit from all sites.

Site	Percent							Mean (mm)	Median (mm)	Sorting Coefficient
	VCOS	COS	MS	FS	VFS	CoSi	FSi			
Andrews (site 28)	0.07	0.13	0.24	2.30	5.48	35.92	55.85	0.022	0.016	2.41
Big Dog (site 7)	0.88	3.78	8.70	5.56	3.92	33.91	43.24	0.083	0.024	2.50
Bishops Head (site 29)	0.13	0.38	0.73	3.75	16.18	32.67	46.17	0.033	0.022	2.54
Blackwalnut Point (site 36)	0.19	0.20	0.52	3.82	8.75	39.87	46.65	0.026	0.022	2.36
Blackwater VC (site 27)	0.09	0.32	3.48	6.23	1.88	35.27	52.72	0.025	0.018	2.45
Centreville North (site 5)	0.82	3.45	6.20	3.67	5.08	39.47	41.31	0.041	0.024	2.33
Centreville Pit (site 4)	0.52	2.82	4.40	2.86	4.91	40.88	43.61	0.027	0.023	2.32
Centreville South (site 6)	0.47	3.10	5.33	3.59	6.24	38.91	42.36	0.036	0.024	2.35
Church Creek (site 26)	0.14	0.69	1.73	1.20	2.80	36.39	57.05	0.022	0.015	2.39
Denny's Farm (site 17)	0.11	0.16	0.54	1.98	10.27	47.82	39.12	0.026	0.025	2.14
Earleville WMA (site 1)	0.53	0.98	1.51	4.85	6.09	43.63	42.42	0.026	0.023	2.26
Eastern Neck Low (site 14)	0.65	1.21	3.35	14.63	31.90	25.03	23.23	0.069	0.052	2.05
Eastern Neck Mid (site 15)	0.31	0.96	3.59	18.06	27.18	25.18	24.71	0.075	0.050	2.17
Holly Harbor (site 24)	0.09	0.13	0.37	1.13	2.51	42.06	53.72	0.021	0.017	2.33
Horn Point (site 25)	0.23	2.40	8.45	12.61	6.48	33.07	36.76	0.090	0.029	2.45
James Island (site 38)	0.09	0.16	0.50	1.17	5.51	43.33	49.24	0.025	0.022	2.31
Jefferson Island (site 34)	0.11	0.37	0.81	2.49	9.83	37.39	49.00	0.026	0.021	2.42

Table 3-5 (continued).

Site	Percent							Mean (mm)	Median (mm)	Sorting Coefficient
	VCOS	COS	MS	FS	VFS	CoSi	FSi			
Kings Creek (site 32)	1.52	6.58	10.28	8.63	2.59	31.80	38.61	0.149	0.028	3.73
Little Neck (site 8)	0.92	3.66	7.76	4.96	3.48	32.56	46.65	0.066	0.022	2.54
Matthews 2 (site 11)	0.55	0.50	0.74	0.83	5.62	46.71	45.05	0.024	0.022	2.24
Matthewstown (site 10)	0.34	0.65	0.86	1.00	5.99	44.47	46.69	0.024	0.021	2.29
Mesa (site 3)	0.36	1.04	2.44	2.36	4.60	47.52	41.68	0.025	0.023	2.19
Oyster Cove Point (site 39)	0.09	0.26	0.59	1.20	6.32	41.92	49.63	0.023	0.020	2.34
Pauls Corner (site 33)	0.22	1.53	22.83	10.76	1.70	22.76	40.19	0.165	0.030	5.36
Paw Paw Cove (site 35)	0.13	1.48	3.53	1.34	7.29	38.32	47.91	0.026	0.021	2.40
Plugge 50 (site 9)	0.28	1.52	2.90	3.46	5.97	43.31	42.56	0.026	0.023	2.27
Princess Anne (site 30)	0.36	1.51	3.35	2.00	3.00	33.90	55.89	0.023	0.016	2.45
Rockhall (site 13)	0.47	0.38	1.63	7.22	9.50	41.37	39.42	0.034	0.025	2.26
Royal Oaks (site 22)	0.12	0.82	3.62	5.70	4.22	38.27	47.26	0.026	0.021	2.40
Sassafras NRMA (site 2)	0.30	1.20	1.83	1.63	6.33	44.88	43.83	0.025	0.023	2.25
Tilghman Island (site 37)	0.15	0.21	0.82	1.90	8.61	39.71	48.60	0.025	0.021	2.37
Todds Corner (site 21)	0.34	0.67	1.77	4.23	3.93	43.04	46.02	0.025	0.022	2.30
Tolchester (site 12)	0.06	0.22	0.27	0.69	8.00	43.09	47.67	0.024	0.021	2.31
Wye Island 1 (site 18)	0.48	0.58	1.71	5.20	5.49	39.90	46.64	0.026	0.022	2.36

Table 3-5 (continued).

Site	Percent							Mean (mm)	Median (mm)	Sorting Coefficient
	VCOS	COS	MS	FS	VFS	CoSi	FSi			
Wye Island 2 (site 19)	0.25	0.44	1.50	3.32	6.69	41.81	45.99	0.025	0.022	2.34
Wye Island 3 (site 20)	0.13	0.47	1.65	3.51	4.16	39.99	50.08	0.024	0.020	2.37

sands were not prevalent at any of the sites. The terrace and upland were similar to each other with regard to particle size distribution and very fine sand and silt contents.

Across the study area the average clay-free mean particle size from each site was coarse silt sized (41 micrometers). Mean particle size fell within the 20 to 40 micrometer range for the vast majority of the pedons with the finest, 21 micrometers, at Holly Harbor (site 24). The coarsest mean particle size, 0.17 millimeters was at Pauls Corner (site 33) which, despite having more than 60 percent clay free-silt, had enough fine and medium sands to make the mean particle size fine sand. No directional trend in the mean particle size was apparent on the interpolated surface map (Figure 3-6), however, from that map it seemed apparent that the sites with the coarsest mean particle size were located on the east side of meander bends in the higher order rivers - Big Dog (site 7), Little Neck (site8), and Centreville (sites 4, 5, 6) at the Chester River and Horn Point (site 25) on the Choptank River - and east of confluences of the higher order rivers - Eastern Neck (sites 14, 15,16) at the confluence of the Chester River and the Cape Charles paleochannel, Kings Creek (site 32) and Pauls Corner (site 33) at the meeting of the Nanticoke, Wicomico, and Manokin rivers. Mean particle size showed local variation but no systematic differences between the upland and the terrace.

Sorting has often been used as an indicator of the depositional environment of sediments with eolian deposits generally better sorted than those of fluvial systems (Prothero and Schwab, 1996). Sediments in the vast majority of the study sites (32 of 36) were well sorted (Table 3-5). Kings Creek (site 32), Little Neck (site 8), and Bishops Head (site 29) were all moderately well sorted and only Pauls Corner (site 33) was poorly sorted with a coefficient of 5.4 (Figure 3-7). As with mean particle size, sorting showed

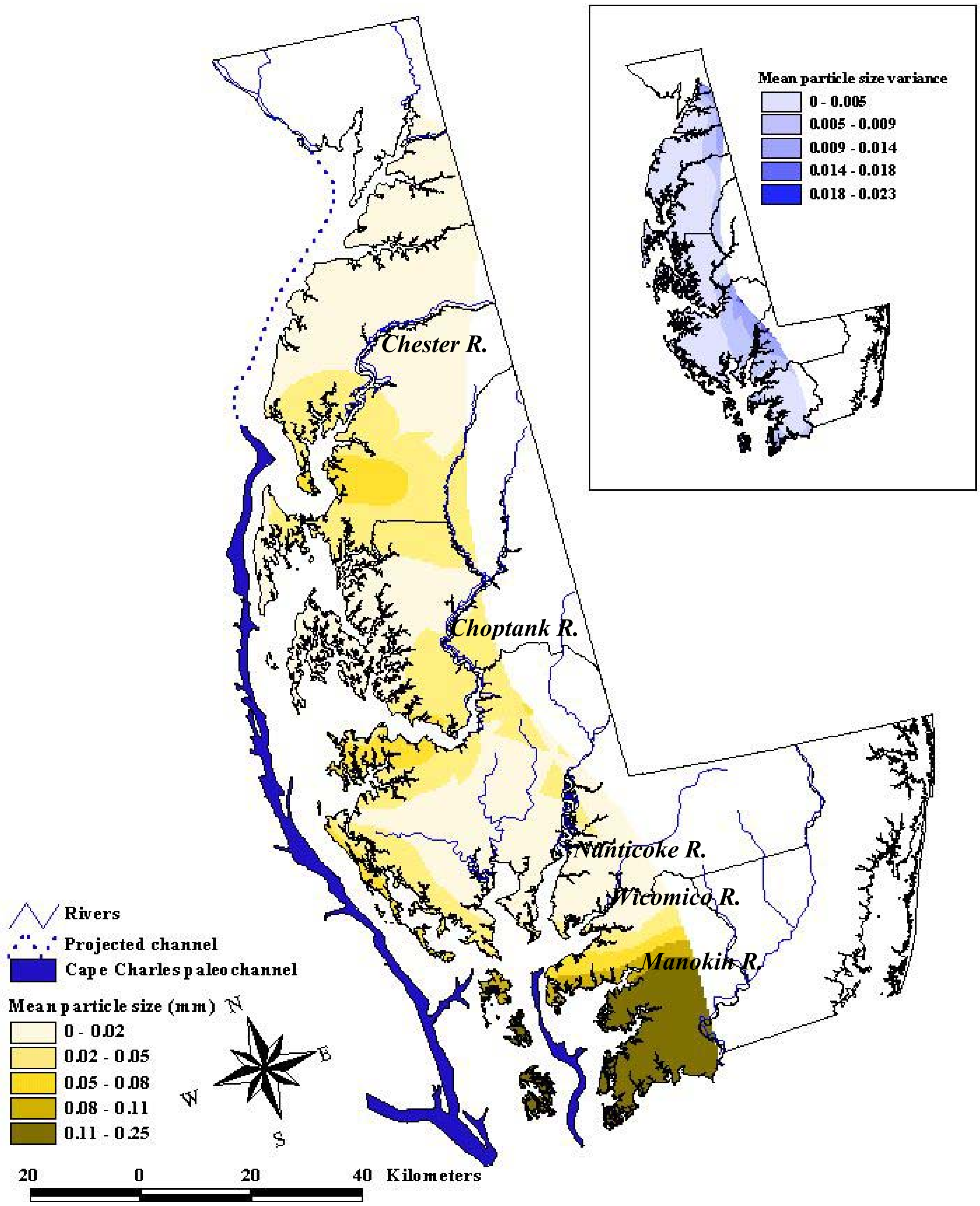


Figure 3-6. Interpolated surface map showing the mean clay-free particle size of the silt deposit. The silt deposit was dominated by fine and coarse silt sized particles. Sites with more coarse mean particle sizes tended to be east of meander bends in the larger rivers or east of river confluences. The inset map shows the variance for interpolated data.

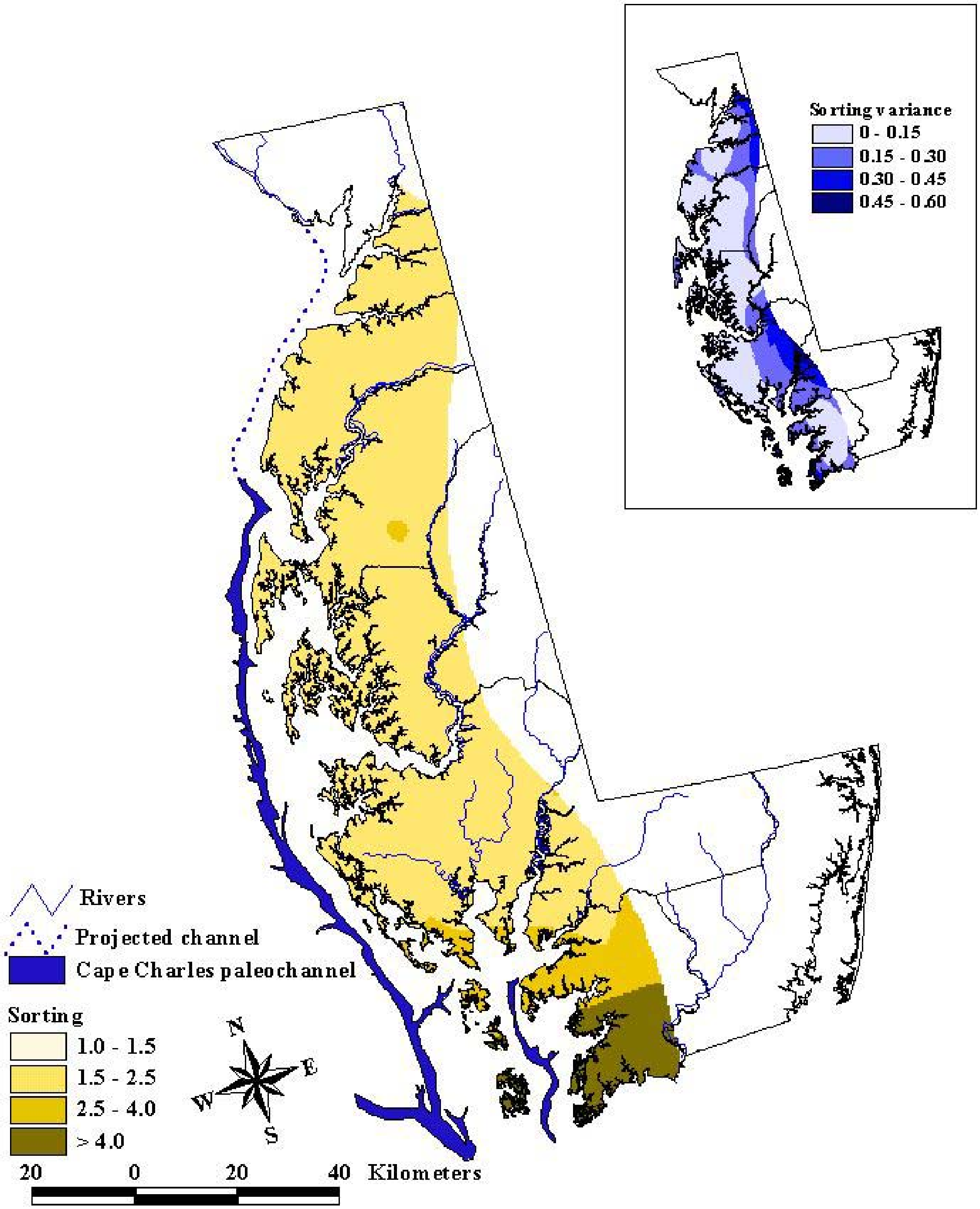


Figure 3-7. Surface interpolation map showing the sorting of sediments in the silt deposit. Sediments were well sorted at most sites. The inset map shows the variance for interpolated data.

some local variation but in the study area as a whole sediments were well sorted and there was no difference between the sediments on the terrace and those on the upland. The sorting of the sediments would seem to eliminate fluvial processes as being responsible for the transportation and deposition of the silty sediments, however, it neither precludes nor is diagnostic of either a low energy estuarine depositional setting or eolian transportation and deposition.

Soils Formed in the Silts

Within profiles, particle size distribution was indicative of pedogenesis, lithologic discontinuities, and mixing at the contact between silts and underlying sands. Plugge50 (site 9) was typical of soils in the study area (Figure 3-8) with less than five percent very coarse through medium sand sized particles in any horizon formed in the silty parent material, two to three percent fine sand, four to six percent very fine sand, more than 63 percent silt, and clay that increased from 13 percent in the surface to 26 percent in the maximum expression of the argillic horizon. In the horizons below the maximum expression of the Bt, clay content decreased and sand content increased in a transitional mixing zone between the silts and sands. Sand content increased to 59 percent in the sediments of the underlying deposit but clay content remained high probably as a result of translocated clay extending from the silts into the sands. Across the study area particle size distribution within the soil profiles was similar with little sand coarser than 0.25 millimeters, high silt contents, and evidence of the translocation and accumulation of clay. The mixing zone at the base of the silts was common as was the welding of the two

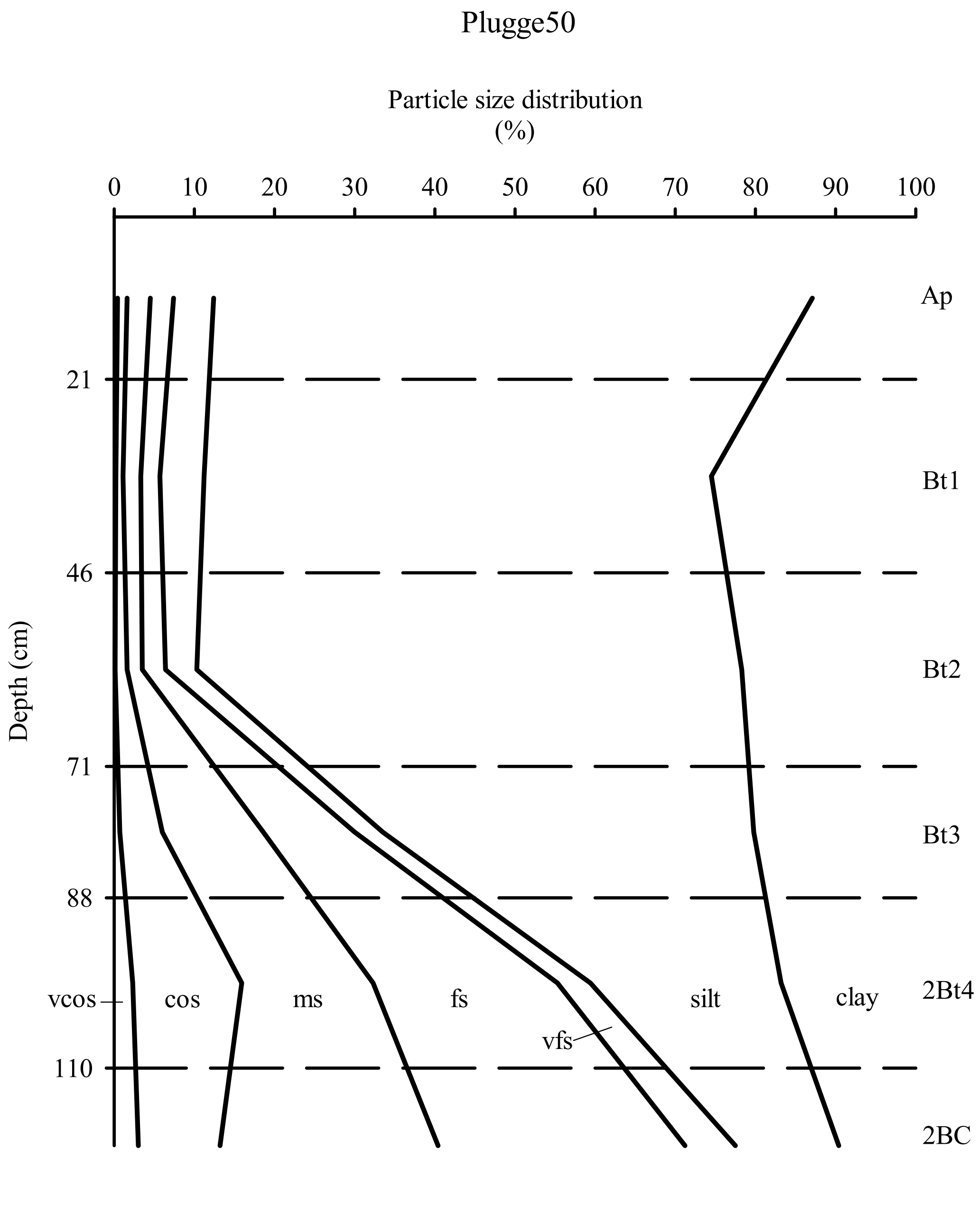


Figure 3-8. Particle size distribution with depth at Plugge50 (site 9). Maximum clay content was in the Bt1 horizon while sand contents increased below 88 cm.

parent materials through pedogenic clay movement. With the exception of the sites at which soils were underlain by a silty paleosol, a marked increase in sand contents, particularly sands coarser than 0.25 millimeters, was indicative of the lithologic discontinuity. Particle size distribution of soils on the terrace was similar to that of soils on the upland. See Appendix B for particle size distribution data for all sites.

SUMMARY AND CONCLUSIONS

No single morphological or physical property of the silts on the Delmarva Peninsula in Maryland was diagnostic of the mode of transportation and deposition of those silts. Silt deposit thickness across the study area and the relationship between deposit thickness and assumed source area was inconclusive with regard to the silts being loess or of fluvial/estuarine origin. Regardless of their mode of transportation and deposition it seems possible, if not likely, that some movement of sediments occurred after deposition.

Coarse fragment contents in the silts were minimal and no morphological features indicative of fluvial/estuarine deposition were identified in the soils of the study area. While this lack of features did not disprove that the silts were deposited by water it also did not diminish the possibility that they had been deposited by wind. Low chroma matrix colors were not the result of the deposition of sediments in a reducing environment but instead reflected modern drainage conditions.

Throughout the study area the silt deposit and soils formed in the silts were similar. The characteristics of the silt deposit, including particle size distribution, silt contents, and sorting were similar across the study area with localized variations, favoring the notion that the silts were emplaced as one deposit. Sediments in the deposit were well sorted throughout the region with only a few moderately well- and one poorly sorted site. This degree of sorting likely reflects transportation of sediments by some means other than fluvial processes, which tend to leave less well sorted deposits, however, it can not be used to distinguish between eolian and low energy estuarine depositional environments.

The relative development of the soils on the terrace was not different from that on the upland and the soil development did not differ from north to south, indicating that the soils across the study area have been undergoing pedogenesis for a comparable period of time. The degree of soil development throughout the study area was moderate and reflected a relatively young soil by comparison with dated analogs from the Midwestern and southeastern U.S. The clay content and hue of the argillic horizons and the solum thickness were indicative of soils that were no older than 30,000 years and likely less than 15,000. If the landscapes on which these soils have formed are and have been stable, and minimal erosion has affected these soils, then the relative development and age of the soils would preclude the possibility that the silty parent sediments were deposited during the last high sea stand in the Mid-Atlantic region which occurred no more recently than approximately 82,000 years B.P. and likely as long as 125,000 years B.P.

Chapter 4. Chemical and Mineralogical Properties of Quaternary Silts and Associated Soils

INTRODUCTION

Soils formed in Quaternary age silts of unknown origin are widespread on the Delmarva Peninsula in Maryland. The mode of transportation and deposition of the silts in which the soils have formed has long been debated. The silts have often been considered part of the same deposit as the sandy sediments which underlie them and, as such, the result of fluvial/estuarine processes during a period of marine transgression. It has been demonstrated, however, that silts on the upland in the northern portion of the Delmarva are loess (Foss et al., 1978). No specific studies have addressed the origin of the silty sediments south of the northern Queen Anne's County, particularly on the low terrace bordering the Chesapeake Bay.

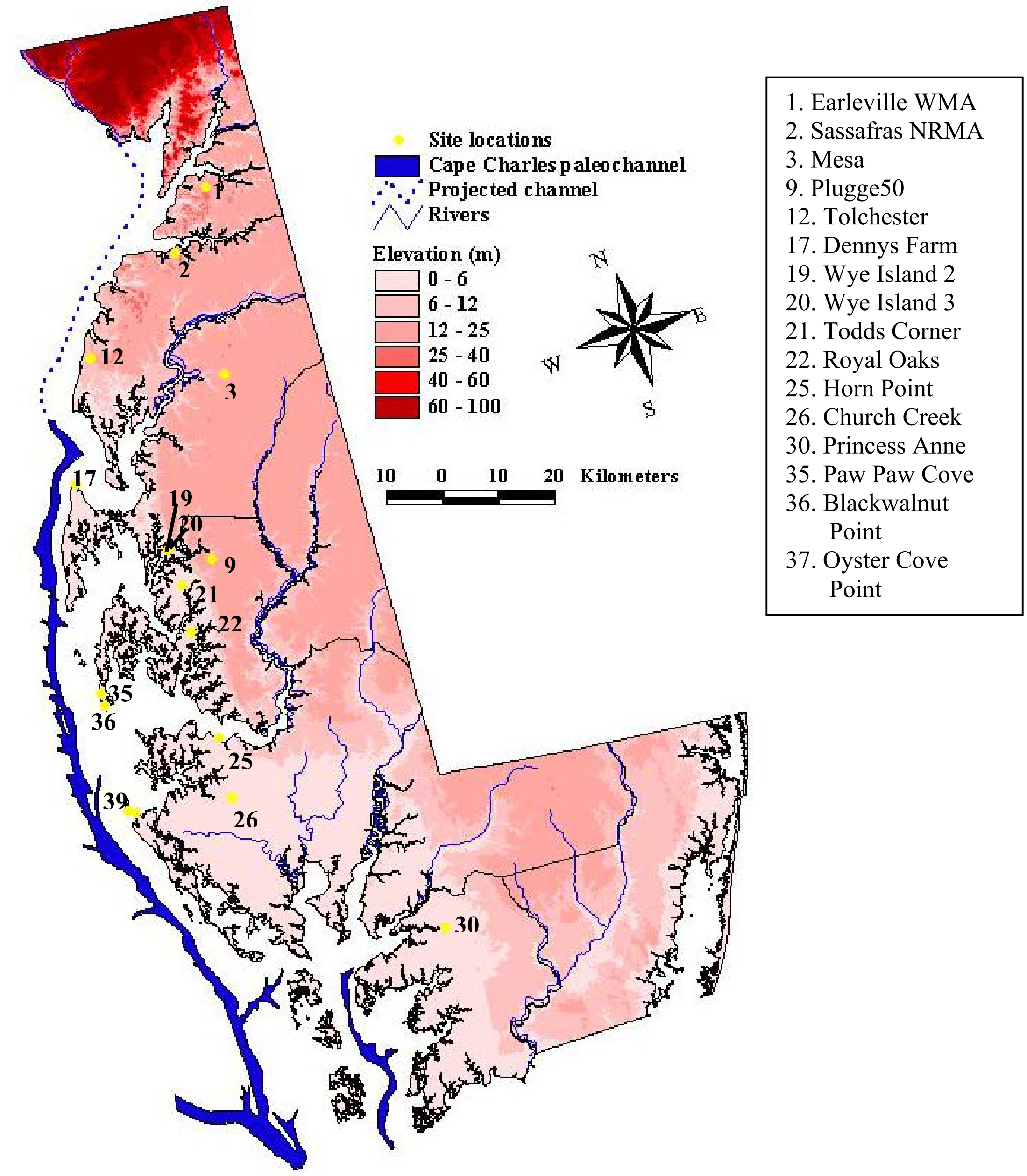
Soil chemistry and mineralogy have been used to help identify loess. In the Midwest, differences in zirconium contents and clay mineral suites between loess and underlying glacial till have been or could have been used to distinguish between the two parent materials (Alexander et al., 1962; Hogan and Beatty, 1963; Fanning and Jackson, 1966, 1967). In Arkansas, Chapman and Horn (1968) used zirconium and titanium to demonstrate that silty soils did not originate as loess.

The objectives of this study were to determine 1) whether the silty sediments on the Delmarva Peninsula were homogeneous across the study area and, therefore, an extension of the northern Delmarva loess, or if more than one distinct silt deposit was present, and 2) if multiple silt deposits were recognized, the mode of transportation and deposition of the silty sediments. Hypotheses tested included 1) the silts were loess, 2) the silts were deposited by fluvial/estuarine processes during periods of high sea level stand, and 3) if multiple, distinct silts deposits were present, that they were deposited by a combination of eolian and fluvial/estuarine processes.

MATERIALS AND METHODS

Soils formed in Quaternary age silts cover an area of approximately 5,000 square kilometers on the Delmarva Peninsula in Maryland. The landforms on which they occur are largely a function of past sea levels, with a broad flat terrace less than six meters above sea level bordering the Chesapeake Bay to the west and an older upland with elevations less than 25 meters above sea level forming the north-south spine of the Delmarva. Soil samples were collected from genetic horizons from auger borings, backhoe pits, and bank cuts from a series of sites on both the terrace and the upland. Figure 4-1 shows the locations from which samples for various chemical and mineralogical analyses were taken while Table 4-1 lists the sites and horizons for which silt and clay mineralogy were determined.

In the laboratory, samples were air dried, crushed, and passed through a number 10 (2 mm) sieve. The less than two millimeter fraction was used for chemical and mineralogical analysis. Organic carbon content was measured using dry combustion (Nelson and Sommers, 1982). Samples for elemental analysis were treated with 30



DEM Source: ArcUSA 1:2,000,000

Figure 4-1. Sampling sites for chemical and mineralogical analysis of the silts.

Table 4-1. Sites and horizons for which silt and clay mineralogy were determined.

	Mineralogy	
Site	Silt	Clay
Sassafras NRMA (site 2)	Ap,Bt2,2Bt4	Ap,Bt2,2Bt4
Plugge50 (site 9)	Ap,Bt2,2BC	Ap,Bt2,2BC
Wye Island 2 (site 19)	A,Bt2,2Ab	A,Bt2,2Ab
Paw Paw Cove (site 35)	Ap2,Bt,Ab,Btxgb3,2BCg	Ap2,Bt,Ab,Btxgb3,2BCg
Church Creek (site 26)	A,Btg1,2Cg	A,Btg1,2Cg
Princess Anne (site 30)	--	A,Btg2,2BCg

percent hydrogen peroxide to remove organic matter and sodium dithionite-citrate buffer (Kunze and Dixon, 1986) to remove iron oxides prior to particle size fractionation. Boric acid was used as the binding agent in creating pellets of the coarse silt fraction (20 -50 μm). Potassium, calcium, zirconium, and titanium contents of samples were then determined through x-ray flouresence (Beavers, 1960; Jones, 1982) with National Bureau of Standards NBS 76, NBS 77, NBS 78, NBS 102, and AGV-1 reference samples used to create the standard curve. Due to past conventions and to easy comparisons with previous studies, results were reported as oxides. Interpolated surface maps showing the distribution of potassium, calcium, zirconium, and titanium across the study area were created using universal kriging in ArcView (Oliver and Webster, 1990).

The mineralogy of the silts and underlying sands was determined on horizons from profiles representing different parts of the study. The fine silt fraction (2 to 20 μm) was isolated after pretreatments to remove organic matter and iron-oxide coatings and analyzed by x-ray diffraction using random oriented powder mounts. The clay fraction (<2 μm) was similarly pretreated and then examined by x-ray diffraction using oriented mounts. One subset of the clay fraction was Mg saturated and ethylene glycol solovated at 25 degrees Celsius, while a second set was potassium saturated and analyzed at 25 degrees Celsius and after heat treatments to 300 and 550 degrees Celsius (Whittig and Allardice, 1986).

Heavy liquid was used to separate the biogenic opal in profiles at three sites along the Chesapeake Bay, Paw Paw Cove (site 35), Blackwalnut Point (site 36), and Oyster Cove Point (site 39). Sodium polytungstate adjusted to specific gravity 2.35 was used to isolate opal particles from the 5 to 100 μm fraction of the soil (Cady et al., 1986).

Permanent mounts of the light fraction (specific gravity < 2.35) were then made and the biogenic opal bodies examined using a petrographic microscope. Based on their morphological properties, the opal bodies were counted using a modified version of the classification system by Twiss (1992).

RESULTS AND DISCUSSION

Organic Carbon

Organic carbon contents were measured to help identify and verify the presence of buried surface horizons especially in soils in which the morphological features, the most distinctive of which is color, of the suspected buried surface were indistinct or had been obscured in some way. Generally, carbon contents were highest in the surface horizons and decreased with depth. Surface horizon carbon contents ranged from 4.5 percent at Wye Island 3 (site 20), which was a poorly drained, wooded site, to 0.92 percent at Earleville WMA (site 1) which was located in a well drained agricultural field. Carbon contents of argillic horizons were less than 0.40 percent at all sites and less than 0.25 percent at most sites. Organic carbon content was not a reliable indicator of buried surface horizons. At Tolchester (site 12) there was a slight increase in organic carbon in the buried surface, from 0.10 percent in the BC2 horizon to 0.41 in the 2Ab1. At Oyster Cove Point (site 39) there was essentially no (0.01 percent) increase (Figure 4-2), and at

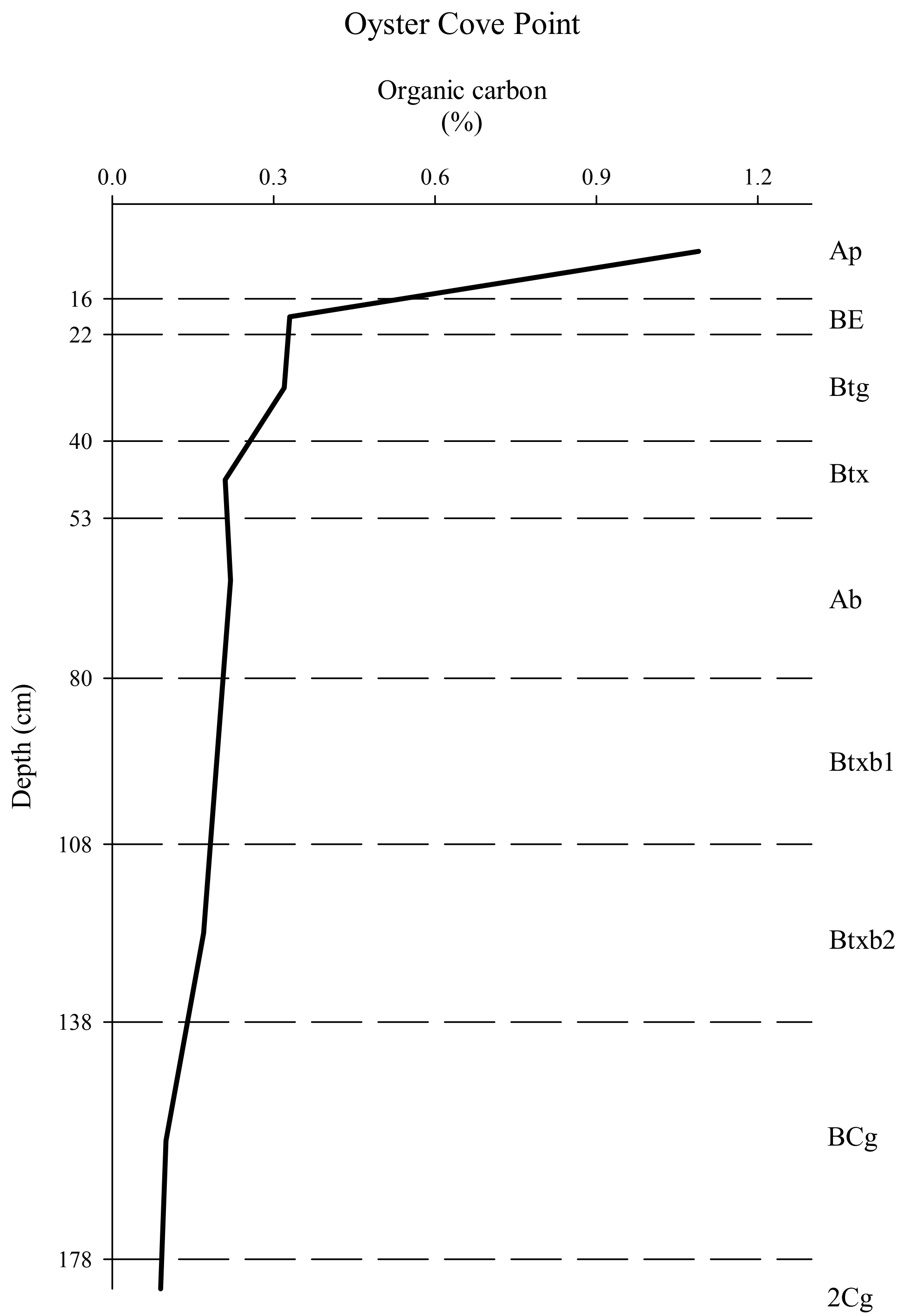


Figure 4-2. Organic carbon distribution with depth at Oyster Cove Point (site 39). Note the minimal increase in organic carbon content in the Ab horizon.

Wye Island 3 (site 20) there was no increase in the buried surface but the organic carbon content did decrease in the horizons below the buried surface. The lowest carbon contents were generally in the underlying sands which had less than 0.10 percent organic carbon. Appendix C lists the organic carbon data from all sites.

Elemental Analysis

Elemental analyses were used to evaluate the homogeneity of the silty deposit across the study area and to examine lithologic discontinuities and identify buried surface horizons in soil profiles. Weighted (proportional to horizon thickness) averages for elemental contents were calculated for the soils formed in the silts in two ways. The first included both surface and subsurface horizons but excluded horizons in which particle size analysis revealed mixing between the silts and underlying soils/sediments, and the second excluded eluvial horizons. Results were similar for the two sets of calculations with only the K_2O content showing a consistent difference, an increase of between three and nine relative percent in the weighted average excluding eluvial horizons, between the two methods of calculation. The following discussion is based on the weighted averages that include surface horizons and Table 4-2 shows the weighted average including surface horizons zirconium, titanium, potassium, and calcium contents of the coarse silts at all sites.

The zirconium content of the silts was uniform throughout the region with a narrow range in the weighted averages from 0.10 to 0.13 percent ZrO_2 (Figure 4-3). Titanium, potassium, and calcium contents varied across the study area with no apparent

Table 4-2. Weighted average ZrO_2, TiO_2, K_2O, and CaO contents of the coarse silt (20-50 μm) fraction of the silt deposit at several sites. Standard deviations were calculated from soil horizons within the pedon at each site including surface horizons but excluding horizons in which mixing with the underlying soil/sediments was apparent.

	ZrO_2		TiO_2		K_2O		CaO	
Site	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.	%	Std. Dev.
Earleville WMA (site 1)	0.13	0.01	1.06	0.09	1.92	0.23	0.81	0.25
Sassafras NRMA (site 2)	0.12	0.02	1.15	0.07	1.74	0.24	0.56	0.08
Mesa (site 3)	0.12	0.01	1.09	0.04	2.03	0.24	0.91	0.14
Plugge50 (site 9)	0.12	0.01	0.98	0.07	1.96	0.16	0.57	0.05
Tolchester (site 12)	0.12	0.03	1.46	0.12	1.59	0.43	0.64	0.29
Dennys Farm (site 17)	0.13	0.01	0.94	0.13	1.48	0.23	0.53	0.14
Wye Island 2 (site 19)	0.10	0.01	1.24	0.09	1.67	0.17	0.81	0.26
Royal Oaks (site 22)	0.10	0.02	1.37	0.11	1.82	0.14	0.81	0.18
Paw Paw Cove (site 35)	0.11	<0.01	0.98	0.05	1.63	0.16	0.45	0.02
Horn Point (site 25)	0.12	<0.01	1.48	0.17	2.15	0.10	0.64	0.02
Oyster Cove Point (site 39)	0.12	0.01	0.96	0.07	1.56	0.17	0.48	0.03
Church Creek (site 26)	0.11	0.01	1.44	0.10	2.01	0.22	0.68	0.13
Princess Anne (site 30)	0.11	0.02	1.36	0.06	1.97	0.22	0.66	0.17
Study Area	0.12	0.01	1.19	0.21	1.81	0.21	0.66	0.14

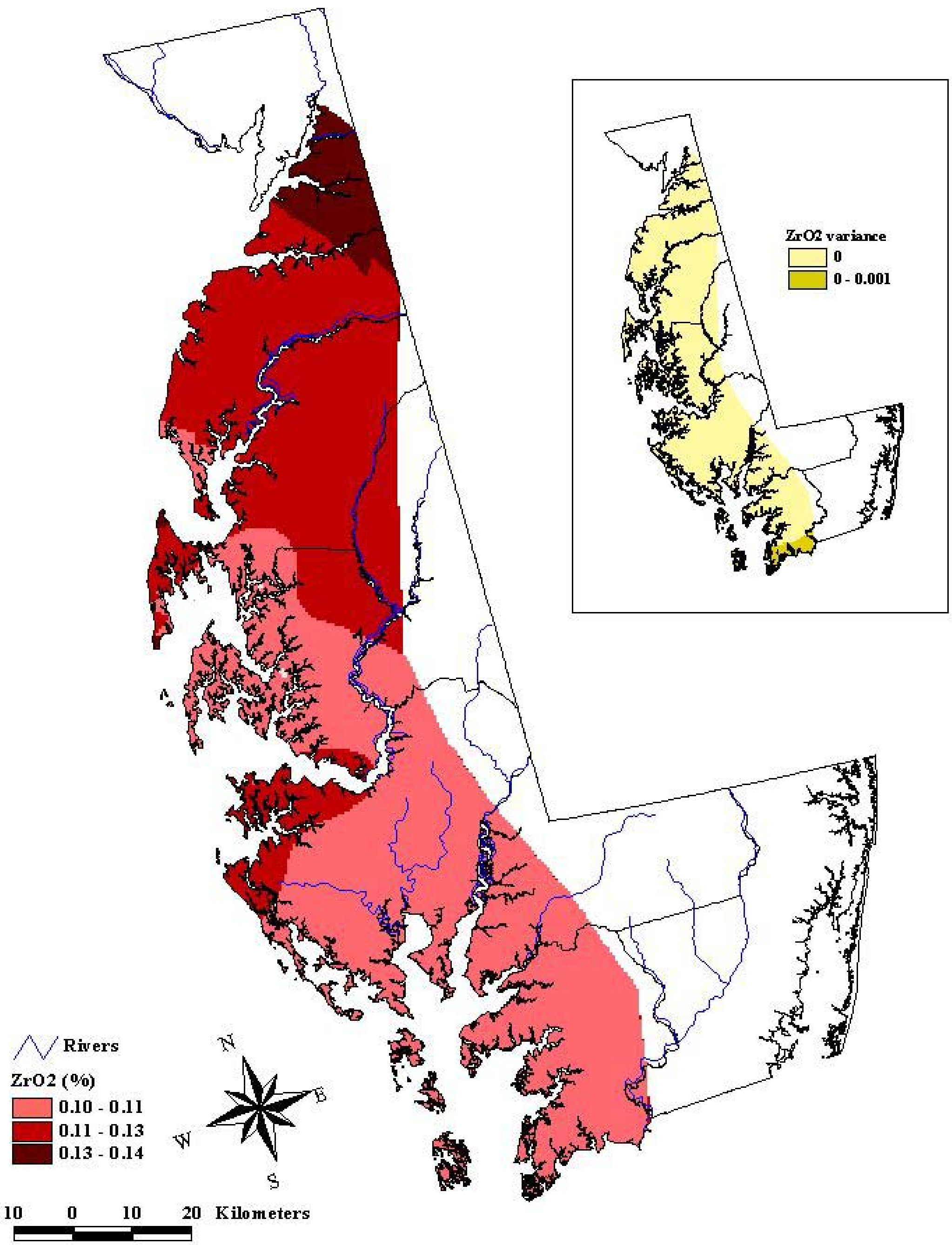


Figure 4-3. Interpolated surface map showing the distribution of zirconium in the coarse silt sized (20 - 50 µm) fraction. The weighted average zirconium contents of soils formed in the silt was uniform across the study area. The inset map shows the variance for interpolated data.

trends to their distribution. Two of the three highest titanium contents were at Horn Point (site 25) and Church Creek (site 26) with 1.48 and 1.44 percent TiO_2, respectively, while the lowest was at the site geographically closest to them, Oyster Cove Point (site 39), with 0.96 percent TiO_2 (Figure 4-4). This juxtaposition of the highest and lowest TiO_2 contents indicated that the differences in TiO_2 were likely a function of local variability rather than a regional trend or an indication of distinct, multiple silt deposits. The range of weighted average potassium contents on the upland was 1.74 to 2.03 percent K_2O, while the range on the terrace encompassed that with 1.59 percent K_2O at Tolchester (site 12) and 2.15 percent K_2O at Horn Point (site 25) (Figure 4-5). Calcium contents, like titanium and potassium, showed some spatial variability with a mean CaO content in the silts of 0.66 percent and a range from 0.91 to 0.45 percent (Figure 4-6).

Greater variability was observed when comparing the weighted average CaO, K_2O, TiO_2, and ZrO_2 of the soils in the study area to those of soils formed in similar texture sediments elsewhere in the region. A Matapex silt loam from the Coastal Plain in Maryland west of the Chesapeake Bay had a weighted average CaO content of 0.22 percent (Wright, 1972) while that of a silt cap over residuum on the Maryland Piedmont was 1.66 percent (Rabenhorst, 1978). The weighted average K_2O, TiO_2, and ZrO_2 contents in the Mattapex soil were 0.98, 0.94, and 0.17 percent, respectively (Wright, 1972).

Across the study area, zirconium, titanium, potassium, and calcium displayed relatively narrow ranges. Spatial variability in contents was not indicative of any patterns or trends that might have been the related to multiple, distinct silt deposits or the result of

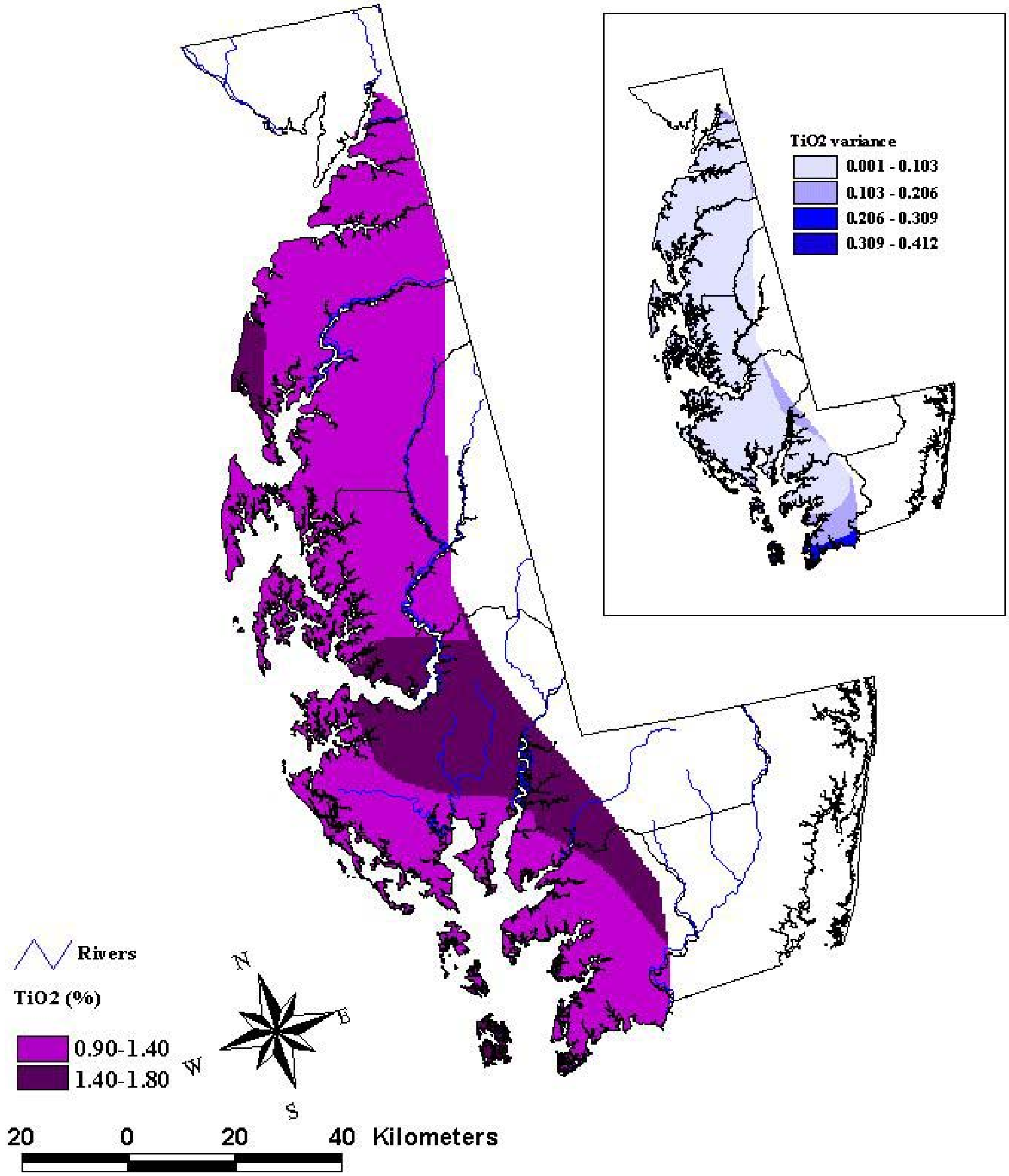


Figure 4-4. Interpolated surface map showing the distribution of titanium in the coarse silt sized (20 - 50 µm) fraction of soils formed in the silts. The inset map shows the variance for interpolated data.

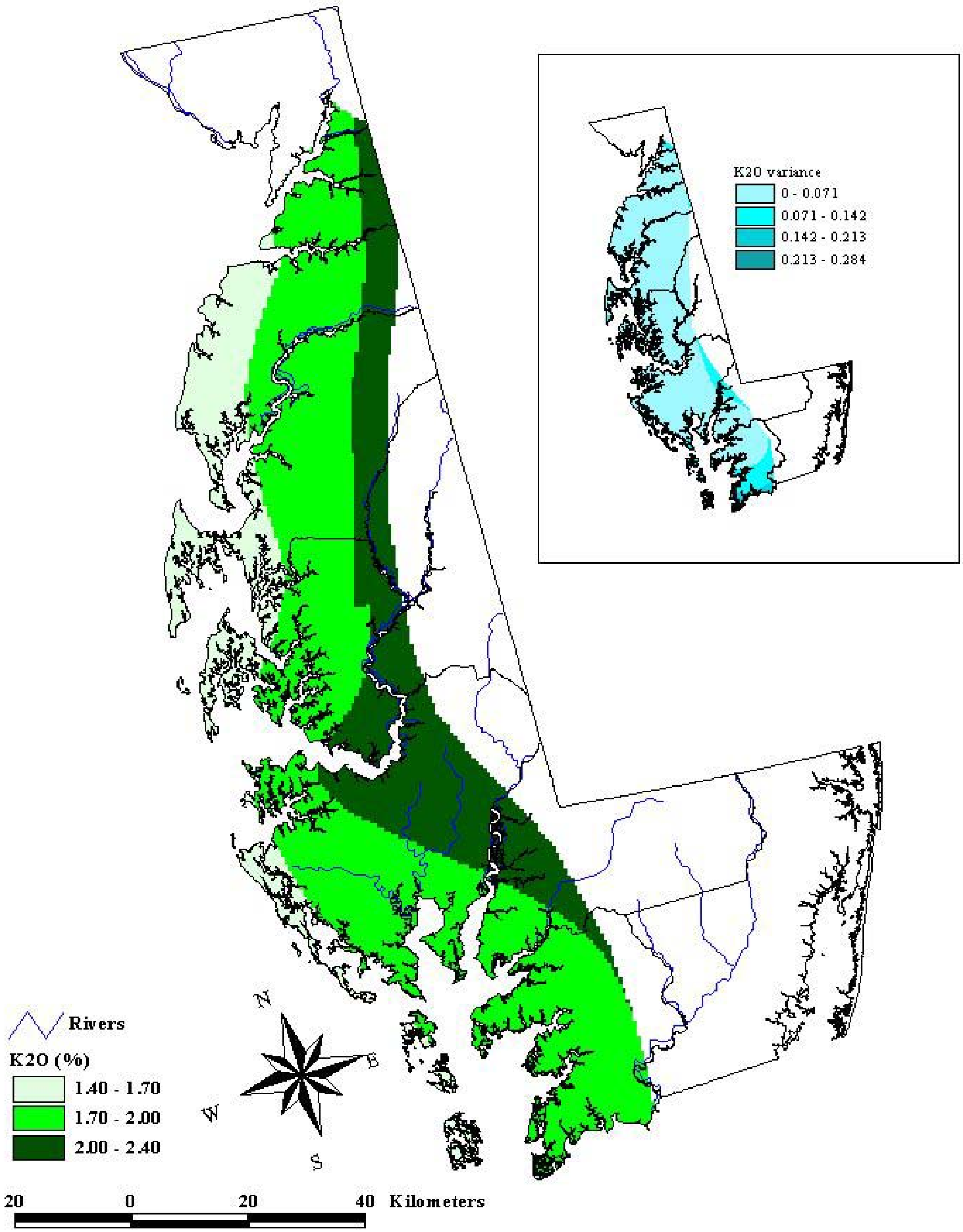


Figure 4-5. Interpolated surface map showing the distribution of potassium in the coarse silt sized (20 - 50 µm) fraction of soils formed in the silts. The inset map shows the variance for interpolated data.

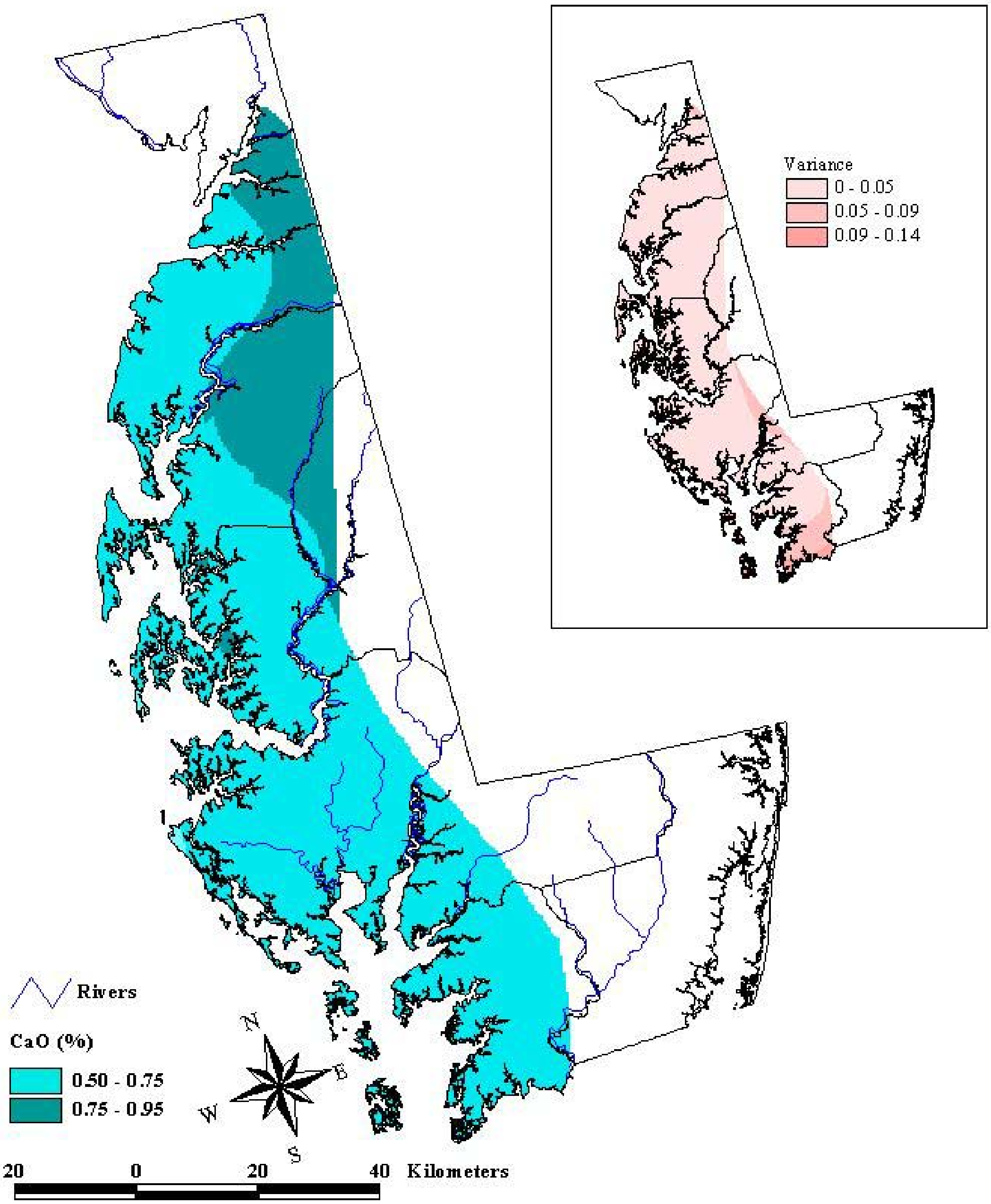


Figure 4-6. Interpolated surface map showing the distribution of calcium in the coarse silt sized (20 - 50 µm) fraction of soils formed in the silts. The inset map shows the variance for interpolated data.

more than one episode of deposition. Rather, the even distribution of these elements across the study area seemed to favor a single, homogeneous deposit. It was not possible, however, to determine the source of sediments or depositional processes responsible for that deposit based on the elemental distribution.

