43RD ANNUAL REUNION
NORTHEAST FRIENDS of the PLEISTOCENE

LATE WISCONSIN STRATIGRAPHY OF THE UPPER CATTARAUGUS BASIN

CONTRIBUTORS
P. E. Calkin
E. H. Muller
R. G. La Fleur

R. H. Fakundiny & NYSGS staff

Scale 500,000
A. F. Hassan, Cartographer
Compiled 1980

1980
GUIDEBOOK

43rd Annual Reunion
NORTHEAST
FRIENDS OF THE PLEISTOCENE

Robert G. LaFleur
Editor

Contributors:
P.E. Calkin & E.H. Muller
R.G. LaFleur
R.H. Fakundiny, R.H. Fickies,
H.H. Bailey, R.H. Dana, Jr. &
S.A. Molello

Technical Editor:
J. J. Sevon

May 1980

Typist:
G.W. Hoffman

Springville, N. Y.
Mirror, mirror on the wall,
Who has the brightest drift of all?
Oh, Lee Ann, is it thou?
Subdued of form, and wonder how
Intimate Kent, so full of clout
Can, too, be drab -- we've found him out!

Lavery and Hiram -- now that's a pair,
Slinging mud from here to there.
Not helping much with motley stones
When what we want are wood and bones,
So tell us, mirror on the wall
Who needs the brightest drift of all?
## CONTENTS

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEOLOGIC SETTING AND GLACIAL OVERVIEW OF THE UPPER CATTARAUGUS BASIN, SOUTHWESTERN NEW YORK</td>
<td>1</td>
</tr>
<tr>
<td>P.E. Calkin and E.H. Muller</td>
<td></td>
</tr>
<tr>
<td>LATE WISCONSIN STRATIGRAPHY OF THE UPPER CATTARAUGUS BASIN</td>
<td>13</td>
</tr>
<tr>
<td>R.G. LaFleur</td>
<td></td>
</tr>
<tr>
<td>Trip log - day one</td>
<td>22</td>
</tr>
<tr>
<td>Trip log - day two</td>
<td>26</td>
</tr>
<tr>
<td>Stratigraphic sections</td>
<td>28</td>
</tr>
<tr>
<td>GEOLOGIC STUDY OF THE BURIAL MEDIUM AT THE LOW-LEVEL RADIOACTIVE-WASTE BURIAL SITE, WEST VALLEY, NEW YORK</td>
<td>39</td>
</tr>
<tr>
<td>R.H. Pakundiny, R.H. Pickies, H.H. Bailey, R.H. Dana, Jr., and S.A. Moleello</td>
<td></td>
</tr>
<tr>
<td>GLACIAL STRATIGRAPHY IN PART OF BUTTERMILK CREEK VALLEY</td>
<td>40</td>
</tr>
<tr>
<td>Geologic sections and test borings</td>
<td>52</td>
</tr>
<tr>
<td>Reports on geohydrology</td>
<td>63</td>
</tr>
</tbody>
</table>
GEOLOGIC SETTING AND GLACIAL OVERVIEW

OF THE UPPER CATTARAUGUS BASIN, SOUTHWESTERN NEW YORK

Parker E. Calkin
Dept. of Geological Sciences
State Univ. of N.Y. at Buffalo
Buffalo, NY 14226

Ernest H. Muller
Dept. of Geology
Syracuse University
Syracuse, NY 13210

The upper Cattaraugus Creek basin lies within the glaciated Southern New York Uplands Section of the Allegheny Plateau, an area characterized by low hills with rounded summits contained within a network of through valleys and breached drainage divides. The underlying bedrock dips southward at about 8 meters per kilometer and consists of interbedded marine shale and siltstone associated with the Upper Devonian Catskill clastic wedge (Tesmer, 1975). Northward, the landscape is furrowed by deep parallel northward trending troughs separated by broad plateau interfluvies. Thick valley fill of the Lake Escarpment Moraine blocks the troughs and comprises the watershed bounding the Cattaraugus drainage basin on the north. Southward from the Cattaraugus basin low hills gradually yield to higher relief and the marks of glaciation become less dominant. A major change in topographic aspect coincides approximately with the Allegheny Valley and marks the northern margin of the unglaciated Salamanca Re-entrun (MacClintock and Apfel, 1944). This high and rugged region, corresponding closely to Allegany State Park, is underlain by sandstone and conglomerate ranging from Upper Devonian to Lower Pennsylvanian (?), and mantled by a thin regolith of frost-shattered, mass-wasted debris. Accordant summits in the Salamanca Re-entrant mark a regional preglacial erosion surface (Cole, 1941). Hypothetical extrapolation of this preglacial surface northward indicates that summit reduction by glacial scour in Cattaraugus County was generally less than 60 m (Muller, 1963). North of Cattaraugus Creek, however, "land forms developed to accommodate glacial flow, virtually eliminating all elements of an earlier fluvially created morphology" (Donahue, 1972, p. 35).

The geomorphic history of the area began with epeirogenic uplift and gentle tilting at the close of Paleozoic sedimentation in the Appalachian geosyncline. Regional erosion has obliterated all evidence of the manner in which initial southward consequent drainage was reversed to a generally northwesterly obsequent system. Broad uplift must have episodically interrupted river cutting, resulting in deep entrenchment of valleys. Among the largest of these valleys in Cattaraugus County was the one cut by the preglacial Cazenovia River (Fairchild, 1932; Calkin et al., 1974) which flowed more than 70 km northward from the present village of Ischua, past Chaffee and East Aurora toward Buffalo. The preglacial Allegheny River
flowed westward along its present course marginal to the Salamanca Re-
entrant, thence northward through the Conewango Valley past present Go-
wanda to Lake Erie approximately following the lower valley of Cattaraugus
Creek (Muller, 1977b; Ellis, 1980). Between the preglacial Cazenovia and
Allegheny rivers, two other major streams had their headwaters in the
upper Cattaraugus basin area. Pre-glacial Buttermilk River, heading near
Ashford, connected West Valley to Springville and followed either the pre-
sent course of West Branch of Cazenovia Creek to Orchard Park or of
Eighteenmile Creek to Hamburg (Hodge, in prep.). The pre-glacial Connoi-
sarauley River flowed from present Plato via Ashford Hollow to Morton
Corners and Eden Valley, following the present South Branch of Eighteenmile
Creek (Fairchild, 1932).

Spreading radially southward from the Ontario and Erie basins, ice of
the continental ice sheet abutted repeatedly against the high land of
the Salamanca Re-entrant. Spotty occurrences of weathered till and gravel
around the margins of the re-entrant have been considered of Illinoian age
(MacClintock and Apfel, 1944; Bryant, 1955; Muller, 1965, 1975, 1977a),
and mark the only pre-Wisconsin glacial exposures in New York. Several
lines of evidence, including two of major importance, indicate a long his-
tory of pre-Wisconsin glaciation. (1) Glacial impoundment of the Allegheny
River and subsequent permanent diversion from its northward course to its
present southerly path to the Ohio River resulted in deep incision across the
Kinzua Col (Muller, 1975; Philbrick, 1976) in northwestern Pennsylvania.
(2) As a result of ice marginal superposition and entrenchment, Cattaraugus
Creek cut a westward course transversely across the Tertiary north-trend-
ing valley system (Fairchild, 1932; Calkin et al., 1974).

Several major drift sheets are recognized in southwestern New York,
reflecting at least two distinct Wisconsin glaciations (Muller, 1963,
1965, 1975, 1977a). As mapped by MacClintock and Apfel (1944), the oldest
Wisconsin drift terminates at the Olean Moraine against the northeastern
flank of the Salamanca Re-entrant. In this area the Olean Moraine marks
the ice border at its Wisconsin maximum. On the basis of stratigraphic,
pedologic, morphologic and lithologic differences, MacClintock and Apfel
(1944) considered it to be distinctively older than the terminal moraine
marginal to the northwest flank of the Re-entrant. Correlation with a
Middle Wisconsin invasion is supported by the interval between events re-
presented in the subsurface in southwestern New York (see below) and tied
to stratigraphic relations in the vicinity of Titusville, Pennsylvania
(Chapman and Craft, 1976; Muller, 1975, 1977a; White et al., 1969). A dif-
ferent correlation is adopted by workers in Pennsylvania who have followed
the Wisconsin glacial border from eastern and northern Pennsylvania to the
Salamanca Re-entrant and consider the border to be of Late Wisconsin age
over the whole distance (Crowl, 1980; see also Dreimanis, 1977a).

Whereas Olean drift is characteristically composed of local materials
and is deeply leached with strongly modified morainal topography, the Kent
Moraine bordering the Salamanca Re-entrant on the northwest displays
sharper relief and brighter, less-weathered deposits. Meltwater channels
incised along the margin of the melting ice sheet effected diversion of
imponded northward-draining valleys. The Kent Moraine, traced northeast from Ohio and western Pennsylvania marks the maximum advance during Late Wisconsin time, an event which is now well bracketed by radiocarbon data. The ice margin had not yet crossed the buried Niagara Gorge in its Late Wisconsin advance at 22,800 yr B.P. (Hobson and Terasmae, 1969); nor had it crossed Rush Creek in the Genesee Basin of south-central New York at 25,500 yr B.P. (Muller et al., 1975); yet by 19,000 to 20,000 years ago, the ice sheet had reached its maximum extent throughout the Erie Basin (Dreimanis and Goldthwait, 1973).

Evidence of extensive glaciation followed by a long, cool interstadial preceding the Olean advance as well as a succeeding shorter interstadial before Kent glaciation is well documented by multiple till exposures and subsurface data at the Gowanda Hospital and Otto, New York, organic sites (Muller, 1964; Calkin et al., 1975, in prep.). At Gowanda, a red till derived from the Erie glacial lobe bears a deeply weathered soil profile and is overlain in turn by gravelly organic silt, a basal till which incorporates some of the silt, and gravels bearing a terrestrial mollusc assemblage indicative of cold forest-tundra conditions. The organic silt carries a Picea-rich pollen spectrum and wood which has been radiocarbon dated from more than 46,000 to a probably finite 51,000 yr B.P. This lower till, soil, organic, and till sequence matches well with the sequence of till, lower organic unit (63,900 yr B.P.), upper organic and gravel unit (more than 52,000 yr B.P.) and overlying till in the well-known Otto site (Muller, 1964). Correlation is based on stratigraphic relations as well as similarity in 14C dates and pollen data (Calkin et al., in prep.). Upper tills of this sequence are in turn correlated with the Olean Drift (Muller, 1975) and tentatively the Middle Wisconsin Cherry-tree Stadial of Ontario. The advance in New York may have begun somewhat earlier than indicated by the 44,000 yr B.P. dates presently recognized as maxima for this stadial in southern Ontario (Dreimanis et al., 1966; Dreimanis, 1977b).

The Otto organic units have in the past been loosely correlated with the Early Wisconsin St. Pierre beds of the St. Lawrence Valley on the basis of similarity of dates. The St. Pierre beds have, however, been redated from 65,000 to 74,000 yr B.P. (Stuiver and Yang, 1977; Stuiver et al., 1978) supporting extension of the Wisconsin chronometric scale as suggested earlier (Dreimanis and Raukas, 1975; Terasmae and Dreimanis, 1976). This extension of the Wisconsin implies backdating of the Middle Wisconsin from 50,000 to at least 70,000 yr B.P. Thus, the soil which represents a long interval of weathering as well as the organic units at both Gowanda Hospital and Otto are assigned to the Middle Wisconsin Port Talbot Interstadial as now presently recognized. Furthermore, underlying tills at each site represent one or more Early Wisconsin advances onto the Allegheny Plateau.

