PIEDMONT BASIN: CURRENT STATUS

GEOLOGY

The Piedmont Basin is found within two physiographic provinces: the Piedmont Province and Atlantic Coastal Plain Province. Delaware's Piedmont Province occupies the northernmost, 6% of the state and is commonly referred to as "Delaware's hard rock country." The basin takes its name from this geologic province in which it primarily resides — "the Piedmont" — which literally means lying at the base or the foot of the mountains. While Delaware's highest elevations, greater than 400 feet above sea level, are found in the Piedmont Province, the basin's elevation generally averages about 250 feet above sea level. Much of the basin is characterized by deeply incised streams, steep slopes, and gently rolling hills. Note that even though they are completely surrounded by the low-lying Atlantic Coastal Plain, Chestnut Hill and Iron Hill (referred to as Piedmont "outliers"), located south of Newark, are included in the Piedmont Province.

The geology of the Piedmont Province consists predominantly of a thick mass of highly deformed metamorphic and igneous rocks estimated to be more than 500 million years old, likely ranging from Proterozoic to early Paleozoic in age (Woodruff and Plank, 1995). These rocks are highly faulted, folded, jointed, and foliated in some areas. Gneisses and schists form the major rock types. Igneous intrusive rocks, including coarse varieties of granite called pegmatites, are also present in some areas. This crystalline mass is overlain with saprolite (weathered rock material) and in some isolated areas is capped with much younger fluvial sedimentary deposits. Recent work by Woodruff and Plank (1995) categorizes the Piedmont crystalline rock complex into five units. Table 2 provides their names, ages, and lithologies.

The Baltimore Gneiss forms the base upon which all the younger Piedmont Basin sediments were deposited. In Proterozoic time, the basin was under water, and the Baltimore Gneiss formed the ocean floor. The Setters, Cockeysville, and Wissahickon formations were originally deposited as sedimentary cover over the Baltimore Gneiss (Woodruff and Plank, 1995).

The Cockeysville Formation resulted from shallow-water deposition of carbonates on a continental margin, while the Wissahickon Formation formed as a result of deep-water sedimentation and turbidity-current deposits. During Paleozoic time, a mountain-building event — the Taconic Orogeny (480 to 435 million years ago) — caused extreme deformation and metamorphism of the sedimentary deposits. This is when the majority of the Wilmington Complex rocks are believed to have formed (Woodruff and Plank, 1995).

Beginning in the Devonian Period (345 to 405 million years ago), much of the Piedmont Province emerged from the ocean

Table 2

ROCKS OF THE PIEDMONT BASIN

(ADAPTED FROM WOODRUFF AND PLANK, 1995)

ROCK UNIT NAME	AGE (millions of years)	GENERAL LITHOLOGICAL DESCRIPTION
Wilmington Complex	340 Early Paleozoic Period	◆ Mafic and felsic gneisses and intrusive igneous rock including gabbroic and dioritic plutons and amphibolites
Glenarm Series		
Wissahickon Formation		◆ Gneisses and schists derived from sandstones and mudstones, amphibolites, and serpentinite
Cockeysville Formation	> 570 Proterozoic Period	◆ Calcareous schists and dolomitic marble
Setters Formation		◆ Impure quartzite
Baltimore Gneiss	> 570 Proterozoic Period	◆ Gneisses of varying lithologies and amphibolites

and remained emerged until Cretaceous time. During this period, thousands of feet of crystalline rock were removed from the area by extensive erosion (Woodruff and Thompson, 1975). Delaware's Piedmont Province continues to undergo this weathering and erosion.

Due to the extensive saprolite mantle — in excess of 80 feet thick in some areas — fresh, unaltered exposures of the aforementioned rock units are not common. The saprolite's thickness in Delaware's Piedmont Province averages approximately 20 to 50 feet (Christopher and Woodruff, 1982).

Of the formations described, the Wilmington Complex and the Wissahickon Formation are by far the most widespread surficial units of the Piedmont Province. In contrast, the Baltimore Gneiss, Setters Formation, and Cockeysville Formation have been mapped only in the northwestern portion of the basin in small, isolated locations. The remainder of this section will focus on the basin's two geological provinces: the Piedmont (Wilmington Complex, Wissahickon and Cockeysville formations, and Piedmont fluvial deposits), and the Atlantic Coastal Plain. See Map 3.

Predominant Geologic Areas of the Piedmont Province

The Wilmington Complex

The Wilmington Complex represents the dominant rock type in the eastern Piedmont Province. This formation is more resistant to chemical and physical weathering than the Wissahickon Formation; for this reason, the eastern Piedmont Province is characterized by relatively gentle slopes and less deeply incised valleys than found in its western portions (Christopher and Woodruff, 1982).

Wilmington Complex rocks are generally massive and do not exhibit significant secondary porosity (faults and joints). These rocks do not readily transmit or store groundwater and do not make good aquifers. An average domestic well in the Wilmington Complex typically yields one gallon per minute or less (Woodruff, 1981). Small quantities of groundwater of questionable quality do exist where the saprolite is of sufficient thickness.

