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PLEISTOCENE CHANNELS OF NEW CASTLE COUNTY, DELAWARE

BY

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ABSTRACT

Two Pleistocene channel-systems are recognized in New Castle County, (1) a system of straight channels located in the area north of the Chesapeake and Delaware Canal and (2) a braided system occupying the area south of the Canal.

Fluctuations of the flow regime of Pleistocene streams were frequent as evidenced by sedimentary structures and widespread distribution of gravels in the channel deposits. During high stream flows most of the study area was submerged, while during low flows large interstream areas and islands emerged.

The transporting agents of the Pleistocene sediments were primarily melt-water streams originating below glaciers which at times advanced to within 100 miles north of New Castle County. Thus, the age of the deposits is thought to be glacial, but there is no indication as to which glacial stage they belong. However, the channels appear to have been formed contemporaneously by a major distributary system.

INTRODUCTION

The continued rapid economic and population growth of the State of Delaware, and particularly New Castle County, requires a commensurate increase in the availability of ground water and mineral resources. The Columbia (Pleistocene) sediments are one of the major sources of both. Where the sands and gravels are thick, they are inherently rich in ground water and engineering materials. Thus, the location of major water users and sand and gravel mining operations is influenced by the location of areas of thick surficial (Columbia) deposits.

The development of scientific techniques for the efficient location of areas containing thick deposits of sand and gravel is both important and challenging. This report presents the results of a geologic investigation utilizing a combination of thickness data from wells together with an interpretation of sedimentary structures in terms of stream directions within the deposits. This approach may add to the understanding of the geologic events affecting this area in Pleistocene time; in addition, it has aided in locating Pleistocene channels.

ACKNOWLEDGMENTS

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PREVIOUS WORK

The vast amount of Pleistocene sediments and the problem of their origin have stimulated the interest of a number of geologists who have worked in the Atlantic Coastal Plain. McGee (1887) introduced the name Columbia for these deposits and this name is retained here.

Jordan (1964) studied the mineralogy, texture, and structure of the Columbia sediments in Delaware. He pointed out that their variable thickness in the northern part of the State is due to their filling of former stream valleys or channels. Groot, Organist, and Richards (1954) used the term "channel" to describe Pleistocene outcrops along the Chesapeake and Delaware Canal. The channels were also recognized by drilling in localities north of the Canal. Rasmussen et al. (1957, 1966) provided highly generalized maps for both the base of the Pleistocene and the Pleistocene channels of the northern part of the State. Their interpretation of the channels as stream valleys cut at different elevations during glacial stages and filled by deposits during interglacial stages is based on the differences in the base elevations of the channels.

The origin of the Columbia sediments has been and still is a controversial subject (Jordan, 1962, 1964). However, at present most workers agree on the fluvial origin of the sediments in the area of this study. Marine and Rasmussen (1955), Ward and Groot (1957), Rasmussen et al. (1960), and Jordan (1964), suggested both melt-water flooded streams and lowered sea level as factors being responsible for the deposition of the Columbia sediments.

GEOLOGIC SETTING OF THE AREA

New Castle County encompasses segments of two regional geologic provinces: the Piedmont Province of the Appalachian Mountain System and the Coastal Plain Province.

The Piedmont Province occupies the northernmost part of the area (Figure 1, insert). It is an area of diversified relief dissected by narrow and deep stream valleys with residual eminences rising above the general upland level. It is composed of folded Paleozoic and Precambrian (?) metamorphic and igneous rocks. In the western part the metasediments (schist, gneiss, and marble) are predominant (Bascom and Miller, 1920) while the eastern part is underlain by banded gneiss, granite, and gabbro (Ward, 1959). The surface of the crystalline rocks of the Piedmont slopes southward and southeastward forming the basement upon which lies the wedge-shaped mass of the sedimentary rocks of the Coastal Plain.

The Coastal Plain is a relatively flat and low area with elevations generally not exceeding 100 feet above mean sea level. The zone adjacent to the Delaware Bay is exposed to tidal flooding and is characterized by conspicuous marshes and estuaries. Most of the streams in this zone are tidal or have at least a tidal segment. Stream valleys are shallow compared with those of the Piedmont. Farther inland, particularly in the southern portion of New Castle County, numerous undrained depressions are present.