The distribution of potassium, calcium, zirconium and titanium in soil profiles reflected the weathering of less resistant minerals and accumulation of more resistant ones. Calcium was likely resident primarily in silt sized feldspar minerals in the deposit, and potassium in micas and feldspars. Zirconium and titanium were probably resident in minerals resistant to weathering such as zircon, rutile, and ilmenite. In surface horizons the potassium and calcium contents were lower than in associated B and C horizons as a result of the weathering of less resistant feldspar minerals at the surface. This resulted in a relative increase in the resistant zirconium and titanium minerals. In general weatherable potassium and calcium mineral contents increased in the Bt and BC horizons and the relative proportion of zirconium and titanium minerals decreased with depth. As was evident in the particle size distributions, there was mixing at the contact between the silts and sands which in some cases resulted in higher than expected weatherable mineral or lower than expected resistant mineral contents in horizons lower in the profile. The K_2O content in the surface horizon at Royal Oaks (site 22) was 1.58 percent and increased progressively to 1.89 percent in the Btg1 horizon then decreased in the buried surface horizon to 1.74 percent (Figure 4-7). The CaO content increased from 0.55 percent in the surface to 0.96 percent in the Btg2 then decreased to 0.73 percent in the Ab. Conversely, ZrO_2 content decreased from 0.13 percent in the surface to 0.08 percent in the Btg1 then increased to 0.11 above the buried surface. TiO_2 content went from 1.53

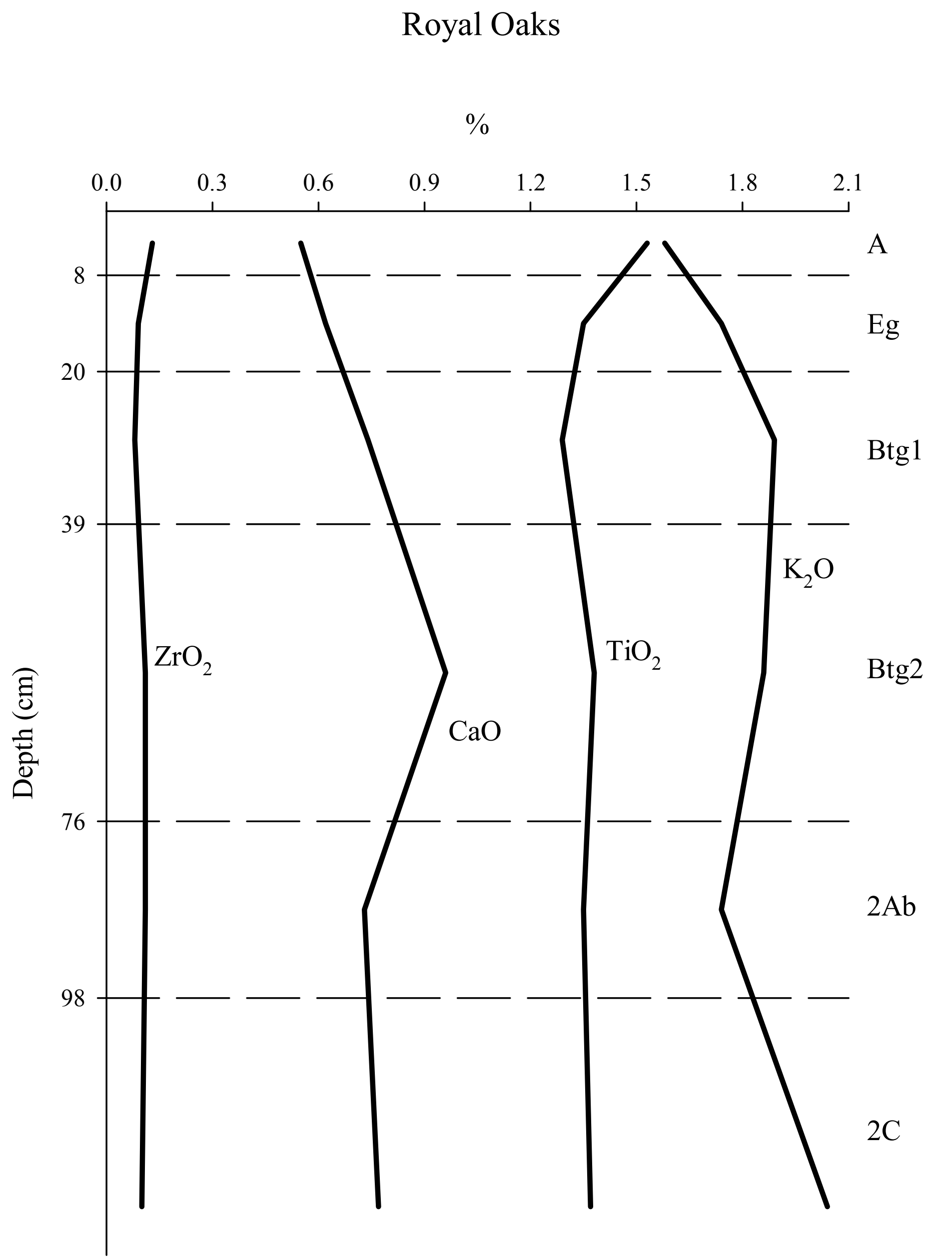


Figure 4-7. Distribution of ZrO_2, TiO_2, K_2O, and CaO with depth at Royal Oaks (site 22). Zirconium and titanium contents were higher in the surface horizon while potassium and calcium contents were low in the surface and buried surface horizons and higher in the argillic horizons.

to 1.29 to 1.38 percent in the profile. Appendix D shows calcium, potassium, titanium, and zirconium data for sites.

Silt Mineralogy

The fine silt (2 to 20 μm) fraction of the soil was examined to evaluate the mineralogical homogeneity of the silt deposit across the study area and to compare the mineralogy of the silts to that of the underlying sediments. At all sites the silt mineralogy was dominated by quartz with small quantities of feldspars and trace amounts of mica and kaolinite. Figure 4-8 shows the x-ray diffraction patterns for the argillic horizons from Sassafras NRMA (site 2) and Plugge50 (site 9) on the upland, and Wye Island 1 (site 18), Paw Paw Cove (site 35), and Church Creek (site 26) on the terrace. Mineralogy of the fine silt fraction of the sandy sediments underlying the silt deposit was made up of a suite of minerals in relative proportions similar to those of the overlying silts. At Plugge50 (site 9), however, the feldspar present in the sandy sediments was different from that in the overlying silty sediments (possibly microcline rather than albite) (Figure 4-9).

That the same mineral suite was present in similar relative proportions in the fine silt fraction of the silty sediments at all sites across the study would seem to argue for the hypothesis that the silts were emplaced as a single deposit and that that deposit is an extension of the loess on the northern Delmarva. However, the same mineral suite that was present in the silty sediments was also present in similar relative proportions in the underlying sandy, fluvial/estuarine sediments. The mineralogical homogeneity of the

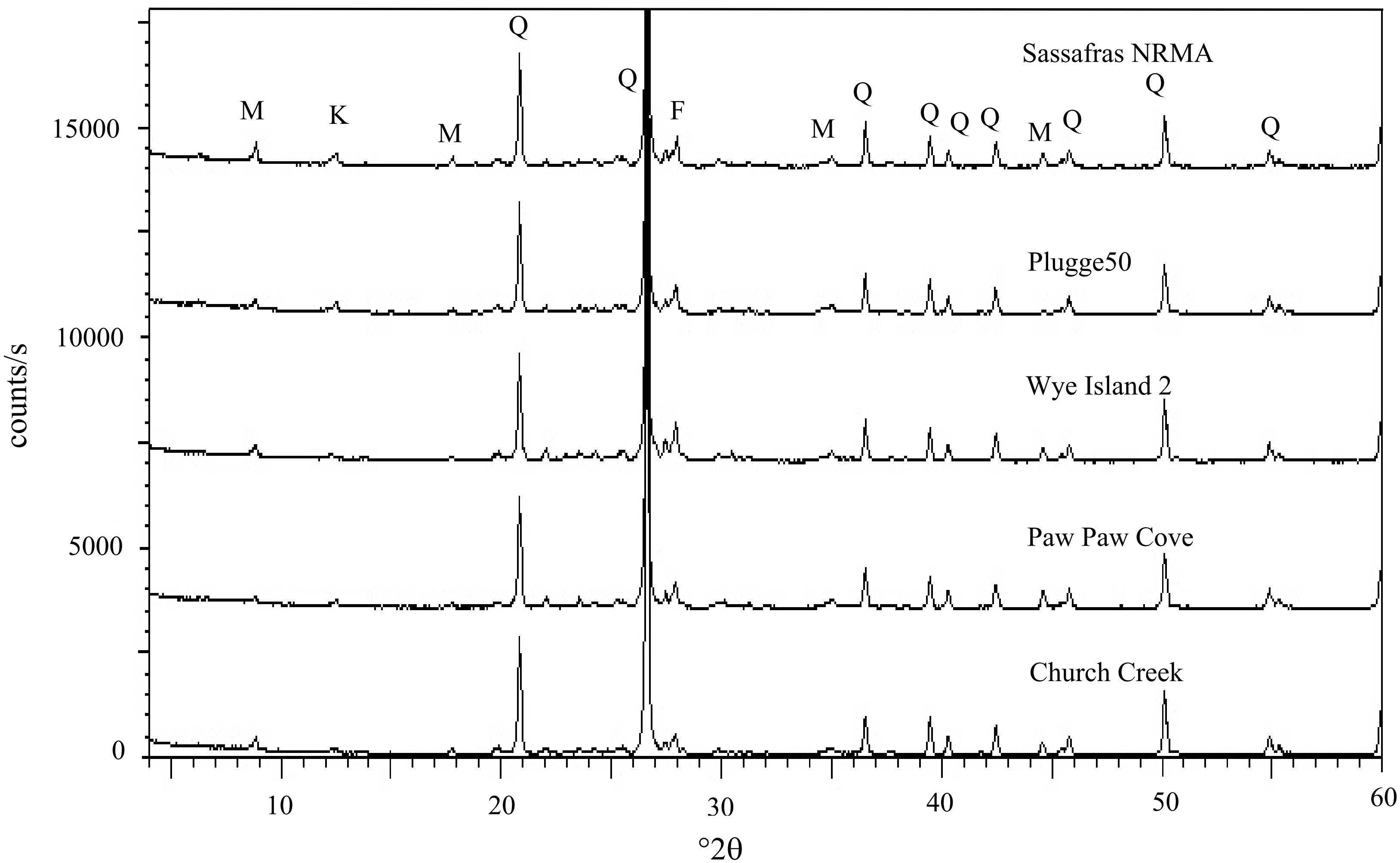


Figure 4-8. X-ray diffraction pattern showing the mineralogy of fine silt fraction (2-20 μm) of the Bt horizons from sites across the study area. Q=quartz, K=kaolinite, M=mica, F=feldspar.

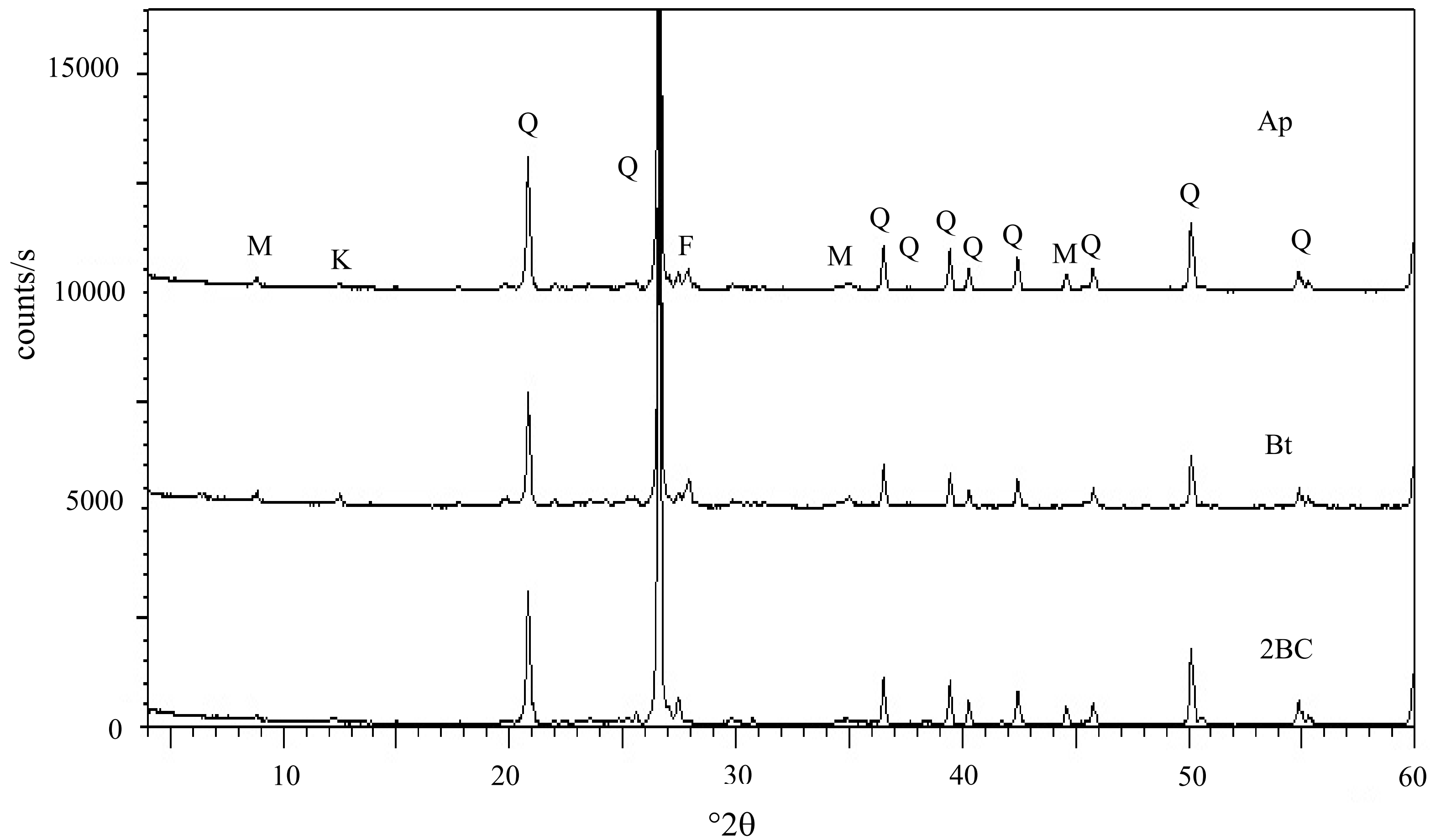


Figure 4-9. X-ray diffraction pattern showing the mineralogy of the fine silt fraction (2-20 µm) from different horizons at Plugge50 (site 9). Note the shift in feldspar minerals between the Ap and Bt horizons formed in the silts and the 2BC horizon from the underlying sands. Q=quartz, K=kaolinite, M=mica, F=feldspar.

silts across the study area, when considered in conjunction with the uniformity of the mineralogy of the fine silt fraction within profiles, including underlying sandy sediments, was not indicative of anything other than a very general similar source for the sediments. X-ray diffraction patterns for the fine silt fraction of all horizons examined are in Appendix E.

Clay Mineralogy

Clay mineral assemblages were also similar in soils across the study area. The mineralogy of the surface horizon at Wye Island 1 (site18) was typical of that found elsewhere with kaolinite and vermiculite being the most abundant minerals, with lesser amounts of chlorite, muscovite, hydroxy-interlayered vermiculite and quartz, and trace amounts of feldspars (Figure 4-10). The relative abundance of minerals varied somewhat from site to site and within profiles, however, the suite of minerals was essentially unchanged. The clay mineralogy did not favor any of the hypotheses over the others with regard to the origin of the silty sediments. X-ray diffraction patterns for the clay samples for all sites are in Appendix F.

Biogenic Opal

Biogenic opal, including phytoliths, sponge spicules, and diatoms, was isolated to verify the presence or absence of microscopic fossils from aquatic organisms in the silty sediments and, if present, to examine their distribution in the soil profile. Biogenic opal

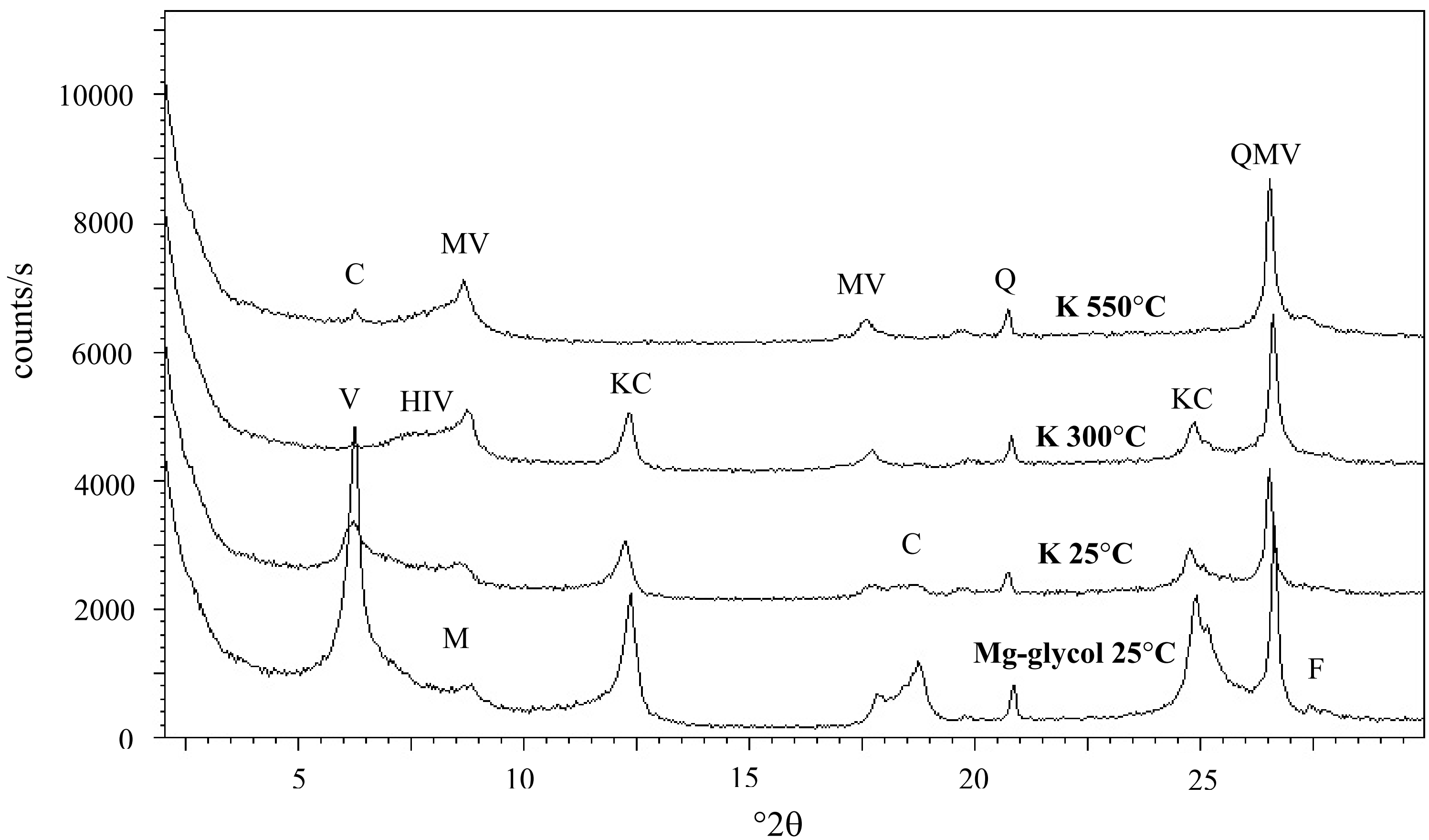


Figure 4-10. X-ray diffraction pattern showing the clay mineralogy of the A horizon at Wye Island 2 (site 19). V=vermiculite, HIV=hydroxy interlayered vermiculite, M=muscovite, K=kaolinite, C=chlorite, Q=quartz, F=feldspar.

made up an average of 0.19 percent of the whole soil in the surface horizons at Paw Paw Cove (site 35), Blackwalnut Point (site 36), and Oyster Cove Point (site 39) and decreased to less than 0.07 percent in the argillic horizons. Sponge spicules and diatoms were present in every horizon of the soils at the three sites comprising 17 percent of the total biogenic opal present. On a whole soil basis, sponge spicules and diatoms averaged 0.005 percent for each horizon with a range from 0.002 to 0.013 percent at Oyster Cove Point (site 39).

As a proportion of the total opal present in the soils, the spicules and diatoms reflected periods of landscape stability and pedogenesis. The relative proportion of spicules and diatoms was lower in surface and buried surface horizons as a result of increases in the quantity of phytoliths being deposited on the soil surface. At Paw Paw Cove (site 35) sponge spicule and diatom content as a percentage of the biogenic opal were lowest in the surface and buried surface horizon, increased in the argillic horizons of the soil and paleosol, and were highest in the underlying sandy sediments (Figure 4-11). On a whole soil basis spicule and diatom content varied by horizon and at Paw Paw Cove (site 35) spicule and diatom contents in the silts were comparable to those in the underlying sandy sediments (Figure 4-12). The majority of spicules and diatoms present in the soils were broken pieces. Biogenic opal data for all horizons at the three sites examined are in Appendix G.

Although sponge spicules and diatoms were present in every horizon of the soil formed in the silty parent sediments, their presence did not favor a fluvial/estuarine mode of transportation and deposition for these silts, as might be expected. Sponge spicules and diatoms in the size range examined were as likely as any other fine grained sediment

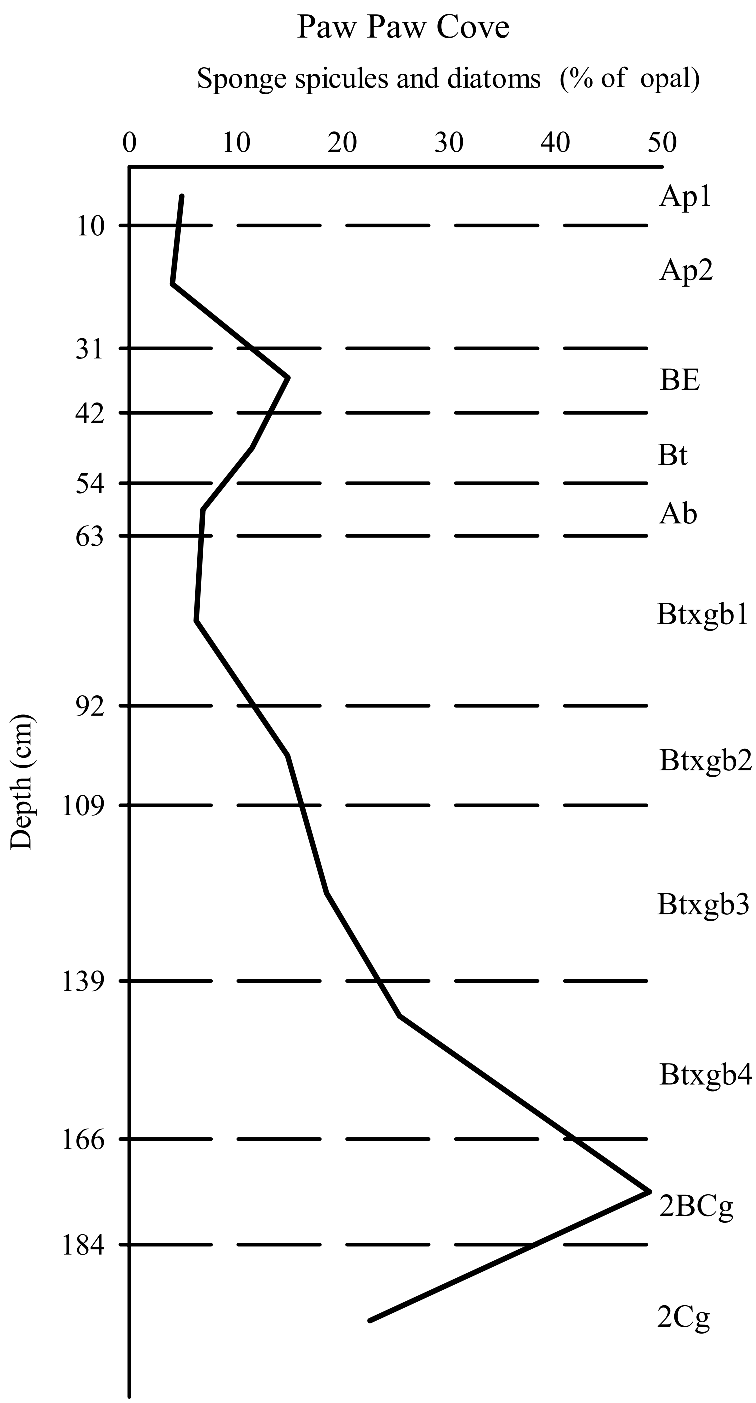


Figure 4-11. Sponge spicules and diatoms distribution with depth as a percentage of the total opal content at Paw Paw Cove (site 35).

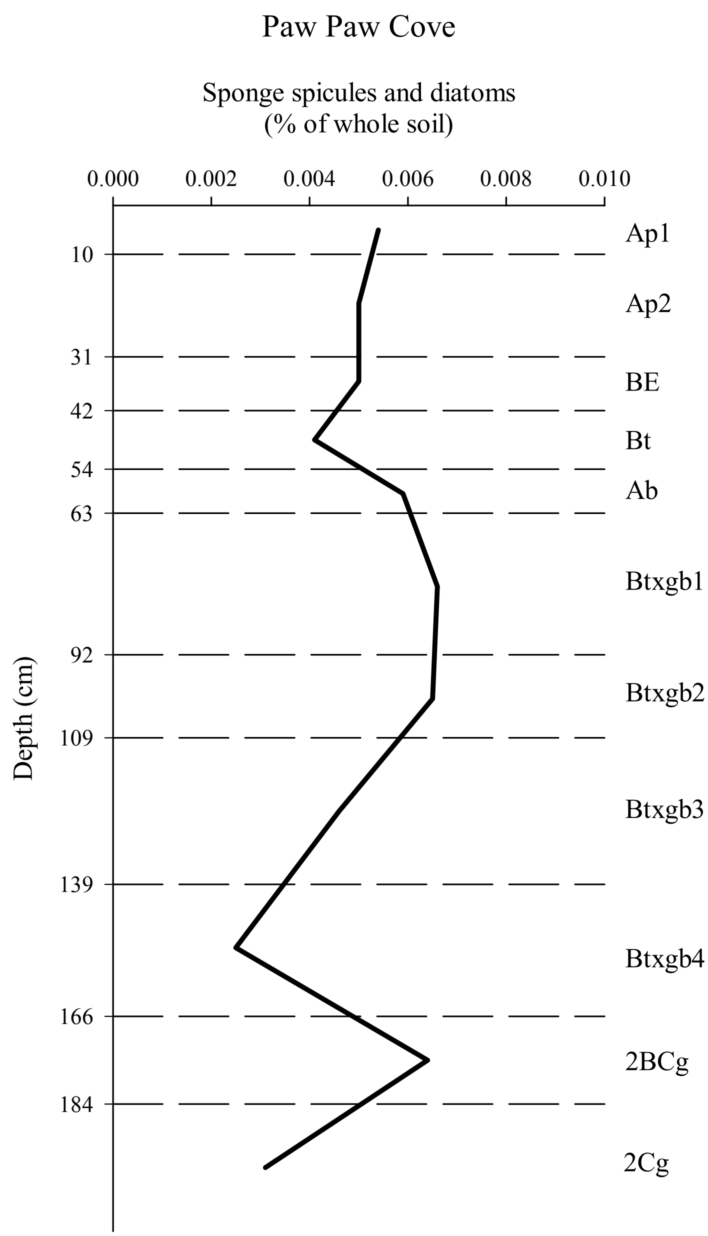


Figure 4-12. Sponge spicule and diatom distribution as a percentage of the whole soil at Paw Paw Cove (site 35). Note the very low spicule and diatom contents throughout the soil profile.

to be transported from their primary (or secondary) depositional area by eolian processes (Jones and Beavers, 1963). Similarly, spicules and diatoms in both the silts and underlying sandy sediments were fragmented and suggested some movement from their primary depositional environment, however, the fragmented nature was not diagnostic of a particular mode of transportation.

SUMMARY AND CONCLUSIONS

No single chemical or mineralogical characteristic of the soils formed in the silty parent sediments on the Delmarva Peninsula was diagnostic of the mode of transportation and deposition of those silty sediments. The ranges of potassium, calcium, zirconium, and titanium contents of soils formed in the silts were relatively narrow with no apparent trends. Their spatial distribution did not suggest the presence of multiple, distinct silt deposits but rather one homogeneous deposit and, therefore, an extension of the loess present on the northern Delmarva. The mineralogy of the fine silt fraction and the clay of the silt deposit were also similar across the study area. They were not, however, distinct from the underlying, sandy fluvial/estuarine sediments and, as a result, could not be used as a measure of the homogeneity of the silt deposit or the mode of transportation of the silty sediments. The presence of sponge spicules and diatoms in the silt deposit did not indicate that the silts had been deposited underwater. The diatoms and spicules were as susceptible to eolian entrainment and transportation as any other particles of that size. That few of the spicules or diatoms were intact suggested that they had been transported from their primary depositional environment, however, their quantity and nature in the silt deposit were comparable to their quantity and nature in the underlying sands. Therefore, the presence and distribution of sponge spicules was not diagnostic of a particular mode of transportation.

Chapter 5. Dating of the Quaternary Silt Deposit on the Delmarva Peninsula.

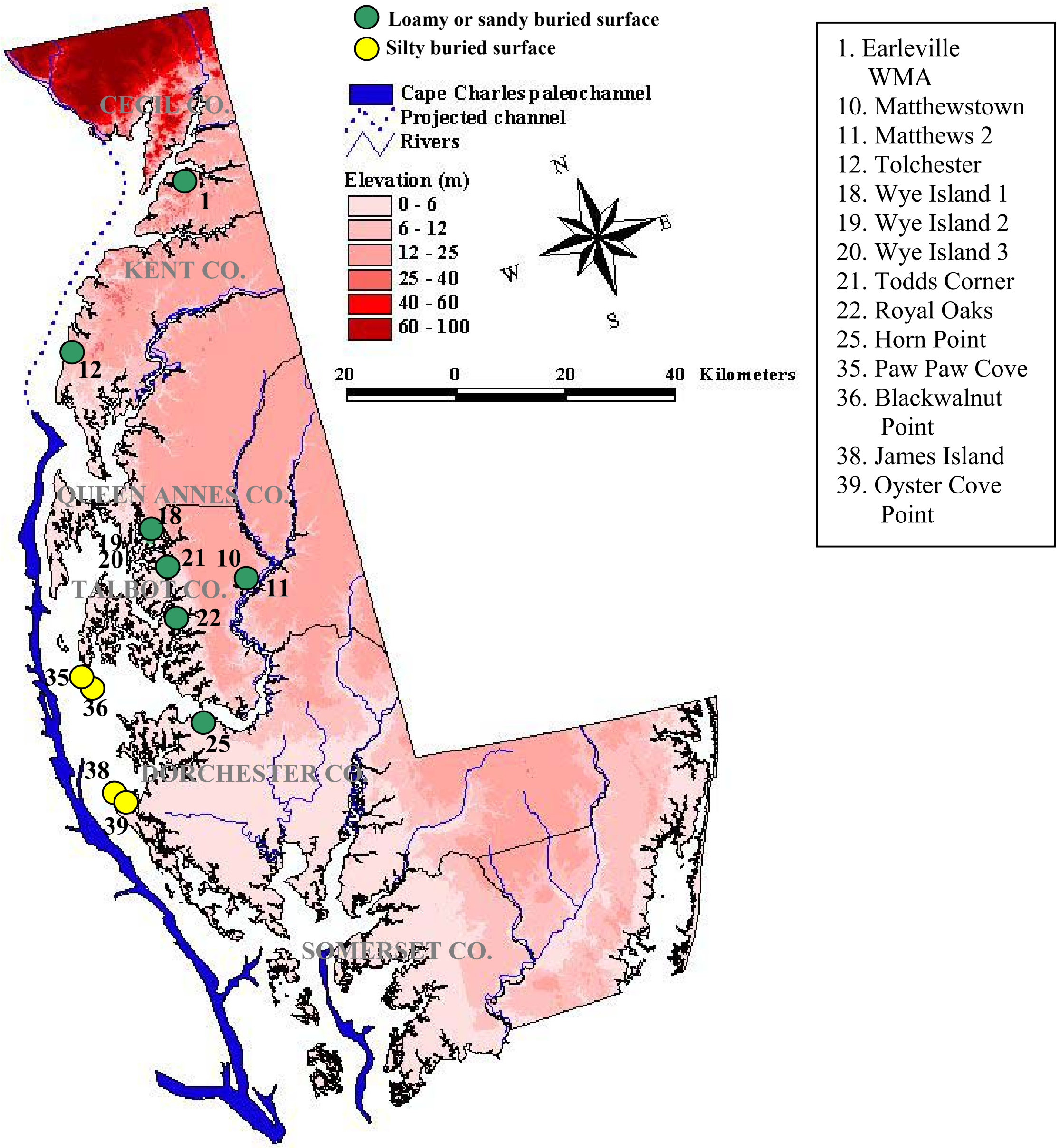
INTRODUCTION

The age of the silt deposit on the Delmarva Peninsula is an important consideration in establishing the mode of transportation and deposition of that deposit. The last episode of marine transgression with sea levels higher than present was likely 125,000 years B.P. (Toscano et al., 1989; Toscano and York, 1992), and no more recently than 82,000 B.P. (Groot and Jordan, 1999). Sediments deposited by fluvial/estuarine processes would then, necessarily, date to that time while eolian sediments could have been deposited any time after the last marine transgression when a suitable sediment source and environmental conditions were available. The pedogenic development of the soils formed in the silts suggested that the soils are relatively young, likely less than 15,000 years old and certainly less than 30,000 (see Chapter 3). Pedogenic processes that result in morphological features used to estimate the age of soils, however, are dependent upon other factors in addition to time which results in a degree of uncertainty in the ages. It is also possible that, while the soils formed on the Delmarva are relatively young, the sediments in which they have formed are considerably older which makes it necessary to date the sediments rather than the soils formed in them. The objective of this study was to establish an absolute date for the silt deposit on the Delmarva Peninsula which would then allow the deposit to be placed in the context of the paleoenvironmental history of the Delmarva and identify its mode of transportation and deposition.

MATERIALS AND METHODS

In the course of describing and sampling soils formed in the silt deposit, buried surface horizons were identified at several sites both on the low terrace bordering the Chesapeake Bay and on the upland. The buried surfaces were silty in some areas while the textures of others were loam and sandy loam. Coarse fragments were also prevalent in some of the more loamy buried surfaces such as that at Wye Island 1 (site 18) and Tolchester (site 12). Figure 5-1 shows the location and nature of buried surface horizons within the study area. In addition to the buried surface horizons encountered in this study, several others were identified during the update of the Talbot County Soil Survey (C. Baker, personal communication, 2002) while still more silty soils with buried surface horizons were mapped as a Mattapex variant in the Soil Survey of Kent County, Maryland (White, 1982).

Neither charcoal nor macro-organics were prevalent in the buried surface horizons at most sites. At Wye Island 1 (site18), however, a small quantity of charcoal was present and it was collected for radiometric dating. The relatively shallow depth of the buried surfaces and low carbon contents made bulk soil samples unattractive for ^{14}C



DEM Source: ArcUSA 1:2,000,000

Figure 5-1. Location of buried surface horizons. Silty buried surface horizons were identified on the low terrace, near the ancestral channel of the Susquehanna River. Loamy and sandy buried surfaces were identified on both the terrace and the upland.

dating due to the likelihood of contamination. Despite this risk, bulk soil samples were collected for ^{14}C dating from the buried surface of a silty paleosol at Blackwalnut Point (site 36) as well as at the base of the sediments in which the paleosol had formed at that site. Charcoal and bulk soil samples were sent to Beta Analytic Inc.[1] for AMS dating.

RESULTS AND DISCUSSION

Results of the ^{14}C dating were mixed. Those from Blackwalnut Point (site 36) were illustrative of at least one of the problems associated with dating bulk samples. The bulk soil sample from the buried surface horizon 90 centimeters below the modern soil surface at Blackwalnut Point (site 36) yielded a date of 20,850 +/- 90 ^{14}C years B.P. (Beta-168267) while the sample from the base of the paleosol, 130 centimeters below the modern soil surface, yielded a date of 15,590 +/- 60 ^{14}C years B.P. (Beta- 168268). This obvious incongruity in ages may have been a result of fluctuation of the water table at this somewhat poorly drained site and the partition and translocation of fine organic carbon materials.

Radiometric dating at Wye Island 1 (site 18) proved more satisfactory. Charcoal recovered from the buried surface horizon, 95 centimeters below the modern soil surface at Wye Island 1 (site 18) was sufficiently large (~ 0.5 cm) to have not been subject to movement in the soil profile at that depth. Also, the area from which it was recovered did not exhibit any evidence of disturbance. The charcoal yielded an AMS date of 17,070 +/- 180 ^{14}C years B.P. (Beta- 165424). The silt deposit overlying the sandy sediments and burying the surface horizon formed in the sandy sediments at Wye Island 1

[1] Beta Analytic Inc., 4985 SW 74 Court, Miami, FL,33155

(site 18) was deposited after approximately 17,000 years B.P. making the deposition of silts much more recent than the last high sea stand in the Mid-Atlantic region.

Additional dating of the silt deposit came from archaeological materials. The silt deposit at Paw Paw Cove (site 35) yielded a diagnostic Late Paleoindian projectile point dating to approximately 10,500 ^{14}C years B.P. Extensive archaeological investigations revealed that the projectile point and other associated stone tools and debitage were in the silt deposit one to two centimeters above the buried surface horizon. Their orientation and spatial distribution did not indicate any post depositional movement (Lowery, 2002). A Late Paleoindian projectile point was also recovered from the buried surface horizon at Oyster Cove Point (site 39) (D.L. Lowery, personal communication, 2002).

At Paw Paw Cove (site 35), in addition to the Paleoindian materials on the buried surface, Early Archaic artifacts, approximately 8,500 ^{14}C years old, were recovered from the silt deposit several centimeters below the plow zone . At Crane Point, approximately 4 kilometers north of Paw Paw Cove (site 35), diagnostic Early Archaic projectile points dating to approximately 9,000 ^{14}C years B.P. were recovered from the argillic horizon of the soil formed in the silt deposit. As with the Paleoindian materials at Paw Paw Cove (site 35) the Early Archiac artifacts did not exhibit any preferred orientation or other indication that they had been disturbed after their deposition and before burial by the silts (Lowery and Custer, 1990). These archaeological materials date the onset of silt deposition to ca. 10,500 ^{14}C years B.P. and the termination to shortly after ca. 8,500 ^{14}C years B.P.

The last high sea stand in the Mid-Atlantic region was no more recent than approximately 82,000 years B.P. and was probably approximately 125,000 years B.P. at which time sea level was 5 to 6 meters above present (Toscano et al., 1989; Toscano and York, 1992; Groot and Jordan, 1999). During the last glacial maximum, ca. 18,000 ^{14}C years B.P., sea level was as much as 120 meters below present (Fairbanks, 1989). At the time at which these sediments began to be deposited sea level was between 26 meters (Kraft et al., 1987) and 30 meters below present (Colman et al., 2000), precluding any possibility that they were deposited by estuarine processes during a period of high sea stand. The elevations above sea level and the intact nature of archaeological deposits also ruled out any possibility that the sediments were deposited by fluvial processes. Thus, the silt deposit at in which the modern soil has formed at Wye Island 1 (site 18), Paw Paw Cove (site 35), and Oyster Cove Point (site 39) was loess.

The initiation of loess deposition in Maryland coincided with the onset of the Younger Dryas cold phase, which lasted from ca. 11,000 to 10,000 ^{14}C years B.P., and during which temperatures were three to five degrees Celsius cooler than present (Peteet et al., 1990; Alley et al., 1993; Peteet et al., 1993). The cold, dry Younger Dryas climate resulted in rapid shifts in vegetation (Peteet et al., 1993; Shuman et al., 2002) which in turn likely destabilized soils and sediments on the landscape exposing them for transportation by eolian processes. At this time dust levels increased in the Dye-3 ice core (Dansgaard et al., 1989) and the GRIP Summit ice core (Taylor et al., 1993) in Greenland. Similarly, in Colorado loess was deposited between ca. 11,000 and 9,000 ^{14}C years B.P. (Muhs et al., 1999).

SUMMARY AND CONCLUSIONS

A radiocarbon date and archaeological materials provided absolute dates for the deposition of the silts on the Delmarva Peninsula. Charcoal from Wye Island 1 (site 18) indicated that silt deposition began after approximately 17,000 ^{14}C years B.P. while Paleoindian and Early Archaic artifacts recovered from the silt further narrowed the time frame in which the silts were deposited. The age of the silt deposit with regard to high sea stands in the Mid-Atlantic precluded the silts from having been deposited by estuarine processes. The elevation of the landscape, between 26 and 30 meters above sea level at the time the silts were deposited and the intact archaeological deposits meant that the sediments were not deposited by flooding events. Therefore, the surficial silt deposit on the Delmarva was undeniably loess.

Chapter 6. Buried Paleosols on the Delmarva Peninsula

INTRODUCTION

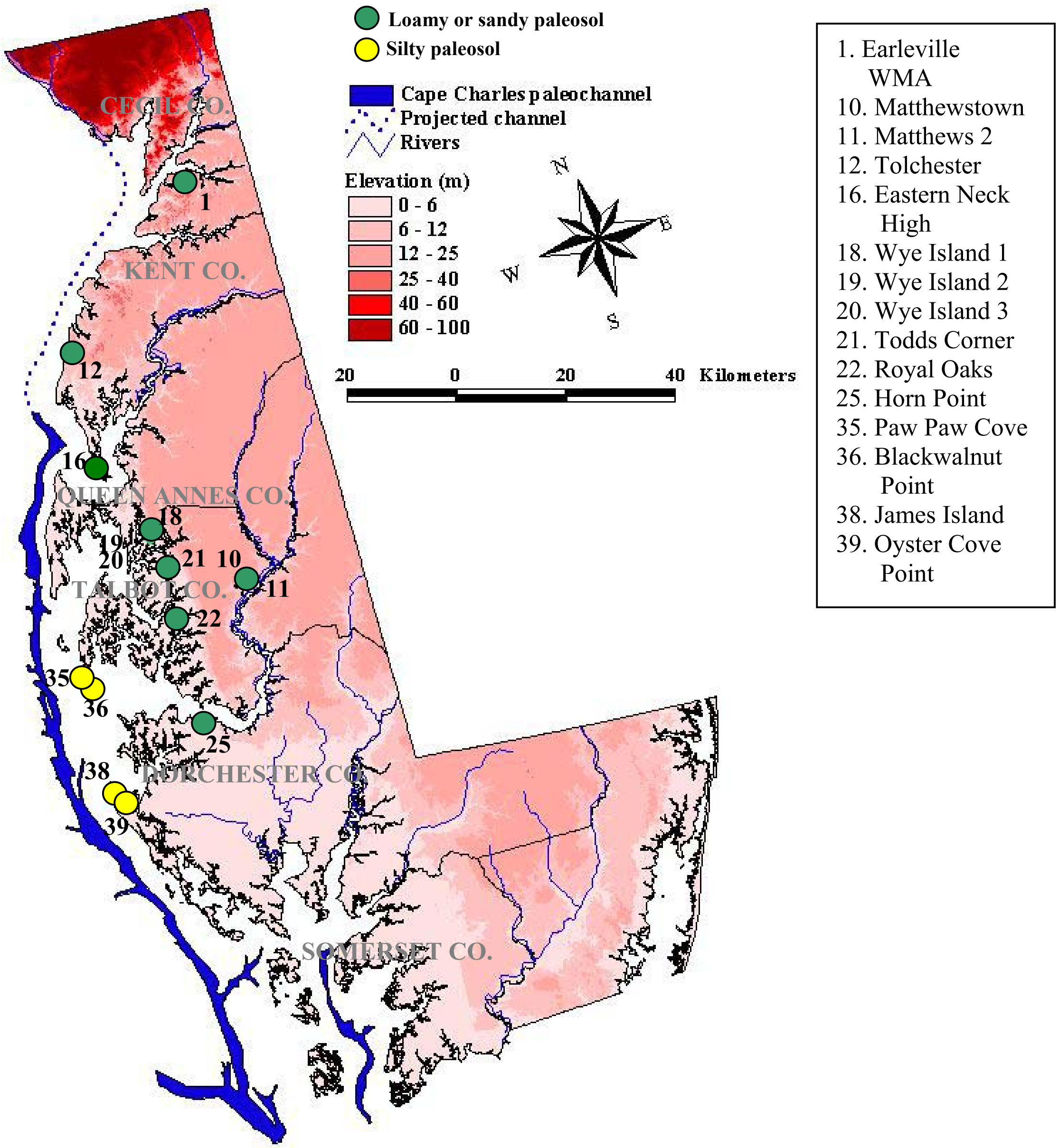
In the course of examining the loess on the Delmarva Peninsula in Maryland, several buried surface horizons and paleosols were identified. The majority of the paleosols are assumed to have formed in fluvial/estuarine sediments deposited during the most recent marine transgression, however, a paleosol formed in silty sediments like those of the surficial loess was also encountered. The parent sediments in which the silty paleosol formed could have been deposited along with the parent sediments of the other paleosols on the Delmarva during the Sangamon high sea stand which occurred no more recently than 82,000 years B.P. (Groot and Jordan, 1999) and possibly only as recently as 125,000 years B.P. (Toscano and York, 1992). Alternatively, they could represent an episode of Wisconsin loess deposition that predates the surficial loess. Paleosols provide information about past environmental conditions and changes that can otherwise be difficult to obtain. The morphological, physical, chemical, and mineralogical properties of paleosols can serve as indicators of past geomorphic process, landscape stability, and climate (Bronger and Catt, 1989; Semmel,1989; Bronger and Heinkele, 1989). The objectives of this research were to gain insight into the landscape stability and geomorphic response to climate change in the late Pleistocene and to determine the mode of transportation and age of the silty parent sediments through the examination of the morphological, physical, chemical, and mineralogical properties of the paleosols.

Hypotheses tested with regard to the latter objective were 1) that the silty sediments represented a remnant of an older, Pleistocene loess deposit that preceded the deposition of the loess in which the modern soil has formed or 2) that the sediments were deposited by fluvial/estuarine process during periods with sea levels higher than present.

MATERIALS AND METHODS

Paleosols underlying the soils formed in loess were identified on both the upland and the terrace at several sites. Figure 6-1 shows the sites at which paleosols were identified and sampled across the study area. The majority of the paleosols on the Delmarva were formed in sandy sediments presumed to be fluvial/estuarine in origin. In the area within 15 kilometers east of the Cape Charles paleochannel (Colman and Mixon, 1988), which supplied sediments for the Pleistocene/Holocene loess deposit, a paleosol formed in silty sediments was identified. This paleosol covers an area of approximately 400 square kilometers along the modern Chesapeake Bay in Talbot and Dorchester counties.

In the field paleosols were described and sampled in backhoe pits, bank cuts and auger borings according to the Soil Survey Manual (Soil Survey Staff, 1993) and the Handbook for Describing and Sampling Soils (Schoenberger et al., 1998). Laboratory analyses were performed on the less than two millimeter size fraction of samples and included the physical, chemical, and mineralogical characterization of soils. Particle size distribution was determined by the pipette method (Gee and Bauder, 1986) with coarse



DEM Source: ArcUSA 1:2,000,000

Figure 6-1. Location of paleosols. A silty paleosol was identified on the low terrace near the ancestral channel of the Susquehanna River. Loamy and sandy paleosols were identified on both the terrace and the upland.

and fine silts divided at 20 micrometers for all samples. Particle size statistics, including clay-free mean and median particle size, were calculated in phi based on cumulative frequency (Reineck and Singh, 1980; Prothero and Schwab, 1996). Sorting was calculated in millimeters (Trask, 1932) and divided into four classes. Soils with a sorting coefficient of 1.0 to 1.5 were excellent, 1.5 to 2.5 well, 2.5 to 4.0 moderately well, and > 4.0 poorly sorted (Carey et al., 1976). Organic carbon contents were determined by dry combustion (Nelson and Sommers, 1982) for paleosols with intact surface horizons. Potassium, calcium, zirconium, and titanium were determined on the coarse silt (20 to 50 μm) fraction of samples from several sites by x-ray spectroscopy (Beavers, 1960; Jones, 1982) with National Bureau of Standards NBS 76, NBS 77, NBS 78, NBS 102, and AGV-1 reference samples used to create the standard curve. Due to past conventions and to easy comparisons with previous studies, results were reported as oxides. Table 6-1 shows the sites for which potassium, calcium, zirconium, and titanium contents were determined and the sites and horizons on which silt and clay mineralogical analysis was performed. Silt mineralogy was determined on the fine silt (2 to 20 μm) fraction by x-ray diffraction using random powder mounts for representative horizons from the paleosol at Wye Island 2 (site 19) and Paw Paw Cove (site 35). Clay mineralogy was determined on the less than two micron fraction by x-ray diffraction on oriented mounts (Whittig and Allardice, 1986) for the same horizons for which silt mineralogy was determined. One set of samples for clay mineralogical analysis was magnesium saturated and ethylene glycol solvated, while the second set was potassium saturated. Analysis was performed on both sets of samples at 25 degrees Celsius while the potassium saturated samples were also heat treated to 300 and 550 degrees Celsius. Samples used for x-ray analysis were

Table 6-1. Sites and horizons for which zirconium, titanium, potassium, and calcium contents and silt and clay mineralogy were determined.

Site	Percent	Mineralogy	
	ZrO_2, TiO_2, K_2O, CaO	Silt	Clay
Wye Island 2 (site 19)	X	A,Bt2,2Ab	A,Bt2,2Ab
Paw Paw Cove (site 35)	X	Ap2,Bt,Ab,Btxgb3,2BCg	Ap2,Bt,Ab,Btxgb3,2BCg
Earleville WMA (site1)	X	--	--
Horn Point (site 25)	X	--	--
Royal Oaks (site 22)	X	--	--
Oyster Cove Point (site 39)	X	--	--

x--analysis was performed on all horizons sampled.

treated to remove organic matter and iron oxides prior to fractionation (Whittig and Allardice, 1986).

RESULTS AND DISCUSSION

A wide range of pedogenic development and intactness was observed in the morphology of the paleosols on the Delmarva, reflecting episodes of erosion and periods of landscape stability of varying lengths. In some instances paleosols were truncated with little pedogenic development after the erosional episode, in others the paleosola seemed complete but with the organic matter of the surface horizon (now buried by loess) oxidized to the extent that it was no longer readily distinguishable in the field, while in still others the paleosola seemed complete and the surface horizon of the paleosol was recognizable.

Truncated Paleosols Formed in Loamy/Sandy Sediments

Paleosols formed in sandy sediments were identified at sites in the study area and several others were noted during the update of the Talbot County Soil Survey (C. Baker, unpublished data, 2001). The paleosols at Wye Island 2 (site 19), Wye Island 3 (site 20), Todds Corner (site 21), and Royal Oaks (site 22) displayed evidence of truncation and the development of a surface horizon after that truncation (see Appendix A for narrative descriptions of soils). Little evidence of further soil development was identified at these sites, however, it should be noted that soil descriptions at these sites were not made to a sufficient depth to draw strong conclusions regarding pedogenesis. The apparent lack of diagnostic subsurface horizons such as cambic or argillic horizons suggested that the soils that had been at these sites were eroded to the relatively unweathered parent sediments followed by a brief period of landscape stability during which A horizon formation took place. This period was then followed by the deposition of loess isolating the paleosol from further weathering processes. Increased coarse fragment contents in the surface horizon of the paleosols at Wye Island 1 (site 18) and Royal Oaks (site 22), often associated with sheet erosion and the winnowing of finer sediments, tended to reinforce the idea that the soils and sediments at those sites had been truncated prior to the formation of the surface horizon (Figure 6-2).

The paleosol at Eastern Neck High (site16), like those at Wye Island 1 (site 18) and Royal Oaks (site 22), also had evidence of truncation in the form of a stone line. At this site, however, the stone line was on the 2Bt horizon of the paleosol with a sandy clay loam texture, 24 percent clay and evidence of translocation of clay, and was directly overlain by a BC horizon of the late Pleistocene loess which had a silt loam texture and 12 percent clay. There was no morphological evidence of the formation of a surface horizon in the truncated paleosol (Table 6-2).

At Tolchester (site12), the paleosol exhibited characteristics similar to those of Eastern Neck High (site16). Coarse fragments increased in the surface horizon of the buried paleosol but the clay content in that horizon was higher than that of the argillic horizon of the paleosol (37 versus 31 percent) which possibly indicated that at that site the paleosol was truncated to the resistant argillic horizon followed by a period of

Figure 6-2. Soil profile from Wye Island 1 (site 18).

Table 6-2. Abbreviated profile description for Eastern Neck High (site 16).* Stone line made up of rounded quartz gravels and some channers was present at 90 cm.

Horizon	Depth (cm)	Color**	Redox.	Texture	Consist.**
A	0-6	10YR3/3	--	L	vfr
AE	6-14	10YR4/4	--	SiL	vfr
EB	14-38	2.5Y6/4	f1f 7.5YR5/6	SiL	fr
Bt1	38-56	2.5Y6/6	c2d 10YR5/8	SiL	fr
Bt2	56-69	10YR5/8	m2d 7.5YR5/6 m2p 2.5Y6/2	VFSL	fr
BC	69-90	10YR5/6	c2f 10YR5/8 f2p 2.5Y6/2	FSL	fr
2Bt	90-104	2.5Y6/4	m2p 7.5YR5/8 c2p 2.5Y6/1	SCL	fr
2BC1	104-121	2.5Y6/6	m2d 10YR5/8 c3p 5Y6/2	FSL	fr
2BC2	121-155	2.5Y5/4	c2d 10YR5/6 c3p 5Y6/2	FSL	fr

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Fieldbook for Describing and Sampling Soils (Schoenberger et al., 1998)
**Moist samples

landscape stability in which organic carbon accumulated in the argillic horizon, which was then on the surface. The paleosol was then buried by loess.

Wide scale soil erosion was common during the late Pleistocene. Leigh and Knox (1994) noted multiple episodes of mass wasting in the Driftless Area of Wisconsin and Illinois between approximately 20,000 and 12,000 ^{14}C years B.P. In Iowa erosion was occurring at the same time loess was being deposited resulting in the incorporation of coarser eroded sediments in the loess deposits. The erosion surface in Iowa was dated to between 22,600 to 17,810 ^{14}C years B.P. (Ruhe, 1983). In the Mid-Atlantic region, Feldman et al. (2000) described an erosional surface and stone line at the base of late Pleistocene loess that dated to approximately 13,800 years B.P.

Intact Paleosols

The paleosols at Earlville (site 1), Matthewstown (site 10), and Mattthews 2 (site 11) did not exhibit any evidence of having been truncated prior to having been buried by loess, however, at each of these sites the (buried) surface horizon was difficult to identify. Recognition of the paleosols at these sites was based on textural changes. Solum thickness of the paleosol at these sites was greater than 150 centimeters. Clay contents in the maximum expression of the argillic horizon were 37, 47, and 42 percent at Earlville WMA (site 1), Matthewstown (site 10), and Mattthews 2 (site 11), respectively. Figure 6-3 shows the particle size distribution for the paleosol and the soil formed in the overlying loess at Earleville WMA (site 1). Organic carbon content of the surface horizon of the paleosol at Earleville WMA (site 1) was 0.14 percent which was slightly

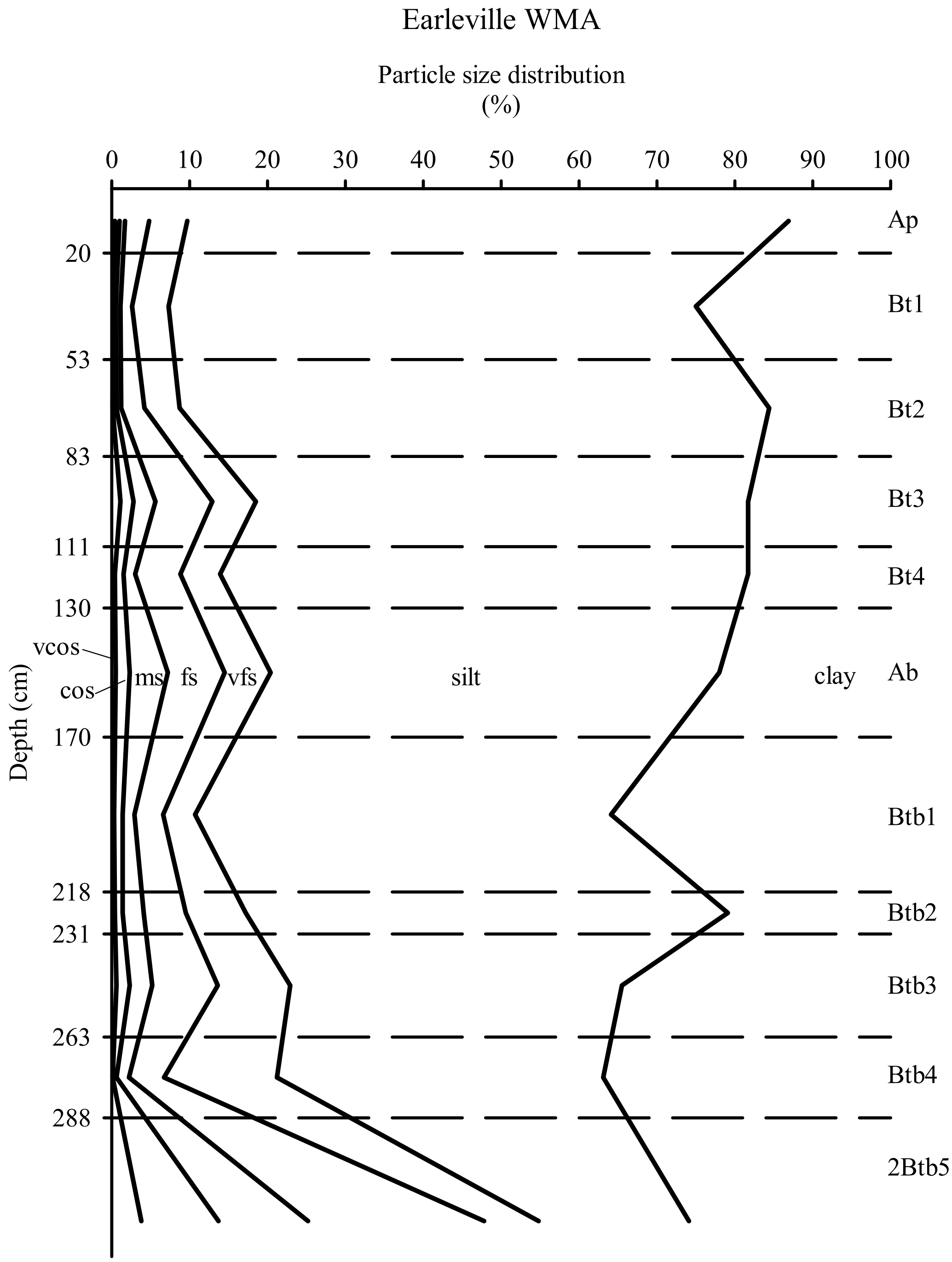


Figure 6-3. Particle size distribution with depth at Earleville WMA (site 1). Note the high clay contents in the argillic horizons of the paleosol.

higher than that of the argillic horizons of the burying loessial soil as well that of the argillic horizons of the paleosol (Figure 6-4).

