DEPARTMENT OF THE INTERIOR
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Preliminary results of coring surficial deposits in the Winchester 30 x 60 minute quadrangle, West Virginia and Virginia

by

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with a section on geophysical logging and monitor well completion of the core holes

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.

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Conversion Factors, Vertical Datum, and Abbreviated Water-Quality Units

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter
	2.54	centimeter
	0.0254	meter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Volume	
gallon (gal)	3.785	liter
	Flow	
gallons per minute (gal/min)	0.06308	liter per second

Chemical concentrations and water temperature in this report are expressed in metric units. Chemical concentration is given in milligrams per liter (mg/L) or in micrograms per liter (μg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight of solute per unit volume of water. One thousand micrograms per liter is equivalent to 1 milligram of water. For concentrations of less than about 7,000 mg/L, the numerical value is about the same as for concentration in parts per million

Water temperature is expressed in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8(°C) + 32$$

Specific electrical conductance of water is expressed in microsiemens per centimeter at 25°C (μS/cm). This unit is identical to micromhos per centimeter at 25°C, formerly used by the U.S. Geological Survey.

Introduction

From late June through July, 1992, a series of shallow, continuously cored, vertical holes were completed in the Appalachian Valley and Ridge province of West Virginia and Virginia in the Winchester 30 x 60 minute quadrangle, which is located in the Potomac River drainage basin (Figs. 1 and 2). The purpose of this coring program was threefold: 1) to provide basic data on the thickness and character of several varieties of regolith widespread in the Valley and Ridge province of the Potomac River basin; 2) to supplement the ongoing Geologic Division research and mapping program in the Winchester 30 x 60 minute quadrangle; and 3) to construct water-quality monitor wells of sites where shallow regolith aquifers were penetrated. Of the eight (8) cored sections through the regolith, seven were geophysically logged and five of the holes were cored, screened, and completed as long-term water quality monitor wells. The holes were cored by the Geologic Division, Branch of Eastern Regional Geology, and partly funded, logged, cased and completed as observation wells by the Water Resources Division, Towson, Md. office, under the auspices of the National Water Quality Assessment (NAWQA) program for the Potomac River basin (Gerhart, 1991).

The holes were cored from the soil zone, through the regolith, with a terminal core of Paleozoic bedrock at each site. All of the holes completed as monitor wells were cased with 2-inch plastic casing, and screened across a porous and permeable zone of sand and gravel which unconformably overlies firm bedrock. A total of 471.2 feet of core were cut with a recovery of approximately 61 percent; most of the core lost was from uphole gravelly colluvium or from the basal sand and gravel zone. In addition to the cored holes, a well-exposed outcrop section (roadside borrow pit) of upland terrace deposits was sampled for stratigraphic analyses and clay determination; another high level terrace deposit and floodplain alluvium along the South Branch Potomac River were spot sampled for comparison.

The sections studied lie at several different topographic levels relative to the floodplains of the adjacent rivers, thus the deposits are believed to be of progressively greater age with increasing relative elevation. All of the cored sections are located in apparent meander cutoffs, where fine-grained, possible overbank or ox-bow lake deposits were most likely to be preserved beneath a blanket of colluvium; furthermore, such surficial deposits were deemed likely to be underlain by basal deposits of fluvial sand and gravel which lie at approximately the same levels as related gravel terraces that discontinuously flank the parent river upstream and downstream.

The chief purpose of this report is to provide the basic data documenting the coring and well completion program as quickly as possible. In addition, some preliminary analytical results and interpretations are included here because of the expected time (1-2 years) needed for some of the analyses to be completed. The core descriptions are based on megascopic descriptions using a 10-power hand lens. The descriptions are supplemented in most cases by interpretation of gamma-ray logs, and in two holes, by single-point induction electric and resistivity geophysical logs as well. Some X-ray diffraction determination of clays have been completed and are included here, and more are underway. Future work includes: geochemical analyses of sands, silts, and clays; heavy mineral separations; microscopic study; palynological analysis of dark gray silty clays; possibly C-14 age-dating studies of carbonaceous clays; and chemical analysis of selected elements in the shallow ground water at the base of the regolith.

Core holes: location, geologic setting, description, and analysis

All eight core holes are situated in apparent meander cutoffs of the Potomac River or its principal north-flowing tributaries in the West Virginia and Virginia parts of the Winchester 30 x 60 minute quadrangle (Figs. 1 and 2). The local geologic setting differs at each site and the regolith cored lies at different elevations; thus each site is described separately with a simplified local geologic map based on the most recent data available, including County soils surveys (Curry and others, 1978; Estepp, 1989).

Site No. 1, Christian Church Road

The cored site is situated in a 0.5 mi (0.8 km) wide, horseshoe-shaped valley perched about 100 ft (30 m) above the bedrock cliffs flanking the eastern bank of the incised Cacapon River. The valley is one of a series of meander cutoffs that flank the east side of the north-flowing Cacapon River (see sites 2 and 3 and Figs. 2 and 4). The valleys lie at different altitudes above the present floodplain of the river, hence are of varying ages, with low-lying valleys being relatively young and high valleys, such as this, considerably older. The bedrock cliffs forming the northwestern limits of the valley along the Cacapon River are formed in the Devonian Chemung Formation, which dips southeasterly at 45 to 55° in this area; about 4 ft (1.2 m) of fine-grained, purplish-red and gray, thin-bedded sandstone of the upper Chemung Formation with apparent dips of 55 to 60° were recovered in the terminal core (depth 75-79 ft; bedrock elevation 860 ft (262.2 m); see Fig. 5).

Boulders and cobbles of sandstones mainly of the Oriskany and Chemung Formations, ranging in thickness from a veneer to as much as 5 ft (1.8 m), unconformably overlie the fresh bedrock at the top of the northeast-trending cliff at approximate elevations of 885 to 890 ft (270-271.5 m). Approximately 8.0 ft (2.5 m) of gravel and light gray, friable, fine- to coarse-grained sand were penetrated at depths of 67.0 to 75.0 ft (elev. 868 to 860 ft (264.6 to 262.2 m). This is about 30 ft (9 m) lower than the exposed contact; as there is no evidence for recent faults at this locality, it is most likely that the core hole penetrated basal lag gravel deposits in a deep scour of the floor of the ancestral Cacapon River at the outer loop of the cut off meander.

About 7.0 ft (2.1 m) of thin-bedded to laminated, light-gray to tan, mottled, silty and sandy clay interbedded with clayey fine grained sand conformably overlie the coarse-grained basal unit. This fine-grained sequence contains abundant fine carbonaceous specks and was sampled for C-14 age dating, palynological, chemical and XRD clay analysis. It may be the preserved upper beds of a fluvial upward-fining sequence or possibly part of an ephemeral (ox-bow) lake deposit, or both.

Diamicton, consisting of pebble-to cobble-sized angular clasts of mainly fresh to weathered red sandstone and green-gray siltstone in a yellowish-orange to red-brown silty clay matrix, is the principal component of regolith at this site, extending from the base of the soil zone to a depth of about 60 ft (18.3 m). At a depth of 25 ft (7.6 m) a one ft (0.3 m) layer of friable, well sorted, medium- to coarse-grained sand and pea-sized, rounded to subrounded gravel was penetrated. The main diamicton unit is undoubtedly colluvium, which mantles all of the upland bedrock slopes adjacent to the site, but the thin pea-gravel may represent a local, probably intermittent, fluvial deposit related to the small alluvial fans that debouch into the valley.

Finally, the terrace deposits occupying the meander cut-off about a mile north and the bulk of the fluvial terrace deposits flanking the Cacapon River in this vicinity occur at average elevations of 860 ft (262.2 m), less than 20 ft (6 m) above the present level of the Cacapon River, thus must be considerably younger than the isolated terrace deposits penetrated in this core hole.

Site No. 2, Lehew Road

The cored site is situated in a 0.5 mi (0.8 km) wide, horseshoe-shaped valley perched about 50 ft (15 m) above bedrock outcrops forming the gently sloping valley floor to the west-northwest. The site is about 1.2 mi (1.9 km) east-southeast of and 155 ft (47 m) above the Cacapon River. The valley is one of a series of meander cut-offs that flank the east side of the Cacapon River (see sites 1 and 3 and Figs. 2 and 6). As at site 1, this is another high-level valley, thus representing a relatively old, perched, abandoned meander. The bedrock slopes adjacent to the site are underlain by the Devonian Chemung Formation, which dips southeasterly at 40 to 50° in this area; about 1.0 ft (0.3 m) of fractured, fine-grained, purplish-red and gray sandstone of the upper Chemung Formation was recovered in the terminal core (depth 90.5-91.5 ft; bedrock elevation 925 ft (282.0 m); see Fig. 7).

Rounded sandstone boulders and cobbles of mainly the Oriskany and Chemung Formations are mixed with colluvial material overlying bedrock in the two small northwestward-flowing tributaries that drain the horseshoe-shaped valley at approximate elevations of 940-960 ft (286.6-292.7 m). Approximately 4.2 ft (1.2 m) of gravel and gray sand were penetrated from 86.3 to 90.5 ft (elev. 929-925 ft; 283.2-282.0 m). This is about 30 ft (9 m) lower than the boulder-veneered bedrock exposed to the west, thus it is likely that the core hole penetrated basal lag gravel deposits in a deep scour of the ancestral Cacapon River near the outer loop of the cut off meander.

About 4.3 ft (1.2 m) of mottled, silty, fragmental clay, mainly light olive gray at the top grades downward to greenish-and bluish-gray and medium to dark gray sandy clay with carbonaceous plant fragments (specks, leaves, stems or branches). It is overlain by 19 ft (5.8 m) of light olive brown, grayish-red to orange, and bluish-gray silty clay with abundant small (1/4 to 1/2 in (0.5-1.0 cm)) sandstone and siltstone clasts and sparse carbonaceous specks. This 23.3 ft (7.1 m) clay-rich sequence was sampled for C-14 age dating, petrographic, palynological, chemical, and XRD clay analysis. It may be the preserved upper beds of a fluvial upward-fining sequence, a mud flow deposit into an ephemeral (ox-bow) lake, or both.

Diamicton, consisting of pebble- to cobble-sized angular clasts of mainly fresh to weathered reddish-brown sandstone and green-gray siltstone in a yellowish-orange to light brownish-gray mottled silty clay matrix is the principal component of regolith at this site, extending from the base of the soil zone to about 63 ft (19.2 m). The diamicton is principally colluvium but may include local mud flow and debris flow deposits.

Whereas the companion perched valley immediately to the southwest doubtlessly has a similar origin and age, the terrace deposits flanking the alluvium of the Cacapon River occur at average elevations of 870 ft (265.2 m), less than 20 ft (6 m) above the present river level, thus are considerably younger than the isolated terrace deposits penetrated in this core hole.

Site No. 3, Bucks Knoll

The site cored is situated a 0.5 mi (0.8 km) wide, horseshoe-shaped valley about a half-mile (0.8 km) northeast of the north-flowing Cacapon River east of Yellow Spring, W. Va. The valley is one of a series of meander cutoffs that flank the Cacapon at different elevations above the present floodplain, with low-lying valleys such as this being relatively young, and higher, perched valleys considerably older (see Sites 1 and 2 and Figs. 2 and 8). The bedrock hills flanking the horseshoe-shaped valley are formed in the Devonian Mahantango and Brallier Formations, which dip southeasterly at 35 to 45°. About 5.0 ft (1.5 m) of bluish-gray, fossiliferous (brachiopods), fractured (pyrite veinlets), thin-bedded, silty shale of the upper Mahantango Formation with apparent dips of about 45° were recovered in the terminal core (depth 33.5 to 38.5 ft; bedrock elevation 882 ft (269 m); see Fig. 9).

About 7.0 ft (2.1 m) of light-gray to dark-greenish-gray, fine- to very coarse-grained, friable, pebbly sand with about 1.5 ft (0.5 m) of basal, loose, well rounded pebbles and fragments of cobbles and boulders of greenish-gray sandstone, white quartzite, and chert were penetrated at depths of 26.5 to 33.5 ft (approximate elevation of top of unit, 889 ft (271 m)). This coarse-grained, fluvial unit is conformably overlain by about 11.0 ft (3.4 m) of medium-gray, silty, mainly massive but fractured micaceous clay with rare disseminated carbonaceous specks and mottled by dark yellowish-orange clay with veinlets of iron and manganese oxides. This fine-grained sequence was sampled for palynological, chemical, and XRD clay analysis. It may be the preserved upper beds of a fluvial upward fining sequence, part of the deposits of a short-lived (oxbow) lake, or both.

Diamicton, consisting of pebble- to cobble-sized angular clasts of reddish-brown sandstone and greenish-gray siltstone in a matrix of yellowish-orange silty and sandy clay was penetrated from the base of the soil zone to about a depth of 15.0 ft (4.6 m). It is probably partly colluvium which mantles the upland bedrock slopes adjacent to the site, but may include some fan deposits from nearby creeks.

The terrace deposits preserved in the meander cutoff apparently grade into the train of low-lying fluvial cobble and boulder terrace remnants flanking the alluvial floodplain of the Cacapon River at an average elevation of 880 ft (268 m), and are doubtless relatively young and related to the coarse basal fluvial section cored. The isolated high level terrace remnant nearby along Route 259 at an average elevation of 1070 ft (326 m - see Outcrop Site 3A), and the conspicuous horseshoe-shaped valley about a mile to the north at an elevation of 970 ft (296 m) are considerably older.

Site No. 4, Ferndale Lake

The site cored is situated in a 1.0 mi (1.6 m) wide, horseshoe-shaped upland valley perched about 100 ft (30 m) above and about a mile (1.6 km) east of the northeast-flowing South Branch Potomac River. The valley, now partly occupied by man-made Ferndale Lake, is one of a few that flank the South Branch at different altitudes relative to the present river level, hence are of varying ages (see Site 5 and Figs. 2 and 10). The western parts of the twin valleys that form the "prongs" of the horseshoe are deeply dissected and floored by shallow bedrock extensively mantled by colluvium and rounded sandstone boulders, whereas the broad flat-bottomed inner loop of the coalesced valleys are extensively mantled by sandstone diamicton and thin bedded silty clays. The bedrock ridges flanking the valley are formed in the Devonian Brallier Formation, which dips southeasterly at 45 to 55° in this area; about 7.0 ft (2.1 m) of fractured (pyrite-filled veinlets), bluish-gray siltstone, shale, and fine- to coarse-grained, pebbly, light-gray, fossiliferous (brachiopods) sandstone of the Chemung Formation with apparent dips of 45 to 50° were recovered from the terminal core (depth 39 to 46 ft; bedrock elevation 651 ft (198.5 m); see Fig. 11).

Rounded boulders, cobbles, and pebbles of red sandstone, white quartzite, chert, and greenish-gray siltstone about 4.5 ft (1.4 m) thick unconformably overlie the fresh bedrock from 34.5 to 39 ft (10.5-11.9 m). The gravel is conformably overlain by about 4.0 ft (1.2 m) of grayish-brown to yellowish-orange, medium- to coarse-grained, rounded to subrounded, well to poorly sorted, friable sand. About 13 ft (4 m) of laminated to thin-bedded, silty, yellowish-brown to light-gray mottled clay conformably overlies the coarse-grained fluvial sand and gravel sequence. This fine-grained sequence contained sparse, widely scattered carbonaceous specks and rootlets and was sampled for C-14 age-dating, palynology, petrology, chemistry, and XRD clay analysis. It may represent the preserved upper beds of the fluvial upward fining sequence or possibly part of a short-lived oxbow lake deposit, or both.

Diamicton, consisting mainly of pebble- to cobble-sized angular clasts of weathered and fresh, red and greenish-gray sandstone in a matrix of yellowish-orange to grayish-pink mottled silty and sandy clay, is the uppermost major component of regolith here, extending from the base of the soil zone to depth of about 18 ft (5.5 m). It is principally colluvium, which also mantles the adjacent bedrock slopes.

The preserved terrace deposits lie at elevations of 659 to 672 ft (201 to 205 m), more than 150 ft (46 m) above the low terraces flanking the South Branch in this vicinity, hence are likely to be much older.

Site No. 5, Buffalo Hollow

The site cored is in a 1.0 m (1.6 km)-wide, horseshoe-shaped valley about 0.8 m (1.2 km) east of the north-flowing South Branch Potomac River near Vance, W. Va. The south arm of the valley (Buffalo Hollow) is drained by Buffalo Creek which has intermittently constructed and incised a boulder and cobble fan in the valley; valleys tributary to the main horseshoe-shaped valley have also produced and incised smaller fan lobes. The valley is one of a few meander cutoffs that flank the South Branch (see Site 4 and Figs. 2 and 12) and lies at a considerably lower elevation than the comparable valley of similar size at Ferndale Lake. In the vicinity of the core hole and flanking the valley, fractured gray siltstone and shale of the Devonian Mahantango Formation dip southeasterly at 40 to 50°. About 13.0 ft (4 m) of fractured and tilted gray siltstone of the Mahantango were recovered in the terminal cores (depth 36 to 49 ft; bedrock elevation 674 ft (205.5 m); see Fig. 13).

About 7.0 ft (2.1 m) of fairly well sorted, rounded, pebble and cobble gravel of sandstone, siltstone, and red, black, and white chert in a coarse-grained sand matrix unconformably overlies the bedrock. The gravel is conformably overlain by about 3.0 ft (1.0 m) of mottled orange, medium-brown, and light-gray silty and clayey, fine- to medium-grained sand; both gravel and sand are fluvial. About 10 ft (3 m) of light-brown to light-bluish-gray, mottled, sandy and silty clay conformably overlies the fluvial sand and gravel sequence. This silty clay was sampled for chemistry and XRD clay analysis. It may represent the preserved upper beds of the fluvial upward-fining sequence or possibly part of a short-lived oxbow lake deposit, or both.

Diamicton, consisting mainly of pebble- to cobble-sized angular to subrounded clasts of weathered and fresh, red, yellow, and gray sandstone and siltstone in a matrix of yellowish-brown mottled sandy and silty clay, is the uppermost major component of regolith here, extending from the base of the soil zone to a depth of about 16 ft (4.9 m). A 1.0 ft (0.3 m)-thick layer of well sorted, well rounded, friable "pea gravel" is present at the base of this unit, and several zones containing subrounded to well rounded pebbles and cobbles occur throughout the diamicton. This unit is probably a mixture of colluvial, fluvial, and fan deposits derived largely from Buffalo Creek and from the adjacent hill slopes that are mantled by colluvium.

The cobbles and boulders at the base of the terrace deposit unconformably overlie bedrock on the west bank of Buffalo Creek near Route 28 at an elevation of 680 ft (207 m). These gravels merge into the low terrace flanking the South Branch floodplain downstream to the north. The top of the preserved terrace deposits in the meander cutoff lies at an elevation of about 690 ft (210 m), the same general elevation of the correlative fluvial terrace flanking the South Branch Potomac River in this vicinity, and about 50 ft (15 m) higher than the present flood plain, thus the terrace deposits cored are likely to be relatively young.

