42'30"

INTRODUCTION

Surficial deposits in the Gladstone quadrangle include fluvial sediments laid down by rivers in flood plains, channels, and terraces; colluvial material eroded from hillslopes and laid down on foot slopes; till laid down by a glacier; and weathered rock materials formed by mechanical and chemical decomposition of bedrock. Most of these deposits are Holocene (10,000 years ago to the present) and Pleistocene (2.6 million [Ma] to 10,000 years ago) in age. Some of the colluvial and weathered-rock material may be of Pliocene age (5 to 2.6 Ma).

The accompanying map and sections show the surface extent and subsurface relations of these deposits. The composition and thickness of the deposits are provided in the Description of Map Units. The chronologic relationships of the deposits and periods of erosion are shown in the Correlation of Map Units. The geomorphic and glacial history of the quadrangle and adjacent areas is described below. Bedrock geology is provided by Houghton and Volkert (1990).

GEOMORPHIC AND GLACIAL HISTORY

The oldest surficial deposit in this quadrangle is pre-Illinoian till (unit Qpt), which is deeply eroded and weathered. It was laid down by a glacier that advanced from the north and northwest as a broad lobe in the Raritan valley. At its maximum (margin M1 on fig. 1), this glacier extended down the Raritan valley nearly to Somerville, lodged against First Watchung Mountain, and looped northward over Second Watchung Mountain. When it was at its maximum position, and for a short time as the ice margin retreated (margins M2 and M3 on fig. 1), the glacier dammed the west-draining valleys of Chambers Brook and Mine Brook to form glacial lakes (fig. 1). Deposits in these lakes have been largely eroded away. No lake sediments were observed in the Mine Brook valley in the Gladstone quadrangle, although they are present upvalley in the Bernardsville quadrangle (Stanford, 2009). In the Chambers Brook valley, sand and silt (unit Qps) was observed in two excavations near Pluckemin. One exposed an oxidized very fine-to-fine sand beneath 15 feet of basalt colluvium, the other exposed three to five feet of interbedded till and silt, very fine sand, and pebbly sand, deformed by cryoturbation or glacial deformation, overlying shale bedrock. A well drilled in 1947 close to the latter excavation (N. J. Geological Survey permanent note 25-22-762) reportedly penetrated 40 feet of fine sand, then 32 feet of till, and then shale bedrock. Field observations suggest these thicknesses may be overstated. Nevertheless, it is possible that Chambers Brook drained northward to the Raritan River along the base of Second Watchung Mountain, northeast of Pluckemin, before the pre-Illinoian glaciation, and that deposition of lake sediment and till, later mostly covered by basalt colluvium, filled the valley. This blockage would have diverted Chambers Brook into its present southwesterly route across the northern tip of First Watchung

The pre-Illinoian glaciation occurred in the early Pleistocene (~2.6 Ma to 800,000 yr. ago). Some pre-Illinoian glacial sediments in New Jersey (Ridge, 2004), eastern Pennsylvania (Sasowsky, 1994), and central Pennsylvania (Gardner, 1994) are magnetically reversed, indicating that they are older than 800,000 yr. In New Jersey, pollen in pre-Illinoian lake sediment (Harmon, 1968), and in a preglacial fluvial deposit that is weathered and eroded about as much as the pre-Illinoian till (Stanford and others, 2001), indicates a Pliocene or early Pleistocene age. These observations suggest that the pre-Illinoian glaciation here correlates with the earliest continental glaciation in North America in the early Pleistocene, dated in the Missouri River valley to >2 Ma (Roy and others, 2004).

In the Gladstone quadrangle, pre-Illinoian till is preserved in erosional remnants on flat to gently sloping divides and hilltops. These flats are typically 50-100 feet above modern valley bottoms, although in places (for example, near Lamington and north of Rockaway Creek) they are as close as 30 feet from the valley bottom. Till is absent on similar flat surfaces below the divides. This the till. If the till had been laid down in the present topography and later eroded from hillslopes, it would remain on all flat surfaces, not just those on divides. Thus, the gently sloping upland on which the pre-Illinoian till rests marks an early Pleistocene land surface that predates incision of the present valley network (fig. 1). This surface extended across the shale lowland between the Watchung Mountains and the Highland escarpment to the north and west. Flat to gently sloping summit areas atop the Watchungs and the Highlands, 200 to 300 feet higher than the early Pleistocene surface (fig. 1) may be remnants of an older surface of late Miocene age. This older, higher surface is more fully developed on Schooleys Mountain, northwest of the Gladstone quadrangle.