The distribution of potassium, calcium, zirconium and titanium at Earlville WMA (site 1) reflected the weathering of less resistant minerals and accumulation of more resistant ones (Table 6-3). Calcium was likely resident primarily in silt sized feldspar minerals in the deposit, potassium in micas and feldspars, and zirconium and titanium were probably resident in zircon, rutile and ilmenite. Neither the zirconium nor titanium contents of the paleosol were greatly different from those of the loessial soil. The weighted average potassium and calcium contents of the paleosol, however, were noticeably lower than those of the soil formed in the overlying loess, with 1.19 percent K_2O and 0.09 percent CaO in the paleosol versus 1.92 percent K_2O and 0.81 percent CaO in the loess. The lower potassium and calcium contents may have represented an increased period of weathering compared to the loessial soil, or possibly reflected differences in the parent materials.

Silty Paleosol

The buried paleosol at Paw Paw Cove (site 35), Blackwalnut Point (site 36), Oyster Cove Point (site 39), and James Island (site 38) was formed in silts up to 125 centimeters thick (Figure 6-5). This paleosol occurred within 15 kilometers of the paleochannel in the central and southern part of the study area and was morphologically distinct. It had silt loam and silty clay loam argillic horizons/fragipan with clay contents ranging from 24 to 35 percent, moderate very coarse prismatic structure, and was

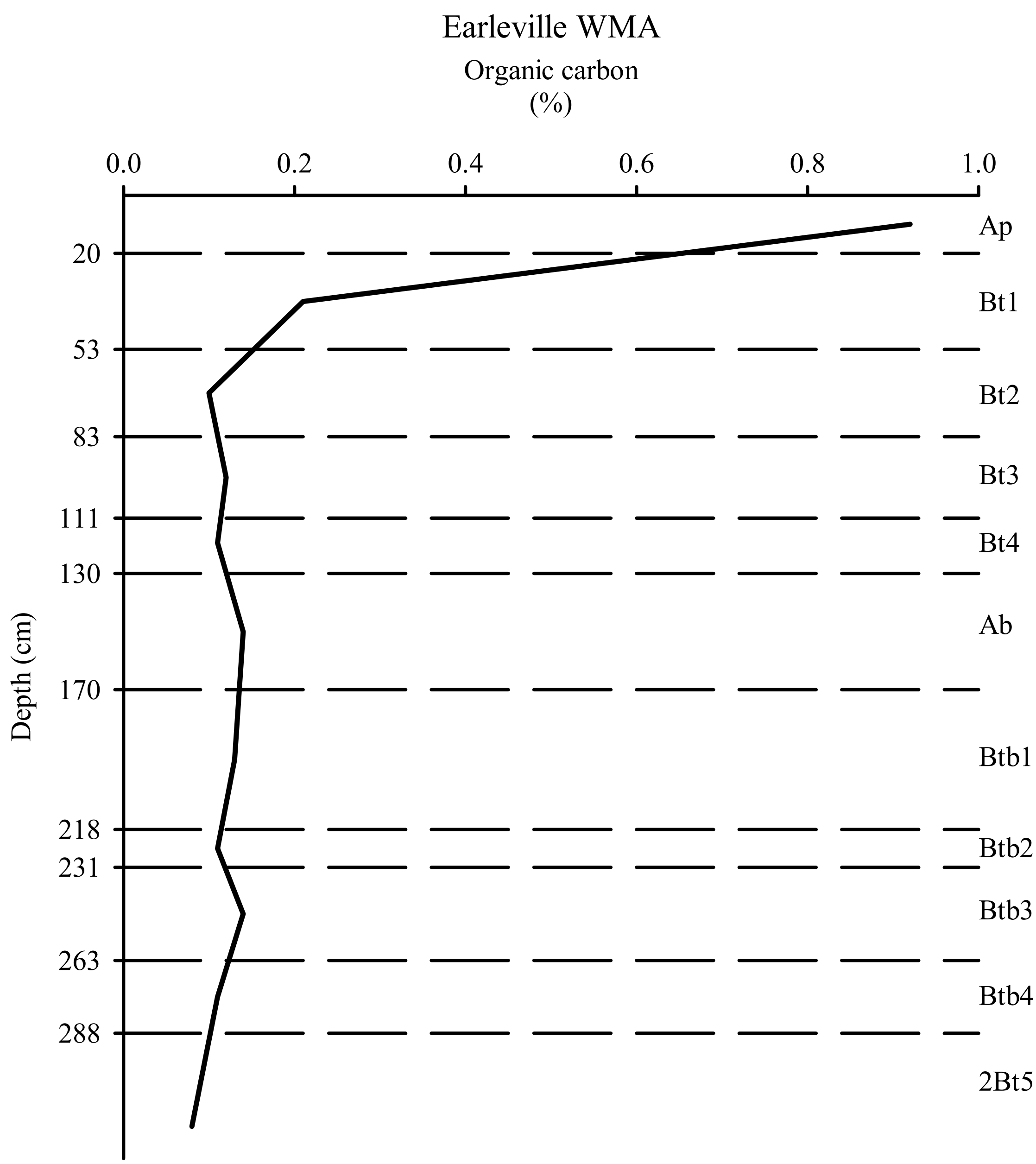


Figure 6-4. Organic carbon content with depth at Earleville WMA (site 1). Note the slight increase in organic carbon content in the Ab horizon.

Table 6-3. Weighted average ZrO_2, TiO_2, K_2O, and CaO contents of the coarse silt fraction (20-50 µm) from all horizons of the paleosol at Earleville WMA, Paw Paw Cove, and Oyster Cove Point compared to those from the overlying loess.

Site	Percent			
	ZrO_2	TiO_2	K_2O	CaO
Earleville WMA (loess) (site 1)	0.13	1.06	1.92	0.81
Paw Paw Cove (loess) (site 35)	0.11	0.98	1.63	0.45
Oyster Cove Point (loess) (site 39)	0.12	.096	1.56	0.48
Earleville WMA (paleosol) (site 1)	0.14	1.16	1.19	0.09
Paw Paw Cove (paleosol) (site 35)	0.10	0.95	1.26	0.24
Oyster Cove Point (paleosol) (site 39)	0.11	1.05	1.16	0.09

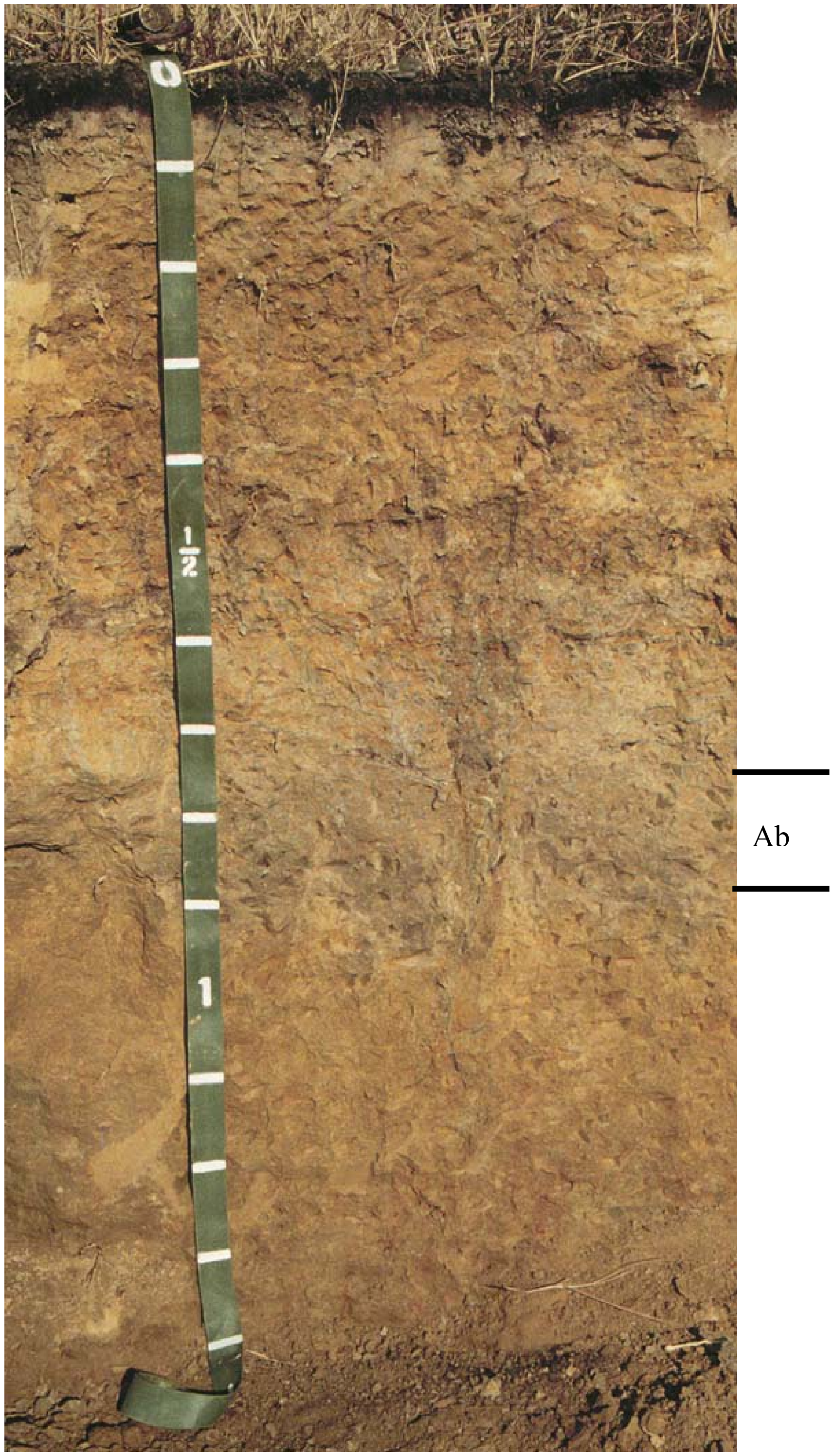


Figure 6-5. Soil profile from Blackwalnut Point (site 36). Note the buried surface horizon.

underlain by stratified sandy sediments. No coarse fragments were present in this paleosol. Table 6-4 is an abbreviated profile description with laboratory determined clay contents for Oyster Cove Point (site 39).

The parent sediments of the silty paleosol were similar to the loess burying them. Table 6-5 shows the clay-free, weighted average particle size distribution, mean particle size, and sorting for each of the pedons of the silty buried paleosol. The average clay-free silt content at Paw Paw Cove (site 35), Oyster Cove Point (site 39), Blackwalnut Point (site 36), and James Island (site 38) was 79 percent. Mean clay-free particle size was coarse silt, 33 micrometers with a range from 25 micrometers at Paw Paw Cove (site 35) to 42 micrometers at James Island (site 38). The sediments of the paleosol were only slightly less well sorted than those of the overlying silts. The silty sediments of the paleosol at Oyster Cove Point (site 39) were well sorted with a coefficient of 2.45, while at Paw Paw Cove (site 35), Blackwalnut Point (site 36), and James Island (site 38) they were all moderately well sorted with coefficients of 2.51, 2.51, and 2.68, respectively. The average sorting coefficient for the paleosol was 2.54, nominally higher than the well sorted loess that buried them and which had an average coefficient of 2.46.

The loess burying the silty paleosol was relatively thin (< 90 cm at all sites) and as such did not isolate the paleosol from continued pedogenesis. The particle size distribution of the paleosol reflected these ongoing processes, particularly the accumulation of clay translocated from the overlying deposit (Table 6-6). As a result of this along with the continued neo-formation of clays in the upper horizons of the paleosol, clay contents in the paleosol were higher than those of the overlying soil and clay contents in the buried surface horizon were higher than those in the buried argillic

Table 6-4. Abbreviated profile description for Oyster Cove Point (site 39).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Clay (%)	Consist.**
Ap	0-16	10YR4/3	--	SiL	15	fr
BE	16-22	2.5Y5/4	c2d 10YR4/6	SiCL	30	fr
Btg	22-40	10YR6/1	m2p 10YR5/8	SiCL	31	fr
Btx	40-53	10YR4/4	c2f 10YR4/6 c2f 10YR5/2	SiCL	30	fi
Ab	53-80	10YR3/1	c2d 10YR4/6	SiCL	32	fi
Btxb1	80-108	2.5Y4/3	m1d 10YR5/6 c2f 10YR5/1	SiCL	29	fi
Btxb2	108-138	2.5Y5/4	m2d 10YR5/8 c2d 10YR5/2	SiCL	24	fr
BCg	138-178	2.5Y6/2	f2d 10YR5/8	SiL	19	fr
3BCg	178-183	2.5Y5/2	f2f 10YR5/6	SL	14	vfr

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Fieldbook for Describing and Sampling Soils (Schoenberger et al., 1998)
**Moist samples

Table 6-5. Clay-free weighted average particle size distribution, mean, median, and sorting of sediments in the silty paleosol.

Site	Percent							Mean (mm)	Median (mm)	Sorting Coefficient
	VCOS	COS	MS	FS	VFS	CoSi	FSi			
Blackwalnut point	0.05	0.03	0.16	2.21	20.98	33.42	43.14	0.034	0.024	2.51
James Island	0.06	0.04	0.17	8.12	23.06	28.60	39.94	0.042	0.028	2.68
Oyster Cove Point	0.00	0.00	0.07	1.15	16.16	35.96	46.66	0.029	0.022	2.45
Paw Paw Cove	0.00	0.08	0.14	1.89	10.95	30.44	56.50	0.025	0.015	2.51

Table 6-6. Particle size distribution for the soil and paleosol at James Island (site 38), Oyster Cove Point (site 39), Paw Paw Cove (site 35), and Blackwalnut Point (site 36).

Site	Horizon	Percent									
		Sand	Silt	Clay	FSi	CoSi	VCOS	COS	MS	FS	VFS
James Island	A 0-9	34.0	49.7	16.3	24.8	24.9	0.2	0.4	2.4	15.9	15.0
(site 38)	Ap 9-22	9.0	79.0	12.0	41.1	37.9	0.2	0.2	0.7	1.7	6.2
	E 22-33	5.6	74.1	20.3	44.8	29.3	0.1	0.1	0.4	0.9	4.0
	BE 33-46	5.2	65.1	29.7	34.1	31.0	0.0	0.2	0.2	0.8	4.0
	Btx 46-59	3.8	73.7	22.5	36.2	37.5	0.0	0.0	0.3	0.4	3.2
	Btxg159-88	6.6	62.5	30.9	33.4	29.1	0.1	0.0	0.2	1.4	5.0
	Ab 88-106	15.5	52.0	32.5	32.5	19.5	0.1	0.1	0.2	5.4	9.7
	Btxb 106-130	24.8	48.1	27.1	30.4	17.7	0.0	0.0	0.2	7.5	17.2
	BC 130-145	27.9	49.2	22.9	26.9	22.3	0.0	0.0	0.0	6.5	21.4
	BCg 145-158	26.5	54.3	19.2	25.2	29.1	0.1	0.0	0.0	3.2	23.2
	2C 158-180	67.4	15.1	17.5	8.5	6.6	0.1	0.1	0.6	58.3	8.3
	2Cg 180-195	42.9	43.9	13.2	15.7	28.2	0.0	0.1	0.1	3.3	39.4
Oyster Cove Point	Ap 0-16	8.8	76.2	15.0	38.9	37.3	0.2	0.4	1.4	1.8	5.0
(site 39)	BE 16-22	5.4	65.0	29.6	37.4	27.6	0.1	0.1	0.3	0.8	4.0
	Btg 22-40	4.7	64.7	30.6	34.1	30.6	0.0	0.2	0.1	0.5	3.9
	Btx 40-53	6.2	64.2	29.6	37.7	26.5	0.0	0.0	0.0	0.5	5.7
	Ab 53-80	9.9	57.9	32.2	34.5	23.4	0.0	0.0	0.1	0.7	9.0
	Btxb1 80-108	12.5	58.7	28.8	35.0	23.7	0.0	0.0	0.1	0.9	11.5
	Btxb2 108-138	15.0	60.7	24.3	33.2	27.5	0.0	0.0	0.0	1.0	14.1
	BCg 138-178	14.0	67.3	18.7	36.0	31.3	0.0	0.0	0.0	0.8	13.2
	2Cg 178-183	58.0	28.1	13.9	13.4	14.7	0.0	0.1	0.3	23.8	33.8

Table 6-6 (continued).

Site	Horizon	Percent									
		Sand	Silt	Clay	FSi	CoSi	VCOS	COS	MS	FS	VFS
Paw Paw Cove	Ap 1 0-10	15.5	71.0	13.5	38.3	32.7	0.5	2.0	4.4	1.7	6.9
(site 35)	Ap2 10-31	18.1	69.0	13.0	36.8	32.2	0.1	2.8	6.8	1.5	6.9
	E 31-42	6.4	69.4	24.2	39.0	30.4	0.0	0.1	0.3	0.7	5.2
	BE 42-54	4.9	65.5	29.6	35.2	30.3	0.0	0.0	0.1	0.4	4.4
	Btx 54-63	5.1	55.5	39.4	35.1	20.4	0.0	0.1	0.1	0.8	4.1
	Ab 63-92	7.8	57.4	34.8	37.6	19.8	0.0	0.0	0.1	1.3	6.4
	Btxgb1 92-109	10.1	59.7	30.2	39.9	19.8	0.0	0.0	0.1	1.4	8.6
	Btxgb2 109-139	9.1	61.7	29.2	41.4	20.3	0.0	0.1	0.1	1.4	7.5
	Btxgb3 139-166	10.4	65.6	24.0	40.0	25.6	0.0	0.1	0.1	1.2	8.9
	2BC 166-184	18.3	62.4	19.3	37.3	25.1	0.0	0.1	0.4	5.6	12.2
	2Cg 184-210	51.2	36.9	11.9	16.4	20.5	0.0	0.1	0.2	15.5	35.4
Blackwalnut Point	A	10.4	78.7	10.9	45.2	33.5	0.3	0.3	0.5	2.5	6.9
(site 36)	E 6-13	9.4	76.2	14.4	43.4	32.8	0.3	0.4	0.6	1.9	6.1
	BE 13-34	7.3	69.1	23.6	38.0	31.1	0.1	0.3	0.4	1.6	4.9
	Bt1 34-67	15.0	65.1	19.9	32.2	32.9	0.1	0.1	0.5	5.5	8.8
	Bt2 67-86	7.8	68.6	23.6	39.5	29.1	0.2	0.0	0.2	0.9	6.4
	Ab 86-109	12.8	59.1	28.1	36.5	22.6	0.1	0.1	0.1	1.1	11.4
	Btxb 109-130	15.9	56.0	28.1	35.0	21.0	0.1	0.0	0.1	1.4	14.2
	Btxgb 130-159	18.0	59.2	22.8	34.9	24.3	0.0	0.0	0.2	1.2	16.6
	BCg1 159-182	19.8	63.6	16.6	32.4	31.2	0.0	0.0	0.1	1.4	18.3
	BCg2 182-204	26.3	60.1	13.6	27.5	32.6	0.0	0.0	0.1	4.0	22.3
	2Cg 204-255	50.5	40.5	9.0	16.5	24.0	0.0	0.1	0.3	13.4	36.5

horizon. It was also possible that the silty paleosol was truncated to the resistant argillic horizon followed by renewed A horizon formation in what had been the argillic horizon during the succeeding period of landscape stability before loess deposition. At Blackwalnut Point (site 36) clay content increased from 24 percent in the Bt2 horizon to 28 percent in the Ab horizon then decreased to 23 percent in the buried argillic (Figure 6-6). Beneath the buried argillic clay content decreased and sand content increased in a mixing zone above the contact with the underlying sands. As in the overlying loess, very coarse, coarse, and medium sand contents were very low in the paleosol.

As was the case at Earleville WMA (site 1), zirconium and titanium contents in the coarse silt fraction of the silty paleosol at Paw Paw Cove (site 35) and Oyster Cove Point (site 39) were similar to those of the overlying loess and potassium and calcium contents were noticeably lower (Table 6-3). The paleosol at Oyster Cove Point (site 39) had a weighted average 1.16 percent K_2O and 0.09 percent CaO while the loess had 1.56 percent K_2O and 0.48 percent CaO. The low potassium and calcium contents in the paleosol were likely a function of an extended weathering period for the paleosol compared to the soil formed in the overlying silts.

The mineralogy of the silt fraction of the silty paleosol at Paw Paw Cove (site 35) was similar to that of the overlying loess (Figure 6-7). It was dominated by quartz with lesser amounts of mica, kaolinite and feldspars (likely albite). Slightly higher mica contents were noted in the silt fraction of the paleosol. Kaolinite and vermiculite were the most abundant minerals in the less than two micrometer fraction of the paleosol at Paw Paw Cove (site 35), with lesser amounts of chlorite, muscovite, hydroxy-interlayered vermiculite and quartz, and trace amounts of feldspars present (Figure 6-8). The relative

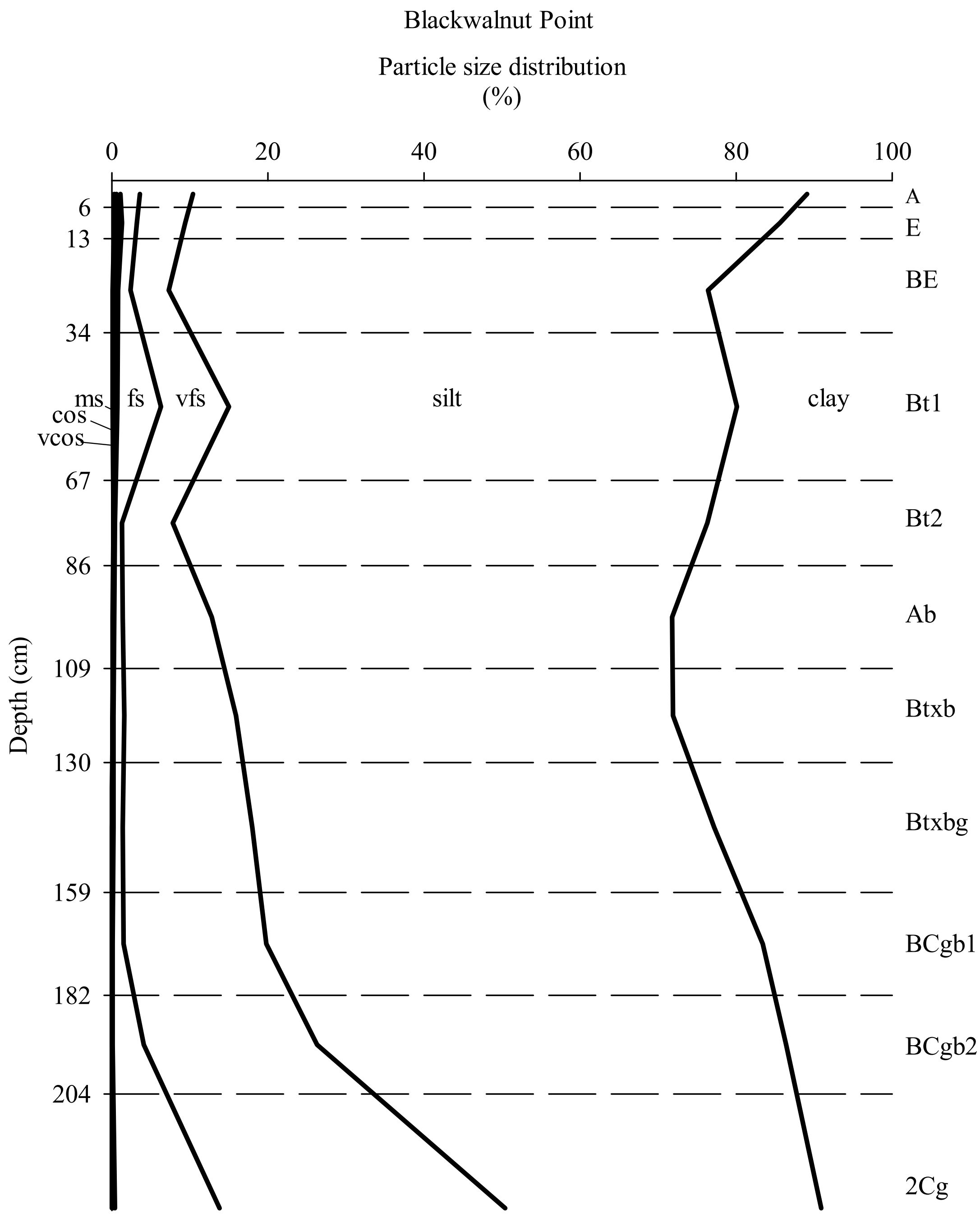


Figure 6-6. Particle size distribution with depth at Blackwalnut Point (site 36). Note the high clay content of the Ab and Btxb horizons.

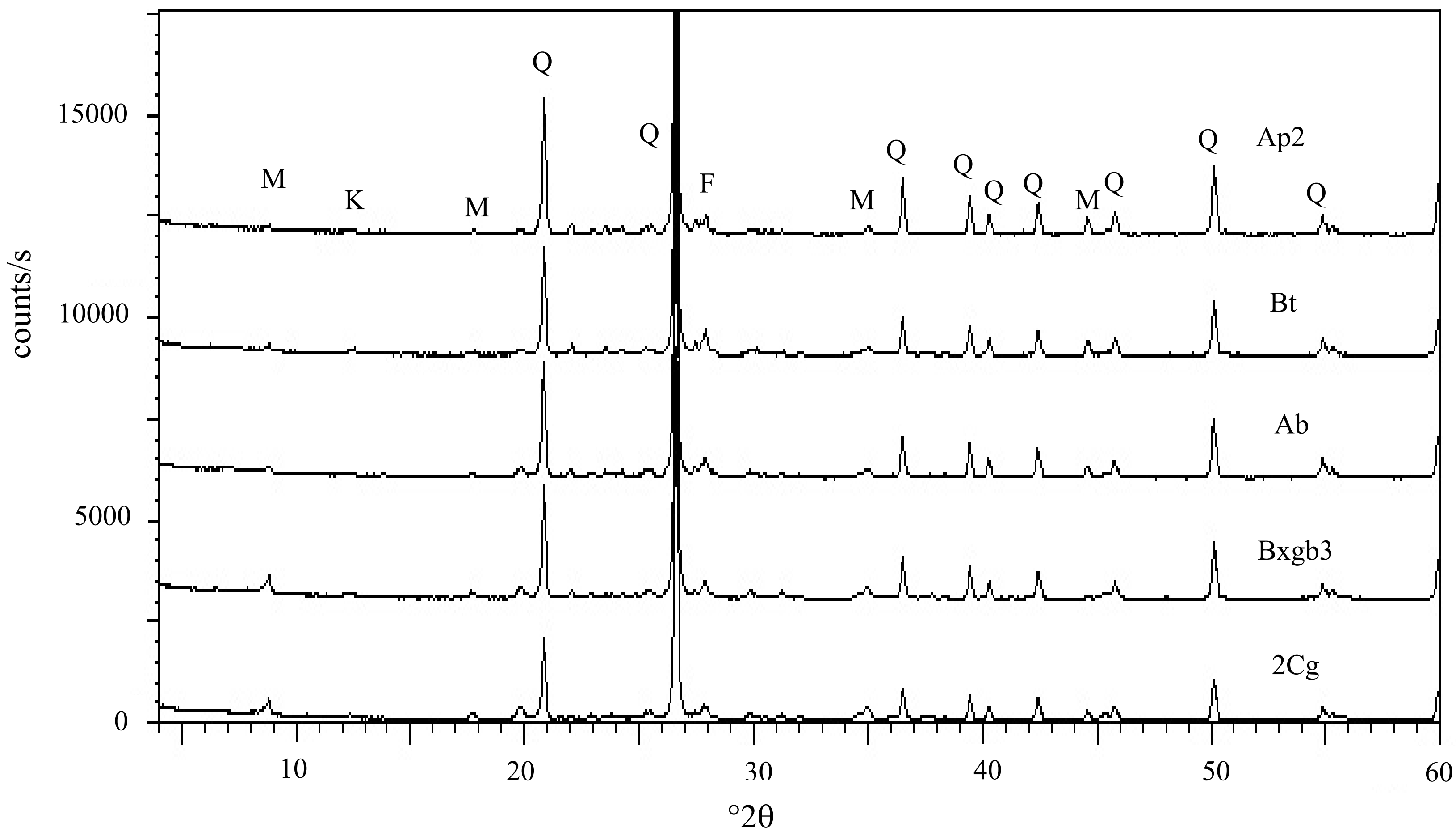


Figure 6-7. X-ray diffraction pattern showing the mineralogy of the fine silt fraction (2-20 μm) from horizons formed in the loess, silty paleosol, and underlying sands at Paw Paw Cove (site 35). Q=quartz, K=kaolinite, M=mica, F=feldspar.

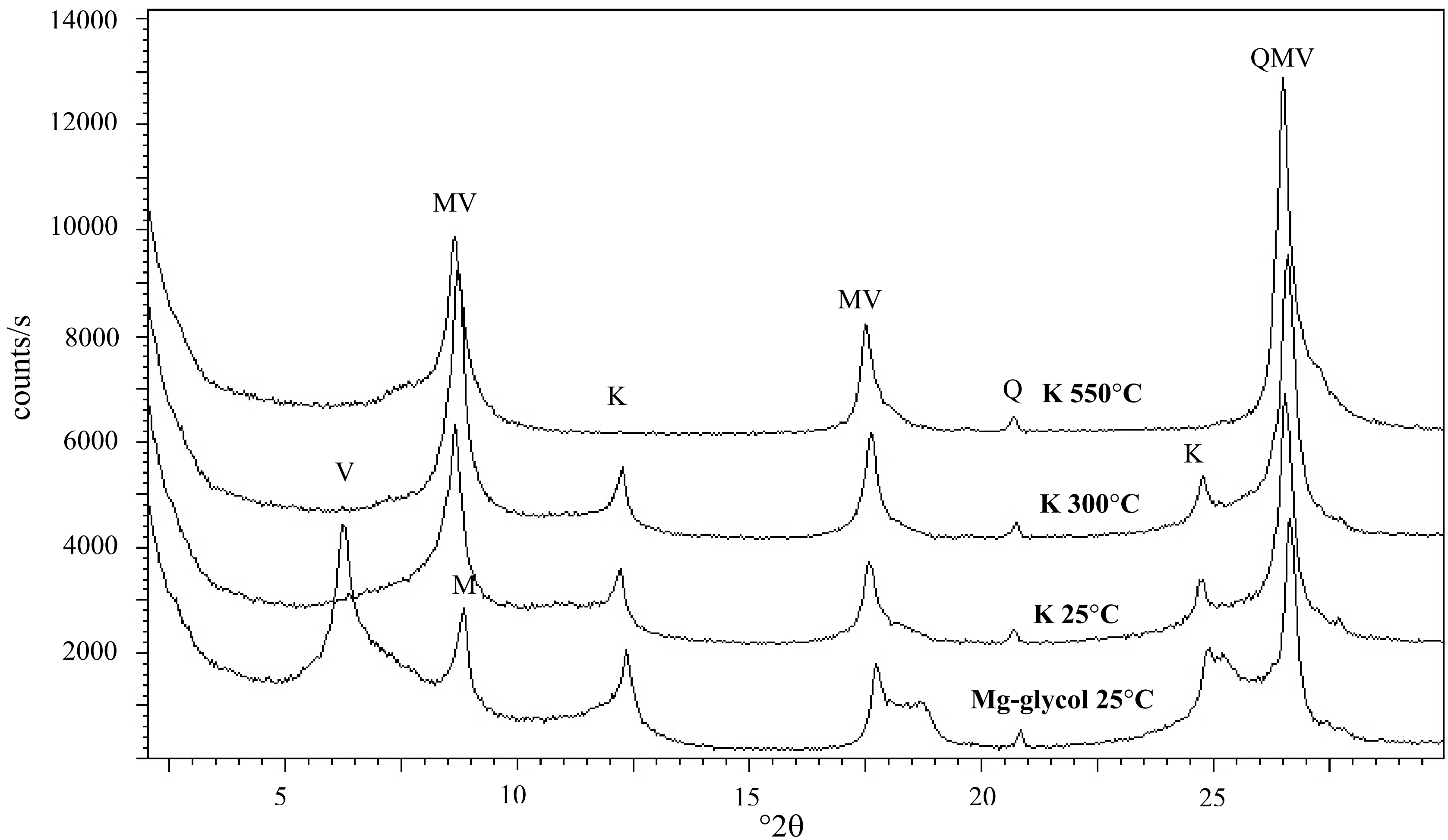


Figure 6-8. X-ray diffraction pattern showing the clay mineralogy of the Btxgb3 horizon at Paw Paw Cove (site 35). V=vermiculite, HIV=hydroxy interlayered vermiculite, M=muscovite, K=kaolinite, Q=quartz, F=feldspar.

abundance of minerals varied somewhat within profiles and between the loess and the paleosol, however, the suite of minerals was unchanged.

SUMMARY AND CONCLUSIONS

Evidence of erosion, including stone lines and increased coarse fragment contents in the surface horizons of the paleosol or at the contact between the loess and the paleosol, was common. At several sites, A horizon development in the truncated sediments indicated at least a short period of landscape stability before the onset of loess deposition. At other sites where the paleosols escaped truncation, low calcium and potassium contents representative of the weatherable minerals in the coarse silt fraction of the paleosol may have indicated that those paleosols had been weathering for a longer time before burial than have the soils formed in the surficial loess. Alternatively, low calcium and potassium contents in the paleosols could be a result of differences in parent materials.

The origin of the silts near the Cape Charles paleochannel in which the paleosol described at Paw Paw Cove (site 35), James Island (site 38), Blackwalnut Point (site 36), and Oyster Cove Point (site 39) was formed is unclear. The extent of this silt deposited is limited, covering only 400 square kilometers. The sediments in the deposit had mean clay-free silt contents and sizes comparable to that of the overlying loess. They were moderately well sorted with a coefficient of 2.54 similar to the sorting of the loess. Soil development in the paleosol suggested that the sediments were undergoing pedogenesis for a longer period than loess in which the modern soil has formed. No dates have yet been acquired to place the deposit into the Quaternary depositional time frame. The paleosol may have been truncated, as were many of the other soils on the Delmarva Peninsula, with renewed A horizon formation occurring before subsequent burial by the loess.

Possible origins for these sediments include deposition by fluvial/estuarine processes during a period of high sea stand above present or an earlier Late Pleistocene episode of loess deposition. The argument for loess lies in the Midwestern United States where two well defined episodes of loess deposition occurred between approximately 33,000 to 25,000 years B.P. (Norton et al., 1988) and 25,000 and 16,000 ^{14}C years B.P. (Ruhe, 1983; Leigh and Knox, 1994). No evidence of multiple episodes of loess deposition has been identified in any of the other loessial areas in the Mid-Atlantic region, however. The Mid-Atlantic may have experienced climates favorable to eolian processes at the times of loess deposition in the Midwest but lacked appropriate sediment sources.

Chapter 7. Biogenic opal in soils along the Chesapeake Bay

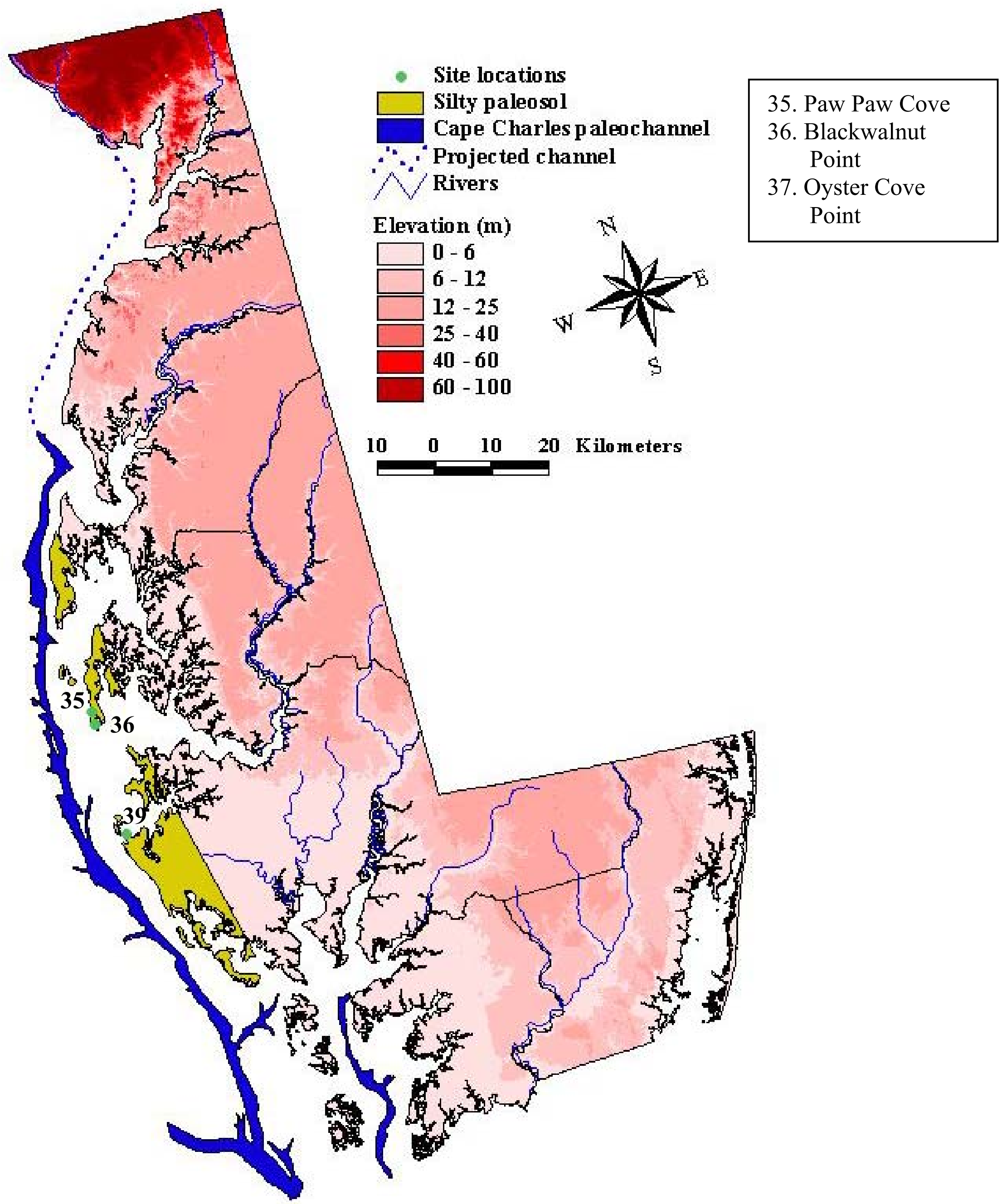
INTRODUCTION

The area along the Chesapeake Bay on Maryland's Eastern Shore has soils formed in a Late Pleistocene/Holocene loess over a paleosol formed in silts of unidentified age and origin underlain by sandy Coastal Plain sediments. The silty sediments in which the paleosol has formed may be from a late Pleistocene episode of loess deposition or may be fluvial/estuarine deposits from the last marine transgression with sea levels higher than present which occurred either 82,000 years B.P. (Groot and Jordan, 1999) or 125,000 years B.P. (Toscano and York, 1992). Biogenic opal includes sponge spicules, diatoms, and phytoliths (Drees et al., 1989). The presence, absence, and relative abundance of certain types of biogenic opal in soils have been used to identify lithologic discontinuities, buried surface horizons, and to assess the uniformity of parent materials (Wilding and Drees, 1968, 1971; Verma and Rust, 1969; Drees et al., 1989), to determine the origin/mode of transportation of sediments (Jones and Beavers,1963; Wilding and Drees, 1971), and to draw conclusions about vegetation (Wilding and Drees, 1968, 1971; Verma and Rust, 1968; Waltman and Ciolkosz, 1995) and past environmental conditions (Blecker et al., 1997; Barboni et al., 1999). This study was initiated as part of a larger investigation of the age, origin, and pedogenic history of Quaternary silts on the Delmarva Peninsula in Maryland. The objectives were to 1) identify lithologic discontinuities and buried surface horizons of the paleosol through the examination of the phytolith distribution in soil profiles, 2) determine the origin of the silty parent sediments in which the paleosol has formed by sponge spicule and diatom contents of the paleosol, and 3) gain insight into the paleoclimate and landscape stability of the region based on the quantity and type of phytoliths present in the paleosol.

MATERIALS AND METHODS

The Study Area

The area in which this study was conducted lies in the Coastal Plain Province on the Delmarva Peninsula in Maryland. The paleosol formed in Quaternary silts blanketed by loess was identified in an area adjacent to the Chesapeake Bay in Queen Anne's, Talbot, and Dorchester counties. The paleosol extends less than 15 kilometers east of the Cape Charles paleochannel of the Susquehanna River (Colman and Mixon, 1988) and covers an area of approximately 400 square kilometers. The soils occupy a broad flat terrace with little relief or topography, elevations less than seven meters above mean sea level, and a minimally incised drainage network. Figure 7-1 shows the extent of the buried paleosol, elevations, and sampling site locations. The area has an udic moisture and mesic temperature regime receiving an average of 1100 millimeters of precipitation annually spread evenly throughout the year with an average annual air temperature of 13.9 degrees Celsius (Brewer et al., 1998). Current vegetation in the area consists of mixed hardwood forest dominated by oak (*Quercus*) with maple (*Acer*), sweet gum



DEM Source: ArcUSA 1:2,000,000

Figure 7-1. Location of the silty paleosol and sampling sites along the ancestral channel of the Susquehanna River.

(*Liquidambar*), poplar (*Populus*), and holly (*Ilex*). Loblolly (*Pinus taeda*) and Virginia pine (*P. Virginius*) are abundant in areas that have been cleared and abandoned. Shrubby species including greenbrier (*Smilax*), bayberry (*Myrica*), and sweet pepperbush azalea (*Clethra alnifolia*) are common as are grasses adapted to the climate (Brown and Brown, 1984; Brewer et al., 1998; Brown and Brown, 1999).

Field and Laboratory Analysis

Two of the three sites used in this study, Paw Paw Cove (site 35) and Blackwalnut Point (site 36) were located on Tilghman Island in southern Talbot County while the third, Oyster Cove Point (site 39), was in eastern Dorchester County (Figure 7-1). The Blackwalnut Point (site 36) and Oyster Cove Point (site 39) sites were both erosional scarps cut by the Chesapeake Bay which, in addition to allowing relatively easy access to the soil profiles, also offered long, continuous exposures which permitted the examination of microtopographic effects on the soil. The Paw Paw Cove site (site 35) was part of an archaeological excavation. Soil profiles were described and sampled using the standard methods and nomenclature of the Soil Survey Manual (Soil Survey Staff, 1993) and Soil Taxonomy (Soil Survey Staff, 1999).

In the laboratory, soil samples were air dried, crushed, and passed through a number 10 (2 mm) sieve. The less than two millimeter fraction was used for analysis. For the isolation and examination of the biogenic opal from these soils, samples were pretreated with 30 percent H_2O_2 to oxidize organic matter and sodium dithionite-citrate buffer to remove iron oxides (Kunze and Dixon, 1986) and then fractionated through centrifugation, sedimentation, and wet sieving. The five to 100 micron fraction was used for the purpose of examining the larger phytoliths produced by trees and by fundamental and bulliform cells of grasses, and the smaller silica bodies produced by more specialized short cells of grasses. Diatoms and most sponge spicules fell within this size range also. Biogenic opal was isolated through heavy liquid separation (Cady et al., 1986) using sodium polytungstate adjusted to specific gravity 2.35. After the light fraction was rinsed and dried, weight percentages of the opaline materials were calculated on a whole soil basis. Permanent mounts were made of the light fraction using Cargille Meltmount[1] with a refractive index of 1.539 and examined using a petrographic microscope. Corrections to the calculated weight percentages for non-opaline inclusions were made based on this microscopic examination.

A modified version of the phytolith classification of Twiss et al. (1969) and Twiss (1992) was used in counting the biogenic opal particles. In addition to the six divisions for grasses (Pooid, Chloridoid, Panicoid, elongate, fan-shaped, and point-shaped) (Twiss, 1992) were added a class for tree phytoliths (Wilding and Drees, 1971; Geis, 1973), a class for phytoliths that were not morphologically distinct and could not be clearly identified as belonging to one of the above classes, a class for sponge spicules, a class for diatoms, and a class for unidentifiable opaline particles that could not be placed into any of the above classes. A minimum of 300 particles were counted per slide.

---

[1] R.P. Cargille Laboratories, Inc., 55 Commerce Rd., Cedar Grove, NJ 07009-1289, USA.

RESULTS AND DISCUSSION

Soils at the three sites studied were morphologically, physically, and mineralogically similar to one another and were formed in a late Pleistocene/early Holocene loess over a paleosol formed in silts underlain by sandy coastal plain sediments. Tables 7-1, 7-2, and 7-3 show abbreviated profile descriptions for the sites. Archaeological materials from the Paw Paw Cove (site 35) and Oyster Cove Point (site 39) sites indicated that deposition of the overlying loess began at the end of the Pleistocene some time shortly before 10,500 ^{14}C years B.P. and continued through the early Holocene at least through the early Archaic period ca. 8,000 ^{14}C years B.P. (Lowery, 2002). Soils formed in the loess in this area had silt loam to silty clay loam argillic horizons. The buried paleosol consisted of a surface horizon, fragipan/argillic horizons with silt loam to silty clay loam textures and coarse prismatic structure, and less weathered BC horizons. Soil forming processes in the relatively thin (< 100 cm) overlying loess resulted in the welding of the modern soil with the paleosol obscuring the morphology of the paleosol somewhat. Additionally, microtopographic effects on the natural soil drainage class have resulted in spatially variable preservation of organic carbon or the appearance of the organic carbon in the surface horizon of the paleosol. In microtopographic highs where the soil was slightly better drained the surface horizon of the paleosol was less readily apparent than in the microtopographic lows.

Table 7-1. Profile description for Paw Paw Cove (site 35).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Structure	Consist.**	Bound.
Ap1	0-10	10YR4/4	--	SiL	1mgr	fr	as
Ap2	10-31	10YR4/4	--	SiL	1mgr	fr	cs
BE	31-42	10YR5/6	--	SiL	1mpl	fr	cs
Bt	42-54	10YR5/6	--	SiCL	1msbk	fr	cs
Btx	54-63	10YR4/3	c2d 10YR5/8 c2d 10YR5/2	SiCL	2copr 2mpl	fi	gs
Ab	63-92	2.5Y4/1	c3d 7.5YR4/6 c3d 10YR4/4	SiCL	2copr 2tkpl	fi	cs
Btxgb1	92-109	10YR5/1	m2d 10YR5/6 c3d 2.5Y6/1	SiCL	2copr 2tkpl	vfi	--
Btxgb2	109-139	2.5Y6/2	m2d 10YR5/6 m2d 10YR5/6 c3f 2.5Y6/1	SiCL	--	vfi	--
Btxgb3	139-166	2.5Y6/2	m2d 10YR4/6 c3f 2.5Y6/1	SiL	--	fi	--
2BCg	166-184	5Y6/2	f2p 7.5YR4/6 c3d 10B6/1	SiL	--	fr	--
2Cg	184-210	5Y6/2	c3p 10YR5/6 c3d 10B6/1	L	--	vfr	--

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Field Book for Describing and Sampling Soils (Schoenberger et al., 1998).
**Moist samples.

Table 7-2. Profile description for Oyster Cove Point (site 39).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Structure	Consist.**	Bound.
Ap	0-16	10YR4/3	--	SiL	2fgr	fr	as
BE	16-22	2.5Y5/4	c2d 10YR4/6	SiCL	1fsbk	fr	cs
Btg	22-40	10YR6/1	m2p 10YR5/8	SiCL	2msbk	fr	cs
Btx	40-53	10YR4/4	c2f 10YR5/6 c2d 10YR5/2	SiCL	2copr 2tkpl	fi	cs
Ab	53-80	10YR3/1	c2d 10YR4/6	SiCL	2copr 2msbk	fi	cw
Btxb1	80-108	2.5Y4/3	m1d 10YR5/6 c2f 10YR5/1	SiCL	2copr 1tkpl	fi	--
Btxb2	108-138	2.5Y5/4	m2d 10YR5/8 c2d 10YR5/2	SiL	--	fi	--
BCg	138-178	2.5Y6/2	f2p 10YR5/8	SiL	--	fr	--
2Cg	178-183	2.5Y5/2	f2d 10YR5/6	FSL	--	vfr	--

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Field Book for Describing and Sampling Soils (Schoenberger et al., 1998).
**Moist samples.

Table 7-3. Profile description for Blackwalnut Point (site 36).*

Horizon	Depth (cm)	Color**	Redox.	Texture	Structure	Consist.**	Bound.
A	0-6	2.5Y4/4	f1d 10YR5/6 f1f 2.5Y7/3	SiL	1fgr	fr	cs
E	6-13	2.5Y6/4	f2d 10YR5/6 c1f 2.5Y7/3	SiL	2tnpl	fr	cs
BE	13-34	2.5Y5/6	f1d 10YR4/6 f1f 2.5Y7/3	SiL	2mpr 2msbk	fr	cs
Bt1	34-67	2.5Y5/6	c2d 10YR5/8 c2d 2.5Y5/2	SiL	2copr 2mpl	fr	cs
Bt2	67-86	2.5Y5/3	m2d 10YR5/8 c2f 2.5Y5/2	SiL	2copr 2mpl	fi	cs
Ab	86-109	10YR3/2	c1d 10YR4/6	SiCL	2copr 2mabk	fi	cs
Btxb	109-130	2.5Y5/4	m2d 10YR5/8 c2d 10YR5/1	SiCL	2copr 2msbk	fi	cs
Btxgb	130-159	2.5Y6/1	f2p 7.5YR5/8 c2d 2.5Y5/4	SiCL	--	fi	--
BCg1	159-182	2.5Y6/2	f2p 7.5YR5/8 f2f 2.5Y6/1	SiL	--	fr	--
BCg2	182-204	2.5Y6/1	f1p 7.5YR5/8	SiL	--	fr	--
2Cg	204-255	2.5Y6/2	m2p 7.5YR5/8	LS	--	fr	--

*Abbreviations from Soil Survey Manual (Soil Survey Staff, 1993) and Field Book for Describing and Sampling Soils (Schoenberger et al., 1998).
**Moist samples.

Biogenic Opal

The biogenic opal content of the soils at all three sites was dominated by morphologically indistinct phytoliths less than 10 micrometers in size while tree phytoliths in the 20 to 50 micron range were almost entirely absent. This lack of phytoliths representing the modern vegetation suggests that the small indistinct phytoliths were, at least in some part, likely fragments of fragile tree phytoliths (Geis, 1973). Grass phytoliths, both large from fundamental and bulliform cells and small from specialized short cells were present in all horizons as were sponge spicules. Diatoms were identified in all horizons except the 2Cg horizon from Paw Paw Cove (site 35) (Figures 7-2 and 7-3). The relative proportions of all types of biogenic opal for all samples are in Appendix G.

Phytolith Distribution within Soil Profiles

Phytolith distribution was a useful indicator of both the lithologic discontinuity and the buried surface horizon of the paleosol (Figures 7-4, 7-5, 7-6). The horizon immediately above the surface of the paleosol at all three sites had an increased phytolith content with respect to the horizon directly above it. This was either a result of mixing of the loess and paleosol at the contact or an indication of a period of a relatively slow silt accumulation at the onset of loess deposition that allowed the incorporation of incoming dust into the existing soil surface and continued vegetation production, followed by an increasing rate of deposition that resulted in the burial of the paleosol.

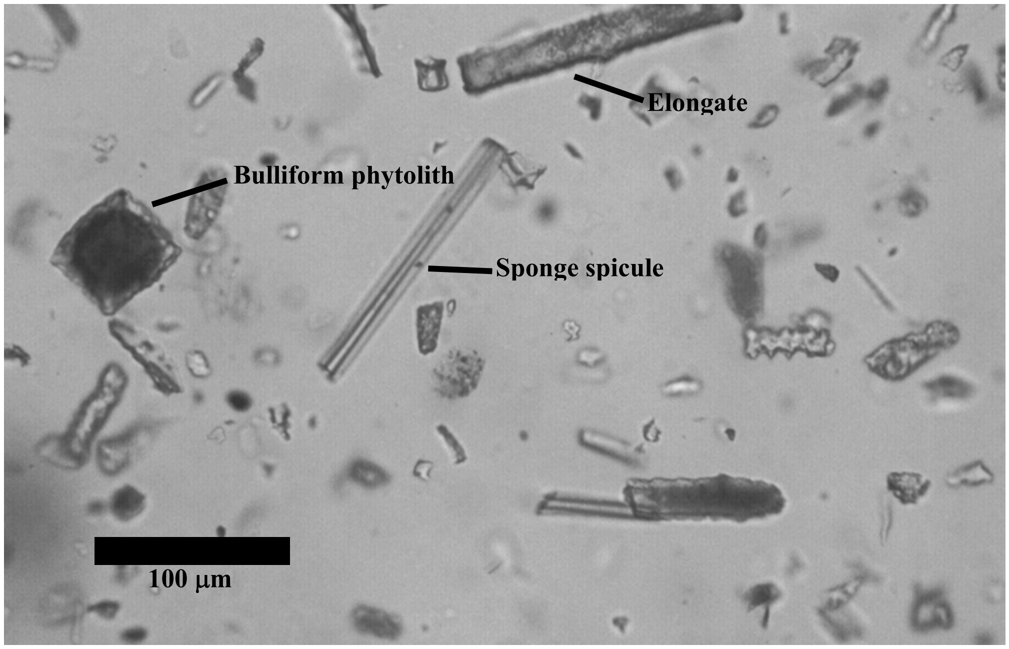


Figure 7-2. Photomicrograph of opaline constituents, including sponge spicules and phytoliths, from E horizon of Blackwalnut Point.

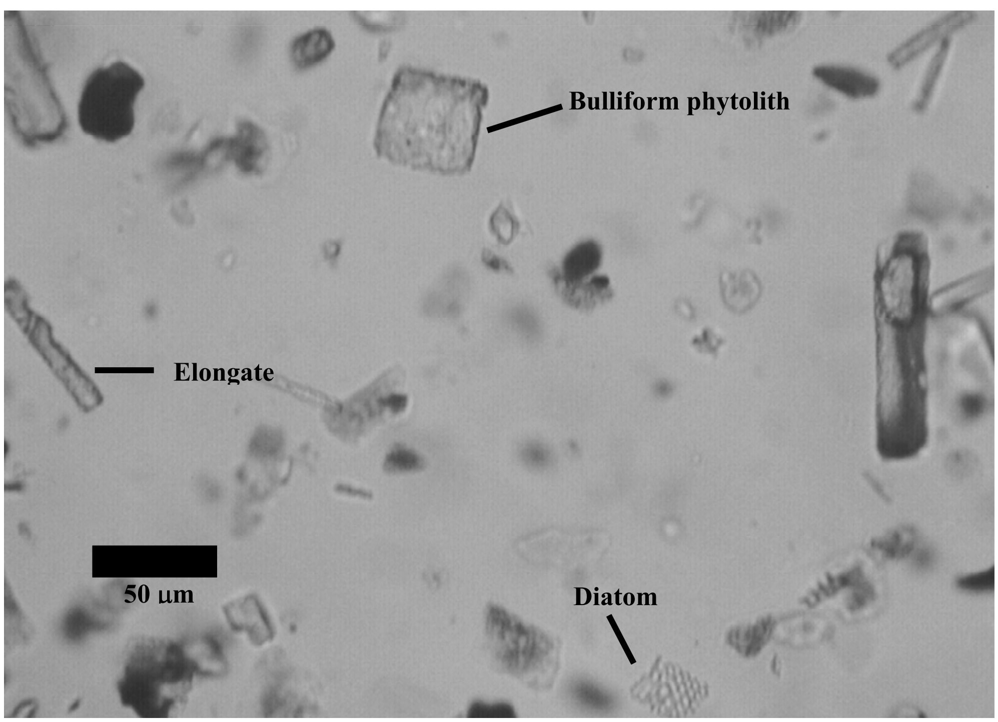


Figure 7-3. Photomicrograph of opaline constituents, including diatom fragment and phytoliths, from BE horizon of Oyster Cove Point.