Site No. 6, Keyser Industrial Park

The site cored is situated in a 0.5 mi (0.8 km)-wide horseshoe-shaped valley about a half-mile (0.8 km) east of the north-flowing North Branch Potomac River east of Keyser, W.Va. The valley is one of a series of meander cutoffs that flank the Potomac and its tributaries at different altitudes above the present floodplain, with low-lying valleys such as this being relatively young, and higher, perched valleys considerably older (see Figs. 2 and 14). The bedrock hills flanking the horseshoe-shaped valley are formed in a tight anticlinal fold mainly in the Silurian Clinton Group, McKenzie and Wills Creek Formations, and the Tonoloway Limestone. About 9 ft (2. 8 m) of dark-brownish-gray fossiliferous limestone and medium- to dark-gray shale of the McKenzie Formation dipping 40 to 45° were recovered in the terminal core (depth 40.6 to 50 ft; bedrock elevation 809.4 ft (246.3 m); see Fig. 15).

About 8.0 ft (2.4 m) of rounded boulders, pebbles and cobbles of red and white sandstone, tan quartzite, gray limestone, and greenish-gray siltstone in a loose sand matrix were penetrated at depths of 32.5 to 40.6 ft (10 to 12.4 m) at an approximate elevation of 809.4 to 818 ft (246.8 to 249 m). This is about 25 ft (7.6 m) lower than boulder gravel exposed in the rounded knoll about 1200 ft (366 m) northwest of the cored-section; reportedly, firm bedrock was encountered at shallow depth beneath boulder gravel during excavation at the crest of the knoll (oral communication, Mr. M.C. Bland, Mineral County Coordinator, Keyser, W. Va., 6/92). It seems likely that the core hole penetrated basal lag gravel deposits in a deep scour of the ancestral North Branch near the outer cut face of the abandoned meander, and that the central knoll is a remnant of the basal gravels deposited on the slip-off inner slope of the meander.

About 21 ft (6.4 m) of thin bedded to nearly massive, soft, sticky, impermeable, pale-olive and greenish- to bluish-gray, mottled, silty, calcareous clay with abundant limy pellets and fragments as much as 0.5 in (1.0 cm) in diameter conformably overlie the basal pebbly sand. This clay-rich sequence contains thin local sandy layers with scattered angular sandstone, siltstone and limestone clasts, and very sparse disseminated carbonaceous specks; it was sampled for petrographic, palynological, chemical, and XRD clay analysis (see Fig. 24). It may be the preserved upper beds of a fluvial upward-fining sequence, part of a short-lived (oxbow) lake deposit, or both. The presence of sparse angular clasts at 12, 17, and 21 ft indicates that possibly debris flow or mud flow deposits are locally incorporated in this predominantly fine-grained sequence.

Diamicton, consisting of angular, pebble- to cobble-sized clasts of fresh to weathered, brownish-gray sandstone and indurated siltstone in a mottled, dark-yellowish-brown to pale-olive and dark-yellow-orange, silty and sandy, soft, sticky clay matrix, is the uppermost unit of regolith at this site. It extends from the base of the soil zone to a depth of about 11.0 ft (3.4 m). This upper diamicton is probably the toe of the colluvium that extensively mantles the upland slopes adjacent to the site and may include thin debris flow or mud flow deposits, or local fan lobes extending into the valley from adjacent creeks.

Finally, the train of gravel-rich, low terraces flanking the alluvial floodplain of the North Branch lie at an average elevation of 800 ft (244 m) and are doubtlessly related to the fluvial sequence cored. Boulder and cobble gravel deposits of sandstone and quartzite north of McCoole, Md., which form flat-topped benches at about 900, 1000, locally at 1100 ft (275, 305, and 335 m), are erosional remnants of a series of intermediate- and high-level Potomac River terraces that are much older.

Site No. 7, Hanging Rock

The cored site is located in a 0.5 mi (0.8 km) wide horseshoe-shaped valley 0.5 mi (0.8 km) west of the North River and U.S. Route 50 at Hanging Rock, West Virginia. The valley is one of a series of low-lying meander cutoffs flanking both banks of the north-flowing North River (see Figs. 2 and 16). These valleys lie at similar altitudes, 10 to 20 ft (3 to 6 m) above the floodplain, thus the meander cutoffs are probably of similar, relatively recent age. Although most of the terrace deposits abut alluvium of the North River, small bedrock scarps and local outcrops indicate that bedrock of the Devonian Chemung and

Brallier Formations is generally shallow beneath the widespread fluvial regolith in this area. In the vicinity of the core hole fine-grained sandstones, siltstones and shales of the Brallier Formation dip northwesterly at 40 to 60°; about 4.0 ft (1.2 m) of fresh, fractured (with calcite veins), steeply dipping, dark-greenish-gray, micaceous, silty, fine-grained sandstone was recovered in the terminal core (28.5-32.5 ft; bedrock elevation 887 ft (270 m); see Fig. 17).

Rounded boulders and cobbles of mostly red sandstone and green-gray siltstone in a gray, pebbly, medium- to very coarse-grained sand matrix about 3.5 ft (1.0 m) thick unconformably overlie the unweathered bedrock at a depth of 25.0 to 28.5 ft (7.7-8.7 m). The gravel is conformably overlain by about 5.0 ft (1.8 m) of light gray, bluish-gray, olive gray and light brown, medium- to coarse-grained, pebbly sand. The basal gravel and overlying sandy sequence are fluvial deposits. About 10 ft (3.0 m) of mottled and fractured, gray to yellowish-orange, thin-bedded, silty and sandy clay, with iron- and manganese-oxide stains and veinlets, conformably overlies the coarse-grained fluvial unit. This fine-grained sequence contained scattered carbonaceous specks in a purplish-gray clay and was sampled for C-14 age dating, palynology, chemistry, and XRD clay analysis (see Fig. 25). It may be the preserved upper beds of a fluvial upward-fining sequence, or possibly part of a short-lived ox-bow lake deposit, or both.

Diamicton, consisting mainly of pebble- to cobble-sized, weathered and fresh, angular clasts of red sandstone and gray, green and black siltstone in a matrix of yellowish-orange and yellowish-gray sandy clay, is the uppermost major component of regolith here, extending from the base of the soil zone to a depth of about 10 ft (3.0 m). It is principally colluvium, which also mantles most of the adjacent bedrock slopes.

The terrace deposits occupying the three prominent meander cutoffs north of the site cored and the fluvial terrace deposits almost continuously bordering the North River in this area occur at average elevations of 900 ft (274 m). This is about 20 ft (6 m) above the present river level, thus they are likely to be relatively young, similar in age to those at the site cored. Locally, small, isolated patches of cobbles and boulders, probably older terrace remnants, lie at about 960 ft (293 m), separated from the low-lying terraces by intervening eroded bedrock scarps.

Site No. 8, Cedar Creek

The site cored is situated in a 0.3 mi (0.5 km)-wide horseshoe-shaped valley 0.5 mi (0.8 km) east of Cedar Creek and Va. Route 621, about 2 mi (3.2 km) south of Gravel Springs and Star Tannery, Va. (see Figs. 2 and 18). The two-pronged valley slopes northwestward from about 940 ft (287 m) near the cored site to about 860 ft (262 m) where it debouches into the floodplain of Cedar Creek, grading into cobble-rich terraces that discontinuously flank the creek. The morphology and depth to bedrock beneath regolith at the cored site suggest that the valley may be a meander cutoff of Cedar Creek. In the vicinity of the core hole the bedrock ridges, extensively mantled by colluvium, are underlain by the Devonian Brallier Formation, which dips northwesterly at 50 to 65°; about 3.0 ft (0.9 m) of thin-bedded to laminated, greenish-gray, fine-grained sandstone of the Brallier Formation were recovered from the terminal core (depth 27 to 30 ft; bedrock elevation 911 ft (278 m); see Fig. 19).

Rounded to subangular pebbles, cobbles, and boulders of mainly greenish-gray sandstone in a coarse- to very coarse-grained rounded sand matrix about 2.0 ft (0.6 m) thick unconformably overlie the fresh bedrock from 25 to 27 ft (7.6-8.2 m). This basal gravel and sand, at least in part fluvial, is overlain by diamicton, which is the chief component of regolith at this site. It consists mainly of pebble- to boulder-sized angular clasts of weathered and fresh, red and greenish sandstone in a matrix of grayish-orange to mottled light-gray and yellow silty and sandy clay. The clay matrix was sampled for XRD clay analysis. A one-foot (0.3 m)-thick, iron-stained, subrounded to subangular gravel zone was penetrated at depths of 14 to 15 ft (4.3 to 4.6 m). The diamicton is probably colluvium that extensively mantles the adjacent upland bedrock slopes mixed with thin debris flow or mud flow deposits and local fan lobes that extend into the valley from adjacent creeks.

Erosion and filling of the perched horseshoe-shaped valley is apparently related to an earlier cycle of fluvial and colluvial processes than is presently operating; however, no direct age determinations or climatic assessments are possible at this site.

Outcrop samples sites: location, geologic setting, description, and analysis

Two artificial exposures of high level terrace deposits and one natural alluvial outcrop were sampled: outcrop site no. 3A on Route 259 east of Yellow Spring, W.Va. (Figs. 2 and 8); outcrop site no. 9, Cunningham Lane north of Moorefield, W.Va. (Fig. 20); outcrop site no. 10, the alluvium of the South Branch Potomac River near Romney, W.Va. (Fig. 2; no large-scale locality map was prepared).

Outcrop Site No. 3A

The site sampled is an isolated roadcut exposure of terrace deposits situated on the north side of Route 259 about a mile east of Yellow Spring, W. Va. (See Figs. 2 and 8). Bedrock at the site is steeply southeast-dipping, interbedded greenish-gray sandy siltstone and fine-grained sandstone of the Devonian Brallier Formation, which is weathered and bleached tan for about 3 ft (1 m) below the basal gravels. The unconformable contact between the basal gravels and weathered bedrock is at an approximate elevation of 1060 ft (323 m), about 200 ft (61 m) above the floodplain of the Cacapon River at Yellow Spring. The basal gravel unit is lenticular and varies in thickness locally from 1 to 3 ft (0.3 to 0.9 m), consisting of well-rounded pebbles and cobbles of light-gray sandstone, chert, and quartzite, commonly with thin but prominent brownish weathering rinds. The gravel is gradationally overlain by an upward-fining sequence 5 to 10 ft (1.5 - 3 m) thick of coarse-, medium-, and fine-grained, buff to brown, rounded, quartzose, friable sand. The fine-grained sands at top grade upward into about 15 ft (4.6 m) of fine sandy and silty, gray and red mottled clay which weathers reddish brown. A relatively fresh sample of clay approximately 15 ft (4.6 m) above the base was sampled for XRD clay analysis (see Fig. 26). The fine-grained terrace sequence is locally capped by a lenticular veneer of diamicton, consisting of flat, angular, reddish-brown to grayish-green, fine-grained sandstone and siltstone clasts in a sticky, silty, clay matrix.

Whereas the terrace succession is mainly of fluvial origin and probably related to an ancestral course of the Cacapon River, it is an isolated deposit that could not be traced laterally. It is probably older than the high-level terrace deposits cored at Sites 1 and 2 nearby.

Outcrop Site No. 9, Cunningham Lane

The site sampled is a roadside borrow pit exposure situated on the north side of Cunningham Lane about 1.5 mi (2.4 km) west of its junction with Route 55, and 2.5 mi (4 km) north of Moorefield, W. Va. (see Figs. 2 and 20). Bedrock exposed at this site is gently southeast-dipping gray silty shale of the Devonian Mahantango Formation, which is weathered and bleached for about 3 ft (1 m) below the basal gravel. The unconformable contact between the basal gravel and weathered shale is at an approximate elevation of 982 ft (300 m), about 200 ft (61 m) above the nearby floodplain of the South Branch Potomac River near Moorefield. The basal gravel unit is about 5 ft (1.5 m) thick, consisting of well-rounded cobbles and pebbles of mainly quartzite with minor sandstone and chert in a poorly sorted matrix of silty, clayey, coarse-grained sand; however, a 1.0 ft (0.3 m)-thick, buff to brown, medium- to coarse-grained, fairly well sorted, friable and porous sand is present near the top of the gravel unit. The gravel and sand unit is conformably but abruptly overlain by 10 ft (3 m) of generally firm, massive, silty clay which is fractured and mottled gray and reddish brown. The entire section was sampled at 1 to 2 ft (0.3 to 0.6 m) intervals for chemistry and XRD clay analysis, including the clay fraction from the basal sand and gravel unit (see Fig. 27). The clay is gradationally overlain by about 3 ft (1 m) of pebbly, sandy loam containing rounded and subangular sandstone clasts.

Whereas the terrace deposits are mainly of fluvial origin and probably related to an ancestral course of the South Branch, it is neither the highest nor the lowest level terrace deposit in this area, thus it is probably an approximate time correlative of the deposit at Site 3A, as it lies at a similar altitude above the flood plain.

Outcrop Site No. 10, South Branch Potomac River

The site sampled is a river bank outcrop of alluvium situated in the northwest bank of the floodplain of the South Branch Potomac River about 300 ft (91 m) southeast of the U.S. Route 50 bridge abutment, one mile (1.6 km) west of Romney, W. Va. (Figs. 1 and 2). A fresh basal pebble and cobble gravel more than 3 ft (1 m) thick, consisting mostly of well-rounded Oriskany Sandstone and gray, white, and black chert, is present at river level (789 ft (238 m). It is conformably overlain by 1 to 3 ft (0.3 to 0.9 m) of medium- to fine-grained, silty clayey sand, which contains sparse small pebbles locally. About 330 ft (100 m) upstream a lenticular layer of edgewise conglomerate about 1 ft (0.3 m) thick is composed exclusively of flattened 0.5 to 1.0-inch (1-2 cm) imbricated black shale pebbles; it is overlain and underlain by medium-grained sand. The sand at the sampled site is conformably overlain by 2 ft (0. 6m) or more of sandy and silty clay with prismatic to blocky structure and with roots and burrows; it is overlain by a thin layer of organic-matter-rich soil.

Representative samples of the clayey sand and sandy clay were collected for XRD analysis (see Fig. 23), and for comparison to XRD plots of clays in the terrace deposits and other regolith cored.

Summary of coring operations, geophysical logging, and completion of holes

Coring Operations

by Michael F. Hoffman

Each of the eight (8) holes was cored by personnel of the Branch of Eastern Regional Geology, using a truck-mounted Mobile B-61 drill rig. The holes were continuously cored from the soil zone through the regolith to bedrock using local fresh water, and a combination of drill systems. The upper zones (those above the basal fluvial gravels) were cored using HQ drill rods and a Christensen wireline core retrieving system producing core with a diameter of 2.4 in (6.1 cm). The basal gravels and underlying Paleozoic bedrock in each hole were cored using NQ rods emplaced inside the HQ rods, which served as surface casing for the upper zone. A Longyear wireline core retrieving system, producing NQ core with a diameter of 1.8 in (4.6 cm), was used. Upon reaching the final depth (3-13 ft (1-4 m) into bedrock), each hole was flushed with fresh water and the NQ rods were extracted from the hole. The HQ rods were, in most cases, left in place to ensure the accessibility of the hole for geophysical logging. The HQ rods were extracted after completion of each hole. Those holes not completed as monitor wells were backfilled and completely sealed using Benseal grout.

Geophysical Logging

by Daniel J. Phelan

Geophysical logs were used to help interpret lithology and to determine intervals to be screened in the coreholes. Natural gamma logs were run in seven holes, and single-point electric logs were also run in two of these holes (see Fig. 22). Below is a brief description of the two types of logs, and the results of some interpretations of the logs. For a detailed discussion of geophysical log interpretation, see Keys (1988).

Gamma Logs

Gamma logs, also called gamma-ray logs or natural-gamma logs, are the most widely used nuclear logs in ground-water applications. The most common uses are for identification of lithology and for stratigraphic correlation (Keys, 1988). Gamma logs can be run in open holes, through most diameters of drill stem, and through steel or PVC casing that is at least 2 in (5 cm) in diameter. Logging through casing or drill stem reduces the signal by about half, depending on the thickness of the pipe and the amount of gamma radiation that occurs naturally within the formations, but does not affect the character of the curve itself.

Relative radioactivity of formations

Gamma logs typically have radioactivity increasing to the right. In unconsolidated sediments, sands generally have lower radiation than clays, unless the sands have high concentrations of shell material or glauconite, that can increase the amount of radiation in the sands. In the sedimentary rocks of the Appalachian region, sandstone, limestone, and dolomite usually have relatively low radiation, with shales usually having the highest readings.

Calibration

The scale on the gamma logs included in this report range approximately from 0 to 100 counts per second full scale, with zero on the left, and 100 on the right. These are not standardized units between different logging probes. If other logging equipment were used to test the same wells, the values would most likely be quite different, but the curves would be very similar. Measured counts per second will change in relation to the size and age of the gamma probe used, therefore the counts cannot be used for comparing logs from different logging equipment quantitatively.

Commercial logging companies serving the petroleum industry usually calibrate gamma systems in a calibration pit periodically, and use the American Petroleum Institute (API) units as the standard scale on gamma logs. The API units are not generally used in water-well logging.

Single Point Electric Logs

The single-point electric (SPE) log includes a measurement of spontaneous potential (in millivolts) between formations, and electrical resistance (in ohms) of the formations adjacent to the borehole. Single-point electric logs can only be run in open (uncased) holes, or in sections of holes that are below surface casing. The SPE log has been widely used in the past for borehole geophysics, and is an excellent tool when used for lithologic interpretation. Quantitative interpretation cannot be made from the single-point resistance logs because unlike inductive resistivity logs, the interpreter cannot assign resistivity or potential values to a particular formation for comparison between wells.

The SPE logs measure differences between formation contacts very close to the side of the borehole (or corehole in this instance), so it provides good definition of contacts between formations (Fig. 22). It does not take an average reading over a specific unit of a formation, as do resistivity logs. The scales on neither of the curves have a zero, thus only differences between formations are measured.

Spontaneous Potential

The spontaneous potential (SP) log is a record of potentials or voltages that develop at the contacts between shale or clay beds and a sand aquifer, where they are penetrated by a borehole (Lynch, 1962; Keys, 1988). The SP curve is typically on the left side of an SPE log. The scale displayed on the graph of the SP log (Fig. 22) shows a range, and a value in millivolts; positive voltages are to the right, and negative to the left. Given a sufficiently deep log, the zero line would be roughly down the middle of the trace. Changes in the conductivity of the borehole fluid will affect the amount of deflection and can change the direction of an SP log. More conductive fluids will increase the deflection in the curve.

Resistance

The resistance log displays formations with higher resistivity to the right and lower to the left (Fig. 22). Fresh-water sands and gravels or other aquifer material usually deflect to the right, and tight clays or silts deflect to the left. Consolidated formations, in this case limestones and sandstones, generally have higher resistances than the unconsolidated deposits overlying the bedrock. While logging most of the coreholes in this study, the probes only entered the consolidated formations, and reliable readings from the deeper zones where generally not achieved.

Completion of Coreholes as Monitor Wells
by Daniel J. Phelan

Five of the coreholes were completed as monitoring wells as part of the Potomac basin National Water Quality Assessment (NAWQA) program. Two-inch (5 cm) PVC casing was installed in each well with either a 2.5- or 5-foot (0.76-1.5 m) section of screen at the desired sampling interval. As each corehole was approximately 4 in (10 cm) in diameter, sand was filled in around each screen as a gravel pack to fill the space between the casing and the hole. Bentonite pellets were then dropped in the hole to isolate the screened interval from other water-bearing zones or from surface contamination by vertical flow. Table 3 lists the corehole number and the respective screened interval. The objective was to screen the holes opposite the basal sand and gravels just above bedrock to determine the chemical characteristics of the regolith portion of the local ground-water flow regime.