A long period of erosion followed the pre-Illinoian glaciation. The valleys of the Lamington River and the North Branch of the Raritan River (hereafter referred to simply as the Raritan River), and their tributaries, were deepened by as much as 120 feet and their routes in the lowland area south of the Highlands became fixed in roughly their present courses. Following this period of erosion and valley deepening, which continued through the early Pleistocene (2.6 Ma to 800,000 yr. ago) and most of the middle Pleistocene (800,000 to about 200,000 yr. ago), the upper terrace deposits (unit Qtu) were laid down. These deposits formed plains as much as a mile wide in the Lamington and Raritan valleys, and extended up tributary valleys as narrow floodplains. They cannot be directly dated but their weathering properties and topographic position are similar to those of glacial deposits to the west and north of the Gladstone quadrangle that are thought to be of Illinoian age (about 150,000 yr. old).

Permafrost and tundra-like vegetation covered the region during the Illinoian glaciation, which reached its southern limit about 10 miles north of Gladstone. Permafrost may also have developed during several earlier glaciations that did not reach New Jersey. Permafrost impeded infiltration of rainfall and snowmelt, and the absence of forest reduced anchoring of soil by tree roots. These effects combined to increase runoff and erosion on hillslopes, which in turn delivered more sediment to streams. In addition, when Illinoian ice was at its maximum position, an ice-dammed lake formed in the Passaic basin to the east of the Gladstone quadrangle (Stanford, 2007). This lake drained through Moggy Hollow into the Raritan River (fig. 1), increasing its flow and transporting more sediment. Rivers deposited the sediment to form the upper terraces. In places, sediment also accumulated at the foot of steep slopes to form aprons of poorly sorted, nonstratified sediment known as colluvium (units Qcg, Qcs, Qcc, Qcb).

As Illinoian ice melted back and climate warmed, forest vegetation returned. Slopes stabilized, hillslope erosion lessened, and rivers carried less sediment. Rivers cut as much as 20 feet into the upper terraces, forming lower, narrower flood plains. In the gorge north of Pottersville in the northwest corner of the map, the Lamington River eroded the toes of several colluvial aprons, leaving the deposits perched on benches 20 to 40 feet above the river. This incision process continued through the interglacial period known as the Sangamon (125,000 to 75,000 yr. ago) and through the early stages of the most recent glacial period, known as the Wisconsinan (75,000 to 10,000 yr. ago). The most extensive advance of the Wisconsinan glacier, known as the late Wisconsinan, reached New Jersey by 20,000 radiocarbon years ago. Permafrost and tundra conditions returned. Renewed hillslope erosion again led to deposition of colluvium on footslopes (where it formed a surface layer atop erosional remnants of earlier colluvium). Likewise, increased sediment in streams again led to deposition of terraces (unit Qtl, lower terrace deposits), this time in the shallow valleys etched into the upper terraces. Alluvial fans (unit Qaf) were deposited where upland streams emptied into lowlands. The late Wisconsinan glacier reached a southernmost position similar to that of the Illinoian and, like the Illinoian, dammed the Passaic valley to form glacial Lake Passaic to the east of Second Watchung Mountain (fig. 1). Again, Moggy Hollow was the outlet for the highest stage of this lake. The hollow was deepened by the lake outflow, and the Raritan discharge increased, enhancing development of the lower terrace downstream from the hollow.

