MASTER

GENERAL GEOLOGY OF WESTERN NEW YORK STATE
AND DETAILED GEOLOGY OF WEST VALLEY AREA

Charles E. Weaver
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia

October 1976

This report was prepared by C. E. Weaver under Consultant Subcontract 7009 with Union Carbide Corporation, Nuclear Division. The subcontract was administered by Oak Ridge National Laboratory and the Office of Waste Isolation.

**UNION
CARBIDE**

OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

*prepared for the U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
under U.S. GOVERNMENT Contract W-7405 eng 26*

This informal document contains information which is preliminary and may be fragmentary or of limited scope. The assumptions, views, and conclusions expressed in this document are those of the author and are not to be interpreted as those of Union Carbide Corporation, Nuclear Division, or USERDA. /

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

**GENERAL GEOLOGY OF WESTERN NEW YORK STATE AND
DETAILED GEOLOGY OF WEST VALLEY AREA**

**Charles E. Weaver
School of Geophysical Sciences
Georgia Institute of Technology**

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

eb
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GENERAL GEOLOGY OF WESTERN NEW YORK STATE AND

DETAILED GEOLOGY OF WEST VALLEY AREA

ABSTRACT

INTRODUCTION

GENERAL GEOLOGY

PRECAMBRIAN	2
CAMBRIAN	2
ORDOVICIAN	3
SILURIAN-DEVONIAN	3
DEVONIAN CLASTIC SEQUENCE	4
OIL AND GAS FIELDS	5
POSTGLACIAL UPLIFT	5
EARTHQUAKES	5

WEST VALLEY AREA

INTRODUCTION	6
ALLEGANY COUNTY	6
Introduction	6
Rock-Stratigraphic Units	7
Supra Conneaut	7
Hinsdale Sandstone	7
Wellsville Formation	7
Conneaut Group	7
Rawson Formation	8
Cuba Formation	9
Machias Formation	9
Canadaway Group	9
Sixtown Creek Formation	10
Rushford Lake Formation	11
Caneadea Shale	13
Perrysburg Formation	13
Interregional Rock-Stratigraphic Correlation	13

ERIE COUNTY	14
Lower Canadaway	14
Hanover Shale	14
Dunkirk Shale Member	14
South Wales Member	14
Hume Shale Member	14
Candeadea Member	15
CHAUTAUQUA COUNTY	15
WEST VALLEY	15

GLACIAL DEPOSITS OF WESTERN NEW YORK

BEDROCK	19
PHYSIOGRAPHY	19
SALAMANCA RE-ENTRANT	20
CATTARAUGUS COUNTY	21
General Relation of the Drifts	21
Illinoian Drift	21
Wisconsinian Glaciation	22
Orlean Drift	22
Binghamton Drift	22
Valley Heads Moraine	23
Drift Thickness	24

APPENDIX

BIBLIOGRAPHY

ABSTRACT

The rocks in western New York are early Paleozoic in age and are overlain by glacial drift deposits. The sediments were deposited in the northwestern portion of the Appalachian Basin and are largely marine sediments deposited westward of thick clastic deposits. The area lies in the Appalachian Plateau; the formation outcrops are aligned in a general east-west direction and dip gently to the south. The oldest rocks (Upper Ordovician) outcrop along the shores of Lake Ontario; the youngest rocks are Upper Devonian-Lower Mississippian which occur along the Pennsylvania-New York border. Upper Devonian rock outcrop in the vicinity of West Valley.

Oil and gas fields are abundant in western New York. Recent earthquake activity has been reported a few kilometers northeast of West Valley.

The Upper Devonian Conneaut Group sediments outcrop in the hills flanking West Valley and to the south. The older Canadaway Group outcrops in the valley of West Valley and to the north. Approximately 600 m of Upper Devonian shales and siltstones underlie the West Valley Area. Black shale are first encountered 280 m below the surface and increase in abundance with depth.

Glacial drift deposits cover most of western New York and generally decrease in thickness from north to south. Deposits are thick in the valley areas and thin on the ridges. Valley fill as thick as 300 m occur in the area of West Valley and in the specific area that was used for waste disposal glacial drift deposits are 60 m thick.

GENERAL GEOLOGY OF WESTERN NEW YORK STATE AND

DETAILED GEOLOGY OF WEST VALLEY AREA

INTRODUCTION

For the purpose of this report western New York is considered to be that portion of the state that lies west of the Finger Lakes region. The area includes the following counties: Chautauqua, Cattaraugus, Allegany, Erie, Wyoming, Genesee, Niagara and Orleans (Fig. 1). The town of specific interest, West Valley, is located in the north central part of Cattaraugus County, 56 km SE of Buffalo. Figure 2 shows the topography in the area of West Valley. The town is situated in the valley of Buttermilk Creek. The valley has an elevation of 457 m. Mountains on either side of the valley rise to 595 m. Buttermilk Creek flows to the north. There is a divide approximately 1 km southeast of West Valley. South of the divide drainage is to the south and a major swamp exists immediately south of the divide.

The rocks in western New York are early Paleozoic sediments and are overlain by Pleistocene glacial deposits. The sediments were deposited in the northwest portion of the Appalachian Basin (Fig. 3). Most of the sediments were deposited as the thin marine edge of thick wedges of clastic sediments derived from an eastern source. Figure 4 is a structure contour map of the top of the Precambrian basement complex beneath the Paleozoic basin fill. Following, and to some extent concurrent with deposition, the mass of sediments were uplifted and deformed. Western New York lies in the mildly deformed area known as the Appalachian Plateau (Fig. 5). The Plateau is a broad, gentle, synclinal basin, whose youngest rocks are Permian (Eardley - 1962).

In western New York the Paleozoic outcrop belt trends east-west (Fig. 6) and dip to the south approximately 6 m per kilometer. The oldest rocks are the Upper Ordovician Queenston shales which parallel the southern shores of Lake Ontario. The rock units are progressively younger to the south. The youngest sediments are the Upper Devonian Chadakoin sandstones and shales which occur in a band along the New York-Pennsylvania border (Fig. 6)

In the vicinity of West Valley the Upper Devonian Conneaut Group outcrops in the high areas and to the south and the Canadaway Group in the valley and to the north (Fig. 6).

Glacial deposits are to be found throughout western New York. In many of the valleys the glacial fill is many hundreds of feet thick. Elsewhere especially in the high hills to the south, the till is but a few feet thick (Bordne - 1960).

GENERAL GEOLOGY

The areal distribution of the principal rock types in the Appalachian basin (Fig. 7) reflects the geographic location of the predominant environments of deposition. Sandstone, siltstone, and red beds make up a relatively high percentage of the stratigraphic column in the eastern and northeastern parts of the basin, where deltaic environments prevailed throughout much of the history of the basin. In the central part of the basin, or the trough of the basin of accumulation, argillaceous rocks constitute a higher percentage of the rock sequence than elsewhere. Carbonate rocks predominate in the southwestern part of the basin where shelf or platform environments prevailed. In western New York shale, claystone and mudstone are the predominant rock type with black shales comprising 20 to 75% of the sediments (Colton - 1970).