Clay Mineralogy: X-ray Diffraction Results
by Michael F. Hoffman

Sample preparation for X-ray diffraction analysis

The clay-bearing core or outcrop samples were wet-sieved using nos. 80 and 200 mesh (0.0070 and 0.0029 inch openings, respectively) to separate the coarse-grained constituents of the sample from the clays, and from the silt and very fine and fine sand for heavy- and light-mineral analysis. A solution to prevent flocculation was added to the clay fraction, then centrifuged to retain only particles of less than 2 μm in diameter. Oriented clay slides were produced from this clay fraction by adding deionized water and placing the resulting clay slurry on a glass slide, allowing 12 hours for the clay to settle and the water to evaporate. The slides were placed in a DIANO Series 2000 X-ray diffractometer (XRD) and scanned from 2θ values of 2 to 14, producing graphic outputs showing 2θ versus counts per second. The slides were then vapor saturated with ethylene glycol (12-15 hours) and rerun from 2θ values of 2 to 40, producing similar graphic outputs.

Using XSPEX software on both outputs, each peak (high counts per second) was given a d-space value in angstroms. Using these values, mineral content was evaluated. The critical clay minerals for this study include illite/smectite and vermiculite, whose 2θ values are 6.0 for unglycolated samples; however, glycolated slides show illite/smectite with $2\theta=5.1$, d-space =17.33, while vermiculite remains at 6.0, d-space = 14.7. Other key minerals, with their 2θ and approximate d-space values, are illite (8.6, 10.3), kaolinite (12.2, 7.3), and an unnamed, intermediate weathering phase between illite and vermiculite (7.5, 11.5). In the absence of vermiculite, quantifications of illite, illite/smectite and kaolinite were performed on a percentage basis using multiplication constants of 1 for illite/smectite, 2 for kaolinite, and 4 for illite, and measuring the width of each peak at one half of the height from the base curve on the glycolated (2-40) outputs.

Clay mineralogy - XRD results

X-ray diffraction analysis was completed on clays in the regolith at five sites (3 outcrop, 2 core holes, total of 35 samples). The clays in the soil zone at core sites 6 and 7 and the alluvium along the South Branch Potomac River near Romney contain illite, vermiculite, and kaolinite (see Figs. 23, 24A and 25A). The clays in regolith immediately below the soils at core sites 6 and 7 are in the matrix of the pebble- and cobble-bearing colluvial diamicton; they also consist mainly of illite, vermiculite, and kaolinite, but may contain a minor component of illite/smectite (Figs. 24B and 25B), and the silty clay at core site 7 is similar (Fig. 25C). Because of the presence of vermiculite in these samples, the relative abundances of the clay mineral species could not be estimated. The clays in the silty clay zones underlying the colluvial diamicton at core site 6, outcrop site 3A, and outcrop site 9 are mainly illite, illite/smectite, and kaolinite (Figs. 24C, 26, 27A, 27B), and the clay component in the pebbly sand and gravel at outcrop site 9 (Fig. 27C) is similar. Because vermiculite is absent from these samples, the relative abundance of the other clays was estimated (Figs. 24C, 27A, 27B, 27C). Illite/smectite is abundant and vermiculite is absent from the older, high-level silty clay deposits, and vermiculite is abundant in the youngest deposits.

The mineralogy of the clays in the regolith is dependent on: (1) provenance, i.e clay mineralogy of the source terrain; (2) stratigraphic position, i.e. clay mineralogy developed in the soil profile due to <u>in situ</u> weathering; (3) age, both relative and absolute; and (4) climate, both present (temperate, humid) and past (possibly periglacial). Because so many of these variables interact, it is not yet possible to draw any conclusions on the basis of data currently available. Future studies of the clay mineralogy of bedrock and of the clays in the regolith at sites not yet sampled may indicate significant similarities or differences and permit reliable generalizations.

Discussion, age interpretation, and geologic synthesis

The core and outcrop sections of regolith studied in the Winchester 30 x 60 minute quadrangle are representative of similar Cenozoic deposits widespread in the Appalachian Valley and Ridge province part of the Potomac River drainage basin. A common stratigraphic pattern of residual soil developed on (1) colluvial diamicton overlying; (2) silty clay that overlies an upward fining sequence of; (3) porous, fluvial, basal sand and gravel unconformable above; (4) fresh Paleozoic bedrock, is present at 7 of the 8 sites cored. Widespread alluvial and terrace deposits upstream and downstream can be tentatively correlated with the lower fluvial sequences cored, but no direct information on the absolute geologic age of these units has yet been determined. Some radiocarbon samples in deposits of the alluvial floodplain of the South Branch Potomac River near Petersburg and Moorefield, W.Va., were previously dated at 2170±180 yr. BP, and 7060±230 yr. BP, respectively (Jacobsen and others, 1989). Furthermore, archeological studies in the basal deposits of the alluvial floodplain of the Shenandoah Valley, which includes some radiocarbon-dated charcoal, indicates ages older than 9310 yr. BP associated with pre-Boreal flora, artifacts, and patterned ground associated with "the end of late glacial times around 10,500 years ago" (Carbone, 1976). Thus it seems likely that the principal alluvial floodplain of the Potomac River and its main tributaries, which enclose dissected remnants of at least two low-lying terraces, is mainly Holocene in age. Because all of the deposits cored and outcrop sites 3A and 9 occur at different relative topographic levels above the floodplains of the adjacent rivers, it is likely that all of the terrace deposits studied are Pleistocene in age, the highest-level deposits possibly older. By using an average rate of modern-day erosion and landscape denudation of 40 mm per 1000 years (Hack, 1980) and calculating local elevation differences between the modern floodplain and the base of the terrace deposits, relative age can be estimated (Southworth, 1988). The lowest level deposits (sites 3 and 7) are 4.2 and 4.6 m higher than the adjoining flood plain, thus might be 107,500 to 115,000 years old (late Pleistocene); intermediate deposits (sites 5 and 6) are 11.6 and 14.9 m higher and might be 290,000 to 372,500 yrs. old (middle Pleistocene); high level deposits (sites, 1, 2, 8) are 22.2, 21, and 22.3 m higher and might be 525,000 to 557,500 yrs. old. Isolated very high level deposits (site 4) are 31.7 m higher, possibly 792,500 yrs. old (early Pleistocene), whereas the outcrop sites 3A and 9 are 61 m higher, possibly 1,525,000 yrs. old (earliest Pleistocene or Late Pliocene).

Although the regolith cored is situated in meander cutoffs of rivers, a ubiquitous component at each site is shallow diamicton, a colluvial deposit that extended from the soil zone to depths as shallow as 10 ft (3 m) or as deep as 63 ft (19.2 m). Colluvium is probably the most widespread component of regolith in the Appalachian Valley and Ridge province, essentially mantling Paleozoic bedrock slopes everywhere but in the stream valleys or where bedrock cliffs and ledges crop out. Therefore, the abundant rainfall that infiltrates the regolith almost invariably passes through the widespread mantle of colluvial diamicton. The field parameters for water quality measured in the fluvial aquifers beneath the colluvium at the monitor wells is invariably quite different from the same components measured in the adjacent rivers, indicating that the mineralogy of the regolith has a significant influence on the chemical quality of the shallow groundwater in the Potomac River drainage basin.

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Table 1. Summary of Core Drilling, Winchester 1° sheet
June 29-July 29, 1992

Site Number	County	7.5 minute quadrangle	Latitude	Longitude	Elevation (feet)	Total Depth (feet)	Depth to Bedrock & Elevation (feet)	Logs	SWL[1] (feet)	Remarks
1	Hampshire	Capon Springs W.Va.	39°13'43"	78°26'41"	935	79.0	74.8 860.2	GR[2]	38.7	Monitor well; screen 70-72.5'
2	Hampshire	Capon Springs W.Va.	39°11'53"	78°28'09"	1015	91.5	90.5 924.5	GR	Est. 45-50	Plugged
3	Hampshire	Yellow Spring W.Va.	39°11'11"	78°30'02"	915	38.5	33.5 881.5	GR	16.5	Monitor well; screen 30.5-33'
4	Hampshire	Levels W.Va.	39°27'51"	78°36'14"	690	45.7	39 651	GR IE-R[3]	10	Plugged
5	Hampshire	Augusta W.Va.	39°22'09"	78°43'39"	710	49.0	36 674	GR	12	Monitor well; screen 27.5-32.5'
6	Mineral	Keyser W.Va.-Md.	39°26'37"	78°56'38"	850	50.0	40.6 809.4	GR IE-R	Flowing	Monitor well; screen 34.5-39.5'
7	Hampshire	Hanging Rock W.Va.	39°16'29"	78°34'06"	915	32.5	28.4 886.5	GR	5	Monitor well; screen 25.3-27.8'
8	Shenandoah	Mountain Falls Va.-W.Va.	39°02'52"	78°26'11"	938	30.0	27 911	----	5	Plugged

[1] SWL = Standing water level
[2] GR = Gamma ray
[3] IE-R = Induction electrical-resistivity

Table 2. Geologic Summary of Core Drilling Regolith in the Winchester 1° sheet

Site Number	Name	Bedrock	Depth to bedrock & elevation (feet)	Adjacent river & elevation of floodplain (feet)	Thickness & elevation of top Sd & Gvl[1] (feet)	Thickness & elevation of top Cl & Slt[2] (feet)	Thickness & elevation of top Diamicton (feet)
1	Christian Church Rd.	Devonian Chemung Fm.	75 860	Cacapon 825	8 868	7 875	60 935
2	Lehew Rd.	Devonian Chemung Fm.	90.5 925	Cacapon 860	4 929	23 952	63 1015
3	Bucks Knoll	Devonian Mahantango Fm.	33.5 882	Cacapon 875	7 889	11 900	15 915
4	Ferndale Lake	Devonian Chemung Fm.	39 651	South Br. Potomac 555	8 659	13 672	18 690
5	Buffalo Hollow	Devonian Mahantango Fm.	36 674	South Br. Potomac 635	10 684	10 694	16 710
6	Keyser Ind. Park	Silurian McKenzie Ls.	41 809	North Br. Potomac 780	9 818	21 839	11 850
7	Hanging Rock	Devonian Brallier Fm.	28 887	North 880	8 895	10 905	10 915
8	Cedar Creek	Devonian Brallier Fm.	27 911	Cedar Creek 840	2 913	-----	25 938

[1] Sd and Gvl = Sand and gravel
[2] Cl and Slt = Clay and silt

Table 3. Water-quality analyses from coreholes and nearby rivers, Winchester 1° sheet (September 21-22, 1992)

Site	Time pumped (min)	Pump rate (gpm)[1]	Gallons in well	Specific Conductance[2] (μS/cm)	Dissolved Oxygen[3] (mg/L)	pH	Water Temp.[4] (°C)	Alkalinity[5] (mg/L)
#1 Christian Church Rd.	90	0.65	6	575	--	5.8	13.5	106
#3 Bucks Knoll	60	1	3	2250	0.6	6.1	13.0	150
Cacapon R. at Yellow Spring	-	-	-	165	11.5	5.5	20	69
#5 Buffalo Hollow	42	2.5	3	170	3.0	--	14	--
S. Branch Potomac R. at Romney	-	-	-	250	8.0	--	21	--
#6 Keyser Ind. Park	105	3	7	660	2.0	--	14	--
N. Branch Potomac R. at Pinto	--	--	--	483	8.1	7.1	17.9	--
#7 Hanging Rock	80	3	3	270	1.6	6.8	14	147
North River at Hanging Rock	-	-	-	132	10.0	6.2	21	52

[1] (gpm) = gallons per minute
[2] Specific conductance = in microsiemens per cm at 25° Celsius
[3] Dissolved oxygen = in milligrams per liter
[4] Water temp. = temperature in degrees Celsius
[5] Alkalinity field = in milligrams per liter, expressed as calcium carbonate ($CaCO_3$) equivalent

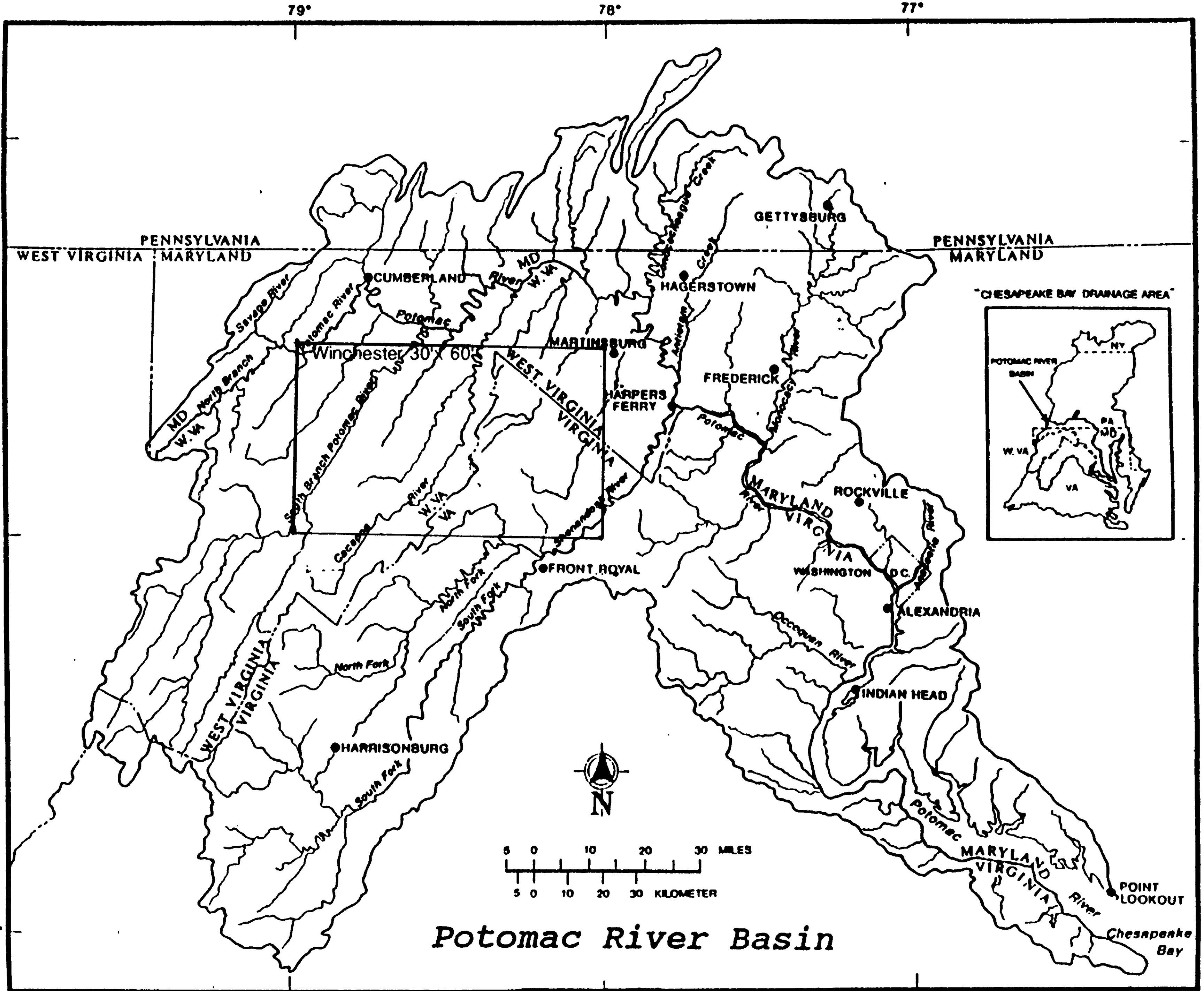

Potomac River Basin
79°
78°
77°
40°
39°
38°
PENNSYLVANIA
WEST VIRGINIA
MARYLAND
PENNSYLVANIA
MARYLAND
"CHESAPEAKE BAY DRAINAGE AREA"
POTOMAC RIVER BASIN
NY
PA
MD
W. VA
VA
GETTYSBURG
HAGERSTOWN
CUMBERLAND
MARTINSBURG
HARPERS FERRY
FREDERICK
ROCKVILLE
WASHINGTON
D.C.
ALEXANDRIA
INDIAN HEAD
POINT LOOKOUT
FRONT ROYAL
HARRISONBURG
Winchester 30' X 60'
WEST VIRGINIA
VIRGINIA
MARYLAND
VIRGINIA
MD
W. VA
VA
Savage River
North Branch
Potomac River
Potomac
South Branch Potomac River
Cacapon River
Shenandoah River
North Fork
South Fork
Antietam Creek
Conococheague Creek
Monocacy River
Occoquan River
Anacostia River
Potomac River
Chesapeake Bay
N
5 0 10 20 30 MILES
5 0 10 20 30 KILOMETER

Figure 1

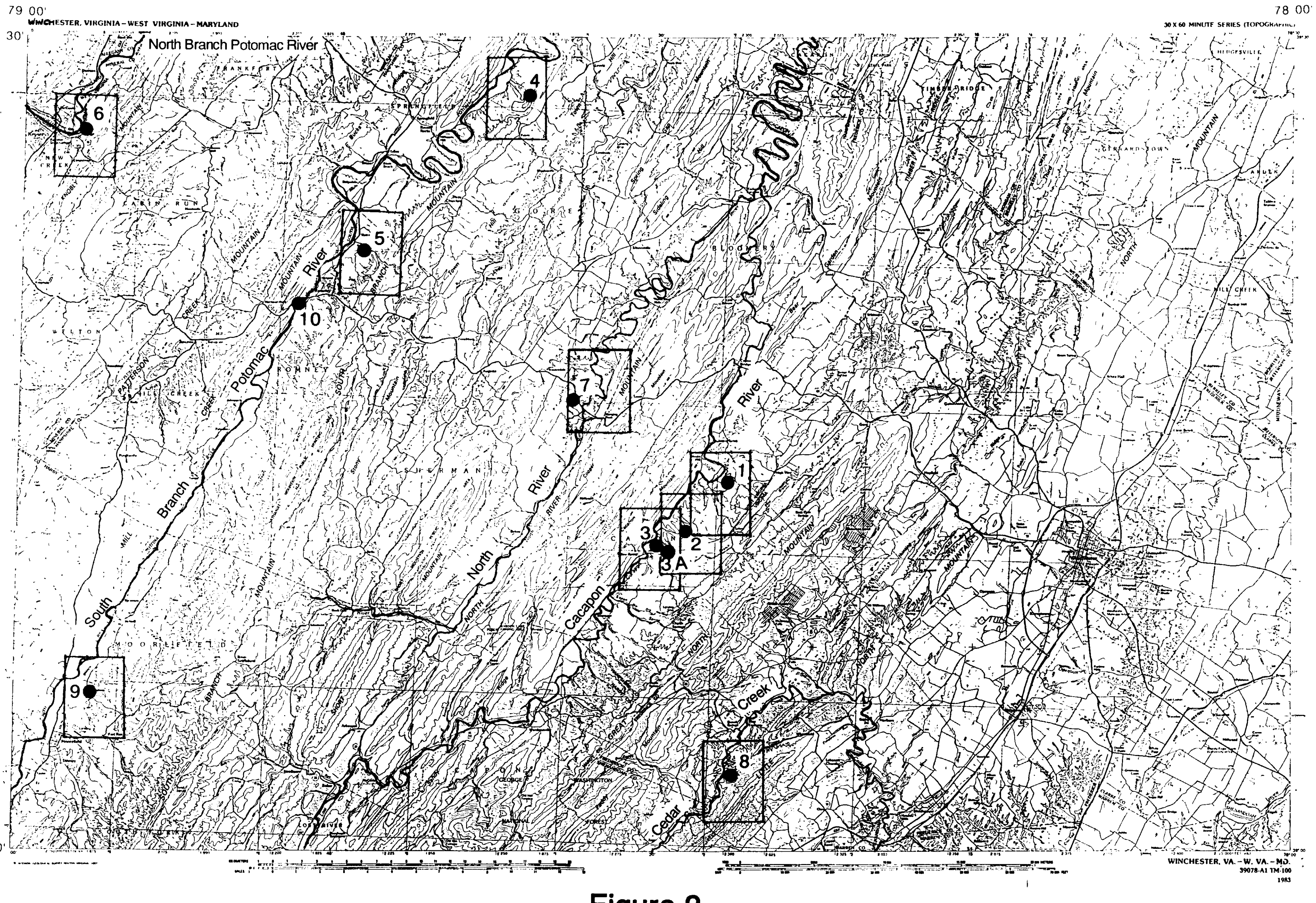

79 00'
78 00'
WINCHESTER, VIRGINIA – WEST VIRGINIA – MARYLAND
30 X 60 MINUTE SERIES (TOPOGRAPHIC)
39 30'
39°00'
North Branch Potomac River
1
2
3
3A
4
5
6
7
8
9
10
River
Potomac
Branch
South
North
River
Cacapon
River
Creek
Cedar
WINCHESTER, VA. – W. VA. – MD.
39078-A1 TM-100
1983