The late Wisconsinan glacier retreated north of New Jersey by about 18,000 yr. ago, and by about 13,000 yr. ago, permafrost had melted and forest had regrown. Again, hillslope erosion slowed. Streams carried less sediment, and so were able to cut down 5 to 10 feet into the lower terraces to form the modern flood plain (unit Qal). Colluvial aprons were also partly incised by bank erosion from streams and gullying from seepage and runoff. These processes continue today, delivering sediment to valley bottoms in headwater areas (unit Qcal). Some colluvium is also of recent origin, accumulating as hillslopes eroded when they were cleared for farming during European colonization. A date of 480 +/-30 ¹⁴C yr. BP (Beta 292100) on plant material beneath four feet of shale colluvium in the southwest corner of the map is a maximum age of burial of the plants by

DESCRIPTION OF MAP UNITS

ARTIFICIAL FILL—Artificially emplaced sand, gravel, silt, clay, and rock fragments, and man-made materials including cinders, ash, brick, concrete, wood, slag, asphalt, metal, glass, and trash. Color variable but generally dark brown, gray, or black. As much as 20 feet thick. In road and railroad embankments, dams, dikes, and made land. Small areas of fill in urban areas are

ALLUVIUM—Sand, silt, clay, pebble gravel, pebble-to-cobble gravel, locally cobble-to-boulder gravel; dark brown, brown, reddish-brown, yellowish-brown, gray; moderately to well-sorted, stratified. Contains variable amounts of organic matter. As much as 15 feet thick. Gravel consists chiefly of gray to white gneiss; red siltstone, shale, and sandstone; and purple to gray quartzite and quartziteconglomerate; with lesser amounts of gray to brown basalt, gray siltstone and sandstone, and dark gray chert. Gravel composition varies depending on bedrock and surficial deposits in the basin upstream of the site of deposition. Sand and gravel are deposited in channels (fig. 2). Fine sand, silt, and clay are deposited on overbank areas, chiefly on broad, flat flood plains. Typically, away from active channels, several feet of overbank sediment from flood deposition overlies gravel and sand channel deposits that were laid down during channel migration. Along the Lamington River north of Pottersville and along the Raritan River north of Ravine Lake, alluvium includes boulder lags formed by winnowing of fine material from weathered gneiss. Along the Lamington River between Pottersville and Interstate Route 78, alluvium includes a lower phase and a higher phase separated by a 2-to-5-foot-high scarp (shown on map where distinct). The high phase may be eroded fragments of the lower terrace deposit (unit Qtl). The high-phase sediments are included with alluvium because they have the same overbank-on-channel-gravel stratigraphy and are subject to

VERTICAL EXAGGERATION 20

Qaf ALLUVIAL FAN DEPOSITS—Pebble-to-cobble gravel, sand, minor cobble-toboulder gravel; brown, yellowish-brown, gray; moderately sorted, poorly stratified. As much as 20 feet thick.

Qcal COLLUVIUM AND ALLUVIUM, UNDIVIDED—Interbedded colluvium as in units Qcg, Qcb, Qcc, and Qcs, and alluvium consisting of dark brown to yellowish-brown to reddish-brown silty sand, sandy silt, and clayey silt (fig. 2). Includes beds and winnow lags of subangular basalt pebbles and cobbles (adjacent to unit Qwb); subangular shale, siltstone, and sandstone chips, pebbles, and fine cobbles (adjacent to unit Qws); subangular to subrounded cobbles and boulders of gneiss (adjacent to unit Qwg); and subangular to subrounded pebbles and cobbles of quartzite (adjacent to unit Qwc). As much as 15 feet thick. Lag accumulations are dominant in steeper reaches of valleys. Fine sediment, with variable amounts of organic matter, dominates in gently sloping reaches.

LOWER TERRACE DEPOSITS—Pebble-to-cobble gravel, silt, sand, and clay; yellowish-brown, reddish-brown, very pale brown; moderately sorted, well stratified to poorly stratified. Gravel composition as in unit Qal. Some gneiss and basalt clasts have surface staining or thin (<0.25-inch) weathering rinds. As much as 20 feet thick. Form fluvial terraces with surfaces 3 to 10 feet above the modern flood plain. Along the Lamington River north of Pottersville, consists of cobble-to-boulder gravel and boulder lag.

Otu UPPER TERRACE DEPOSITS—Pebble-to-cobble gravel, silt, clay, and sand; reddish-brown, brownish-yellow, reddish-yellow; moderately sorted, well stratified to poorly stratified. Gravel composition as in unit Qal. Gneiss, basalt, and some sandstone clasts have thick (>0.25-in) weathering rinds or are fully decomposed. As much as 40 feet thick, generally less than 20 feet thick. Form fluvial terraces with surfaces 10 to 25 feet above the modern flood plain.