The Columbia sediments cover the Cretaceous and Tertiary sedimentary rocks of the Coastal Plain. In the greater part of the area north of the Chesapeake and Delaware Canal the older sediments are nonmarine sands and clays of Early and, partly, Late Cretaceous age. A sequence of marine Upper Cretaceous sands, silts and clays underlies the Columbia in a zone about 10 miles wide extending in a northeasterly direction across the State occupying areas on both sides of the Chesapeake and Delaware Canal. South of this zone the older sediments are represented by a succession of Tertiary marine sands, silts and clays. Most of the marine sand and silt units are glauconitic. All of the Coastal Plain sediments in the study area are unconsolidated and easily eroded.

The Piedmont and Coastal Plain Provinces are separated by the "Fall Zone" (Figure 1, insert). The sedimentological significance of this zone is that it divides the area of predominant erosion (Piedmont Province) from the area of predominant deposition (Coastal Plain Province). The Piedmont streams are characterized by relatively steep gradients and, therefore, most of their sediment load is transported into the Coastal Plain and only a minor part is deposited in their channels and flood plains. The gradients of the Coastal Plain streams draining into Delaware Bay, however, are very gentle and a large part of their sediment load is deposited before reaching the Bay. The process of deposition is particularly effective in the tidal marsh area along the Bay.

LITHOLOGY OF COLUMBIA SEDIMENTS*

Only a brief account of the lithology of the Columbia sediments is presented here. For more detailed information the reader is referred to Jordan's work (1964).

The Columbia sediments are composed mostly of subarkosic sand and gravel. The color of the sediments is tan, brown to reddish-brown, and yellowish-brown. Sands are the dominant component of the Columbia sequence and gravels appear either in individual layers, usually at the base of the sequence, or dispersed throughout the section. Thin beds of silt and clay are present locally.

Cross-bedding is the most common sedimentary structure and is characterized by high variability of the foreset inclinations. Parallel bedding is sometimes displayed in the layers composed of fine-grained sediments. Cut-and-fill and slump structures are also observed.

Sedimentary parameters - cross-bedding thickness, median grain size, and maximum particle size - decrease southward. Conversely, the sorting of the sediments increases. None of these features seems to be interrupted by various depositional episodes. Thus: "The Columbia Formation appears to be, in terms of its lithology and dispersion, essentially a continuum." (Jordan, 1964, p. 35).

The mineralogy of the Pleistocene sands is strongly dominated by quartz which averages more than 80 per cent in the sands examined. The feldspar content varies and averages about 18 per cent. In general, potash-feldspar is about five times as abundant as plagioclase. Mica content varies from locality to locality but its over-all content is about 0.5 per cent. Rock fragments, including chert, comprise about 1 per cent. The gravel portion of the Columbia sediments is dominated by sandstone (mostly quartzite), vein quartz, and chert. Crystalline rock fragments and shale fragments are present only in small amounts. Occasionally, clay balls composed of the underlying Cretaceous sediments are observed.

*The lithological description of the Columbia sediments is generally based on Jordan's work (1964).

The heavy mineral content of the sands averages less than 1 per cent. About 80 per cent of this is opaque minerals. The more abundant nonopaque minerals consist of vari-colored hornblende, epidote, sillimanite, fibrolite, tourmaline, and zircon.

METHOD OF WORK

Cross-bedding, sediment thickness, and thickness trend are integrated in the approach of this study. Theoretically, the combination of these parameters should provide a relatively simple tool for delineation of "fossil" fluvial channels. However, the method is meaningful only if a relatively large number of data are available. The information at hand for this study is considered adequate for the reconstruction of the regional Pleistocene stream systems in the area.

Cross-bedding data incorporated are those measured by Jordan (1964) and consist of 125 measurements at 25 localities in the area of the present study. Thickness data are obtained from 253 wells taken by the author from the files of the Delaware Geological Survey.

A number of features and characteristics of fluvial channels must be considered in reconstructing the regional paleochannel systems. Fluvial channels usually trend normal to the strike of the regional paleoslope. The direction of the paleoslope is determined by measuring the mean direction of the foreset inclinations of cross-bedded units of channel deposits. The foresets are inclined downcurrent (Potter and Olsen, 1954; Potter and Siever, 1956; Potter et al., 1958). Small-scale divergence of channel segments from the mean channel trend is usually indicative of the influence of local topography; large-scale divergence, however, may characterize distributary systems of deltas, fans, and braided rivers.