Figure 2

Symbols and Abbreviations for Generalized Core Logs

- Diamicton
- Silty clay
- Sand
- Gravel
- Siltstone
- Sandstone
- Limestone
- # Pyrite
- ●● Carbonaceous material
- MnO_2 stringers
- Calcareous fragment

c = coarse
diam = diameter
dk = dark
f = fine
ft = feet
g = grained
lt = light
m = medium
MnO_2 = manganese oxide
mod = moderate
ss = sandstone
v = very

Symbols for Geologic Maps

- Anticlinal axis
- Synclinal axis
- Contact-approximately located
- Contact-concealed
- Corehole
- x Exposure
- U/D Fault
- 45 Strike and dip-beds
- 75 Strike and dip-overturned beds
- 50 Strike and dip-joints
- Strike of vertical joints

Abbreviations for X-ray Diffractograms

V = Vermiculite
I = Illite
I/S = Illite/Smectite
K =Kaolinite
Q = Quartz

Figure 3

78°27'30"

39°12'30"

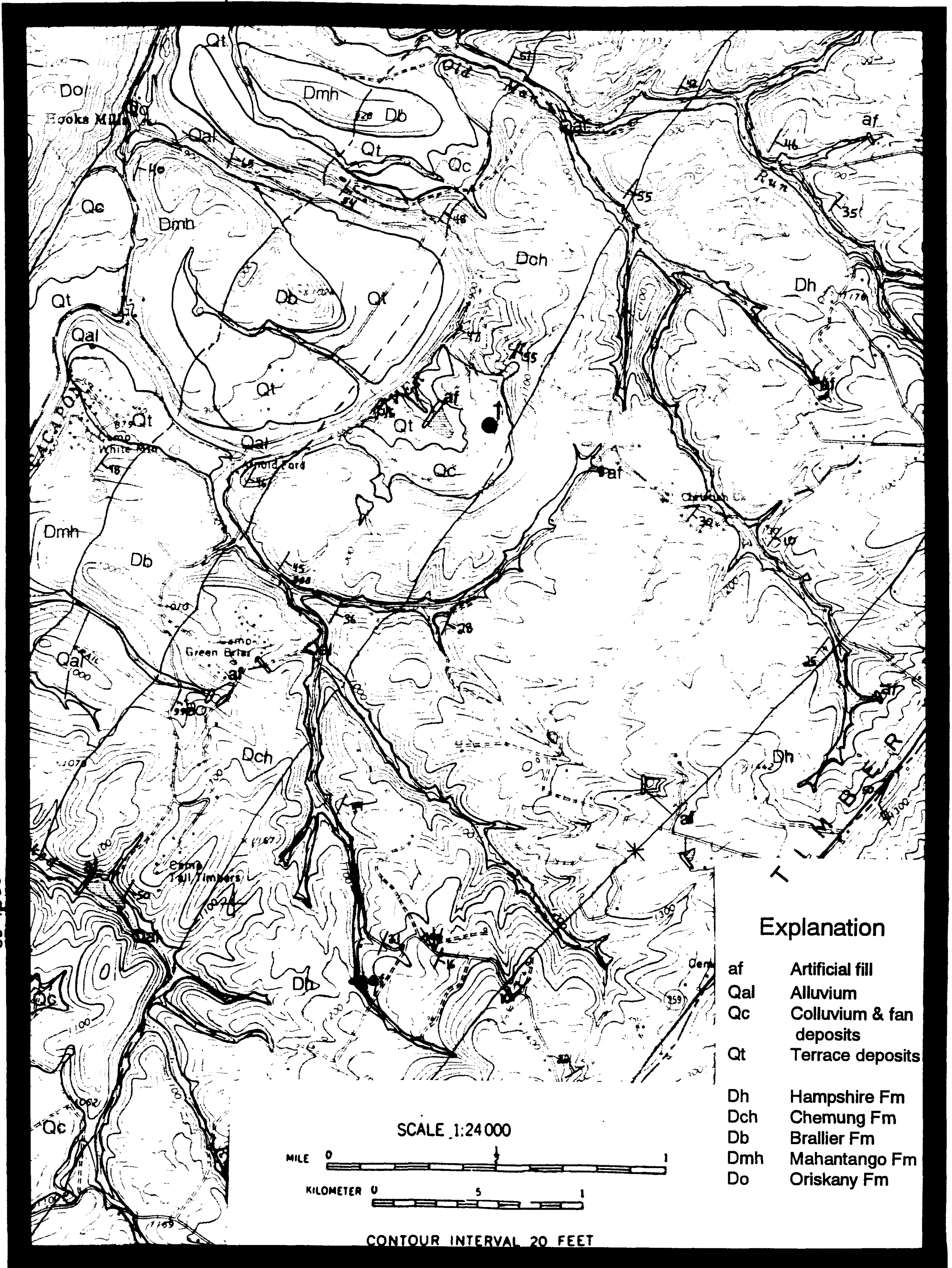
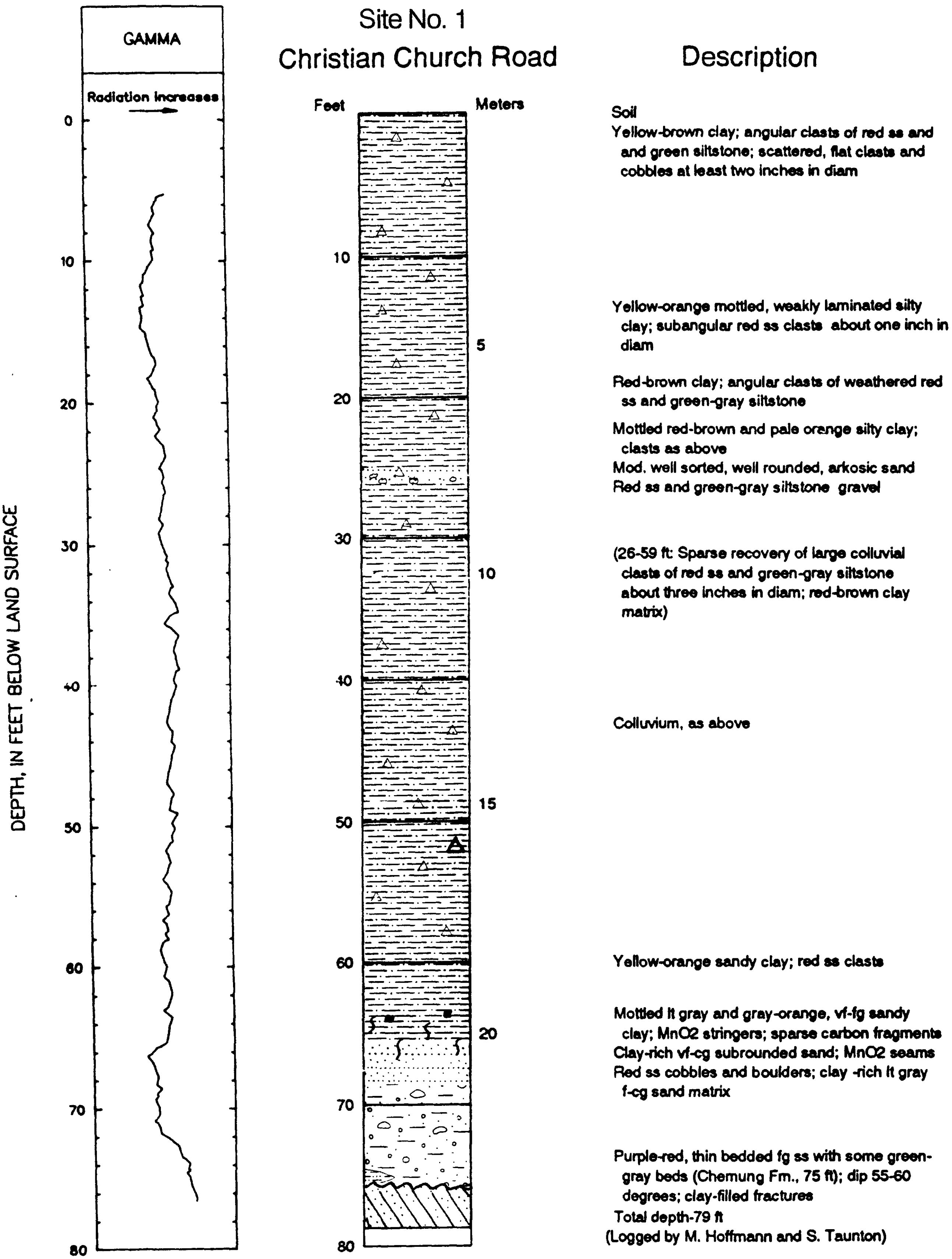


Figure 4

Modified from Dean and others, 1985, by Parker, Froelich, Hoffmann



GAMMA
Radiation increases
DEPTH, IN FEET BELOW LAND SURFACE
0
10
20
30
40
50
60
70
80
Site No. 1
Christian Church Road
Feet
Meters
5
10
15
20
Description
Soil
Yellow-brown clay; angular clasts of red ss and and green siltstone; scattered, flat clasts and cobbles at least two inches in diam
Yellow-orange mottled, weakly laminated silty clay; subangular red ss clasts about one inch in diam
Red-brown clay; angular clasts of weathered red ss and green-gray siltstone
Mottled red-brown and pale orange silty clay; clasts as above
Mod. well sorted, well rounded, arkosic sand
Red ss and green-gray siltstone gravel
(26-59 ft: Sparse recovery of large colluvial clasts of red ss and green-gray siltstone about three inches in diam; red-brown clay matrix)
Colluvium, as above
Yellow-orange sandy clay; red ss clasts
Mottled lt gray and gray-orange, vf-fg sandy clay; MnO2 stringers; sparse carbon fragments
Clay-rich vf-cg subrounded sand; MnO2 seams
Red ss cobbles and boulders; clay -rich lt gray f-cg sand matrix
Purple-red, thin bedded fg ss with some green-gray beds (Chemung Fm., 75 ft); dip 55-60 degrees; clay-filled fractures
Total depth-79 ft
(Logged by M. Hoffmann and S. Taunton)

Figure 5

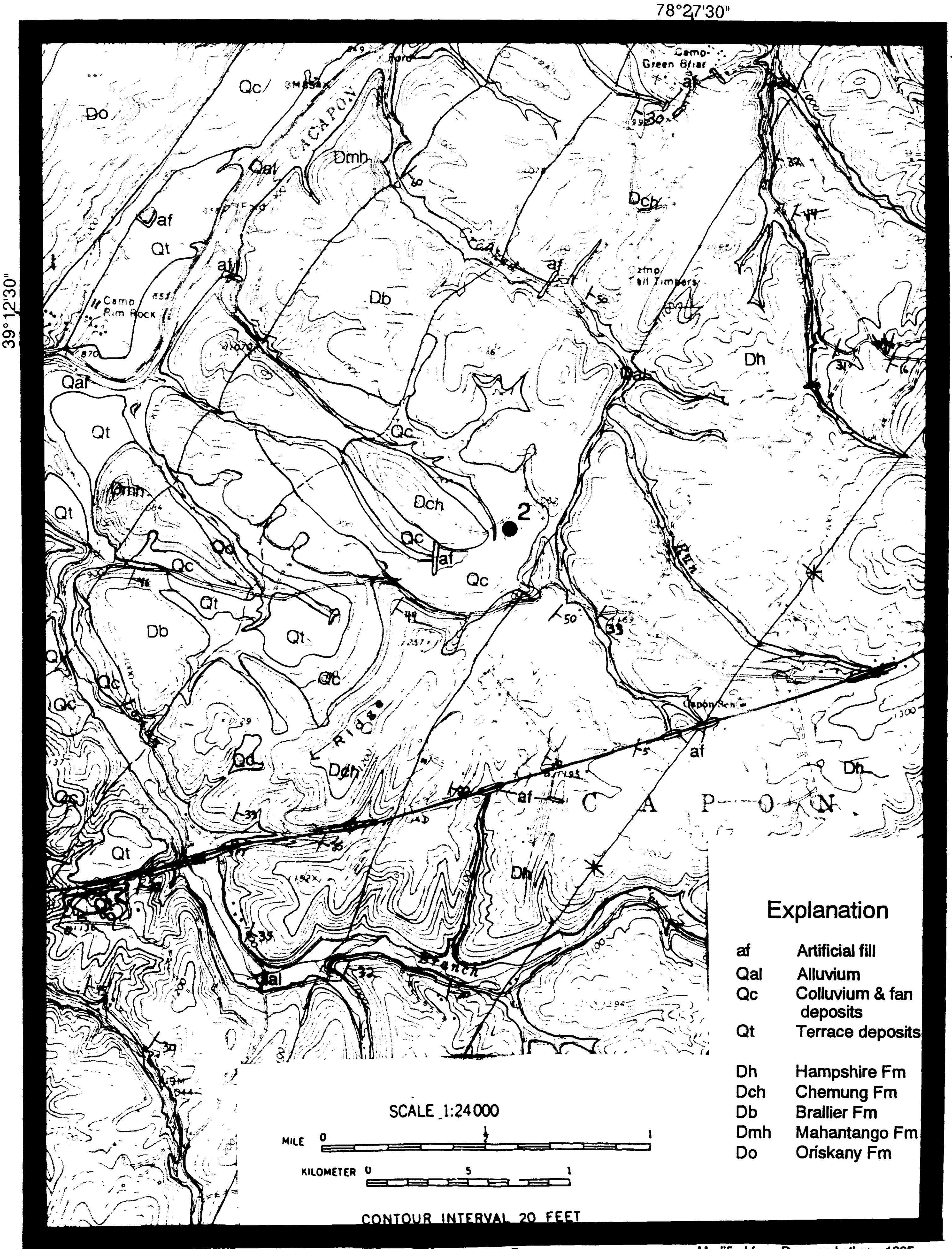
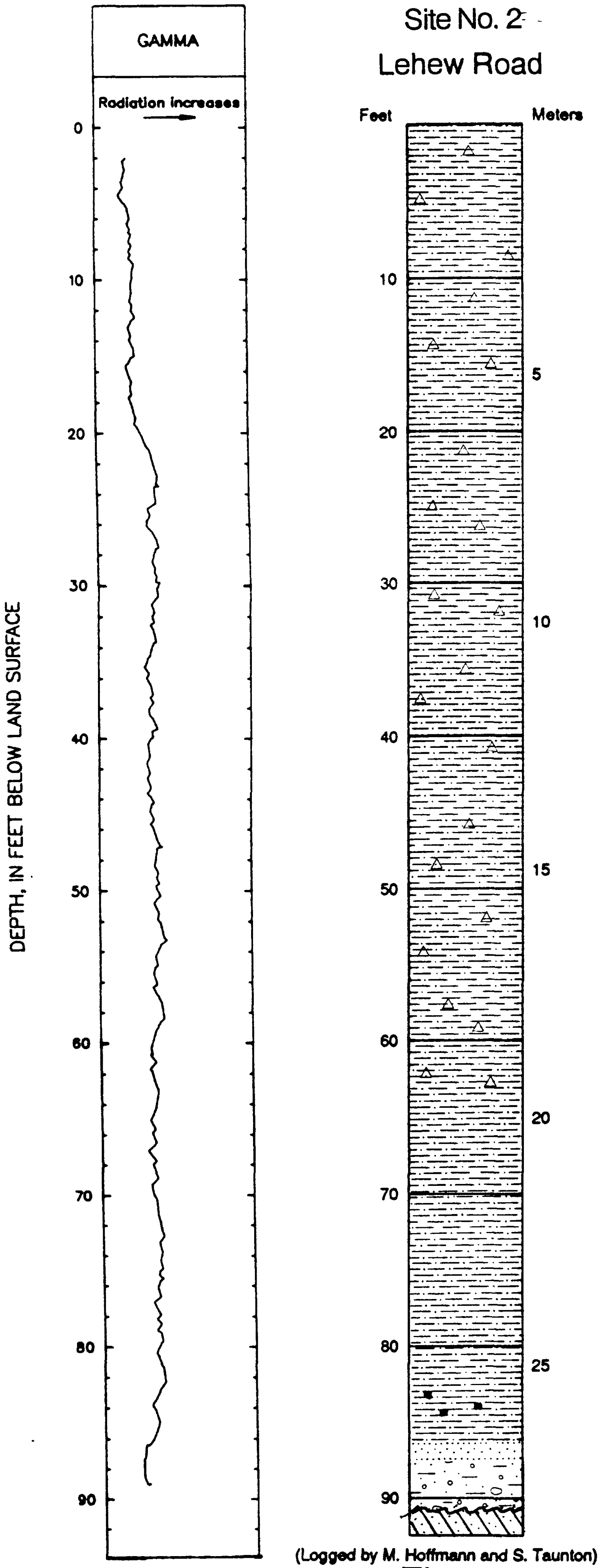


Figure 6

Modified from Dean and others, 1985,
by Parker, Froelich, Hoffmann



Description

Soil

Dk yellow-orange silty clay with lt brown-gray mottles; some weathered, red ss clasts

Lt brown and red brown silty clay;

Lt brown silty-vfg sandy clay; lt gray mottles; sub-rounded, red ss clasts

Lt brown silty clay; angular, red ss clasts

Red ss boulder

Mod red-brown to lt brown silty clay; subangular clasts of red ss exhibiting various degrees of weathering; average clast size: 0.25-0.50 inches; rare clasts of one to two inches in diam

(40-60 ft; poor recovery)

Probably lt brown silty to vfg sandy clay with clasts of 0.5 to 3.0 inches in diam

(60-70 ft: no recovery)

Geophysical log indicates lithologic change at approximately 63 ft; 60-63 ft: probable diamicton in clay matrix as above· 63-70 ft: probably clay as seen after 70 ft

Lt olive and gray-red silty clay; clay clasts; vf mica

Olive-brown silty clay with orange and blue-gray silty clay stringers

Clay, as above; white, fg ss clasts

Lt olive-gray, finely laminated, silty clay

Olive-brown and blue-gray mottled vf-fg sandy clay; laminae and sand pods (weathered ss clasts?)

