BEDROCK GEOLOGY

This map shows the distribution and type of bedrock units in the Fort Drum area. This area is underlain by a variety of metamorphic, igneous, and sedimentary bedrock ranging in age from Precambrian to Middle Ordovician.

Metamorphic Rock (Grenville Complex)

The oldest rocks in the area are the Grenville Complex, consisting mainly of metamorphosed Precambrian quartzite, gneiss, shist, and marble. These rocks stretch in a wide northeast-southwest band across the region and border the igneous Adirondack massif and associated foothills to the east. The Grenville beds, before being metamorphosed, consisted of sandstone, limestone, and shale having a total thickness of 15,000 to 20,000 feet in this region (Buddington, 1934). The metamorphism of the Grenville beds was accompanied by faulting, folding, and igneous intrusive stresses acting along a northwest-southeast line. Most of the originally horizontal Grenville beds are now extensively folded and faulted such that much of the bedding is steeply dipping or nearly vertical.

Igneous complex

The igneous complex in the eastern part of the mapped area consists of at least two series of intrusive rocks; the oldest includes gabbros, diorites, and quartz diorites; the younger includes syenite, quartz syenite, and granite (Buddington, 1934). All of these units are extensively cut by pegmatite veins. The magmas that created this complex were forced along the bedding planes of the Grenville sediments to form sills and sheets. This action fractured and faulted the more brittle beds of the Grenville Complex and folded the more plastic beds. The large granite-gneiss mass in the eastern part of the region is a phacolith, or concave, lens-shaped igneous mass that formed under the partly folded Grenville Complex. Augen gneisses and porphyritic rocks form a belt that borders this main igneous complex, which extends southwest-northeast and west of Lake Bonaparte. Buddington (1934) terms this band of igneous rocks the Diana Complex.

Sedimentary Rock

The next youngest rock units in the area are the sedimentary Potsdam Sandstone and the overlying Theresa Formation, both of Cambrian age. These two units form one of the more productive bedrock aquifers in the Fort Drum vicinity and are present in the central and western parts of the mapped area. They rest unconformably on Precambrian rock and underlie the limestone units of the Black River Group to the southwest. The Potsdam and Theresa Formations have been eroded away in some places; their absence is also due, in part, to the irregularity of the Precambrian bedrock surface on which they were deposited.

The Potsdam Sandstone forms a fringe around the northwest and northern border of the Adirondacks and generally consists of tan to white, even-grained quartz sand with siliceous and calcareous cementation. Locally, some of the basal sandstone beds are red from hematite or green from choritic cementation, and beds of coarse conglomerate are present in some places.

Cushing, Fairchild, and others (1910, p. 60) state that the Potsdam Sandstone is about 125 feet thick in the Alexandria region northwest of Fort Drum. The unit apparently thins rapidly southeastward across the reservation. Buddington, (1934, p. 179) reports the Potsdam to be 60 to 80 feet thick along the west side of Black Lake, north of the reservation. Within the reservation, southeast of the Indian River and Philadelphia, its thickness ranges from 15 to 25 feet. At Herrings, southeast of the reservation, the Potsdam is absent, and the overlying limestone units of the Black River Group rest directly on the Precambrian basement (Buddington, 1934, p. 179). The Potsdam Sandstone may have formed originally as a beach deposit because it grades upward into the Theresa Formation, which is of marine origin (Buddington, 1934).

The Theresa Formation consists primarily of hard, bluish-gray, thinly bedded sandy dolomite with calcareous sandstone layers dominant in the basal part. The upper beds of the Theresa Formation vary in composition and range from calcareous and dolomitic sandstones to sandy dolomite (Johnsen, 1971, p. 11). Calcite seams parallel the bedding, and the dolomite is characterized by numerous fossils (Buddington, 1934, p. 132).

The Theresa Formation is 60 to 70 feet thick in the area between Theresa and Evans Mills but thins to 20 feet north of Perch Lake (Cushing, Fairchild, and others, 1910, p. 64). Within the reservation, about 4 miles south of Antwerp, the Theresa Formation is about 35 feet thick (Buddington, 1934, p. 182), but at Herrings, southeast of the reservation, it and the underlying Potsdam Sandstone are both missing (Buddington, 1934, p. 179). The contact between the Potsdam Sandstone and the Theresa Formation is gradational and thus difficult to place (Johnsen, 1971, p. 11). The Potsdam and Theresa probably underlie most of the Pine Plains delta complex in the Fort Drum area.