Extending eastward along the south side of the Cattaraugus Valley are correlative of the Lavery Till and the overlying Hiram Till with its associated Defiance Moraine. Correlation is based solely upon eastward tracing and on stratigraphic and lithologic correspondence to units mapped in northwestern Pennsylvania (Muller, 1963; 1975, 1977a, 1977b;
Shepps et al., 1959). Stratigraphic relationships and till constitution seem to record an episode of ice marginal reorganization and short readvance following the Kent maximum. Both the Lavery and Hiram tills are generally thin and the latter, in particular, is rich in clay presumed to have been derived from proglacial lake deposits. These ice-marginal lakes developed in northward-draining troughs during a short retreat tentatively correlated with the Erie Interstadial.

South of Gowanda and extending along the watershed north of Cattaraugus Creek are a series of prominent parallel gravelly ridges, the eastward extension of Leverett's (1902) Lake Escarpment Moraine System. These mark an oscillating stand of the ice margin behind the Defiance Moraine. Referred to as the Ashtabula Moraine in western Pennsylvania and Ohio (Muller, 1963; White et al., 1969), the Lake Escarpment ridges are correlative with the equally massive and similarly complex Valley Heads Morainic System in central New York (Muller, 1965, 1975, 1977a, 1977b).

During Valley Heads Glaciation, pitted outwash trains were built southward into the Cattaraugus Basin over valley fills which are as much as 200 m thick in the northwest trending valleys at Chaffee and Springville. Outwash plains were graded to a series of proglacial lakes that reached out 427 m (1400 ft) in the Cattaraugus Valley east of Springville and in Skinner Hollow near Otto during the Valley Heads maximum. These in turn drained westward along the ice margin into the Conewango Valley and so to the Allegheny River.

Ice marginal retreat from the outermost Lake Escarpment ridges may have begun as early as 15,000 yr B.P., followed by encroaching boreal spruce forest. Peat deposited directly on outwash at a mastodon localitya) along Nichols Brook near Chaffee and therefore considered to shortly postdate an early episode of ice-marginal recession, was dated at 14,900, 13,800 and 12,800 yr B.P. at successively higher levels. Wood of 11,210 yr age (Calkin and Miller, 1977) and 12,020 (Merritt and Muller, 1959) obtained from the middle of this section suggested that the older samples might have been contaminated by recycled carbon. Subsequent pollen correlations with well-dated peat at Winter Gulf near North Collins indicate that the older dates may be correct (Calkin and McAndrews, 1980). This allows correlation of the Lake Escarpment ridges with the Port Bruce Stadial of Ontario and relates the succeeding retreat to the Mackinaw Interstadial of Dreimanis and Karrow (1972).

Ice tongues in the several long valleys trending north from Chaffee, Springville, and Morton Corners gave way to a series of short-lived proglacial lakes. Initially, these lakes drained south across the Valley Heads Moraine into the Cattaraugus Basin. Later they found outlet westward via spillways along the north margin of the plateau, building massive kame delta and lacustrine deposits (Hollands, 1975; Owens et al., 1972; Pryor, 1975) en route to glacial Great Lake Arkona (Calkin and Miller, 1977; Calkin and McAndrews, 1980). The Port Huron readvance of about 13,000 yr B.P. that followed retreat north beyond the Niagara Escarpment (Dreimanis and Goldthwait, 1973) may have reached south to the Hamburg Moraine but did not reach the Gowanda or Norfolk (Erie-Long Point) Moraines in

a)Mastodon or mammoth remains elsewhere in the area (Heubsch, 1959) include a mastodon tooth unearthed in 1971 from a kettle on post-Kent outwash gravels in West Valley (Calkin and Miller, 1977)
the Erie Basin. Retreat from the Hamburg Moraine, followed by lowering of glacial Great Lake Whittlesey had taken place by 12,700 yr B.P. (Calkin and McAndrews, 1980). Recent analysis of the Coleoptera assemblage at Winter Gulf (Schwert and Morgan, 1980; Calkin and McAndrews, 1980) suggests that temperate conditions may have prevailed during glacial oscillations into glacial Great Lake Warren. Final recession of the ice margin into the Ontario Basin, initiation of Early Lake Erie and initial cutting of the present Niagara Gorge must have been under way by at least 12,300 yr B.P. (Calkin and Brett, 1978).

REFERENCES


Figure 2. Wisconsin chronology, eastern Great Lakes, from Dreimanis and Goldthwait, 1973.
Figure 3. Wisconsin chronology, eastern Great Lakes, from Dreimanis and Goldthwait, 1973.
Figure 4. Wisconsin chronology of western New York, from Muller, 1977.
Figure 5. Portion of Glacial Map of North America, GSA, 1945. Scale: about 72 miles to the inch.
Figure 6. Outline of study area, LaFleur (1979)
LATE WISCONSIN STRATIGRAPHY
OF THE
UPPER CATTARUGUS BASIN

Robert G. LaFleur
Department of Geology
Rensselaer Polytechnic Institute
Troy, N.Y. 12181

INTRODUCTION

As part of an investigation of factors controlling subsurface movement of radioisotopes near low-level radioactive-waste burial grounds, the U.S. Geological Survey, in cooperation with the New York State Geological Survey, mapped the surficial geology of the area surrounding the Western New York Nuclear Service Center. A detailed glacial geologic map of the study area, prepared at a scale of 1:24,000, includes the Ashford Hollow and West Valley 7½-minute quadrangles and parts of the Ellicottville, Ashford, Springville, and Sardinia 7½-minute quadrangles (Fig. 6). Several freshly exposed sections within this 165-mi² area were measured and described in detail, and cores from test borings near the low-level burial ground were examined. In addition, a large-scale map of the immediate vicinities of the facilities at the Center was prepared to show distribution of surficial deposits in detail and locations of mass movements. The immediate goal of this work was to define the areal extent, stratigraphic position, lithology, and mode of deposition of the till in which the radioactive-waste burial grounds are located. The results of the investigation, undertaken in 1975-76, are reported in LaFleur (1979). Excerpts from this work that bear on stratigraphic relationships among mapped units are included here.

Our focus for the Friends gathering is on the detailed stratigraphy that was assembled during the intensive study of the Nuclear Service Center environs. Of particular interest is the multiple glacial record exposed along dissected valley floors and the age and character of the Olean drift to the south.

STRATIGRAPHY

Four cycles of glacial advance proposed by Muller (1975) - Olean, Kent, Defiance, and Valley Heads - are evidenced areally and stratigraphically in the Cattaragus basin. Lobate ice advance through north-draining valleys, particularly Connoisarauley and Buttermilk valleys, was progressively less ambitious with time. The stratigraphic record in the valleys includes proglacial lacustrine silt and clay, lodgment till, ice-recessional and free-drainage gravel and sand, and erosional unconformity, generally arranged in that ascending order. On the interfluvies an interrupted record of tills and minor stratified drift suggests that only Olean and Kent ice covered the summits; Defiance (Hiram) and Valley Heads (Lake Escarpment) ice did not. The products of each glaciation have distinguishing textures, lithologies and colors, which permit working syntheses of glacial and deglacial episodes. The upper Cattaragus basin may have been accessible to both the Erie and Ontario lobes during Olean and Kent glaciations; but younger Defiance and Lake Escarpment advances involved invasion by only the Erie lobe.

The regional chronology of Dreimanis and Goldthwait (1973) is summarized in Figures 2 and 3, that of Muller (1977), in Fig. 4.
Olean Glaciation

Olean drift described by MacClintock and Apfel (1944) in Cattaraugus County, generally south of the Cattaraugus divide, was correlated by Muller (1977) with the Titusville (middle Wisconsin) glaciation. Crowl (1980) however traced the Woodfordian drift border through Pennsylvania to join the Olean limit in New York. "Drab" Olean drift contains only a small percentage of exotics, is slightly calcareous, and is deeply oxidized. Throughout the Olean landscape, valley walls are commonly colluviated, and morainal deposits are topographically subdued. Muller (1977) used a 20% exotic stone content (carbonates and crystallines) to separate drab Olean from bright Kent tills and ice-contact deposits and a 30% limit to distinguish outwashes.

Exposures along Snake Run Road 2 miles north of the Kent Moraine show, in descending order: drab upland moraine gravel, interfingered drab and very bright tills, red clay and black gravel, and drab greenish-gray to light olive-gray till and gravel (probably all Woodfordian) over Connoisar-auley and East Otto lobes (Fig. 7), which deposited the upper (Kent) part of the Snake Run section, may have competed for space along the interfluve separating their valleys. Each lobe contributed a till substrate of very different lithologic composition, determined only by the location in the ice of bright and drab components. An areal facies relationship between drab and bright Kent drift is clearly required by the interfingered till sequence in the upper Snake Run section. Perhaps this facies relationship also includes the drab greenish-gray tills that extend 42 feet below the base of the interfingered bright and drab units. Should further study prove this 42-foot-thick sequence to be Olean, which it resembles, the lithologic similarity of these units to others higher in the Snake Run section may suggest an early Woodfordian age for Olean till. The basal 66 feet of the section contains oxidized, noncalcareous yellowish-gray clean gravel and faulted sand overlying oxidized and leached till that contains abundant slabs of local bedrock. These units, different from any in the section above, may date from the mid-Wisconsin or earlier.

In spite of the lithologic similarities between Kent and Olean (?) suggested at Snake Run, the outwash that emanated from the ice at the time of emplacement of the Kent Moraine seems to have been laid down in completely deglaciated valleys (Fig. 7). If the Olean should prove to be early Woodfordian, a yet unidentified early Woodfordian interstadial interval of some duration prior to formation of the Kent Moraine would be indicated. Such an interval may have been important in the colluviation and oxidation of the Olean drift.

Kent Glaciation

Muller (1977) traced moraines and drift borders eastward from northwestern Pennsylvania and projected the Kent Moraine northeastward through the study area along an irregular border sharply controlled by topography. He equated the moraine with the Woodfordian glacial limit. The Kent Moraine forms the Cattaraugus divide in Buttermilk Valley (Figs. 7 & 13).

Some of the till and recessional deposits associated with the Kent glacier contain high percentages (20-40 percent) of exotic rocks derived from the Niagara escarpment and the Canadian shield. This bright drift
FIGURE 7
DRIFT BORDERS AND
ICE MARGINS

ICE MARGIN

MELTWATER CHANNEL

OUTWASH

PROGLacial
LAKES
is calcareous, leached to a depth of 1 to 3 feet, and oxidized to a depth of 8 to 10 feet. Morainal topography developed on Kent deposits is fresh and not noticeably colluviated.

North of the Kent Moraine, Muller (1963) recognized in Chautauqua County the Clymer and Findley Lake moraines. These project eastward and may be represented here by recessional moraine loops just inside the Kent Moraine, but tight crowding of these loops precludes accurate correlation (Fig. 7). Dark-gray tills related to active Clymer or Findley Lake ice may be present in the Kent portion of the Connoisarauley Creek section (Fig. 15).

Kent drift is exposed chiefly in the uplands and along the valley sides where it is generally drab (less than 5 percent exotics), weakly calcareous, and greenish gray (5GY5/1) oxidized to grayish orange (10YR7/4); however, some of the Kent till and gravel is highly calcareous, generally pale red (5R6/4), and has a stone content that is 20 to 40 percent exotic (including red and white sandstones, carbonates, and crystalline Canadian Shield lithologies). In the few places where till assigned to the Kent glaciation is exposed along valley floors beneath the Lavery, it is tougher, less clayey, and darker olive-gray (5Y4/1).

Kent Recession - Erie Interstade

After emplacement of the Kent Moraine, the Erie and Ontario lobes withdrew significantly. Pauses in the recession of the Kent ice margin through a proglacial lake in Buttermilk Creek valley permitted accumulation of a more or less continuous series of kame deltas in which topset pebble gravel and clinoform turbidite sand and silt prograded southward over bottomset rhythmic clays. The southernmost delta sequence is exposed at Riceville Station (Fig. 11), and successors are well exposed in bluffs along Buttermilk Creek (Fig. 10).