Green-gray sandy clay; pods of white, red and green sand; mica

Clay, as above; weathered ss clasts; carbon specks

Clay, as above; sparse ss clasts; carbon and mica flakes; leaf cuticles

(86.3-90 ft: questionable transition between sandy clay and basal gravel)

Siltstone boulder

Purple-red fg ss with gray-white swirls (Chemung Fm., 90.5 ft to total depth-91.5 ft)

Figure 7

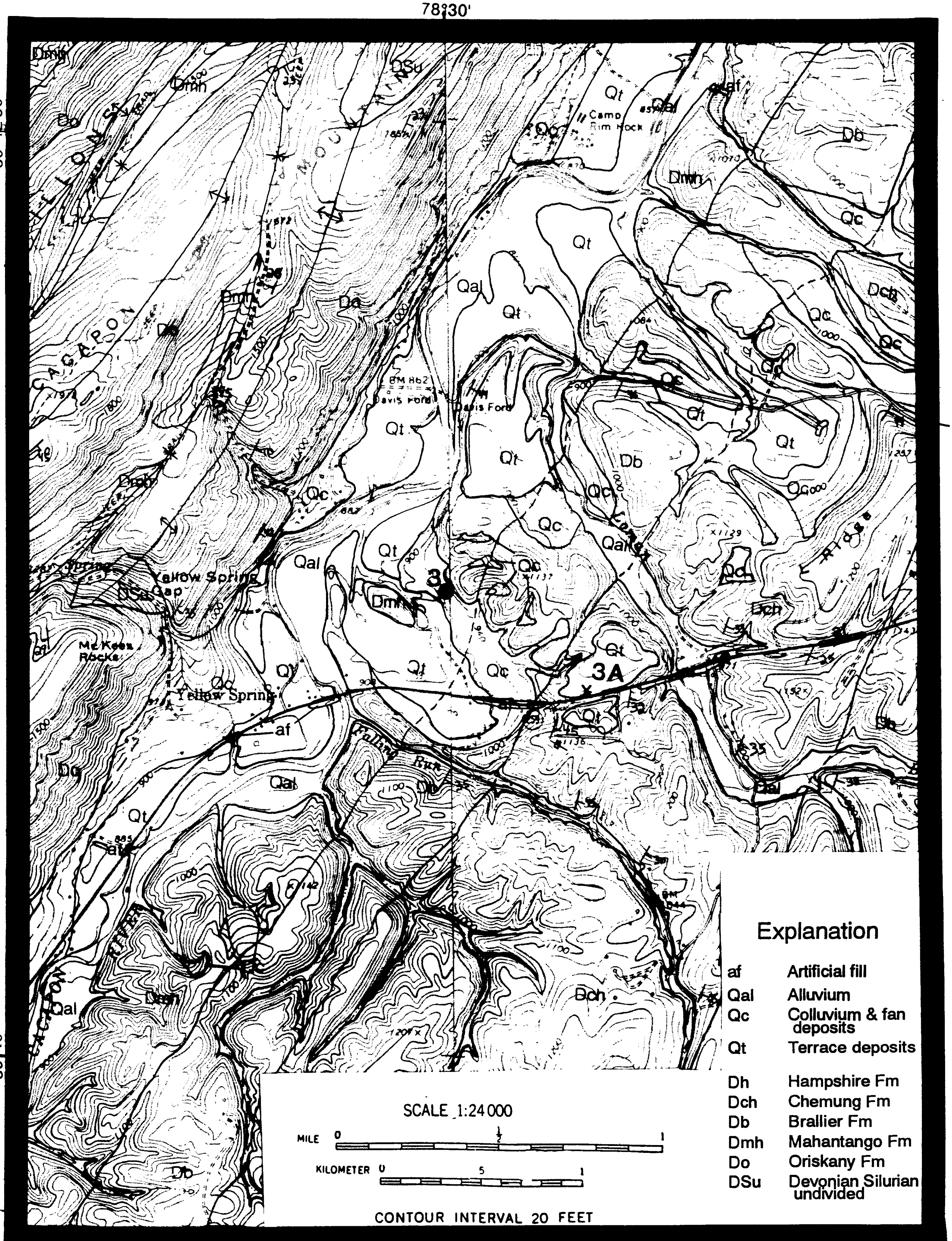
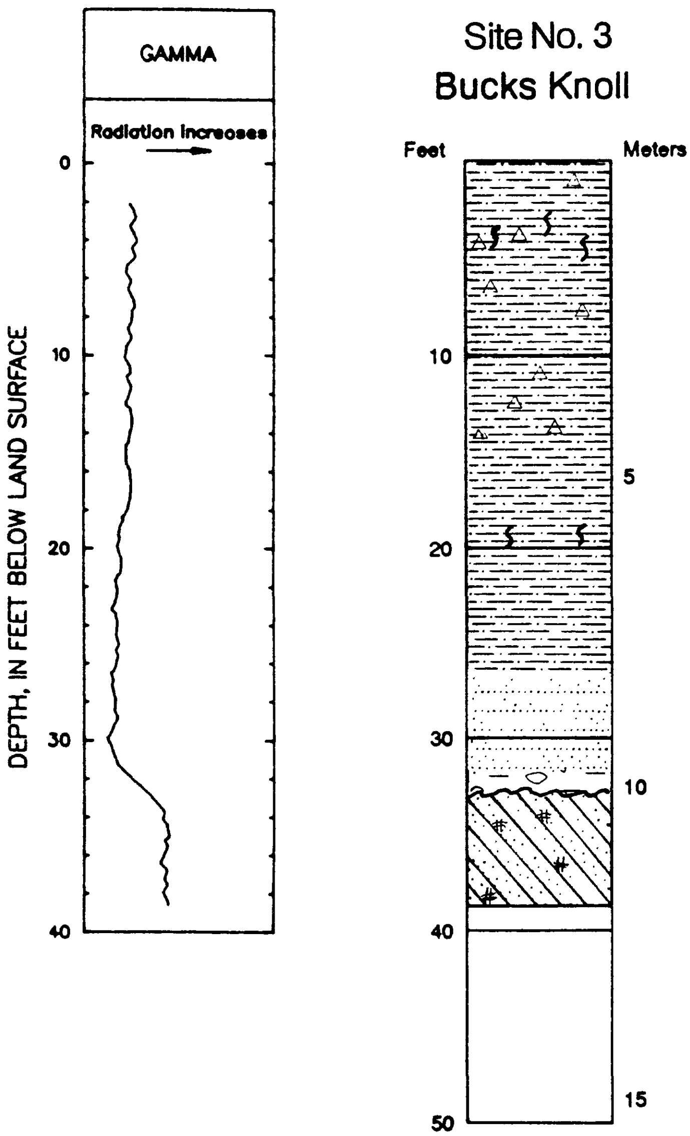


Figure 8

Modified from Dean and others, 1985, by Parker, Froelich, Hoffmann



Description

Soil

Dk yellow-orange, silty clay; angular clasts of red ss and green-gray siltstone; mica; MnO2 in root burrows

Yellow-orange, c-vcg sandy clay; small clasts of red ss and green siltstone

Dk yellow-orange, vfg sandy clay

Lt gray and brown mottled silty, micaceous clay

M gray and yellow-orange mottled, silty clay; MnO2

M gray f-cg subrounded sand

Dk yellow-orange, gray and orange mottled clay-rich f-mg sand

Yellow-brown sandy clay mottled with lt gray, well sorted, fg sand

Lt gray, f-mg sand; green-gray clay mottles

Dk gray, f-vcg sand

Subrounded quartz sand, c-vcg

Boulders-pebbles of chert,quartzite and ss

Fossiliferous, blue-gray, fg ss (Mahantango Fm., 33.5 ft) pyrite on steeply dipping and fractured bedding planes

Total depth- 38.5 ft

(Logged by M. Hoffmann and S. Taunton)

Figure 9

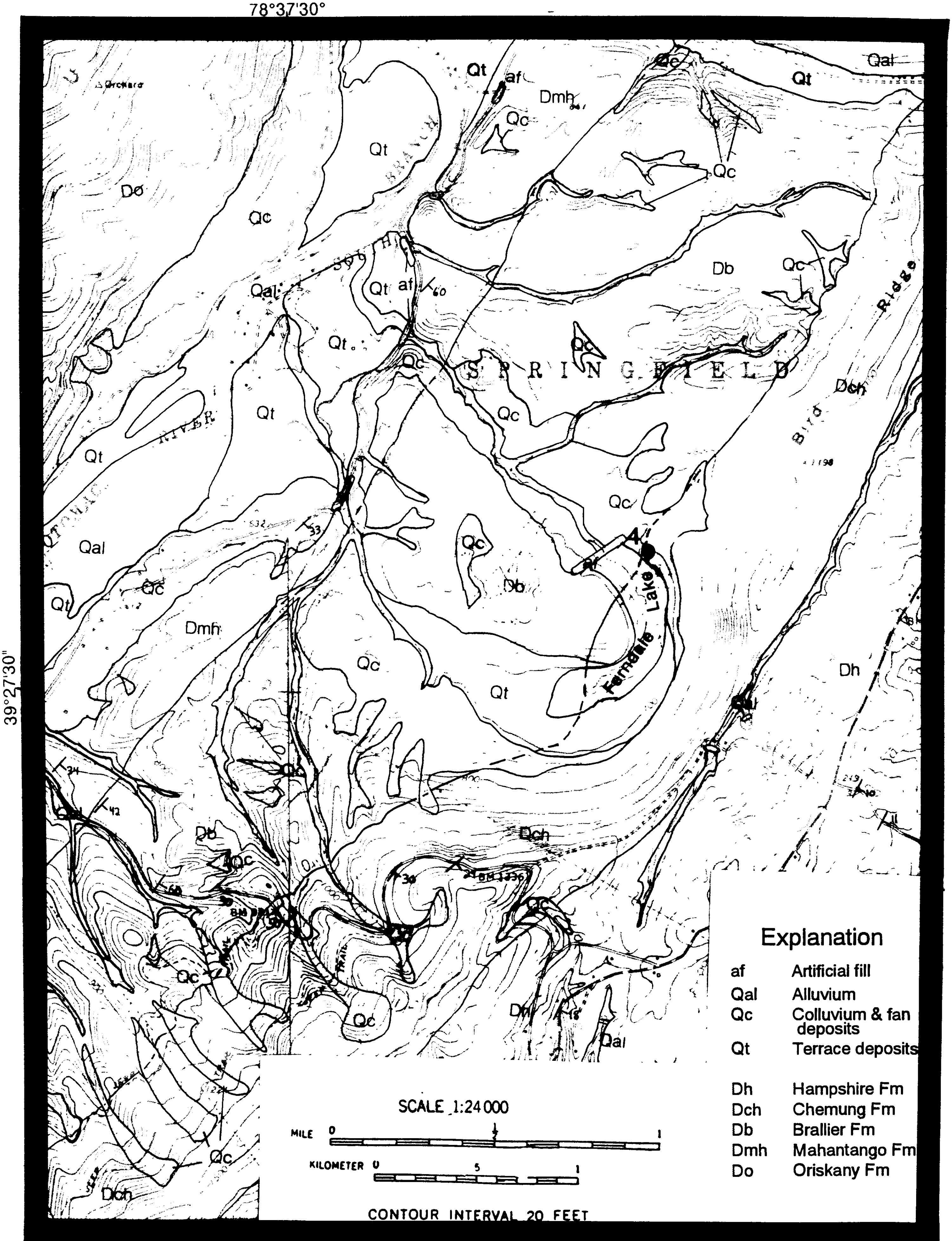


Figure 10

Modified from Schultz, unpub. data, by Froelich, Hoffmann

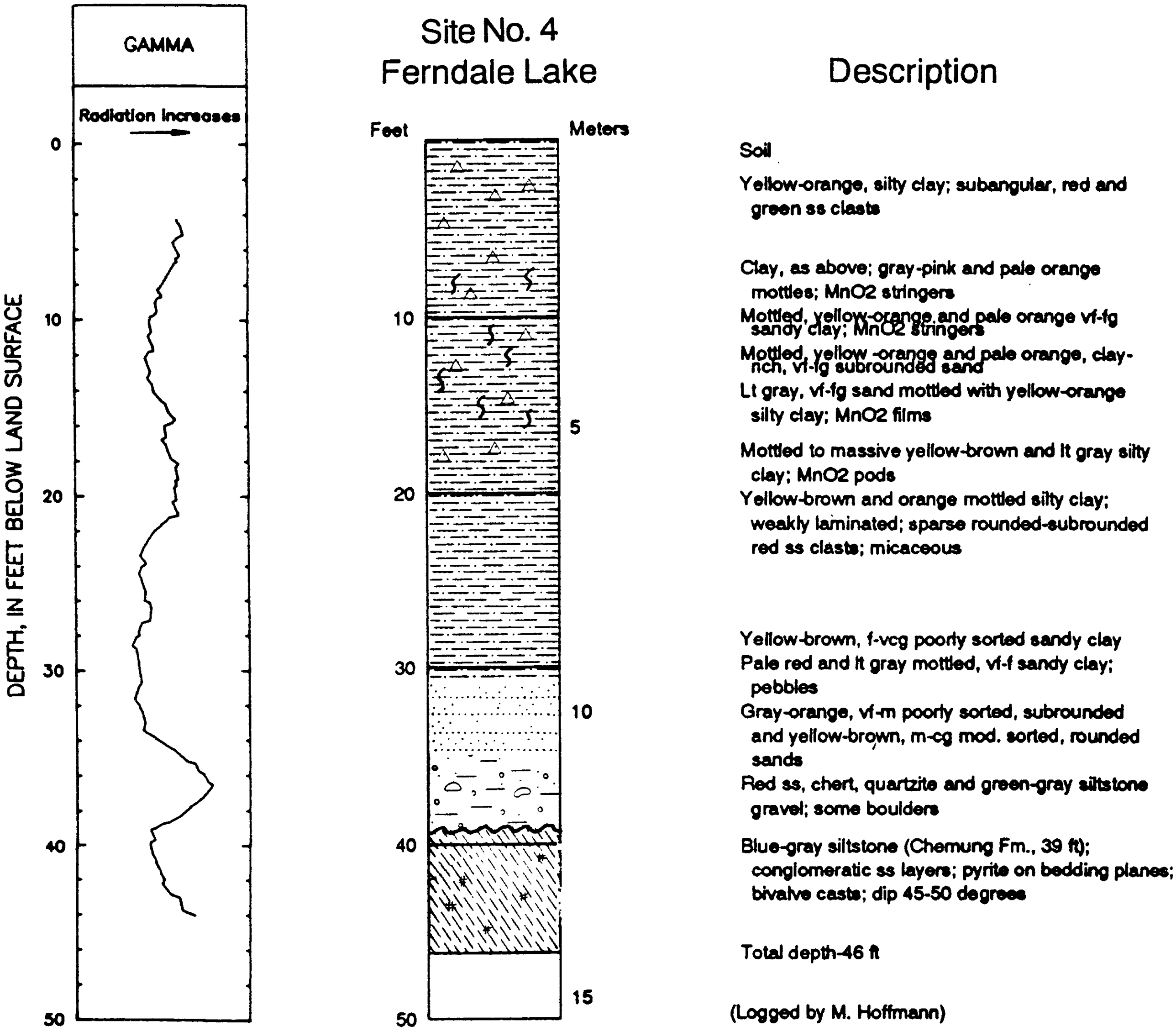

GAMMA
Radiation increases
DEPTH, IN FEET BELOW LAND SURFACE
0
10
20
30
40
50
Site No. 4
Ferndale Lake
Feet
Meters
5
10
15
Description
Soil
Yellow-orange, silty clay; subangular, red and green ss clasts
Clay, as above; gray-pink and pale orange mottles; MnO2 stringers
Mottled, yellow-orange and pale orange vf-fg sandy clay; MnO2 stringers
Mottled, yellow -orange and pale orange, clay-rich, vf-fg subrounded sand
Lt gray, vf-fg sand mottled with yellow-orange silty clay; MnO2 films
Mottled to massive yellow-brown and lt gray silty clay; MnO2 pods
Yellow-brown and orange mottled silty clay; weakly laminated; sparse rounded-subrounded red ss clasts; micaceous
Yellow-brown, f-vcg poorly sorted sandy clay
Pale red and lt gray mottled, vf-f sandy clay; pebbles
Gray-orange, vf-m poorly sorted, subrounded and yellow-brown, m-cg mod. sorted, rounded sands
Red ss, chert, quartzite and green-gray siltstone gravel; some boulders
Blue-gray siltstone (Chemung Fm., 39 ft); conglomeratic ss layers; pyrite on bedding planes; bivalve casts; dip 45-50 degrees
Total depth-46 ft
(Logged by M. Hoffmann)

