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Geologic and Hydrologic Research at the Western New York Nuclear Service Center West Valley, New York

Final Report
August 1982 - December 1983

Prepared by J. R. Albanese, S. L. Anderson, R. H. Fakundiny,
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New York State Geological Survey/State Museum
New York State Education Department

Prepared for
U.S. Nuclear Regulatory
Commission

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Boothroyd, J.C., B.S. Timson, and L.A. Dunne, 1982. Geomorphic Processes and Evolution of Buttermilk Valley and Selected Tributaries, West Valley, New York. Fluvial Systems and Erosion Study, Phase II. NUREG/CR-2862.

Boothroyd, J.C., B.S. Timson, and R.H. Dana, Jr., 1979. Geomorphic and Erosion Studies at the Western New York Nuclear Service Center, West Valley, New York. NUREG/CR-0795.

Dana, R.H., Jr., V.S. Ragan, S.A. Molello, H.H. Bailey, R.H. Fickies, R.H. Fakundiny, and V.C. Hoffman, 1980. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York, Low-Level Burial Site. Final Report, October 1978-February 1980. NYS Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-1565.

Dana, R.H., Jr., S.A. Molello, R.H. Fickies, and R.H., Fakundiny, 1979b. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York Low-Level Burial Site. Annual Report September 1977-September 1978. NYS Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-0794.

Fickies, R.H., R.H. Fakundiny, and E.T. Mosely, 1979. Geotechnical Analysis of Soil Samples from Test Trench at Western New York Nuclear Service Center, West Valley, New York. NYS Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-0644.

Hoffman, V.C., R.H. Fickies, R.H. Dana, Jr., and V.S. Ragan, 1980. Geotechnical Analysis of Soil Samples and Study of Research Trench at the Western New York Nuclear Service Center, West Valley, New York. NYS Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-1566.

ABSTRACT

This report is the last in a series by the New York State Geological Survey on studies funded by the U.S. Nuclear Regulatory Commission. The report covers five important aspects of the geology and hydrology of the Western New York Nuclear Service Center, near West Valley, New York: geomorphology, stratigraphy, sedimentology, surface water, and radionuclide analyses. We reviewed past research on these subjects and present new data obtained in the final phase of NYSGS research at the site. Also presented are up-to-date summaries of the present knowledge of geomorphology and stratigraphy.

EXECUTIVE SUMMARY

This is the final report of the New York State Geological Survey on geologic and hydrologic research, funded by the U.S. Nuclear Regulatory Commission, at the Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. The report contains five chapters on important aspects of this research: geomorphology, stratigraphy, sedimentology, surface water studies and radionuclide analyses, each containing a review of previous work and a summary of present knowledge.

The WNYNSC is drained by Buttermilk Creek, a tributary of Cattaraugus Creek which empties into Lake Erie. Buttermilk Creek flows northward, cutting through sediments occupying a deep bedrock valley. The bedrock valley dips north with its thalwey lying generally in the area as that of the present Buttermilk Creek. The unconsolidated sediments are up to 150 m (500 ft) thick and were deposited during multiple Pleistocene glaciations. Buttermilk Creek and the tributaries that drain the plant exclusion (security) area occupy narrow, V-shaped, post-glacial valleys. The average downcutting rate is approximately 18 cm/century (0.6 ft/century). Most of the sediment carried by the streams probably was supplied most directly from alluvial fans but landslides also are a significant source. Where the valley walls are undercut, landslides supply discrete blocks and slumps to the streams. Data collected from monitoring site runoff and groundwater levels will be incorporated into hydrologic models by the United States Geological Survey.

The entire security area is underlain by an unbedded silt-clay unit with less than 10 percent pebbles and discontinuous pods of silt and sand. This unit, the Lavery till, averages 18 m (60 ft) thick. In the northern half of the security area the Lavery till is overlain by an average of 6 m (20 ft) of gravel. Below the Lavery till is a discontinuous silty sand unit, up to 6 m (20 ft) thick where present. Below that is a unit of laminated silt and clay, generally 3 to 6 m (10 to 20 ft) thick, thinning toward the west. In the deepest holes drilled to date, as many as three more units have been identified above the shale bedrock: two more unbedded silt-clay units (till), separated by another laminated silt-clay unit.

Both the NYS- and NRC-licensed burial areas for solid nuclear waste are contained within the Lavery till, in the southern part of the security area where the unit is exposed at the surface. The sedimentology of the Lavery till is remarkably consistent, with silt and clay comprising 60 to 90 percent of the volume. The major minerals found are

chlorite, illite, and quartz.

Radionuclide analyses have been performed on many types of samples from around the burial areas, including sediment core and water samples from holes recently drilled in cooperative NYSGS-USGS programs. As in earlier studies, no unusual levels of radioactivity have been detected.

In December of 1983 USGS personnel extracted water samples for the first time from holes drilled aound the NRC-licensed burial area in the fall of 1982. Hole 82-5A was found to contain kerosene, contaminated with low concentrations of several radionuclides. This final report was already in review at that time, so we have not attempted to address the problem of kerosene leakage in this report.

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All radiochemical analyses were performed under contract by RSL of NYSDOH.

ABBREVIATIONS

I. Names of Agencies, Companies and Sites

A. State Agencies: NYS-New York State

NYSASDA	Atomic and Space Development Authority (predecessor of NYSERDA)
NYSDEC	Department of Environmental Conservation
NYSDOH	Department of Health
RSL	Radiological Sciences Laboratory (of NYSDOH)
NYSDPW	Department of Public Works
NYSERDA	Energy Research and Development Authority
NYSGS	Geological Survey
NYSPSC	Public Service Commission

B. United States Agencies: US-United States

USDOE	Department of Energy
USEPA	Environmental Protection Agency
USGS	Geological Survey
USNRC	Nuclear Regulatory Commission

C. Companies

D and M	Dames and Moore
NFS	Nuclear Fuel Services, Inc.
WVNS	West Valley Nuclear Services Co.

D. Sites

WNYNSC	Western New York Nuclear Service Center
NRC-licensed burial area	for plant generated solid radioactive waste, licensed by USNRC.
NYS-licensed burial area	for commercial burial of low-level radioactive waste, licensed by NYS.

II. Units of Measurement

cm	centimeter or centimeters
cu	cubic
ft	foot or feet
in	inch or inches
km	kilometer or kilometers
m	meter or meters
mi	mile or miles
mm	millimeter or millimeters
uCi/ml	microcuries per milliliter
uCi/g	microcuries per gram
sec	second or seconds
yr	year or years
YBP	years before present
A	angstrom

1.0 INTRODUCTION

This report is the last in a series of progress, annual, and topical reports from the New York State Geological Survey (NYSGS) on geologic and hydrologic research at the Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. The NYSGS has been involved in studies at the site since 1975, often in cooperation with the United States Geological Survey (USGS) Water Resources Division, and the Radiological Science Laboratory (RSL) of the New York State Department of Health (NYSDOH). Major funding for these studies was obtained from the United States Environmental Protections Agency (USEPA) from 1975 through 1979, and from the United States Nuclear Regulatory Commission (USNRC) from 1979 through 1983.

The primary interests of the NYSGS have been geomorphology, stratigraphy, sedimentology, and surface water hydrology. The NYSGS also has participated with the USGS in a cooperative program to study groundwater hydrology, and with the USGS and RSL in studies related to radionuclide migration pathways and monitoring.

In this final report we present new data from the past year and a half of research. We also provide summaries of past reseach on several topics. Finally, we present up-to-date interpretations of several aspects of the geology. the extensive list of references and the historical summaries can be used as a guide to a majority of the scientific studies that have been done at the site.

2.0 GEOMORPHOLOGY

2.1 History of Glacial, Geology and Geomorphological Investigations

2.1.1 Introduction

Many studies were done from 1961 to the present on the geology and geomorphology. Siting and safety studies at the WNYNSC were also performed. The following is a summary of the highlights of the studies from the first siting study up to the most recent geomorphological investigation.

2.1.2 Preliminary Studies on Plant Area

The geologic studies at the WNYNSC site were started in 1961 by: 1) a private firm - Nuclear Fuel Services (NFS); and 2) state and federal agencies. Much of the initial fieldwork was done by the latter group.

The NYS Department of Public Works (NYSDPW) drilled holes and logged the cores, and ran seismic refraction studies. With this information they compiled cross-sections showing the bedrock valley. They interpreted the glacial material filling the valley to be from 1.5 m to 152 m (5 to 500 ft) thick. Little additional information has been collected subsequently to determine the shape of the bedrock valley Several holes have been drilled purposely to bedrock, at the construction site in the course of foundation planning, and in NYSGS-USGS studies near the burial areas and on the North Plateau (See Plate 1).

J.G. Broughton (NYSGS) and H.G. Stewart (USGS) performed on an initial geologic study. They found two different types of drifts deposited by advancing and retreating glaciers on the surface at the central part of the site: (1) till (silt and clay with minor amounts of sand and stones); and (2) stratified coarse granular deposits (mainly sand and pebbles). Each unit was thought to be up to 7.5 m (25 ft) thick. Drilling revealed two more types of deposits in the subsurface: (3) outwash (stratified, well sorted sands and gravels, in layers up to 3 m (10 ft) thick); and (4) lacustrine material (fine-grained, thin-bedded sands, silts and clays thought to be up to 15 m (50 ft) thick). Cross-sections from their reports show a second till unit under the lacustrine beds, but it is not described in the text (Broughton and Stewart, 1963; Stewart, 1962a, 1962b).

Lab tests were run on 50 samples taken from the four glacial units and the bedrock by the USGS Geochemistry and Petrology

Branch, including determinations of ion exchange capacity, pH, clay mineralogy, semi-quantitative spectrographic analysis, and rapid rock determination of rock chemistry. Samples were also taken near the NYS-licensed burial area by USGS personnel in 1963.

Three potential aquifers were identified by Broughton and Stewart (1963) at this time. Groundwater movement in the stratified coarse granular deposits was estimated incorrectly to be about 1.3 ft/day or .00045 cm/sec.

The first NFS Safety Analysis Report (Nuclear Fuel Services, 1962) used the results of the field work by Broughton and Stewart and the NYSDPW data. One of the reasons for the report was to determine the best location for the fuel reprocessing plant.

Muller (1963), of Syracuse University, worked in the area under contract with the NYSGS. His work was on a regional scale, however, and did not concentrate on the West Valley site specifically. He delineated the glacial oscillations and constructed a time-stratigraphic column, the first for western New York.

2.1.3 Initial Studies for Plant Construction

Dames and Moore (1963), working for Bechtel, drilled 22 holes for foundation studies after the preliminary work had been done in 1961-1962, and described the engineering characteristics of the glacial deposits encountered. Dames and Moore remained active in subsurface investigations throughout the history of site operation. These investigations are reported in more detail in Chapter 3 on Stratigraphy.

After the initial geologic work was done by private firms and State and Federal agencies as required by federal law, the plant permit was issued in 1963 and construction of the plant began. Construction was completed in 1965, and operations began in April 1966.

2.1.4 Studies Related to Plant Expansion Plans

In 1969-1970 NFS considered expanding the plant, and contracted with Dames and Moore (1970) to study the area and determine the feasibility of locating another building on site. The study included two new borings and examination of borings drilled previously. More testing was done on the sediments, confirming the results of previous engineering analyses.

Dames and Moore (1971a and b) produced two reports. The 1971a report consisted of correlations using the existing groundwater and geologic data. The descriptive terms for the glacial materials were redefined. This report mentions the difficulty encountered in differentiating between the till and the lacustrine silts and clays, a problem found in most of the early reports. The 1971b report described two undisturbed samples, and three borings to bedrock.

2.1.5 Initial Work Near the Burial Area**

Duckworth and others (1974), working near the low-level burial area discussed the soil characteristics, the effects of leaching and the methods available for immobilizing the radioactive waste. This paper also reported on a group of test borings on the margins of the NYS-licensed burial area drilled in 1973 and 1974 by New York State Atomic and Space Development Authority (NYSASDA) and NFS.

A paper by Giardina and others (1977), of the USEPA, was a literature review covering past siting studies, outside surveillance reports, NFS surveillance and operational reports, and health effects studies. This paper also discussed the 1973-74 drilling project. Funds from USEPA helped support the second year of that project.

2.1.6 Joint NYSGS-USGS Studies Near the Burial Area

The joint studies were done initially under a cooperative agreement between state agencies and the USG, funded by the USEPA. Later studies, as indicated below, were funded by the USNRC. The USGS also began an independent study of West Valley in 1975, as part of a project on seven low-level radioactive waste burial areas around the nation. The cooperative studies at West Valley were initiated to determine what characteristics control potential radioactive waste migration in groundwater. While this research was in progress engineering studies were also being done on possible expansion of the plant. At this same time, water levels were rising (approx 1 gallon/day) inside Trenches 4 and 5 in the NYS-licensed burial area, under surveillance by the NYSDEC. In March of 1975 water was found to be seeping out through the trench covers. The source of the water entering the trenches was not known, but was thought to be either from precipitation infiltrating through the trench covers, or groundwater entering through the trench floors and walls. Water was removed from the trenches for treatment

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** *A geological sampling report (Waller & Clebsch 1963) by USGS Radiohydrology Section was located after the Final Report Review. NYSGS Open-file.*

to bring down the water level.

Another study of this group was made by Fleming (1976), who produced a USGS Open-file Report containing recommendations for future studies. The report was concerned mainly with landslides in the uppermost till unit.

The first detailed glacial geologic report was written by LaFleur (1979) under contract to NYSGS and funded by a USGS research grant. He produced six maps on a scale of 1:24,000, covering an area of 165 square miles with the WNYNSC approximately in the center, and one map on a scale of 1:200 covering the burial area. He interpreted the uppermost till at the plant and burial ground as Lavery, or possibly Lavery and overlying Defiance (Late Wisconsinan, approx. 15,000 YBP; see Table 1). He defined the lithologies and landforms in terms of glacial depositional environments, glacial geologic history, mode of deposition, and traceable landforms for the first time. See the following section on glacial geology for more detail.

Three research trenches were dug outside the security area but in geologically similar situations to the low-level burial area to simulate the conditions in the trenches already in use. Samples from Research Trench III, dug in 1977, were analyzed and discussed by Mosely (1977) in a letter report to the NYSGS. Tests run included moisture content, unit weight, Atterberg limits, unconfined compression, dispersion, swelling, permeability, and consolidation coefficient. Results on the first year's work were published by Dana and others (1979a, 1979c); and Fickies and others (1979). A major contribution of this study was the documentation of the random distribution, orientation, and disconnectedness of the stratified lenses, and the systematic pattern of and theoretical depth limit of the fractures within the burial till. Fractures were not observed below 5 m and by applying the engineering test data can not exist as open cracks theoretically below 15 m.

Research Trench III was allowed to sit open and collect precipitation for nearly two years. The trench was pumped, then the same engineering tests were run again, and analyzed by Hoffman (1979). Test results showed an increase in moisture content and a decrease in strength and unit weight, indicating a swelling of material. These results were reported in a letter report to the NYSGS by Hoffman (1979), and published by Hoffman and others (1980); and Dana and others, (1980). Moisture-laden trench walls collapsed during the trench flooding period.

Continuing his broad regional studies, Muller (1977b)

Table 1. Stratigraphic Column of Glacial Units for West Valley, New York and Surrounding Area.

Time-Stratigraphic Name	Deposited YBP	Unit Description
HOLOCENE	< 10,000	Predominantly degradational regime.
LATE WISCONSINAN GLACIATION	14,000-10,000	Degradational regime (?) (no radiocarbon dates available for this range)
	14,200-14,000	Valley heads recessional moraines and outwash (north of burial area)
	15,000-14,200	Post-Lavery outwash and alluvial fans (plant area)
	15,500-15,000	Lavery (with overlying Defiance ?) till (NYS-Licensed area)
	16,000-15,500	Subaerial erosion of kame deltas
	18,000-16,000	Post-Kent recessional kame deltas
	22,000-18,000	Kent till
EARLY OR MID WISCONSINAN(?) GLACIATION	> 22,000	Proglacial lacustrines over a third till

* Modified from LaFleur 1979a. 1983, and Muller (personal communication)

refined the chronology of the glacial geology of Western New York in an article in the New York Academy of Science Annals.

Whitney (1977) produced a NYSGS Open-file Report of geochemical analyses done on soil samples taken from two locations along Frank's Creek shown on index map. He found that the till mineralogy reflects the bedrock composition within fifty miles to the north and that mineralogical differences exist between the fresh and weathered clays. An important find was that the pebbles in the streams have a manganese coating, creating a negative surface charge. These pebbles have the potential to become a sink for certain radioactive elements, allowing for the possible accumulation of these radioactive elements along stream bottoms.

Prudic and Randall (1977) of the USGS performed the initial detailed groundwater investigations at West Valley. Piezometers were installed in holes drilled in 1975-1976 near the NYS-licensed burial area; some of these wells continue to be monitored today. The USGS (Ithaca) oversees continued monitoring and files the data. These wells were used to obtain samples for radionuclide analyses and for water levels to be used in a computer model of the groundwater hydrology around the burial trenches. Hydraulic conductivity of the till was determined by both field and laboratory procedures.

Working under contract with the NYSGS, Boothroyd and others (1979) published a report describing the short-term geomorphic processes acting on the Buttermilk Creek valley, based on a systematic and erosion study of a reach of the Buttermilk Creek. They investigated sediment yield and mass wasting to establish a denudation rate for this drainage basin. They produced maps of the environmental geology, areas of mass wasting, and stream drainage patterns. This project was funded as a subcontract to the NYSGS, paid for by the USNRC.

A study of precipitation infiltration into undisturbed Lavery till was done by Dana and others (1979b). They concluded that the high clay content rejects about two-thirds of precipitation and drives it to runoff and evapotranspiration in the warm months, and nearly all to runoff in the cold months.

The Friends of the Pleistocene 43rd Annual field trip was held in West Valley in 1979 at the request of the research team. Considerable detail of the Late Wisconsinan stratigraphy at the WNYNSC and in the general area were presented for the first time in the guidebook, which includes papers by: Calkin and Muller (1980); LaFleur (1980a); Fakundiny and others (1980); and Randall (1980).

In 1980, LaFleur presented two brief studies supported by the USGS as a continuation of the earlier NYSGS study. The first (1980b) report to the USGS contained longitudinal profiles for the Cattaraugus, Connoisarauley and Buttermilk Creeks. A downcutting rate of approximately 0.6 m per 100 years (2 feet per 100 years) through glacial drift and .33 m per 100 years (1.1 ft per 100 years) in bedrock was estimated using radiocarbon dates. The second (1980c) report was a letter report to Prudic (USGS) describing the petrology of Lavery till. LaFleur found no textural indication that the permeability should be greater horizontally than vertically. Clustered laths of illite form a fabric of conjugate incipient shears, with the acute angle of intersection of the conjugate shear sets ranging from 45 to 90 degrees. The shears range up to 5 mm long, and are in bundles 5 to 500 microns thick.

In 1982, Boothroyd and others published the second phase of the geomorphic study of Buttermilk Creek and its tributaries. They determined that most of the erosion, such as bar and channel movements of the unconsolidated sediments takes place during flooding events. According to their studies, Frank's Creek is not yet in equilibrium with the base level of the Buttermilk and will continue to downcut. The lowering of the Buttermilk Creek is, in turn, controlled by the bedrock floor in both the Cattaraugus and lower Buttermilk Creeks. Boothroyd and others also found that slumping and landslides are continuous processes.

The report by Albanese and others (1982) of the NYSGS under contract to the NRC was an update on all available data. Better stream level monitoring was accomplished during this time period. A 1:1200 topographic map was made and the geometry of the North Plateau surficial gravel was determined using 10 new drill holes.

Albanese and others (1983) published a second progress report. One important advance was that a map of the area was made showing five domains of varying landsliding potential within the security area. Monitoring of landslides was begun by Boothroyd and Timson in 1978 and is being continued by the NYSGS.

LaFleur (1983), in a regional study of Buttermilk and Cattaraugus Creeks, found that the long-term (last 6,000 years) erosion of the Buttermilk Creek has been orderly and consistent and that the overall rate of downcutting in the tributaries increases downstream in apparent response to discharge. The rate is, however, variable from stream to stream. He found that initiation of erosion of the bedrock takes place during low flow during the wet-dry cycles, when the stream bed is exposed to sunlight and dries out. By contrast, in the unconsolidated sediments the greatest erosion takes place during flooding events. The rate of erosion in the Cattaraugus Creek increases from the headwaters, peaks, and then decreases as it approaches the Lake Erie base level. Projection of the rate of erosion for the Buttermilk for the next 2,000 years is approximately 0.15 to 0.21 m (0.7 to 0.5 feet) per 100 years.

Boothroyd and Timson (1983) continued the geomorphological investigations on the Buttermilk Creek and its tributaries. They resurveyed the Buttermilk Landslide and continued their studies of clast movement.

2.1.7 Summary

The many studies that have been done over the last 20 years to address federal, state and private concerns at the WNYNSC have provided for a fairly broad background of geologic knowledge. Original studies were done for site location, then for site expansion, then a study of seven low-level areas around the nation to determine what characteristics affect potential for radioactive waste migration, and finally to determine the integrity of the low-level burial area at West Valley, NY.

Delineating the boundaries of the glacial units has been achieved by detailed glacial mapping and aided by the use of well logs. Engineering tests and sediment size analyses have allowed us to define the units more thoroughly.

Short and long term erosional rates have been estimated for the Buttermilk Creek and its tributaries.

The studies discussed in this section are summarized in Table 2.

2.2 Glacial Geology

2.2.1 Introduction

The following section is the present interpretation of the glacial geology in and around the WNYNSC, based on field work and interpretation of drill logs.

Table 2. History of geomorphology studies of the WNYNSC and vicinity. Dates indicate year of study publication.

Work Performed By	Funded By	Results
Broughton & Stewart 1963	NYSGS/ USGS	Found four units: 1) sandy gravelly till; 2) dense silty clayey till; 3) outwash; and 4) lake deposits. Did first chemical analysis of the glacial deposits. Groundwater movements in uppermost coarse granular unit is 1.3 ft/day or .00045cm/sec.
NFS Safety Analysis Report 1962	Bechtel	Summarized results of Broughton & Stewart in a study designed to determine the location for the fuels reprocessing plant.
Dames & Moore 1963	Bechtel	Initial enginnering investigation of two adjacent sites; the present site was chosen. Found glacial sediments 100 ft. thick near plant ranging to 300 ft thick near Buttermilk Creek. Units described with respect to engineering characteristics. Groundwater found 2 to 5 feet below the surface.

Table 2. continued

Work Performed By	Funded By	Results
Muller 1963	NYSGS	Delineated major glaciations and interstades. First glacial geology time-stratigraphic column.
Dames & Moore 1971a	NFS	Glacial materials now called till, lacustrine clay and outwash. Moraines along valley walls. No simple stratification. Determined that valley walls and soil underlying plant are similar in engineering properties.
Duckworth, Jump & Knight 1974	NFS	Concerned with radionuclide transport in groundwater from the low-level burial area. Discussed soil characteristics and effects of leaching in burial till.
Fleming 1976	USGS	Landslide investigation. Determined that depth to failure surface is less than 10 feet on natural slopes.
LaFleur 1979	USGS	Till complex is Late Wisconsinan (see Table 1). Described depositional environments in terms of glacial geologic history and traceable landforms. Units include kame deltas, lake beds, moraines, outwash and alluvial fans. Lavery has three subfacies.
Giardina, Debonis,	USEPA	Literature review of siting, health effects

Table 2 continued

Work Performed By	Funded By	Results
Eng & Meyer 1977		and surveillance studies.
Mosely (Raamot Associates) 1977	NYSGS	Research Trench III initial engineering study. Clay has low to medium plasticity and is considerably disturbed and over consolidated.
Muller 1977a	NYSGS	Mapped glacial geology on a regional scale. Attempted to develop chronology for Western New York.
Muller 1977b		Refined chronology of glacial geology in Western NY in *New York Academy of Science Annals*.
Whitney 1977	NYSGS	Burial till mineralogy reflects bedrock composition within 50 miles to north. Mineralogical differences between fresh and weathered clays. Mn coatings have a negative surface charge, and are therefore a sink for Cesium, Cobalt, etc.
Prudic & Randall 1977	USGS	May be lateral groundwater flow at bottom of lacustrine unit, dry at top. Recharge through cracks in burial till.
Boothroyd, Timson	USNRC	System and erosion study of a reach

Table 2. continued

Work Performed By	Funded By	Results
and Dana 1979		of Buttermilk Creek. Investigated sediment yield and mechanics of erosion and mass wasting to establish a denudation rate for the drainage basin.
Dana, Molello, Fickies and Fakundiny 1979	NYSGS	Precipitation infiltration study. Little infiltration occurs; precipitation goes mainly to runoff and evapotranspiration.
Dana, Fakundiny, LaFleur, Mollello and Whitney 1979	NYSGS	Report on initial study of Research Trench III. Documentation of random, discontinuous and sand and gravel lenses. Detailed glacial investigation documented systematic pattern & reduced frequency with depth of fractures within Lavery till. (Pattern same as regional topographic pattern)
Fickies, Fakundiny and Mosely 1979	USNRC/USEPA	Discussed results of initial standard engineering tests on burial area till from Research Trench III.
Hoffman 1979	USNRC	Letter report to NYSGS on test results of Research Trench III investigations after two years.

Table 2. continued

Work Performed By	Funded By	Results
LaFleur 1980a	FOP Guidebook	Field trips detailing Late Wisconsinan stratigraphy at West Valley and surrounding area.
Calkin and Muller 1980	FOP Guidebook	Geologic setting and glacial overview of the Upper Cattaraugus Basin.
Fakundiny, Fickies, Bailey, Dana, and Molello 1980	FOP Guidebook	Brief overview of site and geology.
Randall 1980	FOP Guidebook	Defined stratigraphy in part of Buttermilk Creek.
Hoffman, Fickies, Dana and Ragan 1980	USNRC	Standard engineering tests done on Trench III two years later confirm 1977 test results. There was an increase in moisture content, a decrease in strength and unit weight, indicating a swelling of the soil.
Dana, Ragan, Molello, Bailey, Fickies, Fakundiny and Hoffman 1980	USNRC	Final report on evaluation of containment capability of low-level solid radioactive waste burial area at West Valley. Testing 2 years later confirmed results of the 1977 Research Trench III Studies.

Table 2. continued

Work Performed By	Funded By	Results
LaFleur 1980c	USGS	Radiocarbon-dated alluvial deposits, Upper Cattaraugus Creek Basin.
LaFleur 1980b	USGS	Petrographic analysis of Lavery till. No textural indication that permeability should be greater horizontally than vertically. Bedding classified by color, not texture.
Boothroyd, Timson and Dunne 1981	USNRC	Second phase of Geomorphic Studies in Buttermilk Creek and tributaries. Suspended sediment discharge in Buttermilk Creek during a one year flood was equal to 69% of the estimated yearly erosion of till in West Valley. (3000 cu m of in-place till). Downslope movement of landslides by slumping is a continuous process. Longitudinal profile of Franks Creek suggests it is unstable and will continue to rapidly downcut. Valley widening will occur by slumping. Lowering of Buttermilk Creek is controlled by bedrock floors in Cattaraugus Creek and lower independently of a change in base level of Buttermilk Creek.
Albanese, Dunne, Rogers & Potter 1982	USNRC	Established geometry of surficial gravel on North Plateau. 1:1200 topographic map was developed. Geometry of North Plateau surficial gravel determined using new drill holes.

Table 2. continued

Work Performed By	Funded By	Results
Prudic 1982	USGS	Determined hydraulic conductivity of the Lavery till using slug tests, lab tests and calculations from mercury porosimeter tests. Determined that horizontal and vertical hydraulic conductivity are almost identical, at 2 x 10-8 cu/sec.(7 x 10-10 ft/sec).
Albanese, Anderson Dunne & Weir 1983	USNRC	Stratigraphy more fully defined. Better correlation of glacial units using drill holes, grain size distributions, and isopach maps. Contining geomorphic studies.
Potter, Albanese, Anderson & Whitbeck	USNRC	Report of fall 1982 joint USGS-NYSGS drilling project. Defined stratigraphy more fully around USNRC burial area.
LaFleur 1983		Erosional study of the Cattaraugus Creek Drainage Basin.
Boothroyd & Timson 1983	USNRC	Continuing geomorphic studies.

2.2.2 Current Interpretation of Glacial Geology

The mapping of the glacial materials and interpretation of the depositional environments of the unconsolidated sediments at the WNYNSC and surrounding area (see Fig. 1) has been an important part of geological studies there, as the solid waste is buried in the uppermost glacial till. The facilities of the Center lie on the late Wisconsin till complex (Table 1) that floors the Buttermilk Creek valley and its tributaries (see Fig. 2).

The bedrock underlying this area is the shale and sandstone of the Upper Devonian Canadaway and Conneaut Groups (Tesmer, 1975). Steep-walled valleys were scoured by glaciation and modified by meltwater early in the glacial history of the area. Repeated glaciations have veneered the plateau and filled the valleys with tills (unsorted, unstratified, unconsolidated material deposited directly by the glacier), lacustrine sediments (deposited in lakes), morainal deposits (any variety of landforms composed of till), and outwash (stratified material deposited by glacial meltwater) (LaFleur, 1979). In the valleys, the glacial deposits are up to 150 m (500 ft) thick (Nuclear Fuel Services, 1962). The till is thinner on the hillsides and is 1.5 m (5 ft) or less in thickness on the summits of hills (LaFleur, 1979). Table 1 lists the major geologic events through this period, with age estimates.

The oldest known sediments found in the Buttermilk Creek valley are deposited on bedrock and constitute a till, older than the Kent. This till is blue gray to dark gray silt and clay, and has < 20 percent clasts and rock fragments. About 5 m (16.4 ft) of this till was found in drill hole 83-4E. This is the only sample of a third till unit in the Buttermilk Valley. Directly overlying this till is a lacustrine deposit, indicating retreat of the ice northward in the Buttermilk Valley. This lacustrine unit is composed of stratified sands, silts and clays. These two pre-Kent units may be of late Mid-Wisconsinan (>24,000 YBP) age (Calkin and Muller, 1980).

The third till and Kent till are not as well documented as Lavery till. The Kent till has been identified in other locations in the field area, but the third till has not been positively identified, or correlated with other pre-Kent tills in the region. Further drilling in the center of the buried valley is needed before any conclusions can be drawn.

As the ice readvanced, Kent till was deposited in early Late Wisconsinan (24,000 YBP to 18,000 YBP). Kent till is exposed chiefly in the uplands and along the valley sides, where it

Figure 1. Map of a portion of the WNYNSC, showing simplified surficial geology (after LaFleur, 1979).

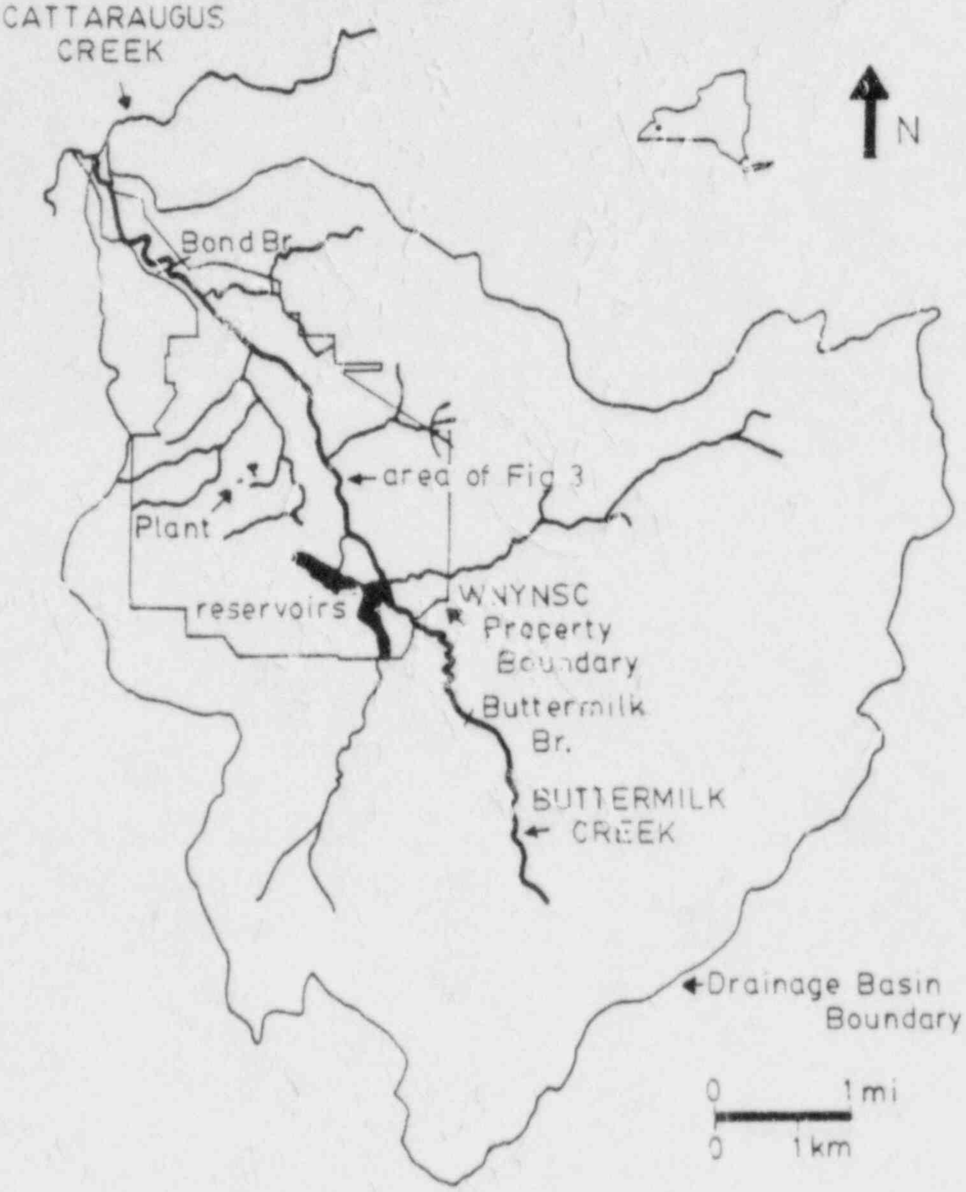


Figure 2. Map of the Buttermilk Creek drainage basin, showing the outline of the WNYNSC. The Buttermilk-Bond Reach studied by Boothroyd and others (1979, 1982, 1983) is between Buttermilk and Bond Bridges.

has less than 5 percent exotics (material, usually pebbles and cobbles, formed elsewhere and brought in by the glacier), is weakly calcareous, and greenish gray, oxidized to grayish orange. However, some Kent till and gravel is highly calcareous, pale red, and contains 20 to 40 percent exotics. The Kent found on the valley floors beneath the Lavery till is of the former type.

After the Kent till was emplaced, the ice withdrew into the Erie basin. The ice retreated past a proglacial lake in the Buttermilk Creek valley depositing at least three sequences of kame deltas, one under the WNYNSC (18,000 - 16,000 YBP) (LaFleur, 1979). These deltas are composed of topset beds of pebble gravel with foreset beds of turbidite sand and silt, prograding southward over bottomset beds of rhythmic clays (LaFleur 1979).

As deglaciation proceeded, the proglacial lake drained (Erie Interstade 16,000 to 15,500 YBP), exposing the kame deltas and lacustrine floor to subaerial erosion.

The ice readvanced only into the valley bottoms during the middle Late Wisconsinan (15,500 to 15,000 YBP). The ice advanced through impounded proglacial lake waters and reworked and deposited the silt- and clay-rich lacustrine sediments as Lavery till. Lavery till is silty with minor interbedded silty clay. At times the ice may have been buoyed up by a hydrostatic head as it overrode the muddy substrate (LaFleur, 1979), forming pods of stratified pebble silts and clays when the ice floated free of the bottom and allowed the deposition of water-sorted sediments to occur. Subsequent regrounding of the ice may account for the structural deformation found in both the till and these "lacustrine pods" (LaFleur, 1979). This advance of ice terminated at the hamlet of West Valley, and formed a valley plugging moraine. This border is about 2 miles north of the Kent till border (LaFleur, 1979).

Alluvial gravel was deposited on top of the Lavery till as the ice front again receded northward (15,000 to 14,200 YBP). A post-glacial alluvial fan was deposited after the ice had retreated. This fan overlaps the outwash gravels (towards the center of the valley). These two gravels are similar in grain size distribution.

2.2.3 Summary

Glacial advances and recessions during Mid- and Late-Wisconsinan time deposited a series of processional and recessional glacial units in the vicinity of West Valley, New York. The burial areas at the WNYNSC are located in the uppermost till. Delineating the stratigraphy is important in determining the integrity of the burial till.

2.3 Fluvial Geomorphology

2.3.1 Introduction

The fluvial geomorphology of the WNYNSC area may have developed as early as 14,000 YBP (the date of deposition of the outwash to the north of the WNYNSC) and is important because it can be used to determine erosion rates at the burial area. The lack of radiocarbon dates between 14,000 YBP and 9,900 YBP leaves a gap in the geologic history of the WNYNSC and surrounding area.

The fluvial geomorphology of the Buttermilk Creek and its tributaries has been studied to determine the short- and long-term changes of the valleys and the possible future effect of erosion on the burial areas at the WNYNSC.

2.3.2 Current Interpretation of Fluvial Geomorphology

Post-glacial incision of the Buttermilk Creek and its tributaries is thought to have begun in the Holocene, prior to 9,920 ± 240 YBP, the age of the oldest dated fluvial terrace. Incision may have begun as early as 14,000 YBP (late Late Wisconsinan) (see Table 1), but radiocarbon dates are lacking for the time interval 14,000 to 9,920 YBP, so the geological environment for that interval can only be inferred through relationships with other units. Alluvial fans were deposited on top of the Lavery till (see the previous section and Fig. 1 for more detail), as the northward flowing drainage developed (Boothroyd and others, 1979). Upon integration this drainage became the Buttermilk and its tributary systems. The Buttermilk Creek has cut through as much as 40 m (130 feet) of unconsolidated material and bedrock since incision began.

The Buttermilk-Bond reach, the most intensively studied section of the Buttermilk Creek (see Fig. 3), is a high-gradient, degrading stream. The gradient-clast size relationship is similar to that of many gravel-bed braided streams (Boothroyd and others, 1979). The bar and channel geometry consists of large bar complexes, each with a complex microtopography. Figure 3 is a diagram of bar complex 4-6 showing bar size and areas of deposition and erosion over the time period 1978-1980 (Boothroyd and others 1982). Distance of movement of these bars varies, but has

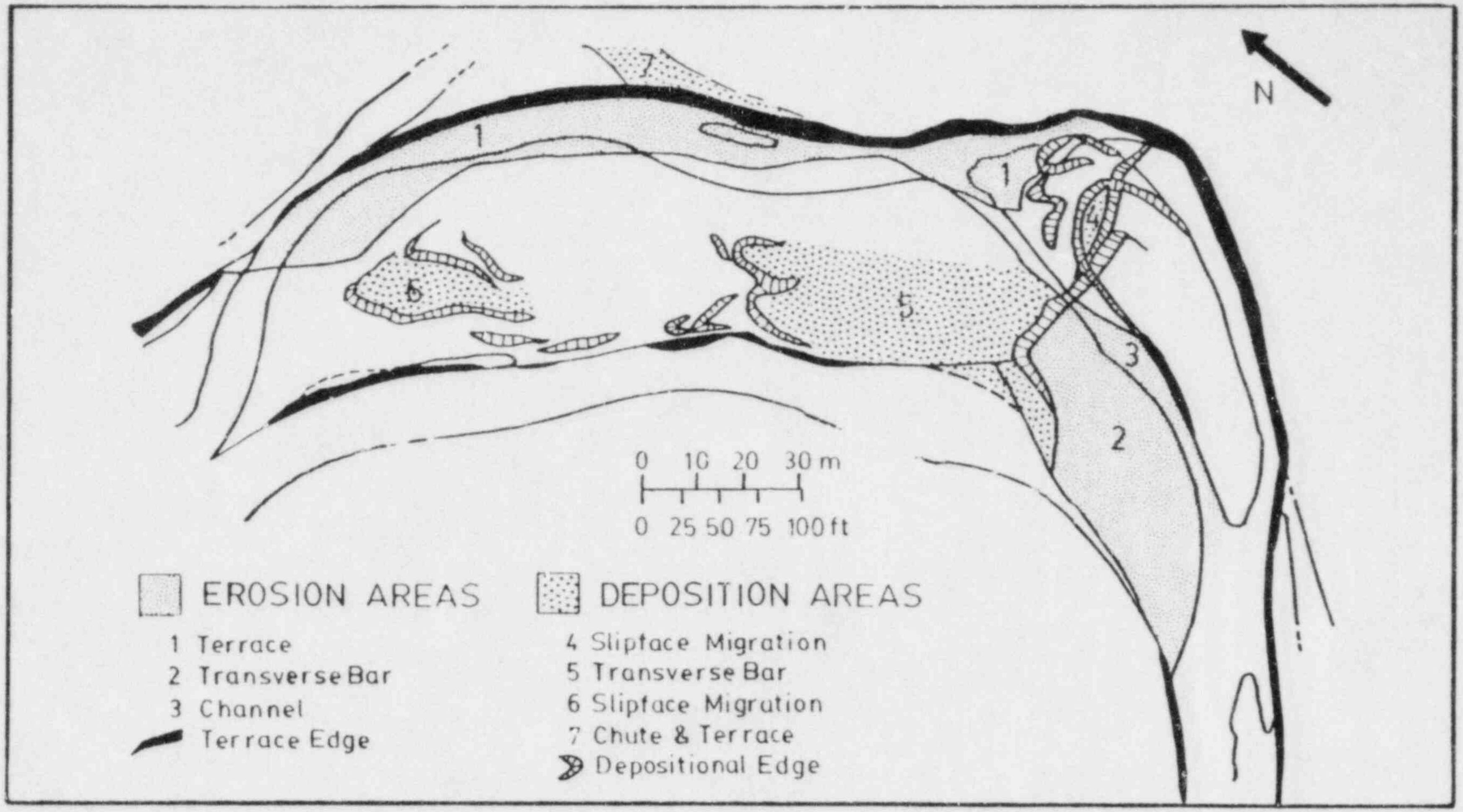


Figure 3. Map of a bar complex on Buttermilk Creek studied by Boothroyd and others (1979, 1982, 1983).

been as much as 60 m during flooding events. Movement of these bars and of cobbles occurs only during high flow. According to Boothroyd and others (1979), movement occurs because more of the bars are under water during high-flow, allowing for the transport of more material. These high-flow situations occur because the tills covering the Buttermilk drainage are clay rich and has a very low infiltration rate, thereby producing high runoff during storms.

During one of the high-flow events in 1979, 69 percent of the estimated yearly erosion of the till in the Buttermilk Valley was moved as suspended sediment. This is equal to 3000 cubic meters of in-place till (Boothroyd and others, 1982).

Lateral erosion and landsliding as a result of channel migration are very active processes in the Buttermilk-Bond reach, particularly in the vicinity of the NYS-licensed burial area. The migrating channel undercuts the bank, causing the slope to become unstable and slump. The toe of the slides at times alters the course of the stream.

LaFleur (1983) determined that the downcutting rates in the Buttermilk are about 0.15 to 0.21 m/100 yr (0.5 to 0.7 ft/100 yr), expected to continue for the next two thousand years. During this time period, base level will lower some 3 to 4.3 m (10 to 14 ft). The mechanisms for downcutting include scarp retreat of the nickpoints in both the bedrock and glacial materials, and wearing away through grain loss and solution (LaFleur 1983).

The longitudinal profile of Frank's Creek, which drains the NYS-licensed burial area, is convex, suggesting that it is unstable and will continue to downcut rapidly until it reaches the same base level as the Buttermilk (Boothroyd and others, 1979).

Actual control over downcutting is maintained more by bedrock than by the glacial sediments, so large scale sediment purge from the glacial sediment reaches may be triggered by expiration of migrating rock nickpoints (LaFleur, 1983).

The downcutting rate in the Buttermilk Creek has not been steady, based on the evidence seen in the stratigraphic record. LaFleur, (1983) concludes from this evidence that no large changes in the rate can be expected in the next two thousand years.

2.3.3 Summary

Based on the stratigraphic record and radiocarbon dates, the geomorphology of the Buttermilk Creek and its tributaries has been investigated. Sediment movement occurs during time of high-flow. Erosion and landsliding are a result of channel migration. Downcutting of the creeks is controlled by bedrock base level. Downcutting rates most probably will be maintained at present values with downstream reaches of Buttermilk Creek cutting in faster than .7 m/century and upstream reaches and headwaters cutting faster, possibly 66 m3/century.

2.4 Landslides

2.4.1 Introduction

Landslides are more conspicuous erosion features than those formed by more gradual processes, such as soil creep or headward erosion of gullies. Landsliding can cause significant changes in topography and in the stability of structures in a short time. In this section we discuss landsliding separately from other erosion processes. In general terms, potential sites for landslides exist where the slope of a fractured or unconsolidated material exceeds the angle of repose for that material. At the WNYNSC such sites are common along the steep valley walls of streams incised in the gently rolling uplands. Most post-glacial streams are eroding unconsolidated alluvium and till; and in places have cut down to the underlying shale bedrock. Within the security area steep-walled tributaries of Buttermilk Creek border the NYS-licensed burial area on the north, east, and south (Plate 1). The tributary along the north end also extends along the north side of the NRC-licensed burial area. A gully into this stream cuts part way along the boundary between the two burial areas.

2.4.2 History

Landsliding has been recognized for some time along the small streams bordering the burial areas. In the long term, larger landslides along Buttermilk Creek can be expected to eventually encroach on the security area. Landslides are an integral mechanism of the erosion processes in this region.

2.4.2.1 First Recognition of Landslides at West Valley

R. Dineen (1971) of the NYSGS was apparently the first geologist to note the importance of landslides at the site. This report was based on a brief review of aerial photographs, at the request of the NYSDEC. Dineen identified large-scale slumps along Buttermilk Creek.

The first formal published study of landslides at the WNYNSC was made by Fleming (1976) of the USGS. Fleming made a preliminary assessment of landslide problems and some suggestions for future study. He observed that landslides were most severe in areas modified by excavation, and on slopes with no vegetation. He pointed out that slides might damage the water treatment lagoons east of the reprocessing plant and recommended special attention be given to that part of the site.

Fleming recommended a five-part, sequential study of landsliding at the WNYNSC, including:

1) preparation of profiles of streams and landslides;

2) mapping of the distribution of landslides on the site, and preparation of detailed maps of slides near the lagoons;

3) detailed studies of a few slides, including excavation of trenches, measurements of erosion and sliding rates, and repeated photographing of slides, including aerial photographs in stereo pairs;

4) a detailed study of the slope near the water treatment lagoons, and development of plans for stabilizing the slope;

5) field tests of the effectiveness of various types of vegetation in controlling slope failures.

To date, studies similar to items 1, 2, and 3 have been carried out, but no special attention has been given to the slopes near the lagoons, and no field tests of the effectiveness of vegetation in controlling slides have been done.

2.4.2.2 Regional Delination of Landslide Prone Areas

At approximately the time that Fleming (1976) made his brief study of landslides at the WNYNSC site, R.G. LaFleur (1979) was working on a regional study of glacial geology and post-glacial geomorphology. LaFleur produced glacial and surficial maps of an area of 63.7 km (165 mi), centered on the WNYNSC center.

This study by LaFleur did not focus specifically on landslides, but he did note on his maps where slides occurred along Buttermilk Creek and other tributaries in steep bluffs where both Lavery till and underlying sands were exposed in the valley walls. He suggested that water seeping out of the sub-Lavery sands might contribute to slope failure.

2.4.2.3 First Site Studies of Landslide Processes

During the USEPA funded phase of NYSGS studies at the WNYNSC no special attention was paid to landsliding. The main focus was to delineate an understanding of potential radionuclide migration pathways around the NYS-licensed burial trenches. Field observations confirmed Fleming's (1976) suggestion that some slides were associated with areas of excavation or fill. In addition, there appeared to be a relationship between landslides and the presence of ponds or depressions on the upland plateaus near valley rims. It was suggested that water in these ponds could lubricate pre-existing fractures and lead to slope failure (Dana and others, 1979b).

Two other parts of this program having indirect relationship with landslide studies were reported in Dana and others (1979b). First, it was noted that vertical fractures in the till followed a regional pattern, not always parallel or perpendicular to the walls of excavations or valleys. Such fractures could act as loci for landslides. Second, three Research Trenches excavated last of the security area provided an opportunity to observe steep walls in Lavery till.

Samples were taken from the walls and floor of Research Trench III for several tests of engineering properties (see Dana and others, 1979b, for results). The trench was then left open for a year and consequently filled with water from rain and snow. The trench was pumped dry and additional samples were taken for testing (Hoffman and others, 1980). It was noted that there had been substantial sloughing of the walls during the intervening year of flooded condition.

2.4.2.4 Second Landslide Study Phase

During 1979 the work most directly related to landslides was done by Earth Surface Research, under a subcontract from NYSGS (Boothroyd and others, 1979). They considered landslides an integral part of the development of Buttermilk Valley.

On the regional scale, J.C. Boothroyd and B.S. Timson developed a geologic map for the whole WNYNSC property, showing areas of outcrop of different types of sediment. They also provided a slope domain map for the whole drainage basin of Buttermilk Creek, covering major parts of the Ashford Hollow and West Valley quadrangles. They remarked that alluvial fans were the most important source of sediment supply to Buttermilk Creek along most of its length, except near the burial areas, where landslides were more common. Boothroyd and Timson suggested that the armored embankment near the bottom of the valley on the east bank for the Baltimore and Ohio Railroad may prevent channel sweeping on the east side and force the channel to sweep more on the west side, closer to the security area.

Boothroyd and Timson identified several landslides along Buttermilk Creek and its tributaries, in the field and on aerial photographs dating back to 1938. They concluded that slides tend to occur where the stream undercuts a steep valley wall, as on the outside of a stream meander. They specifically disagreed with LaFleur's (1979) suggestion that outcrops in the valley walls of sub-Lavery sands played a role in localizing slope failures.

Boothroyd and Timson also began a study of one large landslide on Buttermilk Creek, near the security area and adjacent to the stretch where they measured clast and bar migration in the valley floor, shown in Figure 3. That slide had apparently been studied by Prudic of the USGS as far back as 1975, but not discussed in any publications. Boothroyd and Timson placed stakes and surveyed the topography of this slide.

A second phase of work by Boothroyd and Timson took place in 1980, and is reported in Boothroyd and others (1982). Specific work on landslides was again focused on the large slide on Buttermilk Creek. This slide was resurveyed, and calculations made of the volume and rate of sediment movement. The slide delivered an average of 150 cu m/yr (5300 cu ft/yr) of sediment to Buttermilk Creek. The estimated time for material from the rim to reach the valley floor was 73.3 yr. This report also contains a series of photographs of the Buttermilk Creek slide, taken by D. Prudic of USGS in 1977, 1978, and early 1980, and by Boothroyd and Timson in late 1980.

Based on additional examination of aerial photographs dating back to 1938, Boothroyd and Timson suggested that landslides along Buttermilk Creek occur where the channel has been undercutting the valley wall for at least tens of years.

During the NYSGS studies from August 1979 through July 1981

(Albanese and others, 1982) subcontracts to NYSGS were carried out by Hoffman for studies of soil properties in Research Trench III (Hoffman and others, 1980), and by Boothroyd and Timson for the second phase of their Buttermilk Creek studies (Boothroyd and others, 1982).

A major, but indirect, contribution to the study of landslides was the production of a new topographic contour map, with a two-foot contour interval, and a planimetric base map of the security area, both with a scale of 1:1200. These were produced by Erdman, Anthony, Associates, P.C., on subcontract to NYSGS (Plate 1 in Albanese and others, 1982).

The NYSGS report for this period contains recommendations for studies of landslides and general geomorphology, some of which were carried out in subsequent years.

Albanese and others (1983) covers the continuation of the NYSGS work from August 1981 through July 1982. Studies specifically focused on landslides made up a major part of the work during this period.

Within the security area landslides were identified and drawn on the 1:1200 base map. Sources of information included previous maps, aerial photographs, and field observations. More than fifty slides were identified, most of them small rotational slumps, commonly in rows or clusters along the valley walls.

Within the security area, five slope domains were delineated on the same map with the landslides. The domains were primarily defined on the basis of sediment type and surface slope. In effect, these domains indicate areas of varying landslide risk, ranging from no risk to active sliding.

Using the slope domain map and field observations, criteria were developed to identify areas particularly susceptible to landsliding:

1) a slope steeper than 8 degrees;

2) a valley wall exposing silt-clay till;

3) an active stream channel impinging on the foot of the valley wall;

4) a slope with little or no vegetation.

These criteria also may provide some clues to possible risk-reducing engineering approaches.

One relatively small landslide was examined in detail. The North Trench landslide is on a tributary of Buttermilk Creek, at the north end of the NYS-licensed burial trenches. During the period of this report, the topography of the slide was surveyed twice, and a map was made showing small-scale features. Rates and volumes of sediment transport were calculated, but the time interval between surveys was rather short.

A larger slide was also selected for special study, comparable in size with the slide on Buttermilk Creek examined by Boothroyd and Timson. The Connoisarauley slide is on Connoisarauley Creek, a tributary of Cattaraugus Creek comparable with Buttermilk Creek, west of the WNYNSC. This slide is readily accessible, and developed in Lavery till. Two topographic surveys were made and a detailed map was drawn showing small-scale features. Rates and volumes of sediment transport were calculated for the interval between surveys.

2.4.2.5 Current Studies of Landslides

2.4.2.5.1 Introduction

During the last phase of NYSGS work under USNRC funding additional surveys were mad of the North Trench and Connoisarauley Landslides. LaFleur (1983), under subcontract to NYSGS, continued regional studies of erosion rates and processes in the Cattaraugus drainage basin. Boothroyd and Timson (1983), also under subcontract to NYSGS, carried out the third phase of their study of Buttermilk Creek, including additional work on the large landslide examined in the earlier phases.

2.4.2.5.2 North Trench Landslide

A small landslide area on the northern boundary of the NYS-licensed burial area has been monitored for downslope movement (Albanese and other, 1983). Thirty stakes were set out and their locations and elevations determined in April 1982, June 1982, and June 1983. During this time there were no large scale lateral movements, but gradual decreases in elevations of the monitoring points were observed.

To evaluate this gradual erosion an evenly spaced matrix of 900 calculated points of elevation was defined covering the 3500 sq m (37,500 sq ft) area being monitored on the landslide. For each cell the average elevation was calculated on the basis of each of the three surveys.

Landslide movement was estimated by comparing elevations of these cells, subtracting cell elevations of the second survey from those of the first, and subtracting cell elevations of the third survey from those of the second. Between early April 1982 and the end of June 1982 (sixty days) the cells lost a total of 11.6 m (38.2 ft) of elevation. From June 1982 to June 1983 the aggregate elevation loss was 16.1 m (52.8 ft). The cell areas were used to estimate loss of sediment volume for each cell. The total volume for April 1982 through June 1982 was 42.5 cu m (1500 cu ft). The volume loss for June 1982 to June 1983 was 63.7 cu m (2250 cu ft). Using the differences between the second and third surveys (a period of one year) the average daily rate of sediment removal was 0.18 cu m/day (6.3 cu ft/day). However, for the sixty-day period in spring between the first and second surveys, the rate was four times as high, 0.7 cu m/day (25 cu ft/day).

The one-year measurement of soil loss was used to estimate an average rate of slope retreat, using several assumptions and a nearest-neighbor gridding algorithm. The slope is retreating toward the trenches at a rate of approximately 18 mm (0.06 ft) per year. The primary mechanism is probably sheet wash.

2.4.2.5.3 Connoisarauley Landslide

A landslide along the Connoisarauley Creek, located approximately four miles southeast of the WNYNSC, has been monitored for movement during the past three years. We were temporarily restricted from studying landslides on Buttermilk Creek by the site operator during the first phase of this study. So we moved the research focus to the nearest similar offsite landslides. The Connoisarauley Slide was chosen for its similarity in size, structure and composition to the landslide along the Buttermilk Creek (Boothroyd and others, 1979, 1982). Ninety-three metal posts were placed in this slide and their locations were surveyed in September 1981. These stakes were resurveyed in July 1982 and again in June 1983 yielding a monitoring period of 616 days. During this time, unlike the smaller North Trench Slide, there were small areas of large scale movements as intact blocks of till moved down the face of this slide. As the result of this type of movement, the gridding technique used on the North Trench landslide to evaluate changes in elevation did not produce definitive analysis. The averages of the 1600 grid relative elevations calculated for this landslide are 43.9 m (143.9 ft) in September 1981, 43.9 m (144.1 ft) in July 1982 and 43.9 m (143.9 ft) for the June 1983 survey, all within the margin of error of the surveys (certified to

0.1 ft). Since analysis of vertical movement did not produce significant results, the movement in the horizontal plane, that is, parallel to the slope was analysed. The total horizontal component of the distance moved by the stakes between September and July was 60.2 m (197.4 ft) and from July to June 20.8 m (68.4 ft). The locations of the stakes measured by each survey were compared and distances moved, if greater than 0.1 ft, were calculated. During the September to July monitoring period 70 stakes (75 percent of the total) moved; 73 (78 percent) moved between July 1982 and June 1983. The cause of the large difference in total distances moved is one stake, located at the approximate center of Figure 4. This was on a block that slid 31.5 m (103.2 ft) to the base of the slope. The majority of the individual movements were very small, with only 7.5 percent of the stakes moving more than 1 m (3 ft). The total area of the landslide is 14,000 sq. m (150,000 sq. ft), so each of the 93 points represents an average area of 150 sq. m (1600 sq. ft). Therefore, a large volume of sediment moved a small horizontal distance.

Comparison of the movement measured on the two landslides monitored during this project illustrates the mechanisms of down slope movement active in the Lavery till. Displacements with large horizontal components, as measured on the Connoisarauley slide, are important in moving the large quantities of material during short periods of time. Slope wash, a process invisible to a casual observer, but very active on the North Trench landslide, moves sediment at a more constant, but slower, rate. Constant monitoring of both of these mechanisms must be continued to more accurately predict the rate at which mass movement of sediment effects this area.

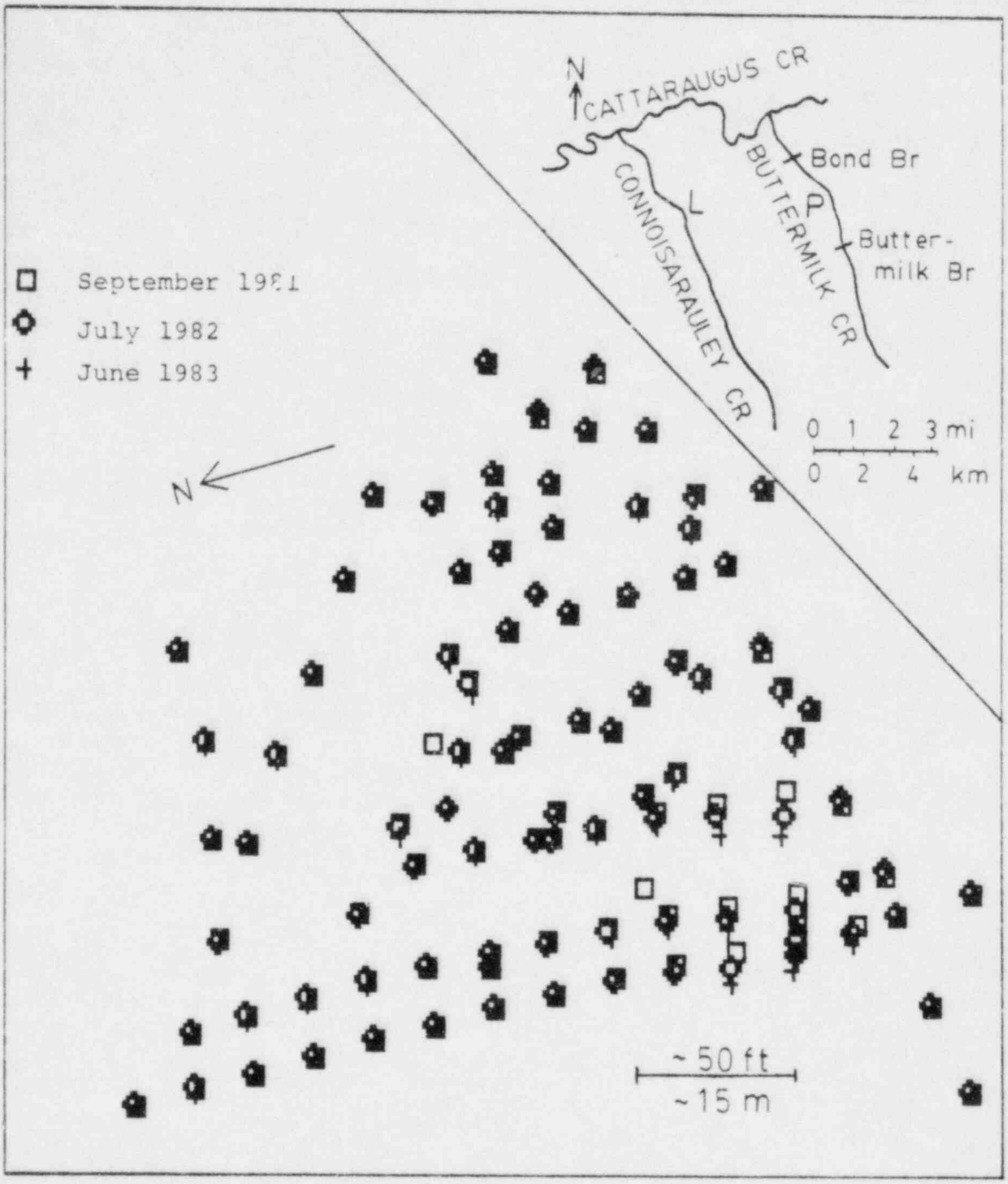


Figure 4. Map of Connoisarauley landslide, showing positions of stakes in three surveys. In the index map, north is not in the same direction, "L" shows the location of the landslide, and "P" shows the location of the plant. The two bridges are also shown on Fig. 2.

3.0 STRATIGRAPHY

3.1 Introduction

Stratigraphic studies at the WNYNSC have focused on Pleistocene and Holocene unconsolidated sediments, deposited on Paleozoic sedimentary rocks. Bedrock is not exposed within the fenced security area. On the rest of the WNYNSC property shale is only exposed in short stretches of stream beds and steeper parts of upland hills, where glacial cover has been eroded.

The main objective of the stratigraphy studies has been to obtain an understanding of the groundwater regime to be used to assess the potential for subsurface migration of radionuclides from the radioactive waste burial areas. Studies by the NYSGS have concentrated on defining the stratigraphic sequence and describing the various lithologies in detail.

This chapter consists of two major sections The first is a review of studies made on and near the site that have contributed to knowledge of the stratigraphy. The second section contains current interpretations of the stratigraphy, incorporating data from 1982 and 1983 drilling programs.

3.2 Review of Stratigraphy Studies

3.2.1 Introduction

Basic stratigraphy investigations have included the following types of studies:

1) surficial mapping;

2) geophysical studies;

3) examination of cores and cuttings from exploratory drilling;

4) examination of open burial trenches and holes;

5) studies of research trenches similar in design to the burial trenches;

6) laboratory studies.

3.2.2 Surficial Mapping

Surficial mapping in and around the site has been the main source of information on the sequence of units, regional correlations, and environments of deposition. These studies are discussed in detail in Chapter 2 on glacial geology and geomorphology. These regional mapping studies, primarily by LaFleur (1979, 1980a, 1980c), have identified the following major lithologies from the surface down to bedrock:

1) Holocene alluvial fan gravel;

2) Late Pleistocene alluvial-fluvial gravels and sands;

3) Lavery till;

4) kame deltas and other coarse-grained deposits;

5) lacustrine beds;

6) Kent till

Alluvial gravels are now exposed at the surface only on the northern half of the security area. The southern half, containing the two burial areas, has Lavery till exposed at the surface, but alluvium may have extended across part of the burial areas before grading and site preparation (LaFleur, 1979).

3.2.3 Geophysical Studies

Two types of geophysical studies have been made at the WNYNSC, areal surveys and logging of exploration holes. Areal studies include two seismic refraction surveys and one electrical resistance survey. Logging studies include gamma ray logging of a few holes near the NYS-licensed burial area, and gamma ray and neutron porosity logging of holes west of the NRC-licensed burial area.

The first seismic refraction study was carried out in 1961-1962 by the NYS Department of Public Works (now NYS Department of Transportation), and covered the entire WNYNSC property. The objective was to determine the depth to bedrock, particularly under the proposed site for the reprocessing plant, and the general form of the buried bedrock surface. A report of this work was included in the original Safety Analysis Report (Nuclear Fuel Services, 1962), and the data were included as attachments to letter reports from the USGS to the NYS Office of Atomic Development (Stewart, 1962a, 1962b). The Safety Analysis

Report contained scale drawings along the three main section lines, as shown in Albanese and others (1983, Plate 2). These cross sections show that the present Buttermilk Creek has cut down into Pleistocene and Holocene sediments that fill a broader, deeper bedrock valley that was cut into Devonian Machias Shale before deposition of the Kent(?) till. The present Buttermilk channel is roughly parallel with the trend of the bedrock valley, but not centered over the thickest accumulation of unconsolidated sediment, which is approximately 150 m (500 ft). The reprocessing plant is on the west edge of the bedrock valley, and shale outcrops occur in stream beds and on ridges west and north of the security area.

In 1981 and 1982 a seismic refraction study was carried out on the northern half of the security area, using a 16-pound sledge-hammer on a steel plate as the energy source. The lines of recording points crossed near the positions of holes drilled in 1980, where the precise depths to the alluvial-till interface were known from sediment cores. This seismic study was more successful than the resistivity survey, done at the same time (discussed below). The results were used to construct two maps included as plates in Albanese and others (1983), one showing the topography of the buried till surface, and the other an isopach map of the surficial gravels. The hammer energy source was not strong enough to produce good signals for interfaces more than approximately 15 m deep (50 ft), so the seismic profiles could not be used to define depth to bedrock under this area.

In 1981 electrical resistivity measurements were taken along lines parallel with the fence around the northern half of the security area. As discussed in Albanese and others (1983), this resistivity survey proved fruitless, probably because of the presence of metal fences, buildings, and underground pipes.

Two studies have been made by the USGS using in-hole geophysical techniques. The first, reported by Prudic and Randall (1977), used in-hole gamma spectral logging, and was designed to detect specific man-made radionuclides, including Co-60 and Cs-137, which were above detection limits at depths of less than 1 m (3 ft) in four holes, E, M, N, and P, near the NYS-licensed burial trenches. This study was not designed to assist in stratigraphic correlation or characterization of lithologies.

The second in-hole geophysical study was done by the USGS in the spring of 1983 in five holes adjacent to or west of the NRC-licensed burial area and consisted of gamma ray and neutron porosity logs. The purpose of this study was to identify significant changes in lithology that could be used for stratigraphic correlation. The results of this study will be published by the USGS upon completion of their study.

3.2.4 Exploratory Drilling

A brief history of drilling projects inside the security area through 1980 was included in Albanese and others (1983), and the joint USGS-NYSGS drilling project for fall 1982 was reported in Potter and others (Appendix D). Table 3 in this report summarizes drilling projects on the whole site through summer 1983. Holes inside the security area are shown on Plate 1, except for any domestic water wells and gas exploration holes drilled before the State acquired the property. Marcel Bergeron of the USGS is preparing a catalog of all known holes on the site (personal communication, 1983).

Exploratory drilling has produced cuttings and core samples for lithologic descriptions. Cores have also been used for radionuclide analyses, petrographic studies, and tests of various material properties. Several holes have been equipped for use as water-level observation wells, and some water samples have also been subjected to radionuclide analysis. Radionuclide analyses of all kinds are discussed in Chapter 6.

Lithologic descriptions have been used to establish correlations of units from hole to hole, and to draw stratigraphic cross sections. These descriptions have also contributed to detailed characterizations of individual units, particularly the Lavery till. Stratigraphic results are discussed in the next section of this chapter. The results of recent laboratory tests and petrographic studies area presented in Chapter 4 of this report.

3.2.5 Observations of Open Burial Trenches and Holes

Direct inspection of the walls and floors of the trenches and holes in the two burial areas were not routinely performed by a trained geologist while the NYS-licensed burial area was in operation. Kernan Davis of NYS Department of Environmental Conservation and G. Lewis Meyer of U.S. Environmental Protection Agency were allowed into Trench 13 when it was being filled (Davis, 1974; Giardina and others, 1977). They observed a sandy zone near the surface on one trench wall, as discussed in Albanese and others (1983).

Table 3. History of drilling projects at WNYNSC.

		Drilling Projects		
Hole Names	Date Drilled	Location	Drilled For or By	References
oil and gas holes	pre-1963	whole site	owners	NYSGS oil and gas records
domestic wells	pre-1963	whole site	owners	USGS records
PAH-n, DH-n	1961-1962	whole site	NYS Dept. of Public Works	Stewart, 1962a,1962b; Dames and Moore, 1971a
1-25	1963	security area, plant site	NFS	Dames and Moore, 1963
1,1A,2,2c, 3,4	1963?	water supply reservoirs S of security area	NFS	Ek, 1963(?)-unpublished map
CH-1 and four others	1967-1969	E of security area	ORNL	de Laguna, 1972 NYSGS oil and gas records Sun and Mongan, 1974; Sun, 1982

Table 3. continued

Drilling Projects-continued

Hole Names	Date Drilled	Location	Drilled For or By	References
26, 27	1970	security area, plant site	NFS	Dames and Moore, 1970b
28-32	1971	security area, plant site	NFS	Dames and Moore, 1971b
33-43	1974	security area	NFS	Dames and Moore, 1975
1-9	1970	near plutonium storage area	NFS	Dames and Moore, 1970a
1-13, 2A-D, 9A-D	1973-1974	perimeter of NYS-licensed burial area	NFS, NYSASDA, USEPA	Davis, 1974; Duckworth and others, 1974; Giardina and others, 1977; Bailey, 1975
B-1 thru B-7, TP-1 thru TP-7	1974	N of NYS-licensed burial area	NFS	Dames and Moore, 1974

Table 3. continued

Drilling Projects-continued

Hole Names	Date Drilled	Location	Drilled For or By	References
B1 thru B5	1975	S and W of security area	NFS	Empire Soils Investigations, Inc., 1975
A-Z, HA-n, EB-n	1975-1980	around NYS-licensed burial area	USGS	Prudic and Randall, 1977
n-na	1976-1977	into trenches of NYS-licensed	USGS	Prudic, 1978, 1979; Dana and others, 1980
80-1 thru 80-10	1980	security area	USGS,NYSGS	Albanese and others, 1982
A82-1,2	1982	E of NYS-licensed burial area	NYSGS	Albanese and others, 1983
82-na	1982-1983	around NRC-licensed burial area	USGS,NYSGS	Potter and others (Appendix D); this report

Table 3. continued

Drilling Projects-continued

Hole Names	Date Drilled	Location	Drilled For or By	References
83-na	1983	W of NRC-licensed burial area	USGS,DOE, NYSGS	this report
83-4E	1983	North Plateau	USGS-NYSGS	this report

Kernan Davis and R.H. Fakundiny of NYSGS also entered Trench 14, in 1974 and 1975, and discovered another sand "pod", halfway up the west wall, near the northwest end of the trench (R.H. Fakundiny, pers. comm. 1983). A sand-rich layer was also found near the top of Trench 14 near the south end, possibly a meter thick and a few meters long. This may have been a remnant of alluvium on top of Lavery till. The oval form of the body was delineated using several backhoe excavations by Nuclear Fuel Services, Inc., as discussed in Albanese and others (1983).

In the NRC-licensed burial area, much of the waste was placed in deep holes and it was probably too dangerous for anyone to enter because of the risk of collapse of the walls. Geologists have occasionally observed burial operations from the surface, such as while drilling was in progress nearby in the fall of 1982 (Potter, personal communication, 1982).

Observations in the burial trenches and holes have only provided views of the Lavery till. These observations have been consistent with surface exposures outside the security area and information from cores regarding the general character of the till and the form of coarser zones and inclusions.

3.2.6 Research Trenches

Three research trenches were excavated for NYSGS in 1976-1977, southeast of the burial areas, as shown in Dana and others (1980, Figure 1). They were designed to be similar in form and execution to trenches in the NYS-licensed burial area, and were outside the security area on a flat upland where Lavery till was exposed at the surface. This area is hydrologically spearated from the burial ground area by the east fork of Frank's Crek. The research trenches provided large, fresh surfaces for observation and sampling of the burial medium, and an opportunity to simulate the mechanical behavior of trench walls in the loosely-filled trenches of the NYS-licensed burial area. In Research Trench III, samples were extracted for laboratory tests of material properties when the trench was first opened (Fickies and others, 1979). The trench was left open, allowed to fill with snow and rain, and then drained and sampled again, after the trench walls had begun to collapse (Hoffman and others, 1980).

3.3 Stratigraphy Studies in 1982-1983

3.3.1 Introduction

Seventeen holes were drilled in the fall of 1982, in a joint USGS-NYSGS project, on the perimeter of the NRC-licensed burial area. Drilling procedures for the 1982 holes are presented in Potter and others (this report- Appendix D).

Two of the holes drilled in 1982 were deepened in the spring of 1983, and five more holes were drilled west of the NRC-licensed burial area, by the USGS under contract with USDOE. A few shallow holes were hand-augered at that time. In the summer of 1983 a 76 m (250 ft) deep hole was drilled on the North Plateau in another USGS-NYSGS joint program. Drilling procedures for all of the 1983 holes are described in Appendix E. of this report.

Geologic logs for all of the 1982 and 1983 holes are in Appendix A, graphic columns in Appendix B, and radionuclide results in Appendix C. The radionuclide results are discussed in Chapter 6.

3.3.2 Up-Date on Stratigraphic Interpretation

The 1982-1983 drilling projects improved our understanding of the stratigraphy of the WNYNSC. First, cores from the new holes improved characterization of the Pleistocene and Holocene sedimentary units. Second, the core logs provided data on the thickness of units and elevations of boundaries in parts of the security area that had not previously been explored. These drilling projects have provided some specific contributions to understanding the stratigraphy of the site, including:

1) more information about the nature and extent of relatively coarse-grained bodies within the Lavery till;

2) more information about units beneath the Lavery till, particularly the kame delta (?) and lacustrine units;

3) the first subsurface samples from a second lacustrine unit and third till underlying the Kent(?) till;

4) greatly improved stratigraphic data for the area of the NRC-licensed burial area, and somewhat improved data for sub-Lavery units under the North Plateau.

3.3.3 New Cross-Sections

3.3.3.1 Three Deep Cross-Sections

Stratigraphic cross-sections are important in the interpretation of sedimentary units. For this report we have drawn three new sections (Plates 2, 3, and 4), which supplement cross-sections presented in our previous reports (Albanese and others, 1982, 1983). We chose the section lines to take advantage of the holes drilled in 1982-1983, combined with deeper holes drilled in earlier projects. The graphic columns shown on these sections have been simplified to show only the basic units, so they are not as detailed as the graphic columns presented in our last annual report (Albanese and others, 1983), and in Appendix B of this report. Each plate shows two sections, one with a vertical exaggeration of 10 times to show lithologies, and the other without vertical exaggeration to show proper geometric relationships. The locations of the three section lines are shown in Figure 5: line A-A' extends east-west across both burial areas; line B-B' runs north-south from the North Plateau, along the east side of the reprocessing plant, and across the east end of the NRC-burial area; line C-C' is also north-south, passing west of the plant and the NRC-licensed burial area. The stratigraphy will be described for each line and then synthesized for the security area as a whole.

3.3.3.2 Line A-A', East-West (Plate 2)

This section line uses several new holes drilled around the NRC-licensed burial area. The line is transverse to the trend of the buried bedrock valley. Bedrock outcrops occur outside the security area, beyond the west end of this line. The line crosses both of the burial areas, and extends eastward nearly to Buttermilk Creek. The following units can be identified in at least one of the columns on this line of section:

1) backfill - up to 2.5 m (8 ft) thick; seen only near the NYS-licensed burial area;

2) alluvium - up to 3 m (10 ft) thick; seen only at the east and west ends of the line, outside the burial areas;

3) Lavery till - up to 37 m (120 ft) thick east of the burial areas, thinning to 8 m (27 ft) west of the NRC-licensed burial area, where bedrock rises closer to the surface; contains many sandy and gravelly bodies or

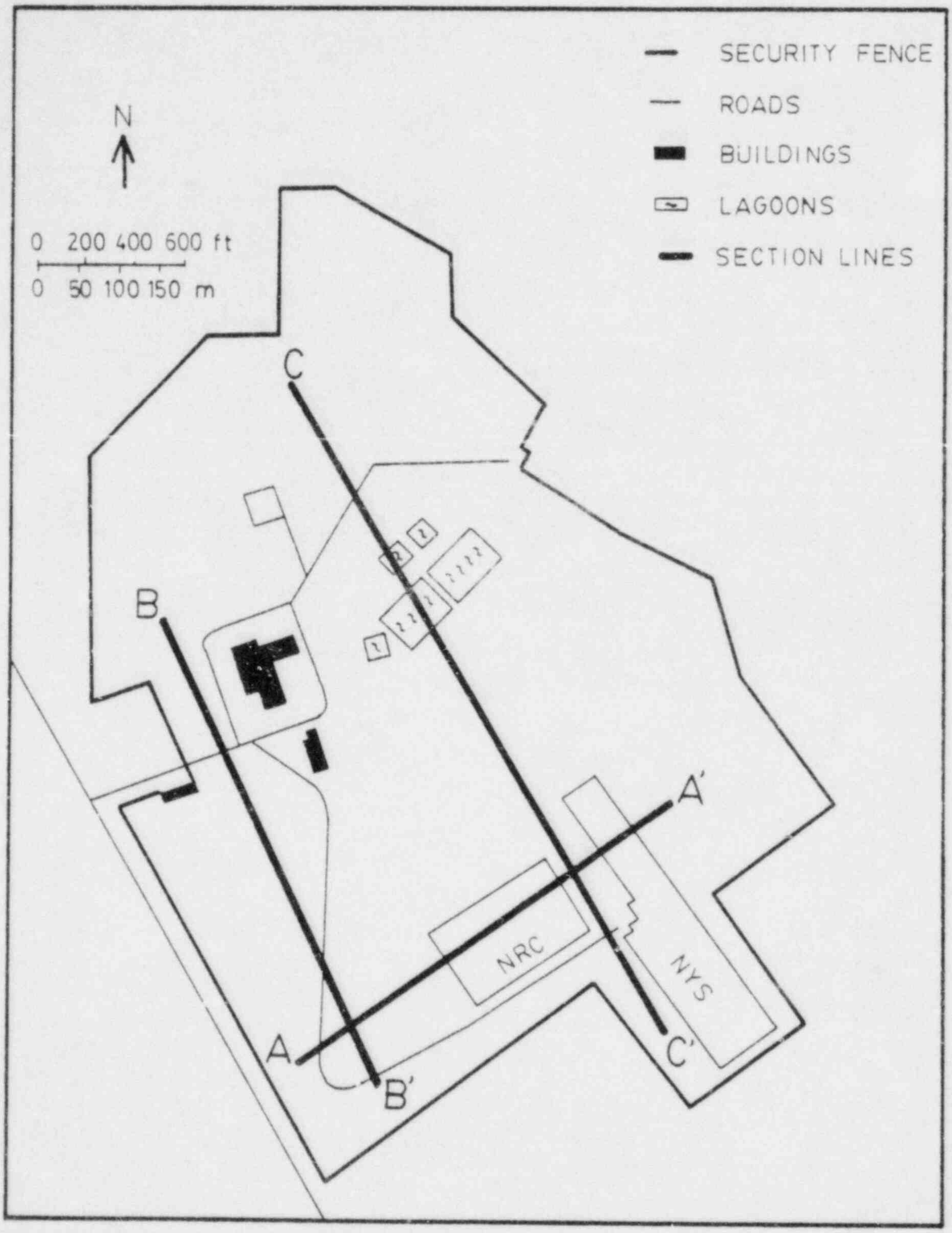


Figure 5. Map of security area showing locations of cross-section lines A-A', B-B', C-C' shown in Plates 2, 3, and 4. See Plate 1 for more detail. The same fenced area is shown in Fig. 1.

zones but many of the holes on this line have more detailed logs than holes elsewhere on the site;

4) kame deltas(?) - up to 6 m (20 ft) thick; sandy, gravelly unit, seen only in two holes east of the burial areas;

5) lacustrine beds - up to 13 m (42 ft) thick east of the burial areas, but only 3 to 6 m (10 to 20 ft) thick under the NRC-licensed burial area; holes around the NYS-licensed burial area are not deep enough to pass through this unit;

6) Kent(?) till - less than 1.5 m (5 ft) thick, in two holes near the NRC-licensed burial area; two other holes pass from the lacustrine unit directly into bedrock, others extend into the till but not to the bedrock;

7) basal gravel(?) - no more than 0.6 m (2 ft) thick; may be weathered bedrock; seen in two holes, between the lacustrine unit and bedrock in one hole and between Kent(?) till and bedrock in the other;

8) rock-shale - seen in four holes near the NRC-licensed burial area at depths of 13 to 27.5 m (42 to 90 ft).

3.3.3.3 Line B-B' Shallow North-South Cross-Section (Plate 3)

This line runs parallel with the trend of the buried bedrock valley near its edge, and close to the western boundary of the security area. The following units were identified:

1) alluvium - usually less than 7.5 m (25 ft) thick, although shown as 18 m (60 ft) in one hole, but that log is very brief; seen in nearly all of the holes in this cross-section;

2) Lavery till - up to 18 m (60 ft) thick, but quite variable; seen in all holes; sand and gravel bodies are not shown as often as in columns on Section A-A' because the logs are much less detailed;

3) kame deltas(?) - about 5 m (17 ft) thick, seen only in one hole at the south end of the line; in other holes the lacustrine unit or bedrock is directly under the Lavery till;

4) lacustrine beds - usually 3 m (10 ft) thick, but up to 6 m (20 ft); not seen in holes at the north end of the line but seen in all holes around the NRC-licensed burial area;

5) gravel - 2.5 m (8 ft) thick; underlying or included in the lacustrine unit in one hole at the south end of this line;

6) Kent(?) till - less than 1.5 m (5 ft) thick; seen in two holes at the south end, but the hole between then did not have core for the critical interval;

7) basal gravel or sand(?) - less than 1.5 m (5 ft) thick; may be weathered bedrock; between Lavery till and rock in hole PAH-71, between lacustrine beds and rock in hole 83-1D, and between Kent(?) till and rock in hole 80-10;

8) rock - seen in all but the shortest holes, 8 to 28 m (27 to 92 ft) below the surface; surface elevation decreases southward, and bedrock may also.

3.3.3.4 Line C-C', Deeper North-South Cross-Section (Plate 4)

This section line is parallel with the trend of the bedrock valley, closer to its mid-line than B-B'. The line uses the new 76 m (250 ft) deep hole on the North Plateau, some of the deep holes drilled by Dames and Moore for construction investigations, and new holes around the east end of the NRC-licensed burial area. The following units can be identified:

1) alluvium - up to 7.5 m (25 ft) thick; not present in the burial area;

2) Lavery till - up to 23.5 m (77 ft) thick; seen in all of the holes;

3) kame deltas(?) - up to 6.7 m (22 ft) thick; seen in two of the deeper holes;

4) lacustrine beds - up to 16.5 m (55 ft) thick, but only 3 m (10 ft) in the burial areas; seen in every hole more than 26 m (85 ft) deep; may thin southward;

5) Kent(?) till - up to 24 m (80 ft) thick; detected in four holes but only two of those pass through the unit;

6) second lacustrine unit - as much as 12 m (40 ft) thick, but seen only in hole 83-4E, which does not have continuous core;

7) third till - up to 6 m (20 ft) thick; seen only in hole 83-4E;

8) basal gravel(?) - 3 m (10 ft) thick in one hole, between Kent(?) till and bedrock;

9) rock - seen in only the two deepest holes, at depths of 62.5 m (205 ft) and 74.5 m (245 ft).

3.4 Summary of Stratigraphy

Based on the three cross-sections presented in this paper, the following Pleistocene-Holocene stratigraphy can be defined:

1) backfill - up to 2.5 m (8 ft) thick, identified only near the NYS-licensed burial area, but might have been included with alluvium in other parts of the site;

2) alluvium - less than 3 m (10 ft) thick east and west of the burial areas, not present in the burial areas, approximately 7.5 m (25 ft) thick in the plant area, except for one hole with 18 m (60 ft) identified in a very brief log; this unit includes both alluvium and coarse fluvial deposits which can be distinguished in surficial mapping but probably not in core samples (Albanese and others, 1983);

3) Lavery till - up to 36.5 m (120 ft) thick east of the burial areas, generally 18 to 24.5 m (60 to 80 ft) thick under the plant and North Plateau, thinning to 9 m (30 ft) west of the burial areas, where the side of the bedrock valley approaches the surface; seen in all holes, exposed at the surface in the burial areas, under alluvium in the plant area and North Plateau;

4) kame deltas(?) - not seen in at least half of the holes that penetrate the lacustrine unit or Kent till; approximately 6 m (20 ft) thick where present; might be alluvial fans or some other type of deposit, but LaFleur identified kame deltas at this level in Buttermilk Creek (LaFleur,1979);

5) lacustrine unit - 3 to 6 m (10 to 20 ft) thick under the burial areas, 12 m (40 ft) thick to east, up to 15 to 18 m (50 to 60 ft) under the plant and North

Plateau; seen in all holes deep enough to go through Lavery till and kame deltas(?); according to LaFleur (1979), deposited in Kent(?) proglacial lake after the glacier had deposited till here and retreated;

6) Kent(?) till - not seen in all holes of apparently sufficient depth; only 1.5 m (5 ft) thick or less under the burial areas, but up to 24.5 m (80 ft) east of the plant and under the North Plateau; correlation with named moraines in the region has not been firmly established (see Chapter 2 of this report);

7) second lacustrine unit - up to 12 m (40 ft) thick, seen only in hole 83-4E under the North Plateau;

8) third till - up to 6 m (20 ft) thick, seen only in hole 83-4E;

9) basal sand or gravel(?) - less than 1.5 m (5 ft) thick, between bedrock and third till, or Kent(?) till, or post-Kent(?) lacustrine unit; not seen in all holes; may be weathered bedrock, or some alluvial or fluvial deposit;

10) bedrock - shale.

Several important observations can be made about this sequence. First, only a few of these units are seen in all of the holes where they might be expected: the Lavery till, the post-Kent(?) lacustrine unit, and bedrock. All of the other units appear to be discontinuous on the scale of the security area at the WNYNSC. Second, any names and ages for these units depend on correlations with units mapped at the surface on a regional scale. Third, the second lacustrine unit and third till have so far been identified only in hole 83-4E. The position of that hole was chosen so that it would be closer to the center of the bedrock valley than any holes drilled previously. However, the early seismic studies indicate that at its deepest the bedrock valley contains as much as 150 m (500 ft) of Pleistocene and Holocene fill, twice the thickness penetrated by hole 83-4E. If coarse-grained and lacustrine units below the Kent(?) till turn out to be important in a groundwater model of the site, then more and deeper holes would be necessary to delineate and sample those units.

4.0 SEDIMENTOLOGY

4.1 Previous Laboratory Studies

Numerous laboratory studies have been made on sediment samples from the WNYNSC, including tests for material properties related to construction of the reprocessing plant, and for permeability, an essential parameter in groundwater modeling. Studies have also been made of grain size distributions, mineralogy, and chemistry.

Numerous tests have been made of material properties mainly in the course of planning for parts of the reprocessing facilities. These tests included evaluations of consolidation, compressibility, plasticity, rigidity, shear strength, moisture content, density, and dispersion (Dames and Moore, 1963, 1970a, 1970b, 1971, 1975) on core samples from holes in the vicinity of the reprocessing plant, and near the plutonium storage building on the east side of Buttermilk Creek.

A somewhat narrower range of studies was done on samples from the walls and floors of Research Trench III, discussed above. Samples were collected in 1977, when the trench was first excavated, and tested by E.T. Mosely of Raamot Associates. These results were reported in Dana and others (1979a, 1979b), and Fickies and others (1979). The trench was drained and sampled again a year later, tests were done by Vernon Hoffman, and reported in Dana and others (1980) and Hoffman and others (1980). At that time similar tests were also done on samples from the caps of actual burial trenches in the NYS-licensed burial area.

Several determinations have been made of permeability, nearly all on samples of the Lavery till. Most have been done in laboratories, using core samples, such as from the original PAH and DH holes drilled before the plant was built (Stewart, 1962b; Nuclear Fuel Services, Inc., 1963). Permeability was also measured in samples from the first phase of NYSGS work at Research Trench III (Dana and others, 1979a, 1979b; Fickies and others, 1979), and from letter-designated holes drilled by the USGS around the NYS-licensed burial area (Prudic, 1982). Slug tests were also done by the USGS, using some of the piezometer-equipped holes near the NYS-licensed burial area (Prudic, 1982; Prudic and Randall, 1977). All results were in the range of 10-7 to 10-8 cm/sec.

Grain size distributions in sediments can be used to describe lithologic variations within a unit, correlate a unit from hole to hole, and distinguish two similar units. Such distributions were determined for samples from some of the PAH and DH holes (Nuclear Fuel Services, Inc., 1963), in the course of planning for modifications and additions to the plant (Dames and Moore, 1971, 1975), and near the NYSERDA warehouse to the east of the Buttermilk valley (see Figure 1) (Dames and Moore, 1970b). Grain size determinations were also included in the second round of tests on samples from Research Trench III and from the trench caps in the NYS-licensed burial area (Hoffman and others, 1980). Such studies were also done on samples collected from the surface and in stream beds near the NYS-licensed burial area, by Whitney (1977). More recently, the NYSGS determined grain-size distributions for core samples from the letter-designated holes near the NYS-licensed burial area and from the 1980 series of holes (Albanese and others, 1983). Boothroyd and others (1982) also included grain-size determinations in their studies of Buttermilk Creek, examining both till samples and present-day stream deposits.

Studies of mineralogy and chemistry are also useful for stratigraphic purposes. These were done on samples from some of the PAH- and DH-series holes (Nuclear Fuel Services, Inc., 1963), samples from the surface and stream beds near the NYS-licensed burial area (Whitney, 1977), and cores from letter-designated holes near the NYS-licensed burial area (LaFleur, 1979, 1980a). LaFleur also examined microfabrics in cores from some of these holes (1980b).

4.2 New Petrography Studies for this Project

4.2.1 Mineral Analysis

Mineral Analysis: Mineral content of sediments commonly changes with grain size, with the more liable minerals becoming less abundant toward the finer end of the grain size distribution. The mineral analyses of the Lavery till were designed to determine the relationship of mineralogy to grain-size.

4.2.2 Procedure

Grain size analyses of the Lavery till, completed during earlier studies show the general character of the grain size distribution to be silt and clay in subequal amounts with minor sand and gravel. Mineral analyses were done on all four size classes: gravel, sand, silt and clay. Each of these was examined with different techniques, which generally become more elaborate with decreasing grain size.

1) Gravel fraction; individual clasts were classified petrographically with a hand lens. Each class was weighed to determine its proportion of the whole sample.

2) Sand fraction; point counts of thin sections made from each of the whole phi-size sand sizes provided mineral percentages in this size range. Point counts were done with a petrographic microscope.

3) Silt and Clay fraction; carefully timed settling procedures were used to prepare grain size separates (four for silt, five for clay), from the mud portion of the samples.

For each separate a suspension of the mud fraction in a Calgon solution was stirred in a 10 liter bucket. The suspension was allowed to stand until all of the coarsest size class had settled past a predetermined depth, which was read from temperature corrected settling-rate curves (Folk, 1974). At the appropriate moment the finer fraction, above the predetermined depth was siphoned off. The residual suspension contained the coarsest fraction of the mud but with part of the finer as well. This residual fraction was refined by resuspension in a graduated cylinder and settling and siphoning off of fines, which were returned to the principal fines fraction. The coarse residual fraction was cleaned of fines remaining by repeated suspension, settling and siphoning in Calgon solution until the supernatant became fairly clear. This settling procedure was repeated on the principal fines fraction for each of nine size classes. This procedure produces a good separation into whole phi-classes down through the 11-12 phi class. Pictures of separates with the scanning electron microscope verified the separation was good. Each size class was analysed by x-ray diffraction. Peak heights were used to establish the relative abundance of different minerals in the samples. The mounts for x-ray analysis were made by smearing a slurry of the sample on a glass slide, using a limber plastic spatula. Duplicate mounts were made for each sample. The peak heights from the duplicates were averaged to get the peak height used for analysis estimating mineral proportions.