PRECAMBRIAN

Where exposed, the complex consists largely of schists, gneisses, and a wide range of intrusive rocks such as granite, granodiorite, quartz syenite, gabbro, and anorthosite. The stratigraphically higher Precambrian stratified sequence is a thick succession of interbedded metasedimentary and metavolcanic rocks unconformably overlying the basement complex. The westward extent of the Late Precambrian stratified rocks along the floor of the Appalachian basin is unknown (Colton - 1970).

CAMBRIAN

Figure 8 shows the thickness of the Lower Cambrian clastic sequence. The sequence is 122 m thick in the eastern portion of western New York, thins to the west and north and is absent along the shores of Lakes Erie and Ontario.

The rocks are predominantly sandstones. Upper Cambrian rocks are apparently missing from this portion of the Plateau.

ORDOVICIAN

The Lower and Middle Ordovician rocks are composed largely of dolomite and limestone with a lesser amount of sandstone. Rock units in central New York from oldest to youngest are: Theresa Dolomite, Little Falls Formation, Black River Group and Trenton Group. These units thin from 915 m near the western portion of the Pennsylvanian-New York border norwestward to 183 m in northwestern New York (Fig. 9). The isopach map in figure 8 is for the Upper Cambrian-Ordovician carbonate sequence. As no Upper Cambrian sediments are present in western New York the thickness values in that region are for the Lower and Middle Ordovician. The Lower Ordovician pinches out to the northwest along a northeast-southwest line that curves slightly north of West Valley an unconformity separates the Lower and Middle Ordovician (Colton - 1970).

The Upper Ordovician rocks are predominantly clastics and conformably overlies the Middle Ordovician. In western New York the rocks thin from 762 m near the Pennsylvanian border to 534 m near the western border of New York and 305 m at the northern border (Fig. 10). The basal unit is the black Utica Shale. This is overlain by the Frankfort Shale and Pulaski Shale. These shales are equivalent to the Martinsburg Shale and Reedsville Shale to the southeast. These basal shales are overlain by the Oswego Sandstone, 0 to 90 m thick. The uppermost member is the Queenston red shales, approximately 300 m thick in western New York (Colton - 1970 and Kay - 1942). It outcrops in an east-west band along the southern shores of Lake Ontario, including the base Niagara Falls.

SILURIAN-DEVONIAN

A Silurian clastic sequence overlays the Upper Ordovician clastic sequence. The sequence thins from 90 to 120 m at the Pennsylvanian border north and northwest to 60 m. It outcrops in an east-west band slightly south of the southern shore of Lake Ontario (Fig. 11). Figure 12 contains a stratigraphic

column for western New York. The relatively thin section contains two thin beds of limestone but is composed largely of thin beds of shale and sandstone (Colton - 1970). Appreciable amounts of oil and gas have been produced from the Medina Sand (Grunsky Sandstone) in western New York. The sandstone is a hematitic quartz sandstone with subordinate amounts of graywacke (Lumsden and Pelletier - 1969).

This clastic unit is overlain by what Colton (1970) calls a Silurian - Devonian carbonate sequence. The rocks range in age from Middle Silurian to Middle Devonian (Fig. 12) and are predominantly limestone, though shales and salt deposits are present near the base of the Upper Silurian (Salina Group). The salt bed is less than 30 m thick in western New York and less than 15 m near West Valley (Fettke - 1955).

This carbonate unit is approximately 365 m thick at the Pennsylvanian border and thins to the northwest. It outcrops in an east-west strip approximately 40 km south of and parallel to the southern shore of Lake Ontario (Fig. 13).

DEVONIAN CLASTIC SEQUENCE

The Middle and Upper Devonian clastic sediments outcrop in a general east-west belt on the southern two-thirds of western New York. As illustrated in figure 14, the Devonian clastic sequence is wedge-shaped, thinning and the sediments becoming finer grained from east to west. The section thins from approximately 1500 m in the eastern portion of western New York to 920 m near the eastern shore of Lake Erie.

A stratigraphic column for western New York is shown in figure 12. The Middle Devonian consists largely of gray and black shales with thin interbedded limestone units. In Erie County the Marcellus formation consists wholly of calcareous black shale; the Skaneateles formation is mostly dark-gray to black shale, with thin limestone at the base. The Ludlowville formation has a fossiliferous limestone at the base, but most of the sequence is of dark-gray shale. The Moscow formation has thinned notably but also contains some dark shale, although it is composed mostly of calcareous blue-gray shale. The Taghanic State (youngest Middle Devonian) saw the deposition of only black shale.

In the country between Cayuga Lake and Erie County, the increasing amounts of poorly fossiliferous black shale are strikingly noticeable. Correlation is accomplished by tracing of thin limestones (Cooper - 1957).

The Upper Devonian - Lower Mississippian section consists of gray and black shales with minor sand. Higher in the section sands, siltstones and silty shales are predominant. Conglomerates and red beds are present in the upper part of the section.

Figure 15 is a lithofacies map of the Upper Devonian in northeastern United States (Sutton - 1957). The map indicates that in western New York the Upper Devonian is composed of 51 to 88% shale of which less than 20% is black shale. A similar map constructed by Ayrton (1963) indicates the sand/shale ratio in this area is $\frac{1}{4}$ and less.

OIL AND GAS FIELDS

Figure 16 shows the location of the oil and gas fields in western New York. Structural contours show elevation in feet of the top of the Devonian clastic sequence (Colton - 1961).

POSTGLACIAL UPLIFT

Figure 17 shows the extent of postglacial uplift in the eastern United States (King - 1965). In western New York uplift varied from zero in the southern portion to 50 m in the central portion.

EARTHQUAKES

Figure 18 is a contour map of the epicenter of all earthquakes of the last 200 years (King - 1965). Western New York lies in an area of moderate seismic activity.

Figure 19 shows the location of recent earthquake epicenters in New York (Chiburis et al. - 1976). Recent seismic activity is reported in an area approximately 60 km northeast of West Valley.

WEST VALLEY AREA

INTRODUCTION

The outcropping sediments in the immediate vicinity of West Valley belong to the Upper Devonian Conneaut Group and the Canadaway Group which are part of the Cassadaga Series and the Chautauquam Series. Most formation names have only local significance and change every few miles. Little detailed geologic mapping appears to have been done in the immediate vicinity of West Valley, Cattaraugus County; however, sufficient mapping has been done to the east, west and north of West Valley to indicate the type of rock that should be present in the West Valley area.