Overlying the Potsdam and Theresa Formations are the limestone units of the Black River Group. These consist of (from bottom to top) the Pamelia and Lowville Formations, and Chaumont Formation of Kay (1929). Together these units form a limestone group that is approximately 140 feet thick in the vicinity of the Black River south of the cantonment area (Sections A-A' and B-B' on pl. 3). The Pamelia Formation is estimated to be about 60 feet thick around Herrings (Cushing and others, 1910, p. 69) and thickens westward and to the south. It is described as a dolomitic limestone, although many beds throughout the Pamelia are limestone, and several beds near the base contain sufficient quartz sand to be termed a dolomitic sandstone (Johnsen, 1971, p. 13). The middle unit, the Lowville Formation, is also about 60 feet thick near Herrings-Great Bend and consists of medium gray fossiliferous, thick- to thinly bedded limestone with shale partings. Fossil coral and worm tubes give the Lowville Formation the common name "birdseye limestone." The upper unit of the Black River Group, the Chaumont Formation of Kay (1929), is about 20 feet thick in the vicinity of Herrings-Great Bend and consists of massive gray, finely textured, cherty limestone containing abundant fossils (Johnsen, 1971, p. 16).

Overlying the Black River Group is the Trenton Group, undivided, which consists of several limestone units. The Trenton Group crops out south of Felts Mills, at the southern border of the map.

AQUIFER CHARACTERISTICS OF BEDROCK

The numerous types of bedrock in the Fort Drum area can be grouped into three major bedrock aquifers--igneous and metamorphic crystalline rock, sandstone units, and carbonate rocks.

Igneous and Metamorphic Rock

Unfractured igneous and metamorphic crystalline rock generally has a porosity of less than 2 percent and a hydraulic conductivity (primary permeability) in the range of 10^{-7} to 10^{-9} ft/d (Freeze and Cherry, 1979, p. 158). Thus, unfractured crystalline rock can be considered impermeable within the scope of most ground-water studies. Practically all ground-water movement and storage in igneous and metamorphic rocks occurs in cracks, joints, and fissures (secondary permeability), most of which are within a few hundred feet of land surface.

Yields from 13 domestic wells (all 6-in. diameter) that tap Precambrian gneiss and metamorphosed Grenville beds in the Fort Drum area ranged from less than 1 gal/min to 27 gal/min and average 5 gal/min (U.S. Geological Survey, unpublished data). The thickness of crystalline rock penetrated ranges from 20 feet to 197 feet and averages 70 feet. Wells with the highest yields penetrate only 20 to 40 feet of rock; the high yields can probably be attributed to a highly weathered zone near the buried Precambrian rock surface. This weathered zone, described by Buddington (1934, p. 174) as areas where "quartzites were thoroughly oxidized, reddened, kaolinized and porous for a depth of 15 feet," is preserved by the overlying Potsdam Sandstone.

Fractures and openings in crystalline rock in this area are most common along foliation and bedding planes. Permeable zones may also lie along the contacts between igneous and metamorphic rocks or may occur as solution zones within the more feldspathic metamorphic rocks (Buddington, 1934, p. 175).

Sandstone Units

Unfractured sandstone exhibits a wide range of primary permeability but generally lies within the same range as unfractured limestone, 10^{-4} to 10 ft/d (Freeze and Cherry, 1979, p. 29). In some areas, the porosity of unfractured sandstone is less than 1 percent, and the hydraulic conductivity can approach that of unfractured siltstone and shale, which is generally less than 10^{-5} ft/d. More commonly, however, the porosity of unfractured sandstone ranges from 4 percent to greater than 30 percent.

A 1978 study of the potential effects of deep-well injection of brine into the Potsdam Sandstone and the Theresa Formation in western New York (Waller, Turk, and Dingman, 1978) provided cores of these formations from depths ranging from 3,800 to 4,150 feet below land surface. The unfractured cores were subjected to laboratory tests for porosity and hydraulic conductivity. Waller and others (1978) report that the primary porosity of samples from both the Potsdam and Theresa Formations ranged from 1 to 13 percent, and that the highest hydraulic conductivity was 9×10^{-3} ft/d for a core of Potsdam Sandstone. The hydraulic conductivity of 73 unfractured cores of the Theresa Formation averaged 0.8×10^{-3} ft/d, and that of 32 unfractured cores of the Potsdam Sandstone averaged 3×10^{-3} ft/d. The hydraulic conductivity and secondary permeability of both these sandstone units are probably higher in the Fort Drum area because their depth of burial is considerably less here than in western New York, thus subjecting existing cracks and fractures to smaller closing stresses.

