ICE READVANCE IN THE VALLEY OF FIVEMILE CREEK, STEUBEN COUNTY, NEW YORK AND THE EFFECT OF THE RESULTING DEPOSITS ON POSTGLACIAL STREAMFLOW

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INTRODUCTION

Fivemile Creek rises near Jubertown swamp in the town of Jerusalem, Yates County, New York and flows southwestward to join the Cohocton River near Kanona in the town of Bath, Steuben County (fig. 1). Stratified drift deposited during the main Wisconsin deglaciation of Fivemile Creek valley is generally mantled by till or related diamicts attributed to a readvance of the ice. Younger deposits, laid down during and after the decay of the readvanced ice, include large areas of clay-silt rhythmites and of organic-rich muck. Most broad valleys of the Susquehanna River basin are floored predominantly by sand and gravel, and the presence of till, clayey silt, and muck at land surface over large areas of the floor of Fivemile Creek valley is chiefly responsible for the remarkably small discharge per square mile from this watershed during periods of low flow.

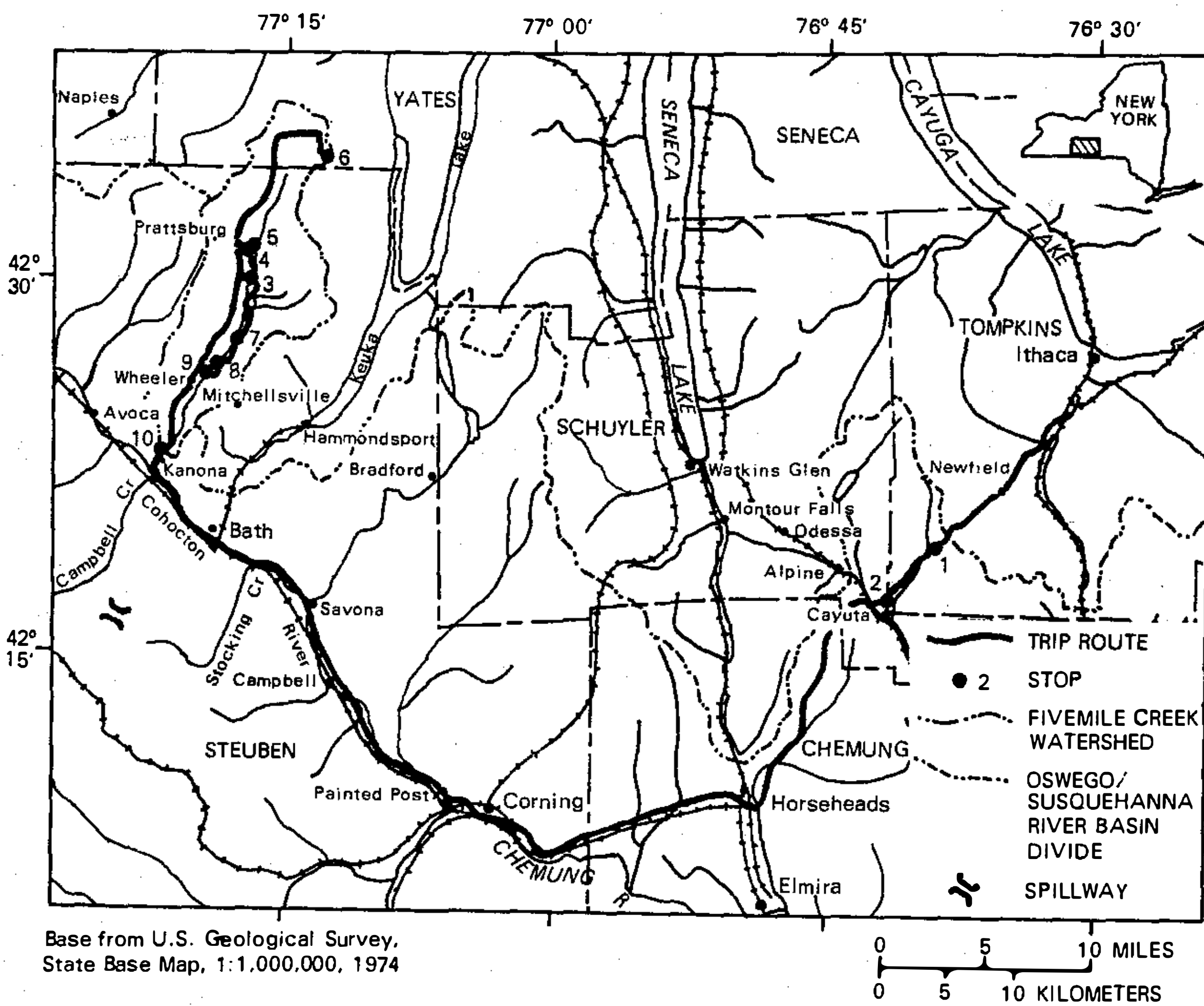


Figure 1.--Location of Fivemile Creek and route of field excursion.

This article can be read as an example of how knowledge of geology can help us understand surface-water hydrology, or of how knowledge of streamflow can require reinterpretation of geology. It was prepared as an offshoot of studies of the interaction of aquifers and streams in the glaciated Northeastern States under the Regional Aquifer Systems Analysis program of the U.S. Geological Survey. It includes an interpretation of surficial geology and deglacial history of Fivemile Creek valley, a summary of evidence supporting that interpretation, and an explanation of the influence of surficial geology on flow of Fivemile Creek and other streams in the Susquehanna River basin. It concludes with an outline of a field excursion designed not only to display the Pleistocene stratigraphy but also to show how streamflow data, depth to water, well records, auger holes, and soils maps can be used to supplement examination of natural and artificial exposures in deciphering surficial geology. The study did not include test drilling, geophysics, regional correlations, nor determination of till fabric or provenance.

GLACIAL DRIFT IN THE SUSQUEHANNA RIVER BASIN

The surface drift over most of the Applachian Plateau of New York, including the Susquehanna River basin, is generally considered to be the product of the ice advance that built the Wisconsin terminal moraine in Pennsylvania. This drift, referred to as "Olean," has been correlated as Altonian by Muller (1977) and as Woodfordian by Crowl and Sevon (1980). As the ice sheet melted, thinned, and gradually disappeared from south to north, upland areas were left with a mantle of till (deposited from the base of the ice as it melted) and related diamicts (emplaced by mass movements that redistributed unstable till and superglacial debris). Meltwater left few deposits in the uplands; apparently the distal few miles of the retreating ice sheet were too crevassed and porous to retain ponded water at high levels, so erosion predominated in the uplands, then as now. In the broad valleys, however, lakes formed in reach after reach as soon as the ice melted down to the level at which water was ponded behind drift previously deposited downvalley. Sediments accumulated in these lakes, typically in three facies (fig. 2). The earliest of these facies, deposited when the valley was still largely choked with ice, is coarse, heterogenous, and commonly silty. Later, as melting exceeded deposition, large expanses of open water formed, in which fine-grained sediment settled on the lake bottom. Much of the fine-grained sediment was eventually capped by deltaic outwash or inwash that filled the shoaling lakes, or by alluvial gravels spread by postglacial streams across their fans and floodplains. Where lakes remained into postglacial time, fine-grained sediment rich in organic matter accumulated. Many factors, including buried ice melting at varying rates and nonsynchronous development of facies in successive reaches of broad valleys as the ice margin retreated, resulted in a complex stratigraphy (Denny and Lyford, 1963; Fleisher, 1977, 1986; MacNish and Randall, 1982; Randall, 1978). At nearly all sites, however, sand or gravel caps the valley fill.

GLACIAL DRIFT IN FIVEMILE CREEK VALLEY

Overview

Much of the drift in Fivemile Creek valley was probably deposited during the retreat of the "Olean" ice sheet across the region. Ice-contact, lacustrine, and outwash facies can be recognized in exposures and records of wells. Next, however, ice apparently readvanced at least as far south as Dineharts (fig. 3B), and deposited atop stratified drift a layer of compact stony sandy clayey silt that resembles the till that covers the bordering uplands. South of Dineharts, a distinctive sparsely pebbly non-bedded silty clay occupies the same stratigraphic position; it may have been deposited in ponded water beneath continually or episodically floating ice.

Decay of the readvanced ice resulted in a new array of stratified deposits in Fivemile Creek valley. Outwash or inwash covers most of the valley floor between Renchans and Marshalls (fig. 3A), and mantles part of the readvance till and pebbly silt between Stickneys (fig. 3B) and Renchans; hummocky topography north of Renchans is indicative of deposition against ice. Later, an extensive lake developed east and north of Stickneys, and near Beans Station (fig. 3B) a delta was built partway across the lake before the flow of meltwater and sediment ceased. At the same time or slightly later, sand and gravel was deposited amid stagnant ice 7 miles to the north near the Yates County line and Jubertown swamp (fig. 3D). These deposits are bordered by large depressions in which fine-grained sediment continued to accumulate after deposition of sandy outwash ended.