X-ray diffraction will not give quantitative results, but relative amounts of minerals within a suite can be determined by comparison of peak heights between samples. To get a more definitive idea of the quantitative mineralogy, several of the finer size fractions were analysed chemically for quartz, feldspar and carbonate. In this fine end of the grain size distribution, the mineral suite consists of chlorite, illite, quartz, feldspar, calcite and dolomite, as determined by x-ray diffraction. The procedures used for chemical analysis permit direct measurment of the quartz-feldspar fraction and the carbonate fraction. The clay mineral fraction is determined by difference. Relative amounts of chlorite and illite and of dolomite and calcite can be determined by comparison of x-ray data. Quartz and feldspar were further separated by chemical analysis.

Samples analysed were:

1) CCRA - weathered Lavery till from the bank of Connoisarauley Creek in west central Ashford Hollow Quadrangle at an elevation of 364 m (1195 ft);

2) CCRB - unweathered Lavery till from the same locality as CCRA;

3) CR-Till - unweathered Lavery till from a roadcut on Connoisarauley Road in west central Ashford Hollow Quadrangle about .8 km (0.5 mi) south of CCRA and CCRB, at an elevation of 395 m (1295 ft);

4) 80-80IA - unweathered Lavery till from drill hole 80-10, west of the burial areas, at an elevation of 422 m (1383 ft), 5 m (17 ft) below the surface;

5)SR-1 - Kent till from a roadcut on Snake River Road in the southwest part of the Ashford Hollow Quadrangle, at an elevation of 518 m (1700 ft).

4.2.3 Results

As described above, the gravel and sand size fractions were examined visually, the silt and clay fractions by x-ray and chemical methods. The data from the gravel and sand analyses are shown graphically in Figure 6, the x-ray and chemical data are summarized in Table 4. Figure 7 shows the quartz content of various size fractions in the silt and clay sizes as a plot of percent quartz vs. height of the 4.26A x-ray peak. This gives a rough relationship of percent quartz = 2.5 times the 4.26A quartz peak. This equation can be used to estimate the quartz content in silt and clay size fractions from x-ray peak height alone.

Quartz was identified with the 4.26A peak because this one is not interferred with by peaks of other minerals. The 7.1A peak was used for chlorite estimates, because it is the strongest chlorite peak. The 10.1A peak for illite was sharp throughout the samples tested, indicating that the illite is

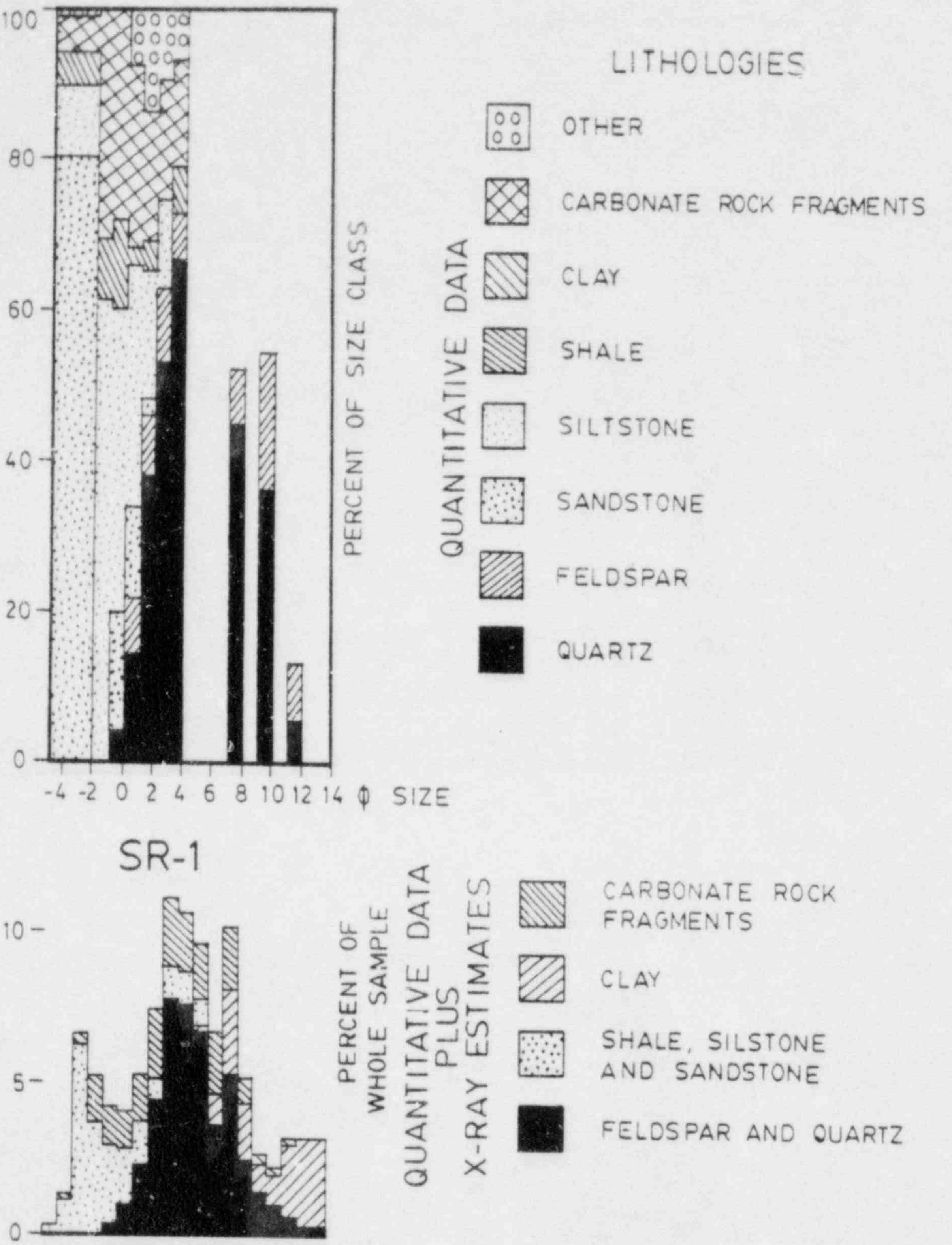


Figure 6. Bar graphs showing components as a percent of each grain size class (above), and as a percent of the whole sample (below). SR-1 is a sample of Kent till; CCRA, CCRB, CR-Till, and 80-10-IA are all samples of Lavery till.

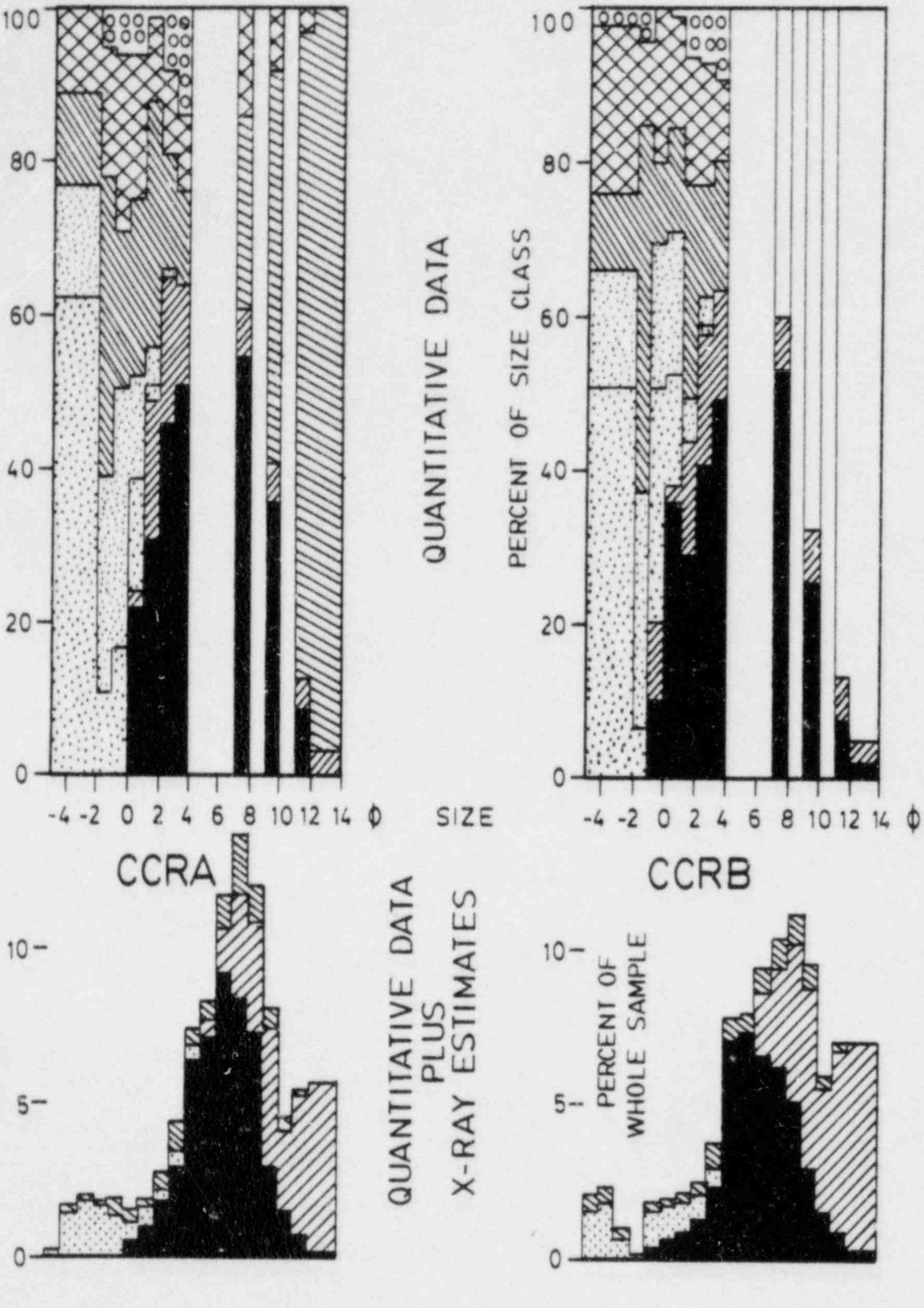


Figure 6. - continued

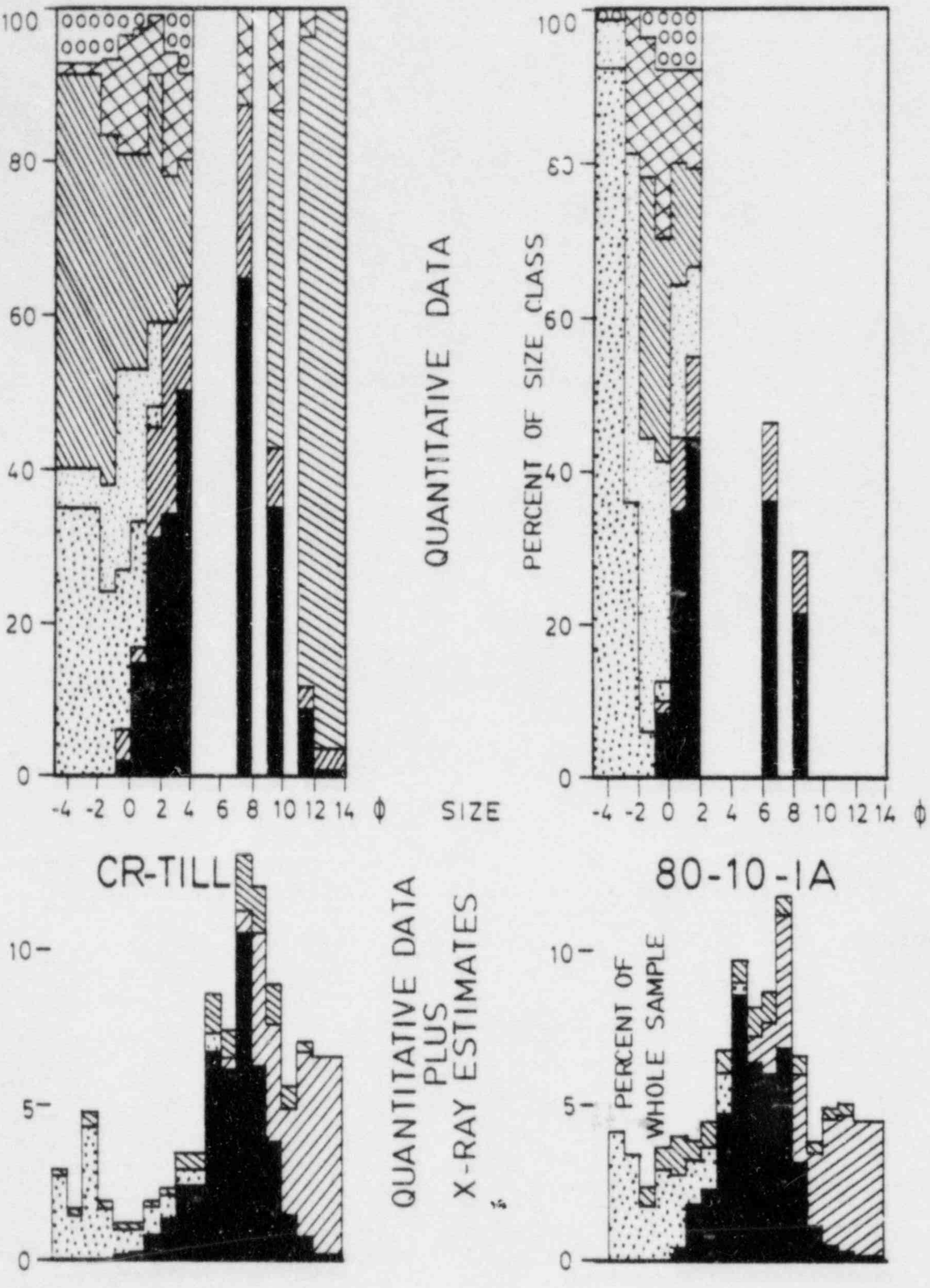


Figure 6. - continued

Table 4a. X-ray Peak Heights[1] and chemical Analyses[2] for Silt and Clay Size Fractions of Lavery Till and Kent Till.

		10.1A ILL	7.1A CHL	4.26A QTZ	3.25A KSPAR	3.19A PLAG	3.04A CALC	2.89A DOLO	%Qtz	%Feld.	%Carb.
CCRA	*1	.50	0.00	22.80	3.80	8.00	4.40	9.80			
	2	2.80	2.30	22.80	2.00	6.00	2.50	5.80			
	3	5.80	5.50	27.50	2.00	8.50	7.00	14.50			
	4	9.80	8.50	24.50	2.00	6.30	7.00	7.30	55.0	6.2	13.8
	5	17.50	14.80	22.00	2.80	5.30	7.80	6.00			
	6	22.80	21.30	16.80	2.50	3.80	6.50	4.80	36.0	5.2	8.0
	7	28.50	20.00	12.80	2.50	3.30	5.80	3.00			
	8	74.80	51.50	5.80	0.00	2.50	2.50	3.30	8.8	3.8	3.0
	9	49.50	21.50	2.80	0.00	0.00	0.00	0.00	1.2	2.6	
CCRB	*1	0.00	0.00	22.90	0.00	9.80	4.00	7.80			
	2	2.30	3.30	21.00	3.00	10.50	0.00	0.00			
	3	6.80	9.30	27.50	4.00	7.80	3.50	11.30			
	4	14.50	16.80	22.80	1.00	5.30	5.80	7.80	53.5	6.4	
	5	18.50	17.80	16.50	1.50	4.50	7.80	5.30			
	6	35.50	36.00	11.80	3.80	4.00	7.00	3.80	25.7	7.0	
	7	38.50	40.00	22.80	3.30	4.80	3.50	0.00			
	8	45.50	49.30	4.50	2.00	1.80	3.30	1.50	7.4	6.0	
	9	52.00	53.50	.80	0.00	2.50	1.80	0.00	2.5	2.9	

1. X-ray diffractograms run with 1960 vintage Phillips, CuKα radiation, 45 Kv, 25Ma, Ni filter, .006 inch receiving slot, 2 degrees 2θ per minute scanning speed, PHS: baseline 100, window 200.

2. Quartz and feldspar were determined by methods developed by Kiely and Jackson, 1965 and Chapman, Syers and Jackson, 1969. Carbonate was determined with the Chittick gasometric apparatus using methods described by Dreimanis, 1962.

Table 4a continued

		10.1A ILL	7.1A CHL	4.26A QTZ	3.25A KSPAR	3.19A PLAG	3.04A CALC	2.89A DOLO	%Qtz.	%Feld.	%Carb.
80-10IA	*1	.30	.80	39.80	0.00	5.90	8.30	0.00			
	2	3.00	3.30	26.00	3.50	6.30	5.30	9.00			
	3	13.80	12.50	26.00	2.00	8.50	5.80	8.00			
	4	23.50	22.30	16.30	.80	4.00	2.30	4.50	35.7	9.9	
	5	31.30	27.30	12.00	1.80	3.50	1.80	2.50			
	6	37.00	36.00	18.30	2.00	2.80	2.80	2.00	21.3	7.8	
	7	28.30	25.30	6.00	.80	2.30	1.80	2.00			
	8	48.30	42.00	3.30	.80	2.30	1.30	2.80			
CR Till	*1	0.00	0.00	31.10	.60	11.80	3.30	10.00			
	2	1.30	2.39	24.50	1.50	6.50	6.30	12.50			
	3	50	5.50	25.80	3.50	7.00	8.00	17.30			
	4	7.50	11.00	23.50	4.30	5.50	11.00	10.50	64.7	22.7	15.3
	5	17.00	21.00	17.50	2.30	4.30	9.80	5.30			
	6	21.30	26.00	14.00	2.30	4.00	10.00	4.50	34.8	7.7	13.5
	7	28.50	35.00	8.50	3.80	4.00	9.30	4.00			
	8	69.50	70.00	3.80	0.00	2.00	4.30	3.00	8.3	3.4	4.0
	9	71.00	63.80	2.00	0.00	0.00	0.00	1.00	0.8	2.7	

Table 4a continued

		10.1A	7.1A	4.26A	3.25A	3.19A	3.04A	2.89A	%Qtz.	%Feld.	%Carb.
		ILL	CHL	QTZ	KSPAR	PLAG	CALC	DOLO			
SR-1	*1	0.00	0.00	28.60	4.10	10.80	4.10	11.10			
	2	3.50	4.30	24.00	2.00	8.80	5.00	9.30			
	3	5.50	8.50	20.00	2.80	6.80	10.00	20.00			
	4	9.80	11.80	19.00	.50	6.30	8.80	10.30	44.9	7.2	
	5	16.30	16.00	14.00	1.80	5.80	3.80	6.00			
	6	16.80	15.00	14.30	1.80	5.30	2.30	6.50	36.3	18.1	
	7	21.50	28.30	9.80	2.00	3.50	1.50	4.30			
	8	39.00	44.00	3.00	0.00	1.80	0.00	1.80	5.7	7.7	
	9	62.00	23.8	1.00	0.00	0.00	0.00	1.00			

* Size Fractions 1, 2, 3, 4 are silt grades: .063-.031mm (4Φ-5Φ); .031-.016mm (5Φ-6Φ); .016-.008mm (6Φ-7Φ); .008-.004mm (7Φ-8Φ). Size Fractions 5, 6, 7, 8, 9 are clay grades: .004-.002mm (8Φ-9Φ); .002-.001mm (9Φ-10Φ); .001-.0005mm (10Φ-11Φ); .0005-.00025mm (11Φ-12Φ); .00025 and finer. The smallest size was set arbitrarily at 14Φ or .000063 mm for purposes of drawing grain size distributions.

Table 4b. Ratios[1] of X-ray Peak Heights. Same Samples as Table 4a.

		ILL/CH	ILL/QTZ	CHL/QTZ	KS/QTZ	PL/QTZ	CA/QTZ	DO/QTZ	K+P/QTZ	C+D/QTZ
CCRA	*1	.00	.02	0.00	.17	.35	.19	.43	.52	.62
	2	1.22	.12	.10	.09	.26	.11	.25	.35	.36
	3	1.05	.21	.20	.07	.31	.25	.53	.38	.78
	4	1.15	.40	.35	.08	.26	.29	.30	.34	.58
	5	1.18	.80	.67	.13	.24	.35	.27	.37	.63
	6	1.07	1.36	1.27	.15	.23	.39	.29	.38	.67
	7	1.42	2.23	1.56	.20	.26	.45	.23	.45	.69
	8	1.45	12.90	8.88	0.00	.43	.43	.57	.43	1.00
	9	2.30	17.68	7.68	0.00	0.00	0.00	0.00	0.00	0.00
CCRB	*1	0.00	0.00	0.00	0.00	.43	.17	.34	.43	.52
	2	.70	.11	.16	.14	.50	0.00	0.00	.64	0.00
	3	.73	.25	.34	.15	.28	.13	.41	.43	.54
	4	.86	.64	.74	.04	.23	.25	.34	.28	.60
	5	1.04	1.12	1.08	.09	.27	.47	.32	.36	.79
	6	.99	3.01	3.05	.32	.34	.59	.32	.66	.92
	7	.96	1.69	1.75	.14	.21	.15	0.00	.36	.15
	8	.92	10.10	10.96	.44	.40	.73	.33	.84	1.07
	9	.97	65.00	66.87	0.00	3.12	2.25	0.00	3.12	2.25
80-10IA	*1	.38	.01	.02	0.00	.15	.21	0.00	.15	.21
	2	.91	.12	.13	.13	.24	.20	.35	.38	.55
	3	1.10	.53	.48	.08	.33	.22	.31	.40	.53
	4	1.05	1.44	.137	.05	.25	.14	.28	.29	.42
	5	1.15	2.61	2.27	.15	.29	.15	.21	.44	.36
	6	1.03	2.02	1.97	.11	.15	.15	.11	.26	.36
	7	1.12	4.72	4.22	.13	.38	.30	.33	.52	.63
	8	1.15	14.64	12.74	.24	.70	.39	.85	.94	1.24

[1] Numbers from Table 4a. were used to calculate ratios.

Table 4b continued

		ILL/CH	ILL/QTZ	CHL/QTZ	KS/QTZ	PL/QTZ	CA/QTZ	DO/QTZ	K+P/QTZ	C+D/QTZ
CR Till*	1	0.00	0.00	0.00	.02	.38	.11	.32	.40	.43
	2	.57	.05	.09	.06	.27	.26	.51	.33	.77
	3	.82	.17	.21	.14	.27	.33	.67	.41	.98
	4	.68	.32	.47	.18	.23	.47	.45	.42	.91
	5	.81	.97	1.20	.13	.25	.56	.30	.38	.86
	6	.82	1.52	1.86	.16	.29	.71	.32	.45	1.04
	7	.81	3.35	4.12	.45	.47	1.09	.47	.92	1.56
	8	.99	18.29	18.42	0.00	.53	1.13	.79	.53	1.92
	9	1.11	35.50	31.90	0.00	0.00	0.00	.50	0.00	.50
SR-1	*1	1.02	0.00	0.00	.14	.38	.14	.39	.52	.53
	2	.81	.15	.18	.08	.37	.21	.39	.45	.60
	3	.65	.28	.43	.14	.34	.50	1.00	.48	1.50
	4	.83	.52	.62	.03	.33	.46	.54	.36	1.01
	5	1.02	1.16	1.14	.13	.41	.27	.43	.54	.70
	6	1.12	1.17	1.05	.13	.37	.16	.45	.50	.62
	7	.76	2.19	2.89	.20	.36	.15	.44	.56	.59
	8	.89	13.00	14.67	0.00	.60	0.00	.60	.60	.60
	9	2.61	62.00	23.80	0.00	0.00	0.00	1.00	0.00	1.00

* Please refer to footnote in Table 4a.

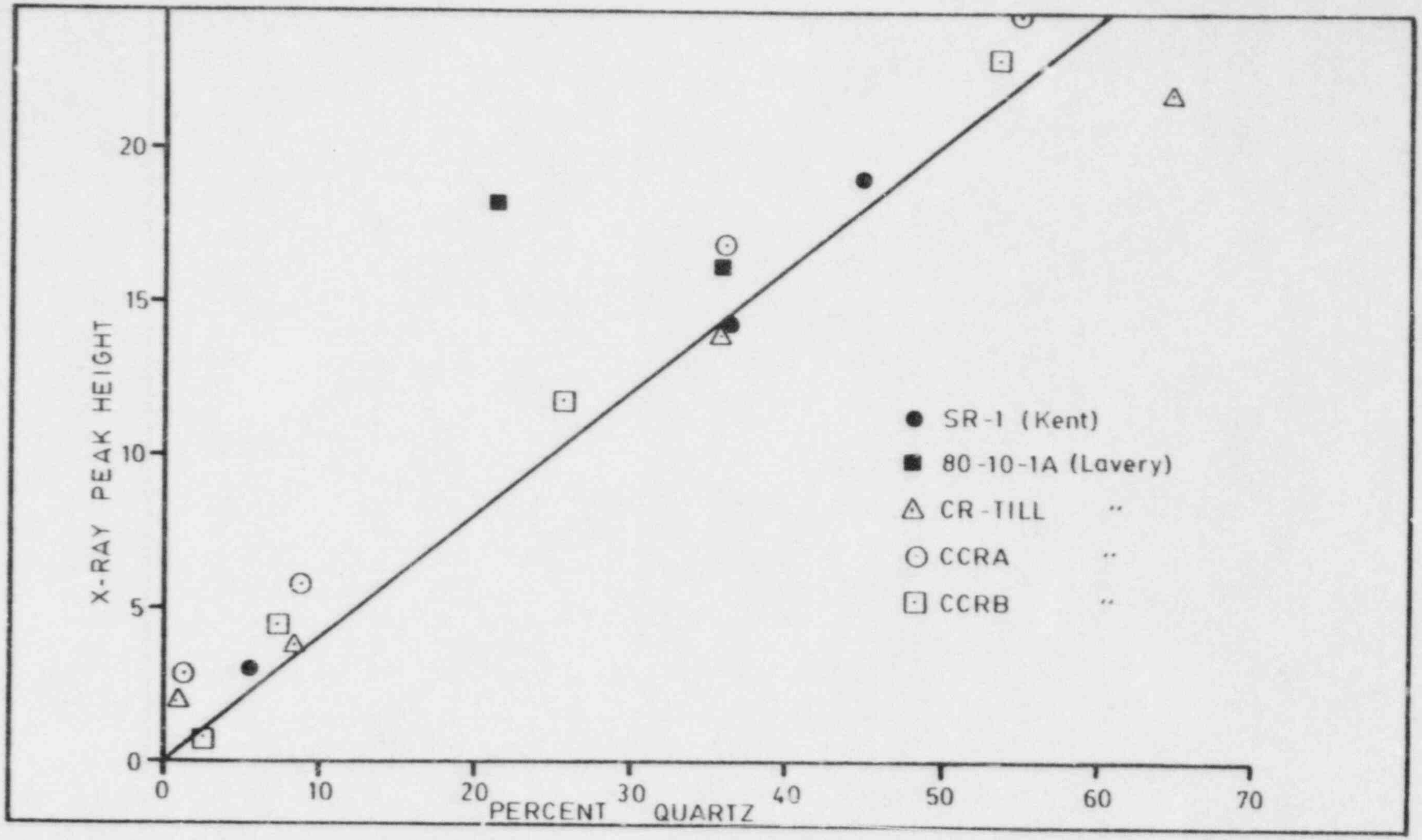


Figure 7. Plot of Quartz Peak Height (4.26A) vs. Percent Quartz in Some Fine Fractions of Lavery and Kent Till.

well crystallized and probably contains much finely ground muscovite. The 3.25A and the 3.19A peaks identified K-feldspar and plagioclase respectively, the 3.04A and 2.89A peaks identified calcite and dolomite, respectively.

Whitney (1977) analysed several samples of the Lavery till, both weathered and unweathered. His x-ray data from the clay fraction (in his work this was smaller than .002 mm) showed only chlorite, illite and quartz. He found no evidence for kaolinite in his samples but did suggest that vermiculite may develop upon weathering, by comparing the 14A/7.1A chlorite peaks. His weathered till samples and soil samples had higher 14A/7.1A values than unweathered samples.

Chlorite was identified by the integral series of basal reflections (001, 002, 003, 004) at about 14A; 7.1A, 4.75A, and 3.5A respectively. These peaks are absent to weak in the coarse and medium silt size, develop in the finer silt fractions and are prominent in the clay sizes. The first and third reflections tend to be weaker than the second and fourth, suggesting that the chlorite is a Fe rich variety (Carroll, 1970, p33.).

Some kaolinite may have developed in the weathering processes. In the size fraction 9-10 phi and finer, from the weathered one of the sample pair CCR, a secondary peak appears on the 3.5A chlorite peak at about 3.53A. This is in the correct position for a kaolinite peak, although it could be a vermiculite peak. Heating of these samples to 300°C for an hour had no effect on this secondary peak, or any other peaks in the defractogram except the 14A peak. This was reduced markedly in size, but not shifted to a smaller d-spacing. These observations suggest that the secondary 3.5A peak is not vermiculite because it was unaffected by the heating, but that the 14A peak may be partly vermiculite because it was reduced markedly in size. However, the position of the 14A did not shift, which casts some doubt on the vermiculite idea. A second heating of these samples to 600°C for an hour strongly enhanced the 14A peak (to about one-half) of its original size) and destroyed the other basal chlorite reflections and the kaolinite peak. This behavior is consistent for a chlorite-kaolinite bearing sample. Unweathered samples did not show any minor kaolinite peaks and furthermore were not much changed by the 300°C heating, confirming that the weathering was the cause of peak modification.

The gravel fraction (larger than 2mm) consists of sedimentary rock fragments with a minor component of high grade metamorphic rock fragments; the latter is composed largely of feldspar and quartz. Pebbles of sandstone tend to be most abundant. The sandstone ranges in color from dark gray through olive, is mostly fine to very fine grained, and consists mostly of quartz, but K-feldspar and plagioclase are important constituents. Sandstone commonly contains chlorite and illite matrix. Siltstone pebbles are similar in composition to the sandstone. Chlorite and illite are important constituents of the clay matrix. Shale pebbles in the gravel fraction consist of dark gray organic stained clay composed of chlorite and illite, with considerable quartz and feldspar silt. Some shale pebbles show laminated structure. Carbonate pebbles are mostly micritic limestone with fossil fragments.

The sand size fraction (2 mm to .063 mm) essentially is a finer grained version of the gravel fraction. The coarser sand grades comprise mostly sedimentary rock fragments similar to those of the gravel fraction. Quartz is an important component as well. Finer sand sizes lose the high percent of rock fragments. This is replaced by individual quartz and feldspar grains. Carbonate grains persist throughout, probably fragments of fossiliferous micritic, as in the gravel fraction.

The silt fraction, analyzed by x-ray and chemical solution, comprised quartz, feldspar, carbonate, illite, and chlorite. X-ray peak heights (Table 4) show that quartz is dominant through the silt grades, feldspar and carbonate vary from moderate to weak, chlorite and illite peaks are small in the coarse and medium silt sizes, and become somewhat larger in the fine and very fine sizes. Chemical solution of the very fine silt fraction shows that quartz forms 35 to 65 percent of this fraction. Clay peaks are highest in this size class of the silt fraction, but other constituents seem to have relatively constant percentages through the sizes. This suggests that quartz and feldspar are more dominant in the coarser silt fractions than in the finer, so that overall mineralogy through the silt size fraction is similar to that of the sand size.

The clay size fractions (finer than .004 mm) show a change with decreasing grain size from quartz rich to a clay dominated mineral content. Quartz peaks are strong in the coarse clay class (.004-.002 mm), moderate in the medium and fine clay classes (.002-.001 and .001-.0005 mm) but drop off sharply in the very fine clay. Feldspar and carbonate contents also diminish with grain size, although not so abruptly as quartz seems to. The analyses suggest that the clay fraction contains about 15 percent total quartz, feldspar and carbonate, even at the .0025 mm size. Clay fractions finer than this appear to be nearly all chlorite and illite. Judging from the illite/chlorite peak height ratio; there is no strong trend in the relative abundance of these two minerals through the grain size distribution.

Figure 6 shows that quartz, feldspar and carbonate are important constituents down to .0005 mm in size, so that these components need to be considered in discussions of chemical behavior of the clay size fraction.

5.0 SURFACE WATER

5.1 History

5.1.1 Initial Work, Including NYSGS Studies Funded by USEPA

In March 1975, laboratory analysis of samples from the New York State Department of Environmental Conservation's monitoring program indicated water within Burial Trench 5 in the NYS-licensed burial area had risen through the soil cover and over the top of the trench. This water build up was monitored previously by DEC using the sumps built into each trench. At this time NFS, the site operator, voluntarily suspended burial operation at the site on recommendations from state and federal agencies. In direct response to this incident the U.S. Environmental Protection Agency (USEPA) requested a research proposal from the New York State Atomic Energy Council that would evaluate the containment ability of the low-level radioactive waste burial area. This request included the preparation of research proposals, the planning and execution of field activities, and the production of reports to the USEPA.

An environmental pathways approach was developed by the New York State Interagency West Valley Task Force Group. This group included: NYSGS, NYS Biological Survey, USGS Water Resources Division, RSL of the New York State Health Department, NYSDEC, NYSERDA, NYS Public Service Commission (NYSPSC), NYS Department of Commerce, and the NYS Attorney General's Office. Various work elements of the study were conducted by the NYSGS or were subcontracted to State and federal agencies. A program to examine the potential for radionuclide migration from the low-level radioactive waste burial site through surface-water pathways was designed and conducted jointly by the NYSGS, USGS and RSL. Other associated projects were subcontracted to various private organizations by the NYSGS and USNRC. Among them was a computer modeling effort intended to simulate the transport of sediments and radionuclides in three small creeks which drain the Western New York Nuclear Service Center conducted by Battelle Pacific Northwest Laboratory in 1978-1979 with USNRC funding. The modeling effort was based on hydrodynamic and radiological data obtained in field experiments conducted at the WNYNSC. Findings were published as quarterly progress reports prepared for the USNRC. More detailed descriptions can be found in Battelle (1979a,d,and e).

Related projects subcontracted by the NYSGS also included a detailed geomorphic and erosion study of the reach of the Buttermilk Creek adjacent to the waste burial area. The primary goal of the study was to investigate sediment yield and mechanisms of erosion in order to establish a rate of denudation for the drainage basin. Collection of various discharge data and stream stage height levels took place over a three year period. More detailed descriptions of the work are available in Boothroyd and others (1979, 1982, 1983).

The entire Cattaraugus Creek drainage basin, of which the Buttermilk is a part, was studied by LaFleur (1983). His study determined the downcutting rate as a function of valley development.

During the main surface-water study conducted by the NYSGS, the USGS was subcontracted to purchase, install and maintain surface monitoring equipment. The RSL was responsible for analyzing the surface water and sediment samples for radiochemical data and interpreting these measurements. Data taken included monitoring rainfall at two sites, surface-water runoff at four surface-water stations, collection of flow proportional stream samples for radiochemical analysis, and suspended sediment samples.

Stream monitoring stations 1, 2, 3, and 4 were located on three small streams that drain approximately one-half of the low-level burial site, part of the NRC-licensed burial area and an area outside the fenced-in portion of the low-level burial area. These stream stations are shown on Plate 1, and on Figures 1 and 2 in Dana and others (1980).

These stream stations were originally equipped with ISCO Model 1470 Float-Activiated Flow Meters and six-inch Parshall flumes. V-notched, steel plate, flow-confining walls were attached to the upstream ends of the flumes at stations 2, 3, and 4 to provide control for flows that exceeded the capacity of the flume. In the spring of 1977, the flumes at stations 2, 3, and 4 were modified to allow the recording of stage levels down to zero discharge and to take flow-proportioned automatic samples at low flows. The digital recorders used at these stations were replaced at this time by graphical recorders which could more accurately record the rapid stage fluctuations, that are characteristic of ephemeral streams. A diagrammatic representation of the stream monitoring equipment is shown in Figure 3 in Dana and others (1980). A complete description of the methods employed and the data collected from this phase of the study are given in Dana and others (1979c, 1980) and Ragan and others (1979).

The conclusions reached as a result of the 1976-1979 phase of the surface-water monitoring study were;

1) Tritium, as tritiated water (H,H-3,O), was the major radioisotope contained in surface-water samples;

2) Tritium activity in samples collected at the onsite stations was approximately one order of magnitude greater than the tritium concentrations measured at Buttermilk Creek at Fox Valley Road, upstream from the security area. This stream gage is on Buttermilk Creek at the southeast edge of the WNYNSC property (see Figure 2 in the Geomorphology chapter of this report). Tritium activity measured at Station 1 was within the range of ambient tritium concentrations off-site. Stream flow at Station 2 accounted for more than 90 percent of the total estimated tritium activity in surface-waters;

3) Total alpha and total beta activities in water samples were frequently below detection limits;

4) Analysis of sediments indicates that activity is confined primarily to the silt- and clay-size fractions;

5) Precise calculations of the total site specific radioactivity contained in the surface waters draining the NYS-licensed burial area was difficult as the result of low concentrations of radioactivity and design limitations of the surface-water monitoring stations.

5.1.2 NYSGS Studies Funded by USNRC

In 1979, with USNRC funding, the NYSGS expanded its surface-water investigations to include the entire security area. A more comprehensive monitoring and sampling program was designed, based on the results of the earlier study, to more accurately describe the overall hydrologic regime. As in previous surface-water investigations, this new program was designed and conducted by the NYSGS, USGS, and RSL. In order to expand the existing network to include the entire site, it was necessary to design and install four new surface-water monitoring stations during the fall of 1980. Stations NP1 and NP3 were installed on two small streams that drain the North Plateau region of the WNYNSC. NP2, a monitoring station consisting of a staff gage, weir plate, and crest gage was installed on a small drainage tributary up on the North Plateau. The third complete stream station, WB1, was installed on a small stream that drains the NRC burial area, approximately 27 m (90 ft) downstream from an older stream station on Lagoon Road (#2). The locations of the new stream stations are shown on Plate 1, and the drainage basins for NP1 and NP3 are shown in Figure 11 in Albanese and others (1982).

Unlike the previous surface-water stations, the new monitoring stations were designed to preserve the natural configuration of the stream channel. This was done in an attempt to study denudation rates on the North Plateau. In order to compensate for the instability of the valley walls, the new stream stations were built on steel I-beam frames that bridged the entire width of the stream, and seven-foot long steel footings were driven into the ground to anchor the corners of the steel frames. A sketch showing the main components of these stream stations is shown in Figure 13 in Albanese and others (1982).

The new stations were located just outside the permanent security fence on the edge of the plateau in overgrown gulleys with no road access available from outside the fenced area. This necessitated the use of a helicopter to airlift the frames into place. Upon installation of the steel I-beam frames, plywood platforms were assembled and small buildings installed to house the stream-monitoring equipment. The stream channel beneath the entire structure was enclosed with styrofoam curtain walls and equipped with propane fueled heaters to permit all-season flow monitoring. Instruments installed in these stations include:

1) an automatic water sampler designed to take either flow-proportioned or time-dependent water samples for radionuclide analysis and suspended sediment measurements;

2) a Manning F300A flow meter;

3) a Stevens Type A Model .71 base recorder.

These pieces of equipment are shown as Figure 13 in Albanese and others (1982).

The operation of the stream gaging stations proved to be more complex than anticipated, resulting in periods of little or no data collection. A major setback occurred when the original operator of the site, NFS, denied the NYSGS access to the site from June 19, 1981, until September 28, 1981, as a result of ongoing litigation with other state agencies involving the future disposition of the site. This condition coupled with a delay in funding from December 1980 until June 1981 caused the NYSGS to interrupt its site investigation and resulted in a 10 month period when little or no data were collected. Also, a condition of the agreement reached between the USNRC and NFS, which allowed the NYSGS to resume site activities, was that no surface-water data could be collected for the purpose of radiochemical analysis. The NYSGS was allowed to analyze core taken from drilling programs.

During the fall of 1981 and spring of 1982, severe slumping of the channel walls enclosed under the new stream stations made data collection difficult. This slumpage resulted in the abandonment of the WB1 surface-water monitoring station from December 1981 through March 1982. Problems with this station could not be overcome and the station was permanently abandoned.

The slumping and associated sediment buildup in the stream channels necessitated daily cleanout of the channels and rendered the automatic sampling units useless. Also, made the ephemeral nature of the small streams, automatic flow-meter data unreliable. The stream channels under the NP1 and NP3 stations froze repeatedly during January and February of 1982 despite propane heated enclosures. As a result, there are major discrepancies in stage-level data. In April 1982, as the result of road construction by the new site operator, West Valley Nuclear Services (WVNS), the channel under NP3 was washed out. That station required significant repair before being reactivated during June 1982.

Data collection at these stations began in the fall of 1981 and continued under supervision by the NYSGS until October 1982. Table 5 shows types of data collected from all of the stream stations and rain gages installed by the NYSGS and USGS. More detailed descriptions of these stations and the collected data are contained in Albanese and others (1982, 1983).

Table 5. Data collection from surface water stations set up in 1980, for the period September 1981 through October 1982.
See Plate 1 for locations of stream stations and rain gages.

Data Type	Station	Frequency	Objectives
discharge measurements	NP1,NP2 NP3,WB1	daily, plus storm events	rating curves and discharge rates
suspended sediment	NP1,NP2, NP3,WB1	same as discharge measurements	sediment concentrations
stage height	NP1,NP3,WB1	daily	rating curves for stage heights
precipitation	rain gages 1,2,4	daily	precipitation amounts and rates

6.0 RADIONUCLIDE ANALYSES

6.1 Introduction

Over the past twenty years a large number and variety of radionuclide analyses on samples from the WNYNSC and vicinity has been done. The variety can be attributed both to the multipurpose nature of the service center, and to the various interests of the agencies, institutions, and organizations that have studied the site.

NYSGS investigations at the site have been focused on geology of the Pleistocene and Holocene sediments, surface and ground water, and possible problems resulting from erosion. Several of these studies have included radionuclide analyses carried out by the Radiological Sciences Laboratory of the NYS Department of Health (RSL). Because the NYSGS does not have expertise in radiological health, we have also relied on RSL for interpretations of their results. This section presents a review of radionuclide studies that have been done at the site, but without an independent interpretation of results in terms of dose or health effects. This review complements the other historical summaries included in this report.

6.2 Review of Past Work.

6.2.1 Potential Sources of Radioactivity

The initial purpose of the WNYNSC was to reprocess spent fuel rods from nuclear reactors to extract uranium and plutonium. The main products were shipped away, but various radioactive by-products were produced, including planned low-level gaseous and liquid effluents, higher level liquid and solid wastes, and contaminated equipment and work space. Additional wastes were brought to West Valley for initial disposal in the commercial low-level waste burial area. As a result of past activities within the WNYNSC, there are several potential sources of radioactive releases into the environment including:

1) the process plant, its cells contaminated during the reprocessing of spent nuclear fuel from 1966 through 1972.

2) an indoor pool for the receipt and storage of spent fuel assemblies pending reprocessing. All of the fuel currently in the pool is scheduled to be returned to its owners before October 1, 1985.

3) underground storage tanks containing 2,270,000 liters (600,000 gal) of high level liquid waste generated during dissolution of the fuel rods and chemical extraction of uranium and plutonium. This waste will be solidified as part of the ongoing West Valley Demonstration Project and will ultimately be disposed of in a federal high level waste repository.

4) low-level liquid waste treatment and lagoon system used to remove radioactivity from low-level liquid waste prior to discharge into onsite surface streams.

5) the NYS-licensed commercial burial area for low-level solid waste. This facility consists of long trenches excavated in Lavery till, filled with low-level solid waste and covered with the disturbed till. Over 2 million cu. ft. of waste was buried between 1963 and 1975; no waste has been buried in this area since 1975.

6) the NRC-licensed burial area, also referred to as the hulls and ends burial area or plant burial area. This area contains plant generated solid waste placed in holes (some as deep as 50 ft) excavated in Lavery till and covered with disturbed till.

6.2.2 Purpose of Analyses

Since there are a variety of site facilities that are potential sources of radioactivity releases to the environment, radionuclide analyses of samples from the WNYNS have been performed for a number of reasons, including:

1) monitoring of facilities to determine the extent of radionuclide migration, if any;

2) comparing ambient conditions on the site with background levels offsite;

3) studying and monitoring potential pathways (e.g., air, surface, sub-surface) for radionuclide release to the environment;

4) studying the nature of the sources of radioactivity on the site and how they change with time;

5) estimating potential doses to humans, either direct or indirect, by means of ingesting plants, animals, air, water, etc.

6.2.3 Types of Studies

Table 6 provides a summary of radionuclide analyses that have been performed, including work involving NYSGS and RSL since 1975. Some additional analyses, for which reports are not readily available, were also performed by the original site operator, Nuclear Fuel Services, Inc., and the present operator, West Valley Nuclear Services, Inc.

The table is subdivided according to the following general type of samples:

1) surface water;

2) suspended and bed load sediment from streams;

3) groundwater;

4) water accumulated in the trenches of the NYS-licensed burial area;

5) ambient air gases generated by decay of organic material in the trenches of the NYS-licnesed burial area, and releases from the stack of the plant during operations;

6) animals, plants, and milk from the vicinity;

7) sediment cores from holes drilled on site near the burial areas;

8) sediment cores from holes drilled through the trenches of the NYS-licensed burial area.

Each entry in Table 6 lists a reference, the specific type of sample analyzed, and the radionuclides measured. The same reference may appear in more than one subdivision of the table, with different types of samples. The raw data are not presented. The table is intended primarily as a guide for those who want to find data from a particular type of sample.

Additional related studies also are listed that did not involve actual analysis of radionuclides but provide supporting information. For example, attempts have been made to reconstruct an inventory of the contents of the trenches in the NYS-licensed burial area. Studies also have been made of non-radioactive aspects of the trench water and gases, such as the organic and inorganic chemistry and the bacteria present. References also are listed for several computer simulation models that have been constructed to study and

Table 6. History of radionuclide analysis performed at the WNYNSC. The studies are grouped by the type of sample examined, and include related studies.

RADIONUCLIDE REFERENCES

Groundwater

Reference	Type of Sample	Radionuclide
Colombo, Weiss, and Francis, 1978	subtrench holes and holes near trenches	gross α, gross β, gross γ, tritium. Some gamma ray spectrometry.
Weiss and Colombo, 1980	holes C2,B,D near trenches	gross α, gross β, gross γ, tritium, Am-241, Cs-134, Cs-137, Co-60
Albanese, Dunne, Rogers and Potter 1982	1980 holes	gross α, gross β, tritium

Table 6. continued

RADIONUCLIDE REFERENCES

Surface Water

Reference	Type of Sample	Radionuclide
Kelleher, 1969	Butt. and Catt. Crs.	Sr-90, gross β, Cs-137, tritium
	Cattaraugus Cr.	Pu-238, Pu-239, U-234, U-235, U-238
Matuszek, Daly, Goodyear, Paperiello, and Gabay, 1974	streams on site, Butt. and Catt. Crs.	I-129
Daly, Goodyear, Paperiello, and Matuszek, 1974	Butt. and Catt. Crs.	I-129
Davis, Dana, Molello, Fakundiny, Matuszek, and Lu, 1978	stream sta. on site, snow melt runoff on site, sub-ice flow runoff on site	gross α, gross β, tritium
Dana, Ragan, Molello, Bailey, Fickies, Fakundiny, & Hoffman 1980	stream sta. on site	gross α, Sr-90, gross β tritium, C-14, Na-22, Fe-55 Co-60, Ni-63, I-129

Table 6. continued

Surface Water-continued

Reference	Type of Sample	Radionuclide
Dana, Molello, Fickies and Fakundiny, 1979b	stream sta. on site, Connoisarauley Cr., background	gross α , gross β , tritium
	Butt. Cr., above site, rain and snowmelt runoff, sub-ice flow runoff, storm grab samples	gross α , gross β , tritium
Ragan, Molello, Dana Fickies and Fakundiny, 1979	stream sta. on site	Sr-90, Cs-134, Cs-137, Co-60, Na-22, Ba-133, inorganic C-14 organic C-14, Ni-63, Fe-55, K-40, Th-232, Pu-238, Pu-239,240, Ra-226
	water off site	gross α , gross β , tritium
Sax, Lemon, Benton and Gabay, 1969	streams on site	Ru-Rh-106, Cs-137, Zr-Nb-95, Cs-134, Co-60
	Buttermilk Creek	Ru-Rh-106, Cs-137, Zr-Nb-95, Cs-134, Co-60
Colombo, Weiss, and Francis, 1978	streams on site	tritium, gross α , gross β , gross γ , gamma spectrometry

Table 6. continued

Surface Water-continued

Reference	Type of Sample	Radionuclide
Weiss and Colombo 1980	streams off site	gross α, gross β, gross γ, tritium, Am-241, Cs-134, Cs-137, Co-60
Battelle, 1979c	Butt. and Catt. Crs.: Phase I (average flow), Phase II (low flow)	gamma ray spectrometry
Ecker and Onishi, 1979	Butt. and Catt. Crs. Phase I (average flow)	gamma ray spectrometry
Onishi, Walters, and Ecker, 1981	Butt. and Catt. Crs.	Cs-137, Cs-134, Co-60, Zr-Nb-95, Eu-155, Ce-144, Ce-141, Ra-224, Ra-226, Ru-106, K-40
Davis and Fakundiny 1978	streams on site	tritium, gross α, gross β
Albanese, Dunne, Rogers and Potter 1982	streams on site	gross α, gross β, tritium

Table 6. continued

RADIONUCLIDE REFERENCES

Sediments from Streams

Reference	Type of Sample	Radionuclide
Kelleher, 1969	silt from Butt. and Catt. Crs.	Sr-90, Cs-137, Ru-106, Cs-134, Zr-Nb-95, Co-60
	silt from Catt. Cr.	Pu-238, Pu-239, U-234, U-235, U-238
Dana, Molello, Fickies, and Fakundiny, 1979b	monthly sediment grab samples	gross α, gross β, tritium
Ragan, Molello, Dana Fickies and Fakundiny, 1979	sediment from Erdman s Brook	gross α, gross β
Sax, Lemon, Benton, and Gabay, 1969	bottom silt from streams on site and Butt. Cr.	Ru-Rh-106, Cs-137, Zr-Nb-95, Cs-134, Co-60
Battelle, 1979a	Phase I: suspended sediment (average flow)	Pu-238, Pu-239, Sr-90, Am-241, Cm-244, tritium, Cs-137,

Table 6. continued

Sediments from Streams-continued

Reference	Type of Sample	Radionuclide
	and bed sediment	Cs-134, Co-60, Zr-Nb-95 Eu-155, Ce-144, Ce-141. Ra-224, Ra-226, Ru-106, K-40
Battelle, 1979c	Phase I sediment (average flow)	Pu-238, Pu-239-240, Sr-90
	Phase II sediment (low flow)	gamma spectrometry
Ecker and Onishi, 1979	suspended and bed sediment (average flow) and dissolved load	Cs-137, Cs-134, CO-60, Zr-Nr-95, Eu-155, Ce-144, Ra-224, Ce-141, Ra-226, Ru-106, K-40, Pu-238, Pu-239-240, Sr-90, Am-241, Cm-244, Rh-101, Sb-125, Pb-210, Th-232, Th-228, U-235, U-238
Onishi, Walters, and Ecker, 1981	suspended, dissolved, and bed load, Phase I and II (average flow and low flow)	Sr-90, Pu-238, Pu-239-240, Am-241, Cm-244, Cs-137, Cs-134, Co-60, K-40, Ra-226, Th-232, Th-228, U-235, U-238, Am-241 Sb-125, Bi-207, Rh-102, Eu-155, Rh-101, Zn-65, Mn-54, Ce-144, Pb-210

Table 6. continued

Sediments from Streams-continued

Reference	Type of Sample	Radionuclide
Onishi, Yabusaki, Kincaid, Skaggs, and Walters, 1982	all three Phases (average, low, high flow)	graphs of various radionuclide data compared with simulation.
Walters, Ecker, and Onishi, 1982	Lake Erie bed sediment at mouth of Catt. Cr.	K-40, Cs-137, Ce-144, Eu-155, Ra-226, Th-228, Th-232, U-235, U-238, Pb-210, Rh-101, Nb-95, Ce-141, Bi-207, Cs-134, Sr-90, Pu-238, Pu-239-240, Am-241, Cm-244, Co-60, Bi-214, Ra-228
	floodplain and channel bar deposits in Catt. Cr.	K-40, Co-60, Cs-134, Cs-137, Ce-144, Bi-207, Th-228, B-214, U-235, U-238, Am-241
Albanese, Dunne, Rogers and Potter 1982	suspended sediment, on site	gross α, gross β

Table 6. continued

RADIONUCLIDE REFERENCES

Sediments from Streams
Related Studies

Reference	Type of Sample	Radionuclide
Battelle, 1979b	modeling and simulation studies, sediment and radionuclide transport in in streams	
Battelle, 1979d	modeling and simulation studies	

Table 6. continued

RADIONUCLIDE REFERENCES

Lagoons and Liquid Effluent

Reference	Type of Sample	Radionuclide
Kelleher, 1969	liquid waste discharge	gross α, gross β, tritium
	waste lagoon water and suspended sediment	gross γ, Sr-90, H-3, U, Co-60, Ru-106, Cs-134, Cs-137, I-129, Sb-125

Table 6. continued

RADIONUCLIDE REFERENCES

Sediment Cores

Reference	Type of Sample	Radionuclide
Dana, Ragan, Molello, Bailey, Fickies, Fakundiny and Hoffman, 1980	trench cap soil	tritium, gross α, gross β
	subtrench cores	tritium, C-14, Sr-90, Cs-134, Cs-137, Pu-238, I-129, Pu-239-240, Am-241, U-234, U-235, U-238
Matuszek, Strnisa, and Baxter, 1976	NFS-NYSASDA holes	tritium, Sr-90
Duckworth, Jump, and Knight, 1974	NFS-NYSASDA holes	tritium
Prudic, 1979	subtrench cores	Cs-137, Co-60, Cs-134, tritium

Table 6. continued

Sediment Cores-continued

Reference	Type of Sample	Radionuclide
Dana, Molello, Fickies and Fakundiny, 1979d,	subtrench cores	(H-3)HO, C-14, Sr-90, Cs-134, Cs-137, Fe-55, Ni-63, Pu-238, Pu-239-240, Am-241, U-234, U-235, U-238, K-40, Th-232, Ra-226, Co-60, Ba-133, Ru-106
Dana, Molello, Fickies, and Fakundiny, 1979e	USGS cores near trenches: F, A2, B, D, E, R, C, D2, E2, N	gross α, gross β, Sr-90, Ru-106, Cs-134, Cs-137, Mn-54 Co-60, Sb-125, Fe-55, I-125, I-129, Pu-238, Pu-239-240, U-234, U-235-236,, U-238
Dana, Fakundiny, LaFleur, Molello and Whitney, 1979a	USGS cores near trenches: A, B, C, D, D2, E, E2, F, N, R	gross α, gross β
	C2, E, I, J, M, N, P	gamma spectrometry
Albanese, Dunne, Rogers and Potter 1982	1980 holes	gross α, gross β, tritium

Table 6. continued

RADIONUCLIDE REFERENCES

Sediment Cores
Related Studies

Reference	Type of Sample	Radionuclide
Colombo and Weiss, 1979a	unweathered till, USGS hole A2, near trenches	sorption coefficients for Sr-85, CS-134, Cs-137, Co-60
Dana, Molello, Fickies, and Fakundiny, 1979e	in-hole gamma spectral logging: USGS holes near trenches.	identified Co-60, Cs-137
Dana, Fakundiny, LaFleur, Molello, and Whitney, 1979a	till from USGS cores near trenches	chemical and mineral composition

Table 6. continued

RADIONUCLIDE REFERENCES

Air and Gas

Reference	Type of Sample	Radionuclide
Kelleher, 1969	particulates in air	gross β
Matuszek, Lu, Dana, Molello, Fickies and Fakundiny, 1979	trench gas	(H-3)CH3, (C-14)H4, (C-14)O2, Kr-85, Rn-222
Cochran, Smith, Magno, and Shleien, 1979	effluent from stack, air in vicinity	Kr-85, I-129, tritium
Cochran, Griffin, and Troianello, 1973	effluent from stack, air in vicinity	tritium
Daly, Manchester, Gabay, and Sax, 1968	air in vicinity	tritium
Matuszek, Kunz, Hutchinson, Mahoney and Dana, 1979	trench gas	(H-3)H, Kr-85, (C-14)H4, (H-3)CH3, (C-14) in complex hydrocarbons, (H-3) in complex

Table 6. continued

Air and Gas-continued

Reference	Type of Sample	Radionuclide
		hydrocarbons, (C-14)O2, (C-14)O, (C-14)total, (C-14)CO, (H-3)HO, Rn-222
	air 2.54 cm (1 inch) above ground	same as above.
	flux box experiment over trenches	(not successful-leaks through fractures in caps)
Davis, Dana, Molello, Fickies, Fakundiny and Matuszek, 1979	trench gas	(H-3)H, Kr-85, (C-14)H4 C(H-3)H3, (C-14) in complex hydrocarbons, (H-3) in complex hydrocarbons, (C-14)O2 (H-3)HO, Rn-222
Davis and Fakundiny, 1978	trench gas	(H-3)H, Kr-85, (C-14)H4, C(H-3)H3, (C-14)H, H-3, (C-14)O, (C-14)O2, Rn-222

Table 6. continued

RADIONUCLIDE REFERENCES

Air and Gas Related Studies

Reference	Type of Sample	Radionuclide
EG&G, Energy Measurements Group 1981	aerial survey of gamma emitters, especially Cs	
Robinson, 1980	model of diffusion of gases from trenches	
Lu and Matuszek, 1978	bulk permeability of trench caps	

Table 6. continued

RADIONUCLIDE REFERENCES

Animals, Plants, Milk

Reference	Type of Sample	Radionuclide
Kelleher, 1969	soft tissues of deer	Cs-137, Cs-134, tritium
	fish	Ru-106, Cs-134, Co-60, Cs-137, K-40, Sr-90
	milk	Sr-90, I-131, Cs-137
Matuszek, Daly, Goodyear, Paperiello and Gabay, 1974	deer thyroids, rabbit & woodchuck thyroids, algae, sucker, trout, salmon, bovine thyroids, milk	I-129
Daly, Goodyear, Paperiello, and Matuszek, 1974	milk	I-129

Table 6 continued

Animals, Plants, Milk-continued

Reference	Type of Sample	Radionuclide
Davis, Dana, Molello, Fakundiny, Matuszek and Lu, 1978	frogs	Cs-134, Cs-137, Pu-238, Pu-239-240, Sr-90, Fe-55, CO-60 Th-228, Ba-133, Na-22, I-129, Ni-63, (H-3)HO, C-14, gross α , gross β
Sax, Lemon, Benton, and Gabay, 1969	algae, fish, clams	Ru-Rh-106, Cs-137, Zr-Nb-95, Cs-134 Co-60
Shleien, 1970	milk, deer, fish	Sr-90, Cs-137, Cs-134, Co-60, Ru-Rh-106, H-3, Kr-85
Cochroan, Griffin, and troianello, 1973	farm vegetables	H-3

Table 6. continued

RADIONUCLIDE REFERENCES

Trench Water

Reference	Type of Sample	Radionuclide
Kelleher and Michael, 1973	trench water	gross α , gross β , tritium Sr-90, I-125, I-129, Cs-137, Ru-106, Sb-125, I-125, Cs-134, Na-22, Fe-55, Co-58 Co-60, Ni-63, Ba-133, Ra-226, Th-228-230, U-234, U-235-236, U-238, Pu-238, Pu-239-240, Am-241, Ru-106, Mn-54, Co-57 Se-75
Dana, Ragan, Molello, Bailey, Fickies, Fakundiny and Hoffman, 1980	trench water and suspended sediment	(H-3)HO, Sr-90, Pu-238, Pu-239-240, Cs-134, Cs-137, Fe-55, Co-60, Ni-63, total(C-14), I-129, U-234, U-235, U-238, Mn-54, Ru-106, gross α gross β , K-40

Table 6. continued

Trench Water-continued

Reference	Type of Sample	Radionuclide
Dana, Molello, Fickies and Fakundiny, 1979c	water pumped out of trenches	gross α, gross β, tritium Sr-90
Dana, Molello, Fickies, and Fakundiny, 1979b	trench water and suspended sediment	(H-3)HO, Sr-90, Pu-238, Pu-239-240, Cs-134, Cs-137, Cs-134, Cs-137, Fe-55, Co-66 Ni-63, C-14, I-129, U-234, U-235, U-238, Am-241, Th-232, Na-22, Ba-133, Mn-54, Ru-106 Sb-125, gross α, gross β
Dana, Molello, Fickies and Fakundiny, 1979d	trench water	(H-3)HO, Sr-90, Pu-238, Pu-239-240, Cs-137, Fe-55, Ni-63
Duckworth, Jump, and Knight, 1974	trench water	gross α, gross β, tritium Sr-90, I-129, I-125, Cs-137, Cs-134, Ru-106, Mn-54 Co-60, Co-57, Na-22, Se-75
Weiss and Colombo, 1980	trench water	gross α, gross β, tritium Sr-90, Pu-238, Pu-239-240 Am-241, Na-22, K-40, Co-60 Ba-133, Cs-134, Cs-137

Table 6. continued

Trench Water-continued

Reference	Type of Sample	Radionuclide
	particulates from trench water	Sr-90, Pu-238, Pu-239-240, Am-241, K-40, Co-57, Co-60 Sb-125, Ba-133, Cs-134, Cs-137
Colombo, Weiss, and Francis, 1979	trench water	gross α, gross β, tritium Am-241, Cs-137, Co-60, Sr-90, Pu-239-240, Pu-238
Colombo, Weiss, and Francis, 1978	trench water	tritium, gross α, gross β, gross γ
Colombo and Weiss, 1979b	trench water	Co-60, Sr-90, Cs-137, Pu-238-239-240, Na-22, Cs-134, Am-241
Colombo and Weiss, 1979c	particulates from trench water	Sr-90, Pu-238, Pu-239-240 Am-241, Cs-134, Cs-137, Co-60 K-40, Ra-226

Table 6. continued

RADIONUCLIDE REFERENCES

Trench Water
Related Studies

Reference	Type of Sample	Radionuclide
Colombo, Weiss, and Francis, 1979	trench water	organic compounds, bacteria
Colombo, Weiss, and and Francis, 1978	trench water	specific conductance, PH, temperature, dissolved organic carbon
Colombo and Weiss, 1979a	trench water	sorption coefficients for Sr-85, Cs-134, Cs-137, Co-60
Colombo and Weiss, 1979b	trench water	pH, Eh, specific conductance, temperature, organic compounds, inorganic compounds
Weiss and Colombo, 1980	trench water	organic compounds, inorganic compounds, bacteria, sorption coefficients for Eu-152

Table 6. continued

Trench Water
Related Studies

Reference	Type of Sample	Radionuclide
		Am-241, Sr-85, Cs-134, Cs-137 Co-60
Dana, Molello, Fickies and Fakundiny, 1979d 1979	trench water	organic compounds, inorganic chemistry
Dana, Ragan, Molello Bailey, Fickies, Fakundiny and Hoffman, 1980	trench water and suspended sediment	Eh, pH, temperature, stable iodide, total nickel

Table 6. continued

RADIONUCLIDE REFERENCES

Inventories

Reference	Type of Sample	Radionuclide
Kelleher and Michael, 1973	trench inventory: isotopes, weights, volumes	
Molello, 1977	isotope inventory for trench 5	
Molello, 1976	locations of containers in trench 5	
Ford, Bacon, and Davis Utah, Inc., 1978	trench inventory: isotopes, volumes	

Table 6. continued

RADIONUCLIDE REFERENCES

Modeling Studies and Estimates of Release Rates

Reference	Type of Sample	Radionuclide
Matuszek, Lu, Dana Molello, Fickies, and Fakundiny, 1979	solute transport in groundwater; gas transport; runoff transport	
Davis and Fakundiny 1979	modeling workshop on West Valley site	
Davis, Dana, Molello Fakundiny, Matuszek, and Lu, 1978	appendix on computer model of site	
Robinson, 1980	modeling of gas diffusion from trenches	
Battelle, 1979b	model of radionuclide transport in rivers	
Battelle, 1979d	model of radionuclide	

Table 6. continued

Modeling Studies-continued

Reference	Type of Sample	Radionuclide
	transport in rivers	
Onishi, Yabusaki, Kincaid, Skaggs, and Walters, 1982	comparison of measurements and model for transport in rivers	
Lu, 1978	model of leaching, tested on hole 12 NFS-NYSASDA	
Shleien, 1970	dose commitment for 1968, from diet, deer, fish, drinking water, air	
Ford, Bacon, and Davis Utah, Inc. 1978	calculated doses from various sources: well water, exhuming waste, tank failure, standing in burial	
	air, breathing air at site boundary, using stream water	
Matuszek, Lu, Dana	estimated annual	

Table 6. continued

Modeling Studies-continued

Reference	Type of Sample	Radionuclide
Molello, Fickies and Fakundiny, 1979	releases from trenches	
Sax, Lemon, Benton, and Gabay, 1969	relative contributions of burial site and reprocessing plant	
Daly, Manchester, Gabay, and Sax, 1968	estimates proportions released by stack, into Buttermilk, and buried	
Lu and Matuszek, 1978	estimated release rate of (H-3)CH3 through trench covers	

predict the migration of radionuclides via various pathways. A workshop on computer modeling for West Valley was held in 1978 by NYSGS for USEPA.

6.3 1982 Drilling Project

The most recent NYSGS study to include radionuclide analyses was the fall 1982 drilling project. Most of the radionuclide data were first reported in Appendix D. Seventeen holes were drilled in five clusters around the NRC-licensed burial area. In each cluster one hole was cored continuously to approximately 15 m (50 ft). Two deeper holes were augered to 15 m (50 ft) and then cored continuously to 26 to 27.5 m (85 to 90 ft). These two holes were later deepened to approximately 30.5 to 33.5 m (100 to 110 ft), in the spring of 1983. Sediment cores and water samples from several of the holes were sent to RSL for analysis. Because of the low permeability of the Lavery till water yields were low, so few water samples of sufficient volume were collected. Additional information on drilling procedures and sample handling can be found in Appendix D.

Radionuclide analyses of sediment cores and water samples obtained during the fall 1982 drilling program were performed by RSL of the NYS Department of Health, with Health Research, Inc., acting as subcontractor to NYSGS. The objective of this drilling program was to delineate the major lithologic boundaries and the character of the major units, and to provide piezometric data for use by the USGS in their groundwater model. The two deep holes extended below the 15 m (50 foot) maximum depth of burial holes in the burial area to identify lithologies extending under the area. The cores from these and from the 15 m (50 ft) holes were examined in detail searching for layers or pods of more permeable sand and gravel within the burial till. Some pods were found, but none of these extended into adjacent holes in the same cluster, less than 3 m (10 ft) away.

The radionuclide data from RSL are presented in Appendix C. In Potter and others (Appendix D), the tritium data presented in that report also were shown on graphs alongside graphic representations of the sediment grain size descriptions from the geologic logs of the cores. These graphic columns are repeated in this report in Appendix B, 1983, and with changes for the two holes deepened in 1983. and additional columns for the holes drilled in 1983.

Several types of analyses were done. One hundred nine sections of core from seven holes were analyzed for tritium in the pore water. Most of these results were reported in

Potter and others (Appendix D). Additional tritium analyses were done on six water samples from four holes. Gross alpha and gross beta determinations were done on three of the water samples. Isotopic gamma spectrum analyses were done on 14 core samples and one water sample, for the isotopes Th-232, Ra-226, Cs-137, Co-60, and K-40. Radiochemical analyses were done for Sr-90, Pu-238, Pu-239, U-234, U-235, and U-238 for 6 core samples, and for Sr-90 for one water sample.

The drilling procedures used in the fall 1982 drilling project were similar to those used in earlier USGS-NYSGS coring projects, for which radionuclide analyses also were performed:

1) several holes drilled around the perimeter of the NYS-licensed burial area in 1975-1977 (Prudic and Randall, 1977);

2) holes drilled through the trenches (Prudic 1979; Dana and others, 1980); and

3) a series of ten holes drilled in 1980, away from the burial areas but inside the security fence (Albanese and others, 1982).

These drilling projects are described in the stratigraphy chapter.

The results for all of the radionuclide analyses done on samples from the fall 1982 project are listed in Appendix C, listed by hole number and sample depth. Table 7 summarizes these data by showing the range of results for each radionuclide or radiation measurement. The 1982 data are compared with data from earlier drilling projects, and one surface water sample (Dana and others, 1980). Analytical procedures used by RSL for all of these projects are basically the same as reported in Dana and others (1980).

Table 7. Comparisons of radionuclide analyses from holes drilled in fall 1982 with results from earlier projects. Unless specified otherwise, samples are cores from drilling projects.

Isotopes or Tests	Ranges of Data		Project Used for Comparison
	Fall 1982	Other Project	
tritium	pore water, near surface cores: 1E-7 to 7.6E-6 µCi/ml	pore water, near surface cores: 5E-6 to 5E-4	1975-1977 drilling, perimeter of NYS-licensed burial area
gross α	water: <0.1E-7 to 0.14E-7 µCi/ml	water: <0.1E-7 to <0.6E-7	1980 drilling, security area
gross β	water: 0.08E-7 to 0.16E-7 µCi/ml	water: <0.4E-7 to <0.7E-7	1980 drilling, security area
Cs-137	<0.3E-7 to 3.9E-7 µCi/g	<1.2E-7 to 5.7E-7	1975-1977 drilling, perimeter of NYS-licensed burial area
Co-60	<0.4E-7 to <0.6E-7 µCi/g	<1.1E-7 to <6E-7	1975-1977 drilling, perimeter of NYS-licensed burial area

Table 7. continued

Isotopes or Tests	Ranges of Data		Project Used for Comparison
	Fall 1982	Other Project	
Sr-90	water: <0.8E-9 μCi/ml (one sample)	water: 6.1E-7 to 1.08E-6	Lagoon Road stream station
Sr-90	0.08E-6 to 0.55 ± 0.16E-6 μCi/g	3E-8 to 7.7E-6	subtrench coring
Pu-238	0.03E-6 to 0.04 ± 0.02E-6 μCi/g	2E-10 to 1.9E-8	subtrench coring
Pu-239,240	0.02E-6 to 0.12E-6 μCi/g	2E-10 to 5E-9	subtrench coring
U-234	0.87 ± 0.12E-6 to 1.07 ± 0.11E-6 μCi/g	5E-7 to 1.1E-6	subtrench coring
U-235	0.031 ± 0.15E-6 to 0.045 ± 0.012E-6 μCi/g	1.3E-9 to 3E-8	subtrench coring

Table 7. continued

Isotopes or Tests	Ranges of Data		Project Used for Comparison
	Fall 1982	Other Project	
U-238	1.00 ± 0.11E-6 to 1.08 ± 0.12E-6 μCi/g	4E-7 to 5.7E-6	subtrench coring

7.0 CONCLUSIONS

The stratigraphy of this area can be summarized as consisting of five studied units underlain by additional till and lacustrine beds in a shale bedrock valley. In many areas the youngest deposit consists of alluvial gravels of both Holocene and Wisconsinan ages. The alluvial gravel of the North Plateau consists of 56 percent gravel, 22 percent sand, 13 percent silt, and 9 percent clay. The permeability is one to two orders of magnitude greater than in the underlying till unit. Below the alluvial fans and exposed at the surface where fans are absent is the Lavery till, a unit of predominantly clay containing some pebbles and discontinuous silt-sand pods. The Lavery till is the unit in which the radioactive material is buried. This till is underlain in some places by a sand-gravel kame delta unit and lacustrine sediments which generally grade downward to varved layers. Below this is the Kent till, which differs from the Lavery by having silt as its predominant grain size. Underlying the Kent till are additional till and lacustrine units but sufficient data to characterize the sediments of the central part of the bedrock valley have not been obtained. The upper part of the shale bedrock has been fractured and it is the major aquifer of this stratigraphic sequence.

Surface and groundwater studies, undertaken in cooperation with the USGS have confirmed that as a result of the sedimentological composition of the Lavery till, this area is one of very low infiltration and consequently highly varying rates of stream flow. Surface water discharge measurements indicate only the streams draining the alluvial gravels of the North Plateau have any base flow; the others contain water only in relation to storm events. Measurements of groundwater in the monitoring wells indicate very slow movement characteristic of a low permeability till. The USGS, expanding the groundwater model of Prudic (1982), is incorporating these measurements in a model of groundwater flow through the southern part of the security area and, with a separate model, characterizing the groundwater in the much more permeable North Plateau. Measurements of radionuclide concentrations taken for many surface and groundwater samples have indicated no concentrations above background levels in the unweathered zone of the till.

The geomorphic character of this region is that of a series of deep bedrock valleys filled with great thicknesses of glacial sediments (up to 150 m (500 ft) in Buttermilk Valley). The present drainage is composed of actively downcutting streams in narrow V-shaped valleys. The hill slopes commonly are covered with landslides and evidence of slump movement during the recent past. The instability of slopes cut in the Lavery till may be the most serious threat to the integrity of the burial areas.

8.0 REFERENCES

Albanese, J.R., S.L. Anderson , L.A. Dunne, and B.A. Weir, 1983. Geologic and Hydrologic Research at the Western New York Nuclear Service Center, West Valley, New York. Annual Report, August 1981-July 1982. NYS Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-3207. 397p.

Albanese, J.R., L.A. Dunne, W.B. Rogers, and S.M. Potter, 1982. Geologic and Hydrologic Research at the Western New York Nuclear Service Center, West Valley, New York. Progress Report, August 1979-July 1981. N.Y.S. Geological Survey Report to U.S. Nuclear Regulatory Commission. NUREG/CR-2381.

Bailey, H.H., 1975. Unpublished geologic logs of cores from the NFS-NYSASDA drilling project at West Valley, New York. Unpublished NYSGS report.

Battelle, Pacific Northwest Laboratory, 1979a. Sediment and Radionuclide Transport in Rivers; Field Sampling Program, Cattaraugus and Buttermilk Creeks, New York; Quarterly Progress Report, October 1978-December 1978. Report to U.S. Nuclear Regulatory Commission. 15p.

Battelle, Pacific Northwest Laboratory , 1979b. Sediment and Radionuclide Transport in Rivers; Quarterly Progress Report, October 1978-December 1978. Report to U.S. Nuclear Regulatory Commission. 9p.

Battelle, Pacific Northwest Laboratory, 1979c. Sediment and Radionuclide Transport in Rivers; Field Sampling Program, Cattaraugus and Buttermilk Creeks, New York; Quarterly Progress Report, December 1978- March 1979. Report to U.S. Nuclear Regulatory Commission. 13p.

Battelle, Pacific Northwest Laboratory, 1979d. Sediment and Radionuclide Transport in Rivers--Transport Modeling; Quarterly Report, January 1979-March 1979. Report to U.S. Nuclear Regulatory Commission. 7p.

Battelle, Pacific Northwest Laboratory, 1979e. Mathematical Simulation of Sediment and Containment Transport in Surface Water. Quarterly Report, January-March 1979. Report to U.S. Nuclear Regulatory Commission.

Boothroyd, J.C., B.S. Timson, and R.H. Dana, Jr., 1979. Geomorphic and Erosion Studies at the Western New York Nuclear Service Center, West Valley, NY. NUREG/CR-0795. 66p.

Boothroyd, J.C., B.S. Timson, and L.A. Dunne, 1982. Geomorphic Processes and Evolution of Buttermilk Valley and Selected Tributaries, West Valley, NY. Fluvial Systems and Erosion Study, Phase II. NUREG/CR-2862. 107.

Boothroyd, J.C., and B.S. Timson, 1983. Geomorphic Processes and Evolution of Buttermilk Valley and Selected Tributaries, West Valley, New York; Fluvial Systems and Erosion Study, Phase III. Unpublished Report to NYSGS.

Broughton, J.G., and H.G. Stewart, 1963. Geology and Hydrology of the Western New York Nuclear Service Center. Geological Society of America Special Paper 76, p.23.

Calkin, P.E., and E.H. Muller, 1980. Geologic Setting and Glacial Overview of the Upper Cattaraugus Basin Southwestern NY. In LaFleur, R.G (ed.), Late Wisconsin Stratigraphy of the Upper Cattaraugus Basin: Northeast Friends of the Pleistocene, 43rd Annual Reunion. p. 1-12.

Carroll, D., 1970. Clay Minerals: Agenda to Their X-Ray Identification. Geological Society of America Special Paper 126. 80p.

Chapman, S.L., Syers, J.K., and Jackson, M.L., 1969. Quantitative Determination of Quartz in Soils, Sediments and Rocks by Pyrosulfate Fusion and Hydrofluorosilicic Acid Treatment. Soil Science. 107:5. p.348-355.

Cochran, J.A., W. R. Griffin, Jr.,and E.J. Troianello, 1973. Observation of Airborne Tritium Waste Discharge from a Nuclear Fuel Processing Plant. U.S. Environmental Protection Agency. EPA/ORP 73-1. 27p.

Cochran, J.A., D. G. Smith, P.J. Magno, and B. Shleien, 1970. An Investigation of Airborne Radioactive Effluent from an Operating Nuclear Fuel Reprocessing Plant. Northeastern Radiological Health Laboratory, U.S. Department of Health, Education, and Welfare, Public Health Service. 39p.

Colombo, P., and A.J. Weiss, 1979a. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Waste Disposal Sites; Progress Report No. 9, April-June 1978. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-50965; NUREG/CR-0707. 28p.

Colombo, P., and A.J. Weiss, 1979b. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Waste Disposal Sites; Progress Report No. 10, July-September 1978. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-51083; NUREG/CR-1037. 37p.

Colombo, P., and A.J. Weiss, 1979c. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Waste Disposal Sites; Progress Report No. 11, October-December 1978. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-51113; NUREG/CR-1167. 53p.

Colombo, P., A.J. Weiss, and A.J. Francis, 1979. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Waste Disposal Sites; Progress Report No. 7, October-December 1977. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-50861. 21p.

Colombo, P., A.J. Weiss, and A.J. Francis, 1978. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Waste Disposal Sites; Progress Report No. 8, January-March 1978. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-50937; NUREG/CR-0537.

Daly, J.C., S. Goodyear, C.J. periello, and J.M. Matuszek, 1974. Iodine-129 Levels in Milk and Water Near a Nuclear Fuel Reprocessing Plant. Health Physics, 26:333-342.

Daly, J.C., A.V. Manchester, J.J. Gabay, and N.I. Sax, 1968. Tritiated Moisture in the Atmosphere Surrounding a Nuclear Fuel Reprocessing Plant. Radiological Health Data and Reports, 9:341-346.

Dames and Moore, 1975. Field Report. Soil and Foundation Investigation, Existing Facilities and Proposed High-Level Waste Facilities, Spent Fuel Processing Plant, West Valley, New York. Report to Nuclear Fuel Services, Inc. 31p.

Dames and Moore, 1974. Report. Foundation and Hydrology Studies, Emergency Water Supply for Cooling at the Spent Fuel Processing Plant, West Valley, New York. Report to Nuclear Fuel Services, Inc.

Dames and Moore, 1971a. Report. Evaluation of Subsurface Conditions, Nuclear Fuels Reprocessing Facility Site, West Valley, New York. Report to Nuclear Fuel Services, Inc. 32p.

Dames and Moore, 1971b. Report. Soils and Foundation Investigation, Proposed High-Level Waste Facility, West Valley, New York. Report to Nuclear Fuel Services, Inc. 33p.

Dames and Moore, 1970a. Report. Soils and Foundation Investigation, Proposed Iodine Recovery Building, West Valley, New York. Report to Nuclear Fuel Services, Inc. 24p.

Dames and Moore, 1970b. Foundation Investigation, Proposed Plutonium Fuel Plant, West Valley, New York. Report to Nuclear Fuel Services, Inc. 33p.

Dames and Moore, 1963. Site Investigation, Proposed Spent Nuclear Fuel Processing Plant near Springville, New York. Report to Nuclear Fuel Services, Inc. 51p.

Dana, R.H., Jr., R.H. Fakundiny, R.G. LaFleur, S.A. Molello, and P.R. Whitney, 1979a. Geologic Study of the Burial Medium at a Low-Level Radioactive Waste Burial Site at West Valley, New York. N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2411. 70p.

Dana, R.H., Jr., S.A. Molello, R.H. Fickies, and R.H. Fakundiny, 1979b. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York Low-Level Burial Site; Annual Report September 1, 1977-September 30, 1978. N.Y.S. Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-0794. 98p.

Dana, R.H.,. Jr., S.A. Molello, R.H. Fickies, and R.H. Fakundiny, 1979c. Research at a Low-Level Radioactive Waste Burial Site at West Valley, New York - An Introduction and Summary. N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2413. 38p.

Dana, R.H., Jr., S.A. Molello, R.H. Fickies, and R.H. Fakundiny, 1979d. Sampling, Analysis, and Study of Migration of Trench Water from a Low-Level Solid Radioactive Waste Burial Ground at West Valley, New York. N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File

79-2408. 63p.

Dana, R.H., Jr., S.A. Molello, R.H. Fickies, and R.H. Fakundiny, 1979e. Study of Ground-Water Flow at a Low-Level Radioactive Waste Burial Site at West Valley, New York. N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2409. 36p.

Dana, R.H., Jr., V.S. Ragan, S.A. Molello, H.H. Bailey, R.H. Fickies, R.H. Fakundiny, and V.C. Hoffman, 1980. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York, Low-Level Burial Site. Final report, October 1978-February 1980. N.Y.S. Geological Survey Report to U.S. Nuclear Regulatory Commission. NUREG/CR-1565, 140 p.

Davis, J.F., R.H. Dana, Jr., S.A. Molello, R.H. Fakundiny, J.M. Matuszek, and A.H. Lu, 1978. Determination of Retention of Radioactive and Stable Nuclides by Fractured Rock and Soil at West Valley, New York. Part I, Phase II. N.Y.S. Geological Survey and N.Y.S. Department of Health. Draft Report Prepared for U.S. Environmental Protection Agency.

Davis, J.F., R.H. Dana, Jr., S.A. Molello, R.H. Fickies, R.H. Fakundiny, and J.M. Matuszek, 1979. Determination of Retention of Radioactive and Stable Nuclides by Fractured Rock and Soil at West Valley, New York. Part II. N.Y.S. Geological Survey. Draft Report Prepared for U.S. Environmental Protection Agency. 130p.

Davis, J.F., and R.H. Fakundiny, 1979. Computer Modeling Workshop on Radionuclide Migration at the West Valley Low-Level Radioactive Waste Burial Site, February 1-4, 1977. N.Y.S. Geological Survey. Draft Report Prepared for U.S. Environmental Protection Agency., NYSGS Open-File 79-2404. 162p.

Davis, J.F., and R.H. Fakundiny, 1978. Determination of the Retention of Radioactive and Stable Nuclides by Fractured Rock and Soil at West Valley, New York. Final Report of Research, Part I, Phase I. Draft Report Prepared for U.S. Environmental Protection Agency.

Davis, K., 1974 (April 19). Subject: on NFS Reprocessing Plant, West Valley, New York: Geologist's Trip Report, Memorandum from Davis, NYSDEC, Office of Environmental Analysis, to Thomas Cashman, NYSDEC, Bureau of Radiation, 10 p.

de Laguna, W., 1972. Hydraulic Fracturing Test at West Valley, New York. Oak Ridge National Laboratory, U.S. Atomic Energy Commission. ORNL-4827. 64p.

Dineen, R J., 1971. Letter Report from Robert J. Dineen, NYSGS, to Dr. Louis North, Nuclear Fuel Services, Inc.

Dreimanis, A., 1962. Quantitative Gasometric Determination of Calcite and Dolomite by Using Chittick Apparatus: Journal Sedimentary Petrol. 32:3. p.520-529.

Duckworth, J.P., M.J. Jump, and B.E. Knight, 1974. Low-Level Radioactive Waste Management Research Project, Final Report. Nuclear Fuel Services, Inc., Report to N.Y.S. Atomic and Space Development Authority.

Ecker, R.M, and Y. Onishi, 1979. Sediment and Radionuclide Transport in Rivers. Phase I: Field Sampling Program during Mean Flow, Cattaraugus and Buttermilk Creeks, New York. Battelle Memorial Instititute, Pacific Northwest Laboratory, U.S. Department of Energy. Report to U.S. Nuclear Regulatory Commission. PNL-3117; NUREG/CR-1030. 102p.

EG&G, Energy Measurements Group, 1981. A Comparison of Aerial Radiological Survey Results of the Nuclear Fuel Services Center (NFS) and Surrounding Area, West Valley, New York. Date of Survey: September 1979. EG&G Survey Report to Remote Sensing Laboratory, USDOE. EP-F-100, 130.

Ek, E.W, P.E. and Associates, 1963(?). Unpublished maps and drawings: Reservoirs, Borings, and Construction for Two Water Supply Reservoirs South of Security Area.

Empire Soils Investigations, Inc., 1975. Site Investigation Report for Nuclear Fuel Services, Inc., Exploratory Borings for Emergency Water Reservoir, West Valley, New York. 10p.

Fakundiny, R.H., R.H. Fickies, H.H. Bailey, R.H. Dana, Jr., and S.A. Molello, 1980. Geologic Study of the Burial Medium at the Low-Level Radioactive Waste Burial Site, West Valley, NY. In LaFleur, R.G. (ed.), Late Wisconsin Stratigraphy of the Upper Cattaraugus Basin: Northeast Friends of the Pleistocene, 43rd Annual Reunion. p. 39.

Fickies, R.H., R.H. Fakundiny, and E.T. Mosely, 1979. Geotechnical Analysis of Soil Samples from Test Trench at Western New York Nuclear Service Center, West Valley, New York. N.Y.S. Geological Survey. Report to

U.S. Nuclear Regulatory Commission. NUREG/CR-0644. 21p.

Fleming, R.W., 1976. Landslide Problems at West Valley Nuclear Service Center, NY. An Assessment and Recommendations for Study. USGS Open-File Report 76-661.

Folk, R.L., 1974. Petrology of Sedimentary Rocks: Hemphill Publishing Co., Austin, Texas. 182p.

Ford, Bacon, and Davis Utah, Inc., 1978. Compilation of the Radioactive Waste Disposal Classification System Data Base. Task Report: Analysis of the West Valley Site. Report to U.S. Nuclear Regulatory Commission. FBDU-247-01. 102p.

Giardina, P.A., M.F. DeBonis, J. Eng, and G.L. Meyer, 1977. Summary Report on the Low-Level Radioactive Waste Burial Site, West Valley, New York (1963-1975). U.S. Environmental Protection Agency. Report 902/4-77-010. 122p.

Hoffman, V.C., 1980. Geotechnical Report for Low-Level Radioactive Waste Burial Area, West Valley, NY., unpublished report to NYSGS.

Hoffman, V.C., R.H. Fickies, R.H. Dana, Jr., and V.S. Ragan, 1980. Geotechnical Analysis of Soil Samples and Study of Research Trench at the Western New York Nuclear Service Center, West Valley, New York. N.Y.S. Geological Survey. Report to U.S. Nuclear Regulatory Commission. NUREG/CR-1566. p.

Keily, P.V., and Jackson, M.L., 1965. Quartz, Feldspar, and Mica Determination for Soils by Sodium Pyrosulfate Fusion. Soil Science American Proc.. 29:159-163.

Kelleher, W.J., 1969. Environmental Surveillance around a Nuclear Fuel Reprocessing Installation 1965-1967. Radiological Health Data and Reports, 10:329-339.

Kelleher, W.J., and E.J. Michael, 1973. Low-Level Radioactive Waste Burial Site Inventory for the West Valley Site, Cattaraugus County, New York. N.Y.S. Department of Environmental Conservation.

LaFleur, R.G., 1983. Downcutting of the Cattaraugus Creek and its Tributaries--History and Prognosis. Unpublished Report to NYSGS.

LaFleur, R.G., 1980a. Late Wisconsin Stratigraphy of the

Upper Cattaraugus Basin. in LaFleur, R.G. (ed.), Guidebook, 43rd Annual Reunion, Northeast Friends of the Pleistocene. p13-38.

LaFleur, R.G., 1980b. Radiocarbon-dated Alluvial Deposits, Upper Cattaraugus Basin. Letter Report to USGS Water Resources Division.

LaFleur, R.G., 1980c. Petrographic Analysis of the West Valley Burial Ground Till. Report to U.S. Geological Survey. 12p.

LaFleur, R.G., 1979. Glacial Geology and Stratigraphy of Western New York Nuclear Service Center and Vicinity, Cattaraugus and Erie Counties, New York. USGS Open-file Report 79-989, 17p.

Lu, A.H., 1978. Modeling of Radionuclide Migration from a Low-Level Radioactive Waste Burial Site. Health Physics, 34:39-44.

Lu, A.H., and J.M. Matuszek, 1978. Transport of Gaseous Tritiated Compounds from Buried Radioactive Wastes. N.Y.S. Department of Health. IAEA International Symposium on the Behavior of Tritium in the Environment, San Francisco, Ca.

Matuszek, J.M., J.C. Daly, S. Goodyear, C.J. Paperiello, and J.J. Gabay, 1974. Environmental Levels of Iodine--129. in Environmental Surveillance Around Nuclear Installations, V. II. International Atomic Energy Agency Vienna.

Matuszek, J.M., C.O. Kunz, J.A. Hutchinson, W.E. Mahoney, and R.H. Dana, Jr., 1979. Studies of Trench Gas at a Low-Level Radioactive Waste Burial Site, West Valley, New York. N.Y.S. Department of Health and N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2407.

Matuszek, J.M., A.H. Lu, R.H. Dana, Jr., S.A. Molello, R.H. Fickies, and R.H. Fakundiny, 1979. Computer Modeling of Radionuclide Migration Pathways at a Low-level Radioactive Waste Burial Site at West Valley, New York. N.Y.S. Department of Health, Radiological Sciences Laboratory, and N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2412. 300p.

Matuszek, J.M., F.V. Strnisa, and C.F. Baxter, 1976.

Radionuclide Dynamics and Health Implications for the New York Nuclear Service Center's Radioactive Waste Burial Site. in Management of Radioactive Wastes from the Nuclear Fuel Cycle. v. II. International Atomic Energy Agency, Vienna. p. 359-372.

Molello, S.A., 1977. Trench 5 Isotope Inventory. N.Y.S. Geological Survey. Unpublished report. NYSGS Open-File 77-2401.

Molello, S.A.,, 1976. Estimated Location of Container Types - Trench 5, Low-Level Radioactive Waste Burial Ground, Nuclear Fuel Services, Inc., West Valley, New York. N.Y.S. Geological Survey. Unpublished report. NYSGS-Open-File 77-2402.

Mosely, E.T., 1977. Report on Laboratory Tests on Soil Samples from Test Trench Dug in July, 1977 near Western New York Nuclear Service Center, Cattaraugus County, NY. Unpublished report to NYSGS. 30p.

Muller, E.H., 1977a. Quaternary Geology of New York, Niagara Sheet: New York State Museum and Science Service, Map and Chart Series 28.

Muller, E.H., 1977b. Late Glacial and Early Post Glacial Environments in Western New York: New York Academy of Science Annals. 288:223-233.

Muller, E.H., 1963. Geology of Chautauqua County, NY. Part II. Pleistocene Geology. NYSGS Museum Bulletin 392, 60p.

Nuclear Fuel Services, Inc., 1974 (September 1). Draft Final Report on Radioactive Waste Management Research Project. Report Prepared for N.Y.S. Atomic and Space Development Authority.

Nuclear Fuel Services, Inc., 1962. Safety Analysis Report, Spent Fuel Processing Plant, Western New York Nuclear Service Center.

