ALLUVIAL FANS IN VERMONT AS RECORDERS OF CHANGES IN SEDIMENTATION RATES DUE TO DEFORESTATION

by

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Abstract

Colonial deforestation in Vermont resulted in the destabilization of hillslopes and increases in erosion and sedimentation. Alluvial fans serve as a recorder of hillslope erosion and provide volumetric information about sediment loss from the associated drainage basins. Well-developed soil horizons in fan deposits provide a marker for periods when little deposition occurred on the fans.

The Huntington River Valley in west-central Vermont contains more than twenty small alluvial fans. All fans identified so far have been deposited on former Huntington River terraces and are located near the active river channel. Material deposited in the fans originated from distinct drainage basins located on one of two types of slopes; either hillsides on the surrounding mountains, or slopes created by the edges of higher Huntington River terraces. Very little deposition appears to be occurring on the fans today, although thin (<1mm) beds of fine silt have been deposited by ephemeral stream activity during severe storms and winter thaws within the past year.

Reconnaissance shovel trenching in a large number of the fans revealed relatively well-defined paleosols. A group of three fans, deposited within several hundred meters of one another, were extensively trenched using a backhoe. The fans are located on one of the lowest Huntington River terraces and contain material deposited fluvially from drainage basins incised into the next highest river terrace. The trench walls revealed that the fans consist primarily of sand and silt and poorly sorted, poorly consolidated gravel. Grain size analysis demonstrated that the highest percentage of sediment had a grain size of around 3.0 phi, was moderately to poorly sorted, and contained very little clay (< 5%). A comparison of samples taken from each of the layers of three successive trenches located on the same fan, indicated that there were no lateral or vertical trends in grain size.

Charcoal and wood were removed from the trench walls and radiocarbon dated to provide constraining ages for packages of sediment on the fans. We have total of seven radiocarbon dates from organic material found in the Aldrich fans in the northern portion of the Huntington Valley. These included a date of 2500±60 (CAMS #22994) 14C years (2746 - 2352 years BP) from the base of one of the fans at four meters below fan surface. Other dates of 840±60 (CAMS #22995) 14C years (918 - 662 years BP) at 1.87 m depth, 570±60 (CAMS #26107) 14C years (660 - 508 years BP) at 1.40 m depth, and 100±60 (CAMS #26108) 14C years (283 - 0 years BP) at 0.90 m depth were determined from wood in higher strata within the same fan. Radiocarbon dates from an adjacent fan include 310±60 (CAMS #26105) 14C years (507 - 0 years BP) at 1.00 m depth, and 230±60 (CAMS #26106) 14C years (431 - 0 years BP) at 1.05 m depth. Four meters below the surface of a third Aldrich fan we obtained wood which was dated <100 (GX-21329) 14C years (238 - 0 years BP). Having recorded the precise locations of the organic material in the trenches, I was able to use the dates to calculate rates of vertical aggradation, as well as volumes of sediment deposited during specific time intervals. The data show that rates of vertical aggradation increased between seven- and ten-fold following the arrival of settlers. The net increase in volume of deposition was from 5 cubic meters yr-1 prior to settlement to 50 cubic meters following settlement in Vermont.

The results of this study are consistent with earlier findings regarding fans in the Huntington River valley (Church and Bierman, 1994), which attribute increases in rates of sedimentation to extensive clear-cutting and agriculture. The existence of cumulative plow layers in the fans I studied confirms the historical use of the area for agriculture. The decline of the farming industry in Vermont has permitted significant forest regrowth in the last 50 to 80 years, most notably on hillsides. The revegetation and concurrent restabilization of the hillsides provides an explanation for the apparent recent decrease in sedimentation on the fans.

Acknowledgments

Among those who deserve thanks for helping me to complete this work are the students and faculty of the UVM Department of Geology and friends who always made themselves available as field assistants. Thanks to my family for their constant moral support. Thank you especially to Paul Bierman for his persistent encouragement, patience, and investment of time throughout this project.

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Chapter 1

Introduction

Alluvial fans are common, yet seldom studied landforms in the Northeast. The purpose of this study is to use alluvial fans in Vermont as recorders of rates of sedimentation, and to quantify increases in erosion and sedimentation due to deforestation. I have divided the thesis into five chapters. Chapter 1 provides the background information for the topic including setting, glacial history, history of deforestation in Vermont, and previous work. Chapter 2 outlines the methods used to acquire the data. Chapter 3 contains the data and discussion, and chapter 4 is a summary.

Setting and Physiography

My study was conducted in the Huntington River Basin (Figure 1) in west-central Vermont, located approximately 20 kilometers southeast of Burlington, Vermont. South of Interstate 89 at Jonesville, Dugway Road follows the Huntington River until it intersects with Route 17, which continues upriver toward Mount Ellen, marking the head of the Huntington basin. My fieldwork was concentrated near the junction of Dugway Road and Route 17, where the Huntington River turns abruptly from a northerly, to more easterly direction of flow.

Elevations in the region of my study range from 150 meters (400 feet) where the Huntington River intersects the Winooski River, to 1225 meters (4083 feet) at the summit of Camel's Hump, 5 km east of Huntington Center. Bedrock is exposed both at higher elevations and in lower lying areas were the river has down-cut, forming dramatic gorges, and exposing smooth rock outcroppings. Between the Huntington River and the base of steep hillsides, farm fields and dense woods occupy the surface of a series of former Huntington River terraces. Hillslopes created by the terraces vary in relief from several meters to several tens of meters. Terraces are most abundant in the northern portions of the basin, where the distance between valley sides is the widest. Terraces are composed

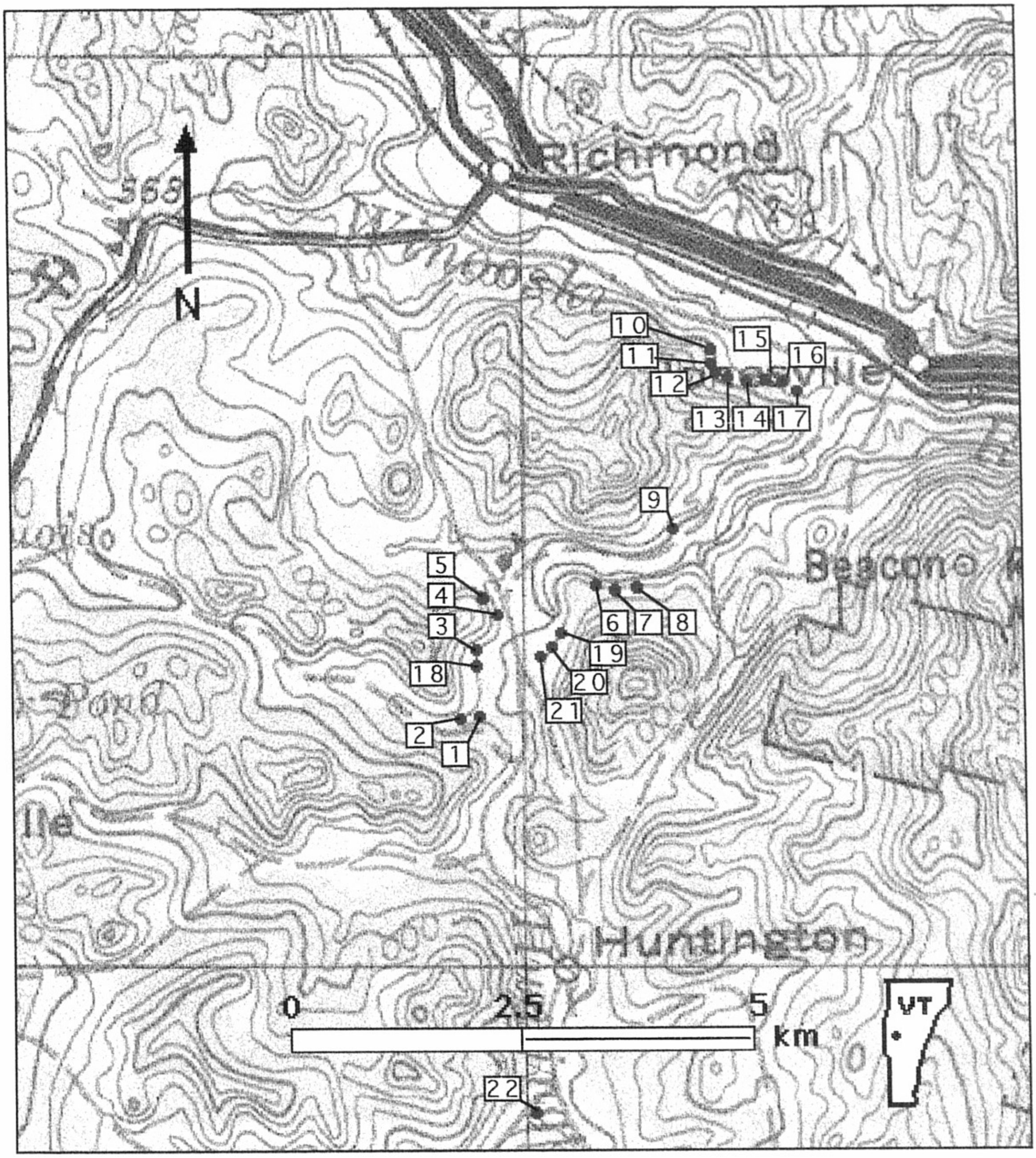

Figure 1. Topographic map showing the location of 22 alluvial fans in the Huntington River Basin of west-central Vermont. Each fan is represented on the map with a red dot. The fans are concentrated near the Huntington River and have been deposited at the base of either hillslopes or river terraces.

primarily of sand and gravel deposited by the Huntington River as it reworked the glacial till. The small alluvial fans I studied emanate from the base of terraces and hillsides along the river. The modern bed of the Huntington River is characterized by sand and well rounded cobbles, and features large glacial erratics located within, or alongside of the river.

Glacial History

The Laurentide ice sheet covered the Champlain Valley repeatedly during the Pleistocene. The ice front during the early Coveville stage of Lake Vermont (Chapman, 1937) stretched as far south as Brandon, VT, ten miles north of Rutland, and was bounded by the Adirondaks to the west and the Green Mountains to the east. Glacial polishing and striations on outcrops in the Huntington River basin indicate that narrow lobes of the glacier remained in this region during retreat. Figure 2 illustrates the extent of the ice sheet, and shows a lobe on the eastern side of the glacier stretching into the Winooski basin. Deposits of glacial till and stratified sediments were left behind overtop of bedrock as the ice sheet disappeared.

The nature of the retreat of the ice front to the north has determined the character of the surficial sediments found in the basin and surrounding areas today. The continued retreat of the glacier, and flow through different outlets produced two distinct stages of Lake Vermont. The stages, as defined by Chapman (1937), are the Coveville Stage, marking the beginning of the lake's formation, and Fort Ann Stage, which lasted until the ice front retreated north across the Canadian border. According to information about lake levels during the two stages (Chapman, 1937), the Huntington Basin was probably at the edge of Lake Vermont during the Coveville Stage, and was most likely covered by lake water during the Fort Ann Stage, the most lengthy of the two periods. Glacial melt water trapped between a topographic barrier to the south and the ice front to the North, resulted in the formation of glacial Lake Vermont. The deposition which resulted included primarily lacustrine clays deposited over bedrock and glacial till.

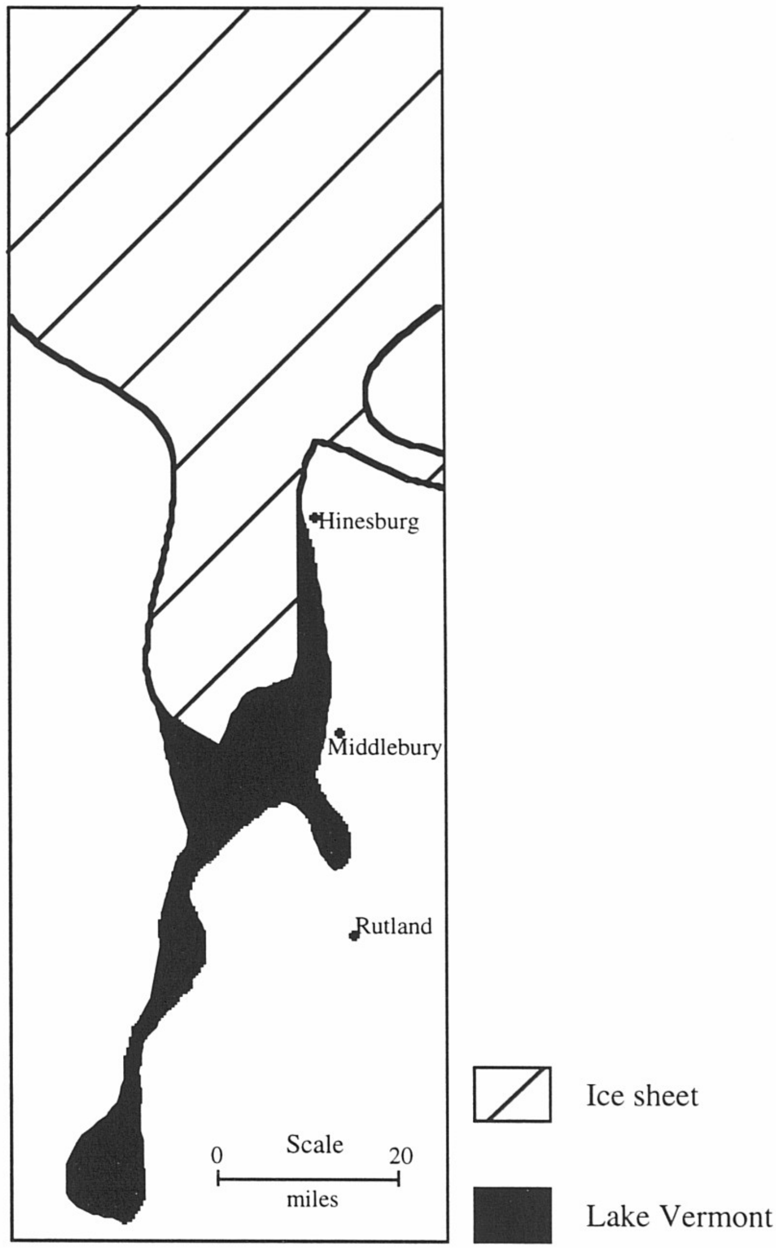

Figure 2. Figure illustrating the extent of the glacier in the Champlain Basin, adapted from Chapman (1937). The ice lobe on the eastern side of the glacier is located within the Winooski River Basin.