As deglaciation proceeded, the glacial lake in Buttermilk Valley drained and exposed the kame deltas and lacustrine floor to subaerial erosion during the succeeding Erie Interstade. The upper part of a section near the former stream gage on Buttermilk Creek (Fig. 9) includes an erosion surface overlain by locally derived gravel beds which in turn are overlain by proglacial lacustrine clay and clayey silt till; these deposits record the advance of the ice after subaerial Erie Interstade erosion. Two earlier glacial-deglacial episodes, the latest of which is of probable Kent age, are also partly recorded in this section. Similar relationships are shown in exposures along Connoisarauley Creek, which drains the next valley to the west (Fig. 15).

Two major exposures suggest the degree of dissection of the Buttermilk-Cattaraugus Valley after the Kent recession. At Felton Bridge, 2,200 feet southwest of the confluence of Buttermilk and Cattaraugus

---

creeks, a narrow, steep-walled channel cut in rock is filled with 30 feet of very bright boulder gravel (50-40 percent exotics) that grades upward to pebbly gravel and underlies Lavery till. The base of the boulder fill is not exposed and lies below the present low-flow level of Cattaraugus Creek. A northwesterly projection of the channel across the modern stream is required to bypass an unbroken shale cliff 130 feet high cut by the post-glacial Cattaraugus.

At a north-bank exposure on the Cattaraugus, 2.2 miles southwest of Sardinia and 7.5 miles upstream from Felton Bridge (Fig. 8), bright ice-contact clinoform gravel beds, dipping westward, are overlain by pro-Lavery deformed rhythmite clay beds that are in turn overlain by Lavery till. The melt-water stream that transported the bright Kent gravel westward from an eastward-receding ice margin followed a profile topographically near that of the present Cattaraugus. Also at this location, deformation sense in the pro-Lavery lacustrine beds indicates dominant southeastward ice flow from the Erie lobe after the Erie Interstade.

Defiance Glaciation
Lavery - Hiram

One of several lobes refilled Eighteenmile Creek valley, which is aligned with Buttermilk Creek valley to the north (Fig. 7), then advanced into Buttermilk Creek valley through impounded lake waters and terminated at or near a valley-plugging moraine at West Valley. A Lavery age is assigned to this advance. In Buttermilk Creek valley, the pro-Lavery glacial lake was controlled by the summit of the Kent moraine at 1,710 feet (Fig. 13). The top of the Lavery till now lies at an altitude of about 1,380 feet at the latitude of the waste-burial site, so the Lavery glacier must have been buoyed up by a hydrostatic head approaching 400 feet as it overrode a saturated, thick, muddy substrate. It emplaced a stony, clayey, silt till with minor interbedded silty clay, which now forms the host formation for the waste-burial ground. The overridden Kent kame deltas experienced only minor alteration from the partly buoyant Lavery ice and retained much of their original sedimentary structure and landform beneath the till.

The Lavery till is concentrated along the valley floor and extends only slightly onto the valley wall. During advance, the glacier sole may have periodically floated free from the substrate and allowed space for rapid accumulation of poorly bedded, pebbly silt and clay. Regrounding of the ice and renewed movement could be responsible for the till deposition as well as its structural deformation. This unit does not appear to be either an overridden, in-place, lacustrine sequence or a flow-till assemblage. Rather, it is a lodgment till complex with minor micro-stratified inclusions that are always torn and deformed.

The thickest Lavery section measured was at the north end of Buttermilk Creek valley, where 130 feet of till is overlain by 6 feet of Defiance (?) outwash gravel. Lavery till averages 80 feet in thickness near the waste-burial site, thins to 16 feet at Riceville Station (Fig. 11), and pinches out near West Valley.

Although the Lavery till has wide areal extent, exposures showing more than a few feet of section are uncommon. Because of its clayey, fine-silty
texture, its thickness of over 100 feet, and its deep postglacial dissection, the till is highly susceptible to slumps and shallow-seated rotational slides. Periodically during mass wasting, sections several feet thick are exposed in slide scars, but are lost by failure within a few weeks. The basal 10 to 15 feet of Lavery till in contact with Kent recessional beds is well exposed along the west wall of Buttermilk Creek and in an east-bank bluff of Connoisarauley Creek 0.6 mile northwest of Connoisarauley Road. Deformed pro-Lavery lacustrine sediments overlying Kent recessional gravel are well exposed in a bluff on Cattaraugus Creek 2.2 miles southwest of Sardinia (Fig. 8).

Lavery till is moderately bright (10 to 15 percent exotics), highly calcareous, and medium olive gray (N5-5Y5/1). In the study area, it is confined to the valley floors. Wherever the Lavery is exposed or clearly shown in test borings, it is an interfingerling complex of three subfacies. The most abundant subfacies, which forms about 70 percent of the formation thickness, is a pebble and cobble till, moderately bright with a clayey silt matrix. Stones constitute 10 to 20 percent of the unit in field exposures although cobbles larger than 2.5 inches could not be recovered in the core barrel during drilling. Textural and mineralogical analyses by Whitney (1977) on three till matrix samples from the waste-burial site show nearly uniform percentages of clay (40 percent), silt (48 percent), and sand (12 percent); silt and clay fractions are dominated by quartz, mica (illite), and chlorite. Textural analyses of two core samples by the U.S. Geological Survey (unpublished) showed 55 percent clay, 25 percent silt, and 20 percent sand and gravel.

The second subfacies is texturally similar to the first, except that stone content is less than 5 percent and the matrix contains thin, torn wisps of light-gray (N8) quartz silt. Rarely, the till includes or grades into layered silt and clay; otherwise, there is no indication of varved or other rhythmic bedding in either of these subfacies. Both subfacies interfinger, and although they have a general stratiform relationship, each is internally deformed. Any particular lens of each subfacies is of small areal extent. Unoxidized matrix color is a consistent medium olive gray (N5-5Y5/1). Oxidation extends to a depth of about 8 feet. Altered matrix colors above this depth are olive gray (5Y6/1) or pale yellowish brown (10YR6/2). The matrix is highly calcareous and leached to a depth of less than 1 foot. X-ray analyses show quartz and illite to constitute well over half the material in each of seven samples of the till (Table 1).

The third subfacies, exposed only in excavations on the burial site at depths of 7 to 12 feet, consists of stratified sand and gravel with included torn masses of till (subfacies 1) and rhythmic clay. Lenticular and discontinuous, this subfacies represents ice-frontal deposits overridden by a late surge of Lavery ice or perhaps by the slightly younger Hiram glacier.

The Lavery commonly contains small inclusions of Kent till and clay, particularly the pale red. For example, a slide scar on the west side of Rock Springs Road 1,500 feet north of the waste-burial site shows Kent red
Table 1.—Mineral composition of selected core samples from Western New York Nuclear Service Center\(^1\)

[All values are in weight percent; locations of test holes are shown in Prudic and Randall, 1977, fig. 1]

<table>
<thead>
<tr>
<th>Minerals</th>
<th>Test-hole identification symbol; depth interval;(^2) and material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
</tr>
<tr>
<td>quartz</td>
<td>24</td>
</tr>
<tr>
<td>potassium feldspar</td>
<td>1</td>
</tr>
<tr>
<td>plagioclase feldspar</td>
<td>7</td>
</tr>
<tr>
<td>calcite</td>
<td>11</td>
</tr>
<tr>
<td>dolomite</td>
<td>5</td>
</tr>
<tr>
<td>chlorite</td>
<td>3</td>
</tr>
<tr>
<td>kaolinite</td>
<td>9</td>
</tr>
<tr>
<td>illite</td>
<td>24</td>
</tr>
<tr>
<td>montmorillonite</td>
<td>0</td>
</tr>
<tr>
<td>mixed-layer clay minerals</td>
<td>4</td>
</tr>
<tr>
<td>Totals</td>
<td>88</td>
</tr>
</tbody>
</table>

\(^1\) Mineral composition determined by B. J. Anderson, U.S. Geological Survey, by X-ray diffraction according to method of Schultz (1964). Totals between 90 and 105 percent are considered normal for this semiquantitative method. Low totals in some samples probably indicate a higher iron content; the fluorescent radiation produced by iron causes loss of peak intensity and therefore generally lower percentages (B. J. Anderson, written commun., 1978).

\(^2\) Depths are in feet below land surface.
clay and greenish-brown silt 50 yards west and uphill from a Lavery till exposure, which contains torn inclusions and stringers of the same Kent lacustrine sediments. Lavery-recessional lacustrine deposits, of local extent only, north of West Valley, also contain Kent red-clay inclusions (Fig. 12).

Soil tests performed for the New York State Geological Survey on Lavery till recovered from an experimental trench show the till to be somewhat overconsolidated. Also, microfabric study of till thin sections shows two sets of conjugate shears, which support the idea that the last mechanical experience of the till was a loading by ice, unbouyed by draining of Buttermilk Creek valley, prior to final ice melt-out (LaFleur, un-pub.). Ponded water dissipated westward, first through outlet channels cut into till and rock on the north-facing Dutch Hill spur. Lacustrine sediments were found between the fluvial gravel blanket and the top of Lavery till at only one locality, along Buttermilk Creek 0.4 mile north of the highway culvert near West Valley (Fig. 12).

Withdrawal of Lavery ice from Buttermilk Creek valley was rapid and accompanied by erosion by upland streams, which deposited as much as 10 feet of channery gravel over small lingering ice masses and on exposed Lavery till in Buttermilk Creek valley. Flow direction indicated by the imbrication of these capping gravels is downstream to the northwest.

As the ice margin receded northward from the Dutch Hill spur to a position coincident with the present south wall of Cattaraugus Valley, a sandy pebble-gravel blanket 15 to 30 feet thick was emplaced directly on Lavery till by melt waters that drained freely to the west. This outwash, kamelike along its north edge, is slightly younger than the fluvial gravel of Buttermilk Creek valley. It was proposed equivalent to the Defiance Moraine (Muller, 1975), which marks the Hiram glacial limit, but may be a recessional feature rather than an end moraine.

Assignment of Lavery age to the burial ground till by LaFleur (1979) was prompted by the following observations: 1) the till extends 6 miles beyond the moraine in the main Cattaraugus Valley correlated by Muller (1975) with the Defiance (Hiram limit), 2) the till is ten times thicker than its predecessors in Buttermilk and Connoisarauley valleys and seems to require an unusually large uptake of lacustrine clay and silt originally foreign to the upper Cattaraugus.

Deposition of Erie Interstade clay and silt locally, rather than in the main Erie basin (suggested by Calkin and Muller, this volume), may be difficult to reconcile with evidence for purging of waters from the Cattaraugus basin during and after the Kent recession. On the other hand, a long transport of lacustrine material by ice out of the Erie basin might be expected to diffuse valley-directed flow paths onto interfluvies more than the observed distribution of Lavery till suggests.

Valley Heads (Lake Escarpment) Glaciation

Extending south through Eighteenmile and Cazenovia valleys, lobate Valley Heads ice barely reached the main Cattaraugus Valley (Figs. 1, 7). Ice-contact topography extends to Springville, at about 1,400 feet, where a 30-foot
thick gravel outwash (about 10% bright components) overlies clayey till. The lower part of the outwash was distributed directly southward, probably into a shallow lake. The upper part shows a westward transport direction in response to open drainage through Zoar Valley. Till beneath the outwash may be Hiram. It is not oxidized appreciably.

From Sardinia, on the east (Fig. 1), outwash spread westward toward Springville, nicely adjusted to falling base levels. Through this reach, locally, right-bank tributaries, draining an ice-free interfluve on the north, contributed channery fan gravel to the Valley Heads system.

REFERENCES CITED


TRIP LOG

Day One

Log begins at intersection of Routes 34 and 219, at western end of village of Springville.

Mile

0.0 Proceed east on Main Street (Rt. 39) through Springville. Road descends from highest Lake Escarpment ice-contact gravel terrace at 1380 feet. Inferior terrace levels inset at 1350 and 1330 feet mark stages in downcutting with more distal distribution of outwash to the southwest through Zoa Valley. Ascend higher terrace, at Chaffee Hospital, on left; leave Springville.