Onishi, Y. , and R. Ecker, 1978. Sediment and Radionuclide Transport in Rivers; Field Sampling Program; Cattaraugus and Buttermilk Creeks, New York; Annual Progress Report, October 1977 to September 30, 1978. Battelle Memorial Institute, Pacific Northwest Laboratory, U.S. Department of Energy. Report to U.S. Nuclear Regulatory Commission. PNL-2551; NUREG/CR-0576.

Onishi, Y., W.H. Walters, and R.M. Ecker, 1981. Sediment and

Radionuclide Transport in Rivers; Field Sampling Program, Cattaraugus and Buttermilk Creeks, New York; Annual Progress Report, October 1978-September 1979. Battelle Memorial Institute, Pacific Northwest Laboratory. Report to U.S. Nuclear Regulatory Commission. PNL-3329; NUREG/CR-1387.

Onishi, Y., S.B. Yabusaki, C.T. Kincaid, R.L. Skaggs, and W.H. Walters, 1982. Sediment and Radionuclide Transport in Rivers: Radionuclide Transport Modeling for Cattaraugus and Buttermilk Creeks, New York. Battelle, Pacific Northwest Laboratory. Report to U.S. Nuclear Regulatory Commisssion. PNL-4111; NUREG/CR-2425.

Prudic, D.E., 1982. Hydraulic Conductivity of a Fine-Grained Till, Cattaraugus County, New York. Ground Water 20(2):194-204.

Prudic, D.E., 1979. Core Sampling Beneath Low-Level Radioactive-Waste Burial Trenches, West Valley, Cattaraugus County, New York. U.S. Geological Survey Open-file Report 78-1532. 55p.

Prudic, D.E., 1978. Installation of Water and Gas Sampling Wells in Low-level Radioactive Waste Burial Trenches, West Valley, Cattaraugus County, New York. U.S. Geological Survey Open-file Report 78-718. 70p.

Prudic, D.E., and A.D. Randall, 1977. Ground-Water Hydrology and Subsurface Migration of Radioisotopes at a Low-Level Solid Radioactive-Waste Disposal Site, West Valley, New York. U.S. Geological Survey Open-file Report 77-566. Also in Carter, M.W., A.A. Moghissi, and B. Kahn, (eds.) 1979. Management of Low-level Radioactive Waste. Pergamon Press, New York 2:853-882.

Ragan, V., S.A. Molello, R.H. Dana, Jr., R.H. Fickies, and R.H. Fakundiny, 1979. Studies of Surface Water Transport of Radionuclides at the Low-Level Radioactive Waste Burial Site at West Valley, New York. 1976-1977. N.Y.S. Geological Survey. Report Prepared for U.S. Environmental Protection Agency. NYSGS Open-File 79-2410. 79p.

Randall, A.D., 1980. Glacial Stratigraphy in Part of Buttermilk Creek Valley. In LaFleur, R.G., (ed.) Late Wisconsin Stratigraphy of the Upper Cattaraugus Basin: Northeast Friends of the Pleistocene, 43rd Annual Reunion, p. 40-64.

Robinson, L.W., Jr., 1980. Modeling Atmospheric Boundary

Layer Transport and Diffusion of Radioactive Gases from a Low-Level Waste Burial Area. Unpublished M.S. Thesis, Rensselaer Polytechnic Institute, Troy, N.Y.

Sax, N.J., P.C. Lemon, A.H. Benton, and J.J. Gabay, 1969. Radioecological Surveillance of the Waterways Around a Nuclear Fuels Reprocessing Plant. Radiological Health Data and Reports. 10:289-296.

Shleien, B., 1970. An Estimate of Radiation Doses Received by Individuals Living in the Vicinity of a Nuclear Fuel Reprocessing Plant in 1968. Northeastern Radiological Health Laboratory, Public Health Service, U.S. Department of Health, Education and Welfare. BRH/Nerhl 70-1.

Stewart, H.G., Jr., 1962a. Letter of April 3, 1962 to J.D. Anderson, N.Y.S. Office of Atomic Development. U.S. Geological Survey. 11p.

Stewart, H.G., Jr., 1962b. Letter of July 10, 1962 to J.D. Anderson, U.S. Geological Survey. 13p.

Sun, R.J., 1982. Selection and Investigation of Sites for the Disposal of Radioactive Wastes in Hydraulically Induced Subsurface Fractures. U.S. Geological Survey Professional Paper 1215. 87p.

Sun, R.H., and C.E. Mongan, 1974. Hydraulic Fracturing in Shale at West Valley, New York: A Study of Bedding-Plane Fractures Induced in Shale for Waste Disposal. U.S. Geological Survey Open-file Report 74-365. 152p.

Tesmer, I.J., 1975. Geology of Cattaraugus County, New York: *Buffalo Society of Natural Sciences Bulletin*. 27:1-105.

Walters, W.H., R.M. Ecker, and Y. Onishi, 1982. Sediment and Radionuclide Transport in Rivers; Summary Report: Field Sampling Program for Cattaraugus and Buttermilk Creeks, New York. Battelle Memorial Institute, Pacific Northwest Laboratory. Report to U.S. Nuclear Regulatory Commission. PNL-3117, v. 4 NUREG/CR-1030.

Weiss, A.J., and P. Colombo, 1980. Evaluation of Isotope Migration; Land Burial: Water Chemistry at Commercially Operated Low-Level Radioactive Wast Disposal Sites. Status Report Through September 30, 1979. Brookhaven National Laboratory. Report to U.S. Nuclear Regulatory Commission. BNL-NUREG-51143; NUREG/CR-1289. 271p.

Whitney, P.R., 1977. Chemical and Mineralogical Investigation of Surficial Materials from the West Valley Nuclear Waste Disposal Site. Unpublished report. NYSGS Open-File Report 2401-46. 13p.

Appendix A. Standardized Geologic Logs for Holes Drilled in 1982 and 1983.

The original geologic logs were written by Steven Potter of the NYSGS, while drilling was in progress using samples from split-spoons, cleanout shoes, bits, and bailers. The logs were then converted to standardized form and down-hole depths were recalculated to elevations above sea-level in meters. The standardization process used was the same as for logs in our last annual report (Albanese and others, 1983, Appendix A). A more detailed explanation can be found at the end of Appendix D of this report.

For each interval, the first line provides information on grain sizes present, with word order and conjunctions used to show estimated volume proportions. The second line describes the color, which can be used to detect differences between oxidized (brown) and unoxidized (gray) till. The third line provides additional information from the original log that can be used to charaterize and distinguish the lithology.

82-1A

depth: 5.64 m, 18.5 ft

surface 421.07 m, 1381.53 ft
no core sample

416.10
till: clay and silt; with rare gravel/pebbles
dark gray; with rare greenish gray
0.06 m of cuttings; uniform, moist; pebbles 2-3%
0.25-0.5 cm av diam; greenish shale fragment
2.0 cm long; no coarse sand at depth of 5.03 to
5.33 m as in 82-1C

415.64
till: clay and silt; with rare gravel/pebbles
dark gray
moister than above

415.43 bottom

82-1B

depth: 10.88 m, 35.7 ft

surface 420.98 m, 1381.22 ft

416.65
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-10%, 0.5-1.0 cm av diam.

416.50
till: silt, with clay, with gravel/pebbles
dark gray

416.47
till: silt, with clay, with coarse gravel/pebbles
dark gray
pebbles to 5.5 cm long

416.35
till: silt, with clay, with coarse gravel/pebbles
greenish gray
breakdown zone; shale fragment 5.0 cm long

416.26
silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, small; no sand

416.01
till: silt, with clay, with gravel/pebbles
dark gray
to WVNS

415.95
till: silt, with clay, with gravel/pebbles
dark gray

415.92
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 3-5%, 0.25-0.5 cm av diam; no wisps; no sand

415.77
till: silt, with clay, with gravel/pebbles
dark gray

415.62
till: silt, with clay, with gravel/pebbles
dark gray

415.46

till: silt, with clay, with gravel/pebbles; with rare
angular rock fragments
dark gray, with greenish gray
shale fragment green; no sand, not saturated, does not
yield water

415.28
no core sample

411.53
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 2-3%, 0.25-0.5 cm av diam.

at 411.32
coarse silt
dark gray
bleb, 1.5 by 2.0 cm

410.92
no core samples

410.80
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles 2-3%, 0.25-0.5 cm av diam.; no sand; no wisps

at 410.16
angular rock fragment
greenish gray
shale, 3.5 cm long

410.10 bottom

82-1C

depth: 14.93 m, 49.0 ft

surface 420.89 m, 1380.94 ft
till: silt, with clay, with gravel/pebbles; with layers of silt
dark grayish brown, with yellow and yellowish brown and gray
oxidized; yellowish brown blebs, gray silty wisps; shale pebbles 0.5-1.0 cm long

419.85
till: silt, with clay; with rare gravel/pebbles and organic material/soil
grayish brown to dark gray, with pale yellow and gray and yellowish brown
oxidized, dry, mottled; crumbles when rolled

419.43
till: silt, with clay; with rare gravel/pebbles
dark grayish brown, with olive brown and light gray
less oxidized; more plastic; light gray wisps; 0.52 m recovered out of 0.89 m

418.54
coarse silt to fine sand
brownish yellow
pod, 45 degrees to core; to Health Dept.

418.48
till: silt, with clay
gray
to Health Dept.

418.33
fine sand; with rare gravel/pebbles
brownish yellow
pod; deformed; pebbles less than 3%, 0.5-1.0 cm

418.27
till: silt, with clay
gray

418.15
coarse silt to fine sand
dark yellowish brown
lens, horizontal

at 418.12 to 418.09
gravel/pebbles
siltstone clast 4.0 cm long

417.99
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, 0.25 cm av diam.

417.54
no core sample

417.51
till:silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.75-1.0 cm av diam.

at 417.35
silt
light gray
bleb

at 417.11
gray
pebble breakdown zone

416.96
no core sample

416.90
till: silt, with clay, with gravel/pebbles
dark gray, with gray
pebbles 10%; gray shale fragment

416.74
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%

416.59
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%

416.44
till: silt, with clay, with gravel/pebbles
dark gray

416.35
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-10%, larger than above

at 416.35 to 416.32
silt, with clay
dark brown
pod, vertical

416.32
till: silt, with clay, with gravel/pebbles and angular rock fragments
dark gray
siltstone and shale fragments, 0.5-1.0 cm

416.17
till: silt, with clay, with gravel/pebbles
dark gray

416.14
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept.

416.01
till: silt, with clay, with gravel/pebbles
dark gray

415.92
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 1.0 cm av diam; water in hole

415.86
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.5 cm av diam.

415.77
till: silt, with clay, with gravel/pebbles
dark gray

at 415.71
fine to medium sand
dark gray
in nose of core; water in hole, sampled

415.71
coarse silt to fine sand
dark gray
grades to next lithology

415.57
till: silt, with clay
dark gray
saturated

415.42
till: silt, with clay
dark gray
to Health Dept.

415.27

till: silt, with clay
dark gray

415.19
no core sample

415.13
silt, with clay
gray

415.10
silt, with clay; with rare gravel/pebbles
gray
pebbles less than 2%, 0.25-0.5 cm av diam.

414.95
silt, with clay; with rare gravel/pebbles and angular rock fragments
gray
siltstone and shale fragments; increasing clay; moist, no water in hole

414.79
till: silt, with clay
gray

414.49
no core sample

414.46
till: silt, with clay, with gravel/pebbles
gray
pebbles less than 10%, 0.25-0.5 cm av diam.

414.18
till: silt, with clay, with gravel/pebbles
gray

414.03
silt, with clay, with gravel/pebbles
gray
increase in pebbles

413.88
till: silt, with clay, with gravel/pebbles
gray

413.85
till: silt, with clay
dark gray

413.79
till: silt, with clay; with rare gravel/pebbles
dark gray

to Health Dept.; pebbles less than 2%, 0.5-0.75 cm av diam.

413.64
till: silt, with clay; with rare gravel/pebbles
dark gray

413.39
no core sample

413.24
till; silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2-3%, 0.5-1.0 cm av diam.

at 413.21 to 413.16
medium sand
greenish gray
pod 6.0 by 1.5 cm

at 413.04
fine sand; with rare gravel/pebbles
greenish gray
stringer, vertical

at 412.87
angular rock fragment
greenish gray
flat shale fragment

412.66
no core sample

412.63
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, 2.0-3.0 cm av diam.

412.48
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles smaller, 0.5-1.0 cm av diam.

412.36
till: silt, with clay; with rare gravel/pebbles
dark gray

412.05
no core sample

411.99
till: silt, with clay; with rare gravel/pebbles
gray to dark gray
cuttings for top 0.12 m; pebbles 2-3%, 0.25-0.5 cm av

diam.

at 411.62
angular rock fragment
dark gray
shale

411.38
no core sample

411.32
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2%, 0.25-0.5 cm av diam.

410.80
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept.

at 410.62
fine sand
dark gray
in nose of core; hole is wet

410.62
till: clay and silt; with rare gravel/pebbles
dark gray
pebbles less than 3%, 0.25-0.5 cm av diam.

at 410.62 to 410.53
fine sand
dark gray
well sorted

at 410.16
coarse silt to fine sand
in nose of core, approx 0.03 m thick

410.16
fine sand
dark gray

410.13
fine sand, with coarse silt
dark gray
saturated

409.83
till: silt, with clay
dark gray
grades from lithology above

409.67

till: silt, with clay
dark gray

409.55
till: silt, with clay; with rare gravel/pebbles
dark gray
plastic, moist

at 409.55
fine sand
dark gray
pod

409.37
till: clay and silt
dark gray
to Health Dept.

409.19
till: clay and silt
dark gray
rolls easily

409.00
till: silt, with clay; with rare gravel/pebbles
dark gray
uniform; pebbles less than 3%, 0.15-0.25 cm av diam.

408.85
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25 cm av diam; shale and siltstone clasts

408.70
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%

at 408.42
gravel/pebbles
light red
one clast

408.45
overlap; 0.15 m of cuttings on top

408.30
silt, with cla ; with rare gravel/pebbles
dark gray, with light gray
pebbles 5%, 0.25-0.5 cm av diam; light gray breakdown zone

408.13

fine sand; with rare gravel/pebbles
dark gray
pod, 1.0 x 3.0 cm; pebbles 3%

408.09
silt, with clay; to fine sand
dark gray
gradational change

407.97
fine sand
light yellowish brown
deformed stringer, vertical, interfingering with till, 1.0 x 0.25 to 0.5 cm

407.88
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 1-2%, 0.5-1.0 cm av diam.

407.78
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25-0.5 cm av diam.; rounded to sub-rounded; uniform, clean

407.63
till: clay, with silt; with rare gravel/pebbles
dark gray
to Health Dept.

407.48
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 5%

407.17
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles 2-3%, 0.1-0.25 cm av diam.; shale clast 3.5 cm long

407.02
till: clay, with silt; with rare gravel/pebbles
dark gray

406.53
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%, 0.15-0.2 cm av diam.

406.41
till: clay, with silt; with rare gravel/pebbles
dark gray

pebbles 2-3%

406.26
till: clay, with silt
dark gray

406.11
coarse silt to fine sand
dark gray
to Health Dept; edge of pod?

405.96 bottom

82-1D

depth: 28.10 m, 92.2 ft

surface 420.91 m, 1381.02 ft
no core sample

405.67
till: silt, with clay; with rare gravel/pebbles
dark gray
cleanout; pebbles less than 3%, 0.25 cm av diam.

404.45
till: silt, with clay, with gravel/pebbles
dark gray
more silt than above; calcareous; moist; rolls easily; pebbles 5-7%, 0.25-0.5 cm av diam.

403.81
till: silt, with clay; with rare gravel/pebbles
dark gray, with olive
pebbles 5%, 0.25-0.5 cm av diam; olive blebs; shale fragments; rolls easily

403.23
till: silt, with clay; with rare gravel/pebbles
dark gray
more silt than above; calcareous; drier; pebbles 5%, 0.25-0.5 cm av diam.

at 402.93
light olive brown
bleb

402.93
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept.

402.78
till: silt, with clay; with rare gravel/pebbles
dark gray

402.62
till: clay and silt, with gravel/pebbles
dark gray
cleanout; pebbles 25-30%, 0.5-1.0 cm av diam, in podlike concentrations

at 402.47
clay and silt and gravel/pebbles
dark gray
pebbles up to 40% in podlike concentrations

at 402.23 to 402.17
clay and silt and gravel/pebbles
dark gray
pebbles up to 40% in podlike concentrations

402.01
till: silt, with clay, with gravel/pebbles
dark gray
pebbles less than 10%, 0.5-1.0 cm av diam.

401.71
till: silt, with clay; with rare gravel/pebbles
dark gray, with olive and olive brown and dark red
pebbles less than 5%, 0.25-0.5 cm av diam; colored blebs

401.50
no core sample

401.40
till: clay and silt, with gravel/pebbles
dark gray
pebbles 20-25%, 0.5-1.0 cm av diam; two calcareous fragments 4.0 x 6.0 cm , 3.5 x 4.0 cm

401.25
till: clay and silt, with gravel/pebbles
dark gray
pebbles 10%, 0.25-0.5 cm av diam.

at 400.95
gravel/pebbles
pale red
pebble 2.0 cm long, sub-rounded, not calcareous

400.86
till: silt, with clay; with rare gravel/pebbles
dark gray
overlap; moist; pebbles less than 2%, 0.25 cm av diam.

400.70
till: silt, with clay
dark gray
no pebbles; very moist

400.58
till: silt, with clay, with gravel/pebbles
dark gray, with olive and dark red
less moist; rolls moderately well to easily; olive and red blebs; pebbles 5-7%

400.23
till: silt, with clay, with gravel/pebbles
dark gray

400.25
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, 0.5-1.0 cm av diam.

at 400.12 to 400.09
olive gray
breakdown zone from disintegrated shale fragment

399.94
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 3%, less than 0.25 cm av diam., calcareous

399.67
no core sample

399.61
till: clay and silt, with gravel/pebbles
dark gray, with olive
cleanout; pebbles 5-10%, 0.25-0.5 cm av diam; olive blebs

at 399.30
clay and silt
pale yellow
bleb

399.00
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles 5%, 1.5 cm av diam.

at 399.00 to 398.93
till: clay, with silt; with rare gravel/pebbles
olive
breakdown zone from shale fragments

at 398.90
pale red
"dirty, gravel-like" bleb

398.84
till: clay, with silt; with rare gravel/pebbles
dark gray, with olive and pale red
cleaner than 0.15 m above; olive and red blebs; pebbles 5%, 0.25-1.5 cm av diam.

398.69
till: clay, with silt; with rare gravel/pebbles
dark gray
no blebs; increasing clay; uniform, clean; pebbles less than 3%, less than 0.25 cm av diam.

398.54
till: clay, with silt; with rare gravel/pebbles
dark gray
no blebs, uniform, clean; pebbles 2-3%, less than 0.25 cm av diam.

398.39
no core samples

398.36
till: clay, with silt; with rare gravel/pebbles
dark gray
cleanout; pebbles 3-5%, 0.25 cm av diam; calcareous; no blebs, no breakdown zones

398.05
till: clay, with silt; with rare gravel/pebbles
dark gray
to Health Dept.

397.90
till: clay, with silt; with rare gravel/pebbles
dark gray

397.87
no core sample

397.75
till: clay and silt; with rare gravel/pebbles
dark gray
cleanout; pebbles 2-3%

397.59
till: clay, with silt, with gravel/pebbles
dark gray

397.44
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-6%; more silt than above; calcareous

397.23
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 20%, 1.0-1.5 cm av diam; dry, "almost gravel-like"

396.86
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 8-10%

396.77

silt and clay; with rare gravel/pebbles; with layers of silt
dark gray, with light gray
light silty wisps; pebbles decrease to 0%; increase in clay; mild reaction to HCl; "appears to be laminated"

396.62
till to lacustrine: silt, with clay
dark gray
cleanout; no blebs, clean, no pebbles; moist; calcareous

396.31
fine sand
light gray
pod, deformed, 1.0 cm thick

396.25
silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2%; drier than 396.62-396.31 m

396.01
lacustrine: coarse silt; with layers of silt, with clay and of silt
grayish brown, with dark gray
silt partings within gray laminated silt with clay

395.70
fine sand
dark grayish brown
well sorted

395.67
silt, with clay
dark grayish brown
gradational from above and to below

395.55
fine sand
dark grayish brown
friable, slightly moist; calcareous

395.34
no core sample

395.31
fine sand; with layers of coarse silt
dark grayish brown
breaks along microlaminations; dry

395.06
lacustrine: layers of coarse silt with fine sand
dark grayish brown
laminated

394.91
fine sand
grayish brown
"looks like sand outcrops on Buttermilk Creek"

at 395.86 to 394.70
overlap, hole collapsed

394.86
fine sand, with gravel/pebbles
dark grayish brown
recovered 0.40 m in 0.61 m cored

394.49
no core sample

394.09
lacustrine: coarse silt to fine sand
dark grayish brown to dark gray
calcareous

393.94
silt and sand; to very fine sand and gravel/pebbles, with silt
gray, with dark red and yellowish brown and olive pebbles up to 2.0-3.0 cm av diam; some reddish fragments; brown and olive breakdown zones around shale fragments

393.78
no core sample

393.48
lacustrine: fine silt, with sand; to fine sand, with silt
dark gray to dark grayish brown
more silt and moisture than below

393.30
lacustrine: fine to medium sand, with silt
dark gray to dark grayish brown
more sand, less moisture than above

393.17
no core sample

393.05
lacustrine: as layers: fine to medium sand; coarse silt
light brownish gray and gray
laminations slightly deformed; colors alternate

392.87

sand
light olive brown
dry; laminations; spoon lost

at 392.81
bottom

82-1D Deepening in 1983

depth 33.22m, 108.99 ft

surface 420.91m, 1381.02 ft

391.59
lacustrine: silt and sand; with rare to no gravel/pebbles
dark gray

at 391.01
lacustrine: fine sand; with rare gravel/pebbles, with layers of clay
dark grayish brown, with weak red
in nose of core; dry sand interfingered with varves of clay, with red blebs; pebbles to 2.5 cm

391.01
no core sample

390.89
fine sand
dark brownish gray
saturated

390.74
till: silt and clay; with rare gravel/pebbles
dark gray
clay appears varve-like; pebbles to 1.5 cm, less than 3%

390.43
no core sample

389.97
till: clay and silt; with rare gravel/pebbles
dark gray
clay is varve-like; pebbles less than 2%, 0.25-0.50 cm av diam

389.61
no core sample

389.58
till: silt and clay; with rare gravel/pebbles and angular rock fragments
dark gray to gray
overlap; moist; shale fragments flat to subrounded; pebbles 2%,2.0 cm av diam

390.13
till: silt and clay; with rare gravel/pebbles
dark gray to gray

overlap; cleanout; removed slumped material

389.52
silt and clay, with fine to medium sand
dark gray to gray
overlap; sand approx. 5%

389.30
silt and clay, with fine to medium sand
dark gray to gray
sand approx. 5%

389.21
as layers: silt; clay; with rare gravel/pebbles
dark gray to gray
laminated, layers horizontal but concave downward;
pebbles 1-2%, 1.0 cm av diam

389.21
cleanout; overlap

388.91
till: silt and clay; with rare gravel/pebbles
dark gray to gray
pebbles 1%, 1.0 cm av diam; some sense of lamination

at 388.85 to 388.81
sand and silt
thin zone

388.91
overlap; cleanout

388.60
till: silt and clay; with rare gravel/pebbles
dark gray; with rare reddish brown and yellowish red
pebbles 1-2%, 0.5-1.5 cm av diam; some exotic pebbles
brown and red

388.30
till: silt and clay; with rare gravel/pebbles
dark gray to gray
pebbles less than 2%, 1.0 cm to 3.0-4.0 cm, mainly
limestone and siltstone, some shale, rounded to
subrounded

at 387.69
bottom

82-2A

depth: 7.28 m, 23.9 ft

surface 422.69 m, 1386.85 ft
no core sample

416.90
till: silt, with clay; with rare gravel/pebbles
gray
unoxidized; pebbles 3%

at 416.78
light olive brown
wisp rimming pebble

416.41
till: silt, with clay; with rare gravel/pebbles
gray, with light gray
pebbles 5%, 0.5-1.5 cm av diam; light breakdown zones;
rolls easily

415.92
no core sample

415.41 bottom

82-2B

depth: 12.92 m, 42.4 ft

surface 422.68 m, 1386.81 ft
   no core sample

411.28
   till: silt, with clay; with rare gravel/pebbles
   gray
   pebbles less than 3%, 0.25-0.5 cm av diam; uniform;
   rolls easily

410.82
   no core sample

409.76 bottom

82-2C

depth: 15.30 m, 50.2 ft

surface 422.66 m, 1386.75 ft
silt, with clay; with rare gravel/pebbles
grayish brown
pebbles 5%, 0.5 cm av diam; rounded to subrounded, less than 2% exotics

421.75
till: silt, with clay, with gravel/pebbles
dark grayish brown, with red and yellow and greenish gray and reddish yellow
pebbles 10%, with gray rims; red breakdown zones around exotic pebbles; yellow oxidation zones

420.83
till: silt, with clay; with rare gravel/pebbles
gray
pebbles 3% include bluish gray siltstone; more silt than above; moist but not saturated

at 420.59 to 420.44
fine sand
yellowish brown
dry

419.92
no core sample

419.46
till: silt, with clay
gray

at 419.37
fine sand
yellowish brown
"zone"

at 419.31
fine sand
yellowish brown
iron oxide staining

at 419.22
coarse silt
gray
wisps

at 419.19
angular rock fragments
greenish gray

shale fragment

419.19
till: silt, with clay; with rare gravel/pebbles
pebbles 3%; increase in silt; rolls easily

418.85
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25-0.5 cm av diam; unoxidized

418.73
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept.

418.61
no core sample

418.55
till: clay, with silt; with rare gravel/pebbles
dark gray, with red
pebbles less than 5%, less than 1.0 cm av diam; red streaks and iron staining

417.78
till: clay, with silt; with rare gravel/pebbles; with layers of silt
dark gray, with greenish gray
pebbles less than 5%, 0.25 cm av diam; greenish silt wisps; rolls easily; uniform

417.17
till: silt, with clay; with rare gravel/pebbles
dark gray
uniform; pebbles less than 3%, 0.5-1.0 cm av diam

416.56
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, 0.5-0.75 cm av diam; more saturated than above

415.95
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-8%, 1.0-2.0 cm av diam.; saturated

415.77
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept.

415.59

till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-8%, 1.0-2.0 cm av diam

415.35
till: silt, with clay, with gravel/pebbles; with layers of silt
gray
0.46 m recovery out of 0.61 m; silt blebs throughout; pebbles 5-8%, 1.0 cm av diam; saturated

414.74
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 1.0-2.0 cm av diam

414.43
till: silt, with clay; with rare gravel/pebbles; with layers of silt
dark gray, with greenish gray
to Health Dept.; one greenish silt pod

414.28
no core sample

414.13
till: silt, with clay, with gravel/pebbles; with layers of coarse silt to fine sand
gray
to Health Dept; pebbles 20%, 0.5-0.75 cm av diam

413.91
till: silt, with clay, with gravel/pebbles
gray

413.88
silt, with clay, with gravel/pebbles
gray
pebbles 5-10%, 0.5-1.0 cm av diam

413.82
till: silt, with clay; with rare gravel/pebbles
gray
pebbles less than 5%, 0.25-0.5 cm av diam; rolls easily

413.52
till: silt, with clay
gray

413.42
till: silt, with clay
gray
moist

at 413.33
silt
greenish gray
wisp

413.33
till: silt, with clay, with gravel/pebbles
gray
increased pebble content

412.91
till: silt, with clay; with rare gravel/pebbles
gray
uniform; pebbles 3-5%, 0.5-1.0 cm av diam, rounded to subrounded

at 412.63 to 412.60
silt, with clay, with gravel/pebbles; with layers of silt
gray, with greenish gray
pebbles 10-15%; greenish silt wisps

412.30
silt, with clay; with rare gravel/pebbles
gray
0.53 m recovery out of 0.61 m; pebbles 5%, 0.25-0.5 cm av diam

412.14
silt, with clay, with gravel/pebbles
gray
increase in pebble content

411.69
till: silt and clay; with rare gravel/pebbles
gray
pebbles less than 5%, 0.25-0.5 cm av diam; uniform; clay=silt

411.08
till: silt, with clay; with rare gravel/pebbles
gray
pebbles less than 3%, 0.25-0.5 cm av diam

410.90
till: silt, with clay; with rare gravel/pebbles
gray

410.71
till: silt, with clay; with rare gravel/pebbles
gray; with rare greenish gray
less pebbles than above; pebbles are greenish siltstone

410.53

till: silt, with clay; with rare gravel/pebbles
gray

410.47
till: silt, with clay; with rare gravel/pebbles; with layers of silt
gray, with light gray
light gray silt wisps; pebbles less than 5%

410.27
till: silt, with clay; with rare gravel/pebbles
gray

409.86
till: silt, with clay, with gravel/pebbles
gray
pebbles 10%, 0.5-1.0 cm av diam; shale fragments

409.71
till: silt, with clay, with gravel/pebbles
gray
pebbles 5-10%

409.55
till: silt, with clay, with gravel/pebbles
gray
pebbles 10%, larger than above

409.25
till: silt, with clay; with rare gravel/pebbles
gray
pebbles less than 5%

409.10
till: silt, with clay, with gravel/pebbles
gray

408.94
silt, to medium to coarse sand
light gray
breakdown zone

408.82
till: silt, with clay, with gravel/pebbles

at 408.76
pale olive
stain around pebble

408.76
coarse silt, with gravel/pebbles
granular silt zone with 2.0 cm long quartz pebble

408.64

till: silt, with clay; with rare gravel/pebbles
gray, with light gray
pebbles less than 5%, 0.5-1.0 cm av diam, rounded to subrounded; light gray wisps rim pebbles

408.03
till: clay and silt; with rare gravel/pebbles
gray
pebbles less than 5%, 0.5-1.0 cm av diam; clay=silt

at 407.82
olive yellow
oxidation stain around pebble

407.42
no core sample

407.36 bottom

82-3A

depth: 6.19 m, 20.3 ft

surface 423.44 m, 1389.31 ft
   no core sample

417.89
   till: silt, with clay, with gravel/pebbles
   dark gray
   pebbles 20-25%, 0.5-1.0 cm av diam, up to 6.5 cm long

417.74
   till: silt, with clay, with gravel/pebbles
   pebbles 10-15%, 0.5-1.0 cm av diam

417.57
   till: silt, with clay; with rare gravel/pebbles
   pebbles 3-5%, 0.5-1.0 cm av diam; calcareous

at 417.25
   bottom

82-3B

depth: 10.97 m, 36.0 ft

surface 423.19 m, 1388.50 ft
   no core sample

412.83
   till: silt, with clay, with gravel/pebbles
   dark gray
   pebbles 5-10%, 0.25-1.0 cm av diam

412.22
   angular rock fragment
   greenish gray
   4.0 cm long

at 412.22
   bottom

82-3C

depth: 15.27 m, 50.1 ft

surface 423.43 m, 1389.29 ft
till: silt, with clay, with organic material/soil; with rare gravel/pebbles
brown
pebbles 3-5%, 0.25-0.5 cm av diam; manganese and iron staining throughout matrix; crumbles when rolled

422.82
till: silt, with clay; with rare gravel/pebbles
brown to yellowish brown
pebbles 3-5%; manganese and iron staining; matrix less oxidized than above

422.18
till: clay and silt; with rare gravel/pebbles
dark gray to dark brown
pebbles 3-5%, 0.25-0.5 cm av diam

421.77
medium sand, with gravel/pebbles
brown
pebbles 15-20%, 0.5-1.0 cm av diam; dry, crumbles

421.66
till: silt and clay; with rare gravel/pebbles
dark gray to dark brown
pebbles 3-5%, 0.25-0.5 cm av diam

421.60
till: clay and silt; with rare gravel/pebbles
gray
overlap; 0.37 m recovered out of 0.61 m; pebbles 2-3%. less than 0.25 cm av diam

421.54
till: clay and silt, with gravel/pebbles
brown
more oxidized

421.51
fine to coarse sand, with gravel/pebbles
yellowish brown
highly oxidized; manganese and iron staining; friable

at 421.51 to 421.33
fine to coarse sand, with gravel/pebbles
yellowish brown
to Health Dept

421.60
silt, with clay; to coarse sand; to fine gravel/pebbles
overlap, cleanout, 0.40 m recovered out of 0.61 m;
similar to sand in first coring attempt

420.99
till: clay and silt; with rare gravel/pebbles
grayish brown to dark gray
pebbles 3-5%, 0.25-0.5 cm av diam

420.84
fine to medium sand
dark gray
unit 0.5 cm thick, well sorted

420.82
till: clay and silt; with rare gravel/pebbles
grayish brown to dark gray

420.69
till: clay and silt; with rare gravel/pebbles
grayish brown to dark gray
to Health Dept

at 420.69 to 420.67
fine sand
light yellowish brown
well sorted; band 20 degrees to horizontal

420.53
till: clay and silt; with rare gravel/pebbles
grayish brown to dark gray

420.38
till: clay and silt, with gravel/pebbles
dark gray

420.35
coarse gravel/pebbles
light brown
grades back into silt and clay

420.26
till: clay and silt, with gravel/pebbles
dark gray

419.77
till: clay and silt; with rare gravel/pebbles
dark gray
pebbles 5%, 0.5-1.0 cm av diam

419.16
till: silt, with clay, with gravel/pebbles

dark gray

418.86
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%

418.68
fine sand
dark gray
coating 0.1 cm thick on outside of core

418.68
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%

418.55
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 0.25-0.5 cm av diam

at 418.55 to 418.51
fine sand
dark gray
lens, 45 degrees to axis of core

at 418.37
reddish brown
breakdown zone, 0.75 x 0.5 cm

at 418.13 to 418.10
coarse silt to fine sand
dark gray

417.94
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2%, less than 0.25 cm av diam

417.79
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-10%

417.64
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept.

417.49
till: silt, with clay, with gravel/pebbles
dark gray
pebbles more than 10%

417.43
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 20%

at 417.36
fine sand
dark gray
lens 0.25 cm thick, concave upward

417.33
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2%; clean

417.24
till: silt, with clay, with gravel/pebbles
dark gray, with reddish gray
pebbles 20-25%, 0.5-1.0 cm av diam; reddish breakdown zones

416.72
till: clay and silt, with gravel/pebbles
dark gray
to Health Dept.; pebbles 30%

416.57
till: clay and silt, with gravel/pebbles
dark gray

416.54
till: clay and silt; with rare gravel/pebbles
dark gray
pebbles less than 2%

416.12
till: clay, with silt; with rare gravel/pebbles
dark gray; with rare greenish gray
pebbles less than 3%, 0.25-0.5 cm av diam; greenish shale fragment 4.5 x 5.0 cm

415.57
no core samples

415.51
till: clay and silt, with gravel/pebbles
dark gray

at 415.35
silt
light gray
pod 0.25 x 1.0 cm, well sorted

415.20
till: clay and silt; with rare gravel/pebbles
dark gray
pebbles 5%, 0.5-1.0 cm ave diam

415.05
till: clay and silt; with rare gravel/pebbles
dark gray

at 414.99
gravel/pebbles
quartz pebble 1.0 cm long

414.99
till: clay and silt; with rare gravel/pebbles
dark gray
pebbles less than 5%

414.90
till: clay and silt, with gravel/pebbles
dark gray
cleanout; pebbles 10%, 0.5-1.0 cm av diam; clay=silt

414.29
till: clay and silt, with gravel/pebbles
dark gray
pebbles 0.25-0.5 cm av diam

413.68
till: clay and silt; with rare gravel/pebbles
dark gray
core deformed, jammed pebble; pebbles 5%, 0.25-0.5 cm av diam

413.10
no core sample

413.07
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, 0.25 cm av diam

412.91
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept.; pebbles less than 3%, 0.25 cm av diam

412.76
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 0.5-1.0 cm av diam

412.61
till: silt, with clay; with rare gravel/pebbles

dark gray
pebbles 5%

412.46
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.75 cm av diam

411.91
no core samples

411.85
till: silt, with clay; with rare gravel/pebbles
dark gray
cleanout to 411.24 m; pebbles 3-5%, 0.25-0.5 cm av diam

411.70
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 3-5%

411.54
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 3-5%, 0.25-0.5 cm av diam

411.24
till: silt, with clay; with rare gravel/pebbles
dark gray
cleanout to 410.63 m; pebbles 5%, 0.25-0.5 cm av diam

410.63
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-10%, 0.5-1.0 cm av diam

410.17
till: silt, with clay; with rare gravel pebbles
dark gray
pebbles less than 3%

410.02
till: silt, with clay, with gravel/pebbles
dark gray, with olive and light gray
pebbles 5-10%, 0.25-0.5 cm av diam; drier than above; breakdown zones olive; pebble disintegration zones are light gray

409.71
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept; pebbles 5-10%

409.56

till: silt, with clay, with gravel/pebbles
dark gray
pebbles 5-10%

409.41
till: silt, with clay, with gravel/pebbles
dark gray
cleanout; pebbles 20-25%, 0.5-1.0 cm av diam; crumbles when rolled

408.80
till: silt, with clay, with gravel/pebbles
dark gray'
pebbles 10-15%, 0.5 cm av diam

at 408.34
coarse silt to fine sand
greenish gray
hard; pod 3.0 cm long

408.22
no core sample

408.16 bottom

82-3D

depth: 26.76 m, 87.8 ft

surface 422.76 m, 1387.07
no core sample

406.91
till: silt, with clay, with gravel/pebbles
dark gray, with olive and olive yellow
cleanout; pebbles 20%, 0.25-0.5 cm av diam; olive and yellow breakdown zones

at 406.61
weak red
bleb

406.36
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 25%, 0.25-1.0 cm av diam

406.00
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept; pebbles 25%

405.84
light olive brown
blebs; "gravel-like in appearance"

405.69
till: silt, with clay, with gravel/pebbles
dark grayish brown to dark gray, with olive brown
pebbles 20-25%, 0.5-1.0 cm av diam; olive breakdown zones

405.08
till: silt, with clay, with gravel/pebbles
dark gray; with rare light olive brown
crumbles when rolled; brown blebs

404.63
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, smaller than above; shale fragment 3.0 cm long

404.47
till:silt, with clay, with gravel/pebbles
dark gray, with olive brown
cleanout; pebbles 15-20%, 0.5-1.0 cm av diam; greenish gray shale fragment 4.0 cm; calcareous; olive brown

breakdown zones

403.86
fine sand
yellow
0.52 m recovered out of 0.61 m

at 403.83
fine sand
yellowish brown

at 403.65
fine sand
yellow
rim around large sandstone(?) clast

at 403.71 to 403.53
gravel/pebbles
greenish gray
clast 6.0 x 3.0 cm

at 403.56
gravel/pebbles
black
pebble 5.5 x 3.5 cm, calcareous

403.56
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%

403.31
silt, with clay
dark gray

403.25
till: silt and clay, with gravel/pebbles
dark gray
calcareous, large carbonate pebbles; pebbles 20-25%,
0.5-1.0 cm av diam.

403.10
till: silt and clay, with gravel/pebbles
dark gray
pebbles 10%, 0.25-0.5 cm av diam

at 402.80
gravel/pebbles
pale red
pebbles 2.0 cm av diam, non-calcareous

402.55
till: clay and silt; with rare gravel/pebbles
dark gray

pebbles less than 5%, 1.0 cm av diam; calcareous

402.34
fine sand
light brownish gray
pod

402.31
silt, with clay
dark gray

402.25
coarse silt and fine sand
dark gray, with light brownish gray
sand lighter than silt; calcareous

402.17
till: silt and clay, with gravel/pebbles
dark gray

402.10
no core sample

402.03
till: silt, with clay, with gravel/pebbles
dark gray
cleanout; pebbles 15%, 1.0 cm av diam

401.70
coarse silt and fine sand
dark gray and light brownish gray
sand pod nearly vertical; interfingers with silt;
calcareous

401.52
till: silt, with clay, with gravel/pebbles
dark gray
pebbles less than 10%

401.42
silt, with clay; with rare gravel/pebbles
dark gray
cleanout; first 0.24 m are cuttings; pebbles less than 2%; dry, crumbles

at 401.17
light yellowish brown
pebble breakdown zone

400.86
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 1%

400.36
lacustrine: silt, with clay; to coarse silt
dark gray to gray
horizontal microlaminations

400.27
no core sample

400.21
lacustrine: clay, with silt
gray
breaks along microlaminations

at 399.99
fine sand
gray
pod; dry, crumbles; calcareous; no pebbles

399.90
lacustrine; silt, with clay
gray
overlap; cleanout; top 0.46 m of core not recovered

399.84
lacustrine: silt, with clay
gray
cleanout; top 0.46 m of core not recovered;
almost saturated; no blebs; breaks along vertical
microlaminations

399.66
lacustrine:silt, with clay
gray
breaks along microlaminations

at 399.54
fine sand
gray
layer 0.25 cm thick

399.46
lacustrine: silt, with clay
gray
to Health Dept.

399.29
lacustrine: silt, with clay
gray

399.20
lacustrine: silt, with clay
gray
more saturated; calcareous; breaks along
microlaminations

399.08
lacustrine: silt, with clay
gray

399.05
lacustrine: coarse silt, with clay
gray
cleanout; moist; no pebbles nor sand

398.74
lacustrine: coarse silt
gray
saturated; no pebbles; rolls easily

398.50
very coarse silt
drier than above, breaks when rolled

398.41
no core samples

398.38
lacustrine: coarse silt
gray
moist; breaks along microlaminations

at 398.07
fine sand
gray, with dark reddish brown
brown blebs

397.78
no core samples

397.62
lacustrine: coarse silt
gray
cleanout; moist: no pebbles nor blebs; breaks along
microlaminations

397.36
silt, with clay; with rare gravel/pebbles
dark gray
pebbles 2%, 0.5-1.0 cm av diam; grades from above

397.16
till: silt, with clay; with rare gravel/pebbles
dark gray to gray

396.85
till: silt, with clay; with rare gravel/pebbles
gray to dark gray
pebbles 1%

at 396.79 to 396.76
fine sand
gray

396.73
lacustrine: coarse silt; and silt, with clay
gray
interfingering; calcareous; breaks along
microlaminations

396.61
till: silt, with clay; with layers of silt
dark gray, with light gray
light silty wisps throughout

at 396.34 to 396.30
fine sand
dark gray
pod with 20 degree dip

396.15
clay, with silt; with rare layers of silt
dark gray, with light gray
no pebbles; a few light gray silty wisps; almost pure
clay

396.00 bottom

82-3D Deepening in 1983

depth: 30.94 m, 101.5 ft

surface 422.76m, 1387.07 ft

396.85
till: silt and clay; with rare gravel/pebbles
dark grayish brown, with dusky red and yellowish brown
pebbles 5%, possibly limestone,0.5-1.0 cm av diam; red breakdown zones, brown staining

396.70
till: silt and clay; with rare gravel/pebbles
dark gray
pebbles 5%,0.5-1.0 cm av diam; quartz

396.55
till: silt, with clay; with rare gravel/pebbles
dark gray, with dusky red and yellowish brown
pebbbles 2-3%; red stain, brown breakdown zones

396.40
till: silt with clay; with rare gravel/pebbles
dark gray, with dusky red and yellowish brown
pebbles 2-3%, red stain, brown breakdown zones

396.24
till: silt and clay; with rare gravel/pebbles; with layers of silt
dark gray, with light gray to gray
pebbles 2%; lighter silt wisps

396.09
silt, with clay; with rare gravel/pebbles; with layers of silt
dark gray to gray, with light gray; with rare weak red and olive gray
mottled; light gray silt wisps; pebbles 2%, including weak red metamorphic rock fragment; olive gray breakdown zone

at 396.09 to 396.03
fine sand
dark grayish brown
coating core

396.03
clay, with silt; with rare gravel/pebbles; with layers of silt
dark gray, with light gray
overlap; light gray silt wisps; clay appears varved

395.94
clay, with silt; with rare gravel/pebbles; with layers of silt
dark gray, with light gray
light gray silt wisps; clay appears varved

395.84
silt, with clay; with rare gravel/pebbles; with layers of silt
dark gray to dark grayish brown, with light gray
4pebbles less than 1%; appears varved; light gray silt wisps throughout

395.66
lacustrine: coarse silt to fine sand
gray to light gray
clean

395.51
lacustrine: fine sand; with layers of coarse silt
gray, with light gray
light gray silt wisps

395.33
clay and silt, with sand, with gravel/pebbles
gray, with olive and weak red
pebbles 10%, 1.0 cm av diam, up to 3.0 cm; olive crystalline rock fragment, weak red rounded pebbles

395.12
till: silt and clay, with gravel/pebbles; with layers of silt
dark gray to grayish brown, with light gray; with rare weak red and olive
pebbles 20%, 1.0-3.0 cm, subrounded; shale fragments; red and olive breakdown zones and blebs; light gray silt wisps

394.93
till: silt and clay, with gravel/pebbles
dark gray to dark grayish brown, with greenish olive and weak red
mottled; pebbles 20%,2.0-2.5 cm av diam; olive and red breakdown zones, large siltstones and sandstones.

at 394.90
angular rock fragment
greenish gray
sandstone

394.78
overlap

394.72
coarse silt to fine sand; with rare clay and
gravel/pebbles
dark gray to dark grayish brown; with rare greenish gray
pebbles 2%, 0.5-1.0 cm av diam; moist but does not roll
easily; greenish gray breakdown zone

394.63
coarse silt to fine sand; with rare clay and
gravel/pebbles
dark gray to dark grayish brown
moist, saturated at bottom; pebbles 5%

394.48
silt and fine sand; with rare clay
dark gray
clean

394.38
silt and fine sand, with clay; with rare gravel/pebbles
dark gray; with rare dark greenish gray
pebbles 5%, 2.0-3.0 cm av diam; greenish gray shale;
moist, rolls easily

394.32
till; silt and clay, with gravel/pebbles
dark gray to dark grayish brown, with greenish gray and
yellowish brown
pebbles 15-20%, 1.0-2.0 cm av diam; siltstone, shale;
mottled, greenish gray and brown breakdown zones; "very
dirty"

394.17
no core

393.65
till: silt and clay, with gravel/pebbles
dark grayish brown
pebbles 15-20%, 0.5-1.0 av diam; dry

393.59
till: silt and clay, with gravel/pebbles
dark grayish brown
pebbles 5-10%, 1.0-1.5 cm av diam; up to 3.0 cm

393.29
fine sand to coarse silt
dark gray

at 392.98
clay, with gravel/pebbles
dark gray
varved, in nose of core

392.98
fine sand, with gravel/pebbles
cleanout, overlap; possibly varved, dry

393.04
fine sand, with gravel/pebbles
overlap

392.98
fine sand, with gravel/pebbles

392.43
sand and clay
dark gray
varved

392.25
till: silt and clay; with rare gravel/pebbles
dark gray
some layering in silt and clay; 3% pebbles

at 391.82
bottom

82-4A

depth: 5.03 m, 16.5 ft

surface 422.02 m, 1384.64 ft
   no sample recovered

416.99
   bottom

82-4B

depth: 11.43 m, 37.5 ft

surface 421.91 m, 1384.28 ft
no core sample

418.25
till: silt, with clay; with rare gravel/pebbles

418.10
fine sand
light olive brown to olive
gradation in color; dry

418.05
till: silt, with clay; with rare gravel/pebbles
dark gray
drier than 418.25 to 418.10

417.64
no core sample

411.09
fine sand
dark gray
well sorted

411.03
till: silt, with clay
dark gray
moist

410.94
silt, with clay, with gravel/pebbles
dark gray
pebbles 10-15%, 1.0 cm av diam

410.48 bottom

82-4C

depth: 15.82 m, 51.9 ft.

surface 421.96 m, 1384.46 ft
alluvium: silt and clay; with rare gravel/pebbles
dark grayish brown, with yellow
core compressed, 0.29 m recovered out of 0.61 m;
weathered till; pebbles 5%, 0.5-1.0 cm av diam; root
zones, organic material, yellow iron stain

421.35
no core sample

420.13
no core sample
"drilled through old NFS excavation area"

419.52
no core sample

419.16
backfill
dark grayish brown and grayish brown and dark gray
mottled, reworked till, root zones, organic material;
pebbles 5%, 1.0-1.5 cm av diam

419.00
backfill
olive yellow
with blebs

418.85
backfill
dark grayish brown and grayish brown and dark gray
mottled; pebbles 5%, 1.0-1.5 cm av diam

418.73
backfill
dark grayish brown and grayish brown and dark gray
to Health Dept; mottled; pebbles 5%, 1.0-1.5 cm av diam

418.67
till: silt, with clay; with rare gravel/pebbles
dark gray
less oxidized; pebbles 5%, 0.25-0.5 cm av diam

418.58
till: silt, with clay; with rare gravel/pebbles
dark gray
unoxidized; pebbles less than 5%, 0.25-0.5 cm av diam

418.39

till: silt, with clay; with rare gravel/pebbles
dark gray
increasing silt content; moist; rolls with difficulty

418.30
till: silt, with clay
dark gray
unweathered; no pebbles

418.00
till: silt, with clay
dark gray
to Health Dept; no pebbles; unoxidized

at 417.88 to 417.85
fine sand
olive brown
to Health Dept; pods, 2.0 cm thick

417.85
fine sand
olive brown
pods, 2.0 cm thick

417.81
silt, with clay
dark gray
no pebbles nor sand; moist

417.69
till: silt, with clay
dark gray
no pebbles; moist

417.39
till: silt, with clay
dark gray
to Health Dept; no pebbles; moist; unoxidized

417.24
till: silt, with clay; with rare gravel/pebbles
dark gray, with grayish brown and dark reddish gray
mottled, brown and reddish blebs; pebbles 2-3%, 0.25-0.5 cm av diam

417.08
till: silt, with clay; with rare gravel/pebbles
dark gray
recovered 0.38 m out of 0.61 m

416.63
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept; clean, uniform; few to no pebbles

at 416.53 to 416.47
fine sand
dark gray
saturated

416.47
till: silt, with clay: with rare gravel/pebbles
dark gray
not as moist as above

at 416.47 to 416.46
coarse silt to fine sand
dark gray

at 416.35
fine sand
dark gray
deformed stringer 0.25 x 3.0 cm

at 415.96
gravel/pebbles
pebble 1.0 cm long

415.86
till: silt, with clay: with rare gravel/pebbles
dark gray
increase in pebbles

415.56
till: silt, with clay: with rare gravel/pebbles
dark gray
to Health Dept.

415.41
till: silt, with clay; with rare gravel/pebbles
pebbles less than 5%, 0.25-0.5 cm av diam

at 415.32
silt with clay
no pebbles

415.32
till: silt, with clay: with rare gravel/pebbles
dark gray

at 415.25
reddish brown
bleb

415.25
till: silt, with clay: with rare gravel/pebbles
dark gray
pebbles 2-3%, 0.25-0.5 cm av diam

at 415.10 to 414.95
coarse gravel/pebbles
pebble 4.0 cm long

at 414.80 to 414.65
coarse gravel/pebbles
pebble 3.75 cm long

414.65
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 1-2%, less than 0.25 cm av diam

414.34
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept.; pebbles less than 1-2%, less than 0.25 cm av diam

414.19
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 1-2%, less than 0.25 cm av diam

at 414.04
coarse gravel/pebbles
pebble 3.75 cm long

414.04
till: silt, with clay; with rare gravel/pebbles
dark gray
increase in silt content; moist; no wisps or blebs; pebbles less than 2%; rolls easily

413.88
till: silt, with clay, with rare gravel/pebbles
dark gray
pebbles less than 2%

413.43
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 1%, 0.1-0.25 cm av diam

at 413.33
gravel/pebbles
pink
pebble 0.25 cm long

413.12
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 2%

412.97
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 3%, up to 5.5 cm long

412.62
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 1-2%, 0.25-0.5 cm av diam

412.27
till: silt, with clay; with rare gravel/pebbles
dark gray
overlap; pebbles less than 1%

412.21
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 1-25%, 0.25-0.5 cm av diam

412.08
silt, with clay
dark gray
no pebbles; moist

411.81
silt, with clay
dark gray
to Health Dept; no pebbles; moist

411.63
no core sample

411.60
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles 5%; moist; "stretches like taffy"; no wisps or blebs

410.99
no core sample

410.90
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%; moist; rolls easily

at 410.62 to 410.59
fine sand
dark gray

at 410.29
angular rock fragments

greenish gray
shale fragment in nose of core

410.38
till: silt, with clay, with gravel/pebbles
dark gray
overlap; pebbles 5-10%

410.29
till: silt, with clay, with gravel/pebbles
dark gray
overlap; pebbles 5-10%

at 410.26 to 410.16
angular rock fragments
greenish gray
shattered shale fragments; breakdown zone

409.77
till: silt, with clay; with rare gravel/pebbles
dark gray, with gray
moist but not saturated; pebbles less than 5%; poor recovery, shale fragment in spoon

409.16
till: silt, with clay, with gravel/pebbles
dark gray
cleanout; pebbles 10-20%, 0.5-1.0 cm av diam

at 409.16 to 409.01
clay and silt, with gravel/pebbles
moist; clay=silt, pebbles 20%

408.55
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, 0.25-0.5 cm av diam

408.24
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept; moist; "dirty till - gravel-like"

408.09
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, 0.25-0.5 cm av diam

407.94
till: silt, with clay, with gravel/pebbles
dark gray
cleanout; pebbles 10%

at 407.64

coarse gravel/pebbles
4 pebbles 3.5-4.0 cm long

407.64
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, smaller than above; silt 60%, clay 40%

407.33
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%

407.18
till: silt, with clay, with gravel/pebbles
dark gray
to Health Dept; pebbles 10%, 0.5-1.0 cm av diam

407.03
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10%, 0.5-1.0 cm av diam

406.72
till: silt, with clay, with gravel/pebbles
dark gray
cleanout; pebbles 10-15%, 0.5-1.0 cm av diam

406.11
overlap, collapse

406.14
no core sample

406.11
bottom

82-5A

depth: 6.13 m, 20.1 ft

surface 420.08 m, 1378.29 ft
   no core sample

414.56
   till: silt, with clay; with rare gravel/pebbles
   dark gray
   pebbles 5%, 0.25-1.0 cm av diam; moist but not saturated

414.29
   clay, with silt; with rare gravel/pebbles
   fewer pebbles than in 414.56 to 414.29

at 414.26
   coarse gravel/pebbles
   pebble 5.5 cm long

413.98
   no core sample

413.95 bottom

82-5B

depth: 13.56 m, 44.5 ft

surface 419.98 m, 1377.97 ft
no core sample

407.15
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25-1.0 cm av diam

407.00
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 0.5-1.0 cm av diam

406.81
till: silt, with clay, with gravel/pebbles
pebbles 5-10%, 0.1-0.25 cm av diam

406.63
till: silt, with clay, with gravel/pebble.
pebbles 10%, 0.75 cm av diam

406.51
no core sample

406.42 bottom

82-5C

depth: 15.42 m, 50.6 ft

surface 419.99 m, 1377.99 ft
till: silt, with clay; with rare gravel/pebbles
brown, with brownish yellow
pebbles less than 5%; iron stains; root zones, organic
material; dry, breaks apart easily; yellow blebs

419.38
no core sample

419.32
till: silt, with clay, with gravel/pebbles
brown, with pale yellow
brittle, dry, breaks easily; root zones, organic
material; yellow blebs

at 419.17
angular rock fragment
gray
shale clast 4.5 cm long

at 418.74
brown
stain

418.71
till: silt, with clay; with rare gravel/pebbles
dark grayish brown
moist; oxidized; pebbles 5%, 0.5-1.0 cm av diam

418.41
till: silt, with clay; with rare gravel/pebbles
dark grayish brown
to Health Dept.

418.25
till: silt, with clay; with rare gravel/pebbles
dark grayish brown
pebbles 5%, 0.5-1.0 cm av diam

at 418.25 to 418.19
with light yellowish brown
blebs

at 418.16
coarse gravel/pebbles
pebble 2.5 cm long

at 418.13 to 418.10
coarse silt to fine sand; with rare gravel/pebbles

overlap with till

418.10

coarse silt to fine sand; with rare gravel/pebbles
crumbles easily; organic material; pebbles less than 5%, 0.5-1.0 cm av diam

417.95

till: silt, with clay, with gravel/pebbles
dark grayish brown
oxidized

417.64

gravel/pebbles
pebbly zone; ncr calcareous; iron stain around pebbles

417.55

till: silt, with clay; with rare gravel/pebbles
dark grayish brown
overlap with pebbly zone

417.52

till: silt, with clay; with rare gravel/pebbles
dark grayish brown
dry, partly oxidized; pebbles 5%, 0.25-0.5 cm av diam

417.40

till: silt, with clay; with rare gravel/pebles
dark grayish brown
to Health Dept; partly oxidized

417.25

till: silt, with clay; with rare gravel/pebbles
dark grayish brown, with yellowish brown
yellowish blebs

417.09

till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
becoming less oxidized

416.94

till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
pebbles 5%; partly oxidized; moist; rolls with slight crumbling

416.79

till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
to Health Dept; pebbles 5%

416.64

till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray, with yellowish brown
yellow iron staining

416.48
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray, with dark reddish brown
root zones; manganese and iron staining; rounded reddish
brown pebbles

416.33
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
pebbles less than 5%; 0.25-0.5 cm av diam

416.24
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray, with reddish black
reddish black manganese stain in small fracture zone

416.18
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray, with reddish black
to Health Dept; black manganese stain in small fracture
zone

416.09
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
to Health Dept; pebbles less than 5%, 0.25-0.5 cm av
diam

416.03
till: silt, with clay; with rare gravel/pebbles
dark grayish brown to dark gray
pebbles less than 5%, 0.25-0.5 cm av diam

415.75
till: silt, with clay, with gravel/pebbles
dark grayish brown to dark gray
overlap with till above; more pebbles

415.72
till: silt, with clay, with gravel/pebbles
dark grayish brown to dark gray

at 415.63
fine sand
yellowish brown
pod 1.5 x 1.0 cm, horizontal

415.60
till: silt, with clay, with gravel/pebbles
dark grayish brown to dark gray

moister than above; rolls easily

415.45
till: silt, with clay, with gravel/pebbles
dark grayish brown to dark gray

415.14
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25-0.5 cm av diam.

at 415.11
fibre-like micaceous material

414.99
fine to medium sand
dark gray
to Health Dept; pod

414.84
silt, with clay
dark gray
more silt than above

414.69
till: silt, with clay; with rare gravel/pebbles
dark gray
moister than above; pebbles less than 5%, 0.25-0.5 cm av diam

414.53
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 0.25-1.0 cm av diam; moist

at 414.38 to 414.29
weak red
breakdown zone

413.92
no core sample

413.89
till: silt, with clay: with rare gravel/pebbles
dark gray
moist like 414.53 to 414.92; pebbles less than 3%

413.28
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, less than 0.25 cm av diam

412.68
till: silt, with clay; with rare gravel/pebbles

dark gray, with olive yellow
pebbles less than 2%; yellow blebs; rolls easily

till: silt, with clay, with rare gravel/pebbles
dark gray, with olive yellow
to Health Dept.; pebbles less than 2%; yellow blebs; rolls easily

412.37
till: silt, with clay; with rare gravel/pebbles
dark gray, with olive yellow
pebbles less than 2%; yellow blebs; rolls easily

412.16
till: silt, with clay; with rare gravel/pebbles
dark gray
overlap with till above; trimmed off 0.08 m from top of core

412.07
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 2%; moist

411.91
till: silt, with clay, with gravel/pebbles
dark gray, with dark red
higher pebble content than above; red blebs

411.76
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10-20%

411.61
no core sample

411.46
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%; moist; uniform

411.30
till: silt, with clay; with rare gravel/pebbles
dark gray, with light gray
light wisps; pebbles 0.25-0.5 cm av diam; more silt than above; not as moist as 412.68 to 411.46 m

411.15
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%

411.00
sand
dark gray
deformed pod, thin, horizontal

410.88
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, 0.25-0.5 cm av diam

410.69
till: silt, with clay; with rare gravel/pebbles
dark gray
to Health Dept; pebbles less than 3%, 0.25-0.5 cm av diam

at 410.69 to 410.63
to Health Dept; shale disinegration zone

410.54
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 3%, 0.25-0.5 cm av diam

410.30
till: clay with silt; with rare gravel/pebbles
dark gray
pebbles 3%, 0.25-0.5 cm av diam

409.66
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%; clean, uniform

409.49
till: clay, with silt; with rare gravel/pebbles
dark gray
to Health Dept; pebbles less than 2%

409.32
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%

409.08
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%, 0.15-0.25 cm av diam

408.93
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 1%, 0.1-0.2 cm av diam

408.77
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%

408.62
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%

408.47
sand
dark gray
pod 1.5 x 0.5 cm

at 408.38
till: clay with silt; with rare gravel/pebbles
dark gray
pebbles less than 2%, 0.15-0.2 cm av diam

407.94
fine sand
to Health Dept; pod

407.89
fine sand
dark gray
to Health Dept; lens 0.05 m thick; dry

407.84
till: clay, with silt; with rare gravel/pebbles
dark gray
to Health Dept; pebbles less than 2%, 0.15-0.2 cm av diam

407.89
fine sand
dark gray
overlap with till

407.80
fine sand
dark gray
saturated, water bearing

407.28
no core sample

407.25
fine sand
dark gray
well sorted; saturated, water in hole

at 406.85 to 406.82
till and fine sand
dark gray
interfingering

406.79
no core sample

406.52
coarse silt to fine sand, with gravel/pebbles
dark gray

406.37
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles less than 5%, 0.25-0.75 cm av diam

406.09
medium to coarse sand
dark gray

406.03
no core sample

405.97
silt, with clay; with rare gravel/pebbles
dark gray; "same as 406.37 to 406.09 m"

405.36
till: silt, with clay; with rare gravel/pebbles
dark gray
pebbles 5%, 0.25-0.5 cm av diam

405.12
till: silt, with clay; with rare gravel/pebbles
dark gray, with light olive gray
light blebs

404.57
no core sample

404.57 bottom

83-1D

depth: 18.44 m, 60.5 ft

surface 425.25m, 1395.26 ft
alluvium: silt and clay; with rare gravel/pebbles
dark brown
many roots; pebbles 2-3%; Fe and Mn staining

425.10
alluvium: silt and clay; with rare gravel/pebbles
brown to yellowish brown
mottled; pebbles 2-3%; Fe and Mn staining

424.82
till: silt and clay, with gravel/pebbles
brown to yellowish brown
pebbles 15-20%, 1.5 cm av diam; up to 3.0 cm; Fe and Mn staining

424.55
silt
dark brown
roots throughout; "silty zone"

424.46
till: silt and clay; with rare gravel/pebbles
dark gray to dark grayish brown to dark brown
pebbles 3-5%, 0.5-1.0 cm, up to 3.5 cm

423.91
cleanout; cuttings from above

423.82
till: silt and clay, with gravel/pebbles
dark grayish brown to dark gray to dark brown
more clay than above, more consolidated; pebbles 2-3%, 0.25-0.5 cm av diam;

at 423.63 to 423.57
angular rock fragment
5.5 cm long

423.54
till: silt and clay; with rare gravel/pebbles
dark grayish brown, with dark black
pebbles 1%, up to 1.5-1.0 cm; weathered, but less oxidized than above

423.06
fine sand to coarse silt
olive brown
pod 1.0 by 2.0 cm, distorted

422.93
fine sand
olive brown
in nose of core; dry

422.90
till: silt and clay; with rare gravel/pebbles
dark gray
less oxidized; pebbles less than 1%

at 422.90 to 422.87
fine sand to coarse silt
olive brown

at 422.81 to 422.78
fine sand to coarse silt
brownish yellow

at 422.42 to 422.38
fine sand
brownish yellow
pod, concave upward

422.32
till: silt and clay; with rare gravel/pebbles
dark gray
clean; pebbles less than 1%; unweathered, not oxidized

at 422.05 to 422.02
silt and clay, with gravel/pebbles
dark gray
pebbles 20%, 0.5-1.0 cm av diam; up to 1.5 cm

421.71
silt and clay, with gravel/pebbles
0.21 m recovered, first 0.12 m cuttings; pebbles 0.5-1.0 cm av diam;

421.20
no recovery

420.59
till: silt and clay; with rare gravel/pebbles
dark gray
cleanout

at 420.59 to 420.40
silt, with gravel/pebbles
pod, vertical along edge of core; pebbles 5%, 0.5 cm av diam;

420.37
till: silt, with clay, with gravel/pebbles

dark gray
0.30 m recovered; moist

at 420.13 to 420.10
silt, with clay; with rare gravel/pebbles
less clay than above; pebbles 3-5%, some shale

419.92
silt and clay, with gravel/pebbles
dark gray
pebbles 10%, 0.5-3.0 cm, including siltstone, shale, chert, metamorphic rock fragment; moist but not saturated

419.46
till: silt, with clay, with gravel/pebbles
dark gray; with rare yellow brown and olive gray overlap; colored breakdown zones; pebbles 15%, includes shale, siltstone, limestone, sandstone

419.31
till: silt, with clay, with gravel/pebbles
dary gray; with rare yellow brown and olive gray colored breakdown zones; pebbles 15%, includes shale, siltstone, limestone, sandstone

419.15
no recovery

419.09
till: silt and clay, with gravel/pebbles
dark gray
pebbles 15-20%, shale, siltstone, sandstone

418.48
till: silt and clay, with gravel/pebbles
dark gray
overlap; cleanout; pebbles 25-30%

418.18
till: silt and clay, with gravel/pebbles
dark gray
less pebbles, more clay than above

417.97
till: clay, with silt, with gravel/pebbles
dark gray
pebbles 10%, av diam 1.0-1.5 cm, up to 5.0 cm, shale and siltstone

417.33
till: silt and clay, with gravel/pebbles
dark gray
cleanout, poor recovery; pebbles 10-15%, av diam 1.0-2.0

cm, up to 4.5 cm; more silt

416.59
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 35-40%, av diam 0.5-1.0 cm, up to 5.0 cm, shale

416.08
no recovery

415.74
till: silt and clay, with gravel/pebbles
dark gray
pebbles 20%, 0.5-1.0 cm av diam; up to 3.0-4.0 cm

416.11
till: silt and clay, with gravel/pebbles
dark gray
cleanout, overlap; pebbles 30-35%

415.50
till: silt and clay, with gravel/pebbles
dark gray
overlap

415.31
till: silt and clay, with gravel/pebbles
dark gray
pebbles 25%, 0.5-1.0 cm av diam; up to 2.5-3.0 cm

414.95
till: silt and clay, with gravel/pebbles
dark gray
pebbles 5%, 0.25-1.0 av diam; more clay

414.86
till: silt and clay; with rare gravel/pebbles
dark gray
overlap; pebbles 3-5%, 0.25-0.5 cm av diam metamorphic rock fragments up to 4.0 cm

414.80
till: silt and clay; with rare gravel/pebbles
dark gray
pebbles 3-5%, 0.25-0.5 cm; more clay than above

414.22
no recovery

414.16
till: silt and clay
dark gray

at 414.16 to 414.06

silt and clay, with gravel/pebbles pod, 40-50% gravel, dry

at 414.06 to 413.79
till: silt and clay, with gravel/pebbles
pebbles 5-7%, av diam 0.5-1.0 cm

at 413.79
coarse gravel
cobble 5.0 cm

at 413.79 to 413.70
till: silt and clay, with gravel/pebbles
pebbles 5-7%, 0.5-1.0 cm

413.70
till: silt and clay; with rare gravel/pebbles
pebbles 1%, 0.25-0.50 cm; more clay

413.58
till: silt and clay, with gravel/pebbles
dark gray
overlap; pebbles 5-10%, av diam 0.5-1.0 cm, up to 1.5-1.0 cm

413.55
till: silt and clay, with gravel/pebbles
dark gray
pebbles 5-10%, av diam 0.5-1.0 cm, up to 1.5-2.0 cm

413.27
till: silt and clay; with rare gravel/pebbles
gray
pebbles less than 1%, 0.25-0.5 cm

412.88
till: silt, with clay; with rare grvel/pebbles
gray
pebbles less than 3%

412.81
till: silt,with clay, with gravel/pebbles
gray
pebbles 35-40%

412.69
silt, with clay; with rare gravel/pebbles
gray
pebbles less than 2%; dry

412.48
silt, with clay, with gravel/pebbles
dark gray, with pink
pebbles increase

412.27
till: silt, with clay; with rare gravel/pebbles
dark gray, with pink
pebbles 2-3%, av diam 0.1-0.13 cm, up to 1.5 cm

411.78
no recovery

411.66
Shelby tube sample

411.63
till: silt and clay, with gravel/pebbles
dark gray
cleanout, overlap; pebbles less than 10%, av diam 0.25-0.5 cm

at 411.08 to 411.02
increase in silt in nose of core

411.02
till; silt and clay, with gravel/pebbles
dark gray

410.93
silt
friable

410.86
silt, with clay
dark gray
saturated

410.53
sand and silt; with rare gravel/pebbles
moist

410.47
silt
dark gray

410.21
no recovery

410.19
fine to coarse silt
dark gray
saturated

410.12
sand, with silt
dark gray
dry, friable

409.98
coarse silt to fine sand; with rare gravel/pebbles

409.86
silt, with sand
dark gray, with pink
pinkish tint shows lamination

409.80
gravel/pebbles, with silt

409.74
silt, with gravel/pebbles

409.64
no recovery

409.61
coarse silt to fine sand
dark gray
tried to get Shelby tube sample: ruined tube

409.40
fine sand
dark gray

409.25
coarse silt to fine sand
saturated

408.91
no recovery

408.88
sand, with silt
dark gray
dry

408.73
coarse silt to fine sand
moist

408.58
sand, with silt

408.49
coarse sand, with fine pebbles; to fine sand to coarse silt
gritty; weathered shale fragments

408.33
no recovery

408.21
silt, with sand; to sand, with gravel
moist

408.06
sand, with silt

407.91
angular rock fragments
bluish gray
weathered bedrock, shale

407.60
bedrock and angular rock fragments
dark gray
weathered bedrock, shale

at 406.81
bedrock
solid
bottom

83-1E

depth: 20.57 m, 67.5 ft

surface 425.26 m, 1395.29 ft
augered

422.21
Shelby tube

421.68
augered

418.83
Shelby tube

418.55
augered

415.95
Shelby tube

415.51
augered

at 406.52
bedrock

406.52
rotary drilled in bedrock

at 404.69
bottom

83-2D

depth:25.91 m, 85.0 ft

surface 424.64 m, 1393.25 ft
augered

404.83
no recovery

404.52
till: silt and clay, with gravel/pebbles
dark gray
pebbles 20%

404.37
till: clay, with silt, with gravel/pebbles
dark gray
pebbles 20%

404.28
till: silt and clay; with rare gravel/pebbles
dark gray
dry

404.22
no recovery

403.92
no recovery

401.78
silt and clay, with fine sand
dark gray
dry

401.69
coarse silt to fine sand
dark gray
dry

401.57
angular rock fragment
disintegrated sandstone; dry

401.51
coarse silt to fine sand; with rare gravel/pebbles
gray
dry; pebbles less than 1%

401.17
no recovery

399.34
coarse silt, with fine sand; with rare gravel/pebbles
gray to dark gray
pebbles 5%; moist

399.04
angular rock fragments, with coarse silt to fine sand
weathered bedrock; water in hole

at 398.73
bottom

83-2E

depth: 28.65 m, 94.0 ft

surface 424.60 m, 1393.11 ft
augered

421.69
Shelby tube sample

421.31
till: clay, with silt; with rare gravel/pebbles
dark gray
pebbles 3-5%, av diam 0.2 cm; 0.34 m
recovery

at 421.31
angular rock fragment
sandstone, 1.0 by 0.5 cm

at 420.94
angular rock fragment
shale, 5.0 cm

420.82
augered

418.50
Shelby tube sample: tube wet from 6.25-6.40 m

418.20
no recovery

418.17
till: silt and clay, with gravel/pebbles; with rare
layers of silt
poor recovery: core sheared along one side by rock in
nose of spoon; pebbles 5-10%, 1.0-1.5 cm av diam; silt
wisps and blebs throughout

417.56
till: silt and clay, with gravel/pebbles
dark gray
pebbles 10-12%, 0.2-0.4 cm av diam;

at 417.38
angular rock fragment
bluish gray
disintegrated sandstone, 7.0 cm long; in nose of core

417.25
augered

411.86
till; clay, with silt, with gravel/pebbles
dark gray
pebbles less than 10%, 0.5-1.0 cm av diam; up to 1.5-2.0 cm; more clay; rolls easily; moist

411.25
augered

409.36
Shelby tube sample

408.78
no recovery

408.72
till: silt and clay; with rare gravel/pebbles; with rare layers of silt
dark gray
pebbles less than 1%, 0.25-0.5 cm av diam; silt wisps throughout

at 408.69
medium to coarse sand
dark gray
pod, less than 0.5 cm thick, concave downward; dry

at 408.63 to 408.60
medium sand
dark gray
pod, 20 degrees from vertical, less than 0.25 cm thick

at 408.51
coarse silt to fine sand
light gray
pod, concave downward

408.39
augered

406.62
failed attempt to get Shelby tube sample

406.43
till: silt, with clay, with gravel/pebbles
dark gray
overlap; pebbles 20-25%,2.0-3.0 cm av diam; dry

406.31
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 20-25%, 2.0-3.0 cm av diam; dry

405.95

no recovery

405.52
Shelby tube sample

405.24
augered

403.26
Shelby tube sample; sand in bottom

402.94
no recovery

402.84
fine sand, with coarse silt
dark gray
dry

402.72
silt, with sand
dark gray
slightly moist

402.50
fine sand; with coarse silt
dark gray
saturated

402.41
silt, with sand
dark gray
dry, perhaps because compacted by nose of spoon

402.35
no recovery

400.83
fine sand, with silt
gray
dry, crumbles to touch

at 400.83
coarse gravel/pebbles
bluish gray
broken cobble, 6.0-6.5 cm

400.60
no recovery

400.22
fine to medium sand, with silt
dark gray
dry

400.10
fine silt to coarse sand; with rare gravel/pebbles
gray
pebbles less than 5%

at 399.64
gravel/pebbles

399.64
augered

at 396.74
bedrock
weathered; with water

396.74
no recovery; all bedrock, shale

at 395.95
bottom

83-3E

depth: 26.52 m, 87.0 ft

surface 420.48 m, 1379.58 ft
augered

417.43
no recovery

417.40
cuttings

417.37
till: clay, with silt
gray to dark gray
moist

417.10
till: clay, with silt
gray to dark gray
not as moist; clean

416.94
till: silt, with clay; with rare gravel/pebbles
gray to dark gray
drier; pebbles less than 1%

416.79
augered

414.38
Shelby tube sample

413.84
till: silt, with clay, with gravel/pebbles
dark gray
overlap; pebbles 10-15%,0.5-1.0 cm av diam, up to 2.5 cm; dry

413.77
till: silt, with clay, with gravel/pebbles
dark gray
pebbles 10-25%,0.5-1.0 cm av diam, up to 2.5 cm; dry

413.26
augered

411.34
till: silt and clay; with rare gravel/pebbles; with layers of silt dark gray, with light gray and olive green
dry; pebbles 5%,0.5-1.0 cm av diam, up to 1.5 cm; green

breakdown zones; light gray silt wisps

410.73
augered

408.01
Shelby tube sample

407.68
no recovery

407.40
till: silt and clay
dark grayish brown, with dark red
red staining

407.25
sand
light brownish gray
concave upward

407.22
no recovery

407.10
till: silt and clay
dark grayish brown
moist

at 407.01
coarse silt to fine sand
dark grayish brown
pod, concave upward

407.01
till: silt, with clay
moister

406.95
silt and clay
dark gray
appears laminated; moist

406.86
till: silt and clay; with layers of fine sand
dark gray
sand pods up to 1.0 cm diam; moist

406.80
augered

at 406.76
water in hole

405.24
Shelby tube sample

404.94
no recovery

404.63
till: silt and clay, with gravel/pebbles
dark gray
large shale fragment lodged in split spoon; 0.3 m recovery

at 404.45 to 404.33
fine sand
dark gray
dry; appears laminated

at 404.33
0.46 m (1.5 ft) of water in hole

405.24
overlap; cutting

404.33
augered

402.19
Shelby tube sample

401.92
no recovery

401.58
coarse sand dary gray
dry

401.40
till: silt and clay, with gravel/pebbles
pebbles 15-20%

401.25
silt and clay, with coarse angular rock fragments
drk gray
sandstone fragments 2.0-2.5 cm

401.19
augered

399.14
failed attempt to get Shelby tube sample

398.99
lacustrine: silt, with clay; with layers of silt
dark gray with light gray

dry; light gray silt wisps throughout

398.84
lacustrine: silt and clay
dark gray
moist; laminated

398.69
lacustrine: fine silt and clay, with layers of silt
laminated; silt wisps

at 398.60
fine sand
dry; rims nose of core

398.60
augered

395.94
lacustrine: silt and clay
dark gray
almost saturated

at 395.85
angular rock fragments
shattered shale and sandstone

395.85
lacustrine: silt and clay; with rare gravel/pebbles
dark gray

395.67
lacustrine: silt and clay
dark gray
almost saturated

at 395.61
saturated

395.61
lacustrine: sand and silt and clay, with gravel/pebbles
pebbles less than 10%

at 395.55
fine sand
in nose of core

395.55
augered

394.42
bedrock and angular rock fragments
greenish gray to bluish gray
weathered bedrock and shattered shale fragments

at 393.96
bottom; 0.55 m of water in hole in weathered bedrock

83-4E

depth: 75.04 m, 246.21 ft

surface 420.91, 1381.0 ft
alluvium: sand, with silt, with gravel/pebbles
brown
bit sample: dry

419.39
alluvium: sand, with silt, with gravel/pebbles
brown
bit sample: saturated

417.25
no core recovery

416.64
till: silt and clay, with gravel/pebbles
brownish gray
bit sample: weathered, oxidized

416.34
no core recovery

414.81
silt and clay; with rare gravel/pebbles
dark gray to gray
bit sample

414.51
no core recovery

413.90
till: clay, with silt; with rare gravel/pebbles
dark gray
split spoon sample: pebbles less than 5%, av diam
0.5-1.0 cm, up to 6.0 cm long

413.29
no core recovery 412.07
till: silt and clay; with rare gravel/pebbles
dark gray
bit sample

411.77
no core recovery

410.55
till: silt and clay; with rare gravel/pebbles
dark gray bit sample

410.24

no core recovery

at 409.63
till: silt, with clay; with rare gravel/pebbles
bit sample: drier than last bit sample

409.63
no core recovery

408.72
till: clay, with silt, with gravel/pebbles
dark gray
split spoon sample: pebbles 10%, 4.5-5.0 cm av diam;

408.41
till: clay, with silt, with gravel/pebbles
dark gray
split spoon sample: to Health Dept.; pebbles 10%, 4.5-5.0 cm av diam;

408.26
till: clay, with silt, with gravel/pebbles
dark gray
split spoon sample; pebbles 10%, 4.5-5.0 cm av diam;

408.11
no core recovery

404.45
till: silt and clay and gravel/pebbles
dark gray
bit sample: very pebbly

404.15
no core recovery; possible water production

403.60
till: silt and clay, with gravel/pebbles
dark gray
split spoon sample: recovered 0.15 m in 0.61 m possible water production to 402.62 m

402.99
no core recovery

401.40
till: silt and clay; with rare gravel/pebbles
dark gray
bit sample

401.10
no core recovery

399.88

till: silt and clay; with rare gravel/pebbles
dark gray
bit sample: compacted

399.57
no core recovery

at 398.05
till: silt and clay; with rare gravel/pebbles
dark gray
bit sample

396.83
till: clay, with silt; with rare gravel/pebbles
dark gray
split spoon sample: very dry and compact; pebbles av
diam 0.51-1.0 cm, up to 3.0 cm

396.22
no core recovery

395.61
till: silt and clay and gravel/pebbles
dark gray
bit sample: very pebbly, "gravel-like"

395.31
no core recovery

394.09
sand and gravel/pebbles
brownish gray
bit sample: no clay

393.78
no core recovery

392.26
sand and silt and gravel/pebbles
brownish gray
bit sample: no clay

391.96
no core recovery

391.04
gravel/pebbles
split spoon sample: "pea-size gravel", av diam 0.5 cm,
up to 2.0 cm

390.89
as layers: fine sand; gravel/pebbles
olive gray
split spoon sample: dry; laminated sand and gravel

390.74
as layers: fine sand; gravel/pebbles
olive gray
split spoon sample: small pebbles, no silt nor clay;
curved layers of sand alternating with gravel

390.66
no core recovery

388.48
fine to medium silt; with layers of coarse sand
olive gray
split spoon sample: sand partings between silt layers
0.1-1.25 cm thick; dry; no clay nor gravel; silt moist,
sand dry

387.96
no core recovery

387.38
as layers: silt with coarse sand; clay with coarse sand
dark gray, with olive gray
bit sample: varve-like layers

385.86
no core recovery

381.90
as layers: silt; medium sand
dark gray, with light gray
split spoon sample: laminated silt and sand, layers
0.1-0.3 cm thick, with some lighter sand partings

381.29
no core recovery

377.94
silt and clay and medium sand
dark gray
bit sample: no pebbles

377.63
no core recovery

372.45
till: gravel/pebble with silt and clay
dark grayish brown
split spoon sample: pebbles 40-50%, up to 8.0 cm long;
dry, compact; pinkish color; may be Kent till

371.84
no core recovery

365.96
till: clay, with silt; with rare gravel/pebbles; with layers of medium sand
dark gray, with grayish brown
split spoon sample: grayish brown deformed stringers of sand throughout, some saturated and some not

365.35
no core recovery

364.83
till: silt and clay, with angular rock fragments
dark gray, with black
bit sample: compact, dry; black shale fragments, large

364.52
no core recovery

at 363.61
till: fine sand, with clay
gray, with red
bailer sample: red clay in balls; 2.65 liters/min (0.7 gpm) water

363.61
no core recovery

at 363.46
dry

363.46
no core recovery

at 360.87
fine sand
bailer sample: saturated

360.87
no core recovery

359.95
fine sand, with coarse silt; with rare gravel/pebbles and coarse sand
dark grayish brown
split spoon sample: saturated; pea gravel; 4.6 m of water in hole

359.34
no core recovery

358.12
fine sand, with silt
dark gray
bit sample

357.82
no core recovery

at 355.99
fine sand, with silt
dark gray
bit sample

355.99
no core recovery

355.69
coarse silt to fine sand
dark gray
bit sample: no clay nor pebbles

355.38
no core recovery

at 353.86
coarse silt to fine sand
dark gray
bit sample: saturated

353.55
coarse silt to fine sand
dark gray
split spoon sample: clean, saturated, no pebbles

352.97
no core recovery

352.64
fine gravel/pebbles and angular rock fragments
bailer sample: very small pebbles of shale, siltstone, metamorphic rock

352.33
gravel/pebbles, with clay
bit sample: shale pebbles, 2.0-2.5 cm long

352.18
no core recovery

at 351.42
gravel/pebbles
bluish gray
bailer sample: shale pebbles, 3.0-4.0 cm av diam, some exotics

at 350.81
gravel/pebbles, with fine silt and coarse sand: with rare clay

bluish gray
bailer sample: gravel and till intermixed

350.50
coarse gravel/pebbles, with coarse silt, with fine sand and clay
very dark gray
split spoon sample 0.15 m recovered in 0.30 m, difficult to drive spoon; pebbles 50-60%, cobbles of siltstone and shale, well rounded to subrounded, up to 8.0 cm long; small pebbles in matrix, 0.5-3.0 cm av diam; bluish tint in matrix; some parts of matrix have more sand than silt

350.20
no core recovery

at 349.29
fine gravel/pebbles, with coarse sand
bailer sample: pebbles 0.1-0.2 cm av diam, well sorted, subangular shale; red sandstone

at 348.98
silt and clay, with gravel/pebbles
bailer sample: pebbles 30-40%, small; water being produced

348.68
gravel/pebbles; with rare coarse sand
bailer sample: attempted split spoon sample but no recovery; pebbles small, well sorted, subangular shale, siltstone, quartz, sandstone, limestone, metamorphic rock; some water being produced

348.37
no core recovery

at 348.22
gravel/pebbles
bailer sample

348.22
gravel/pebbles, with silt and sand and clay
dark gray to gray
split spoon sample: pebbles 75%, small, subangular, shale; saturated

348.10
silt and clay, with fine sand; with rare gravel/pebbles
dark gray to gray
split spoon sample: pebbles less than 5%; dry

347.70
no core recovery

at 346.54
silt and clay, with gravel/pebbles
dark gray
bit and bailer sample: pebbles 20-30%, 0.5-1.0 cm av diam

at 346.21
angular rock fragments
bailer sample: casing met refusal, drilled until bit got hung up; weathered bedrock; hole producing 37.85 liters/min (10 gpm) water

at 345.87
rock
bottom; shale; producing 49.21-56.78 liters/min (13-15 gpm) water from weathering rock zone; hole cased to 346.24 m; no water in solid rock

Appendix B. Graphic Columns Showing the Stratigraphy in Holes Drilled in 1982 and 1983.

These columns were drawn using the standardized geologic logs in Appendix A. The symbol conventions are the same as used for graphic columns in Albanese and others (1983). The basic symbols are:

1) clay - short dash

2) silt - small dot

3) sand - large dot

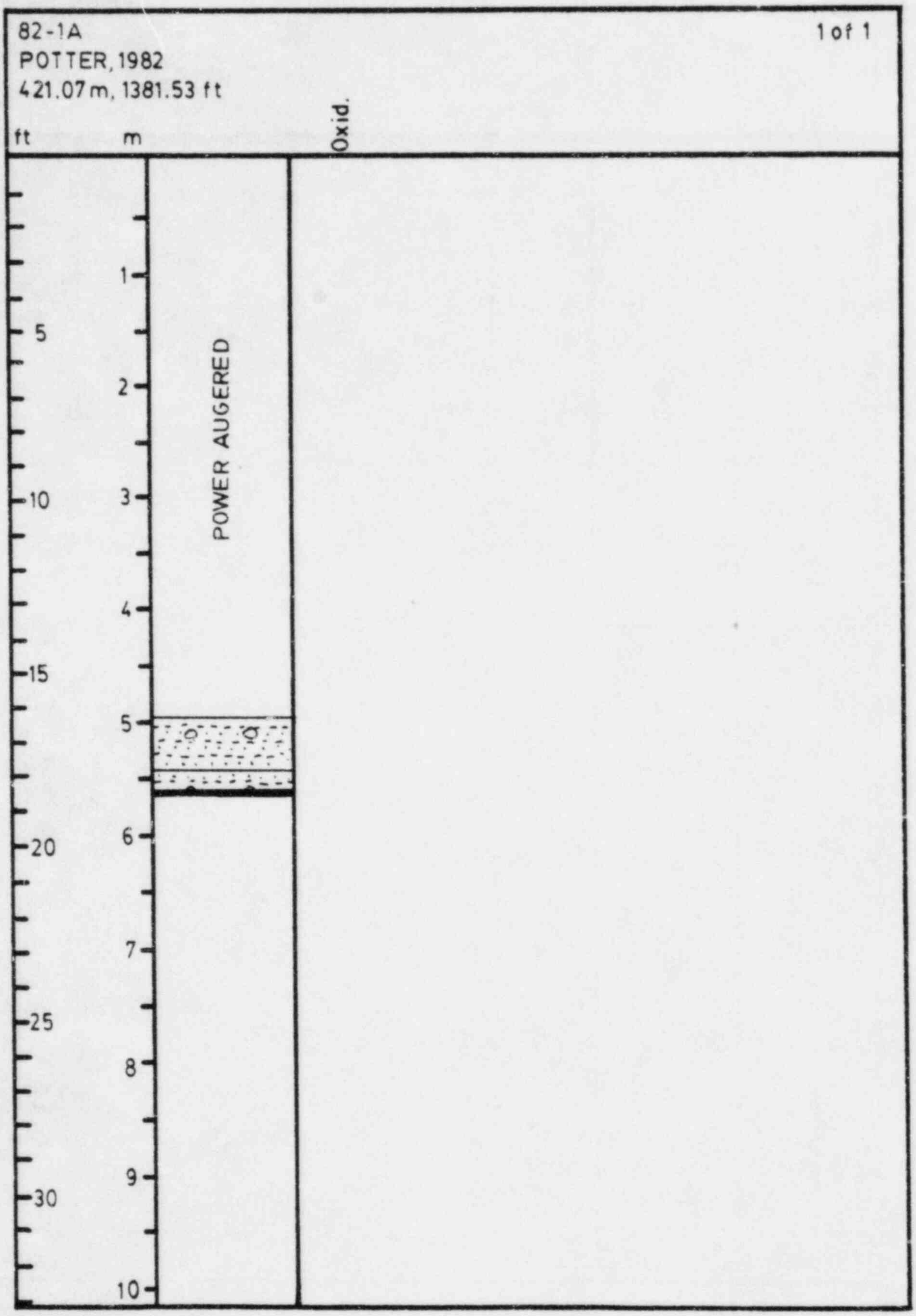
4) gravel/pebbles - open circle

5) angular rock fragments - open triangle

The proportions of these symbols in a given interval reflect the volume proportions of grain sizes present in that sample. A more detailed discussion of the use of symbols is given in Albanese and others (1983), and at the end of Appendix D of this report.

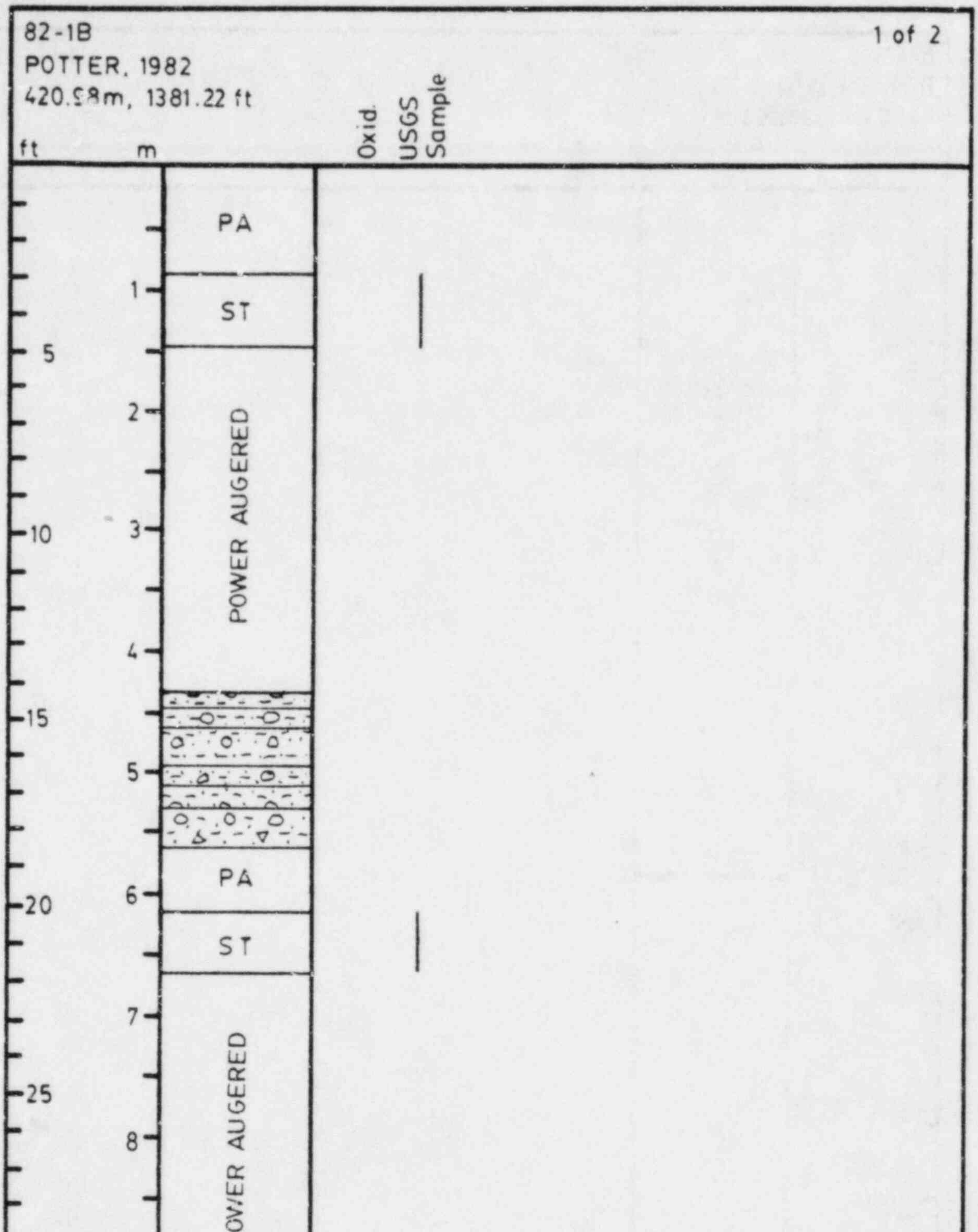
Several of the columns for the 1982 holes show additional information. Oxidized intervals (brown, yellow, or red in color) are shown by line segments to the right of the symbolic column, under the abbreviation "Oxid". Farther to the right, line segments are used to show allocation of samples to Dames and Moore (D&M), USGS, and NYS Department of Health (NYSDOH). On the right half of some pages graphs have been drawn showing variations in tritium content with depth. Samples shown at 2E-7 microcuries permilliliter on the scale above the graph should be read as being less than or equal to that value, which is the detection limit for the methods used by RSL. For comparison, the USEPA maximum allowable tritium content for drinking water is 200E-7 microcuries per milliliter.