The wide extent of surficial till or related diamict in Fivemile Creek valley is unusual. A few investigators have postulated ice readvances several miles southward into the Susquehanna basin (Muller, 1966; Fleisher and Cadwell, 1984). They cited as evidence ice-contact landforms, a few scattered till exposures, and the logs of wells that penetrated gravel atop extensive lake silt, but they neither claimed nor cited evidence that a layer of till is widespread atop or within the valley fill. A layer of till at or near the top of the valley fill has been reported in several through valleys near the northern divide of the Susquehanna River basin (Randall and others, in press). In these valleys, however, the till layer is not known to extend more than 1 or 2 miles south of the divide. Surficial silts and clays are likewise rare. Silts or clays were deposited

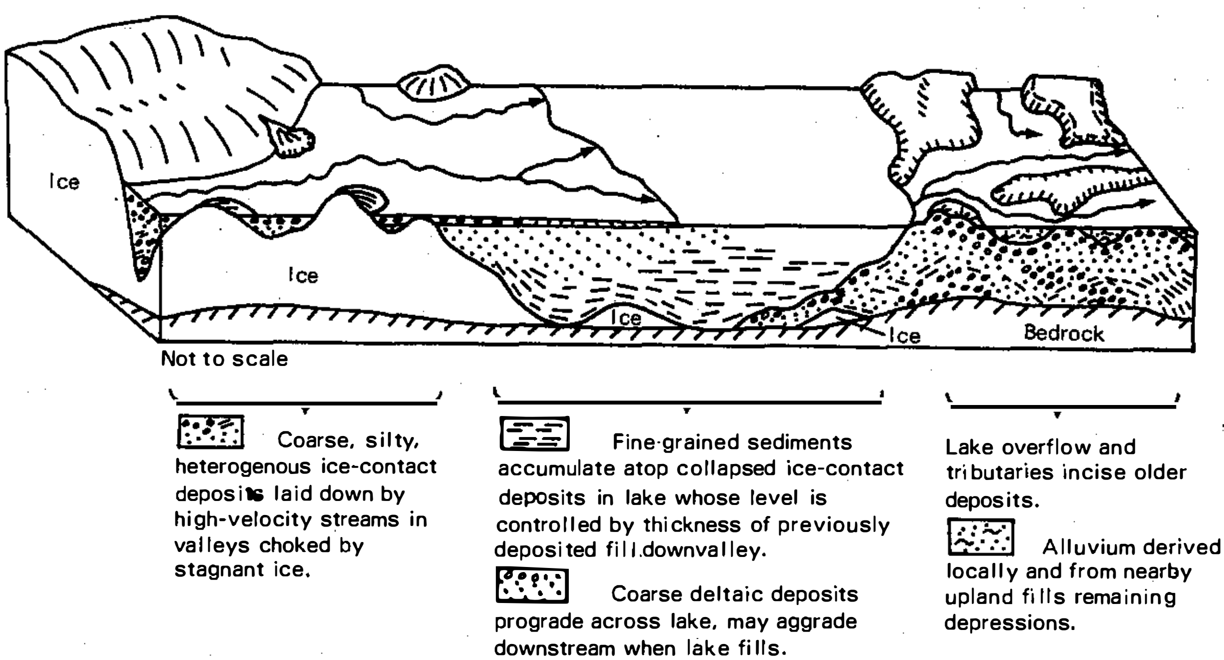


Figure 2.--Idealized diagram of typical broad valley during deglaciation.

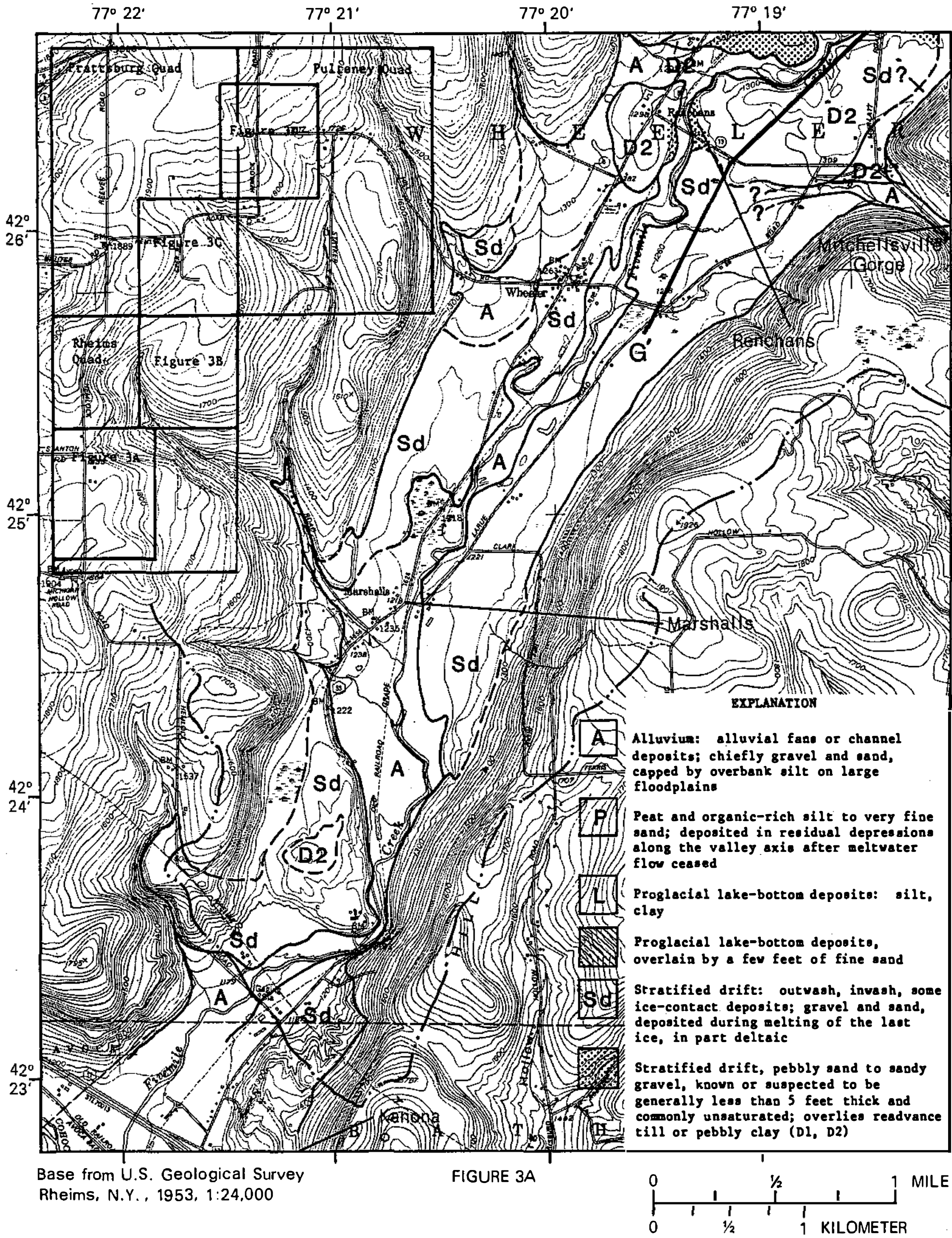
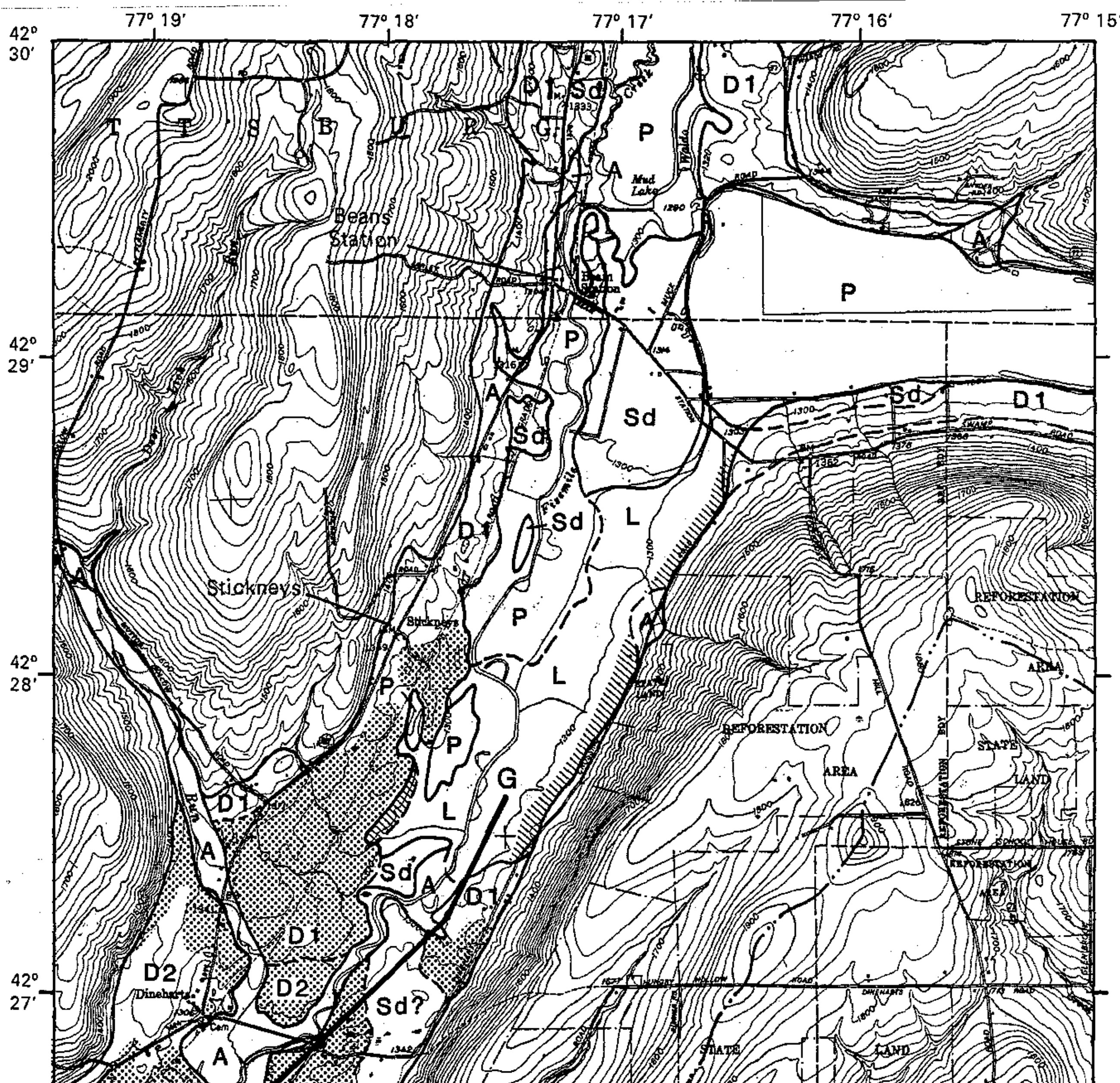