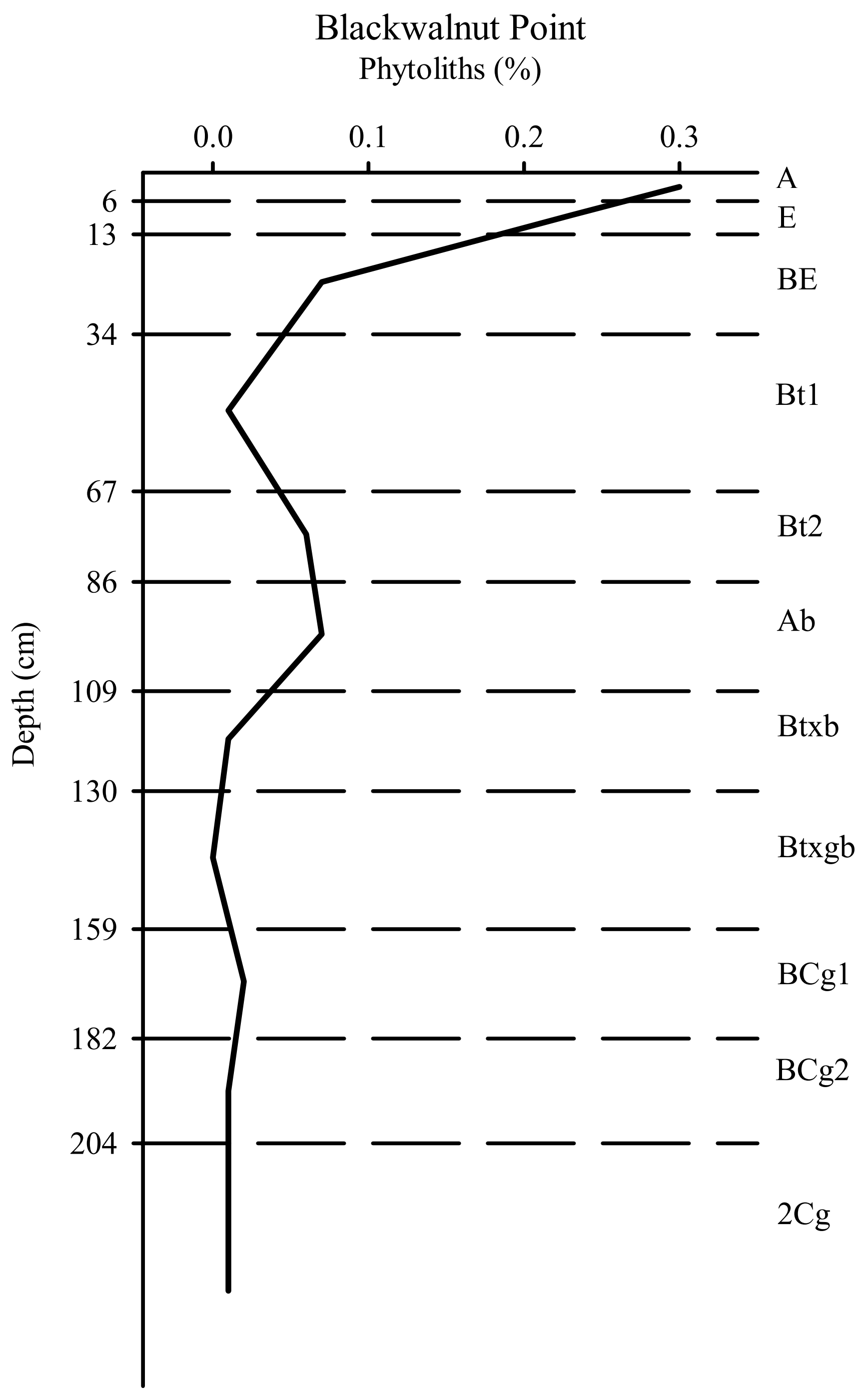


Figure 7-4. Phytolith distribution with depth at Blackwalnut Point. Note the increase in phytolith content in the Ab horizon

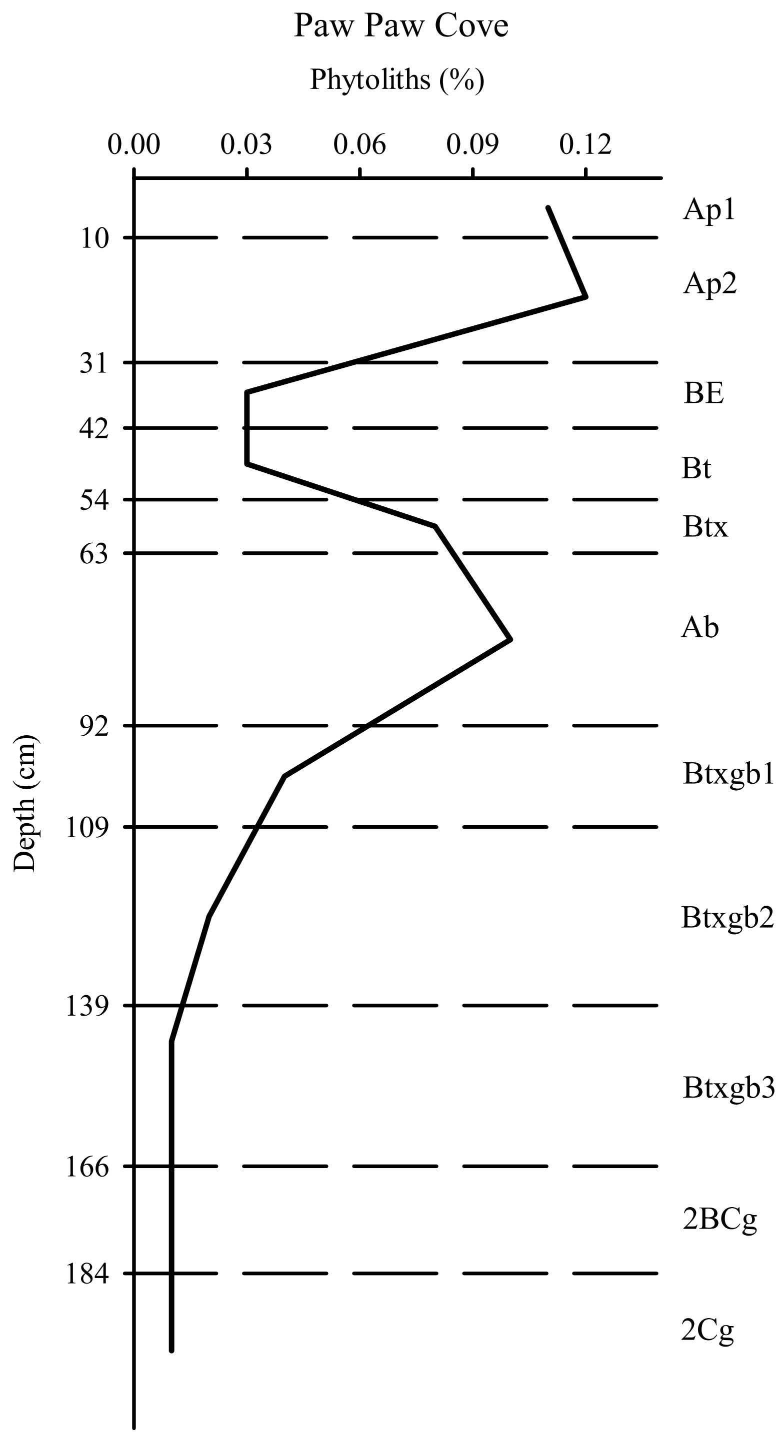


Figure 7-5. Phytolith distribution with depth at Paw Paw Cove.

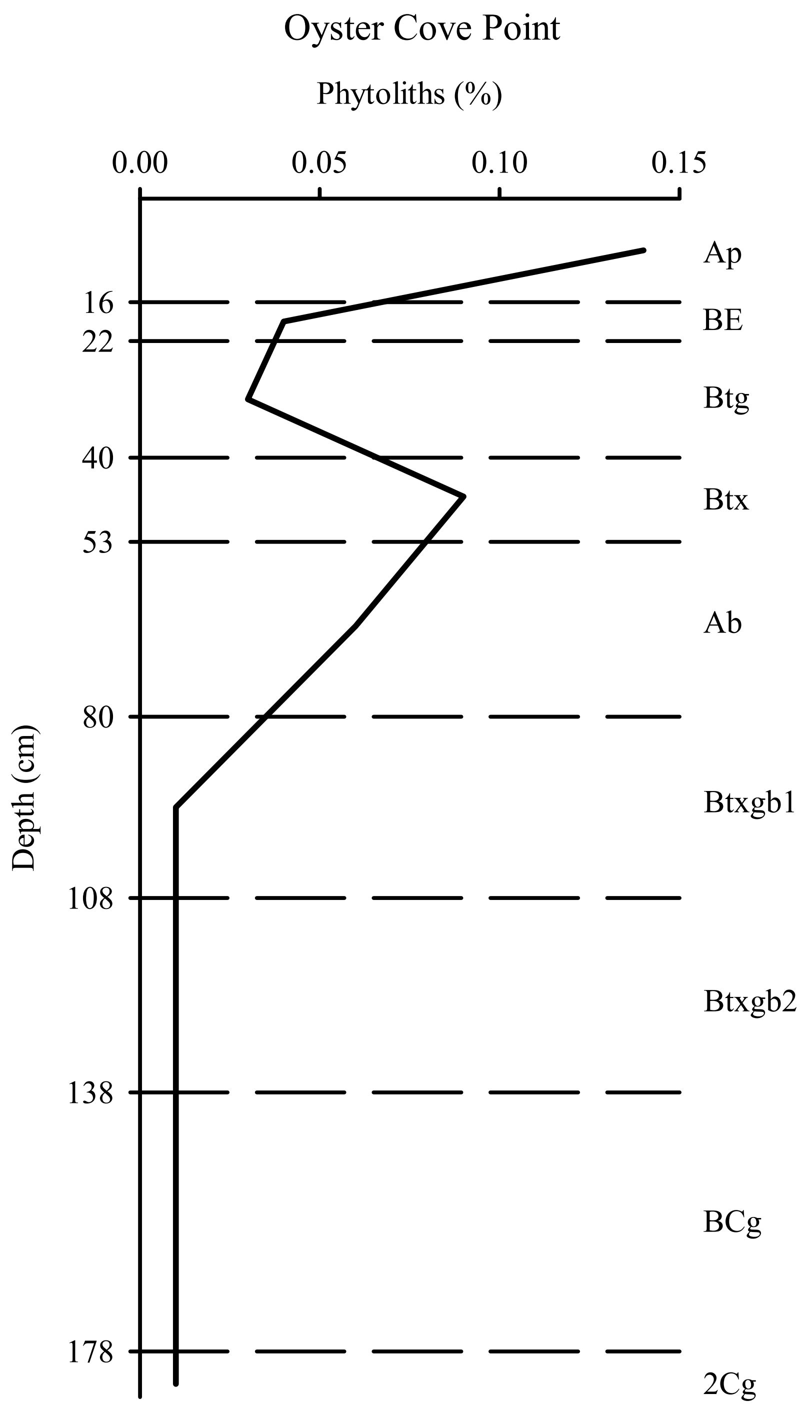


Figure 7-6. Phytolith distribution with depth at Oyster Cove Point.

The phytolith content of the modern surface horizons on a whole soil basis was similar to that found by Wilding and Drees (1971) for Ohio soils. It averaged 0.16% with 0.30, 0.11, and 0.14% at Blackwalnut Point (site 36), Paw Paw Cove (site 35), and Oyster Cove Point (site 39), respectively, and decreased to less than 0.04% in the argillic horizon of the loessial soil. The surface horizons of the paleosol had an average phytolith content of 0.07% that decreased with depth (Figures 7-4, 7-5, and 7-6).

Sponge Spicules and Diatoms

Of the total biogenic opal present in the three soils an average of 17 percent was made up of sponge spicules and diatoms (Figures 7-7, 7-8, 7-9). Their distribution reflected the three different episodes of parent material deposition as well as the periods of landscape stability during which phytoliths were deposited in surface horizons and the percentage of biogenic opal made up of spicules and diatoms decreased accordingly. In general, the proportions of sponge spicules and diatoms were lowest in the surface and buried surface horizons as a result of the additions of plant opal in these horizons, and highest in the sandy coastal plain sediments with decreasing amounts in the silty parent materials of indeterminate origin and in the loess. On a whole soil basis spicule and diatom content did not exhibit a strong relationship with parent material. At Paw Paw Cove (site 35) spicule and diatom contents in the silts were comparable to those in the underlying sandy sediments (Figure 7-10). From the distribution it is not possible to determine whether the silty parent sediments in which the paleosol formed were transported and deposited by wind or by fluvial/estuarine processes. Similarly, the

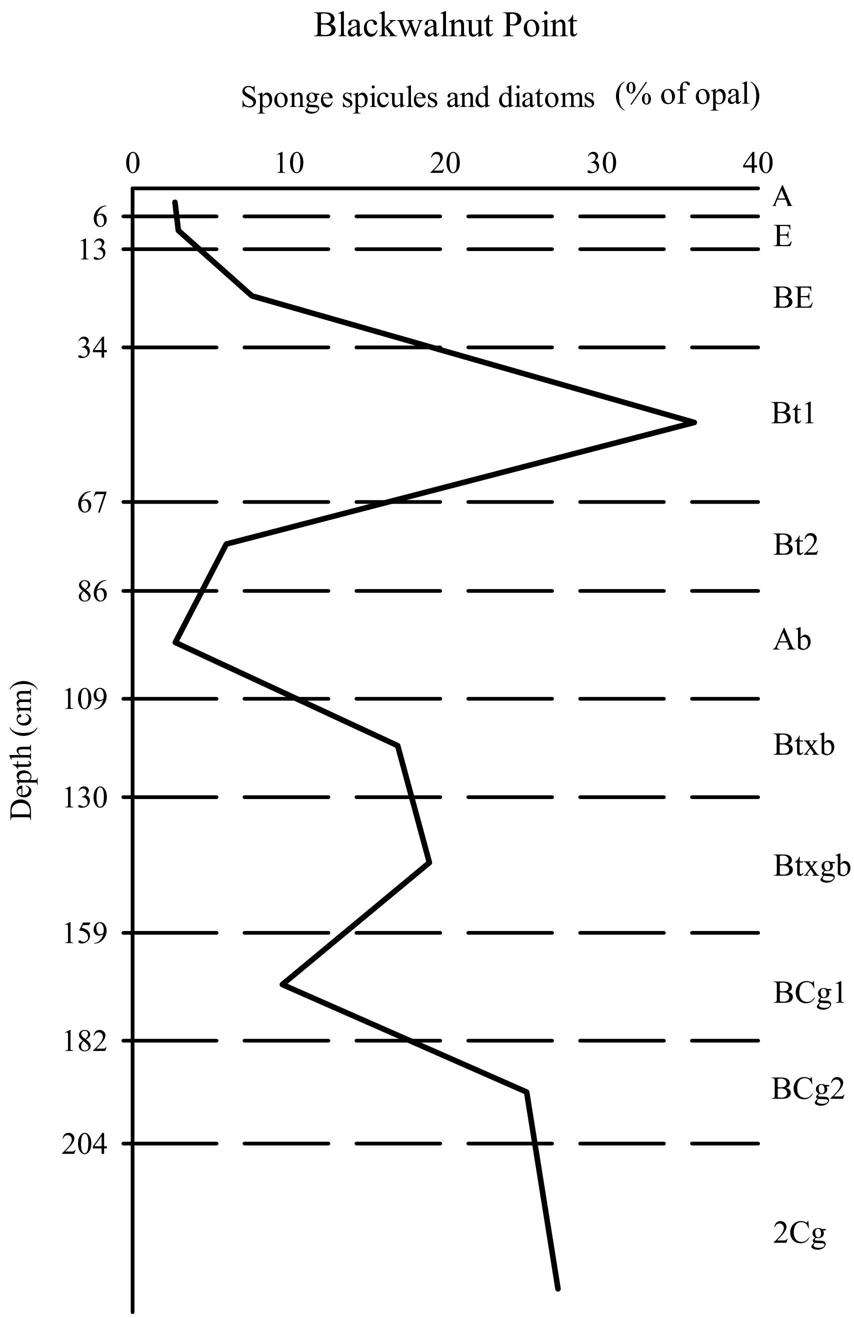


Figure 7-7. Sponge spicule and diatom distribution as a percentage of the opal at Blackwalnut Point.

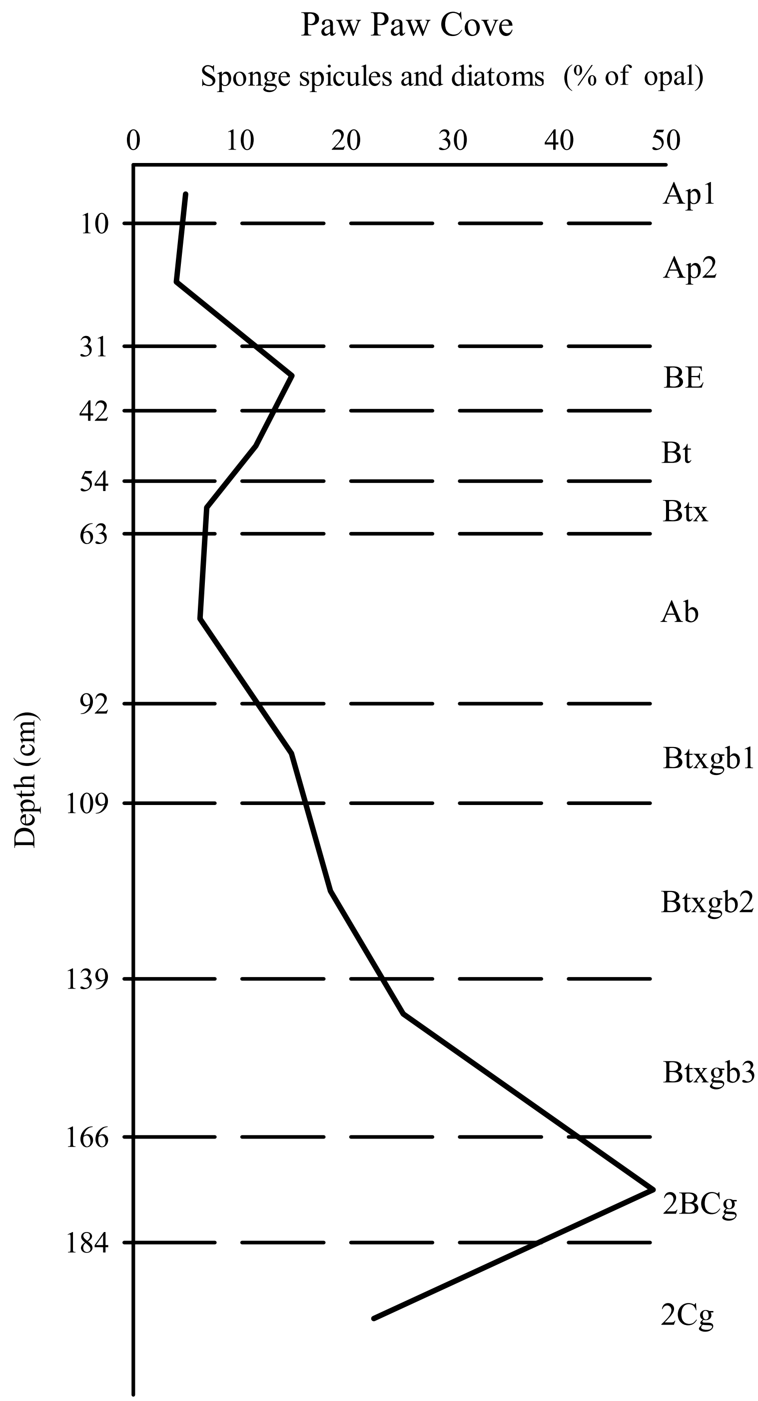


Figure 7-8. Sponge spicules and diatoms as a percentage of the opal at Paw Paw Cove.

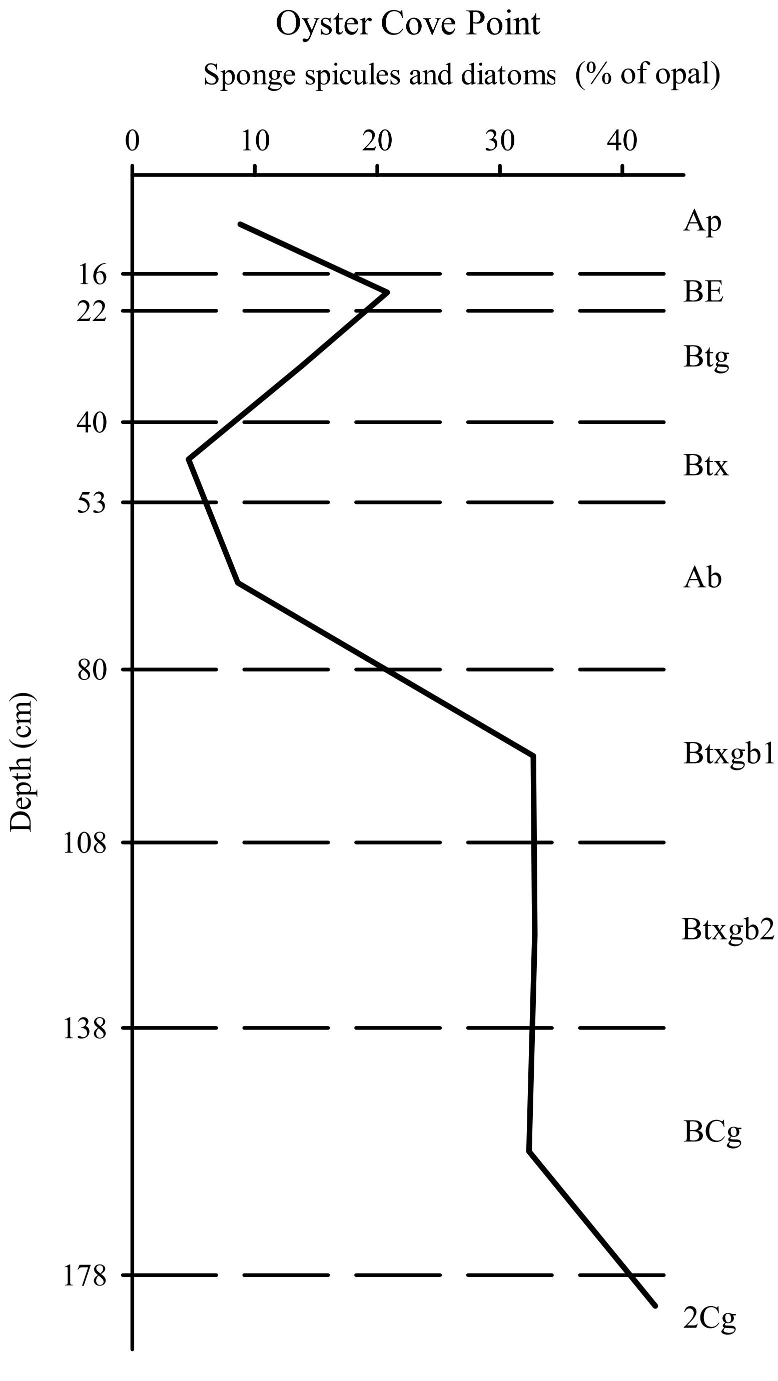


Figure 7-9. Sponge spicules and diatoms as a percentage of the opal at Oyster Cove Point.

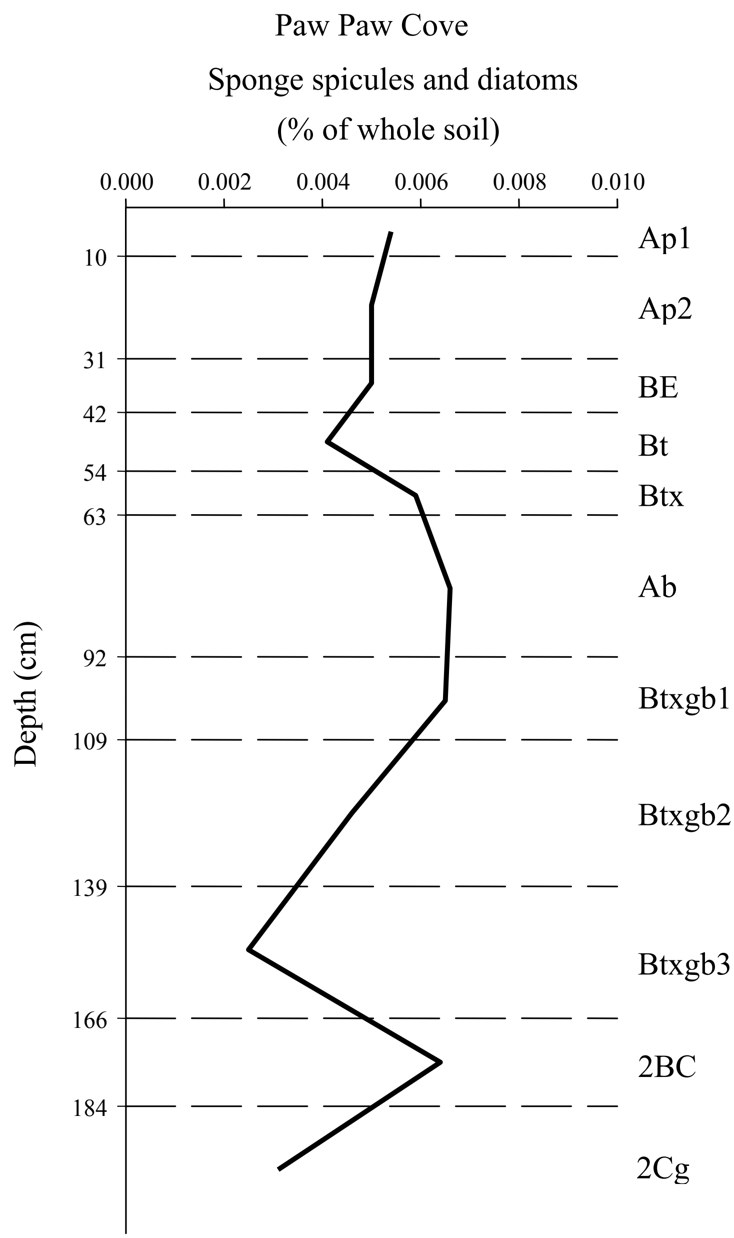


Figure 7-10. Sponge spicule and diatom distribution as a percentage of the whole soil at Paw Paw Cove (site 35). Percent sponge spicules and diatoms was low throughout the profile.

condition of the sponge spicules and diatoms in these soils was not diagnostic of a particular mode of transportation as the vast majority from the loess, silty paleosol, and sandy coastal plain sediments were broken fragments.

Phytolith Contents as Measures of the Duration of Landscape Stability

Phytolith contents of the surface horizons were somewhat lower than those found in soils in prairie settings (Wilding and Drees, 1971; Waltman and Ciolkosz, 1995). The Ap horizons from Oyster Cove Point (site 39) and Paw Paw Cove (site 35) yielded 3.30 Mg ha^{-1} and 3.76 Mg ha^{-1}, respectively, while the combined A and E horizons from Blackwalnut Point (site 36) yielded 4.49 Mg ha^{-1}. Using the estimates for phytolith yield in different size ranges Jones and Beavers (1963) demonstrated that it is possible to calculate an estimated residence time for certain broad vegetation groups on a landscape and found that the soils that they studied had been under prairie grasses for 4,000 to 5,000 years. While the yields for prairie grasses were not applicable to the Delmarva Peninsula in the Holocene, it was possible to develop a temporal framework for phytolith deposition based on the residence time of soils in stable landscape settings. The average phytolith content in the surface horizons of the soils formed in the loess was 3.85 Mg ha^{-1} over a period of approximately 8,500 calendar years since the end of loess deposition, equaling 0.45 kg ha^{-1} per year. This applied to the buried surface horizon of the paleosol with phytolith contents of 3.17, 3.85, and 3.20 Mg ha^{-1} at Oyster Cove Point (site 39), Paw Paw Cove (site 35), and Blackwalnut Point (site 36), respectively, yielded an estimated residence time of 7,600 years. This estimate accorded well with a date of 17,070 +/- 180

^{14}C years B.P. obtained from charcoal from a loess buried surface horizon on Wye Island 1 (site 18) approximately 10 kilometers east of the silty buried paleosol. While this could only be a rough estimate - as it uses broad assumptions regarding the composition of the vegetation community and differing levels of phytolith production from different plant species, hiatuses and decreases or increases in phytolith production due to less or more favorable environmental conditions, an uncertain quantity of phytoliths deposited with the parent sediments, and possible dissolution of some portion of the phytoliths while in the soil - it did give an indication of the order of magnitude of the length of time this buried soil was subaerial. From this it seems clear that this soil had not been subaerial and undergoing soil forming process since the Sangamon interglacial. It was possible, however, that an erosive event truncated the paleosol formed in Sangamon fluvial/estuarine silts followed by the formation of a new A horizon prior to burial. It was equally possible that the silty parent sediments in which the paleosol has formed were from an earlier episode of loess deposition. Post Sangamon loess deposits from approximately 33,000 to 25,000 years B.P. (Norton et al., 1988) and 25,000 to 16,000 ^{14}C years B.P. (Ruhe, 1983; Leigh and Knox, 1994) have been thoroughly documented in the midwestern United States. These sediments could either have been from the earlier loess deposition and then truncated or they could have been deposited at the time of the last glacial maximum (ca. 18,000 B.P.) at which time climatic conditions were favorable for the wind transportation and deposition of silts from earlier glacial activity.

Phytolith Content as a Proxy for Vegetation and Climate

Grass phytoliths were abundant at all three sites and gave some insight regarding changes in the vegetative communities and climate. At Blackwalnut Point (site 36) and Oyster Cove Point (site 39) the percentage of grass phytoliths, Pooid, Chloridoid, Panicoid, and non-diagnostic fundamental and bulliform, was higher in the buried surface than in the modern surface implying a vegetative community in which grasses were more abundant in the past. At Paw Paw Cove (site 35) the percentage of grass phytoliths was approximately the same in the modern surface horizon as in the buried surface.

The abundance and distribution of phytoliths from specialized cells was similarly indicative of the make up of the grass community present at the sites and, by extension, of the climate. At all three sites the percentage of Panicoid phytoliths was markedly higher in the modern surface than in the buried surface. Pooid phytolith contents varied throughout the three profiles but were higher in the buried surface than the modern surface at Blackwalnut Point (site 36) and Oyster Cove Point (site 39) while the opposite was true at Paw Paw Cove (site 35). Chloridoid phytolith contents were relatively low at all three sites (Figures 7-11, 7-12 and 7-13). This increase in Panicoid and decrease in Pooid phytoliths in the modern surface compared to the buried surface is indicative of a warming trend and a shift from C_3 grasses adapted to cooler climates at the time the paleosol was subaerial to a warmer climate with moderate available soil moisture at the time during which the modern soil was forming (Twiss, 1992). This agrees with climatic

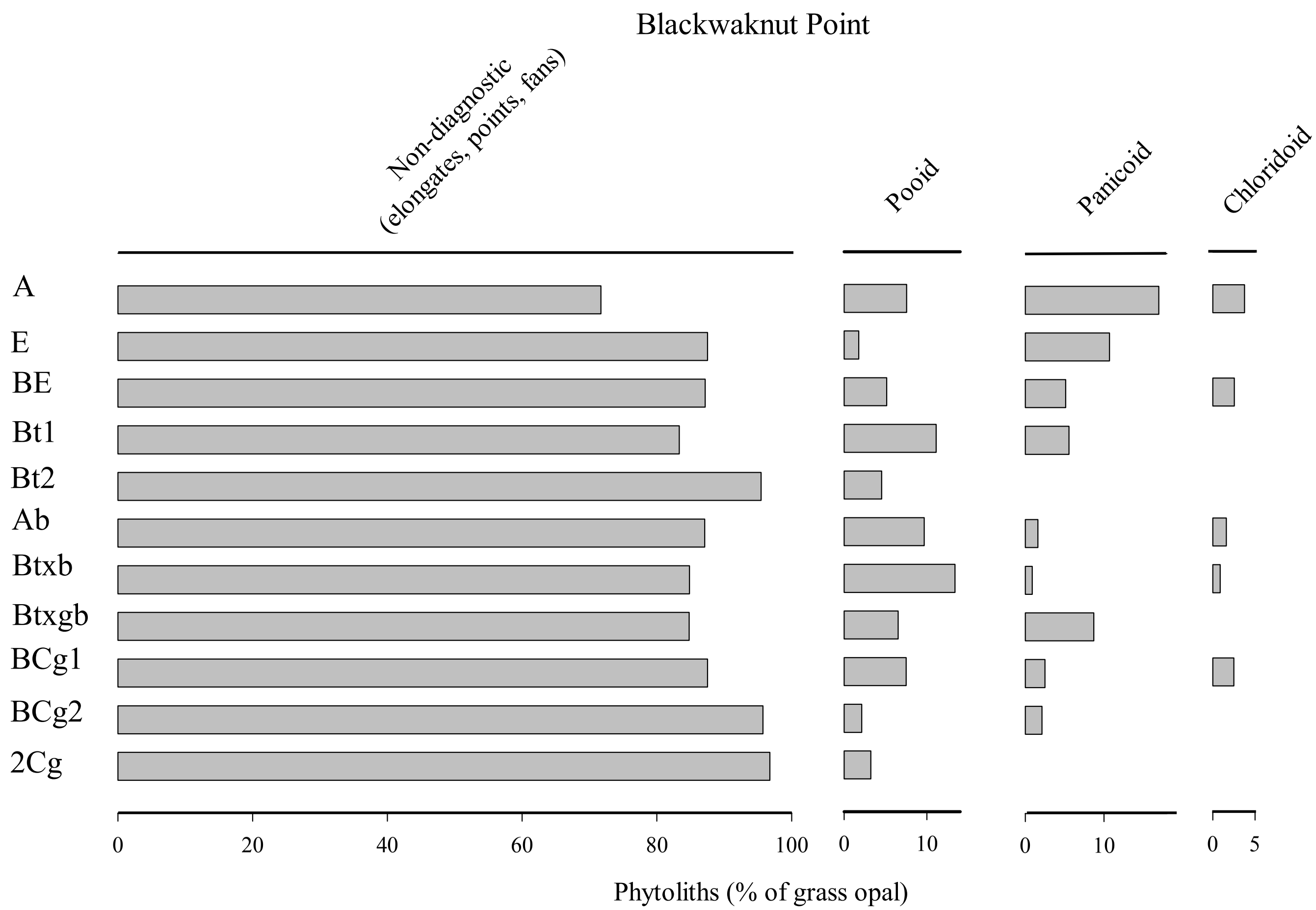


Figure 7-11. Grass phytolith distribution at Blackwalnut Point (site 36). Note the decrease in Pooid and increase in Panicoid phytoliths in the modern surface horizon compared to the surface horizon of the buried paleosol.

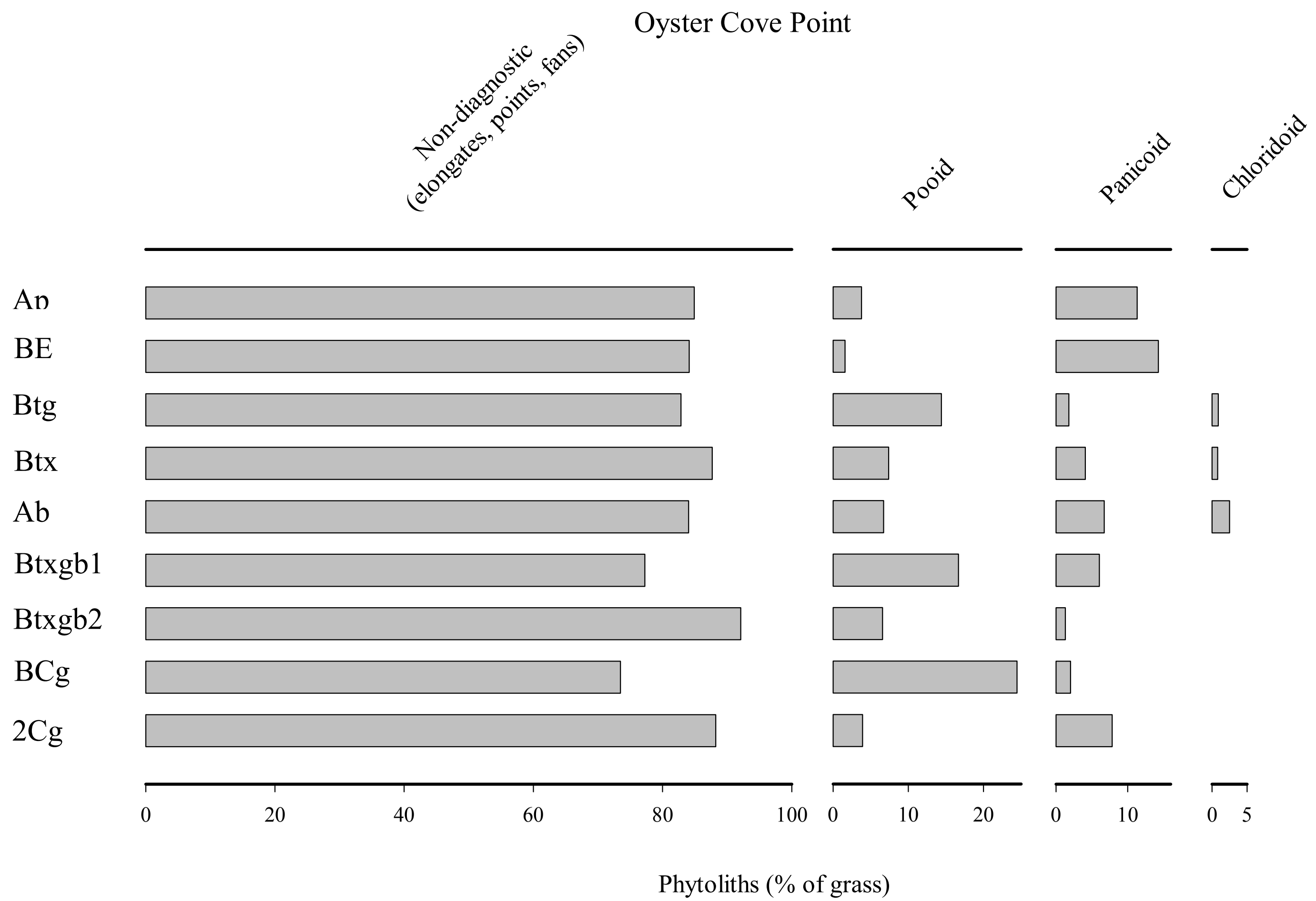


Figure 7-12. Grass phytolith distribution at Oyster Cove Point (site 39). Note the decrease in Pooid and increase in Panicoid phytoliths in the modern surface horizon compared to the surface horizon of the buried paleosol.

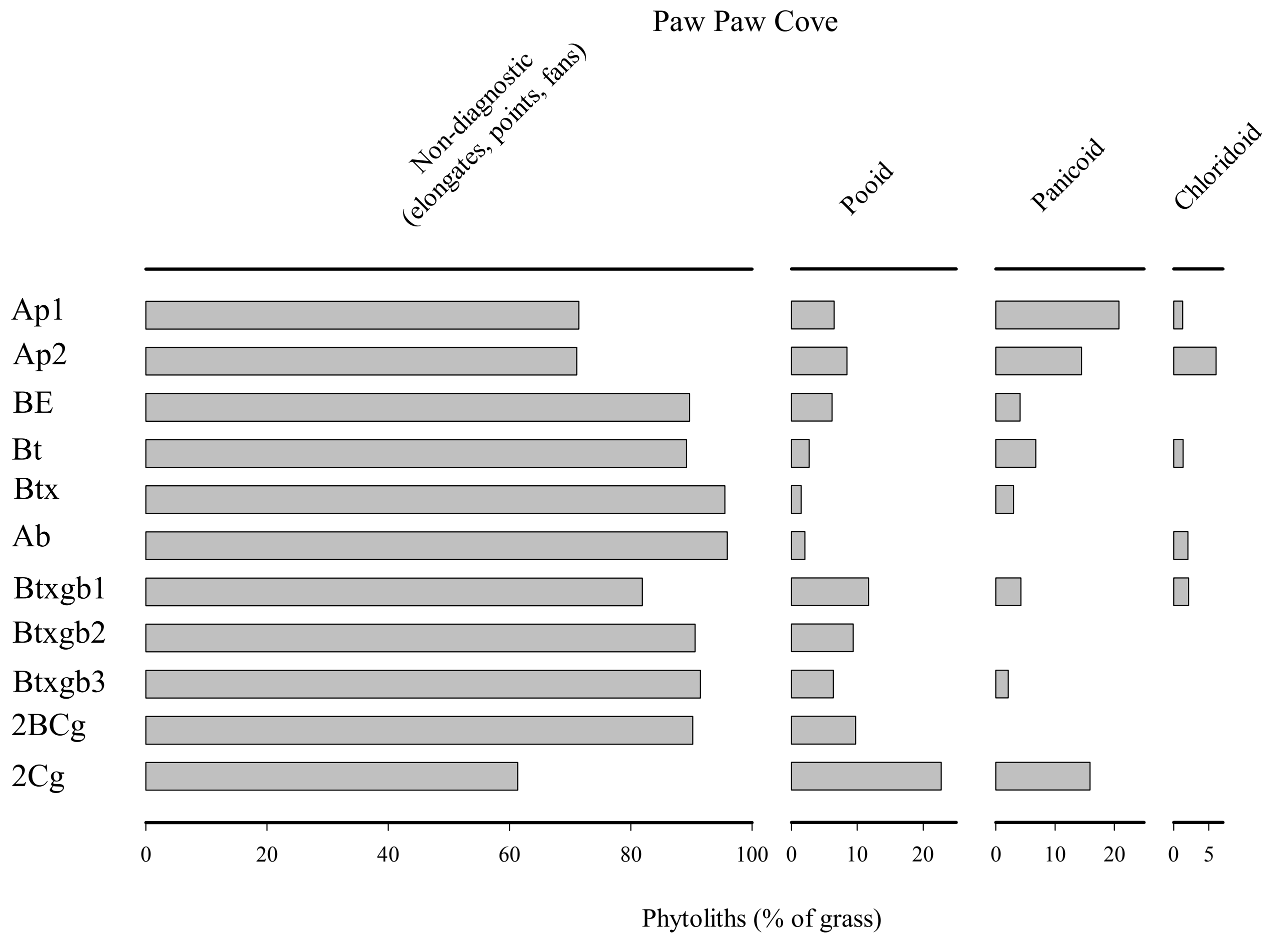


Figure 7-13. Grass phytolith distribution from Paw Paw Cove (site 35). Note the increase in Panicoid phytoliths in the modern surface horizon compared to the surface horizon of the buried paleosol.

reconstructions for the late Pleistocene from pollen assemblages for the region (Sirkin, 1977).

SUMMARY AND CONCLUSIONS

The examination of biogenic opal proved useful in discriminating lithologic discontinuities and in assessing the rate of loess deposition, the length of time the paleosol was subaerial, and past vegetation and climate for soils along the Chesapeake Bay. It was not, however, possible to determine the mode of deposition of parent sediments based on biogenic opal. The vast majority of biogenic opal present in these soils was made up of small (< 20 μm), morphologically indistinct pieces of phytoliths at least a portion of which were likely to have been fragments of fragile tree phytoliths as intact tree phytoliths were not present in the 20 to 50 μm size range. Sponge spicules, and diatoms were ubiquitous throughout the three soil profiles. Phytolith contents were highest in the surface and buried surface horizons and decreased with depth to the respective lithologic discontinuities.

The quantity of spicules and diatoms in the paleosol was comparable to that of both the wind transported loess and the fluvial/estuarine sandy coastal plain sediments and a majority of the spicules and diatoms in all three of the deposits were broken. Neither the quantity of spicules and diatoms nor their physical condition was indicative of the mode of transportation and deposition of the silty parent sediments in which the paleosol formed.

The rate of phytolith accumulation based on the phytolith content of the modern surface horizon and the approximate amount of time the land form has been stable allowed the calculation of an estimated time period that the paleosol was subaerial and receiving phytolith inputs. That estimated time was approximately 7,200 years which accorded well with ^{14}C dates for the buried surface at a nearby site. There are, however, a number of unverified assumptions used in calculating the rate of phytolith accumulation regarding changes in the vegetation community and phytolith production and preservation. As a result the calculated time for the paleosol being subaerial was only an estimate.

The proportion of non-diagnostic grass phytoliths and morphologically distinct phytoliths from specialized grass cells were indicative of the shift in the abundance of grasses in the vegetative community, as well as changes within the grass portion of the vegetation community over time. The paleosol had an increased content of non-diagnostic grass phytoliths compared to the modern surface signaling a greater abundance of grasses on the landscape at that time. Similarly, the paleosol had a greater proportion of Pooid and far fewer Panicoid phytoliths than the modern surface horizon which implied a change from a cooler climate to the modern subtropical humid climate.

Chapter 8. Dissertation Summary and Conclusions

The surficial silt deposit and soils formed in the silts on the Delmarva Peninsula were morphologically, physically, chemically, and mineralogically similar across the study area. The deposit was dominated by silt sized particles and was well sorted, throughout. No spatial trends were apparent in the distribution of zirconium, titanium, potassium, or calcium that might have suggested the presence of more than one silt deposit. Similarly, the same suite of minerals in similar relative proportions was present in the fine silt fraction of the soils from across the study area. This was also true of the clay mineralogy. The soil development in the silts across the study area was comparable.

No features diagnostic of fluvial/estuarine deposition, such as abundant coarse fragments, stratification, marine fossils, or evidence of past sulfidic conditions were identified in the silts. Sponge spicules and diatoms in the silt deposit ranged to very fine sand sized but by and large were silt sized and subject to transportation by water or wind. The broken nature of the spicules and diatoms suggested that the had been transported, by some means, from their primary depositional environment.

The soils formed in the silts had morphological characteristics indicative of a moderate level of development. Clay contents and colors of argillic horizons, and solum thicknesses, when compared to dated analogs from across the United States suggested that they had likely been undergoing pedogenesis for less than 15,000 years and certainly less than 30,000 years.

Differences in natural soil drainage conditions resulting from microtopgraphy were noted on the terrace. Well drained and poorly drained soils in close proximity to one another and at the same elevation indicated that low chroma matrix colors of soils reflected modern drainage conditions rather than a reducing underwater depositional environment of the parent sediments.

Silts were present on the upland at elevations above those reached by the last high sea stand which implied that they had been deposited by some mechanism other than fluvial/estuarine processes. That the sediments in silt deposit were predominately well sorted was not a clear indicator of the mode of transportation. It did suggest, however, that the sediments were not the result of fluvial process which tend to result in less well sorted deposits. The sorting could have been from either eolian processes or a low energy estuarine environment.

Surface horizons preserved by the deposition of the silty sediments were fairly common in the study area and were integral to the determination of the origin of the silts. A ^{14}C date from the buried surface at a site on the terrace indicated that the silt deposition began sometime after approximately 17,000 years ago. Diagnostic archaeological materials from the buried surface further refined the timing of the onset of the deposition of the silts to shortly before 10,500 ^{14}C years B.P. The age of the silty sediments precluded them from having been deposited by the most recent high sea stand, which had occurred more than 70,000 years before the initiation of silt deposition. At the time the silts were deposited, sea level was between 24 and 30 meters below present and the archaeological materials did not show any preferential orientation or other signs of post-depositional disturbance, indicating that the silts were not waterborne.

No single characteristic of the silt deposit was diagnostic of the mode of transportation and deposition of the silty sediments on the Delmarva Peninsula in Maryland. The age of the sediments, however, determined by ^{14}C dates on buried surface horizons and diagnostic archaeological materials on the buried living surface, proved that the sediments were young which precluded them from having been deposited by high sea stands, and that the silts were, therefore, loess. The combination of the physical, chemical, and mineralogical properties, demonstrated that the surficial silts across the study area were of one deposit and that the silts on the upland above the level of high sea were the same as the dated deposit on the terrace.

Other archaeological materials recovered from the deposit were indicative of the duration of the loess deposition. Diagnostic artifacts from below the plow zone were evidence that the loess was being deposited until after 8,500 ^{14}C years B.P. The dates also confirmed that the moderate soil development observed across the study area reflected the age of the sediments. Variations in silt deposit thickness were likely due to reworking upon deposition or to local topographic impediments to loess deposition.

The initiation of loess deposition was at the time of the Younger Dryas cold phase which lasted from approximately 11,000 to 10,000 ^{14}C years B.P. and during which temperatures were three to four degrees cooler than present. The rapid onset of the Younger Dryas resulted in a shift in vegetation and a destabilization of sediments which were then transported by wind. The loess on the Delmarva Peninsula was evidence of the magnitude and extent of the Younger Dryas Cold episode and its affect on the Mid-Atlantic region.

Paleosols and buried surface horizons were indicators of landscape stability. Truncated paleosols and stone lines were evidence of widespread soil and landscape destabilization and erosion prior to loess deposition. Paleosols with A horizon development associated with stone lines were evidence of at least a short period of landscape stability after truncation and before burial. The exact timing of the and nature of the episode or episodes of erosion and stability were not clear.

The effect of the erosion, however, was noted in the mean particle size of the loess at sites to east of confluence of the larger rivers with the ancestral channel of the Susquehanna River and east of meander bends in the larger rivers. Sediments eroded prior to the onset of loess deposition were transported by the larger rivers on the Delmarva and deposited at confluences and in meander bends. When cooler, drier conditions prevailed and loess deposition began, these eroded sediments mixed with those transported by the Cape Charles paleochannel from glaciated regions in New York and Pennsylvania resulting in localized variations in deposit textures. Mean particle size at those sites east of confluences and meander bends was coarser than at other sites.

Phytoliths were also useful for the examination of buried surfaces and paleosols and vice versa. Together they could be used as indicators of past vegetative and climatic conditions and to estimate the duration of landscape stability. The type and relative proportions of phytoliths from the buried surface horizon at several sites signaled a shift from a greater abundance of grasses at the time at which the now buried surface was subaerial to the present plant community represented in the modern surface horizon. They also indicated that the climate at the time the paleosol was subaerial was cooler than present. The quantity of phytoliths in the buried surface yielded an estimate of approximately 7,500 years of landscape stability prior to burial.

Soil development and calcium and potassium contents of the paleosols that escaped truncation or at least were not wholly truncated offered evidence as to the age of the sediments or the period of landscape stability in which they had formed. Soil morphological features were more strongly developed and calcium and potassium bearing minerals less abundant in the paleosol than in the modern soil suggesting that the paleosol had been undergoing pedogenesis for a longer period of time. This assessment, however, was incongruous with observations on landscape stability from the phytolith analyses which might indicate that the paleosols from which phytoliths were examined had been truncated to a resistant horizon followed by formation of a new A horizon during the ensuing period of landscape stability. Alternatively, lower calcium and potassium contents in the paleosol might have been a function of differences in parent materials between the paleosols and loess.

A nearly continuous paleosol formed in silts was identified in an area extending 15 kilometers east of the paleochannel. The deposit was dominated by silt sized particles and was only slightly less well sorted than the overlying loess deposit. Phytolith analysis of the loess and paleosol suggested that the surface horizon of the paleosol (now buried) had been stable and subaerial for approximately 7,000 years, though this is likely a low end estimate. There were no diagnostic features of either fluvial/estuarine or eolian processes and no readily dateable materials were recovered.

Further investigations are need to elucidate the depositional environments of parent sediments, pedogenesis of soils, and climatic history of the Delmarva Peninsula during the late Pleistocene. It was not possible to identify the mode of transportation and deposition of the parent sediments of the silty paleosol along the Chesapeake Bay, however, it seems likely that the silty paleosol is the remnants of an earlier Wisconsin loess deposit. Additionally, eolian sands have been noted in several areas on Maryland's Eastern Shore but their extent, their relationship to other sediments in the region, and their relationship to climatic events have not been carefully studied. Archaeological materials seem to indicate that there have been at least two episodes of eolian sand deposition during the Holocene and it is entirely possible that eolian sands were also deposited during the Pleistocene. Mapping, dating, and correlation of these deposits would be invaluable to understanding climate during the late Quaternary and the prehistory of the Delmarva Peninsula and Mid-Atlantic region.

Appendix A. Narrative descriptions for sampling sites.

Andrews (site 28)

Location: 145 m north of Andrews Rd; 0.2 mi east of intersection of Andrews and Robbins Rds.
Lat./Long.: 38°21'23.28" N 76°06'23.40" W
County: Dorchester
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Very poorly drained
Parent material:
Vegetation: Pine
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 17, 2000; sampled by auger.

A—0 to 28 cm; very dark gray (10YR3/1) silt loam; friable.

BEg—28 to 39 cm; gray (10YR5/1) silt loam; few fine distinct yellowish brown (10YR5/6) masses of Fe; friable.

Btg1—39 to 50 cm; gray (10YR5/1) silty clay loam; common medium distinct yellowish brown (10YR5/6) masses of Fe; friable;

Btg2—50 to 74 cm; gray (10YR6/1) silt loam; common medium distinct yellowish brown (10YR5/6) masses of Fe; firm.

2BCg1—74 to 88 cm; grayish brown (10YR5/2) loam; common medium faint yellowish brown (10YR5/6) and few medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

2BCg2—88 to 100 cm; gray (10YR5/1) sandy clay loam; friable.

Appendix A (continued).

Big Dog (site 7)

Location: 50 m east of Back Starr Rd; 0.3 mi south of intersection of Back Starr and Little Eagle Rds.
Lat./Long.: 39°00’06.21” N 76°01’47.45” W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 1%
Aspect: 340°
Drainage: Well drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 16, 2000; sampled by auger.

A—0 to 10 cm; very dark grayish brown (10YR3/2) silt loam; very friable.

AE—10 to 23 cm; light olive brown (2.5Y5/4) silt loam; friable.

Bt1—23 to 37 cm; yellowish brown (10YR5/6) silt loam; few fine faint pale brown (10YR6/3) Fe depletions; friable.

Bt2—37 to 67 cm; yellowish brown (10YR5/6) silty clay loam; friable.

2Bt3—67 to 90 cm; yellowish brown (10YR5/6) loam; few fine faint yellowish brown (10YR5/8) masses of Fe; common medium faint pale brown (10YR6/3) Fe depletions; friable.

2BC—90 to yellowish brown (10YR5/8) sandy loam; common fine faint strong brown (7.5YR5/8) and few fine faint dark yellowish brown (10YR4/6) masses of Fe; few fine faint pale brown (10YR6/3) Fe depletions; friable.

Appendix A (continued).

Bishops Head (site 29)

Location: 10 m north of Buck Ridge Rd; 0.4 mi east of intersection of buck Ridge and Bishops Head Rds.
Lat./Long.: 38°16’36.77” N 76°03’50.44” W
County: Dorchester
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Very poorly drained
Parent material:
Vegetation: Pine and poison ivy
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 17, 2000; sampled by auger; Oi horizon ~ 6 cm thick.

A—0 to 8 cm; very dark gray (10YR3/1) silt loam; friable.

BEg—8 to 30 cm; grayish brown (2.5Y5/2) silt loam; common medium distinct yellowish brown (10YR5/6) masses of Fe along roots; friable.

Btg1—30 to 49 cm; gray (2.5Y6/1) silt loam; many medium distinct yellowish brown (10YR5/6) masses of Fe; friable.

Btg2—49 to 60 cm; gray (2.5Y6/1) silty clay loam; few medium distinct yellowish brown (10YR5/6) masses of Fe; friable.

Btg3—60 to 80 cm; gray (2.5Y5/1) silty clay loam; common medium faint light yellowish brown (2.5Y6/4) and few fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Btg4—80 to 100 cm; gray (2.5Y6/1) silty clay loam; common coarse distinct yellowish brown (10YR5/6) masses of Fe; firm.

Btg5—100 to 130 cm; gray (2.5Y6/1) silt loam; many medium faint light yellowish brown (2.5Y6/4) and common fine distinct yellowish brown (10YR5/8) masses of Fe; firm;

2BCg1—130 to 160 cm; gray (2.5Y6/1) loam; many medium distinct olive yellow (2.5Y6/6) and common fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Appendix A (continued).

2BCg2—160 to 185 cm; gray (2.5Y6/1) very fine sandy loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

Appendix A (continued).

Blackwalnut Point (site 36)

Location: Bay cut exposure on southern tip of Tilghman Island; 100 m west of Black Walnut Point Rd.
Lat./Long.: 38°40'31.50" N 76°20'27.00" W
County: Talbot
Landform: Terrace
Relief:
Elevation: 1 m
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Grasses, burnt pine
Notes: Described and sampled by John Wah on January 17, 2002 and by Charlie Hanner and John Wah on January 29, 2002. Sampled below 130 cm by auger. Charcoal from buried surface horizon (94 cm) recovered and used for ^{14}C dating. Interstratified material in 2Cg horizon, silt layer 225 to 232 cm.

A—0 to 6 cm; light olive brown (2.5Y5/4) silt loam; few fine distinct yellowish brown (10YR5/6) soft masses of Fe; few fine faint pale yellow (2.5Y7/3) Fe depletions; weak fine granular structure; friable, clear smooth boundary.

E—6 to 13 cm; light yellowish brown (2.5Y6/4) silt loam; few medium distinct yellowish brown (10YR5/6) soft masses of Fe; common fine faint pale yellow (2.5Y7/3) Fe depletions; moderate thin platy structure; friable; clear smooth boundary.

BE—13 to 34 cm; light olive brown (2.5Y5/6) silt loam; few fine distinct yellowish brown (10YR4/6) soft masses of Fe; few fine faint pale yellow (2.5Y7/3) Fe depletions; moderate medium prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt1—34 to 67 cm; light olive brown (2.5Y5/6) silt loam; common medium distinct yellowish brown (10YR5/8) soft masses of Fe; common medium distinct grayish brown (2.5Y5/2) Fe depletions; moderate coarse prismatic parting to moderate medium platy structure; friable; clear smooth boundary.

Bt2—67 to 86 cm; light olive brown (2.5Y5/3) silt loam; many medium distinct yellowish brown (10YR5/8) soft masses of Fe; common medium faint grayish brown (2.5Y5/2) Fe depletions; moderate coarse prismatic parting to moderate medium platy structure; firm, clear smooth boundary.

Appendix A (continued).

Ab—86-109 cm; very dark grayish brown (10YR3/2) silty clay loam; common fine distinct yellowish brown (10YR4/6) soft masses of Fe; moderate coarse prismatic parting to moderate medium angular blocky structure; firm; clear smooth boundary.

Btxb—109 to 130 cm; light olive brown (2.5Y5/4) silty clay loam; many medium distinct yellowish brown (10YR5/8) soft masses of Fe; common medium distinct gray (10YR5/1) Fe depletions; moderate coarse prismatic parting to moderate medium subangular blocky structure; firm; clear smooth boundary.

Btxgb—130 to 159 cm; gray (2.5Y6/1) silt loam; few medium prominent strong brown (7.5YR5/8) and common medium distinct light olive brown (2.5Y5/4) soft masses of Fe; friable.

BCg1—159 to 182 cm; light brownish gray (2.5Y6/2) silt loam; few medium prominent strong brown (7.5YR5/8) soft masses of Fe; few medium faint gray (2.5Y6/1) Fe depletions; friable.

BCg2—182 to 204 cm; gray (2.5Y6/1) silt loam; few fine distinct strong brown (7.5YR5/8) soft masses of Fe; friable.

2Cg—204 to 255 cm; light brownish gray (2.5Y6/2) loamy sand; many fine distinct strong brown (7.5YR5/8) soft masses of Fe; friable.

Appendix A (continued).

Blackwater Visitor Center (site 27)

Location: 100 m east of visitor center at Black Water Natural Wildlife Refuge; 200 m south of Key Wallace Dr.
Lat./Long.: 38°26’45.82” N 76°07’03.27” W
County: Dorchester
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Clover cover
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 17, 2000; sampled by auger.