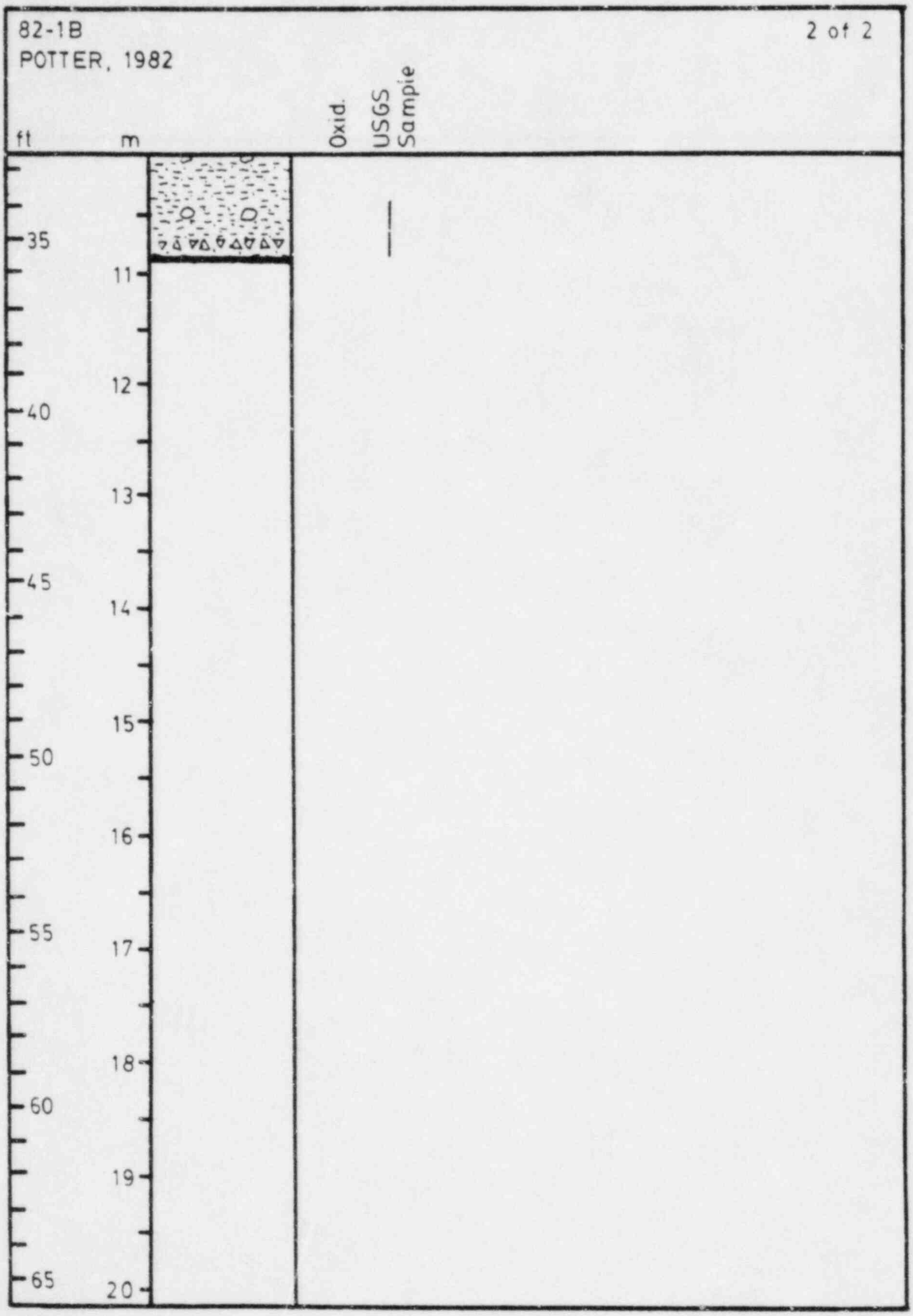
Additional information is also shown on the columns for hole 83-4E. Vertical line segments are used to indicate the type of sample: split-spoon, bit, or bailer. The processes involved in retrieving bit, and especially, bailer samples tend to remove the silt and clay and produce a bias toward sand and pebbles.

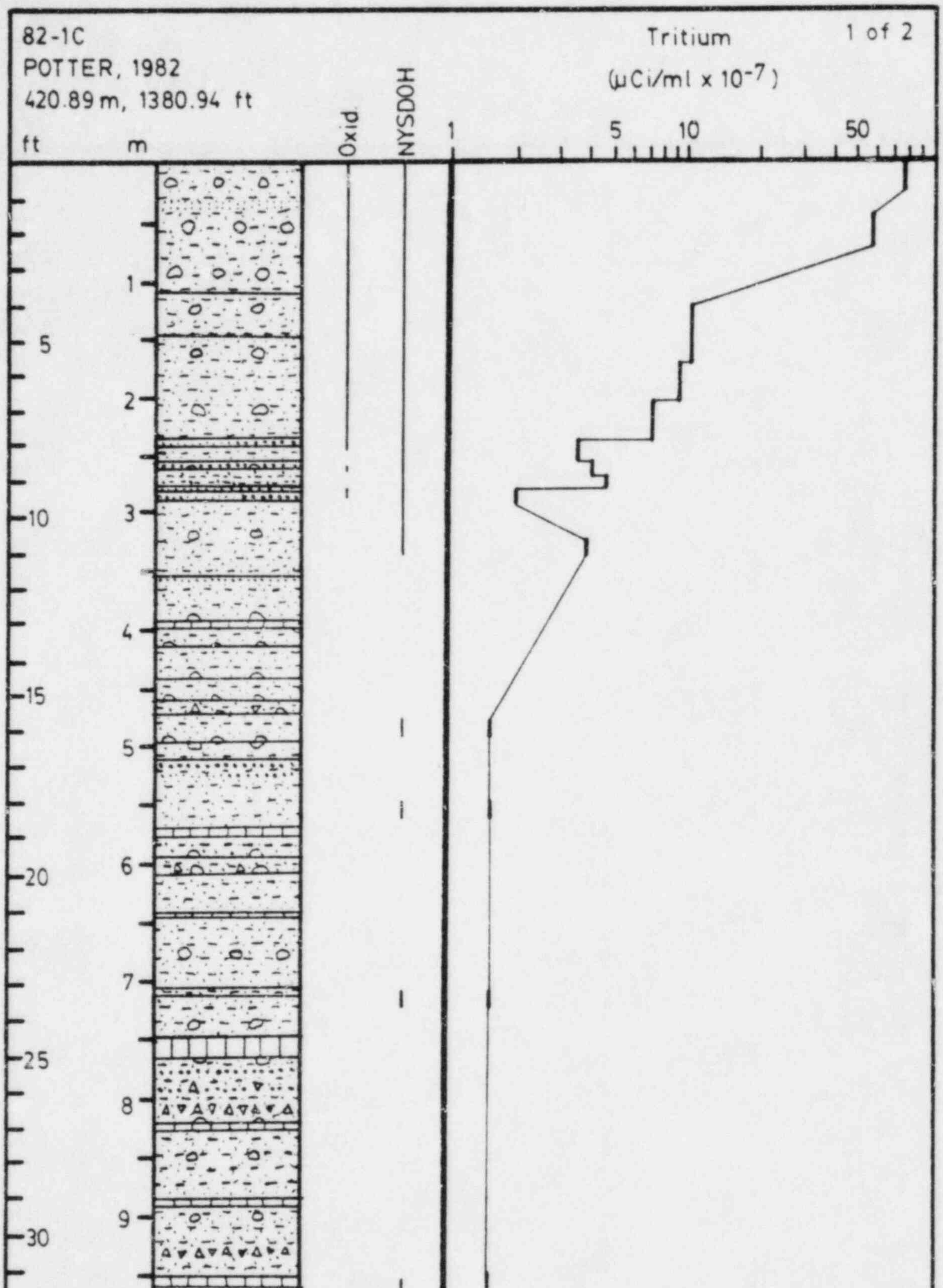


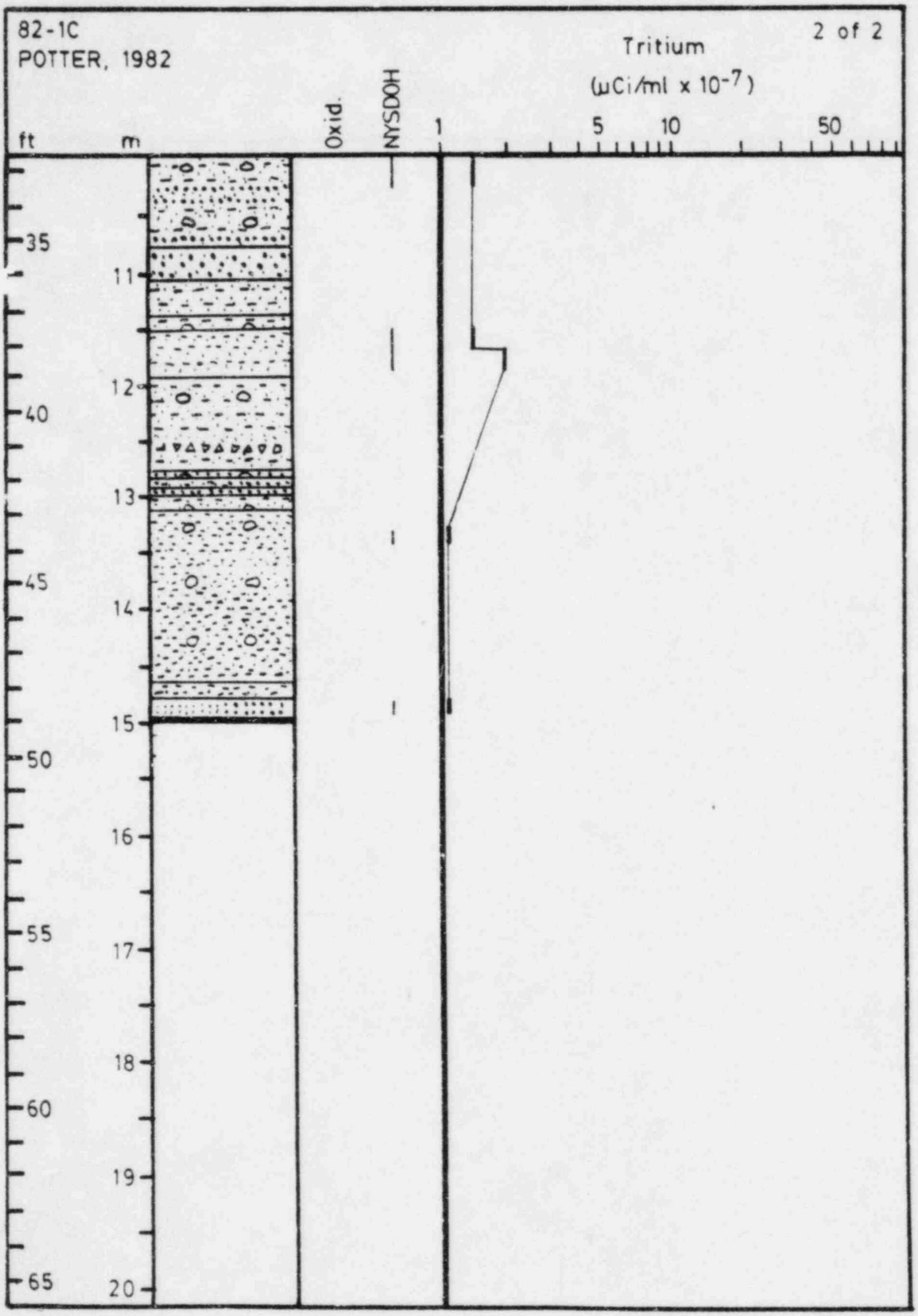
82-1A
POTTER, 1982
421.07 m, 1381.53 ft

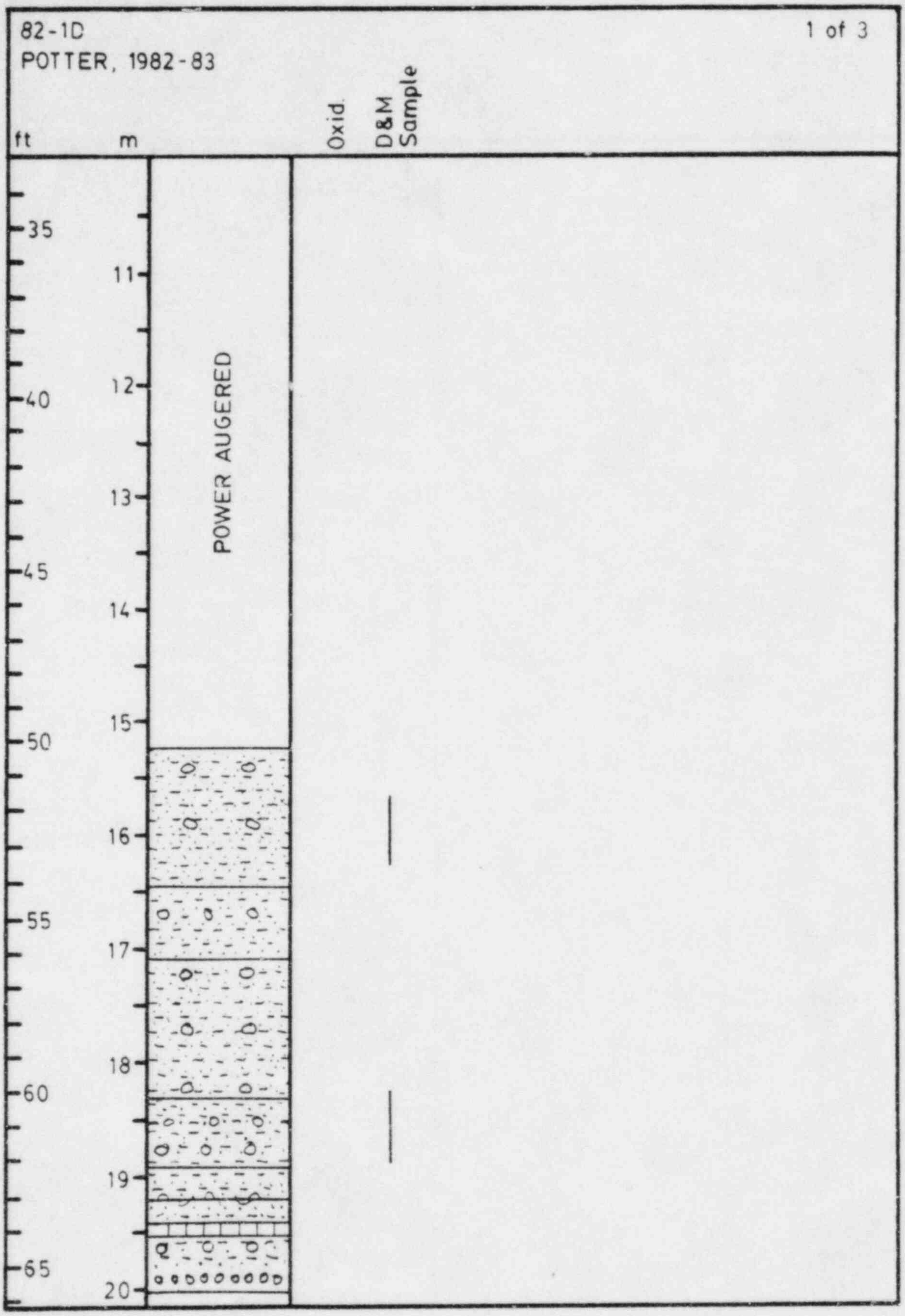
1 of 1

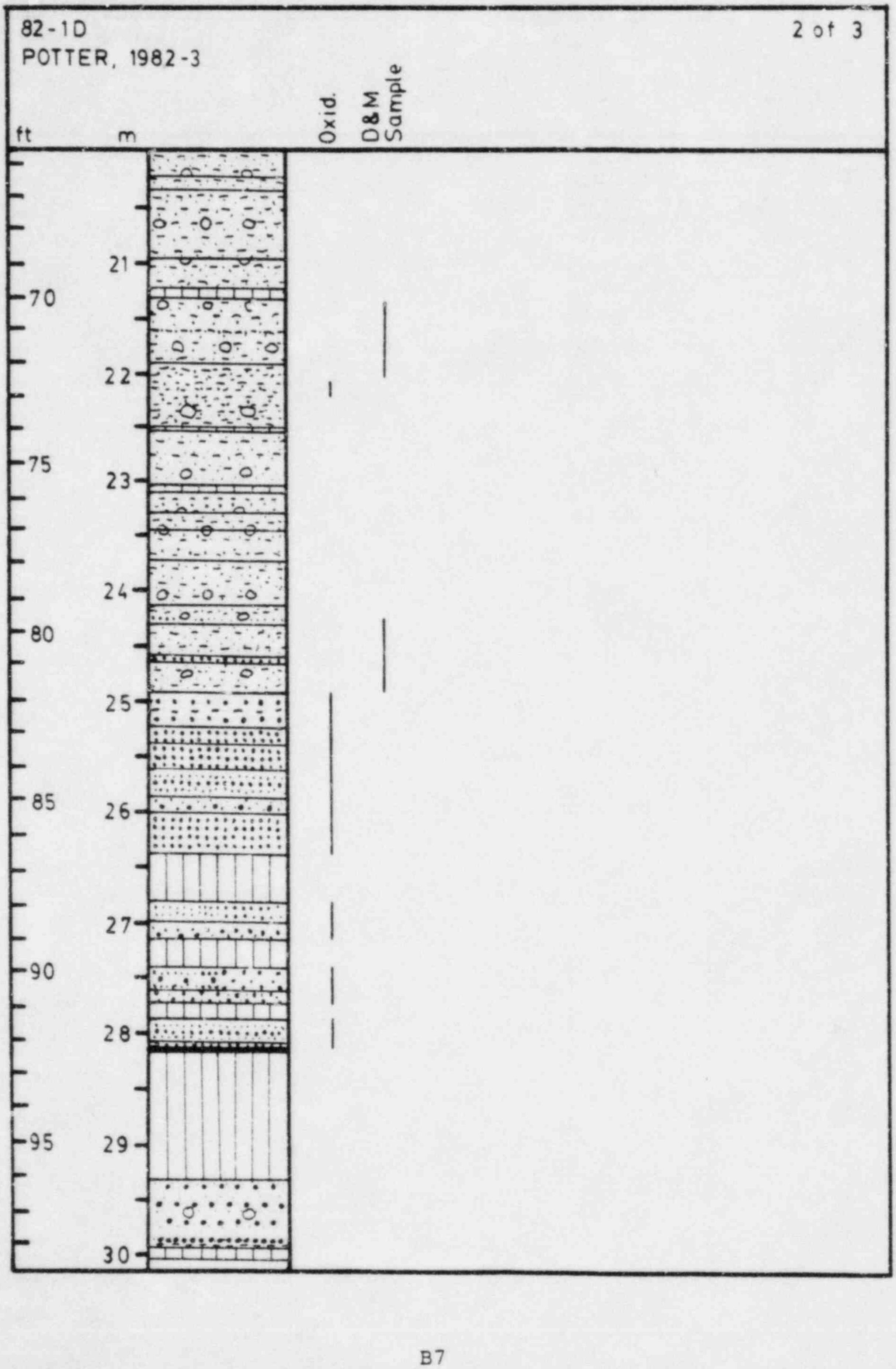

82-1B
POTTER, 1982
420.98m, 1381.22 ft
1 of 2
ft
m
Oxid.
USGS Sample
PA
ST
POWER AUGERED
PA
ST
POWER AUGERED
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10


82-1B
POTTER, 1982
2 of 2
ft
m
Oxid.
USGS Sample
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20


82-1C
POTTER, 1982
420.89 m, 1380.94 ft
Tritium
1 of 2
(µCi/ml x 10-7)
Oxid.
NYSDOH
1
5
10
50
ft
m
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

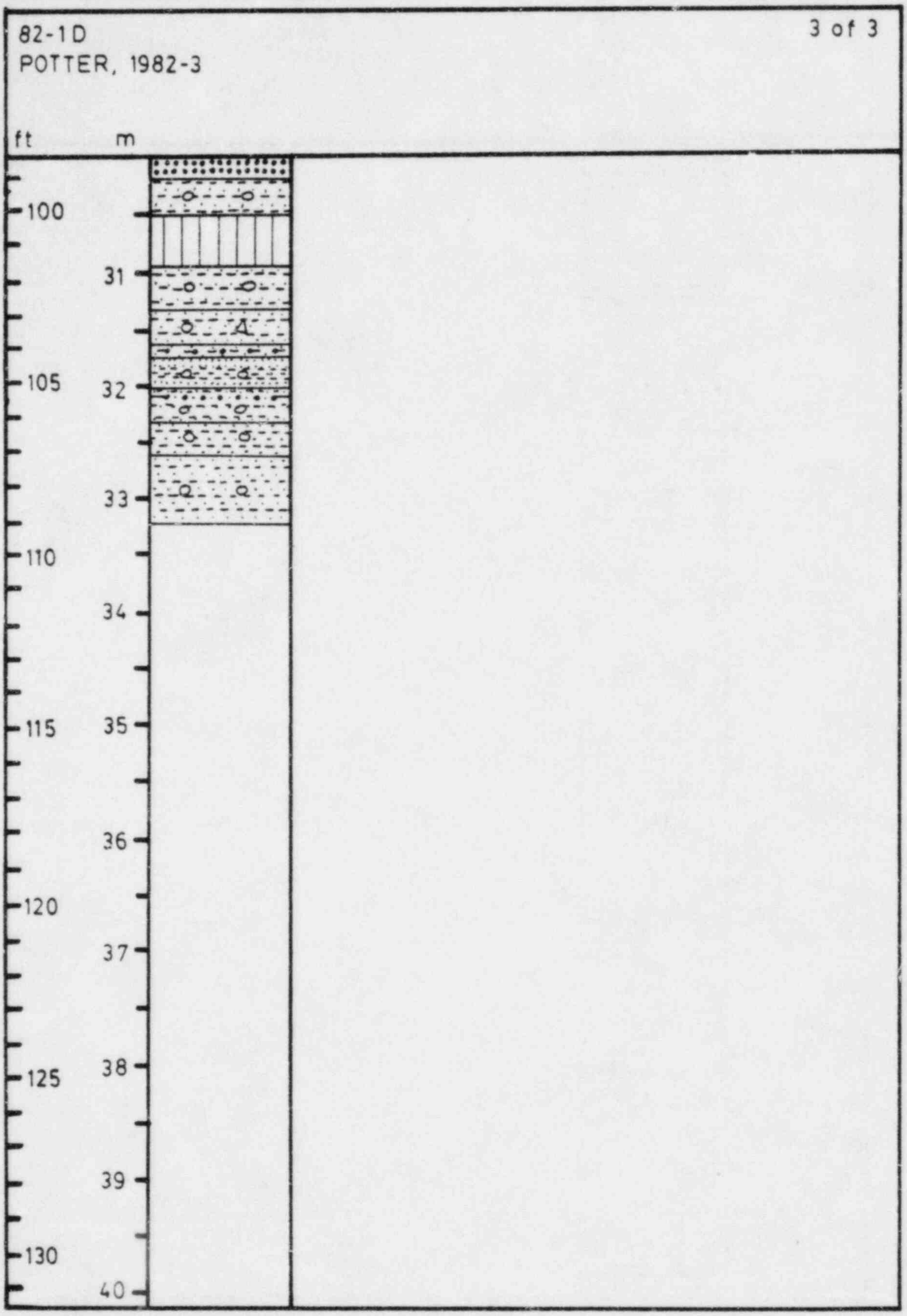

82-1C
POTTER, 1982
2 of 2
Tritium
(µCi/ml x 10⁻⁷)
ft
m
Oxid.
NYSDOH
1
5
10
50
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

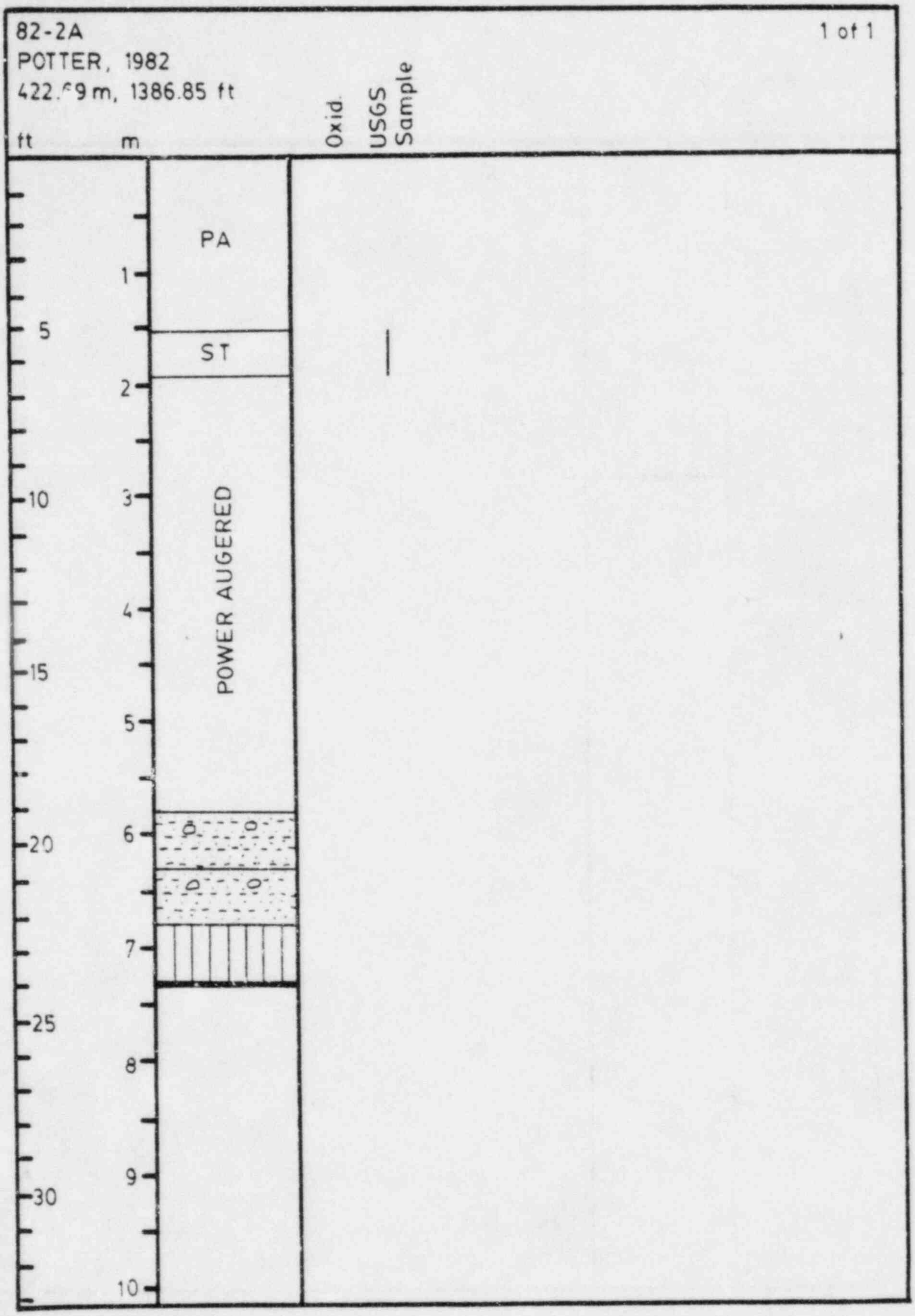

82-1D
POTTER, 1982-83
1 of 3
ft
m
Oxid.
D&M Sample
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20
POWER AUGERED


82-1D
POTTER, 1982-3
2 of 3
ft
m
Oxid.
D&M Sample
70
75
80
85
90
95
21
22
23
24
25
26
27
28
29
30

82-1D
POTTER, 1982-3

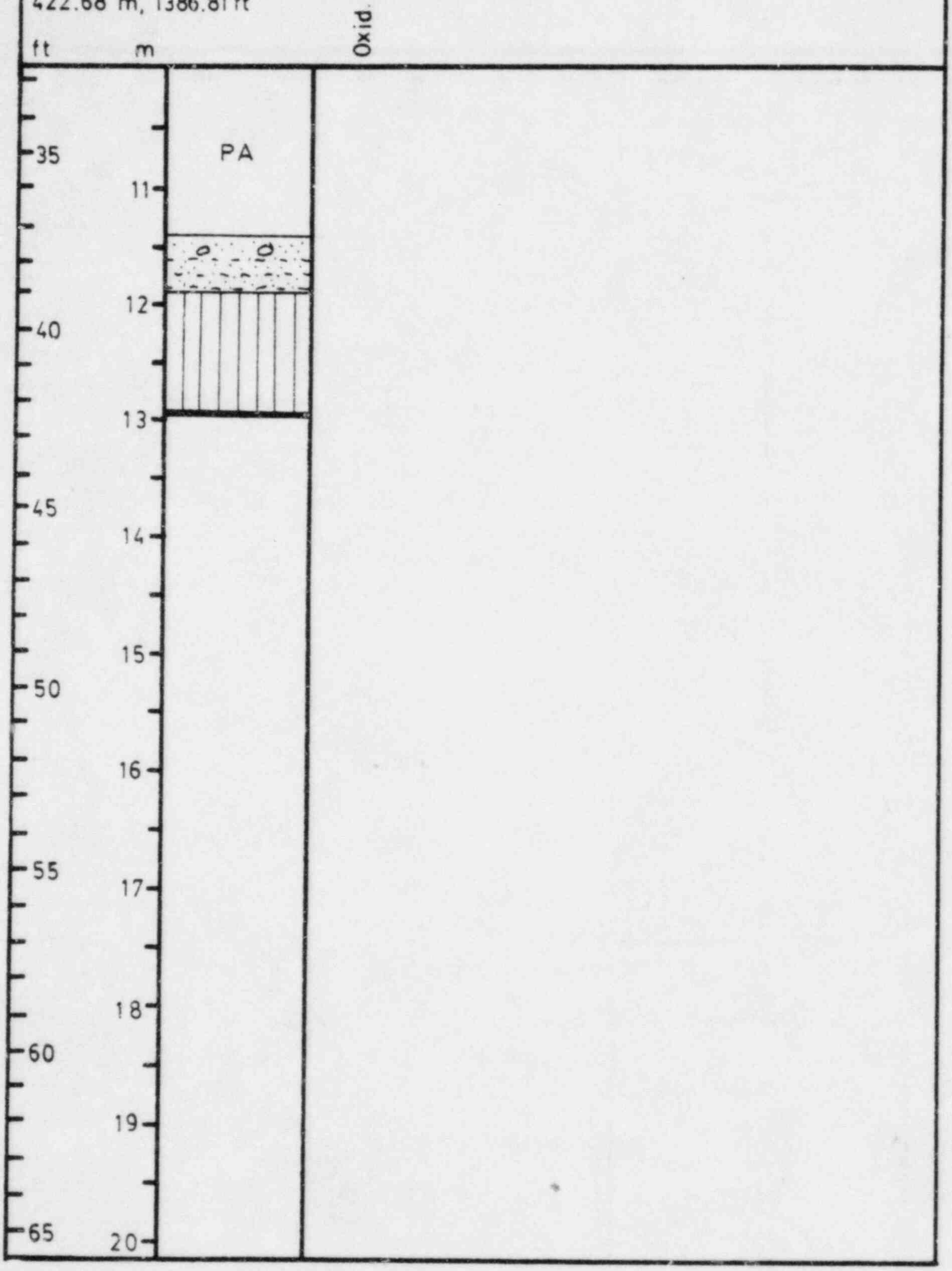
3 of 3

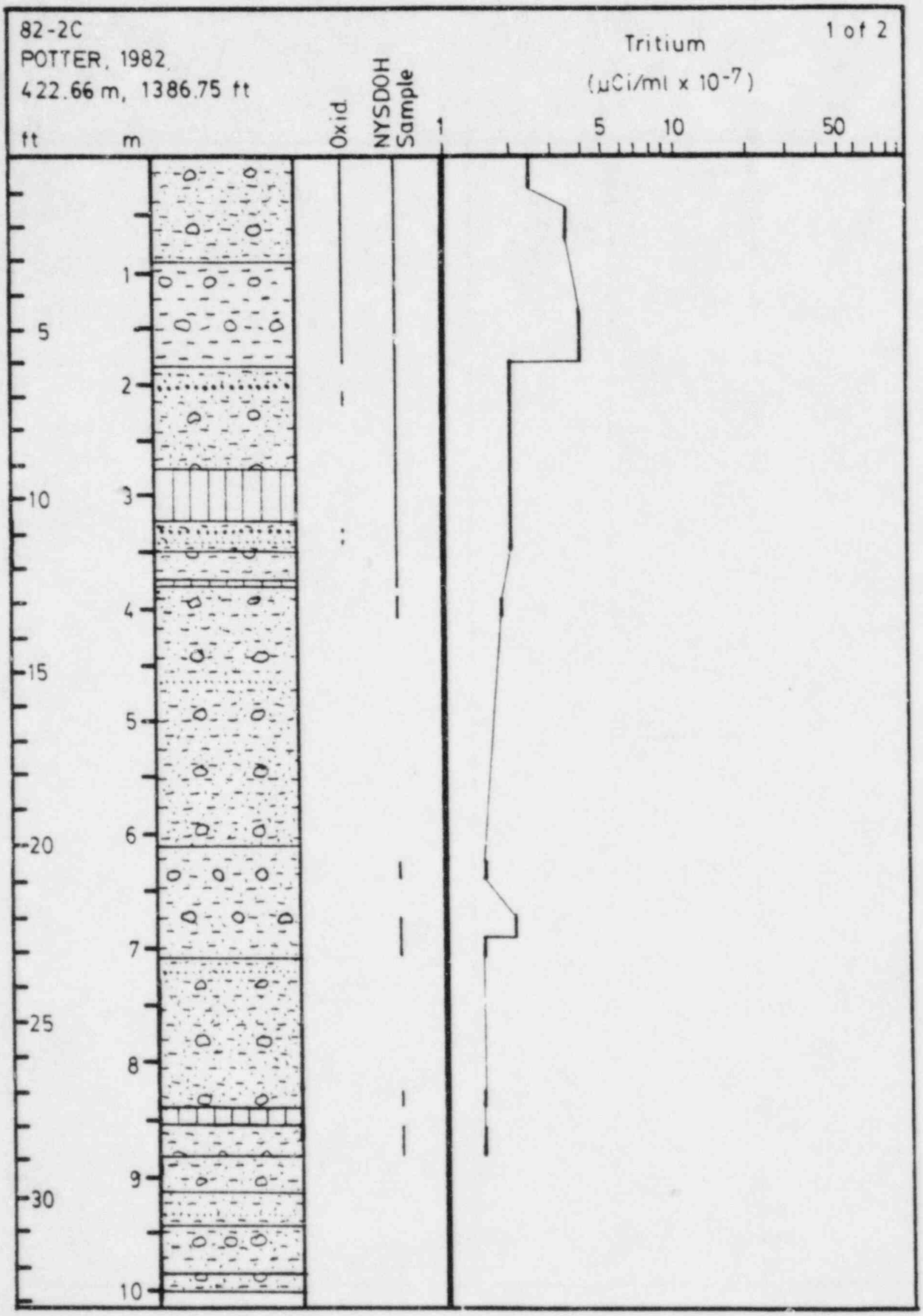


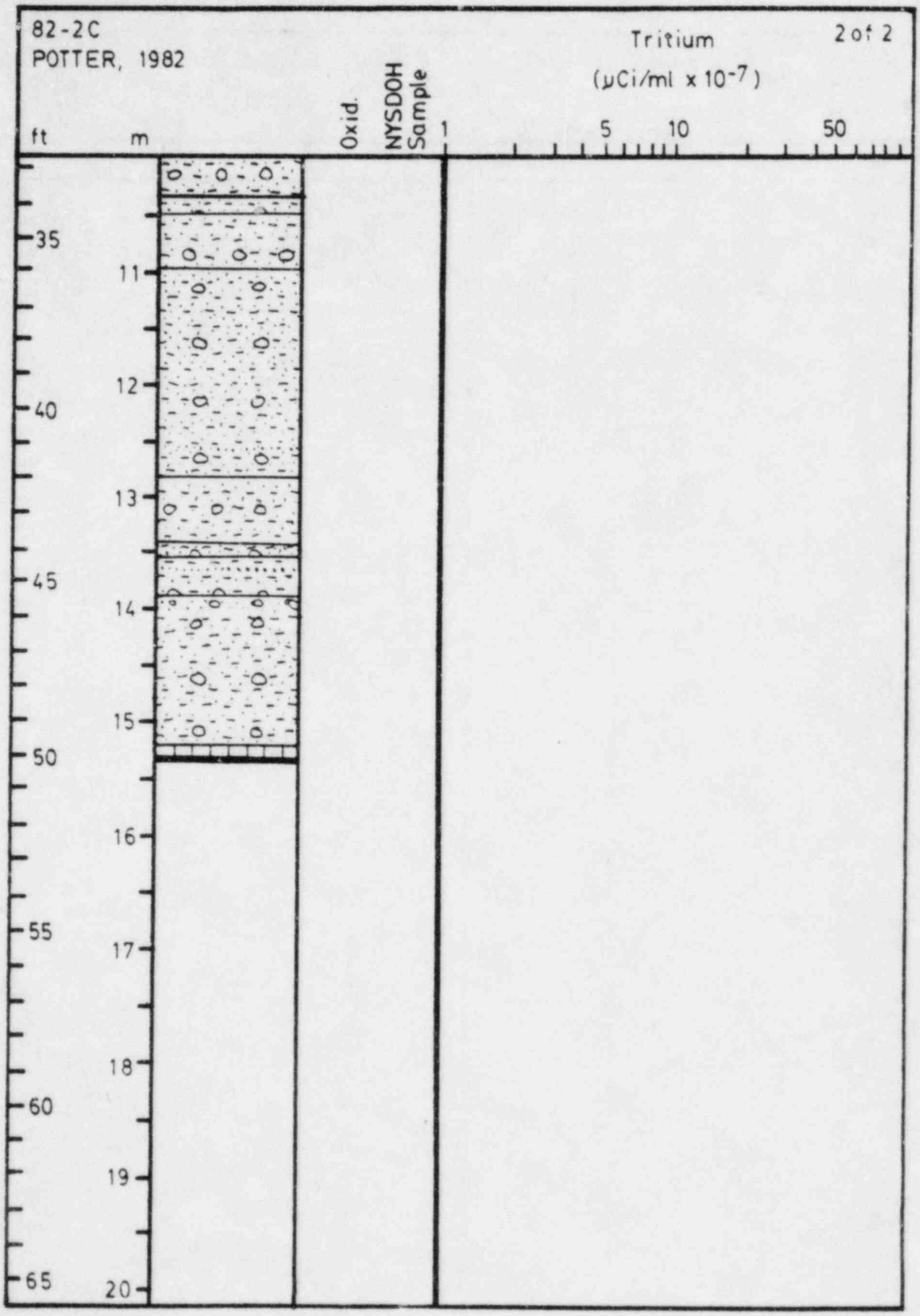

82-2A
POTTER, 1982
422.69 m, 1386.85 ft
1 of 1
ft
m
Oxid.
USGS Sample
PA
ST
POWER AUGERED
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

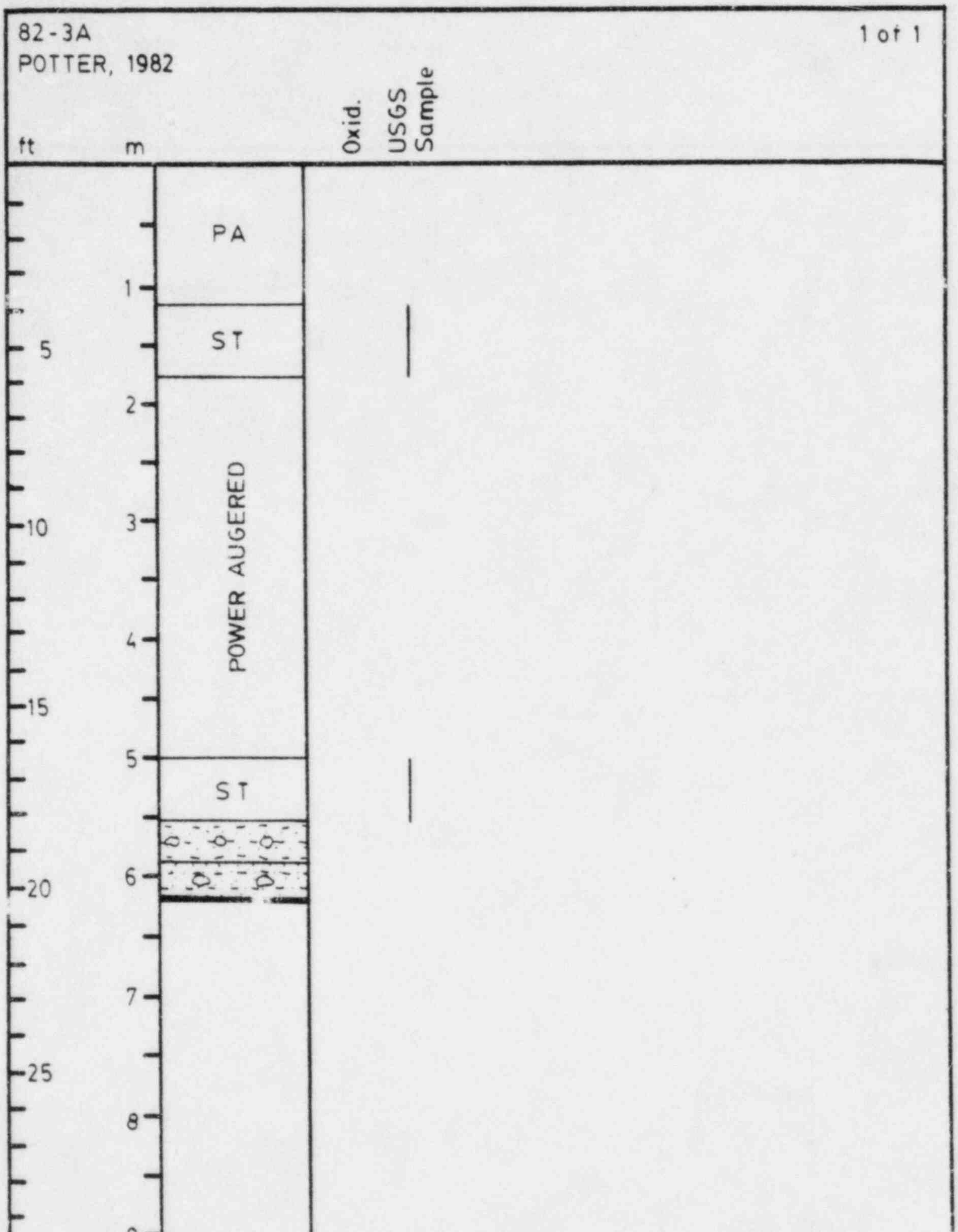
82-2B
POTTER, 1982
422.68 m, 1386.81 ft

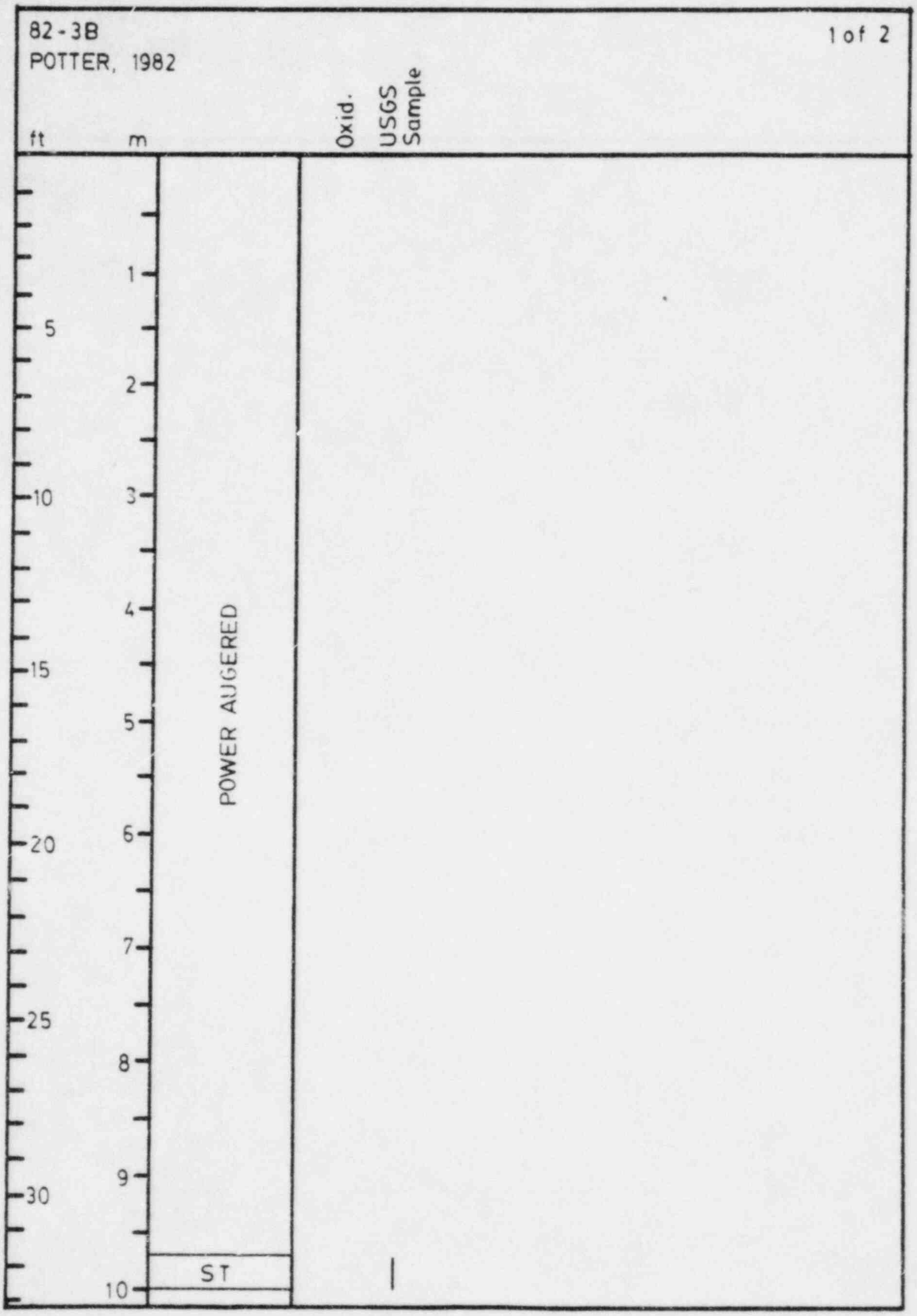
1 of 1




82-2C
POTTER, 1982
422.66 m, 1386.75 ft
1 of 2
Tritium
(µCi/ml x 10-7)
ft
m
Oxid.
NYSDOH Sample
1
5
10
50
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10


82-2C
POTTER, 1982
Tritium
2 of 2
(μCi/ml x 10-7)
ft
m
Oxid.
NYSDOH Sample
1
5
10
50
35
11
12
40
13
45
14
15
50
16
55
17
18
60
19
65
20

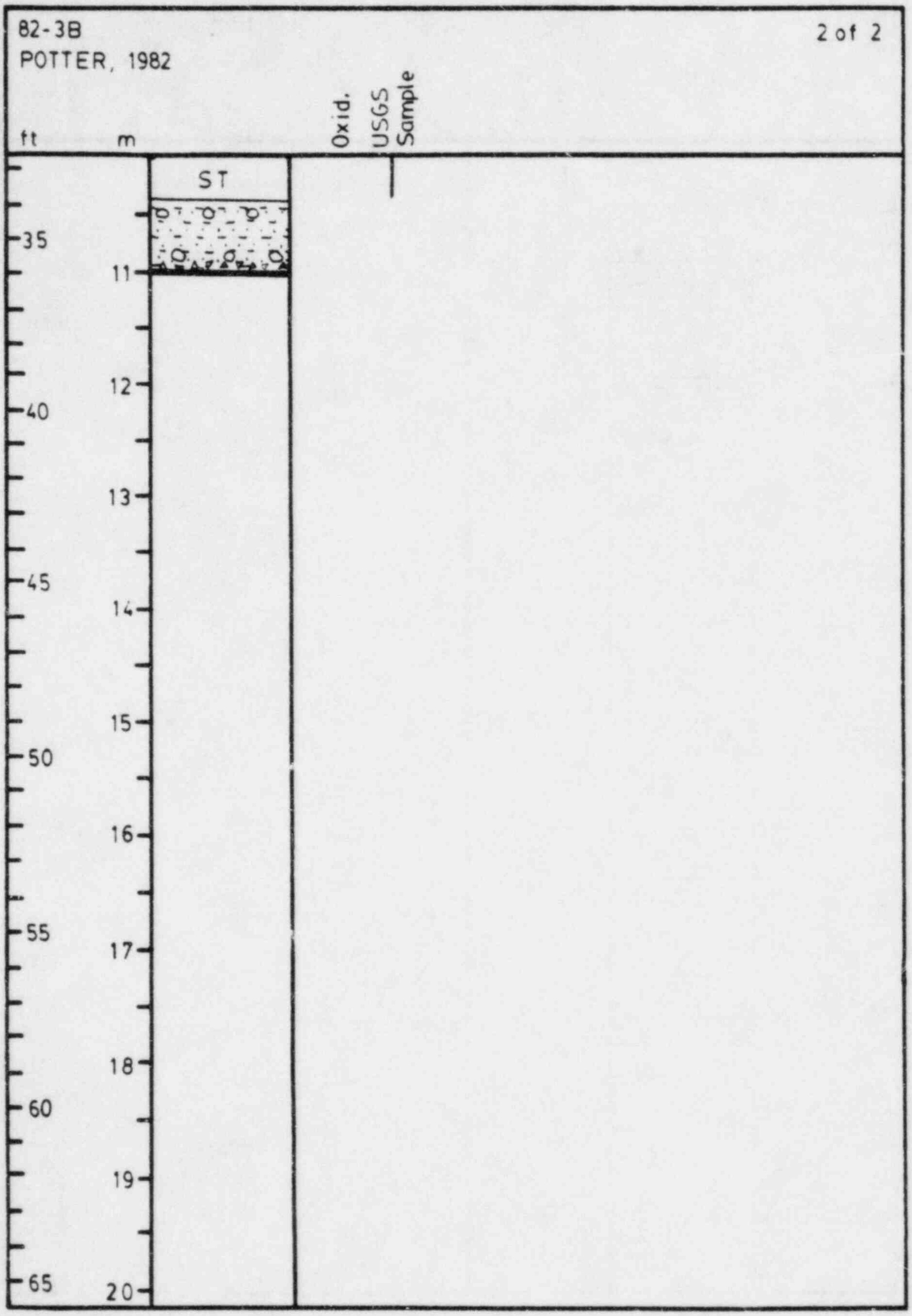

82-3A
POTTER, 1982
1 of 1
ft
m
Oxid.
USGS Sample
PA
ST
POWER AUGERED
ST
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

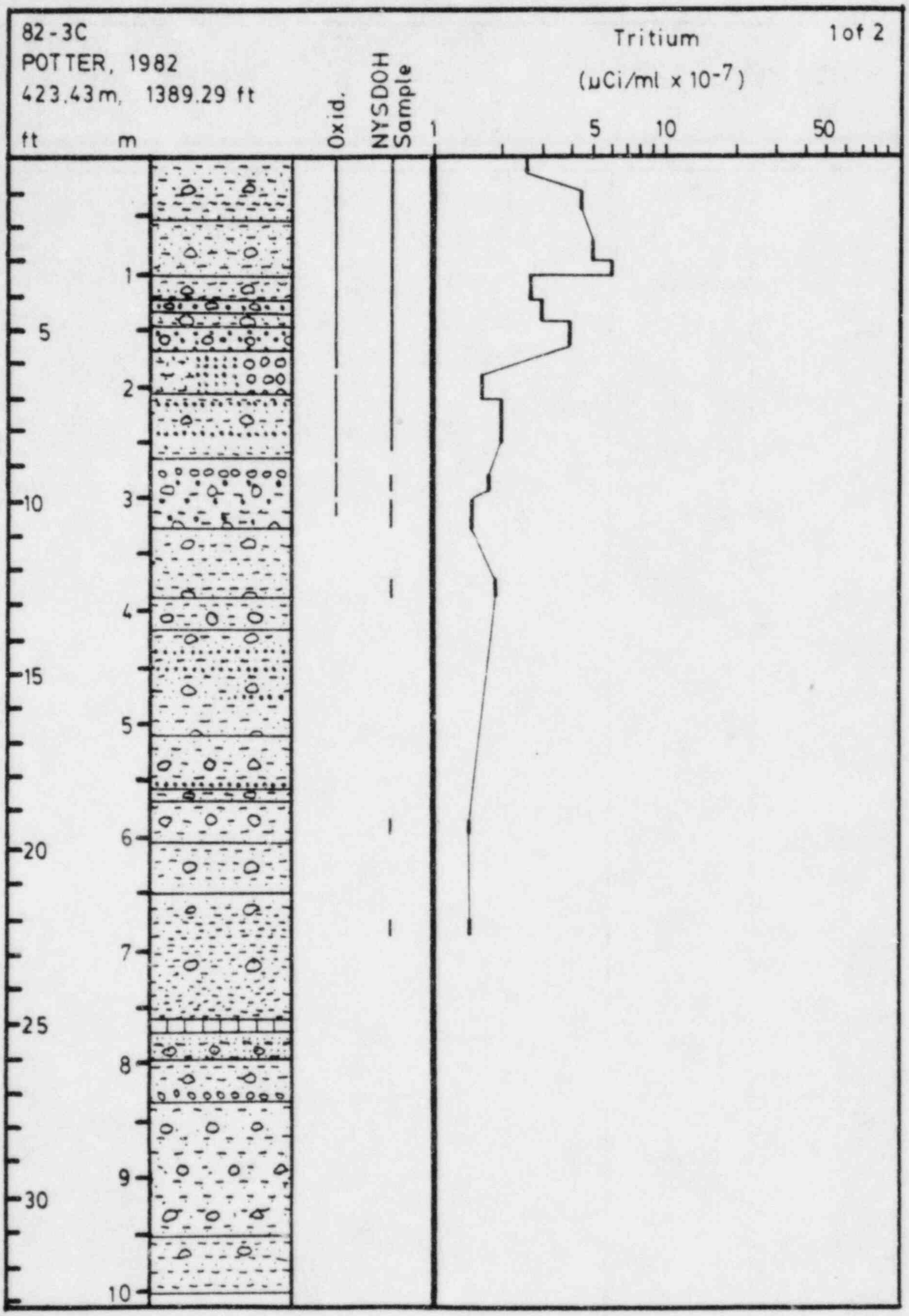


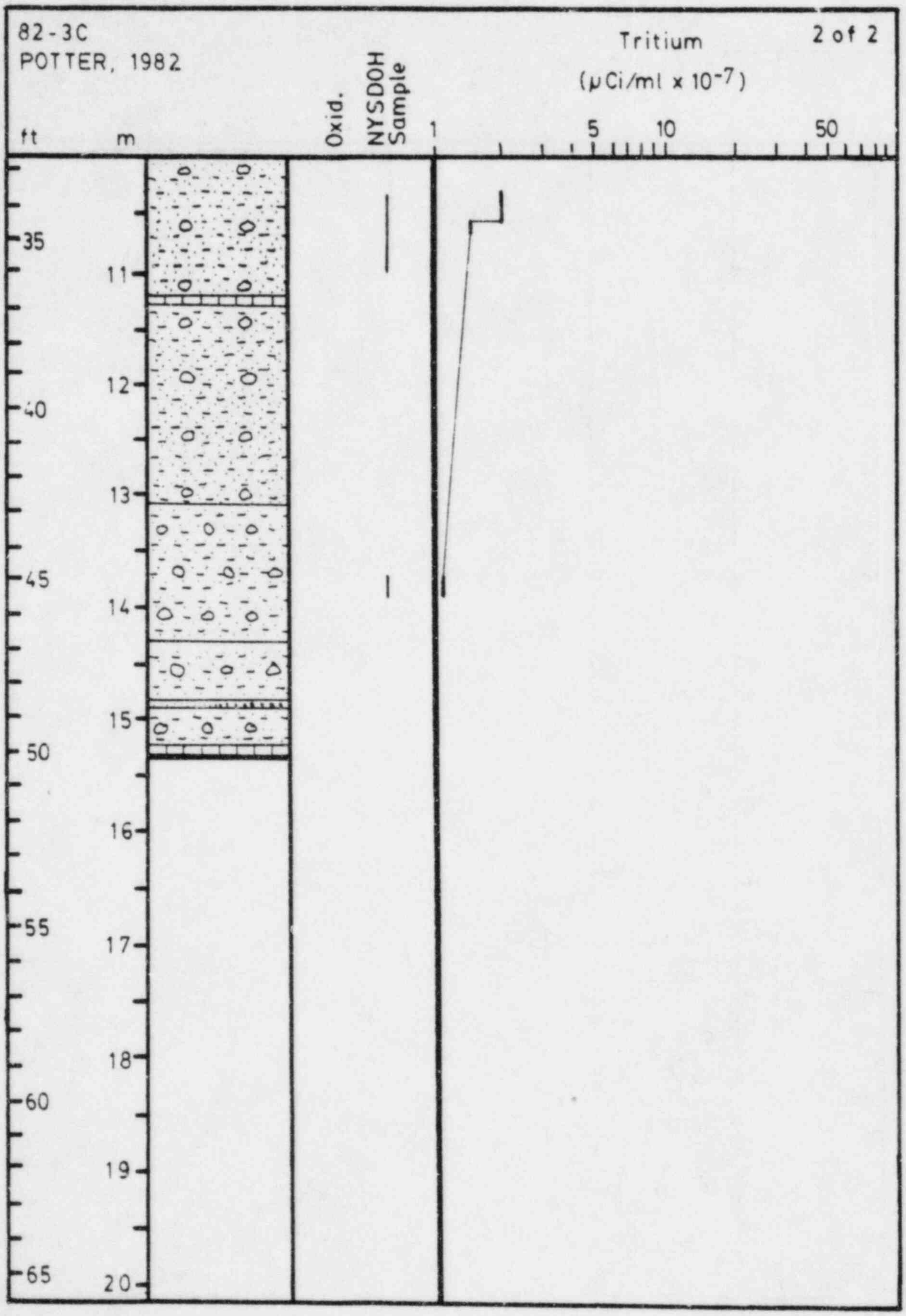
82-3B

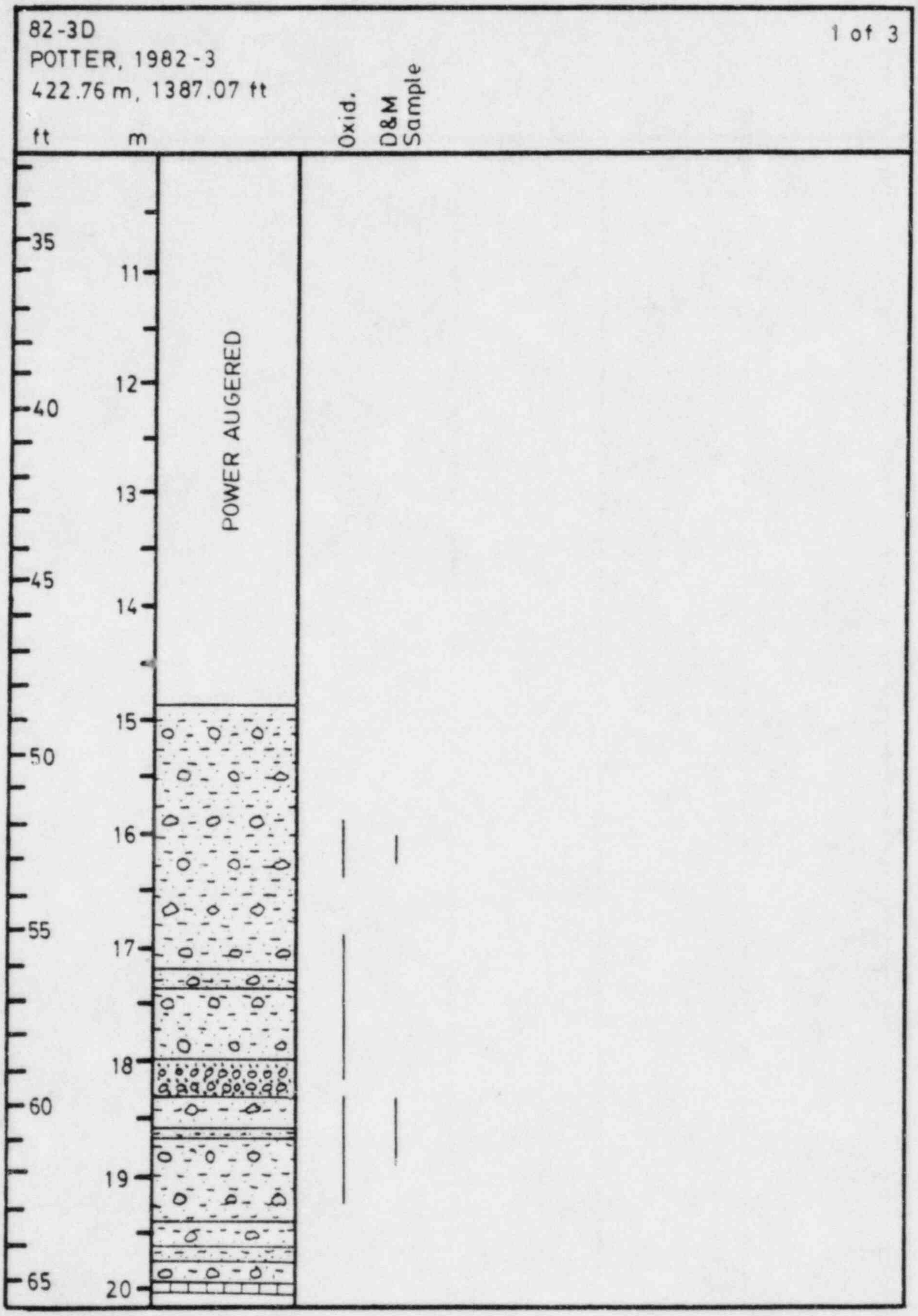
POTTER, 1982

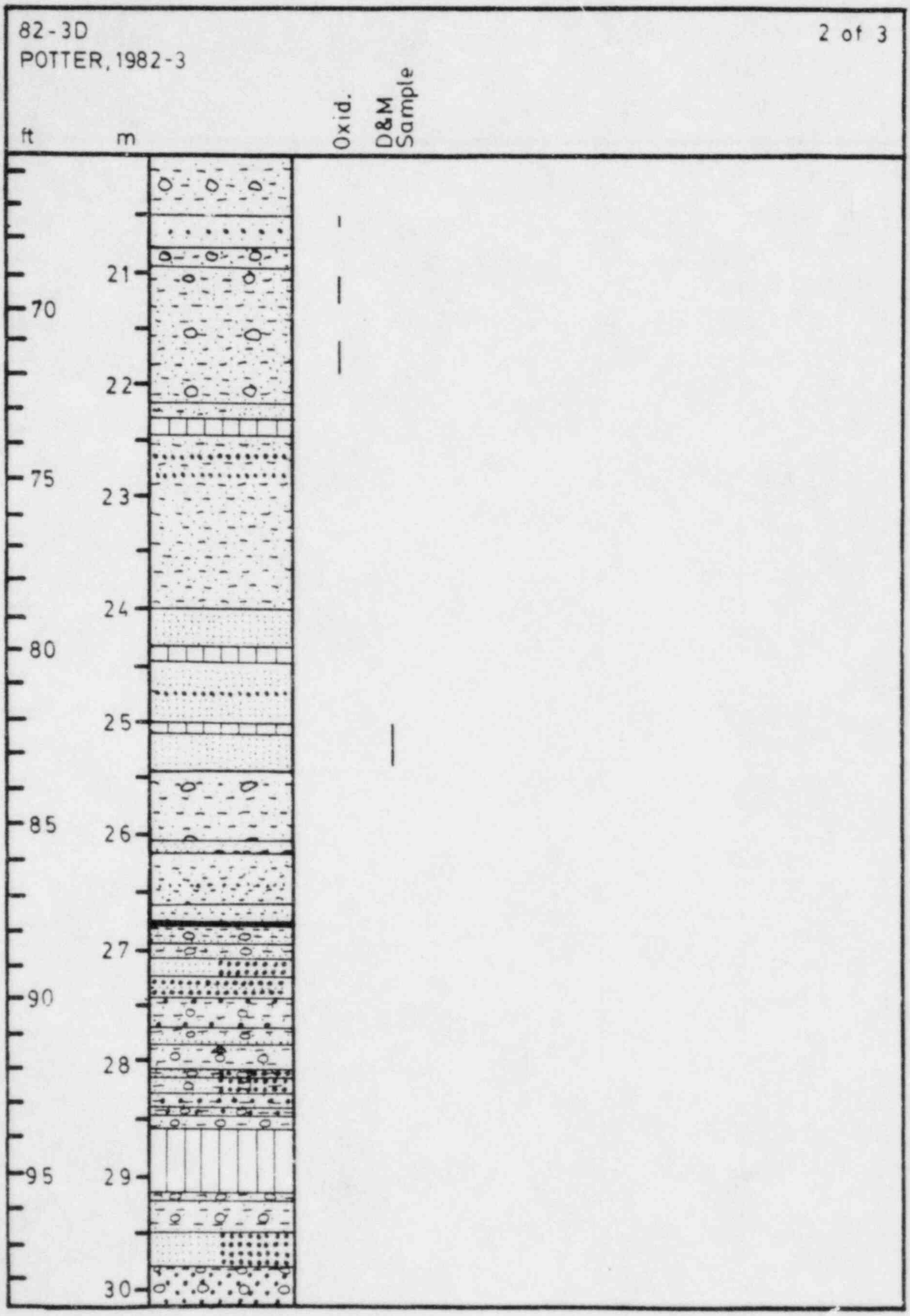
1 of 2


82-3B
POTTER, 1982
2 of 2
Oxid.
USGS Sample
ft
m
ST
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20


82-3C
POTTER, 1982
423.43m, 1389.29 ft
1 of 2
Tritium
(µCi/ml x 10-7)
ft
m
Oxid.
NYSDOH Sample
1
5
10
50
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

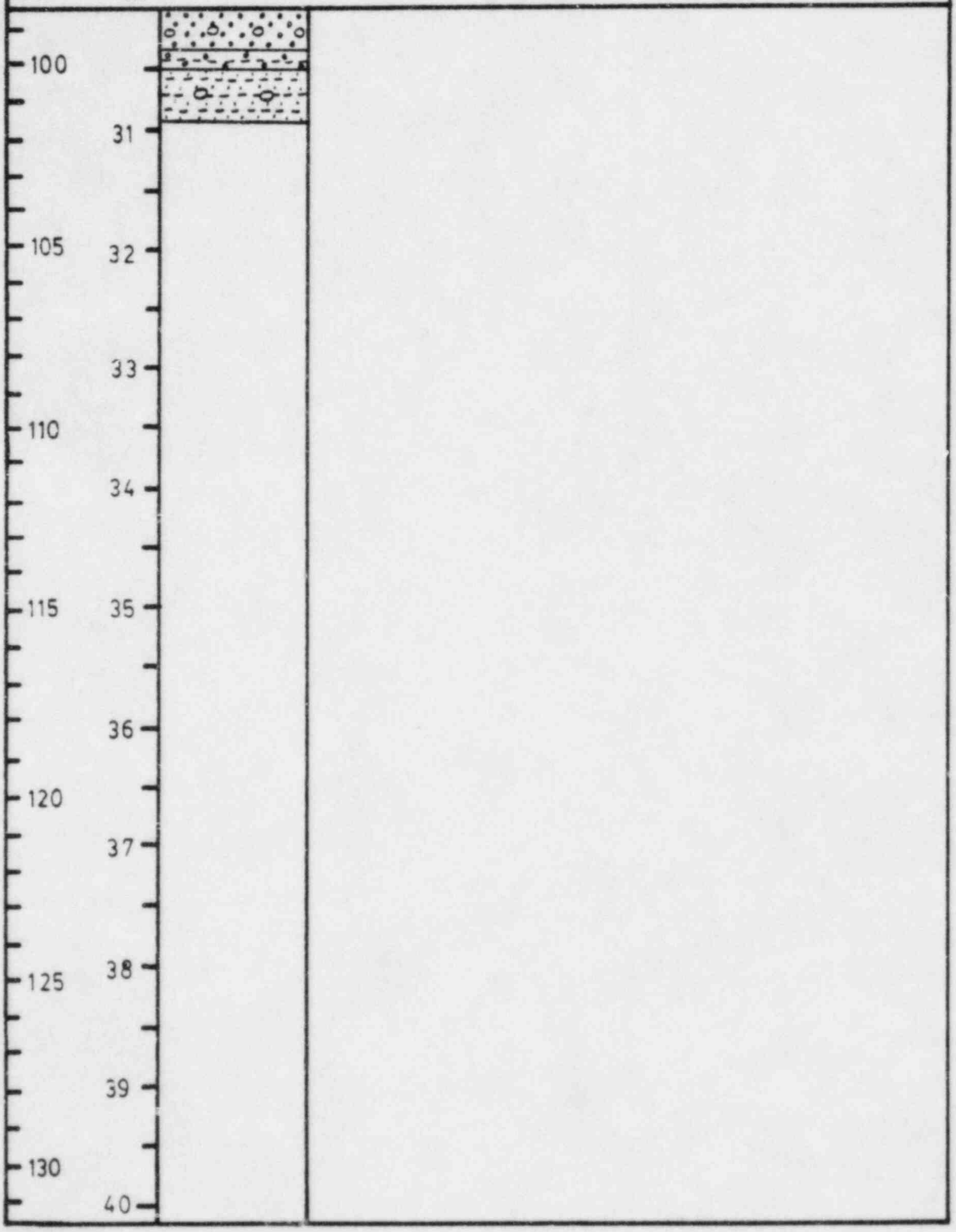

82-3C
POTTER, 1982
2 of 2
Tritium
(µCi/ml x 10-7)
Oxid.
NYSDOH Sample
ft
m
1
5
10
50
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

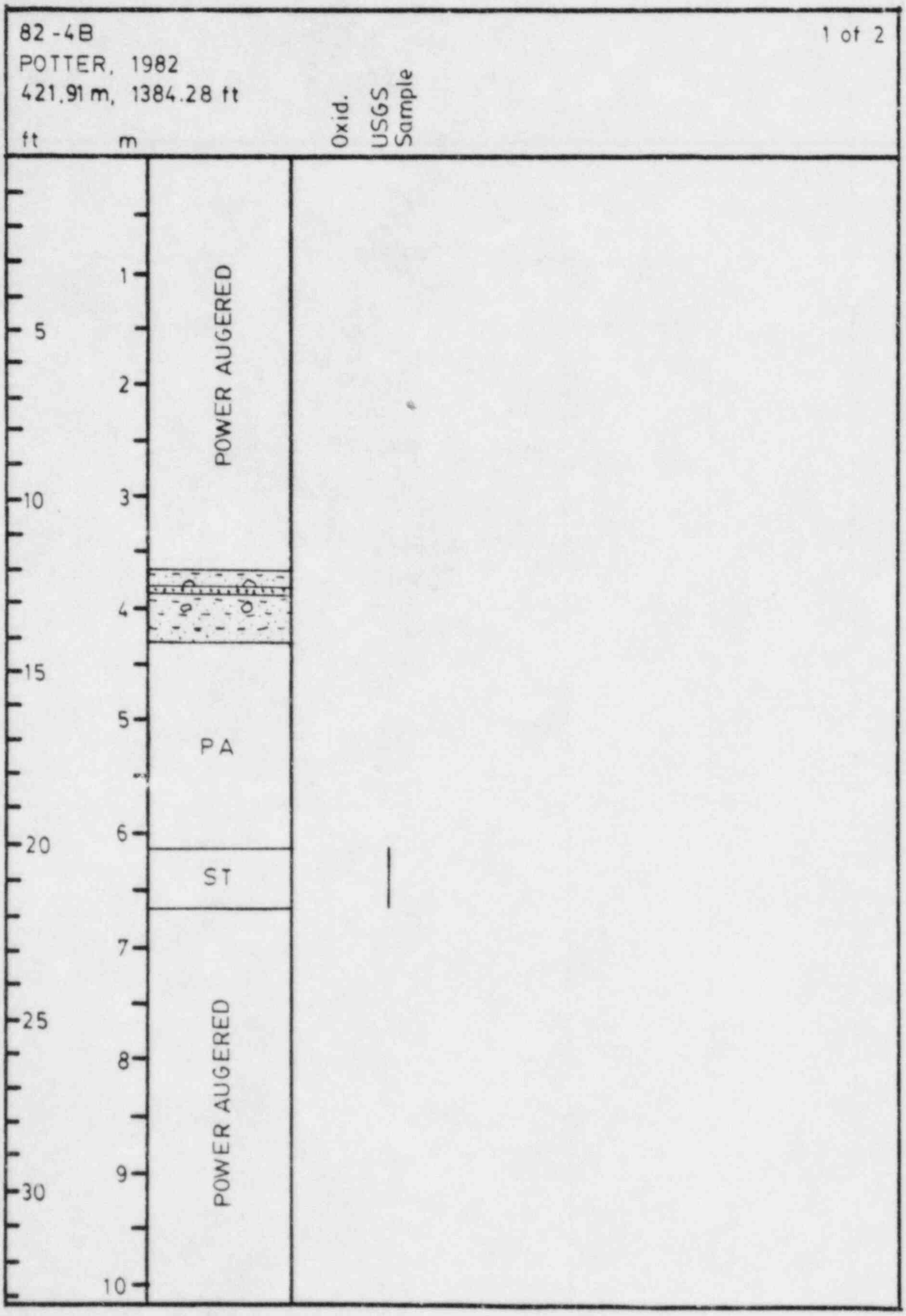

82-3D
POTTER, 1982-3
422.76 m, 1387.07 ft
1 of 3
ft
m
Oxid.
D&M Sample
POWER AUGERED
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

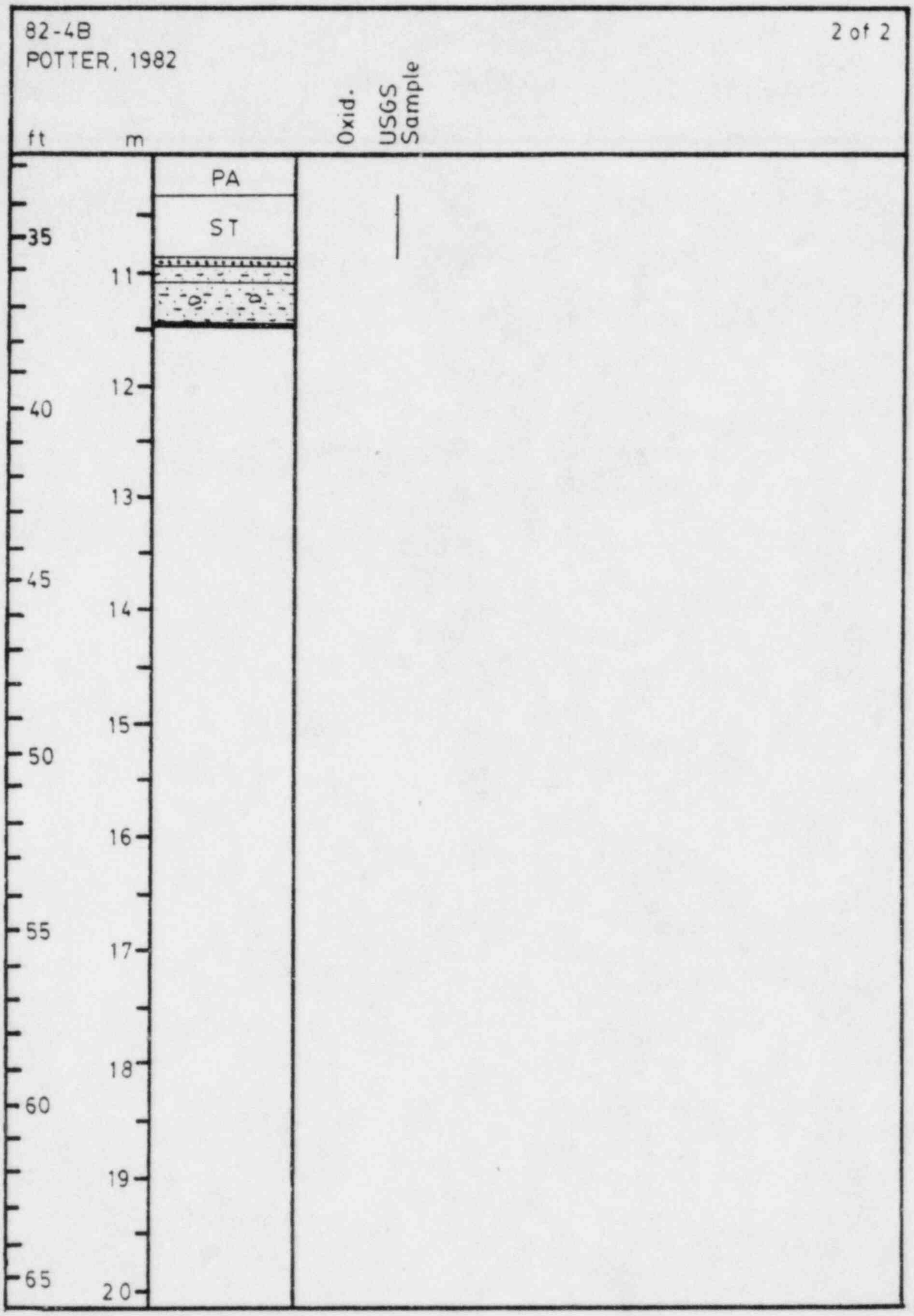

82-3D
POTTER, 1982-3
2 of 3
ft
m
Oxid.
D&M Sample
70
75
80
85
90
95
21
22
23
24
25
26
27
28
29
30

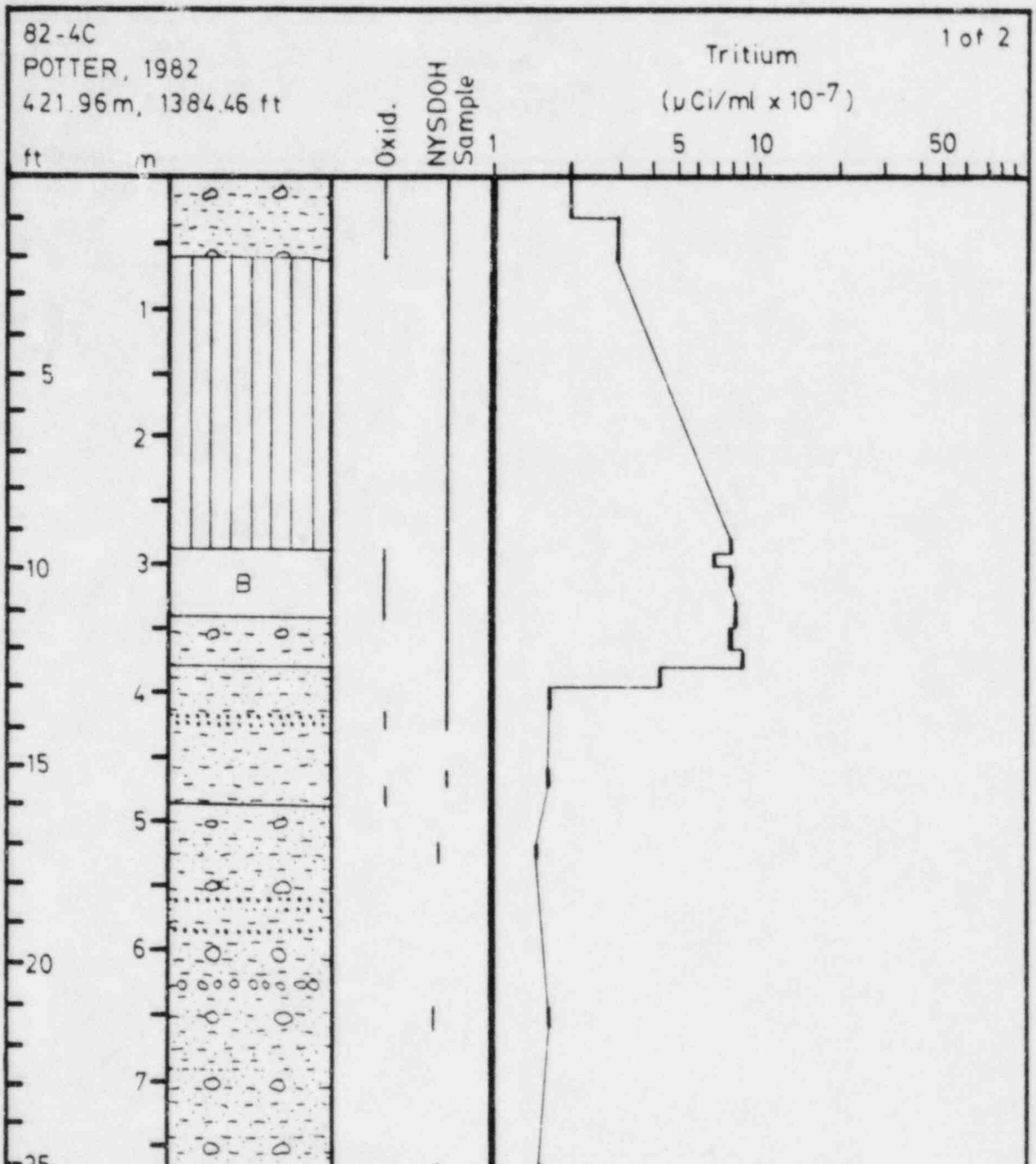
82-3D
POTTER, 1982-3

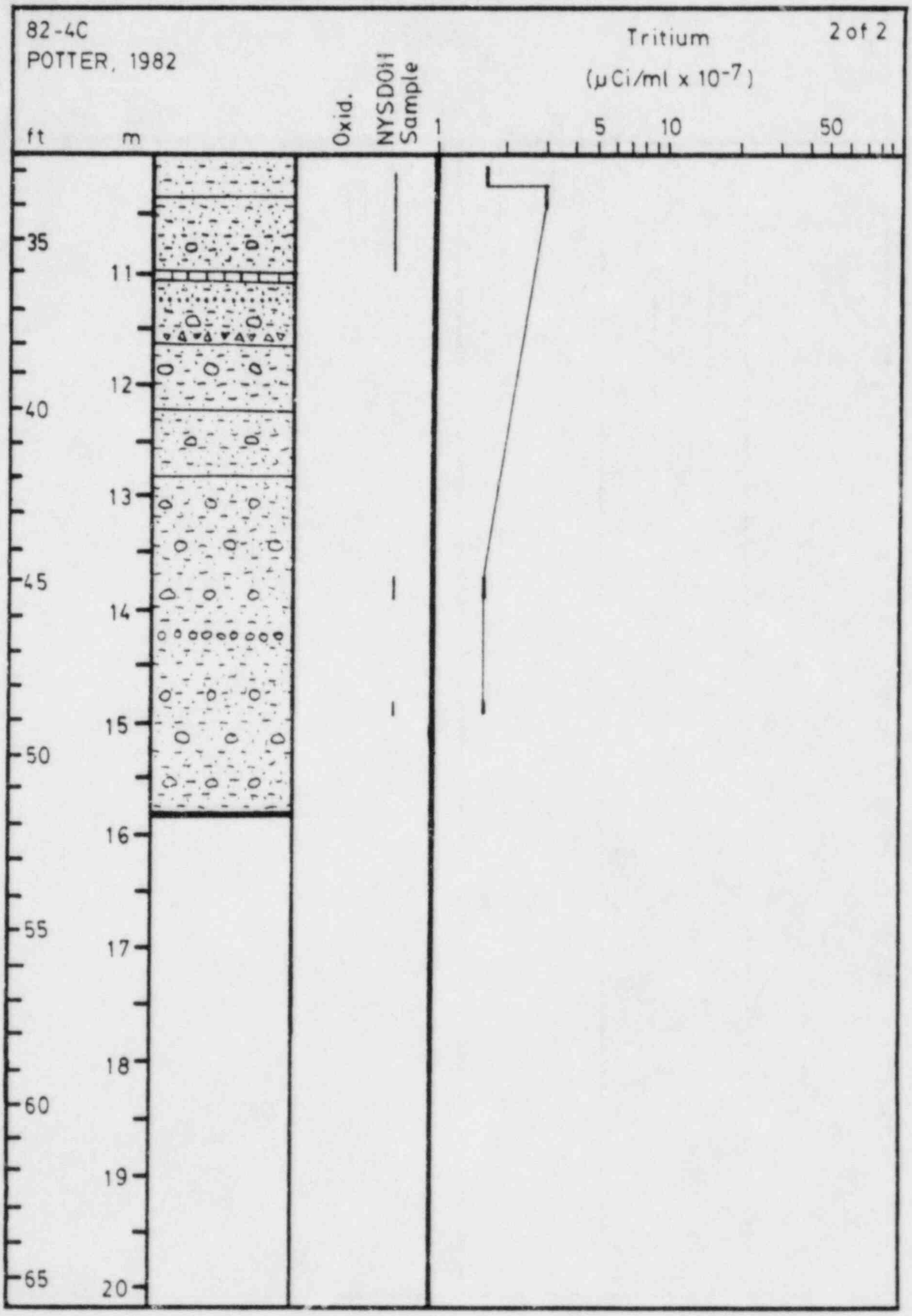
3 of 3




82-4B
POTTER, 1982
421.91 m, 1384.28 ft
1 of 2
ft
m
Oxid.
USGS Sample
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
POWER AUGERED
PA
ST
POWER AUGERED

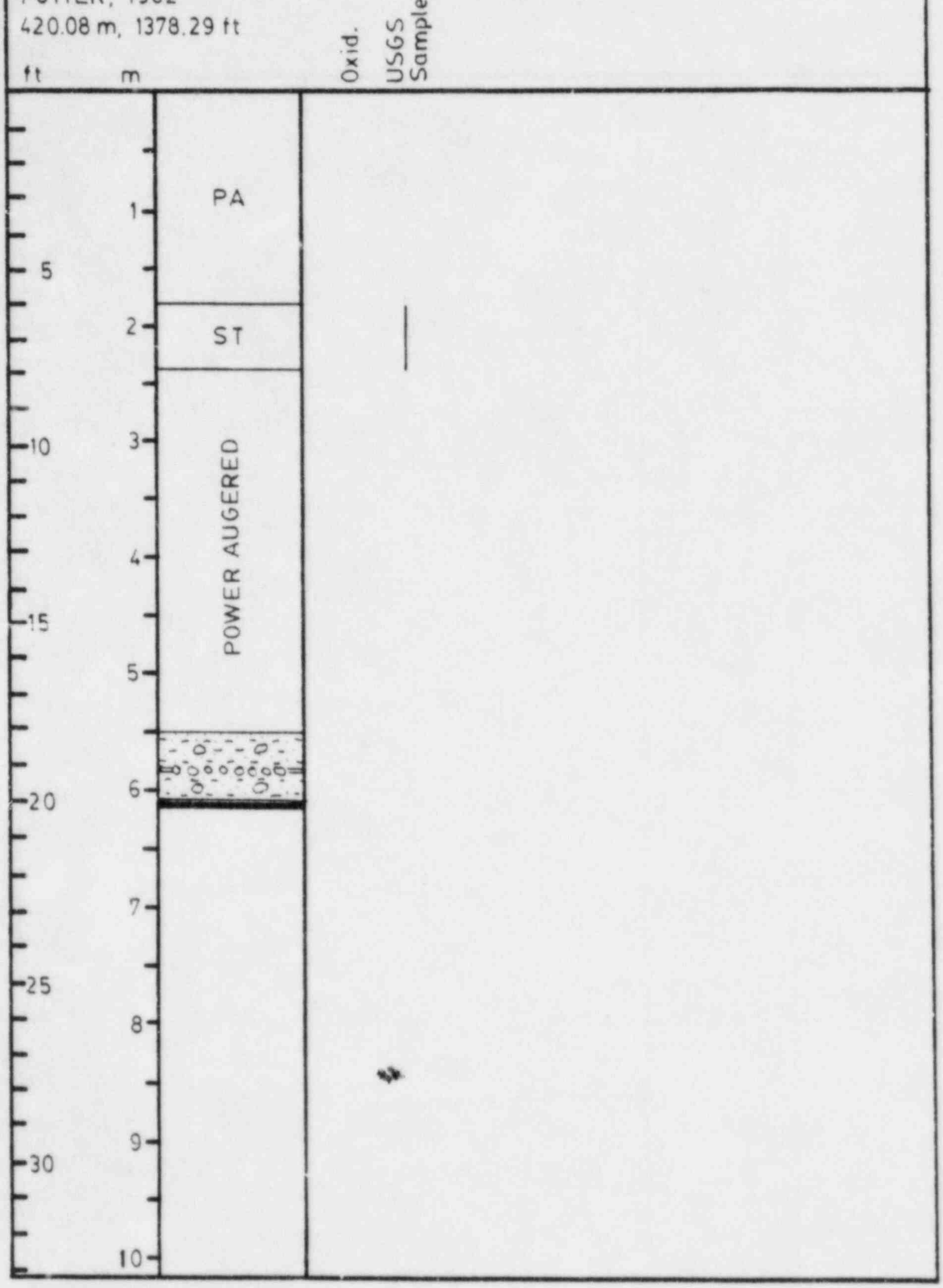

82-4B
POTTER, 1982
2 of 2
ft
m
Oxid.
USGS Sample
PA
ST
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20


82-4C
POTTER, 1982
421.96m, 1384.46 ft
1 of 2
Tritium
(μCi/ml x 10⁻⁷)
Oxid.
NYSDOH Sample
ft
m
1
5
10
50
B
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10


82-4C
POTTER, 1982
2 of 2
Tritium
(µCi/ml x 10-7)
ft
m
Oxid.
NYSDOH Sample
1
5
10
50
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