ALLEGANY COUNTY

Introduction

Manspeizer (1963) described the stratigraphy of the Upper Devonian Chautauquan Series of Allegany County and the northwestern part of Cattaraugus County. His cross sections extend to within 11 to 22 km of West Valley. Figure 20 is a correlation chart of the Chautauquan Series from southeastern Allegany County westward to Jamestown, Chautauqua County. West Valley would occur in approximately the middle of the cross-section but 29 to 32 km to the north. As the rock units become younger from north to south and dip gently to the south the rocks outcropping near West Valley would be slightly older than the surface rocks along the line of section. Figures 21 and 22 are stratigraphic cross-sections showing the east to west facies variations.

The rocks in the area of study includes the Canadaway and Conneaut Groups and the Supra Conneaut. Although the contacts of these groups transgress time to the west, many beds within the groups extend laterally for many miles and may well approximate local time-stratigraphic horizons. Two such horizons are the Cuba Formation and the Alfred Station Coquinite. Both horizons occur throughout much of western New York and northern Pennsylvania, maintain a fairly constant stratigraphic separation of about 150 m.

Rock-Stratigraphic Units

Three groups, each differing by some objective physical criteria, are recognized in the area of study. In ascending order, the groups and their major rock types are: (1) black and gray shales with sole-marked sandstones and siltstones, a thin but widespread coquinite, a shoestring sand, and blanket-like sandstones and shales of the Canadaway Group; (2) fossiliferous sandstones and mudstones with barren shales of the Conneaut Group; and (3) "Catskill" type beds of the Supra Conneaut (informal usage).

Supra Conneaut

Included in this grouping are the beds between the base of the Wellsville Formation and the base of the Wolf Creek Conglomerate along the Genesee Valley (Fig. 20). The sequence, is about 150 m thick and is lithologically transitional between the fossiliferous strata of the underlying Conneaut Group and the overlying Cattaraugus red beds (Upper-most Devonian).

Hindsdale Sandstone - The Hindsdale Sandstone is 4.5 to 9 m thick, fine-grained, in part pebbly, massively bedded, and red-brown to chocolate-colored. It occurs about 76 m above the Cuba Formation (Figs. 21 and 22).

Wellsville Formation - The formation is about 76 m thick, containing gray-colored interbeds of sandstone, shale, mudstone, and coquinite near the lower contact and siltstone and red-brown shale near the upper contact. Because the coquinite-mudstone association characterizes the older Machias Formation and the red-brown shale characterizes the younger "Catskill" beds, the lower contact of the formation is placed above the topmost stratum resembling the Machias; the remaining beds are assigned to the Rawson Formation of the Conneaut Group. The two formations complement each other in thickness with the Wellsville Formation thinning to the west from a depositional high in eastern Allegany County (Figs. 21 and 22).

Conneaut Group

In Allegany County the Conneaut Group is about 150 m thick and is marked by the very fossiliferous Rawson, Cuba, and Machias Formations.

Rawson Formation - The formation, which is wedge-shaped, everywhere overlies the Cuba Formation; it underlies and interfingers with the Wellsville Formation in Allegany County and underlies the Hinsdale Sandstone in Cattaraugus County.

The following description of the Rawson Formation type section (eastern Cattaraugus County) serves as a guide of the formation's general lithology.

<u>Thickness in Meters</u>	<u>Description</u>
2.1	Sandstone (Hinsdale), gritty, poorly consolidated, and weathering to a dull chocolate color.
10.2	Concealed zone (Rawson Formation); the stream channel is laden with coquinites and sandstones.
9.6	Shale (Wellsville tongue), gray with thin interbeds of light-gray siltstone.
0.6	Sandstone and coquinite interbeds.
6.6	Shale, gray, silty, and fossiliferous; contains interbeds of sandstone, siltstone, and coquinite.
3.6	Siltstone, gray with thick interbeds of fossiliferous mudstone.
4.2	Sandstone, gray, fossiliferous, fine- and medium-grained, and massively bedded; contains intercalations of coquinite, mudstone, siltstone, and gray shale.
6.6	Sandstone, gray, fine-grained, ripple-marked, channel-grooved, sole-marked (strike N. 49° - 52°W.), massively bedded and intercalated with mudstones and coquinites.
1.2	Mudstone, gray, silty, micaceous, and fossiliferous.
10.8	Sandstone, gray, thick- and massive-bedded, fine-grained near upper contact; coarse-grained and pebbly near lower contact; contains mudstones and coquinites near contacts.
10.8	Shale, gray, weathering brown to rust.
12.3	Sandstone (Cuba Formation), gray, clay-galled, fine-grained, fossiliferous, ripple-marked, and sole-marked; elevation at lower contact 497 m.

The Rawson Formation is lithologically and paleontologically similar to the Machias Formation.

Cuba Formation - The formation is about 12 m thick, blanket-like, and is composed of lenticular gray siltstones and shales with thick-bedded, coarse-grained feldspathic and fossiliferous sandstones. It occurs about 75 m below the Hinsdale Sandstone.

Machias Formation - The type section for the Machias Formation occurs 10 km east of West Valley. The Machias Formation is a 120 m wedge-shaped body that is abundantly fossiliferous. It is thickest along a northeast-southwest line in south-central Allegany County and thins to the northwest and west at a rate of about 0.2 and 0.6 m per km respectively (Figs. 11 and 22). The formation overlies and interfingers with the Sixtown Creek formation to the northwest, overlies the Rush Creek Member to the west and east, and underlies the Cuba Formation throughout the area. The unit has a relatively high shale content in the vicinity of the West Valley.

The Machias, which is characteristically coquinitic, is recognized in well samples by the concentration of shell fragments. Light-gray massive-bedded mudstones, massive-bedded clay-galled sandstones, and light-to-dark-gray and olive-green shales with siltstone interbeds constitute other major rock types within the formation. Commonly, the sandstones and mudstones are fossiliferous and the shales are barren.

Canadaway Group

The upper contact of the Canadaway rises westward at a rate equal to the rate of thinning of the Machias, which is about 1.3 m per km to the northwest and 0.2 m per km to the west. By projecting an average rate of thinning of 1.0 m per mile, the Cuba theoretically should be the youngest formation of the Conneaut Group and the oldest formation of the Canadaway Group near Jamestown, New York.

The Canadaway Group includes the Sixtown Creek, Scholes, and Rushford Lake Formations (new names), Caneadea Shale, and Perrysburg Formation. The group was deposited prior to and partly during the McHenry Valley Substage (Fig. 11).

Sixtown Creek Formation - The Sixtown Creek formation is a wedge-shaped body that thins south from a depositional center in northeastern Cattaraugus and northwestern Allegany Counties, where it is about 120 m thick (Fig. 21). The formation is nonfossiliferous and is the northern time-stratigraphic complement of the Machias wedge. The formation interfingers with the Machias Formation.