The glacial retreat eventually allowed marine waters to enter the Champlain Valley, attaining elevations of around 100 m (340’), well below modern-day elevations of the Huntington River. Drainage through the Huntington Basin resulted in the reworking of glacial till, and the deposition of sand and gravels. This period in the history of the Huntington River was characterized by the deposition the sediment forming the high terraces most visible in the northern reaches of the valley. The continual incision of the river has resulted in the formation of a series of terraces composed primarily of river sand and gravel.

History of Deforestation in Vermont

The first settlers arrived in Vermont in the mid-eighteen hundreds, when the state was nearly 95 percent forested (Meeks, 1986). The logging industry, as well as agriculture, soon became profitable throughout much of the Northeast, and by the nineteen hundreds dramatic changes in landscape began to take place. Intensive clear-cutting resulted in depletion of forest cover to only 20 percent over the entire state, with almost all trees below 650 m (2000’) in elevation having been removed by 1880. Verbal communication with residents of the Huntington and Richmond regions (H. Moultrop, D. Aldrich) has verified that much of the land in the area of study was cleared of forest growth even until the early 1900s.

The decline of logging and farming in Vermont since 1900 has allowed much of the once cleared land to support dense, healthy forests. Today, >80% of Vermont is covered with forested land (Meeks, 1986). Although farmland continues to occupy many Vermont lowlands such as the Huntington River Valley, the farm fields are generally limited to the low, flat-lying areas, while the forest often extends entirely down the valley sides to the break in slope with the valley bottom.

Alluvial fans in the North-Eastern United States

The morphology, sedimentology and processes of alluvial fans are largely dependent on the climate in which they are deposited. Kochel and Johnson (1984) identified arid region alluvial fans as being formed by alternating periods of abrupt deposition and non-deposition. Humid-glacial fans are characterized as deposits of material aggraded by the activity of braided streams on outwash plains. Humid-tropical fans and humid-temperate are formed either by seasonal activity of braided streams or by debris flows. The alluvial fans studied in Vermont are characterized as humid-temperate fans which remain undefined.

Humid region alluvial fans in the Appalachian Mountains have been separated into two categories (Kochel,1990); debris-flow-dominated fans and fluvially dominated fans. The alluvial fans we have observed in Vermont appear to be fluvially dominated, but differ in that they are aggrading, while Kochel's fans are being dissected. He proposes a variety of factors controlling the nature of deposition on the fans, including location in drainage basin, the regularity of depositional events and vegetative recovery rates on hillslopes. Kochel attributes the occurrence of episodes of deposition to periods of intense rainfall and hillslope instability. He mentions the influence of deforestation on increases in erosion and sedimentation.

Costa (1975) constructed a sediment budget for surficial sediments in the Piedmont province of Maryland in order to quantify amounts of erosion due to agricultural land use. He determined percentages of agricultural sediment stored in flood plains and in colluvial and alluvial deposits, as well as the amount of sediment evacuated by streams. Costa used radiocarbon dating to establish ages of deposits and to determine rates of sedimentation. Costa concluded that rates of sedimentation were significantly increased due to agricultural land use and that depositional rates decreased with the decline of agriculture and the application of soil conservation practices.

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Church and Bierman (1995) used radiocarbon dating methods to determine rates of aggradation in an alluvial fan found in the Huntington River Valley of west-central Vermont. The sediment in the fan, overlying Huntington River gravels, has been deposited episodically over the past 8,000 14C years. They determined that rates of aggradation were highest during the last 300 years of settlement and deforestation.

Chapter 2

Methods

Mapping

I began this project by mapping alluvial fans in the Huntington River Valley. I did this by driving and hiking along the breaks in slope on either side of the river. Fans were identified on the basis of shape, slope, location, and presence of definitive drainage basins or ephemeral stream beds on the hillside directly above. The fans appear as lobes of sediment in the shape of a portion of a right circular cone, with an apex located at the mouth of ephemeral streams. Often the fan surfaces are covered with grass, and are always clear of large woody vegetation. Once a fan was identified, it was photographed, described in a field notebook, and its location on a topographic map was recorded.

Using Pentax total station surveying equipment, many of the fans, trenches and adjoining drainage basins were surveyed. The data collected by each survey were downloaded into the Microstation and Siteworks CAD/CAM programs which plotted and automatically contoured field points. The programs also provided information which facilitated the calculation of areas and volumes of the fans.

Trenching

Using a shovel, many of the fans identified in the initial mapping were trenched. Generally, a single trench was made on the surface of each of the selected fans, with the studied wall facing away from the apex. Trenches varied from one to two meters in depth and two to three meters in width. Although this trench work served primarily as reconnaissance work, detailed logs were made of the trench walls and both soil and organic samples were taken.

Larger trenches were made using a backhoe at the Aldrich farm (Figure 1; fan #6, fan #7 and fan #8) and the Audubon Society (Figure 1; fan #1 and #2). A single 8 m long trench was dug in one of the two Audubon fans and was oriented such that it stretched from near the apex to the distal portion of the fan, with a maximum depth of 2 m. A series of six excavations were made at the Aldrich farm, each comparable in size and oriented with the trench walls facing away from the apex. Generalized and detailed stratigraphic logs were made in each of the trenches. In order to accomplish this task safely, trench depths could be no deeper than two meters while working between the walls. The backhoe was able to dig to a depth of four meters, and generalized logs were completed by inspecting sediment brought up in the backhoe bucket.

Radiocarbon dating

Samples of organic material were retrieved from the trench walls for radiocarbon dating, the results of which were used to constrain the age of certain packages of sediment and to calculate of rates of sedimentation over time. The samples collected were primarily wood and charcoal, found by carefully examining the trench walls. Organic-rich soil horizons contained much datable material, and were easily identifiable features in the trench stratigraphy. Before removal of samples from the trench wall, the location of each sample was plotted precisely on the trench logs. Samples were then placed individually in plastic viles and given identification codes, which were noted on the trench logs. Upon returning from the field, the samples were placed in a refrigerator, where they were stored before analysis.

A total of seven wood specimens were selected for radiocarbon dating at Geochron Laboratories and the Center of Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory, with the help of John Southon. Before being submitted for analysis, each sample was carefully probed under a microscope to ensure that it was free of rootlets. The process involved washing the wood in distilled water and subjecting it to a brief ultrasound treatment which softened the samples so that they were easily broken apart. The clean wood was then dried overnight in an oven before being sent for analysis.

Radiocarbon dates were calibrated using Radiocarbon Calibration Program REV 3.0.3c (Stuiver M. and Reimer, 1993). The calibration is a correction for the changing initial 14C, and produces a more realistic age of the specimen being dated. When an organism dies, its remains contain a specific activity of 14C which reflects the amount of 14C that was in the atmosphere at the time of death. Over time, the proportion of 14C declines due to radioactive decay and conversion into 14N. Radiocarbon dating assumes the initial amount of 14C. At different times in the past, the atmosphere contained differing amounts of 14C.

<u>Grain Size Analysis</u>

Samples for grain size analysis were collected from specific locations in the trench walls. The samples were placed in aluminum pie plates and oven dried. About 100 grams was aliquoted from each sample and placed in a sieve stack with a range of -2 to 3 phi, with 0.5 phi increments between each sieve. The stack was then placed in a sieve shaker for a period of fifteen minutes, after which the sieves were separated, the amount of sediment in each sieve was weighed, and the weight recorded. Sediment smaller than phi size of 3 was set aside for settling tube analysis. The analysis involved using 1000 milliliter graduated cylinders which were filled with distilled water and 5 grams of dispersant (sodium hexametaphosphate). For each analysis, fifteen grams of sediment were weighed out from the pan fraction remaining after the dry sieving, poured into the cylinder, and stirred. Twenty milliliters of the water, sediment and dispersant mixture were drawn from the tube at specific time intervals, each interval representing a different phi size. The liquid and sediment was placed in a beaker, dried, and the resulting sediment was weighed.

Results from the dry and wet sieving were combined and statistically analyzed using techniques described by Bob Folk (1980). Mean grain size, skewness, kurtosis and sorting were calculated for each of the samples. Percentages of clay, sand and silt content of the samples was determined and plotted on a ternary diagram.

Tree Coring

In order to supplement the information we gathered about deforestation in Vermont, I cored trees to determine the age of the forest that now stabilizes the hillslopes. Using coring equipment provided by Terry Turner of the University of Vermont School of Natural Resources, I cored ten trees located on the slopes above the Aldrich fans including 5 quaking aspens, 2 hemlocks, 1 birch, 1 white pine and 1 oak tree. Upon returning from the field, cores were brushed with an iodine solution to make tree rings more visible for counting. Student Jeff Urbanus of the University of Vermont School of Natural Resources assisted me in identifying tree species and approximate ages of the trees, and to provide much of the interpretation of tree ages discussed in this thesis.

Chapter 3

Data and Discussion

Alluvial Fans in the Huntington Valley

The location of the 22 alluvial fans which I have identified in the Huntington River region are shown in Figure 1 and logs are given in both this chapter and Appendix I. The map includes only the northern third of the Huntington River Basin which extends southward from the Winooski River to Mount Ellen. Although I searched for fans throughout the entire basin, I could not positively identify any fans south of Huntington Center. All of the fans I was able to identify were along an eight kilometer stretch of the Huntington River and where it flows into the Winooski River. The upstream portions of the basin are not well suited for the formation of alluvial fans as the hillsides themselves form the banks of the river.

The fans range in size from about 600 to 2500 m2 and are all deposited on Huntington River terraces. Drainage basins developed on terraces seem to be more heavily incised into the slopes above fans than drainage basins found on the valley sides. Differences in depth of the drainage basins is related to the type of sediment found on the hillslopes. Finer sediments are generally found on the terraces while the hillsides tend to be more rocky, with occasional bedrock exposures. Both types of drainage basins contain ephemeral steam beds with large cobbles, which may be part of glacial till deposits.

In the late summer and early fall of 1995, I hand trenched and augured the 22 fans I had mapped in the Huntington Basin. Attempts to augur a large proportion of the fans were unsuccessful because of the rocky nature of the upper strata of the fans. Those that were successfully augured, were eventually hand trenched to provide more accurate logs of the stratigraphy. I also attempted to hand trench some of the more cobbly fans with little success. Figures 23, 24, 25, 27 and 28 illustrate the general stratigraphic logs for a group of the fans also labeled on Figure 1. Tables 11 through 15 provide the descriptive information for the strata in the trench logs, but do not contain interpretations due to the lack of data.

The primary goal when hand trenching the fans for reconnaissance work was to locate paleosol A horizons which may represent the period of surface stability before the arrival of settlers. Previous and concurrent work has indicated that the fans in this region often contain a buried soil horizon 0.75 to 4 m below the fan surface which correspond to the period of relative fan surface stability. In several of the trenches (fan #9, #18 and #20) I located what I interpreted to be paloesol A horizons, none of which appear as bold and defined as those studied in the Aldrich trenches. In the more cobbly fans, the depth of the trenches were often limited by the presence of large cobbles and boulders. Wood and charcoal fragments were found in the trench walls, but were not sent for radiocarbon dating.

<u>Aldrich Farm Physiography</u>

The area in which the Aldrich fans have been deposited contains morphological features which have been influenced primarily by Huntington River activity. The Aldrich field is characterized by uneven terrain varying in relief by about one meter. The Huntington River marks the northern boundary of the Aldrich farm, where it has incised nearly 2 m below the surface elevation of the field. Swales between higher deposits of sediment are often filled with puddles following rainstorms and snow melting events. The Aldrich field dips southward near the break in slope of the higher Huntington River terrace that supplies sediment to the fans, and may indicate a former meander of the Huntington River. The fans radiate almost 80 meters into the field, and coalesce with one another in places.

A steep slope formed by the higher Huntington River terrace leads upward from the apecies of the fans, gaining about 40 vertical meters of relief until reaching the terrace top. Dramatic drainage basins on the higher terrace contain ephemeral streams leading to the fans below and are filled with ice and flowing water in the winter and spring months. Groups of very small stream beds on the terrace top converge at the head of the drainage basins. During winter, thin layers of fine, tan silt were suspended on top of the ice which can also be seen coating the surfaces of the fans. Clasts ranging in size from very large cobbles to small pebbles form the stream beds the apecies of the fans. Deposits of sand and silt have been exposed along the steep sides of the drainage basins, and in some places have plunged into the stream beds as small land slides (5 - 10 m3) containing wet and cohesive sediment. The scarps of the slides appear as hollows below a thick (≈ 25 centimeters) matting of vegetation.

Aldrich Farm Trenches

A group of six Aldrich trenches with logs and radiocarbon dates have enabled me to interpret the development of the fans found in the Aldrich field. The following series of five sections describe each Aldrich trench separately and provides interpretations of the individual stratum within the fans. Figure 4 is a schematic diagram of the Aldrich field showing the location of three fans relative to one another and to the Huntington River. The fans have been designated as #6, #7 and #8, and have been labeled as such on the diagrams (Figures 1 and 4). Figure 3 is a topographical map of the Aldrich field showing the three fans and the location of the series of trenches placed in the mid to distal portions of the fan surfaces. General stratigraphic logs for each trench are illustrated in Figures 6 through 11. Tables 1 through 6 provide detailed descriptions and interpretations for the strata from each trench.

Fans #6 and #7 have been formed very close to one another, and coalesce in the upper middle and distal portions. It is difficult to differentiate between the two fans when standing near the toes, however, each fan has a distinct apex and drainage basin. All three of the fans are small, with surface areas of 1900 m2 (fan #8) and 4050 m2 (fans #6 and #7 combined). The fans contain total volumes of 5500 m3 (fan #8) and 18,000 m3 (fans #6 and #7 combined).