The Wissahickon Formation

The Wissahickon Formation forms the dominant rock type in the northwestern Piedmont Province and may be greater than 8,000 feet thick (Woodruff and Plank, 1995). This formation is less resistant to chemical and physical weathering than the Wilmington Complex. Thus, deeply incised stream valleys and steep slopes characterize this portion of the basin. Amphibolites and gneisses of the Wissahickon support ridges while mica schists erode to form deep-sided valleys (Christopher and Woodruff, 1982). The formation has considerably more secondary porosity than the Wilmington Complex and therefore has more capacity to store and transmit groundwater. Although high densities of joints and faults exist in some locations and may be able to support initial groundwater yields of 300 to 400 gallons per minute, groundwater typically yields 10 gallons per minute (Woodruff, 1981).

The Cockeysville Formation

This formation occupies relatively small geographical areas in the Hockessin/Yorklyn and Pleasant Hill valleys in the northwestern portion of the Piedmont Province. The Cockeysville marble is estimated to range from 400 to 800 feet thick. The overlying saprolite of the Cockeysville varies in thickness, ranging from several feet to 50 feet thick. The unweathered portion of the formation is massive. Where weathered, the Cockeysville Formation serves as an excellent aquifer and is the most highly productive crystalline rock aquifer in the state (Woodruff and Plank, 1995). Aquifer tests in the Pleasant Hill area indicate that the Cockeysville Formation is capable of yielding groundwater at a rate of several hundred gallons per minute (Woodruff and Plank, 1995).

The Cockeysville Formation receives significant quantities of recharge water due to sinkholes that have developed in the streambeds (Woodruff and Plank, 1995). These and other sinkholes characteristic of the formation put the aquifer at considerable risk of being quickly contaminated by human activities that introduce contaminants to streams and land areas within the valleys underlain by the Cockeysville.

Due to the Cockeysville Formation's significance as a water supply source, the Water Resources Agency for New Castle County has mapped it as a Water Resource Protection Area (WRPA), which is protected by New Castle County ordinance. The WRPA ordinance is designed to protect the quality and quantity of ground- and surface water for water-supply purposes through controls that restrict the percent impervious and density of new developments.

Piedmont Fluvial Deposits

As mentioned previously, unconsolidated, fluvial deposits (silts, sands, and gravels) cap the Piedmont Province rocks in some areas. These sediments are generally less than 50 feet thick, with the Columbia Formation comprising the bulk of the sediment volume. The majority of the deposits occur in the southern portion of the Piedmont Province just north of the Fall Line (the boundary between Piedmont rocks and Atlantic Coastal Plain sediments). A relatively thin cover of Columbia sediments also occurs in the eastern portion of the Piedmont Province, along the Delaware River. The gravels of the Bryn Mawr Formation (whose age currently is unknown) occur in three isolated areas north of Wilmington (Woodruff and Thompson, 1972 and 1975). Neither the Columbia nor the Bryn Mawr formation is considered a significant aquifer due to their limited areal extent and relative thinness. The Columbia Formation will be discussed in more detail in the next section.

The Atlantic Coastal Plain Province

The Christina River watershed lies primarily within the Atlantic Coastal Plain, which consists of an unconsolidated mass of caustic sediments that increases in thickness south of the Fall Line. Within the Christina River watershed, Delaware Geological Survey maps indicate that this sediment mass ranges from approximately 20 to 50 feet deep just south of the Fall Line to more than 500 feet deep near the southern portion of the basin. Two geologic formations — the Potomac Formation and the Columbia Formation—comprise the bulk of the Atlantic Coastal Plain sediments in the study area. Relatively small volumes of recent (less than 10,000 years old) and primarily fine-grained Holocene deposits are also found in some stream stretches, ponds, and marshes in the area. See Map 3.

The Potomac Formation

Deposition of the Potomac Formation occurred during the early to late Cretaceous period (Woodruff and Thompson, 1975). The sands, silts, and clays of this formation were derived from the emergent Appalachian chain and were laid down in a fluvial to deltaic depositional environment (Woodruff, 1977). The Potomac Formation is generally much thicker than the Columbia Formation and reaches a maximum thickness within the Christina River basin of approximately 450 feet around Bear, Delaware.

The Potomac Formation is primarily a fine-grained, vari-colored unit composed of pink, white, and gray clays (Woodruff, 1981). Sandy units do occur but are generally thin and not horizontally extensive in the northern portion of the Christina River basin where the formation is thin. To the south, where the formation thickens, lower sand units become thicker and more extensive. The thick sandy units are good aquifers; wells installed in these zones are capable of yielding 400 to 500 gallons per minute. In other areas, thin sandy zones are capable of yielding only several gallons per minute to wells (Woodruff, 1977). The largest percentage of groundwater used in upper New Castle County is derived from the Potomac Formation.