BASALT COLLUVIUM—Reddish-yellow, yellowish-brown, brown, reddishbrown clayey silt, silty clay, minor fine-sandy silt with some (5-10% by volume) to many (10-40%) subangular basalt pebbles and cobbles (fig. 3). Long dimensions of clasts typically are aligned parallel to the hillslope. Nonstratified to poorly stratified, poorly sorted. As much as 20 feet thick. Includes few to some chips and angular pebbles to fine cobbles of red shale and mudstone where

QCS SHALE, SILTSTONE, AND SANDSTONE COLLUVIUM—Reddish-brown, brown, and yellowish-brown clayey silt with some to many chips to subangular pebbles and fine cobbles of red and gray shale and siltstone, and, where pre-Illinoian till (Qpt) occurs upslope, subangular to subrounded gneiss and quartzite pebbles and cobbles. Nonstratified, poorly sorted. As much as 10 feet thick.

CONGLOMERATE COLLUVIUM—Reddish-brown, yellowish-brown, light gray clayey silt to silty sand with some subangular chips, pebbles, and fine cobbles of siltstone and sandstone, and some to many subangular to subrounded pebbles and cobbles of purple quartzite and quartzite-conglomerate. Nonstratified, poorly sorted. As much as 20 feet thick.

GNEISS COLLUVIUM—Yellowish-brown, reddish-yellow, brown, very pale brown sandy silt, silty sand, to sandy clayey silt, with some to many subangular gneiss pebbles and cobbles, in places underlain by or interbedded with thinly layered reddish-yellow to pinkish-white clayey sand and sandy clay with few angular pebbles and cobbles. Nonstratified to poorly stratified, poorly sorted. Long dimensions of clasts typically are aligned parallel to the hillslope. Upper blocky colluvium is derived from downslope movement of fractured, weathered bedrock; lower, layered colluvium is derived from downslope movement of saprolite. Deposits near Peapack and Gladstone contain subangular pebbles and cobbles of gray quartzite and coarse quartz sandstone where quartzite (unit Qwq) crops out upslope. As much as 30 feet thick.

PRE-ILLINOIAN TILL—Reddish-brown, reddish-yellow, yellowish-brown silty clay, sandy clayey silt, to silty fine sand, with some to many subrounded to Nonstratified, poorly sorted. Gravel includes, in approximate order of abundance, gray and purple quartzite and quartzite-conglomerate, gray and white gneiss, gray and red siltstone and sandstone, and dark gray chert. Boulders are chiefly gray gneiss and quartzite. The gneiss, siltstone, and sandstone gravel clasts have thick (>0.5 in) weathering rinds or are completely decomposed. As much as 40 feet thick. Equivalent to the Port Murray Formation, till facies, of Stone and others (2002).

PRE-ILLINOIAN STRATIFIED DEPOSITS—Very-fine-to-fine sand, silt, fineto-medium sand, pebbly sand; reddish-yellow, very pale brown, yellowishbrown. Poorly stratified to well stratified, well sorted. Maximum thickness unknown but probably less than 20 feet. Observed beneath basalt colluvium and pre-Illinoian till in two exposures near Pluckemin (indicated by symbols on map). Equivalent to Port Murray Formation, stratified facies, of Stone and others

WEATHERED BASALT—Reddish-yellow, reddish-brown, light gray, yellowish-brown clayey silt, silty clay, to clayey coarse sand with some to many subangular pebbles and cobbles of basalt and, in places, gabbro. Nonstratified to poorly stratified, poorly sorted. Most clasts have thin (<0.25-in) clayey-silty reddish-yellow weathering rinds. Includes mixed clast-and-matrix sediment, granular decomposed rock, fractured rock rubble, and saprolite that preserves original rock structure (fig. 3). As much as 20 feet thick. Qwbt indicates areas where weathered material is thin or absent and fractured rock rubble abundant.

WEATHERED SHALE, SILTSTONE, AND SANDSTONE—Reddish-brown, brown, yellowish-brown clayey silt, silty clay, and sandy silt with some to many Gwst shale chips, subangular to subrounded pebbles and cobbles of siltstone and sandstone and, near contact with weathered conglomerate, few (<5%) to some subangular to subrounded pebbles and cobbles of quartzite and quartziteconglomerate. Nonstratified, poorly sorted. May contain traces of gneiss pebbles and cobbles and chert pebbles where pre-Illinoian till occurs uphill. As much as 20 feet, but generally less than 5, thick. Qwst indicates areas where weathered material is thin or absent on steep streambanks.

