1.4 Bedrock Geology

As explained in the previous section, physiographic provinces are characterized by the geologic formations they contain. The following discussion will outline the geology unique to each province in WMA 6. In addition to the underlying bedrock geology, the surficial geology of WMA 6 consists of glacial deposits, which contribute to the uniqueness of the landforms and hydrology of each province. Surficial geology is the topic of the next section in this report (see Section 1.5). The following discussion describes the geology unique to each province in WMA 6 and relates how they are amenable to the formation of aquifers. A discussion of the aquifers in WMA 6, including significance of aquifer hydraulic properties to watershed management and the contribution of geochemistry to the quality of aquifer water is discussed in Section 1.8, which describes the groundwater system in greater detail.

Newark Basin Physiographic Subprovince

The Newark Basin formed as a consequence of the tensional forces associated with the opening of the Atlantic Ocean. Similar provinces are found from Nova Scotia to North Carolina (Van Houten 1969), including the Gettysburg Basin in south-central Pennsylvania and the Connecticut River Basin. As older references indicate, these basins were once called the "Piedmont Lowlands."

The principal rocks in the basin (Plate 1.4.1) were formed mostly from land-derived sediment, which accumulated during the Late Triassic and Early Jurassic Periods (Olsen 1980). These include: reddish-brown siltstone and shale (the Brunswick Group); hard, dark gray shale (the Lockatong Formation); and light brown sandstone (the Stockton Formation). Between and within these sedimentary rock strata, crystalline rocks, which include lava sheets (flood basalts) and intrusives of basaltic composition, also occur. In WMA 6, the bedrock strata tend to dip to the northwest, typically at an angle of 3 to 12 degrees from the horizontal.

The majority of WMA 6 in the Newark Basin is underlain by the sandstone, siltstone, and shale sequences of the Brunswick Group, which form the major aquifers in the area. This group consists of several formations, represented by basalts as well as sedimentary rocks. In WMA 6, the sedimentary deposits may be found in the Towaco and Boonton Formations (Drake *et al*. 1996). These are primarily distinguishable by their stratigraphic position with respect to the Hook Mountain Basalt flow. The Boonton was deposited upon the Hook Mountain lava sheets, whereas the lava covered and ended the deposition of the Towaco Formation (Olsen 1980). There are minor lithological and paleontological differences between the two formations as well. The Preakness Basalt, which underlies the Towaco Formation is also represented in WMA 6. This formation forms the ridge crest of the Second Watchung Mountain, along which a topographic divide runs that represents the southern and southeastern boundaries of WMA 6.

A typical sedimentary sequence in the Brunswick Group consists of alternating blocky and friable units of red siltstone (Carswell and Rooney 1976). These units both range up to 10 feet or more in thickness and each unit ultimately pinches out laterally, to be replaced by the other unit. The friable units form the aquifers. The blocky units function as leaky aquitards. Consequently, Brunswick Group aquifers tend to become confined at depth, even if they are unconfined at the surface (Gill and Vecchioli 1965).

The basaltic lava was particularly fluid. Periodically during the early Jurassic Period, basaltic magma would reach the surface through a fissure and erupt forming flat, laterally extensive sheets that covered the surface of the sediments that had been accumulating in the basin (Van Houten 1988). During the periods of time that elapsed between lava flows, additional sediments were deposited. When the composite strata were tilted and eroded during the Cretaceous Period, the basalt, being more resistant to erosion, stood out in relief, forming the ridges of the Watchung Mountains. The aquifers in the basalt tend to be unconfined, except where covered by glacial till.

During the Early Cretaceous Period, the Newark Basin may have been below sea level for a time. From the Late Cretaceous until the present time, most of the basin has been above sea level.

Highlands Physiographic Province

The origin of the bedrock of the Highlands Province is very complex. Most of the rocks are Middle Proterozoic in age (Lyttle and Epstein 1989; Drake *et al*. 1996). Many of these consist of earlier sedimentary rocks that were metamorphosed by heat and pressure during the Grenville Orogeny approximately 1,100 million years ago. Others may be metamorphosed volcanic rocks or are of mixed sedimentary and igneous origin. The mineral associations are consistent with the hornblende-granulite metamorphic facies. Depending upon the pre-existing rock type, the resulting granulite facies metamorphic rock would be either: marble (from relatively pure limestone), or quartzite (from relatively pure sandstone), or one of various types of gneiss (from shales or other pre-existing rocks of complex composition). Some of the different rocks encountered in the area are related to one another, such as the oligoclase-rich gneisses and granites of the Losee Metamorphic Suite (Drake *et al*. 1996), which are considered to have been deposited earlier than the metasedimentary rocks. In addition there are commonly encountered amphibolite, hypersthene-quartz-oligoclase gneiss, or metamorphic diorite bodies in the Highlands with unknown origins or affinities.

At approximately the same time that the metamorphism was taking place, the rocks were intruded by magma, resulting in various types of granite and syenite. Some of these may be assigned to the Byram or the Lake Hopatcong Intrusive Suites. Concurrently, the rocks were also being intensely folded and faulted.

From the Middle Proterozoic to the beginning of the Paleozoic Era there was considerable erosion. The deposition of the sands that would become the Cambrian Hardyston Quartzite was rather widespread over these rocks, indicating they were deposited over a surface that was worn somewhat flat. There is a gradational boundary between the Hardyston and the dolomite of the overlying Cambrian Leithsville Formation.

The rocks of the Silurian and Devonian Green Pond Outlier include ridge-forming conglomerates and sandstones, separating formations composed of less-resistant shale and limestone, which form long, narrow, rather straight stream valleys. These formations of the Green Pond Outlier are brought into contact with the Hardyston and the Leithsville and with the crystalline rocks of the Highlands by lateral and vertical displacement along faults. These faults trend primarily northeast to southwest and include high-angle dip-slip and strike-slip faults as well as low-angle thrust faults. The displacement along a thrust fault can extend for miles and the width of the Highlands represents considerable shortening in the direction of the thrust, typically with several successive thrust sheets piled on top of one another, their fault planes parallel and dipping to the southeast. These repeated slices of the crust were exposed by erosion, which took place both during and subsequent to the thrust faulting. A succession of several slices can be seen as one traverses the Highlands from the southeast to the northwest.

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