The Columbia Formation

The Columbia Formation lies on top of the Potomac Formation. While the thickness of the Columbia Formation is highly variable, it generally averages 20 to 30 feet thick in the Piedmont Basin. The poorly sorted sands, gravels, and silts of the Columbia Formation are much younger (Pleistocene) than the Potomac Formation and were deposited by glacial streams. These streams cut deeply into the underlying Potomac Formation in some areas and formed relatively deep valleys (paleochannels) that contain thick sections of the Columbia Formation (Woodruff, 1981). Areas with relatively thick deposits of Columbia sediments, and which may be indicative of paleochannels, include an area just east of Chestnut Hill and Iron Hill, from Brookside to just north of Cooch's Bridge; an area just northeast of Bear; and an area in the vicinity of Cherry Island, Delaware.

Where thick, the Columbia Formation makes a highly productive aquifer capable of producing well yields of several hundred gallons per minute. Due to its permeability, the Columbia Formation serves as a recharge area for the underlying Potomac aquifers. In some locations, the Columbia sands are in contact with underlying sands of the Potomac Formation. In these areas, the two formations serve as a single hydrogeologic unit or aquifer (Woodruff, 1981).

Table 3 provides a summary of the age relationships and lithology of the Atlantic Coastal Plain sediments within the Piedmont Basin.

Table 3

ROCKS OF THE ATLANTIC COASTAL PLAIN — PIEDMONT BASIN

ROCK UNIT NAME	AGE (millions of years)	GENERAL LITHOLOGICAL DESCRIPTION
Columbia Formation	Pleistocene Age 1.8 – 0.01	◆ Brown and tan, poorly sorted sands, gravels, and clays.
Potomac Formation	Cretaceous Age 140 – 65	◆ Predominantly vari-colored reddish white and gray clay and silt. ◆ Sandy zones are present.

The Influence of Geology on Stream Flow and Stream Quality

Most major streams in Delaware are considered to be *gaining streams*. In addition to receiving water directly through rainfall, gaining streams receive groundwater from the geologic formation in which they are in contact. The amount of groundwater discharged to streams is governed largely by the aquifer characteristics of the underlying and surrounding geologic formations. As noted earlier, formations such as the Wilmington Complex have limited aquifer potential and do not contribute as much water to a crossing stream as does the highly transmissive Columbia Formation.

Due to its acidic and slow-moving nature, groundwater is able to dissolve certain minerals from the formations that surround it and discharge these ions to streams. If groundwater constitutes a significant volume of the total water in a stream, then the chemistry of the area's geology may significantly affect stream chemistry. Thus, we can determine which streams would most likely be significantly influenced geochemically and make comparisons between existing and predicted stream water quality based on an area's leachable minerals. Information gathered from such comparisons may prove useful in studying and identifying surface-water contaminants.

Table 4 describes the major geologic formations that comprise each of the watersheds in the Piedmont Basin.

Table 4

MAJOR GEOLOGIC FORMATIONS COMPRISING THE PIEDMONT BASIN'S SIX WATERSHEDS

PIEDMONT WATERSHED	MAJOR GEOLOGIC FORMATION	GENERAL DESCRIPTION
Naamans Creek	Wilmington Complex	Limited Columbia Formation deposits occur near the Delaware River.
Shellpot Creek	Wilmington Complex	Most of the Bryn Mawr Formation deposits occur within this watershed. A small southern portion of the watershed contains Atlantic Coastal Plain sediments.*
Brandywine Creek	Wissahickon Formation Wilmington Complex	The Wissahickon Formation is highly faulted and occupies the northwest portion of the watershed. The Wilmington Complex predominates in other areas.
Christina River	Columbia Formation Potomac Formation	The majority of the watershed lies within the Atlantic Coastal Plain. Wilmington Complex rocks exist in a substantial area in the northeast portion of the watershed.
Red Clay Creek	Wissahickon Formation	Wilmington Complex rocks exist in the southern portion of the watershed. A small portion of the Cockeysville Formation occurs in the northern portion of the watershed in the Yorklyn area.
White Clay Creek	Wissahickon Formation	Wilmington Complex rocks exist in the southern portion of the watershed. Most of the Cockeysville Formation occurs in this watershed. The Cockeysville Formation is found in the Hockessin and Pleasant Hill areas.

** Based on field survey data obtained by DNREC's Division of Water Resources, Environmental Services Section, Piedmont streams do not deeply incise the Atlantic Coastal Plain. Comparisons of stream depths and Columbia Formation thickness indicate that most of the stream bottoms occur within the Columbia Formation. Groundwater contributions to the streams in the Atlantic Coastal Plain are therefore primarily through the Columbia, not the Potomac Formation. As stated previously, all six watersheds — with the exception of Naamans Creek — contain Atlantic Coastal Plain sediments in relatively small areas in their extreme southern portions.*