Figure 3.--Surficial geology of Fivemile Creek valley. Mapping is based on examination of earth materials at 110 points, on 70 well and testhole records, and on soils survey (French and others, 1978).



Base from U.S. Geological Survey
Rheims, N.Y., 1953, 1:24,000

FIGURE 3B

0 ½ 1 MILE
0 ½ 1 KILOMETER

EXPLANATION (continued)

[ ] Till, overlying bedrock in upland areas; all or lower part predates all other glacial drift.

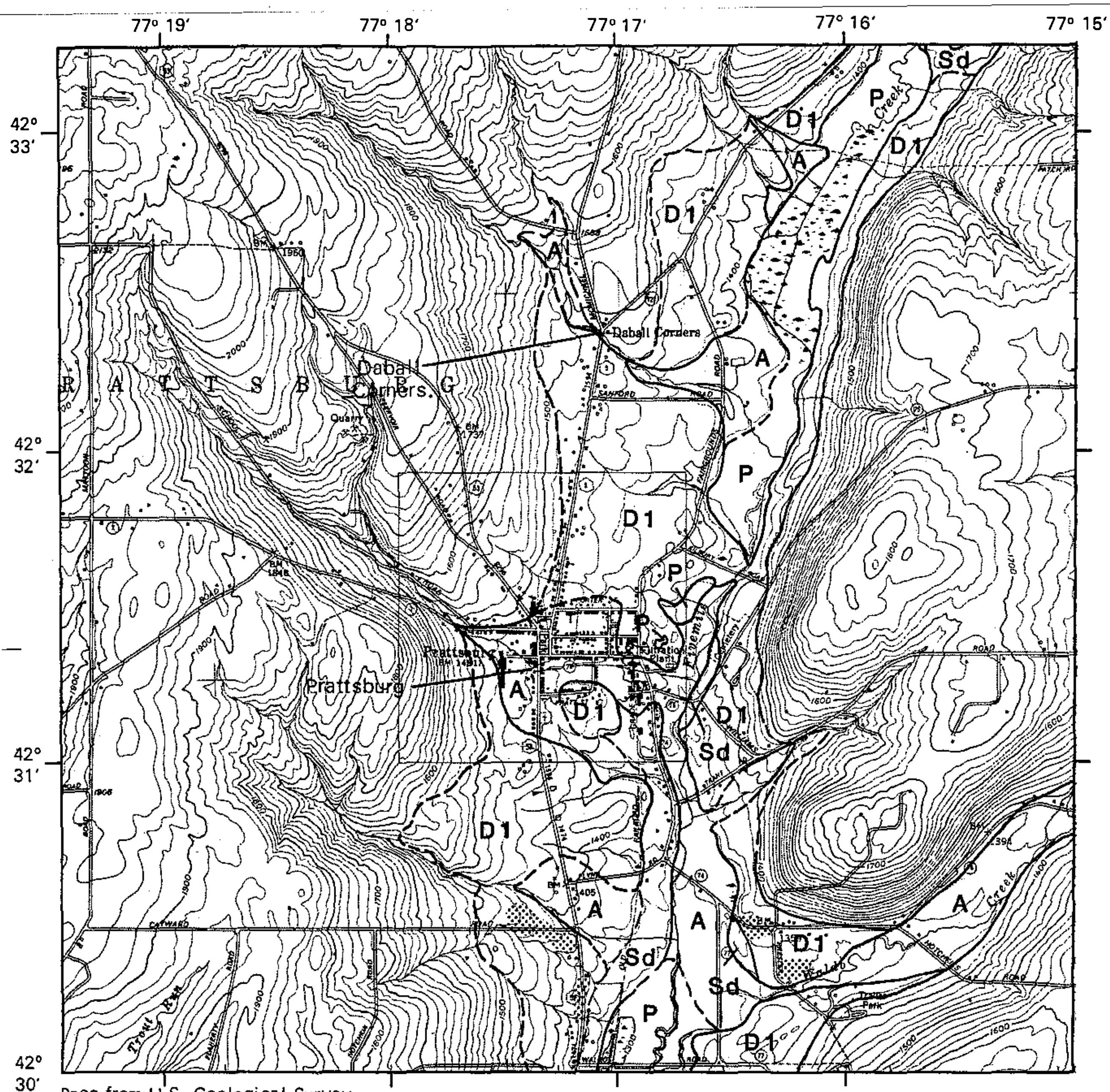
D1 Till and related diamicts, at or near land surface in areas of constructional topography, generally overlying ice-contact deposits; generally a compact stony sandy clayey silt containing some rounded stones; locally angular and rounded stones in a loose fine-sandy silt matrix; deposited during an ice readvance.

D2 Pebbly silty clay; generally nonbedded, locally contains deformed wisps of silt

Contact between geologic units, dashed where approximate

Drainage divide, Fivemile Creek watershed

G—G' Line of geologic section (fig. 4)



Base from U.S. Geological Survey
Prattsburg, N.Y., 1942, 1:24,000

FIGURE 3C

0 ½ 1 MILE
0 ½ 1 KILOMETER

EXPLANATION

A Alluvium: alluvial fans or channel deposits; chiefly gravel and sand, capped by overbank silt on large floodplains

P Peat and organic-rich silt to very fine sand; deposited in residual depressions along the valley axis after meltwater flow ceased

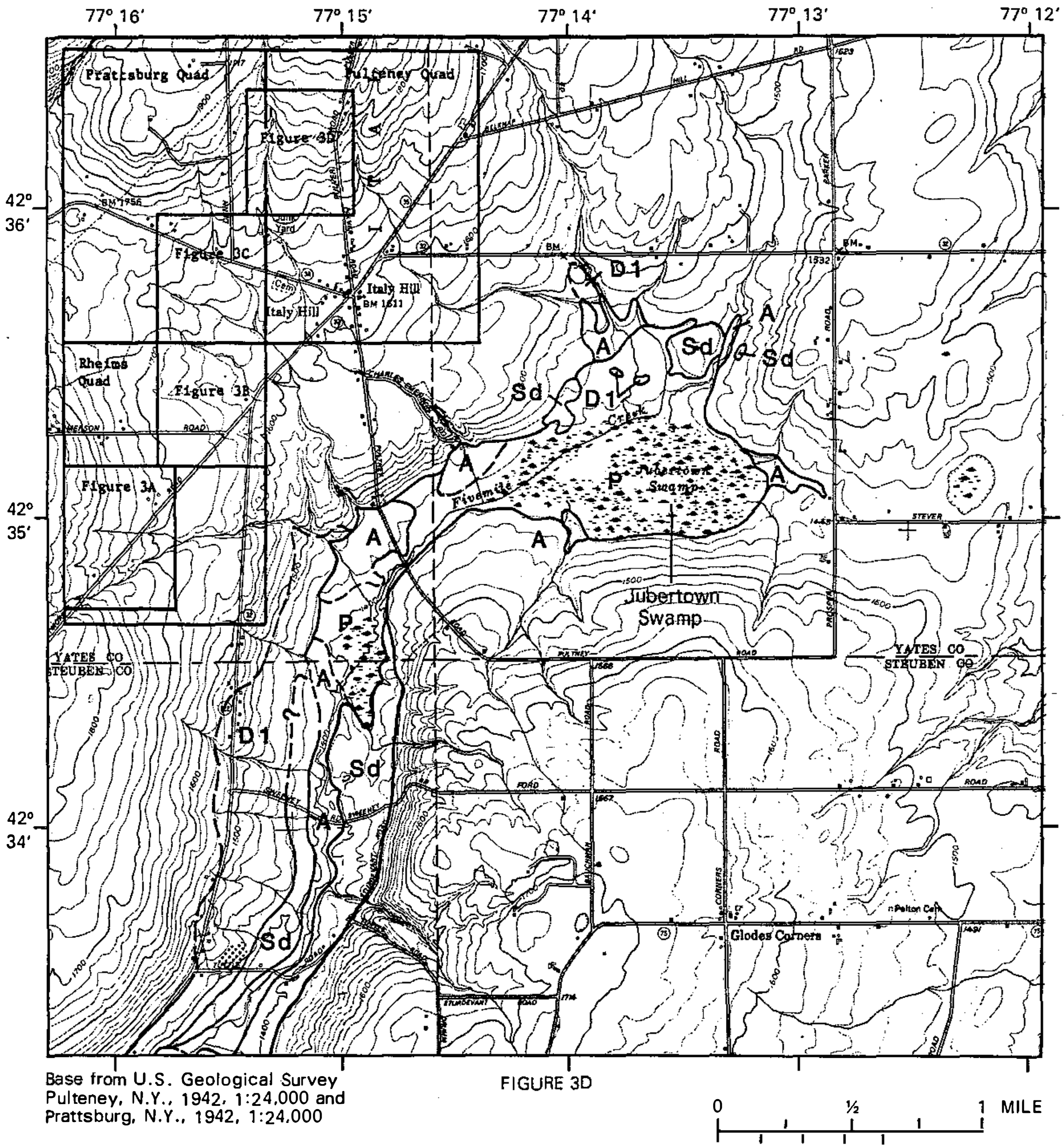
L Proglacial lake-bottom deposits: silt, clay