2.5 Intersection Rt. 240. Continue east on Rt. 39 along north valley wall of Cattaraugus Creek.

3.8 Richmond Gulf. Road descends through about 25 feet of Lake Escarpment outwash into clay-silt Lavery till. Shallow-seated, rotational slumps impart a geomorphic signature to Lavery till throughout the Cattaraugus basin.

8.0 STOP 1. Lord Hill. Section along Cattaraugus Creek exposes deformed, overridden pro-Lavery clay rhythmites overlying bright Kent-recessional gravel and clay. See Figure 8. Ferruginous gravel and peat form first terrace, accessible at low-water level. Turn around and proceed west on Rt. 39. Re-enter Springville.


15.0 Turn south on Rt. 240. Road descends through Lake Escarpment outwash and partial section of Lavery till onto 1340-foot high terrace of Cattaraugus Creek that correlates with late Lake Escarpment outwash to the east.

15.9 Elk Street intersection. PICTURE STOP. View to west of slumped Lavery till outcropping beneath 1260-foot fluvial terrace. To south, across Cattaraugus Creek, Lavery till is exposed on proximal side of ice-contact, fine-gravel outwash, previously correlated with the Defiance Moraine.

16.1 Bigelow Bridge. Cross Cattaraugus Creek.

16.7 Turn west on Bond Road.

17.2 OPTIONAL STOP. Pit in 1360-foot gravel outwash, somewhat kamic on north side; about 30 feet thick. Proceed west and south to

17.9 Thomas Corners Road. PICTURE STOP. From 1360 feet, gravel surface slopes gently southwest. Proceed west on Thomas Corners Road.
Descend outwash onto 1300-foot terrace, then descend steeply through Lavery till.

18.9 Buttermilk Creek. 8-ton bridge. DISEMBARK. Walk across bridge. Exposures of slumped Lavery till along road.

19.2 Dutch Hill Road. Turn north.

19.4 Felton Bridge, Re-cross Cattaraugus Creek. 

LUNCH
Proceed south on Dutch Hill Road.

19.9 6-ton bridge over railroad. DISEMBARK. Road ascends proximal side of outwash onto 1360-foot summit, same surface as seen at PICTURE STOP.

20.4 Schwartz Road. Turn west. Gullied Lavery till to south of road.


21.7 Route 219. Turn south.

22.0 Enter Connoisarauley Creek drainage basin.

23.3 Turn east. Road follows lowest (at 1460') of three outlet channels that cut across Dutch Hill spur and connected ice-choked Buttermilk and Connoisarauley valleys during Lavery (and older?) deglacial episodes.

24.1 Turn southeast on Cross Road.

24.6 Road crosses middle, 1590-foot channel.

24.7 Dutch Hill Road. Turn north. Highest, 1640-foot channel approaches from east, at road intersection.

24.8 1590-foot channel, here ice defended on north side.

25.2 Cross lowest, 1460-foot channel. Drainage flow sense appears to be east to west. Significance of channels in Lavery ice recession from Buttermilk Valley will be discussed at next stop.

25.9 Schwartz Road. Turn east.
26.2 (Access dirt road to Buttermilk Creek section. See Fig. 9. Permission from Nuclear Fuel Services is necessary to examine)

New road enters Buttermilk Valley along west wall. Lavery till, about 100 feet thick, floors valley to east.

27.2 Along road to the west are outcrops of red clay and reddish-brown cobble gravel. The red beds, probably derived from Kent-recessional deposits, interfinger with Lavery olive-gray till 50 yards to the east.

27.8 STOP 5. Western New York Nuclear Service Center. Fuel reprocessing plant and radioactive-waste burial ground, previously operated by Nuclear Fuel Services, Inc., is now shut down. Immediately east of burial ground is the Buttermilk Creek slide section, described in Fig. 10. A.D. Randall and D.E. Prudic will discuss stratigraphic and hydrologic investigations in Buttermilk Valley as they relate to the burial ground.

Proceed to Fox Valley Road on new road.

29.7 Turn northeast.

30.1 Cross Buttermilk Creek. Park at Town of Ashford Garage.

STOP 6. Riceville Station section. See Fig. 11. Section exposes clinoform turbidites, sand, and bright gravel, probably Kent recessional, overlain by pro-Lavery clay, Lavery till, and east of the Highway Garage, by Lavery-recessional gravel. Proceed southwest on Fox Valley Road to intersection.

30.4 Turn southeast.

31.8 PICTURE STOP. Culvert under West Valley Rd. Section along creek 2,000 feet downstream shows Lavery-recessional lake clay and ice-contact gravel absent in Buttermilk Creek valley farther north. See Fig. 12.

32.0 Route 240. Turn south. Enter hamlet of West Valley.

32.8 Leave West Valley. Southernmost exposure of Lavery till in creek west of road.

33.8 Rosick Hill Road. Turn east. St. Johns Cemetery.

34.1 STOP 6. Gravel moraine at 1700 feet plugs Buttermilk Valley one mile south of Lavery till limit. See Fig. 13. Pit 1/4 mile north on proximal side exposes about 20 feet of lobate pebble gravel and sand, about 10% bright, with deformed masses of blue-gray coarse silt (Kent?). This moraine may represent a Kent recessional stand, perhaps Clymer, or a Lavery terminus.
34.3 Turn around at railroad crossing. Tracks occupy small outlet channel at 1690 feet, which drained Lavery melt water south through dissected Kent Moraine.

34.9 Return to Rt. 240. Turn south.

35.9 Canada Hill Road. Turn east.

36.2 STOP 7. Gravel pit in Kent Moraine. Boulder lithologies are like those of Pelton Bridge channel filling (STOP 3). Swamp to south is southward continuation of Lavery drainage through breached Kent Moraine. Refer to Fig. 13. Return to Route 240.

36.6 Turn south.

37.3 Beaver Meadows Road. Turn west.

37.7 Colluviated slope and thin Olean till to south of Beaver Meadows Creek. Road continues west through dissected Olean gravel moraine, following outlet channel complex that drained Kent glacier.

40.1 Route 219. Turn north into Connoisarauley basin.

50.9 Intersection of Route 39, Springville. End trip log for day one.
Day Two

0.0 Log begins at intersection of Routes 39 and 219, Springville. Proceed south on 219 toward Ashford Hollow.

7.2 Snake Run Road. Turn west. Road ascends through Kent ground moraine, including red, calcareous till and clay, exposed in scattered outcrops south of road.

9.2 STOP 1. Snake Run Road section. See Figure 14. Roadcuts expose interbedded bright and drab tills and stratified units over drab till and gravel. Comparison will be made between these units and till exposures that lie beyond the Kent limit.

Proceed south on Snake Run Rd.

9.8 East Flats Road. Turn east, then south.

10.3 Intersection Meyer Hill Road. Turn east, then southeast.

10.9 Bailey Hill Road. Turn south. Climb, then descend Bailey Hill, onto Kent recessional moraine.

12.3 STOP 2. Till exposure along west side of road. Position is such that Kent ice might have barely covered this locality. Compare with the tills of Snake Run.


13.6 Plato Road, turn east.

15.3 Rainbow Lake. Kent Moraine.

15.8 Mason Hill Road. Bear east. Timber Lake on south.

16.5 Rohr Hill Road. Bear right. Kent end moraine immediately to north.

16.8 Plato. Continue across 1900-foot outlet channel that drained east. Continue southeast on Jackman Hill Road.

17.8 STOP 3. Till exposure on west side of road. This position is 1.5 miles beyond the Kent limit. Compare with tills at Snake Run and last stop.

18.4 Turn around at Route 219.

Proceed north on Jackman Hill Road.

19.3 Through Plato.

19.7 North on Rohr Hill Road.

19.8 STOP 4. Pit east of road. Kent end moraine. See Fig. 15.

Continue north on Rohr Hill Road,
20.9 Kent Moraine

21.4 1900-foot outlet channel to west, connecting two Kent-recessional moraine segments

22.0 LUNCH. Sculpture Park.

22.6 Ahrens Rd. Proceed north.


26.1 Connoisarauley Road. Turn west.

26.6 Walk about 1000 feet north on dirt road.

STOP 5. Radiocarbon-dated, wood-bearing alluvial terrace forms east bank of Connoisarauley Creek. See Fig. 16.

(Fig. 17 shows the section 2000 feet farther downstream on the west side, well exposed in 1975-76 but now totally lost to large mass movements. This section shows the most complete Kent-Lavery succession in the upper Cattaraugus. Those able to visit this locality on occasion might check its future accessibility.)

27.1 Return to Rt. 219. Turn north.

31.8 Routes 39 and 219, Springville. End of log.
FIGURE 10

SLIDE SECTION
West bank Buttermilk Creek within
Western New York Nuclear Service Center
Section strikes N60°E, beds dip 2-10° SW
Ashford Hollow Quad.

TILL, hard, N4-5Y4/1, about 5 percent pebbles up to ½ inch diameter; about 80 feet thick.

GRAVEL, rounded pebbles and a few cobbles up to 4-inch diameter in a clean sand matrix, 10YR 6/4, about 20 percent bright lithologies; cemented sand layer 1 inch thick at contact with till; dip is 20° southwest, imbricate channels dip north.

SAND, fine, and SILT, laminated, minor ripples.

PEBBLES and GRANULES, calcareous, 20 percent bright lithologies; imbricate pebbles dip north.

CLAY 5YR 6/4, borders oxidized to 5Y 7/2, calcareous, 3½ inch thick.

SAND, fine, and coarse SILT, 5Y 7/2 with rare stains of 10YR 6/4 on bedding surfaces; microlaminations; also some ripples with axes slightly west of north.

CLAY 5Y 8/1 and graded SAND, in cycles 10 to 12 inches thick.

GRANULES with manganese coatings; iron coating 10YR 6/4 on basal contact.

SILT and fine SAND, 5Y 7/2 and 10YR 7/4; 10YR 6/4 stains along bedding surfaces; rare clay pebbles 5Y 7/2; calcareous, rippled and laminated beds ½-3 inches thick.

TILL, bright pebbles in a silt matrix, N5-5YR 5/1, top & inches oxidized to 5Y 6/4, calcareous; contains blebs of rose-colored clay.

CLAY and SILT rhythmites, no pebbles, 5Y 6/2 in top 5 ft, N5 below; clay is greenish 5G 6/1 under till at north end of exposure, oxidized to 5G 6/1; calcareous; beds ½ to ½ inch thick.

CLAY, rose 5YR 6/1 interbedded with gray N5, with blebs of stiff red clay 10R 6/2; beds ¼ to ½ inch thick.

CLAY, fat and solid, N5-5Y 6/1 with minor interbeds of 5YR 6/1, beds somewhat contorted by flow.

SCALE
10 FEET
Riceville Station Section
East bank Buttermilk Creek
near railroad crossing on Fox Rd.
Ashford Hollow Quadrant

FIGURE 11

Gravel

Till

CLAY, no stones, fat, NS-5Y 5/1; joints at N 62°E and N 28°W, manganese stain on joint surfaces

SILT 5Y 7/2, and fine SAND 10YR 7/6, some coarse sand; massive graded beds deformed by slumping.

GRANITIC, pebbles up to 2 inches diameter; bright, derived from ice, well-bedded, minor ferruginous coatings.

SAND 10YR 6/2, coarse, and SILT 10YR 7/4; minor pebbly sand and clay in 3-inch graded beds; rippled in upper part of cycles.

CLAY NS-5Y 5/1, oxidized to 5Y 5/1 in upper 1 inch

SILT, as Slow inter-beds 10Y 5/2, 5Y 7/2

CLAY NS-5Y 5/1

SILT 10Y 5/2, inter-beded with CLAY NS-5Y 5/1; graded beds, deformed by slumping.