Figure 11

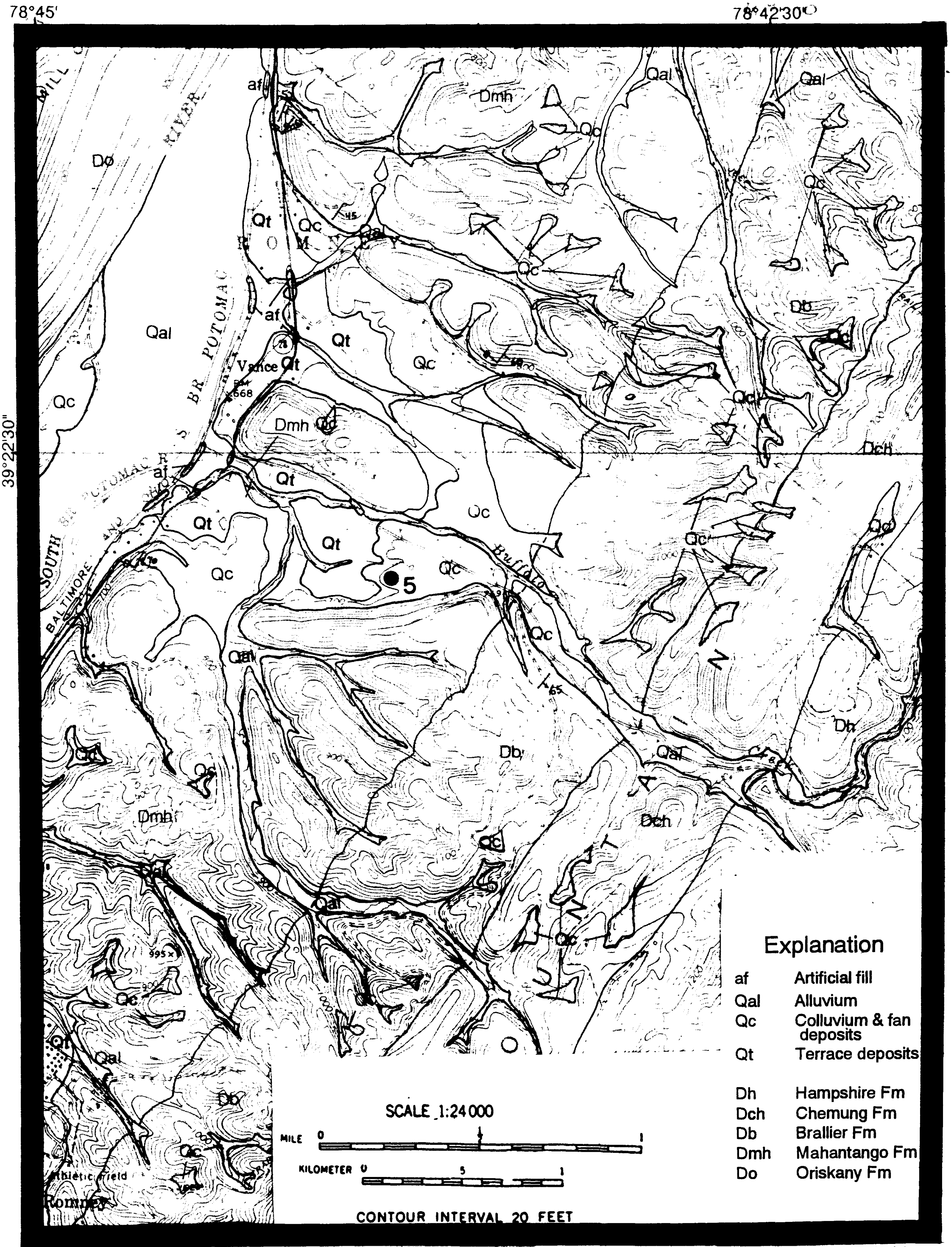
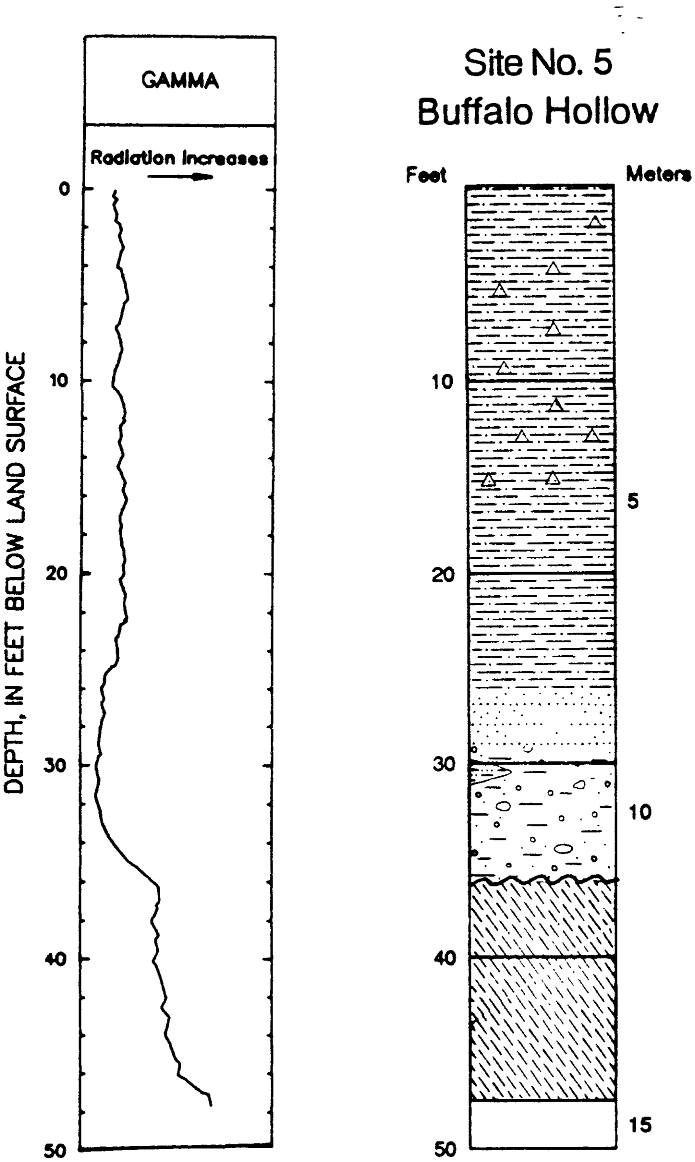


Figure 12

Modified from Parker, unpub. data, by Froelich, Hoffmann



Description

Soil
Brown, sandy clay; angular and subrounded pebbles
Yellow-brown, sandy clay; siltstone pebbles

Red and yellow, subangular ss cobbles
Mottled yellow-brown, sandy clay; ss pebbles

Subangular-subrounded, red ss cobbles in poorly sorted sand matrix
Yellow-orange, silty clay; sand pods
Siltstone cobbles
Yellow-brown, silty clay; lt gray mottles

Lt brown, silty clay; red-brown and blue-gray mottles

Sandy clay
Yellow-orange and lt gray clayey sand
f-mg sand; angular and rounded clasts
f-mg sand; flat, angular pebbles

Siltstone and fg ss gravel
Black, white and red chert, ss and siltstone, gravel in cg sand matrix
Siltstone and ss cobbles
Blue-gray siltstone (Mahantango Fm., 36 ft); dip 45-60 degrees

Total depth- 47.7 ft
(Logged by M. Hoffmann and S. Taunton)

Figure 13

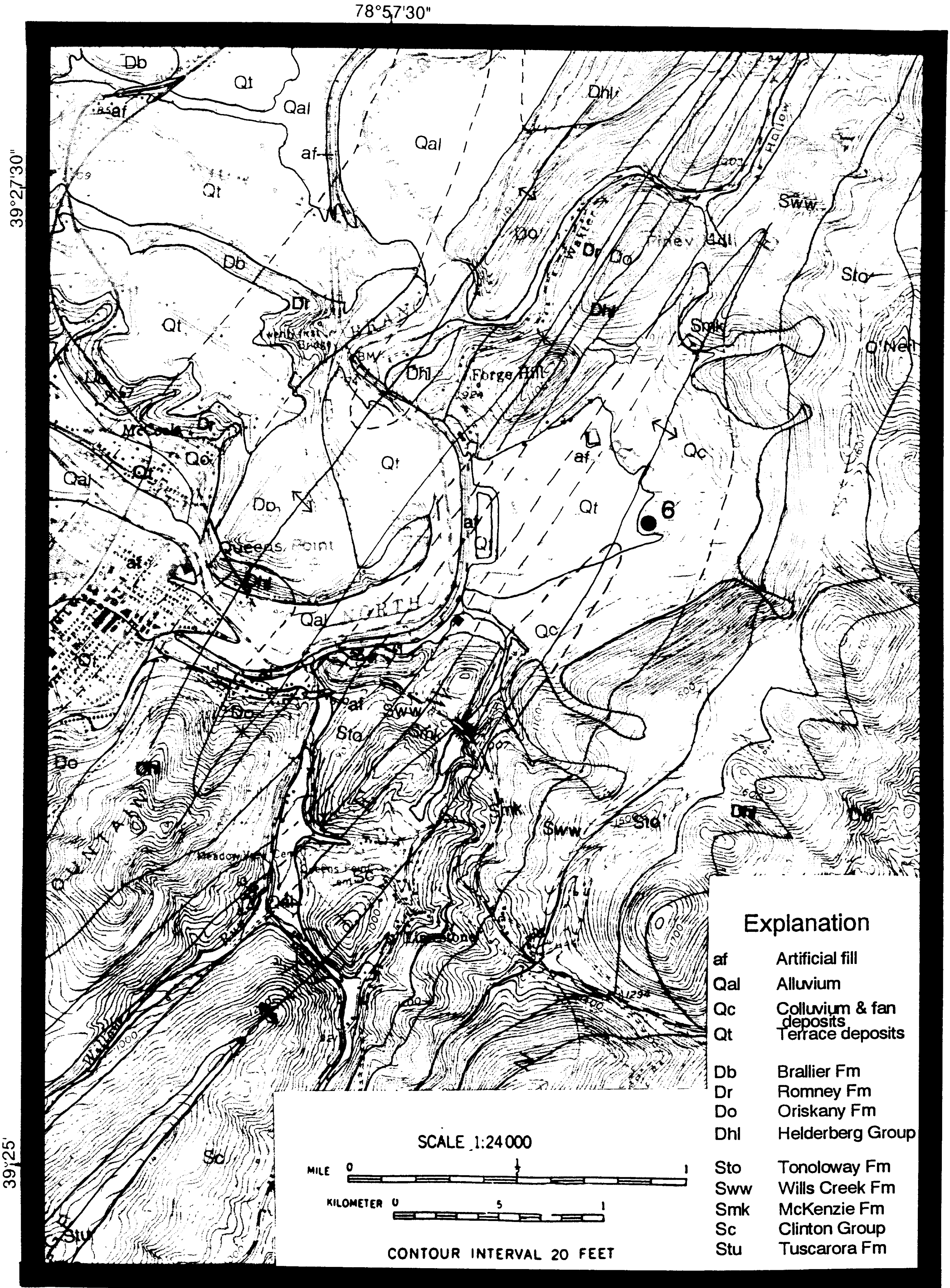
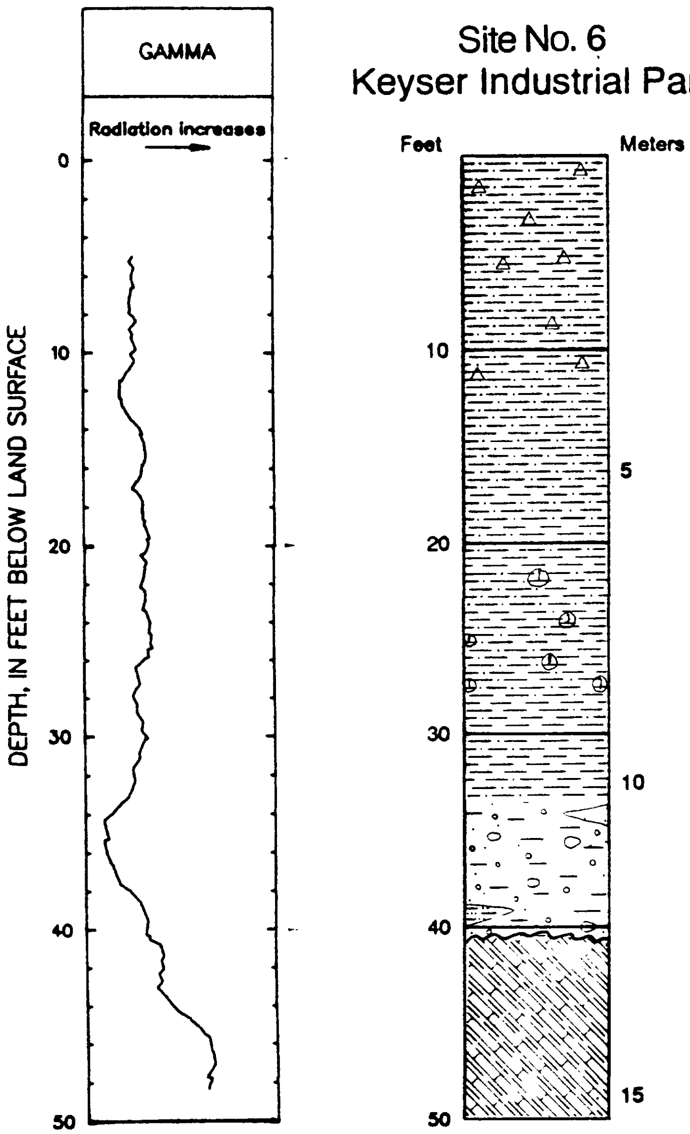


Figure 14

Modified from Dennison, 1963, by Froelich, Hoffmann

Site No. 6
Keyser Industrial Park



Description

Soil
Dk yellow-brown to lt brown sandy clay; clay clasts
Gravel with clay rich vfg sand matrix
Silty- vfg sandy clay

Pale olive, calcareous clay mottled with yellow-orange non-calcareous clay
Blue tinted clay with pebbles
Pale green vf-fg sand
Green-gray clay
Pale olive silty clay with gray-blue mottles; red and white ss clasts

Lt. olive brown and blue-gray mottled clay; angular-subangular ss clasts; white lime chips
Clay, as above; mg sand; lime chips

Pebbles and pelletal lime in silty-vfg sandy clay

Mod to dk gray and yellow-brown mottled fg sandy clay; white ss cobble

Red ss and gray-green siltstone cobbles

Tan-gray quartzite boulder
Mod to dk gray limestone and red ss cobbles

Mod to dk gray, fossiliferous, thin bedded limestone with some silty layers apparent dip 40-45 degrees (McKenzie Fm., 40.6 ft to total depth-50 ft)

(Logged by M. Hoffmann and S. Taunton)

Figure 15

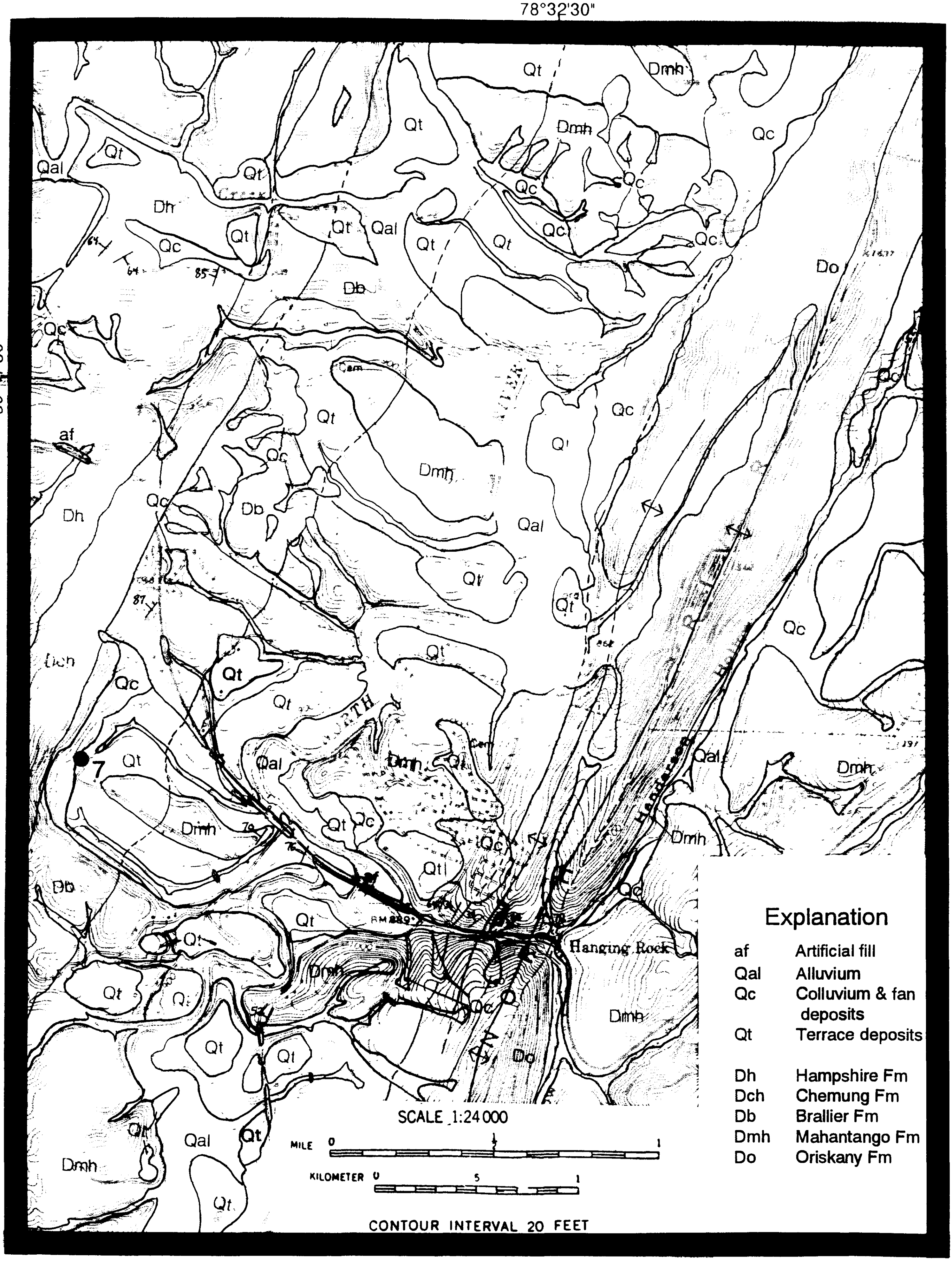
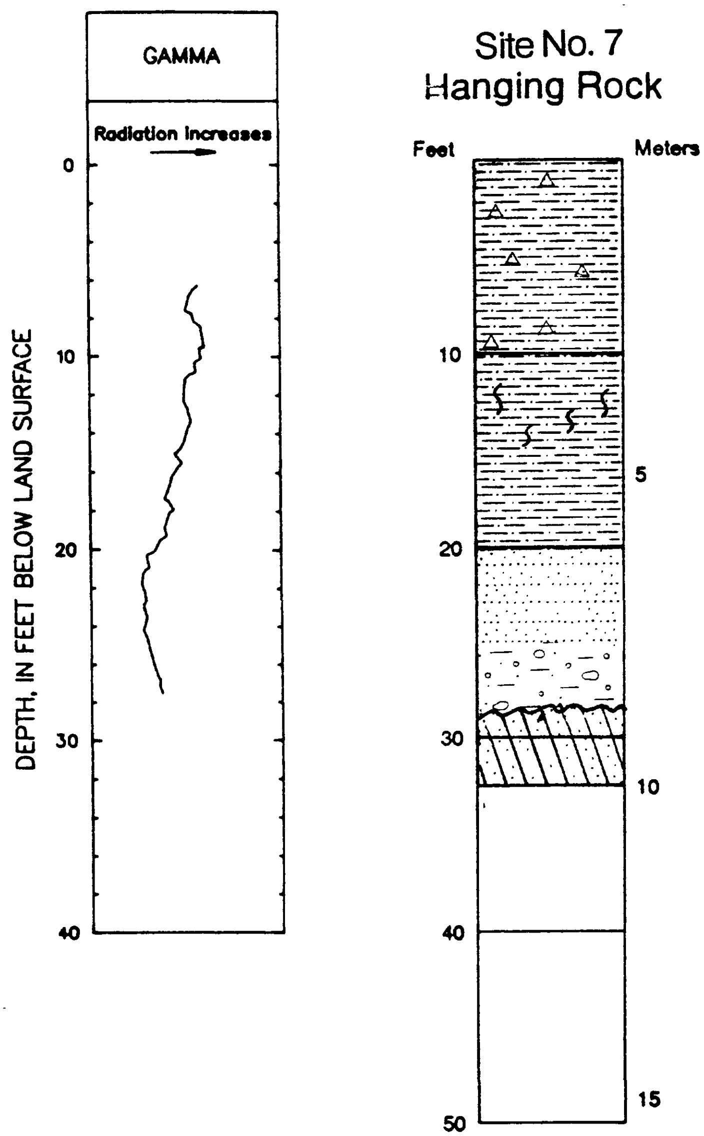


Figure 16

Modified from Schultz, unpub. data, by Froelich, Hoffmann



Description

Soil
Dk yellow-orange and gray mottled sandy clay; mica; angular, red ss gravel
Yellow-orange sandy clay; angular clasts of green-gray and black siltstone
Yellow-gray sandy clay; green-gray and black siltstone clasts

Medium- gray and yellow-orange mottled silty clay; MnO_2
Yellow-orange sandy clay (highly oxidized) MnO_2 along fractures

Sand fraction increases from about 10-30 percent

Lt blue-gray and gray-orange c-vcg sand with clay matrix; rounded siltstone clasts
Olive-gray to brown-gray, m-vcg sand; mica and lithic fragments
Cobble-boulders in m-cg sand matrix