(hatched) Proglacial lake-bottom deposits, overlain by a few feet of fine sand

Sd Stratified drift; outwash, inwash, some ice-contact deposits; gravel and sand, deposited during melting of the last ice, in part deltaic

(stippled) Stratified drift, pebbly sand to sandy gravel, known or suspected to be generally less than 5 feet thick and commonly unsaturated; overlies readvance till or pebbly clay (D1, D2)

Figure 3 (continued)



Base from U.S. Geological Survey Pulteney, N.Y., 1942, 1:24,000 and Prattsburg, N.Y., 1942, 1:24,000

FIGURE 3D

EXPLANATION (continued)

(blank box)	Till; overlying bedrock in upland areas; all or lower part predates all other glacial drift.
D1	Till and related diamicts, at or near land surface in areas of constructional topography, generally overlying ice-contact deposits; generally a compact stony sandy clayey silt containing some rounded stones; locally angular and rounded stones in a loose fine-sandy silt matrix, deposited during an ice readvance.
D2	Pebbly silty clay; generally nonbedded, locally contains deformed wisps of silt
—— — —	Contact between geologic units, dashed where approximate

in many proglacial lakes throughout New York, and in the Lake Ontario lowland they constitute the uppermost unit over large areas, but in the Susquehanna River basin they are generally mantled by sand or gravel. Because the surficial deposits of ice readvance in Fivemile Creek valley are atypical, they are documented in the next section.

Deposits Resulting from Readvance

The lower sides and floor of Fivemile Creek valley are characterized by constructional topography and by slopes much less steep than those of the upper valley walls. Small terraces are found locally, but more commonly land surface is hummocky or irregular. Hummocky terrain is common on the floor and the lower sides of valleys in the Susquehanna River basin and is generally associated with ice-contact stratified drift. Nevertheless, in Fivemile Creek valley many shallow exposures and drainage features indicate that a diamict layer lies at or within a few feet of land surface all across the valley except for the lowest terraces and the floodplain.

Till

The surficial diamict north of Dineharts is interpreted as a readvance till because of its lithology and its ubiquitous presence atop older stratified drift. It is generally similar to upland till in that it has a matrix of clayey silt, although in several places it is more stony or contains more rounded stones than typical upland till. A few knolls consist of angular to rounded stones in a plentiful matrix of loose silty fine sand; this material may be redeposited ablation debris. Many shallow depressions are filled with water or swampy vegetation even though they are well above the nearest stream, which would not be true unless poorly permeable material such as till lay at shallow depth. East of the highway on the western side of the valley between Daball Corners (fig. 3C) and the Yates County line, till was exposed in several places on the lower valley walls, wet spots were common in April 1984, and small streams carried flow all the way to Fivemile Creek. (By contrast, on the eastern side of the valley several equally small streams went dry about 150 feet from where they began to cross a low stratified-drift terrace. Infiltration would not be so rapid if till were immediately below the stream channels, so the terrace is inferred to cap a post-readvance gravel deposit that is at least several feet thick.) Sites at which exposures or wells completed above bedrock demonstrate that sand or gravel underlie a near-surface till layer are listed in table 1.

Much of the area interpreted in figure 3 as readvance till overlying ice-contact deposits is mapped on the most recent Steuben County soils survey (French and others, 1978) as "Howard-Madrid complex". Although French and others describe this mapping unit as about half Howard soils (well-drained, formed on high-lime gravel) and half Madrid soils (well drained, formed on till), in the present study till was observed much more commonly than gravel at land surface. Furthermore, according to French and others (1978, p. 26), the till that constitutes the C-horizon of Madrid soils is generally underlain by gravel where the topography is "undulating," which includes most areas of these soils on the valley floor. Thus the soils survey provides some support for the concept of readvance in this valley.

Possible Subaqueous Diamict

From Dineharts south to Wheeler, diamict is widely observed at or very close to land surface (fig. 3A) but its lithology is rather different from that exposed north of Dineharts (fig. 3B). The stratigraphy shown in figure 4 is inferred from exposures in the bluffs along Fivemile Creek between Dineharts and Wheeler and from several well records, including some not shown in the figure.

The diamict (unit 3 in fig. 4) may be described more fully as follows: The predominant lithology is massive silty clay containing scattered angular to rounded pebbles, granules, and coarse sand that generally constitute from 1 to 5 percent by volume but locally from 10 to 15 percent. A few small lenses or masses of silty clay contain from 25 to 40 percent pebbles. Locally, the silty clay is nearly free of pebbles but contains blebs or severely deformed wisps of silt or clayey silt. No bedding can ordinarily be recognized, except for rare thin layers of sand or gravel. This diamict, although generally containing much less sand and stones than typical till, occupies the same stratigraphic interval as the readvance till north of Dineharts. The areas shown as pebbly silty clay (D2) in figure 3 correspond generally to areas mapped by French and others (1978) as Niagara and Collamer soils. These soils are silt loams and are described by French and others (1978, p. 20, p. 34) as formed on lake-laid silt, clay, and very fine sand.

The gravel layer termed "older outwash" (unit 2) in figure 4 is at least 20 feet thick in the bluff along Fivemile Creek, and is tapped by wells 0.5 mile to the east, near the intersection of Mitchellsville and

Table 1.--Evidence for till over stratified drift in Fivemile Creek valley

Location		Land-surface altitude	
Latitude ° ' "	Longitude ° ' "	(feet)	Description
4227 25	7718 30±	1,345	Gravel soil; small pond and swamp. Well 40 feet deep, reported to penetrate hardpan over gravel; large yield.
4228 30	7713 06	1,370	Roadcut is till; two wells reported to obtain water from gravel at 23 feet.
4230 05	7716 33	1,335	Eight-foot roadcut is till, probably overlies silty gravel near base. Well 40 feet deep, ends in gravel. Earlier well reported to penetrate fine sand 60± to 130± feet; abandoned.
4230 27	7716 09	1,355	Exposures 1,000 feet south, west: a few feet of gravel over till. House here: large rocks reported in cellar hole, poor drainage; well 30 feet deep, small yield from gravel.
4230 33	7717 12	1,405	Ditch: alluvial gravel 0-5 feet. Dug well nearby, poor yield. Drilled well reported to penetrate gray gravel and clay, no water 0-35 feet (mostly till?); small yield from gravel or broken shale 35-38 feet, water level 13 feet.
4231 16	7716 26	1,500	Sidehill pit: till and very stony diamicts 0-20 feet, cobble gravel 20-30 feet, sand and fine gravel 30-60 feet, tough unoxidized till at 60 feet.
4231 17	7716 41	1,362	Till exposed 400 feet west and beyond. Two industrial and one municipal well, all screened in gravel between 60 and 100 feet in depth, each yields >100 gallons per minute.
4232 31	7716 41	1,445	Till soils; drilled well ends in gravel at 23 feet.
4232 51	7716 18	1,400	Streambank 17 feet high: till at 9 feet, sandy silty gravel at 16 feet.
4233 06	7716 11	1,425	Till soils; stones and dirt (hard at 8 feet) and poor drainage reported in house foundation; well ends in gravel at 40 feet, large yield.

Gardner Roads, where its thickness exceeds 36 feet. As suggested in figure 4, it may correlate with a unit described as "pebbly gumbo with water" in a well east of Renchans (4226 15 7719 09). On the other hand, wells 1000 feet east and west of Fivemile Creek near Renchans (4226 15 7719 09, 4226 22 7719 34) obtain water from gravel layers 3 to 4 feet thick, apparently within the pebbly clay diamict (unit 3). Both of these gravel layers lie at altitudes of about 1260 feet, the same as the top of the "older outwash" in the most downstream exposure along Fivemile Creek. Perhaps it is these thin gravel layers that should be interpreted as the southward continuation of unit 2. In either case, unit 2 apparently pinches out a short distance south of Renchans. Records of several wells near the intersection of Wheeler and LaRue Roads, 0.4 mile east of Wheeler (fig. 3A), indicate that about 25 feet of surficial gravel are underlain by 125 feet or more of fine-grained sediments.