WEATHERED GNEISS--Yellowish-brown, yellow, very pale brown, reddishyellow, silty sand to clayey silty sand with few to many subangular pebbles and cobbles of gneiss. Nonstratified to poorly stratified, poorly sorted. Includes mixed clast-and-matrix sediment, granular decomposed rock, fractured rock rubble, and saprolite that preserves original rock structure. Clasts range from unweathered to fully decomposed. Well records indicate that, on gentle to moderate slopes, clast-and-matrix sediment (described by drillers as "overburden", "hardpan", "sandy hardpan", "soil", and "clay hardpan"), which is fractured rock mixed with sandy-clayey saprolitic material by colluviation, cryoturbation, and bioturbation, is generally 5 to 30 feet thick and commonly overlies or grades downward to saprolite (described by drillers as "rotten rock", "sandstone", "rotten granite", and "soft granite") that may be as much as 50 feet thick over unweathered rock. On steep slopes, fractured-rock rubble, generally less than 20 feet thick, overlies unweathered bedrock. Total thickness of weathered material is as much as 100 feet but is generally less than 25 feet. The uppermost, clast-and-matrix material may contain traces of erratic quartzite, chert, and gray sandstone and mudstone pebbles and cobbles derived from pre-Illinoian till. Qwg also includes small areas of granular weathered diabase near Pottersville and Peapack. Qwgt indicates areas where weathered material is thin or absent and fractured outcrop is abundant, typically on the steepest slopes and

WEATHERED CARBONATE ROCK—Yellowish-brown, brown, very pale brown, reddish-yellow, light gray clayey silt to silty clay, minor sandy silt, with some to many light gray to yellow angular chips and pebbles of carbonate rock. Nonstratified, poorly sorted. May contain traces of gneiss pebbles and cobbles and chert pebbles where pre-Illinoian till occurs uphill. As much as 20 feet thick.

Qwq WEATHERED QUARTZITE—Subangular pebbles and cobbles of gray, white and brown quartzite and coarse quartz sandstone with brown to yellowish-brown silty medium-to-coarse sand matrix. As much as 10 feet thick (estimated). Nonstratified, poorly sorted.

WEATHERED CONGLOMERATE—Reddish-brown, reddish-yellow sandy silt to clayey silt with some to many subangular to subrounded pebbles and cobbles **Qwct** of purple and gray quartzite and quartzite-conglomerate and some subangular to subrounded red and gray shale chips and pebbles to fine cobbles of red siltstone and sandstone. Nonstratified to poorly stratified, poorly sorted. May contain traces of gneiss pebbles and cobbles and chert pebbles where pre-Illinoian till occurs uphill. As much as 40 feet thick. Qwct indicates areas where weathered material is thin or absent on steep streambanks.

MAP SYMBOLS

Contact—Long-dashed where approximately located, short-dashed where gradational or feather-edged, dotted where removed by excavation or concealed by water. Contacts are mapped from 1:12,000 stereo aerial photographs taken in 1979, and from field observations. Some contacts are based on soil mapping by Jablonski (1974) and Kirkham (1976).

•3 Material observed in hand-auger hole, exposure, or excavation—Number, if present, indicates thickness of surficial material overlying weathered bedrock or, if stated for a weathered-rock material, overlying bedrock.

480+/-30 • Radiocarbon date—With error and laboratory number. Obtained on plant material at a depth of 4 feet.

Qcb15/Qps Pre-Illinoian stratified deposit observed—Notation "Qpt-Qps" indicates pre-Illinoian stratified deposits observed beneath and interbedded with pre-Illinoian till. Notation "Qcb15/Qps" indicates pre-Illinoian stratified deposits observed beneath 15 feet of basalt colluvium.

o Material formerly observed—Reported in N. J. Geological Survey permanent

Excavation perimeter—Line on perimeter, excavation within perimeter. Outlines

Bedrock ridge or scarp—Line on crest. Low ridges or scarps formed on resistant siltstone or sandstone beds or basalt flows.

VERTICAL EXAGGERATION 20

★ Quarry—Inactive in 2010.