The shale member is approximately 60 m thick and is composed of gray shales and mudstones with thin sandstone interbeds. Occasionally, the shales weather red brown, and the sandstones are ripple-marked. The member is sparsely fossiliferous near Machias, New York (10 km east of West Valley).

The Scholes member is named for the 40 m sequence of nonfossiliferous massively bedded sandstones and gray shales exposed along a south-flowing tributary of Black Creek, 0.8 km south of Scholes in Allegany County. The member is thickest in northern Allegany County and thins to the south, where it is pervaded by tongues of the Machias.

<u>Thickness in Meters</u>	<u>Description</u>
5.4	Sandstone (Machias Formation), gray, thick-and massive-bedded, fossiliferous, and intercalated with thick beds of coquinite.
6.9	Concealed zone
5.7	Shale (Scholes Formation), olive green to gray, and fissile.
5.2	Sandstone, gray, massively bedded (avg. 1.5 m), and worm-burrowed; siltstone interbeds are common near the contacts.
2.4	Concealed zone.
1.8	Mudstone, gray, blocky with sandstone lenses near upper content.

<u>Thickness In Meters</u>	<u>Description</u>
5.4	Sandstone, gray, thick- and massive-bedded
7.5	Concealed zone
11.1	Sandstone, gray, coarse-grained, and massively bedded (avg. 2.4 m)
16.5	Shale, (Rush Creek Shale Member of the Rushford Lake Formation), gray to dark gray, fissile and interbedded with worm-burrowed and clay-galled sandstones.
15.5	Interbeds of coquinite, fossiliferous sandstone, mudstone, shale, and siltstone (Alfred Station Coquinite Member of the Rushford Lake Formation).
2.7	Concealed zone
3.6	Shale (Caneadea Shale), brownish gray and silty; elevation 496 m.

Rushford Lake Formation - The Rushford Lake Formation overlies the Caneadea Shale and underlies the Scholes Formation of the Canadaway Group to the north and the Machias Formation of the Conneaut Group to the south (Figs. 21 and 22). At the type section, 90 m south of the Rushford Lake and Caneadea Storage Dam on Caneadea Creek, two thick sandstone units are present and are separated by 22 m of shale with siltstone and sandstone interbeds. The geometry of these sand bodies differs markedly. The younger sand, which is the Scholes Formation, is blanket-like; the older sandstone (the Rushford Sandstone) is a shoestring sand, which laterally gives way to a remarkably persistent coquinite bed, the Alfred Station Coquinite. The third member of this formation, the Rush Creek, overlies both the shoestring sand and the coquinite.

A description of the Rushford Lake Formation type section, which is also the type section of the Rushford Sandstone and Rush Creek Members of the formation and the typical section of the Scholes Formation, is as follows:

<u>Thickness in Meters</u>	<u>Description</u>
24.6	Sandstone (Scholes Formation), gray, massively bedded (avg. 2.4 m)
1.8	Sandstone, gray, massively bedded (3 to 4.5 m), fossiliferous.
16.4	Shale (Rush Creek Member of the Rushford Lake Formation), gray and silty with numerous interbeds of dark gray micaceous and slightly fossiliferous siltstone and sandstone; the approximate shale, siltstone, and sandstone percentages are 45%, 35%, and 20% respectively.
1.8	Sandstone, light gray, thin-bedded, sparsely fossiliferous, and intercalated with light-gray silty shales.
3.9	Shale, mudstone, and siltstone interbeds; light-gray mudstones with siltstone interbeds are prominent in the lower 1.2 m; blue-gray shales with siltstone interbeds are common in the remainder of the bed.
6.9	Sandstone (Rushford Sandstone Member of the Rushford Lake Formation), gray, massively bedded, and micaceous; the bed grades laterally into shales with sandstone interbeds.
3.9	Shale, gray, and silty with intercalations of thin sandstone beds.
1.2	Mudstone, gray, blocky, and very silty.
0.9	Sandstone, gray, clay-galled, massively bedded; the bed grades laterally into shales with siltstone and sandstone interbeds, bearing flute casts that strike N. 18°W. (steep side south); flow rolls with long axes oriented N. 20°W., and groove casts that strike N. 88°E.
40.3	Shale (Caneadea Shale), gray with few siltstone and sandstone interbeds.

Caneadea Shale - The Caneadea Shale is composed of fissile gray shale with numerous interbeds of siltstone and sandstone, and an occasional olive-green, black, and red-brown-weathering. The siltstones and sandstone are commonly thin-bedded and laterally persistent.

Perrysburg Formation - The Perrysburg Formation includes three members (Dunkirk, South Wales and Gowanda) in western Cattaraugus County and five members (Dunkirk, South Wales, Canaseraga, Hume, and Caneadea) in the Genesee River Valley.

The Hume Shale is best exposed and most typically developed in north-western Allegany County. There the member is a black shale with intercalations of dark-gray to olive-green shale and layers of limestone nodules and septaria. Elsewhere (Fig. 21) the member is interbedded with siltstones and sandstones.

The Canaseraga Sandstone Member is a thick wedge-shaped deposit that thins to the west and northwest. Siltstones and sandstones make up most of the member.

The South Wales Shale is composed essentially of gray and dark-gray silty micaceous shale with intercalations of calcareous nodules, black shale, and thin-bedded siltstone.

The Dunkirk Shale is 2 to 2.5 m thick, black and thinly laminated shale with small ellipsoidal nodules. It rapidly thickens westward and is from 36 to 60 m thick in wells of Cattaraugus County (Fig. 22).

Interregional Rock-Stratigraphic Correlation

Most Upper Devonian rock-stratigraphic units of New York and Pennsylvania are time transgressive. The lower contact of the Conneaut Group attests to such a transgression.

If there is a consistency of lithology and uniformity of transgression beyond the confines of this study, then the Conneaut Group should occur time-stratigraphically younger to the west and older to the east.

Mangpeizer considers the Machias, Cuba, and Rawson Formations of Allegany County to be a rock-stratigraphic correlative of the Conneaut Group at its standard section near Jamestown in Chautauqua County.

Manspeizer's study demonstrates that the Upper Devonian rock units in western New York have limited lateral continuity and that facies changes occur in all time-stratigraphic units.

ERIE COUNTY

Lower Canadaway

Pepper and deWitt (1951) described the Lower Canadaway (Upper Devonian) group of rocks which outcrop in an east-west band 20 to 32 km north of West Valley. These rocks and the ones described in the preceding pages should be similar to those that occur in the vicinity of West Valley.

Figure 23 is a generalized east-west cross section. West Valley would project on the cross section at a point approximately 56 km east of the western terminus. The section is composed predominantly of gray shales and siltstones and black shales with the sandstone content increasing to the east. The unit was named the Perrysburg Formation by Pepper and deWitt. Figures 24 and 25 are lithofacies maps of the lower and upper part of the section. Shales and siltstones are the predominant rock types in western New York and in the vicinity of West Valley.