Creek, ~ 1320'
FIGURE 12

BUTTERMILK CREEK SECTION
2000' north of culvert under
West Valley Rd. West Valley Quad.

HUMMOCKY
Peb. & Cob.
GRAVEL

FEET
10
0

terrace

tan silt & peb
GR., mottled,
grey@ base

Clear CLAY & SILT, N5 & 5Y 5/1 with
N8 Silt iness-beds

LAVERY
RECESS

~ 10 orange fine SAND & 5Y 5/6 SILT rhythmites
dirty peb GRAVEL, cemented, ferrug.
CLAY & SILT VARVES, N4 & 5Y 5/1 with N8 Silt
& rose clay beds, blebs, & red shale pebs.

contact covered ~ ~ ~

LAVERY
CREEK

~ 1392'

TILL, clayey, 5Y 5/1, < 5% pebbles

~ ~
Figure 13. Portion of West Valley and Ashford quadrangles showing valley-plugging moraines.
FIGURE 14

SNAKE RUN ROAD SECTION
Roadcut section along east side of Snake Run Road,
1.8 miles southwest of Ashford Hollow
Ashford Hollow Quad.

Undulating gravel moraine surface

GRAVEL, pebbles, cobbles, and a few boulders up to
12 inches, chennery, about 5 percent bright lithologies;
silty at base; top 5 feet oxidized to IOYR 6/6.

CLAY, IOYR 6/2, top 1 foot oxidized to IOYR 7/4
SILT 5Y7/2 and CLAY 5G8/1, IOYR 6/2; with layers of fine
sand and 2-in. pebbles (flowtill), turbidites, and graded
beds 3 in. thick.

TILL, basal 4 ft. is drab, 5Gy-5Y6/1, slightly calcareous, silty,
pebbly but less than 5 percent exotic lithologies, with deformed
clay and turbidite layers in lowest 4 in.; upper 5 ft is very
bright, 5R5/2, very calcareous, about 70 percent stones of
which half are exotic lithologies including many boulders,
but contains rinds of drab slightly calcareous unleached till.

SILT, fine SAND, and CLAY, graded beds, IOYR 7/2, 5GY6/1, very
calcareous, deformed by ice override toward west.

GRAVEL, pebble sizes; 5 percent exotic lithologies with much
olive siltstone, slightly calcareous, imbrication indicates slow to west.

TILL, clayey, slightly calcareous, drab, 5Gy-5Y6/1, top 6 in. oxidized
to IOYR 7/4; contains torn clay fragments 5YR6/1.

CLAY and SILT rhythmites, 5GY6/1-8/1 noncalcareous, interbedded
with 5YR6/1 calcareous; oxidized Top 6 in IOYR 7/4, basal 4 in.
10YR 6/6; lateral facies change to red and green material overlying
red bright till, then silt and sand 5Y8/4 over red till over red clay, silt
GRAVEL, subrounded, drab, block manganese coatings, fine sand
matrix 5Y6/2, slightly calcareous;

TILL, 46 percent drab; 40 percent pebbles of which 5 percent are
exotic lithologies; very slightly calcareous, 5GY6/1, top 16 in.
oxidized to 5GY6/2; contains silt streaks 10R5/4.

SAND, fine, and SILT, mass bedded, very slightly calcareous, 5Y6/2
with 5R6/2 layer at base; is graded turbidite beds.

TILL, about 60 percent pebbles with a few slabbly
boulders up to 12 in. drab, less than 5 percent of
stones are exotic lithologies, very slightly calcareous,
5GY6/1, top 14 inches oxidized to IOYR 7/4.

GRAVEL, pebble and cobble sizes; subrounded to
angular; less than 2 percent exotic lithologies, with
dirty sharp sand; drab, 5Y6/1; weak imbrication
suggests slow to south (Colluvium? Washed till?)

continued
SNAPKE RUN ROAD SECTION (contd.)

TILL, 20 percent pebbles to boulders of which less than 2 percent are exotic lithologies, matrix of silt and gritty sharp sand, noncalcareous, 5Y-5GY 6/1, hard, dense; poorly exposed.

--- Contact covered ---

GRAVEL, pebbles in basal 10 feet grading upward to rounded cobbles, less than 2 percent exotic lithologies, noncalcareous, open, clean, 5Y7/2

SAND, fine, and SILT, graded beds, a few 1/4-inch clay beds, mass bedded, faulted, noncalcareous, 5Y6/2, dip 20° E.

TILL, fine silty matrix, about 40 percent pebbles and cobbles, about 2 percent of stones are exotic (crystalline, white and red quartzite, gray fossiliferous limestone); noncalcareous, oxidized 5Y7/2 except 5B7/1 near blue-gray siltstone cobbles; slabby boulders up to 3 feet diameter near top; 3 feet of washed till in lower part, within which imbrication indicates flow to west.

Base of exposure, altitude about 1600 feet.
FIGURE 15
TIMBER LAKE SECTION

X on road north of lake,
Ellicottville Quad.

Chamney: drab
colluvium (?), slabby
& subrounded boulders
40-2' diam.

KENT

SAND
20-30%
foresets  bright

END

pebble
pebble
GRAVEL
GRAVEL

MOR.

SILT & pebble SILT
5Y 7/2
**CONNOISARAULEY CREEK**

DATED WOOD-BEARING ALLUVIAL TERRACE

east bank, 1000 feet north of Connoisarauley Rd.
Ashford Hollow Quad.

**FIGURE 16**

North-dipping terrace

Interbedded lenticular pebble GRAVEL & pebble SAND, all abundantly wood-bearing; irregular ferruginous coating throughout, non- limy

Generally finer grained than beds below log, color is the same

Interbedded sandy SILT & pebble GRAVEL, 4"-8" beds, all wood-bearing
N 4 & 10 YR 6/2

Blue-green & gray GRAVEL

Channery, pebble GRAVEL with round exotic stones, non-limy, ferruginous coating
5 YR 5/6 & 10 YR 6/6

*6" x 12' log*

Silty CLAY, with thin ½" pebble SILT beds, poorly bedded, slightly limy, inorganic

5Y 6/1 with red silt clasts, 5R 6/2

---

*4725 ± 170*

*2200 ± 145*

*1335 ± 130*
CONNOISARAULEY CREEK SECTION
West bank, 3000 feet west-northwest
of Connoisarauley Road bridge
Ashford Hollow Quad.

FIGURE 17

TILL, oxidized 10YR5/2,
leached about 1 foot
pebble gravel 1 inch thick
near base.

TILL, clayey and silty, 5Y5/1, 43 feet thick;
5 to 10 percent pebbles and some cobbles,
except less stones in basal 5 feet, fairly bright;
silt mess beds; joints N7°E, N80°W with
10YR6/4 oxidation rims on either side, joints
die out 1 foot above base.

SCALE

10 FEET

CLAYEY SILT 5Y5/1 and SILT 5Y7/1, about 60 varves
SILT to fine SAND 5Y7/1, interbedded with clayey silt;
beds 1/4 to 1/2 inch thick, except silt 5Y5/1 1-inch thick
1 ft below top.

SAND, medium, laminated and rippled, top and base
oxidized to 10YR6/6.

TILL, pebbly, 5Y5/1 mottled with 10YR5/2, hard and dense.

TILL, pebbles in silt to sandy matrix, hard, N6°
strings of coarse silt N7°, 1/16 inch thick

SILT, fine, 5Y5/1
SAND, coarse, and pebble GRAVEL, loose, unoxidized,
uncemented, dark olive-gray 5Y5/1

TILL, clayey, pebbly, dark olive-gray 5Y5/1, hard,
dense; curved joints.

CLAY, like that below except mess bedded.
CLAY, silty, gray N4° and SILT, coarse, greenish 5Y8/1,
about 75 varves.

CLAY, massive, gray N4°; some SILT 10YR6/2 in planar beds
1/64 inch thick, microlaminations, and mess bedding.

TILL, gray N4°, gritty, pebbles to 1/2 in.; blebs of rose to brick red.

CLAY, gray N4°
SAND and coarse SILT, 5Y8/4, beds 1/4 to 1 inch

TILL, N4°, pebbles and cobbles; with blebs, and rims on
limestone cobbles; of brick red.

SILT, coarse 10YR7/4; SAND, medium, yellow; and SILT,
5Y8/1; very thin beds, some deformed by loading; some
ice-rafted cobbles.

SILT, 5Y8/1, in beds 1 to 4 inches thick
SAND and coarse SILT, yellow-brown.

GRAVEL, pebble sizes, rounded, and SAND, coarse; loose,
uncemented, level-bedded, brown-gray, ferruginous bands.

CLAY, N5° laminated, with moss beds of SILT N8

TILL, clayey matrix, 25 percent pebbles and cobbles up to
6 in., some striated, many fresh gray-green shale, slightly
calcitic; contains torn masses of 10YR5/2 clayey till or
very fine silt, and stringers of silt 5YR6/1 and N8.
GEOLOGIC STUDY OF THE BURIAL MEDIUM AT THE LOW-LEVEL
RADIOACTIVE-WASTE BURIAL SITE, WEST VALLEY, NEW YORK

R.H. Fakundiny, R.H. Fickies, H.H. Bailey
R.H. Dana, Jr., and S.A. Molello

The West Valley low-level radioactive-waste burial site is located in Cattaraugus County, approximately 50 km (30 miles) south of Buffalo, New York. Average elevation is 450 m (1400 feet) above sea level and 260 m (800 feet) above Lake Erie.

The burial site is an area of 4.5 hectares (11 acres) within the 1 km² (225 acres) fenced security area of the Western New York Nuclear Service Center. This security area also encompasses a nuclear fuel reprocessing plant with 4 interim high-level waste storage tanks and a second burial area for spent fuel hardware (hulls and ends) and other waste from the reprocessing operations.

Because so many new geological features, such as sand lenses, newly formed erosion scars, and landslides had been discovered in the area since the original site investigations, it was decided jointly by the NYSGS and the USGS that new geologic mapping of the site and the region around the site was required to determine the geological framework for groundwater movement in the burial area. This work was performed by Robert G. LaFleur. Further work by Allan Randall and David Prudic of the USGS and by Jeffrey Pferd and Wendy Goldschmidt of the NYSGS has refined the work of LaFleur at the site and is reported below. Jon Boothroyd and Barry Timson have been continuing the study by evaluating the geomorphic processes acting in the Buttermilk Creek drainage basin.

The trenches, which contain the low-level radioactive waste, at West Valley, New York, are emplaced in surficial glacial deposits (Lavery, Late Wisconsinan) consisting of a clayey silt till approximately 30 m thick. These deposits overlie lacustrine deposits and till (Kent, Late Wisconsinan) which in turn are inferred to overlie tills and lacustrine deposits (Olean, Late (?) Wisconsinan) which are not exposed in the area of the site. The burial till contains discontinuous, randomly distributed, distorted, silt, sand and gravel pods and lenses. Because of the discontinuous lateral and vertical distribution of these features within the enclosing very low-permeability clayey silt, they do not appear to form preferential permeability systems for ground-water movement.

The burial till has a very low permeability with vertical permeabilities ranging from 1.25 x 10⁻⁸ cm/sec to 4.33 x 10⁻⁸ cm/sec and horizontal permeabilities of 3.72 x 10⁻⁷ and 7.46 x 10⁻⁷ cm/sec. Landslide and slope failures exist in the general area and small-scale slope movements occur in man-made ground on the margins of the site.

¹New York State Geological Survey, Cultural Education Center, Albany, N.Y. 12230
GLACIAL STRATIGRAPHY IN PART OF BUTTERMILK CREEK VALLEY

BY

ALLAN D. RANDALL

U.S. GEOLOGICAL SURVEY, ALBANY, N.Y.