Ap—0 to 20 cm; dark grayish brown (2.5Y4/2) silt loam; friable.

BEg—20 to 40 cm; grayish brown (2.5Y5/2) silt loam; common medium faint light olive brown (2.5Y5/4) masses of Fe; friable.

Btg1—40 to 55 cm; dark gray (10YR4/1) silty clay loam; common medium distinct strong brown (7.5YR5/8) masses of Fe; few fine faint light gray (2.5Y7/1) Fe depletions; friable.

2Btg2—55 to 60 cm; gray (10YR5/1) loam; many medium prominent strong brown (7.5YR5/8) masses of Fe; friable.

2Cg1—60 to 70 cm; light gray (2.5Y7/2) loamy fine sand; common medium distinct olive yellow (2.5Y6/6) and few fine prominent yellowish brown (10YR5/8) masses of Fe; very friable.

2Cg2—70 to 80 cm; light brownish gray (2.5Y6/2) loamy fine sand; common medium distinct olive yellow (2.5Y6/6) and few fine prominent yellowish brown (10YR5/8) masses of Fe; very friable.

Appendix A (continued).

Centreville North (site 5)

Location: 0.25 mi south of White Marsh Rd; 1.5 mi east of intersection of Rt. 213 and White Marsh Rd; 65 m north of Centreville Pit.
Lat./Long.: 39°04'02.68" N 76°01'54.92" W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Well drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Philip Zurheide and Ellen Henrikson on August 2, 2000; sampled by auger; coloring and texturing performed in the lab?; missing redoximorphic features.

A—0 to 10 cm; dark yellowish brown (10YR3/4) silt loam; very friable.

AE—10 to 31 cm; olive yellow (2.5Y6/6) silt loam; very friable.

Bt1—31 to 74 cm; olive yellow (2.5Y6/6) silt loam; friable.

Bt2—74 to 102 cm; light olive brown (2.5Y5/6) silt loam; friable.

Bt3—102 to 132 cm; yellowish brown (10YR5/6) silt loam; friable.

Bt4—132 to 158 cm; light olive brown (2.5Y5/6) silt loam; friable.

2BC—158 to 168 cm; brownish yellow (10YR6/8) sandy loam; friable.

Appendix A (continued).

Centreville Pit (site 4)

Location: 0.25 mi south of White Marsh Rd; 1.5 mi east of intersection of Rt. 213 and White Marsh Rd.
Lat./Long.: 39°04'02.30" N 76°01'55.94" W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Well drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Philip Zurheide and Ellen Henrikson on August 2, 2000; structure and boundaries not described for some reason.

A—0 to 10 cm; very dark grayish brown (10YR3/2) silt loam; very friable.

BE—10 to 28 cm; yellowish brown (10YR5/6) silt loam; friable.

Bt1—28 to 71 cm; yellowish brown (10YR5/6) silt loam; friable.

Bt2—71 to 91 cm; yellowish brown (10YR5/6) silt loam; common medium distinct strong brown (7.5YR5/8) and few fine distinct strong brown (7.5YR4/6) masses of Fe; common medium faint pale brown (10YR6/3) Fe depletions; friable.

Bt3—91 to 114 cm; pale brown (10YR6/3) silt loam; many medium distinct yellowish brown (10YR5/8) and few fine distinct strong brown (7.5YR4/6) masses of Fe; firm.

Bt4—114 to 122 cm brownish yellow (10YR6/8) silt loam; many medium distinct light brownish gray (10YR6/2) Fe depletions; firm.

Bt5—122 to 137 cm; yellowish brown (10YR5/6) silt loam; many medium distinct light brownish gray (10YR6/2) Fe depletions; firm.

2BC—137 to 145 cm; yellowish brown (10YR5/6) loam; common medium distinct light brownish gray (10YR5/2) and common fine prominent gray (N5) Fe depletions; friable.

Appendix A (continued).

Centreville South (site 6)

Location: 0.25 mi south of White Marsh Rd; 1.5 mi east of intersection of Rt. 213 and White Marsh Rd; 0.65 m south of Centreville Pit.
Lat./Long.: 39°04'01.07" N 76°01'57.29" W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Well drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Philip Zurheide and Ellen Henrikson on August 2, 2000; sampled by auger.

A—0 to 6 cm; very dark brown (10YR3/2) silt loam; very friable.

E—6 to 15 cm; yellowish brown (10YR5/4) silt loam; friable;

BE—15 to 28 cm; light yellowish brown (10YR6/4) silt loam; friable.

Bt1—28 to 56 cm; yellowish brown (10YR5/8) silt loam; friable.

Bt2—56 to 90 cm; yellowish brown (10YR5/6) silt loam; friable.

Bt3—90 to 114 cm; yellowish brown (10YR5/8) silt loam; friable.

2Bt4—114 to 130 cm; strong brown (7.5YR5/6) sandy loam; many coarse faint brownish yellow (10YR6/6) masses of Fe; very friable.

2Bt5—130 to 168 cm; strong brown (7.5YR5/6) sandy clay loam; common medium faint yellowish brown (10YR5/6) masses of Fe; friable.

2BC—168 to 175 cm; brownish yellow (10YR6/8) sandy loam; common medium distinct strong brown (7.5YR5/8) masses of Fe; very friable.

Appendix A (continued).

Church Creek (site 26)

Location: 1.08 mi west of intersection of Egypt and Old Field Rds; 10 m south of Old Field Rd.
Lat./Long.: 38°29’23.01” N 76°07’22.24” W
County: Dorchester
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Pine/hardwood
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 18, 2000; sampled by auger; ~ 10% gravels in 2BCg horizon.

A--0 to 4 cm; very dark gray (10YR3/1) silt loam; friable.

Eg--4 to 18 cm; grayish brown (10YR5/2) silt loam; few medium faint yellowish brown (10YR5/6) soft masses of Fe; friable.

BEg--18 to 31 cm; gray (2.5Y6/1) silt loam; common medium distinct yellowish brown (10YR5/6) soft masses of Fe; friable.

Btg1--31 to 58 cm; grayish brown (10YR5/2) silty clay loam; many medium distinct strong brown (7.5YR5/8) soft masses of Fe; friable.

Btg2--58 to 89 cm; gray (10YR5/1) silty clay loam; many coarse prominent strong brown (7.5YR5/8) and few medium faint yellowish brown (10YR5/6) soft masses of Fe; friable.

2BCg--89 to 100 cm; gray (10YR5/1) clay loam; few medium distinct strong brown (7.5YR5/8) and few medium faint yellowish brown (10YR5/8) soft masses of Fe; firm.

2Cg--100 to 110; gray (10YR6/1) loamy sand; common medium faint brownish yellow (10YR6/6) and few fine distinct yellowish brown (10YR5/8) soft masses of Fe; friable.

Appendix A (continued).

Crosiadore (site 23)

Location: 200 m west of end of Otwell Rd.
Lat./Long.: 38°41’53.60” N 76°07’53.80” W
County: Talbot
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Grass, soybean
Notes: Described by Jim Brewer and Carla Baker on September 22, 2000; sampled on September 25, 2000; NRCS pit.

Ap—0 to 25 cm; brown (10YR4/3) silt loam; weak fine and medium subangular blocky structure; friable; abrupt smooth boundary.

BE—25 to 40 cm; light olive brown (2.5Y5/4) silt loam; common fine faint yellowish brown (10YR5/4) masses of Fe; common fine distinct light gray (2.5Y7/2) Fe depletions; weak medium subangular blocky structure; friable; clear smooth boundary.

Bt—40 to 61 cm; light olive brown (2.5Y5/4) silt loam; common fine and medium distinct dark yellowish brown (10YR4/6) and few fine prominent strong brown (7.5YR4/6) masses of Fe; common medium distinct gray (2.5Y6/1) Fe depletions; weak medium prismatic parting to moderate medium angular blocky structure; firm; clear wavy boundary.

Btg1—61 to 71 cm; light olive gray (5Y6/2) silt loam; common medium and coarse prominent yellowish brown (10YR5/6) and common fine prominent strong brown (7.5YR5/8) masses of Fe; common fine distinct white (5Y8/1) Fe depletions; strong medium prismatic parting to moderate medium subangular blocky structure; firm; abrupt wavy boundary.

2Btg2—71 to 84 cm; gray (10YR5/1) sandy clay loam; common medium prominent strong brown (7.5YR5/6) and common medium distinct yellowish brown (10YR5/4) masses of Fe; many fine distinct white (5Y5/8) Fe depletions; moderate coarse prismatic parting to moderate very thick platy structure; 3% coarse fragments; firm; clear wavy boundary.

Appendix A (continued).

2BC—84 to 94 cm; light olive brown (2.5Y5/4) sandy loam; common medium prominent yellowish red (5YR4/6) masses of Fe; common medium distinct gray (5Y5/1) Fe depletions; 3% coarse fragments; friable; abrupt smooth boundary.

Appendix A (continued).

Denny's Farm (site 17)

Location: 500 m east of Rt. 18; 3 mi north of Rt. 50; on Denny's farm.
Lat./Long.: 39°1'41.70" N 76°18'22.60" W
County: Queen Annes
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Moderately well drained
Parent material:
Vegetation: Soybeans
Notes: Described and sampled by John Wah and Philip Zurheide on August 8, 2000; sampled by auger; below 126 cm may represent a truncated paleosol or different episode of silt deposition.

Ap—0 to 21 cm; brown (10YR4/3) silt loam; friable.

Bt1—21 to 37 cm; yellowish brown (10YR5/6) silt loam; common medium faint yellowish brown (10YR5/8) masses of Fe; friable.

Bt2—37 to 60 cm; yellowish brown (10YR5/6) silty clay loam; common medium distinct strong brown (7.5YR5/8) and few fine distinct strong brown (7.5YR4/6) masses of Fe; friable.

Bt3—60 to 77 cm; light olive brown (2.5Y5/4) silt loam; common medium distinct strong brown (7.5YR5/6) masses of Fe; common medium faint light yellowish brown (2.5Y6/3) Fe depletions; friable.

Bt4—77 to 98 cm; light olive brown (2.5Y5/4) silt loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; common medium faint pale brown (10YR6/3) Fe depletions; friable.

Bt5—98 to 126 cm; light olive brown (2.5Y5/4) silt loam; common fine distinct yellowish brown (10YR5/8) and few fine prominent strong brown (7.5YR4/6) masses of Fe; many medium distinct light brownish gray (10YR6/2) Fe depletions; friable.

Bt6—126 to 158 cm; light olive brown (2.5Y5/4) silt loam; many medium prominent strong brown (7.5YR5/8) and common fine prominent strong brown (7.5YR4/6) masses of Fe; many medium distinct light brownish gray (10YR6/2) Fe depletions; friable.

Appendix A (continued).

2Btg—158 to 185 cm; gray (2.5Y6/1) loam; few medium prominent yellowish brown (10YR5/8) masses of Fe; friable.

2Bt—185 to 200 cm; light yellowish brown (2.5Y6/4) loam; many medium prominent strong brown (7.5YR5/8) masses of Fe; common medium faint pale olive (5Y6/3) Fe depletions; friable.

2BC—200 to 230 cm; pale olive (5Y6/3) sandy loam; common medium prominent yellowish brown (10YR5/8) masses of Fe; very friable.

Appendix A (continued).

Earleville Wildlife Management Area (site 1)

Location: 180 m northeast of bend in trail; 0.25 mi north of parking area north of Schoolhouse Rd; 0.75 mi east of intersection of Schoolhouse and Glebe Rds.
Lat./Long.: 39°26’51.21” N 75°54’47.06” W
County: Cecil
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Moderately well
Parent material:
Vegetation: Fallow field
Notes: Described and sampled by John Wah and Philip Zurheide on August 8, 2000; sampled by auger; Bt5 horizon possible buried surface, OM oxidized.

Ap—0 to 20 cm; dark yellowish brown (10YR4/6) silt loam; friable;

Bt1—20 to 53 cm; yellowish brown (10YR5/8) silt loam; few medium faint strong brown (7.5YR5/8) masses of Fe; friable.

Bt2—53 to 83 cm; yellowish brown (10YR5/8) silt loam; common medium distinct reddish yellow (7.5YR6/8) masses of Fe; common coarse distinct light yellowish brown (10YR6/3) Fe depletions; friable.

Bt3—83 to 111 cm; yellowish brown (10YR5/6) silt loam; common medium distinct strong brown (7.5YR5/8) and few fine prominent red (2.5YR4/6) masses of Fe; many medium prominent light brownish gray (2.5Y6/2) Fe depletions; friable.

Bt4—111 to 130 cm; yellowish brown (10YR5/6) silt loam; few fine distinct strong brown (7.5YR5/8) masses of Fe; few fine prominent pale yellow (2.5Y8/2) Fe depletions; friable.

Ab or Bt5—130 to 170 cm; light olive brown (2.5Y5/6) silt loam; few fine distinct strong brown (7.5YR5/8) masses of Fe; few fine faint light yellowish brown (2.5Y6/3) Fe depletions; friable.

Btb1—170 to 218 cm; light olive brown (2.5Y5/6) silty clay loam; many medium faint brownish yellow (10YR6/8) masses of Fe; few medium faint light yellowish brown (2.5Y6/3) Fe depletions; friable.

Appendix A (continued).

Btb2—218 to 231 cm; yellowish brown (10YR5/8) silt loam; common medium faint strong brown (7.5YR5/8) and few distinct strong brown (7.5YR4/6) masses of Fe; common medium distinct light yellowish brown (2.5Y6/3) Fe depletions; friable.

Btb3—231 to 263 cm; brownish yellow (10YR6/8) clay loam; common medium faint strong brown (7.5YR5/8) masses of Fe; common fine distinct light gray (7.5YR7/1) Fe depletions; friable.

Btb4—263 to 288 cm; light yellowish brown (2.5Y6/4) clay loam; common medium prominent yellowish red (5YR4/6) and many medium prominent red (2.5YR5/6) masses of Fe; many fine distinct gray (10YR6/1) Fe depletions; friable.

2Btb5—288 to 313 cm; brownish yellow (10YR6/6) sandy loam; many medium prominent yellowish red (5YR4/6) masses of Fe; many medium distinct light gray (10YR7/1) Fe depletions; friable.

Appendix A (continued).

Eastern Neck High (site 16)

Location: Eastern Neck Island; 300 m southeast of parking area.
Lat./Long.:
County: Kent
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Moderately well drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Philip Zurheide and John Wah on August 22, 2002; stone line containing gravels and some channers at contact between BCt and 2Bt horizons.

A--0 to 6cm; dark brown (10YR3/3) silt loam; weak fine granular structure; very friable; clear smooth boundary.

AE--6 to14cm; dark yellowish brown (10YR4/4) silt loam; weak fine subangular blocky structure; very friable; clear wavy boundary.

EB--14 to 38cm; light yellowish brown (2.5Y6/4) silt loam; common medium distinct yellowish brown (10YR5/6) soft masses of Fe; moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt1--38 to 56cm; olive yellow (2.5Y6/6) silt loam with common medium distinct yellowish brown (10YR5/8) soft masses of Fe; many medium to coarse faint light yellowish brown (2.5Y6/4) Fe depletions; moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt2--56 to 69cm; yellowish brown (10YR5/8) very fine sandy loam; many medium distinct strong brown (7.5YR5/6) soft masses of Fe; many medium prominent light brownish gray (2.5Y6/2) Fe depletions; weak coarse prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

BCt--69 to 90cm; yellowish brown (10YR5/6) fine sandy loam; common medium faint yellowish brown (10YR5/8) soft masses of Fe; light yellowish brown (2.5Y6/4) and light yellowish gray (2.5Y6/2) Fe depletion; weak coarse prismatic parting to moderate medium platy structure; friable; abrupt smooth boundary.

Appendix A (continued).

2Bt--90 to104cm; light yellowish brown (2.5Y6/4) sandy clay loam; many medium prominent strong brown (7.5YR5/8) soft masses of Fe; common medium prominent gray (2.5Y6/1) iron depletions; weak coarse prismatic parting to weak to moderate medium subangular blocky structure; friable; clear smooth boundary.

2BC1--104 to 121cm; olive yellow (2.5Y6/6) fine sandy loam; common medium distinct yellowish brown (10YR5/8) soft masses of Fe ; common coarse prominent light olive gray (5Y6/2) Fe depletions; weak coarse prismatic parting to moderate medium subangular blocky structure; friable clear smooth boundary.

2BC2--121 to 155cm; light olive brown (2.5Y5/4) fine sandy loam; many coarse to very coarse gray (5Y6/1) Fe depletions; weak medium subangular blocky and weak medium platy structure; friable.

Appendix A (continued).

Eastern Neck Low (site 14)

Location: Eastern Neck Island; 300 m southeast of parking area.
Lat./Long.: 39°01'51.14" N 76°13'17.77" W
County: Kent
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Marty Rabenhorst, Philip Zurheide, Suzy Park, Steve Burch, Phil King, and John Wah on November 28, 2001; Sampled by auger below 170 cm; 2 to 5 % coarse fragments at contact between parent materials.

A--0 to 9 cm; very dark gray (10YR3/1) silt loam; moderate medium granular structure; friable; abrupt smooth boundary.

AE--9 to 18 cm; brown (10YR4/3) silt loam; few fine faint strong brown (7.5YR4/6) soft masses of Fe; moderate fine subangular blocky structure; friable; clear wavy boundary.

BE--18 to 35 cm; light yellowish brown (2.5Y6/4) silt loam; common medium distinct dark yellowish brown (10YR4/6) soft masses of Fe; many medium faint light yellowish brown (2.5Y6/3) Fe depletions; weak coarse subangular blocky structure; friable; clear smooth boundary.

Bt1--35 to 45 cm; pale brown (10YR6/3) silt loam; many medium distinct dark yellowish brown (10YR5/6) soft masses of Fe; weak coarse prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt2--45 to 65 cm; yellowish brown (10YR5/8) loam; many medium faint strong brown (7.5YR5/6) soft masses of Fe; common medium distinct pale brown (10YR6/3) Fe depletions; weak coarse prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

2Bt3--65 to 80 cm; yellowish brown (10YR5/6) loam; many medium faint strong brown (7.5YR5/6) soft masses of Fe; common medium distinct light brownish gray (2.5Y6/2) Fe depletions; weak very coarse prismatic parting to moderate medium platy and subangular blocky structure; friable; clear smooth boundary.

Appendix A (continued).

2BC1--80 to 115 cm; yellowish brown (10YR5/4) fine sandy loam; many medium distinct strong brown (7.5YR4/6) soft masses of Fe; common medium distinct gray (2.5Y6/1) Fe depletions; weak very coarse prismatic parting to moderate thick platy structure; friable; clear smooth boundary.

2BC2--115 to 146 cm; light olive brown (2.5Y5/6) fine sandy loam; common medium distinct strong brown (7.5YR5/6) soft masses of Fe; common medium prominent gray (10YR6/1) Fe depletions; weak coarse subangular blocky structure; friable; gradual smooth boundary.

2BC3--146 to 170 cm; yellowish brown (10YR5/6) fine sandy loam; common medium faint strong brown (7.5YR5/6) soft masses of Fe; many medium prominent gray (10YR6/1) Fe depletions; weak coarse subangular blocky structure; friable; clear smooth boundary.

2Cg--170 to 182 cm; light gray (2.5Y7/1) fine sandy loam; common medium prominent reddish yellow (7.5YR6/8) soft masses of Fe; friable.

Appendix A (continued).

Eastern Neck Middle (site 15)

Location: Eastern Neck Island; 300 m southeast of parking area.
Lat./Long.: 39°01’50.96” N 76°13’18.21” W
County: Kent
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by Marty Rabenhorst, Philip Zurheide, Suzy Park, Steve Burch, Phil King, and John Wah on November 28, 2001; Sampled by auger below 140 cm; coarse fragments at contact between parent materials at 72 cm.

A--0 to 12 cm; very dark gray (10YR3/1) silt loam; moderate medium granular structure; very friable; clear wavy boundary.

AE--12 to 18 cm; brown (10YR4/3) silt loam; moderate medium subangular blocky structure; very friable; clear wavy boundary.

BE--18 to 31 cm; light yellowish brown (2.5Y6/4) silt loam; many medium yellowish brown (10YR5/6) soft masses of Fe; weak medium subangular blocky structure; friable; clear smooth boundary.

Bt1--31 to 48 cm; strong brown (7.5YR5/6) silt loam; common medium faint yellowish brown (10YR5/8) soft masses of Fe; common medium distinct light yellowish brown (2.5Y6/3) Fe depletions; moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt2--48 to 72 cm; yellowish brown (10YR5/6) loam; many medium distinct yellowish brown (10YR5/8) soft masses of Fe; common medium prominent light gray (2.5Y7/2) Fe depletions; moderate medium subangular blocky structure; friable; clear smooth boundary.

2Bt3--72 to 95 cm; yellowish brown (10YR5/6) fine sandy loam; many medium distinct strong brown (7.5YR5/8) soft masses of Fe; common medium prominent light brownish gray (2.5Y6/2) Fe depletions; weak very coarse prismatic parting to moderate coarse subangular blocky structure; friable; clear smooth boundary.

Appendix A (continued).

2BCg--95 to 140 cm; gray (10YR5/1) fine sandy loam; common medium prominent yellowish brown (10YR5/8) soft masses of Fe; common medium faint light gray (2.5Y7/2) Fe depletions; weak very coarse prismatic parting to moderate thick platy structure; friable; clear smooth boundary.

2BC--140 to 160 cm; light yellowish brown (2.5Y6/4) sandy clay loam; common medium distinct yellowish brown (10YR5/8) soft masses of Fe; many medium distinct gray (10YR6/1) Fe depletions; friable.

2C1--160 to 195 cm; light yellowish brown (2.5Y6/4) very fine sandy loam; many medium distinct yellowish brown (10YR5/6) soft masses of Fe; common medium distinct light gray (2.5Y7/1) Fe depletions.

Appendix A (continued).

Holly Harbor (site 24)

Location: 300 m southeast of the intersection of Holly Harbor and Evergreen Rds; 100 m west of Holly Harbor Rd.
Lat./Long.: 38°40’33.94” N 76°08’47.66” W
County: Talbot
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 15, 2000; sampled by auger.

A—0 to 8 cm; dark gray (10YR4/1) silt loam; friable.

Eg—8 to 16 cm; gray (10YR6/1) silt loam; friable.

Btg1—16 to 39 cm; gray (10YR5/1) silty clay loam; common medium distinct brownish yellow (10YR6/8) masses of Fe; common fine faint light gray (10YR7/1) Fe depletions; friable.

Btg2—39 to 70 cm; gray (10YR5/1) silty clay loam; many medium distinct yellowish brown (10YR5/8) masses of Fe; common fine faint gray (2.5Y6/1) Fe depletions; friable.

BCg1—70 to 80 cm; gray (2.5Y6/1) silt loam; many fine distinct brownish yellow (10YR6/8) and few fine distinct dark yellowish brown (10YR4/6) masses of Fe; very friable.

2BCg2—80 to 97 cm; gray (2.5Y6/1) loam; common fine distinct brownish yellow (10YR6/8) masses of Fe; friable.

2BCg3—97 to 110 cm; gray (10YR5/1) fine sandy loam; few fine distinct brownish yellow (10YR6/6) masses of Fe; friable.

Appendix A (continued).

Horn Point (site 25)

Location: Horn Point Research Facility, 200 m west of Choptank River.
Lat./Long.: 38°35'13.09" N 76°07'24.95" W
County: Dorchester
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Moderately well drained
Parent material:
Vegetation: Grass, mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on July 25, 2000; sampled in backhoe pit; below 100 cm sampled by auger; 10% rounded quartz coarse fragments in 2Ab horizon; 15% gravels at 120 and 130 cm.

Ap--0 to 29 cm; brown (10YR4/3) silt loam; weak fine subangular blocky structure; friable; abrupt smooth boundary.

BE--29 to 48 cm; brown (10YR5/3) silt loam; moderate medium prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt1--48 to 67 cm; yellowish brown (10YR5/8) silt loam; few medium distinct strong brown (7.5YR5/8) soft masses of Fe; common medium distinct pale brown (10YR6/3) Fe depletions; moderate coarse prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt2--67 to 78 cm; yellowish brown (10YR5/6) silt loam; many medium distinct strong brown (7.5YR5/6) soft masses of Fe; common medium distinct pale yellow (2.5Y8/2) Fe depletions; moderate coarse prismatic parting to moderate medium subangular blocky structure; friable; clear smooth boundary.

2Ab--78 to 100 cm; very dark gray (2.5Y3/1) silty clay loam; firm.

2Btb1--100 to 110 cm; black (2.5Y2.5/1) loam; firm.

Appendix A (continued).

James Island (site 38)

Location: Southern end of James Island, erosional bank cut; boat access.
Lat./Long.: 38°46’3.4” N 76°22’17.1” W
County: Talbot
Landform: Terrace
Relief:
Elevation: ~1.1 m
Slope: 0-1%
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Grass, shrub, remnant pine
Notes: Described and sampled by Dan Wagner and John Foss on September 22, 2000; below 100 cm sampled by auger.

A--0 to 9 cm; dark yellowish brown (10YR4/4) silt loam; weak medium platy structure; friable; abrupt smooth boundary.

Ap--9 to 22 cm; brown (10YR4/3) silt loam; weak fine granular structure; friable; abrupt smooth boundary.

BE--22 to 33 cm; yellowish brown (10YR5/6) silt loam; weak medium platy parting to weak medium subangular blocky structure; friable; clear smooth boundary.

Bt--33 to 46 cm; yellowish brown (10YR5/6) silt loam; common medium distinct grayish brown (2.5Y5/2) Fe depletions; weak medium subangular blocky structure; friable; clear smooth boundary.

Btx--46 to 59 cm; yellowish brown (10YR5/6) silt loam; common fine distinct yellowish red (5YR5/6) soft masses of Fe; many coarse prominent light brownish gray (2.5Y6/2) Fe depletions; strong very coarse prismatic parting to moderate coarse platy structure; very firm; clear smooth boundary.

Btxg--59 to 88 cm; grayish brown (2.5Y5/2) silt loam; common coarse prominent strong brown (7.5YR4/6) soft masses of Fe; strong very coarse prismatic parting to moderate coarse platy structure; very firm; clear smooth boundary.

Ab--88 to 106 cm; dark gray (2.5Y4/1) silty clay loam; many coarse distinct grayish brown (2.5Y5/2) soft masses of Fe; strong very coarse prismatic parting to moderate coarse platy structure; very firm.

Appendix A (continued).

Btxb--106 to 130 cm; light olive brown (2.5Y5/4) silty clay loam; common coarse distinct yellowish brown (10YR5/6) soft masses of Fe; many coarse distinct grayish brown (2.5Y5/2) Fe depletions; very firm.

BC--130 to 145 cm; strong brown (7.5YR5/8) silt loam; common medium prominent light brownish gray (10YR6/2) Fe depletions; friable.

BCg--145 to 158 cm; light brownish gray (10YR6/2) silt loam; common medium prominent strong brown (7.5YR5/6) soft masses of Fe; friable.

2C--158 to 180 cm; strong brown (7.5YR5/8) sandy loam; common medium prominent gray (2.5Y6/1) Fe depletions; friable.

2Cg--180 to 195 cm; gray (2.5Y6/1) very fine sandy loam; common coarse prominent strong brown (7.5YR5/8) soft masses of Fe; friable.

Appendix A (continued).

Jefferson Island (site 34)

Location: East side of Jefferson Island, erosional bank cut; boat access.
Lat./Long.: 38°46’3.4” N 76°22’17.1” W
County: Talbot
Landform: Terrace
Relief:
Elevation: ~1.3 m
Slope: 0
Aspect: -
Drainage: Moderately well drained
Parent material:
Vegetation: Grass, shrub, remnant pine
Notes: Described and sampled by Dan Wagner on May 18, 2000; nearly continuous clay films in Bt and Btx horizons.

A--0 to 9 cm; very dark grayish brown (10YR3/2) silt loam; weak fine granular structure; friable; clear wavy boundary.

E--9 to 20 cm; yellowish brown (10YR5/4) silt loam; weak medium platy structure; friable; clear smooth boundary.

BE--20 to 33 cm; yellowish brown (10YR5/6) silt loam; moderate medium subangular blocky structure; friable; clear smooth boundary.

Bt--33 to 50 cm; dark yellowish brown (10YR4/6) silt loam; common medium distinct brown (10YR5/3) Fe depletions; friable; gradual smooth boundary.

Btx--50 to 75 cm; dark yellowish brown (10YR4/4) silt loam; common medium distinct strong brown (7.5YR5/6) soft masses of Fe; many coarse prominent grayish brown (2.5Y5/2) Fe depletions; very firm.

Appendix A (continued).

Kentuck (site 31)

Location:
Lat./Long.: 38°11'39.42" N 75°44'27.12" W
County: Somerset
Landform: Terrace
Relief:
Elevation: 3 m
Slope: 1%
Aspect:
Drainage: Very poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: NRCS Somerset County review site; auger profile described and sampled in lab by John Wah on September 29, 2001.

A—0 to 20 cm; black (10YR2/1) silt loam; friable.

Btg1—20 to 35 cm; gray (2.5Y5/1) silt loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

Btg2—35 to 61 cm; gray (2.5Y5/1) silt loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

2Btg3—61 to 89 cm; gray (2.5Y6/1) sandy loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

3BCg—89 to 133 cm; grayish brown (2.5Y5/2) gravelly sandy loam; very friable.

Appendix A (continued).

Kings Creek (site32)

Location: 100 m east of Rt. 13; 0.4 mi north of intersection of Rt. 13 and Rt. 413.
Lat./Long.: 38°08’32.42” N 75°42’03.19” W
County: Somerset
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah on August 24, 2000; sampled by auger.

A—0 to 12 cm; very dark gray (10YR3/1) silt loam; friable.

BEg—12 to 25 cm; gray (2.5Y5/1) silt loam; few fine distinct yellowish brown (10YR5/6) soft masses of Fe; friable.

Btg1—25 to 40 cm; gray (2.5Y5/1) silt loam; common medium distinct yellowish brown (10YR5/6) soft masses of Fe; friable.

Btg2—40 to 60 cm; gray (2.5Y5/1) silt loam; common medium distinct yellowish brown (10YR5/6) and few fine prominent dark yellowish brown (10YR4/6) soft masses of Fe; firm.

2BCg—60 to 80 cm; gray (2.5Y5/1) sandy loam; few fine distinct yellowish brown (10YR5/6) soft masses of Fe; friable.

Appendix A (continued).

Little Neck (site 8)

Location: 0.3 miles south of intersection of Little Eagle and Back Starr Rds. 50 m east of Back Starr Rd. of Matthewstown.
Lat./Long.: 39°00'04.89" N 76°01'43.24" W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 1-2%
Aspect: 340°
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 16, 2000; sampled by auger.

A--0 to 8 cm; very dark gray silt loam; very friable.

AE--8 to 15; brown (10YR4/3) silt loam; few fine faint yellowish brown (10YR5/6) soft masses of Fe; friable.

BE--15 to 20 cm; light yellowish brown (2.5Y6/3) silt loam; few fine faint yellowish brown (10YR5/6) soft masses of Fe; friable.

Bt--20 to 40 cm; light yellowish brown (2.5Y6/3) silt loam; many medium distinct brownish yellow (10YR6/8) soft masses of Fe; few fine distinct grayish brown (2.5Y5/2) Fe depletions; friable.

Btg--40 to 60 cm; gray (2.5Y6/1) silty clay loam; many medium prominent yellowish brown (10YR5/8) soft masses of Fe; friable.

2BC--60 to70 cm; yellowish brown (10YR5/8) loam; common medium prominent gray (2.5Y6/1) Fe depletions; friable.

Appendix A (continued).

Matthews2 (site 11)

Location: 50 m north of Discovery Dr; 0.3 mi east of intersection of Discovery Dr and Kingston Landing Rd; 15 m east of Matthewstown.
Lat./Long.: 38°47'54.32" N 75°57'29.86" W
County: Talbot
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Philip Zurheide on August 8, 2000; sampled by auger; horizon 57 to 90 cm may be buried surface/ truncated paleosol.

A—0 to 8 cm; dark grayish brown (10YR4/2) silt loam; very friable.

BEg—8 to 26 cm; gray (2.5Y6/1) silt loam; many medium prominent yellowish brown (10YR5/6) masses of Fe; friable.

Btg1—26 to 40 cm; gray (2.5Y6/1) silt loam ; common medium prominent yellowish brown (10YR5/6) masses of Fe; friable.

Btg2—40 to 57 cm; gray (2.5Y6/1) silt loam; few fine prominent yellowish brown (10YR5/6) masses of Fe; friable.

2Btgb1—57 to 90 cm; light brownish gray (2.5Y6/2) silty clay loam; many medium prominent yellowish brown (10YR5/6) and few fine prominent strong brown (7.5YR4/6) masses of Fe; friable.

2Btgb2—90 to 110 cm; dark gray (2.5Y4/1) silty clay loam; common medium prominent strong brown (7.5YR5/8) masses of Fe; firm.

2Btb—110 to 145 cm; dark yellowish brown (10YR4/6) clay loam; common coarse prominent olive gray (5Y5/2) Fe depletions; firm.

B'tgb1—145 to 170 cm; white (2.5Y8/1) silty clay loam; many medium prominent yellowish brown (10YR5/8) masses of Fe; firm.

Appendix A (continued).

2B'tgb2—170 to 200 cm; gray (10YR6/1) clay; many medium prominent yellowish brown (10YR5/6) masses of Fe; firm.

2'Bt—200 to 220 cm; yellowish brown (10YR5/8) clay loam; few fine distinct strong brown (7.5YR4/6) masses of Fe; many coarse prominent gray (10YR6/1) Fe depletions; firm.

Appendix A (continued).

Matthewstown (site 10)

Location: 50 m north of Discovery Dr; 0.3 mi east of intersection of Discovery Dr and Kingston Landing Rd.
Lat./Long.: 38°47’53.72” N 75°57’30.51” W
County: Talbot
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Philip Zurheide on August 1, 2000; sampled by auger; 109 to 125 may be 2Ab horizon.

A—0 to 9 cm; very dark brown (10YR2/2) silt loam; very friable.

EB—9 to 28 cm; light yellowish brown (2.5Y6/4) silt loam; friable.

Bt—28 to 56 cm; light yellowish brown (2.5Y6/4) silt loam; common fine distinct brownish yellow (10YR6/8) and few fine prominent strong brown (7.5YR4/6) masses of Fe; few fine faint light gray (2.5Y7/1) Fe depletions; friable.

Btg1—56 to 77 cm; gray (2.5Y6/1) silt loam; common fine prominent strong brown (7.5YR5/6) masses of Fe; common fine faint white (N8) Fe depletions; friable.

Btg2—77 to 109 cm; gray (2.5Y5/1) silty clay loam; few fine prominent strong brown (7.5YR5/8) masses of Fe; firm.

2Btgb—109 to 125 cm; grayish brown (2.5Y5/2) silty clay loam; many medium prominent strong brown (7.5YR5/8) masses of Fe; firm.

2Btb—125 to 150 cm; strong brown (7.5YR5/8) clay; common medium prominent gray (2.5Y2/1) Fe depletions; very firm.

2B’tgb1—150 to 167 cm; grayish brown (2.5Y5/2) clay loam; many medium prominent strong brown (7.5YR5/8) masses of Fe; very firm.

2B’tgb2—167 to 200 cm; light gray (2.5Y7/1) clay loam; many fine prominent strong brown (7.5YR5/8) masses of Fe; very firm.

Appendix A (continued).

Mesa (site 3)

Location: 50 m north of Hall Rd; 1.3 mi west of intersection of Rt 301 and Hall Rd.
Lat./Long.: 39°08’52.90” N 75°57’15.50” W
County: Queen Annes
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 16, 2000; sampled by auger; fragic properties 61-79 cm.

A—0 to 10 cm; very dark grayish brown (10YR3/2) silt loam; very friable.

E—10 to 29 cm; light brownish gray (2.5Y6/2) silt loam; common medium faint olive yellow (2.5Y6/6) and few fine distinct yellowish brown (10YR5/8) masses of Fe; very friable.

Btg—29 to 61 cm; gray (2.5Y6/1) silt loam; common medium distinct brownish yellow (10YR6/8) and few fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Bt1—61 to 79 cm; brownish yellow (10YR6/8) silt loam; few medium faint yellowish brown (10YR5/8) masses of Fe; few medium distinct light brownish gray (2.5Y6/2) Fe depletions; firm.

Bt2—79 to 95 cm; strong brown (7.5YR5/8) silt loam; many medium faint yellowish brown (10YR5/8) masses of Fe; common fine distinct gray (10YR6/1) Fe depletions; friable.

Bt3—95 to 115 cm; yellowish brown (10YR5/6) silt loam; common fine distinct strong brown (7.5YR4/6) masses of Fe; common fine distinct gray (10YR6/1) Fe depletions; friable.

2BCg1—115 to 145 cm; gray (10YR6/1) loam; common medium distinct brownish yellow (10YR6/6) and yellowish brown (10YR5/8) masses of Fe; friable.

Appendix A (continued).

2BCg2—145 to 170 cm; gray (2.5Y6/1) loam; many coarse distinct yellowish brown (10YR5/6) masses of Fe; friable.

Appendix A (continued).

Oyster Cove Point (site 39)

Location: Bay cut exposure; south of Slaughter Creek
Lat./Long.: 38°29'55.47" N 76°19'30.773" W
County: Dorchester
Landform: Terrace
Relief:
Elevation: 1 m
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Grasses
Notes: Described and sampled by Dan Wagner and John Wah on March 3, 2001; Paleoindian projectile point recovered from buried surface horizon by Darrin Lowery; below 108 cm sampled with auger; depleted prism faces Btx through Ab horizon

Ap—0 to 16 cm; olive brown (2.5Y4/3) silt loam; moderate fine granular structure; friable; abrupt smooth boundary.

BE—16 to 22 cm; light olive brown (2.5Y5/4) silt loam; common medium distinct dark yellowish brown (10YR4/6) masses of Fe; weak fine subangular blocky structure; friable; clear smooth boundary.

Btg—22 to 40 cm; gray (10YR6/1) silty clay loam; many medium prominent yellowish brown (10YR5/8) masses of Fe; moderate medium subangular blocky structure; friable; clear smooth boundary.

Btx—40 to 53 cm; dark yellowish brown (10YR4/4) silty clay loam; common medium faint dark yellowish brown (10YR4/6) masses of Fe; common medium faint grayish brown (10YR5/2) Fe depletions; moderate very coarse prismatic parting to moderate thick platy structure; firm; clear smooth boundary.

Ab—53 to 80 cm; dark gray (10YR4/1) silty clay loam; common medium distinct dark yellowish brown (10YR4/6) masses of Fe; moderate very coarse prismatic parting to moderate medium subangular blocky structure; firm; clear wavy boundary.

Btxb1—80 to 108 cm; olive brown (2.5Y4/3) silty clay loam; many fine distinct yellowish brown (10YR5/6) masses of Fe; common fine faint gray (10YR5/1) Fe depletions; moderate very coarse prismatic parting to weak thick platy and weak coarse subangular blocky structure; firm.

Btxb2—108 to 138 cm; light olive brown (2.5Y5/4) silty clay loam; many medium distinct yellowish brown (10YR5/8) masses of Fe; common medium distinct gray (10YR5/2) Fe depletions; firm.

BCg—138 to 178 cm; light brownish gray (2.5Y6/2) silt loam; few medium prominent yellowish brown (10YR5/8) masses of Fe; friable.

2Cg—178 to 183 cm; grayish brown (2.5Y5/2) sandy loam; few medium distinct yellowish brown (10YR5/6) masses of Fe; very friable.

Appendix A (continued).

Pauls Corner (site 33)

Location: 50 m south of Rt. 667; 0.65 mi east of intersection of Rt. 667 and Burnettsville Rd.
Lat./Long.: 38°02’23.23” N 75°44’04.01” W
County: Somerset
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 24, 2000; sampled by auger.

A—0 to 8 cm; very dark brown (10YR2/2) silt loam; friable.

Eg—8 to 18 cm; gray (10YR5/1) silt loam; few medium faint yellowish brown (10YR5/4) soft masses of Fe; friable.

Btg1—18 to 43 cm; gray (10YR5/1) loam; common medium distinct yellowish brown (10YR5/6) soft masses of Fe; friable.

2Btg2—43to 60 cm; gray (10YR5/1) loam; many medium distinct yellowish brown (10YR5/6) and common fine prominent strong brown (7.5YR5/6) soft masses of Fe; friable.

2Cg—60 to 70 cm; gray (10YR6/1) loamy fine sand; common medium distinct yellowish brown (10YR5/4) soft masses of Fe; very friable.

Appendix A (continued).

Paw Paw Cove (site 35)

Location: Tilghman Island; Paw Paw Cove; 1.8 mi S of Bridge on Rt. 33; ~ 30 m E of Chesapeake Bay
Lat./Long. 38°41'44.18" N 76°20'35.35" W
County: Talbot
Landform: Terrace
Relief:
Elevation: ~ 1.8 m MSL
Slope: 0
Aspect: -
Drainage: Moderately well drained
Parent material:
Vegetation: Grass
Described by: D.P. Wagner, J.E. Foss, and J.S. Wah on September 22, 2000
Notes: Ap horizon likely overthickened from house grading, divided at 10 cm for sampling; below 100 cm described and sampled with auger.

Ap--0 to 31 cm; dark yellowish brown (10YR4/4) silt loam; weak medium granular structure; friable, abrupt smooth boundary.

BE--31 to 42 cm; brownish yellow (10YR6/6) silt loam; weak medium platy structure; friable; clear smooth boundary.

Bt--42 to 54 cm; yellowish brown (10YR5/6) silty clay loam; weak medium subangular blocky structure; friable; clear smooth boundary.

Btx--54 to 63 cm; brown (10YR4/3) silty clay loam; common medium distinct yellowish brown (10YR5/8) soft masses of Fe; common medium distinct grayish brown (10YR5/2) Fe depletions; moderate coarse prismatic parting to moderate medium platy structure; firm; thin nearly continuous clay skins; clear smooth boundary.

Ab--63 to 92 cm; dark gray (2.5Y4/1) silty clay loam; common coarse distinct strong brown (7.5YR4/6) and dark yellowish brown (10YR4/4) soft masses of Fe; moderate coarse prismatic parting to moderate thick platy structure; firm; continuous clay films on prism faces and most plates; gradual smooth boundary.

Btxgb1--92 to 109 cm; gray (10YR5/1) silty clay loam; many medium distinct yellowish brown (10YR5/6) soft masses of Fe; common coarse faint gray (2.5Y6/1) Fe depletions; moderate coarse prismatic parting to moderate thick platy structure; very firm; continuous clay films on prism faces and most plates.

Appendix A (continued).

Btxgb2--109 to 139 cm; light brownish gray (2.5Y6/2) silty clay loam; many medium distinct yellowish brown (10YR5/6) and dark yellowish brown (10YR4/6) soft masses of Fe; common coarse faint gray (2.5Y6/1) Fe depletions; very firm.

Btxgb3--139 to 166 cm; light brownish gray (2.5Y6/2) silt loam; many medium distinct dark yellowish brown (10YR4/6) soft masses of Fe; common coarse faint gray (2.5Y6/1) Fe depletions; firm.

2BCg--166 to 184 cm; light olive yellow (5Y6/2) silt loam; few medium prominent strong brown (7.5YR4/6) soft masses of Fe; common coarse distinct gray (N6) Fe depletions; friable.

2Cg--184 to 210 cm; light olive yellow (5Y6/2) fine sandy loam; common coarse prominent yellowish brown (10YR5/6) soft masses of Fe; common coarse faint gray (10YR6/1) Fe depletions; very friable.

Appendix A (continued).

Plugge 50 (site 9)

Location: 25 m south of Plugge Rd; 100 m east of intersection of Rt 50 and Plugge Rd.
Lat./Long.: 38°52’06.07” N 76°03’37.49” W
County: Talbot
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Well drained
Parent material:
Vegetation: Corn
Notes: Described and sampled by John Wah and Ellen Henrikson on August 15, 2000; sampled by auger.

Ap—0 to 21 cm; light olive brown (2.5Y5/4) silt loam; friable.

Bt1—21 to 46 cm; yellowish brown (10YR5/8) silt loam; common fine faint light yellowish brown (10YR6/4) Fe depletions; friable.

Bt2—46 to 71 cm; yellowish brown (10YR5/8) silt loam; many medium faint Yellowish brown (10YR5/4) Fe depletions; friable.

2Bt3—71 to 88 cm; yellowish brown (10YR5/6) loam; common fine faint light yellowish brown (10YR6/4) Fe depletions; friable.

2Bt4—88 to 110 cm; yellowish brown (10YR5/6) sandy loam; common medium faint light yellowish brown (2.5Y6/4) Fe depletions; friable.

2BC—110 to 120 cm; brownish yellow (10YR6/6) loamy sand; common medium faint light yellowish brown (2.5Y6/4) Fe depletions; very friable.

Appendix A (continued).

Princess Anne (site 30)

Location: 50 m east of Pine Pole Rd; 0.1 miles south of the intersection of Pine Pole and Black Rds.
Lat./Long.: 38°13’4.14” N 75°44’53.03” W
County: Somerset
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation:
Notes: Described by John Wah, Philip Zurheide, and Ellen Henrikson on August 24, 2000; sampled by auger; possible compaction, mixing in surface from recent clear cutting; pockets of clay, 10% COF in 2BCg horizon.

A—0 to 10 cm; dark gray (2.5Y4/1) silt loam; friable.

Btg1—10 to 28 cm; gray (N5) silty clay loam; many medium distinct light yellowish brown (2.5Y6/3) and common fine prominent strong brown (7.5YR5/8) masses of Fe; firm.

Btg2—28 to 46 cm; gray (2.5Y6/1) silty clay loam; many medium distinct light yellowish brown (2.5Y6/3) and many medium distinct strong brown (7.5YR5/8) masses of Fe; firm.

2Btg3—46 to 59 cm; gray (10YR5/1) clay loam; many coarse prominent dark yellowish brown (10YR4/6) and few medium prominent strong brown (7.5YR4/6) masses of Fe; firm.

2BCg—59 to 80 cm; gray (10YR5/1) sandy clay loam; few medium prominent strong brown (7.5YR4/6) masses of Fe; few fine faint gray (2.5Y6/1) Fe depletions; 10% coarse fragments; friable.

Appendix A (continued).

Rockhall (site 13)

Location: 50 m south of Lovers Lane; 0.5 mi east of intersection of Lovers Lane and Rt. 20.
Lat./Long.: 39°09'24.38" N 76°13'03.51" W
County: Kent
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly
Parent material:
Vegetation: Mixed hardwood, pine
Notes: Described and sampled by John Wah, Philip Zurheide, and Ellen Henrikson on August 24, 2000; sampled by auger.

A—0 to 9 cm; very dark brown (10YR2/2) silt loam; friable.

BE—9 to 20 cm; yellowish brown (10YR5/6) silt loam; few fine distinct yellowish red (5YR5/8) masses of Fe; common medium distinct grayish brown (10YR5/2) Fe depletions; friable.

Btg—20 to 53 cm; gray (2.5Y6/1) silt loam; many medium distinct yellowish brown (10YR5/4) masses of Fe; friable.

2BC—52 to 70 cm; light yellowish brown (2.5Y6/3) loamy fine sand; few medium prominent strong brown (7.5YR5/6) masses of Fe; common medium faint light gray (2.5Y7/1) Fe depletions; very friable.

Appendix A (continued).

Royal Oaks (site 22)

Location: 150 m north of Travelers Rest Rd; 0.5 mi east of intersection of Rt. 33 and Travelers Rest Rd.
Lat./Long.: 38°45'37.78" N 76°08'06.30" W
County: Talbot
Landform: Terrace
Relief:
Elevation:
Slope: 1%
Aspect: 130°
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood, young pine
Notes: Described and sampled by John Wah and Philip Zurheide on August 1, 2000; sampled by auger.

A—0 to 8 cm; dark grayish brown (10YR4/2) silt loam; friable.

Eg—8 to 20 cm; gray (10YR6/1) silt loam; common fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Btg1—20 to 39 cm; gray (2.5Y5/1) silty clay loam; common fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Btg2—39 to 76 cm; gray (2.5Y6/1) silt loam; common fine prominent strong brown (7.5YR5/8) masses of Fe; friable.

2Ab—76 to 98 cm; very dark grayish brown (10YR3/2) fine sandy loam; common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

2C—98 to 150 cm; gray (2.5Y5/1) loamy fine sand; very friable.

Appendix A (continued).

Sassafras NRMA (site 2)

Location: 0.8 miles west of Turner Creek Rd. on unnamed gravel road at Sassafras NRMA; 30 m east of gate in field.
Lat./Long.: 39°26'16.55" N 76°00'08.31" W
County: Kent
Landform: Upland
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Well drained
Parent material:
Vegetation: Corn
Notes: Described and sampled by John Wah and Ellen Henrikson on August 4, 2000; sampled by auger; small hill (~ 4 m higher) 300 m to the northeast (hidden by corn in the summer), probably some overwash/deposition on surface at sampling site.

Ap—0 to 31 cm; dark yellowish brown (10YR4/4) silt loam; very friable.

Bt1—31 to 53 cm; yellowish brown (10YR5/6) silt loam; friable.

Bt2—53 to 80 cm; yellowish brown (10YR5/8) silt loam, friable.

Bt3—80 to 115 cm; yellowish brown (10YR6/5) silt loam; few fine distinct strong brown (7.5YR5/8) soft masses of Fe; many medium faint light yellowish brown (10YR6/4) and common fine distinct very pale brown (10YR7/3) Fe depletions; friable.

2Bt4—115 to 140 cm; yellowish brown (10YR5/8) sandy clay loam few fine distinct strong brown (7.5YR4/6) and few fine distinct strong brown (7.5YR5/8) soft masses of Fe; common fine distinct pale brown (10YR6/3) Fe depletions; very friable.

Appendix A (continued).

Tilghman Island (site 37)

Location: 100 m south of Paw Paw Cove; 100 m east of Chesapeake Bay.
Lat./Long.: 38°41’40382” N 76°20’33.92” W
County: Talbot
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Grass, shrub
Notes: Described and sampled by John Wah and Ellen Henrikson on October 27, 2000; sampled by auger; fine and very fine sands in bottom two horizons.

Ap--0 to 18 cm; Dark gray (10YR4/1) silt loam; very friable.

AE--18 to 30 cm; grayish brown (2.5Y5/2) silt loam; common medium prominent strong brown (7.5YR5/6) soft masses of Fe; friable.

Bt1--30 to 61 cm; yellowish brown (10YR5/4) silt loam; friable.

Bt2--61 to 88 cm; yellowish brown (10YR5/4) silt loam; many medium prominent gray (2.5Y6/1) Fe depletions; firm.

Btg--88 to 105 cm; gray (2.5Y6/1) silt loam; many medium prominent yellowish brown (10YR5/6) soft masses of Fe; firm.

2BCg1--105 to 145 cm; gray (2.5Y6/1) loam; common medium distinct light yellowish brown (10YR4/6) and few medium prominent strong brown (7.5YR5/6) soft masses of Fe; friable.

2BCg2--145 to 180 cm; gray (2.5Y6/1) very fine sandy loam; common medium distinct light yellowish brown (10YR4/6) and few medium prominent strong brown (7.5YR5/6) soft masses of Fe; friable.

Appendix A (continued).

Todds Corner (site 21)

Location: 100 m west of intersection of Todds Corner and Kintore Rds.
Lat./Long.: 38°50’10.13” N 76°07’54.96” W
County: Talbot
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 15, 2000; sampled by auger.

A—0 to 6 cm; dark gray (10YR4/1) silt loam; friable.

E—6 to 14 cm; light yellowish brown (2.5Y6/3) silt loam; friable.

BE—14 to 40 cm; light yellowish brown (2.5Y6/4) silt loam; common medium faint yellowish brown (10YR5/6) masses of Fe; common medium faint light brownish gray (2.5Y6/2) Fe depletions; friable.

Bt1—40 to 52 cm; light olive brown (2.5Y5/4) silty clay loam; common medium distinct yellowish brown (10YR5/8) and few medium prominent strong brown (7.5YR4/6) masses of Fe; common medium faint gray (2.5Y6/1) Fe depletions; friable.

Bt2—52 to 74 cm; olive yellow (2.5Y6/6) silt loam; common medium distinct yellowish brown (10YR5/8) and common medium faint brownish yellow (10YR6/6) masses of Fe; many medium distinct light gray (2.5Y7/1) Fe depletions; friable.

Btg1—74 to 98 cm; light brownish gray (2.5Y6/2) silt loam; common medium prominent strong brown (7.5YR5/6) masses of Fe; common fine faint gray (2.5Y6/1) Fe depletions; friable.

Btg2—98 to 110 cm; gray (2.5Y6/1) silt loam; few fine distinct brownish yellow (10YR6/6) masses of Fe; common medium faint gray (2.5Y5/1) Fe depletions; friable.

2Ab—110 to 130 cm; dark gray (2.5Y4/1) loam; few fine distinct yellowish brown (10YR5/6) masses of Fe; few fine faint light brownish yellow (2.5Y6/2) Fe depletions; friable.

Appendix A (continued).

2BC—130 to 140 cm; brown (10YR4/3) loamy fine sand; few medium faint light yellowish brown (10YR6/4) masses of Fe, very friable.

Appendix A (continued).

Tolchester (site 12)

Location: 10 m east of Bay Shore Rd; 0.3 mi north of intersection of Bay Shore and Tolchester Beach Rds.
Lat./Long.: 39°13’11.51” N 76°13’23.49” W
County: Kent
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah and Ellen Henrikson on August 4, 2000; sampled by auger; smectitic clays below 132 cm.

A—0 to 6 cm; dark gray (10YR4/1) silt loam; very friable.

Eg—6 to 22 cm; grayish brown (2.5Y5/2) silt loam; many medium distinct yellowish brown (10YR5/8) masses of Fe; very friable.

Btg—22 to 55 cm; gray (2.5Y6/1) silty clay loam; many medium prominent yellowish gray (10YR5/8) masses of Fe; friable.

Bt—55 to 80 cm; yellowish brown (10YR5/4) silt loam; many medium faint yellowish brown (10YR5/8) and common medium faint dark yellowish brown (10YR4/6) masses of Fe; many medium distinct gray (10YR6/1) Fe depletions; friable.

BCg1—80 to 100 cm; light brownish gray (2.5Y6/2) silt loam; few fine prominent strong brown (7.5YR4/6) masses of Fe; very friable.

BCg2—100 to 132 cm; light brownish gray (2.5Y6/2) silt loam; common medium distinct brownish yellow (10YR6/6) and few fine prominent strong brown (7.5YR4/6) masses of Fe; very friable.

2Ab1—132 to 150 cm; very dark gray (2.5Y3/1) clay loam; friable.

2Ab2—150 to 160 cm; very dark gray (10YR3/1) clay loam; common medium faint dark yellowish brown (10YR4/4) masses of Fe; firm.

Appendix A (continued).

2Btgb—160 to 175 cm; grayish brown (10YR5/2) clay loam; common medium distinct strong brown (7.5YR4/6) and yellowish brown (10YR5/8) masses of Fe; 10% coarse fragments; friable.

Appendix A (continued).

Wye Island 1 (site 18)

Location: 10 m west of Wye Island Rd; Wye Island.
Lat./Long.: 38°53'39.66" N 76°08'49.69" W
County: Queen Annes
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah on July 21, 2000; charcoal sampled for ^{14}C dating from 2Ab horizon.

A—0 to 6 cm; very dark grayish brown (10YR3/2) silt loam; weak medium granular structure; very friable; abrupt smooth boundary.

Eg—6 to 17 cm; grayish brown (2.5Y5/2) silt loam; few fine distinct yellowish brown (10YR5/6) masses of Fe; weak fine and medium subangular blocky structure; friable; clear smooth boundary.

Btg1—17 to 33 cm; grayish brown (2.5Y5/2) silt loam; common medium distinct yellowish brown (10YR5/8) and few medium prominent strong brown (7.5YR4/6) masses of Fe; moderate medium subangular blocky structure; friable; gradual smooth boundary.

Btg2—33 to 56 cm; gray (2.5Y5/1) silt loam; common fine and medium distinct yellowish brown (10YR5/8) masses of Fe; moderate medium subangular blocky structure; friable; clear smooth boundary.

Btg3—56 to 80 cm; gray (2.5Y6/1) silt loam; common medium prominent strong brown (7.5YR5/8) and few fine prominent strong brown (7.5YR4/6) masses of Fe; weak coarse prismatic parting to moderate medium subangular blocky structure; firm; clear wavy boundary.

2Ab—80 to 100 cm; very dark gray (2.5Y3/1) loam; few medium distinct dark yellowish brown (10YR4/6) masses of Fe; weak medium subangular blocky structure; 5% coarse fragments; friable.

Appendix A (continued).

Wye Island 2 (site 19)

Location: 10 m west of Wye Island Rd; Wye Island; 70 m south of Wye Island 1.
Lat./Long.: 38°53'42.20" N 76°08'50.60" W
County: Queen Annes
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Somewhat poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah on July 21, 2000; sampled by auger.

A—0 to 10 cm; dark brown (10YR3/3) silt loam; very friable.

E—10 to 28 cm; light olive brown (2.5Y5/4) silt loam; very friable.

Bt1—28 to 45 cm; light olive brown (2.5Y5/6) silt loam; common fine faint yellowish brown (10YR5/6) masses of Fe; common medium faint light brownish gray (2.5Y6/2) Fe depletions; friable.

Bt2—45 to 73 cm; light olive brown (2.5Y5/4) silty clay loam; common fine distinct strong brown (7.5YR5/8) masses of Fe; many medium distinct light gray (2.5Y7/1) Fe depletions; friable.

Bt3—73 to 110 cm; light olive brown (2.5Y5/3) silt loam; common fine prominent strong brown (7.5YR4/6) masses of Fe; many medium faint gray (2.5Y6/1) Fe depletions; friable.