Hanover Shale - The Hanover shale underlies the basal member of the Perrysburg formation. The upper part of the Hanover shale contains many nodules and several thin limy siltstones. The shale contains many plant fossils; plant stems ranging from 1 to 4 inches in width and from 1 to 2 feet in length are common.

Dunkirk Shale Member - This shale is massive and consists of alternating beds of black, olive-black and brown shales and thin siltstones. Carbonized plant stems are common.

South Wales Member - The South Wales member is composed of gray silty shale, gray silty mudstone, small amounts of black, brown, and very dark-gray shale, and some thin-bedded gray siltstone.

Hume Shale Member - The Hume shale consists predominately of black, brown, and dark-gray shales.

Caneadea Member - The lower part of the Caneadea member consists of gray siltstone ranging in thickness from 1 to 50 cm., which is interbedded with gray silty shale. The middle part is largely shale containing some siltstone. The upper part of the Caneadea member, is shale containing many thin beds of siltstone.

CHAUTAUQUA COUNTY

Tesmer (1963) described the geology of Chautauqua County and a bordering 5 km large strip of western Cattaraugus County. Both counties are underlain by approximately 600 m of predominantly marine shales, siltstones and conglomerates of Upper Devonian age. Figure 26 is a generalized geologic column of Chautauqua County. The strike of formations trends east-west; the dip is to the south 4 to 10 m per km. The formations and lithologies are similar to those described in the preceeding pages.

No major faults were found in the area, although local minor folds in incompetent beds may occasionally show faults with a displacement of a few inches.

WEST VALLEY

The area around West Valley does not appear to have been mapped in detail. As of 1970 (Rickard and Fisher - 1970) there was no geologic map of Cattaraugus County. However, a test well was cored at the beginning of the hydraulic fracturing experiments at West Valley. It is described by Laguna (1973).

Calculations indicated the Lower-Middle Devonian Onondaga Limestone should be at a depth of 762 m. The overlying material belongs to the Middle and Upper Devonian clastic sequence. For economic reasons the core hole was drilled to only 464 m. Most of the rock penetrated was shale, but much of the shale did not break easily or cleanly along the bedding planes. About 30 m of the rock penetrated was a sandy siltstone, in part thick-bedded to massive, but even the better bedded siltstone did not tend to break parallel to the bedding. The core samples and the electric log suggest that the siltstone, unlike the shales, has at least some permeability. Some of the dark gray or black shales penetrated, particularly near the bottom of the well, have a distinct odor of petroleum when freshly broken. These oil shales may be the upper part of the Rhinestreet Shale of the Java and

West Falls Groups, and the overlying shales and siltstone probably belong to the Canadaway Group. All these formations are of Upper Devonian Age. The log of the well follows: The notations "good," "fair," and "poor" indicate the apparent suitability of the rock for hydraulic fracturing. "Good" means that the core can be easily broken by hand and that the break is closely guided by the bedding planes, although these may be slightly irregular in detail. The notation "fair" means that the core may be broken by hand, but only with some difficulty, and that the break, in general, is guided by the bedding. The notation "poor" means that the core can only be broken by a sharp blow, as with a hammer, and that the break is but little guided by the bedding.

The specific gravity of the shales range from 2.49 to 2.79 indicating there is considerable variation in composition. As the clay mineral suite is probably relatively uniform (illite > chlorite), the variation is most likely due to difference in organic and carbonate mineral content.

Log of NX Core Hole, West Valley, New York

Drilled May 1969

Meters

0-60.1	Till; clay, silt, a little sand and a few cobbles.
60.1-167.4	Medium-gray silty shale; thin bedded but bedding is irregular in detail; about 5% is thin beds of light-gray calcareous siltstone showing cross bedding. Good.
167.4-201.6	Medium-gray silty shale; thin bedded but bedding irregular in detail; 10% or more is thin beds of light-gray calcareous siltstone. Fair; locally good or poor.
201.6-217.8	Dark gray shale; few scattered beds of medium- to light gray calcareous siltstone. Locally faint oily smell. Fair, or fair to good.

- 217.8-244.0 Medium-gray and dark-gray shale interbedded; a few scattered thin beds of calcareous siltstone. Locally faint smell of oil. Fair to good.
- 244.0-280.6 Very fine-grained olive-green shale showing very little bedding, interbedded and irregularly intermixed with dark-gray shale which shows some bedding. Poor.
- 280.6-292.2 Black shale, with distinct petroleum smell, interbedded with and irregularly mixed with light-gray sandy siltstone and olive-green shale. Bedding poorly developed. Poor.
- 292.2-319.6 Light- to medium-gray sandy siltstone, locally calcareous; bedding generally indistinct, locally easily visible. Does not break on bedding planes. Poor.
- 319.6-333.3 Dark-gray shale, bedding indistinct, interbedded and mixed with light-to medium-gray siltstone, locally calcareous. Poor to fair.
- 333.3-370.3 Medium-gray shale and dark-gray shale, interbedded. Bedding shows clearly, but rock does not break easily on bedding. Locally contains beds of light-gray siltstone. Fair.
- 370.3-388.6 Medium-to dark-gray shale; bedding thin, regular, and well-developed. Locally faint smell of oil. Good.
- 388.6-400.5 Dark gray shale, almost black. Bedding hardly visible. No oily smell. Fair.
- 400.5-430.0 Black carbonaceous shale, locally faint smell of oil. Bedding almost invisible, but rock is thin bedded. Breaks fairly well on bedding, but considerable force required. Fair.
- 430.0-445.0 Black shale; thin bedding visible when wet; strong oily smell; interbedded with dark gray shale with more evident bedding; faint oily smell. Fair.
- 445.0-463.6 Black carbonaceous shale; thin bedded, but bedding not easily visible. Bedding is regular and rock breaks fairly cleanly on bedding, but considerable force required. Strong oily smell. Fair.

Of interest is the fact that the well penetrated 60 m of glacial till. The underlying Upper Devonian shale, silty shale and siltstone sequence is similar to the Upper Devonian rocks, previously described, from the areas slightly east, north and west of West Valley.

Sun (1973) in discussing the same core hole quotes G. H. Chase (U.S.G.S.) as saying the rocks dip southward one or two degrees and that the area is blanketed by as much as 60 m of glacial drift.

A west to east projection of the formations shown on the geologic map of Chataqua County (Tesmer - 1963), 29 km west of West Vally, indicates the Dexterville Siltstone (Conneaut Group) and Northeast Shale (Canadaway Group) should outcrop in the vicinity of West Valley. This extrapolation is probably reasonably reliable. The generalized geologic map of New York indicates the younger Conneaut Group sediments outcrops in the hills on either side of West Valley and to the south. The older Canadaway Group sediments outcrop in the valley in which West Valley is located and to the north. (Fig. 6).