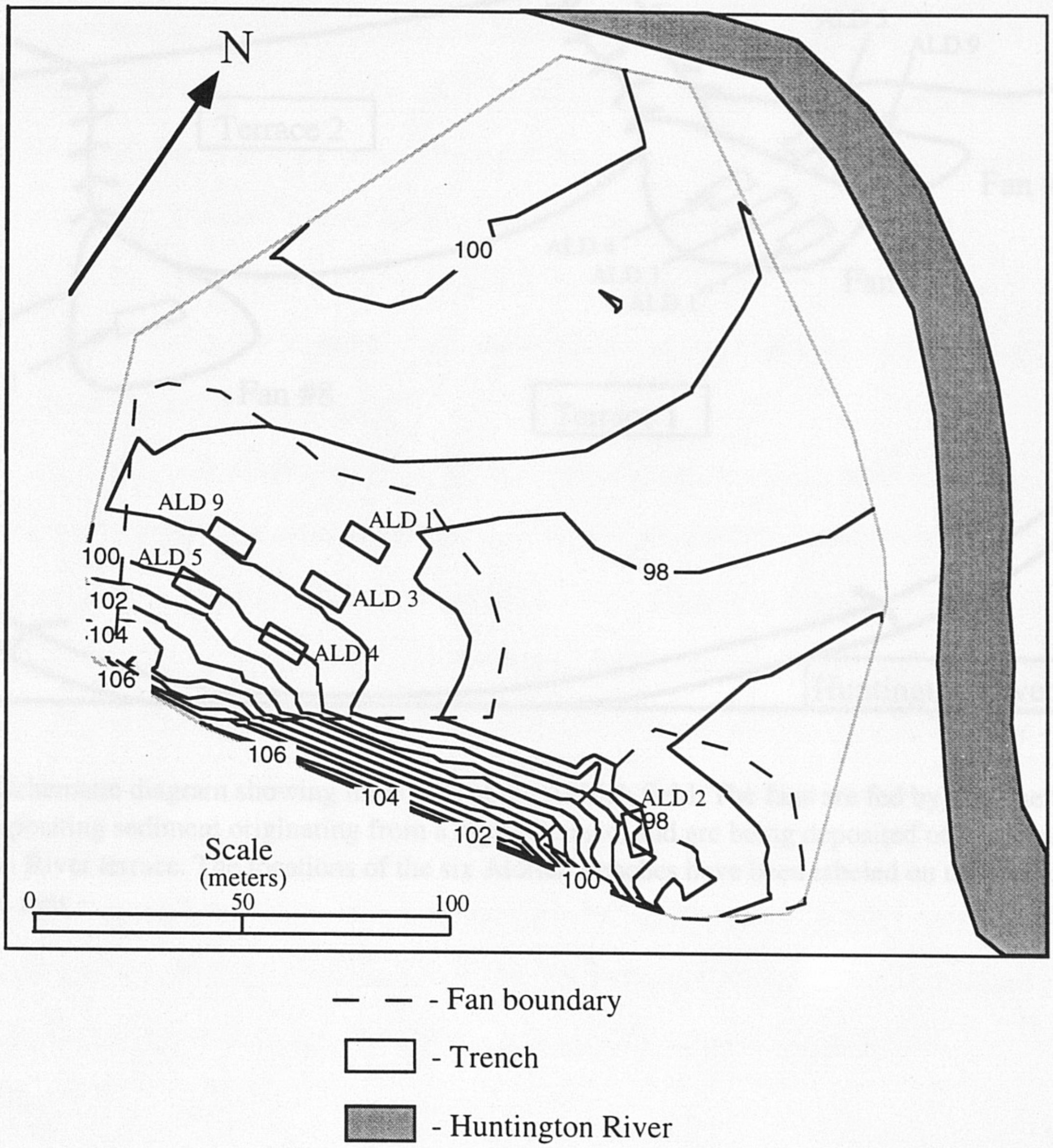

Figure 3. Contour map of the Aldrich field showing the location of 6 trenches dug by the backhoe. Elevations are relative to an arbitrary benchmark.

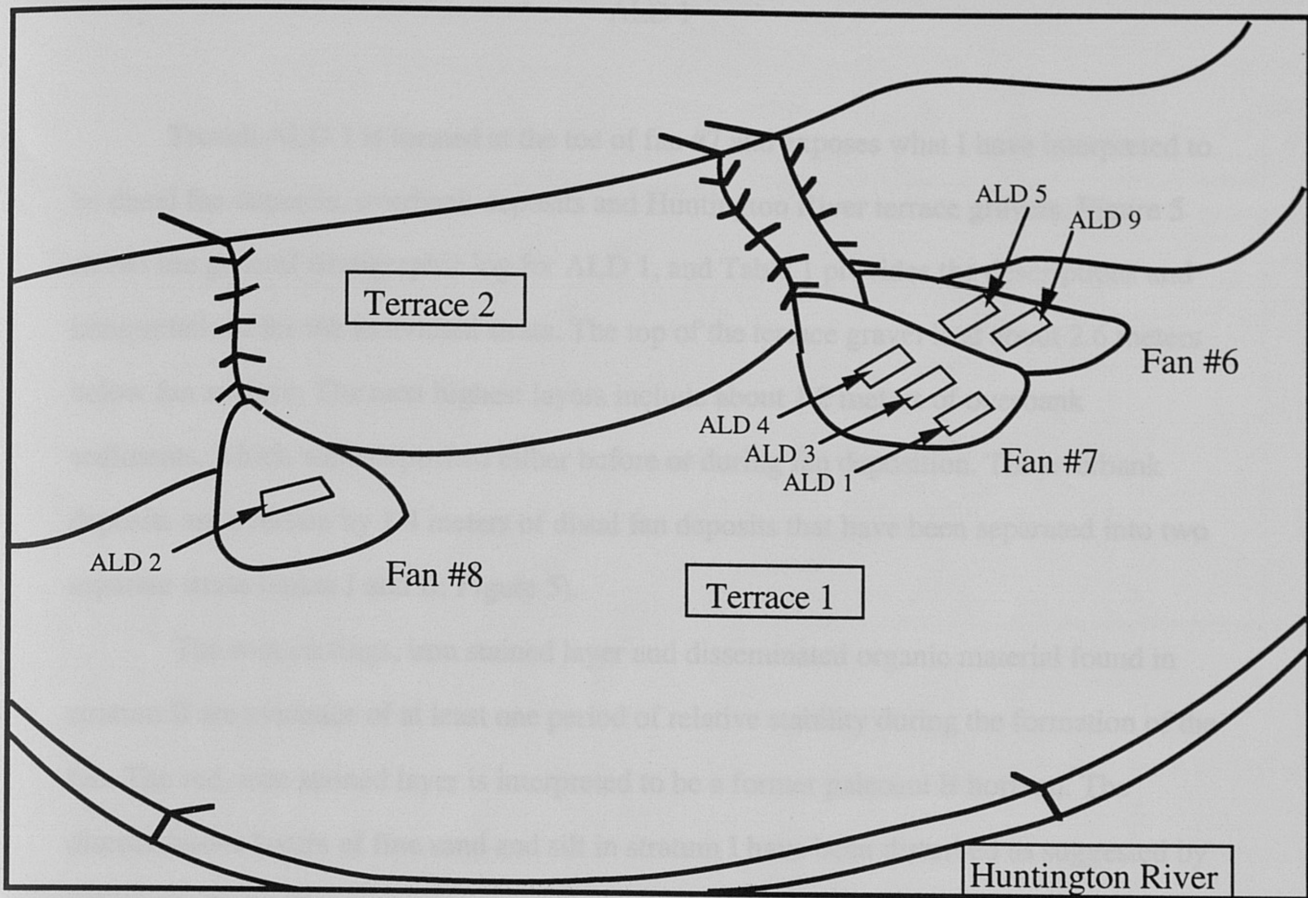

Figure 4. Schematic diagram showing three fans at the Aldrich field. The fans are fed by ephemeral streams depositing sediment originating from a higher terrace, and are being deposited on top of a lower Huntington River terrace. The locations of the six Aldrich trenches have been labeled on the surfaces of each of the fans.

ALD 1

Trench ALD 1 is located at the toe of fan #7 and exposes what I have interpreted to be distal fan deposits, overbank deposits and Huntington River terrace gravels. Figure 5 shows the general stratigraphic log for ALD 1, and Table 1 provides the descriptions and interpretations for the individual strata. The top of the terrace gravel is at about 2.6 meters below fan surface. The next highest layers include about 1.2 meters of overbank sediments, which were deposited either before or during fan deposition. The overbank deposits are overlain by 1.4 meters of distal fan deposits that have been separated into two separate strata (strata I and II; Figure 5).

The root castings, iron stained layer and disseminated organic material found in stratum II are evidence of at least one period of relative stability during the formation of the fan. The red, iron stained layer is interpreted to be a former paleosol B horizon. The discontinuous layers of fine sand and silt in stratum I have been disturbed as suggested by silt rip-up clasts. The disturbance and the abrupt basal contact of this layer imply that it is a cumulative plow zone, and that the distinct A horizon seen in the higher trenches was shallow enough to be incorporated into the plowed material. The sharp contact between strata I and II may mark the base of what was originally the paleosol A horizon now part of the plow zone. The A horizon has been interpreted to be the period of stability immediately preceding settlement in Vermont. Stratum I is interpreted to be post-settlement fan deposition.

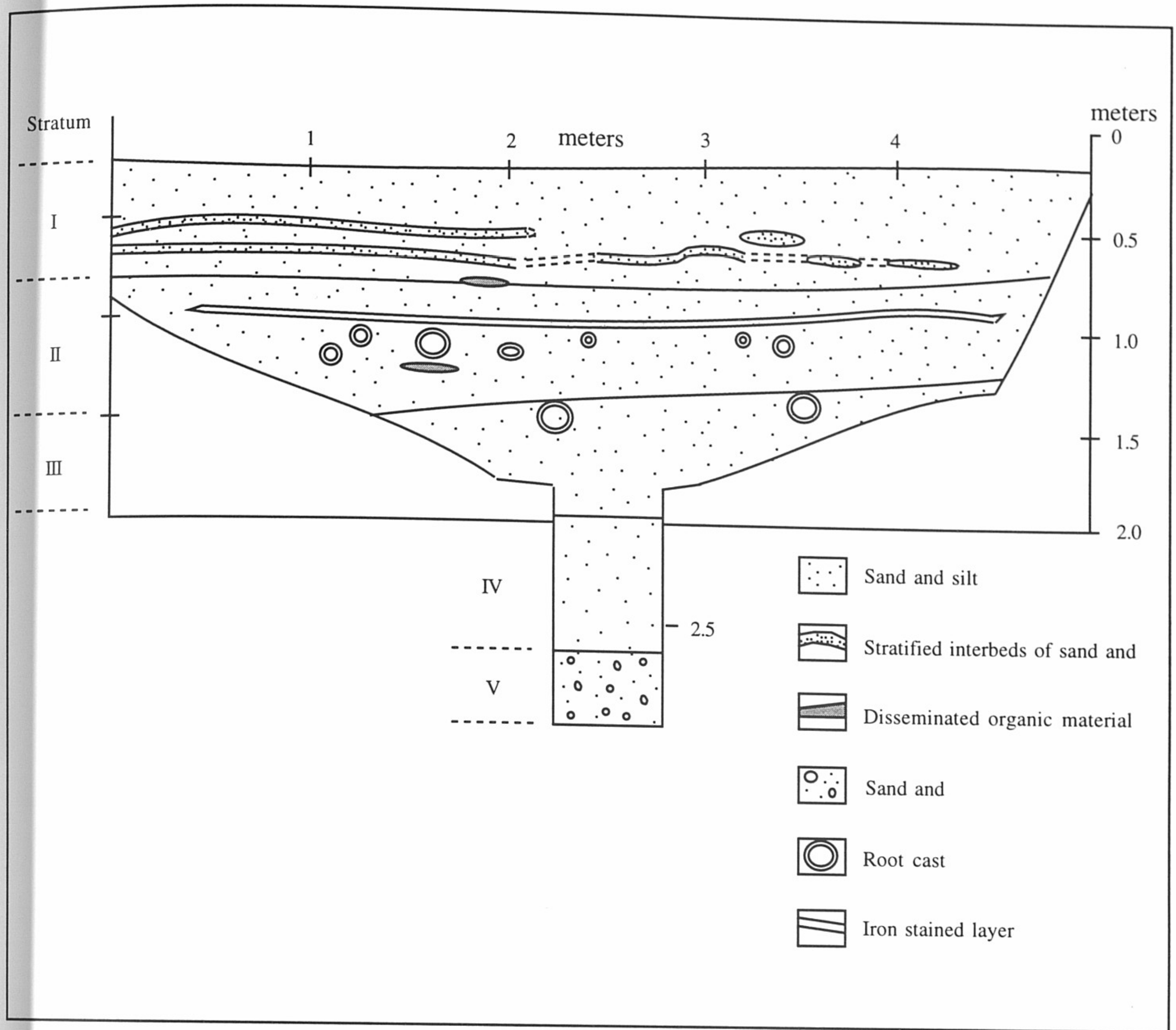

Figure 5. General stratigraphic log for trench ALD 1 showing strata as identified in the field. The top of the trench is at an elevation of 98.09 meters relative to an arbitrary benchmark. Table 1 provides descriptions and interpretations for each stratum.

TABLE 1. ALD 1- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Chocolate brown, poorly sorted, massive fine sand and silt with occasional pebbles. Discontinuous stratified interbeds of grey silt and tan sand in bottom 15 cm. Worm burrows at contact with stratum II.	Post-settlement fan deposition, contains plow zone.
II	Red brown, poorly sorted, medium to fine sand and silt with abundant darker red and brown bands. Worm burrows penetrate upper boundary of stratum. Contains thin (3 cm) tan and very thin (1 cm) red stained beds. Abundant horizontal root casts.	Distal fan or overbank deposits. Contains former cumulative paleosol B horizon, pre-settlement
III	Tan, moderately sorted fine sand and silt. Few patches of red staining. Worm burrowed root casts.	Overbank deposits, pre-settlement.
IV	Tan, poorly sorted medium and coarse sand	Overbank deposits, pre-settlement.
V	Reddish brown, poorly sorted sand and gravel. Well rounded clasts, up to 10 cm.	Pre-settlement Huntington River terrace sand and gravels, pre-settlement

Figure 6. Photograph of trench ALD 1. The plow zone appears as the chocolate brown layer just below fan surface.

ALD 3

ALD 3 is the middle trench in a series of three trenches dug into fan #7 and is located in the mid to distal portion of the fan (Figure 4). Figure 7 illustrates the stratigraphic log for ALD 3, and corresponds to Table 2 containing descriptions and interpretations. The backhoe dug to a depth of 4 meters, exposing almost a meter of Huntington River terrace sand and gravels. On top of the gravels is about 0.75 meters of fine sand interpreted to be part of the same overbank deposits observed in ALD 1. Above the overbank sediments is 2.2 meters of fan deposition, which have been subdivided into 6 strata.