★ Gravel pit—Inactive in 2010.

• 25-36673 Well or boring with thickness of surficial material—Location accurate within 100 feet. First number is well identifier. Identifiers of the form 25-xxxxx are N. J. Department of Environmental Protection well permit numbers. Identifiers of the form 25-xx-xxx are N. J. Atlas Sheet coordinates of logs in the N. J. Geological Survey permanent note collection. Second number is thickness of surficial materials, including weathered rock. Anomalous thicknesses are queried. Hyphenated numbers for some wells in unit Qwg indicate depth of base of clast-and-matrix sediment (described as overburden or hardpan) followed by depth of base of saprolite (described as rotten rock or sandstone). For wells where log detail allows identification of multiple surficial units, the depth of the base of each unit is indicated before the unit symbol. Final number

²⁵⁻²³⁹⁸² Well or boring with thickness of surficial material—Location accurate within 500 feet. Identifiers and depths same as above.

Large bedrock outcrop—Small outcrops, chiefly in streambeds, streambanks, roadcuts, and on steep slopes, are not shown. Refer to Houghton and Volkert (1990) for additional outcrop locations.

Well on sections

Fluvial scarp—Line at top of scarp, ticks on slope.

is total depth of well or boring.

Seepage scarp—Line at base of scarp, at position of groundwater seepage. figure 3 • Photograph location

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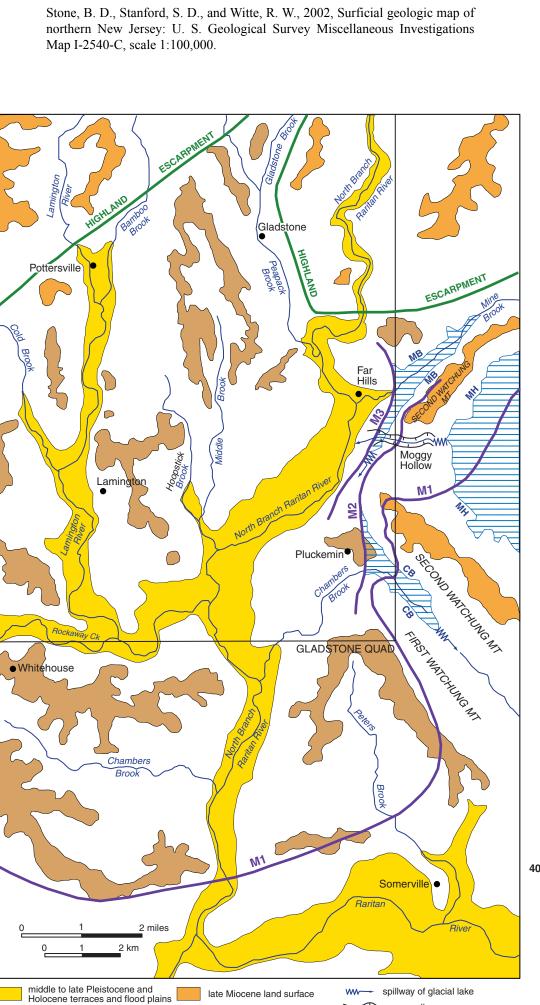
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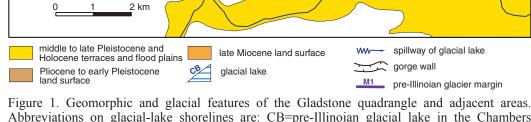
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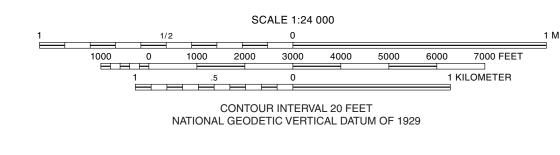


Abbreviations on glacial-lake shorelines are: CB=pre-Illinoian glacial lake in the Chambers Brook valley, MB=pre-Illinoian glacial lake in the Mine Brook valley, MH=Moggy Hollow stage of glacial Lake Passaic, of late Wisconsinan age. Abbreviations on ice margins are: M1=maximum extent of pre-Illinoian glacier, M2=last pre-Illinoian ice margin before drainage of lake in the Chambers Brook valley, M3=last pre-Illinoian ice margin before drainage of lake in the Mine Brook valley