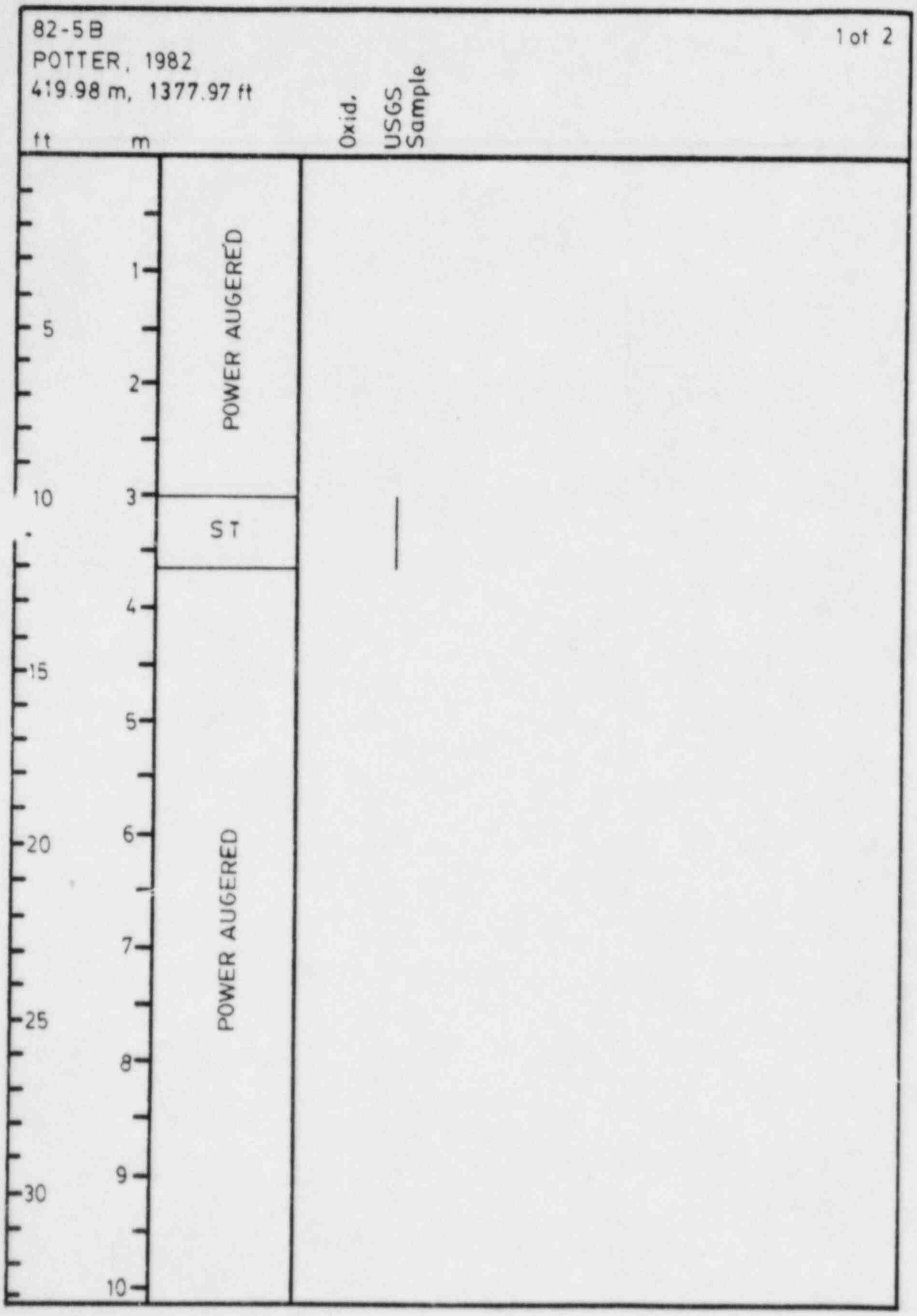
82-5A
POTTER, 1982
420.08 m, 1378.29 ft

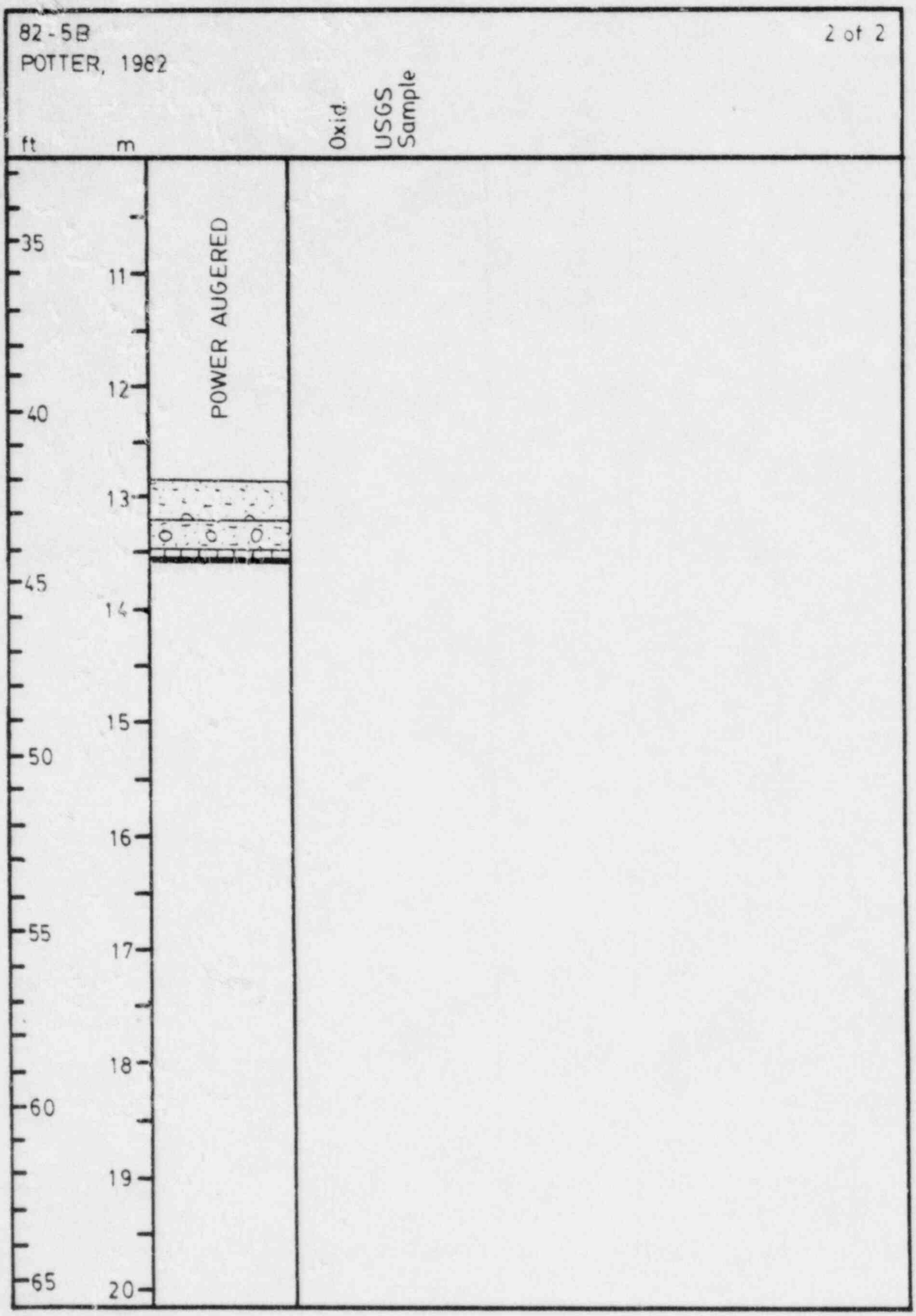
1 of 1

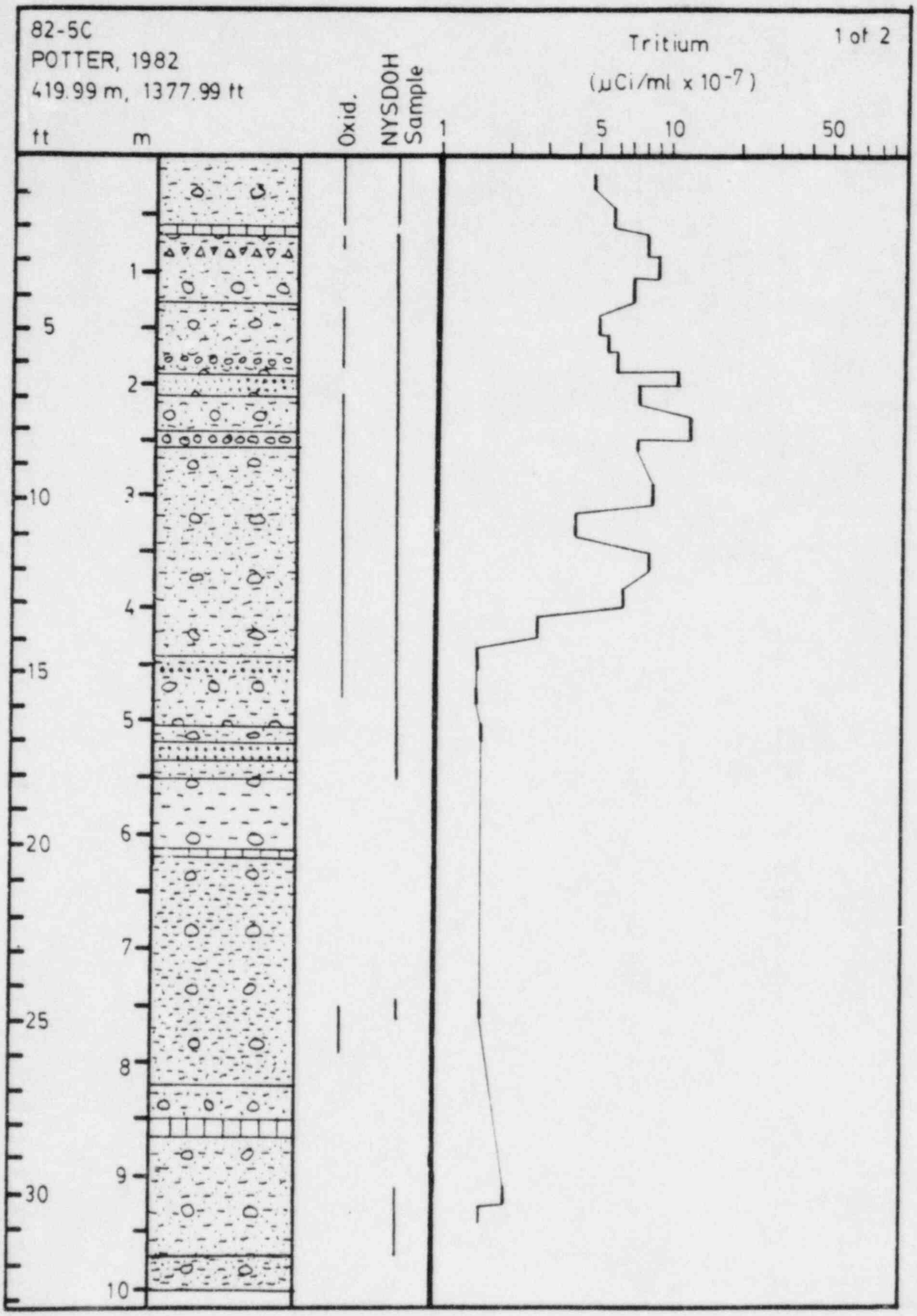


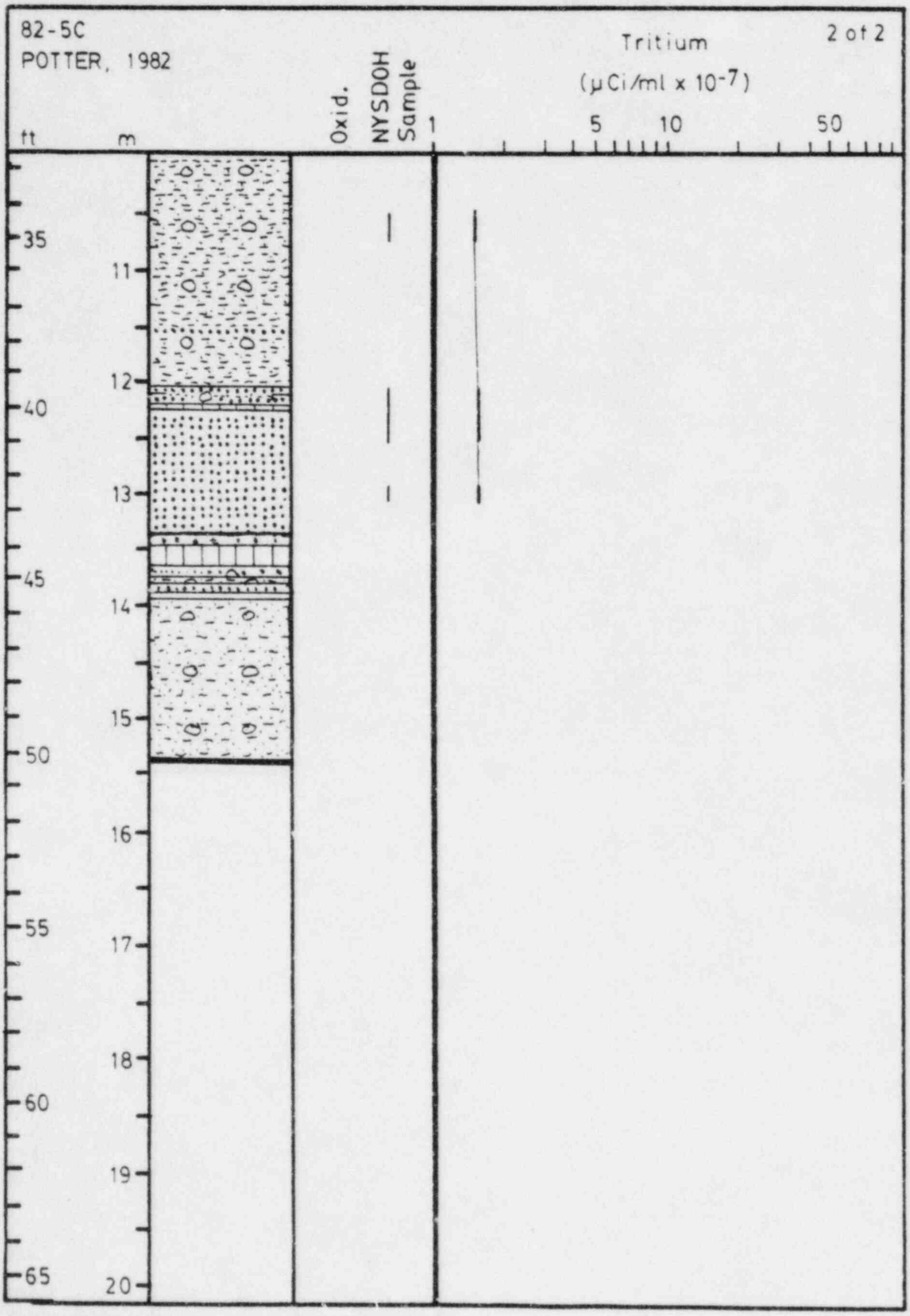
82-5B
POTTER, 1982
419.98 m, 1377.97 ft

1 of 2



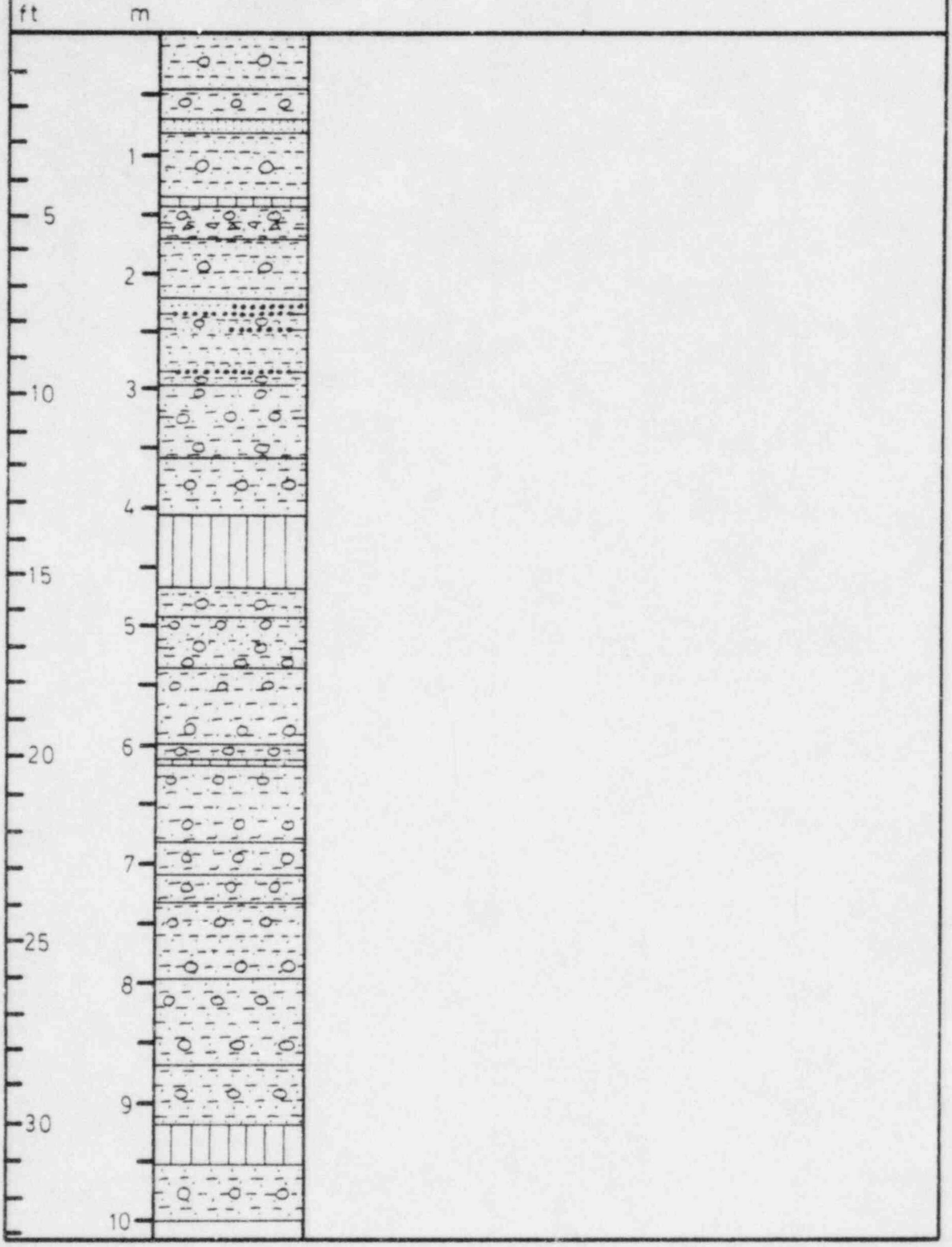

82-5B
POTTER, 1982
2 of 2
ft
m
Oxid.
USGS Sample
POWER AUGERED
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

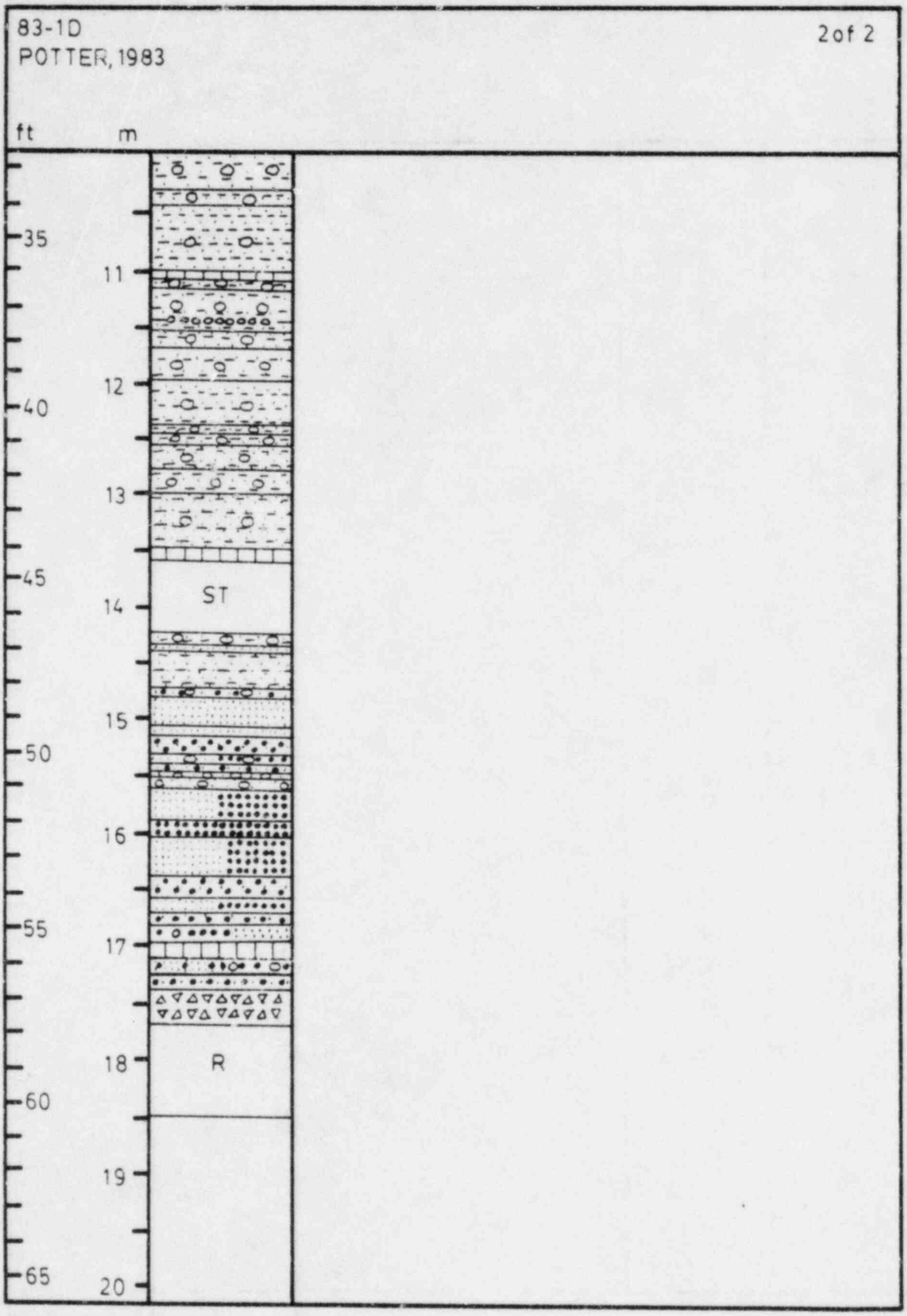

82-5C
POTTER, 1982
419.99 m, 1377.99 ft
Tritium
(µCi/ml x 10⁻⁷)
1 of 2
ft
m
Oxid.
NYSDOH Sample
1
5
10
50
1
2
3
4
5
6
7
8
9
10
5
10
15
20
25
30


82-5C
POTTER, 1982
2 of 2
Tritium
(μCi/ml x 10-7)
Oxid.
NYSDOH Sample
ft
m
1
5
10
50
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

83-1D
POTTER, 1983

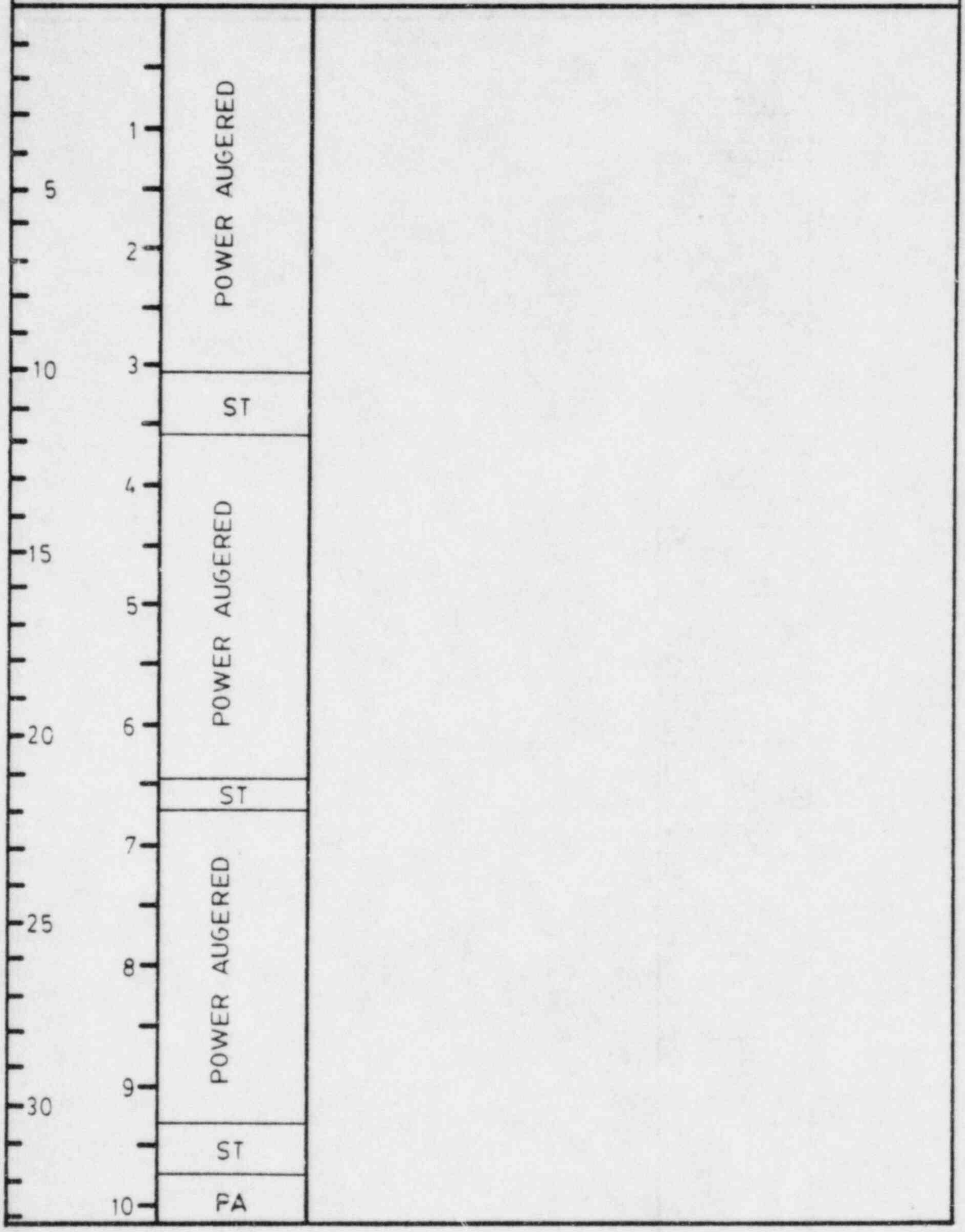
1 of 2

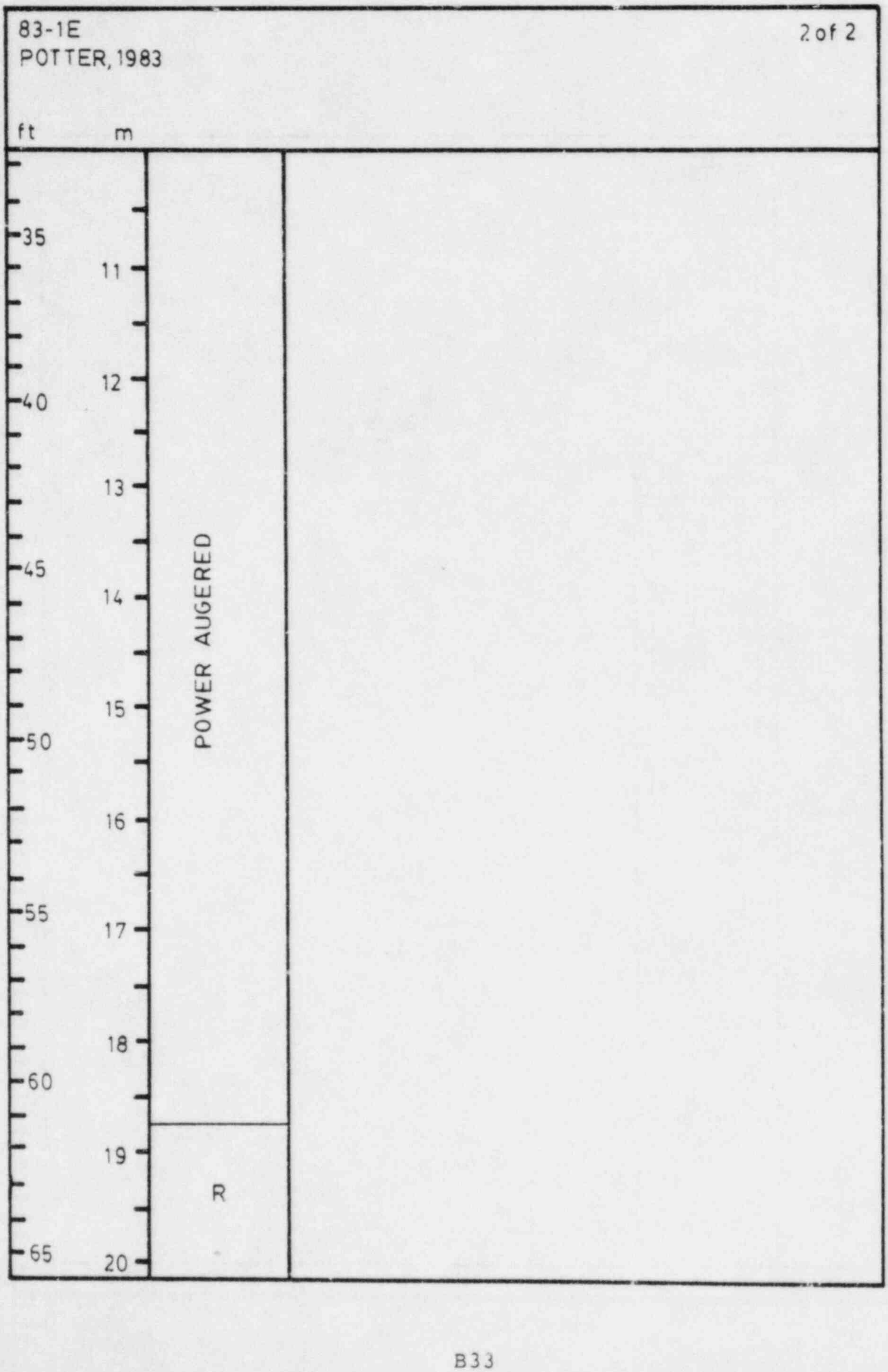


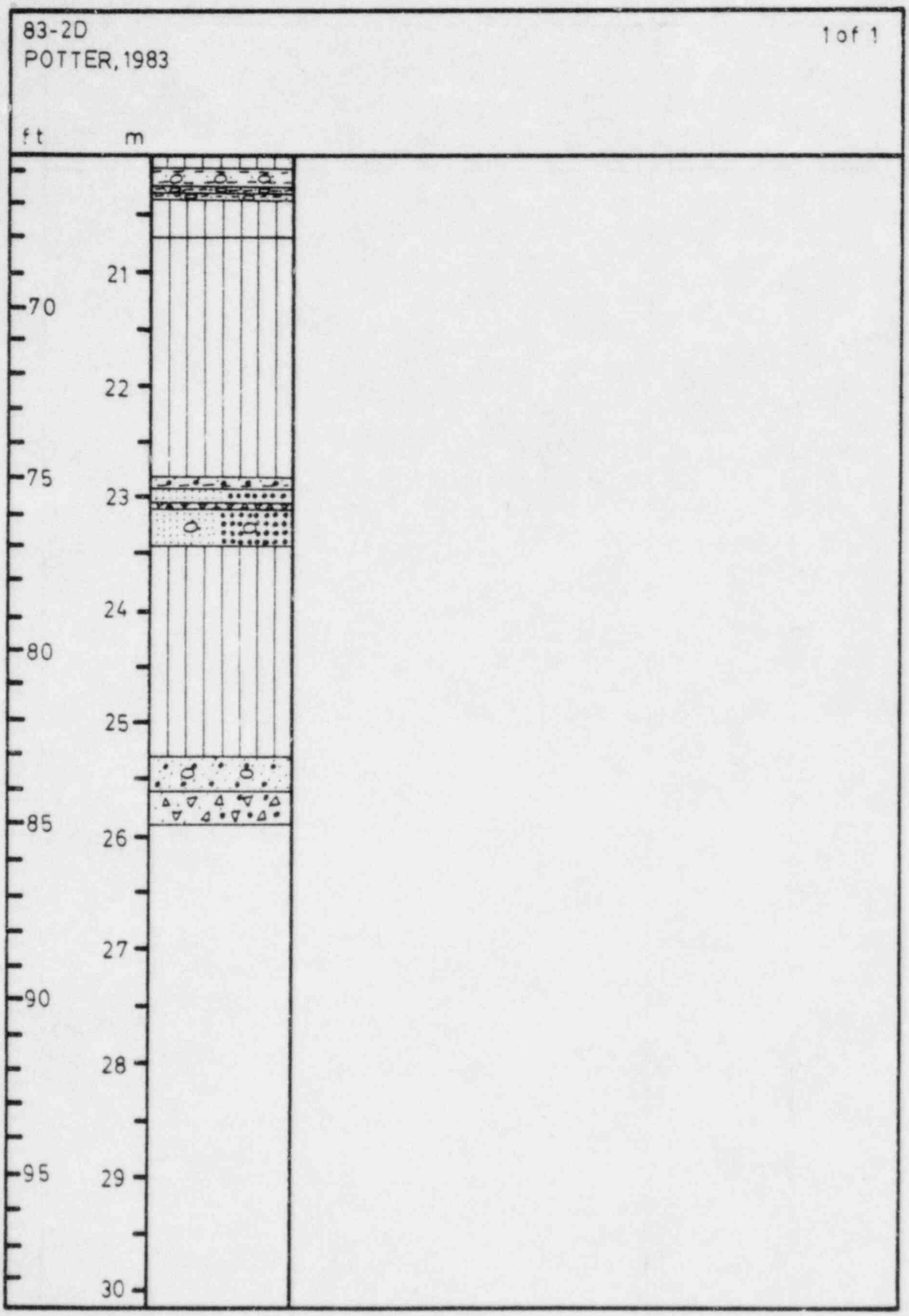

83-1D
POTTER, 1983
2of 2
ft
m
35
11
12
40
13
45
ST
14
15
50
16
55
17
18
R
60
19
65
20

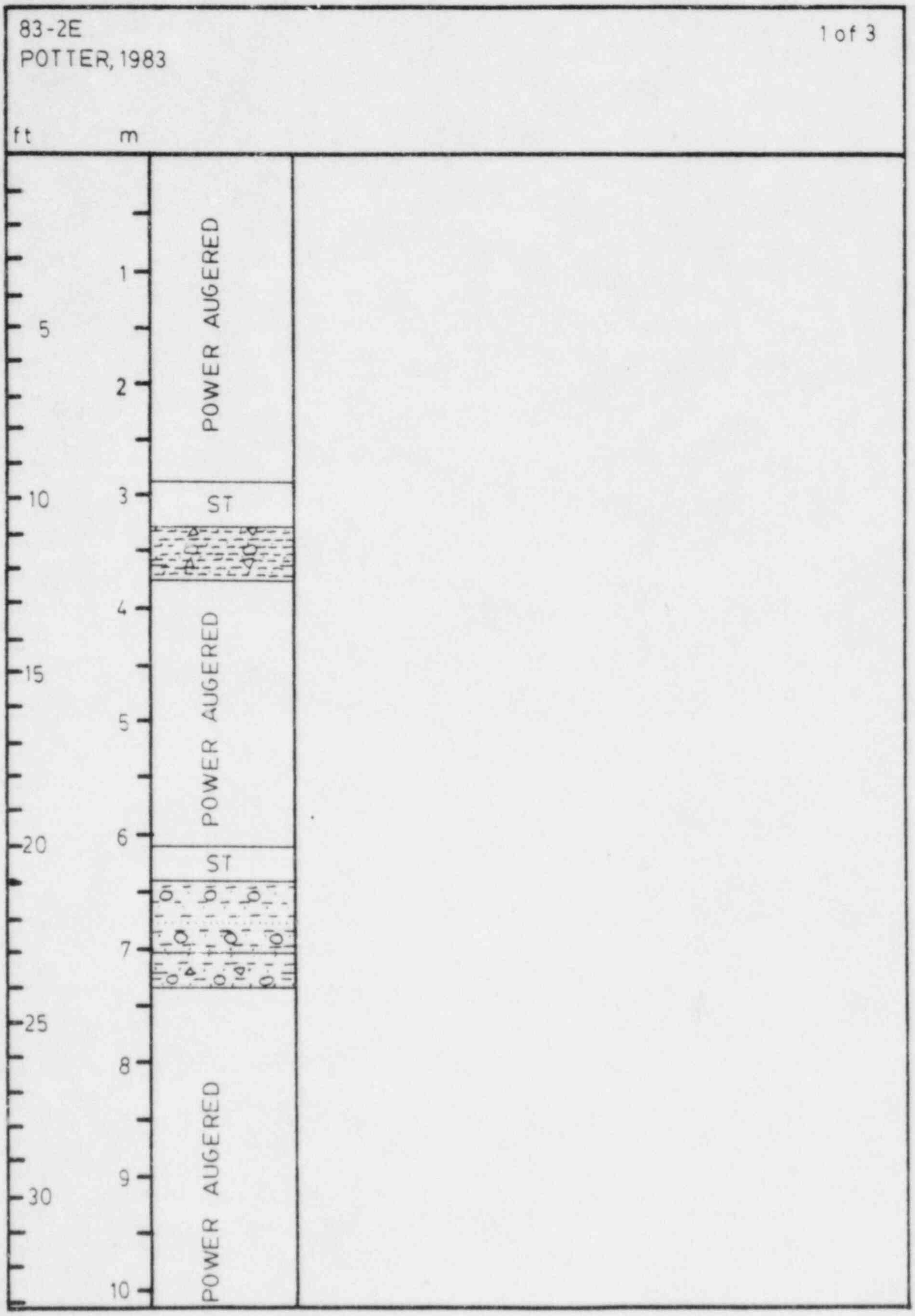
83-1E
POTTER, 1983

1 of 2



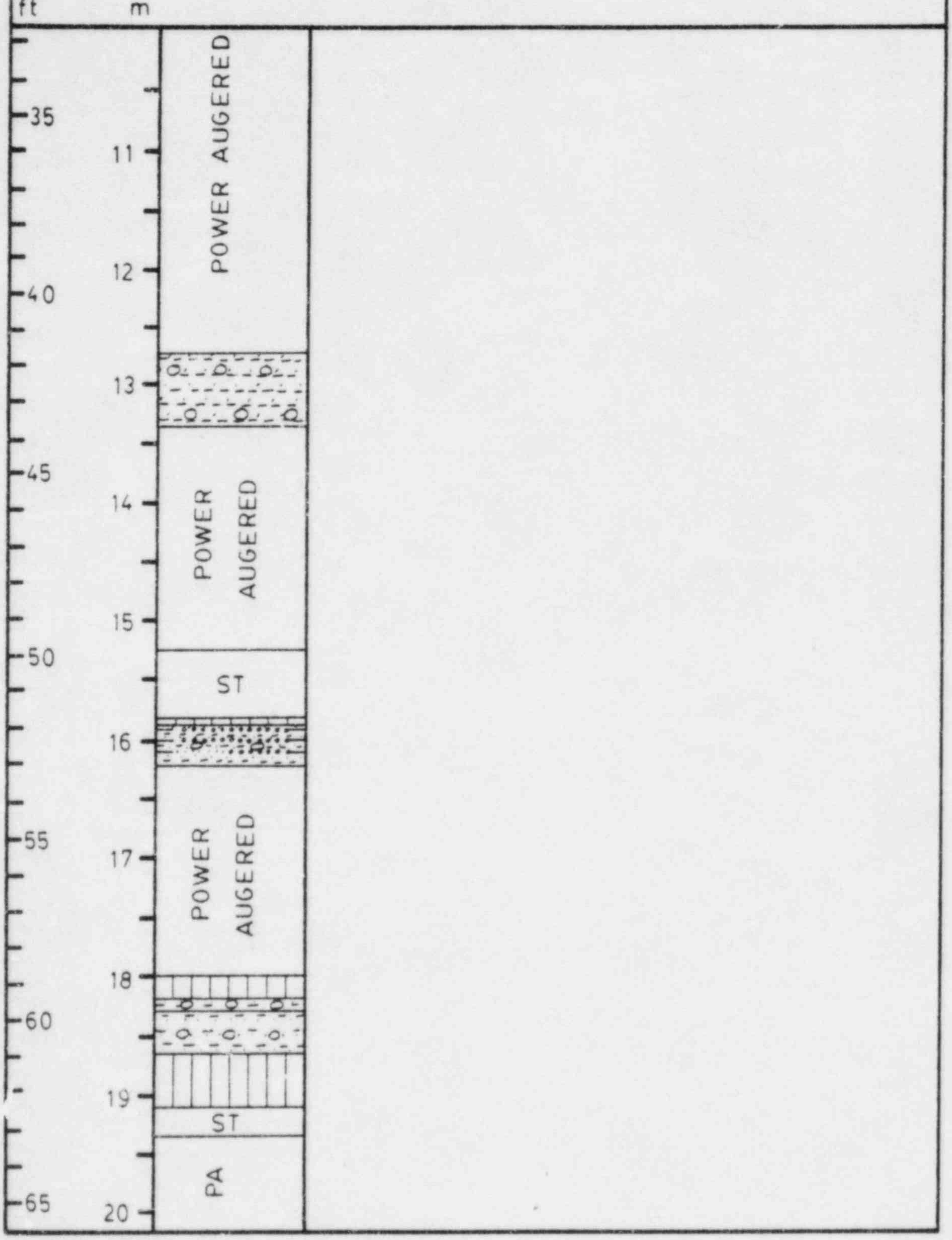

83-1E
POTTER, 1983
2 of 2
ft
m
35
11
12
40
13
45
14
15
50
16
55
17
18
60
19
65
20
POWER AUGERED
R

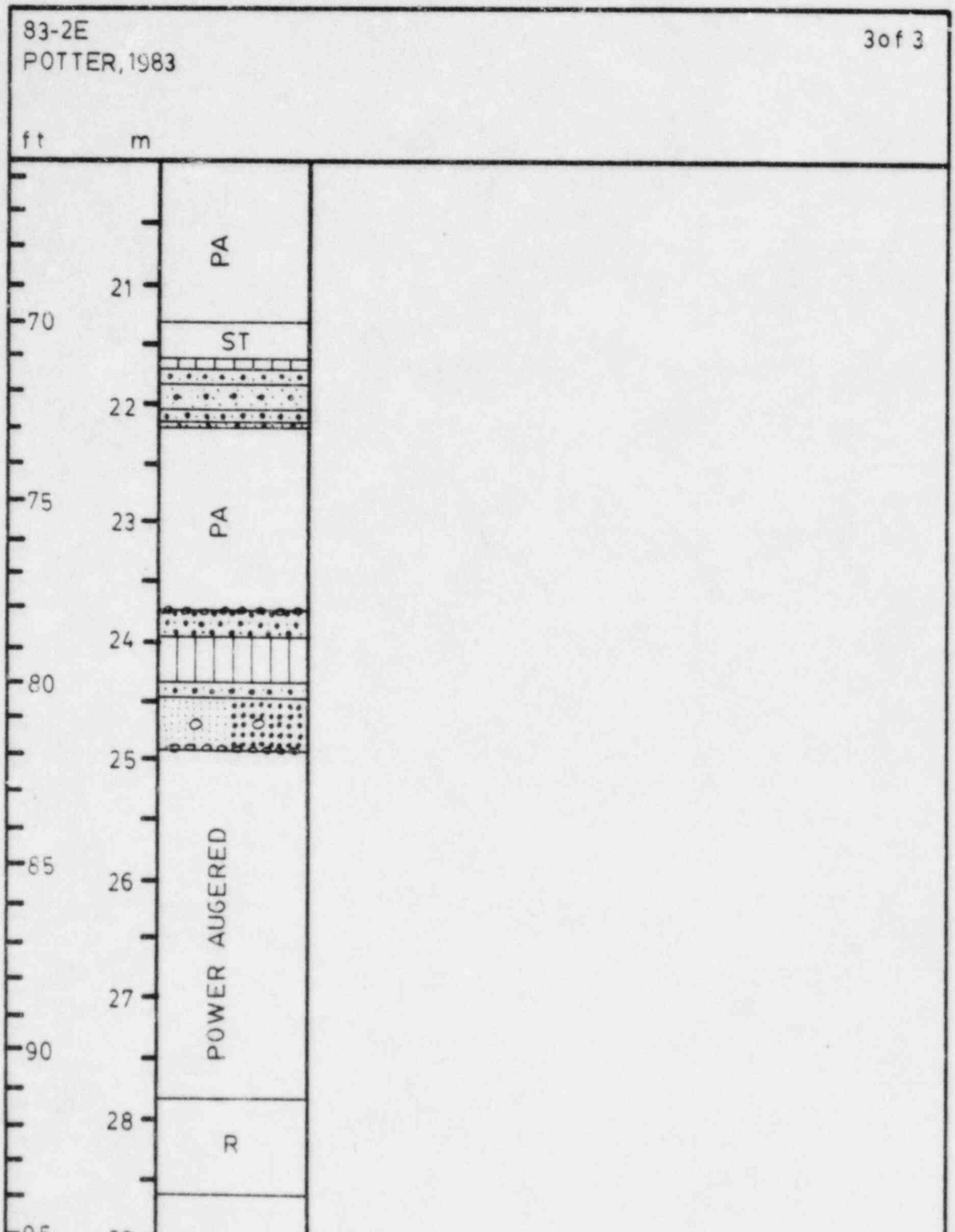

83-2D
POTTER, 1983
1 of 1
ft
m
21
70
22
75
23
24
80
25
85
26
27
90
28
95
29
30

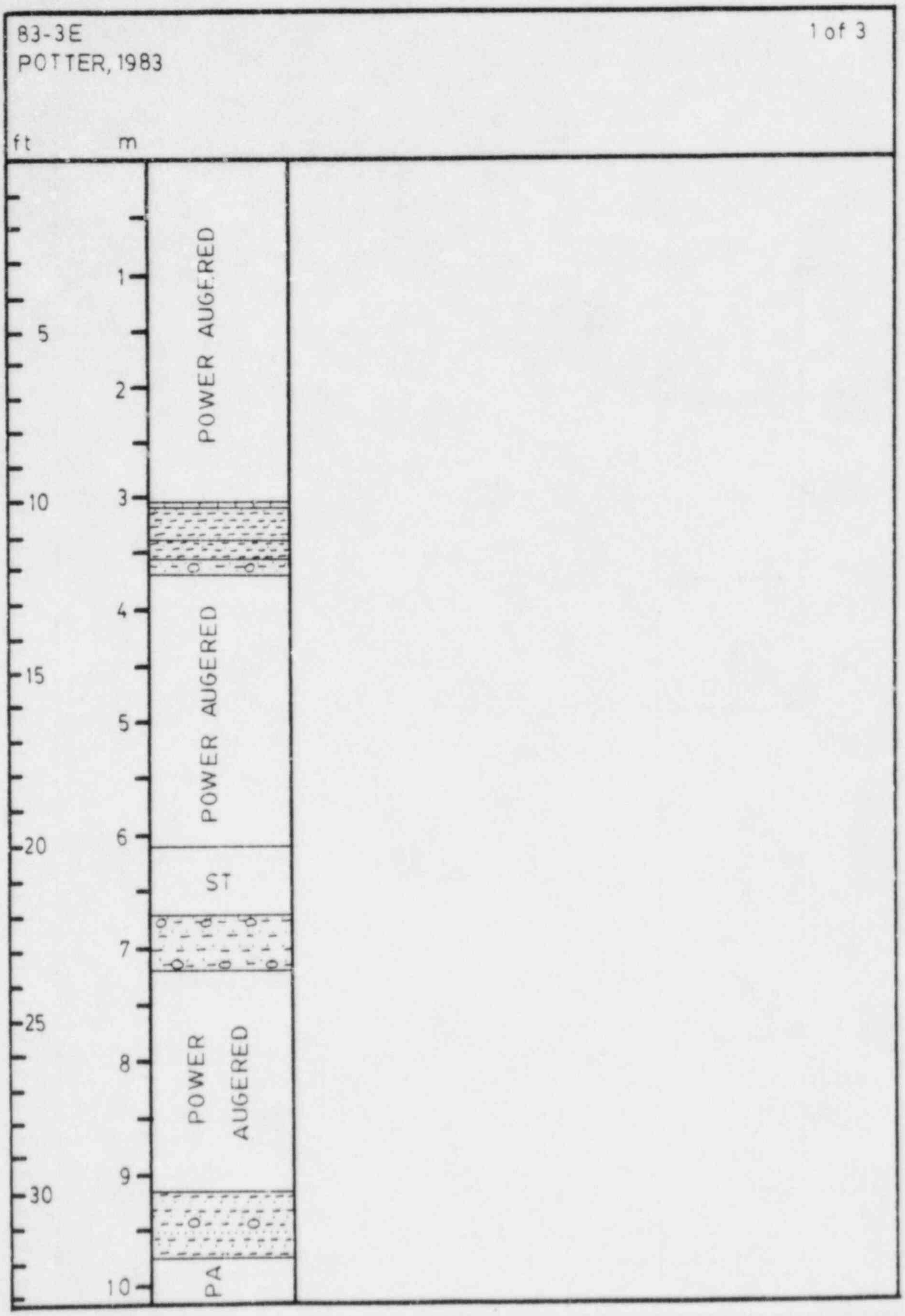

83-2E
POTTER, 1983
1 of 3
ft
m
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
POWER AUGERED
ST
POWER AUGERED
ST
POWER AUGERED

83-2E
POTTER,1983

2of 3

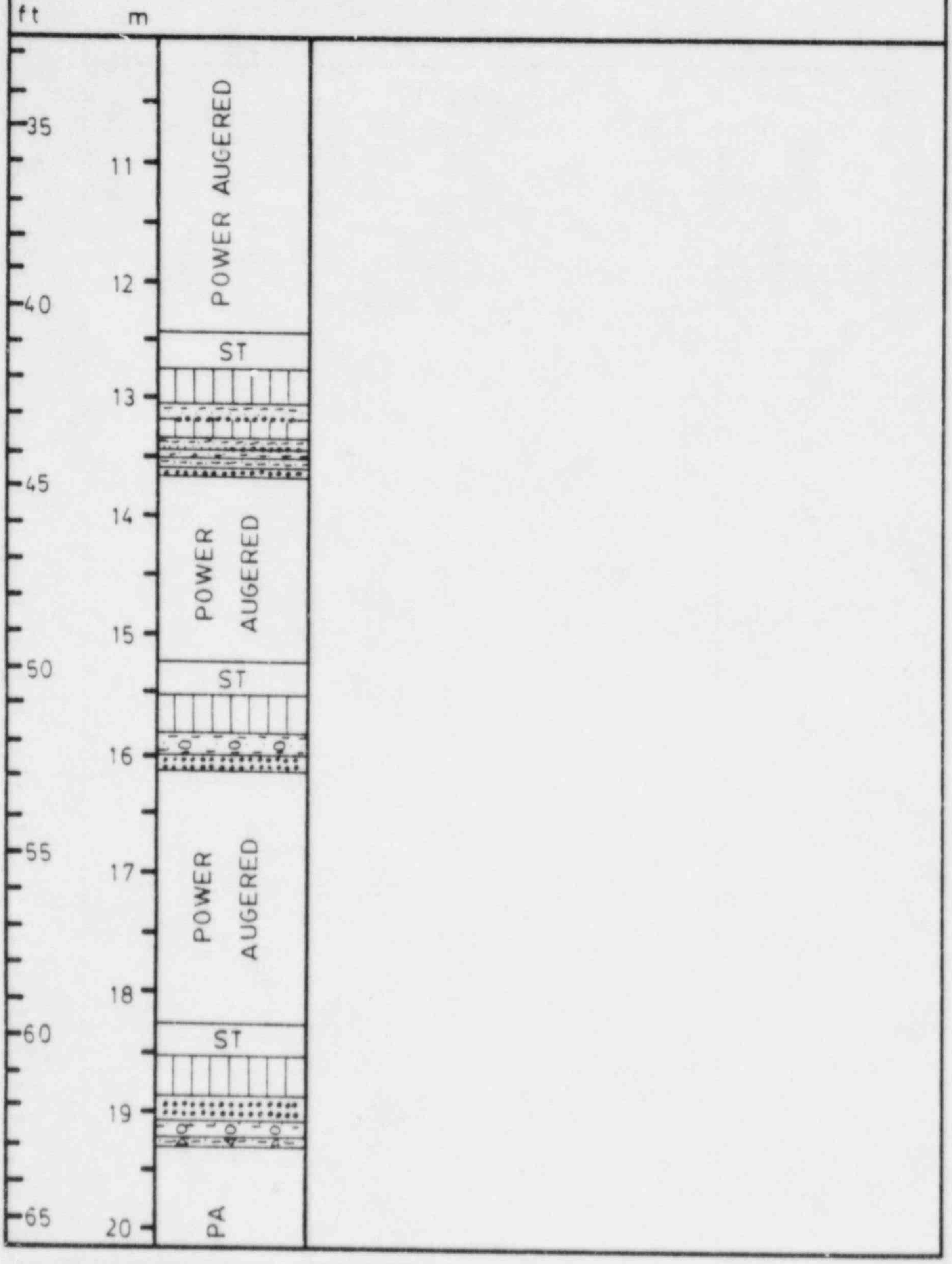


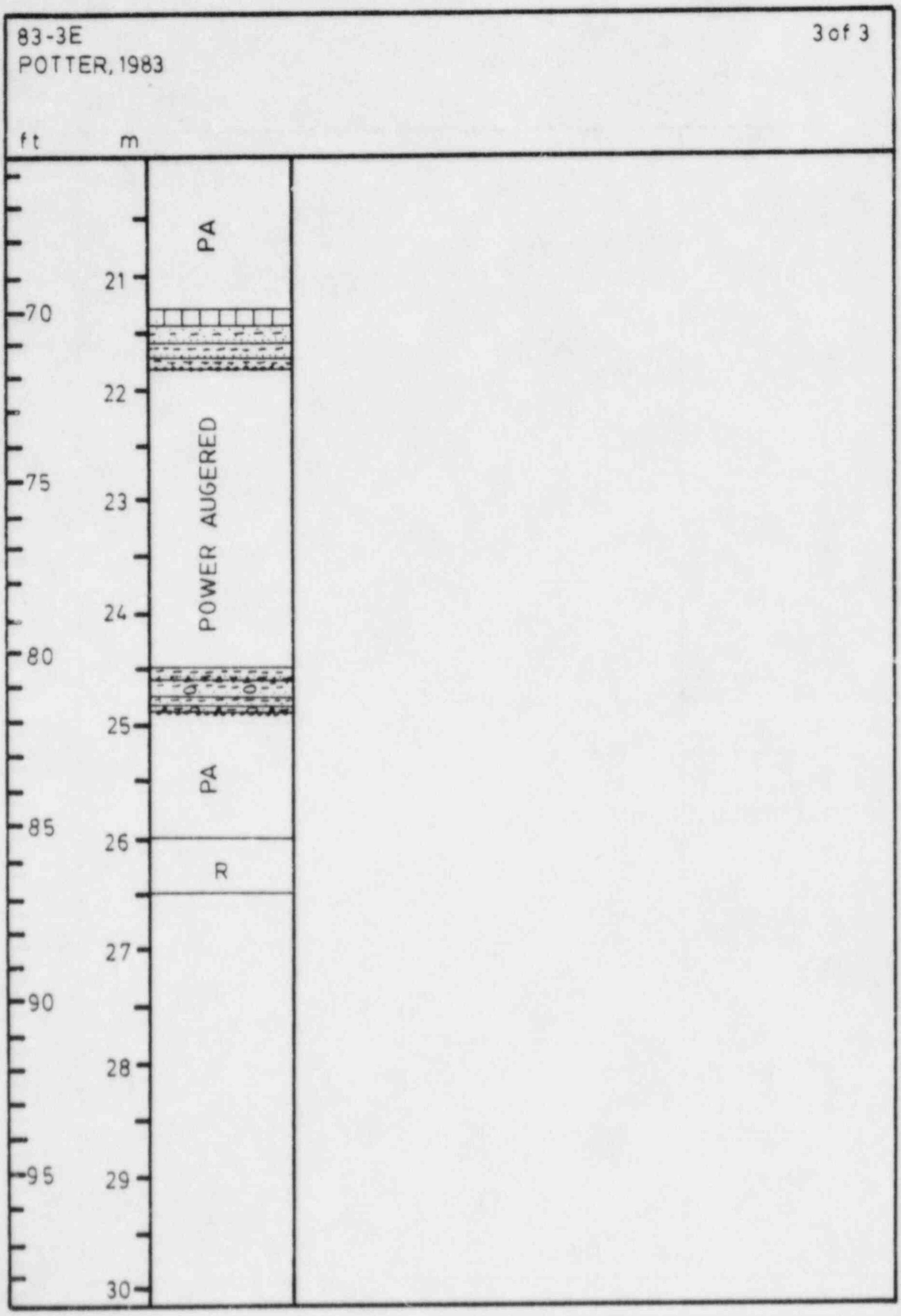

83-2E
POTTER, 1983
3of 3
ft
m
PA
21
70
ST
22
75
PA
23
24
80
25
85
26
POWER AUGERED
27
90
28
R
95
29
30

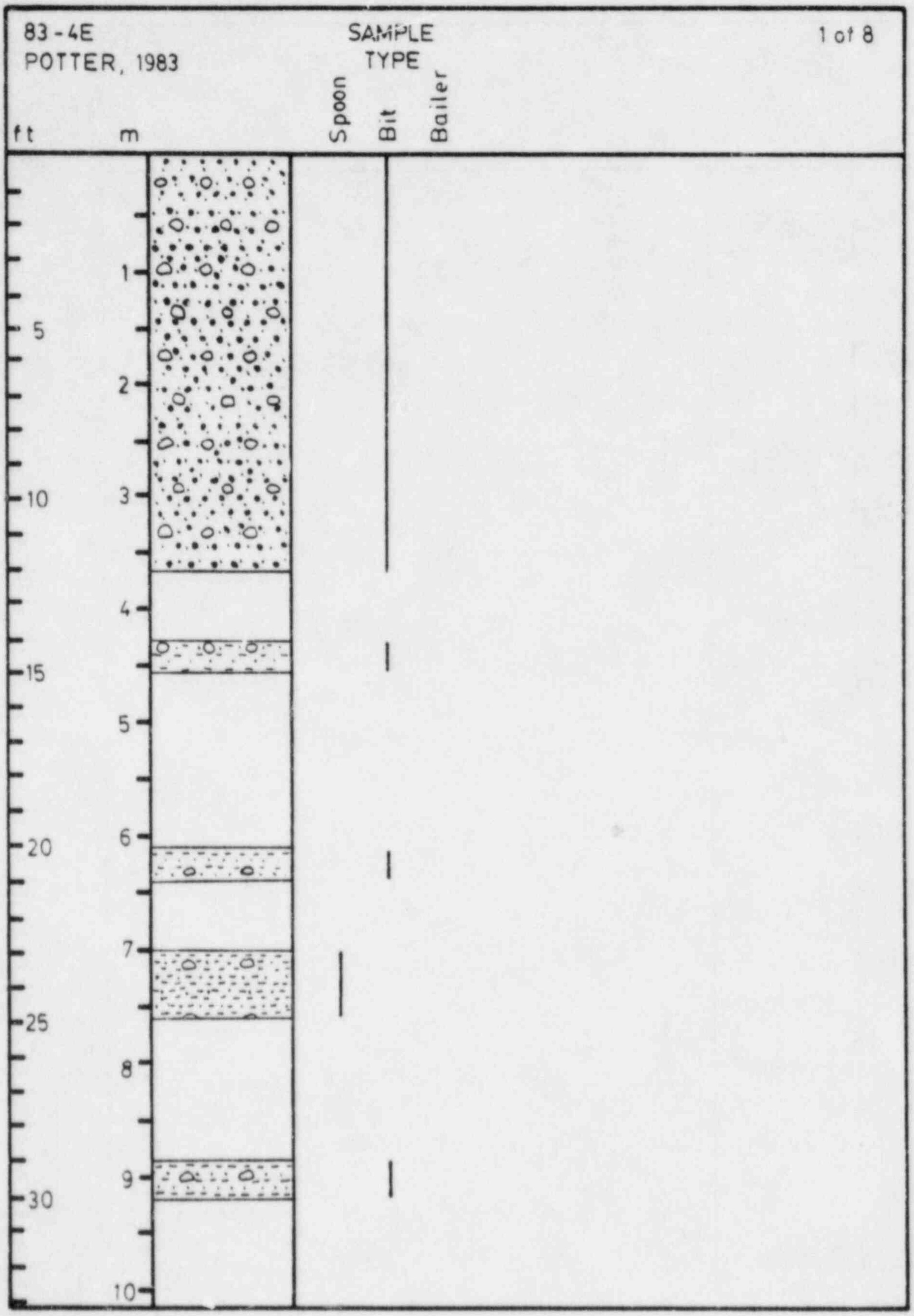

83-3E
POTTER, 1983
1 of 3
ft
m
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10
POWER AUGERED
POWER AUGERED
ST
POWER AUGERED
PA

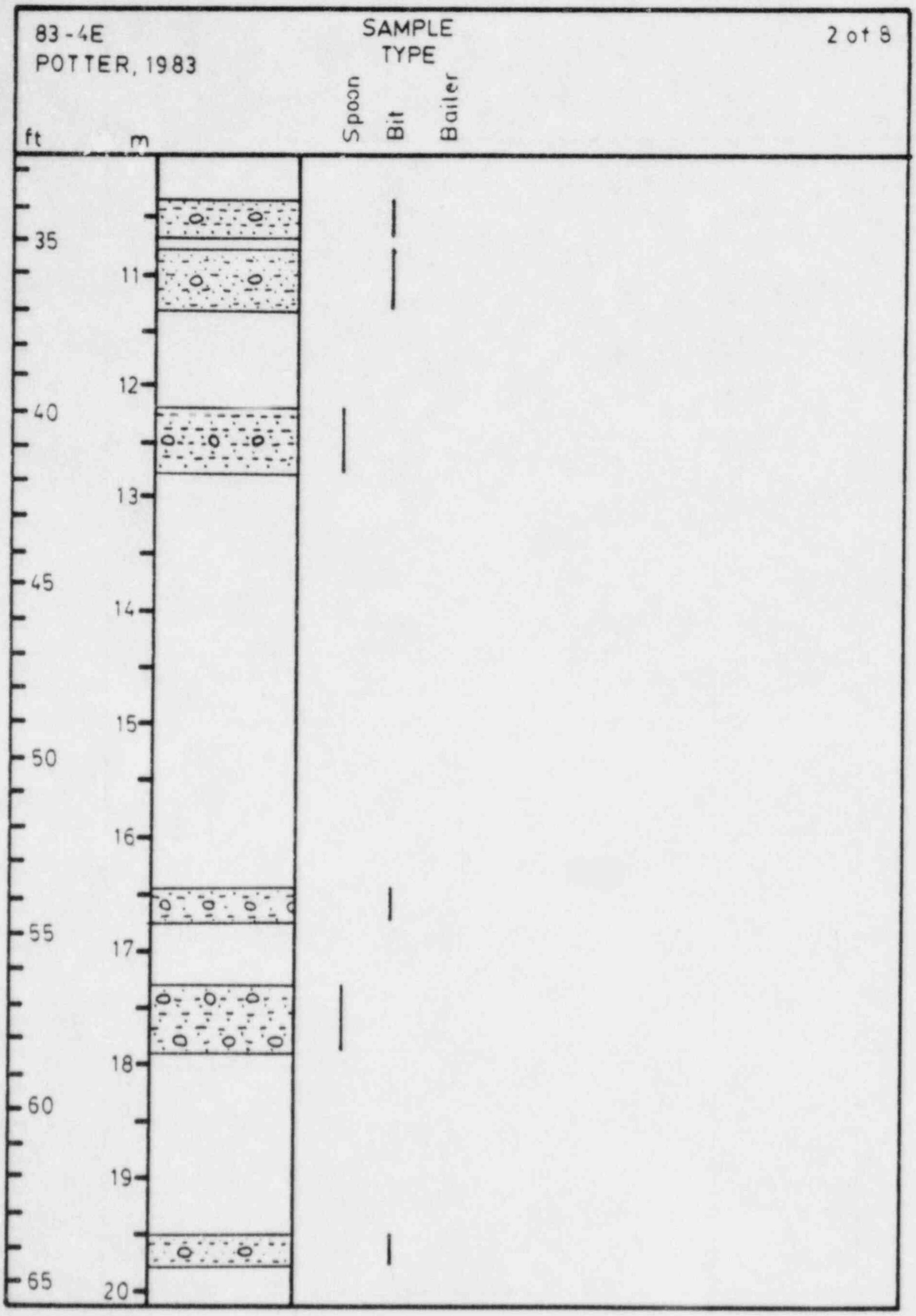
83-3E
POTTER, 1983

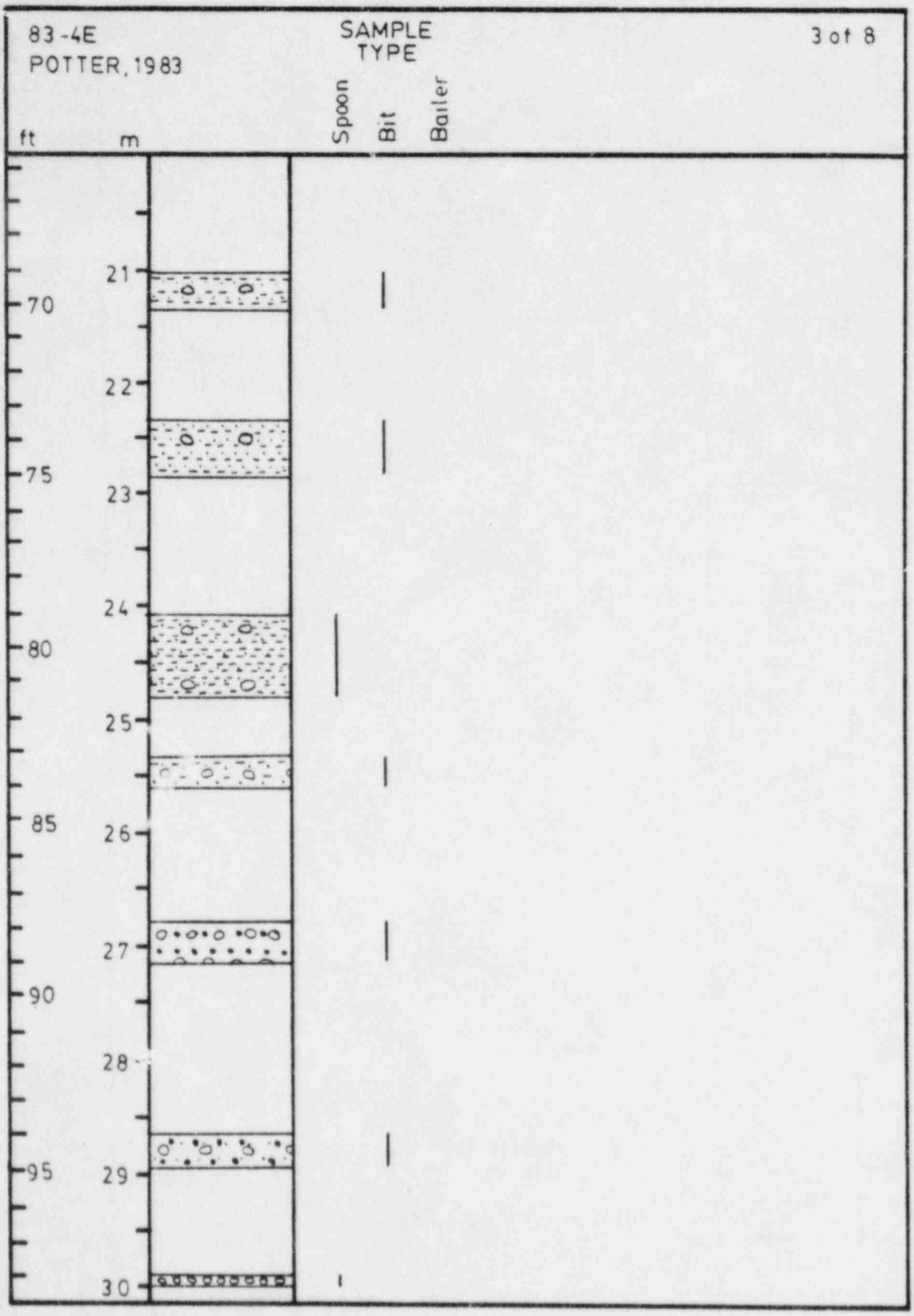
2of 3

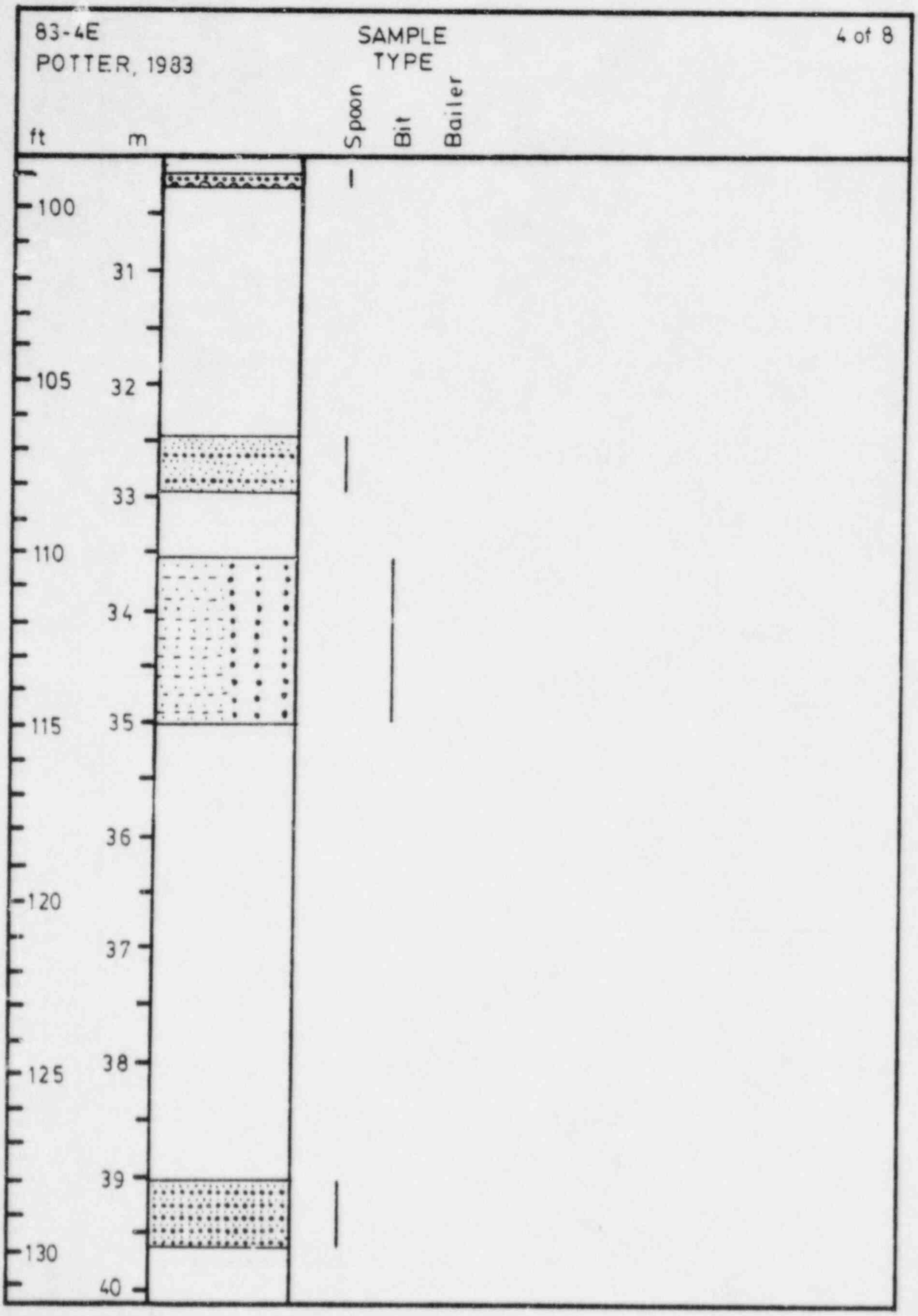


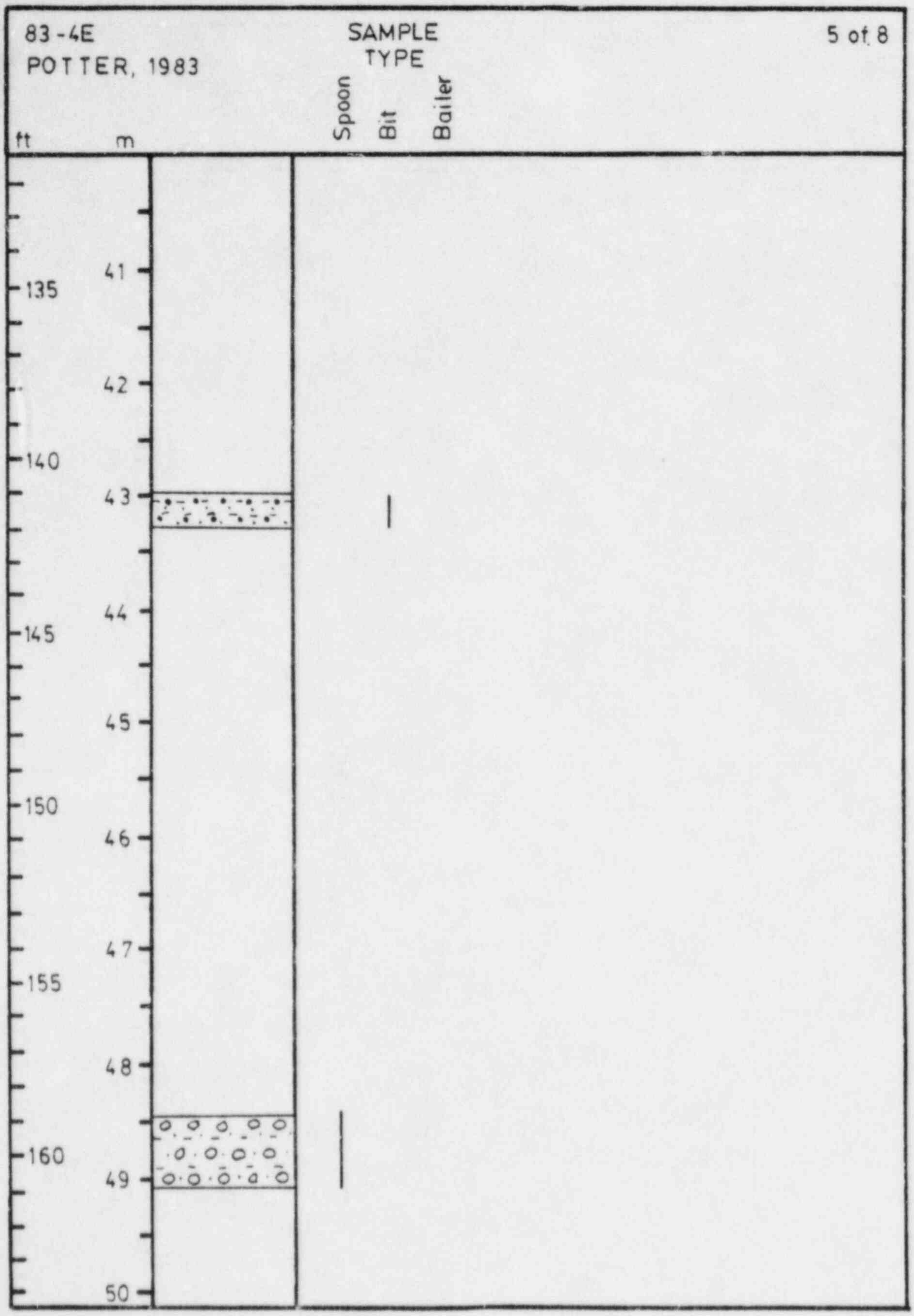

83-3E
POTTER, 1983
3 of 3
ft
m
70
75
80
85
90
95
21
22
23
24
25
26
27
28
29
30
PA
POWER AUGERED
PA
R

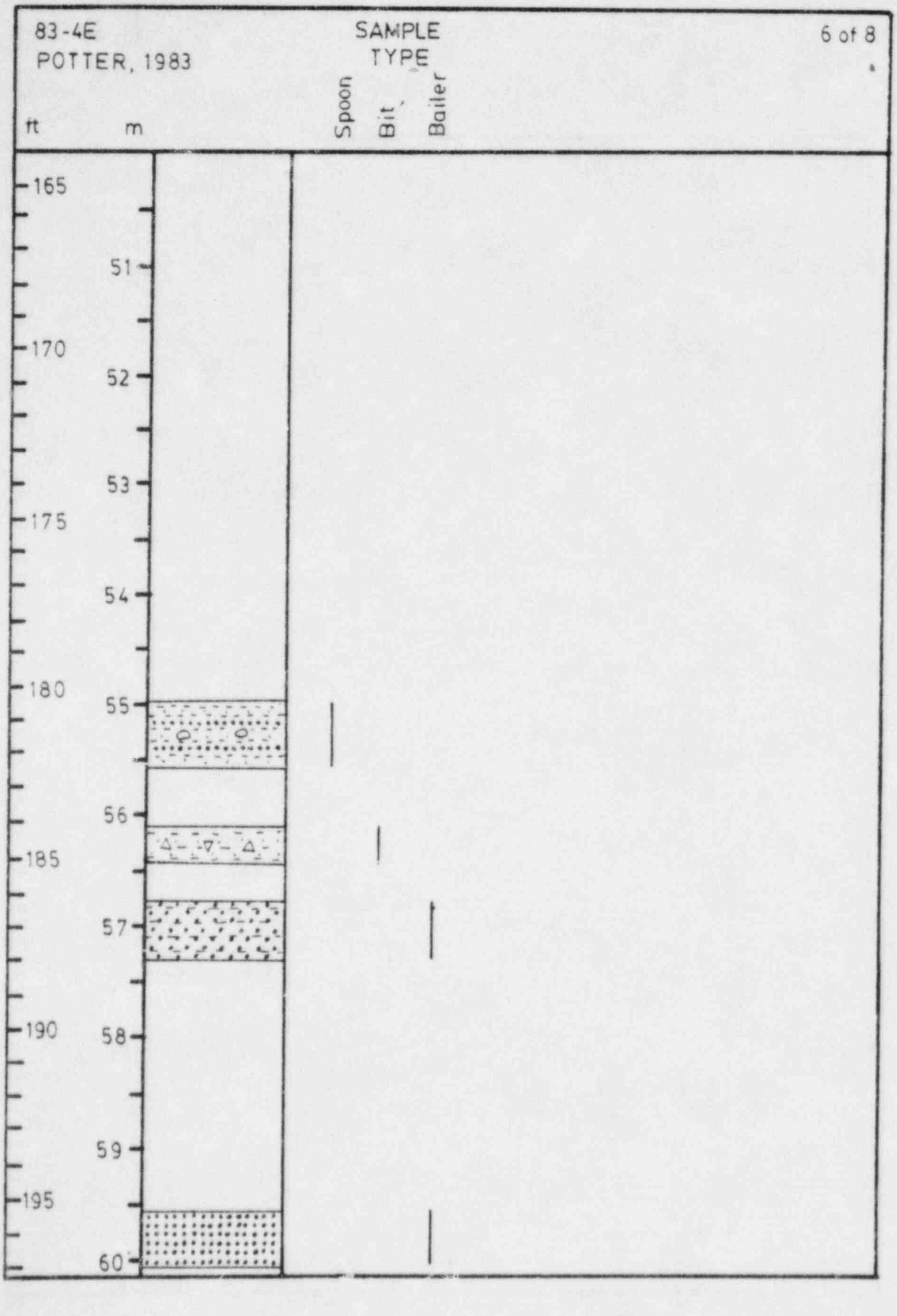

83-4E
POTTER, 1983
SAMPLE
TYPE
1 of 8
Spoon
Bit
Bailer
ft
m
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

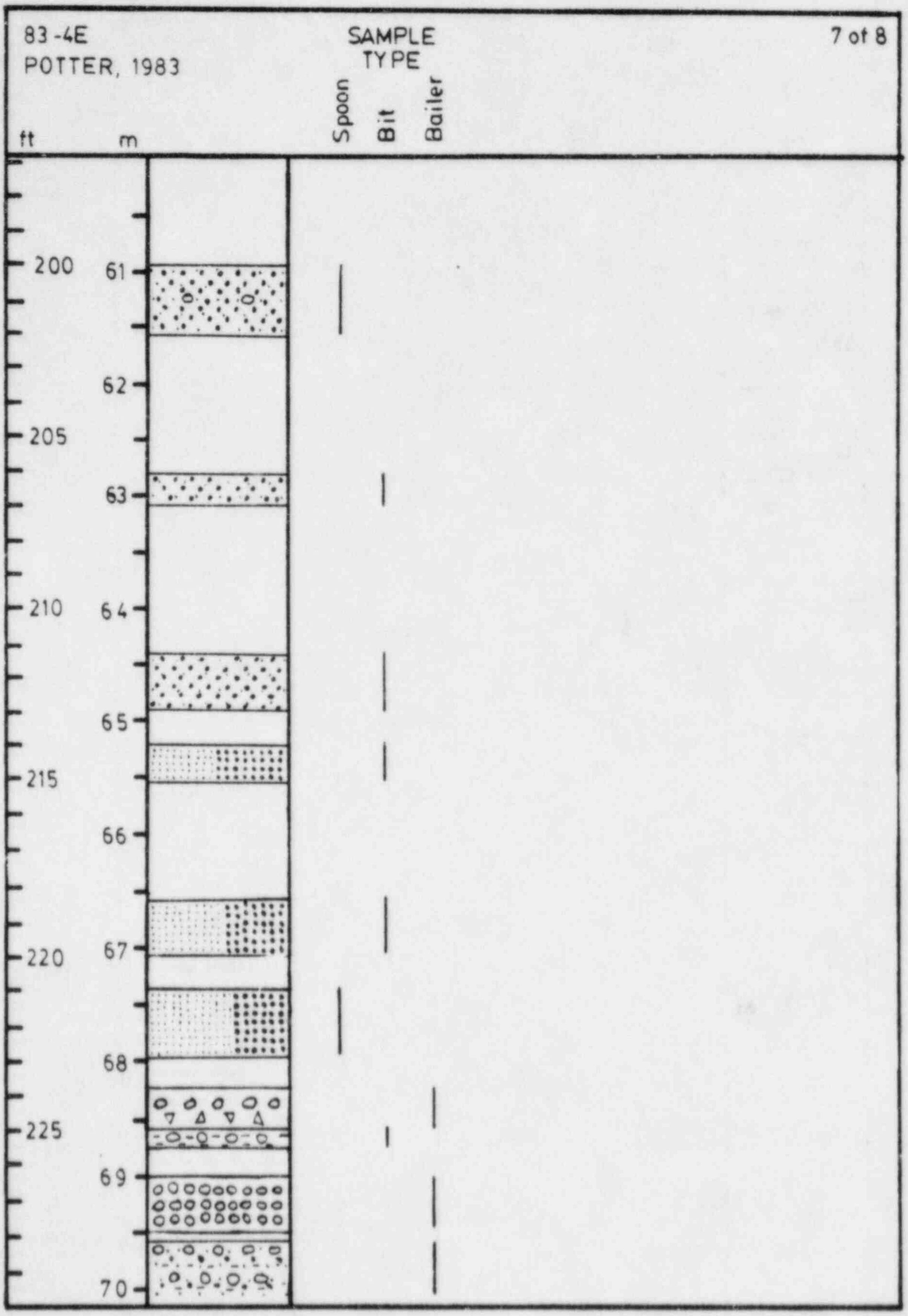

83-4E
POTTER, 1983
SAMPLE TYPE
2 of 8
Spoon
Bit
Bailer
ft
m
35
40
45
50
55
60
65
11
12
13
14
15
16
17
18
19
20

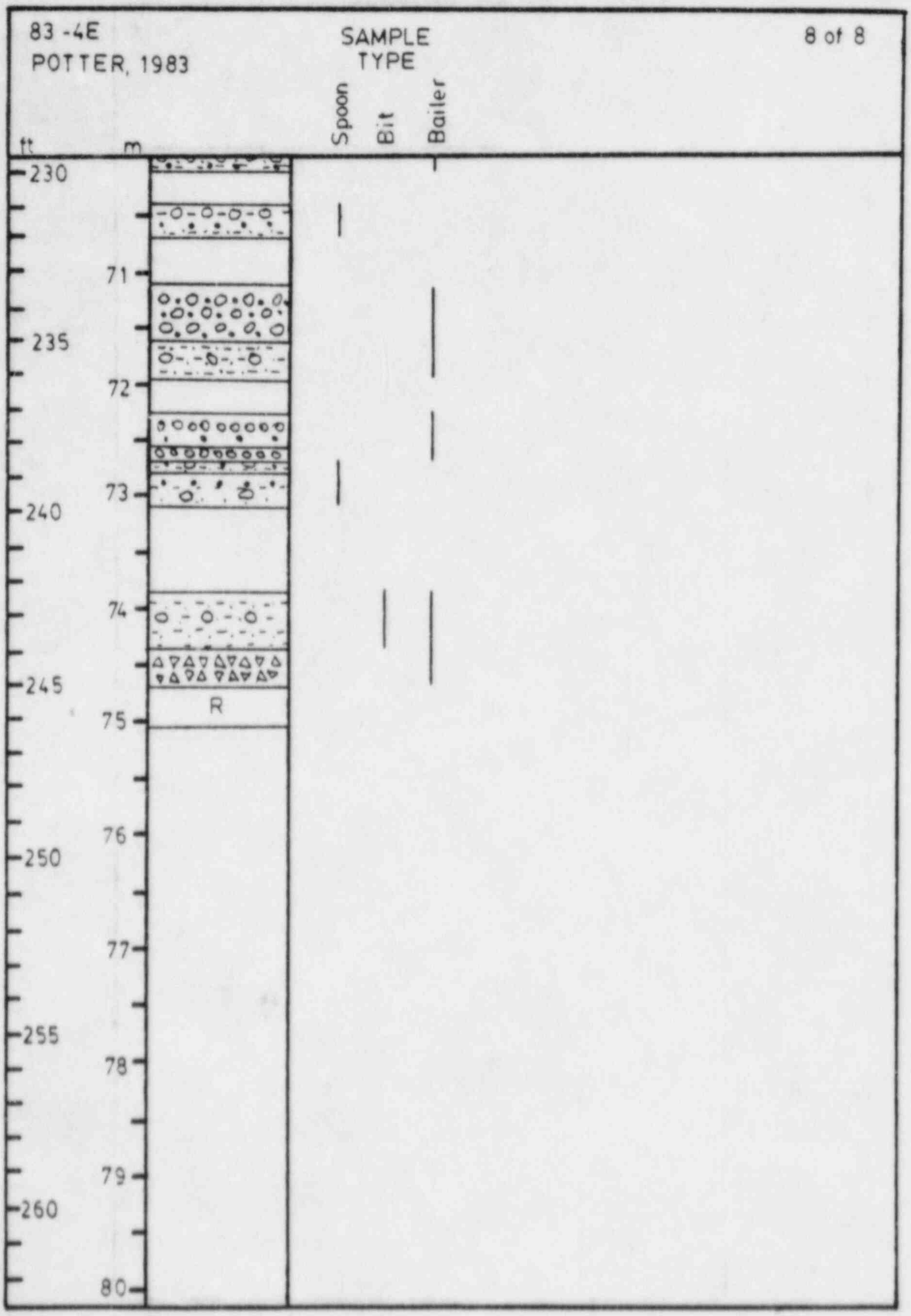

83-4E
POTTER, 1983
SAMPLE TYPE
3 of 8
Spoon
Bit
Bailer
ft
m
21
70
22
75
23
24
80
25
85
26
27
90
28
95
29
30


83-4E
POTTER, 1983
SAMPLE TYPE
4 of 8
Spoon
Bit
Bailer
ft
m
100
31
105
32
33
110
34
115
35
36
120
37
38
125
39
130
40


83-4E
POTTER, 1983
SAMPLE TYPE
Spoon
Bit
Bailer
5 of 8
ft
m
135
140
145
150
155
160
41
42
43
44
45
46
47
48
49
50


83-4E
POTTER, 1983
SAMPLE TYPE
Spoon
Bit
Bailer
6 of 8
ft
m
165
170
175
180
185
190
195
51
52
53
54
55
56
57
58
59
60


83-4E
POTTER, 1983
SAMPLE TYPE
Spoon
Bit
Bailer
7 of 8
ft
m
200
205
210
215
220
225
61
62
63
64
65
66
67
68
69
70


83 -4E
POTTER, 1983
SAMPLE TYPE
8 of 8
Spoon
Bit
Bailer
ft
m
230
235
240
245
250
255
260
71
72
73
74
75
76
77
78
79
80
R

Appendix C. Radionuclide Analysis Results for Samples from Holes Drilled in 1982.

Selected core and water samples from the 1982 holes were given to RSL for radionuclide analysis. The results are all presented here; most of the tritium results are also present in the 1982 drilling report (Appendix D). In the list that follows, each entry gives the results of all analyses done on a single sample. The entries are arranged by hole number and then by depth in feet. Approximate depths are shown for samples that were subdivided by RSL. The RSL number is a sample number assigned by the Radiological Science Laboratory. The whole format, with units for the analyses, is shown at the beginning of the list. Note that for many of the isotopes the units are per milliliter for water and per gram for sediment samples. For tritium the units are per milliliter for both kinds of samples; the pore water was extracted from core samples and then analyzed, so the actual samples were tritiated interstitial water.

The analytical procedures used by RSL were essentially the same as described in Dana and others (1980).