GLACIAL DEPOSITS OF WESTERN NEW YORK

BEDROCK

Figure 27 shows the Pre-Pleistocene bedrock topography of western New York and adjacent areas. The Paleozoic bedrock has an elevation of approximately 600 m at the Pennsylvania border and decreases northward to approximately 60 m at the south shore of Lake Ontario (Horberg and Anderson - 1959). A break in slope occurs near the eastern tip of Lake Erie and extends to the east. The southern portion of the area is called the Appalachian Uplands. The northern area is called the Erie Ontario Lowlands (Cressey - 1941).

PHYSIOGRAPHY

The following general discussion of the glacial geology of western New York is after Muller (1965). The Appalachian Upland includes all of the southern half of New York except for the eastern strip that is structurally more complex. Principal drainage lines in the southern part of the Appalachian Upland trend dominantly southwestward and flow into the Delaware, Susquehanna, and Allegheny systems from southeast to southwest respectively (Fig. 28). Southward penetration into the plateau by headwaters of the northward-draining obsequent streams is limited. Most such streams are short with steep gradients and small drainage basins, but the Genesee River and Cattaraugus Creek drain significant areas south of the Valley Heads Moraine. Glacial modification of the dissected plateau is most intense along its north margin and seems focused near the northern ends of Cayuga and Seneca Lakes and in the Genesee basin. Southward the intensity of glaciation decreases toward the state line, though scoured uplands and a network of troughs ("through valleys") distinguish the glaciated from the unglaciated parts of the plateau.

A semicircular area of the Appalachian Upland south of the Allegheny River in southwestern New York bears no evidence of glaciation. This area otherwise continuous with and similar to the adjacent upland to the north, is the Salamanca re-entrant, the northernmost unglaciated area in the region between the Mississippi River and the Atlantic Ocean.

The Erie-Ontario Lowland differs from the previously discussed uplands only because of the erosional susceptibility of its underlying bedrock. Developed largely on carbonate and fine clastic sediments, this area is almost entirely below 250 m above sea level. Its cuesta-form nature is particularly evident in the west, where the Niagara and Onondaga scarps are separated by broad lowlands developed on Salina shales. Glacial modification of the lowland has been intense. As a consequence the topography is strongly drumlinized.

Consistent stratigraphic relationships and continuous tracing of moraines are the most widely reliable criteria for correlation of glacial deposits. Both are particularly difficult to apply in areas of moderate to high relief such as the Appalachian Uplands. Glacial deposits of the Erie-Ontario Lowland were laid down in proglacial lakes, resulting in subdued topographic expression of moraines that might otherwise be readily followed. These factors have frustrated effective tracing of moraines and correlation from one valley to the next.

SALAMANCA RE-ENTRANT

In southwestern New York (southern Cattaraugus County) the drift margin is marked by a major northward re-entrant bordered approximately by the course of the Allegheny River where it flows northwest to Salamanca, thence recurves southwest toward Warren, Pennsylvania. This triangular area of New York escaped glaciation partly because of its elevation, with summit accordance approaching 730 m above sea level. The unglaciated re-entrant owes its existence partly to its location between glacier lobes from the Ontario and Erie basins.

Although no direct evidence of pre-Illinoian glaciation is recognized in the Salamanca re-entrant, its existence may be inferred from relationships of subsequent deposits. Prior to glaciation, the Ancestral Allegheny flowed northwest to the Erie Basin, its headwater divides being essentially at the level of accordant summits. Pre-Illinoian and early Illinoian ice extended far enough south across New York to impound the Ancestral Allegheny, diverting its flow southward across the lowest available cols.

CATTARAUGUS COUNTY

General Relation of the Drifts

MacClintock and Apfel (1944) mapped the glacial drifts in the Salamanca re-entrant and adjacent areas, including West Valley (Fig. 29). Four drift sheets are identified. They are the Illinoian and three Wisconsin sheets designated from older to younger: the Olean, the Binghamton, and the Valley Heads (Fig. 30). The Illinoian drift extends only a few miles south of the boundary of younger drift. In turn the drift of each Wisconsin substage covers more or less of the preceding drift, so that essentially the only places where one drift sheet may be studied lie between its border and that of the next succeeding drift.

Illinoian Drift

The oldest drift found in Cattaraugus County correlates with the Illinoian. It comprises both till and gravel, the latter mostly in terraces along the Allegheny Valley. This older drift is limited to isolated patches, left after Sangamon erosion had largely idsmembered what may well have been a fairly continuous drift sheet. Beyond that Wisconsin drift border the exposures of the older drift, where not stripped and kept fresh by surface erosion, are deeply weathered and show unmistakable evidence of their age. However, within the Wisconsin drift border the overriding younger ice has normally stripped away the weathered part of the older drift. In these latter places on the east side of the re-entrant, the older drift is recognized by the sharp difference in lithology between it and the overlying and surrounding Wisconsin drift.

Patches of till have been found at eight places north of the Allegheny River. Probably a more detailed survey would disclose other occurrences. Outcrops of till range from 3 to 18 m thick.

A series of gravel terrace remnants are present in the Allegheny Valley. Those 3 and 6 m above mean river level are of Wisconsin age as judged by relatively slight dissection and weathering, but the higher ones, 15 to 30 m above river level, as judged by the same criteria, are Illinoian. Some deposits are more than 10 m thick.

Wisconsinian Glaciation

Orlean Drift - The Orlean drift is composed dominantly of the sandstones, siltstones, and shales from the bedrock constituting the plateau. Some of these have a small percentage of calcium carbonate in them.

The drift border (Fig. 30) is intimately related to the bedrock topography, for, at the edge of the ice sheet, tongues of ice projected in the valleys. At the ends of these ice tongues looped moraines of till and kame gravel were commonly formed. Drift on the uplands is so thin that morainal topography there is seldom present.

The Olean is a thin and topographically relatively unimportant drift sheet. It may well be described as an insignificant coating of till over the uplands with looped moraines in the valleys at the drift border and kame terraces against the lower parts of the valley sides north of the border. In the valley's drift deposits are commonly 30 to 60 m thick.

Binghamton Drift - The Binghamton drift differs strikingly from the Olean drift in having an abundance of both igneous erratics and of limestones. The drift border enters New York from Pennsylvania on the east side of Conewango Valley, 5.6 km east of Fentonville and 14.4 km southeast of Jamestown. It trends northward as a 1.6 km wide belt of terminal moraine along the valley wall rising to 610 m in altitude at several places. It turns eastward to form the large and striking moraine across the capacious preglacial valley north of Steamburg (Fig. 30): Thence it passes northward, still as a strong morainic belt, with lobes into the valleys. The border then turns eastward, projecting to make strong morainal patches in the north branch of Little Valley Creek and in Toad Hollow. It is traced eastward past Plato to the kames 8 km south of West Valley. It then trends southeast to Ischua. From Ischua the border was traced eastward to the Genesee Valley.