Data from 12 domestic wells near Fort Drum that tap either the Theresa Formation or Potsdam Sandstone indicate that the wells penetrate from 16 to 55 feet of sandstone; the average thickness of sandstone is 32.5 feet (U.S. Geological Survey, unpublished data). Data from five of these wells indicate that yields range from 3 gal/min to over 30 gal/min, with an average of 23.5 gal/min. The wells with the highest yields tap 20 to 32 feet of sandstone, indicating that the upper part of these units, namely the Theresa Formation, may be the more fractured and transmissive of the water-bearing zones. Two of these wells penetrate 48 and 79 feet of limestone (Pamelia limestone) before tapping the underlying sandstone, and both driller's logs report that very little water was obtained from the limestone.

Carbonate Rocks

Carbonate aquifers in the Fort Drum region consist of limestone and dolomite units of the Black River Group. These units--the Pamelia and Lowville Formations and the Chaumont Formation of Kay (1929) in ascending order--are present in the southwestern part of the Fort Drum area and overlie either the Potsdam Sandstone and Theresa Formation or Precambrian bedrock. The Lowville and Chaumont Formations are limestone units; the Pamelia is regarded as a dolomite or dolomitic limestone.

The hydraulic conductivity of unfractured limestone commonly ranges from 10^{-4} to 10^{0} ft/d, whereas that of karst limestone can range from 10^{0} to 10^{4} ft/d (Freeze and Cherry, 1979, p. 29). Thus, carbonate aquifers can have a large secondary permeability as a result of openings along bedding planes, joints, and vertical fractures due to faulting. These openings may be enlarged as a result of calcite or dolomite dissolution by ground water. The presence of bedding-plane openings is a greater factor in well yield than vertical openings because the probability of a well encountering horizontal bedding-plane openings is much greater than for vertical or steeply-dipping openings such as joints.

Data from 14 domestic wells tapping limestone or dolomite formations of the Black River Group near Fort Drum show that the thickness penetrated ranged from 14 to 68 feet and averaged 36 feet (U.S. Geological Survey, unpublished data). Yields from eight of these wells averaged 21 gal/min and ranged from 5 to more than 30 gal/min. Three of these wells yield more than 30 gal/min from less than 26 feet of limestone or dolomite, indicating, as with other bedrock types in the region, that most of the highly fractured rock lies within 50 feet of the bedrock surface and constitutes the primary producing zone for this aquifer.

Fort Drum Wells

The Pamelia and Lowville Formations form the most productive units in the bedrock aquifer, as shown by well yields. Wells 7, 11, and 12, which tap these units, each have yields of approximately 300 gal/min. The yields of the remaining six bedrock wells, which tap sandstone units, vary greatly. Wells 2 and 5 have yields of about 450 and 475 gal/min, respectively, whereas nearby wells 1 and 3 yield only about 150 gal/min each. Wells 9 and 10 both have yields of about 230 gal/min.

The wide range in yields of wells tapping sandstone is the result of several factors: (1) variability in the permeability of the overlying sediments, (2) the degree of weathering of the sandstone, (3) the size and number of joints and fractures intersected by the well bore, and (4) the degree of cementation of the sandstone grains. Both of the high-yielding sandstone wells (nos. 2 and 5) are also screened in permeable sand and gravel deposits that directly overlie the bedrock surface and contribute greatly to the well yield. By comparison, wells 1 and 3, whose yields are about 150 gal/min, penetrate a thick section of clay or clayey sand and gravel of low permeability that directly overlies the sand and gravel zone and the bedrock. This clayey unit acts as a confining bed and locally reduces the amount of recharge available to the pumping well. The three wells that tap limestone units (7, 11, and 12) have consistently high yields of 200 to 300 gal/min as a result of two factors: (1) the presence of extensive joints and fractures, particularly at the surface of the unit, and (2) more important, the overlying thick section of permeable lake sand, which is in hydraulic contact with and contributes additional recharge to limestone units under pumping conditions. (See section B-B', pl. 2.)