The lowest stratum of pre-settlement fan deposition contains evidence of several periods of surface stability, with root castings, worm burrows, faint paleosol A horizons and a cumulative B horizon. The paleosol A horizon in this trench (stratum V) appears as a pronounced, dark brown layer separating post-settlement and pre-settlement fan deposition. Wood pieces retrieved from this layer were radiocarbon dated, and provided dates of 310 ± 60 and 230 ± 60 14C years. Table 7 contains the results of the calibration of the two dates which suggest that the paleosol A horizon is historic, or post-settlement. The ages suggest that the sediment above 1.2 meters in trench ALD 3 can be interpreted as historic deposition, or deposition following settlement. With this information, it becomes evident that approximately one half of the vertical aggradation of sediment at this point in the fan was deposited after the arrival of settlers. About 0.5 meters of preserved fan deposits overly the paleosol A horizon (stratum IV). Stratum III represent the last period of plowing on the Aldrich field which we know to be before 1960. Episodic fan deposition probably representing storm or melting events since forest regrowth returned to the hillside comprise strata I and II.

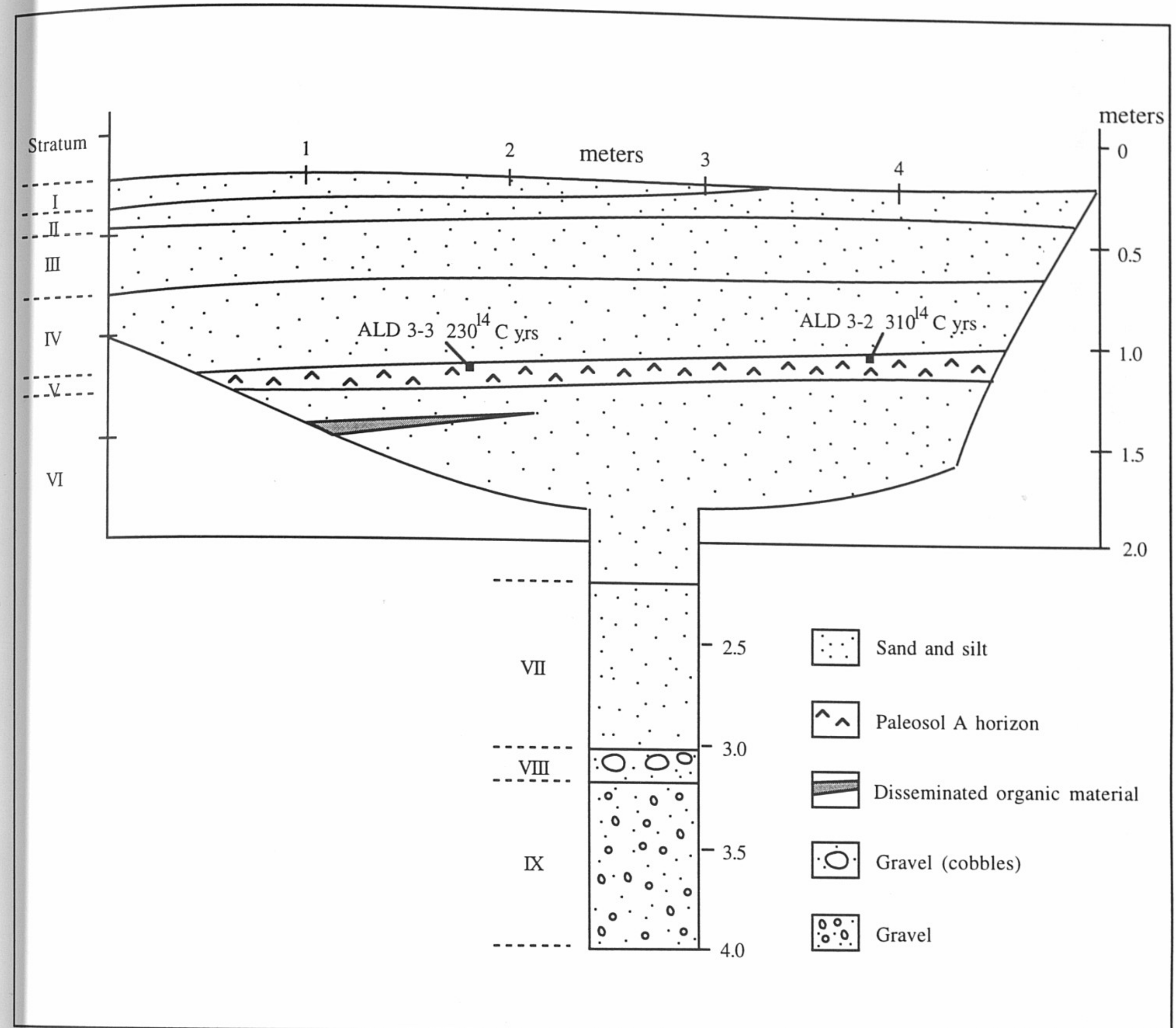

Figure 7. Stratigraphic log of trench ALD 3 showing strata as interpreted in the field. The top of the trench is at an elevation of 98.76 meters relative to an arbitrary benchmark. Table 2 provides descriptions and interpretations of each stratum.

TABLE 2. ALD 3- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Moderately sorted, tan, fine sand. Noncohesive. Sharp basal contact.	Post-settlement fan deposition, post plowing (>1960)
II	Alternating beds of fine, tan sand and grey sand and silt. Abundant worm burrows. Sharp basal contact.	Post-settlement fan deposition, post plowing (>1960)
III	Massive, brown fine sand and silt with pebbles (to 4 cm) and isolated pockets of clean, fine sand. Occasional pieces of charcoal. Sharp basal contact.	Post-settlement fan deposition, plow zone
IV	Olive green/grey very fine sand. Contorted pockets of tan, fine to medium sand. Abundant charcoal and worm burrows. More continuous beds lower in unit. Sharp basal contact.	Post-settlement fan deposition
V	Dark brown organic-rich stratum. Poorly sorted fine sand. Abundant worm casts and charcoal.	Paleosol, A-horizon, pre-settlement.
VI	Red-brown, poorly sorted, coarse silt. Abundant root casts. Few worm burrows. Faint darker bands which may be buried and decomposed A-horizons.	Fan deposition, cumulative B-horizon, pre-settlement.
VII	Tan, poorly sorted, fine sand.	Overbank deposits, pre-settlement.
VIII	Reddish brown sand and gravel. Cobbles to 15 cm.	Huntington River terrace deposits, pre-settlement.
IX	Reddish brown sand and gravel. Pebbles to 4 cm.	Huntington River terrace deposits, pre-settlement

Figure 8. Photograph of trench ALD 3. The paleosol A horizon appears as a dark brown band of sediment stretching across the trench.

Figure 9. Close-up photograph of the paleosol A horizon found in trench ALD 3.

ALD 4

ALD 4 one of the three trenches dug into fan #7 and is located about midway up the fan surface, about 30 meters from the apex. Figure 10 shows the stratigraphic log for ALD 4, and corresponds to Table 3 containing descriptions and interpretations of individual strata. The trench stratigraphy revealed by the backhoe reaches to a depth of nearly four meters, where it uncovered a relatively thin (≈0.3 meters) layer of fine sand representing overbank deposits. Seven strata interpreted as fan deposition are shown in the log, and achieve a total depth of 3.5 meters at this position below the fan surface.

More than one meter of fan deposition occurred overtop of the overbank deposits until a period of surface stability was reached (stratum V). Stratum V represents a pre-settlement paleosol A horizon which appears as a distinct dark band in the trench stratigraphy. The next period of fan aggradation containing decomposed A horizons and abundant worm burrows indicates that several episodes of relative surface stability occurred. The sharp paleosol A horizon seen in trench ALD 3 also appears in trench ALD 4 as stratum III. The layer marks the beginning of post-settlement fan deposition which accounts for the next 1.3 meters of deposition below the surface of the fan. The stratified fine sand, medium sand and silt in stratum II show individual periods of deposition, exemplifying the episodic nature of alluvial fan deposition. Stratum I can be subdivided into several sections. The lowest, massive section represents a cumulative plow zone corresponding to those seen in trenches ALD 1 and ALD 3. The uppermost section, containing stratified sand and gravel has been extensively waterwashed and is the least well consolidated of all strata in this trench.

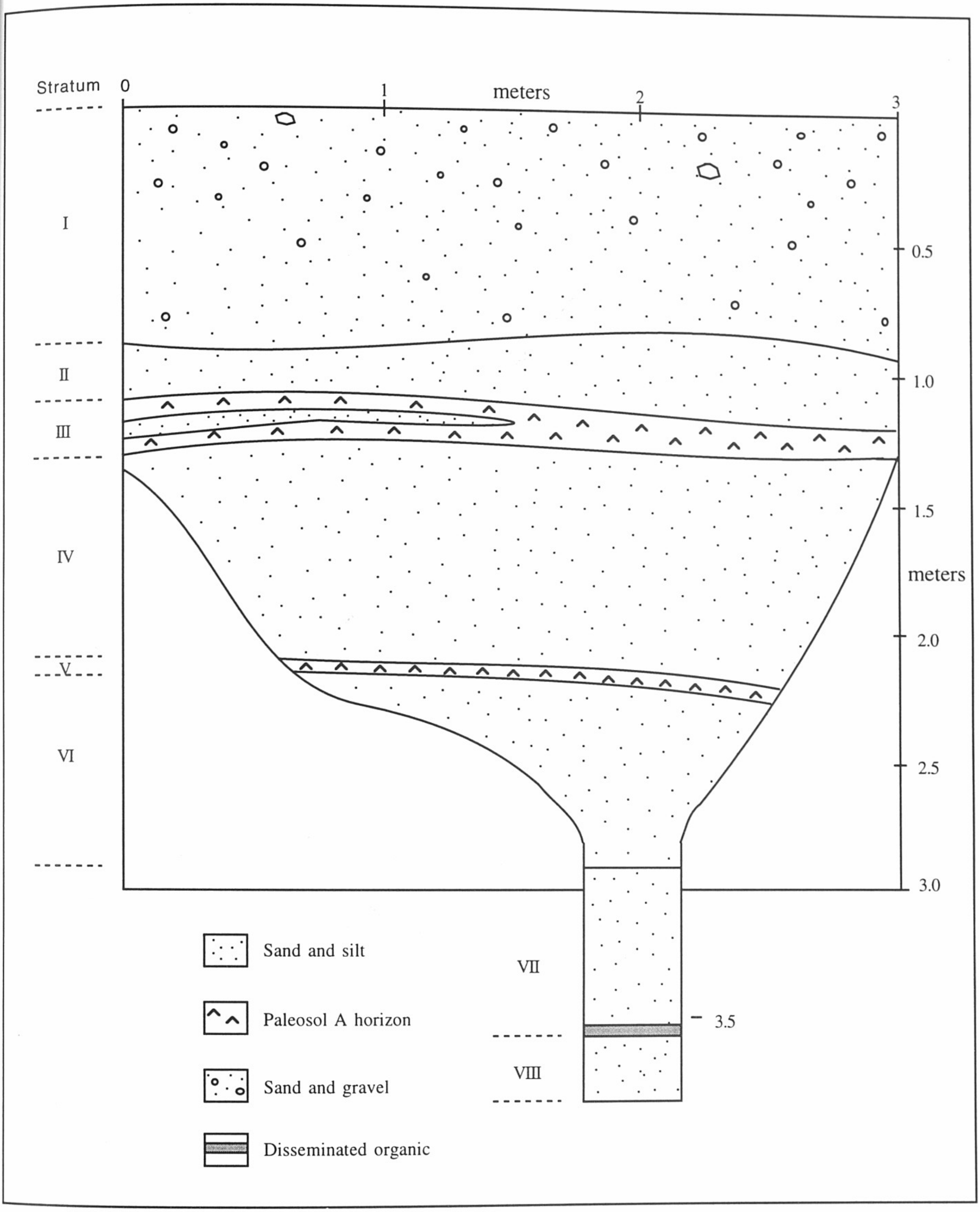

Figure 10. General stratigraphic log of trench ALD 4 showing strata as identified in the field. The top of the trench is at an elevation of 99.99 meters relative to an arbitrary benchmark. Table 3 provides descriptions and interpretations of each stratum.

TABLE 3. ALD 4- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Composed primarily of stratified sand and gravel in upper portion. Lower portion is massive silt and fine sand with isolated pebbles, gravel and cobble clasts. Occasional wood and charcoal pieces.	Post-settlement fan deposition, heavily waterwashed. Lower portion represents cumulative plow zone.
II	Green grey stratified fine sand, medium sand and silt with gravel and coarse sand lenses. Abundant charcoal and worm burrows.	Post-settlement fan deposition
III	Dark brown, sandy soil horizon. Lightens in color downward. Poorly sorted fine sand. Abundant wood and charcoal fragments and worm burrows.	Paleosol A horizon
IV	Stratified grey brown fine sand and silt with some orange mottling. Contains beds and pockets of coarse sand and brown fine sand. Contains darker layers and abundant worm burrows.	Pre-settlement fan deposition with buried and decomposed A horizons
V	Brown, sandy soil horizon.	Paleosol A horizon
VI	Poorly sorted, grey brown, fine sand and silt with orange mottling.	Pre-settlement fan deposition
VII	Brown, very fine, poorly sorted sand and silt.	Pre-settlement fan deposition
VIII	Grey silt and fine sand.	Pre-settlement distal fan or overbank deposits

Figure 11. Photograph of trench ALD 4. The paleosol A horizon appears as a dark grey band of sediment.

Figure 12. Close-up photograph of the paleosol A horizon found in trench ALD 4. The location of a sample removed for radiocarbon dating is shown.

ALD 5

ALD 5 is the uppermost of the two trenches dug in fan #6 (Figure 4). The general stratigraphic log for this trench if shown in Figure 13 and Table 4 provides the descriptions and interpretations for the strata. The trench depth reached four meters below fan surface where we identified the bottom of the fan deposit. Wood fragments were discovered at the basal contact with overbank deposits at 4 meters, and were radiocarbon at 2500 14C years with a calibrated age between 2708 and 2402 BP (see Table 7). This date provides the age of sediment stored at this point in the fan, and provides an approximate age of the entire fan itself.