The U.S. Geological Survey is investigating the sources and movement of ground water near several low-level radioactive-waste burial grounds across the nation, including one at West Valley in the town of Ashford, Cattaraugus County, New York. The objective of this study is to develop geohyrdologic guidelines for the siting of radioactive-waste burial grounds. Part of the work at West Valley has been done in cooperation with the New York Geological Survey, the lead agency responsible for a separate, comprehensive evaluation of this particular burial ground. A list of reports released to date on various aspects of hydrology and geology near the West Valley site is included in this guidebook.

Glacial stratigraphy in and around the town of Ashford has been described by La Fleur (1979), largely on the basis of a few well-exposed but widely separated geologic sections. Because of the need to define ground-water flow paths and rates near the burial ground more closely than is usual in water-resources investigations, it was important to determine rather precisely the stratigraphy and geometry of the glacial drift nearby. Therefore, numerous closely spaced sections were measured in the bluffs along Buttermilk Creek and its tributaries from Riceville Station to the mouth of Franks Creek (Fig. 1), and were compared to the logs of test holes drilled nearby. The first interpretation of these results is included in plates 7-8 of La Fleur (1979); some revision and additional detail are presented in this paper. Further refinement is expected in the final report on the U.S. Geological Survey study.

The steep walls of the inner valley of Buttermilk Creek provide abundant evidence of mass movements -- tilted trees, rotated reverse-sloping slide blocks, and amorphous mudslides that encroach upon stream channels. At first, it was expected that shallow excavations on these slopes might be a useless and potentially misleading venture in repeated reexamination of the same material on its way from the top to the bottom of the slope. In many localities, however, a valid geologic section can be pieced together from a stepwise succession of auger holes 5 to 20 feet deep, perhaps interspersed with shovel excavations on small, steeper scarps or recent slide scars. Nearly everywhere, the uppermost 1 to 3 feet consists of colluvium, which is easily recognized by its soft texture, high water content, and embedded leaves. Evidence that the underlying materials were in place was provided by similar sequence and altitude of units in nearby sections, in some sections by similar results from overlapping auger holes started at different altitudes, and by lack of obvious colluvial or mixed materials except for the uppermost 1 to 3 feet.

Lithostratigraphic units identified within the glacial drift of Buttermilk Creek valley from Riceville Station to the mouth of Franks Creek are described in Table 1. Their inferred geometry is illustrated in three cross sections (Figs. 2-4). The location of the cross section
lines, and of the geologic sections, test borings, and wells on which
the table and cross sections are based, are shown in Figure 1. The descrip-
tions that follow are based in part on those of La Fleur (1979) and in
part on independent observations. Several of the individual geologic sec-
tions and well logs prepared during the current study are included at the
end of this paper. Geologic names in this paper are those of La Fleur (1979).

The striking difference in lithology between the drift above and below
unit 7 is a difference of degree more than of kind. Essentially, units
5 and 6 together (Lavery drift of La Fleur, 1979) consist predominantly of
silt-clay till with subordinate, commonly displaced small fragments of
lacustrine deposits. By contrast, units 8-11 (Kent drift of La Fleur,
1979) consist predominantly of in-place lacustrine clay, silt, and locally
fine sand, with subordinate till and other evidence of the periodic brief
presence of floating or readvancing ice. For example, large folds were observed
at sections 1J and 1C; zones replete with pebbles, sandy silt blebs and
till chunks were recognized in many test holes and geologic sections. Each
ice advance into north-draining Buttermilk Creek valley presumably created
a similar potential for ponding; why the difference in response? Did re-
duced water depth due to accumulation of drift reduce buoyancy of the ice?
It probably did, but not abruptly. The deeper northern part of unit 5 is
lower in altitude than much of units 8-10 (Fig. 3). Did erosion progres-
sively lower the spillway(s) into Allegheny basin south of West Valley?
Mapping by La Fleur (1979) shows no evidence of appreciable spillway erosion
during or after deposition of these units. Could a change in regional ice-
front alignment have permitted frequent westward drainage through a spill-
way on the north flank of Dutch Hill (Fig. 1) during deposition of unit 5,
thereby lowering lake levels below 1,500 feet and grounding the ice much
of the time, whereas during deposition of units 8-11 the lake remained gen-
erally at the 1,700-foot level and was not completely drained even when
the ice retreated briefly?

The widespread presence of gravel (unit 7) between the near-surface
till and the predominantly lacustrine sequence beneath supports La Fleur's
(1979) interpretation of a significant interruption in glaciation, which
he referred to the Erie Interstade. The gravel is probably absent below
the burial ground (Fig. 2) owing to glacial erosion although a layer only
a foot or so thick might have been missed in some test holes. La Fleur in-
terpreted the gravel in Sections A, F, and 1E (Fig. 3) as kame-delta top-
sets and predicted (1979, p. 13) the presence elsewhere at this horizon
of channel gravels deposited by subaerial drainage during the Erie Inter-
stade. The widespread thin gravel (unit 7) of consistent elevation inferred in
Figure 3 suggests a fluvial blanket comparable to unit 4 but thinner,
rather than alluvium along distinct incised channels. The fine sand and
silt (unit 8) underlying the gravel near section A is probably deltaic;
the northward coarsening inferred in Figure 3 suggests a kame delta depos-
it by meltwater at the ice front. On the other hand, the low altitude
and the northward and westward flow sense in the sand and silt at section
A suggest sediment derived from local streams deposited in a persistent
late-glacial lake.

The correlations in Figures 2-4 are based on simple principles analogous
to walking out a contact -- one obtains sections close enough together that the contact between any two units of interest is at nearly the same altitude in successive sections and thus it can be drawn between them with confidence. No unique mineralogical or textural properties of particular units have been identified; thus, it is possible that some miscorrelations have been made. For example, the sequence of till/thin proglacial lacustrine gravels, fine sand/silt and clay in sections 1B and 1C (north of Riceville Station) is quite similar to that of units 5 to 9 in sections F, B, and A farther north. Therefore, correlation of these units with section 1B was considered, which would require that unit 5 (Lavery till of La Fleur, 1979) be split into two tongues in this locality. This choice was rejected only because of the apparent continuity of other gravel and lacustrine beds above section 1B. Extension of some sections and interpolation of additional sections is planned and should eliminate most questions, but in the absence of unique marker beds some uncertainty may remain.

Figure 4, based entirely on test holes and sections drilled and described by others prior to the current study, illustrates some problems in correlation of the deeper deposits. Units 4, 5, and 7 can be recognized all across the valley at about the same altitudes found elsewhere. At greater depth, however, test-hole logs seem mutually inconsistent. Samples from DH-6, DH-9, and DH-14 were examined in 1962 by geologist H.G. Stewart (writ. comm., 1962). DH-9, sampled only at 20-ft intervals, apparently penetrated a thick section of lacustrine sediment below unit 7; no till equivalent in altitude to unit 10 was recognized. At DH-6, by contrast, till or possible till was reported in much of the interval occupied by the lacustrine deposits of unit 9 in nearby sections and holes. La Fleur (1979, plate 8) correlated the deeper deposits penetrated by DH-6 with a succession of Wisconsinan ice advances, presumably reasoning that each gravel layer could represent an interglacial interval of subaerial drainage. This correlation implies that post-Illinoian ice advances caused little erosion in Buttermilk Creek valley and made no contribution to scouring the bedrock valley, the shape of which is inferred in Figure 5. A different interpretation, sketched in Figure 4, implies either that a) stratified silt and clay with ice-rafted pebbles and grit found in cores from DH-6 was misinterpreted as till, or b) readvancing ice tongues were grounded near DH-6 and deposited till, but at the same time they were afloat elsewhere and produced disturbed pebbly zones in unit 9. Conceivably the ice could have been grounded near DH-6 but not elsewhere if remnants of older drift were present on the valley floor only in this locality. In either case, this correlation implies an active ice margin locally at the time of unit 9 (Kent drift of La Fleur, 1979).

REFERENCES CITED


EXPLANATION

C Line of cross section
B2 Well or test hole, with identifying number or name
IE Measured geologic section, with identifying letter or number
Spillway (LaFleur, 1979)

Base from U.S. Geological Survey
Ashford Hollow 7½ min quad.

Figure 1. Cross section lines of figures 2-4, Buttermilk Creek Valley

SCALE 1:24,000

1 1 MILE
1000 2000 3000 4000 5000 6000 7000 FEET
1 1 KILOMETER

CONTOUR INTERVAL 20 FEET
EXPLANATION, Figures 2-4

Site identification (written vertically, above land surface)

A, B, C, 1A, 1B, etc. Measured geologic section (F by H.G. Stewart, IE by R. La Fleur, remainder by A.D. Randall and/or D.E. Prudic: all written comm.)

Well J, Well V, etc. Test hole drilled for the current study

DH6, DH14, etc. Engineering test boring drilled in 1962 as part of site evaluation; drive-spoon samples examined by geologist

B1, B7 etc. Engineering test boring drilled for engineering design of proposed structures; log by Empire Soils Investigations

Other names: Wells or test wells drilled for private owners.

Materials identification (written horizontally beside each well or section)

T till, silty clay matrix
T till, stony silty clay
G gravel
S fine to coarse sand
F fine to very fine sand
L silt
Y clay
P pebbly
* Zone with abundant pebbles and/or sandy silt or till blebs and/or distorted bedding

Macro-scale folding (1 ft amplitude)

Top of bedrock

Correlation

1 2 etc. Lithostratigraphic units, described in table.
<table>
<thead>
<tr>
<th>Unit Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(youngest)</td>
<td>Table 1. Lithostratigraphic units shown on Figures 2-4.</td>
</tr>
<tr>
<td>(1) (2) (3)</td>
<td>Postglacial colluvium, alluvium, terrace alluvium (not shown in some cross sections).</td>
</tr>
<tr>
<td>(4)</td>
<td>Gravel and sand, deposited by local streams draining northward in low areas, perhaps around lingering ice, on a freshly exposed till plain.</td>
</tr>
<tr>
<td>(5) 16 ft (Riceville Station) to 130 ft (mouth of Franks Creek)</td>
<td>Till; silty clay matrix with about 25 percent sand and stones; grades or interfingers randomly into similar till containing torn, deformed wisps and blebs of light-gray silt; incorporates randomly oriented pods or masses of stratified sand, gravel, silt, and rhythmic clay-silt which have lateral dimensions of a few meters or less and seem to be more abundant in the interval from 1,350 to 1,370 feet altitude.</td>
</tr>
<tr>
<td>(6) 0-8 ft</td>
<td>Clay or clay-silt rhythmites: commonly grades up into layered clay with scattered pebbles, then into the overlying till; proglacial. Widespread but commonly less than 2 ft thick and easily overlooked. Bottom 1-2 cm commonly lime cemented.</td>
</tr>
<tr>
<td>(7) 0-15 ft</td>
<td>Gravel: pebbles and small cobbles in fine to coarse sand, clean to moderately silty; where thick, may contain interbedded sand or clay layers or grade down into pebbly sand. Recognized in all sections and test holes near Buttermilk Creek and in some to the west (including E7, DM6, and well V on fig. 1).</td>
</tr>
<tr>
<td>(8) 0-28 ft</td>
<td>Sand, chiefly fine to very fine, interbedded with silt that becomes predominant with depth; grades into underlying unit. Thickest east and west of the burial ground; may be gradationally present at top of the lacustrine section further south.</td>
</tr>
<tr>
<td>(9) 20-50 ft</td>
<td>Interbedded coarse silt, fine silt, and clay, generally in rhythmic partings and layers up to several millimeters thick; some thick fine silt layers, but close inspection commonly reveals regular partings of coarse silt; some layers with internal deformation; olive gray, except some clay layers pale grayish red. Most sections include one or more intervals containing scattered pebbles, blebs or streaks of reddish-brown or greenish-gray sandy silt, rare masses of olive-gray till a few centimeters to a foot thick, and disturbed stratification.</td>
</tr>
<tr>
<td>(10) 10-25 ft</td>
<td>Till, similar to unit 5, perhaps darker and less clayey; locally includes deformed silt wisps, crude stratification, and rare inclusions of grayish-red till. Currently inferred distribution (fig. 3) suggests a pulsating readvance.</td>
</tr>
<tr>
<td>(11)</td>
<td>Clay and silt, locally deformed in folds with amplitude of a few feet; exposed only south of Buttermilk Hill Road. As much as 350 ft of glacial drift lies below Buttermilk Creek grade along the axis of the bedrock valley; a few deep wells and test holes report predominantly lacustrine clay-silt andorre) till. Two wells (NFS #8, Ashford Town Barn; fig. 1) penetrated gravel of modest permeability just above bedrock at depths close to 300 ft.</td>
</tr>
<tr>
<td>(12) (oldest)</td>
<td>Till, much more sandy and stony than units 5 and 10, exposed and reported in test holes near the west side of the valley, atop or near bedrock.</td>
</tr>
</tbody>
</table>
* = Log inferred from geophysical data and other wells
Figure 5. Contours on top of bedrock, Buttermilk Creek Valley