2Ab1—110 to 140 cm; dark gray (2.5Y4/1) sandy loam; few fine faint dark yellowish brown (10YR4/6) masses of Fe; friable.

2Ab2—140 to 150 cm; dark gray (2.5Y4/1) sandy loam; very friable.

2C1—150 to 165 cm; light olive brown (2.5Y5/3) loamy fine sand; 8% coarse fragments; very friable.

2C2—165 to 180 cm; light yellowish brown (2.5Y6/3) gravelly loamy fine sand; 15% coarse fragments; very friable.

Appendix A (continued).

Wye Island 3 (site 20)

Location: 25 m east of Wye Island Rd; Wye Island; 70 m south of Wye Island 1.
Lat./Long.: 38°53’41.31” N 76°08’52.47” W
County: Queen Annes
Landform: Terrace
Relief:
Elevation:
Slope: 0
Aspect: -
Drainage: Poorly drained
Parent material:
Vegetation: Mixed hardwood
Notes: Described and sampled by John Wah on July 25, 2000; sampled by auger.

A—0 to 7 cm; very dark grayish brown (10YR3/2) silt loam; very friable.

BEg—7 to 21 cm; gray (2.5Y6/1) silt loam; many medium distinct brownish yellow (10YR6/6) and few fine distinct yellowish brown (10YR5/8) masses of Fe; friable.

Btg1—21 to 47 cm; gray (2.5Y6/1) silt loam; many medium distinct yellowish brown (10YR5/8) and common fine distinct dark yellowish brown (10YR4/6) masses of Fe; friable.

Btg2—47 to 77 cm; light brownish gray (2.5Y6/2) silt loam; common medium distinct yellowish brown (10YR5/8) and common fine distinct brownish yellow (10YR6/6) masses of Fe; friable.

Bt—77 to 83 cm; yellowish brown (10YR5/8) silt loam; many coarse distinct gray (2.5Y6/1) Fe depletions; friable.

Btg—83 to 103 cm; grayish brown (2.5Y5/2) silt loam; common fine prominent strong brown (7.5YR4/6) and common medium distinct yellowish brown (10YR5/8) masses of Fe; friable.

2Ab—103 to 111 cm; dark gray (10YR4/1) loam; common medium faint gay (10YR6/1) Fe depletions; friable.

2C—111 to 120 cm; white (10YR8/1) loamy fine sand; very friable.

3Ab—120 to 137 cm; dark gray (10YR4/1) loamy fine sand; very friable.

Appendix B. Particle size distribution.

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Sassafras NRMA	Ap 0-33	11.7	74.7	13.6	32.6	42.2	0.6	1.6	1.9	1.9	5.7
Sassafras NRMA	Bt1 33-53	10.2	68.6	21.2	37.1	31.6	0.3	0.9	2.0	1.5	5.5
Sassafras NRMA	Bt2 53-80	7.1	68.6	24.3	35.8	32.8	0.0	0.8	0.8	1.1	4.3
Sassafras NRMA	Bt3 80-115	7.9	74.1	17.9	37.1	37.1	0.1	0.6	1.3	0.8	5.1
Sassafras NRMA	2Bt4 115-140	49.2	37.9	12.9	20.2	17.7	7.6	15.3	12.0	10.6	3.8
Mesa	A 0-10	9.3	76.8	14.0	29.6	47.2	0.1	1.3	1.6	2.1	4.1
Mesa	E 10-29	9.7	75.6	14.7	36.0	39.7	0.8	1.3	2.3	2.3	2.9
Mesa	Btg 29-61	6.4	70.8	22.8	38.2	32.6	0.1	0.5	1.3	1.5	3.0
Mesa	Bt1 61-79	9.9	72.3	17.8	28.8	43.5	0.1	0.4	2.4	2.0	5.0
Mesa	Bt2 79-95	11.3	65.7	23.0	27.0	38.7	0.5	1.1	2.7	2.3	4.7
Mesa	Bt3 95-115	7.8	69.4	22.9	33.7	35.7	0.2	0.8	1.9	1.7	3.2
Mesa	Bt4 115-145	38.2	43.2	18.5	24.8	18.5	2.0	10.6	10.6	10.5	4.7
Mesa	2BC 145-170	46.3	34.9	18.8	18.1	16.8	3.4	9.8	17.4	11.2	4.4
Plugge 50	Ap 0-21	12.4	74.7	12.9	35.4	39.3	0.4	1.2	2.9	2.9	5.0
Plugge 50	Bt1 21-46	11.2	63.3	25.5	31.4	31.9	0.2	0.9	2.2	2.4	5.4
Plugge 50	Bt2 46-71	10.3	68.0	21.7	34.9	33.1	0.1	1.5	1.9	2.9	3.8
Plugge 50	Bt3 71-88	33.5	46.3	20.2	28.7	17.7	0.7	5.3	12.6	11.4	3.4
Plugge 50	2Bt4 88-110	59.4	23.8	16.8	16.2	7.6	2.3	13.6	16.4	23.0	4.2
Plugge 50	2BC 110-120	77.5	13.9	8.6	9.4	4.5	3.0	10.2	27.2	30.8	6.2

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Wye Island 2	A 0-10	9.0	73.3	17.8	40.7	32.5	0.7	0.9	1.5	3.1	2.8
Wye Island 2	E 10-28	11.2	72.5	16.4	43.2	29.2	0.3	0.7	1.8	3.4	4.9
Wye Island 2	Bt1 28-45	8.7	69.0	22.3	39.5	29.5	0.3	0.4	1.3	2.2	4.4
Wye Island 2	Bt2 45-73	8.9	58.1	33.0	26.4	31.7	0.0	0.1	0.8	1.6	6.4
Wye Island 2	Bt3 74-110	9.4	71.0	19.7	36.2	34.8	0.1	0.2	0.9	3.0	5.1
Wye Island 2	2Ab1 110-140	51.6	32.5	15.9	21.4	11.1	0.4	1.5	6.9	37.1	5.7
Wye Island 2	2Ab2 140-150	70.9	11.3	17.8	8.0	3.2	0.7	2.0	8.9	52.5	6.8
Wye Island 2	2C 150-165	82.5	8.8	8.7	5.7	3.1	1.2	2.7	10.1	61.2	7.2
Wye Island 2	3C 165-180	87.5	5.3	7.2	4.2	1.0	2.4	2.3	9.6	67.8	5.4
Royal Oaks	A 0-8	23.8	61.2	15.1	36.7	24.5	0.3	1.5	8.0	11.1	2.9
Royal Oaks	Eg 8-20	19.5	59.2	21.4	36.8	22.4	0.2	1.1	6.5	8.5	3.1
Royal Oaks	Btg1 20-39	10.2	55.6	34.2	33.0	22.6	0.1	0.9	2.2	4.2	2.8
Royal Oaks	Btg2 39-76	5.7	68.1	26.3	34.5	33.6	0.0	0.1	0.8	1.5	3.3
Royal Oaks	2Ab 76-98	59.1	26.6	14.3	15.9	10.7	0.9	5.8	16.7	32.8	2.9
Royal Oaks	2C 98-150	79.9	16.2	4.0	9.0	7.1	0.5	4.3	28.3	43.4	3.3
Holly Harbor	A 0-8	3.1	79.7	17.2	51.5	28.2	0.1	0.2	0.5	1.1	1.3
Holly Harbor	E 8-16	3.8	80.0	16.2	52.1	27.9	0.0	0.2	0.5	1.5	1.7
Holly Harbor	Btg1 16-39	2.8	61.0	36.3	36.4	24.5	0.0	0.1	0.3	0.6	1.7
Holly Harbor	Btg 2 39-70	2.2	60.8	36.9	30.0	30.8	0.1	0.0	0.1	0.2	1.8
Holly Harbor	BCg 1 70-80	4.8	73.8	21.3	40.4	33.5	0.1	0.2	0.3	2.6	1.6
Holly Harbor	2BCg2 80-97	37.2	43.9	18.9	27.7	16.2	0.1	1.1	6.5	26.8	2.6
Holly Harbor	2BCg3 97-110	62.2	23.4	14.4	17.2	6.2	0.9	3.7	8.6	46.1	2.9

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Horn Point	Ap 0-29	27.6	57.4	14.9	30.1	27.4	0.3	2.2	8.5	11.1	5.5
Horn Point	BE 29-48	20.0	62.6	17.5	35.0	27.6	0.1	1.9	4.5	8.5	5.0
Horn Point	Bt1 48-67	21.4	58.8	19.9	30.5	28.3	0.1	1.2	6.3	8.4	5.3
Horn Point	Bt2 67-78	34.5	50.7	14.9	24.4	26.3	0.2	3.3	8.9	16.2	5.8
Horn Point	2Ab 78-100	17.8	61.9	20.3	29.2	32.7	0.4	1.7	4.0	4.8	7.0
Horn Point	100	39.4	46.3	14.3	33.4	12.9	1.1	3.7	7.8	8.5	18.3
Horn Point	110	44.7	31.8	23.5	18.4	13.4	1.5	5.7	6.7	11.3	19.6
Horn Point	120	49.7	28.9	21.3	16.7	12.2	4.3	7.1	12.4	10.6	15.4
Horn Point	130	39.4	33.6	27.0	20.3	13.3	1.4	3.6	3.6	8.4	22.4
Andrews	A 0-28	5.7	71.1	23.2	43.6	27.5	0.1	0.1	0.2	1.4	3.9
Andrews	BEg 28-39	4.9	70.9	24.2	45.5	25.4	0.0	0.1	0.2	1.6	3.1
Andrews	Btg1 39-50	3.2	65.6	31.1	42.1	23.5	0.1	0.1	0.1	0.6	2.4
Andrews	Btg2 50-74	8.7	66.9	24.4	38.1	28.7	0.0	0.1	0.2	2.7	5.7
Andrews	BCg1 74-88	46.2	34.6	19.1	20.1	14.5	0.0	0.1	1.8	20.0	24.3
Andrews	2 BCg2 88-100	55.6	23.4	21.0	11.3	12.1	0.0	0.1	0.8	25.8	28.8
Blackwater VC	Ap 0-20cm	10.2	69.8	20.0	40.4	29.4	0.1	0.3	2.9	5.4	1.4
Blackwater VC	BEg 20-40cm	8.4	68.3	23.4	42.3	25.9	0.1	0.2	2.4	4.2	1.4
Blackwater VC	Btg1 40-55cm	8.1	56.0	36.0	33.5	22.5	0.0	0.2	2.4	4.2	1.3
Blackwater VC	2Btg2 55-60cm	41.1	41.8	17.0	25.9	15.9	0.2	0.9	13.9	24.9	1.2
Blackwater VC	2Cg1 60-70cm	79.0	16.7	4.3	10.1	6.6	0.7	1.6	24.9	50.0	1.8
Blackwater VC	2Cg2 70-80cm	81.8	13.7	4.5	10.3	3.4	0.8	2.1	27.3	50.0	1.6

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Church Creek	A 0-4	9.2	73.3	17.5	42.4	30.9	0.3	1.4	2.7	2.3	2.5
Church Creek	Eg 4-18	8.5	75.8	15.7	47.2	28.6	0.2	1.4	2.8	2.1	1.9
Church Creek	BEg 18-31	6.1	68.5	25.4	40.5	28.1	0.2	0.4	2.0	1.2	2.3
Church Creek	Btg1 31-58	3.7	63.5	32.7	40.6	22.9	0.0	0.3	1.1	0.7	1.7
Church Creek	Btg2 58-89	3.0	61.5	35.5	36.4	25.1	0.1	0.3	0.3	0.3	2.0
Church Creek	2BCg 89-100	29.0	47.3	23.7	27.0	20.3	1.2	5.4	12.1	8.4	1.9
Church Creek	2Cg 100-110	79.3	13.0	7.7	9.4	3.6	3.3	9.7	42.4	21.6	2.2
Princess Anne	A 0-10	10.5	77.0	12.5	44.4	32.7	0.6	1.5	3.5	2.0	2.9
Princess Anne	Btg1 10-28	5.2	63.8	31.0	40.4	23.5	0.1	0.8	1.6	0.9	1.8
Princess Anne	Btg2 28-46	8.6	63.0	28.5	40.2	22.8	0.3	1.3	2.9	1.8	2.3
Princess Anne	Btg3 46-59	36.8	28.0	35.2	22.1	5.9	3.4	10.0	10.8	8.7	3.9
Princess Anne	2BCg 59-80	52.2	24.6	23.1	18.6	6.0	4.2	10.9	20.3	10.9	6.0
Paw Paw Cove	Ap 1 0-10	15.5	71.0	13.5	38.2	32.7	0.5	2.0	4.4	1.7	6.9
Paw Paw Cove	Ap2 10-31	18.1	69.0	13.0	36.8	32.1	0.1	2.8	6.8	1.5	6.9
Paw Paw Cove	BE 31-42	6.4	69.4	24.2	39.0	30.5	0.0	0.1	0.3	0.7	5.2
Paw Paw Cove	Bt 42-54	4.9	65.5	29.6	35.2	30.3	0.0	0.0	0.1	0.4	4.4
Paw Paw Cove	Btx 54-63	5.1	55.5	39.4	35.1	20.4	0.0	0.1	0.1	0.8	4.1
Paw Paw Cove	Ab 63-92	7.8	57.4	34.8	37.6	19.9	0.0	0.0	0.1	1.3	6.4
Paw Paw Cove	Btxgb1 92-109	10.1	59.7	30.2	39.9	19.8	0.0	0.0	0.1	1.4	8.6
Paw Paw Cove	Btxgb2 109-139	9.1	61.7	29.2	41.4	20.3	0.0	0.1	0.1	1.4	7.5
Paw Paw Cove	Btxgb3 139-166	10.4	65.6	24.1	40.0	25.6	0.0	0.1	0.1	1.2	8.9
Paw Paw Cove	2BC 166-184	18.3	62.5	19.3	37.3	25.1	0.0	0.1	0.4	5.6	12.2
Paw Paw Cove	2Cg 184-210	51.2	36.9	11.9	16.5	20.5	0.0	0.1	0.2	15.5	35.4

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
James Island	A 0-9	34.0	49.7	16.4	24.8	24.9	0.2	0.4	2.4	15.9	15.0
James Island	Ap 9-22	9.0	79.0	12.0	41.1	37.9	0.2	0.2	0.7	1.7	6.2
James Island	E 22-33	5.6	74.1	20.3	44.8	29.2	0.1	0.1	0.4	0.9	4.0
James Island	BE 33-46	5.2	65.1	29.7	34.0	31.0	0.0	0.2	0.2	0.8	4.0
James Island	Btx 46-59	3.8	73.7	22.5	36.2	37.5	0.0	0.0	0.3	0.4	3.2
James Island	Btxg159-88	6.6	62.5	30.9	33.4	29.1	0.1	0.0	0.2	1.4	5.0
James Island	Ab 88-106	15.5	52.0	32.5	32.5	19.5	0.1	0.1	0.2	5.4	9.7
James Island	Btxb 106-130	24.8	48.0	27.1	30.4	17.7	0.0	0.0	0.2	7.5	17.2
James Island	BC 130-145	27.9	49.1	22.9	26.9	22.3	0.0	0.0	0.0	6.5	21.4
James Island	BCg 145-158	26.5	54.3	19.2	25.2	29.0	0.1	0.0	0.0	3.2	23.2
James Island	2C 158-180	67.4	15.1	17.5	8.5	6.6	0.1	0.1	0.6	58.3	8.3
James Island	2Cg 180-195	42.9	43.9	13.2	15.7	28.2	0.0	0.1	0.1	3.3	39.4
Oyster Cove Point	Ap 0-16	8.8	76.2	15.0	38.9	37.3	0.2	0.4	1.4	1.8	5.0
Oyster Cove Point	BE 16-22	5.4	65.0	29.6	37.4	27.6	0.1	0.1	0.3	0.8	4.0
Oyster Cove Point	Btg 22-40	4.7	64.7	30.6	34.1	30.6	0.0	0.2	0.1	0.5	3.9
Oyster Cove Point	Btx 40-53	6.2	64.2	29.6	37.7	26.5	0.0	0.0	0.0	0.5	5.7
Oyster Cove Point	Ab 53-80	9.9	57.9	32.3	34.5	23.4	0.0	0.0	0.1	0.7	9.0
Oyster Cove Point	Btxb1 80-108	12.5	58.7	28.8	35.0	23.8	0.0	0.0	0.1	0.9	11.5
Oyster Cove Point	Btxb2 108-138	15.0	60.7	24.3	33.2	27.5	0.0	0.0	0.0	1.0	14.1
Oyster Cove Point	BCg 138-178	14.0	67.3	18.7	36.0	31.3	0.0	0.0	0.0	0.8	13.2
Oyster Cove Point	2Cg 178-183	58.0	28.1	13.9	13.4	14.7	0.0	0.1	0.3	23.8	33.8
Rockhall	A 0-9	17.3	65.3	17.4	29.6	35.6	0.9	0.5	1.8	6.2	8.0
Rockhall	BE 9-20	19.2	66.6	14.2	31.7	34.9	0.9	0.8	1.6	7.7	8.1
Rockhall	Btg 20-53	14.5	67.6	17.9	33.8	33.7	0.1	0.1	1.1	5.4	7.8
Rockhall	2C 53-70	77.0	16.4	6.6	8.2	8.2	0.1	0.5	2.2	62.8	11.4

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Wye Island 1	A 0-6	9.0	70.5	20.5	42.5	28.1	0.4	0.7	1.3	3.8	2.7
Wye Island 1	EB 6-17	13.3	71.2	15.4	45.5	25.7	0.3	0.9	2.0	5.6	4.5
Wye Island 1	Btg1 17-33	11.0	63.9	25.2	26.5	37.3	1.0	0.6	1.7	3.4	4.2
Wye Island 1	Btg2 33-56	8.8	66.9	24.3	33.9	33.0	0.1	0.2	0.7	2.5	5.2
Wye Island 1	Btg3 56-80	10.5	64.6	24.9	38.2	26.4	0.2	0.3	1.3	5.2	3.5
Wye Island 1	2Ab 80-108	47.8	33.7	18.5	24.2	9.5	0.5	1.5	6.0	33.3	6.6
Wye Island 3	A 0-7	7.4	75.2	17.4	43.4	31.8	0.3	0.6	1.4	2.6	2.4
Wye Island 3	EBg 7-21	5.6	73.3	21.1	45.4	27.9	0.2	0.4	1.0	1.8	2.3
Wye Island 3	Btg1 21-41	5.4	72.5	22.0	46.5	26.1	0.1	0.4	1.0	1.7	2.2
Wye Island 3	Btg2 41-77	10.5	66.2	23.3	33.2	33.0	0.0	0.4	1.9	3.8	4.4
Wye Island 3	Bt 77-83	8.6	70.8	20.6	35.1	35.7	0.3	0.6	1.1	2.8	3.7
Wye Island 3	Btg3 83-103	6.6	73.5	20.0	38.8	34.7	0.1	0.1	0.7	2.6	3.0
Wye Island 3	2Ab 103-111	29.8	49.6	20.6	30.5	19.2	0.3	1.1	4.3	21.5	2.6
Wye Island 3	2C 111-120	81.6	13.7	4.7	9.9	3.8	1.4	3.7	13.5	58.8	4.1
Wye Island 3	3Ab 120-137	83.8	5.6	10.6	4.2	1.5	2.7	4.7	14.3	58.7	3.2
Dennys Farm	Ap 0-21	14.4	73.4	12.2	33.8	39.7	0.3	0.2	0.8	1.9	11.2
Denny's Farm	Bt1 21-37	12.0	69.6	18.4	35.8	33.8	0.1	0.3	0.5	1.4	9.7
Denny's Farm	Bt2 37-60	11.6	66.3	22.1	31.8	34.5	0.1	0.2	0.4	2.0	8.9
Denny's Farm	Bt3 60-77	13.4	70.1	16.6	31.9	38.2	0.1	0.1	0.7	1.8	10.7
Denny's Farm	Bt4 77-98	12.4	70.0	17.6	28.0	42.0	0.0	0.1	0.4	2.4	9.5
Denny's Farm	Bt5 98-126	9.5	76.4	14.1	31.3	45.2	0.1	0.1	0.5	1.3	7.6
Denny's Farm	Bt6 126-158	6.0	72.8	21.2	33.3	39.5	0.0	0.0	0.1	1.0	4.9
Denny's Farm	Bt7 158-185	31.4	48.0	20.6	26.0	22.0	0.0	0.1	0.4	10.3	20.6
Denny's Farm	2Bt8 185-200	42.1	36.4	21.4	17.2	19.2	0.0	0.1	0.2	14.4	27.5
Denny's Farm	2BC 200-230	58.0	28.7	13.3	12.7	16.0	0.0	0.0	0.4	17.7	39.9

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Todds Corner	A 0-6	14.1	74.6	11.3	39.1	35.5	0.4	0.9	2.2	5.7	4.8
Todds Corner	E 6-14	15.0	75.5	9.6	42.0	33.4	0.6	1.6	3.0	6.1	3.6
Todds Corner	BE 14-40	10.5	72.9	16.6	40.7	32.1	0.2	0.7	1.9	4.5	3.3
Todds Corner	Bt1 40-52	7.8	62.6	29.5	32.0	30.6	0.2	0.5	1.2	3.1	2.9
Todds Corner	Bt2 52-74	7.5	66.1	26.4	32.0	34.1	0.3	0.3	1.1	2.7	3.0
Todds Corner	Btg1 74-98	5.2	73.2	21.6	36.0	37.2	0.2	0.2	0.6	1.5	2.6
Todds Corner	Btg2 98-110	11.7	66.5	21.8	36.1	30.4	0.3	0.7	2.6	6.3	1.7
Todds Corner	2Ab 110-138	49.3	30.8	20.0	18.6	12.1	1.8	5.7	9.0	30.2	2.6
Todds Corner	2 BC 130-140	82.0	6.9	11.1	4.9	2.0	2.3	6.7	20.7	49.1	3.1
Bishops Head	A 0-8	11.7	69.4	18.9	39.3	30.1	1.1	0.4	0.4	2.1	7.6
Bishops head	BEg 8-30	12.6	63.1	24.3	39.8	23.3	0.2	1.0	1.4	2.4	7.6
Bishops head	Btg1 30-49	4.9	74.7	20.4	44.9	29.7	0.0	0.1	0.1	0.8	4.0
Bishops head	Btg2 49-60	7.7	64.1	28.2	39.1	25.1	0.0	0.0	0.3	1.0	6.4
Bishops head	Btg3 60-80	19.3	52.5	28.3	30.8	21.6	0.0	0.2	0.4	3.4	15.3
Bishops head	Btg4 80-100	20.2	50.7	29.1	30.0	20.8	0.0	0.1	0.7	2.7	16.7
Bishops head	Btg5 100-130	23.6	52.7	23.7	27.5	25.2	0.0	0.1	0.3	4.9	18.3
Bishops Head	2BCg1 130-160	40.0	44.5	15.5	18.8	25.7	0.1	0.0	0.1	2.7	37.1
Bishops Head	2BCg2 160-185	66.1	24.4	9.5	11.3	13.1	0.0	0.1	0.1	12.1	53.9
Pauls Corner	A 0-8	30.5	54.6	14.8	34.0	20.6	0.4	2.6	16.4	9.8	1.4
Pauls Corner	Eg 8-18	29.5	55.0	15.5	35.5	19.5	0.2	1.9	16.3	9.7	1.4
Pauls Corner	Btg1 18-43	29.9	48.2	21.8	30.9	17.3	0.1	0.6	19.8	8.0	1.4
Pauls Corner	2Btg2 43-60	44.1	36.4	19.5	23.7	12.7	0.3	0.9	28.6	13.0	1.3
Pauls Corner	2Cg 60-70	86.2	7.0	6.8	4.3	2.7	0.5	3.2	48.1	32.6	1.8

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Jefferson Island	A 0-9	11.6	73.5	14.8	41.7	31.9	0.2	0.6	1.2	2.2	7.4
Jefferson Island	E 9-20	11.8	78.0	10.2	41.4	36.6	0.3	0.6	0.9	2.9	7.0
Jefferson Island	BE 20-33	10.1	71.0	18.9	40.1	30.9	0.0	0.2	0.7	1.7	7.5
Jefferson Island	Bt 33-50	8.1	68.8	23.2	37.6	31.2	0.1	0.2	0.3	1.7	5.8
Jefferson Island	Btx 50-75	13.0	65.7	21.3	39.4	26.3	0.0	0.2	0.6	2.0	10.3
Tilghman Island	Ap 0-15	12.3	70.7	17.0	40.0	30.7	0.3	0.5	2.3	3.9	5.3
Tilghman Island	AE 15-30	9.5	77.9	12.6	42.0	35.8	0.2	0.3	0.9	1.4	6.8
Tilghman Island	Bt1 30-61	7.9	68.2	23.8	38.1	30.2	0.1	0.0	0.2	1.0	6.6
Tilghman Island	Bt2 61-88	8.8	65.9	25.3	35.5	30.3	0.0	0.1	0.2	0.9	7.7
Tilghman Island	Bt3 88-105	12.4	62.0	25.7	32.4	29.5	0.0	0.0	0.2	2.3	9.8
Tilghman Island	2BC1 105-145	41.9	42.5	15.6	17.9	24.5	0.1	0.0	0.1	7.2	34.6
Tilghman Island	2BC2 145-180	53.8	31.8	14.4	13.5	18.3	0.2	0.1	0.1	16.2	37.3
Earleville WMA	Ap 0-20	9.7	77.2	13.1	38.5	38.7	0.4	0.6	0.7	3.1	4.9
Earleville WMA	Bt1 20-53	7.3	67.7	25.0	34.6	33.1	0.2	0.3	0.6	1.5	4.7
Earleville WMA	Bt2 53-83	8.7	75.7	15.5	36.2	39.5	0.1	0.5	0.6	3.0	4.5
Earleville WMA	Bt3 83-111	18.5	63.2	18.3	29.7	33.5	1.1	1.7	2.8	7.3	5.6
Earleville WMA	Bt4 111-130	13.9	67.8	18.3	34.5	33.3	0.4	1.1	1.5	5.8	5.1
Earleville WMA	2Ab/Bt5 130-170	20.4	57.7	21.9	34.1	23.7	0.5	1.8	4.9	7.3	5.9
Earleville WMA	2Btb1 170-218	10.7	53.4	35.9	28.2	25.2	0.3	1.1	1.5	3.7	4.2
Earleville WMA	2Btb2 218-231	17.2	61.9	20.9	35.2	26.7	0.4	1.0	2.7	5.4	7.7
Earleville WMA	2Btb3 231-263	22.9	42.7	34.5	23.5	19.2	0.6	1.7	2.8	8.4	9.4
Earleville WMA	2Btb4 263-288	21.2	41.9	36.9	23.1	18.8	0.1	0.5	1.6	4.5	14.4
Earleville WMA	3Btb5 288-331	54.8	19.3	25.9	12.1	7.2	3.8	9.9	11.5	22.6	7.0

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Centreville Pit	A 0-10	14.2	69.9	15.8	38.6	31.3	0.8	2.9	5.1	2.7	2.8
Centreville Pit	E 10-28	13.7	72.1	14.2	40.7	31.4	0.3	2.2	4.8	2.5	4.0
Centreville Pit	Bt1 28-71	10.4	63.0	26.6	34.1	28.8	0.4	2.2	2.6	2.0	3.2
Centreville Pit	Bt2 71-91	16.0	62.8	21.3	28.6	34.2	0.7	2.4	5.0	2.8	5.2
Centreville Pit	Bt3 91-114	9.7	69.7	20.5	31.5	38.3	0.2	1.8	1.8	1.6	4.5
Centreville Pit	Bt4 114-122	13.3	63.1	23.6	35.4	27.8	0.2	2.1	4.6	2.9	3.4
Centreville Pit	Bt5 122-137	18.9	59.1	22.0	33.9	25.2	0.4	4.3	5.4	5.4	3.5
Centreville Pit	BC 137-150	45.3	36.3	18.4	22.4	13.9	2.4	8.9	17.4	12.2	4.4
Centreville South	A 0-6	22.0	70.5	7.5	40.7	29.8	1.2	4.6	6.6	4.4	5.2
Centreville South	E 8-15	15.9	71.2	12.9	42.7	28.5	0.6	3.7	4.3	3.7	3.7
Centreville South	BE 15-28	14.0	66.3	19.8	38.8	27.5	0.5	2.1	4.7	2.5	4.1
Centreville South	Bt1 28-56	13.5	62.4	24.1	33.0	29.3	0.3	2.6	3.4	2.7	4.4
Centreville South	Bt2 56-90	16.3	64.2	19.5	29.1	35.1	0.3	2.0	4.8	2.8	6.3
Centreville South	Bt3 90-114	27.2	53.0	19.8	23.8	29.2	1.2	2.9	4.0	9.9	9.1
Centreville South	2Bt4 114-130	60.6	21.0	18.5	10.7	10.3	4.5	11.2	22.0	17.7	5.1
Centreville South	2Bt5 130-168	55.9	20.8	23.3	11.4	9.5	6.0	12.1	19.8	13.2	4.8
Centreville South	2BC 168-200	72.5	14.7	12.8	8.2	6.5	2.9	11.8	32.2	20.4	5.2
Centreville North	A 0-10	18.6	70.1	11.2	40.4	29.7	1.1	3.5	6.4	3.7	3.9
Centreville North	AE 10-30.5	14.1	71.9	14.1	39.6	32.3	0.8	2.6	5.0	2.7	3.0
Centreville North	Bt1 31-74	11.7	62.7	25.6	31.9	30.8	0.4	1.7	3.5	2.1	3.9
Centreville North	Bt2 74-102	13.4	64.5	22.1	31.0	33.5	0.2	2.2	3.2	3.1	4.6
Centreville North	Bt3 102-132	22.4	59.0	18.7	29.2	29.8	1.2	4.7	8.2	3.8	4.3
Centreville North	Bt4 132-158	27.4	53.4	19.2	33.5	19.9	0.6	4.9	11.4	6.9	3.5
Centreville North	2BC 158-200	54.0	29.0	17.0	18.3	10.7	2.5	9.8	22.4	14.9	4.4

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Big Dog	A 0-10	21.4	64.8	13.9	35.6	29.2	1.1	4.3	7.7	4.5	3.8
Big Dog	AE 10-23	18.9	68.3	12.8	36.8	31.4	0.9	4.3	5.6	4.8	3.5
Big Dog	Bt 1 23-37	13.0	63.2	23.8	37.9	25.3	0.9	2.1	4.7	2.8	2.4
Big Dog	Bt2 37-67	18.7	54.8	26.5	30.3	24.5	0.4	2.5	7.9	4.8	3.0
Big Dog	Bt3 67-90	34.7	44.3	21.0	21.3	23.0	0.5	6.9	12.0	11.2	4.1
Big Dog	2BC 90-112	55.6	29.3	15.2	12.9	16.4	2.2	10.0	23.6	15.5	4.2
Little Neck	A 0-8	22.1	65.5	12.4	35.2	30.3	0.8	5.4	6.7	5.9	3.3
Little Neck	AE 8-15	24.3	65.4	10.4	37.2	28.1	0.8	4.4	9.5	5.8	3.7
Little Neck	BE 15-20	18.0	70.4	11.6	43.5	26.9	0.7	3.1	7.5	4.7	2.1
Little Neck	Bt 20-40	17.8	65.9	16.3	40.6	25.3	1.0	2.9	7.5	4.4	2.0
Little Neck	Bt2 40-60	11.9	60.7	27.4	35.3	25.4	0.5	1.8	3.9	2.5	3.2
Little Neck	2BC 60-70	51.0	37.2	11.8	17.7	19.5	1.8	12.1	17.1	15.5	4.4
Matthewstown	Ap 0-9	6.6	73.9	19.6	40.4	33.4	0.6	0.7	1.0	1.1	3.2
Matthewstown	EB 9-28	6.9	75.4	17.7	40.8	34.6	0.1	0.4	0.8	0.9	4.8
Matthewstown	Bt 28-56	7.4	66.5	26.1	31.1	35.4	0.3	0.5	0.7	0.8	5.2
Matthewstown	Btg 56-77	6.0	70.5	23.5	30.5	40.1	0.3	0.3	0.3	0.4	4.7
Matthewstown	Btgb1 77-109	6.5	66.3	27.2	38.2	28.1	0.2	0.6	0.7	0.8	4.1
Matthewstown	Btgb2 109-125	18.1	47.4	34.5	27.8	19.5	1.1	2.3	2.7	3.0	9.1
Matthewstown	2Btb1 125-150	20.0	33.5	46.5	18.2	15.3	1.8	2.4	2.9	3.7	9.2
Matthewstown	2Btgb1 150-167	21.3	40.8	37.9	21.3	19.5	2.4	3.4	2.7	2.7	10.1
Matthewstown	2Btgb2 167-200	28.7	37.8	33.5	16.8	21.0	1.5	3.1	2.9	1.7	19.5

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Matthews 2	A 0-8	7.1	77.0	16.0	42.1	34.9	0.6	0.6	0.7	1.0	4.2
Matthews 2	BEg 8-26	7.7	74.4	17.8	38.7	35.8	0.8	0.5	0.8	0.8	4.8
Matthews 2	Btg1 26-40	5.7	73.1	21.2	34.5	38.6	0.2	0.3	0.5	0.5	4.2
Matthews 2	Btg2 40-57	6.0	71.5	22.5	32.3	39.2	0.2	0.3	0.4	0.5	4.6
Matthews 2	Btgb1 57-90	5.2	67.0	27.8	32.9	34.1	0.2	0.4	0.5	0.5	3.7
Matthews 2	Btgb2 90-110	11.6	50.6	37.8	30.0	20.6	0.8	2.1	1.9	1.2	5.6
Matthews 2	Btb 110-145	22.8	41.2	36.0	19.8	21.4	3.6	5.0	4.7	3.7	5.9
Matthews 2	Btgb3 145-170	19.8	41.1	39.1	20.6	20.5	1.7	2.8	2.7	2.0	10.6
Matthews 2	Btgb4 170-200	19.1	39.1	41.8	22.8	16.3	1.6	3.8	4.5	2.3	6.9
Matthews 2	2Bt 200-220	27.0	37.5	35.5	25.5	12.0	4.0	4.0	6.3	6.0	6.7
Blackwalnut Point	A	10.4	78.6	10.9	45.2	33.5	0.3	0.3	0.5	2.5	6.9
Blackwalnut point	E 6-13	9.4	76.3	14.4	43.4	32.8	0.3	0.4	0.6	1.9	6.1
Blackwalnut point	BE 13-34	7.3	69.1	23.6	38.0	31.1	0.1	0.3	0.4	1.6	4.9
Blackwalnut point	Bt1 34-67	15.0	65.0	19.9	32.2	32.9	0.1	0.1	0.5	5.5	8.8
Blackwalnut point	Bt2 67-86	7.8	68.6	23.7	39.5	29.1	0.2	0.0	0.2	0.9	6.4
Blackwalnut Point	Ab 86-109	12.8	59.1	28.2	36.5	22.6	0.1	0.1	0.1	1.1	11.4
Blackwalnut point	Btxb 109-130	15.9	56.0	28.1	35.0	21.1	0.1	0.0	0.1	1.4	14.2
Blackwalnut point	Btxbg 130-159	18.0	59.2	22.8	34.8	24.3	0.0	0.0	0.2	1.2	16.6
Blackwalnut point	BCgb1 159-182	19.8	63.6	16.6	32.4	31.2	0.0	0.0	0.1	1.4	18.3
Blackwalnut point	BCgb2 182-204	26.3	60.1	13.6	27.5	32.6	0.0	0.0	0.1	4.0	22.3
Blackwalnut point	2Cg 204-255	50.5	40.5	9.0	16.6	24.0	0.0	0.1	0.3	13.4	36.5

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Eastern Neck Low	A 0-9	29.1	49.2	21.7			1.5	0.1	2.3	9.7	14.8
Eastern Neck Low	AE 9-18	34.3	51.0	14.7	--	--	0.0	0.1	2.7	12.0	18.5
Eastern Neck Low	BE 18-35	--	--	--	--	--	--	--	--	--	--
Eastern Neck Low	Bt1 35-45	38.8	44.3	16.9	24.0	20.4	0.4	0.8	2.7	11.6	23.3
Eastern Neck Low	Bt2 45-65	44.7	37.7	17.6	19.1	18.6	0.6	1.1	2.8	12.3	27.9
Eastern Neck Low	2Bt3 65-80	60.3	21.2	18.5	10.2	10.9	0.1	0.3	1.4	12.2	46.3
Eastern Neck Low	2BC1 80-115	67.5	12.1	20.4	5.9	6.2	0.2	1.1	5.0	32.1	29.2
Eastern Neck Low	2BC2 115-146	75.0	10.7	14.3	6.5	4.2	0.3	1.7	6.7	46.5	19.8
Eastern Neck Low	2BC3 146-170	69.9	11.6	18.4	7.1	4.6	0.2	1.1	4.4	36.2	28.0
Eastern Neck Low	2Cg 146-170	78.6	11.8	9.7	6.8	5.0	0.1	1.2	4.0	31.2	42.1
Eastern Neck Low	2C 182-202	82.1	8.3	9.5	4.0	4.4	0.1	0.4	1.5	33.0	47.1
Eastern Neck Low	2C'g 202-218	83.3	8.4	8.3	4.1	4.3	0.1	0.7	2.4	40.5	39.5
Eastern Neck Low	2C1 218-260	82.7	8.4	8.9	5.5	2.9	0.2	0.7	2.3	33.5	46.0
Eastern Neck Low	2C2 260-310	78.0	13.9	8.1	5.1	8.8	0.0	0.3	0.9	11.1	65.7
Eastern Neck Mid	A 0-12	31.5	47.9	20.6	--	--	1.1	0.1	2.7	13.0	13.7
Eastern Neck Mid	AE 12-18	35.1	47.6	17.3	--	--	0.5	1.1	3.2	13.1	17.2
Eastern Neck Mid	BE 18-31	--	--	--	--	--	--	--	--	--	--
Eastern Neck Mid	Bt1 31-48	37.2	46.4	16.4	25.0	21.4	0.2	0.8	2.7	13.3	20.2
Eastern Neck Mid	Bt2 48-72	45.3	38.5	16.2	18.3	20.2	0.3	0.8	3.2	16.4	24.6
Eastern Neck Mid	2Bt3 72-95	59.3	23.2	17.5	10.6	12.6	0.1	0.3	2.2	16.1	40.5
Eastern Neck Mid	2BCg 95-140	72.1	9.7	18.3	3.7	6.0	0.1	1.7	7.3	44.7	18.3
Eastern Neck Mid	2BC 140-160	69.9	13.9	16.1	6.7	7.2	0.1	0.9	3.6	28.2	37.1
Eastern Neck Mid	2C1 160-195	68.4	12.1	19.5	5.8	6.2	0.2	1.1	4.4	32.6	30.1
Eastern Neck Mid	2C2 195-240	91.9	5.4	2.7	1.5	3.9	0.1	0.3	1.8	40.5	49.2

Appendix B (continued).

Pedon	Sample	% sand	%silt	% clay	% FSi	% CoSi	%vcos	%cos	%ms	%fs	%vfs
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Eastern Neck High	A 0-6	37.4	47.4	15.2	--	--	0.5	1.2	3.5	14.0	18.2
Eastern Neck High	AE 6-14	34.8	51.2	14.0	--	--	0.4	1.0	3.3	13.0	17.1
Eastern Neck High	EB 14-38	34.8	53.7	11.5	--	--	0.1	0.8	3.0	13.3	17.5
Eastern Neck High	Bt1 38-56	33.4	49.9	16.8	--	--	0.2	0.9	3.1	12.3	16.8
Eastern Neck High	Bt2 56-69	53.8	30.6	15.6	--	--	0.2	1.6	5.1	20.5	26.4
Eastern Neck High	BCt 69-90	76.6	11.1	12.4	--	--	0.1	1.7	7.7	37.7	29.4
Eastern Neck High	2Bt 90-104	52.0	23.6	24.4	--	--	0.1	0.3	1.1	7.6	42.9
Eastern Neck High	2BC1 104-121	65.9	14.7	19.4	--	--	0.1	0.7	3.7	26.8	34.5
Kings Creek	A 0-12	29.7	52.2	18.1	32.6	19.7	1.3	6.3	12.0	8.3	1.9
Kings Creek	BEg 12-25	26.9	53.9	19.2	34.7	19.2	1.7	6.9	8.2	8.3	1.9
Kings Creek	Btg1 25-40	21.8	54.4	23.8	17.1	37.2	1.2	3.7	8.5	6.2	2.2
Kings Creek	Btg2 40-60	18.3	58.2	23.6	36.1	22.1	0.8	4.6	5.4	5.4	2.0
Tolchester	A 0-6	9.8	74.7	15.5	45.6	29.1	0.1	0.3	0.6	0.8	8.0
Tolchester	E 6-22	10.2	76.3	13.5	44.9	31.4	0.2	0.9	0.7	1.7	6.7
Tolchester	Btg 22-55	5.3	60.8	33.9	36.0	24.8	0.0	0.1	0.1	0.4	4.7
Tolchester	Bt 55-80	6.4	72.5	21.1	37.4	35.1	0.1	0.0	0.1	0.3	5.9
Tolchester	BCg1 80-100	9.5	75.1	15.4	34.3	40.9	0.0	0.2	0.3	0.6	8.4
Tolchester	BCg2 100-132	6.9	76.3	16.7	35.0	41.3	0.0	0.0	0.1	0.3	6.6
Tolchester	2Ab1 132-150	11.9	51.1	37.0	32.2	18.9	0.6	1.9	1.9	3.4	4.1
Tolchester	2Ab2 150-160	21.6	43.6	34.9	28.0	15.6	1.5	2.7	5.0	5.9	6.4
Tolchester	2Btbg 160-175	26.1	42.9	31.1	26.9	16.0	2.0	2.9	5.8	7.5	7.8

Appendix C. Organic carbon data.

Pedon	Sample	Organic carbon (%)	Pedon	Sample	Organic carbon (%)
-------	------	------	-------	------	------
Wye Island 3	A 0-7	4.49	Oyster Cove Point	Ap 0-16	1.09
Wye Island 3	EBg 7-21	0.41	Oyster Cove Point	BE 16-22	0.33
Wye Island 3	Btg1 21-41	0.34	Oyster Cove Point	Btg 22-40	0.32
Wye Island 3	Btg2 41-77	0.20	Oyster Cove Point	Btx 40-53	0.21
Wye Island 3	Bt 77-83	0.19	Oyster Cove Point	Ab 53-80	0.22
Wye Island 3	Btg3 83-103	0.18	Oyster Cove Point	Btxb1 80-108	0.19
Wye Island 3	2Ab 103-111	0.17	Oyster Cove Point	Btxb2 108-138	0.17
Wye Island 3	2C 111-120	0.05	Oyster Cove Point	BCg 138-178	0.10
Wye Island 3	3Ab 120-137	0.10	Oyster Cove Point	2Cg 178-183	0.09
Earleville	Ap 0-20	0.92	Horn Point	Ap 0-29	1.01
Earleville WMA	Bt1 20-53	0.21	Horn Point	Bt1 48-67	0.22
Earleville WMA	Bt2 53-83	0.10	Horn Point	Bt2 67-78	0.20
Earleville WMA	Bt3 83-111	0.12	Horn Point	2Ab 78-100	0.21
Earleville WMA	Bt4 111-130	0.11	Horn Point	100	0.41
Earleville WMA	Ab 130-170	0.14	Horn Point	110	0.29
Earleville WMA	Btb1 170-218	0.13	Horn Point	120	0.18
Earleville WMA	Btb2 218-231	0.11	Horn Point	130	0.19
Earleville WMA	Btb3 231-263	0.14			
Earleville WMA	Btb4 263-288	0.11	Tolchester	A 0-6	2.04
Earleville WMA	2Btb5 288-331	0.08	Tolchester	E 6-22	1.01
			Tolchester	Btg 22-55	0.28
Royal Oaks	A 0-8	2.69	Tolchester	Bt 55-80	0.16
Royal Oaks	Eg 8-20	0.64	Tolchester	BCg1 80-100	0.11
Royal Oaks	Btg1 20-39	0.56	Tolchester	BCg2 100-132	0.10
Royal Oaks	Btg2 39-76	0.25	Tolchester	2Ab1 132-150	0.41
Royal Oaks	2Ab 76-98	0.27	Tolchester	2Ab2 150-160	0.56
Royal Oaks	2C 98-150	0.12	Tolchester	2Btbg 160-175	0.34
Todds Corner	A 0-6	3.94			
Todds Corner	E 6-14	1.67			
Todds Corner	BE 14-40	0.23			
Todds Corner	Bt1 40-52	0.22			
Todds Corner	Bt2 52-74	0.17			
Todds Corner	Btg1 74-98	0.18			
Todds Corner	Btg2 98-110	0.19			
Todds Corner	2Ab 110-138	0.15			
Todds Corner	2 BC 130-140	0.10			

Appendix D. Elemental analyses.

Site	Sample	ZrO_2 (%)		K_2O (%)		CaO (%)		TiO_2 (%)
------	------	------		------		------		------
Mesa	A 0-10	0.14		1.72		0.79		1.14
Mesa	E 10-29	0.11		1.79		0.75		1.06
Mesa	Btg 29-61	0.12		2.04		0.86		1.14
Mesa	Bt1 61-79	0.13		2.38		1.15		1.10
Mesa	Bt2 79-95	0.13		2.17		0.98		1.07
Mesa	Bt3 95-115	0.12		1.97		0.93		1.03
Mesa	Bt4 115-145	0.14		1.46		0.43		1.07
Mesa	2BC 145-170	0.15		1.21		0.15		1.12
Church Creek	A 0-4	0.13		1.67		0.54		1.52
Church Creek	Eg 4-18	0.11		1.69		0.52		1.40
Church Creek	BEg 18-31	0.10		1.99		0.60		1.28
Church Creek	Btg1 31-58	0.11		2.07		0.61		1.44
Church Creek	Btg2 58-89	0.12		2.17		0.86		1.53
Church Creek	2BCg 89-100	0.10		1.96		0.79		1.33
Church Creek	2Cg 100-110	0.13		1.49		0.41		1.42
Princess Anne	A 0-10	0.12		1.84		0.46		1.45
Princess Anne	Btg1 10-28	0.10		2.10		0.63		1.31
Princess Anne	Btg2 28-46	0.10		1.92		0.79		1.36
Princess Anne	Btg3 46-59	0.13		1.58		0.41		1.34
Princess Anne	2BCg 59-80	0.14		1.46		0.28		1.39
Horn Point	Ap 0-29	0.13		2.04		0.65		1.54
Horn Point	BE 29-48	0.12		2.19		0.61		1.50
Horn Point	Bt1 48-67	0.12		2.23		0.62		1.53
Horn Point	Bt2 67-78	0.12		2.26		0.66		1.18
Horn Point	2Ab 78-100	0.13		1.74		0.46		1.46
Horn Point	2Btb1 100-110	0.16		1.26		0.30		1.71
Horn Point	110	0.16		1.27		0.25		1.75
Horn Point	120	0.15		1.55		0.32		1.64
Horn Point	130	0.17		1.28		0.17		1.71
Royal Oaks	A 0-8	0.13		1.58		0.55		1.53
Royal Oaks	Eg 8-20	0.09		1.74		0.62		1.35
Royal Oaks	Btg1 20-39	0.08		1.89		0.74		1.29
Royal Oaks	Btg2 39-76	0.11		1.86		0.96		1.38
Royal Oaks	2Ab 76-98	0.11		1.74		0.73		1.35
Royal Oaks	2C 98-150	0.10		2.04		0.77		1.37

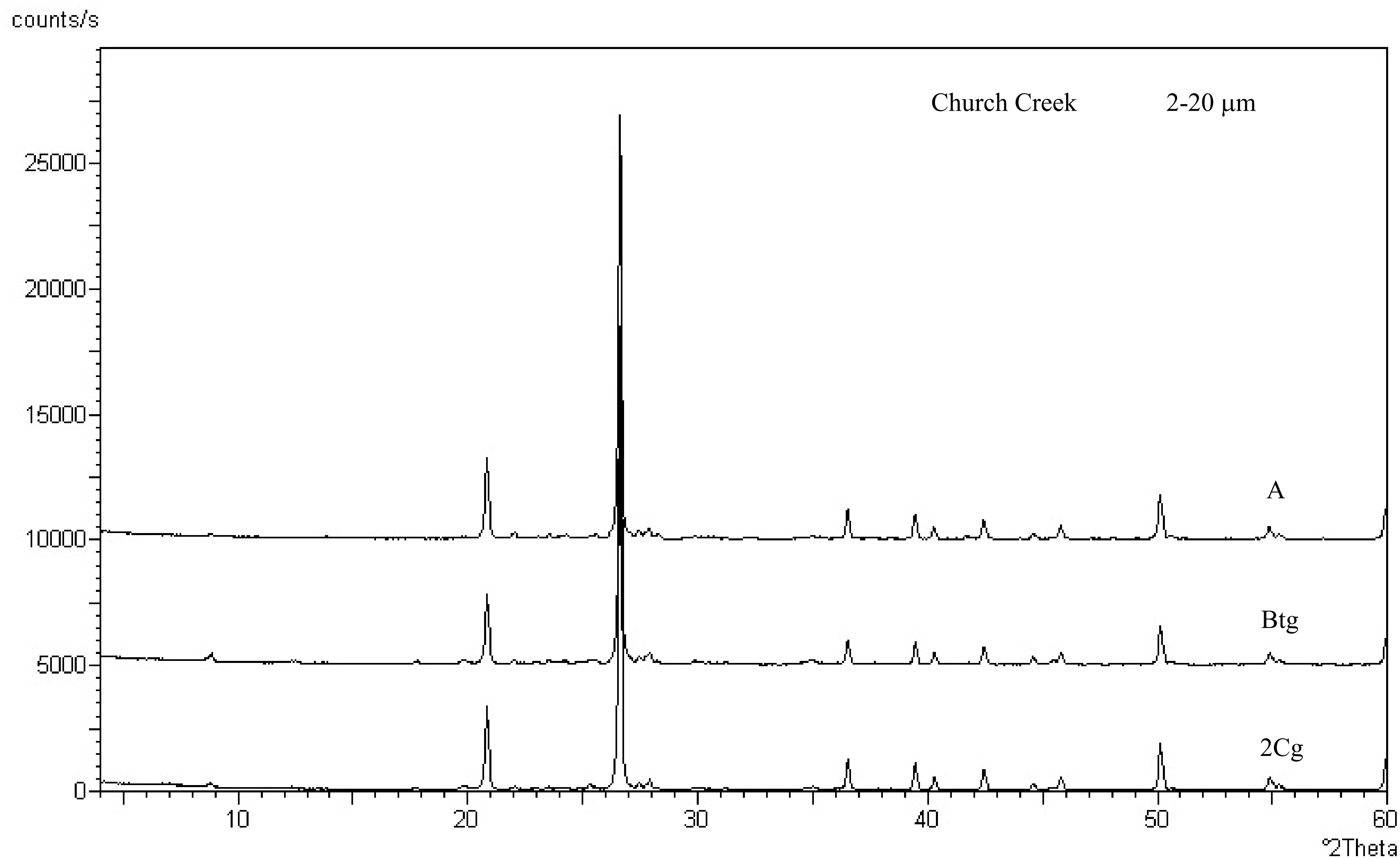
Appendix D (continued).

Site	Sample	ZrO_2 (%)		K_2O (%)		CaO (%)		TiO_2 (%)
------	------	------		------		------		------
Plugge 50	Ap 0-21	0.13		1.74		0.57		1.05
Plugge 50	Bt1 21-46	0.11		2.13		0.58		0.97
Plugge 50	Bt2 46-71	0.12		1.98		0.57		0.94
Plugge 50	Bt3 71-88	0.11		1.91		0.48		0.87
Plugge 50	2Bt4 88-110	0.13		2.00		0.32		0.87
Plugge 50	2BC 110-120	0.15		2.53		0.18		0.89
Oyster Cove Pt	Ap 0-16	0.14		1.70		0.49		1.04
Oyster Cove Pt	BE 16-22	0.12		1.74		0.50		1.00
Oyster Cove Pt	Btg 22-40	0.11		1.53		0.48		0.92
Oyster Cove Pt	Btx 40-53	0.11		1.36		0.44		0.90
Oyster Cove Pt	Ab 53-80	0.12		0.93		0.20		1.01
Oyster Cove Pt	Btxb1 80-108	0.11		0.92		0.07		1.04
Oyster Cove Pt	Btxb2 108-138	0.12		1.09		0.06		1.08
Oyster Cove Pt	BCg 138-178	0.10		1.53		0.06		1.07
Oyster Cove Pt	2Cg 178-183	0.16		1.77		0.12		1.25
Sassafras NRMA	Ap 0-33	0.12		1.45		0.49		1.07
Sassafras NRMA	Bt1 33-53	0.09		1.61		0.51		1.15
Sassafras NRMA	Bt2 53-80	0.13		1.90		0.56		1.23
Sassafras NRMA	Bt3 80-115	0.14		1.97		0.66		1.17
Sassafras NRMA	2Bt4 115-140	0.13		1.92		0.53		1.12
Tolchester	A 0-6	0.13		1.03		0.33		1.46
Tolchester	E 6-22	0.06		1.04		0.33		1.27
Tolchester	Btg 22-55	0.13		1.42		0.41		1.52
Tolchester	Bt 55-80	0.11		2.15		0.59		1.33
Tolchester	BCg1 80-100	0.13		1.70		0.93		1.52
Tolchester	BCg2 100-132	0.14		1.66		0.96		1.54
Tolchester	2Ab1 132-150	0.12		1.21		0.51		1.31
Tolchester	2Ab2 150-160	0.13		0.87		0.28		1.34
Tolchester	2Btgb1 160-175	0.13		1.02		0.33		1.47
Paw Paw Cove	Ap1 0-10	0.11		1.63		0.48		1.01
Paw Paw Cove	Ap2 10-31	0.11		1.62		0.46		1.01
Paw Paw Cove	BE 31-42	0.12		1.86		0.44		1.00
Paw Paw Cove	Bt 42-54	0.11		1.63		0.45		0.94
Paw Paw Cove	Btx 54-63	0.10		1.40		0.41		0.91
Paw Paw Cove	Ab 63-92	0.10		1.15		0.31		0.90
Paw Paw Cove	Btxgb1 92-109	0.11		1.13		0.19		0.94
Paw Paw Cove	Btxgb2 109-139	0.10		1.27		0.22		0.98
Paw Paw Cove	Btxgb3 139-166	0.08		1.47		0.20		0.97
Paw Paw Cove	2BCg 166-184	0.09		1.40		0.16		1.01
Paw Paw Cove	2Cg 184-210	0.11		1.52		0.14		1.01

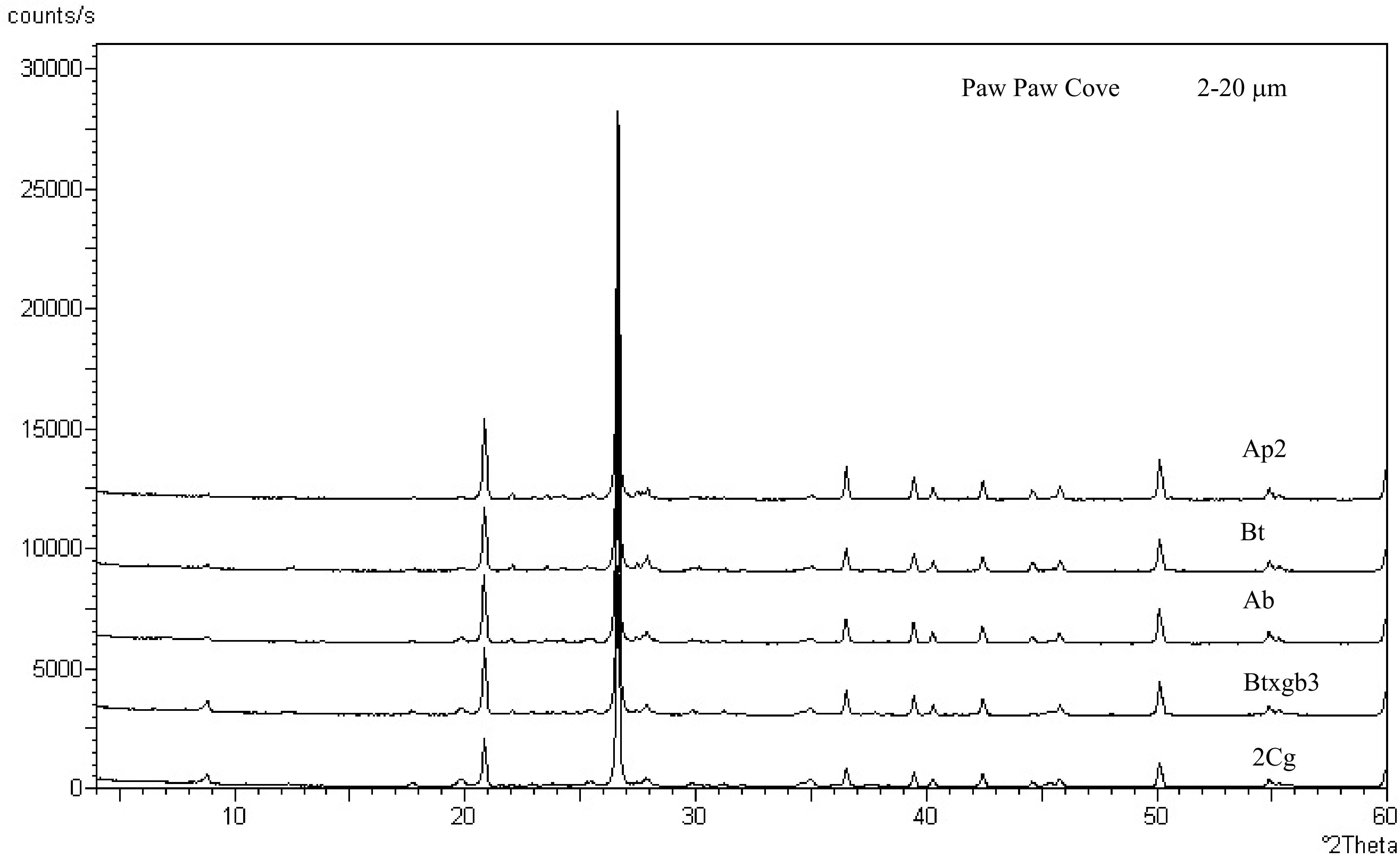
Appendix D (continued).