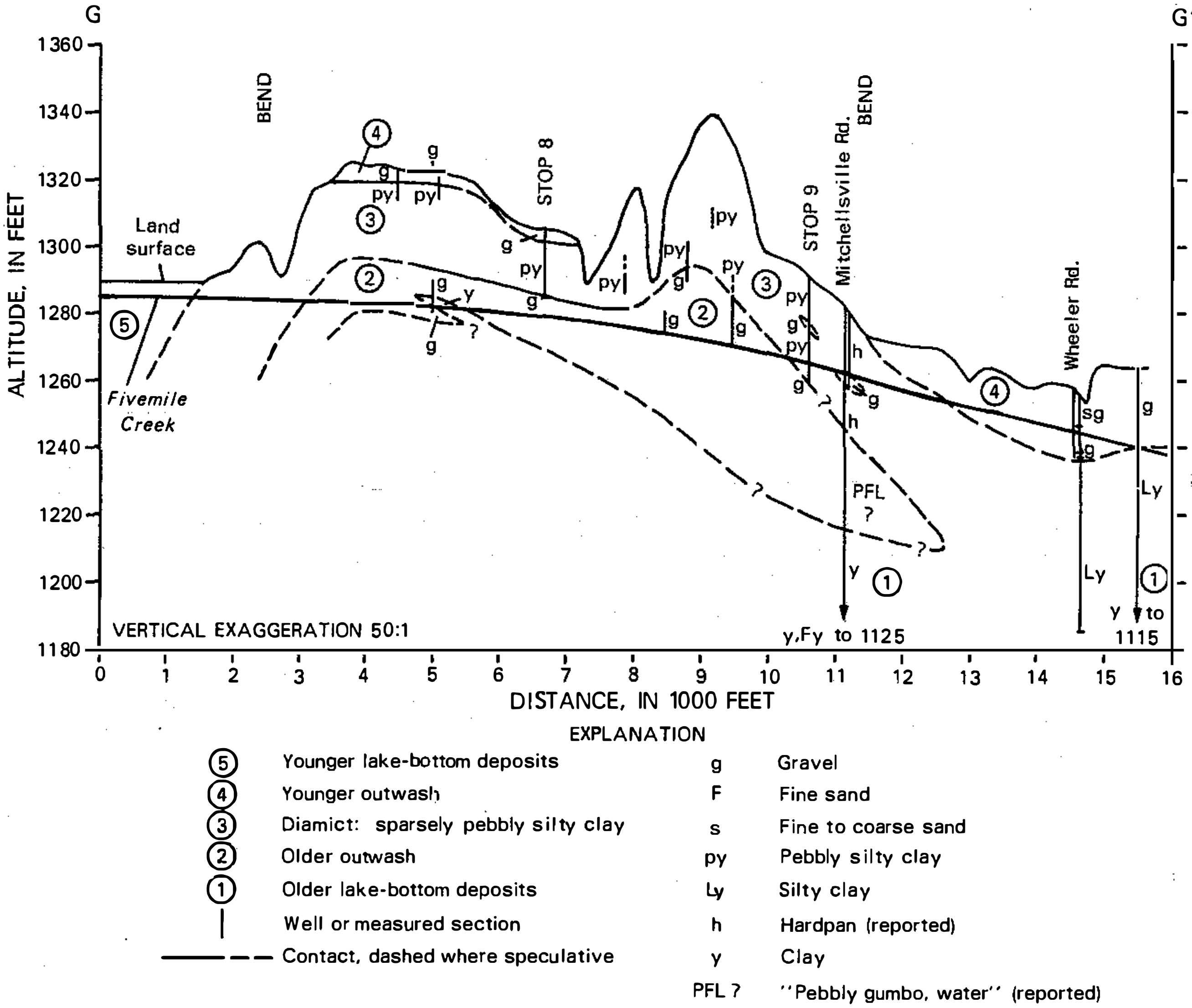


Figure 4. Geologic section near Renchans in Fivemile Creek valley. (Location of section shown in figure 3.)

The silty-clay diamict (unit 3) is interpreted to be the product of ice readvance into standing water south of Dineharts. Presumably the ice terminus was at least partly floating; perhaps the pebbles and sand could have been deposited from calved icebergs as well as from an attached floating ice tongue. This interpretation is based primarily on analogy with till in Buttermilk Creek valley in western New York, where the ice must have advanced into standing water and much of the till has a low pebble content and wisps of silt (LaFleur, 1979, 1980; Randall, 1980). Similar interpretations have been suggested by others for pebbly silty clays observed on field trips. However, P. J. Fleisher (State University of New York, written commun., 1986) reports that exposures of similar diamicts in the eastern part of the Susquehanna River basin are numerous and so widely distributed that interpreting them to be subaqueous readvance tills would unreasonably complicate deglacial history.

Ponded water in Fivemile Creek valley is easily explained by the geometry of nearby through valleys. The Hammondsport valley extends from Keuka Lake through Hammondsport to Bath, nearly parallel to Fivemile Creek valley (fig. 1). Because Hammmondsport valley is much broader and, especially to the north, much deeper to bedrock than Fivemile Creek valley, presumably the tongue of active ice in Hammondsport valley would have advanced more rapidly. Once it reached the west wall of the Cohocton valley at Bath (fig. 1), it would have impeded or blocked the natural southward drainage of all tributaries north of Bath, including Fivemile Creek. If so, the resulting lake level must have been controlled either by a spillway now at 1,450 feet altitude between Campbell and Stocking Creeks (fig. 1), 8 miles south of the confluence of Fivemile Creek and Cohocton River at Kanona, or by the ice tongue at Bath, whichever was lower. Deltaic sand and gravel high on the valley wall near Bath and Kanona might date from such a lake ponded during readvance rather than during the previous retreat; beds commonly dip north or northwest at altitudes of 1,380 to 1,440 feet and are not known to be mantled by the pebbly silty clay or other lake-bottom deposits. Several feet of compact silty diamict containing about 20 percent pebbles, many of them rounded, are exposed atop gravel in a pit cut into a terrace at Mitchellsville, 3 miles southeast of Renchans. The form and altitude of the terrace suggests a delta deposited by meltwater flowing north from the Hammondsport valley through the Mitchellsville gorge (figure 3) but if so the surficial diamict implies that ice subsequently readvanced in Hammondsport valley at least far enough to block the Mitchellsville gorge.

Before readvance, a lake probably occupied the low-lying central and eastern parts of Fivemile Creek valley north of Dineharts, where older till-mantled stratified drift is absent or buried by younger sediments. The altitude of the highest part of the pebbly clay diamict exposed near Dineharts is 1,340 feet, not far below the spillway into Stocking Creek south of Kanona even if some allowance for postglacial rebound were added. Perhaps careful evaluation of plausible lake depths and lithology of the pebbly clay south of Dineharts might lead to a conclusion that incorporation of lacustrine sediment into grounded ice as it readvanced is a more plausible explanation of the origin of this diamict.

Denny and Lyford (1963, p. 14-17) observed diamicts overlying stratified drift at several sites in the Southern Tier of New York and in adjacent

Pennsylvania. These diamicts ranged in texture from rubble to silty clay loam that resembled upland till, were thickest near the valley wall, and were interpreted to be colluvium emplaced by mass movement. Colluvium may be found locally in Fivemile Creek valley, but the complex hummocky topography in some diamict-mantled areas, the absence of surficial diamict on younger terraces, and the thin fluvial gravel capping the diamict in some localities all require that emplacement of diamict ceased before ice and meltwater disappeared from the basin, an unlikely history for mass movement.

Lacustrine Deposits

The valley floor near Beans Station includes three principal geomorphic elements: a broad sandy terrace at an altitude of about 1,310 feet immediately southeast of Beans Station, a gently sloping plain extending southward another 1.5 miles, and the "Prattsburg muck," a huge drained swampland extending east about 2 miles. The Beans Station terrace is capped by pebbly coarse sand. A well near the center of the terrace (4228 55 7716 51) penetrated 300 feet of fine sand to silt that was interbedded with some medium-to-coarse sand to a depth of about 60 feet. West, south, and southeast of low scarps that bound the mapped extent of outwash, several holes drilled to depths of 70 to 110 feet penetrated only fine sand, silt, and clay. Near the west side of the valley floor a well (4229 01 7717 17) penetrated through fine-grained alluvium into sand that may be equivalent to the sand that forms the Beans Station terrace. All this information suggests the Beans Station terrace is an outwash delta, whose south and southeast margins (near the 1300 foot contour) may be the open-water delta front. While the delta was being deposited, ice blocks occupied parts of the valley floor to the east (the present Prattsburg muck), to the north (near Mud Lake and several small kettles), and probably to the west. The delta and the lake-bottom deposits overlap the older ice-contact deposits and readvance till along the west side of Fivemile Creek valley. Along the east side of the valley lake-bottom clay-silt rhythmites overlap till. Within 250 feet of the base of the till-covered slope the rhythmites are overlain by a few feet of fine to very fine sand, presumably a beach or shoreline deposit.