Channel depth may be highly variable but, in general, it increases in two directions: across the channel toward its deepest part and along the channel. The rate of increase is usually greater across than along it. Locally and regionally, however, the depth may vary greatly. The thickness of the sediments deposited in a channel varies in accordance with the channel's original morphology.

The geographic distribution of thickness data is an important factor which determines the accuracy and, therefore, the validity of the reconstructed channels. Valid channel reconstruction and the identification of such features as bars, islands, and noses can be accomplished when most thickness data are concentrated in the channel areas. The interchannel areas are usually covered with a relatively thin blanket of deposits and are readily recognized.

As the thickness of the Columbia sediments varies within relatively short distances, the isopach map (Figure 1) was constructed on the basis of local thickness trends. Parts of the map constructed in this manner were then correlated and the over-all map compiled. It is apparent from the map that an uneven distribution of data prevails and where the data are scarce the construction is of an interpretive and preliminary nature.

INTERPRETATION OF RESULTS

The factors that have been considered in the paleo-geomorphological interpretation of the isopach map are: morphology of the Columbia sedimentary bodies as reflected in their thickness variability, character of the sedimentary structures and lithology. The interpretation is shown in Figure 2. It reveals a distinct channel-pattern. The term "channel" as used throughout this study refers to a valley or topographic low which is filled partly, or entirely, by Pleistocene fluviatile sediments. Two major channel systems are recognized; a system of straight channels located in the area north of the Chesapeake and Delaware Canal and a braided system occupying the area south of the Canal.

System of Straight Channels

Two major channels are recognized in the area north of the Chesapeake and Delaware Canal (Figure 2).

The western channel, which runs north-south, has its base at about +40 feet sld (sea-level datum) and its present surface at about +85 to +90 feet sld. The average thickness of the sediments deposited in the channel is about 40 feet; the maximum thickness recorded is 75 feet. The width varies but does not exceed two miles.

The eastern channel runs southwest for a considerable length and in the vicinity of Delaware City turns toward the south. The average elevation of its base is about -10 feet sld while the land surface is about +90 feet sld. The average thickness of the channel deposits is about 55 feet and the maximum thickness recorded is 133 feet. The channel ranges in width from less than one mile to more than three miles.