Site	Sample	ZrO_2 (%)	K_2O (%)	CaO (%)	TiO_2 (%)
------	------	------	------	------	------
Wye Island 2	A 0-10	0.10	1.56	0.58	1.33
Wye Island 2	E 10-28	0.08	1.40	0.49	1.11
Wye Island 2	Bt1 28-45	0.09	1.58	0.54	1.22
Wye Island 2	Bt2 45-73	0.10	1.71	0.95	1.30
Wye Island 2	Bt3 73-110	0.11	1.85	1.07	1.24
Wye Island 2	2Ab1 110-140	0.11	1.41	0.66	1.20
Wye Island 2	2Ab2 140-150	0.10	0.87	0.28	1.30
Wye Island 2	2C1 150-165	0.15	0.95	0.31	1.62
Earleville WMA	Ap 0-20	0.11	1.59	0.55	1.06
Earleville WMA	Bt1 20-53	0.14	1.84	0.60	1.16
Earleville WMA	Bt2 53-83	0.13	2.23	1.18	1.09
Earleville WMA	Bt3 83-111	0.12	1.97	0.87	0.98
Earleville WMA	Bt4 111-130	0.12	1.86	0.79	0.93
Earleville WMA	Bt5/Ab 130-170	0.15	1.17	0.22	1.07
Earleville WMA	Btb1 170-218	0.15	1.42	0.07	1.29
Earleville WMA	Btb2 218-231	0.13	1.74	0.08	1.21
Earleville WMA	Btb3 231-263	0.13	0.86	0.02	1.08
Earleville WMA	Btb4 263-288	0.13	0.89	0.02	1.14
Earleville WMA	2Btb5 288-331	0.13	1.58	0.05	1.14
Dennys Farm	Ap 0-21	0.14	1.22	0.37	1.22
Dennys Farm	Bt1 21-37	0.14	1.16	0.32	1.03
Dennys Farm	Bt2 37-60	0.14	1.49	0.42	0.99
Dennys Farm	Bt3 60-77	0.14	1.69	0.61	1.05
Dennys Farm	Bt4 77-98	0.14	1.70	0.68	1.01
Dennys Farm	Bt5 98-126	0.12	1.55	0.56	0.80
Dennys Farm	Bt6 126-158	0.12	1.50	0.65	0.69
Dennys Farm	Bt7 158-185	0.17	1.00	0.35	0.91
Dennys Farm	2Bt8 185-200	0.19	0.69	0.13	1.06
Dennys Farm	2BC 200-230	0.22	0.92	0.12	0.99

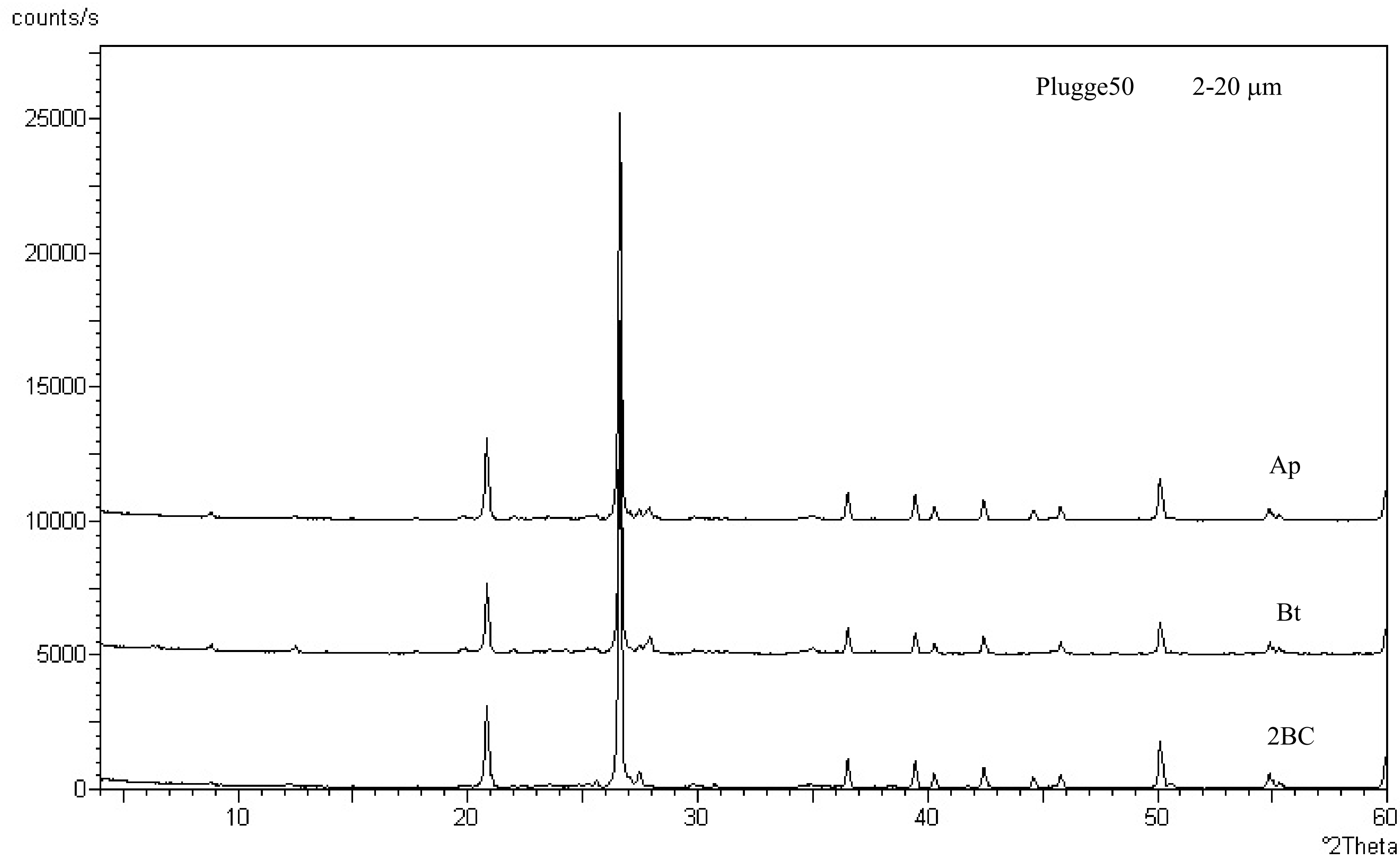
Appendix E. X-ray diffraction patterns of the mineralogy of the fine silt sized fraction.



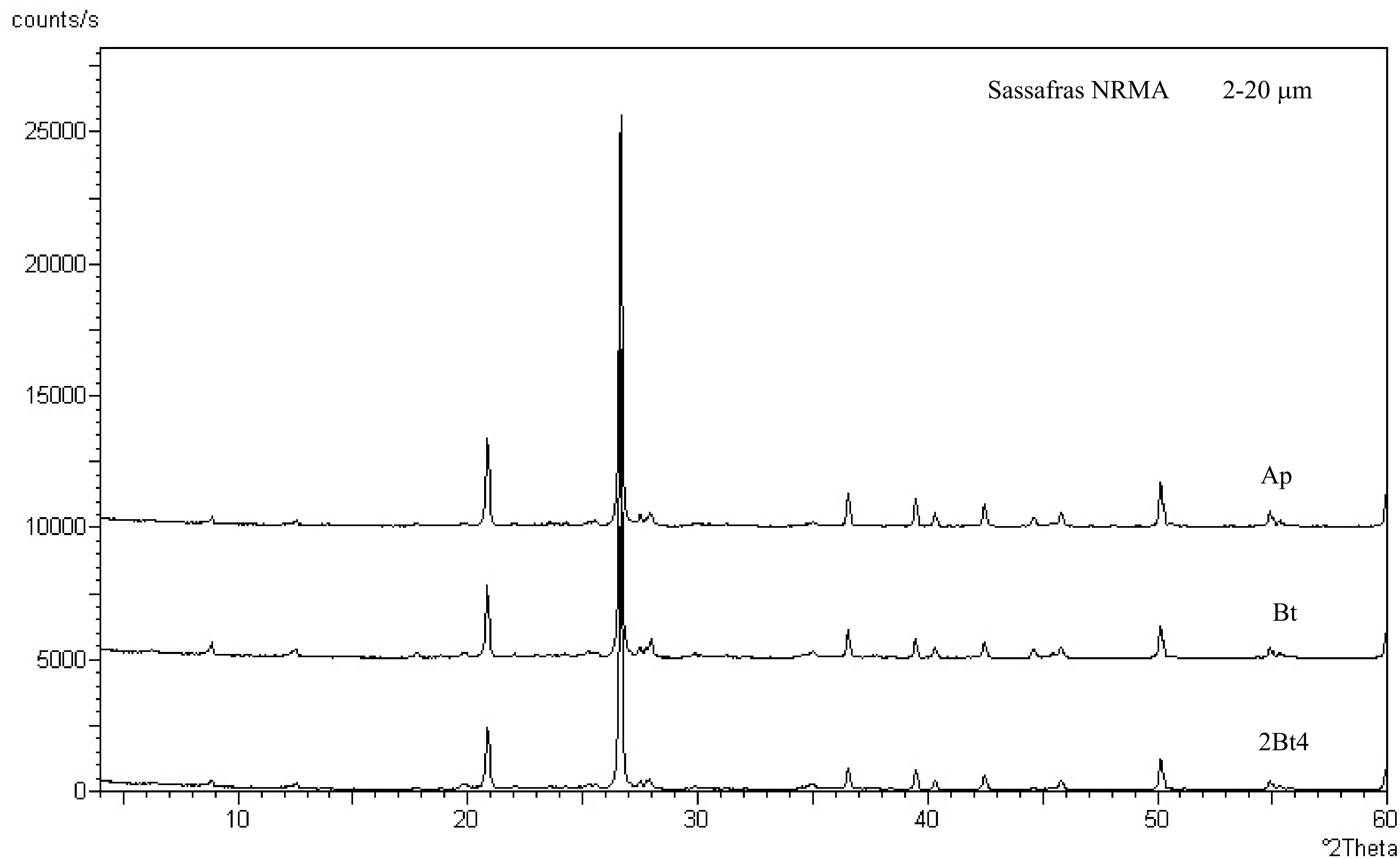
Appendix E (continued).



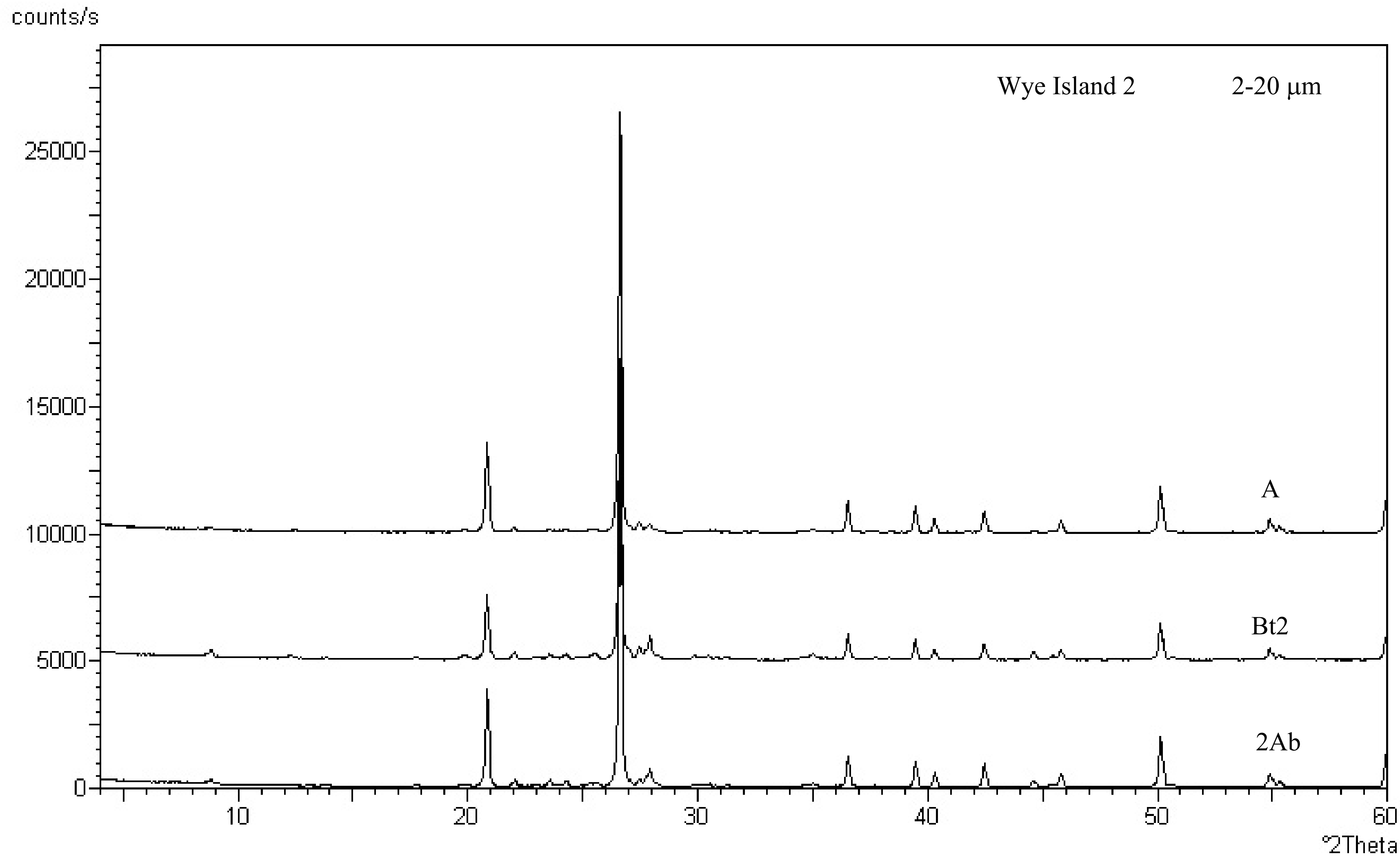
Appendix E (continued).



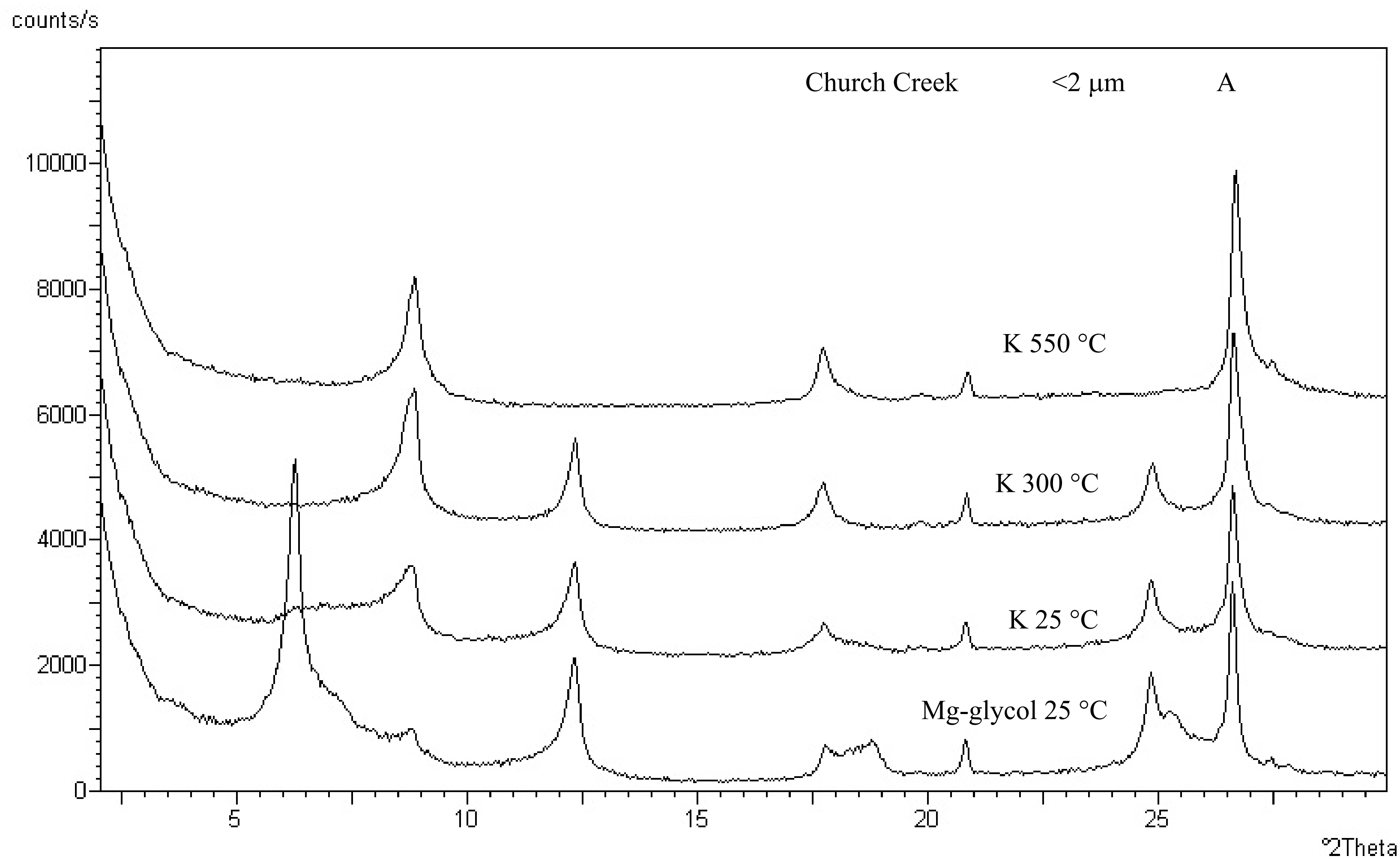
Appendix E (continued).



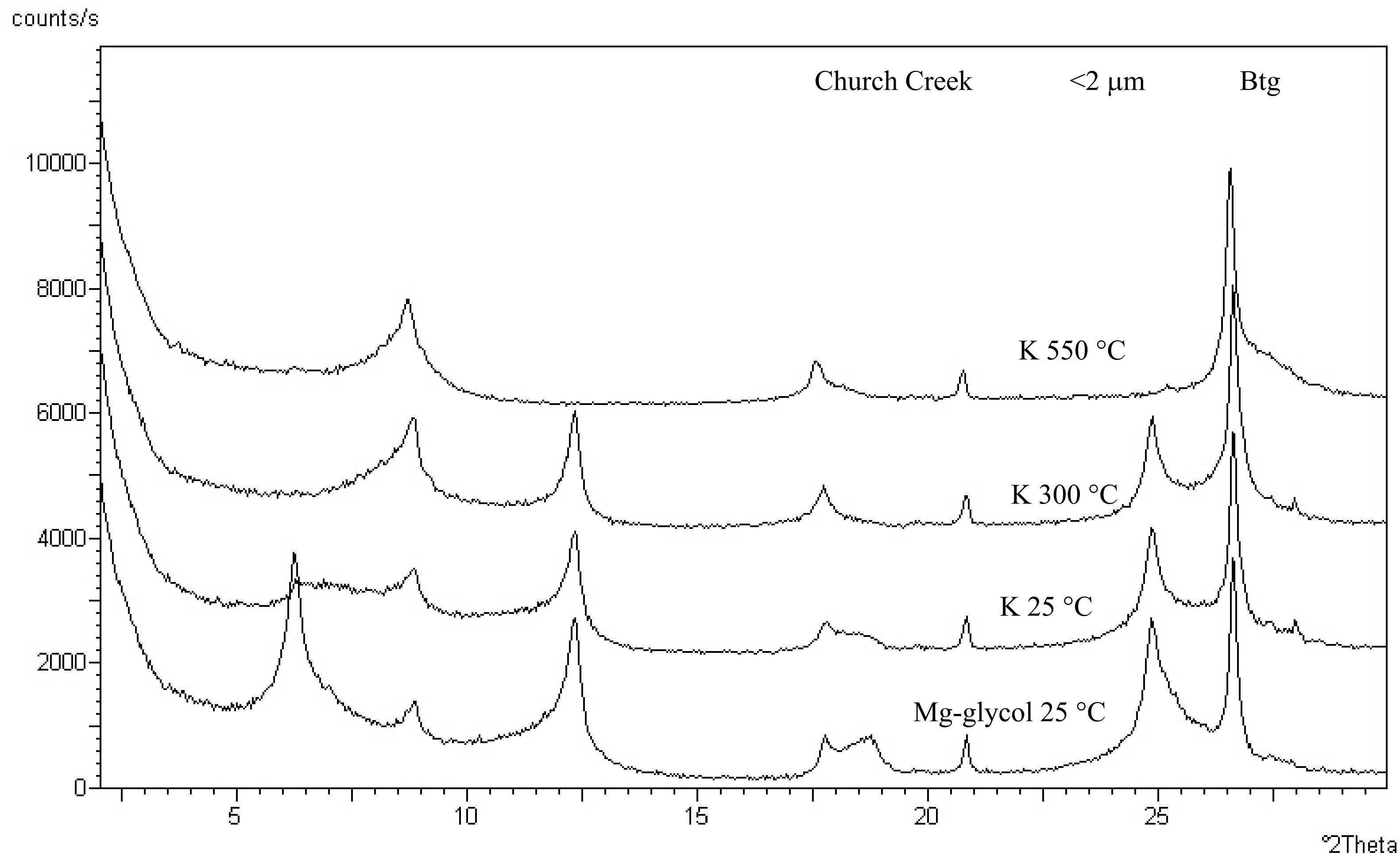
Appendix E (continued).



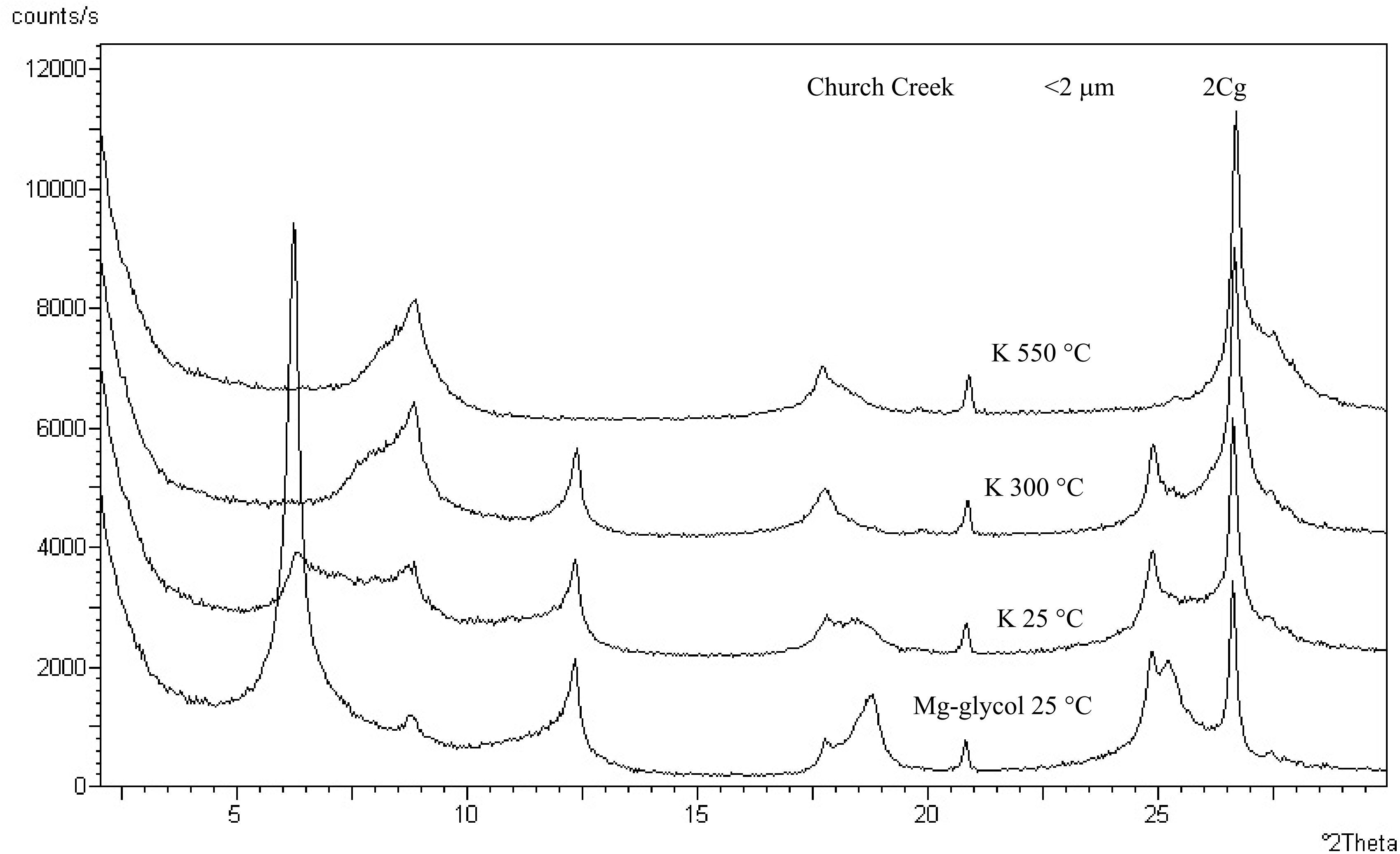
Appendix F. X-ray diffraction patterns of clay mineralogy.



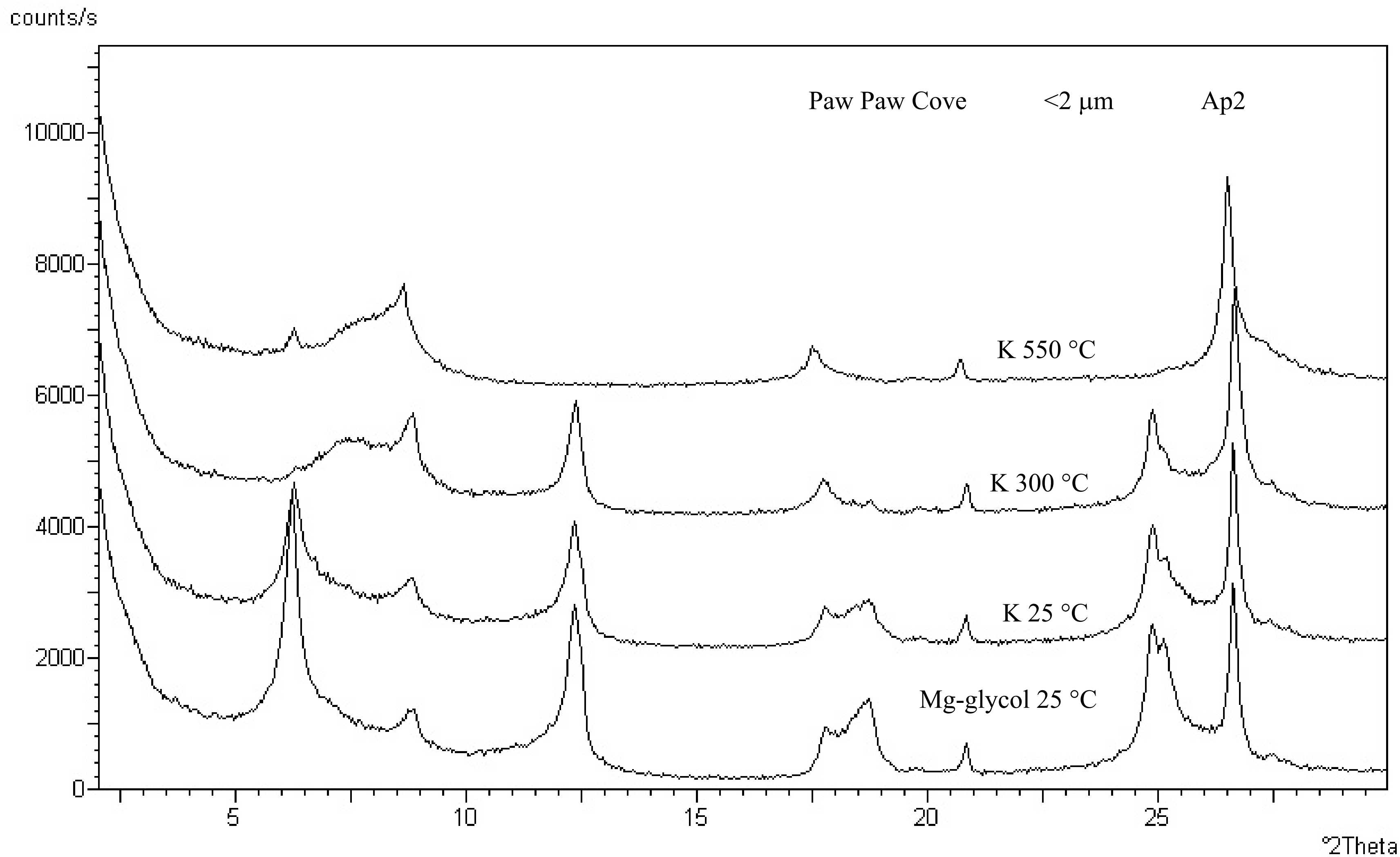
Appendix F (continued).



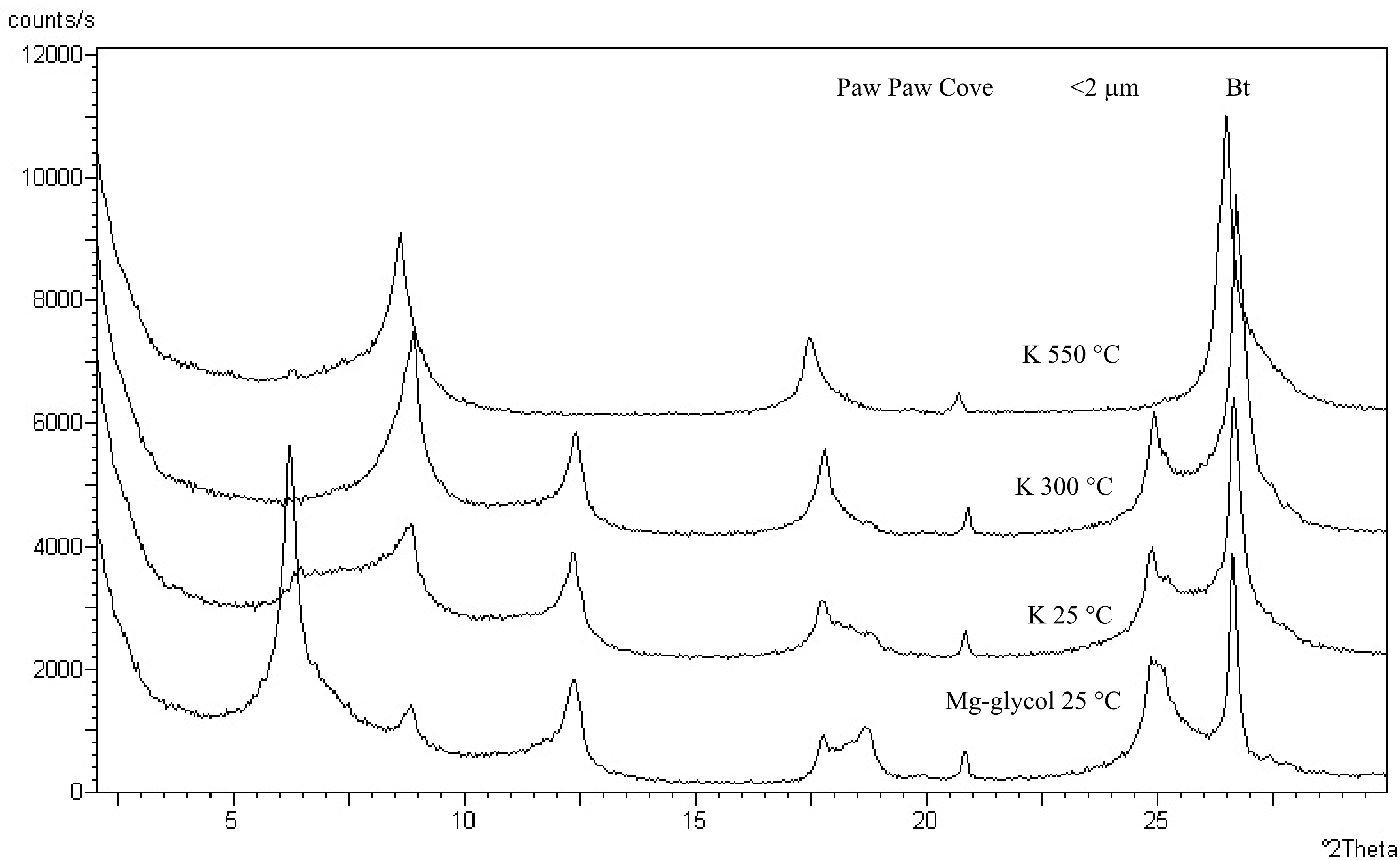
Appendix F (continued).



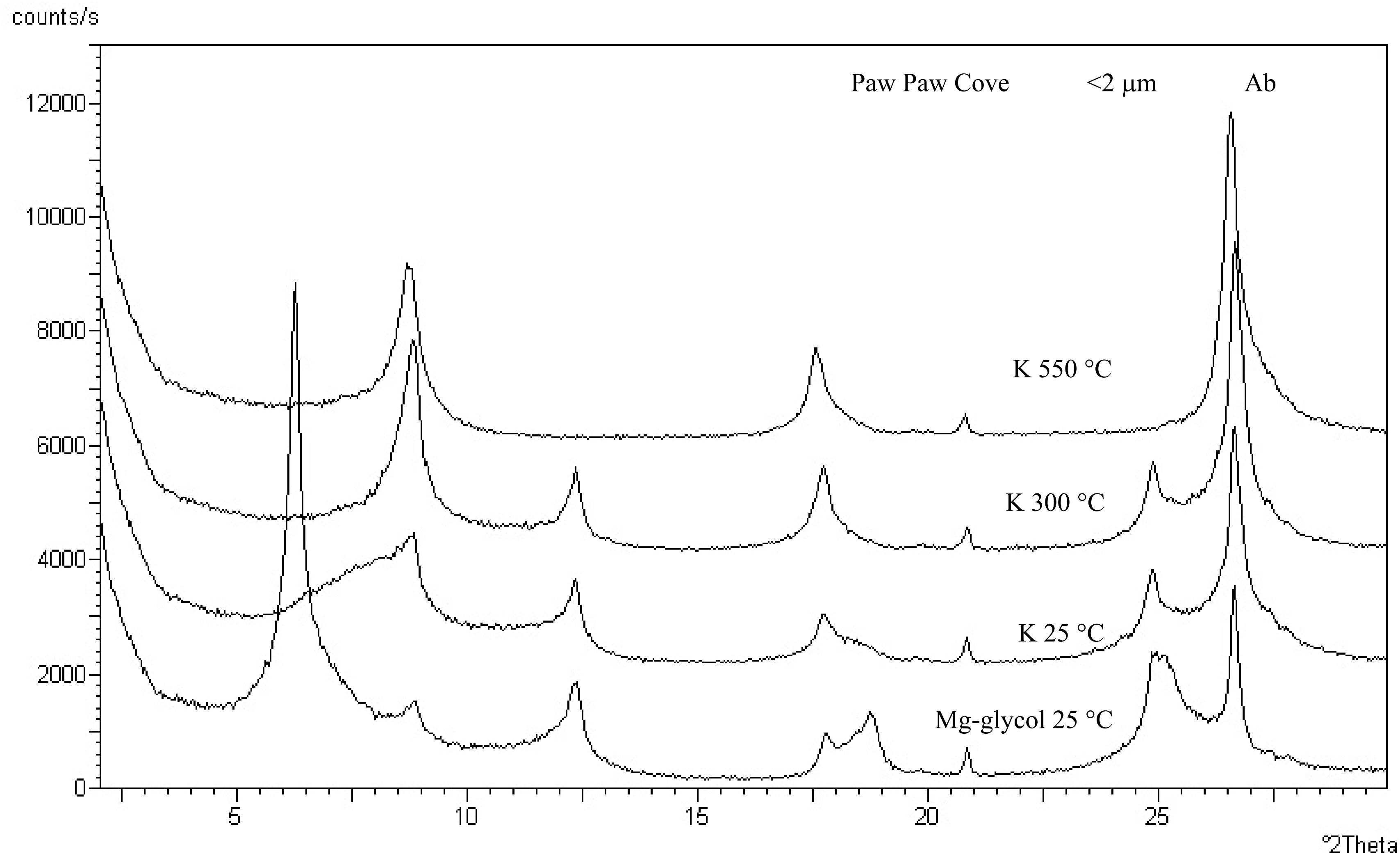
Appendix F (continued).



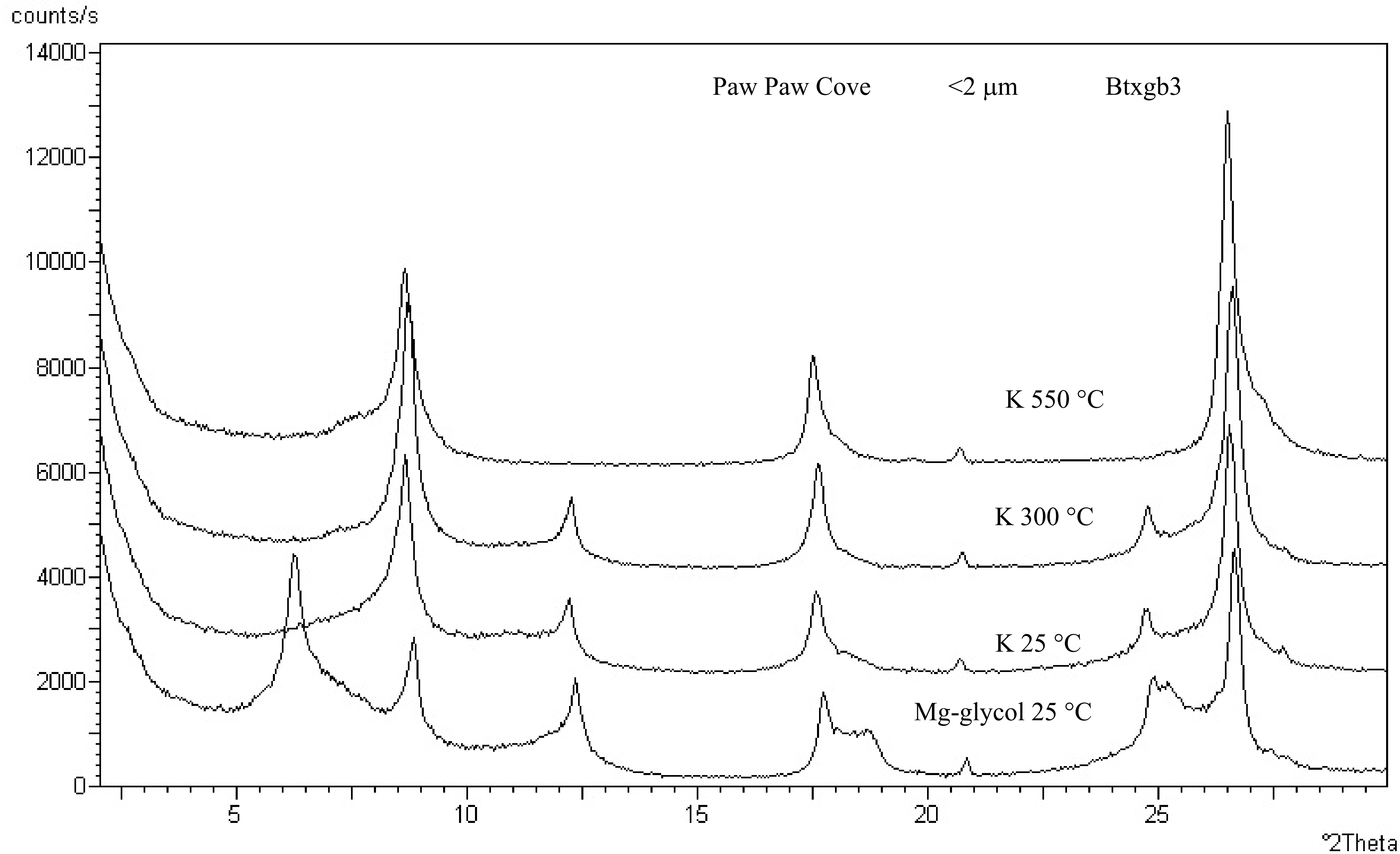
Appendix F (continued).



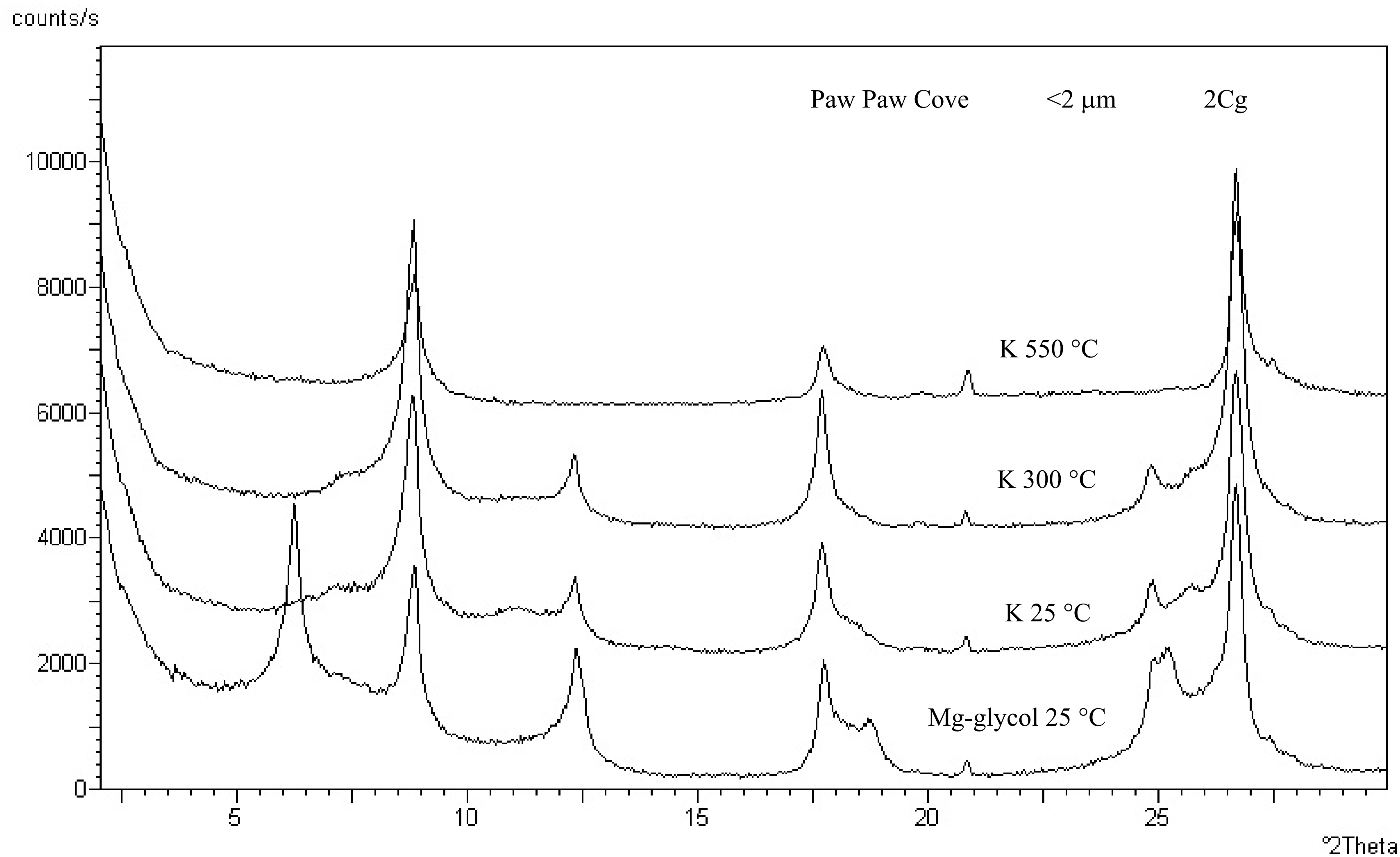
Appendix F (continued).



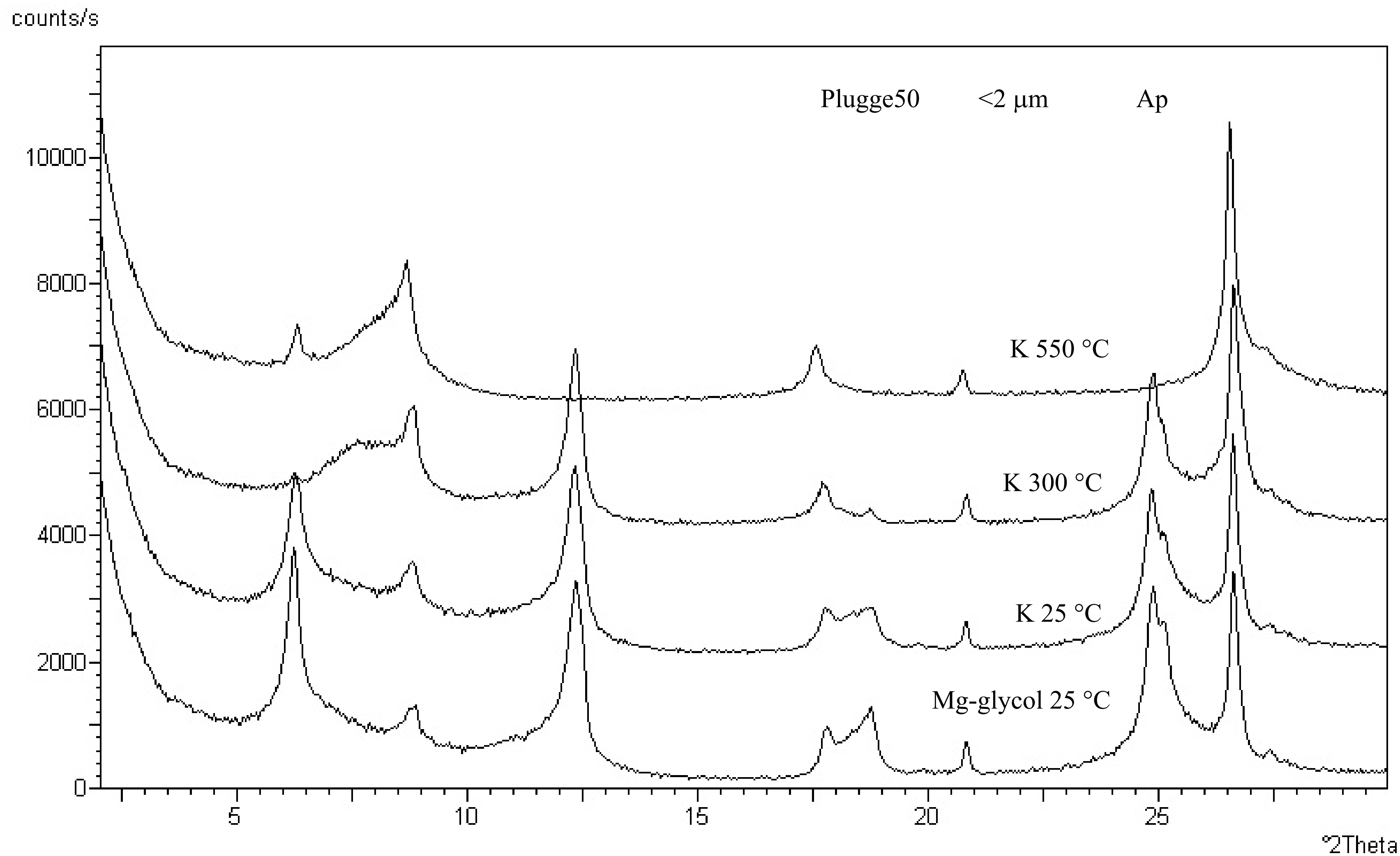
Appendix F (continued).



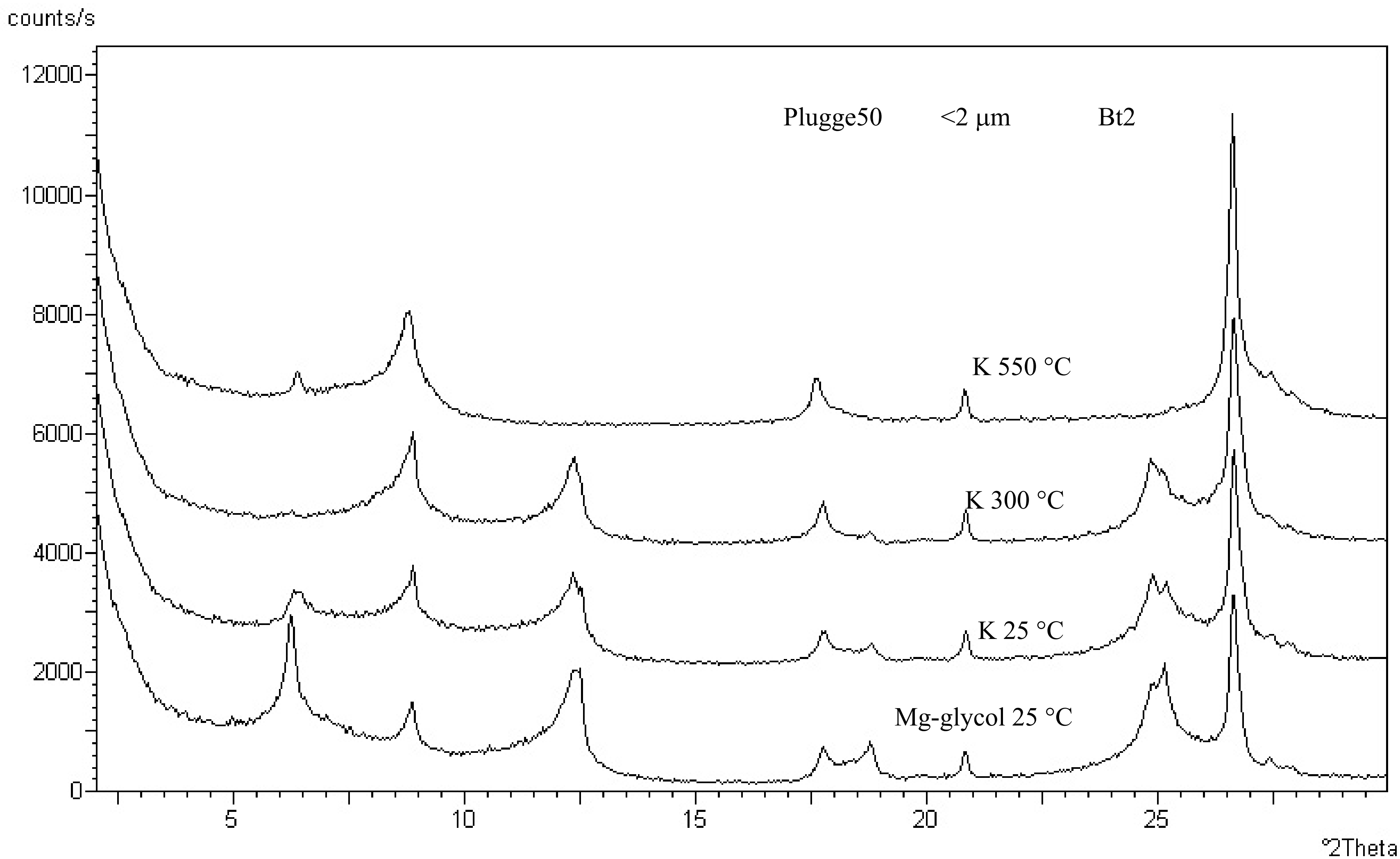
Appendix F (continued).



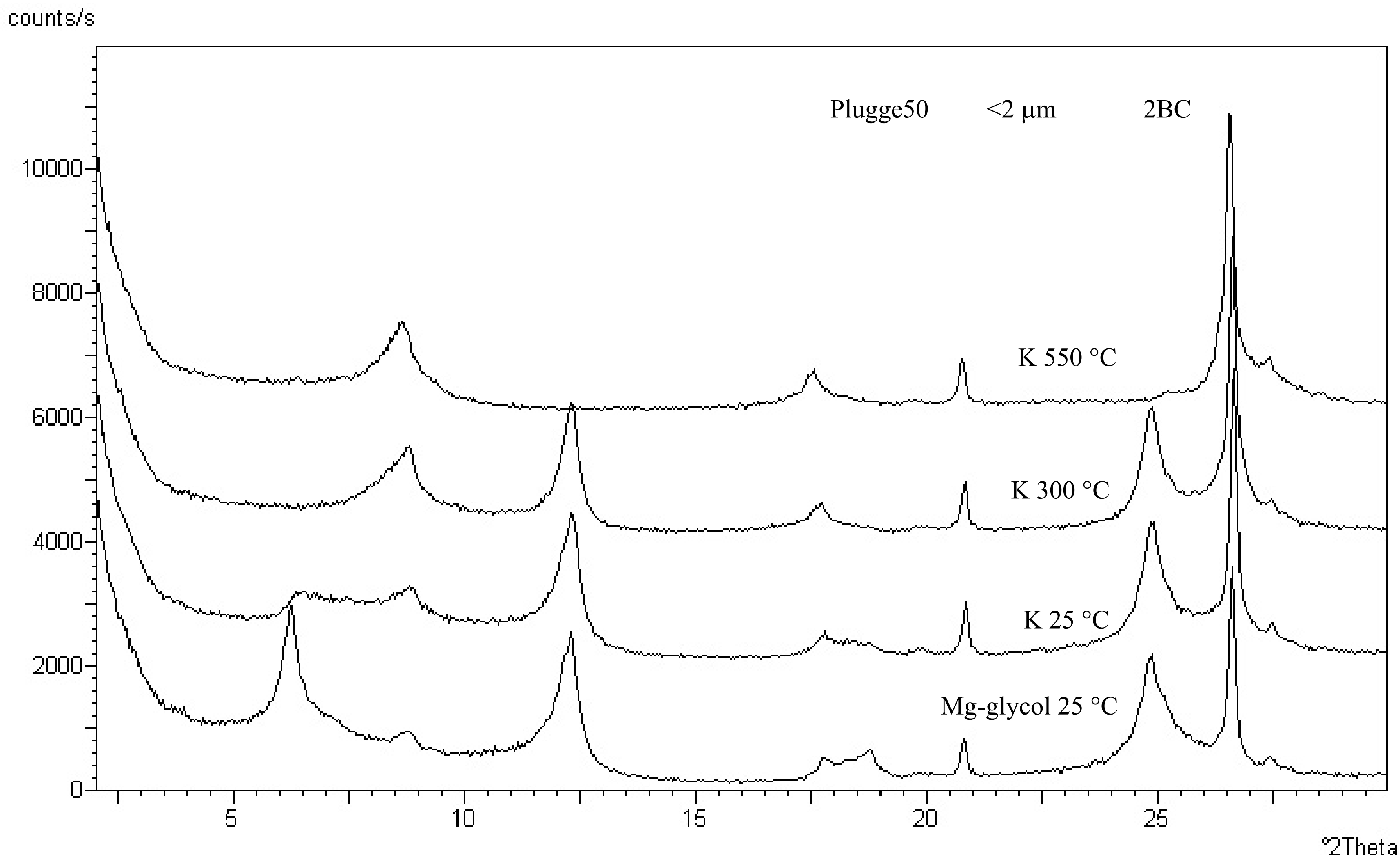
Appendix F (continued).



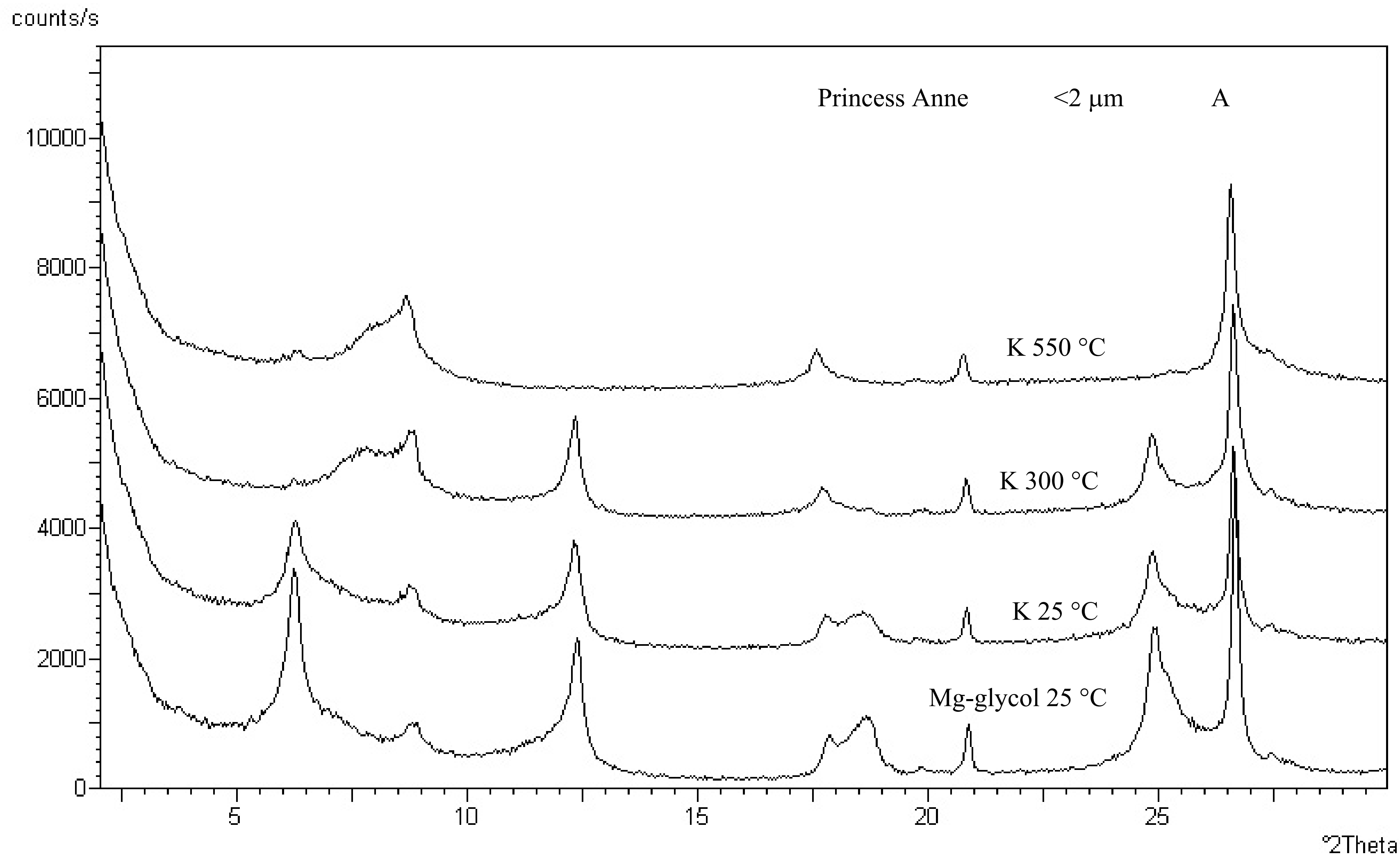
Appendix F (continued).