In most broad valleys of the Susquehanna River basin, low outwash or fluvial terraces of pebbly coarse sand or gravel mantle late-deglacial lacustrine deposits. The lack of late outwash in Fivemile Creek valley is a direct result of the fact that the valley is not quite a through valley: both the main valley (at Jubertown Swamp) and the principal spur (at Elmbois, east of Beans Station) head at till-covered saddles that were doubtless lowered by glacial erosion but nevertheless begin high on the side of the much deeper Hammondsport valley. Once ice ceased to flow into Fivemile Creek valley through these saddles or across the adjacent upland, meltwater from the north quickly was diverted to the deeper Hammondsport valley. Because the flow of meltwater was cut off so quickly, lake-bottom deposits south of Beans Station were never mantled with outwash, nor was there much sediment to fill the large kettleholes that developed as remaining stagnant ice blocks melted. The result was unusually abundant and extensive accumulations of peat (in Jubertown Swamp, a swamp northeast of Daball Corners, the Prattsburg muck east of Beans Station, and smaller swamps) and organic silt (along Fivemile Creek north and south of Beans Station). A lack of outwash and an abundance of large or coalesced ice-block depressions are also evident in broad non-through valleys in the eastern part of the Susquehanna River basin (Fleisher and Cadwell, 1984, p. 194) and have also been attributed to glacier thinning over the the divide and subsequent stagnation downvalley (Fleisher, 1986).

Regional Considerations

The readvance in Fivemile Creek valley proposed in this article seems consistent with drift borders in this region postulated by Connally (1964). He inferred, primarily on the basis of heavy mineral separations and distribution of constructional topography, that the surface drift in the northwestern part of the Chemung River basin was younger than the widespread "Olean" drift to the south. His younger drift was distinguished by predominance of purple over red garnet, many exotic pebbles, stream-rounded stones in till in the valleys, and sparsely stony till overlying contorted lacustrine deposits at "many" unspecified valley locations. Connally thought that the younger drift was probably of Kent age, and that its southern boundary lay somewhere near Kanona but "may prove to be correlative with one of the moraines in the Prattsburg (Fivemile Creek) valley". He described these moraines as located at Renchans and south of Prattsburg.

Multiple layers of till, attributed to repeated oscillations or readvances of the ice, have been recognized in two valleys immediately north of the Appalachian Plateau, near Dryden (T. Miller, U.S. Geological Survey, oral commun., 1985) and Herkimer (Ridge and others, 1984). In Fivemile Creek valley, logs of wells and test borings near Prattsburg (4231 17 7716 41, table 1) might be interpreted as having penetrated multiple layers of till. However, exposures and well records near Waldo Creek (4230 05 7716 33, table 1) are suggestive of a single layer of till capping an earlier delta. Generally, subsurface data in Fivemile Creek valley are inadequate as a basis for deciding whether more than two till layers are present.

INFLUENCE OF GLACIAL DRIFT ON POSTGLACIAL STREAMFLOW

The areal extent of surficial sand and gravel in a watershed is strongly correlated with streamflow draining from the watershed during the periods of minimum flow that recur in summer or early autumn each year and recur with greater severity in occasional drought years, as shown by studies in Connecticut (Thomas, 1966; Randall and others, 1966; Cervione and others, 1972; Cervione and others, 1982) and New York (Ku and others, 1975; Barnes, in press). The powerful influence of surficial sand and gravel on low flow is illustrated in figure 5, which represents 73 watersheds in the Susquehanna River basin. The percentage of watershed area underlain by sand and gravel is compared to a statistical index of low flow; namely, the 7-day low flow having a 10-year recurrence interval. The term "7-day low flow" refers to the mean flow averaged over the 7 consecutive days of lowest flow in a year. To state that a particular 7-day low flow has a 10-year recurrence interval means that over several decades, in 1 year out of 10 the mean flow for the 7 days of lowest flow in that year would be equal to or less than the value stated.

Regression analysis of the set of data plotted in figure 5 demonstrated that percentage of watershed area underlain by sand and gravel explains 86 percent of the variation in low flow per square mile of streams in the Susquehanna River basin (Ku and others, 1975, table 4). At least three properties of surficial sand and gravel deposits contribute to their superior low-flow yields as compared with till-mantled bedrock: greater transmissivity and infiltration capacity, greater specific yield, and sufficiently greater depth to the water table to result in less evapotranspiration of ground water (Rorabaugh, 1964; also unpublished trial computer simulations). However, the scatter in the set of data evident in figure 5 means that other variables and (or) errors in the data must influence the relationship. In 1983, additional variables were incorporated into the set of data in hopes of explaining the scatter. Watersheds with abundant lakes and swamps were found to have subnormal flows (fig. 5), so wetland area in each watershed was tested as an independent variable and proved to be significant. Watersheds having a large discrepancy between observed and predicted low flow were individually reevaluated. Low flow of Fivemile Creek was predicted to be eight times as great as observed flow, the largest discrepancy in the set of data. Three possible causes were investigated:

1) Underflow. In any valley, streamflow constitutes that fraction of runoff that cannot move downvalley through the ground as underflow. Commonly, streamflow predominates, and underflow is only a small fraction of runoff. If perchance the stratified drift in Fivemile Creek valley near the gaging station were unusually permeable, underflow would exceed that along other valley reaches and streamflow would be correspondingly reduced,

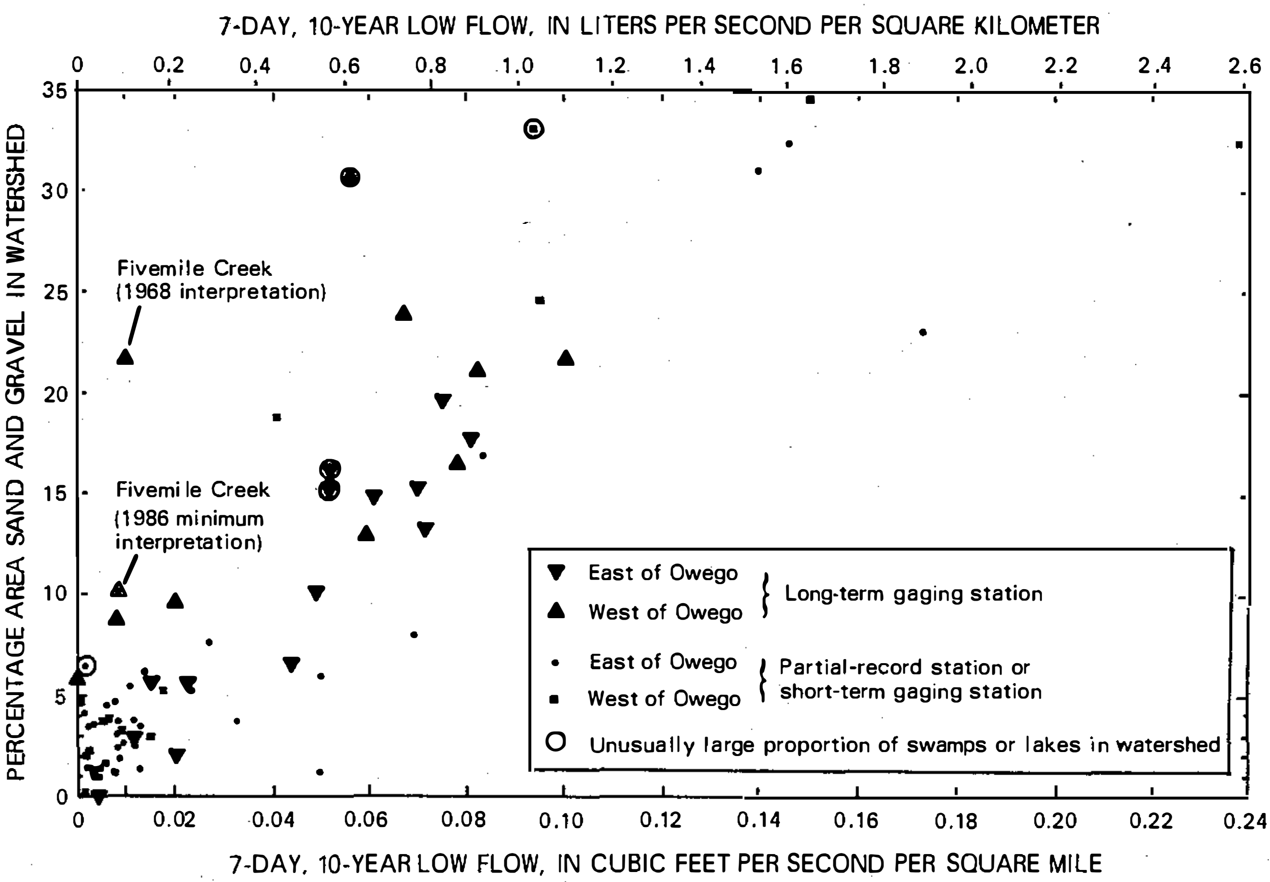


Figure 5. Relation of low flow to percentage area of sand and gravel in watershed. (From Ku and others, 1975.)

the greatest percentage reduction would be at low flow. However, three wells near the gaging station penetrated mostly poorly permeable fine-grained sediment below a depth of 20 feet. Furthermore, consistent gains in streamflow along both Fivemile Creek and the adjacent reach of the Cohocton River proportional to the area of sand and gravel were recorded by streamflow measurements in August 1982 and September 1983 (U.S. Geological Survey, 1983, 1984). Thus, no evidence of unusually large underflow near the Fivemile Creek gaging station has been obtained.