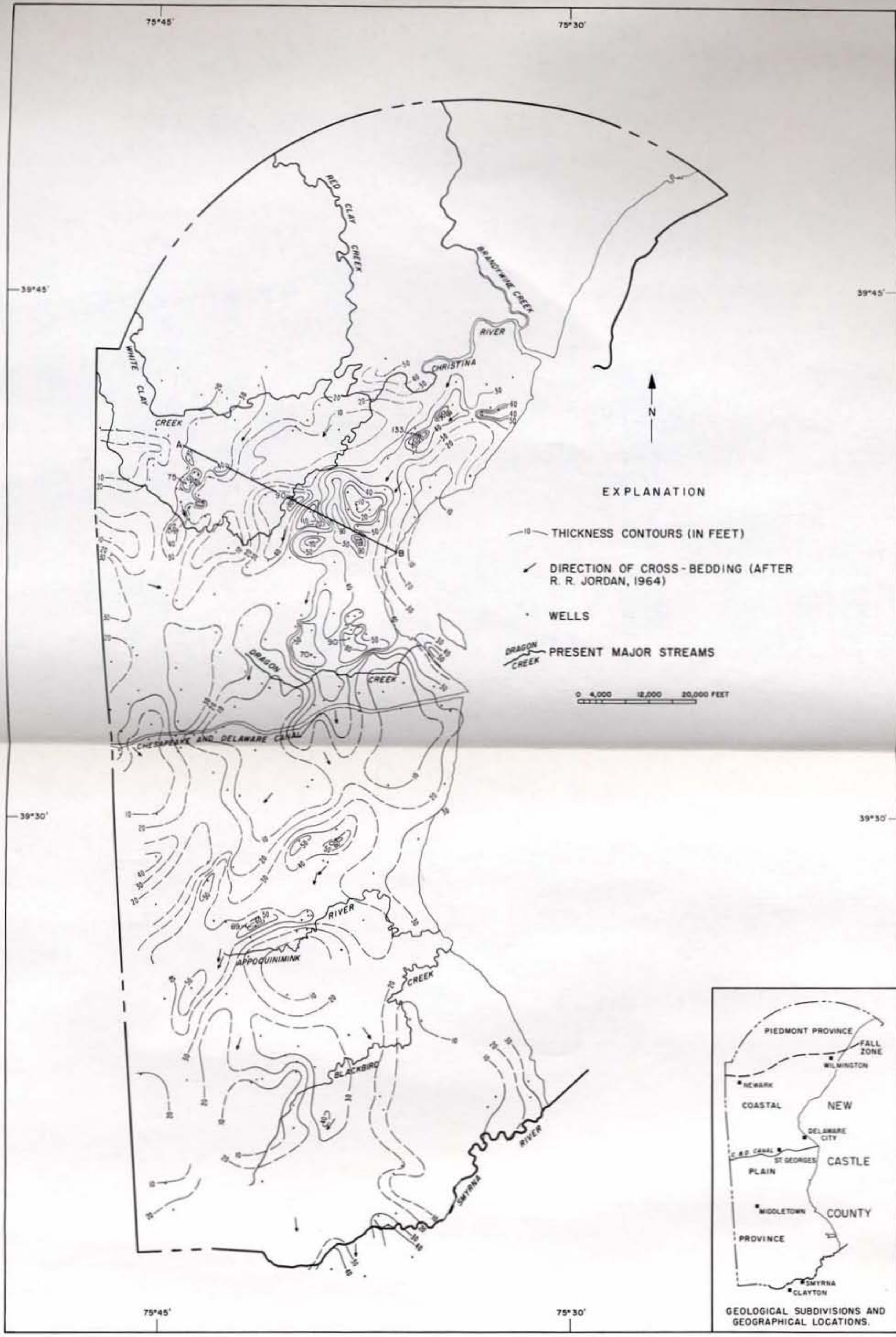

Figure 1. Isopach map of the Columbia sediments with insert map showing geological subdivisions and geographic locations.