HOLE NO. : 82-1C
RSL NO. : 634051
DEPTH : ~ 0.0-0.8
TYPE : SEDIMENT
HTO : 76 ± 4
90-SR : 0.55 ± 0.16
238-PU : 0.04 ± 0.02
239-PU : <0.02
234-U : 0.98 ± 0.11
235-U : 0.044 ± 0.01
238-U : 1.08 ± 0.12
232-TH : 9.5 ± 0.8
226-RA : 10.4 ± 1.1
137-CS : 3.9 ± 0.6
60-CO : <0.4
40-K : 270 ± 15

HOLE NO. : 82-1C
RSL NO. : 634051
DEPTH : ~ 0.0-0.8
TYPE : SEDIMENT
HTO : 76 ± 4

HOLE NO. : 82-1C
RSL NO. : 634052
DEPTH : ~ 0.8-1.6
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 634053
DEPTH : ~ 1.6-2.5
TYPE : SEDIMENT
HTO : 57 ± 3
232-TH : 14.3 ± 1.0
226-RA : 10.6 ± 1.3
137-CS : 1.1 ± 0.5
60-CO : <0.4
40-K : 232 ± 15

HOLE NO. : 82-1C
RSL NO. : 634053
DEPTH : ~ 1.6-2.5
TYPE : SEDIMENT
HTO : 57 ± 3

HOLE NO. : 82-1C
RSL NO. : 634054
DEPTH : 2.5-3.4
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 634001
DEPTH : 3.4-~ 4.1
TYPE : SEDIMENT
HTO : 10 ± 2

HOLE NO. : 82-1C
RSL NO. : 634002
DEPTH : ~ 4.1-4.8
TYPE : SEDIMENT
HTO : 10 ± 2
90-SR : <0.09
232-TH : 15.5 ± 1.2
226-RA : 10.8 ± 1.5
137-CS : <0.3
60-CO : <0.5
40-K : 270 ± 20

HOLE NO. : 82-1C
RSL NO. : 634003
DEPTH : 4.8-~ 5.8
TYPE : SEDIMENT
HTO : 10 ± 2

HOLE NO. : 82-1C
RSL NO. : 634004
DEPTH : ~ 5.8-~ 6.7
TYPE : SEDIMENT
HTO : 9 ± 2

HOLE NO. : 82-1C
RSL NO. : 634005
DEPTH : ~ 6.7-7.7
TYPE : SEDIMENT
HTO : 7 ± 2

HOLE NO. : 82-1C
RSL NO. : 624004
DEPTH : 7.7-8.3
TYPE : SEDIMENT
HTO : 3.5 ± 1.8

HOLE NO. : 82-1C
RSL NO. : 634006
DEPTH : 8.3-~ 8.7
TYPE : SEDIMENT
HTO : 4 ± 2

HOLE NO. : 82-1C
RSL NO. : 634007
DEPTH : ~ 8.7-9.0
TYPE : SEDIMENT

HTO : 4.4 ± 1.9

HOLE NO. : 82-1C
RSL NO. : 634055
DEPTH : ~ 9.0-9.5
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 634056
DEPTH : 9.5-10.0
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 634057
DEPTH : 10.0-10.5
TYPE : SEDIMENT
HTO : 3.8 ± 1.8

HOLE NO. : 82-1C
RSL NO. : 624005
DEPTH : 15.6-16.0
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-1C
RSL NO. : 624002
DEPTH : 17.0
TYPE : WATER
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 624006
DEPTH : 17.95-18.45
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-1C
RSL NO. : 624007
DEPTH : 23.3-23.8
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-1C
RSL NO. : 624008
DEPTH : 33.1-33.7
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-1C
RSL NO. : 624003
DEPTH : 33.7
TYPE : WATER

HOLE NO. : 82-1C
RSL NO. : 624009
DEPTH : 37.8-38.4
TYPE : SEDIMENT
HTO : <1.5
90-SR : <0.08
238-PU : <0.05
239-PU : <0.07
234-U : 1.07 ± 0.11
235-U : .045 ± 0.012
238-U : 1.06 ± 0.11
232-TH : 12.4 ± 0.9
226-RA : 10.6 ± 1.3
137-CS : <0.3
60-CO : <0.4
40-K : 276 ± 17

HOLE NO. : 82-1C
RSL NO. : 634008
DEPTH : 38.4-39.0
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-1C
RSL NO. : 624010
DEPTH : 43.5-44.0
TYPE : SEDIMENT
HTO : <1.2

HOLE NO. : 82-1C
RSL NO. : 624011
DEPTH : 48.5-49.0
TYPE : SEDIMENT
HTO : <1.2

HOLE NO. : 82-1D
RSL NO. : 624047
DEPTH : 58.5-60.0
TYPE : SEDIMENT
HTO : <1.2

HOLE NO. : 82-1D
RSL NO. : 624048
DEPTH : 75.0-75.5
TYPE : SEDIMENT
HTO : <1.2

HOLE NO. : 82-1D
RSL NO. : 634100
DEPTH : 76.0-76.5
TYPE : SEDIMENT
HTO : <2

```
HOLE NO. : 82-1D
    RSL NO. : 634100
    DEPTH : 76.0-76.5
    TYPE : SEDIMENT
    232-TH : 15.4 ± 1.2
    226-RA : 11.1 ± 1.6
    137-CS : <0.4
    60-CO : <0.5
    40-K : 270 ± 20

HOLE NO. : 82-2C
    RSL NO. : 634059
    DEPTH : 0.0-0.8
    TYPE : SEDIMENT
    HTO : 2.4 ± 1.6

HOLE NO. : 82-2C
    RSL NO. : 634060
    DEPTH : 0.8-1.5
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 634061
    DEPTH : 1.5-2.3
    TYPE : SEDIMENT
    HTO : 3.5 ± 1.8

HOLE NO. : 82-2C
    RSL NO. : 634009
    DEPTH : 3.0-~ 4.5
    TYPE : SEDIMENT
    HTO : 4 ± 2

HOLE NO. : 82-2C
    RSL NO. : 634010
    DEPTH : ~ 4.5-6.0
    TYPE : SEDIMENT
    HTO : 4 ± 2

HOLE NO. : 82-2C
    RSL NO. : 634011
    DEPTH : 6.0-~ 7.0
    TYPE : SEDIMENT
    HTO : <2
    232-TH : 13.2 ± 1.0
    226-RA : 9.9 ± 1.3
    137-CS : <0.3
    60-CO : <0.4
    40-K : 249 ± 16

HOLE NO. : 82-2C
    RSL NO. : 634012
    DEPTH : ~ 7.0-8.0
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 634013
    DEPTH : 10.3-~ 11.4
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 634014
    DEPTH : ~ 11.4-12.5
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 624012
    DEPTH : 12.7-13.3
    TYPE : SEDIMENT
    HTO : <1.7

HOLE NO. : 82-2C
    RSL NO. : 624013
    DEPTH : 20.5-21.0
    TYPE : SEDIMENT
    HTO : <1.5

HOLE NO. : 82-2C
    RSL NO. : 634015
    DEPTH : 22.6-23.0
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 624014
    DEPTH : 22.6-23.2
    TYPE : SEDIMENT
    HTO : <1.5

HOLE NO. : 82-2C
    RSL NO. : 634016
    DEPTH : ~ 23.0-~ 23.3
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 634017
    DEPTH : ~ 23.3-~ 23.7
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-2C
    RSL NO. : 634018
    DEPTH : ~ 23.7-24.0
```

TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-2C
RSL NO. : 624015
DEPTH : 27.0-27.5
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-2C
RSL NO. : 624016
DEPTH : 28.0-28.7
TYPE : SEDIMENT
HTO : <1.5
232-TH : 12.9 ± 1.1
226-RA : 9.4 ± 1.4
137-CS : <0.3
60-CO : <0.4
40-K : 219 ± 17

HOLE NO. : 82-3C
RSL NO. : 634063
DEPTH : 0.0-0.5
TYPE : SEDIMENT
HTO : 2.6 ± 1.8

HOLE NO. : 82-3C
RSL NO. : 634065
DEPTH : 1.0-1.5
TYPE : SEDIMENT
HTO : 4.5 ± 1.8

HOLE NO. : 82-3C
RSL NO. : 624021
DEPTH : 1.19-19.5
TYPE : SEDIMENT
HTO : <1.5

HOLE NO. : 82-3C
RSL NO. : 634019
DEPTH : 2.0-~ 2.5
TYPE : SEDIMENT
HTO : 5 ± 2

HOLE NO. : 82-3C
RSL NO. : 634020
DEPTH : ~ 2.5-~ 3.1
TYPE : SEDIMENT
HTO : 6 ± 2

HOLE NO. : 82-3C
RSL NO. : 634021
DEPTH : ~ 3.1-~ 3.6
TYPE : SEDIMENT
HTO : 4 ± 2

HOLE NO. : 82-3C
RSL NO. : 634022
DEPTH : ~ 3.6-4.1
TYPE : SEDIMENT
HTO : 2.7 ± 1.9

HOLE NO. : 82-3C
RSL NO. : 634023
DEPTH : 4.1-~ 4.8
TYPE : SEDIMENT
HTO : 3 ± 2

HOLE NO. : 82-3C
RSL NO. : 634024
DEPTH : ~ 4.8-~ 5.5
TYPE : SEDIMENT
HTO : 4 ± 2
232-TH : 14.9 ± 1.2
226-RA : 9.6 ± 1.5
137-CS : <0.3
60-CO : <0.5
40-K : 268 ± 19

HOLE NO. : 82-3C
RSL NO. : 634025
DEPTH : ~ 5.5-6.2
TYPE : SEDIMENT
HTO : 3.3 ± 1.9

HOLE NO. : 82-3C
RSL NO. : 634026
DEPTH : 6.0-8.3
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-3C
RSL NO. : 624017
DEPTH : 6.3-6.9
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-3C
RSL NO. : 624018
DEPTH : 9.0-9.5
TYPE : SEDIMENT
HTO : <1.8

HOLE NO. : 82-3C
RSL NO. : 624019
DEPTH : 10.1-10.7
TYPE : SEDIMENT
HTO : <1.7

```
HOLE NO. : 82-3C
     RSL NO. : 624020
     DEPTH : 12.1-12.7
     TYPE : SEDIMENT
     HTO : 1.9 ± 1.7

HOLE NO. : 82-3C
     RSL NO. : 624022
     DEPTH : 22.0-22.5
     TYPE : SEDIMENT
     HTO : <1.5
     232-TH : 10.0 ± 0.9
     226-RA : 11.1 ± 2.3
     137-CS : <0.4
     60-CO : <0.4
     GALPHA : 244 ± 16

HOLE NO. : 82-3C
     RSL NO. : 624023
     DEPTH : 34.5-35.0
     TYPE : SEDIMENT
     HTO : <1.5

HOLE NO. : 82-3C
     RSL NO. : 634027
     DEPTH : 35.0-~ 35.3
     TYPE : SEDIMENT
     HTO : <2

HOLE NO. : 82-3C
     RSL NO. : 634028
     DEPTH : ~ 35.3-~ 35.7
     TYPE : SEDIMENT
     HTO : <2

HOLE NO. : 82-3C
     RSL NO. : 634029
     DEPTH : ~ 35.7-36.0
     TYPE : SEDIMENT
     HTO : <2

HOLE NO. : 82-3C
     RSL NO. : 624024
     DEPTH : 45.0-45.5
     TYPE : SEDIMENT
     HTO : <1.2

HOLE NO. : 82-3C
     RSL NO. : 624025
     DEPTH : 53.8-56.0
     TYPE : SEDIMENT
     HTO : <1.2

HOLE NO. : 82-3D
     RSL NO. : 624050
     DEPTH : 73.0-73.5
     TYPE : SEDIMENT
     HTO : <1.2
     232-TH : 11.6 ± 0.9
     226-RA : 10.3 ± 1.3
     137-CS : <0.3
     60-CO : <0.4
     40-K : 262 ± 16

HOLE NO. : 82-3D
     RSL NO. : 624049
     DEPTH : 76.5-77.0
     TYPE : SEDIMENT
     HTO : <1.2

HOLE NO. : 82-4A2
     RSL NO. : 634095
     TYPE : WATER
     HTO : 5 ± 2
     GALPHA : <0.1
     G BETA : 0.14 ± 0.06

HOLE NO. : 82-4A2
     RSL NO. : 634095
     TYPE : WATER
     HTO : 5 ± 2

HOLE NO. : 82-4A3
     RSL NO. : 634094
     TYPE : WATER
     HTO : 5 ± 2
     GALPHA : 0.14 ± 0.11
     G BETA : 0.08 ± 0.04

HOLE NO. : 82-4A3
     RSL NO. : 634094
     TYPE : WATER
     HTO : 5 ± 2

HOLE NO. : 82-4A
     RSL NO. : 634093
     TYPE : WATER
     HTO : 4 ± 2

HOLE NO. : 82-4A
     RSL NO. : 634093
     TYPE : WATER
     HTO : 4 ± 2
     90-SR : <0.8
     232-TH : <5
     226-RA : <2
     137-CS : <1.6
```

60-CO : <1.4
40-K : <30

HOLE NO. : 82-4A
RSL NO. : 624001
DEPTH : 12.5
TYPE : WATER
HTO : 4 ± 2

HOLE NO. : 82-4C
RSL NO. : 634031
DEPTH : ~ 1.1-2.1
TYPE : SEDIMENT
HTO : 3 ± 2

HOLE NO. : 82-4C
RSL NO. : 634030
DEPTH : 0.0- ± 1.1
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 634096
DEPTH : 3.6-36.9
TYPE : SEDIMENT
HTO : <2
90-SR : <0.09
238-PU : <0.09
239-PU : <0.12
232-TH : 12.2 ± 0.9
226-RA : 9.5 ± 1.2
137-CS : <0.3
60-CO : <0.4
40-K : 257 ± 17

HOLE NO. : 82-4C
RSL NO. : 634096
DEPTH : 3.6-36.9
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 634032
DEPTH : 9.2-~ 9.7
TYPE : SEDIMENT
HTO : 8 ± 2

HOLE NO. : 82-4C
RSL NO. : 634033
DEPTH : ~ 9.7-~ 10.2
TYPE : SEDIMENT
HTO : 7 ± 2

HOLE NO. : 82-4C
RSL NO. : 634034
DEPTH : ~ 10.2-~ 10.6
TYPE : SEDIMENT
HTO : 8 ± 2

HOLE NO. : 82-4C
RSL NO. : 624026
DEPTH : 10.6-11.1
TYPE : SEDIMENT
HTO : 8.5 ± 1.9
90-SR : <0.2
238-PU : <0.03
239-PU : <0.04
234-U : 0.87 ± 0.12
235-U : 0.04 ± 0.02
238-U : 1.00 ± 0.13
232-TH : 14.6 ± 1.1
226-RA : 9.0 ± 1.4
137-CS : <0.3
60-CO : <0.4
40-K : 247 ± 18

HOLE NO. : 82-4C
RSL NO. : 634036
DEPTH : 11.2-~ 11.6
TYPE : SEDIMENT
HTO : 8 ± 2

HOLE NO. : 82-4C
RSL NO. : 634037
DEPTH : ± 11.6-12.0
TYPE : SEDIMENT
HTO : 9 ± 2

HOLE NO. : 82-4C
RSL NO. : 634067
DEPTH : 12.0-12.5
TYPE : SEDIMENT
HTO : 4.5 ± 1.8

HOLE NO. : 82-4C
RSL NO. : 634068
DEPTH : 12.5-13.0
TYPE : SEDIMENT
HTO : 4.0-1.9

HOLE NO. : 82-4C
RSL NO. : 624027
DEPTH : 13.0-13.5
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-4C
RSL NO. : 624028

DEPTH : 15.0-15.5
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-4C
RSL NO. : 624029
DEPTH : 17.5-18.0
TYPE : SEDIMENT
HTO : <1.6

HOLE NO. : 82-4C
RSL NO. : 624030
DEPTH : 21.0-21.5
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-4C
RSL NO. : 624031
DEPTH : 25.0-25.5
TYPE : SEDIMENT
HTO : <1.06

HOLE NO. : 82-4C
RSL NO. : 624032
DEPTH : 33.3-33.9
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-4C
RSL NO. : 634038
DEPTH : 34.0- ± 34.5
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 634039
DEPTH : ~ 34.5-~ 35.0
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 634040
DEPTH : ~ 35.0-~ 35.5
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 634041
DEPTH : ~ 35.5-36.0
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-4C
RSL NO. : 624033

DEPTH : 45.0-45.5
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-4C
RSL NO. : 624034
DEPTH : 48.5-49.0
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-5C
RSL NO. : 634071
DEPTH : 0.5-1.0
TYPE : SEDIMENT
HTO : 4.8 ± 1.9

HOLE NO. : 82-5C
RSL NO. : 634073
DEPTH : 1.5-2.0
TYPE : SEDIMENT
HTO : 5.9 ± 1.9

HOLE NO. : 82-5C
RSL NO. : 634042
DEPTH : 2.2-~ 2.9
TYPE : SEDIMENT
HTO : 8 ± 2

HOLE NO. : 82-5C
RSL NO. : 634043
DEPTH : ~ 2.9-~ 3.5
TYPE : SEDIMENT
HTO : 9 ± 2

HOLE NO. : 82-5C
RSL NO. : 634044
DEPTH : ~ 3.5-4.2
TYPE : SEDIMENT
HTO : 7 ± 2

HOLE NO. : 82-5C
RSL NO. : 634045
DEPTH : 4.2-~ 4.9
TYPE : SEDIMENT
HTO : 7 ± 2

HOLE NO. : 82-5C
RSL NO. : 634046
DEPTH : ~ 4.9-~ 5.5
TYPE : SEDIMENT
HTO : 5 ± 2

HOLE NO. : 82-5C
RSL NO. : 624035

```
    DEPTH : 5.2-5.7
    TYPE : SEDIMENT
    HTO : 5.4 ± 1.9
    90-SR : <0.15
    238-PU : <0.04
    239-PU : <0.05
    234-U : 0.97 ± 0.11
    235-U : .031 ± .015
    238-U : 1.0 ± 0.11
    232-TH : 11.0 ± 0.9
    226-RA : 10.0 ± 1.3
    137-CS : <0.3
    60-CO : <0.4
    40-K : 253 ± 17

HOLE NO. : 82-5C
    RSL NO. : 634047
    DEPTH : ~ 5.5-6.2
    TYPE : SEDIMENT
    HTO : 6 ± 2

HOLE NO. : 82-5C
    RSL NO. : 634074
    DEPTH : 6.1-6.6
    TYPE : SEDIMENT
    HTO : 11 ± 2

HOLE NO. : 82-5C
    RSL NO. : 624036
    DEPTH : 6.6-7.1
    TYPE : SEDIMENT
    HTO : 7.5 ± 1.9

HOLE NO. : 82-5C
    RSL NO. : 634076
    DEPTH : 7.6-8.1
    TYPE : SEDIMENT
    HTO : 13 ± 2

HOLE NO. : 82-5C
    RSL NO. : 634077
    DEPTH : 8.0-8.5
    TYPE : SEDIMENT
    HTO : 7.5 ± 1.9

HOLE NO. : 82-5C
    RSL NO. : 624037
    DEPTH : 8.5-9.0
    TYPE : SEDIMENT
    HTO : 7.5 ± 1.9

HOLE NO. : 82-5C
    RSL NO. :.634078
    DEPTH : 9.0-9.5
    TYPE : SEDIMENT
    HTO : <2

HOLE NO. : 82-5C
    RSL NO. : 634079
    DEPTH : 9.5-10.0
    TYPE : SEDIMENT
    HTO : 8.7 ± 1.9

HOLE NO. : 82-5C
    RSL NO. : 624038
    DEPTH : 10.5-11.0
    TYPE : SEDIMENT
    HTO : 4.1 ± 1.8

HOLE NO. : 82-5C
    RSL NO. : 634082
    DEPTH : 11.5-12.0
    TYPE : SEDIMENT
    HTO : 8.6 ± 1.9

HOLE NO. : 82-5C
    RSL NO. : 624039
    DEPTH : 12.5-13.0
    TYPE : SEDIMENT
    HTO : 6.4 ± 1.9

HOLE NO. : 82-5C
    RSL NO. : 634085
    DEPTH : 13.5-14.0
    TYPE : SEDIMENT
    HTO : 2.9 ± 1

HOLE NO. : 82-5C
    RSL NO. : 634065
    DEPTH : 13.5-14.0
    TYPE : SEDIMENT
    HTO : 2.9 ± 1.8

HOLE NO. : 82-5C
    RSL NO. : 634086
    DEPTH : 13.9-14.4
    TYPE    : SEDIMENT
    HTO : <1.7

HOLE NO. : 82-5C
    RSL NO. : 634086
    DEPTH : 13.9-14.4
    TYPE : SEDIMENT
    HTO : <1.7

HOLE NO. : 82-5C
    RSL NO. : 634087
    DEPTH : 14.4-14.9
```

TYPE : SEDIMENT
HTO : <1.6

HOLE NO. : 82-5C
RSL NO. : 634087
DEPTH : 14.4-14.9
TYPE : SEDIMENT
HTO : <1.6

HOLE NO. : 82-5C
RSL NO. : 634089
DEPTH : 15.4-15.9
TYPE : SEDIMENT
HTO : 1.6

HOLE NO. : 82-5C
RSL NO. : 624040
DEPTH : 16.4-16.9
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-5C
RSL NO. : 634092
DEPTH : 17.4-17.9
HTO : SEDIMENT
GALPHA : <0.1
G BETA : 0.16 ± 0.06

HOLE NO. : 82-5C
RSL NO. : 624041
DEPTH : 24.5-25.0
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-5C
RSL NO. : 634048
DEPTH : 29.9-~ 30.5
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-5C
RSL NO. : 624042
DEPTH : 30.5-31.0
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-5C
RSL NO. : 634049
DEPTH : ~ 30.5-~ 31.2
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-5C
RSL NO. : 634050
DEPTH : ~ 31.2-31.8
TYPE : SEDIMENT
HTO : <2

HOLE NO. : 82-5C
RSL NO. : 624043
DEPTH : 34.5-35.0
TYPE : SEDIMENT
HTO : <1.6

HOLE NO. : 82-5C
RSL NO. : 624044
DEPTH : 39.55-40.05
TYPE : SEDIMENT
HTO : <1.7

HOLE NO. : 82-5C
RSL NO. : 624045
DEPTH : 41.1-41.7
TYPE : SEDIMENT
HTO : <1.7
232-TH : 13.1 ± 1.5
226-RA : 9.8 ± 1.8
137-CS : <0.4
60-CO : <0.6
40-K : 230 ± 20

HOLE NO. : 82-5C
RSL NO. : 624046
DEPTH : 42.3-42.8
TYPE : SEDIMENT
HTO : <1.7

Appendix D. Report on the Fall 1982 Drilling Project.

This section is a self-contained report on drilling done in the fall of 1982. This report was completed before the drilling projects of 1983 began, and also before some of the radionuclide analyses by RSL had been completed. This report provides detailed information on drilling, sampling, and well completion procedures including installation of piezometers. Refer to Appendices A, B, and C for complete data. In this report, the contents of Appendices A and B have been removed, in the interests of saving space, but the explanations have been retained. Use these explanations for the data now contained in Appendices A and B of the main report.

REPORT OF THE 1982 COOPERATIVE DRILLING PROJECT AT THE WESTERN NEW YORK NUCLEAR SERVICE CENTER WEST VALLEY, NEW YORK

Prepared by S.M. Potter, J.R. Albanese, S.L. Anderson,
L.F. Whitbeck

New York State Geological Survey/State Museum
New York State Education Department

Prepared for the U.S. Nuclear Regulatory Commission

ABSTRACT

The NYSGS-USGS cooperative drilling program of fall 1982 installed 17 test holes adjacent to the U.S. Nuclear Regulatory Commission-licensed burial area at the Western New York Nuclear Service Center (WNYNSC) near West Valley, New York. The program was part of a continuing effort to define the geology and subsurface hydrology, and to examine the possibility of radioisotope migration at the WNYNSC. Test holes 15.2, 12.2 and 6.2 m (50, 40, and 20 ft) deep were drilled in five clusters around the burial area, and deeper holes, 26.8 and 28 m in depth (88 and 92 ft), were drilled at its western and southern borders. This report presents lithologic descriptions and preliminary geologic interpretations of the cores obtained. Further work with these samples is planned to refine the understanding of the site stratigraphy and hydrology. Results of tritium analyses of core and water samples are also presented. Concentrations of tritium are below detectable limits except near the surface, within weathered sediment. Additional radioisotope analyses will be performed. The holes were finished as piezometers, and water levels within them will be used to extend the hydrologic model, developed by the USGS, of the adjacent New York State-licensed burial area, into the area of the USNRC burial pits.

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ACKNOWLEDGEMENTS

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We also wish to thank WVNS for providing site access and health physics protection during this investigation.

All radiochemical analyses were performed under contract by the Radiological Sciences Laboratory of the New York State Department of Health.

LIST OF ABBREVIATIONS

ft	feet
cm	centimeter
m	meter
ID	inner diameter
OD	outer diameter
uCi/ml	microcuries per milliliter
PVC	polyvinyl chloride
NYSDOH	New York State Department of Health
NYSGS	New York State Geological Survey
RSL	Radiological Sciences Laboratory of the New York State Department of Health
USGS	United States Geological Survey, Water Resources Division
USNRC	United States Nuclear Regulatory Commission
WNYNSC	Western New York Nuclear Service Center
WVNS	West Valley Nuclear Services, Inc.

1.0 Introduction

The Western New York Nuclear Service Center (WNYNSC), near West Valley in Cattaraugus County, New York, has been the subject of a cooperative study involving the New York State Geological Survey (NYSGS) and U.S. Geological Survey (USGS) Water Resources Division, since 1976. The major objective of this continuing study is to define the geologic and hydrologic processes operating at the site.

The WNYNSC contains facilities for processing and isolating radioactive material: 1) a commercial nuclear fuel reprocessing plant, which operated from 1966 through 1972; 2) a storage pool for spent fuel rods; 3) underground storage tanks containing 560,000 gallons of liquid high-level waste; 4) a commerical burial area for low-level solid waste, licensed by the State of New York, last used in 1975; and 5) a burial area for solid waste, primarily generated in the plant, licensed by the USNRC.

Most of the prior studies by the NYSGS and USGS at this site have concentrated on the State-licensed burial area, but the 1982 cooperative drilling program was part of a recent expansion of studies to other parts of the security area. The program was designed to obtain sediment core samples and water samples, and to install piezometers. The core samples were primarily used for describing the detailed stratigraphy. The initial descriptions and some preliminary geologic interpretations are included in this report. Some cores were extracted with Shelby tubes and will be used by the USGS for geotechnical analyses. Several core samples, and the few water samples obtained during drilling, were analyzed for tritium by the Radiological Sciences Laboratory (RSL) of the New York State Department of Health. These results are included in this report. Additional analyses for other radioisotopes are planned. Water level records from the piezometers will be used by the USGS to extend a mathematical hydrologic model, calibrated for the State-licensed burial area, westward across the USNRC-licensed burial area.

2.0 Locations

A drilling rig owned by the USGS was used to drill seventeen holes around the USNRC- licensed burial area, all of them less than 30.5 m (100 ft) deep because of the physical limitations of the rig and the drilling technique. These holes were in five clusters, as shown in Figure 1, which also shows the topography of the area, including branches of a small tributary around the northeast corner of the burial

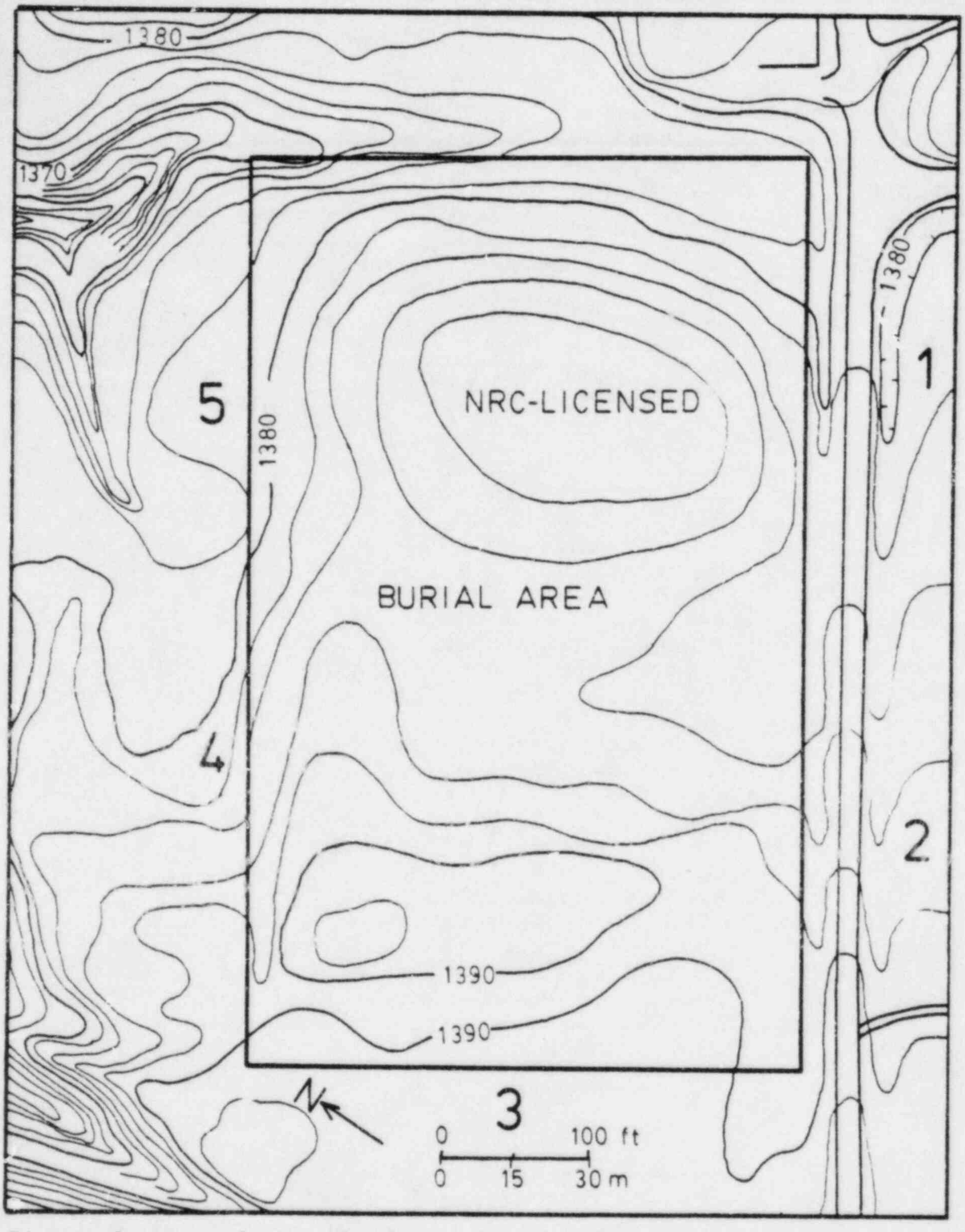

Figure 1. Map of the NRC-licensed burial area, as shown on Plate 1. The numbers show the locations of the five clusters of holes drilled by the USGS rig in fall 1982, with topography and roads.

area. The NYS-licensed burial area is to the north east, just beyond the upper edge of this map.

Each cluster contained three or four holes, as shown in Figure 2. Each hole was assigned a code number, such as "82-3A". The "82" refers to the year of drilling, the "-3" designates the cluster, and the "A" indicates the general depth. The "A" holes are all approximately 6.1 m (20 ft) deep, "B" holes 12.2 m (40 ft), "C" holes 15.2 m (50 ft), and two "D" holes 27.4 m (90 ft). The D holes were deepened in the spring of 1983. The locations and depths at the end of the fall 1982 project are shown in Figure 2.

The depth ranges for the A, B, C, and D holes were somewhat arbitrarily chosen, but specific depths were adjusted to take advantage of any sandy or silty layers for installation of piezometers. The C holes, which were continuously cored, were intended to sample the full thickness of the material penetrated by the deepest burial pits in the USNRC-licensed burial area.

3.0 Objectives

The cooperative drilling program had several objectives related to the geologic and hydrologic interests of the two Surveys. Continuous coring to 15.2 m (50 ft) in the C holes provided a detailed record of the character of the burial medium (Lavery till) down to the approximate depth of the deepest burial pits in the USNRC-licensed burial area, with holes distributed on three sides of the burial area. The two deeper D holes were cored from 15.2 m (50 ft) to approximately 27.4 m (90 ft) in order to examine materials that would be expected to extend under the burial area, and to attempt to locate and sample units known to be beneath the Lavery till. As described in Albanese and others (1982), the next distinct unit down consists of sand and sandy silt, possibly deposited as kame deltas. Beneath are interlayered proglacial(?) lacustrine clays and silts. Both units were probably deposited late in or shortly after the time of Kent glaciation. Below these lacustrine units is the Kent(?) till, another silty-clayey till similar to the Lavery. These pre-Lavery units have been identified in deep holes elsewhere on the site. The kame delta sand unit, in particular, may be important in the hydrology of the area, and has been recognized at depths of 15.2 to 30.5 m (50 to 100 ft) on the site.

The sixteen piezometers installed during the project are being used by the USGS to determine piezometric head in the vicinity of the USNRC-licensed burial area. They will also be used for pumping tests of field permeability, when the

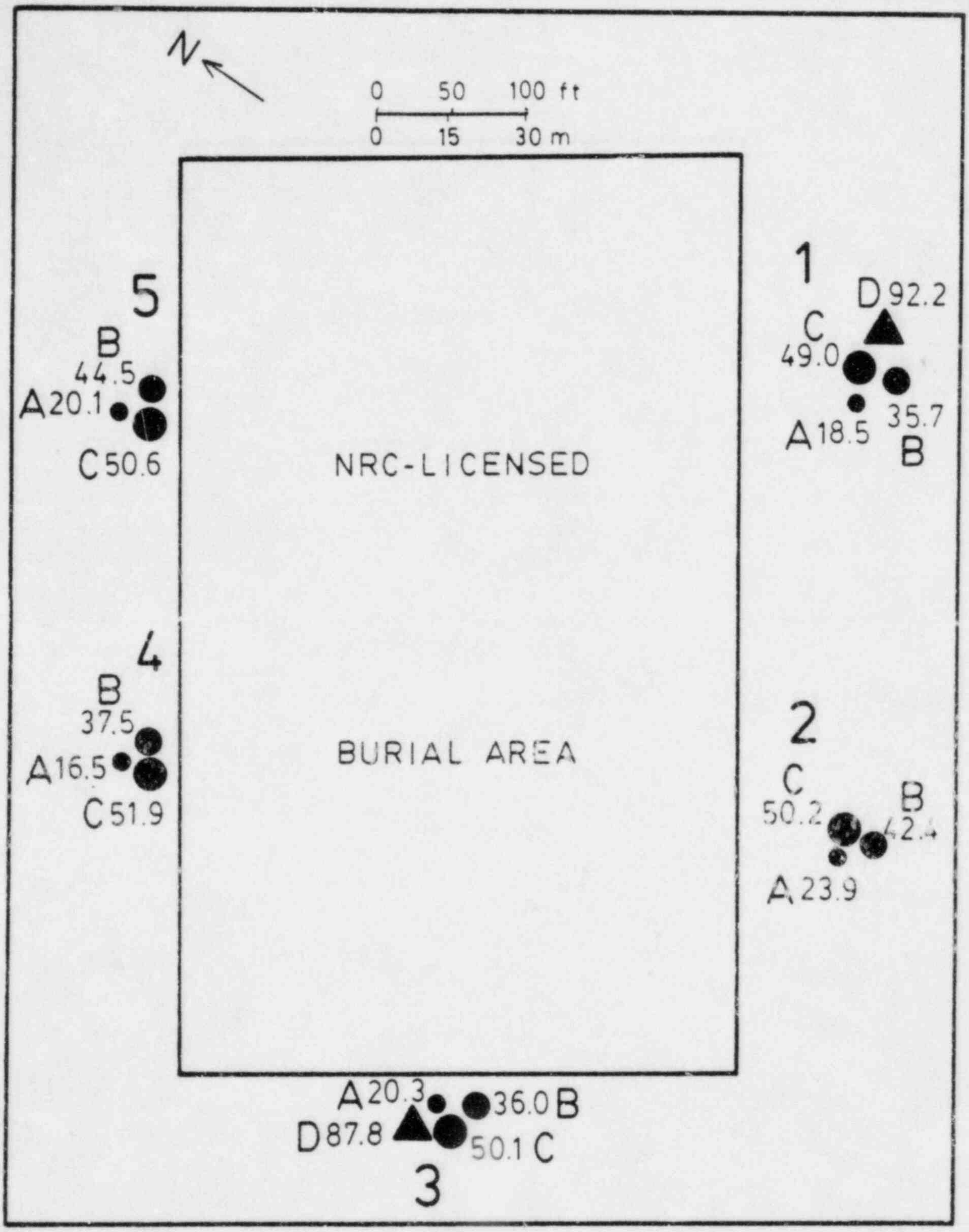

Figure 2. Map of the NRC-licensed burial area showing locations and depths (in feet) of holes drilled in the 1982 program. Cluster numbers are the same as on Fig. 1. Holes with approximately the same depth have the same letter and are shown with the same symbol.

water levels reach stability. The data from the piezometers will be used to extend the hydrologic model developed by the USGS for the New York State-licensed burial area westward across the USNRC-licensed burial area. This model can then be used to estimate migration rates of groundwater in the area.

Selected cores, and the few water samples obtained, were sent to the RSL. Tritium analyses have been performed, and other isotopes also will be examined. The objective in this case was to determine whether soluble radionuclides from the burial area have migrated in the subsurface.

A few cores were obtained from the shallower A and B holes using Shelby tube samplers. The tubes were sealed and capped as soon as they were removed from the holes in order to preserve water content. These samples will be used by the USGS for tests of permeability and porosity and other geotechnical characteristics that can be used in the groundwater model.

4.0 Drilling Techniques

In each cluster the first hole drilled was the C hole. The procedure, described in detail below, involved driving steel casing, then driving a 6.4 cm (2.5 inch) diameter split spoon sampler ahead of the casing in 0.6 m (2 ft) increments. For the two deep D holes, the upper 15.2 m (50 ft) were drilled with a 1.8 cm (6 inch) diameter, hollow-stem power auger. A casing was lowered into the hole, and then the coring-casing technique used in the C holes was used for the remaining 15.2 m (50 ft). The short A and B holes were drilled with the power auger to nearly the planned depth, then the coring-casing technique was used for the last meter or so in order to obtain records of materials present at the depths at which the piezometers were installed.

In detail, the coring-casing technique consisted of three main steps, repeated for every 0.6 m (2 ft) of advance, as shown in Figure 3, parts 1 through 3 and again in 4 through 6:

1) A coring device was driven to obtain a soil sample 0.6 m (2 ft) ahead of driven steel flush-joint casing. The casings sizes used were NW: (7.6 cm (3 inch) inner diameter (ID) by 8.9 cm (3-1/2 inch) outer diameter (OD)); BW: (6 cm (2-3/8 inch) ID by 7.3 cm (2-7/8 inch) OD), and AW (4.8 cm (1-29/32 inch) ID by 5.7 cm (2-1/4 inch) OD). Sampling was done with a 5.1 cm (2 inch) ID by 6.4 cm (2-1/2 inch) OD split spoon sampler within

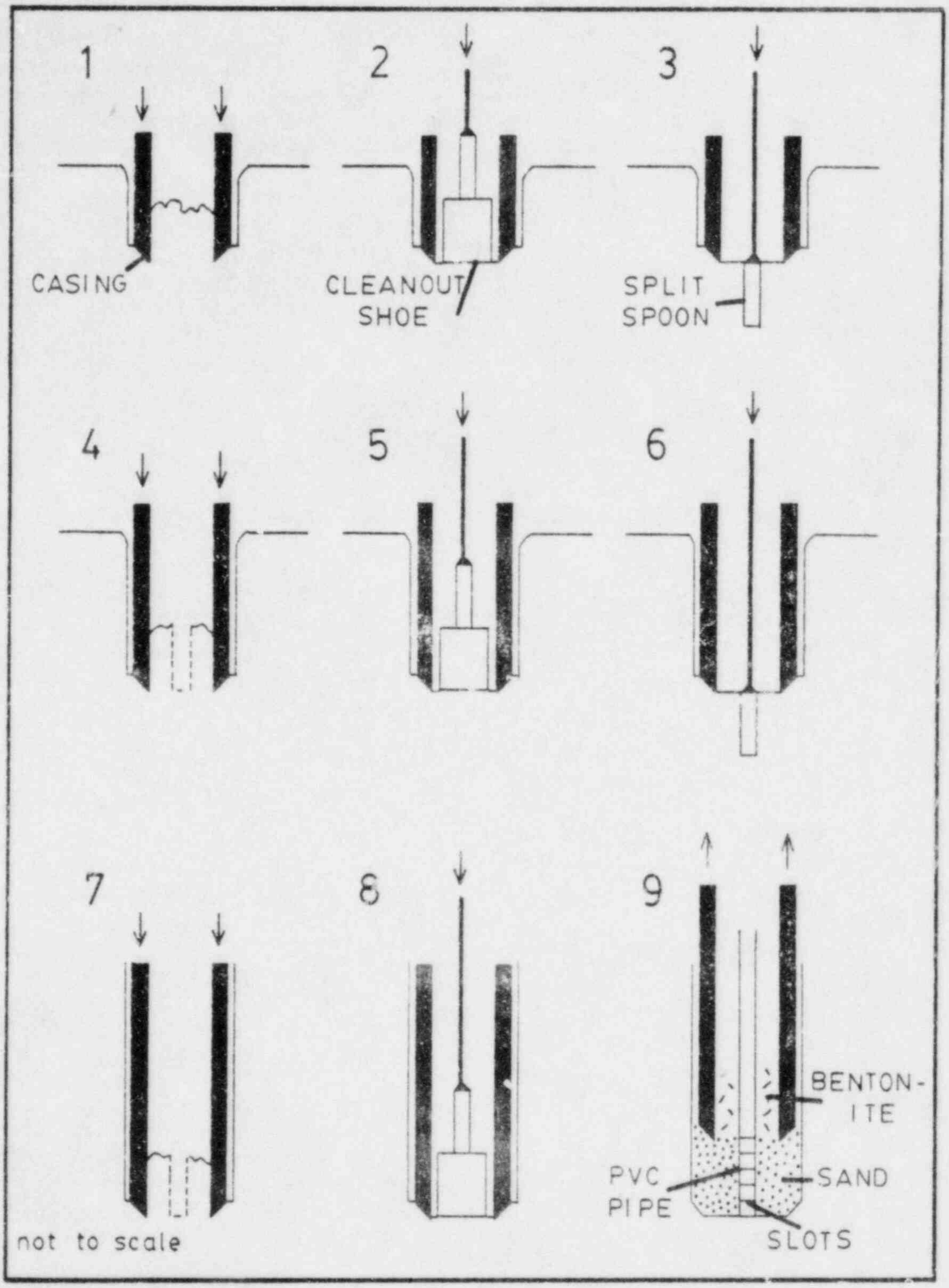

Figure 3. Steps in drilling procedure for continuously cased holes in the 1982 program, shown in successive cross-sections. In practice, there is no space between the casing and the soil wall of the hole, but one is shown here in order to emphasize the position of the casing.

the NW casing, or a 3.8 cm (1-1/2 inch) ID by 4.4 cm (1-3/4 inch) OD Shelby tube sampler within the AW casing.

2) Following the core sampling, the steel flush-joint casing was driven to the bottom of the cored interval.

3) The hole was then cleaned out with the coring device used in the core sampling. Within the BW casing, a special cleanout shoe built up to a 5.7 cm (2-1/4 inch) OD was used in place of the normal drive shoe of the 5.1 cm (2 inch) OD split spoon sampler for the cleanout step.

This sequence was repeated down the hole by advancing the steel casing 0.6 m (2 ft) to the depth to which the split-spoon had last been advanced. The process is slow, particularly in dense Lavery till, and the maximum depth possible with the USGS rig was found to be less than 30.5 m (100 ft). However, this procedure provided undisturbed, uncontaminated, continuous cores. The power auger was used whenever cores were not required, in order to save time and to penetrate deeper, in the case of the D holes.

5.0 Well Finishing

Piezometers were installed in all tes holes drilled except one. Test hole 82-1D was temporarily capped after a portion of a Shelby tube sampler was lost in the hole at a depth of about 28.3 m (93 ft).

For test holes drilled primarily with the coring-casing technique, piezometers were installed using the following procedures:

1) After the casing was driven to the target depth and the hole was properly cleaned out, a piezometer consisting of a length of 2.5 cm (1 inch) ID PVC flush-joint pipe was lowered into the hole. The bottom 0.6 m (2 ft) of the pipe was slotted at 5.1 cm (2 inch) intervals and wrapped with fine mesh polypropylene gauze. The bottom end was capped.

2) The pipe was held in place while a sand envelope was poured into the hole to cover the slotted portion of the pipe.

3) The driven casing was then pulled back to expose the sand envelope and slotted pipe to the formation materials.

4) Bentonite was poured in between the PVC pipe and the metal casing, on top of the sand envelope.

For test holes drilled with the power auger technique, the following steps were used:

1) After the target depth was reached, the entire string of augers was pulled from the hole.

2) A piezometer as described above was lowered to the bottom of the hole and held in place while a sand envelope was poured into the hole to cover the slotted portion of the pipe.

For the continuously cased test holes (C-holes), bentonite was poured down the hole between the PVC pipe and the casing, extending 0.6 to 1.5 m (2 to 5 ft) above the sand. Non-shrink cement grout was then poured in up to the surface of the hole. For the power augered A and B holes, the casing was pulled up to 1.5 m (5 ft) from the surface, sand was poured in covering the slotted portion of the PVC pipe, and bentonite over this, filling the hole up to the bottom of the casing. At the top, the spaces between the PVC pipe and the casing and between the casing and the soil were filled with cement grout.

The PVC pipe was cut off near the surface so that it does not extend above the top of the steel casing. The casing was covered with a PVC cap, which can be removed for taking water level measurements or drawing samples. A diagram of a finished well for a C hole is shown in Figure 4.

6.0 On-Site Radioactivity Monitoring

Special precautions were taken to protect the health and safety of the drilling crew and to minimize the chances of contamination in the holes and on the surface. All of the holes were outside of the USNRC-licensed burial area at positions agreed upon by USGS, NYSGS, and West Valley Nuclear Services, Inc. (WVNS), the site operator. Before drilling, each site was surveyed for surface contamination and then roped off. Only personnel directly associated with the drilling operation were allowed inside the roped area. A portable shelter was located at the single entry point; anyone leaving the area was required to stop in the shelter and use a hand-held Geiger-Muller meter to check for radioactive contamination on clothing and equipment.

The drilling and completion techniques were designed to minimize spreading contamination into or out of the holes.

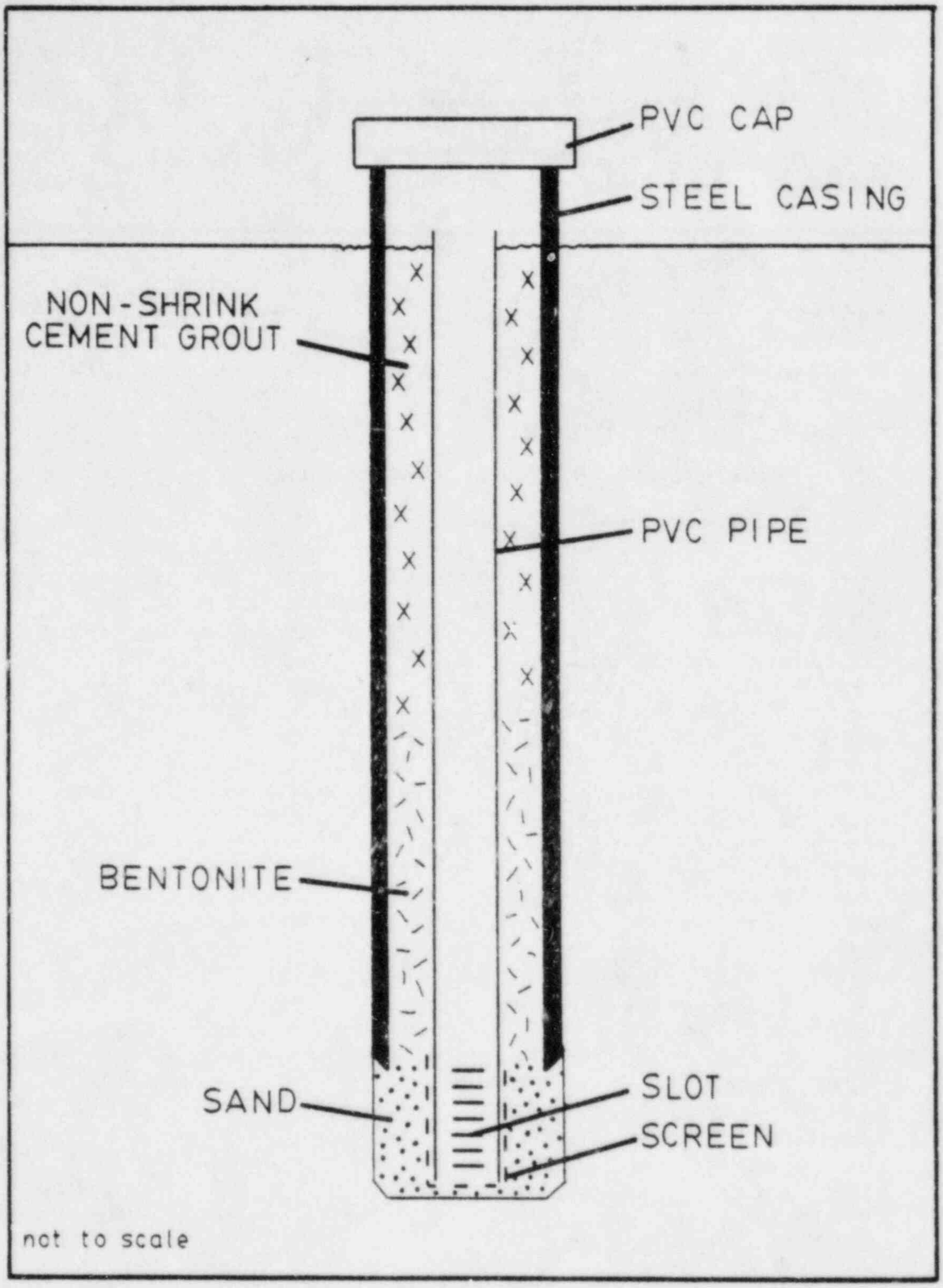

Figure 4. Cross-section of a typical continuously cased hole (C-hole), finished with a piezometer. The bentonite extends 2 to 5 feet (.61 to 1.5 m) above the bottom of the metal casing. See text for procedures for finishing A, B and D holes.

No water or circulating mud was added to the holes, and all samples and cleanout materials were kept inside the roped area until checked for radioactivity. The coring-casing technique was adapted from that developed by the USGS for use in 1977 on holes drilled through the burial trenches in the New York State-licensed burial area (Prudic, 1978).

A qualified Environmental and Occupational Technician, David Biela, from the WVNS staff, was present during drilling to supervise special handling of samples and equipment; in addition, the drilling crew and geologists were required to pass an examination on radioactive safety. All samples brought up out of the holes were examined for radioactivity by the technician before they were passed to the geologists for photographing, logging, labeling, and packaging.

7.0 Handling and Distribution of Samples

Several different types of samples were obtained to serve various purposes. The graphic logs show which organizations received what samples (Appendix B).

Approximately 97.5 linear m (320 linear ft) of split-spoon cores were obtained. As each section of core was removed from the hole, it was extracted from the sampler, photographed, and described in detail by Marcel Bergeron (USGS) and Steven Potter (NYSGS). Their logs are the basis for stratigraphic studies of the burial till and underlying units penetrated in these holes. Most of these samples were wrapped in thick plastic, labeled, and put in cardboard boxes. Those samples that have not been used for other purposes are currently stored at the NYSGS in Albany, NY. Stratigraphic information will be added to that from earlier holes and used to improve our knowledge of the site geology. Results of these studies will be included in the final report to the USNRC from the NYSGS.

Some core samples from the C holes were packaged differently. Sections approximately 15.2 m (6 inches) long were taken at 1.5 to 3 meter (5 to 10 foot) intervals, or at any point where coarser material, such as silty sand, was encountered. These samples were wrapped in aluminum foil, then plastic film, and placed in glass canning jars, with lids firmly screwed on. These samples were sent to the RSL in Albany, New York, for tritium analyses. The special handling was designed to minimize loss of water and to prevent contamination of the cores by water vapor at the site, which may be measureably higher in tritium than in the laboratories at the RSL. After the specially wrapped samples were analyzed, the Laboratory requested additional samples, particularly from the near-surface weathered zone. These samples came from the cores that were given normal handling, as described above. Control tests were done using samples adjacent to those already analyzed, including one sample from deep in each of the C holes, at depths at which the specially handled cores produced no detectable tritium. The less rigorously handled samples gave the same results so it appears that the latter were not significantly contaminated by surface air. The analytical procedures used were essentially the same as those used by RSL for samples drilled by the USGS and NYSGS in 1980, as described in Dana and others (1980).

Shelby tube samples were taken from several of the A and B holes for a total of 5.7 m (18.6 ft) of core. These were left in the tubes, capped, and sealed with paraffin. They will be sent to Empire Soils Investigations, Inc., in Groton, New York, for tests of permeability and porosity. Those values will then be used in the USGS hydrologic model for the USNRC burial area.

The site operator, WVNS, was given water samples for tritium analyses, and also some of the cleanout samples from the D holes. They plan to use them for their ongoing studies of site geology, and for comparison with results from the other laboratories involved.

Only two holes yielded significant amounts of water during the drilling operations, hole 82-4A at an elevation of 418.1 m (1371.78 ft), and hole 82-1C at elevations of 415.4 m (1363.0 ft) and 410.6 m (1347.24 ft). The RSL was given these initial water samples for tritium analyses. After water levels in the piezometers stabilize, the USGS has agreed to obtain more water samples for tritium analyses.

8.0 Preliminary Results

The most important results of the 1982 cooperative drilling program will develop as the data obtained is combined with information from other parts of the site to improve the conceptual and mathematical models of the geology and hydrology. Similarly, the usefulness of the piezometers comes from the records of water levels they will provide over time. At this time lithologic descriptions and some preliminary geologic interpretations are presented.

Detailed descriptions from the logs of split-spoon cores by Steven Potter (NYSGS), with additional material from logs by Marcel Bergeron (USGS), have been translated into the standardized format that was used for the logs of previous holes on the site in Albanese and others (1983). The standardized logs are in Appendix A. These logs were then used to draw the graphic columns in Appendix B, which are similar to the columns for several other holes in Albanese and others (1983). Additional information shown adjacent to the columns includes color, as an indication of weathering, distribution of samples to various laboratories, and the results of tritium analyses by the RSL. The tritium results are also shown in tabular form in Table 1.

Using the stratigraphic and radiologic data some preliminary interpretations have been developed. The burial medium in the USNRC burial area is Lavery till, predominantly composed of silt and clay, with minor gravel and scattered thin zones of silt and sand. This material is the same as that seen at comparable depths in holes elsewhere on the site, for example, in the numerous holes drilled by the USGS in and around the State-licensed burial area. The closely spaced holes in each cluster allowed evaluation of the lateral extent of relatively coarse zones within the Lavery till. In no case was it possible to trace a sandy or silty zone on a horizontal plane from one hole to another, even over a lateral distance of less than 1.5 m (5 ft) . This confirms observations made elsewhere of the Lavery till suggesting that included coarse-grained zones are pod-like or irregular in shape, rather than extensive horizontal layers.

The tritium analyses show that tritium in the unweathered Lavery till is at concentrations below detectable limits, less than 2E-7 microcuries per milliliter. Although not all the cores were measured, the data suggest that tritiated water from any buried waste has not migrated beyond the security fence via a subsurface pathway. The pattern of tritium levels in the weathered till is somewhat different from the patterns seen in holes near the north end of the New York State-licensed burial area (Prudic and Randall, 1979). There the tritium levels were highest within 1.5 m (5 ft) of the surface and then gradually declined within the weathered zone, down to the detection limit. As noted by Dr. John Matuszek of the NYS Department of Health, RSL, (pers. comm., 1983), with the exception of the upper 1.2 m (4 ft) of hole 82-1C, the tritium levels in the 1982 holes do not approach the highest levels seen in the earlier holes, and the levels are constant throughout the weathered zone, dropping to the detection limit only at the boundary between weathered and unweathered Lavery till.

The holes in Cluster 4 presented an anomaly that is currently being studied further by the USGS. Hole 82-4A was the only one that provided abundant water during the drilling operation, at a depth of less than 6.1 m (20 ft). The other holes in the cluster, even though they all penetrated the same depth, did not immediately provide

Table 1. Summary of tritium concentrations on samples obtained from the five 1982 "C" series holes. Approximate depths are given for cores that were cut into sections at RSL.

Hole 82-1C

DEPTH (below surface)		TRITIUM*
Meters	Feet	(μCi/ml E^{-7})
∿0 - .24	∿0 - 0.8	76 ± 4
∿.49 - .76	∿1.6 - 2.5	57 ± 3
∿1.03 - 1.25	∿3.4 - 4.1	10 ± 2
∿1.25 - 1.46	∿4.1 - 4.8	10 ± 2
∿1.46 - 1.77	∿4.8 - 5.8	10 ± 2
∿1.77 - 2.07	∿5.8 - 6.8	9 ± 2
∿2.07 - 2.35	∿6.8 - 7.7	7 ± 2
2.35 - 2.53	7.7 - 8.3	3.5 ± 1.8
∿2.53 - 2.65	∿8.3 - 8.7	4 ± 2
∿2.65 - 2.74	∿8.7 - 9.0	4.4 ± 1.9
∿2.74 - 2.90	∿9.0 - 9.5	<2
∿3.04 - 3.2	∿10.0 - 10.5	3.8 ± 1.8
4.75 - 4.88	15.6 - 16.0	<1.5
5.47 - 5.62	17.95 - 18.45	<1.5
7.61 - 7.25	23.3 - 23.8	<1.5
10.09 - 10.27	33.1 - 33.7	<1.5
11.52 - 11.7	37.8 - 38.4	<1.5
∿11.7 - 11.89	∿38.4 - 39.0	<2
13.26 - 13.41	43.5 - 44.0	<1.2
14.78 - 14.93	48.5 - 49.0	<1.2

* Tritium analyses performed by the Radiological Sciences Laboratory of the New York State Department of Health in Albany, N.Y.

Table 1. continued

Hole 82-2C

DEPTH (below surface) Meters	 Feet	TRITIUM* (µCi/ml E^{-7})
∿0 - .24	∿0.0 - 0.8	2.4 ± 1.6
∿.46 - .70	∿1.5 - 2.3	3.5 ± 1.8
∿.91 - 1.37	∿3.0 - 4.5	4 ± 2
∿1.37 - 1.83	∿4.5 - 6.0	4 ± 2
∿1.83 - 2.13	∿6.0 - 7.0	<2
∿2.13 - 2.44	∿7.0 - 8.0	<2
∿3.14 - 3.47	∿10.3 - 11.4	<2
3.87 - 4.05	12.7 - 13.3	<1.7
6.25 - 6.4	20.5 - 21.0	<1.5
6.7 - 6.89	22.0 - 22.6	<2
6.89 - 7.07	22.6 - 23.2	<1.5
8.23 - 8.38	27.0 - 27.5	<1.5
8.53 - 8.75	28.0 - 28.7	<1.5

* Tritium analyses performed by the Radiological Sciences Laboratory of the New York State Department of Health in Albany, N.Y.

Table 1. continued

Hole 82-3C

DEPTH (below surface)		TRITIUM*
Meters	Feet	(μCi/ml E^{-7})
~0 - .15	~0.0 - 0.5	2.6 ± 1.8
~.30 - .46	~1.0 - 1.5	4.5 ± 1.8
~.61 - .76	~2.0 - 2.5	5 ± 2
~.76 - .91	~2.5 - 3.0	6 ± 2
~.91 - 1.07	~3.0 - 3.5	4 ± 2
~1.07 - 1.25	~3.5 - 4.1	2.7 ± 1.9
~1.25 - 1.46	~4.1 - 4.8	3 ± 2
~1.46 - 1.68	~4.8 - 5.5	4 ± 2
~1.92 - 2.1	~6.3 - 6.9	<1.7
~2.1 - 2.53	~6.9 - 8.3	<2
2.74 - 2.90	9.0 - 9.5	<1.8
3.08 - 3.26	10.1 - 10.7	<1.7
3.69 - 3.87	12.1 - 12.7	1.9 ± 1.7
5.79 - 5.94	19.0 - 19.5	<1.5
6.7 - 6.86	22.0 - 22.5	<1.5
~10.36 - 10.52	~34.0 - 34.5	<2
10.52 - 10.67	34.5 - 35.0	<1.5
13.72 - 13.87	45.0 - 45.5	<1.2

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* Tritium analyses performed by the Radiological Sciences Laboratory of the New York State Department of Health in Albany, N.Y.

Table 1. continued

Hole 82-4C

DEPTH (below surface)		TRITIUM*
Meters	Feet	(μCi/ml E^{-7})
$\sim$0. - .3	$\sim$0.0 - 1.0	<2
$\sim$.3 - .64	$\sim$1.0 - 2.1	3 ± 2
$\sim$2.8 - 2.93	$\sim$9.2 - 9.6	8 ± 2
$\sim$2.93 - 3.02	$\sim$9.6 - 9.9	7 ± 2
$\sim$3.02 - 3.14	$\sim$9.9 - 10.3	8 ± 2
$\sim$3.14 - 3.23	$\sim$10.3 - 10.6	7 ± 2
3.23 - 3.38	10.6 - 11.1	8.5 ± 1.9
$\sim$3.41 - 3.54	$\sim$11.2 - 11.6	8 ± 2
$\sim$3.54 - 3.66	$\sim$11.6 - 12.0	9 ± 2
3.66 - 3.81	12.0 - 12.5	4.5 ± 1.8
3.96 - 4.11	13.0 - 13.5	<1.7
4.57 - 4.72	15.0 - 15.5	<1.7
5.33 - 5.49	17.5 - 18.0	<1.6
6.4 - 6.55	21.0 - 21.5	<1.7
7.62 - 7.77	25.0 - 25.5	<1.6
10.15 - 10.33	33.3 - 33.9	<1.7
10.36 - 10.52	34.0 - 34.5	<2
13.72 - 13.87	45.0 - 45.5	<1.7
14.78 - 14.93	48.5 - 49.0	<1.7

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* Tritium analyses performed by the Radiological Sciences Laboratory of the New York State Department of Health in Albany, N.Y.

Table 1. continued

Hole 82-5C

DEPTH (below surface)		TRITIUM*
Meters	Feet	(μCi/ml E^{-7})
~.15 - .3	0.5 - 1.0	4.8 ± 1.9
~.46 - .61	1.5 - 2.0	5.9 ± 1.9
~.67 - .88	2.2 - 2.9	8 ± 2
~.88 - 1.07	2.9 - 3.5	9 ± 2
~1.07 - 1.28	3.5 - 4.2	7 ± 2
~1.28 - 1.43	4.2 - 4.7	7 ± 2
~1.43 - 1.58	4.7 - 5.2	5 ± 2
1.58 - 1.74	5.2 - 5.7	5.4 ± 1.9
~1.74 - 1.89	5.7 - 6.2	6 ± 2
~1.86 - 2.01	6.1 - 6.6	11 ± 2
2.01 - 2.16	6.6 - 7.1	7.5 ± 1.9
~2.32 - 2.47	7.6 - 8.1	13 ± 2
~2.44 - 2.59	8.0 - 8.5	7.5 ± 1.9
~2.9 - 3.05	9.5 - 10.0	8.7 ± 1.9
3.2 - 3.35	10.5 - 11.0	4.1 ± 1.8
~3.51 - 3.66	11.5 - 12.0	8.6 ± 1.9
3.81 - 3.96	12.5 - 13.0	6.4 ± 1.9
4.11 - 4.27	13.5 - 14.0	2.9 ± 1.8
4.39 - 4.54	14.4 - 14.9	<1.6
4.69 - 4.85	15.4 - 15.9	<1.6
5.0 - 5.15	16.4 - 16.9	<1.7
7.47 - 7.62	24.5 - 25.0	<1.7
9.11 - 9.30	29.9 - 30.5	<2
9.30 - 9.45	30.5 - 31.0	<1.7
10.52 - 10.67	34.5 - 35.0	<1.6
12.07 - 12.19	39.6 - 40.0	<1.7
12.10 - 12.53	39.7 - 41.1	<1.7
12.89 - 13.04	42.3 - 42.8	<1.7

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* Tritium analyses performed by the Radiological Sciences Laboratory of the New York State Department of Health in Albany, N.Y.

water. Also, hole 82-4C encountered loose backfill to a greater depth than any of the other holes. WVNS staff recalled that a heavy piece of contaminated machinery was once buried near there in the USNRC burial area. Normally, the site operator excavated vertical holes and lowered waste packages into them, but in this case a wide ramp was excavated from the side of the burial area and the equipment was carried in on a grader. It may be that hole 82-4C was drilled into fill in this ramp, while the others in the cluster were not, and the surface water is seeping in and gradually filling up the hole and moving up the ramp. In any case, the water from hole 82-4C did not contain significant tritium.

Only two of the holes, 82-1D and 82-3D, extended through the Lavery till and into underlying units. Both encountered sand and layered silt and sand, probably part of the late or post-Kent kame delta and proglacial lacustrine lithology. In hole 82-1D the first sign of such material was at a depth of approximately 24.6 m (80.7 ft), and continued to the bottom of the hole at 28.1 m (92.2 ft). In hole 82-3D, lacustrine material was first recorded at a depth of approximately 22.6 m (74 ft) and continued to a depth of 25.6 m (84 ft). From there to the bottom of the hole at 26.8 m (87.8 ft) the lithologies appeared to alternate between till and lacustrine material, suggesting that the underlying Kent(?) till might have been encountered.

9.0 References

Albanese, J.R., Anderson, S.L., Dunne, L.A., and Weir, B.A. (1983). Geologic and Hydrologic Research at the Western New York Nuclear Service Center, West Valley, New York: Annual Report, August 1981-July 1982. Report to the U.S. Nuclear Regulatory Commission.

Albanese, J.R., Dunne, L.A., Rogers, W.B., and Potter, S.M., 1982. Geologic and Hydrologic Research at the Western New York Nuclear Service Center, West Valley, New York: Progress Report, August 1979-July 1981. Report to U.S. Nuclear Regulatory Commission, NUREG/CR-2381, 103 pp.

Dana, R.H., Jr., V.S. Ragan, S.A. Molello, H.H. Bailey, R.H. Fickies, R.H. Fakundiny, and V.C. Hoffman, 1980. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York, Low-Level Burial Site. Final Report, October 1978-February 1980. NYSGS Report to USNRC. NUREG/CR-1565.

Prudic, D.E., 1978. Installation of Water and Gas-Sampling Wells in Low-Level Radioactive Waste Burial Trenches, West Valley, New York. U.S. Geological Survey Open-File Report 78-718, 70 pp.

Prudic, D.E., and Randall, A.D., 1979. Ground-water Hydrology and Subsurface Migration of Radioisotopes at a Low-Level Solid Radioactive-Waste Disposal Site, West Valley, New York. in Carton, M.W., Moghissi, A.A., and Kahn, B. (eds.), Management of Low-Level Radioactive Waste, vol. II, p. 853-882.

APPENDIX A - Standardized Logs

Procedures for Standardization

Standardization of logs focused on factors that could be used to characterize and distinguish lithologic units and to define stratigraphic boundaries. The most important element is the description of the proportions of the grain sizes present. Another important element describes the degree of stratification of the unit, ranging from entirely homogeneous to entirely laminated. Additional information available from some of the logs describes deformation and continuity of layers, roundness of pebbles, composition of large clasts, and color as an indication of oxidation.

Intervals in the original logs were sometimes defined only as lithologic boundaries, but in other cases they represent separate samples. In the standardized logs, interval boundaries from the original logs have been retained, as well as additional depths indicated for any lithologic changes within those intervals. As a result, no interval in the standardized logs contains more than one distinct lithologic unit, but a single unit may continue down through several intervals that represent, for example, successive 0.6 m (2 ft) sections of core. All internal boundaries are stated as m of elevation above mean sea level.

Subintervals were used for cases in which the original log indicated the presence of a thin unit of different material at a specific depth or for a very small interval. On the standardized logs such subintervals are indicated by lines beginning with "at nnn m". Such subintervals were often used to indicate a distinct layer or change in lithology within a larger lithologic unit above and below. In a few cases, subintervals were used for a thin distinct lithology at the bottom of a larger lithologic unit.

Explanation of Standardized Format

Line 1

The first line of the description of an interval or subinterval is primarily a description of the grain sizes and volume proportions. In some of the intervals such a description was abbreviated in the original log by using a general genetic term, such as "till". In some cases this was followed by a more specific statement using grain size classes. In many instances, the grain size description stood alone. In the standardized logs, if a general genetic term was used, it appears as the first item in the first line for each interval or subinterval. "Till", "lacustrine", and "alluvium", are the three most common terms used. "Till" implies a homogeneous sediment consisting mainly of clay and silt, with some gravel or pebbles. "Lacustrine" implies layered sediment, primarily composed of clay and silt. "Alluvium" implies a relatively homogeneous material with a markedly higher proportion of gravel or pebbles than in till. Other general genetic terms found in the original logs and used in the standardized logs are "colluvium", "backfill", "organic material/soil", "bedrock", and "fluvial".

The grain size classes used in Line 1 are: "clay", "silt", "sand", "gravel/pebbles", and "angular rock fragments". The modifiers "fine", "medium", and "coarse", are included if they were specified in the original log. If two or more classes occur in approximately equal amounts then the classes are arbitrarily listed in order from fine to coarse. Otherwise, the order of grain size classes and uses of conjunctions indicate decreasing volume proportions. The matrix material is listed first in sediments with subordinate layers in a homogeneous matrix. Next in the list are the size classes making up the subordinate layers. If the sediment is entirely layered then this line begins with "as layers:" and the layers are listed after the colon, in order from fine to coarse.

The following conjunctions are used to indicate proportions in a homogeneous matrix or within an individual layer: "and", "with", "with rare", and "to". The examples below indicate their use for a material with two size classes:

A and B: the two size classes are present in approximately equal amounts, mixed together and arbitrarily listed from fine to coarse. In some cases this construction may have been used in the original logs without any intention of showing proportions, merely to list the classes present.

A with B: A is the dominant size class, and B is present in lesser amounts, but as more than a mere trace. The two classes are mixed together in the unit. In the original logs a form often used was "silty clay". In the standardized logs this is converted to "clay with silt", in order to place the most abundant class at the start of the list.

A, with rare B: A is by far the dominant size class, with B present only in small amounts. The two classes are mixed together. Equivalent statements in the original logs would be "trace", "very few", or "less than 5 percent".

A to B: part of the unit consists entirely of class A and part purely of B, with a transition from one to the other through all intermediate size classes. The change may be either vertical or lateral, but is most likely to be vertical in order to be seen in a core sample.

The following examples illustrate constructions used for three or more size classes in a homogeneous matrix or within a single layer:

A and B and C: all three are present in approximately equal amounts and mixed together.

A and B, with C: A and B are present in equal amounts and make up most of the sediment. C is present in a significant amount, but less than either A or B.

A and B, with rare C: A and B are present in equal amounts and make up nearly all of the sediment. C is present in only trace amounts. All three classes are mixed together.

A, with B and C: A is dominant, with lesser amounts of B and C, which are equal to each other. B and C are each present in significant amounts. All three classes are mixed together.

A, with rare B and C: A makes up nearly all of the sediment, with trace amounts of B and trace amounts of C. All three classes are mixed together.

A, with B, with C: A is dominant, with a lesser, but significant amount of B, and an even lesser amount of C, but still more than a trace. All three classes are mixed together.

A, with B, with rare C: A is dominant, with a lesser, but significant amount of B, and with only a trace of C. All three classes are mixed together.

Line 2

The second line of the description for each interval or subinterval concerns color, which can be an indication of the oxidation state in the sediments. Standard Munsell color codes were used in some of the USGS logs, but could not be created for the other logs in which the color description was much less specific. The second line for each interval in the standardized logs uses normal English to describe the colors, and the same constructions used in Line 1 are used here to indicate proportions.

Line 3

The third line of the description for each interval or subinterval was reserved for any information that could be used to characterize or distinguish the units but which did not fit in Line 1 or Line 2. Such information includes descriptions of deformation, continuity, or thickness of layers or blebs; degree of firmness; comments about oxidized or unoxidized portion; presence of fractures; occurrence of calcareous material, large cobbles, or shale fragments; and comments on the type or state of the sample used.

APPENDIX B - Graphic Columns

Construction of Stratigraphic Columns

Stratigraphic columns were drawn for the holes drilled during the 1982 Drilling Program. These columns were drafted in the standardized form using the same procedure as that used in Albanese and others (1983).

The heading for each column contains the name of the hole, the name of the person who logged the core on-site, the year of the drilling, and the elevation of the ground surface above sea level in both meters and feet.

The center section of each column contains a graphic representation of the grain sizes present at each level and their volume proportions. The numbers to the left are depths below the surface in meters, and the vertical scale is 1:50. A scale in feet is included on the far left-hand side of the sheet.

Straight horizontal lines across the graphic columns correspond with the interval boundaries of the standardized logs. Where the boundaries are so close together that the grain size symbols would not fit in the space, interval boundaries are shown as pairs of line segments at the edges of the column. That same convention is used for subinterval boundaries.

In some of the standardized logs sediments were described only in general genetic terms, without any specific statement of grain sizes and proportions present. In these cases, the graphic columns contain letters abbreviating general genetic terms:

~ = organic material

B = backfill

The horizontal squiggle is used alone, as a general genetic term, or in combination with grain size class symbols to indicate organic materials. Other abbreviations used on the columns include:

PA = power augered

ST = Shelby tube sample

SS = split spoon sample

|| = no sample recovered

The following symbols for grain size classes were used:

clay = dashes

silt = small dots

sand = large dots

gravel/pebbles = open ovals

angular rock fragments = open triangles

For each size class, six patterns of different symbol densities were devised, (Figure 5). Combinations of these thirty patterns represent various proportions, as expressed verbally in the standardized logs. The patterns were superimposed to indicate proportions, rather like combining color correction filters in photography. The examples in Figure 6 show how the patterns were used to translate the standardized logs, using a simple code as an intermediate step. These examples are all homogeneous materials occupying an entire interval or a particular layer. Note that for "clay to silt" the graphic form shows the transition as lateral, usually with the fine material on the left. This representation is used when the original log did not specify the direction of the change, which may well be vertical in the hole.

If the standardized log specified a homogeneous matrix with subordinate layers, then the layers are shown at arbitrary positions within the unit. If the log specified "with rare layers", no more than one layer per centimeter is shown. In intervals described in the logs as entirely layered, each type of layer is shown at least once, at arbitrary depths.

The first vertical line to the right of the graphic column represents the color of that particular section of core. Most of the core is olive-gray, and those sections with a vertical line in the color column are brown, red or yellow in color. This may indicate weathering of the material.

The second vertical line to the right of the graphic column indicates which sections of the core were used by other agencies for analyses. In the A and B holes, the USGS (labeled USGS) took certain sections as Shelby tube samples. These were sent to Empire Soils Investigations, Inc. for permeability and water content testing, and grain size distribution analyses. These results will be kept on file at the USGS office in Ithaca.

In the C holes, the NYSDOH (labeled NYSDOH) took split spoon

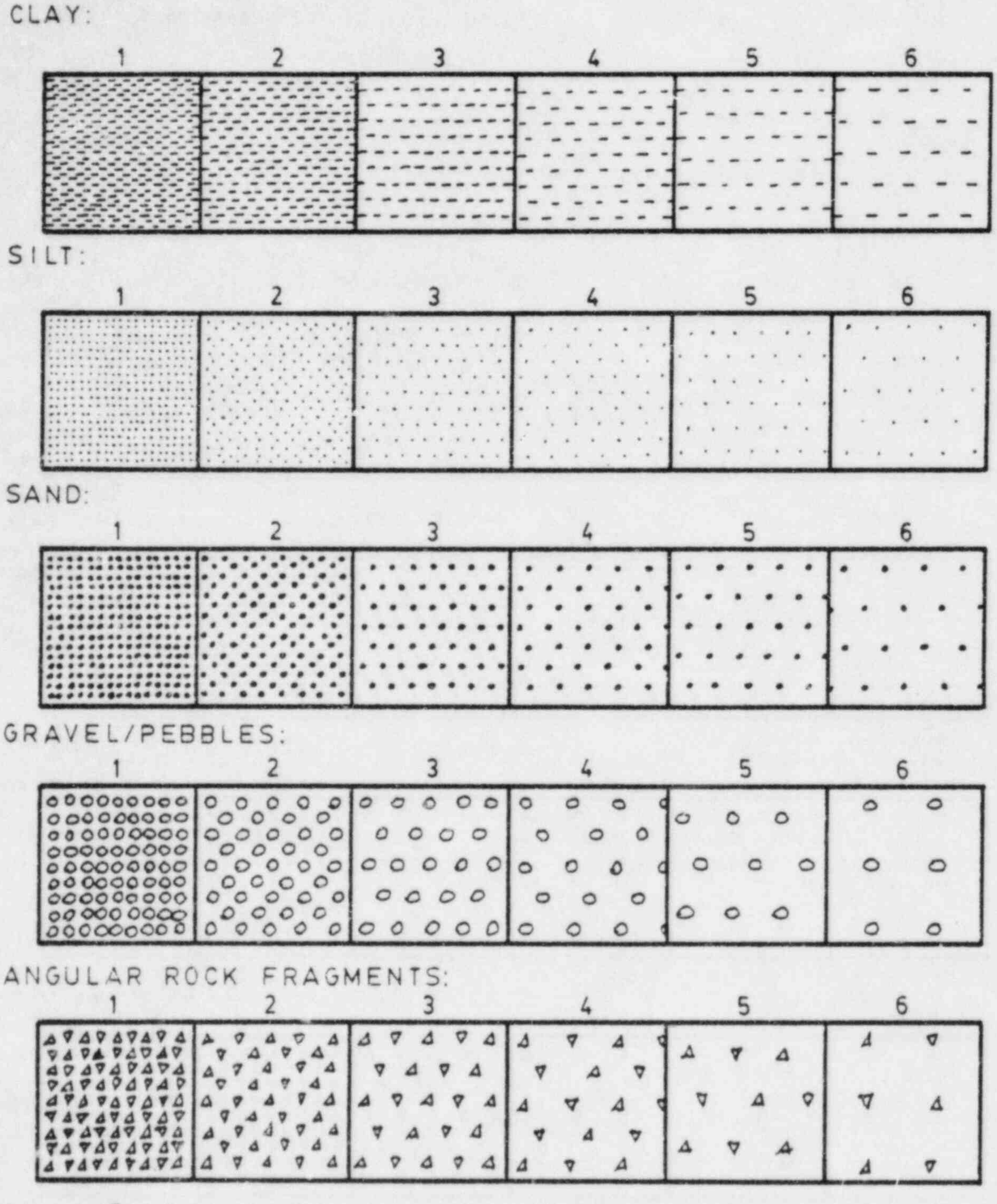


Figure 5. Symbols for graphic columns. Densities represent different proportions of each grain size class, from pure (density 1) to rare (density 6). These are combined to represent various combinations of grain sizes.

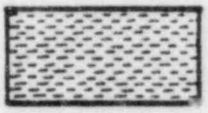
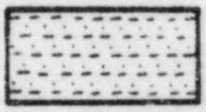
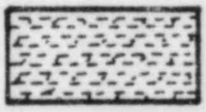
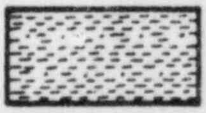
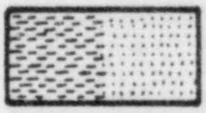
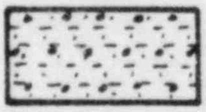
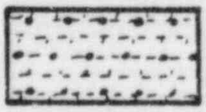
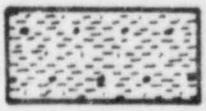
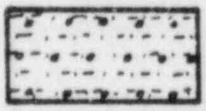
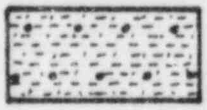
FROM LOG	CODE	GRAPHIC
CLAY	C1	
CLAY AND SILT	C3,L3	
CLAY WITH SILT	C2,L4	
CLAY, WITH RARE SILT	C1,L6	
CLAY TO SILT	C1→L1	
CLAY AND SILT AND SAND	C5,L5,S5	
CLAY AND SILT, WITH SAND	C4,L4,S5	
CLAY AND SILT, WITH RARE SAND	C3,L3,S6	
CLAY, WITH SILT AND SAND	C3,L5,S5	
CLAY, WITH RARE SILT AND SAND	C1,L6,S6	
CLAY, WITH SILT, WITH SAND	C3,L4,S5	
CLAY, WITH SILT, WITH RARE SAND	C2,L4,S6	

Figure 6. Examples of translations from standardized logs, through a simple code, to the form used in the graphic columns.

samples for tritium analyses. Dames and Moore (labeled D&M), subcontractor for WVNS, took several cleanout samples from the D holes.

The results of the tritium analyses done by the NYSDOH are shown in Table 1, and graphically on the right hand side of the graphic columns. The tritium is measured in microcuries per milliliter times .0000001 (E-7) and the scale, shown at the top of the graph, is logarithmic. A black vertical line indicates how much of the core was used for the analysis, and what the measured level was in that section. Samples with results below 2 microcuries per milliliter times E-7 are all "less than" that value, the detection limit of RSL procedures. For example, in hole 82-1C, the results for the section of core 2.7 to 2.9 m (8.9 to 9.7 ft) in depth should be read as "less than 2 microcuries per milliliter times E-7." Successive samples are connected together with thin black lines for ease of reading.

For comparison purposes, the U.S. Environmental Protection Agency maximum tritium level for drinking water is 200E-7 microcuries per milliliter.

Appendix E. Procedures Used in the 1983 Drilling Projects.

The following section is a self-contained report, describing the drilling, sampling, and completion procedures used during the 1983 drilling projects. No radionuclide analyses have been done on samples from these holes. Refer to Appendices A and B for logs and graphic columns.

Procedures Used in the 1983 Cooperative USGS-NYSGS Drilling Projects at the Western New York Nuclear Service Center, West Valley, New York

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ABSTRACT

In the spring of 1983 the USGS and USDOE deepened two holes drilled near the NRC-licensed burial area at the WNYNSC, and drilled five more holes to the west. The NYSGS assisted in geologic logging of the cores. The drilling and sampling procedures were similar to those used in 1982 in the USGS-NYSGS drilling project. In the summer of 1983, the USGS and NYSGS cooperated in drilling a hole on the North Plateau using a contracted drilling rig. The procedures used were different from those used in 1982, but allowed the project to go to greater depth. Together these holes added substantially to knowledge of the character and extent of lithologic units at the WNYNSC. The North Plateau hole penetrated a pre-Kent (?) lacustrine sequence and an underlying till. Neither of these units had been identified in any holes drilled previously at the site.

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Robert H. Fakundiny, State Geologist, for his guidance as Principal Investigator;

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1.0 INTRODUCTION

The first phase of the NYSGS-USGS cooperative drilling program, during the spring of 1983, completed work begun in the fall of 1982. Two test holes adjacent to the NRC-licensed burial area were deepened, and the NYSGS assisted the USGS in drilling an additional five test holes west of the NRC-licensed burial area as part of a contract between the USGS and the USDOE. The second phase of the 1983 cooperative drilling program by the USGS and NYSGS consisted of drilling a test hole to bedrock (83-4E) in the North Plateau area of the Western New York Nuclear Service Center. The drilling was done by A.W. Kincaid Drilling Co. of Canastota, N.Y. and the geologic logging was done by personnel from both the NYSGS and USGS. The program was part of a continuing effort to define the geology and subsurface hydrology in and around the USNRC-licensed burial area.

Two test holes (82-1D, 82-3D) previously drilled in 1982 were deepened to 31 m (102.0 ft) and 33 m (109.0 ft), and five new test holes west of the NRC-licensed burial area were drilled to 18.4 m (60.5 ft), 20.6 m (67.5 ft), 25.9 m (85.0 ft), 26.5 m (87.0 ft) and 28.6 m (94.0 ft). The test hole on the North Plateau is 75.0 m (246.2 ft) deep. The locations of these holes are shown on Plate 1, standardized logs are included in Appendix A, and graphic columns are in Appendix B. Table 1 shows the hole names, depths, and the type of lithology found at the bottom of each hole.

All eight holes were finished as piezometers, and water levels within them will be used as data to extend the hydrologic model, developed by the USGS, of the NYS-licensed burial area into the NRC-licensed burial area and the rest of the security area.

The following sections describe the procedures used for drilling and completing the holes, and some lithologic descriptions of the core samples. Geologic interpretations are included in Chapter 3 on stratigraphy .

Table 1. Data on Holes Deepened and Drilled in 1983 in Cooperative USGS-NYSGS Programs.

Hole Name	Depth(m)	Depth(ft)	Lithology at Bottom
82-1D	33.2	109.0	Kent(?) till
82-3D	30.9	101.5	Kent(?) till
83-1D	18.4	60.5	rock
83-1E	20.6	67.5	rock
83-2D	25.9	85.0	rock
83-2E	28.7	94.0	rock
83-3E	26.5	87.0	rock
83-4E	75.0	246.2	rock

2.0 DRILLING PROCEDURES

2.1 Deepening of Holes 82-1D and 82-3D

During the Fall 1982 drilling program test holes 82-1D and 82-3D were not completed to the desired depths because the drilling rig in use could not drive casing deep enough. These test holes were originally drilled using the flush joint casing method described in Potter and others (1982).

In both 82-1D and 82-3D, well casing had been driven to a depth of 26.21 m (86.0 ft) where it met with refusal. In the spring of 1983 the drilling crew attempted to obtain core at depths below 26.21 m (86.0 ft) by using the air rotary method. This method employed a 1.22 m (4.0 ft) long soft-formation corebarrel equipped with a diamond drag bit, connected to an air compressor to supply pressure to force cuttings into the corebarrel and up the hole. This method proved inadequate, so these holes were finished by driving a split spoon sampler at 0.61 m (2.0 ft) intervals to collect core samples. The only difference between the flush joint casing method used in 1982 and this method was that no casing was driven beyond the 26.21 m (86.0 ft) depth. This method involved two basic steps:

1) A split spoon sampler was driven 0.61 m (2.0 ft) to obtain a core sample;

2) Cuttings were cleaned out of the hole with a split spoon sampler equipped with an oversize cleanout shoe.

The sequence was repeated until the target depth was reached. As shown in Table 1, hole 82-1D was deepened to 33.2 m (109.0 ft), and hole 82-3D was deepened to 31.1 m (101.5 ft). Both holes ended in Kent(?) till.

2.2 Holes 83-2D, 83-3D, 83-1E, and 83-2E

With the exception of test hole 83-1D, the holes drilled for USDOE were drilled using a hollow stem spiral auger. The auger sections were 1.52 m (5.0 ft) in length and connected to form a continuous flight. The auger stem was turned by a rotary drive head mounted on a hydraulic feed mechanism that could push the stem down or pull it back. This method is limited to drilling through formations containing enough clay so that the borehole will stand for a time without collapsing.

The general procedure used while drilling test holes 83-1E, 83-2D, 83-2E and 83-3D is shown in Figure 1, and consisted of these steps:

1) The auger was advanced to a depth of 3.05 m (10.0 ft). A split spoon sampler equipped with an oversize cleanout shoe was left in the hole (inside the auger flight) in order to clean out cuttings as the auger removed material;

2) The cleanout spoon was pulled up out of hole to remove cuttings;

3) A Shelby tube sampler was driven or pushed 0.61 m (2.0 ft) beyond the auger (through the auger flight) in order to retrieve a core sample for tests of engineering properties;

4) A split spoon sampler was then driven or pushed (through the auger flight) 0.61 m (2.0 ft) beyond the hole created by the Shelby tube sampler, in order to obtain core for geological analysis.

Steps 2, 3, and 4 were repeated until the target depth was reached. Then appropriate size well casing was lowered down the hole through the auger flight and the auger flight was then pulled back out of the hole. This was done in order to prevent the hole from collapsing.

2.3 Hole 83-1D

This test hole was drilled using the flush joint casing technique used in the fall of 1982 as described in Potter and others (Appendix D) and shown in Figure 2. Continuous core samples were taken, each 0.61 m long (2.0 ft).

The procedure consisted of three basic steps:

1) Steel flush joint casing was driven to a specified depth.

2) Cuttings in the hole were cleaned out using a split spoon sampler equipped with an oversize cleanout shoe.

3) A 0.61 m (2.0 ft) core sample was collected ahead of the driven casing using a small diameter split spoon sampler.

This sequence was repeated down the hole until the target depth was reached.

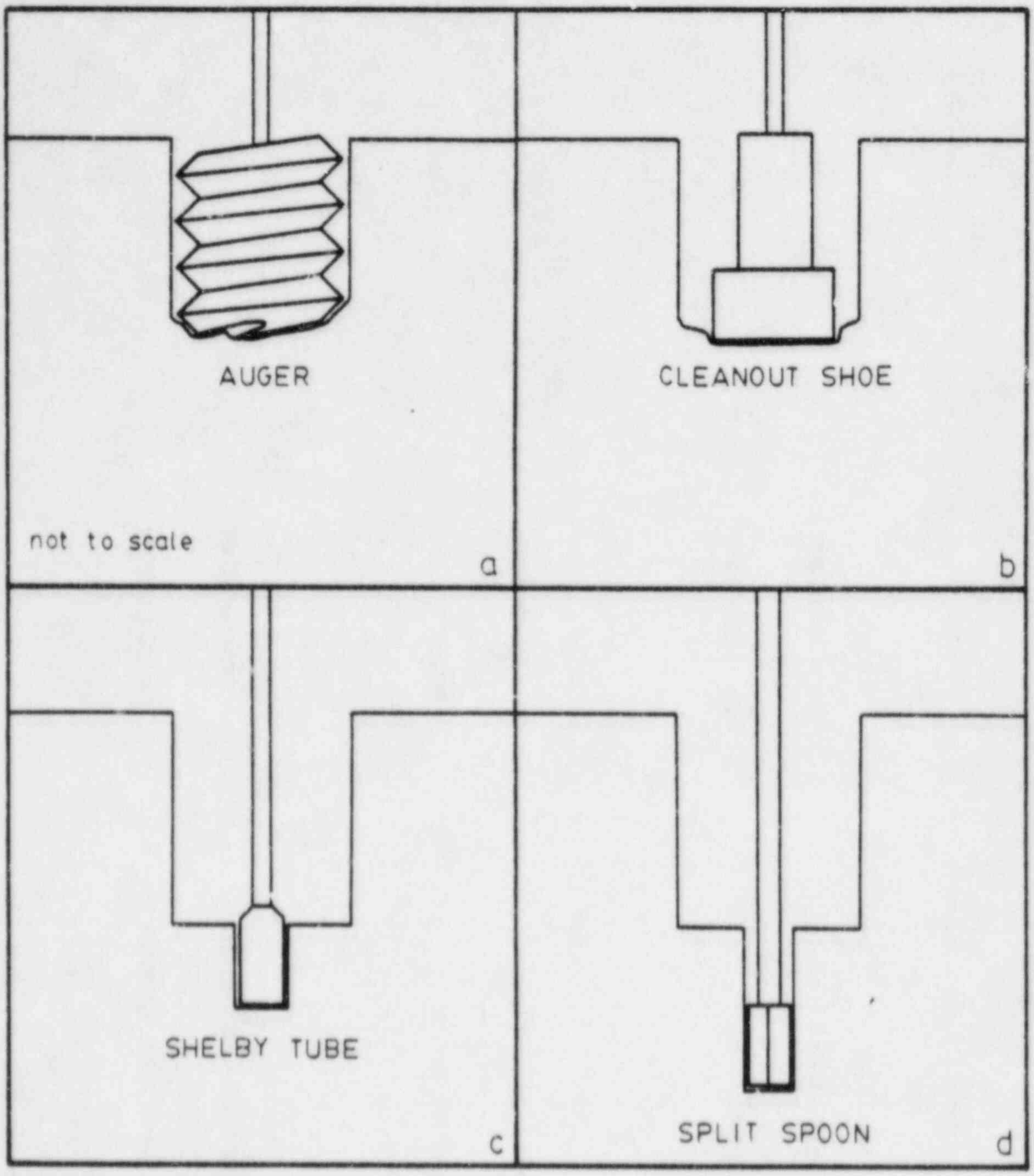

Figure 1. Holes 83-1E, 83-2D, 83-2E, 83-3D: four-step sequence of steps in the drilling procedure.

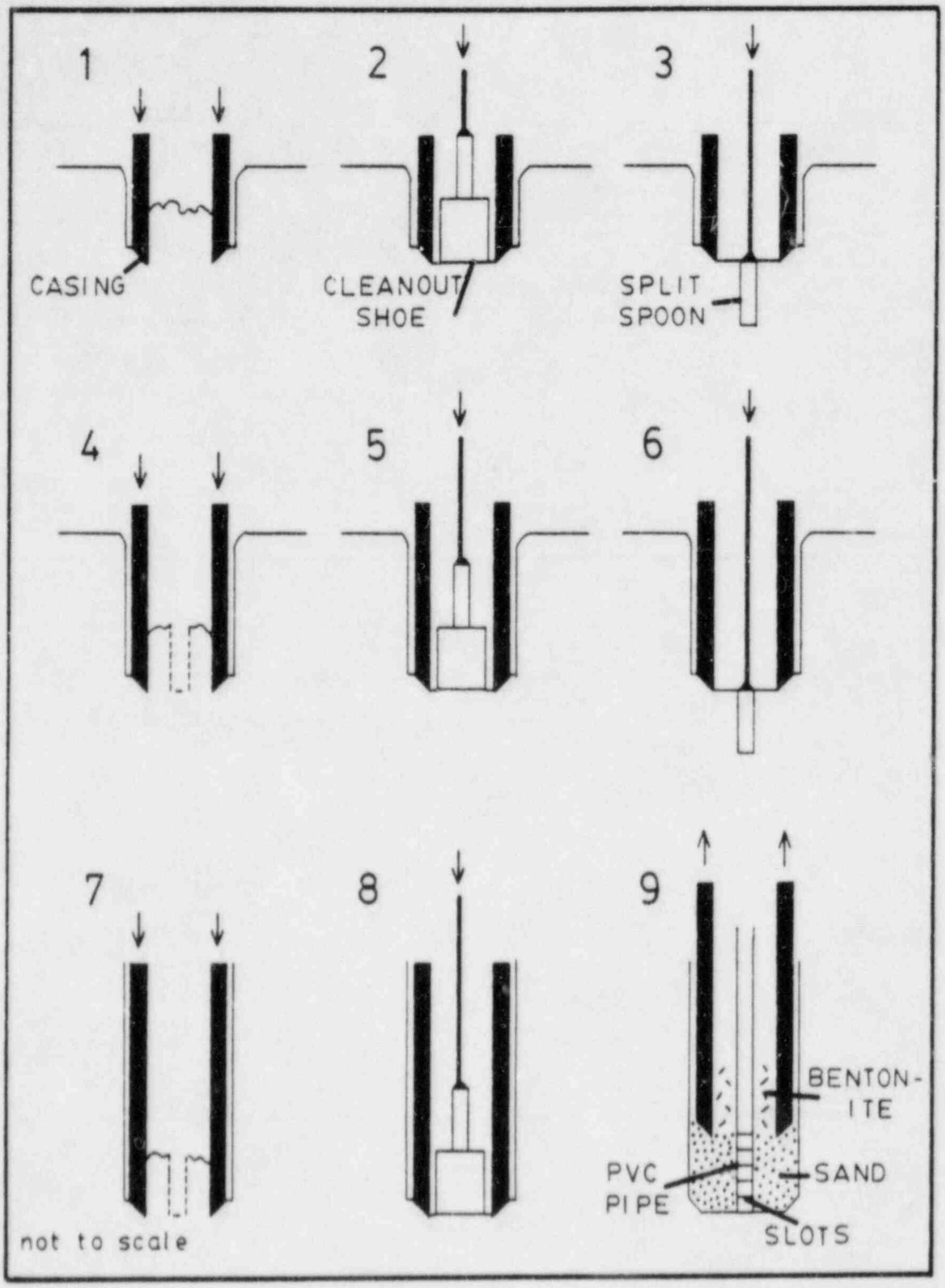

Figure 2. Hole 83-1D: nine-step sequence of steps in the drilling procedure, also used for holes drilled in fall 1982.