2) Irrigation pumpage. In the western part of the Susquehanna River basin, some farmers whose lands abut major streams have dug pits in or adjacent to stream channels and used portable pumps to occasionally withdraw water for irrigation. If substantial amounts of water had been pumped regularly from Fivemile Creek for irrigation over many years, the statistical indices of flow during the irrigation season would presumably have been less than natural flow by an amount equal to the typical rate of pumpage. However, interviews with current and former owners and managers of farms revealed that annual irrigation pumpage in Fivemile Creek valley was substantial only during 1966-69, and took place almost exclusively from June through mid-August, well before the annual minimum flow in nearly every year. Thus, irrigation pumpage seems to have had little or no effect on the 7-day 10-year low flow of Fivemile Creek.

3) Surficial geology. The area of sand and gravel within the watershed of Fivemile Creek was interpreted by Ku and others (1975) from a brief reconnaissance of the surficial geology in 1965 and an earlier soil survey (Pearson and others, 1931). Till and fine-grained lake-bottom sediments seemed to be more abundant in Fivemile Creek valley than in most others, and were presumed to be interbedded within the stratified drift, but no method was devised to represent this possibility in regression analysis. The geologic reexamination described in this article resulted in the hypothesis that for purposes of regression analysis all parts of the valley fill where fine-grained lake deposits or diamict are at or very close to land surface should perhaps be classified with till-mantled upland rather than with sand and gravel. These poorly permeable units are commonly underlain by sand or gravel that is tapped by wells and that comes in contact with streambeds southeast of Dineharts and perhaps elsewhere. However, water stored above stream grade in sand and gravel is the principal source of ground-water discharge at low flow, and is probably less abundant where shallow diamicts limit recharge than where sand and gravel extend from land surface to below stream grade. The diamicts are overlain by a few feet of outwash gravel in some places, but much of this thin mantle seems to be drained and unsaturated during low flow. Perhaps such areas would yield as little water at low flow as areas of till-mantled upland.

The area of surficial sand and gravel in Fivemile Creek watershed was recalculated in accordance with the foregoing hypothesis. Areas of surficial till, silt, and clay were excluded. The recalculation brought low flow predicted by regression analysis into much closer agreement with low flow calculated from streamflow records (table 2). Several areas mapped as sand and gravel in 1984 were not examined in the field, or no indication of surficial gravel thickness was obtained. Perhaps some of these areas should have been excluded, inasmuch as predicted low flow is still greater than observed (table 2).

Some confirmation of the hypothesis that till-mantled stratified drift should be treated as till in predicting low flow comes from other parts of the Susquehanna River basin. Along the west side of the West Branch Tioughnioga River valley near Homer, and along its tributaries Factory Brook and Cold Brook, rounded benches a few tens of feet above the valley floor seem to be capped by till, but gravel is exposed in a few deep excavations. The county soil survey (Sery, 1961) generally classified these benches as "Bath-Howard soils" or some similar hybrid of till and gravel soils. The surficial diamict may have been deposited atop older kame terraces during a readvance, as in Fivemile Creek valley, or may be the product of mass movements as described by Denny and Lyford (1963). These areas have been excluded from the stratified drift in regression analyses to date, and including them would increase the error in the prediction of low flows; hence, exclusion seems proper.

Table 2.--Effects of revised geologic interpretation on prediction of low streamflow, Fivemile Creek valley

Date of mapping	Drainage area (square miles)	Extent of sand and gravel: Basis	Extent of sand and gravel: Area (square miles)	Extent of sand and gravel: Percent of drainage area	7-day 10-year low flow (cubic feet per second): observed[a]	7-day 10-year low flow (cubic feet per second): predicted[b]
1968	66.8	Maximum	>14.8	>22.2	0.6	>5.1
	66.8	Average	14.4	21.6	0.6	4.9
	66.8	Minimum[c]	14.0	21.	0.6	4.7
1984	66.8	Maximum	7.9	11.8	0.6	2.2
	66.8	Minimum[d]	6.7	10.0	0.6	1.6

a/ For period of record through 1975; 0.7 for 1931-60.

b/ Predicted by best-fit provisional regression equation applied to set of data assembled by Ku and others (1975) and revised in 1983.

c/ Excludes areas where identification as sand or gravel seemed questionable.

d/ Excludes areas where thin surficial sand or gravel, thought to be less than 5 ft thick and unsaturated at times of low flow, overlies till or lake-bottom silt and clay. Both minimum and maximum exclude areas of surficial till, lake-bottom silt and clay, and postglacial organic-rich silt to very fine sand regardless of what may underlie them.

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LOG OF FIELD EXCURSION

Stops 1 and 2 show conditions in a typical valley of the Susquehanna River basin, to be contrasted later with conditions in Fivemile Creek basin. Stops 3-5 present evidence for till overlying stratified drift. Stop 6 and nearby hesitation stops overlook the divide at the head of Fivemile Creek. Stops 7-9 show diamict and other deposits in proglacial lakes during and after the inferred ice readvance. Stop 10 considers the hydrologic implications. The road log begins at the entrance to Buttermilk Falls Park along Route 13 just south of Ithaca.

Total miles	Miles from last point	
0.0	0.0	Proceed south on Route 13. The route follows the valley of Cayuga Inlet, a trough greatly overdeepened by glacial erosion. Bedrock is more than 400 ft below the valley floor and is below sea level.
2.0	2.0	Junction with Route 96; continue south on Route 13.
2.4	.4	View to left of continuation of the Cayuga Inlet trough.
3.8	1.4	Views to left across Cayuga Inlet trough, next 0.5 mile.
5.0±	1.2	Entering valley of West Branch Cayuga Inlet, a tributary valley also enlarged by glacial erosion, but not as deeply.
7.5	2.5	Turn right on paved road at sign "Sebring Rd Tavern"
8.0	.5	Turn left at T junction; views left across valley next 1.1 mile.
9.1	1.1	HESITATION STOP, near crest of hill: view to left of hummoky valley fill; note absence of stream channel.
9.5	.4	Park along road near barn bearing sign "Chuck's Marine Service". STOP 1: VIEW OF THROUGH VALLEY. To the right, valley floor is relatively smooth, slopes gently southwest, and is underlain by outwash gravel. To the left, valley floor is hummoky, slopes irregularly northeast, and is underlain by the same outwash gravel, deposited in part over buried ice that did not melt until after the flow of meltwater and sediment cased. Most large streams in the Susquehanna River basin head in one or more through valleys like this: broad valleys that transect the drainage divide and served as a channel for ice during glaciation and for meltwater during

deglaciation. Alluvial fans of small tributaries are visible at the base of the far valley wall; these streams flow southwest on the valley floor but lose water by seepage and are usually dry. The trees that form a line across the valley floor to the southwest border Carter Creek, a larger tributary that also loses water by seepage; the ground-water mound thus created near Carter Creek constitutes the ground-water divide in this valley.

9.6	.1	Junction with Route 13, continue straight ahead on Route 13.
10.3	.7	Cross Carter Creek. For next 3 miles the route descends a valley train of outwash augmented by alluvial fans of tributaries.
12.2	1.9	Cross Pony Hollow Creek.
12.7	.5	Cayuta Road on left.
12.9	.2	Cross dry channel leading from Hendershot Gulf, a meltwater spillway and incipient through valley.
13.0	.3	Turn left on dirt road into gravel pit.
13.3	.3	STOP 2: COARSE OUTWASH. The lower terraces in most broad valleys in the Susquehanna River basin are underlain by outwash gravel. The gravel exposed here is coarser and richer in clasts of local shale bedrock than most outwash, because it lies immediately downgradient from a remarkable 4-mile-long spillway cut in bedrock, from which many of the clasts were doubtless eroded.
13.6	.3	Leave pit, turn left (south) on Route 13.
14.8	1.2	Junction Routes 13 and 224. Proceed to Kanona, N.Y. following Route 13 south to junction with Route 17 near Elmira, then Route 17 west to Corning, Bath, and Kanona (about 53 miles).

Road log resumes at junction of Routes 17 and 53 at Kanona, N.Y.