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EXPLANATION

Sedmientary Units

ORDOVICIAN

- Ot — TRENTON GROUP, UNDIVIDED--thin- to thick-bedded, gray, fine- to coarse-textured limestone with shale interbeds. Fossiliferous and occasionally cross-bedded.

BLACK RIVER GROUP

- Oc — CHAUMONT FORMATION of Kay (1929)--massive, gray, finely textured, cherty limestone with silicified fossils.
- Ol — LOWVILLE FORMATION--fine- to medium-textured, gray, conchoidally fracturing limestone.
- Op — PAMELIA FORMATION--principally greenish-gray and medium-gray conchoidally fracturing dolomite with some gray limestone interbeds. Basal few feet may be more quartzose or feldspathic.

CAMBRIAN

- €t — THERESA FORMATION--hard, bluish-gray, thinly bedded dolomite and calcareous sandstone. Upper beds range from calcareous and dolomitic sandstone to sandy dolomite. Dolomite beds exhibit bedding-plane calcite seams and fossils.
- €p — POTSDAM SANDSTONE--medium- to thickly bedded tan to grayish-white quartz sandstone with siliceous and calcareous cement. Basal few feet may be conglomeratic and (or) feldspathic and may be reddish from iron stain or greenish from chloritic cementation. This formation, together with the overlying Theresa Formation, forms one of the principal bedrock aquifers in the Fort Drum area.

Igneous Rock

PRECAMBRIAN

DIANA COMPLEX

- p€gf — GRANITE GNEISS--granite intrusion, generally fine grained; gneissoid structure indistinct.
- p€gg — GRANITE-SYENITE GNEISS--reddish, fine-grained, cut by pegmatite veins parallel to foliation planes.
- p€hg — HORNBLENDE GRANITE-SYENITE GNEISS--coarsely porphyritic, well foliated, quartz weathers out in relief forming ribbed surface.
- p€sg — HORNBLENDE-SYENITE GNEISS--coarsely porphyritic gneiss, reddish, weathering to light gray.
- p€ag — AUGITE-SYENITE GNEISS--green augite-syenite; interbedded red and green gneiss occurs near contact with adjacent hornblende-syenite. Weathers to drab gray.
- p€bg — BASIC AUGITE-SYENITE GNEISS--similar to augite-syenite gneiss except rich in augite and magnetite and greenish.
- p€an — ANORTHOSITE--green to greenish-white gabbroic anorthosite cut by narrow granite dikes.

GRENVILLE COMPLEX

- p€gc — GRANITE GNEISS--granite intrusion appearing as coarse porphyritic dikes within older syenite gneisses.

Metamorphic Rock Units

- p€m — MARBLE--white crystalline marble of the Grenville series.
- p€q — QUARTZITE--crystalline limestone with intercalated white quartzite, quartz schist, and siliceous beds.
- p€s — SCHIST--schist with thin crystalline bands, pegmatite lenses or nodules, quartz stringers, and disseminated silicate.
- p€g — BIOTITE-GARNET GNEISS--deformed Grenville beds intercalated with pegmatite veins and sheets of granite.
- p€a — AMPHIBOLITE--gabbro amphibolite injected by pegmatic veins. Probably highly metamophosed Grenville beds.
- p€pg — PYROXENE GNEISS--metamorphosed calcareous beds injected by pegmatite and syenite and intruded by sheets of granite syenite.
- p€ug — UNDIVIDED GNEISSES--biotite, cordierite, garnet, sillimanite, and pyrite gneisses injected by pegmatite and granite veins.
- p€qg — QUARTZ-BIOTITE GNEISS--of uncertain origin.

——— CONTACT BETWEEN LITHOLOGIC UNITS--approximately located.

- - - - - CONTACT BETWEEN SHALLOW BEDROCK UNITS AND OVERLYING QUATERNARY COVER--Approximately located.

Bedrock Aquifer Classification

- CARBONATE AQUIFERS--consist of Middle Ordovician limestones and dolostones of the Trenton and Black River Groups.
- SANDSTONE AQUIFERS--consists of Potsdam Sandstone and overlying Theresa Formation.
- CRYSTALLINE AQUIFERS--predominantly Precambrian igneous and metamorphic granite, gneiss, and schist.