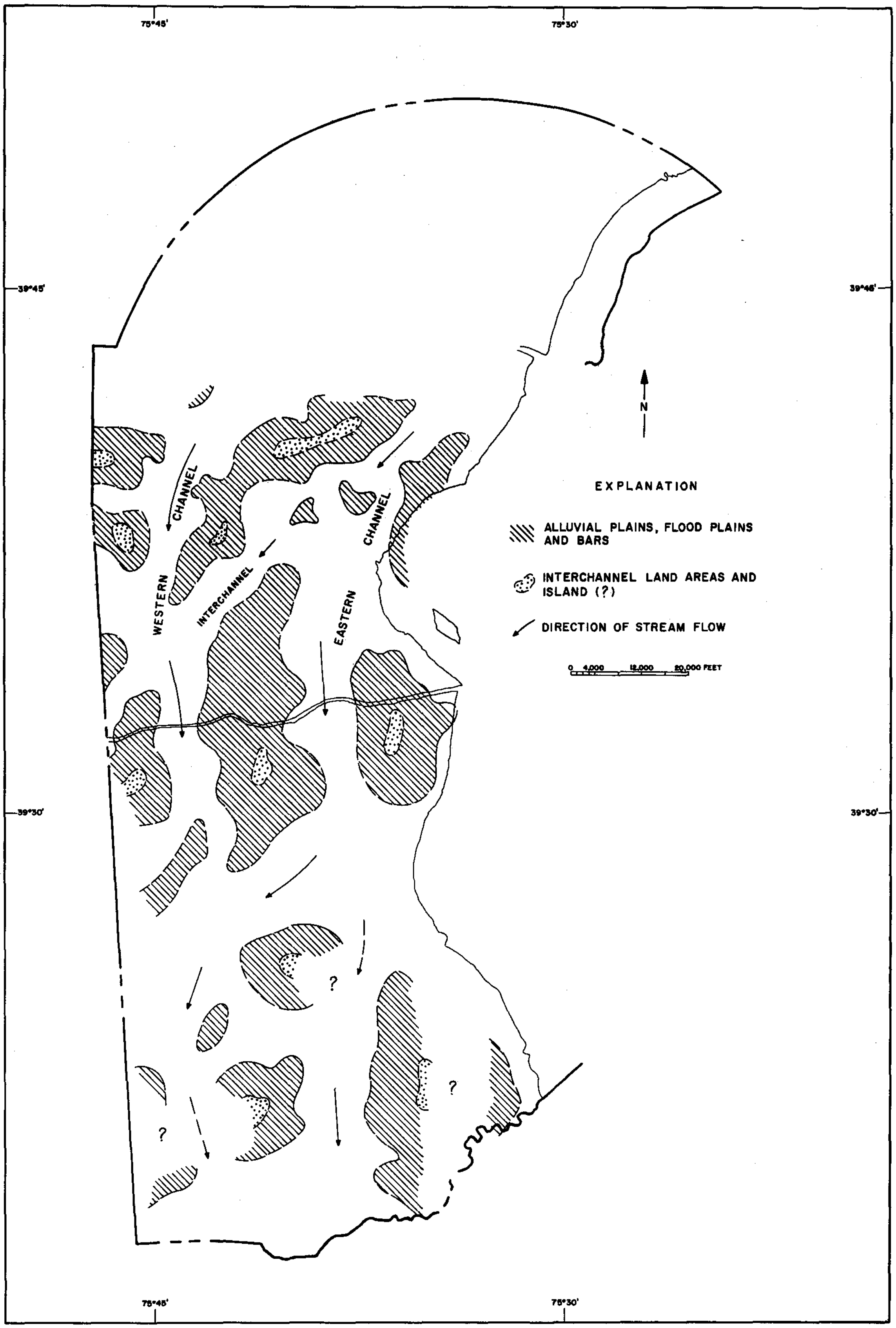

Figure 2. Map of Pleistocene channels.

The eastern channel is larger, wider and deeper than the western channel. The magnitude of the cross-bedded units is also larger and, therefore, the capacity and the size of the stream (or streams) which formed the eastern channel were greater than those which formed the western one. Consequently, the difference in the base elevation between the two channels does not necessarily reflect different base levels existing at different intervals of Pleistocene time, as suggested by Rasmussen et al. (1957, 1966).

The difference in the thickness of the channel-filling sediments is directly related to the size of the channels; thus, the larger eastern channel accommodated a greater amount of sediments than the smaller western channel.

The regional slope between the eastern and western channels - from west toward east - is about 4 feet per mile. They are connected by a relatively shallow interchannel (Figure 2). The base elevation of this interchannel varies from about +40 feet sld in the northeastern part to about +50 feet sld in the southwestern part. Between these two the elevation of the base rises to about +60 feet sld. The land surface elevation of the interchannel is about +80 to +85 feet sld, and it seems, therefore, that the interchannel was submerged during high flows only.

Braided System

The identities of the eastern and western channels in the area south of the Chesapeake and Delaware Canal are lost. Here, the channel system has a braided pattern with individual channels divided by islands and bars. The term "braided system" refers to a large-scale braided pattern which was most probably produced by a number of relatively small braided streams developed within the individual channels. The channel trends widely diverge from the main north-south direction of the regional paleoslope. The width of the channels, as well as the thickness of the sediments deposited in them, is variable. Sedimentary structures, dispersion of sediments, and the morphology of sedimentary bodies suggest that Pleistocene streams were characterized by rapid shifting and reworking of bed materials and continual changing of channel positions. It is possible that divergent flows deposited fan-like noses which may have contributed to changing of positions of channel-alignments by imposing barriers across active anabranches. Coarse material, which was available to the Pleistocene streams, might have encouraged the formation of bars by selective deposition, thus diverting the flow and increasing the erosional attack on the banks. It seems, however, that the main cause for the formation of the braided system in this area was the sediment load of the Pleistocene streams which was too large to be carried by a single channel. Variations in the amount of sediment discharge apparently affected the nature of the system with high discharges being responsible for the formation of a braided pattern and low discharges producing a meandering pattern. During low discharges a number of temporary cutoff meanders and similar features were formed and a part of the area "emerged" forming the Pleistocene land. During high flows, however, most of the area was covered by streams and flood plains and only a small portion of the land area remained above general water level as islands and interchannel land areas.