The Binghamton drift sheet exhibits a considerable variety of topographic forms which may, for simplicity, be grouped into five types: (1) terminal moraine, (2) ground moraine, (3) drumlin, (4) kame terrace, (5) "valley stopper" moraine.

(1) The terminal moraine is a belt of thickened drift about 1.5 km wide within which drift controls the topography. Kames are common, and undrained depressions numerous. It is mappable from the Ohio State line northeastward across western Pennsylvania and western New York as far as Little Valley in the Cattaraugus, New York, quadrangle.

(2) Ground moraine blankets the interfluve uplands of the region covered by this drift sheet. It consists predominantly of till, though a few small kames and kame fields have been noted.

(3) Drumlins dominate the topography of the ground moraine in a considerable area in western New York. They are 15-24 m high and between 0.8 km and 1.6 km long. Their axes show that the direction of ice motion was south-southeast at the time of their formation.

(4) Kame terraces are banked against the lower slopes of most of the major valleys.

(5) "Valley stopper" moraine. Within the plateau region many valley bottoms sloped northward. When an ice tongue lay in such a valley north of the bedrock divide, for a considerable time, marginal and frontal accumulation of a till and kame moraine took place, and a noteworthy valley train was formed, the top of which sloped southward from the morainal area to, and some cases across, the earlier divide. Numerous examples are seen of streams that head at the morainic area and flow southward on the outwash plains across the old divides. An exposure in such outwash near the head of Hinman Valley, Ellicottville quadrangle, shows 3.6 m of medium coarse gravel on 30 m of buff to blue-gray silt.

Twenty-three "valley stopper" moraines were mapped (Fig. 30) including a relatively large one immediately south of West Valley.

Valley Heads Moraine - The inner, or north, edge of the Binghamton drift is covered by the Valley Heads drift. This moraine, like the older ones, reflects the effect of the dissected plateau surface on the ice flow. The Valley Heads moraine is the most conspicuous accumulation of drift in New York State, and both its topographic and drainage influence are well displayed. The principal morainic masses are in the deep valleys of the plateau, with valley trains extending southward from them. Streams generally flow southward,

over the outwash, and northward from the moraine which therefore constitute a divide. Most of the valley segments of this moraine then are "valley stoppers".

The Valley Heads moraine enters New York State from the west as the continuation of the Lake Escarpment morainic system. It appears as a morainic belt 1.5 to 5 km wide extending east-northeast for some 80 km. At the western State line and over a considerable part of this distance the moraine is a single belt which may include locally two or more minor ridges. At the valley crossings, especially where the valleys are deep, a separate ridge is found south or outside of the main morainic accumulation.

At Arkwright a belt of moraine about 1.5 km wide crosses at the headwaters of Conewango Creek and swings down to connect with the great pile of morainic material east of Dayton in Cattaraugus Valley, where some 180 m of relief consists largely of drift. This blocking has had important influences on the local drainage of the Cattaraugus quadrangle.

Drift Thickness

Muller (1963) reports drift thickness in Chautaugua County commonly are in excess of 60-90 m and that near Markham (Cattaraugus County) 29 km west of West Valley the drift is 300 m thick. Muller (1960) reported a thickness of 189 m in a well near Gowanda (26 km west of West Valley). To the southwest, near the Pennsylvania border he described outcrops of drift 20 m thick.

Though no detailed description of the glacial deposits in the vicinity of West Valley was found, Sun (1973) quotes G. H. Chase (U.S.G.S.) as stating that the area in which the hydraulic fracturing test was run was blanketed by as much as 60 m of glacial drift.

APPENDIX

LE # 018420-000 SEP. 10, 1976
NT # THRESHOLD WT. 00000

BASE SEARCHED: LSGRDR V 73

TERM NO.	TYPE	WEIGHT	TERM
1	TXT	00000	GEOLOG*
2	TXT	00000	PLEISTOCENE
3	TXT	00000	GLACIAL
4	TXT	00000	GLACIER*
5	TXT	00000	DRIFT*
6	TXT	00000	TILL*
7	TXT	00000	MAP*
8	TXT	00000	STRATIGRAPH*
9	TXT	00000	STRUCTUR*
10	TXT	00000	ROCK*
11	TXT	00000	SHALE*
12	TXT	00000	LANDFORM*
13	TXT	00000	NEW YORK
14	TXT	00000	NY
15	TXT	00000	N.Y.
16	TXT	00000	N. Y.
17	TXT	00000	CHAUTAUQUA
18	TXT	00100	CATTARAUGUS
19	TXT	00000	ERIE
20	TXT	00000	ALLEGANY
21	TXT	00000	WYOMING
22	TXT	00000	GENESEE
23	TXT	00000	OLEAN
24	TXT	01000	WEST*
25	TXT	00000	MAYVILLE
26	TXT	00000	JAMESTOWN
27	TXT	00000	LITTLE VALLEY
28	TXT	00000	BELMONT
29	TXT	00000	WARSAW
30	TXT	00000	PERRY
31	TXT	00000	BATAVIA
32	TXT	00000	LE ROC
33	TXT	00000	ORLEANS
34	TXT	00100	ASHFORD
35	TXT	00000	BUFFALO

.EXP.G001&G002&G003

- Ayrton, W. G. (1963) Isopach and lithofacies map of the Upper Devonian of Northeastern United States, in Symposium on Middle and Upper Devonian Stratigraphy of Pennsylvania and Adjacent States, Shepps, V. C. ed., Penna. Geol. Survey, Bull. G-39, p. 3-6.
- Bordne, E. F. (1960) Water resources of a western New York region. Syracuse Univ. Press, 149p.
- Chiburis, E. F., Ahner, R. O. and Pomeroy, P. W. (1976) Northeastern U.S. Seismic Network, Bull. Seismicity N.E.U.S., March, 13 p., June, 25p.
- Colton, G. W. (1961) Geologic summary of the Appalachian basin, with reference to the subsurface disposal of radioactive waste solutions, U. S. Geol. Survey Trace Elements Inv. Rept. 791, 121p., U.S. Geol. Survey open-file report.
- Colton, G. W. (1970) The Appalachian Basin - its depositional sequences and their geologic relationships, in: Studies of Appalachian Geology: central and southern, Fisher, G. W. et al., ed., Interscience Publ. N. Y., 5-48.
- Cooper, G. A. (1957) Paleogeology of Middle Devonian of Eastern and Central United States, Geol. Soc. Amer., Memoir 67, 249-278.
- Cressey, G. B. (1941) Land-form regions of New York State (Abst.) Geol. Soc. Amer. Bull., 52, 1893-1894.
- Eardley, A. J. (1962) Structural Geology of North America, Harper & Row Publ., N. Y., 743 p.
- Fettke, C. R. (1955) Preliminary report on occurrences of rock salt in Pennsylvania. Penna. Geol. Survey, 4th ser. Progress Rpt. 145.
- Horbert, L. and Anderson, R. C. (1956) Bedrock topography and Pleistocene glacial lobes in central United States, J. Geol., 64, 101-116.
- Kay, M. (1942) Development of the northern Allegheny synclinorium and adjoining regions, Geol. Soc. Am. Bull., 53, 1601-1656.
- King, P. B. (1965) Tectonics of Quaternary time in middle North America, in: The Quaternary of the United States eds. Wright, Jr. H. E. and D. G. Fley, Princeton Univ. Press, Princeton, N. J. 831-870.
- Laguna, W. De (1973) Hydraulic fracturing test at West Valley, New York, Oak Ridge Natl. Lab., Rep. No. 4827, 62p.