EXPLANATION

- **1400** Altitude of the bedrock surface, in feet. Contour interval 100 feet.
- **875** Well or test hole; altitude of bedrock surface.
- **1096** Well or test hole; altitude of bottom of hole.
- **X860** Seismic shot point or point from seismic cross section (Nuclear Fuels Services, 1962)
- **DD** Bedrock outcrop (in part from Lofleur, 1979)

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET
Logs of 8 geologic sections on the bluffs along Buttermilk Creek and tributaries, and 2 test wells, are given on the following pages. Sections were based on multiple auger holes and small exposures examined by A.D. Randall and/or D.E. Prudic 1976-79; altitudes were determined by hand-leveling up from creek grade whose altitude was estimated from a topographic map of the Western New York Nuclear Service Center (5-foot contours, 1 inch = 400 feet) by Lockwood, Kessler, and Bartlett. Well logs were based on examination of cable-tool drill cuttings supplemented by split-spoon cores, the latter collected at 5 to 10-foot intervals below an altitude of 1325 feet; altitudes were determined by spirit levelling from nearby benchmarks. Locations of wells and sections are shown in Figure 1.

Site E

West bluff of Buttermilk Creek
along nose immediately north of powerline
about 1500 ft north of Buttermilk Road

1380
Terrace Surface

1380-1324
Not examined

1324-1315
Till, predominantly silt and clay with 5-15 percent stones and coarse sand; oxidized top 3 ft, unoxidized with oxidized mottling and/or oxidized fractures 3-9 ft; pebbly at base.

1315-1313
Clay or silty clay, with deformed partings and thin layers of silt; many layers nearly free of pebbles and coarse sand, others have abundant pebbles; many layers have reddish-gray silt blebs; mainly unoxidized, but strongly oxidized yellowish brown 0.5 feet at base.

1313-1309?
Gravel, pebbles with a few small cobbles, slightly silty; layers of pebbly sand; thickness at least 2 ft, base not examined; oxidized.

1309?-1287
Silt, well layered, with a few partings or thin layers of clay and rare thin layers of silty very fine sand; oxidized at top, variably oxidized below 1394 ft; numerous irregular masses as large as 10 x 20 mm of grayish-red silt with a few granules at about 1294 ft.

1287-1274
Clay and clayey silt, with some thin silts, generally in regular rhythmic layers; clays are reddish or purplish gray; some blebs and thin lenses of brighter grayish-red silt, a few layers with scattered pebbles; a few layers show internal deformation.

1242
Buttermilk Creek grade
Site M  
Left bank of Franks Creek and Right bank of tributary, at junction 1200 feet upstream from railroad

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1246</td>
<td>Top of sharp interstream ridge</td>
</tr>
<tr>
<td>1246-1242</td>
<td>Covered; in part oxidized till interbedded with wisps of sand. Possibly colluvium.</td>
</tr>
<tr>
<td>1242-1237</td>
<td>Pebble gravel, poorly exposed; overlying coarse to very coarse sand with small pebbles; dark yellowish brown 10YR4/2. Possibly a remnant of older alluvium of Franks Creek.</td>
</tr>
<tr>
<td>1237-1230½</td>
<td>Till: silty clay with subordinate sand and pebbles, un-oxidized olive-gray 5Y½/1; 0.2 feet of layered clay and silt locally present at base.</td>
</tr>
<tr>
<td>1230½-1228</td>
<td>Sand, coarse to very fine, and fine pebble gravel, layered, oxidized moderate yellowish brown 10YR5/4.</td>
</tr>
<tr>
<td>1228-1217</td>
<td>Silt and clay, interbedded in horizontal layers, light olivine gray.</td>
</tr>
<tr>
<td>1217-1214</td>
<td>Covered.</td>
</tr>
<tr>
<td>1214</td>
<td>Junction of tributary with Franks Creek.</td>
</tr>
</tbody>
</table>
Site N  Bluff along RR 1650 feet south of Franks Creek, 
1300 feet north of RR bridge over Buttermilk Creek

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1257-1249</td>
<td>Clay and silt; dry and oxidized 1257-1252 feet, gray with subordinate oxidation below; a few pebbles 1255-1254 ft, otherwise none; no bedding recognized.</td>
</tr>
<tr>
<td>1249-1235</td>
<td>Till, unoxidized, sparse pebble content below top 1 foot (estimated &lt; 5%), grades to pebble-free silty clay at 1237 feet.</td>
</tr>
<tr>
<td>1235-1234.2</td>
<td>Distorted thin layers of gray clay and white coarse silt, with rare blebs of rust-colored silt.</td>
</tr>
<tr>
<td>1234.2-1233.5</td>
<td>Silt, with partings and layers &lt; 3 mm thick of clay.</td>
</tr>
<tr>
<td>1233.5-1232.8</td>
<td>Pebble gravel and coarse sand, clean.</td>
</tr>
<tr>
<td>1232.8-1213</td>
<td>Silt, in layers commonly 2 to 10 mm thick with subordinate clay partings and layers 1 to 3 mm thick; rare thin layers of silty, very fine sand; saturated below 1225 feet.</td>
</tr>
<tr>
<td>1213-1196</td>
<td>Not augered.</td>
</tr>
<tr>
<td>1196</td>
<td>Buttermilk Creek grade.</td>
</tr>
</tbody>
</table>
**Site Z**
South bluff, Tributary to Buttermilk Creek North of Heinz Road, above bedrock in channel 1000 feet east of RR

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1310-1307</td>
<td>Till: stony silt, unoxidized.</td>
</tr>
<tr>
<td>1307-1304</td>
<td>Not examined.</td>
</tr>
<tr>
<td>1304-1303½</td>
<td>Silt and very fine sand, oxidized.</td>
</tr>
<tr>
<td>1303½-1296</td>
<td>Sand, fine to coarse, with granules and pebbles, loose, clean; grading to pebble gravel; layer of layered oxidized clay 0.3 ft thick, also layers of medium to fine sand.</td>
</tr>
<tr>
<td>1296-1291½</td>
<td>Silt, with layers of silty very fine sand, oxidized; thin clay layers near base.</td>
</tr>
<tr>
<td>1291½-1289</td>
<td>Silt to clayey silt, unoxidized, gray; layer silty fine sand 0.1 ft thick; layer of till-like pebbly clayey silt 0.2 ft thick.</td>
</tr>
<tr>
<td>1289</td>
<td>Refusal,</td>
</tr>
<tr>
<td>1272</td>
<td>Bedrock exposed in creek bed.</td>
</tr>
</tbody>
</table>
Site ID | Description
--- | ---
1408 | Top of slope, level surface.
1408-1390 | Not examined, probably gravel.
1390-1386 | Gravel, pebbles and small cobbles with clean coarse sand.
1386-1364 | Till; chiefly clay and silt with 10 to 15 percent gravel and coarse sand; olive gray, top 0.7 foot oxidized. Examined only at top and base; remainder covered.
1364-1355 | Not examined, probably mostly till.
1355-1354 | Clay, massive and very fat, unoxid., gray with faint red tinge, soft.
1354-1353½ | Clay and silty clay, layers 5-10 mm thick, with scattered small pebbles; oxid., very firm.
1353½-1348 | Gravel; pebbles and small cobbles with clean coarse sand at top, fine gravel at base.
1348-1346½ | Clay, gray to pinkish gray; and silt, gray to yellow-brown, in thin discontinuous and somewhat flow-distorted layers; a few thin layers of very fine sand.
1346½-1344 | Clay, gray to pinkish gray, and silt, gray to brownish gray, in thin regular horizontal layers; a few thin layers of very fine sand, oxidized; calcite-cemented layer 5 mm thick at base.
1344-1336 | Gravel, small pebbles with abundant coarse sand, silty near top.
1336-1329 | Clay, reddish gray, alternating with silt, olive gray, in layers generally 0.02 to 0.07 ft thick, although the clay layers include additional silt partings; grades into nearly massive silty clay that contains rare to abundant blebs of light reddish-gray clay and silt, rare wisps of silt, rare faint layering, and very rare pebbles.
1329-1328½ | Silt, massive, light gray, saturated; no clay or pebbles.
1328-1320 | Till, predominantly clay and silt, about 10% pebbles and coarse sand, unoxid.; a few deformed silt wisps.
1320-1314 | Silt, interlayered with silty very fine sand, fine sand, and clay; sandy units oxid., silts variably oxid. (oxidation may be a surface phenomenon)
1314-1308½ | Silt to fine sand
1308½-1308 | Till, oxidized. may be slumped material.
1308-1300 | Not examined.
1300 | Gooseneck Creek.
Site 1F  Bluff above B&O RR immediately north of Gooseneck Creek

1410  Top of Slope

1410-1402  Gravel, pebbles and cobbles to 5 inches maximum with clean coarse sand.

1402-1366  Till, predominantly silt and clay with 10-15 percent stones and coarse sand; some surficial oxidation. Examined at several points, not continuously.

1366-1362  Clay with deformed thin layers of silt increasing in abundance downward; also a few scattered pebbles; gray, except strongly oxidized dark yellowish orange and yellowish brown bottom 0.5 to 1 ft. Pinches out or grades into till laterally. Calcite-cemented layer 5 mm thick at base.

1362-1354  Gravel; variable at top, ranging from sandy moderately silty pebble gravel to openwork fine-pebble gravel; subrounded to subangular pebbles and cobbles in silty sand matrix at base; examined only at top and base of this interval.

1354-1350  Not examined.

1350-1344  Layers of bedded silt, silt with embedded pebbles, a silty very fine sand, clean fine to coarse sand, and clean sandy pebble gravel; oxidized.

1344-1342½  Silt, oxidized.

1342-1341½  Gravel and coarse sand, clean, saturated.

1341½-1332  Layered clay, clayey silt, clay with silt partings; unoxidized gray and pale reddish gray; no pebbles.

1332-1324  Clay or silty clay, faint layering and silt partings, scattered pebbles; plastic; unoxidized.