Sediment Load

The sediment load of the Pleistocene streams was provided primarily by glacial erosion of the rocks of the Appalachian Mountain System. Rock fragments contained in some Columbia sediments indicate that they were derived from the Middle Paleozoic and younger rocks of the Appalachian Mountains, while the metamorphic heavy minerals suggest that their source was in the rocks of the Piedmont and Reading Prong (Jordan, 1964). A minor, but not negligible part was supplied by the erosion of Pleistocene stream channels and banks which is evidenced by the presence of rock fragments and minerals (glauconite) derived from the underlying Cretaceous sediments in the Columbia deposits.

The transporting agents of the Pleistocene (Columbia) sediments were primarily meltwater streams originating below glaciers which were located approximately 100 miles north of New Castle County. Fahnestock (1963, p. A61) who studied the hydrology of the White River in the State of Washington concluded: "... although the regimen of the glacier has long-term effects in providing debris to the stream, the short-term effects of weather and runoff determine the rate of deposition and erosion, the hydraulic characteristics, and the pattern of the stream." This conclusion may be applicable to the Pleistocene streams in New Castle County; thus, the frequent fluctuations of the flow regime are indicative of the short-term climatic changes rather than long-term effects of glaciers. The age of the Columbia deposits is thought to be glacial; however, at present it is not possible to determine to which glacial stage they belong.

Pleistocene Flow Regime

Sedimentary structures and dispersion of sediments were the only factors considered in reconstructing the general nature of the flow regime of Pleistocene streams, which is here considered to be a range of flows that have similar characteristics and produce similar sedimentary structures.

The evidence offered by the sedimentary structures of the Columbia sediments suggests frequent fluctuations of the flow regime. Foreset inclinations of the cross-bedded units display significant variations laterally along individual beds as well as vertically across different layers of the Pleistocene sequence. A transition from angular planar cross-strata with relatively small trough sets to tangential concave cross-stratified units with large trough sets is commonly observed. The transition is gradational or it may be sharp with the tangential units being indicative of the upper and upper-lower, and angular ones of the lower flow regime (Harms and Fahnestock, 1965). The widespread distribution of gravels also seems to indicate fluctuations of the flow regime. Harms and Fahnestock (1965) showed that pebbles larger than one inch in diameter with a specific gravity of 2.0 or more were transported only in the upper flow regime. Therefore, the widespread horizontal and vertical distribution of the Columbia gravels throughout the study area can be explained by frequent flow regime fluctuations of the Pleistocene streams and continual reworking of the sediments. Increase in the stream competency apparently resulted in erosion and channel widening while the decrease in competency was accompanied by deposition of transported material. These two processes were probably operating intermittently during most of the time the streams were in existence. Laterally persistent parallel-bedded layers of silt and clay interbedded in the sequences of coarser sediments suggest periods of deposition under quiet conditions which probably occurred in the cut-off meanders and similar features during low stream discharges.

RELATIONSHIP BETWEEN PLEISTOCENE MORPHOLOGY AND PRESENT STREAMS

Comparison of the isopach map of the Pleistocene with the locations of present major streams (Figure 1) reveals a remarkable relationship: major streams now tend to flow in the areas which were topographic highs (interchannel areas) in the Pleistocene time.

The Christina River enters the area of investigation northwest of Newark and flows southeastward for about 10 miles. There it turns nearly 90 degrees and flows northeastward. For the greater part of its length the river is located in the areas of relatively thin Columbia sediments. In its middle part it flows in the interchannel area where the Columbia sediments are not present.

Dragon Creek, which is located just north of the Chesapeake and Delaware Canal, flows from west to east and in the vicinity of St. Georges it crosses the eastern channel. Sediments in the channel at this location are relatively thin. North of this location the Columbia sediments in the same channel attain a thickness of more than 90 feet. The course of the Dragon Creek clearly displays the adjustment of the flow direction around the thick part of the ancient channel.

The Appoquinimink River flows southwest-northeast. Again, the river quite clearly has been influenced by the thick Pleistocene channel deposits east of Middletown.