The lowest 2.2 meters of the fan stratigraphy in ALD 5 contain stratified sand beds. The beds in stratum IV indicate the occurrence of pre-settlement episodic fan deposition. Stratum III includes a group of three separate paleosol A horizons representing three periods of relative fan surface stability. Three wood samples were collected from different depths within stratum III (see Figure 13) and have been radiocarbon dated. The dates of 840 14C years, 570 14C years and 100 14C years facilitate the correlation of layers with those found in other trenches and enable calculation of rates of vertical aggradation at this point in the fan (see Table 7 for calibrations) The uppermost of the paleosol A horizons is interpreted to be the same horizon observed in the other trenches according the 14C date. Approximately one meter of post-settlement deposition overlies above this layer.

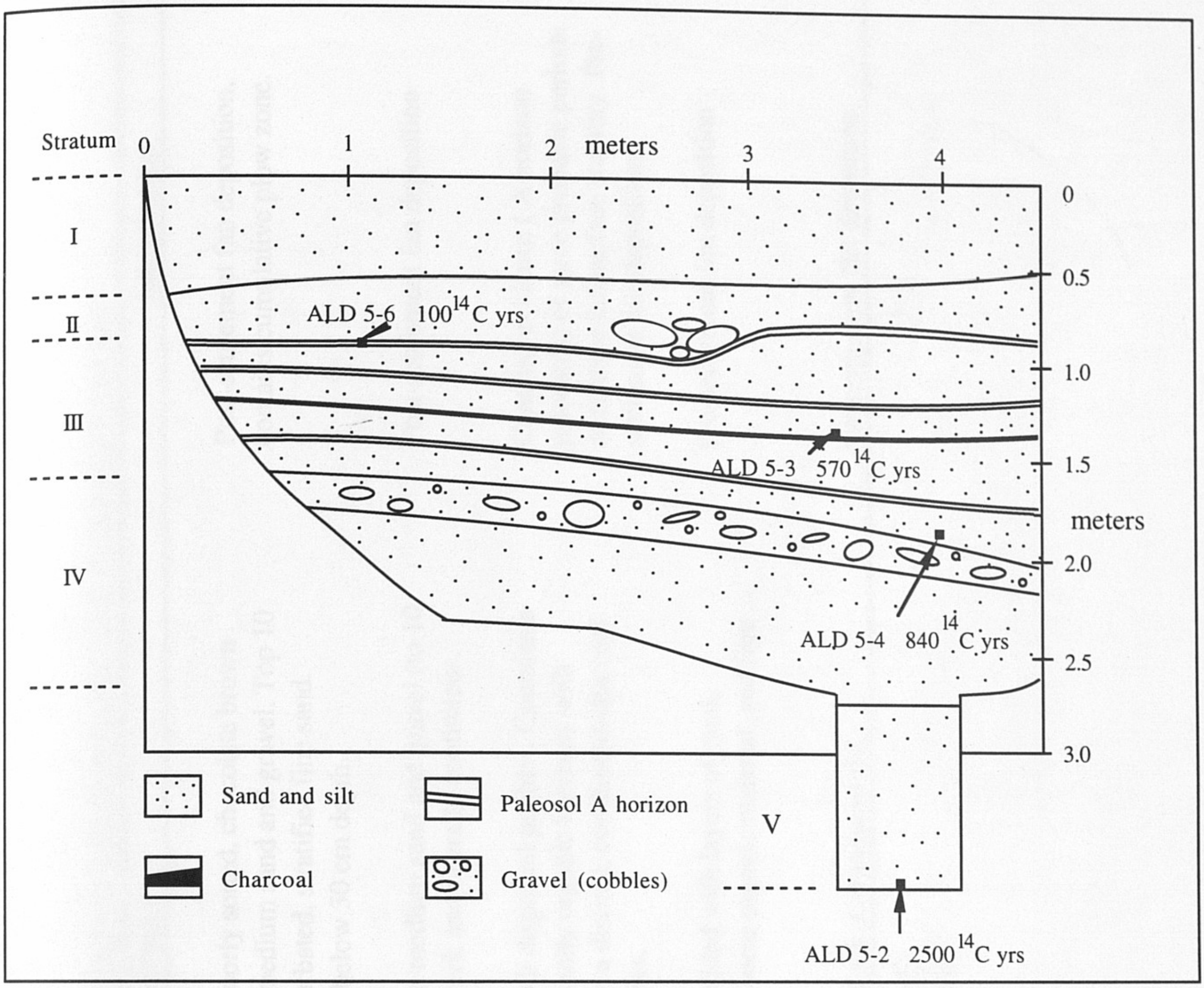

Figure 13. General stratigraphic log of Ald 5 showing strata as interpreted in the field. The top of the trench is at an elevation of 100.48 meters relative to an arbitrary benchmark. Radiocarbon dates of wood pieces retrieved from the trench walls are shown. Table 4 provides descriptions and interpretations for each stratum.

TABLE 4. ALD 5- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Very poorly consolidated, poorly sorted, chocolate brown and tan interbedded fine to medium sand and gravel. Top 10 centimeters consists of bioturbated, stratified fine sand. Undisturbed beds of gravel below 30 cm depth.	Post-settlement fan deposition, contains cumulative plow zone.
II	Grey green, stratified, fine to medium sand and gravel (to 10 cm). Layers are 2 to 4 cm thick and laterally continuous.	Post-settlement fan deposition
III	Brown, fine sand and silt with dispersed pebbles. Contains a series of three, dark brown sandy organic horizons with wood and charcoal. Contains a distinct, continuous charcoal layer. Frequent worm burrows.	Contains evidence (A horizon paleosols) of three probable periods of relative fan surface stability. Pre-settlement fan deposition.
IV	Greyish green gravel interbedded with layers of sand. Stratified sand beds contain some organic material, and fine downward in unit.	Pre-settlement fan deposition
V	Cohesive, grey fine sand and silt. Contains wood.	Pre-settlement fan deposition

Figure 14. Photograph of trench ALD 5. The series of paleosol A horizons can be seen near the shovel head.

ALD 9

ALD 9 is located in the middle to distal portions on the surface of fan #6. A generalized stratigraphic log of the trench is shown in Figure 15 and Table 5 provides the descriptions and interpretations of the individual strata. The backhoe reached to a depth of 2.7 meters below fan surface at which point a bedrock ledge was exposed. Above the bedrock ledge are about 0.5 meters of Huntington River terrace deposits (stratum VIII) overlain by about 0.3 meters of overbank deposits (stratum VII). Approximately 2 meters of fan sediments have been deposited.

At 2 meters below fan surface there is approximately 1 meter of pre-settlement fan deposition containing relatively few distinguishable features. At one meter depth, a paleosol A horizon marks the shift from pre-settlement to post-settlement deposition and represents the most recent period of fan surface stability. This horizon likely correlates with the paleosol A horizon observed in trench ALD 5 which was dated 100 ± 60 14C years. There is no well defined stratum indicating a plow zone above the paleosol A horizon. A distinct, undisturbed charcoal layer rests at a depth of 0.85 meters below fan surface. There is approximately 1 meter of post-settlement fan deposition above the paleosol A horizon.

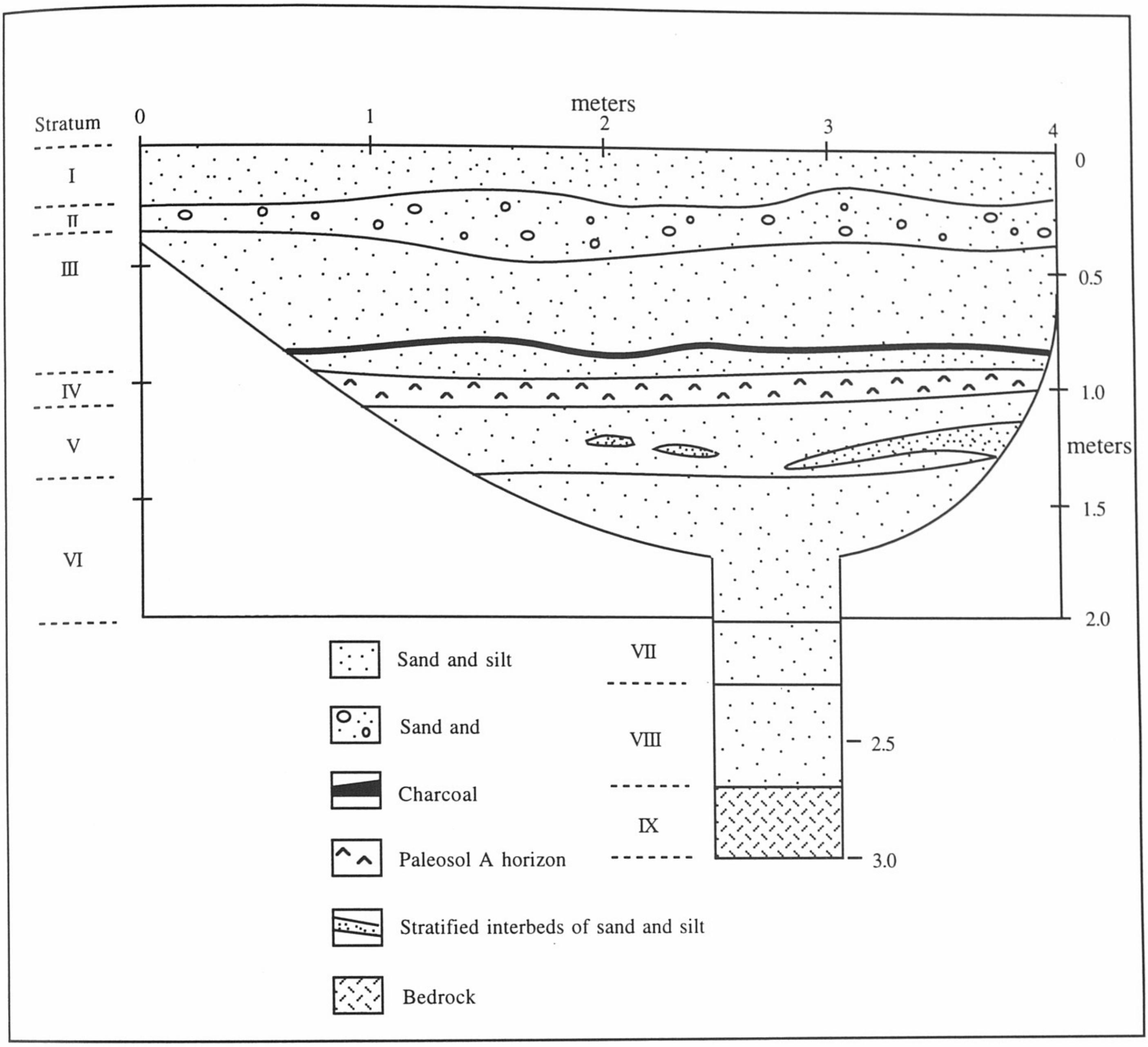

Figure 15. General stratigraphic log of trench Ald 9 showing strata as interpreted in the field. The top of the trench is at an elevation of 98.99 meters relative to an arbitrary benchmark. Table 5 provides descriptions and interpretations for each stratum.

TABLE 5. ALD 9- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Poorly sorted, brown fine to medium sand and silt with a few pebbles. Faintly stratified. Sharp basal contact.	Post-settlement fan deposition.
II	Alternating layers of brown sand and gravel and thinly bedded fine sand and silt. Worm burrows.	Post-settlement fan deposition.
III	Grey brown, moderately sorted fine sand and silt. Contains distinct, continuous layer of charcoal.	Post-settlement fan deposition.
IV	Dark brown, fine sandy organic horizon. Contains abundant worm burrows. Frequent wood and charcoal.	Paleosol A horizon, pre-settlement.
V	Grey, fine sand and silt. Contains pockets of coarse sand.	Pre-settlement fan deposition.
VI	Grey, fine sand and silt with orange staining.	Pre-settlement fan deposition.
VII	Grey, fine sand.	Overbank deposits, pre-settlement.
VIII	Red brown, medium sand.	Huntington River terrace deposition, pre-settlement
IX	Bedrock	

Figure 16. Photograph of trench ALD 9. The thin charcoal layer and paleosol A horizon can be seen about 1 m below fan surface.

ALD 2

Figure 17 is a general stratigraphic log for trench ALD 2 from fan #8, and Table 6 contains descriptions and interpretations of the individual stratum. A large chunk of wood was recovered from four meters below the surface of fan #8 and was radiocarbon dated to be < 100 14C years (see Table 7 for calibration). The four meters of sediment stored above the wood is interpreted to be post-settlement fan deposition. This is at a location along the fan surface were I have interpreted there to be approximately 5 meters of total fan deposition. This implies that nearly four fifths of the vertical aggradation at this location on fan #8 is composed of post-settlement fan deposition. Fan # 8 is the closest to the Huntington River of the group of three Aldrich fans, and as a result may be the most recent of the fans to begin depositing material. At a depth of 2.5 meters, a thin layer of disseminated organic material was exposed which may contain organic material that was carried downslope with the deposition of fine sand and silt.