2.4 Hole 83-4E

2.4.1 Drilling Procedures

The method chosen to drill the deep test well was the cable tool percussion method. This method operates by repeatedly lifting and dropping at regular intervals a heavy string of drilling tools in the borehole. The reciprocating action of the tools mixes the crushed or loosened material with water to form a slurry. The water needed to form a slurry is added to the borehole if no water is present in the formation. The slurry is removed at regular intervals from the borehole by a bailer.

During drilling, the string of tools shown in Figure 3 was used. The drill bit resembles a large chisel; the drill stem gives weight to the bit, and its length helps to keep the hole straight; the wrench squares provide points for attachment of clamps; the rope socket connects the string of tools to the cable; and the drill line is 1.5 to 2.5 cm (5/8 to 1 inch) diameter steel cable. The tools are screwed together at the tool joints. The length of the drill line in the hole is controlled by a winch at the surface. The drilling motion must be kept in step with the gravity fall of the tools for good results. The bit must strike the bottom of the hole with the cable taut, to prevent tangles, and be lifted quickly on the upward stroke.

When drilling in unconsolidated formations, casing must follow the drill bit closely as the well is deepened to keep the borehole open and prevent caving. A drive shoe made of hardened and tempered steel is attached to the lower end of the string of casing. The shoe prevents damage to the bottom of the casing. A drive head is fitted to the top of the casing to serve as an anvil. A pair of heavy forged steel drive clamps is attached to the wrench square near the top of the drill stem, as shown in Figure 4. The drive clamps provide the hammer face and the string of tools provide the weight for driving the pipe. The usual procedure is to drive the casing 0.3 to 2.0 m (1 to 6 ft) ahead of the bit. A plug of relatively undisturbed material is left inside the casing. The clamps are removed and the bit is used to loosen the material in the plug, which is mixed with water to form a slurry and removed with the bailer.

When friction on the outside of the casing increases to the point at which the pipe cannot be driven deeper, or when further driving might damage it, a string of smaller casing must be inserted inside the larger size casing. Drilling is then continued by advancing the smaller casing in front of the large casing. In this particular case, two casing

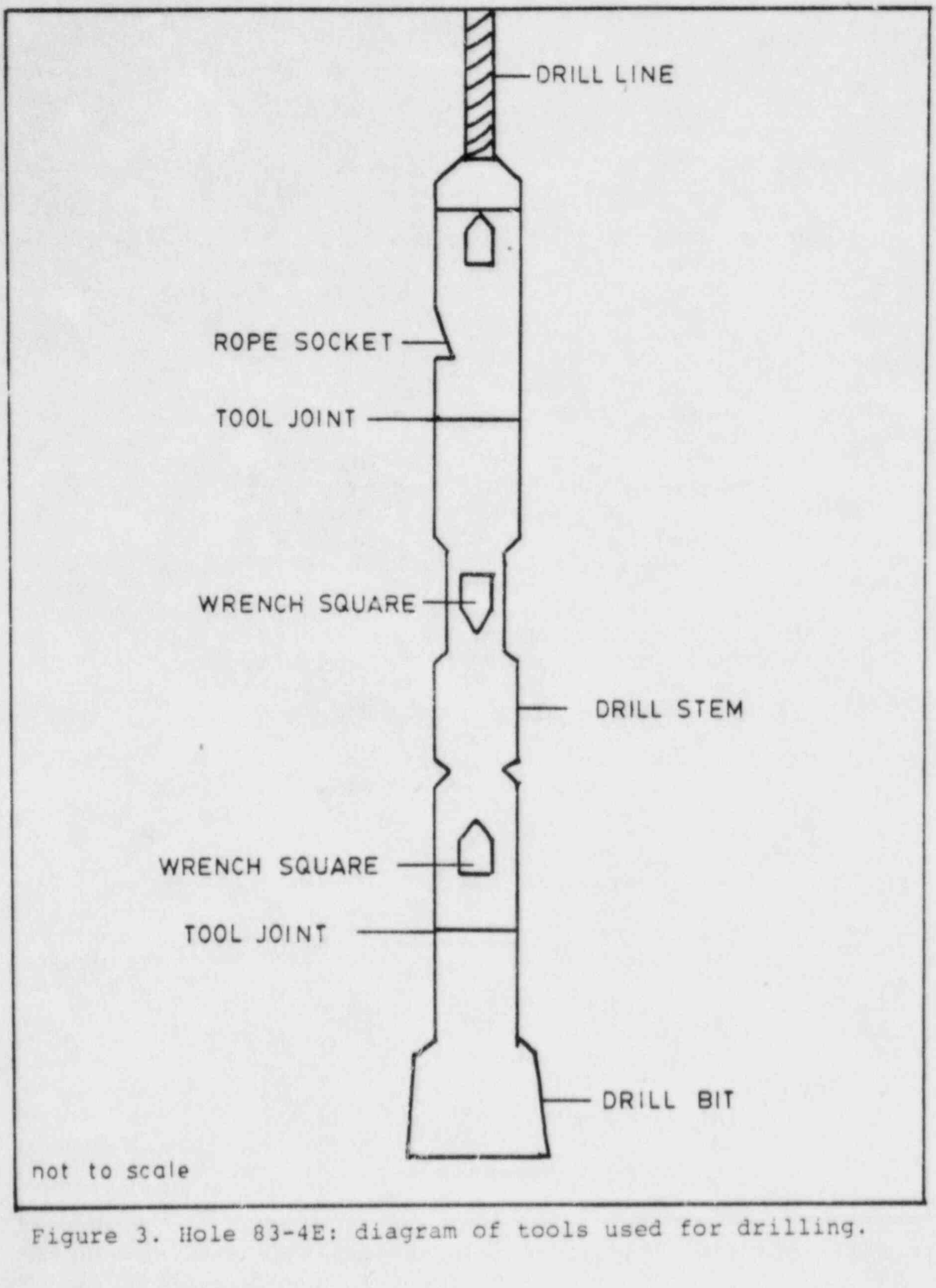

Figure 3. Hole 83-4E: diagram of tools used for drilling.

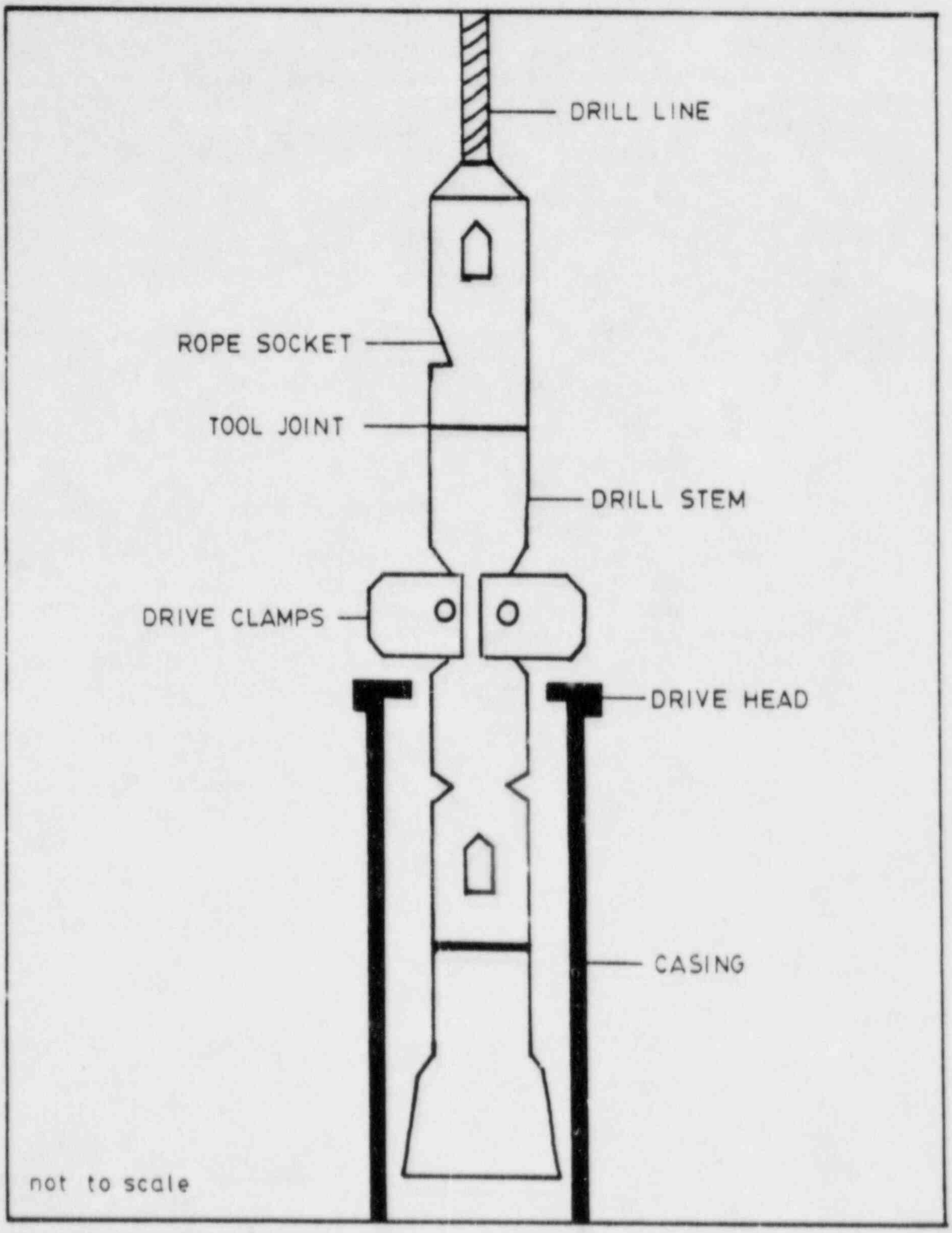

Figure 4. Hole 83-4E: diagram of tools used for driving casing.

reductions were used to sink the well to the desired depth: approximately 30 cm (12 inches) diameter surface casing was lowered to a depth of approximately 7 m (23.1 ft), approximately 25 cm (10 inch) casing was then lowered to a depth of approximately 40 m (130 ft). Finally, approximately 15 cm (6 inch) casing was lowered to a depth of 75 cm (246.2 ft), where bedrock was encountered.

2.4.2 Sampling in Hole 83-4E

The string of tools was changed for obtaining split spoon samples. The configuration shown in Figure 5 uses drilling jars in place of the drill stem, and a split spoon in place of the chisel bit. The drilling jars are two linked steel bars. The upper jar impacts on the lower to add to the force driving the split spoon.

Samples were taken for the purpose of geological logging at approximately 6 m (20.0 ft) intervals or at other intervals when deemed necessary. A 60 cm (24 inch) long, 10 cm (4 inch) ID, 13 cm (5 inch) OD split spoon sampler was used (Figure 5). Additional samples were obtained from the bit and/or bailer at approximately 1.6 (5 ft) intervals. In some instances, samples obtained from the bit and/or bailer influenced split spoon sample selection.

Eight 0.15 m (0.5 ft) core sections from split spoon samples were sent to the New York State Health Department for radiochemical analysis. These samples were trimmed, wrapped in plastic and aluminum foil and shipped to RSL of the NYS Health Department.

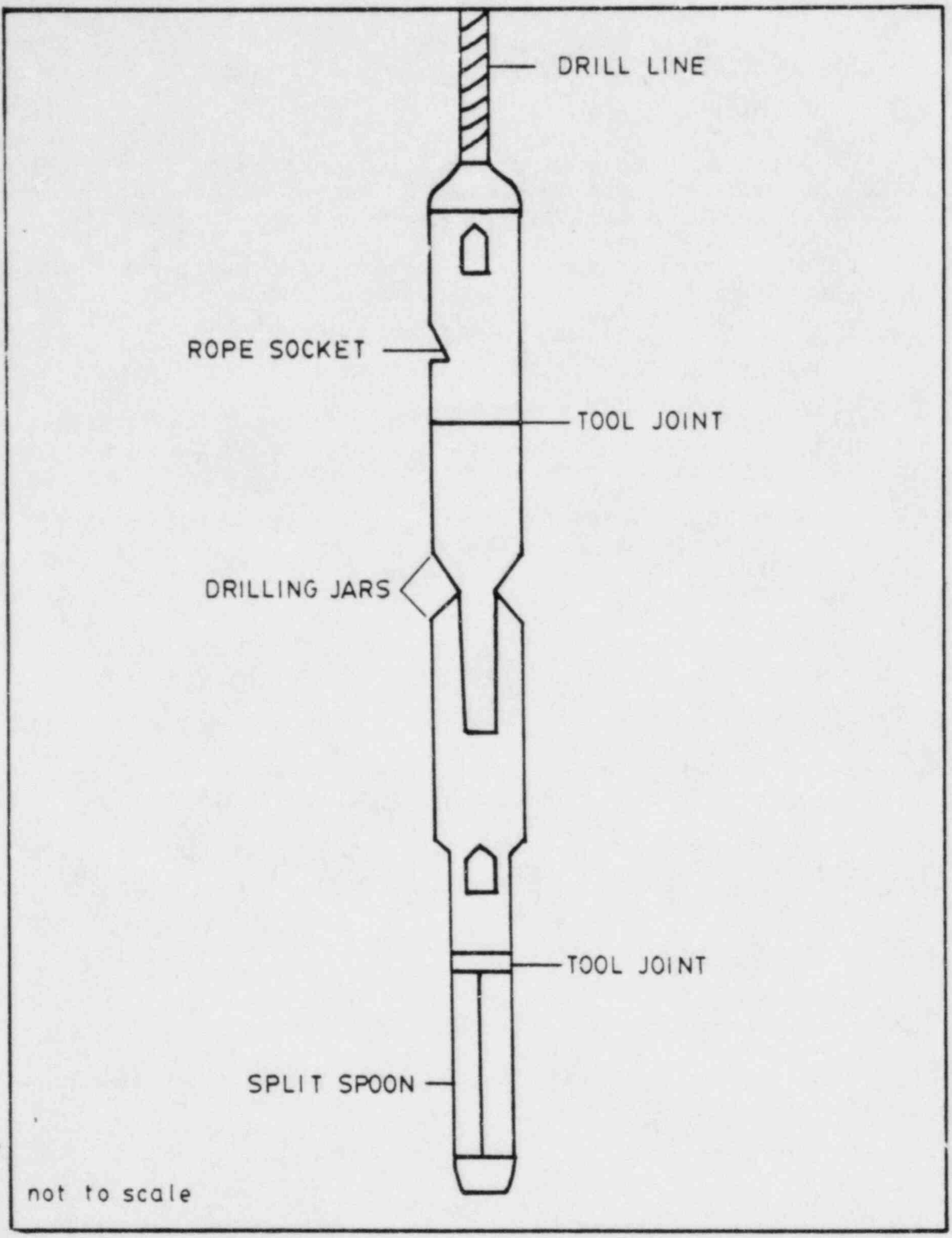

Figure 5. Hole 83-4E: diagram of tools used for split-spoon sampling.

3.0 WELL COMPLETION PROCEDURES

3.1 Holes 82-1D and 82-3D

For these two test holes the casing extends to a depth of 26.21 m (86.0 ft) but the hole is deeper. To complete each of these holes as a piezometer, AW rod was lowered down the hole, equipped with a 0.61 m (2.0 ft) long, 7 slot, 80 gage well point wrapped in fine mesh stainless steel gauze. The diameter of the hole created by the split spoon sampler used to extend the hole was the same diameter as the AW rod, so there was no annulus below 26.21 m (86.0 ft). The well was finished in the following manner, as shown in Figure 6:

1) from the bottom of the hole to a depth of 26.21 m (86.0 ft) no annulus exists outside the AW rod, so no grout or sand envelope was necessary;

2) from 26.21 m (86.0 ft) to approximately 6.10 m (20.0 ft) from the surface, portland cement was poured down the hole inside the BW casing and outside the AW casing;

3) from 6.10 m (20.0 ft) to the surface, bentonite was poured down the hole between the BW and AW casings;

4) a 1.52 m (5.0 ft) length of NW casing was placed in the hole around the BW casing and extending approximately 0.61 m (2.0 ft) above the ground surface to protect access for measuring water levels;

5) concrete was used to cement the NW casing in place and a PVC cap was added.

3.2 Holes 83-1E and 83-2E

Test holes 83-1E and 83-2E were drilled to bedrock and the completion procedures were as follows:

1) a string of BW casing was lowered down the hole through the auger flight. The auger flight was pulled back out of the hole. No well screen was used because the well casing was resting on bedrock;

2) Portland type cement was poured down the hole between the wall of the borehole and the outside of the BW casing to a depth of approximately 6.10 m (20 ft) from the surface;

3) bentonite was poured down the hole outside of the BW

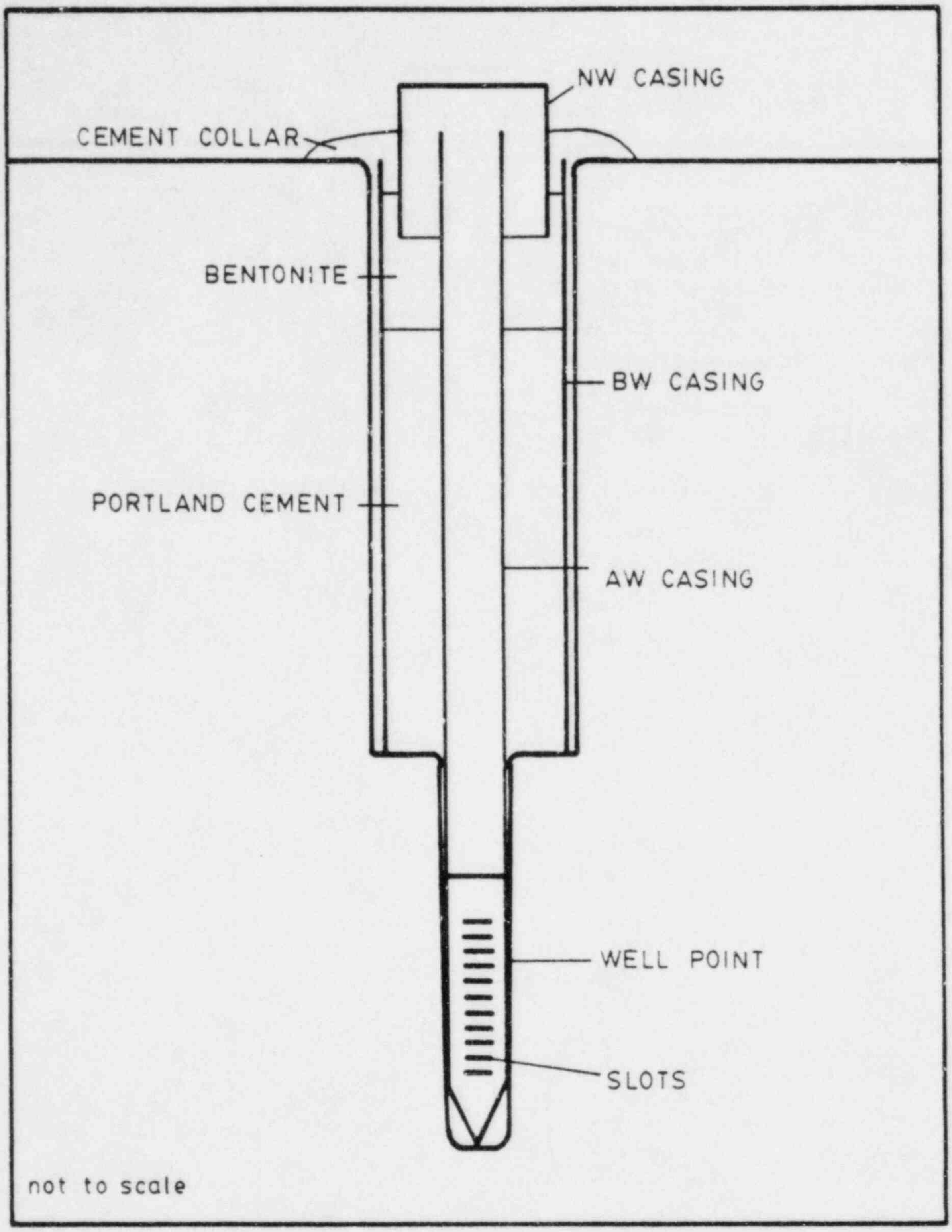

Figure 6. Holes 82-1D, 82-3D: diagrammatic cross-section showing well completion.

casing from 6.10 m (20 ft) to the surface;

4) a 1.52 m (5.0 ft) length of NW well casing was emplaced around the BW casing so that approximately 0.61 m (2.0 ft) was above the suface to protect access for measuring;

5) concrete was used to cement the NW length and hold it in place. A PVC cap was placed on the NW casing.

The finished well looks quite similar to that shown in Figure 6, except that there is no separate well point, and the bottom of the casing is in weathered bedrock rather than unconsolidated sediment.

3.3 Holes 83-1D, 83-2D, and 83-3D.

These test holes were finished in unconsolidated sediments. Upon reaching the target depth, a string of AW casing equipped with a 0.61 m (2.0 ft) long, 7 slot, 80 gage well point wrapped in steel mesh gauze was lowered down the hole, through the augers, and then the auger flight was pulled back out of the hole. The well was finished in the following manner, as shown in Figure 7:

1) approximately 1 m (3.0 ft) of fine sand was poured down the hole between the wall of the auger hole and the outside of the AW casing to envelope the screened portion of the well point;

2) bentonite was poured down the hole, between the BW and AW casings, for approximately 1.52 m (5.0 ft) above the sand envelope;

3) Portland cement was then poured down the hole between the BW and AW casings, to approximately 6.10 m (20.0 ft) from the surface;

4) bentonite was poured down the hole between the BW and AW casings from 6.10 m (20.0 ft) to the surface;

5) a 1.52 m (5.0 ft) length of NW casing was placed around the the BW casing and extends approximately 0.61 m (2.0 ft) above the surface;

6) concrete was added to cement the NW casing up to the surface and a PVC cap was placed on top.

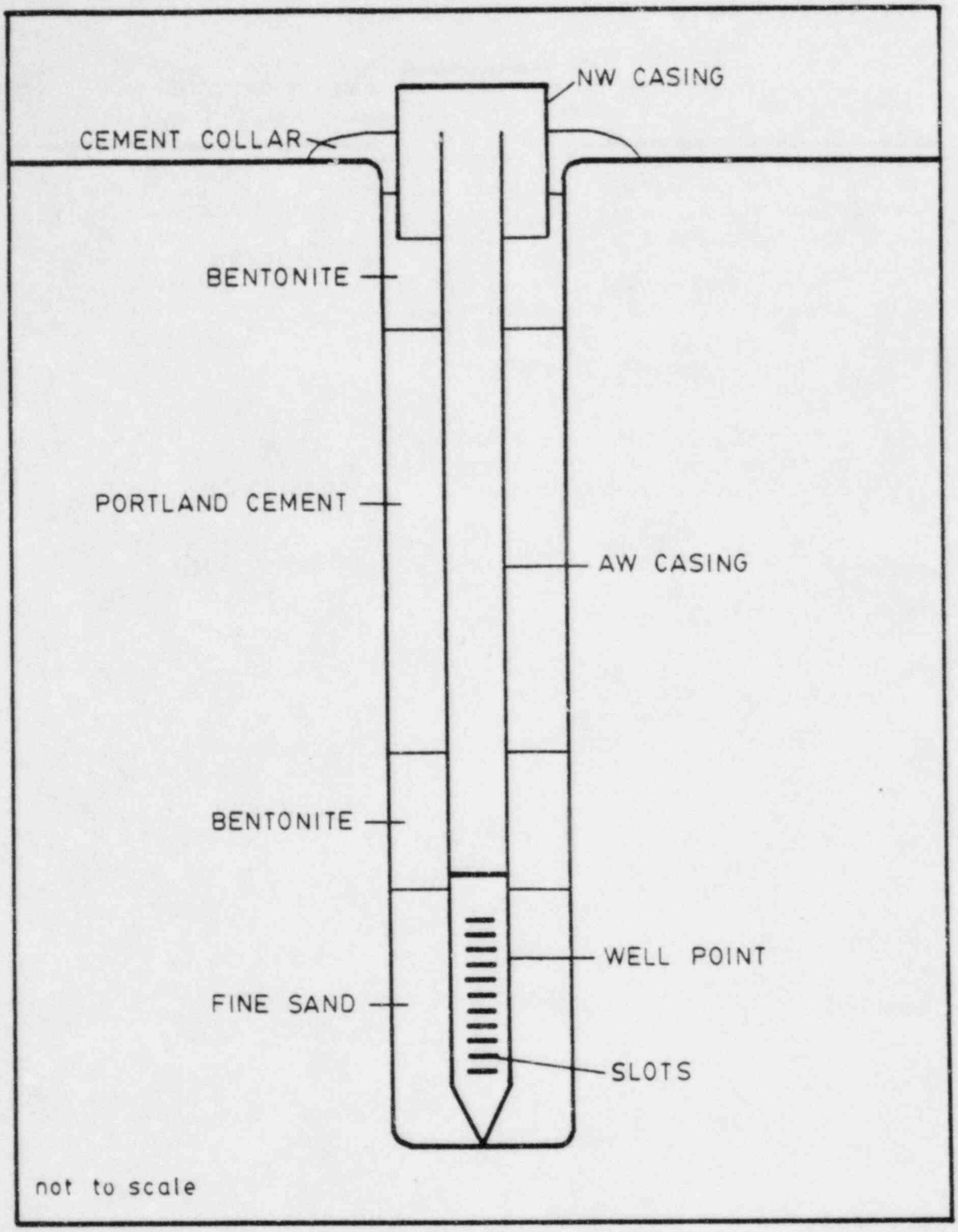

Figure 7. Holes 83-1D, 83-2D, 83-3D: diagrammatic cross-section showing well completion.

3.4 Hole 83-4E

Test hole 83-4E was completed to bedrock at a depth of 75.0 m (246.2 ft). The 15 cm (6 inch) casing rests directly on bedrock. No piezometer was installed in the 15 cm (6 inch) casing. A 6.4 (2.5 inch) ID PVC pipe was installed as a piezometer in the annulus between the 15 cm (6 inch) and 25 cm (10 inch) casing to a depth of 39.8 m (130.5 ft) where a water bearing sand unit was encountered. In summary, the hole was finished as follows, as shown in Figure 8:

1) the 15 cm (6 inch) casing extends to bedrock at 75 m (246 ft), the 25 cm (10 inch) casing extends to 39.8 m (130.6 ft) around the smaller casing; and the 30 cm (12 inch) casing extends to 7 m (23 ft) around both smaller casings;

2) a well point of slotted PVC pipe was placed in the annulus between the 15 cm (6 inch) and 25 cm (10 inch) casings to a depth of 40 m (131 ft);

3) silica sand was poured into the annulus between the 15 cm (6 inch) and 25 cm (10 inch) casings up to a depth of 37.9 m (124.5 ft) to act as a screen around the PVC well point;

4) in the same annulus, bentonite was poured in up to a depth of 37.0 m (121.5 ft);

5) in the same annulus, Portland type cement was poured in from 37.0 m (121.5 ft) up to the surface;

6) Portland type cement was poured in to fill the entire annulus between the 25 cm (10 inch) and outermost 30 cm (12 inch) casings;

7) a concrete collar was poured around the outside of the 30 cm (12 inch) casing;

8) a steel cap was placed on top of the 30 cm (12 inch) casing at the surface.

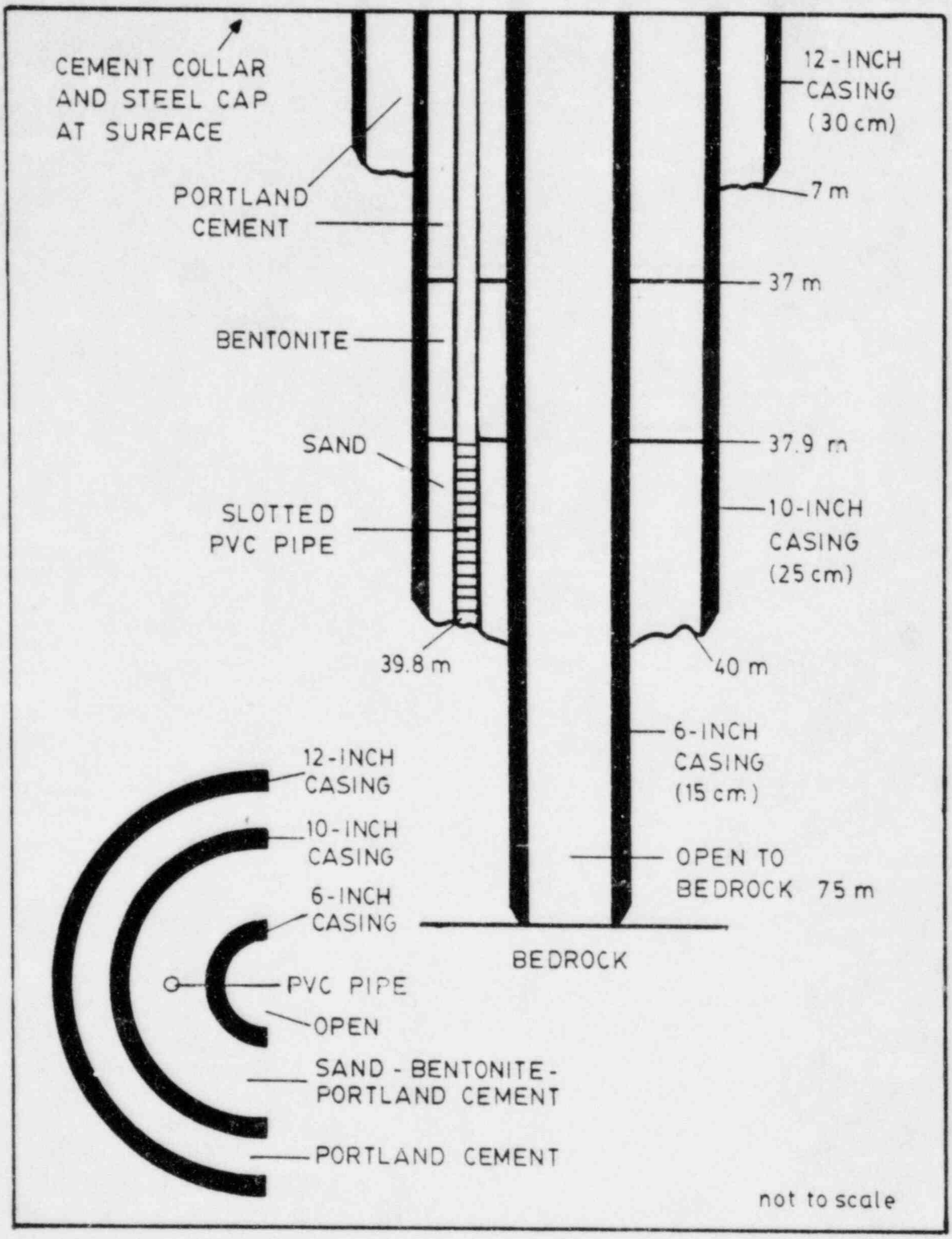

Figure 8. Hole 83-4E: diagrammatic cross-section showing well completion.

Appendix F. Downcutting by Cattaraugus Creek and Tributaries- History and Prognosis.

This section is a self-contained report by Robert G. LaFleur, supported by a grant from the New York State Geological Survey. This report analyzes erosional-depostional processes occurring near the WNYNSC as they are the result of overall drainage basin geomorphological development

DOWNCUTTING BY CATTARAUGUS CREEK AND TRIBUTARIES - HISTORY AND PROGNOSIS

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ABSTRACT

Dissection of the Cattaraugus drainage basin of western New York began during Late Woodfordian deglaciation. The rate of valley downcutting by Cattaraugus Creek and three tributaries - South Branch, Connoisaurauley, and Buttermilk - is determined by several methods that use geomorphic and alluvial stratigraphic data, controlled by 28 radiocarbon dates.

Temporary base levels established during deglaciation are preserved, mainly as terraces of aggradation, from about 15,000 years ago to about 12,300 ybp when Lake Erie came into existence. These surfaces, later dissected, provide reference horizons for downcutting rate determinations; during the Holocene, woody materials were incorporated in fluvial deposits and provide radiocarbon dates ranging from 9,900 ybp to the near-present. Within the post-glacial sedimentary record are aggradational-degradational relationships that can be temporally quantified.

For the past several millenia, downcutting rate, in feet per century, is in the range of about 1.7 to 0.5 ft C^{-1} for much of the Cattaraugus basin. Downcutting has not been constant through time, nor is it uniform among valleys.

Prognosis for Buttermilk Valley and the environs of the West Valley radioactive-waste burial ground for the next two millenia suggests a downcutting rate of between 0.7 - 0.5 ft C^{-1} will apply there.

Geomorphic processes responsible for valley deepening vary greatly in stream reaches that are founded on shale and siltstone and in reaches that traverse glacial sediments. Downcutting rate may actually increase through rock and be retarded in glacial sediment reaches where sediment purging is more difficult because of landslide activity and boulder lag buildup.

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ACKNOWLEDGEMENTS

This investigation was supported by a grant from the New York State Geological Survey; field assistance was provided by Luanne Wheeler, for which appreciation is expressed.

Radiocarbon dates were provided by the U.S. Geological Survey in 1976 for a preliminary investigation of alluvial stratigraphy undertaken at that time. Geochron Laboratories provided radiocarbon dates for this investigation.

1.0 INTRODUCTION

1.1 Purpose and Scope

This study was undertaken to provide information on the downcutting history of the Cattaraugus drainage basin in western New York during glacial and post-glacial time. Quantified data on rates of past and ongoing downcutting should permit projection of valley deepening rate into the next two millenia, with accuracy acceptable for engineering design purposes, and for modeling studies that relate downcutting to sediment discharge, mass wasting, and gully extension.

The study area includes the main Cattaraugus Valley from Arcade to Lake Erie and three major left-bank tributaries, South Branch, Connoisarauley, and Buttermilk. All four valleys contain wood-bearing alluvial material that permits dating of inset terrace deposits extending back several thousand years (Plate 1). Particular interest focuses on tributary Buttermilk Valley where landscape integrity around the West Valley radioactive-waste burial ground must be determined and forecasted. Field work was conducted in summer of 1982, supported by the New York State Geological Survey. Radiocarbon dates were provided by the U.S. Geological Survey in 1976, and by Geochron Laboratories in 1982.

1.2 Methods

Determination of downcutting rates is based in part on the timing of a series of lowering temporary base levels. For the older, higher base levels, an assignment of age is based on known sequences of glacial and deglacial events in western New York (Muller, 1977a, Calkin, 1982, Fullerton, 1980). Detailed stratigraphic description and mapping by the author (LaFleur, 1979, 1980) was extended in this study from the vicinity of the Western New York Nuclear Service Center east to East Arcade, and west from near Springville to Lake Erie. This work was necessary to locate glacial borders and define drainage episodes that affected both ends of the main Cattaraugus Valley simultaneously or sequentially. The left bank tributary valleys had a deglacial style of their own that related not to episodic through-valley discharge westward, as befitted the Cattaraugus, but to a more orderly ice border withdrawal northward. Correlation of deglacial deposits that record temporary base levels, such as outwash, and fluvial terraces, was accomplished by physical tracing between tributary valleys and the main Cattaraugus Valley, and through the length of the Cattaraugus.

Determination of age of Holocene base levels is based on radiocarbon-dated terrace deposits. Only one date in the 14000-6000 years before present (ybp) range exists. However, many dates within aggrading and degrading fluvial sedimentary sections in the four valleys that are younger than 6000 yrs permit a good estimate of the time differences among older and younger inset flood plains, thalwegs, and channel-bar facies. Longitudinal plots of the four valleys include modern stream level and projected base levels between segmented older terraces. Those levels for which a reasonably good timing could be assigned served as references between which vertical dissection could be expressed as feet per century (ft C^{-1}). Measured field sections, many with datable woody material, are located on Plate 1, and are shown in Figures 1-24. Plates 2 and 3 show curves for general downcutting and rate of downcutting through time respectively, based on profiles from several valleys. Plate 4 shows data for Buttermilk Valley in particular.

2.0 GLACIAL AND DEGLACIAL REGIONAL SYNTHESIS

2.1 Previous Work

Regional syntheses and overviews of Wisconsin glaciations in western New York have been developed by Muller (1963) (1964) (1975) (1977a) (1977b), Calkin (1970) (1982), Calkin and Muller (1980) and Fullerton (1980). Detailed mapping and stratigraphic syntheses for the environs of the radioactive-waste burial ground by LaFleur (1979) are expanded in this study to allow correlation of glacial events throughout the Cattaraugus and selected tributary valleys.

2.2 Time Assignment

No new radiocarbon dates applicable to deglacial events were obtained in this study. The time frame for the deglacial part of the base-level study, shown in Table 1, is based on summaries by Calkin (1982) and Fullerton (1980). Several age assumptions and formalized morphostratigraphic units are discussed later. These are shown on Table 1 (with an asterisk).

TABLE 1

Timing of Glacial-deglacial Events

(After Calkin (1982), Fullerton (1980)
LaFleur (1980), (this paper*)

	kybp	
	12.3	Lake Erie
	12.35	Lake Dana
	12.4	E. Lake Algonquin
	12.47	Lake Lundy
	12.5	Lake Wayne
Port Huron (Stade)	12.6	Lakes Warren II, III
	12.7	Lake Warren I
	13.0	Lake Whittlesey
Mackinaw (Interstade)		
	13.6	Versailles moraine*
	13.7	Gowanda moraine
Port Bruce (Stade)	13.9	West Perrysburg moraine*
	14.0	Perrysburg-Sardinia moraine and outwash*
	14.2	Dayton-Zoar-Chaffee moraine and outwash*
	15.0	Markhams moraine*
	15.5	Defiance moraine*
Erie (Interstade)	16.0	
	16.9	Delevan, Spring Brook, Faun Lake moraines
Nissouri (Stade)	17.8	Lime Lake-Sandusky-Eagle moraine
	18.0	Toad Hollow-Plato-Farmersville moraine (Kent)

* see Section 2.2 - Time Assignment

2.3 Early Woodfordian

Position of the Kent glacial border and recessional glacial margins are shown on Plate 5. Note the southward drainage during the existence of these ice borders.

2.4 Erie Interstade

Recession of Kent ice from the Cattaraugus basin was sufficient to allow dissection of Kent valley fills to base levels about 40 feet above modern stream grade during the Erie Interstade. See Figure 1 and Plate 4.

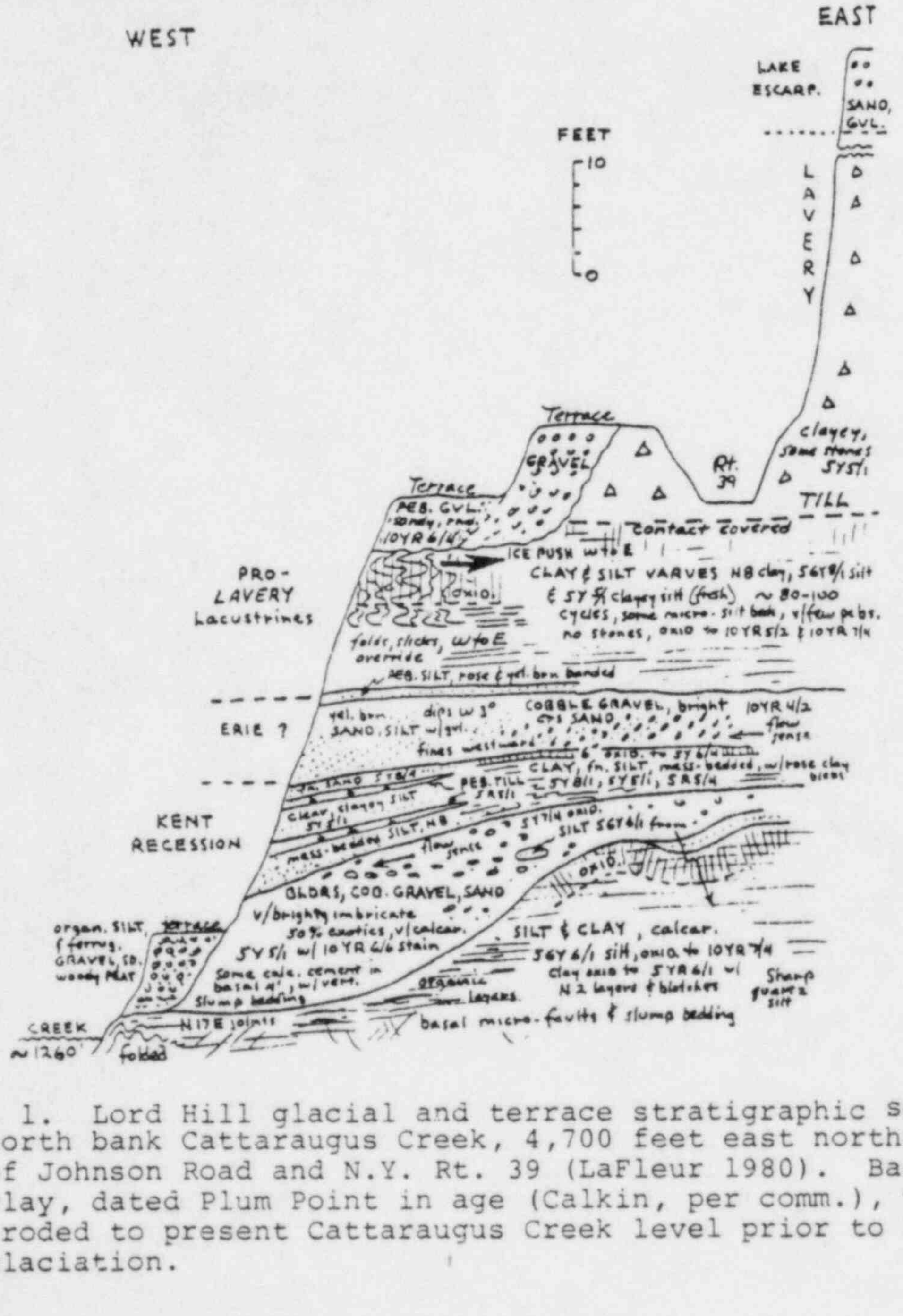

Fig. 1. Lord Hill glacial and terrace stratigraphic section; north bank Cattaraugus Creek, 4,700 feet east north-east of Johnson Road and N.Y. Rt. 39 (LaFleur 1980). Basal clay, dated Plum Point in age (Calkin, per comm.), was eroded to present Cattaraugus Creek level prior to Kent glaciation.

Paths and destination of Erie drainage west and north through the Cattaraugus basin are not well known, but it does not appear that post-Kent streams occupied any of the rock gorges now being cut by the Cattaraugus or its tributaries. This is a concept important to understanding rates of formation of later post-Lavery gorges, none of which show indication of exhumation. We may dispense with the earlier Woodfordian deposits and events because they do not bear on erosional history pertinent to this study.

2.5 Post-Erie Interstade Events

2.5.1 Lavery glaciation

Previous regional syntheses overlook the importance of the Lavery glaciation. The radioactive-waste burial ground medium is Lavery till (LaFleur, 1979, 1980) derived from glaciolacustrine deposits of post-Kent and Erie age north and west of the main Cattaraugus Valley. Extent of Lavery till and terminus of the Lavery readvance is shown on Plate 6; along this ice margin can be found abundant moraine, correlatable with the Defiance moraine. Recession of ice from this position is estimated at about 15,500 ybp or slightly later; it is from this event that the erosional history of the Cattaraugus is first reckoned. Note the proximity of the Lavery border to the Kent, and the nearly complete cover by Lavery till of all the Cattaraugus basin valley bottoms. Note also the Lavery till and Defiance morainal gravel at the top of the Otto section, Figure 2, and the relation of Lavery till to Kent deposits near Yorkshire, Figure 3.

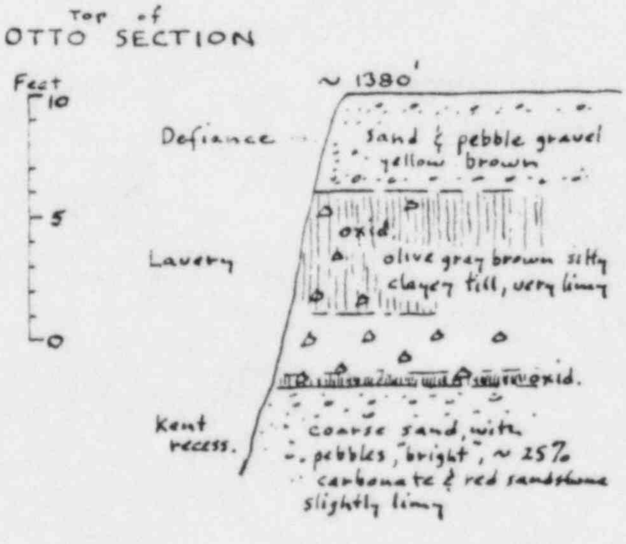

Figure 2. Lavery till beneath Defiance moraine gravel; top of section (Muller 1964) at Otto.

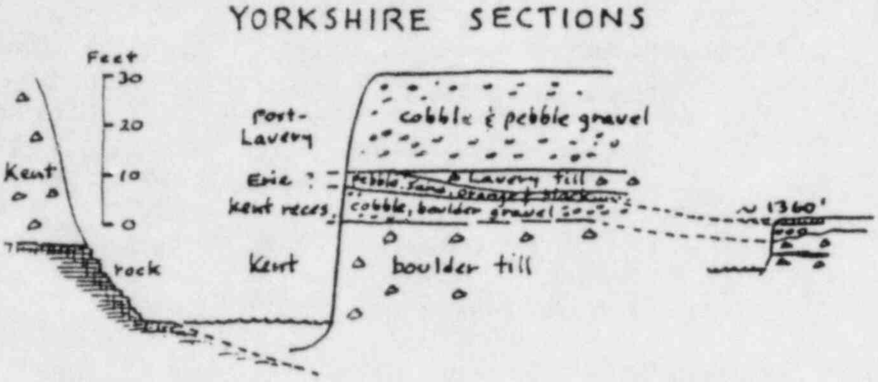

Figure 3. Glacial stratigraphic relationships along Cattaraugus Creek near Yorkshire, west of Rt 16 bridge, showing Kent-Lavery - outwash sequence.

2.5.2 Lavery recession

Style of recession from the Defiance moraine equivalent near West Valley is suggested by an exposure in upper Buttermilk Valley, Figure 4, where glaciolacustrine clays in the ice-dammed valley were covered by kettled gravel inwash as lake drainage proceeded. But in the much larger, low-gradient valleys to the west, near Gowanda, shallow glacial lake conditions lingered until final valley unblocking, and a deglacial, coarse-grained fluvial record is subdued or absent.

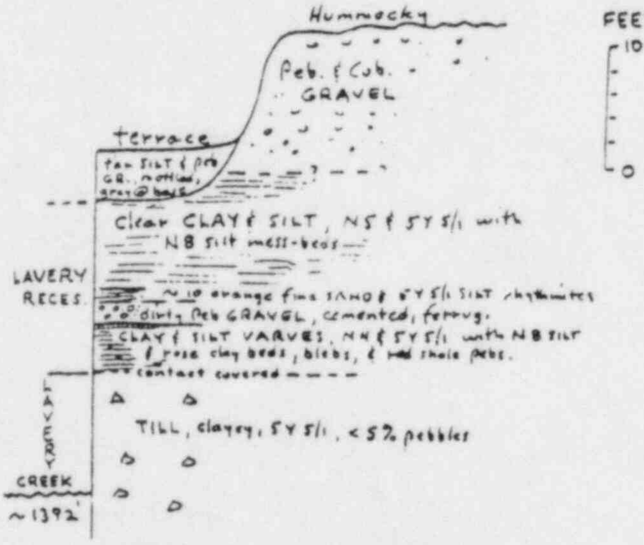

Figure 4. Stratigraphic details of Lavery glacial recession; upper Buttermilk Valley; 2,000 feet north of West Valley Road culvert.

2.5.2.1 Markhams Moraine and Outwash

A stillstand in ice recession, or a slight readvance, established moraine and outwash along the margin shown on Plate 6. This position may equate to the Hiram glaciation, but no till clearly separable from Lavery has been located, at least in the upper Cattaraugus basin. Unblocking of left-bank tributaries east from Connoisarauley Valley allowed a sloping gravel outwash with ice on the north edge to form from east to west along the mouth of Buttermilk and other north-trending valleys. Southwest of Gowanda, on the broad flats in the Town of Dayton are interlobate moraine loops, newly named here the Markhams moraine, that appear coeval with the earliest Cattaraugus outwash described above. Muller (1975) suggested a Defiance correlation for this ice-border outwash but its age is younger.

In Buttermilk Valley, gravel that caps Lavery till is close in age to the Markhams outwash, and serves as the oldest, highest base level datum. In the upper Cattaraugus Valley near Sardinia, olive gray clays covered by outwash suggest lake ponding at the east end of the Markhams ice lobe. An age of about 15,000 ybp is estimated for these events.

2.5.3 Lake Escarpment - Valley Heads Glaciation

Recession of ice from the Markhams position may have allowed dissection of Lavery till in the Cattaraugus Valley and in valleys to the north, but the consequences of the drainage, albeit it lasted several hundred years, do not appear significant. The return of ice over an unknown distance restored outwash and lake conditions as shown on Plate 7, which illustrates the maximum stand of Lake Escarpment-Valley Heads ice, or very nearly so. The Thatcher till, identified by Calkin (1982) near Gowanda, is correlative.

Outwash complexes spread south into the main Cattaraugus out of lobate ice in major north-trending valleys. Drainage east and southwest of Gowanda was ice-blocked. Lake conditions in the Zoar section of Cattaraugus Valley are suggested by fine sands of the Zoar moraine at about 1400 feet, and by now-isolated remnants of sand along the Cattaraugus gorge rim. The cumbersome but useful name Wango-Cottage-Dayton-Zoar-Wyandale-Springville-Chaffee-Java Lake complex suggests locations of elements of outwash and moraine in valleys, from west to east; a shorter version, Dayton-Zoar-Chaffee, will suffice. This outwash provides the next base level datum for early main Cattaraugus downcutting. The constructional surface is set into and behind the Markhams outwash east from Zoar valley and Springville and is estimated at about 14,200 ybp in age.

2.5.3.1 Perrysburg-Sardinia Moraine and Outwash

Continued recession of the Lake Escarpment-Valley Heads ice margin established a position, shown on Plate 8, from which a second generation of outwash was inset into the earlier Springville-Chaffee outwash. A drop of about 30 feet in base level took place in the eastern Cattaraugus Valley. Much of the Sardinia outwash is reworked Chaffee outwash. Grain size of the deposits becomes finer downstream. At the western end of the basin ice-border channels passed into and out of the ice around Perrysburg. East of Gowanda the Cattaraugus was still imponded. Ice border deposits there are fine grained. Leakage of lake water into the ice was likely. Water surges from ice margin streams entering at Springville and Sardinia perhaps were responsible for ice-plug deterioration downstream. Timing for this margin position is near 14,000 ybp. This was the last glacial border that furnished meltwater through the main Cattaraugus.

2.5.3.2 West Perrysburg Moraine - Proto-Cattaraugus Creek

Demise of high meltwater discharge was followed by a period of nominal stream flow, sustained by high groundwater outflow from a dissecting (Springville-Chaffee) gravel aquifer of very large capacity. Recession of ice to the West Perrysburg margin position (Plate 8) coincides with earliest Cattaraugus Creek. At the north end of South Branch Valley, ice-border, gravel deltas record vigorous discharge of South Branch, more fluvial in character than previously when a glaciolacustrine embayment of a broader valley collected fine sand. Timing of this ice border position is about 13,900 ybp.

2.5.4 Gowanda Moraine

Recession and readvance of the Erie lobe, at about 13,700 ybp, established the Gowanda moraine at elevations between 940-1,000 feet (Plate 8). Reworked Lavery till underlies the fine-grained moraine, deposited in a pro-glacial lake. South of the ice border near Gowanda are fine-grained gravelly deltas of small streams fed in part by groundwater discharge from the Lavery till flat broadly exposed throughout the Town of Persia. The Zoar reach of the Cattaraugus by this time was beginning to dissect bedrock. Lack of a fluvial terrace record in the Zoar section, thereafter, hinders good base level correlations between Cattaraugus reaches on either side of Zoar.

2.5.5 Versailles Moraine

A pause in ice recession from the Gowanda moraine at about 13,600 ybp caused emplacement of the Versailles moraine (new) along the ice border shown in Plate 8. The Cattaraugus must have built a delta against the ice at Gowanda, but only small terrace remnants now record this. North from the Gowanda State Hospital grounds, an extensive flat underlain by gravel, shows evidence of ice contact on its western edge. Ice-border channels west of Perrysburg continued to carry westward drainage into and out of the ice as Erie basin glacial lake levels continued to fall through the Mackinaw Interstade.

2.6 Glacial Lakes

2.6.1 Lake Whittlesey

The level of Lake Whittlesey, about 13,000 ybp, is well shown by beach features at 835 feet but is not well recorded by a Cattaraugus delta (Plate 9). A small delta of North Branch of Clear Creek is preserved north of the Cattaraugus. What sedimentary record the Cattaraugus left in Lake Whittlesey was later swept away and relocated into Lake Warren I.

2.6.2 Lake Warren I

The most extensive delta of the Cattaraugus built into Lake Warren I, at about 12,700 ybp (Plate 9). Lake level stood at 797 feet, well marked by beaches. Despite probable loss of record by reworking of Whittlesey and Versailles accumulations, it is likely a heavier discharge from Cattaraugus and South Branch occurred during Lake Warren I time, or a longer tenure for Lake Warren I was responsible. The Warren I delta is the youngest extensive base-level datum in the western Cattaraugus basin.

2.6.3 Later Glacial Lakes

Lakes Warren II at 780 feet and Warren III at 765 feet are expressed by beach segments and sandy bottom land. Successive glacial lakes Wayne (740 feet), Grassmere (715 feet) Lundy (695 feet), Early Algonquin (622 feet) and Dana (610 feet) are shown by nips of shale rubble and by local gravel terraces. Table 1 shows the briefness of each lake stage; a recorded Cattaraugus depositional response is expectedly weak.

3.0 RATES OF DOWNCUTTING BY CATTARAUGUS CREEK AND TRIBUTARIES

3.1 Previous Work

In a fluvial transport and erosion study of Buttermilk Valley, Boothroyd, Timson and Dunne (1982a and b) were concerned with short and long-term changes in stream channel geometry, movement rates of clasts, sediment, and slides, and establishment of a denudation rate for the environs of the radioactive-waste burial ground. Their study, of necessity, drew upon short-term observations of stream and valley dynamics that were not impacted upon by considerations of change in base level.

3.2 Approach and Methods

The present study deals only with the vertical aspect of dissection, not dynamics of sediment moving downslope or through the stream system. Short-term, qualitative observations are important to this study, but most of its results are based upon an historical record some 15,000 years in duration. Two areas of investigation soon came into parallel focus, addressed by the following questions:

First

1. At what rate or rates has the Cattaraugus system lowered its valley floor to where it is today?
2. Can preserved late glacial and Holocene base levels be placed in a time frame?
3. How does rate of downcutting vary throughout a stream length from head to confluence?
4. Is rate of downcutting constant through time?
5. What is it now?
6. What will it be over the next two millenia?

Second

1. How does the stream thalweg actually lower itself into the valley floor?
2. Can geomorphic agents, processes, and forms be identified that directly cause downcutting?
3. If they can, to what extent to they interact? Are interactions smooth and continuous? controlled by thresholds?
4. Do the processes that cause downcutting have rates reasonably in agreement with rates suggested by stratigraphic evidence?

Temporary and local base levels are commonplace in a deglaciating region, preserved as sloping terrace surfaces (of aggradation mostly) that are progressively inset as base level lowers. Also, rates of lowering during deglaciation may be unusually high due to rapid changes in lake levels, moving glacial borders, and sudden fluvial outbursts. Base level is restored by glacial readvance, to begin to fall again. Despite these complexities, a reasonably good record is preserved of early base levels that are datable by mapping of glacial deposits, and reference to a regional deglacial time scale. These early base levels provide the upper datum horizons throughout most of the Cattaraugus basin, and are in the 15,000-13,500 ybp range. See Plate 4, for example.

For post-glacial time, however, some other method of dating must be found. Fortunately, part of the abundant Holocene forest of the Cattaraugus basin has been incorporated, as logs, twigs and leaves in alluvial terrace sediments. Deposits in this time span, from about 10,000 ybp on, are best dated since about 5,000 ybp.

Plate 4 is a composite longitudinal diagram of Buttermilk Valley showing various methods of determining downcutting rates, elements of glacial stratigraphy, and landscape surfaces from which vertical dissection is measured. Those items in parentheses pertain when the diagram is used as a stratigraphic cross-section; the remaining lines and line segments apply geomorphically to surfaces, such as terraces, abandoned meander scars, modern floodplain, and thalweg, that relate to downcutting of the glacial sediment pile and shale bedrock. Numbers are radiocarbon dates, located at appropriate horizons in alluvial sediments. Calculations of downcutting rate in feet per century (ft C^{-1}) are shown; rates are enclosed in circles, squares or triangles, depending on the method of calculation. See the legends and keys to symbols of Plates 2 and 4 for explanation.

Plate 4 is one of ten profiles/sections prepared for stream reach segments of the main Cattaraugus and tributary Buttermilk, Connoisarauley, and South Branch. The Buttermilk section is selected as an example because of its pertinence, because all of the methods of rate determination can be applied here, and because the greatest range of radiocarbon dates comes from this valley. The remaining nine sections, in worksheet form, are on open file with the NYS Geological Survey.

3.3 Determinations of Base Level Change

Since its formation more than 12,000 years ago, Lake Erie has served as Cattaraugus base level, for 80 percent of the time we are interested in. Most likely modern downcutting rates are lower than early rates. Particularly from the record of the past few hundred years or a millenia at most we should obtain data that enable prognoses to be made. Indeed, late Holocene alluvial deposits abound with datable woody material contained in generally aggradational terrace sequences along modern streams. These exposed sections can be misleading. Some may prompt, from a first impression, the conclusion that a long (up to several thousand years) episode of terrace buildup was terminated by onset of downcutting commencing at, say, 1,000 years ago. See Figures 5, 6, 7, 8. Observational bias is introduced because the stratigraphic record is mostly a constructional one that preserves former streamway (bar and channel) or floodway (floodplain) deposits, rather than destructional events. If aggradational - degradational cycles existed, their duration is not, at any scale in the basin, consistently shown. The idea of suddenly terminated terrace buildup due to downstream nickpoint deterioration is promoted in a later section of this paper. Intuitively, initiation of cycles of sudden downcutting is more likely measured in hundreds rather than thousands of years. Superimposed on any aggrade-degrade cyclicity must be an ongoing downcutting, whose rate is the concern of this investigation.

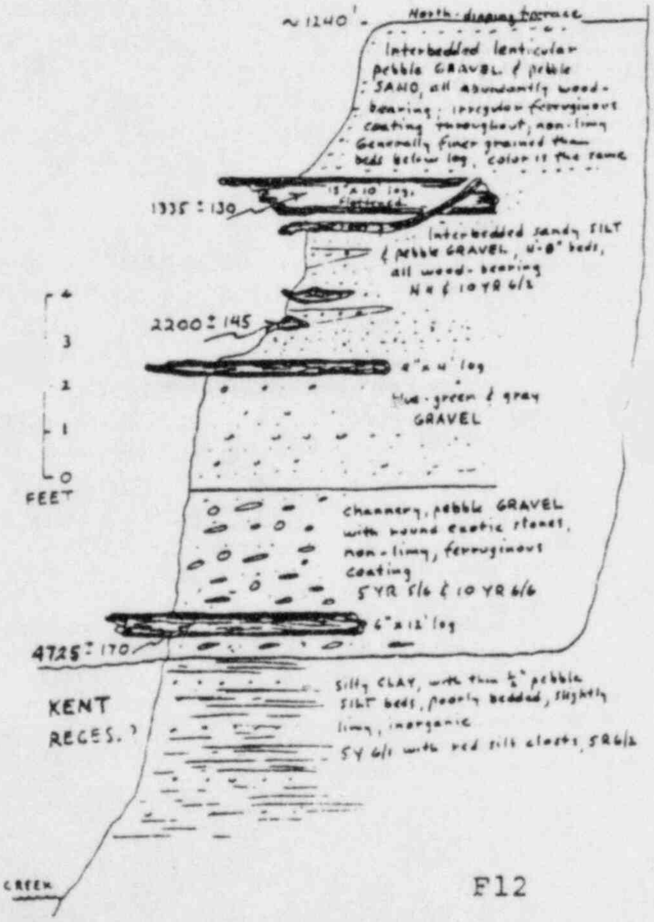

Figure 5. Aggrading channel - floodplain section overlying glaciolacustrine clay; east bank Connoisarauley Creek, 1,000 feet north of Connoisarauley Road.

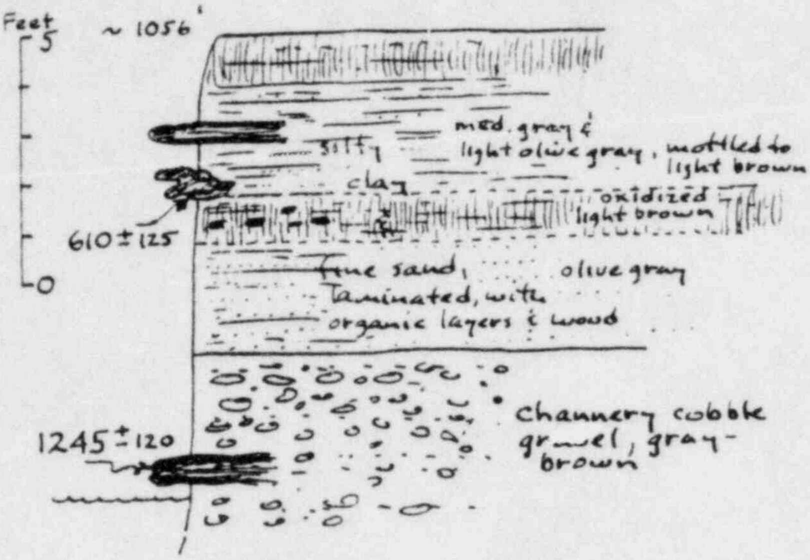

Figure 6. Aggrading channel - floodplain section containing datable oxidized zone; east bank Connoisarauley Creek, 4,000 feet south of Cattaraugus confluence.

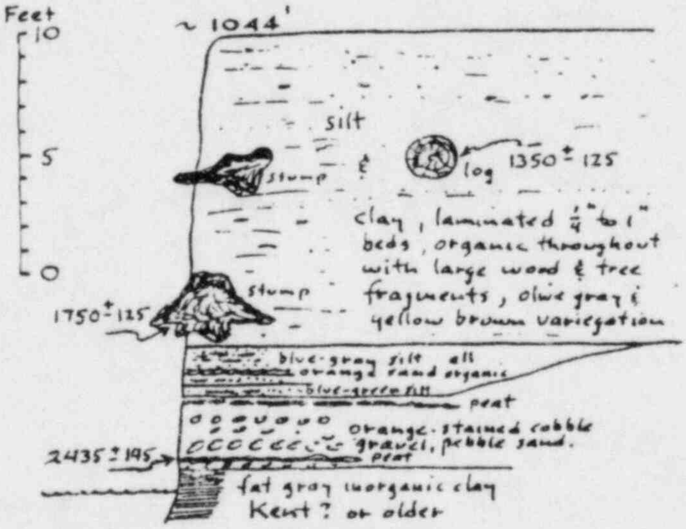

Figure 7. Aggrading channel - floodplain section; north bank Cattaraugus Creek, 3,500 feet east of Frye Bridge.

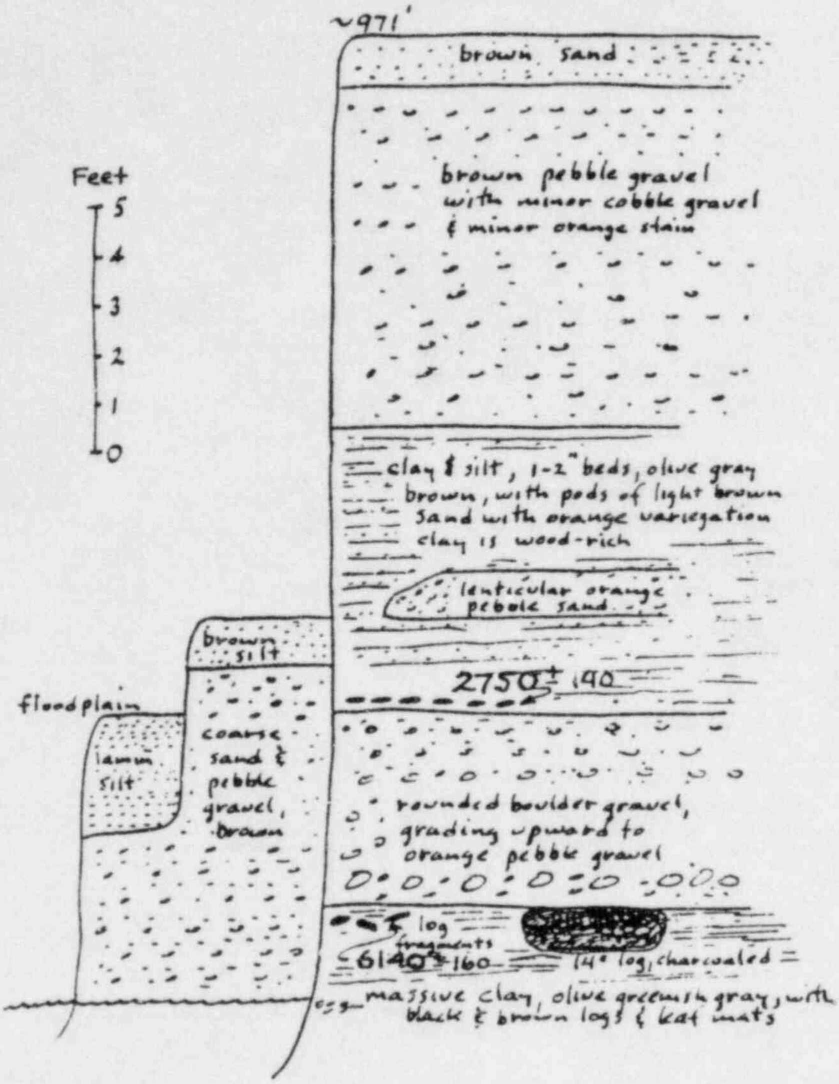

Figure 8. Multiple aggrading channel - floodplain section; north bank Cattaraugus Creek, 2,900 feet west of Coon Brook confluence.

Inspection of Plate 2 shows that rates derived from radiocarbon dated alluvial deposits plot fairly well in Buttermilk Valley with respect to other points derived by "less precise" methods, but appear to be too high in South Branch, too low in Connoisarauley, and too high in upper Cattaraugus. Much of this apparent contradiction may relate to a) difficulty in establishing a time of abandonment of the first terrace surface above the modern floodplain, b) the tendency of young dates to be less reliable than older ones, and c) establishing the relation between streamway relief and its contained bar facies and floodplain deposits preserved in superjacent terraces. Comparison of Figure 9 with Figure 10 might prompt the question "how do we know any downcutting has occurred in the past 885 years, so long as the entire deposit thickness is no more than the relief of the modern streamway"? But more often the record of fluvial terraces resembles that of Figures 8 and 15 from which a better feel for the downcutting aspect can be obtained.

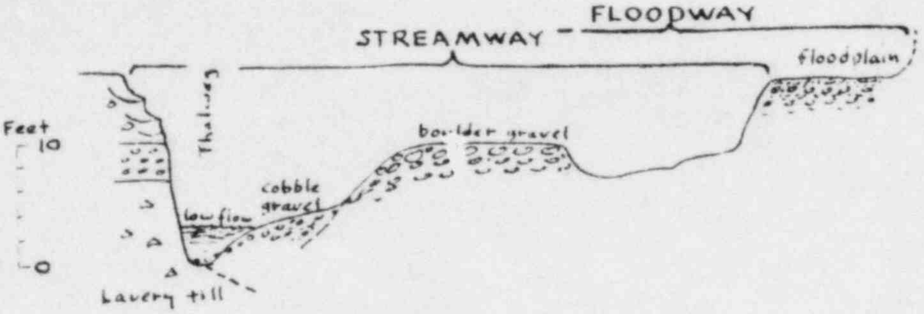

Figure 9. Streamway relief, facing upstream, Buttermilk Creek, 1700' south of Buttermilk Road crossing.

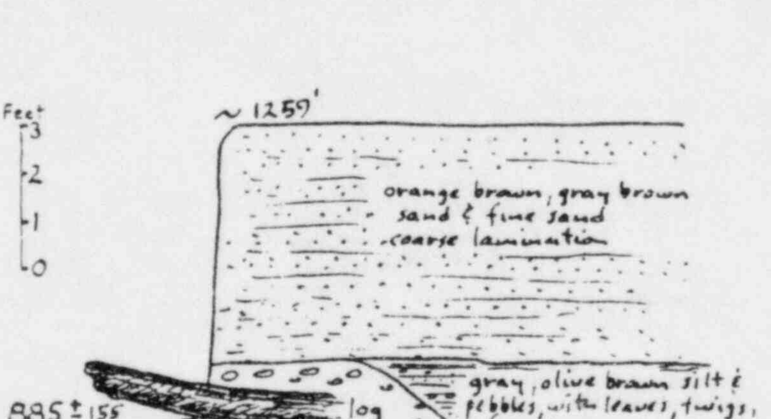

Figure 10. Exposure 200 feet north of location of Figure 13. Organic silt is same as silt unit of Figure 13. Buttermilk Creek, west bank, 600 feet north of Buttermilk Road crossing.

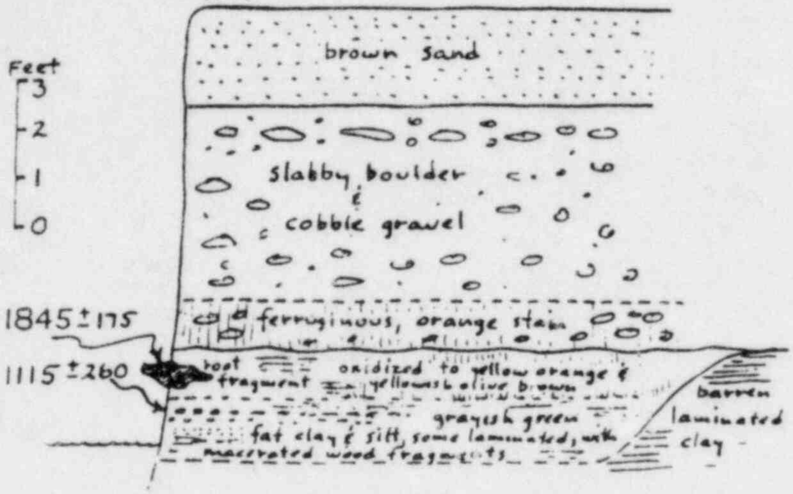

Figure 11. East bank exposure of four facies, ascending: glacial lake clay, alluvial valley lake clay, channel gravel, flood plain sand; Buttermilk Creek, 3,600 feet southeast of gaging station.

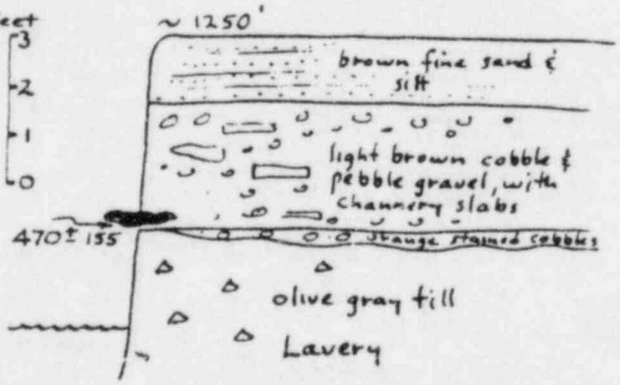

Figure 12. Exposure showing erosion surface (thalweg or near-thalweg) on Lavery till, overlain by bar and modern floodplain sediments; east bank Buttermilk Creek, 1,000 feet north of Buttermilk Road.

3.3.1 Data Analysis

Using field data obtained from glacial geologic and valley floor mapping and from measured alluvial sections, a longitudinal plot of the Cattaraugus and three tributaries was made. Included on each work sheet is the present stream grade, all previous stream level indicators that could be identified, and alluvial sections containing dated organic material. Plate 4, of Buttermilk Valley, is an example.

Several methods of working out downcutting rates were used, with rates, in feet per century, ft C^{-1}, summarized on Plate 2. This plot (Plate 2) relates rates, determined by the following methods, to geographic position in the drainage system only. See the legend of Plate 2 for diagrams.

A. Rate of downcutting between constructional surface of known or estimated age and modern streamway. This method cannot reflect change in rate through time and can be particularly distorted by very high rates, up to 20 ft C^{-1} that occurred during or between outwash insetting episodes. The method is more reasonably used in tributaries where downcutting is in more of a steady state. It may provide an upper limit of value for modern rates. Rates determined by this method are plotted as, or enclosed in squares on Plates 2 and 4.

B. Rate of downcutting between constructional surface of known age and dated streamway, not of modern age. This method is valuable if the age of the older dated streamway is relatively old, say many thousands of years, and it gives good approximation of earlier rates. Rates determined by this method are plotted as, or enclosed in circles on Plates 2 and 4.

C. Rate based on stratigraphic spatial relationships among dated old and young streamways (bar facies), floodplains, and thalwegs. This method uses the dated woody alluvium along the modern streams. With dates generally in the hundreds of ybp range, the method suffers some from wide deviation from stated date due to young age. Rates determined by this method are plotted as, or enclosed in triangles on Plates 2 and 4. Figures 5-8, 10-18 show the measured sections on which dated similar facies or surfaces can be compared.

3.4 Sources of Error in Age

Age errors due to contamination or dead carbon inclusion are less likely than errors that would result from incorporation of relict or "fossil" wood (of age significantly greater than the age of the deposit in which the dated wood is found). For example the basal date of 6140 ybp of Figure 8 seems too old to date valley floor position and an inversion in stratigraphic ordering is indicated in Figure 11 by the 1845 ybp date. However, stratigraphic order is maintained very well in the great majority of sections; see particularly Figures 5, 7 and 15.

Another source of imprecision is in the (±) deviation when the date is very young (a few hundreds of years before present). Figure 13 shows 3 dates that can all overlap; Figure 17 shows a section where an iron bucket is buried with wood that seems too old.

Despite these difficulties, all the data were plotted, and a large scatter expectedly resulted. Referring to Plate 2, one could conservatively conclude that a downcutting rate of about 1.3 feet ± 1.0 foot per century satisfies nearly all the points anywhere in the study area. But trend lines drawn by eye through the data envelopes permit some useful geomorphic inferences, and average out, to some degree, spurious dates.

3.5 General Trends in Downcutting

After all points, regardless of method of rate determination were plotted (Plate 2), trend lines approximately besecting the scatter were drawn. One might conclude from Plate 2 that

1) overall rate of downcutting in tributaries increases downstream in apparent response to increasing discharge (bed shear). Increases in rates are variable from stream to stream, but there is always good agreement between rate of downcutting of the tributary and that of the major stream at the tributary confluence. (Playfair's Law is obeyed, but is actually somewhat violated, as explained later.)

2) the tightest data envelope is for Buttermilk Creek; perhaps Buttermilk has had a more orderly erosional history compared with the others.

3) Cattaraugus Creek rates decline downstream after peaking, as the Lake Erie base level is approached. Perhaps

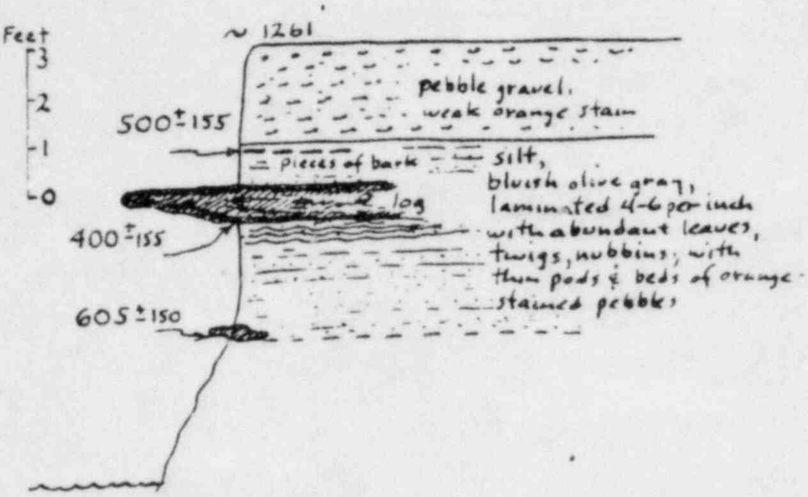

Figure 13. Aggrading floodplain or fluvio-lacustrine silt overlain by fine floodplain(?)gravel; west bank Buttermilk Creek, 400 feet north of Buttermilk Road.

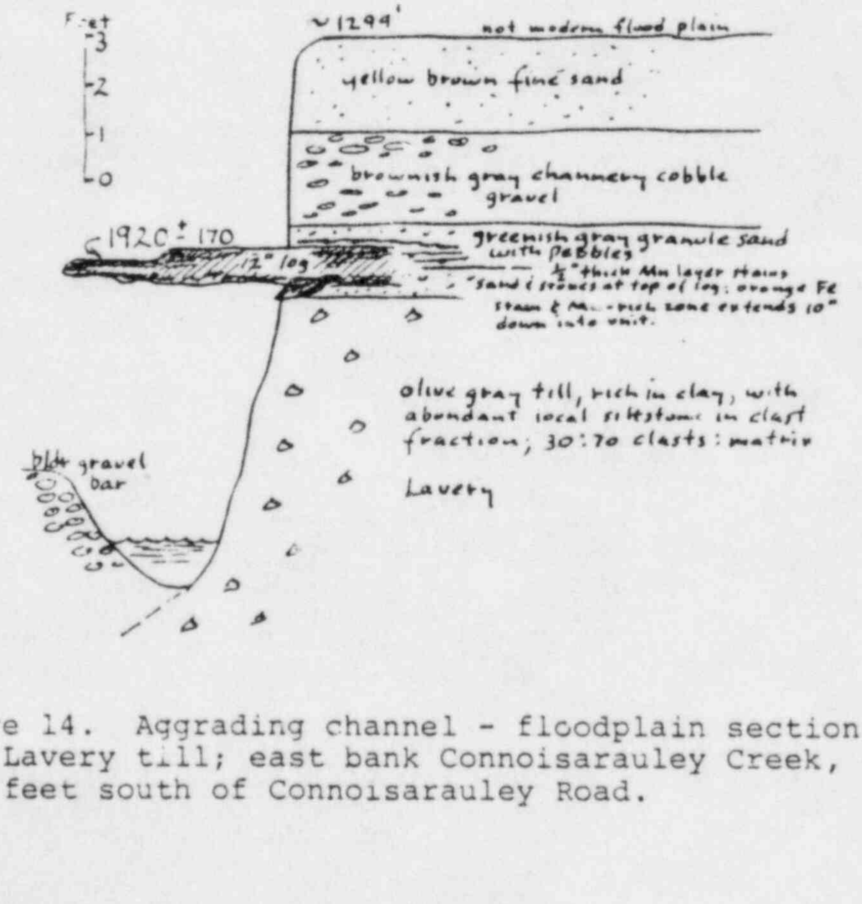

Figure 14. Aggrading channel - floodplain section overlying Lavery till; east bank Connoisarauley Creek, 3,600 feet south of Connoisarauley Road.

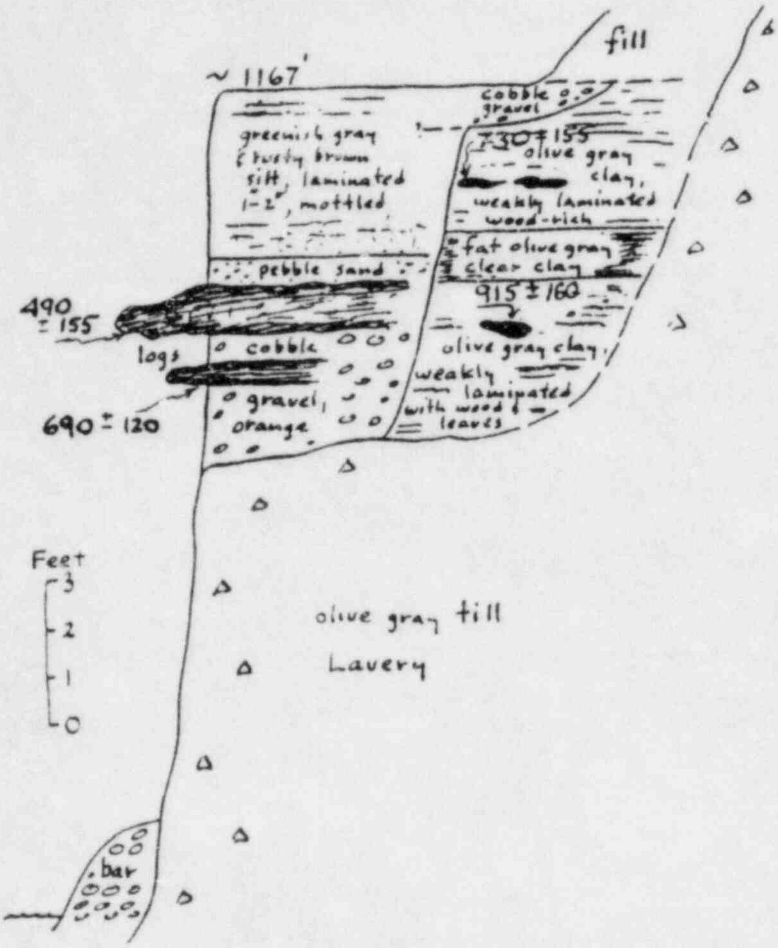

Figure 15. Aggrading channel - floodplain sequence inset on lacustrine clay; overlying Lavery till; east bank of South Branch Cattaraugus Creek, beneath road culvert at New Albion town line.

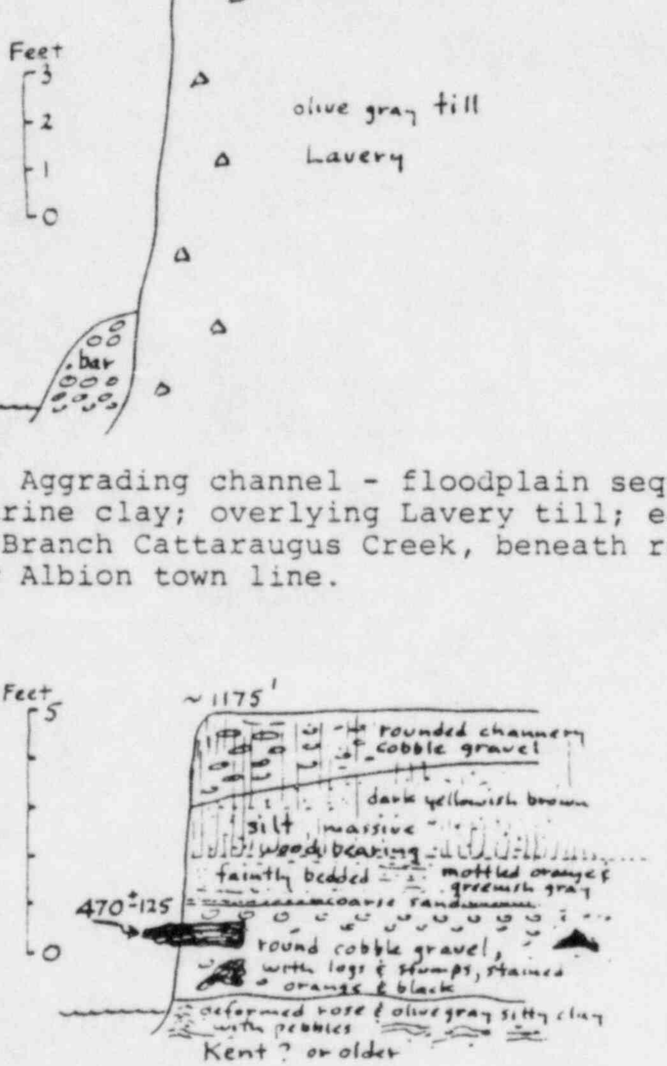

Figure 16. Channel(?)gravel overlying aggrading channel - floodplain section; west bank Connoisarauley Creek at ford, 4,300 feet north of Connoisarauley Road.

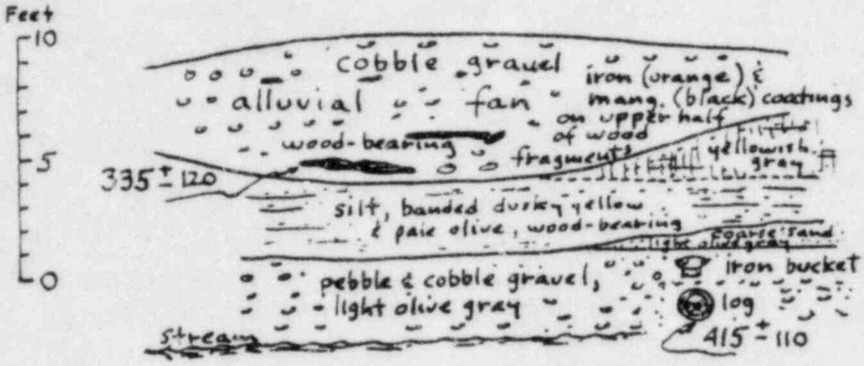

Figure 17. Artifact-bearing channel gravel and floodplain silt overlain by alluvial fan gravel; north bank Cattaraugus Creek, 700 feet east of Johnson Road.

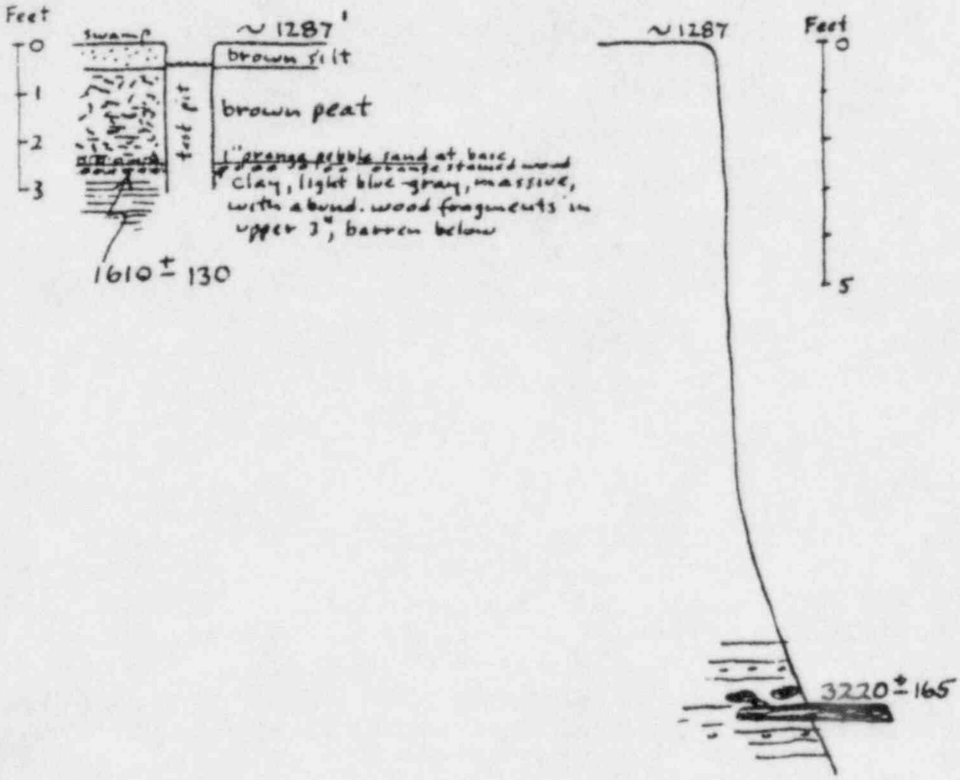

Figure 18. Test pit section in swamp in abandoned meander, and related south bank exposure on Cattaraugus Creek, at Blumont ski center.

reworking of glaciolacustrine deposits in the Erie Lowland combines with the anticipated drop in rate as gradient is lowered to give a descending trend line.

3.6 Rate Changes Through Time

The trend lines of Plate 2 do not address the question of rate change through time. They do provide some control and may help quantify rates that vary with respect to location.

Plate 3 is a plot that compares downcutting rates with time. The position on the time axis is given by the midpoint in time between the oldest and youngest dated base levels, paying particular attention to the more ancient time intervals. For example, a plot of the 15,000 to 9,900 ybp interval places that average rate in ft C^{-1} at the 12,450 ybp point. There are not enough old dates to allow a more sophisticated plot of rates with respect to both time and position on a stream; Plate 3 does not take stream position into account. But the trends established by these few points may allow prediction of future rates and more realistic evaluation of rates of the very recent geological past.

3.7 Prognosis for Buttermilk Valley

Projection of the curve for Buttermilk Valley shows a rate of about 0.7 ft C^{-1} to 0.5 ft C^{-1} continuing for the next two millenia. These figures, applied to the environs of the burial ground, suggest a lowering of Buttermilk Creek of 10-14 feet will occur in that time.

4.0 DOWNCUTTING AGENTS AND FORMS

From one stream reach to the next, Cattaraugus Creek and its tributaries are cutting through either horizontal Devonian Canadaway shale and siltstone or glacial sediments of fine grain size, usually either Lavery or Kent tills. Stream gradient expectedly increases through the rock reach. Downcutting is a deepening of the thalweg - other activities along the stream such as downstream migration of bar gravel and lateral migration of the meandering channel may not always contribute to thalweg deepening and may actually impede the process. A comparison of bedrock and glacial sediment reaches along a stream may be helpful.

4.1 Rock Reaches

The interbedded calcareous shale and siltstone is very wet-dry sensitive. Only where the bedrock is always immersed in water does it show structural integrity. Above the stream surface, dew-sunshine and raining-drying cycles constantly torment the outcrop so that break-up to small angular blocks and chips less than an inch across is chronic. On the other hand, where water constantly runs over the rock, it forms a surface so smooth that the fingers cannot detect any bedding planes or joint fractures. This surface texture contrast is striking and the contact is sharp at the low-water line. Two agents operate on the rock simultaneously, depending on the saturation environment. One acts to promote roughness by enhancing fracture, the other acts to perpetuate surface smoothness by removal of individual rock grains and cement.