Blackbird Creek flows through an area where the Columbia sediments are uniformly thin, and it appears that the course of the creek is governed mostly by the regional slope.

The Smyrna River shows a tendency similar to that of Blackbird Creek; the river follows the regional slope of the land surface. However, it is deflected in the vicinity of Clayton and Smyrna. Here, the thickness of the Columbia sediments rapidly increases on the southern side of the river with the river course being deflected to the north.

The location of major streams and their flow directions indicate that the present land surface slopes eastward and that the present topographic heights are structurally controlled by thicker accumulations of the Columbia sands and gravels (Figure 3).

SUMMARY AND CONCLUSIONS

(1) Pleistocene streams formed a system of straight channels in the area north of the Chesapeake and Delaware Canal. The eastern and western channels differ in the mutually related morphological features of size, thickness of the sediments deposited, and base elevations. There are no significant differences in their textures, mineralogy and sedimentary structures, nor in present land surface

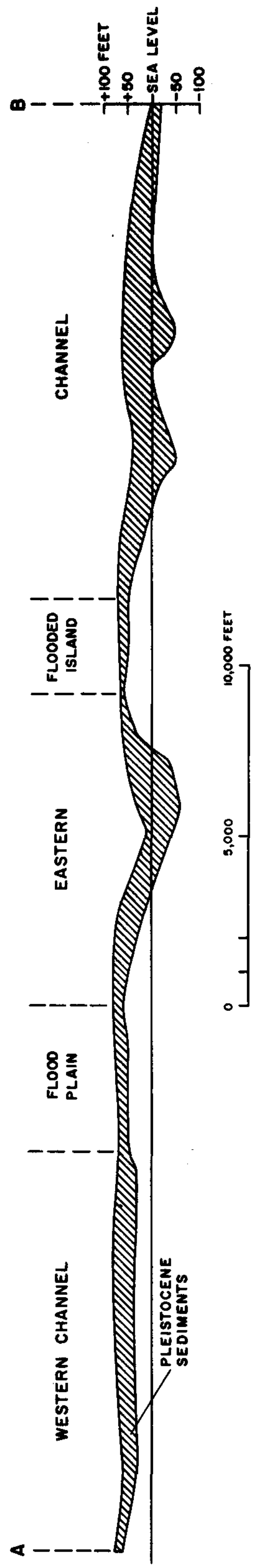

Figure 3. Cross-section showing variability of thickness of the Columbia sediments.
(Location of the cross-section shown on Figure 1)

elevations. The sedimentary structures do, however, differ in size with the cross-bedded units in the eastern channel being larger than those in the western channel.

Fluctuations of the flow regime and discharge were frequent and during very high flows most of the area was submerged below flood waters. During low flows, however, all water was concentrated in the channels and the rest of the area emerged forming the Pleistocene land. The changes from high to low flows resulted in widening and filling of existing channels rather than shifting of the over-all stream courses.

(2) The nature of the depositional environment of the Pleistocene sediments in the area south of the Chesapeake and Delaware Canal was different from that north of the Canal. The fluctuations of the flow regime, which were frequent in this area as well, had a significant effect on the morphology of Pleistocene streams. High flows produced a braided pattern which covered almost the entire area. During low flows the braided pattern was probably partly replaced by a meandering system leaving some of the cut-off meanders as individual water bodies. The deposition under quiet conditions in such bodies produced thin layers of parallel-bedded silt and clay. It seems that the morphology and hydrology of the Pleistocene streams changed with great rapidity in response to fluctuations of the flow regime as suggested by the sedimentary structures and the random deposition of gravels throughout this part of the study area.

(3) The Pleistocene channels seem to have been formed contemporaneously by a large distributary system, the most conclusive evidence for this being the similar land surface elevations of the channels, particularly those north of the Chesapeake and Delaware Canal.

(4) The effect of erosion on post-Pleistocene (Recent) topography is not known. It seems, however, that the topography existing after the deposition of Columbia sediments resembled the present low and flat area and the processes of erosion operating during all of Recent time (up to the present) have been similar to those operating today. Therefore, it appears that the topographic modifications were small and the Pleistocene channel systems were well preserved.

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