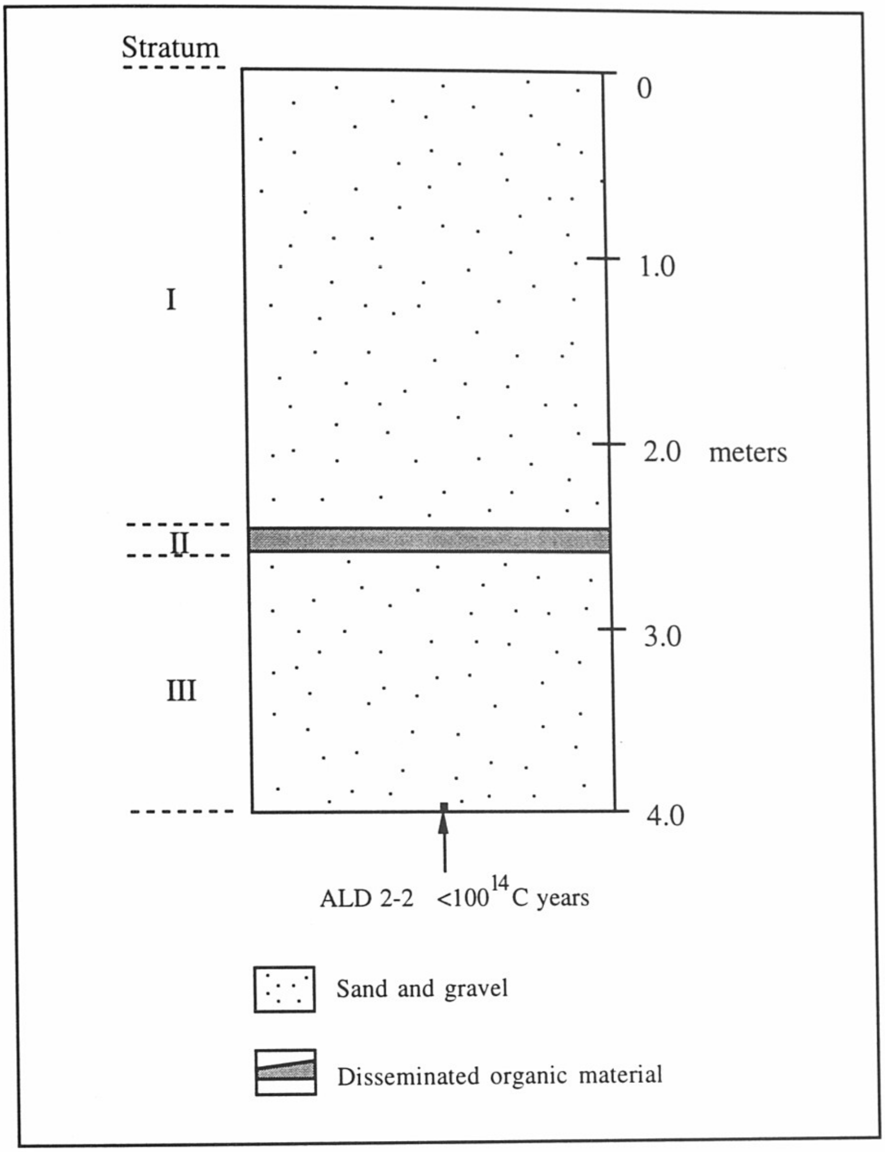

Figure 17. General stratigraphic log of trench ALD 2-2. The trench is located approximately in the middle of the surface of fan #8. Descriptions and interpretations for the individual strata are provided in table 6.

TABLE 6. ALD 2- STRATUM DESCRIPTIONS AND INTERPRETATIONS

Stratum	Description	Interpretation
I	Grey, fine sand and gravel.	Post-settlement fan deposition
II	Dark brown sand and silt layer containing disseminated organic material.	Post-settlement fan deposition Paleosol A horizon
III	Grey, fine sand and silt. Wood fragments found at base of trench.	Post-settlement fan deposition

TABLE 7. RADIOCARBON DATES FROM ALDRICH FANS

Sample	Lab #	Material	Depth	14C Date	Calibrated date (BP)	1σ range (BP)	2σ range (BP)
Ald 2-2	GX - 21329	Wood	400 cm	< 100	62 - 0	128 - 0	238 - 0
Ald 3-2	CAMS #26105	Wood	100 cm	310 ± 60	312	459 - 294	507 - 0
Ald 3-3	CAMS #26106	Wood	105 cm	230 ± 60	286	305 - 0	431 - 0
Ald 5-2	CAMS #22994	Wood	400 cm	2500 ± 60	2708 - 2402	2735 - 2363	2746 - 2352
Ald 5-3	CAMS #26107	Wood	140 cm	570 ± 60	544	629 - 523	660 - 508
Ald 5-4	CAMS #22995	Wood	187 cm	840 ± 60	735	793 - 674	918 - 662
Ald 5-6	CAMS #26108	Wood	90 cm	100 ± 60	62 - 0	268 - 0	283 - 0

Note: Calibration by Stuiver and Becker (1993)

Sedimentation Rates

Rates of vertical aggradation at specific points in the fans and volumes of sediment deposited over time can be calculated. The rates of sedimentation are directly related to rates of hillslope erosion. In this study, the radiocarbon dates provide the basis for calculation of the changes in rates of sedimentation over time, with the goal of identifying the increase in sedimentation rates following the destabilization of hillslopes due to deforestation.

The most accurate calculation of vertical aggradation rates occurs in the trenches which contain radiocarbon dated material. ALD 5 (Figure 13), for example, contains four radiocarbon dates including one indicating the time at which the fan began to form, and three located at various depths below the surface of fan #7. Between the radiocarbon dates is sediment that was deposited at a rate found by calculating the amount of the accumulation over time. Table 8 contains the results from the calculation of rates between all of the calibrated dates throughout trench ALD 5. The rates of sedimentation previous to settlement were very constant, with values of 1 to 2 millimeters of deposition per year on average. Following settlement, rates of sedimentation increased to 15 millimeters of deposition per year on average. Figure 18 is a graph showing the change in aggradation rates over time.

The radiocarbon dates from trench ALD 3 also facilitated calculation of post-settlement vertical aggradation rates. The results indicate that rates following settlement were at a minimum rate of 3 to 4 millimeters per year on average. Considering that the tree rings providing material for the radiocarbon dating may have been much older than clear-cutting, the calculated the rates of aggradation may be underestimated. The radiocarbon date from trench ALD 2 suggest a dramatic rate of aggradation (64 millimeters per year) on average since the time of settlement.

I calculated total volumes of sediment in the fans as well as volume of sediment deposited since the time of settlement. Fans #6 and #7 were combined for the calculation. The total volume of sediment contained in fans #6 and #7 is approximately 18000 m3. The volume of sediment deposited following settlement is 5000 m3, nearly one third of the total

TABLE 8. RESULTS OF THE CALCULATION OF AGGRADATION RATES AT TRENCH ALD 5

Samples included	Age range (BP)	Period of deposition (years)	Amount of deposition (meters)	Rate of Deposition (meters/year)	Historic time of Deposition
ALD 5-2 & 5-4	2708 - 735	1973	2.13	1	pre-settlement
	2402 - 735	1667		1	pre-settlement
ALD 5-2 & 5-3	2708 - 544	2164	2.60	1	pre-settlement
	2402 - 544	1858		1	pre-settlement
ALD 5-2 & 5-6	2708 - 62	2646	3.10	1	pre-settlement
	2402 - 62	2340		1	pre-settlement
ALD 5-4 & 5-3	735 - 544	191	0.47	2	pre-settlement
ALD 5-4 & 5-6	735 - 62	673	0.97	1	pre-settlement
ALD 5-3 & 5-6	544 - 62	482	0.50	1	pre-settlement
ALD 5-6 to present	62 - 0	62	0.90	15	post-settlement

Graph of changes in aggradation rates over time

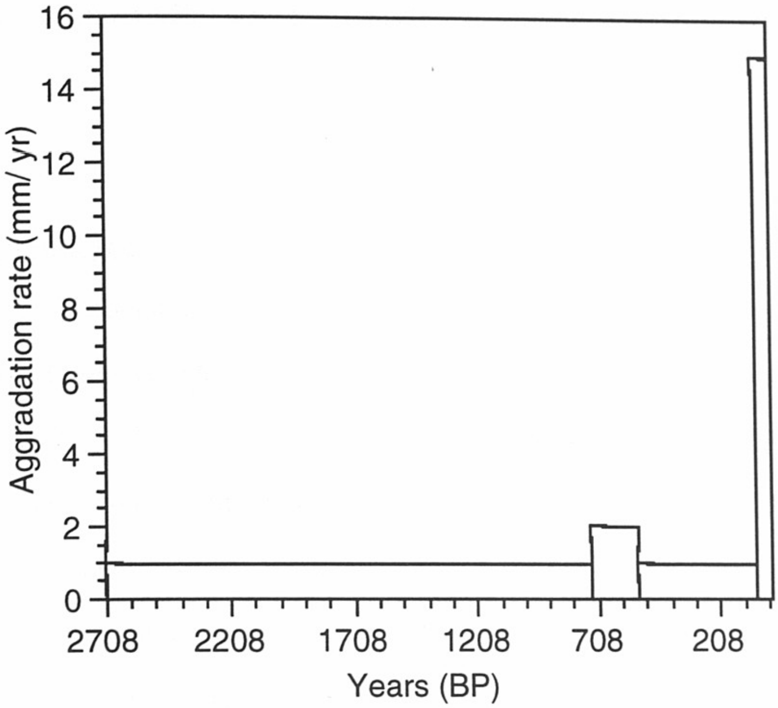

Figure 18. Graph illustrating the changes in rates of fan aggradation over time. The data for the graph are based on calibrated radiocarbon dates from trench ALD 5 in fan #7.

volume stored in the fans. Rates of deposition on the fans in terms of volume increased ten-fold on average following settlement in Vermont. Deposition following settlement on fan #8 amounts to about 5500 m3, approximately two-thirds of the total fan deposition (8500 m3).

Grain Size Analysis

Table 8 contains the results from the statistical analysis of the grain samples. For the analysis I used samples collected from a group of three trenches at the Aldrich farm; trenches ALD-1, ALD 3, and ALD 4. Figure 19 is a ternary diagram relating the percentages of sand, silt and clay in the samples analyzed. The diagram illustrates the extremely low clay content of, and a relatively high and variable abundance of sand and silt. Most of the samples contain greater than 50% sand content.

Mean grain size remained relatively constant throughout each of the successive layers, ranging from 0.95 phi (coarse sand) to 4.43 phi (coarse silt) (Table 9). The majority of samples were in the 3 phi range (very fine sand). Results from the statistical test for sorting revealed that sediment in the fans could be categorized as moderately to poorly sorted. The statistical test for skewness, or symmetry of the distribution of grain sizes relative to a normal distribution, showed that the samples contained an excess of coarse grains. The measure of kurtosis, the peakedness of the sediment or the concentration around the mean, classified the sediment a leptokurtic to extremely leptokurtic. This implies that sorting was best among grains of a size similar to that of the mean.

Grain size of fan sediments reflect the source of fan sediment. All of the sediment originates from the drainage basin incised into higher Huntington River terrace. The sediment on the terrace is composed of sand, silt and gravel from reworked glacial till, which is deposited as terrace sediments or overbank deposits. The samples that were collected did not contain any of the large pebbles or cobbles that can be observed in the drainage basin. This may be a result of the locations of the trenches in the lower portions of the fan surfaces.

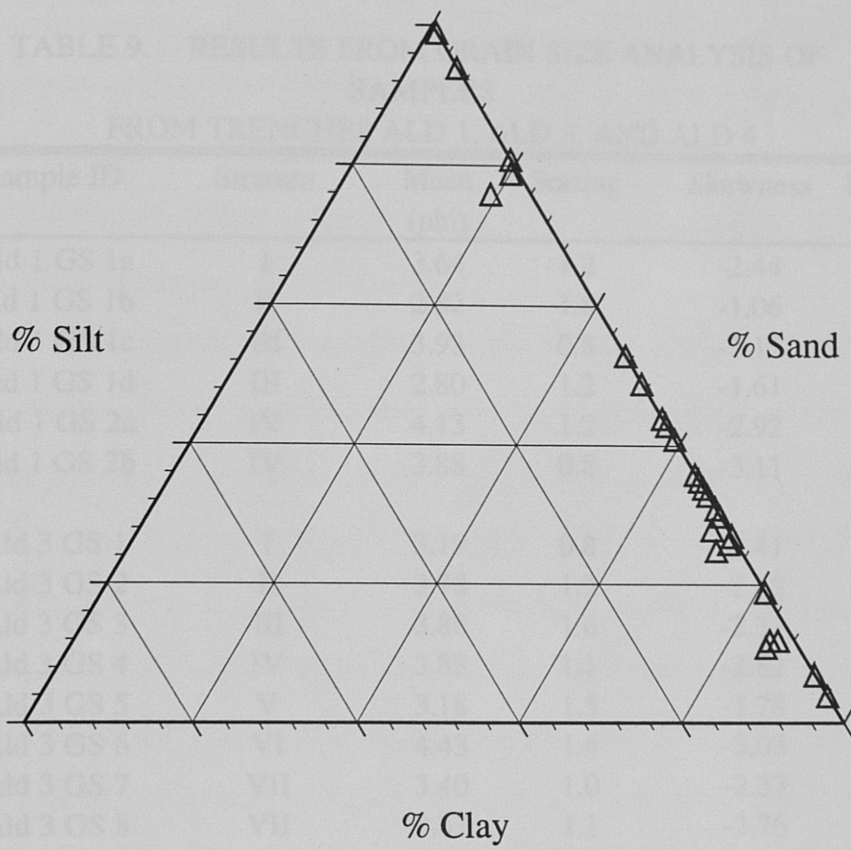

Figure 19. Ternary diagram illustrating the percentage content of clay, silt and sand in samples collected from trenches ALD 1, ALD 3 and ALD 4.

TABLE 9. RESULTS FROM GRAIN SIZE ANALYSIS OF SAMPLES
FROM TRENCHES ALD 1, ALD 3, AND ALD 4

Sample ID	Stratum	Mean (phi)	Sorting	Skewness	Kurtosis
Ald 1 GS 1a	I	3.64	1.2	-2.44	3.31
Ald 1 GS 1b	II	2.82	1.8	-1.06	3.57
Ald 1 GS 1c	III	3.93	0.8	-3.17	0.98
Ald 1 GS 1d	III	2.80	1.2	-1.61	3.49
Ald 1 GS 2a	IV	4.13	1.2	-2.92	2.80
Ald 1 GS 2b	IV	3.88	0.8	-3.11	0.98
Ald 3 GS 1	I	3.19	0.8	-2.41	1.25
Ald 3 GS 2	II	3.78	1.2	-2.58	3.55
Ald 3 GS 3	III	3.88	1.6	-2.31	5.11
Ald 3 GS 4	IV	3.88	1.1	-2.82	3.21
Ald 3 GS 5	V	3.18	1.5	-1.78	2.92
Ald 3 GS 6	VI	4.43	1.4	-3.03	4.34
Ald 3 GS 7	VII	3.40	1.0	-2.37	1.64
Ald 3 GS 8	VII	3.83	1.1	-2.76	2.18
Ald 3 GS 9	VIII	0.95	0.7	-0.34	1.42
Ald 4 GS 1	I	3.87	1.5	-2.35	5.50
Ald 4 GS 2	II	3.23	1.4	-1.91	2.91
Ald 4 GS 3	III	3.88	1.5	-2.37	5.65
Ald 4 GS 4	IV	2.37	1.2	0.34	11.16
Ald 4 GS 5	V	3.65	1.4	-1.20	2.50
Ald 4 GS 6	VI	3.72	1.2	-2.50	4.07
Ald 4 GS 7	VII	3.70	1.2	-2.48	3.04

Cross-sections

Two cross-sections of the Aldrich fans (#6 and #7) are shown in Figures 20 and 21. The important stratigraphic information includes terrace sand and gravels, bedrock, overbank deposits, fan deposition, paleosol A horizons and the cumulative plow zone. The history of the formation of fans #6 and #7 is very similar, and is best described by comparison and explanation of the cross-sections.