- Lumsden, D. N. and B. R. Pelletier (1969) Petrology of the Grimsby Sandstone (Lower Silurian) of Ontario and New York, *J. Sedimentary Petrology*, 39, 521-530.
- MacClintock, P. and E. T. Apfel, 1944, Correlation of the drifts of the Salamanca re-entrant, New York, *Geol. Soc. Am. Bull.*, 55, 1143-1164.
- Manspeizer, W. (1963) A restudy of the Chautauqua Series of Allegheny County, New York, in *Symposium on Middle and Upper Devonian Stratigraphy of Pennsylvania and Adjacent States*, Shepps, V. C. ed., Penna. Geol. Survey, Bull. G-39, p. 259-277.
- Muller, E. H. (1960) Glacial geology of Cattaraugus County New York. *Friends of Pleistocene Geol. 23rd Ann. Meeting. Guidebook*, Syracuse Univ., 33p.
- Muller, E. H. (1963) Geology of Chautauqua County New York, Part II Pleistocene Geology, *New York State Mus. and Sci Service Bull.* 392, 60 p.
- Muller, E. H. (1965) Quaternary geology of New York, *The Quaternary of the United States*, ed. Wright, Jr., H. E. and D. G. Reay, Princeton Univ. Press, Princeton Univ., N. J., 99-112.
- Pepper, J. F. and de Witt, W. (1951) Stratigraphy of the Late Devonian Perrysburg Formation in western and west central New York. U. S. Geol. Survey Oil and Gas Inv. Chart OC45.
- Rickard, L. V. and Fisher, D. W. (1970) Geol. Map of New York, Niagara New York Mus. and Sci. Service Map and Chart Series No. 15.
- Sun, R. J. (1973) Hydraulic fracturing as a tool for disposal of wastes in shale in: *Underground Waste Management and Artificial Recharge*, V. 1, 219-270, *Am. Assoc. Pet. Geol.*, Tulsa, Oklahoma.
- Sutton, R. G. (1957) Lithofacies map of Upper Devonian in eastern United States, *Am. Assoc. Petroleum Geologist Bull.*, 41, 750-755.
- Tesmer, I. H. (1963) Geology of Chautauqua County, New York, Part I, Stratigraphy and Paleontology. *N. Y. State Mus. Sci. Service, Bull.*, 391, 65p.

Fig. 1 Counties of western New York. Black dot shows location of West Valley.

Fig. 3 Map of eastern North America relating major geologic and physiographic features to the study area. After Colton (1970).

Fig. 4 Configuration of the Precambrian basement floor in the Appalachian.
 After Colton (1970).

Fig. 5 Index map of the structural systems of the eastern margin of the continent.
After Eardley (1962).

Fig. 6 Geologic maps. Dct = Conneaut Group; Dcy = Canadaway Group.

Fig. 7 A, B, and C, distribution of principal lithologies composing the Paleozoic basin fill shown by lines of equal percentage: some restoration of younger Paleozoic rocks toward peripheral parts of basin. D and E include parts of the rock types shown in A-C. After Colton (1970).

Fig. 8 Isopach map of Lower Cambrian clastic sequence. After Colton (1970).

Fig. 9 Isopach map of Cambrian-Ordovician carbonate sequence. After Colton (1970).

Fig. 10 Isopach map of Upper Ordovician clastic sequence. After Colton (1970).

Fig. 11 Isopach map of Silurian clastic sequence. After Colton (1970).

Fig. 12 Stratigraphic sections for western New York. After Colton (1970).

Fig. 13 Isopach map of Silurian-Devonian carbonate sequence. After Colton (1970).

Fig. 14 Stratigraphic diagram from west to east in New York State showing the clastic wedge structure of the Devonian rocks and details of their lithology and thickness. After Kay (1942).

Fig. 15 Lithofacies map of Upper Devonian in northeastern United States.
After Sutton (1957).

Fig. 16 Oil and gas fields in western New York. Contours show elevation on the top of the Devonian clastic sequence. After Colton (1961).

Oil and gas fields

Fig. 17 Amount of postglacial uplift in northeastern Nor America.
After King (1965).

Fig. 18 Map of Middle North America showing distribution of recorded earthquake epicenters as of 1957. After King (1965).

Fig. 19 Earthquake epicenter October - December 1975 (Upper)
January - March 1976 (Lower). After Chiburis et al.
(1976).

Fig. 20 Correlation chart of Chautauquan Series from southeastern Allegany County to Jamestown, Chautauqua County, New York. After Manspeizer (1963).

Fig. 21 Stratigraphic cross section CD. After Manspeizer (1963).

Fig. 22 Stratigraphic - cross section EF. After Manspeizer (1963).

FIGURE 29 DIAGRAMMATIC CROSS SECTION SHOWING THE RELATIONSHIP OF THE MEMBERS OF THE PERRYBURG FORMATION IN WESTERN AND WEST-CENTRAL NEW YORK AFTER PEPPER AND deWITT (1951).

EXPLANATION

FIGURE 24 DISTRIBUTION OF SEDIMENTS IN LATE CANASERAGA TIME
AFTER PEPPER AND deWITT (1951).

EXPLANATION

FIGURE 25 DISTRIBUTION OF SEDIMENTS IN LATE CANADEA TIME
AFTER PEPPER AND deWITT (1951).

Fig. 26 Generalized geologic column of Chautauqua County area.
After Tesmer (1963).

Fig. 27 Pre-Pleistocene bedrock topography. After Horberg and Anderson (1959).

Fig. 28 New York, showing cities, rivers, and physiographic units.
After Muller (1965).

Fig. 29 Index map of the Salamanca region. After MacClintock and Apfel (1944).

Fig. 30 Drift deposits of Cattaraugus County. After MacClintock and Apfel (1944).