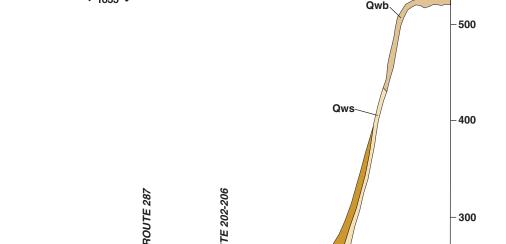
CORRELATION OF MAP UNITS

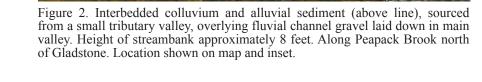
SURFICIAL GEOLOGY OF THE GLADSTONE QUADRANGLE SOMERSET, HUNTERDON, AND MORRIS COUNTIES **NEW JERSEY**

Scott D. Stanford 2011









Geology mapped 1988, 2009-2010

Research supported by the U.S. Geological Survey, National Cooperative

The views and conclusions contained in this document are those of the author

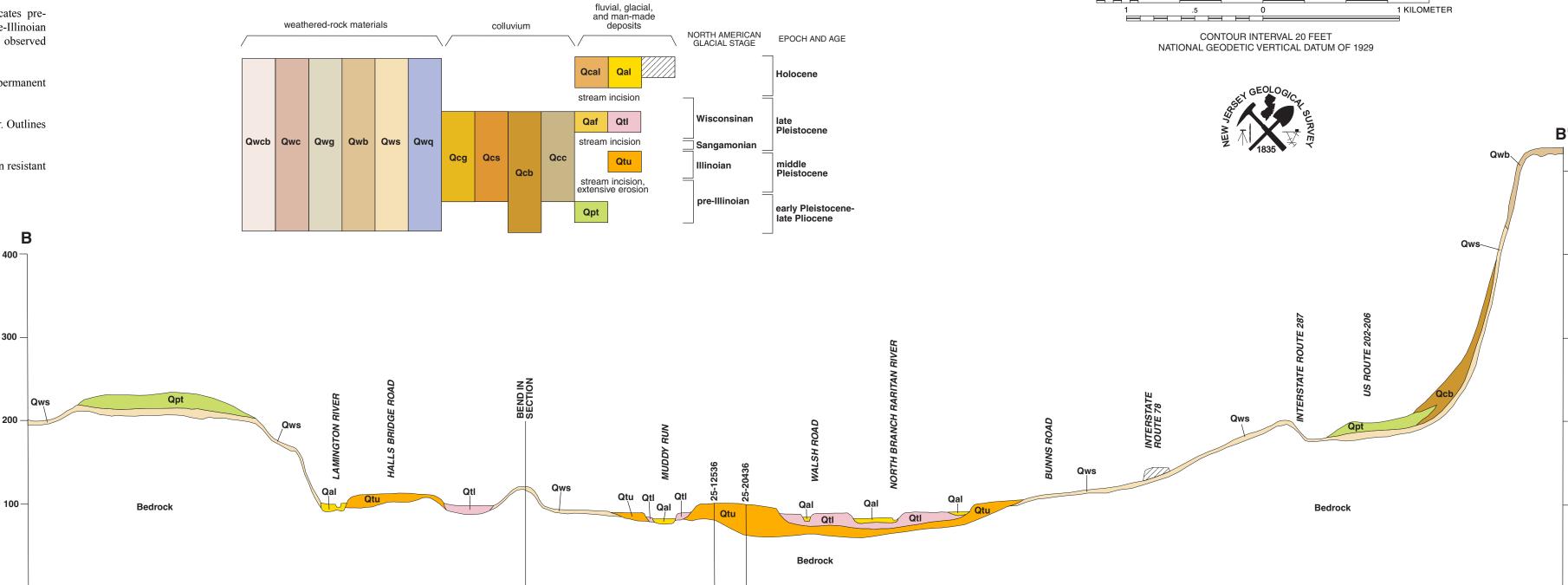
Geologic Mapping Program, under USGS award number G09AC00185.

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Figure 3. Basalt colluvium (above line) overlying basalt saprolite at foot of Second Watchung Mountain near Pluckemin. Location shown on map and inset.



Base from U. S. Geological Survey, 1995