Before 2735 years BP, the Huntington River was depositing the sand and gravels observed at an elevation of below 96 meters in the fan #7 cross-section (Figure 20), and was in direct contact with the bedrock ledge shown in Figures 15 and 21. As the river continued to incise over time, what is now the Aldrich field was likely a series of point bars and levees which were slowly covered by overbank deposits. The river channel, or separate meander of the river flowed at the base of the higher Huntington River terrace, where the fans exist today. As long as the river was close, any sediment originating from the drainage basins was immediately carried away by the river and deposited elsewhere.

Eventually, as the river continued to incise, the Aldrich field was abandoned entirely as a flood plain. Occasional flooding from storm events increased river levels sufficiently to deposit overbank sediments on the field. Simultaneously, sediment descending from the drainage basins was being deposited on fans, interfingering with the overbank deposits and extending the toes of the fans out into the field. Assuming that the hillside formed by the higher Huntington River terrace was vegetated, minor episodic fan deposition similar to that observed today was probably occurring. Significant storm events would have resulted in more major episodes of fan and overbank deposition. Between storm events, the Aldrich field was stable enough to provide a site for vegetative growth and the formation of paleosol A horizons.

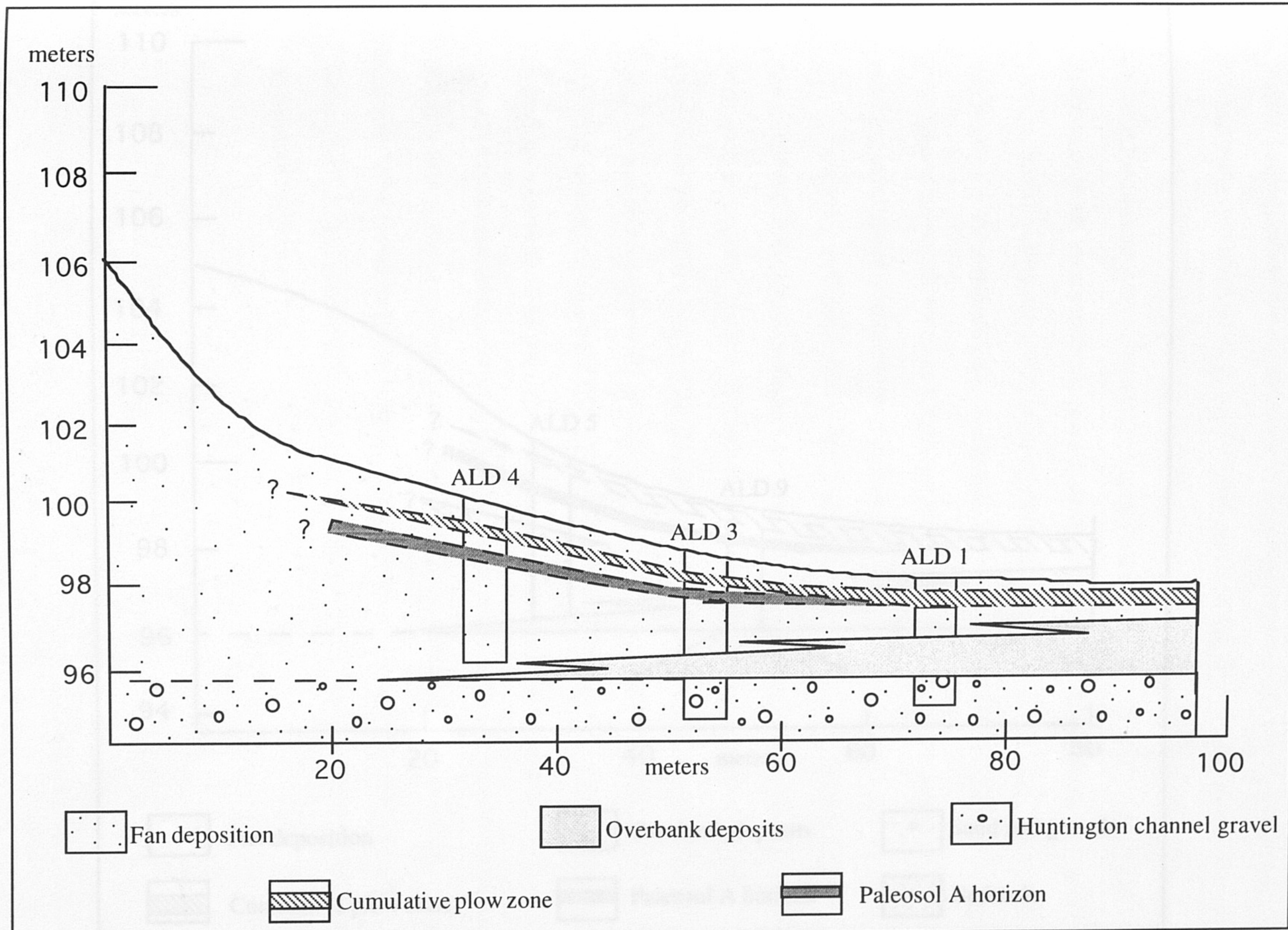

Figure 20. Cross-section of Aldrich fan incorporating stratigraphic information from ALD 1, ALD 3 and ALD 4. Elevations are relative to an arbitrary benchmark.

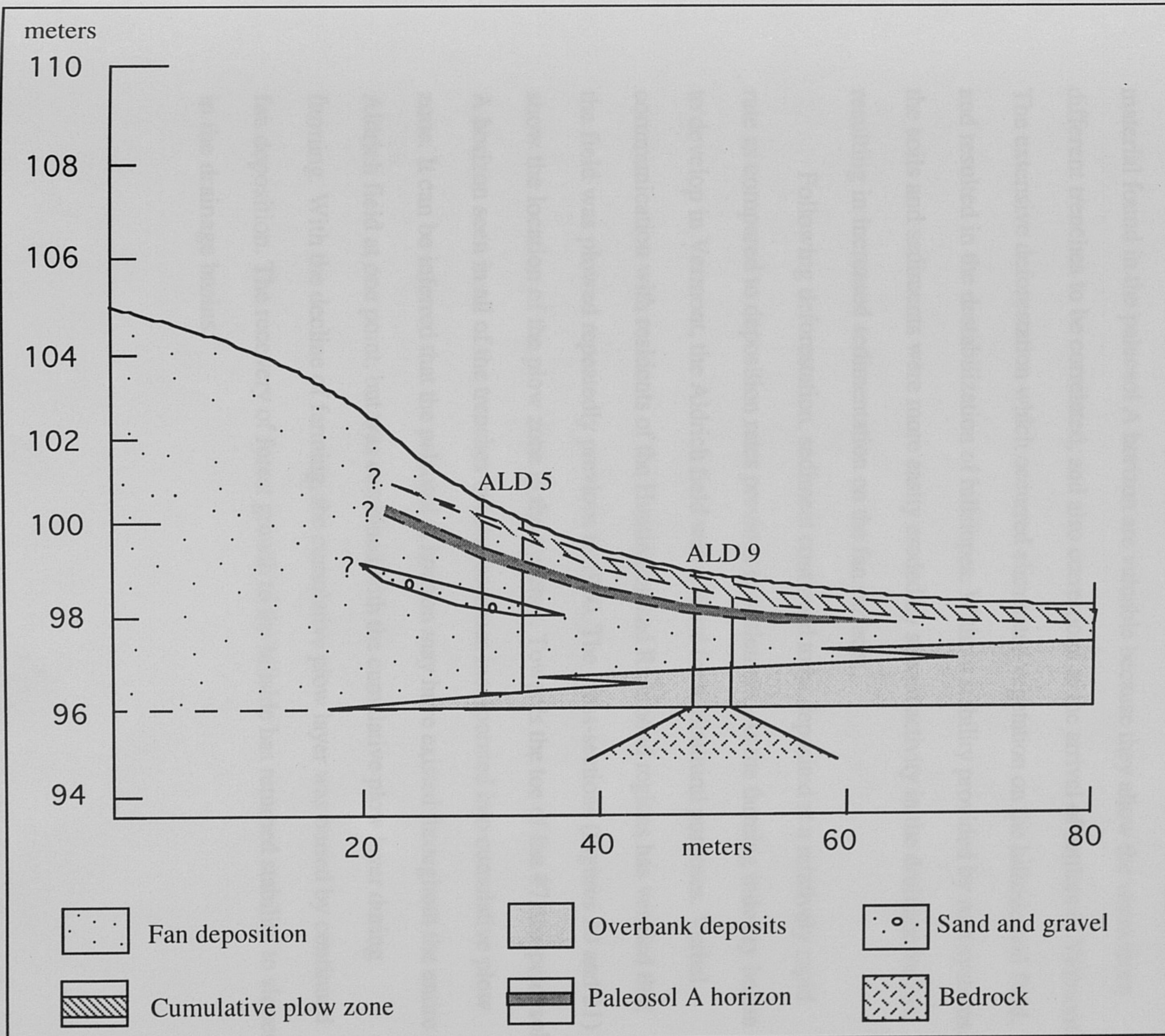

Figure 21. Cross section of Aldrich fan incorporating stratigraphic information from ALD 5 and ALD 9. Elevations are relative to an arbitrary benchmark.

A significant period of relative fan surface stability is marked by the paleosol A horizon I identified in most trenches. This layer represents a period when vegetative growth became well established on the fan surface, and also indicates that vegetative growth on the hillside provided sufficient stability. The radiocarbon dates determined from organic material found in the paleosol A horizon are valuable because they allow the strata from different trenches to be correlated, and also correspond to the arrival of settlers in Vermont. The extensive deforestation which occurred eliminated vegetation on the hillside and field, and resulted in the destabilization of hillslopes. Without stability provided by root systems, the soils and sediments were more easily eroded by stream activity in the drainage basins, resulting in increased sedimentation on the fan surfaces.

Following deforestation, sediment continued to be deposited at a relatively rapid rate as compared to deposition rates previous to settlement. As the farming industry began to develop in Vermont, the Aldrich field was utilized for agricultural purposes. Verbal communication with residents of the Huntington and Richmond regions has verified that the field was plowed repeatedly previous to 1960. The cross-sections (Figures 20 and 21) show the location of the plow zone in the trenches. Towards the toe of fan #7, the paleosol A horizon seen in all of the trenches but one becomes incorporated into cumulative plow zone. It can be inferred that the paleosol A horizon may have existed throughout the entire Aldrich field at one point, but was combined with the cumulative plow layer during farming. With the decline of farming, the cumulative plow layer was buried by continued fan deposition. The recovery of forest growth to the hillside has returned stability to slopes in the drainage basins.

Modern Forest Cover

Table 10 shows the results from the tree coring on the hillslopes above the Aldrich fans. The data are based on tree rings counted from a variety of trees, the majority of which are quaking aspen. The oldest appearing trees were selected for the investigation, but the forest is primarily composed of un-even aged mixed hardwoods on the middle to bottom portions of the hillslope, and larger conifers towards the top and within the drainage basins. Quaking aspen were selected for coring because they are a pioneer species, probably the first species of tree to grow following a clear-cut. The ages of the aspens suggest that the last time that the hillslope was cleared of vegetation was between 1910 ad 1930. The two oldest trees were hemlocks, with ages of 96 and 122 years. The hemlocks display evidence of having been exposed to direct sunlight for extended periods of time, with thick lower branches that have since died. The branches indicate that these trees may have survived clear-cutting as saplings and were exposed to sunlight until surrounding forest began to regenerate.

The modern forest on the hillslope fits the description of a Vermont forest following human induced modifications according to Meeks (1986). Old growth forests in Vermont typically were much simpler, containing mostly northern hardwoods including birch, beech and maple. Younger forests contain a much broader species range including those found at the Aldrich farm. The variety of relatively young, un-even aged trees support the interpretation that this landscape was modified by logging and agriculture. The character of the forest at the Aldrich farm suggests that it is relatively young.

TABLE 10. RESULTS FROM ALDRICH FARM TREE CORING

Tree Species	Age (years)
Quaking Aspen	86
Quaking Aspen	88
Quaking Aspen	88
Quaking Aspen	66
Quaking Aspen	61
Hemlock	95
Hemlock	122
Birch	83
Oak	87
White Pine	30

Notes:

- Quaking Aspens require significant amounts of sunlight and would be among the first trees to grow following a clearcut. These trees are probably not much younger than the clearcut.
- The Hemlocks that were cored appeared to have grown when sunlight was able to reach the forest floor more readily than it does today. Evidence of older branches from these periods of growth exist low to the ground. These lower branches have since been broken and show no sign of recent growth, while the majority of leaf growth exists on the upper braches with more exposure to sunlight.

Chapter 4

Summary

Our data show that alluvial fans in Vermont are useful as recorders of rates of sedimentation, and serve as effective tools for identifying the effects that Vermont settlement had on changes in landscape. The character of alluvial fans in the Huntington River basin shows that river terraces provide excellent platforms for deposition. The small size of Vermont fans makes them advantageous for field study because of the ease in observing fan processes as a whole and using backhoe trenches to dig below fan statigraphy. Surveys of the fans and respective drainage basins can be completed with accuracy in relatively short periods of time. The abundance of organic material such as wood and charcoal in the fan stratigraphies facilitates the use of radiocarbon dating methods for obtaining ages of sediment and rates of deposition.

From data collected at the Aldrich field, including seven radiocarbon dates and the calculated rates of fan aggradation, there is substantial evidence that rates of sedimentation increased significantly following settlement in Vermont. Modern evidence of increased soil erosion following clear-cutting events in various regions of the world (Dunne and Leopold, 1978) support the notion that clear-cutting was probably a dominant factor in destabilizing hillslopes in Vermont. The effects of clear-cutting also include increases in water yield and runoff due to rising water tables. Loss of water by the interception and evapotranspiration processes performed by vegetation play an important role in minimizing runoff (Dunne and Leopold, 1978). Without vegetation, dramatic changes in the morphology of the landscape begin to take effect.