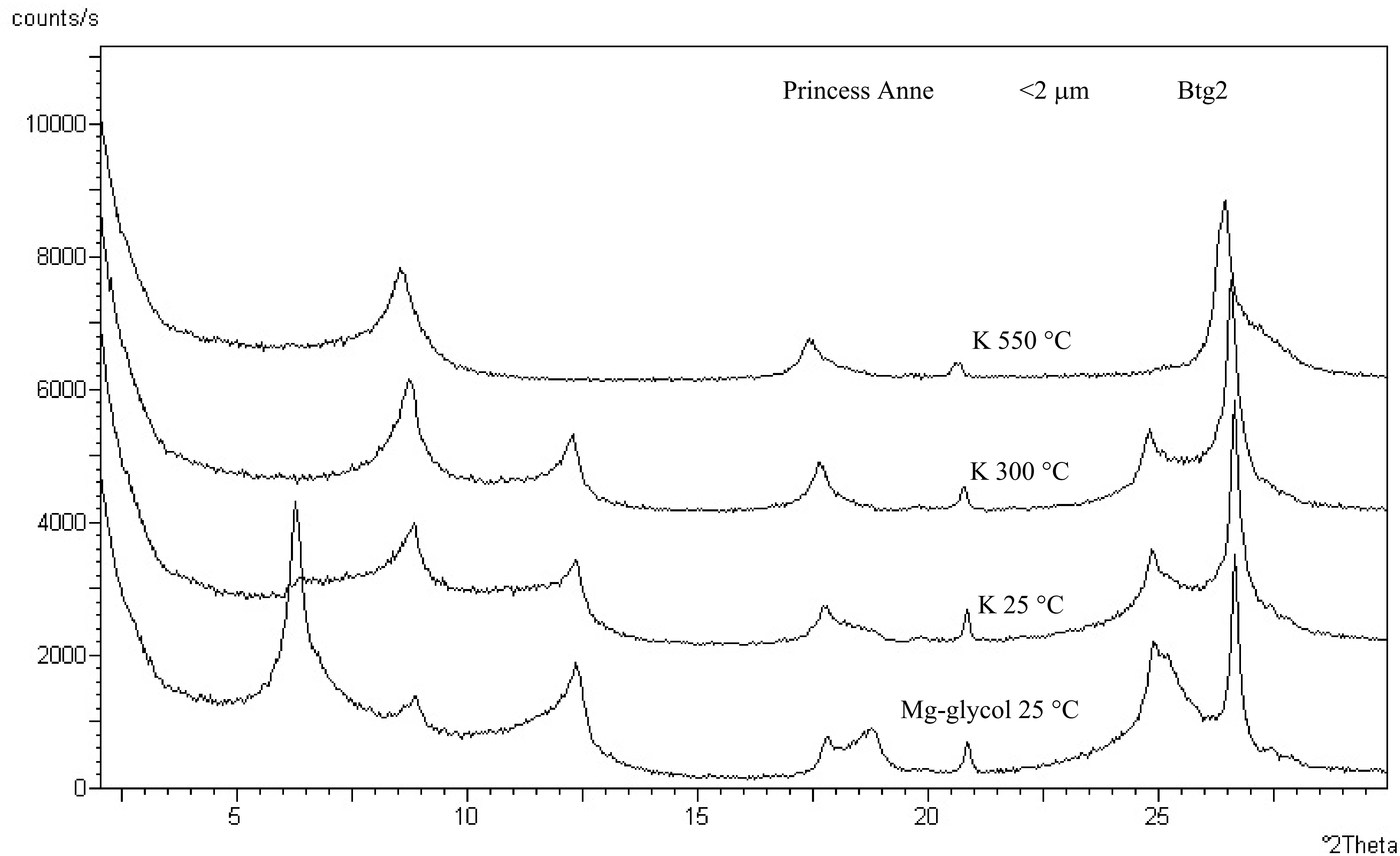
Appendix F (continued).



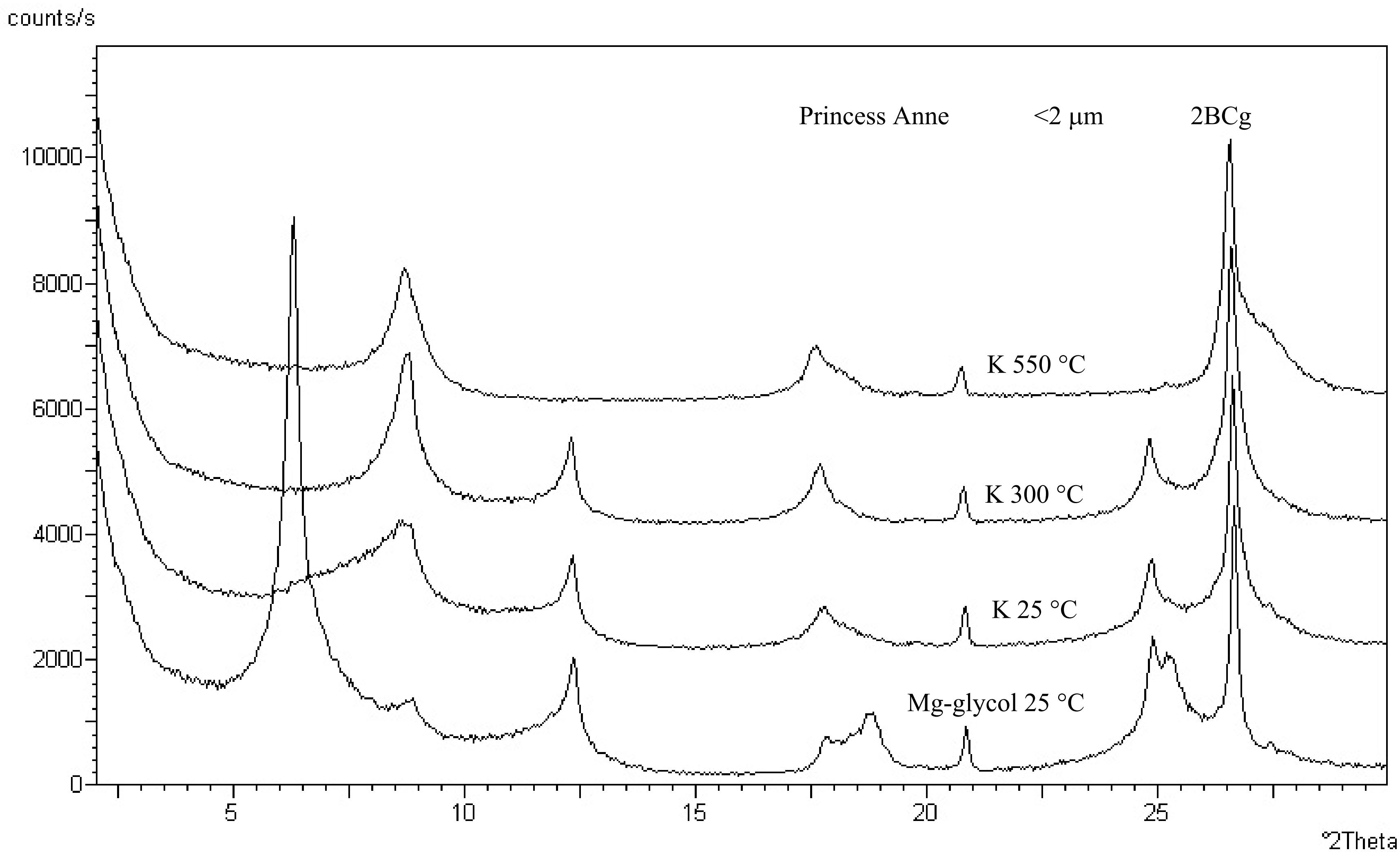
Appendix F (continued).



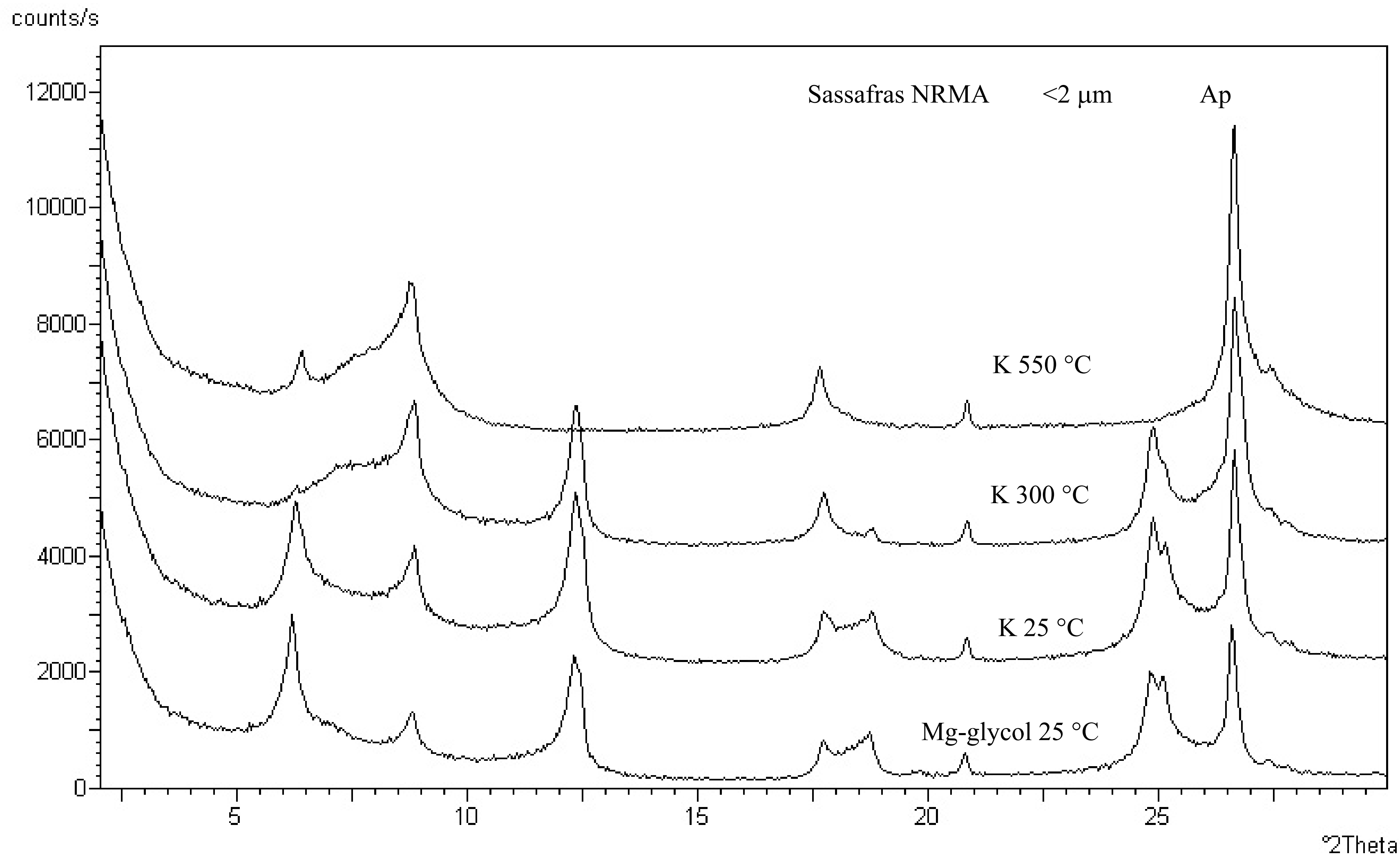
Appendix F (continued).



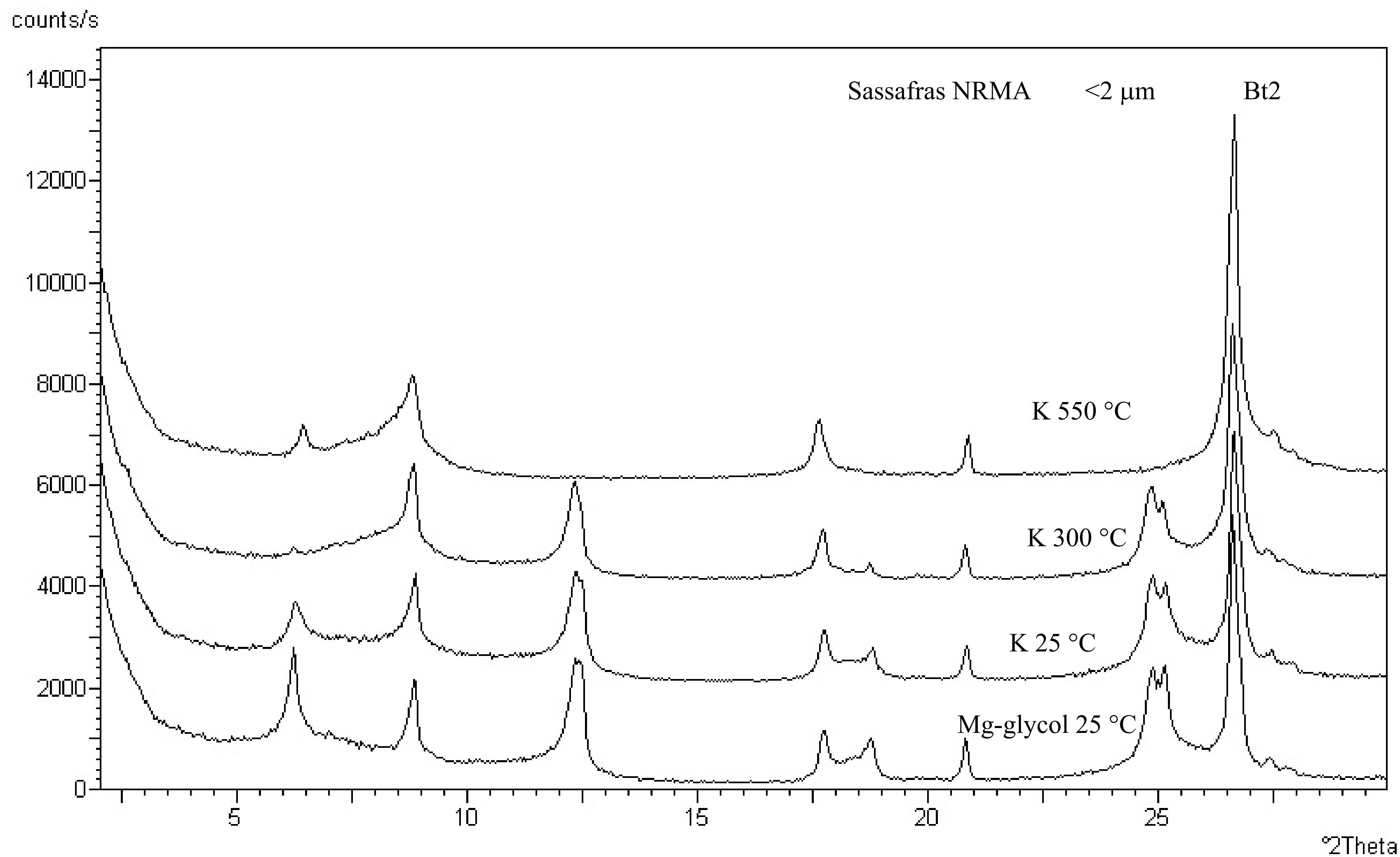
Appendix F (continued).



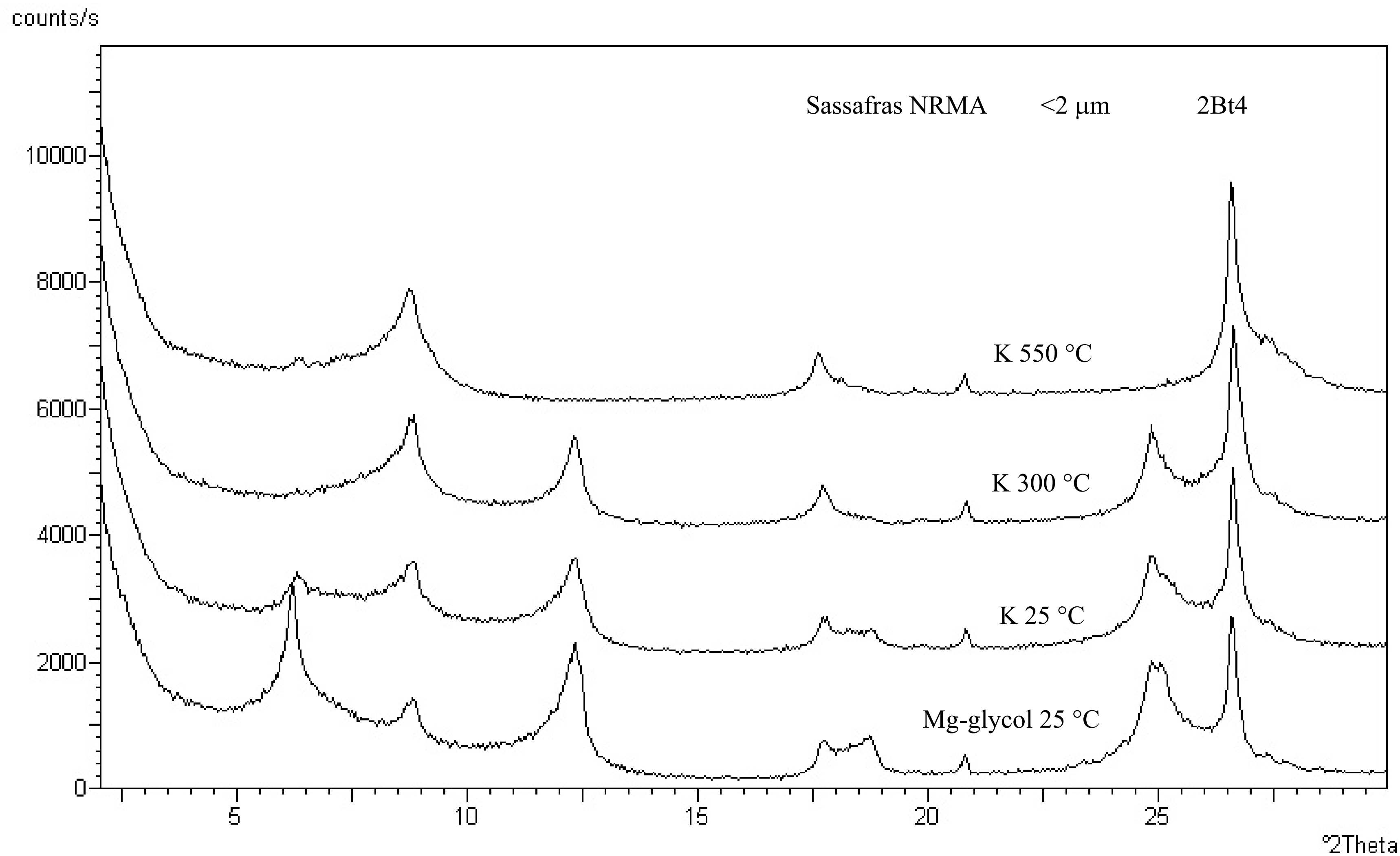
Appendix F (continued).



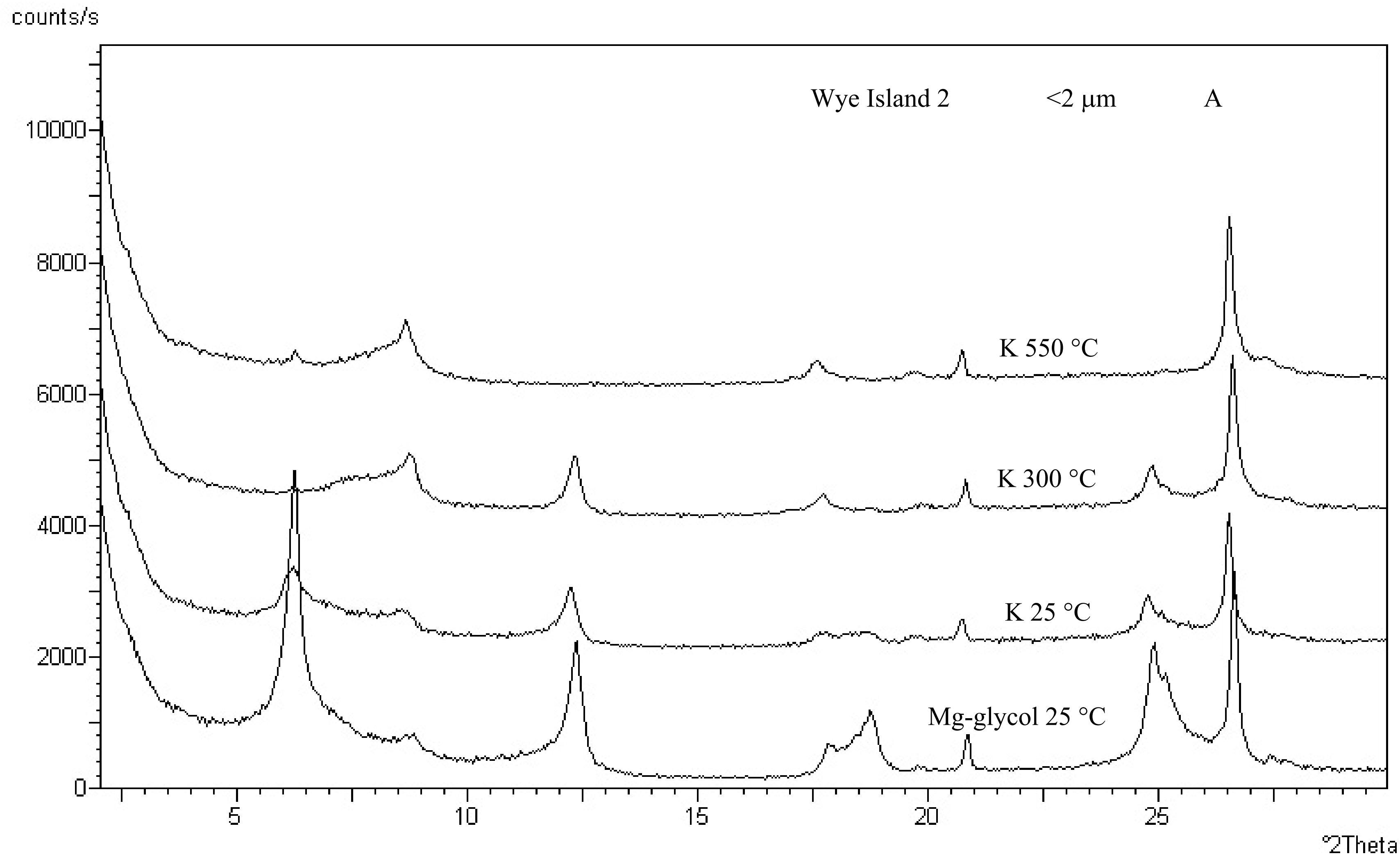
Appendix F (continued).



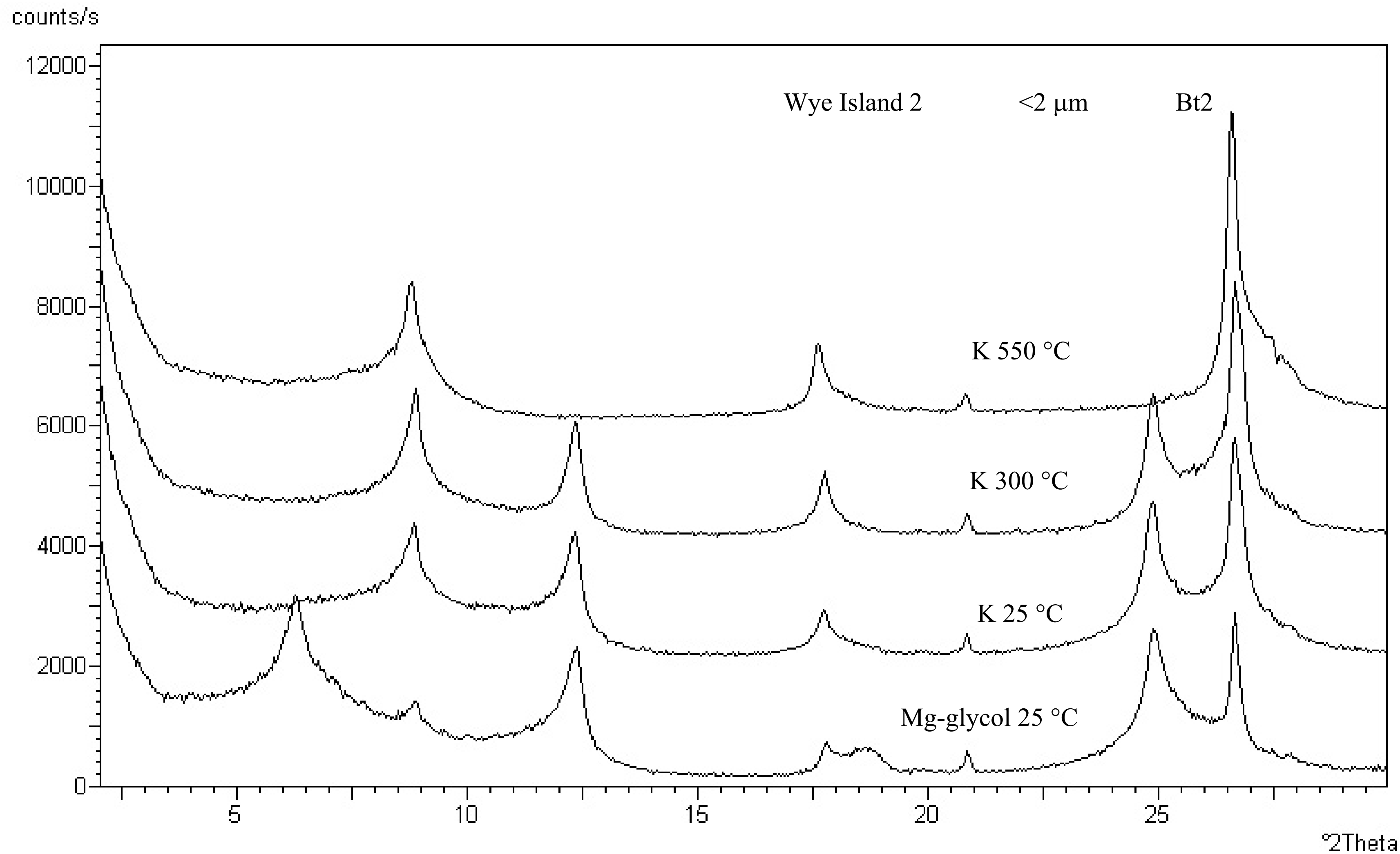
Appendix F (continued).



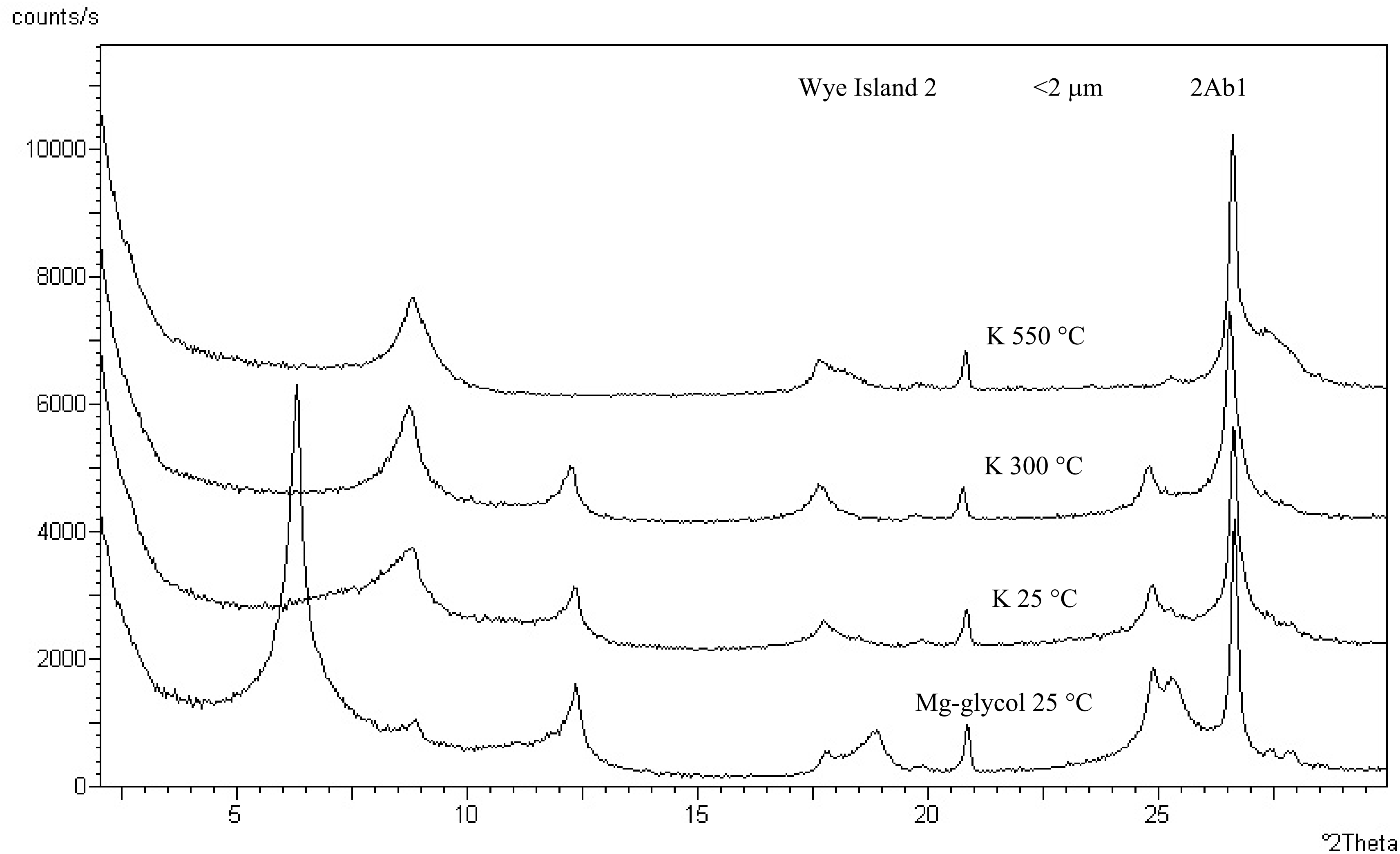
Appendix F (continued).



Appendix F (continued).



Appendix F (continued).



Appendix G. Biogenic opal data.

Site	Sample	Biogenic opal (% of soil)	Spicules & diatoms (% of opal)	Phytoliths (% of opal)	Festucoid (% of phytoliths)	Chloridoid (% of phytoliths)	Panicoid (% of phytoliths)	Non-diagnostic (elongates, bulliforms, points) (% of phytoliths)	Unidentified plant opal (% of phytoliths)
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Oyster Cove Point	Ap	0.14	8.82	91.18	0.60	0.00	1.81	13.60	83.99
Oyster Cove Point	BE	0.04	20.82	79.01	0.35	0.00	3.15	18.53	77.97
Oyster Cove Point	Btg	0.03	13.76	86.24	4.56	0.28	0.57	26.21	68.38
Oyster Cove Point	Btx	0.09	4.60	95.34	2.45	0.27	1.36	29.08	66.85
Oyster Cove Point	Ab	0.06	8.62	91.38	2.29	0.86	2.29	28.57	66.00
Oyster Cove Point	Btxgb1	0.00	32.74	67.26	4.87	0.00	1.77	22.57	70.80
Oyster Cove Point	Btxgb2	0.01	32.85	66.83	1.82	0.00	0.36	25.55	72.26
Oyster Cove Point	BCg	0.01	32.37	67.63	5.13	0.00	0.43	15.38	79.06
Oyster Cove Point	2Cg	0.00	42.69	56.80	1.06	0.00	2.13	23.94	72.87
Blackwalnut Point	A	0.30	2.71	97.29	0.86	0.43	1.93	8.15	88.63
Blackwalnut Point	E	0.23	2.93	97.07	0.30	0.00	1.81	14.80	83.08
Blackwalnut Point	BE	0.07	7.64	92.33	0.72	0.36	0.72	12.27	85.92
Blackwalnut Point	Bt1	0.01	35.93	63.95	1.06	0.00	0.53	7.98	90.43
Blackwalnut Point	Bt2	0.06	6.00	93.98	0.71	0.00	0.00	14.95	84.34
Blackwalnut Point	Ab	0.07	2.74	97.24	1.89	0.32	0.32	17.03	80.44
Blackwalnut Point	Btxb	0.01	16.96	83.01	3.53	0.24	0.24	22.35	73.65
Blackwalnut Point	Btxgb	0.00	18.99	80.90	1.11	0.00	1.48	14.39	83.03
Blackwalnut Point	BCg1	0.02	9.58	90.40	0.94	0.31	0.31	10.94	87.19
Blackwalnut Point	BCg2	0.01	25.20	74.73	0.36	0.00	0.36	16.36	82.91
Blackwalnut Point	2Cg	0.01	27.21	72.61	0.45	0.00	0.00	13.64	85.91

Appendix G (continued).

Site	Sample	Biogenic opal (% of soil)	Spicules & diatoms (% of opal)	Phytoliths (% of opal)	Festucoid (% of phytoliths)	Chloridoid (% of phytoliths)	Panicoid (% of phytoliths)	Non-diagnostic (elongates, bulliforms, points) (% of phytoliths)	Unidentified plant opal (% of phytoliths)
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Paw Paw Cove	Ap1	0.11	4.93	95.07	1.30	0.26	4.15	14.25	80.05
Paw Paw Cove	Ap2	0.12	4.05	95.94	1.56	1.11	2.67	13.14	81.51
Paw Paw Cove	BE	0.03	14.90	84.97	1.61	0.00	1.07	23.32	73.99
Paw Paw Cove	Bt	0.03	11.51	88.37	0.75	0.38	1.88	24.81	72.18
Paw Paw Cove	Btx	0.08	6.91	93.06	0.28	0.00	0.55	17.68	81.22
Paw Paw Cove	Ab	0.10	6.27	93.69	0.32	0.32	0.00	15.06	84.29
Paw Paw Cove	Btxgb1	0.04	14.85	85.15	3.43	0.62	1.25	23.99	70.72
Paw Paw Cove	Btxgb2	0.02	18.52	81.42	1.14	0.00	0.00	11.03	87.83
Paw Paw Cove	Btxgb3	0.01	25.36	74.19	1.19	0.00	0.40	17.00	81.42
Paw Paw Cove	2BCg	0.01	48.81	51.19	2.67	0.00	0.00	24.67	72.67
Paw Paw Cove	2Cg	0.01	22.59	77.12	5.49	0.00	3.85	14.84	75.82

REFERENCES

Alexander, J.D., A.H. Beavers, and P.R. Johnson. 1962. Zirconium contents of coarse silt in loess and till of Wisconsin age in northern Illinois. Soil Soc. Am. Proc. 26:189-191.

Alley, R., G. Bond, J. Chappellaz, C. Clapperton, A. D. Genio, L. Keigwin, and D. Peteet. 1993. Global Younger Dryas? Eos 74:587-589.

Barboni, D., R. Bonnefille, A. Alexandre, and J. D. Meunier. 1999. Phytoliths as paleoenvironmental indicators, west side Middle Awash Valley, Ethiopia. Palaeo. Palaeo. Palaeo. 152:87-100.

Beavers, A. H. (1960). Use of x-ray spectrographic analysis for the study of soil genesis. 7th International Congress of Soil Science, Madison, Wisconsin.

Bilzi, A. F., and E. J. Ciolkosz. 1977. A field morphology rating scale for evaluating pedological development. Soil Science 124:45-48.

Birkeland, P.W. 1984. Soils and Geomorphology. Oxford University Press, New York.

Blecker, S. W., C. M. Yonker, C. G. Olson, and E. F. Kelly. 1997. Paleopedologic and geomorphic evidence for Holocene climate variation, Shortgrass Steppe, Colorado, USA. Geoderma 76:113-130.

Bonnett, O. T. 1972. Silicified cells of grasses: A major source of plant opal in Illinois. University of Illinois, Urbana, Illinois.

Bradley, R. S. 1999. Paleoclimatology - Reconstructing Climates of the Quaternary. Harcourt Academic Press, New York.

Bratton, J.F., S.M. Colman, P.C. Baucom, and R.R. Seal. 2000. Trace Metal, Stable Isotopes, and Biogenic Silica from Cores Collected at *Marion-Dufresne* Site MD99-2209, Chesapeake Bay. *In* T.M. Cronin (ed.) Initial Report on the IMAGES V Cruise of the Marion-Dufresne to the Chesapeake Bay June 20 - 22, 1999. U.S. Geological Survey, Open-File Report 00-306 Online Version 1.0 [Online] (verified 10 Feb. 2003).

Brewer, J. E., G. P. Demas, and D. Holbrook. 1998. Soil Survey of Dorchester County, Maryland. USDA-NRCS, Washington, D.C.

Bronger, A., and J.A. Catt. 1989. Paleosols: Problems of Definition, Recognition, and Interpretation. p. 1-7. *In* A. Bronger and J.A. Catt (ed.) Paleopedology: Nature and Application of Paleosols. Catena Verlag, Germany.

Bronger, A., and T. Heinkele. 1989. Paleosol Sequences as Witnesses of Pleistocene Climatic History. p. 163-186. *In* A. Bronger and J.A. Catt (ed.) Paleopedology: Nature and Application of Paleosols. Catena Verlag, Germany.

Brown, M. L., and R. G. Brown. 1984. Herbaceous Plants of Maryland. Port City Press, Inc., Baltimore, MD.

Brown, R. G., and M. L. Brown. 1999. Woody Plants of Maryland. Port City Press, Baltimore, MD.

Cady, J. G., L. P. Wilding, and L. R. Drees. 1986. Petrographic Microscope Techniques. p. 185-218. *In* A. Klute (ed.) Methods of Soil Analysis Part 1 - Physical and Mineralogical Methods. Soil Science Society of America, Madison, WI.

California Academy of Sciences. 2002. Department of Invertebrate Zoology and Geology diatom collection [Online]. Available at http://www.calacademy.org/research/diatoms/ (Verified 18 Sept. 2002).

Carey, J. B., R. L. Cunningham, and E. G. Williams. 1976. Loess identification in soils of southeastern Pennsylvania. Soil Sci. Soc. Am. J. 40:745-750.

Chapman, S.L., and M.E. Horn. 1968. Parent material uniformity and origin of silty soils in northwest Arkansas based on zirconium-titanium contents. Soil Soc. Am. Proc. 32:265-271.

Colman, S. M., J. F. Bratton, and P. C. Baucom. 2000. Radiocarbon dating of Marion-Dufresne cores MD99-2204, -2207, -2209, Chesapeake Bay. *In* T.M. Cronin (ed.) Initial Report on the IMAGES V Cruise of the Marion-Dufresne to the Chesapeake Bay June 20 - 22, 1999. U.S. Geological Survey, Open-File Report 00-306 Online Version 1.0 [Online] (verified 10 Feb. 2003).

Colman, S. M., and R. B. Mixon. 1988. The record of major Quaternary sea-level changes in a large Coastal Plain estuary, Chesapeake Bay, eastern United States. Palaeo. Palaeo. Palaeo. 68:99-116.

Cooper, S.R. 1999. Estuarine paleoenvironmental reconstruction using diatoms. p. 352-373. *In* E.F. Stoermer and J.P. Smol (ed.) Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, Cambridge, UK.

Cronin, T. M. 1999. Principles of Paleoclimatology. Columbia University Press, New York.

Crowl, G. H., and W. D. Sevon. 1980. Glacial border deposits of late Wisconsin age in northeastern Pennsylvania. Pennsylvania Geological Survey, Harrisburg, PA.

Dansgaard, W., J. W. C. White, and S. J. Johnsen. 1989. The abrupt termination of the Younger Dryas climate event. Nature 339:532-534.

Darmody, R.G., and J.E. Foss. 1982. Soil-landscape relationships in the Piedmont of Maryland. Soil Sci. Soc. Am. J. 46:588-592.

Dawson, A. G. 1992. Ice Age Earth: Late Quaternary Geology and Climate. Routledge, New York.

Denny, C. S., and J. P. Owens. 1979. Sand dunes on the central Delmarva Peninsula, Maryland and Delaware. United States Government Printing Office, Washington, D.C.

Denny, C. S., J. P. Owens, L. A. Sirkin, and M. Rubin. 1979. The Parsonsburg Sand in the central Delmarva Peninsula, Maryland and Delaware. United States Government Printing Office, Washington, D.C.

Denys, L., and H. De Wolf. 1999. Diatoms as indicators of coastal paleoenvironments and relative sea-level change. p. 297. *In* E.F. Stoermer and J.P. Smol (ed.) Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, Cambridge, UK.

Dillon, W. P., and R. N. Oldale. 1978. Late Quaternary sea-level curve: Reinterpretation based on glacioeustatic influence. Geology 6:56-60.

Dorronsoro, C., and P. Alonso. 1994. Chronosequence in Almar River fluvial-terrace soil. Soil Sci. Soc. Am. J. 58:910-925.

Drees, L. R., L. P. Wilding, N. E. Smeck, and A. L. Senkayi. 1989. Silica in soils: Quartz and disordered silica polymorphs. p. 913-974. *In* J. B. Dixon and S. B. Weed (ed.) Minerals in Soil Environments. Soil Science Society of America, Madison, Wisconsin.

Eash, N. S., and J. A. Sandor. 1995. Soil chronosequence and geomorphology in a semi-arid valley in the Andes of southern Peru. Geoderma 65:59-79.

Ehlers, J. 1996. Quaternary and Glacial Geology. John Wiley and Sons, New York.

Fairbanks, R. G. 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature 342:637-642.

Feldman, S. B., L. W. Zelazny, M. J. Pavich, and H. T. Millard. 2000. Late Pleistocene eolian activity and post-depositional alteration on the Piedmont of northern Virginia. Southeastern Geology 39:183-198.

Fanning, D. S., and M.L. Jackson. 1966. Clay minerals weathering in southern Wisconsin soils developed in loess and in shale-derived till. Clays and Clay Minerals 13:175-191.

Fanning, D.S. and M.L. Jackson. 1967. Zirconium content of coarse silt from some Wisconsin soils and sediments. Soil Sci. 103:253-260.

Foss, J. E., D. S. Fanning, F. P. Miller, and D. P. Wagner. 1978. Loess deposits of the Eastern Shore of Maryland. Soil Sci. Soc. Am. J. 42:329-334.

Foss, J. E., and A. V. Segovia. 1984. Rates of soil formation. p. 1-17. *In* R. G. LaFleur (ed.) Groundwater as a Geomorphic Agent. Allen and Unwin, Inc., Boston.

Frye, J. C., H. D. Glass, and H. B. Willman. 1962. Stratigraphy and mineralogy of the Wisconsin loesses of Illinois. Illinois State Geological Survey, Urbana.

Gallup, C. D., R. L. Edwards, and R. G. Johnson. 1994. The timing of high sea levels over the past 200,000 years. Science 263:796-800.

Gee, G. W., and J. W. Bauder. 1986. Particle-size Analysis. p. 383-411. *In* A. Klute (ed.) Methods of Soil Analysis Part1 -- Physical and Mineralogical Methods. Soil Science Society of America, Madison, Wisconsin.

Geis, J. W. 1973. Biogenic opal in selected species of deciduous angiosperms. Soil Sci. 116:113-119.

Groot, J. J., and R. R. Jordan. 1999. The Pliocene and Quaternary deposits of Delaware: Palynology, ages, and paleoenvironments. Report of Investigations No. 58. University of Delaware, Newark, DE.

Harden, J. W. 1982. A quantitative index of soil development from field descriptions: Examples from a chronosequence in central California. Geoderma 28:1-28.

Hogan, J.D., and M.T. Beatty. 1963. Age and properties of Peorian loess and buried paleosols in southwestern Wisconsin. Soil Soc. Am. Proc. 27:345-350.

Jones, A. A. 1982. X-ray Flouresence Spectrometry. p. 85-121. *In* A. L. Pageet et al. (ed.) Methods of Soil Analysis Part 2 -- Chemical and Microbiological Properties. Soil Science Society of America, Madison, Wisconsin.

Jones, R. L., and A. H. Beavers. 1963. Sponge spicules in Illinois soils. Soil Sci. Soc. Am. Proc 27:438-440.

Jones, R. L., and A. H. Beavers. 1964. Aspects of catenary and depth distributions of opal phytoliths in Illinois soils. Soil Sci. Soc. Am. Proc. 28:413-416.

Kellner, M., and D. Peteet. 1993. Late-Quaternary climate in the Ridge and Valley of Virginia, U.S.A.: Changes in vegetation and depositional environment. Quaternary Science Reviews 12:613-628.

Kraft, J. C., M. J. Chrzastowski, D. F. Belknap, M. A. Tuscano, and C. H. Fletcher. 1987. The transgressive barrier-lagoon coast of Delaware: Morphostratigraphy, sedimentary sequences and responses to relative rise in sea level. p. 129-143. *In* D. Nummedal et al. (ed.) Sea-level fluctuation and coastal evolution. Society of Economic Paleontologists and Mineralogists, Tulsa, OK.

Kunze, G.W., and J.B. Dixon. 1986. Pretreatment for Mineralogical Analysis. p. 91-100. *In* A. Klute (ed.) Methods of Soil Analysis Part1 -- Physical and Mineralogical Methods. Soil Science Society of America, Madison, Wisconsin.

Leigh, D. S. 1996. Soil chronosequence of Brasstown Creek, Blue Ridge Mountains, USA. Geoderma 26:99-114.

Leigh, D. S., and J. C. Knox. 1994. Loess of the Upper Mississippi Valley Driftless Area. Quaternary Research 42:30-40.

Lowery, D. L. 2002. A Time of Dust: Archaeological and Geomorphological Investigations at the Paw Paw Cove Paleo-Indian Site Complex in Talbot County, Maryland. Chesapeake Bay Watershed Archaeological Research Foundation, Tilghman, MD.

Lowery, D. L., and J. F. Custer. 1990. Crane Point: An Early Archaic site in Maryland. Journal of Middle Atlantic Archaeology 6:75-120.

Markewich, H. W., M. J. Pavich, M. J. Mausbach, R. L. Hall, R. G. Johnson, and P. P. Hearn. 1987. Age relations between soils and geology in the Coastal Plain of Maryland and Virginia. United States Government Printing Office, Washington, D.C.

Matthews, E. D. 1959. Soil Survey of Dorchester County, Maryland. U.S.D.A. Soil Conservation Service, Washington, D.C.

Matthews, E. D., and R. L. Hall. 1966. Soil Survey of Somerset County, Maryland. U.S.D.A. Soil Conservation Service, Washington, D.C.

Matthews, E. D., and W. U. Reybold. 1966. Soil Survey of Queen Anne's County, Maryland. U.S.D.A. Soil Conservation Service, Washington, D.C.

Meixner, R. E., and M. J. Singer. 1981. Use of a field morphology rating system to evaluate soil formation and discontinuities. Soil Science 131:114-123.

Mixon, R. B. 1985. Stratigraphic and geomorphic framework of uppermost Cenozoic deposits in the southern Delmarva Peninsula, Virginia and Maryland. United States Government Printing Office, Washington, D.C.

Mott, R. J., D. R. Grant, R. Stea, and S. Occhietti. 1986. Late-glacial oscillation in Atlantic Canada equivalent to the Allerød/younger Dryas event. Nature 323:147-250.

Muhs, D. R., J. N. Aleinikoff, T. W. Stafford, R. Kihl, J. Been, S. A. Mahan, and S. Cowherd. 1999. Late Quaternary loess in northern Colorado: Part I--Age and paleoclimatic significance. GSA Bulletin 111:1861-1875.

Mulholland, S. C., and G. Rapp. 1992. A morphological classification of grass silica-bodies. p. 65-89. *In* G. Rapp and S. C. Mulholland (ed.) Phytolith Systematics: Emerging Issues. Plenum Press, New York.

Nelson, D. W., and L. E. Sommers. 1982. Total Carbon, Organic Carbon, and Organic Matter. p. 539-579. *In* A. L. Pageet et al. (ed.) Methods of Soil Analysis Part 2 -- Chemical and Microbiological Properties. Soil Science Society of America, Madison, Wisconsin.

Norton, L. D., L. T. West, and K. McSweeney. 1988. Soil development and loess stratigraphy of the midcontinental USA. p. 145-159. *In* D. N. Eden and R. J. Furkert (ed.) Loess: Its Distribution, Geology and Soils. A.A. Balkema, Rotterdam.

Oliver, M. A., and R. Webster. 1990. Kriging: a method of interpolation for geographical information systems. International Journal of Geographical Information Systems 4:313-332.

Olson, C.G. 1989. Soil Geomorphic Research and the Importance of Paleosol Stratigraphy to Quaternary Investigations, Midwestern USA. p. 129-142. *In* A. Bronger and J.A. Catt (ed.) Paleopedology: Nature and Application of Paleosols. Catena Verlag, Germany.

Owens, J. P., and C. S. Denny. 1979. Upper Cenozoic deposits of the central Delmarva Peninsula, Maryland and Delaware. U.S. Government Printing Office, Washington, D.C.

Perkins, S. O., and M. Hershberger. 1929. Soil Survey Report of Talbot County, Maryland. U.S.D.A., Washington, D.C.

Perkins, S. O., and H. B. Winant. 1931. Soil Survey Report of Queen Anne's County, Maryland. U.S.D.A., Washington, D.C.

Peteet, D. M., R. A. Daniels, L. E. Heusser, J. S. Vogel, J. R. Southon, and D. E. Nelson. 1993. Late-glacial pollen, macrofossils and fish remains in northeastern U.S.A. - The Younger Dryas oscillation. Quaternary Science Reviews 12:597-612.

Peteet, D. M., J. S. Vogel, D. E. Nelson, J. R. Southon, R. J. Nickmann, and L. E. Heusser. 1990. Younger Dryas climatic oscillation in northeastern USA? AMS ages for an old problem. Quaternary Research 33:219-230.

Piperno, D. R. 1988. Phytolith Analysis: An Archaeological and Geological Perspective. Academic Press, Inc., New York.

Prothero, D. R., and F. Schwab. 1996. Sedimentary Geology. W.H. Freeman and Company, New York.

Pye, K. 1996. The nature, origin and accumulation of loess. Quaternary Science Reviews 14:653-667.

Rabenhorst, M.C. 1978. A Study of the Soils Derived from Serpentinite and Associated Rocks in Maryland. M.S. thesis University of Maryland, College Park.

Rabenhorst, M.C., J.E. Foss, and D.S. Fanning. 1982. Genesis of Maryland soils formed from serpentinite. Soil Sci. Soc. Am. J. 46:607-616.

Reineck, H. E., and I. B. Singh. 1980. Depositional Sedimentary Environments with Reference to Terrigenous Clastics. Springer-Verlag, New York.

Reybold, W. U. 1970. Soil Survey of Talbot County, Maryland. U.S.D.A. Soil Conservation Service, Washington, D.C.

Richardson, J.L., and R.B. Daniels. 1993. Stratigraphic and hydraulic influences on soil color development. p. 109-125. *In* J.M. Bingham and E.J. Ciolkosz (ed.) Soil Color. Soil Sci. Soc. Am., Inc., Madison, WI.

Richmond, G. M., and D. S. Fullerton. 1986. Summation of Quaternary glaciations in the United States of America. Quaternary Science Reviews 5:183-196.

Ruhe, R. V. 1969. Quaternary Landscapes in Iowa. Iowa State University Press, Ames, Iowa.

Ruhe, R. V. 1983. Depositional environment of Late Wisconsin loess in the midcontinental United States. p. 130-137. *In* S. C. Porter (ed.) Late Quaternary Environments of the United States Volume 1: The Late Pleistocene. Univ. of Minn. Press, Minneapolis, MN.

Schoenberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson. 1998. Field Book for Describing and Sampling Soils. Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, Nebraska.

Semmel, A. 1989. Paleopedology and Geomorphology: Examples from the western part of Central Europe. p. 143-162. *In* A. Bronger and J.A. Catt (ed.) Paleopedology: Nature and Application of Paleosols. Catena Verlag, Germany.

Shields, D.A., and S.L. Davis. 2001. Soil Survey of Queen Anne's County, Maryland. USDA-NRCS, Washington, D.C.

Shuman, B., T. W. III, P. Bartlein, and J. W. Williams. 2002. The anatomy of a climatic oscillation: vegetation change in eastern North America during the Younger Dryas chronozone. Quaternary Science Reviews 21:1777-1791.

Simonson, R. W. 1982. Loess in soils of Delaware, Maryland, and northeastern Virginia. Soil Science 133:167-178.

Sirkin, L. 1977. Late Pleistocene vegetation and environments in the Middle Atlantic Region. p. 207-217. *In* W. S. Newman and B. Salwen (ed.) Amerinds and their Paleoenvironments in Northeastern North America. The New York Academy of Sciences, New York.

Smiley, T. L., R. A. Bryson, J. E. King, G. J. Kukla, and G. I. Smith. 1991. Quaternary paleoclimates. p. 13-44. *In* R. B. Morrison (ed.) Quaternary Nonglacial Geology: Conterminous U.S. Geological Society of America, Golden, CO.

Stoermer, E.F., and J.P. Smol. 1999. Applications and uses of diatoms: prologue. p. 3-8. *In* E.F. Stoermer and J.P. Smol (eds.) Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press, Cambridge, UK.

Snyder, J. M., and W. C. Jester. 1926. Soil Survey Report of Dorchester County, Maryland. U.S.D.A., Washington, D.C.

Soil Survey Staff. 1993. Soil Survey Manual. USDA, Washington, D.C.

Soil Survey Staff. 1999. Soil Taxonomy. USDA, Washington, D.C.

Taylor, K. C., C. U. Hammer, R. B. Alley, H. B. Clausen, D. Dahl-Jensen, A. J. Gow, N. S. Gundestrup, J. Kipfstuhl, J. C. Moore, and E. D. Waddington. 1993. Electrical conductivity measurements from the GISP2 and GRIP Greenland ice cores. Nature 366:549-552.

Tedrow, J., and P. MacClintock. 1953. Loess in New Jersey soil materials. Soil Sci. 75:19-29.

Trask, P. D. 1932. Origin and Environment of Source Sediments of Petroleum. American Petroleum Institute, Gulf Publishing Company, Houston, Texas.

Toscano, M. A., R. T. Kerhin, L. L. York, T. M. Cronin, and S. J. Williams. 1989. Quaternary stratigraphy of the Inner Continental Shelf of Maryland. Maryland Geological Survey, Baltimore.

Toscano, M. A., and L. T. York. 1992. Quaternary stratigraphy and sea-level history of the U.S. Middle Atlantic Coastal Plain. Quaternary Science Reviews 11:301-328.

Twiss, P. C. 1992. Predicted world distribution of C_3 and C_4 grass phytoliths. p. 113-128. *In* G. Rapp and S. C. Mulholland (ed.) Phytolith Systematics: Emerging Issues. Plenum Press, New York.

Twiss, P. C., E. Suess, and R. M. Smith. 1969. Morphological classification of grass phytoliths. Soil Sci. Soc. Am. Proc. 33:109-115.

Verma, S. D., and R. H. Rust. 1969. Observations on opal phytoliths in a soil biosequence in southeastern Minnesota. Soil Sci. Soc. Am. Proc. 33:749-751.

Waltman, S. W., and E. J. Ciolkosz. 1995. Prairie soil development in northwestern Pennsylvania. Soil Sci. 160:199-208.

White, E. A. 1982. Soil Survey Report of Kent County, Maryland. U.S.D.A., Washington, D.C.

Whittig, L. D., and W. R. Allardice. 1986. X-Ray Diffraction Techniques. p. 331-362. *In* a. Klute (ed.) Methods of Soil Analysis Part 1 -- Physical and Mineralogical Methods. Soil Science Society of America, Madison , Wisconsin.

Wilding, L. P., and L. R. Drees. 1968. Biogenic opal in soils as an index of vegetative history in the Prairie Peninsula. p. 96-103 . *In* R. E. Bergstrom (ed.) The Quaternary of Illinois. University of Illinois College of Agriculture.

Wilding, L. P., and L. R. Drees. 1971. Biogenic opal in Ohio soils. Soil Sci. Soc. Am. Proc. 35:1004-1010.

Winant, H. B., and J. P. Bewley. 1930. Soil Survey Report of Kent County, Maryland. U.S.D.A., Washington, D.C.

Wright, W. R. 1972. Pedogenic and geomorphic relationships of associated paleudults in southern Maryland. Ph.D. dissertation University of Maryland, College Park.

Yaalon, D.H. 1983. Climate, Time, and Soil Development. p. 233-251. *In* L.P. Wilding et al. (ed.) Pedogenesis and Soil Taxonomy I. Concepts and Interactions. Elsevier, New York.

Yu, Z. C., and H. E. Wright. 2001. Response of interior North America to abrupt climate oscillations in the North Atlantic region during the last deglaciation. Earth-science Reviews 52:333-369.