Dk green-gray, micaceous, fg ss (Brallier Fm., 28.5 ft); high angle bedding; calcite veins

Total depth- 32.5 ft

(Logged by M. Hoffmann)

Figure 17

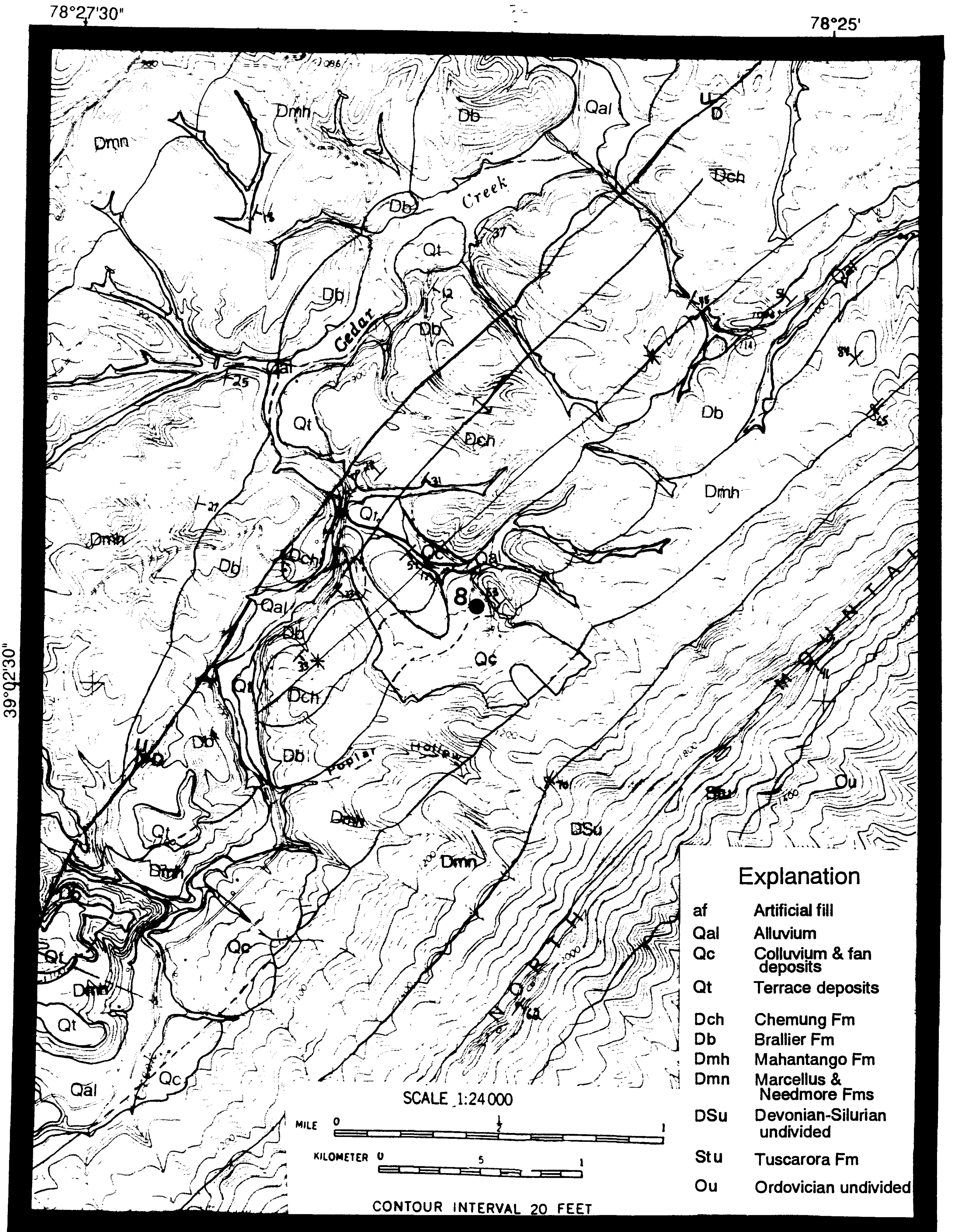
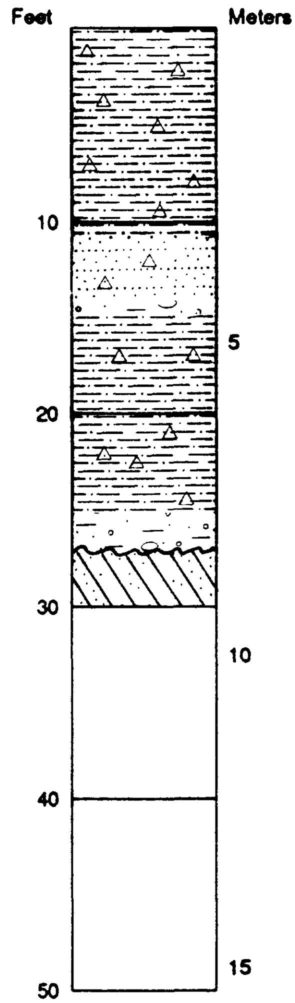


Figure 18

Modified from McDowell, unpub. data, by Froelich, Hoffmann

Site No. 8
Cedar Creek



Description

Soil

Gray-orange, silty to vfg sandy clay; flat, angular colluvial clasts

Yellow and orange sandy clay with clasts of red and green-gray ss

Yellow-orange mottled with lt gray; clay-rich, vf-fg sand with weathered red ss clasts

Gravel zone at 14-15 ft

Yellow-orange silty clay with angular to subrounded ss clasts

Green-gray ss boulders and cobbles in c-vcg quartz sand

Thinly bedded gray ss (Brallier Fm., 27 ft) dip 45-50 degrees

Total depth-30 ft

(Logged by M. Hoffmann and S. Taunton)

Figure 19

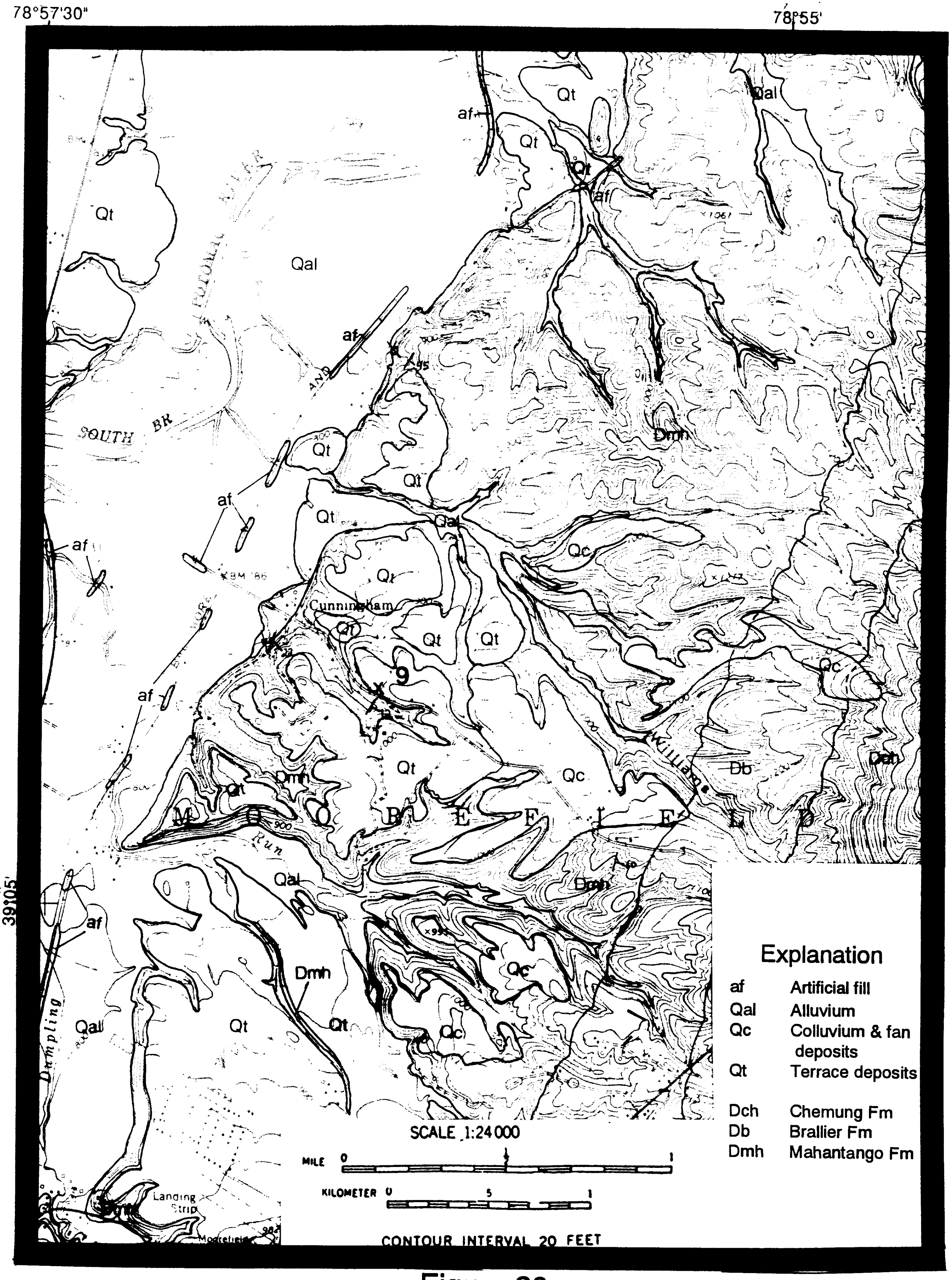
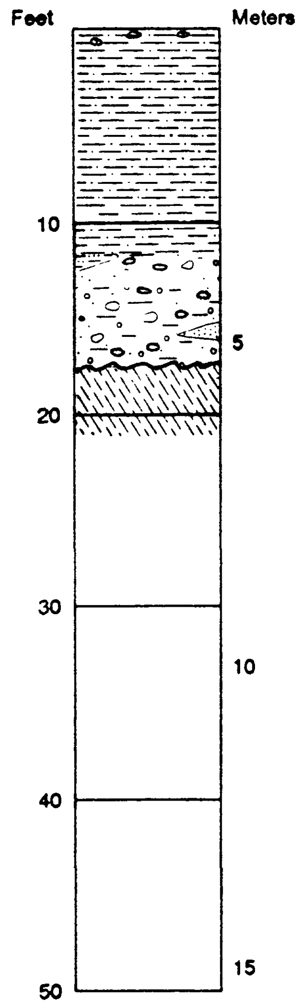


Figure 20

Modified from Parker, unpub. data, by Froelich, Hoffmann

Site No. 9

Cunningham Lane



Description

Soil, pebbly, sandy

Mottled gray and red-brown silty
clay, fractured

Gravel, pebble, lt gray, silty-sandy matrix
Buff-brown m-cg-pebbly sand
Lt gray gravel, rounded-subrounded
pebbles, cobbles of quartzite, sandstone
and chert in silty-sandy matrix,
Lt gray to tan weathered shale grading to
Dk gray, fissile silty shale
(Mahantango Fm., 18 ft)

Figure 21

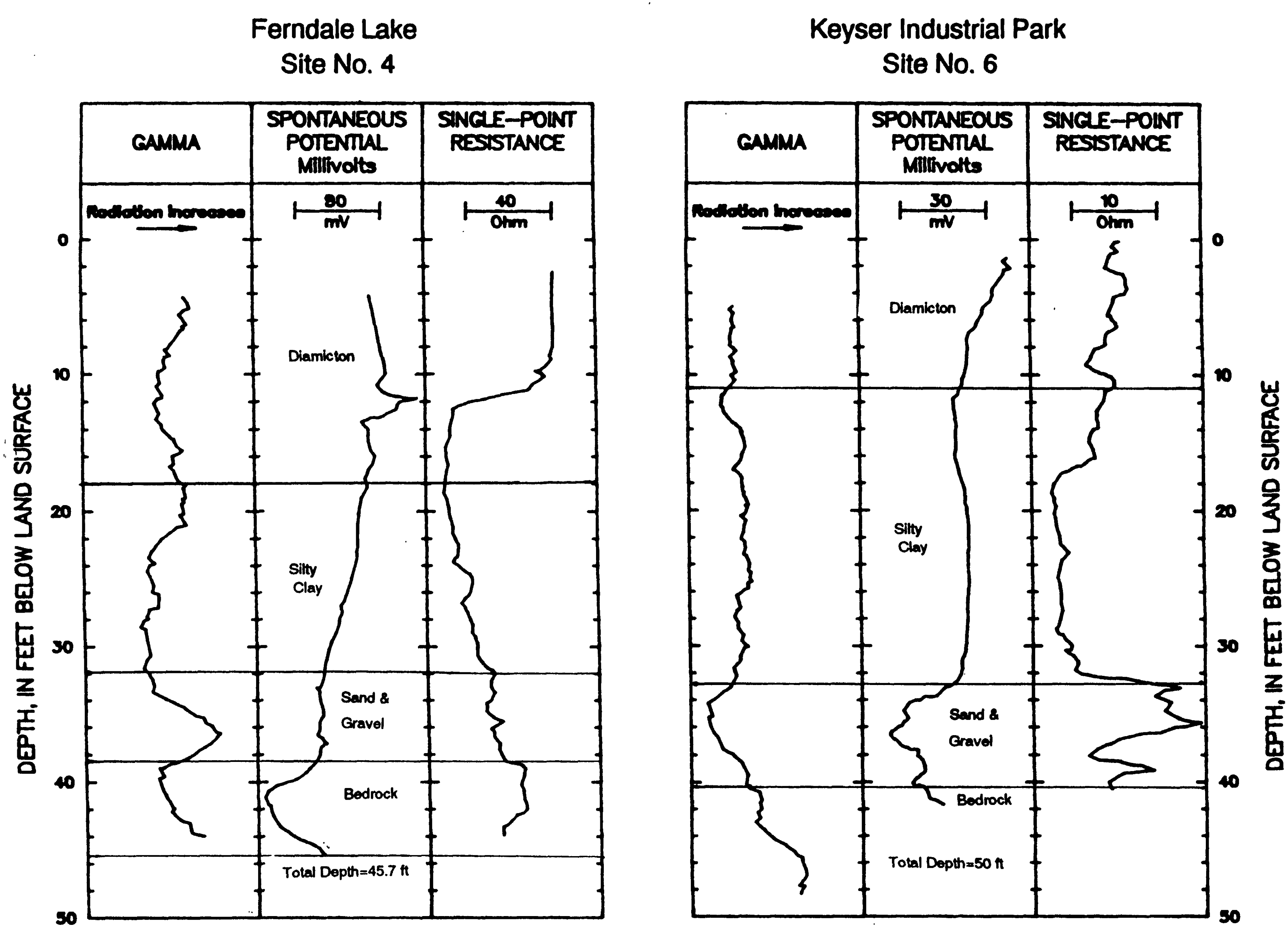

Ferndale Lake
Site No. 4
GAMMA
Radiation increases
SPONTANEOUS POTENTIAL Millivolts
80
mV
SINGLE-POINT RESISTANCE
40
Ohm
Diamicton
Silty Clay
Sand & Gravel
Bedrock
Total Depth=45.7 ft
DEPTH, IN FEET BELOW LAND SURFACE
0
10
20
30
40
50
Keyser Industrial Park
Site No. 6
GAMMA
Radiation increases
SPONTANEOUS POTENTIAL Millivolts
30
mV
SINGLE-POINT RESISTANCE
10
Ohm
Diamicton
Silty Clay
Sand & Gravel
Bedrock
Total Depth=50 ft
DEPTH, IN FEET BELOW LAND SURFACE

Figure 22

Outcrop Site No. 10
South Branch Potomac River, Romney
(Glycolated)

Alluvium
(Clay matrix of pebbly sand)

Illite>Vermiculite>Kaolinite

Alluvium
(Silty clay)

Illite>Vermiculite>Kaolinite

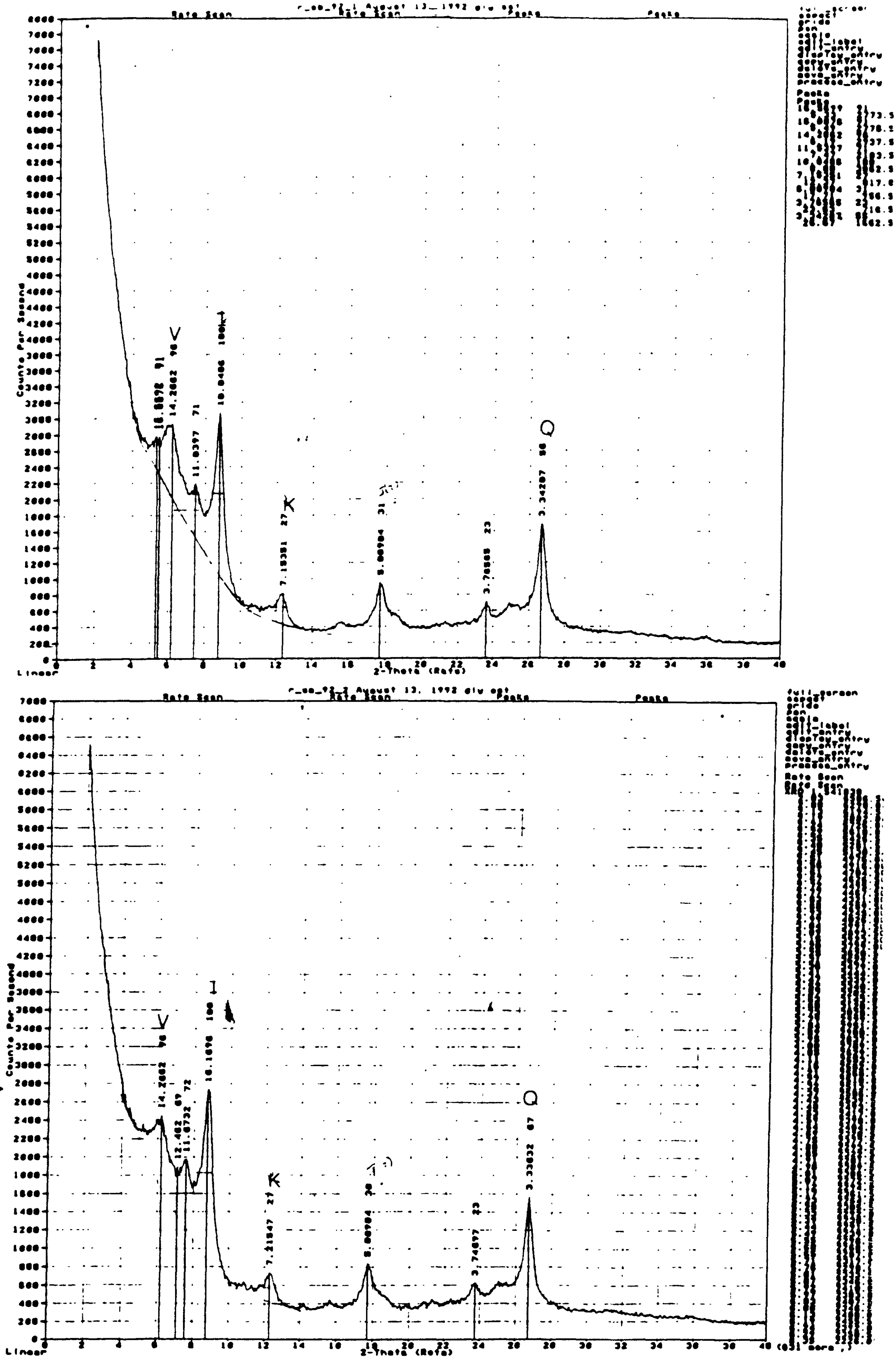
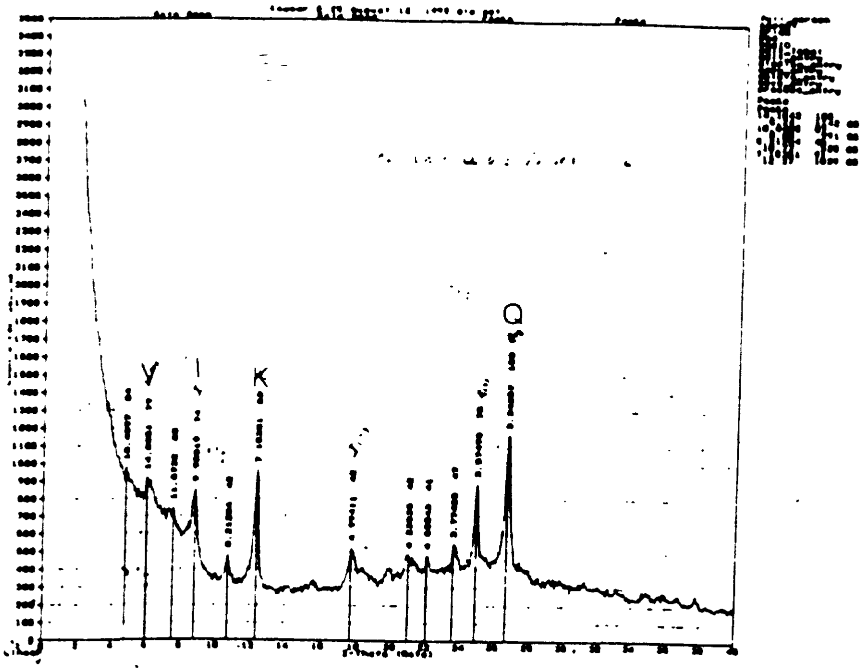