0.0	0.0	Turn right (north) on Route 53; enter Fivemile Creek valley. For the next 0.8 mile, ice-contact stratified drift mantles the lower valley walls (both sides), up to more than 200 feet above road level.
1.0	1.0	Cross Fivemile Creek.
1.2	.2	Road is cut through "valley choker" moraine; test borings (Randall, 1972) suggest that till constitutes more than 50 percent of its mass; road borders north edge for the next mile. Fivemile Creek is briefly incised in bedrock at east side of valley.
4.0	2.8	Wheeler; Route 53 is on outwash, overlapped by alluvial fans from the west; views to the left of fans next 0.3 mile.
4.6	.6	Avoca-Wheeler Rd on left. For next 1.3 miles land surface is mostly a pebbly clay diamict (to be examined at stops 8 and 9)
6.4	1.8	Large barn on left; shallow pond on right. Near pond, a well was reported to penetrate "hardpan" (till), then obtain a large yield from gravel at a depth of 40 feet.
7.0	.6	Wetland to right of road.
9.7	2.7	Turn right on Waldo Road.
10.2	.5	Road intersection; continue 400 feet ahead and park. STOP 3: TILL-MANTLED STRATIFIED DRIFT. Topography, as shown on topographic map and as visible from this point, is suggestive of a kame terrace; a moderately level surface, hummoky in detail, 40 feet above the floodplain. At the trailer to the north, a well is finished in gravel at a

depth of 40 feet, after another well was abandoned at about 130 feet after penetrating many feet of fine sand. However, roadcuts 400 to 800 feet east and 400 feet north of the intersection reveal till.

10.2 .0 Turn left (north) at intersection.

10.8 .6 Turn left at T-junction onto Steuben County 74, Pultney Road

11.0 .2 Cross Fivemile Creek, bear right.

11.8 .8 Intersection; creamery visible ahead; park 100 ft beyond intersection. Walk 300 ft down driveway to the right (east). Small depressions north of driveway are kettles floored with peat.

STOP 4: TILL-MANTLED STATIFIED DRIFT. Till is exposed in a small excavation here. Wells in the two small buildings on the valley floor immediately to the southeast supply 150,000 gallons per day to the creamery; the village of Prattsburg obtains most of its water from a well 250 feet further south. Drillers' logs of these wells and nearby test holes differ in detail but all indicate that silty or clayey gravels and stony clay (or hardpan) predominate. The well nearest the creek reportedly penetrated

0-13 feet soft clay
13-32 feet boulders, clay hardpan
32-66 feet mostly gravel, silty, yields some water
66-72 feet gravel, yields more water
72-89 feet hardpan.

Walk 300 feet downstream along Fivemile Creek to view exposure of post-till gravel on opposite bank. Return to main road.

11.8 .0 Turn around, head south on Mill St. (Pultney Road).

12.0 .2 Turn left on paved road; pass Narcissa Prentiss house.

12.2 .2 Cross Fivemile Creek, then turn left. Cemetery on left.

12.45 .25 Turn right into gravel driveway.

12.6 .15 Prattsburg Town Highway Dept. garage.

STOP 5: TILL-MANTLED STATIFIED DRIFT. High excavation to east was described in 1984 as follows:

1500-1480 feet altitude: includes definite till and much problematic diamict (>50% stones in a till-like matrix).
1480-1470 Cobble gravel.
1470- Layered sands, clean to gummy from interstitial clay, and fine gravels.
1440- Till, tough, unoxidized.
1400 Base of slope, garage level

Top of cut is 150 feet west of base of steep valley wall.

12.6 .0 Turn around, head out driveway.

12.75 .15 Turn left on paved road. Note swamp on left at corner.

13.0 .25 Turn right at intersection. Note swamps and pond on left and ahead.

13.2 .2 Turn right on Mill St.

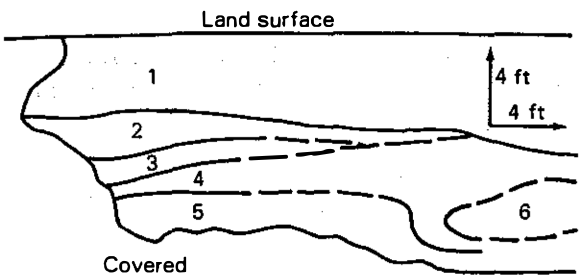
13.4 .2 Creamery and stop 4; turn left on Mechanic St.

13.7 .3 Turn right on North Main St., pass Prattsburg village green on left.

15.3 1.6 Paved road to right. HESITATION STOP: View to right across upper Fivemile Creek Valley. Exposure of till over gravel in woods ahead, 1000 ft east of road. Flat valley floor is underlain by peat.

17.9	2.6	Enter Yates County, town of Italy.
18.2	0.3	HESITATION STOP: View to right across Jubertown Swamp (head of Fivemile Creek). Skyline beyond swamp is not marked by deeply incised saddle or through valley.
19.6	1.4	20 mph turn, Blue Eagle tavern; bear right.
21.3	1.7	Turn right on Prosser Road
21.5	.2	Crest of hill. HESITATION STOP: Views to right (northwest) and to the rear (north) of gentle saddles on basin divide.
22.3	.8	Turn left on Stever Hill Road; follow this road as it crosses saddle on basin divide.
22.9	.6	Crest of saddle. STOP 6: VIEW OF BASIN DIVIDE: This saddle, the lowest on the Fivemile Creek divide, shows no incision or deposition due to meltwater flow. The slope ahead (east) descends to Keuka Lake, 730 feet below this saddle. The deeper valley presumably captured most ice and meltwater flow when the ice surface was above this saddle, and certainly when it was below. Turn around and retrace route to Prattsburg.
32.3	9.4	Prattsburg Village Green; turn right, then turn left on Route 53.
33.1	.8	Swampy depression beside road on right.
33.3	.2	Side road on left. For next 0.2 mile, land surface is underlain by 5 feet of flatstone gravel, an alluvial fan of a brook.
33.5	.2	Cayward Hill Road on right. Till exposed at base of knoll on right, overlain by 10 feet of silty gravel, fine sand, and sandy gravel, presumably late-glacial inwash.
34.0	.5	Turn left on Waldo Road.
34.25	.25	Cross Fivemile Creek. Floodplain downstream from here is underlain by silt, clay, peat, and organic-rich muck that extends at least 5 to 15 feet below stream grade.
34.5	.25	Road intersection and stop 3; continue straight.
35.2	.7	Turn 160° right.
35.55	.35	HESITATION STOP: View of "Prattsburg Muck". This large ice-block depression, underlain by many feet of peat, is drained by buried tiles to perimeter ditches, which drain (or, if necessary, are pumped) into Mud Lake and thence into Fivemile Creek. Crops of lettuce and onions are grown here. The muckland occupies most of a broad tributary valley that heads at a gentle saddle overlooking the Keuka Lake-Hammondsport valley, like the saddle at stop 6.
36.2	.55	Turn left (southeast) at T-junction. Road crosses the BS outwash delta. Surficial sediment is pebbly medium to coarse sand. A well drilled in 1949 near the buildings south of the junction was abandoned at a depth of 320 feet, after penetrating mostly "quicksand" (silt to very fine sand) and clay.
36.6	.4	Turn right on gravel road. A well drilled here in 1983 was abandoned at 70 feet depth after penetrating only clay and silt.
38.1	1.5	Cleared cropland to right. STOP 7: LAKE-BOTTOM DEPOSITS. Auger holes 270 and 820 feet west of road penetrated layered silt and clay, capped (near the road) by very fine sand.
39.2	1.1	Road bends sharply right.
39.3	.1	Pond and swamps on left.

39.5 .2 Turn left and stop. Walk along far side of the field west of the road to a small exposure in the bluff above Fivemile Creek.
STOP 8: PEBBLY CLAY DIAMICT. This exposure is plotted on figure 4. The sketch shows its appearance in 1983.



1. Pebble-cobble gravel; sandy streaks, silty at base
2. Silty very fine sand.
3. Fine to very fine sand, interbedded with medium to very coarse sand.
4. Oxidized 5. Unoxidized massive silty clay with sparse pebbles.
6. Lens of silty pebble gravel. Pebbles numerous in underlying clay.

40.3 .8 Turn right at T-junction on Mitchellsville Road. View left, at turn, of outlet of former spillway from Mitchellsville.
40.5 .2 Wells nearby are finished in gravel beneath surficial pebbly clay.
41.05 .55 Approaching Fivemile Creek. Park along road, walk 1000 feet upstream (right) along edge of field to exposure in bluff.
STOP 9: PEBBLY CLAY DIAMICT. This exposure is plotted in figure 4. It was described in 1986 as follows
0-12 ft Clay or silty clay, containing 1 to rarely 5 percent rounded to sharply angular pebbles and coarse sand; no regular bedding recognized, but a few deformed streaks or blebs of coarse silt observed; oxidized.
12-15 ft Pebble-cobble gravel, rounded, a few exotics, generally very silty, appears to grade northward into very pebbly clay.
15-20 ft (exposed) 20-30 ft (augered) Sparsely pebbly clay, like that above but unoxidized, plastic.
30 ft Gravel; could not penetrate.
Property owner reports accelerated recession of this bluff 1984-86 since channel of tributary entering from the west was excavated for flood control, which owner believes has caused deflection of the flow of Fivemile Creek against this bank.
41.25 .2 Turn left on Route 53.
45.1 3.85 Cross Fivemile Creek.
45.5 .4 John Walsh Sales on right; turn right on gravel road.
45.7 .2 Approaching Fivemile Creek.
STOP 10: FIVEMILE CREEK GAGING STATION. Records of stage and flow have been collected here since February 1937. The operation of the station will be explained, and the influence of surficial geology on the minimum flow measured here will be discussed.
45.9 .2 Return to Route 53, turn right.
46.5 .6 Intersection with Route 17. End of Road Log.