Although channel morphology is optimized at bankfull discharge, and streambed shear improves with discharge, it is clear that considerable preparation for downcutting takes place during times of extremely low flow. Low flow conditions prevailed during much of the droughty 1982 field season, and permitted observation of freshly breaking rock at the lowest possible location adjacent to the stream water. Higher discharges, from passing storms of modest intensity, were then able by hydraulic plucking and simple traction to quarry away the debris, up to the high water mark for that minor flood event. It was not even necessary to achieve bankfull conditions to accomplish this.

Where interbeds of siltstone as thin as 2 or 3 inches appear at stream level, falls up to several feet in height form. These small nickpoints travel upstream by scarp retreat. Insidious scarp failure also continues, during times of very low flow, aided by near-surface groundwater seepage along the falls face. Much of this seepage may evaporate or run out quickly, but it is available to cause wetting and drying. Whether the nickpoints travel the whole rock reach depends on stratigraphic continuity of the beds involved. Along South Branch are several migrating nickpoints about 3,000 feet apart; one is nearing the upstream end of the rock reach. As soon as it disappears, an increased gradient will be applied to the glacial sediment reach above, causing cessation of any aggradation in that reach and accelerated downcutting.

Inspection of nearly all of the measured and dated alluvial sections suggests a rather sudden change from aggradation to degradation can take place, perhaps triggered by nickpoint deterioration. For example, the falls in Connoisarauley gorge, when they expire into the glacial sediment reach upstream, should impact on the gradient of all of the Connoisarauley Valley above by 10-14 feet. Unlike South Branch and Connoisarauley, Buttermilk does not have migrating scarp nickpoints of serious dimension; rather, "micronicks" formed on-low relief stratal edges that travel as rapids.

Although terrace remnants and minor floodplains exist in rock reaches, much more of the thalweg rests in the host material (bedrock) than it does in the glacial sediment reaches. There, storage of slowly moving alluvium in coarse gravel bars is more common. Many segments of rock reaches are cleanly swept of fluvial debris wall to wall, particularly where the gorge narrows. But in the glacial sediment reaches the gravel bars shield the underlying till from the full brunt of downcutting to some degree.

4.2 Glacial Sediment Reaches

Broader valley floors with more gentle gradient form between the dissected rock gorge reaches. Clay-silt tills, mainly Lavery are the thalweg host materials, and pools develop in the till with asymmetrical long profile as shown in Figure 19. Abrupt relief of 3 to 4 feet is not uncommon at the head of each pool. The till headwall, like the rock nickpoint, migrates upstream, even in the presence of an armoring channel gravel cap. Preparation of till in banks in the vicinity of the pool during very low flow may include mudcracking on the till face that could respond to hydraulic plucking by subsequent higher discharge. But along straight reaches much of the Lavery till erodes rather into smooth-walled, corrugated channels with relief and width of several inches, more or less by grain loss.

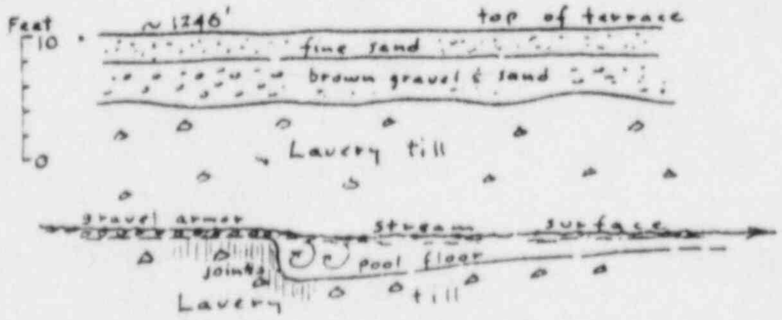

Figure 19. Longitudinal profile of thalweg pool cut in jointed Lavery till. Stream flow is left to right. West bank Buttermilk Creek, 2,700 feet north of Buttermilk Road.

Nickpoints other than headwalls of pools take the form of local increased-gradient reaches where subjacent Kent tills, more consolidated and clast-rich than the Lavery, host the thalweg. These short, steeper reaches are never so abrupt as falls, but nonetheless they migrate upstream, e.g. in Connoisarauley Valley.

4.3 Stream Confluences

To return to the notion that minor violations of Playfair's Law are useful, it is observed that at nearly every confluence there is an abrupt increase in gradient of the tributary stream. Best examples of this are provided where both the tributary and major stream cut in rock, as at the end of South Branch. Most of the time the balance of discharge between tributary and master stream is in favor of the larger stream, especially under areally variable storm intensity conditions of passing fronts. The effect is to maintain a tendency for nickpoint formation in the tributary at the confluence even in the smallest order streams.

Perpetuation of headward migrating nickpoints originating at the confluence is assured; additional lithologically-induced nickpoints may be added within the rock reach as downcutting encounters lenticular siltstone beds.

Whether headward migration of nickpoints is more important in rock downcutting than <u>in situ</u> downwearing by microfracturing and solution is not known. Probably it is not; these processes likely work in concert to accomplish reasonably uniform rock valley floor gradients through time.

4.4 Temporal Changes in the Geomorphic System

Much of the data (Plate 3) show a trend toward reduction of downcutting rate through the past several millenia. Dissection of a large part of the Cattaraugus basin has taken place through tills of considerable thickness, particularly Lavery and Kent. The following scenario is suggested for Buttermilk and Connoisarauley Valleys.

As dissection of thick tills continues, a growing lag of till stones, not readily purged by stream flow, collects in the glacial sediment reaches. These clasts form bars and clutter channels, thereby consuming hydraulic energy that could be directed toward deepening the thalweg. It is actually the removal of till matrix fines - something the stream does easily - that keeps downcutting active. Compounding the lag-armor gravel buildup is the mass movement of Lavery till in landslides that ofter impinge directly on the stream channel. As the valley deepens, slope failures worsen. Clast transport and mass movement processes thereby combine, in the long-term presence of a more-or-less steady-state climatic condition of the Holocene, to retard the rate of downcutting.

On the other hand, rock reaches, with their high cliffs, have been shielded from direct down-the-bank till clast input for many millenia. Their steeper gradients allow easier passage of boulders that do enter, so the rock reach stays relatively free from lag, save the occasional rock fall, which readily deteriorates.

We might test the idea that the shale and siltstone is more quickly downcut by referring to Plate 3 and noting that South Branch downcutting rate appears to be anomalously increasing with time. The ratios of rock reach length to the total stream length studied in South Branch, Buttermilk (Figure 4) and Connoisarauley Valleys are 0.61, 0.28, and 0.23, respectively. These values reinforce the idea that valley deepening may be encouraged by abundant bedrock exposure as in South Branch, and hindered by widespread glacial sediment fills that typify Buttermilk, Connoisaurauley and much of the main Cattaraugus.

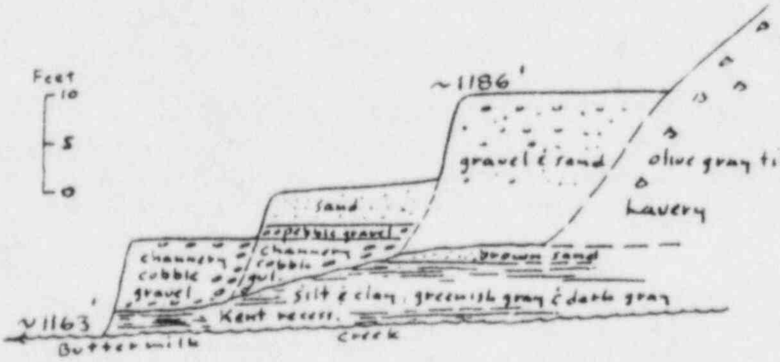

Figure 20. Inset terraces, east bank of Buttermilk Creek, 2,700 feet southeast of gaging station.

Figure 21. Channeled glacial sediments overlain by channel bar gravel and incompletely oxidized silt of former floodplain; east bank of Buttermilk Creek, 1,000 feet south of railroad bridge.

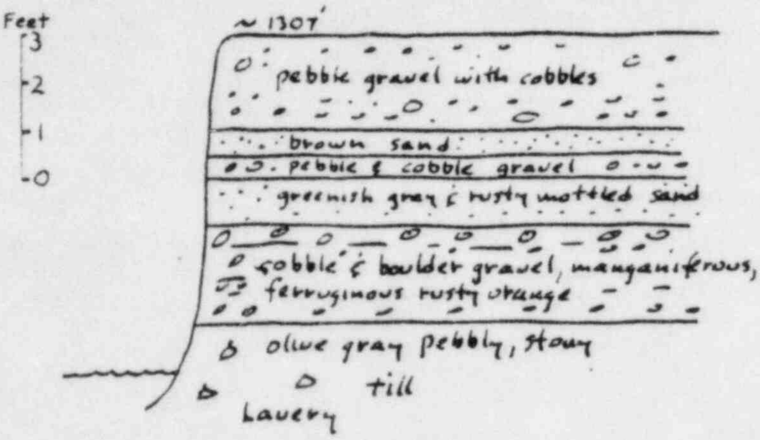

Figure 22. Mixed channel section overlying Lavery till; east bank Connoisarauley Creek, 4,600 feet south of Connoisarauley Road.

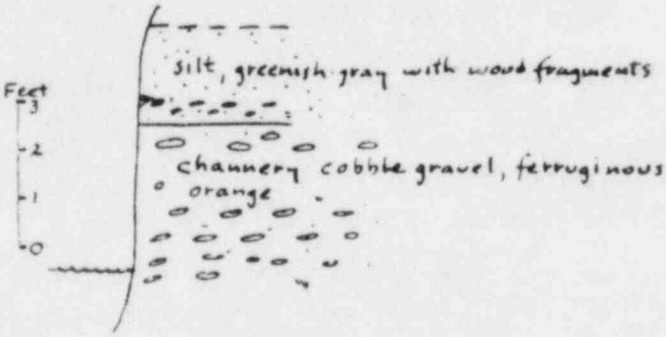

Figure 23. Section 150 feet north of location of Figure 6 apparently correlatable with lower half of section in Figure 6.

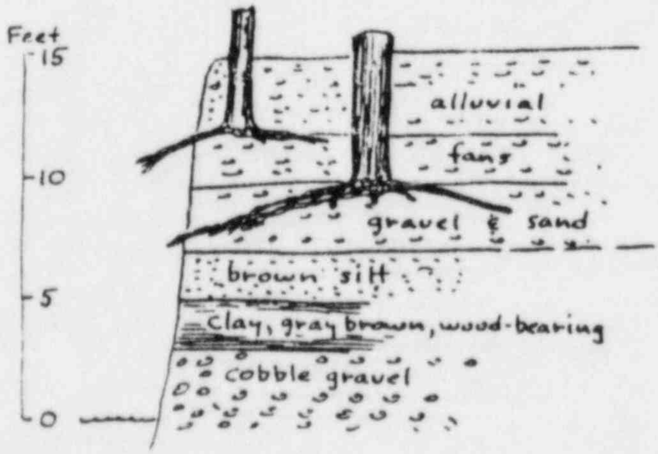

Figure 24. Tree-bearing alluvial fan gravel overlying Cattaraugus alluvium; west side of Gunbarrel Creek at confluence with Cattaraugus.

5.0 CONCLUSIONS

1. Valley deepening rates (downcutting, in feet per century) are presently in the range of 1.7 to 0.5 ft C^{-1} for Cattaraugus Creek and tributaries east of Gowanda. Lower rates may apply west of Gowanda.

2. Downcutting by Buttermilk Creek is projected for the next two millenia at a rate of about 0.7 to 0.5 ft C^{-1} in the vicinity of the West Valley radioactive-waste burial ground.

3. Sudden increases in downcutting rate in the past are suggested by the stratigraphic record, but none seem likely, except in South Branch, within the next 2000 years.

4. Downcutting mechanisms include upstream scarp retreat of nickpoints in both rock and glacial sediments, and downwear by grain loss and minor solution. None of these are quantified but are seen to operate today.

5. Control of rate of downcutting may be maintained by the rock reaches. Increased stream gradient may be applied to a glacial sediment stream reach by expiration of a migrating rock nickpoint.

6. Long-term retardation of downcutting rate may result from till-clast lag buildup and from landslide interference with the stream channel in valleys where glacial sediment reaches predominate, as in Buttermilk and Connoisarauley Valleys. The rock-reach length/total stream length ratio in these valleys is about 1/4.

7. Contrarily, increase in downcutting rate is apparent in South Branch where the ratio of bedrock-reach length to total stream length approaches 2/3.

6.0 REFERENCES

Boothroyd, J.C., B.S. Timson, L.A. Dunne, 1982a, Geomorphic processes and evolution of Buttermilk valley and selected tributaries West Valley, New York, Fluvial systems and erosion study, Phase II, NUREG/CR-2862.

Boothroyd, J.C., B.S. Timson, L.A. Dunne, 1982b, Sedimentologic and geomorphic processes and evolution of Buttermilk valley, West Valley, New York, in Guidebook for NY State Geol. Assn., Buehler, E.S. and P.E. Calkin, editors, p. 325-353.

Calkin, P.E., 1970, Strand lines and chronology of the glacial Great Lakes in northwestern New York: Ohio Journal of Science, v. 70, p. 78-96.

Calkin, P.E., 1982, Glacial geology of the Erie lowland and adjoining Allegheny plateau, western New York, in Guidebook for NY State Geol. Assn., Buehler, E.J. and P.E. Calkin, editors, p. 121-148.

Calkin, P.E. and E.H. Muller, 1980, Geologic setting and glacial overview of the upper Cattaraugus Basin, southwestern New York, in LaFleur, R.G., Late Wisconsin stratigraphy of the upper Cattaraugus Basin: Northeast Friends of the Pleistocene, guidebook for 43rd annual reunion, Springville, N.Y.

Fullerton, D.S., 1980, Preliminary correlation of post-Erie interstadial events (16,000-10,000 radiocarbon years before present), central and eastern Great Lakes region, and Hudson, Champlain, and St. Lawrence lowlands, United States and Canada: U.S. Geol. Survey, Professional Paper 1089, 52 p., 2 correlation charts.

LaFleur, R.G., 1979, Glacial geology and stratigraphy of Western New York Nuclear Service Center and vicinity, Cattaraugus and Erie counties, New York: U.S. Geol. Survey Open-File Report 79-789, 17 p.

LaFleur, R.G., 1980, Late Wisconsin stratigraphy of the upper Cattaraugus Basin: Northeast Friends of the Pleistocene, guidebook for 43rd annual reunion, Springville, N.Y.

Muller, E.H., 1963, Geology of Chautauqua County New York, part II, Pleistocene geology: New York State Museum Bulletin 392, 60 p.

Muller, E.H., 1964, Quaternary section at Otto, New York: American Journal of Science, v. 262, p. 461-478.

Muller, E.H., 1975, Physiography and Pleistocene geology, in Geology of Cattaraugus County, New York by I.H. Tesmer, Buffalo Society of Natural Sciences Bulletin 27, p. 10-20.

Muller, E.H., 1977a, Quaternary geology of New York, Niagara Sheet: New York State Museum and Science Service, Map and Chart Ser. No. 28, scale 1:250,000.

Muller, E.H., 1977b, Late glacial and early postglacial environments in western New York: Annals of the New York Academy of Science, v. 288, p. 223-233.

Appendix G. Bar Modification and Landslide Processes, Buttermilk Valley, West Valley, New York. Fluvial Systems and Erosion Study, Phase III

This section is a self-contained report by Jon C. Boothroyd and Barry S. Timson of Earth Surface Research, Inc., supported by a grant from the New York State Geological Survey. This report completes the three part study of geomorphic porcesses occurring in the Buttermilk Creek drainage basin.

BAR MODIFICATION AND LANDSLIDE PROCESSES, BUTTERMILK VALLEY, WEST VALLEY, NEW YORK

Fluvial Systems and Erosion Study, Phase III

Technical Report
prepared for:
New York State Geological Survey

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December, 1983

ABSTRACT

The specific objectives of the Phase III study were to re-examine bar modification, landslide processes, and gravel transport in Buttermilk Valley.

We conclude that yearly autumn storm events or a moderate spring freshet do not substantially alter the bar complexes, although some gravel transport does occur.

Stream discharges of 15-20 cu m/sec appear to be quite common events approximately bi-monthly. These events, while transporting a significant quantity suspended sediment, move only the very fine gravel. As such, they are not bar or channel modifying events. We believe that bar and channel changes are affected only by 40 cu m/sec events and above. A 40 cu m/sec event may be the 1-year return flood, as stated in the Phase II report.

Continued monitoring of landslide movement by slumping and earthflow corroborates earlier (Phase II) estimates of downslope movement of 1.5 cu m/yr. Movement initiated by toe undercutting during Hurricane Frederic, 1979, is continuing. Valley-wall failure appears to occur in a step-wise upslope progression involving, first, failure of the lower third of the landslide slope followed by failure of the mid-slope, and then the upper slope to the valley wall rim. At BC-6, failure of the mid-slope area appears to have just been initiated.

Studies carried out during Phase III lend detail and support to rates of processes and denudation determined during the Phase II study.

SUMMARY

The major objectives of the fluvial system and erosion study at West Valley are: 1) determine the seasonal, annual, and long-term modification of Buttermilk Creek and tributary drainage adjacent to the waste-burial, lagoon, and other areas of the Western New York Nuclear Service Center; 2) develop a denudation rate for the Buttermilk Creek drainage basin.

The specific objectives of Phase III were to: 1) reexamine and remeasure some features outlined during Phase II, 1980, and reported by Boothroyd and others (1982), 2) examine the new features and areas outlined below under work elements and information products.

The Phase III work was intended to be a study of spring freshet discharge and bar changes on Buttermilk Creek as outlined in Table 1. However, initiation of the project at a later date than anticipated precluded study of the freshet. Major work on the BC-6 landslide area and work on Frank's Creek was substituted. The new tasks are summarized below.

Changes in bar and channel geometry, as indicated by remapping of bar complex 4-6, were limited to: 1) the upstream end of the complex, 2) along the erosional bank and low-stage channel, and 3) at the downstream end of the complex. Changes were limited to channel switching in the transect 5-8 area, and growth of new longitudinal bars in the transect 16 area.

We conclude that yearly autumn storm events or a moderate spring freshet do not substantially alter the bar complexes, although some gravel transport does occur.

Stream discharges of 15-20 cu m/sec appear to be quite common events approximately bi-monthly. These events, while transporting a significant quantity of suspended sediment, move only the very fine gravel. As such, they are not bar- or channel-modifying events. We believe that bar and channel changes are affected only by 40 cu m/sec events and above. A 40 cu m/sec may be the 1-year return flood as stated in the Phase II report.

Mean-clast size (long axis) of the Frank's Creek clasts is 35 cm, about 10 cm larger than Buttermilk. However, inspection of the size diagram indicates that the upper 2 km of Frank's show a mean size similar to Buttermilk; whereas the lower 1 km has clasts that are significantly larger (average over 50 cm). We do not, as yet, have an explanation for the abundance of large clasts in lower Frank's Creek.

Continued monitoring of landslide movement at the landslide opposite BC-6 corroborates earlier estimates of average downslope movement at 1.5 cu m/yr. Movement initiated by toe undercutting by the Hurricane Frederic flood event in 1979 is still ongoing on the mid- and lower slopes of the landslide, the last monitored movement being a sudden downslope movement of a small, discrete block to the base of the slide during the November 4 flood and precipitation event.

Landslide evolution occurs in discrete steps from the base of the slide to the valley wall rim, each step involving a third of the landslide slope. Block failure and removal downslope to form base earthflow deposits initiates the same processes over the middle third of the slide and, eventually, the top part of the slide. Landslide surface morphologies adjacent to the present active area suggest this step-wise upslope progression. Too little monitoring data exist to apply a rate to this upslope progression of processes.

Studies carried out during Phase III lend detail and support to rates of processes and denudation determined during the Phase II study.

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Robert H. Fakundiny (State Geologist), Jim Albanese and Steven Potter of the New York State Geological Survey for helpful suggestions, logistical help and administrative support.

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1.0 INTRODUCTION

1.1 Purpose of Study

The major objectives of the fluvial system and erosion study at West Valley are:

1) determine the seasonal, annual, and long-term modification of Buttermilk Creek and tributary drainage adjacent to the waste-burial, lagoon, and other areas of the Western New York Nuclear Service Center;
2) develop a denudation rate for the Buttermilk Creek drainage basin.

The specific objectives of Phase III were to:

1) reexamine and remeasure some features outlined during Phase II (1980) and reported by Boothroyd and others (1982);
2) examine the new features and areas outlined below under work elements and information products.

The Phase III work was intended to be a study of spring freshet discharge and bar changes on Buttermilk Creek as outlined in Table 1. However, initiation of the project at a later date than anticipated precluded study of the freshet. Major work on the BC-6 landslide area and work on Frank's Creek was substituted. The new tasks are summarized below.

1.2 Work Elements and Information Products

The Buttermilk Creek work elements include:

1) topographic remapping of bar complex 4-6 to document changes since the last map as constructed in 1980.
2) measure clast movement at transects 5, 11, and 16 on bar complex, 4-6.
3) remap Landslide BC-6 to document changes since 1980. New elevation points were determined in order to expand coverage area of detailed topographic mapping.
4) measure flood events on Buttermilk Creek as they occur. Measure velocity/depth/discharge at Thomas Corners Road bridge and tie to flood hydrographs recorded by the NYSGS stage recorder.

The Frank's Creek work elements include:

1) measurement of average largest clast size (3 axes) 100 meter intervals along Frank's Creek.

Table 1. Original Tasks and Objectives.

	Tasks	Objectives
Task 1:	Monitor spring freshet of Buttermilk Creek. Monitoring to include measurements of discharge velocity, stage and suspended sediment load every three to six hours.	Establish discharge characteristics of an annual flood event to determine contribution of high-discharge event to total annual bedload and suspended sediment load discharge through the drainage basin.
Task 2:	Monitor clast movement at transects 5 and 11 of Bar Complex 4-6. task to include locating tagged clasts and measuring amount of movement which occurred during the freshet.	Determine bedload transport rates during annual flood event.
Task 3:	Remap all or portions of Bar Complex 4-6 to document changes caused by freshet flow.	Determine volume of bedload transport during annual flood event.
Task 4:	Prepare final report with integration of monitoring phase data with previous reports.	Integrate freshet data with phase I and II data and update conclusions.

1.3 Scope and Conditions of Study

This study (Phase III) was intended to add some additional detail to specific features or areas that were investigated at length during the Phase II study. Major conclusions have not been altered as a result of this phase of the study, but only have been updated.

The bar and channel mapping, profiling, and clast measurement was carried out during low-flow conditions in the fall of 1982. Buttermilk Creek is highly accessible, whereas Frank's Creek and the smaller tributaries are difficult to work in because downed trees create log jams that block the main channel of the creeks. We were on site for two storm discharge events on November 4 and 12, 1982. The events were of similar magnitude.

1.4 Previous Work

We will refer to the Phase II report of the geomorphic and erosion study (Boothroyd and others, 1982) and integrate our new results with the prior study. LaFleur (1979) summarizes the glacial geology and stratigraphy of the Nuclear Service Center site and surrounding drainage basins. A continuing series of technical reports issued by the New York State Geological Survey (NYSGS) on various aspects of site geology, chemistry, and engineering have proved useful (Hoffman and others, 1980; Dana and others, 1979; Dana and others, 1980).

Groundwater properties of till underlying the low-level burial site are contained in reports by Prudic (1979) and Prudic and Randall (1979).

2.0 PROCEDURES

2.1 Field Methods

General Location - Bar complex and longitudinal profile stake locations installed during Phase II were replaced and resurveyed for this study phase in the Buttermilk- Bond reach. Specific locations identified by name follow the Phase II nomenclature (Boothroyd and others, 1982).

Bar Mapping - A topographic survey of bar complex 4-6 was completed using standard transit and rod techniques. Twenty Phase II transects were reoccupied and other bar-edge elevations were obtained. Many stations were unchanged from 1980 and were not remapped. Remapped stations totaled 538. Instrument stations at each transect were tied by survey to the USGS benchmark at the B&O railroad bridge over Buttermilk Creek, at the bar complex 10.

Clast Movement Stations - The three transects (5, 11, 16) on bar complex 4-6 were resurveyed for movement of clasts that occurred since the summer of 1980. Transect lines were re-marked with yellow paint to identify smaller clasts but no new medium or large clasts were painted.

Landslide Mapping - the landslide on the west valley wall above bar complex 6 was resurveyed by transit and rod method. Elevation of 10 stakes emplaced during Phase I, and 39 stakes emplaced during Phase II, were determined. The elevation of 175 additional points was determined in order to complete a detailed topographic map. The control net of stakes was tied to the benchmark at the railroad bridge.

Discharge Measurements - three sets of velocity/area/discharge measurements were made on Buttermilk Creek at Thomas Corners Road bridge. One of these sets was obtained by Steven Potter (NYSGS). The measurements were of moderate discharge events, two in November, 1982, and one during the 1982 spring freshet (Potter). The November, 1982 data was collected using a Marsh-McBirney electromagnetic current meter (direct readout) and suspension gear. Measurements were made at three stations across the section at 0.6 depth.

Clast Size (Franks's Creek) - Clasts were measured at stations located on bar tops approximately 100 meter intervals along the Creek. The techniques are as follows: 1) the bar complex was inspected for concentrations of large clasts and a likely location was chosen; 2) a 3-meter distance was marked in the direction of sediment transport; 3) the 10 largest clasts falling on or within one clast length of the line were marked; and 4) the 3 axes (L, I, S) were measured to 0.5 cm. This technique is similar to that followed in the Phase I report for Buttermilk Creek.

Photographic Documentation - Approximately 135 color slide photos of bar-surface features, bar-and-channel geometry, tributary channel and valley geometry, and landslide morphology were taken during the field season. The BC-6 landslide was documented in detail.

2.2 Office Work

Bar Mapping - A topographic map of the Fall 1982 morphology of bar complex 4-6 was produced at the same scale as the Phase I map (Boothroyd and others, 1979, Plate 4) and the Phase II map (Boothroyd and others, 1983, Plate 4) to facilitate comparison. The scale of these maps is approximately 1:235.

Landslide Mapping - A topgraphic map and a separate downslope-movement map were produced at the same scale (1:310) so that they can be superimposed for ease of interpretations. They are the same scale as the Phase II (1982, Plate 7) map.

3.0 RESULTS

The general location of the West Valley area is shown in Figure 1; Figure 2 is an aerial view of the West Valley Nuclear Center (WVNC) security area and the surrounding plateau.

3.1 Bar Mapping

Topographic Mapping - The purpose of remapping bar complex 4-6 was to document changes that have occurred to bar-and-channel geometry and bar surface features since summer 1980. Field reconnaissance revealed that the 1980 geometry has been somewhat modified by spring freshet and other storm-induced discharges. The new topographic map is shown as Plate 1. Simplified morphologic maps derived from the topographic maps are shown in Figure 3.

Bar-and-Channel Pattern Changes - The changes in bar-and-channel pattern from 1980 to 1982 were limited to the upstream and downstream ends of the complex. The upstream end of the large transverse bar at transect 5 has been downed 40-60 cm and the main channel has switched from the eastern side of the bar to the central chute location (Figures 3b, 4a). The old channel between transects 5-8 has been abandoned and 30-40 cm of sediment has been deposited when a damming and flow separation effect was caused by a large willow that fell into the channel just downstream of transect 5 (Figure 4b).

Transect 11 is essentially unchanged except for some accretion in the low-stage channel.

A 20 m-long by 5 m-wide section of terrace on the east side of the low-stage channel at transect 6 has been eroded with consequent migration of the low-stage channel about 5 m to the east. Several new longitudinal bars have been deposited in the low-stage channel and on the downstream flank of the major bar complex (Figure 3c). Bar lengths are 15-20 m and thicknesses range from 20-30 cm.

3.2 Landslide (BC-6)

The active landslide area just southeast of bar complex 6 remained active through 1982. The panoramic view, taken on October 24, 1982 illustrates the lower slide area earthflow accumulation and slide faces (Figure 5). Similar past views (1977, 1978, April 1980 and October 1980) were presented in the Phase II report (Boothroyd and others, 1982).

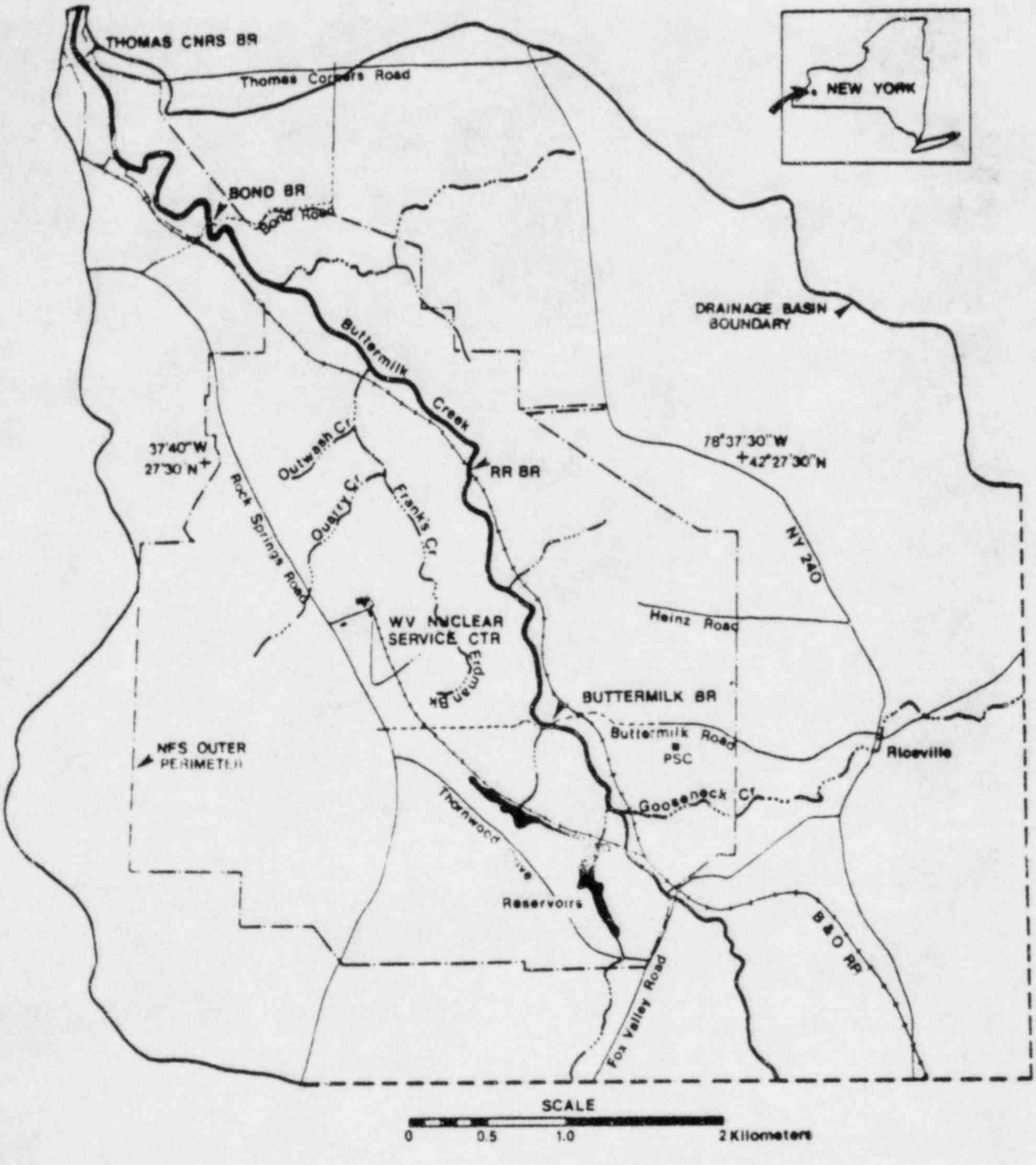

Figure 1. Location map of the northern part of the Buttermilk Creek drainage basin. Note the location of the West Valley Nuclear Service Center (WVNSC).

Figure 2. Vertical aerial photo of the WVNSC site, showing the waste burial sites, and the general plateau area. A part of Buttermilk Creek is shown at the top of the photograph (taken April 22, 1980) by Erdman, Anthony Associates.

Figure 3a,b,c. Morphologic maps of bar complex 4-6.

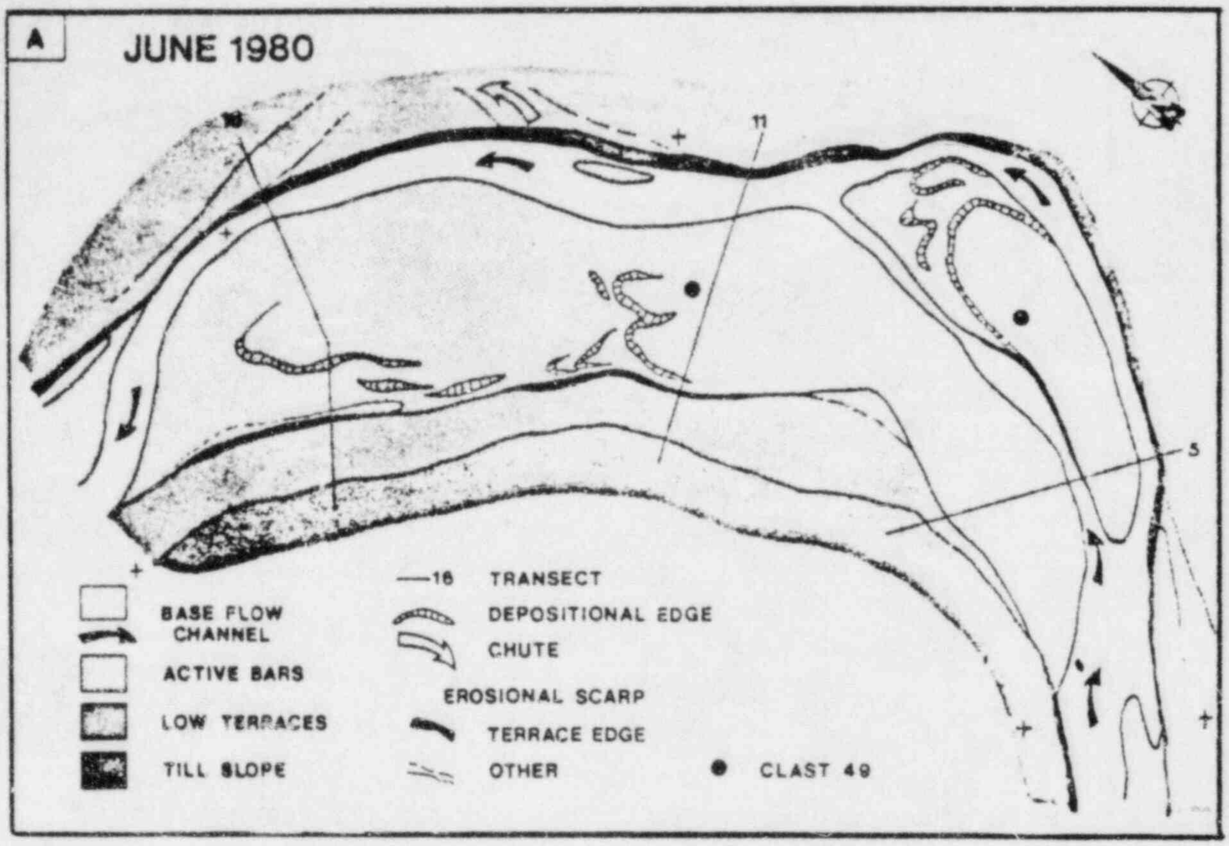

Figure 3a. 1980 - Bar and channel configuration developed during Hurricane Frederic flooding. Notice the very large, discrete transverse bars.

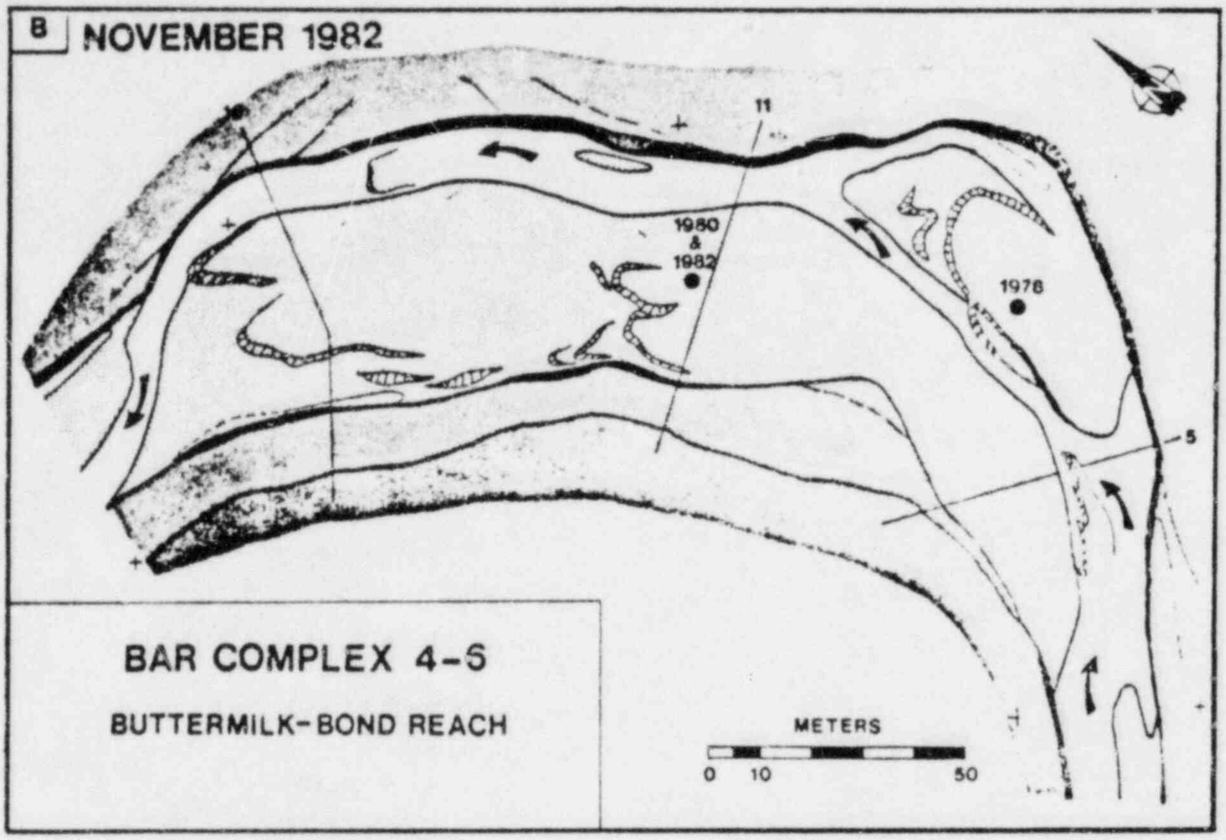

Figure 3b. 1982 - Some downcutting and channel switching has occurred at transects 3-8; small longitudinal bars have developed at transects 5 and 16.

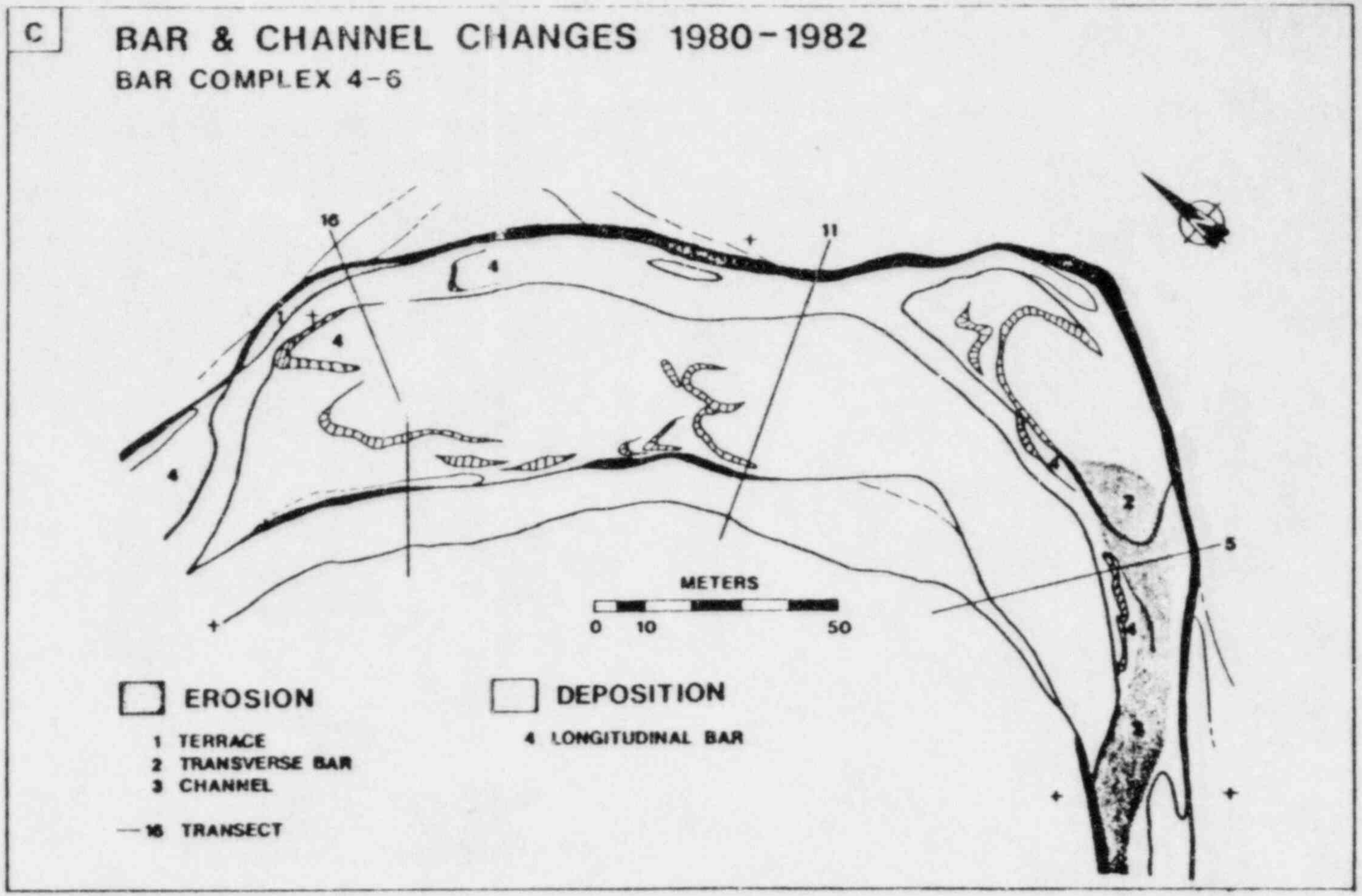

Figure 3c. Selected erosional and depositional changes. Use 4a and 4b for comparisons.

Figures 4a and b. Bar complex 4-6.

Figure 4a. View downstream (NW direction) at transect 5, illustrating the new location of the low-stage channel.

Figure 4b. View upstream (SE direction) at transect 6, showing abandoned channel and sedimentation adjacent to a downed willow. Photos taken October, 1982.

Figures 5a,b,c. Photomosaics of large landslide on the west wall of Buttermilk Creek at BC-6

Figure 5a. Photomosaic of the mid- and lower parts of the landslide prior to November 4 flood event. Horizontal movement up to 35 m, and vertical movement up to 18 m occurred between 1980 and 1982. Photograph taken October 25, 1982.

Figure 5b. Lower portion of the active landslide slope showing scarp with a few slump blocks (arrow points) to small E4 block and lower earthflow deposits at base of photograph. Photograph taken October 25, 1982.

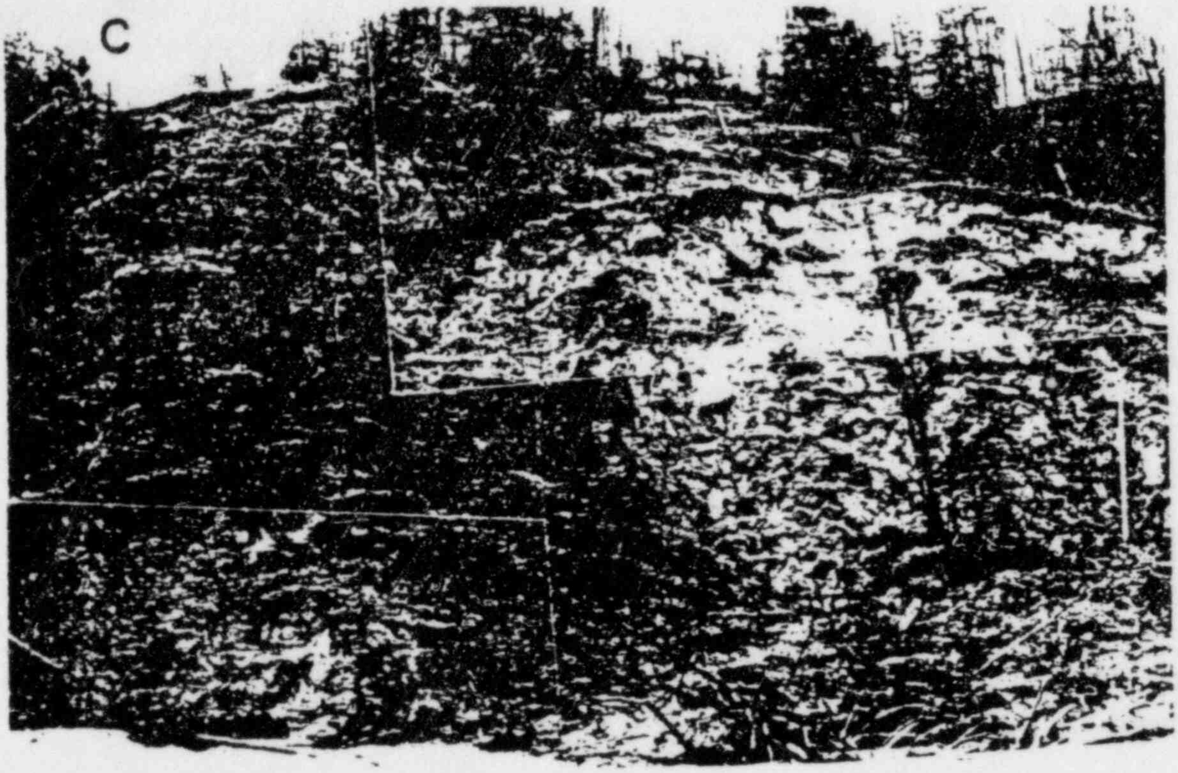

Figure 5c. Photograph of small E4 block after moving downslope 11.5 m vertically during November 4 flood event. Dashed line indicates block movement trajectory. Photograph taken November 12, 1983. Dashed line shows vertical displacement.

Monitoring Stations - The landslide complex was marked, first in October of 1978 with wooden stakes and, again, with additional steel stakes in July of 1980. Movement of the 1978 stakes was monitored in 1980 (Boothroyd and other, 1982) with 20 of the original 35 stations recovered. Continued movement of the 20 stakes and movement of 44 new stakes placed in 1980 were monitored in October and November of 1982. All stations and their monitored movement vectors are shown on Plate 2A, with movement tabulated in Table 2 and Appendix A.

In addition to retrieving designated monitoring posts, 175 additional elevation points throughout the landslide area were determined to construct a detailed topographic base map of the landslide complex (Plate 2B).

A total of 49 monitoring stations of the 64 placed or retrieved in 1980 were located in 1982. Twenty stations, mostly along the margins or upper reaches of the landslide complex, showed no vertical or horizontal movement. The remaining 29 stations indicated downslope movement of 0.5 to 12 meters horizontally and 0.4 to 11 meters vertically. Several of the unrecovered monitoring stations are assumed to have moved to the base of the slide. These stations would have moved downslope 4 to 35 meters horizontally and 2 to 18 meters vertically. Downslope movement occurs either as coherent slump blocks during discrete events or as hummocky earthflow masses at the base of the slide which can move slowly or rapidly out into the Buttermilk channel area.

Substantial downslope movement occurred over the lower third of the landslide. Slump blocks marked by 1978 or 1980 stakes moved to the base of the landslide in response to removal of the material during Hurricane Frederic flooding in 1979 and subsequent flood events. This movement was still occurring as late as November of 1982 when a discrete block moved to the base of the slide (Station E4, Plate 2A) in response to a heavy rainfall that lubricated its glide plane surface.

Slump blocks which moved 10 to 20 meters on the mid-portion of the slide between 1978 and 1980, moved from 2 to 5 meters horizontally between 1980 and 1982. Blocks on the upper parts of the landslide, initially marked in 1980, exhibited horizontal movement of 0 to 2 meters. Movement of these blocks probably occurs during rainfall events when glide-plane surface friction and tension-crack hydrostatic pressure are respectively reduced and increased to initiate downslope movement.

Table 2. 1980-1982 Downslope Movement, BC-6 Landslide

October 1982

Monitoring Station	Horizontal Movement (m)	Vertical Change (m)	Downslope Trajectory ($m \cdot m^{-1}$)
(1978 stakes)			
2N NR			
3C NR			
3N NR			
4N NR(A)	27	-14.3	.529
4C NR(A)	20	-9.7	.485
4DB NR			
4UB NR			
4UE	5.0	-5.56	1.112
5S NR(A)	26	-12.2	.469
5C NR(A)	28	-17.5	.625
5N NR(A)	38	-19.5	.513
6N	4.3	-2.55	.593
6C	5.2	-2.87	.552
6UA NR			
7S	7.75	-4.74	.612
7C	3.0	-2.89	.963
7N	5.2	-.63	.121
8N	4.4	-2.21	.502
8C	6.8	-4.88	.717
8S	8.6	-3.01	.35
(1980 stakes)			
A1 NC			
A2 NC			
B1 NC			
B2 NR(A)	4.	-3.	.75
B3	4.	-1.	.25

Table 2. continued

B4		7.5	-3.0	.4
B5		1.9	-.89	.468
B6	NR			
B7	NC			
C1	NC			
C2	NR(A)	16.5	-8.1	.491
C3	NR(A)	15.	-6.2	.413
C4	NR(A)	18.	-8.	.444
C5		1.4	-1.07	.764
C6	NC			
C7		2.4	-.54	.225
C8	NC			
D1		1.1	-.36	.327
D2	NR			
D3	NR(A)	24.	-11.8	.492
D4		5.75	-3.74	.650
D5		9.5	-.6	.063
E1	NC			
E2		3.9	-1.34	.343
E3		4.1	-.71	.173
E4	*	5.4	-2.81	.520
E4	**	19.2	-11.5	.599
E5		.4	-.85	2.125
E6		5.8	-1.54	.265
E7		12.25	-11.32	.924
E8		1.8	-.62	.344
F1		2.5	-2.02	.808
F2	NC			

Table 2. continued

F3		2.1	-1.91	.909
F4	NC			
G1	NC			
G2	NC			
G3	NC			
G6		1.8	-1.38	.756
H1	NC			
H2		.9	-.24	.266
H3	NC			
IS#1	NC			
IS#3	NC			
IS#4	NC			
IS#5	NC			

NR	Not recovered
NR(A)	Not recovered - horizontal and vertical movement assumed
NC	No vertical or horizontal movement
*	1980 - October 23, 1982 movement
**	October 23 - Nov. 12, 1982 movement

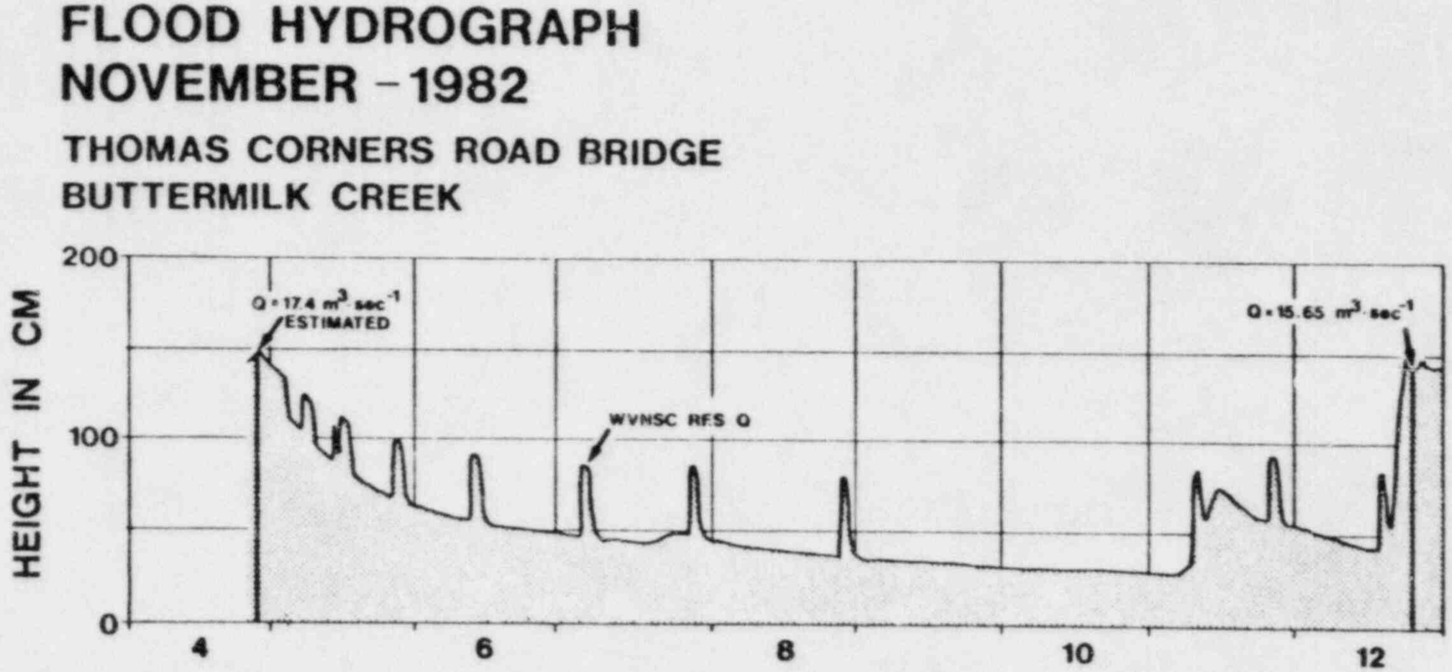

Figure 6. Stage-height record, Thomas Corners Road bridge (NYSGS), November 1982. Flood hydrographs of the November 4 and November 12 events illustrating the rapid onset of flooding. Both were moderate magnitude events (15-20 cu m/sec). Also see Plate 3 for the March-April 1982 spring freshet hydrograph.

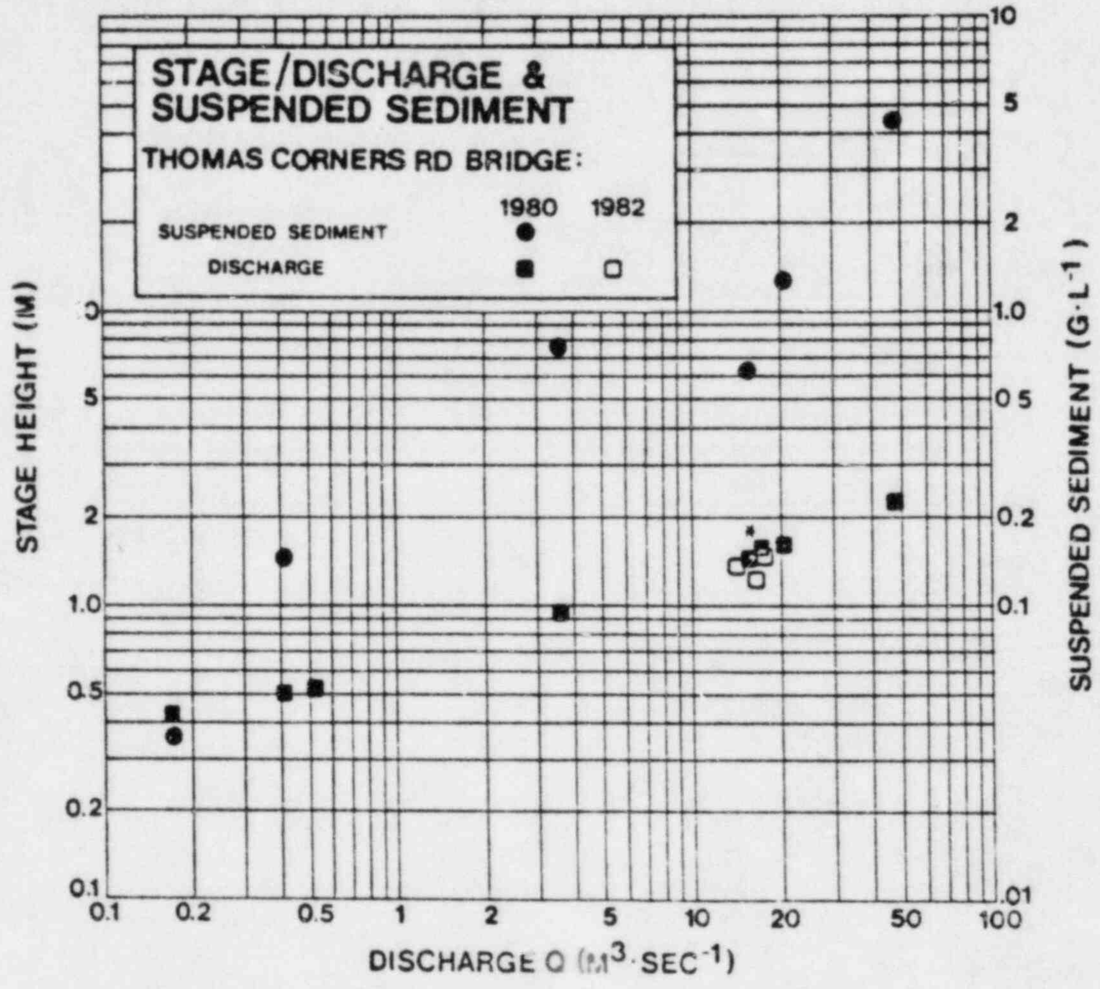

Figure 7. Stage-discharge and suspended sediment plot, Thomas Corners Road bridge. 1983 data has been added to graph reproduced from the Phase II report (Figure 15, Table 7; Boothroyd and others, 1982).

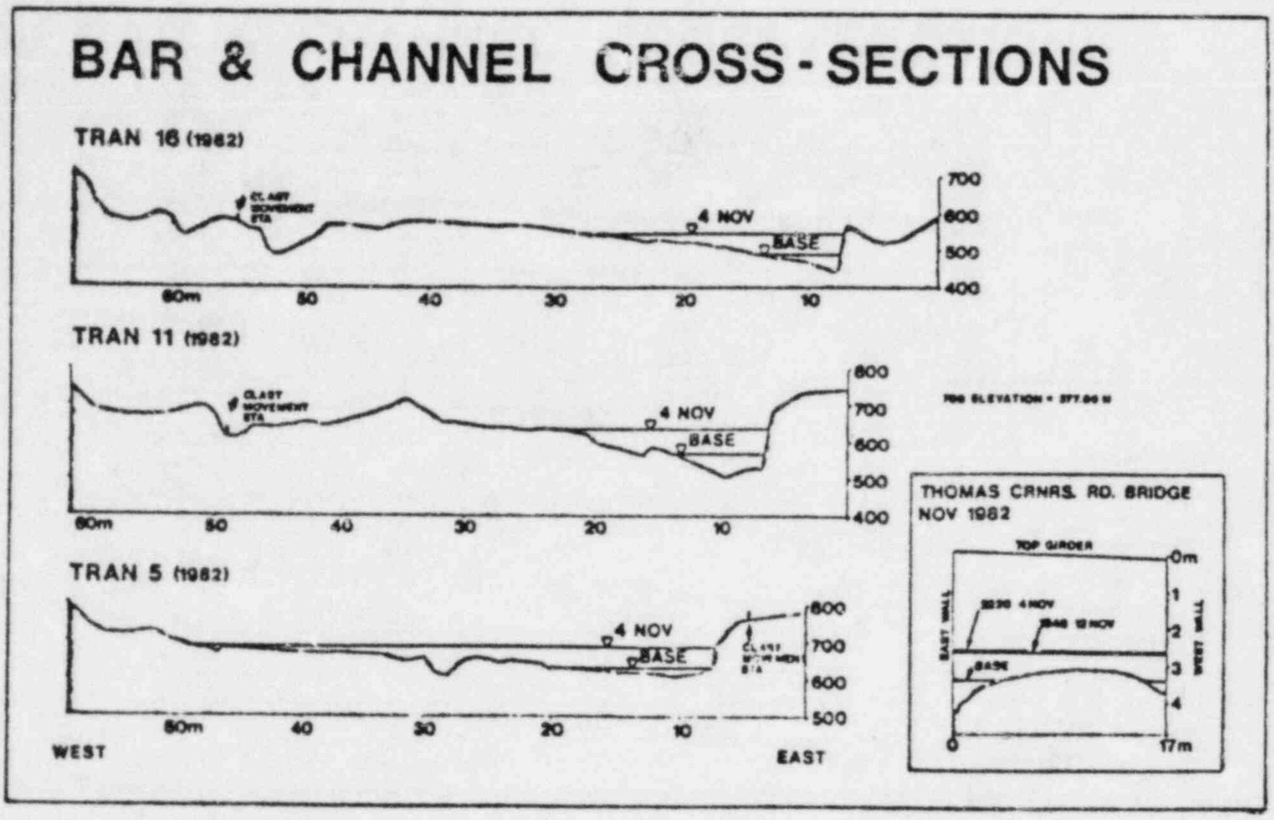

Figure 8. Bar and channel cross-sections, bar complex 4-6. Sections were constructed at locations of the clast movement stations using topography from the bar map (Plate 1). Water-surface elevations are indicated for base flow and the November 4, 1982 flood event. Also included is the flood discharge measuring station at Thomas Corners Road bridge.

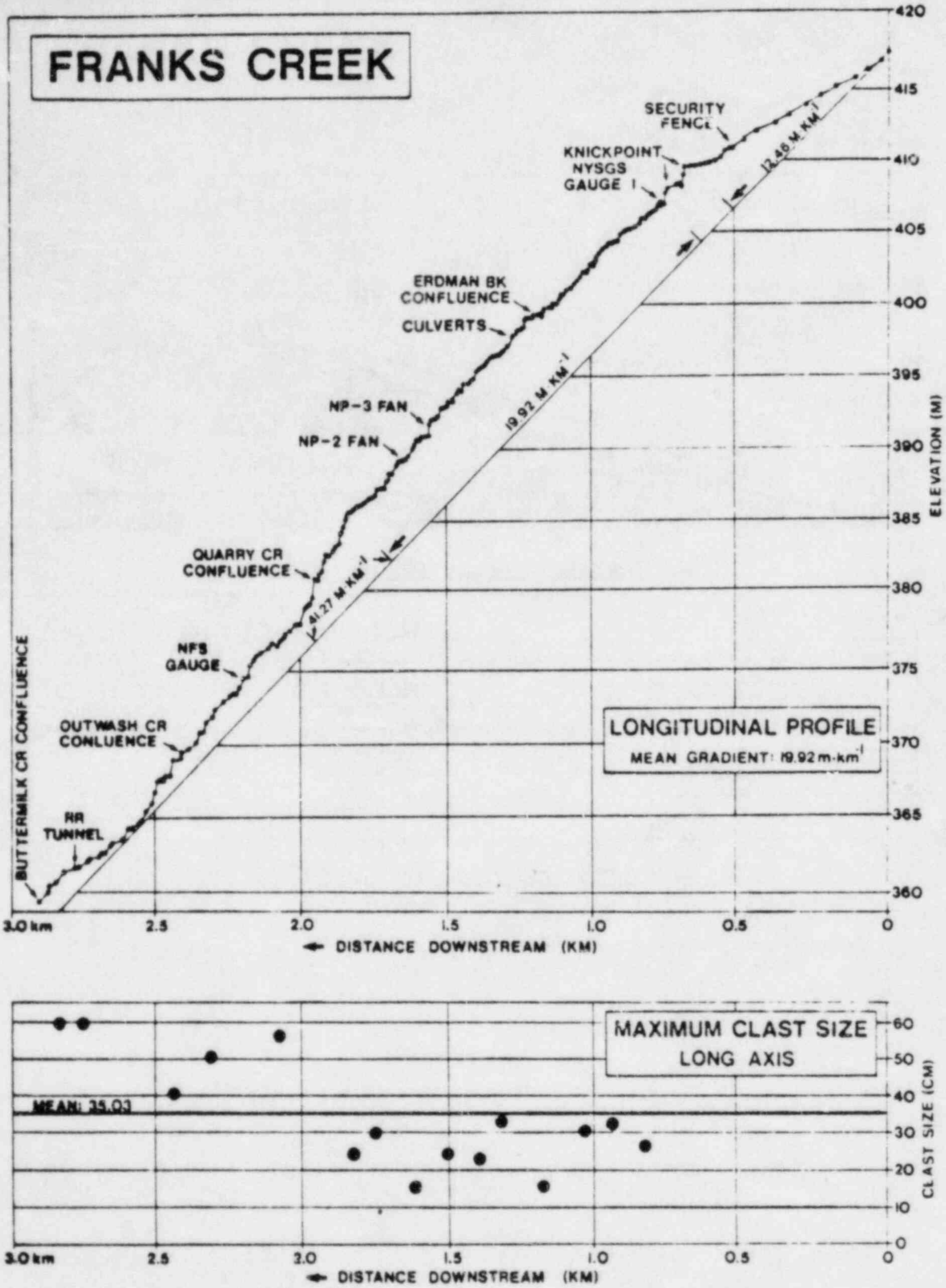

Figure 9a. Frank's Creek. Mean gradient is 19-92 m/km; mean maximum clast size (L-axis) is 35 cm.

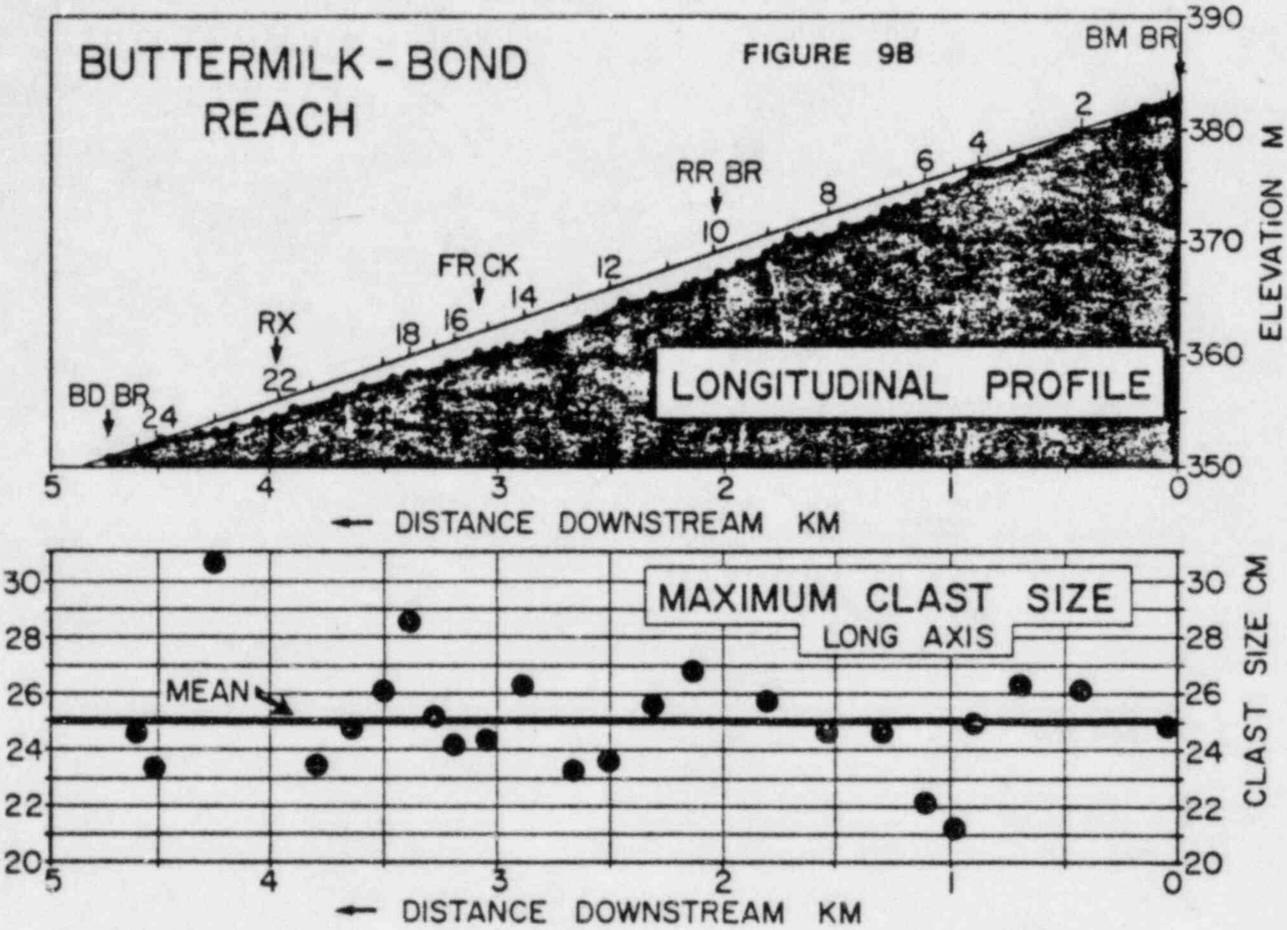

Figure 9b. Buttermilk Creek. Mean gradient is 6.76 m/km; mean maximum clast size is 25 cm.

3.3 Buttermilk Stage and Discharge

Stage-height records were available for the period of July 23, 1981 to August 16, 1982, and for November 4-12, 1982. The stage recorder was maintained by the NYSGS at the Thomas Corners Road bridge.

Selected stage-height records for the 1982 spring freshet period are shown in Plate 3; records for the storm period of November 4-12, 1982 are shown on Figure 6. Velocity-area information collected during the present study are shown on a modified Phase II stage-discharge plot (Figure 7).

Flood Events - The hydrograph of the 1982 spring freshet (Plate 3) shows moderate flood events with a general "non-spikey" discharge in contrast to the November 4 and 12, 1982 discharge from storms (Figure 7). The November discharge hydrographs are similar to those events of similar and greater magnitude recorded during the Phase II study period (Figure 14, Boothroyd and others, 1982).

The three discharge events that were measured ranged from 15-18 cu m/sec. Inspection of the available hydrographs and of measured discharge (Figure 7) indicated that the 15-20 cu m/sec event appears to be quite common bi-monthly.

The flood level of November 4, 1982 is shown for transects 5, 11, and 16 on Figure 8.

3.4 Clast Movement

Clast movement stations at transects 5, 11, and 16 were resurveyed in October, 1982 and yellow marker lines for small clasts were repainted. Clasts moved from transects 5 and 16 are indicated on Plate 4; none of the clasts were recovered. No movement was recorded at transect 11.

The November 4, 1982 event moved small clasts on transects 5 and 16. Movement is shown on Plate 4 and tabulated in Appendix A. The direction of transport is assumed to be perpendicular to the painted line because there is no way to identify the former position of the unnumbered clasts.

3.5 Clast Size, Frank's Creek

A clast size and gradient diagram for Frank's Creek is shown as Figure 9A; a similar diagram for Buttermilk Creek is reproduced from the Phase I report (Boothroyd and others, 1979) as Figure 9B.

Mean clast size (long axis) of the Frank's Creek clast is 35 cm, about 10 cm larger than Buttermilk. However, inspection of the size diagram indicates that the upper 2 km of Frank's Creek show a mean size similar to Buttrmilk; whereas the lower 1 km has clasts that are significantly larger (average over 50 cm).

4.0 DISCUSSION

4.1 Bar and Channel Geometry

Bar Formation and Migration - The limited erosional and depositional changes to bar complex 4-6 occurred during discharge events greater than 20 cu m/sec, and probably of the magnitude of the October 25, 1980 event (40 cu m/sec). Table 3 lists the volume changes.

Erosion of the upstream end of the large transverse bar and lowering of the channel at transects 3-6 resulted in the removal of about 170 cu m of gravel. This gravel was redeposited as small longitudinal bars in the immediate area (Figure 3) and the excess was transported down to the vicinity of transcect 13-16. Somewhat larger longitudinal bars, (larger than the ones at transect 5) have accumulated in the low-stage channel and on the flank of the major bar complex. Deposition on the bar-complex flank forced the main channel to the east and resulted in removal of terrace material.

Gravel Budget - Table 3 indicates that a total volume of 450 cu m was eroded and that 170 cu m was deposited, for a net deficit 280 cu m. The 150 cu m of terrace material probably was moved to the next bar complex downstream leaving an imbalance of 130 cu m to be deposited between transect 15 and 20.

The total volume of gravel eroded from BC 4-6 between 1980 and 1982 (450 cu m) is about 20 percent of that removed during the Hurricane Frederic event (2240 cu m) as indicated in the Phase II report (Boothroyd and others, 1982).

Thus, the 1980-1982 period was not a time of major redistribution, but rather a time of bar modification.

4.2 Discharge Events and Gravel Transport

Clast Movement - The November 4, 1982 flood was a bi-monthly event and did not move the medium-sized or larger clasts, although smaller clast (up to 15 cm L-axis) were transported. These clasts moved a maximum of 18 m at transect 16 (Plate 4C). Movement of medium-sized and larger clasts did occur at some time after the October 1980 survey (Boothroyd and others, 1982) especially transect 5 (Plate 3A).

Indirect Measurement - Additional calculations were performed using Hurricane Frederic flood levels and the

Table 3. Bar Complex 4-6 Volume Changes

	Dimension Changes		Volume Change (m^3)
	Distance (m)	Elevation (cm)	
1) Terrace	length 20 m width 5 m	eroded 150 cm	-150
2) Transverse bar	length 40 m	eroded 50 cm	-300
3) Channel	width 15 m		
4) Longitudinal bars			
Transect 5	10 m x 10 m	deposited 35 cm	35
	10 m x 5 m	40 cm	20
Transect 11-16	15 m x 10 m x 3 bars	deposited 25 cm	112.5

October 25, 1980 discharge data (46 m/s; Boothroyd and others, 1982) and flood elevations at transects 5 and 16 of bar complex 4-6. Bottom-shear stress was calculated using the known depth of water over the clasts, an estimated water-surface slope, and the well-known DuBoys equation:

$$BSS=DgdS \qquad (1)$$

where BSS is the boundary shear stress (kgm^2), D the density of the water, d the depth of water, S the water-surface slope, and g the acceleration of gravity.

Baker and Ritter (1975) present a graph, reproduced as Figure 10, for estimating threshold of movement of gravel-sized particles knowing the boundary-shear stress. A regression line has been fitted to various gravel transport data taken from the literature.

The solid line (Figure 10) indicated the Hurricane Frederic threshold conditions of shear stress and maximum clast size (I-axis) calculated for bar complex 4-6. All clasts smaller than 120 cm I-axis could have been moved during Frederic. The average largest I-axis size on the bar was 15-20 cm, thus substantial movement of these clasts occurred, as is known from later mapping.

The dashed line (Figure 10) indicates threshold conditions for the October 25, 1980 flood event, as calculated using an average depth and slope for the entire bar complex. The two data points on the regression line are for clasts at transect 5 (430, 438) that did move (Plate 4A). These data suggest that conditions were at the threshold for movement. The two points below the regression line are for transect 16 (652, 653) where movement of up to 5 m occurred for the larger clasts, indicating that threshold conditions were exceeded by a wider margin.

The indirect calculations, compared with measurements made for data plotted on Plate 3, show a good correlation, suggesting that the Baker and Ritter curve can be applied to gravel-bed rivers such as Buttermilk Creek. Thus, an estimate of gravel transport can be made, if flood levels are known.

4.3 Landslide Processes

Movement of slide blocks and earthflow masses on the BC-6 landslide, as recorded on Plate 2A and Table 2 provide more data for interpreting the nature and rate of landslide processes on Buttermilk Creek.

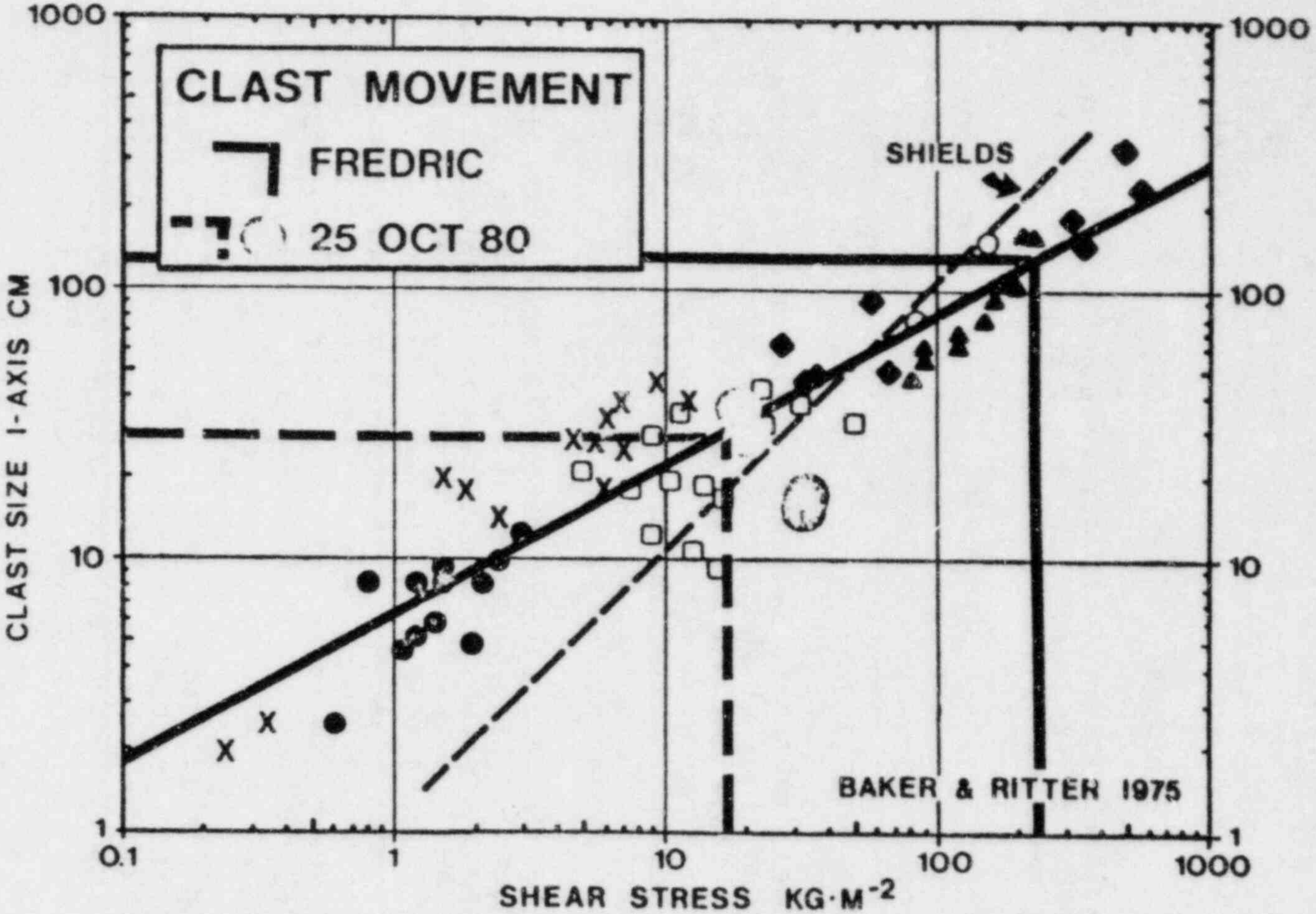

Figure 10. Plot of clast size vs. shear stress.

The calculated mean value of downslope vertical movement, based on 1980 stakes recovered in 1982, is 2.96 m, or about 1.5 cu m/yr. This rate is slightly less than the rate determined in the Phase II report (Boothroyd and others, 1982) based on the movement of stakes from 1978 to 1980, but equivalent to the estimated rate of downslope movement assumed to occur when the Buttermilk low-flow channel is at or near the slide toe. As noted in the Phase II report, more rapid movement is expected, if undercutting by large flood events occurred.

The detailed mapping of the landslide complex at BC-6, coupled with a second phase of downslope-movement measurements suggests that landslide processes proceed upslope in distinct phases.

Initially, till-slope undercutting by lateral channel migration initiates movement in the lower part of the slope. Slump-block failure of the lower slope results in a steep cut-slope with earthflow deposits at the base. If further channel undercutting does not occur, the unstable slope initiates block failure of the mid-portion of this slide. Downslope movement results in overlapping earthflow deposits over the lower part of the landslide. Finally, failure of upper part the slide results.

Evidence for past failure of the mid-portions of the slide, resulting in a steep slope, is the slope just below monitoring station F4 (Plate 2A). The steep slope that encompasses the upper part of the slide, on which the G1 (Plate 2A) block rests, is a relict slide-area just upchannel from the present active slide-area. If this upslope progression of slide failure occurs, catastrophic mass-wasting along the valley wall rim can occur. The configuration of the wall rim at monitoring station H3 (Plate 2A) suggests that past catastrophic failure occurred with the downslope removal of a slump block, which could have been from 15 to 25 m thick and 40 m wide. Upstage progression of the slide activity, now evident along the lower part of the landslide, should result in a similar valley-rim failure in the area between station H1 and H2 (Plate 2A).

4.4 Integration with Phase II Study

Study of bar modification, landslide processes, and clast movement during Phase III add detail, and support, the overall conclusions of the Phase II study in regard to magnitude of processes and estimation of a denudation rate for Buttermilk Valley.

5.0 CONCLUSIONS

Changes in bar and channel geometry, as indicated by remapping of bar complex 4-6, were limited to: a) the upstream end of the complex, b) along the erosional bank and low-stage channel, and c) at the downstream end of the complex. Changes were limited to channel switching in the transect 5-8 area, and growth of new longitudinal bars in the transect 16 area. These changes are illustrated in Figure 3 of Boothroyd and others, 1980.

We conclude that yearly autumn storm events or a moderate spring freshet do not substantially alter the bar complexes, although some gravel transport does occur.

Stream discharges of 15-20 cu m/sec appear to be quite common events approximately bi-monthly. These events, while transporting a significant quantity suspended sediment, move only the very fine gravel. As such, they are not bar or channel modifying events. We believe that bar and channel changes are affected only by 40 cu m/sec events and above. A 40 cu m/sec event may be the 1 year return flood as stated in the Phase II report.

Mean clast size (long axis) of the Frank's Creek clasts is 35 cm, about 10 cm larger than Buttermilk. However, inspection of the size diagram indicates that the upper 2 km of Frank's Creek show a mean size similar to Buttermilk; whereas the lower 1 km has clasts that are significantly larger (average over 50 cm). We do not as yet have an explantion for the abundance of large clasts in lower Frank's Creek.

Continued monitoring of landslide movement at the landslide opposite BC-6 corroborates earlier estimates of average downslope movement at 1.5 cu m/yr. Movement initiated by toe undercutting by the Hurricane Frederic flood event in 1979 is still ongoing on the mid- and lower slopes of the landslide - the last monitored movement being a sudden downslope movement of a small, discrete block to the base of the slide during the November 4 flood and precipitation event.

Landslide evolution occurs in discrete steps from the base of the slide to the valley wall rim, each step involving a third of the landslide slope. Block failure and removal downslope to form base earthflow deposits initiates the same processes over the middle third of the slide and, eventually, the top portion of the slide. Landslide surface morphologies adjacent to the present active area suggest this step-wise upslope progression. Too little monitoring data exist to apply a rate to this upslope progression of processes.

Studies carried out during Phase III lend detail and support to the rates of processes and denudation determined during the Phase II study.

6.0 REFERENCES

Baker, V.R., and D.F. Ritter, 1975. Competence of Rivers to Transport Coarse Bedload Material: Geol. Soc. America Bull., 86:975-978.

Boothroyd, J.C., B.S. Timson, and R.H. Dana, Jr., 1979. Geomorphic and Erosion Studies at the Western New York Nuclear Service Center, West Valley, N.Y.: U.S. Nuclear Regulatory Commission Technical Report NUREG/CR-0795, 66 p.

Boothroyd, J.C., B.S. Timson, and L.A. Dunne, 1982. Geomorphic Processes and Evolution Buttermilk Valley and Selected Tributaries, West Valley, New York; Fluvial System and Erosion Study, Phase II: U.S. Nuclear Regulatory Commission Technical Report NUREG/CR-2862, 107 p., 10 Plates.

Dana, R.H., Jr., R.H. Fakundiny, R.G. LaFleur, S.A. Molello, and P.R. Whitney, 1979. Geologic Study of the Burial Medium at a Low-Level Radioactive Waste Burial Site at West Valley, New York: New York State Geological Survey Final Report NYSGS/79-2411, to U.S. Environmental Protection Agency, 70 p.

Dana, R.H., Jr., V.S. Ragan, S.A. Molello, H.H. Bailey, R.H. Fickies, R.H. Fakundiny, and V.C. Hoffman, 1980. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York Low-Level Burial Site, Final Report, 1978-1980: U.S. Nuclear Regulatory Commission Technical Report NUREG/CR-1565, 140 p.

Hoffman, V.C., R.H. Fickies, R.H. Dana, Jr., and V. Ragan, 1980. Geotechnical Analysis of Soil Samples and Study of a Research Trench at the Western New York Nuclear Service Center, West Valley, N.Y.: U.S. Nuclear Regulatory Commission Technical Report NUREG/CR-1566, 70 p.

LaFleur, R.G., 1979. Glacial Geology and Stratigraphy of Western New York Nuclear Service Center and Vicinity, Cattaraugus and Erie Counties, New York: U.S. Geol. Survey Open-file Report 79-989, 17 p.

LaFleur, R.G. , 1980. Late Wisconsin Stratigraphy of the Upper Cattaraugus Basin: Guidebook for 43rd Annual Reunion, Northeast Friends of the Pleistocene, 64 p.

Prudic, D.E., 1979. Recharge to Low-Level Radioactive-Waste Burial Trenches 11 through 14, West Valley, New York: U.S. Geol. Survey Open-file Report 79-990, 5 p.

Prudic, D.E., and A.D., Randall, 1979. Groundwater Hydrology and Subsurface Migration of Radioisotopes at at Low-Level Solid Radioactive-Waste Disposal Site, West Valley, New York: p. 853-882 in Carter, M.W., A.A. Moghissi and B. Kahn, (eds.), Management of Low-level Radioactive Waste, v. II, Pergamon Press.

APPENDIX A. Clast Movement

Average 10 Largest Clasts
Frank's Creek
West Valley
Nov. 10 & 13, 1982

Sta. #	Distance from BC Confluence	Long.	Int.	Short axis (cm)
F1	66 m	1) 68	42	31
		2) 60	42	35
		3) 48	41	21
		4) 67	48	37
		5) 96	74	56
		6) 47	36	17
		7) 46	28	7
		8) 66	25	10
		9) 49	28	16
		10) 50	37	10
		Ave. 59.7 cm		
F2	148 m	1) 68	42	31
		2) 60	42	35
		3) 48	41	21
		4) 67	48	37
		5) 96	74	56
		6) 47	36	17
		7) 46	28	7
		8) 66	25	10
		9) 49	28	16
		10) 50	37	10
		Ave. 59.7 cm		
F3	394.5 m	1) 44	40	19
		2) 38	34	17
		3) 32	30	20
		4) 49	22	6

Appendix A. continued

			L	I	S
		5)	37	35	6.5
		6)	46	27	5.5
		7)	40	27	6
		8)	35	29	8
		9)	41	25	4
		10)	41	22	3
		Ave.	40.3 cm		
F4	522.5 m	1)	74	40	9
		2)	71	53	28
		3)	86	52	8
		4)	41	29	22
		5)	35	31	24
		6)	47	35	20
		7)	41	34	12
		8)	61	41	15
		9)	65	47	8
		10)	65	52	22
		Ave.	51.5 cm		
F5	759 m	1)	65	46	4.5
		2)	67	46	6
		3)	45	31	9.5
		4)	48	30	6
		5)	53	35	5.5
		6)	80	55	12
		7)	48	42	7.5
		8)	54	52	24
		9)	58	36	4
		10)	48	26.5	8
		Ave.	56.6 cm		

Appendix A. continued

			L	I	S
F6	966 m	1)	33	19	9
		2)	20	15	12
		3)	21	20	9.5
		4)	34	28	3
		5)	29	14	4
		6)	24	14.5	3
		7)	22	14	5.5
		8)	24	18.5	3
		9)	20	15	3
		10)	21	11	8
		Ave.	24.8 cm		
F7	1050 m	1)	36	25	17
		2)	20	16	13
		3)	43	37	6
		4)	22	19	15
		5)	26	21	12
		6)	46	29	4
		7)	23	18	9
		8)	25	24	12
		9)	22	17	12
		10)	30	17	3
		Ave.	29.3 cm		
F8	1186 m	1)	17	12	4
		2)	11	8.5	5
		3)	15	10	6.5
		4)	14	14	10
		5)	19	14.5	1.5
		6)	23	12	4.5
		7)	9	8	4
		8)	18	12	2
		9)	15	9	6

Appendix A. continued

			L	I	S
		10)	16	13	3.5
		Ave.	15.7 cm		
F9	1297 m	1)	30	20	1
		2)	30	23	7
		3)	34	22	2.5
		4)	22	20	8
		5)	22	15	10
		6)	24	12	5
		7)	26	22	3
		8)	20	16	4
		9)	22	13	7
		10)	19	11	8
		Ave.	24.9 cm		
F10	1476 m	1)	23	17	5
		2)	21	17	4
		3)	30	21	3
		4)	19	14	11
		5)	20	18	11
		6)	22	21	14
		7)	25	14	2
		8)	35	27	13.5
		9)	23	14	11
		10)	18	15	13
		Ave.	23.6 cm		
F11	1476 m	1)	43	26	11
		2)	28	18	15
		3)	27	22	15
		4)	40	27	15
		5)	27	17	14
		6)	29	24	16

Appendix A. continued

			L	I	S
		7)	26	23	11
		8)	38	13	5
		9)	28	22	17
		10)	44	29	5
		Ave.	33 cm.		
F12	1612 m	1)	18	10	5
		2)	16	7.5	5.5
		3)	21	14	3
		4)	13.5	10.5	6.5
		5)	21	15.5	6
		6)	14	13	4
		7)	13.5	9	8
		8)	12.5	12	4
		9)	11.5	10	5
		10)	18.5	12	2
		Ave.	15.95 cm		
F13	1726 m	1)	35	24	18
		2)	48	25	3.5
		3)	29	15	7
		4)	28.5	24	22
		5)	21	17	13.5
		6)	23	17	14
		7)	26	19	10
		8)	24	22	5
		9)	39	22	7.5
		10)	33	28	8.5
		Ave.	30.65 cm		

Appendix A. continued

			L	I	S
F14	1820 m	1)	35	27	2
		2)	31	27	9
		3)	36.5	28	3
		4)	29	20	2
		5)	32	13	8
		6)	20	17	9
		7)	28	21	4
		8)	35	25	7
		9)	37	29	23
		10)	43	38	23
		Ave.	32.65 cm		
F15	1924 m	1)	21	19	14
		2)	26	22	13
		3)	23	22	12
		4)	31	31	6
		5)	31	23	14
		6)	36	18	4
		7)	27	20	14
		8)	28	22	9
		9)	27	20	4
		10)	21	19	5
		Ave.	27.1 cm		

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16. ABSTRACT *(200 words or less)*

This report is the last in a series by the New York State Geological Survey on studies funded by the U.S. Nuclear Regulatory Commission. The report covers five important aspects of the geology and hydrology of the Western New York Nuclear Service Center, near West Valley, New York: geomorphology, stratigraphy, sedimentology, surface water, and radionuclide analyses. We reviewed past research on these subjects and present new data obtained in the final phase of NYSGS research at the site. Also presented are up-to-date summaries of the present knowledge of geomorphology and stratigraphy. The report contains a significant bibliography of previous West Valley studies. Appendices include a report on the Fall 1983 Drilling Project and the procedures used, history and prognosis of Cattaraugus Creek and tributaries down cutting, and bar modification and landslide processes of Buttermilk Valley.

17. KEY WORDS AND DOCUMENT ANALYSIS

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