Figure 23

Core Site No. 6
Keyser Industrial Park
(Glycolated)

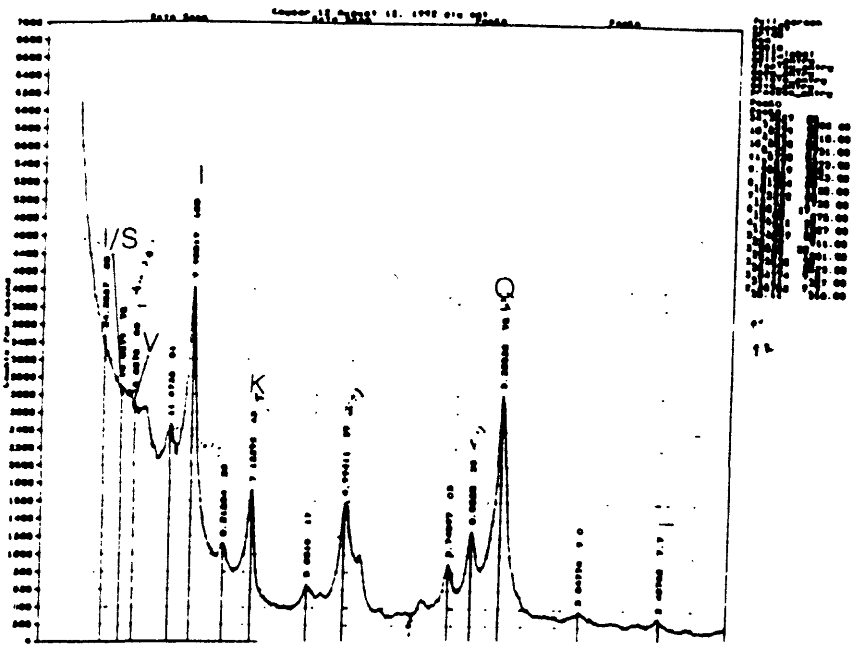
A Soil zone
Depth=0.25 ft

Kaolinite>Vermiculite>Illite



B Diamicton
Depth=12.0 ft

Illite>Illite/Smectite>Vermiculite>Kaolinite



C Silty clay
Depth=21.6 ft

Illite/Smectite>Illite>Kaolinite
47% 45% 8%

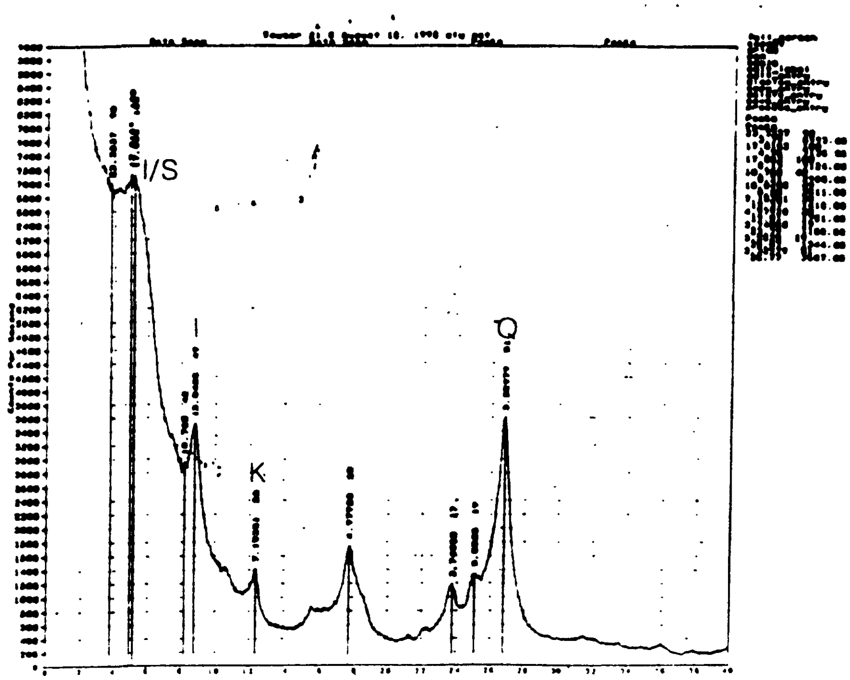
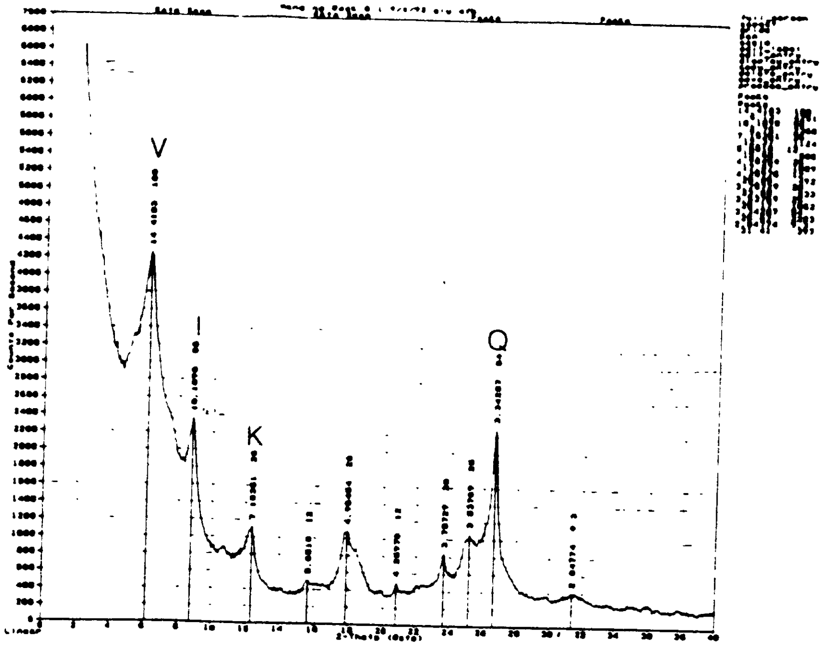


Figure 24

Core Site No. 7
Hanging Rock
(Glycolated)

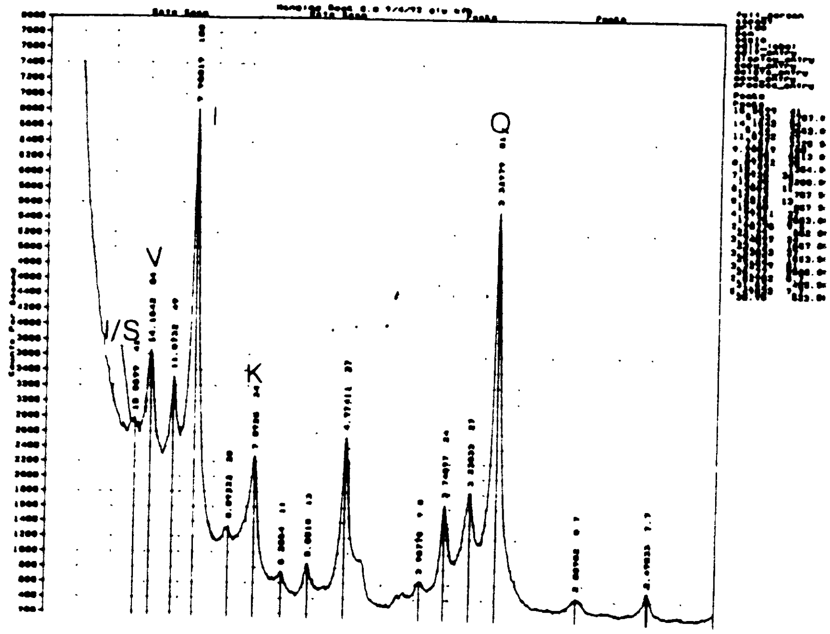
A Soil zone
Depth=0.1 ft

Vermiculite>Illite>Kaolinite



B Diamicton
Depth=6.0 ft

Illite>Vermiculite>Kaolinite>Illite/Smectite



C Silty clay
Depth=21.7 ft

Illite>Vermiculite>Illite/Smectite>Kaolinite

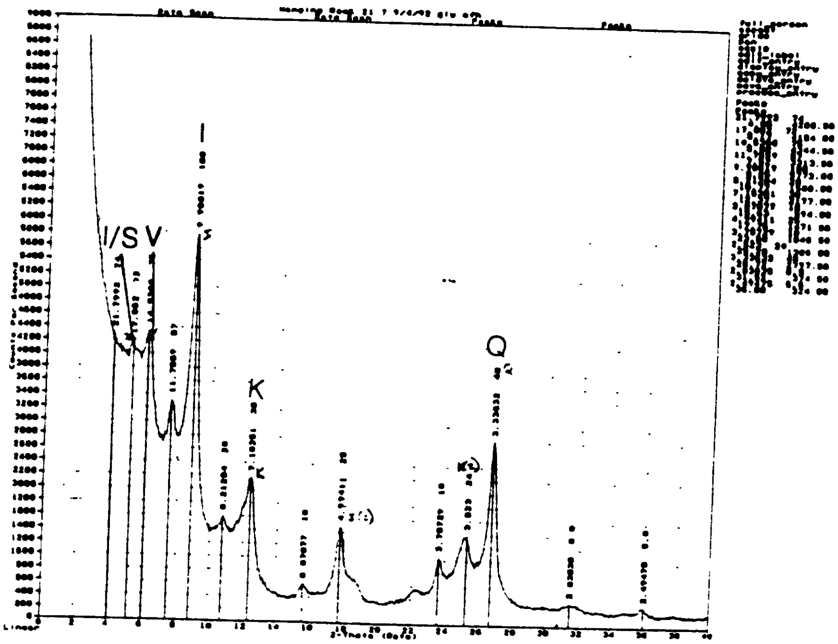


Figure 25

Outcrop Site No.3A
Route 259, Capon Springs
(Elevation=1080 ft)

(Glycolated)

Silty clay

Illite>Kaolinite>
66% 33%
Illite/Smectite
<1%

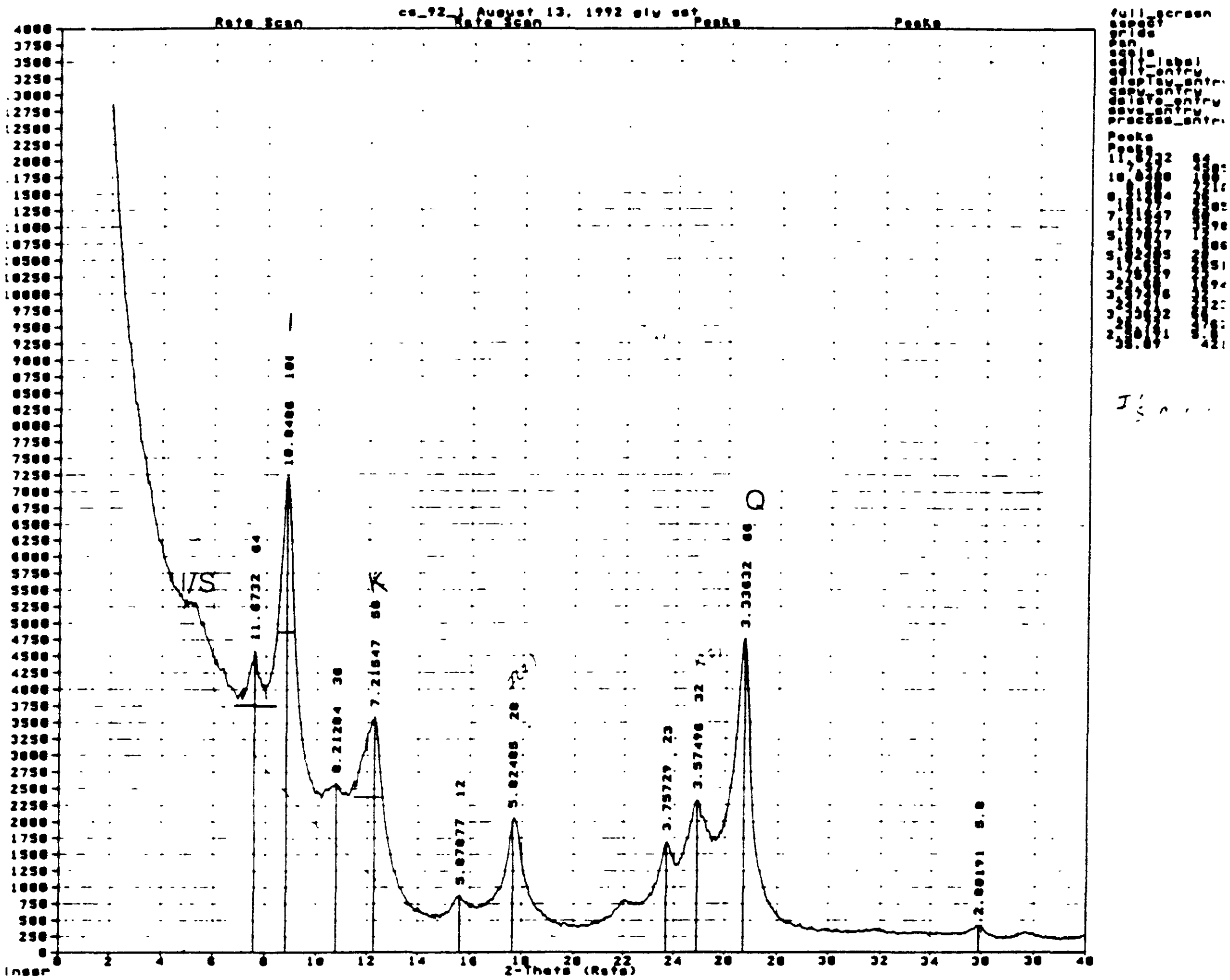


Figure 26

Outcrop Site No. 9
Cunningham Lane
(Elevation=1000 ft)

(Untreated partial curve above glycolated curve)

A Silty clay below soil zone
Depth=3.0 ft

Illite>Illite/Smectite>Kaolinite
50% 34% 16%

B Silty clay above sand and gravel
Depth=12.0 ft

Illite/Smectite>Illite>Kaolinite
75% 19% 6%

C Clay matrix of sand and gravel
Depth=16.0 ft

Illite>Kaolinite>Illite/Smectite
45% 29% 26%

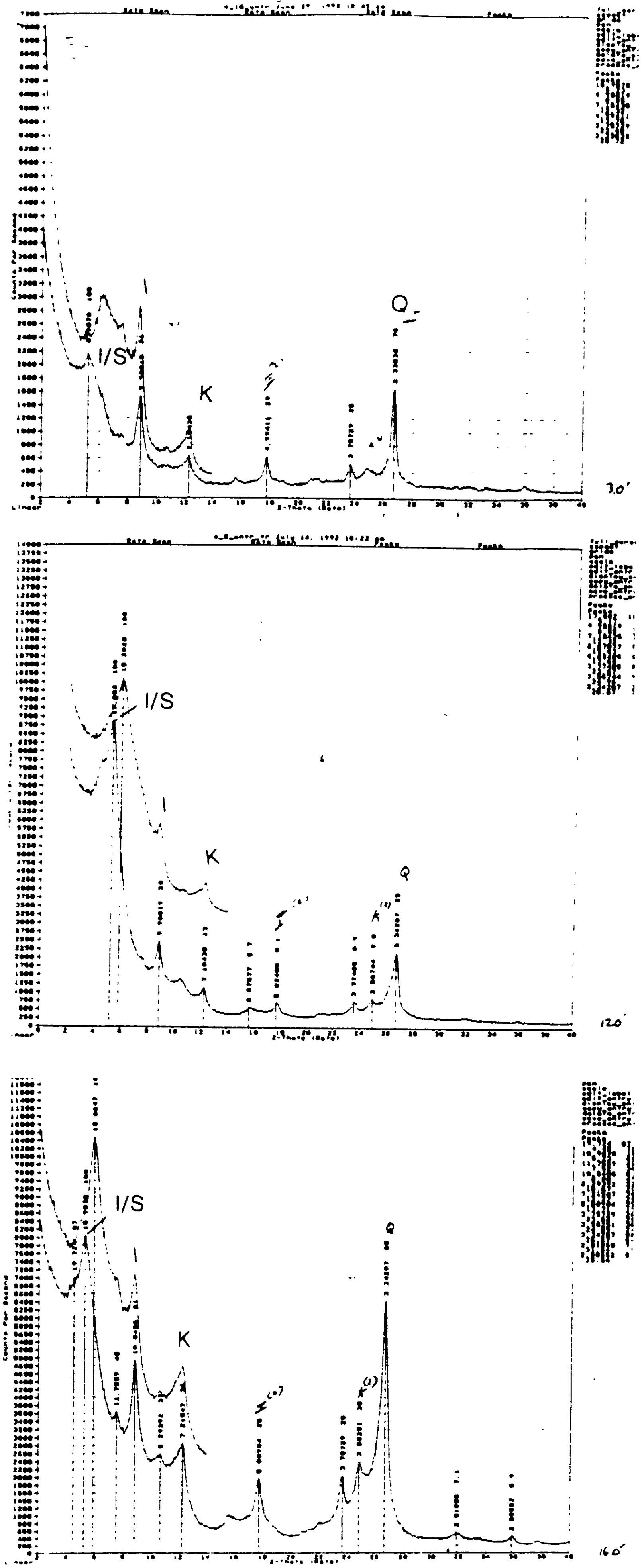


Figure 27