1330  RR Grade
Site 1G  
Left Bank of tributary to Buttermilk Creek, 450 feet downstream from dam for western NFS water-supply lake

1400  Top of slope, level surface
1400-1363  Not examined.
1361-1331  Till; silty clay with pebbles; fully oxidized 0-3 ft, oxidation along root tubes, fractures and mottled areas 3-6 ft, un-oxidized and plastic below (oxidized zone descends along slope); scattered deformed silt and clay beds 1340-1339, 1331-1330.
1330-1328  Clay, gray, with subordinate thin layers of oxidized light yellowish brown silt; two layers of pebbly clay with disturbed bedding 0.1 and 0.2 ft thick.
1328-1326  Gravel, sandy, clean (top) to silty (base); strong oxidation at base.
1326-1324  Clay, top 0.5 ft oxidized, remainder gray; subordinate thin silt layers or partings, commonly oxidized;
1324-1320  Not examined.
1320-1318  Silty clay and silt, layered.
1318-1314.5  Clay, gray, plastic; a few pebbles near base.
1314.5-1312.5  Silty clay, friable.
1312.5-1311.5  Clayey silt with clay partings, scattered pebbles, and probably disturbed bedding.
1311.5-1310  Till, sparsely pebbly at top, traces of deformed coarse silt layers at base.
1310-1308  Silt, gray.
1308-1304  Not examined.
1304-1297  Sand; chiefly fine or medium to very fine sand and silty very fine sand; lenticular parallel bedding, oxidized, included irregular masses of unoxidized gray silt with flow boundaries; slumping or flow of silt is original, not recent slumping on the slope.
1297-  (Stream grade)
1297-1287  Till, clayey, tough and dense; traces of deformed silt layers at top; upper surface is 2 ft higher a few feet away.
Site 1J  Exposures and auger hole along Buttermilk Creek  
from Buttermilk Road South to Gooseneck Creek  

A. Nearby continuous exposure 2 ft high along right bank 500 to 700 south 
of Buttermilk Hill Road, and 5 to locally 12 ft high 800 to 900 feet 
south of road.  

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1271-1265</td>
<td>Till (?) probably as below, poorly exposed.</td>
</tr>
</tbody>
</table>
| 1265-1259       | Till: unoxidized silty clay with uniformly scattered sand, 
                  pebbles, and very rare cobbles; partings and slivers of 
                  coarse white silt 1 to 3 mm thick and a few centimeters long 
                  are common, generally occurring in clusters or lenses as 
                  much as 0.4 ft thick, deformed but crudely horizontal; no 
                  gross stratification visible. |
| 1259-1256       | Till (?): unoxidized gray silty clay with sparse scattered 
                  sand and small pebbles, also abundant wisps of coarse silt 
                  and blebs of rose silt; crude stratification visible, in- 
                  cluding some folds. |

B. Auger hole and continuous exposures 1100 to 2000 feet south of Buttermilk 
Hill Road; last exposure 350 feet north of mouth of Gooseneck Creek.  

| 1275-1268       | Clay, with partings of silt etched by stream erosion; de- 
                  formed in broad folds 1 to 2 feet or more in amplitude, some 
                  limbs nearly vertical; locally abundant silt wisps; no stones 
                  or sand. |
| 1268-1259.5     | Clay, gray, unoxidized, plastic, very infrequent silt part- 
                  tings, no stones or sand. No folding visible 1268-1263, auger 
                  hole below. |
| 1259.5-1259.5   | Clay, plastic, with abundant silt in partings, deformed 
                  streaks, and regular layers as thick as 0.1 ft; blebs of 
                  rose silt at 1258; very rare scattered pebbles and no sand. |

Comment: Perhaps the exposure at A marked the advance of a floating ice 
tongue into a lake, dropping grit and stones into lacustrine deposits sim- 
ilar to those to the south. If ice advance caused the folding at the top 
of the section at B and nearby, some time must have elapsed before it 
crossed the area.
### Well V

Altitude of land surface: 1385.9  
Altitude of top of 6-inch casing: 1389.5

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-44</td>
<td>Till: predominantly silt and clay, with a little randomly distributed coarse sand to pebbles (est. 10-15% 0-15 ft, 5% or less 15-35 ft, 10-15% 35-43 ft); oxidized 0-9 ft, grading 9-16 ft to unoxidized; relatively clayey 40-44 ft with minor wisps or partings of coarse silt.</td>
</tr>
<tr>
<td>44-49</td>
<td>Lacustrine: layers of coarse silt, clay with rare silt partings and pebbles, rhythmic-laminated dark gray clay and light gray silt, and probably fine to coarse sand.</td>
</tr>
<tr>
<td>49-69</td>
<td>Till: relatively clayey; includes occasional lenses of rhythmic clay and silt, and silt partings; coarse sand to pebbles estimated about 5 percent 49-53 ft, generally greater below.</td>
</tr>
<tr>
<td>69-83</td>
<td>Till: predominantly silt and clay; randomly distributed coarse sand to pebbles generally about 10 percent, but some relatively pebbly till may be present 75-78 feet; unoxidized; possibly unsaturated 81.5-83 feet.</td>
</tr>
<tr>
<td>83-94</td>
<td>Gravel: probably mostly small pebbles and granules, with very coarse to very fine sand, traces of silt; poorly sorted; oxidized; unsaturated; pebble counts at 85 and 90 feet show 18 and 21 percent exotic lithologies respectively, among broken or rounded stones 1-3 cm diameter.</td>
</tr>
<tr>
<td>94-99</td>
<td>Sand: fine to very fine, with 20 to 50 percent medium to very coarse; traces of silt; rare granules; rare thin layers of grayish red clay with embedded very coarse sand; oxidized, unsaturated.</td>
</tr>
<tr>
<td>99-99½</td>
<td>Gravel: fine pebbles and granules.</td>
</tr>
<tr>
<td>99½-103½</td>
<td>Sand: very fine to fine, layered; a few thin layers and partings of silt; oxidized, unsaturated; small gray concretions.</td>
</tr>
<tr>
<td>103½-107</td>
<td>Lacustrine: upper part mostly silt and(or) clay, no samples; lower part dark clay with numerous partings of unoxidized silt, a few layers of oxidized very fine sand to silt, and occasional round blebs or augen as large as 5 mm of grayish red silty sand and rarely of gray silt or silty sand; unoxidized except very fine sand as noted.</td>
</tr>
</tbody>
</table>
Lacustrine: silt; chiefly as rhythmic layers of coarse silt 1/4 to 3 mm thick alternating with generally thinner layers or partings of dark gray, fine, clayey silt; some thicker layers of coarse silt; one layer of very fine sand 116.6-.7; silt and sand weakly oxidized, generally pale yellowish brown 10YR-5Y 6/2; unsaturated; a few layers with complex internal soft deformation; a few partings of red clay near base.

Disturbed lacustrine: Fine or clayey silt, gray to olive gray, regular fine beds < 1 to 3 mm thick, with a few beds of brownish-gray clay 5YR 5/1 as much as 5 mm thick, and a few partings or very thin beds of coarse silt, which together constitute 50 percent or more of interval; interbedded with layers of disturbed material ranging from severely contorted rhythmic thin layers to irregular mottled blebs of fine to coarse silt, commonly with scattered grains of coarse sand to granules and with scattered blebs or aligned blebs of grayish red 10R 4/2 to light brown 5YR 5/5 silt to sandy silt and one bleb of brown layered clay and silt; at 124 ft, disturbed material includes three layers each 2 to 3 cm thick of structureless clayey silt with randomly distributed pebbles to coarse sand, gray (N5-5GY 6/1) mottled with dark gray (N4), grayish red (10R 4/2), and/or pale yellowish brown, more stony than the till above 83 ft.

Lacustrine: silt, medium to fine, generally in regular beds < 1 to 20 mm thick with slight contrast in grain size between beds, but with partings of coarse silt below 138 ft and beds of coarse silt 1-6 cm thick below 149 ft; olive gray, barely plastic; graded silt beds at 134 ft; a few zones of folded, disturbed beds; rare clay beds up to 7 mm thick; rare scattered coarse sand grains and pebbles 146-149 ft; beds above 135 ft have zero or negative (unsaturated) pressure head.
Well W

Land surface altitude = about 1383 feet  
MP is top of 6-inch casing, altitude = 1386.30

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-91</td>
<td>Till, predominantly clay and silt, generally less than 15% coarse sand and fine gravel; includes some very thin rhythmic beds of clay and clayey silt 12-32 ft, which become abundant but contain embedded fine pebbles 30-32 ft; unusually stony 71-84 ft; includes scattered thin layers of silt or clayey silt 81-91 ft. Oxidized 0-8 or more, oxidized fractures or root tubes to 10½ ft or more.</td>
</tr>
<tr>
<td>91-108</td>
<td>Silt, with subordinate very fine sand and clay, oxidized and largely unsaturated, some layers with scattered pebbles. Individual layers recognized include very fine sand (only between depths of 93 and 95 feet), very fine sandy silt with traces up to 25% scattered coarse sand to fine pebbles, and coarse to fine silt (all these buff colored); also dark brownish-gray clay with rhythmic silt partings, and one layer of dark brownish gray silty clay with coarse silt partings and large embedded pebbles 107-108 ft. Pebby layers subordinate, but pebbles as large as 2-inch diameter recovered.</td>
</tr>
<tr>
<td>108-136</td>
<td>Predominantly silt: layers &lt; 1 to 5 mm thick of fine silt (olive gray) with thinner layers or partings of darker, clayey silt and equally thin layers or partings of coarse silt (light gray to light olive gray), unoxidized and probably saturated. Rare embedded coarse sand to fine pebbles 108-112, 126-127, and 135-136 ft. A few partings and layers of clay (brownish-olive gray) up to 20 mm thick. Many layers appear parallel and subhorizontal, but some sets show severe internal deformation, being folded, squeezed, and(or) discontinuous. Rare blebs of rose-colored coarse sandy silt &lt; 2 mm 126-127.5 ft.</td>
</tr>
<tr>
<td>136-138</td>
<td>Silt, coarse; in part interbedded with fine silt in layers generally 3-10 mm thick; highly disturbed, with predominant steep to vertical dips and with small-scale-plastic deformation, discontinuities, and convoluted fine layers around flowed masses of coarse silt.</td>
</tr>
</tbody>
</table>
REPORTS ON GEOHYDROLOGY

Following is a list of recent published reports concerned with the geo-
hydroslogy and radiochemistry of the low-level radioactive-waste burial ground
at West Valley. Other reports are in press and in preparation. U.S. Geological
Survey open-file reports were printed in small editions; copies may be available
on loan from the USGS, P.O. Box 1350, Albany, N.Y. or reproductions may be
purchased from Open-File Services Section, Branch of Distribution, U.S.
Geological Survey, Box 25425, Federal Center, Denver, CO 80225.

Boothroyd, J. C., Timson, B. S., and Dana, R. H., Jr., 1979, Geomorphic
and Erosion Studies at the Western New York Nuclear Service Center, West

Carter, M. W., Moghissi, A. A., and Kahn, Bernd, eds., 1979, Management of
Includes the following articles:
Husain, Liaquat, Matuszek, J. M., Hutchinson, J. A., and Wahlen, Martin,
Chemical and radiochemical character of low-level radioactive waste,
Matuszek, J. M., Husain, Liaquat, Lu, A. H., Davis, J. F., Fakundiny, R. H.,
Pferd, J. W., Application of radionuclide pathways studies to
management of shallow, low-level radioactive waste burial facilities,
v. 2, p. 901-916.
Prudic, D. E., and Randall, A. D., Ground-water hydrology and subsurface
migration of radioisotopes at a low-level, solid radioactive-waste
(Identical to USGS Open-file report 77-566.)

migration-land burial, water chemistry at commercially operated low-level
radioactive-waste disposal sites: Upton, N.Y., Brookhaven National Laboratory,
Department of Nuclear Energy, Progress Report 7, BNL-NUREG/50861, 26 p.

Colombo, Peter, and Weiss, A. J., 1979, Evaluation of isotope migration-land
burial, water chemistry at commercially operated low-level radioactive waste
disposal sites: Upton, N.Y., Brookhaven National Laboratory, Department of

Dana, R. H., Jr., Mollello, S. A., Fickies, R. H., and Fakundiny, R. H., 1979,
General investigation of radionuclide retention in migration pathways at the
West Valley, New York, low-level burial site: Albany, N.Y., New York State

Fickies, R. H., Fakundiny, R. H., and Mosely, E. T., 1979, Geotechnical analysis
of soil samples from test trench at Western New York Nuclear Service Center,
West Valley, New York: Albany, N.Y., New York State Geological Survey,

report on the low-level radioactive waste burial site, West Valley, New York
(1963-1975): U.S. Environmental Protection Agency, Report 9024-77-010,
122 p.