The adverse effects of human induced modifications of forest growth on landscape change indicate that there is a need for prudent land management techniques. Rapid restoration of forest cover following clear-cutting is necessary to preserve established soils, which play an important role in regenerating forest growth. In return, vegetation requires nutrients provided by the soils. The mass wasting of soil hinders the restoration of forest growth. The re-establishment of the forest at the Aldrich hillslopes appears to have slowed sedimentation on the alluvial fans, with deposition within the past year amounting to only a thin layer of silt in isolated parts of the fans.

One of the goals for this research was to provide general, descriptive data concerning alluvial fans in the Huntington River region, including location maps and reconnaissance trenching, to set the stage future work in the area. The concurrent study by Church and Bierman combined with results from this study show that there is a wide range in ages between the fans of this region. In addition to providing sedimentation rates, the basal dates of fans deposited on terraces can be used to determine the approximate time of abandonment of the terraces. More extensive trenching is necessary in other fans of the region, which could contribute to the development of the post-glacial historical time line of the Huntington River basin. Further research into the changes in sedimentation rates within alluvial fans in Vermont would be useful in drawing additional conclusions relating the arrival of settlers to the region.

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Appendix I

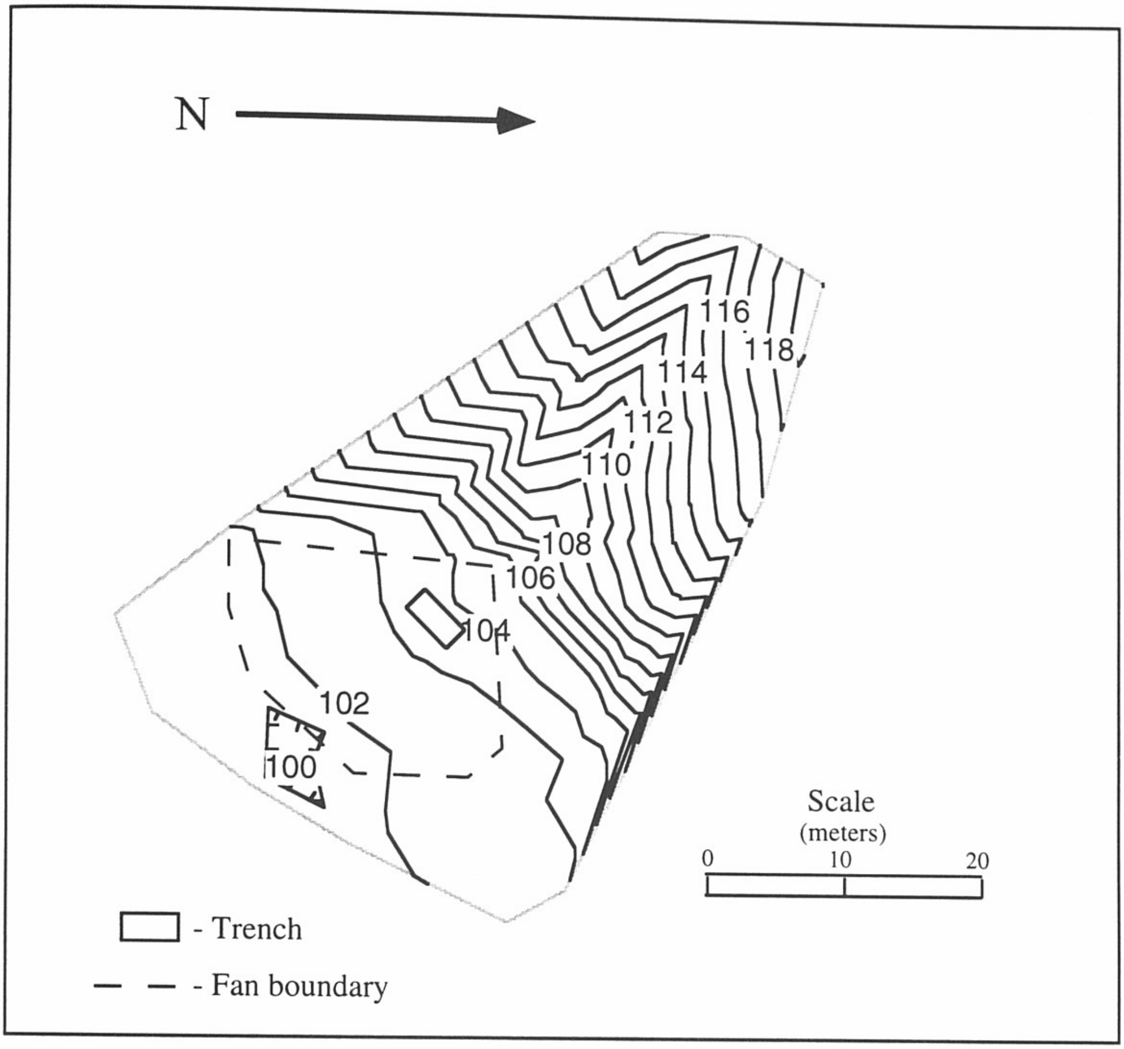

Figure 22. Contour map of fan #3 with elevations relative to an arbitrary benchmark. The trench in figure #23 is shown. The fan is 350 m2 in area and contains approximately 1000 m3 of sediment.

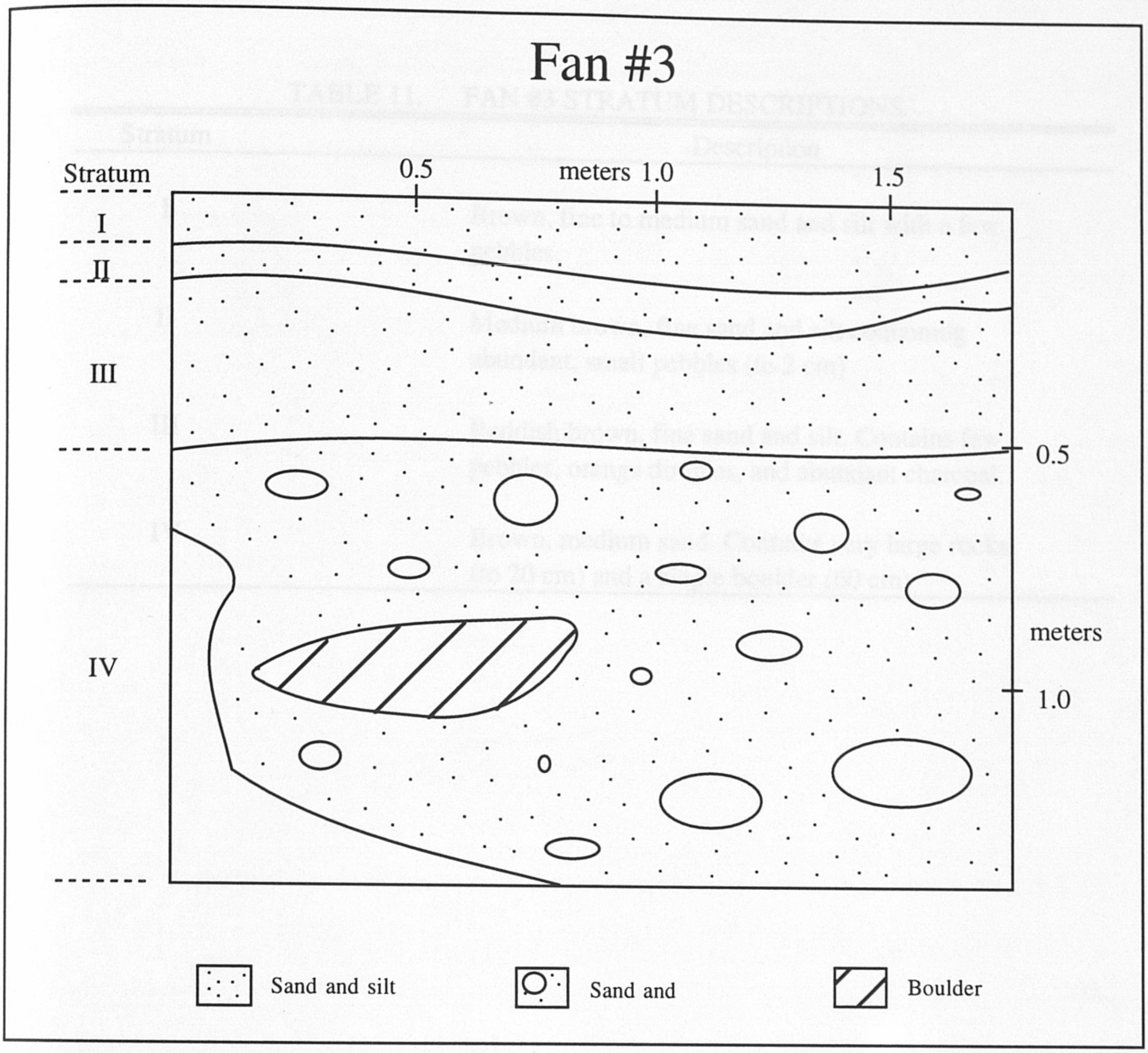

Figure 23. General stratigraphic log for a trench in fan #3. The trench wall is located approximately in the middle of the fan surface and faces away from the apex. Table 11 provides the descriptions for each stratum.

TABLE 11. FAN #3 STRATUM DESCRIPTIONS

Stratum	Description
I	Brown, fine to medium sand and silt with a few pebbles.
II	Medium brown, fine sand and silt containing abundant, small pebbles (to 2 cm)
III	Reddish brown, fine sand and silt. Contains few pebbles, orange dimples, and abundant charcoal.
IV	Brown, medium sand. Contains very large rocks (to 20 cm) and a single boulder (60 cm)

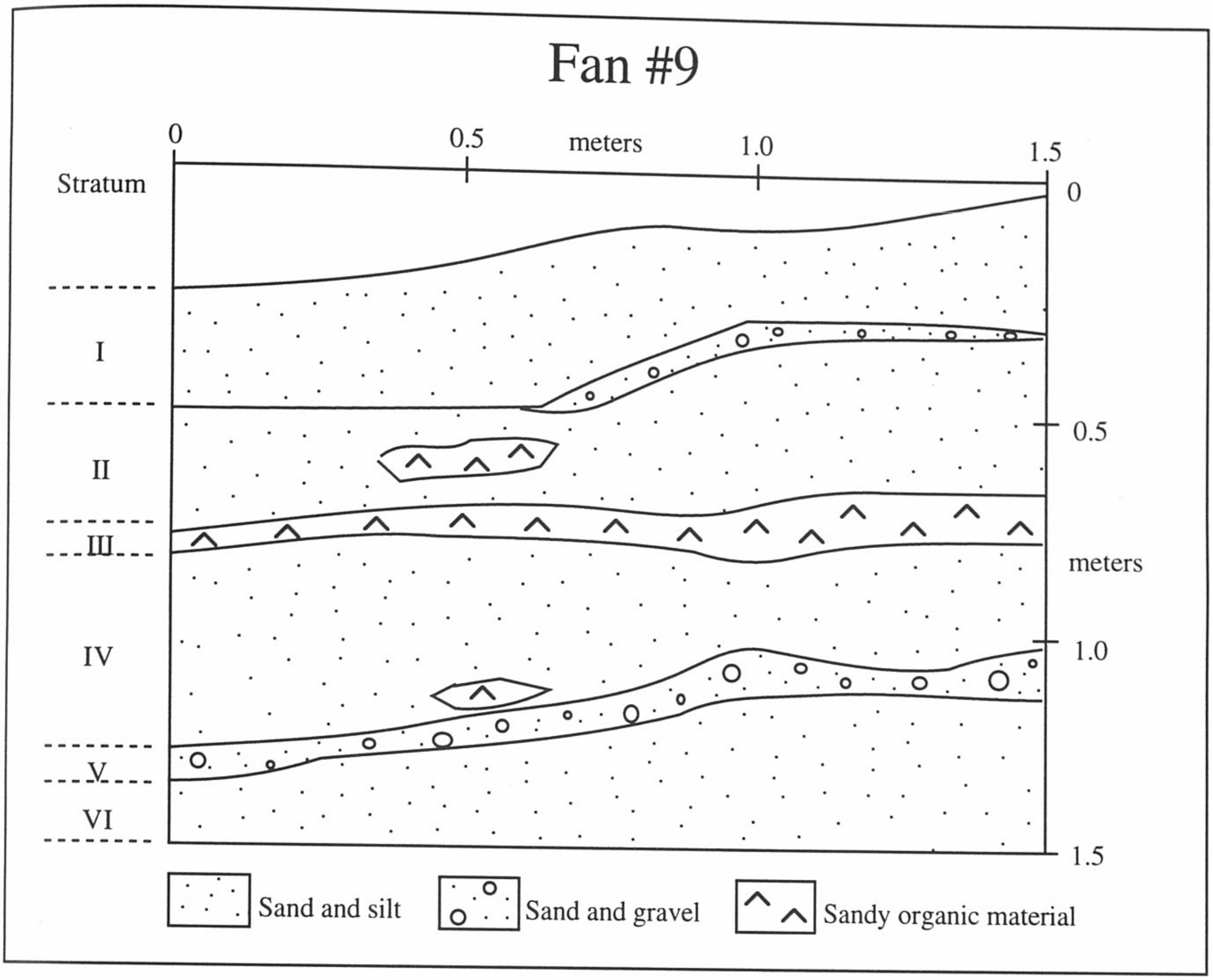

Figure 24. General stratigraphic log for a trench in fan #9. The trench wall is located approximately in the middle of the fan surface and is oriented lengthwise down the fan. Table 12 provides the descriptions for each stratum.

TABLE 12. FAN # 9- STRATUM DESCRIPTIONS

Stratum	Description
I	Dark brown, fine sand and silt. Contains discontinuous layer of coarse sand and pebbles.
II	Light brown, fine to medium sand with scattered pebbles (to 2 cm). Moderately abundant charcoal fragments; highest concentration in darker patch of sand containing organics.
III	Distinct, dark fine sand and silt organic horizon. Abundant charcoal.
IV	Brown, fine to medium sand with scattered pebbles (to 3 centimeters). Few charcoal fragments.
V	Brown, fine to medium sand and gravel.
VI	Grey silty clay with reddish orange mottling.

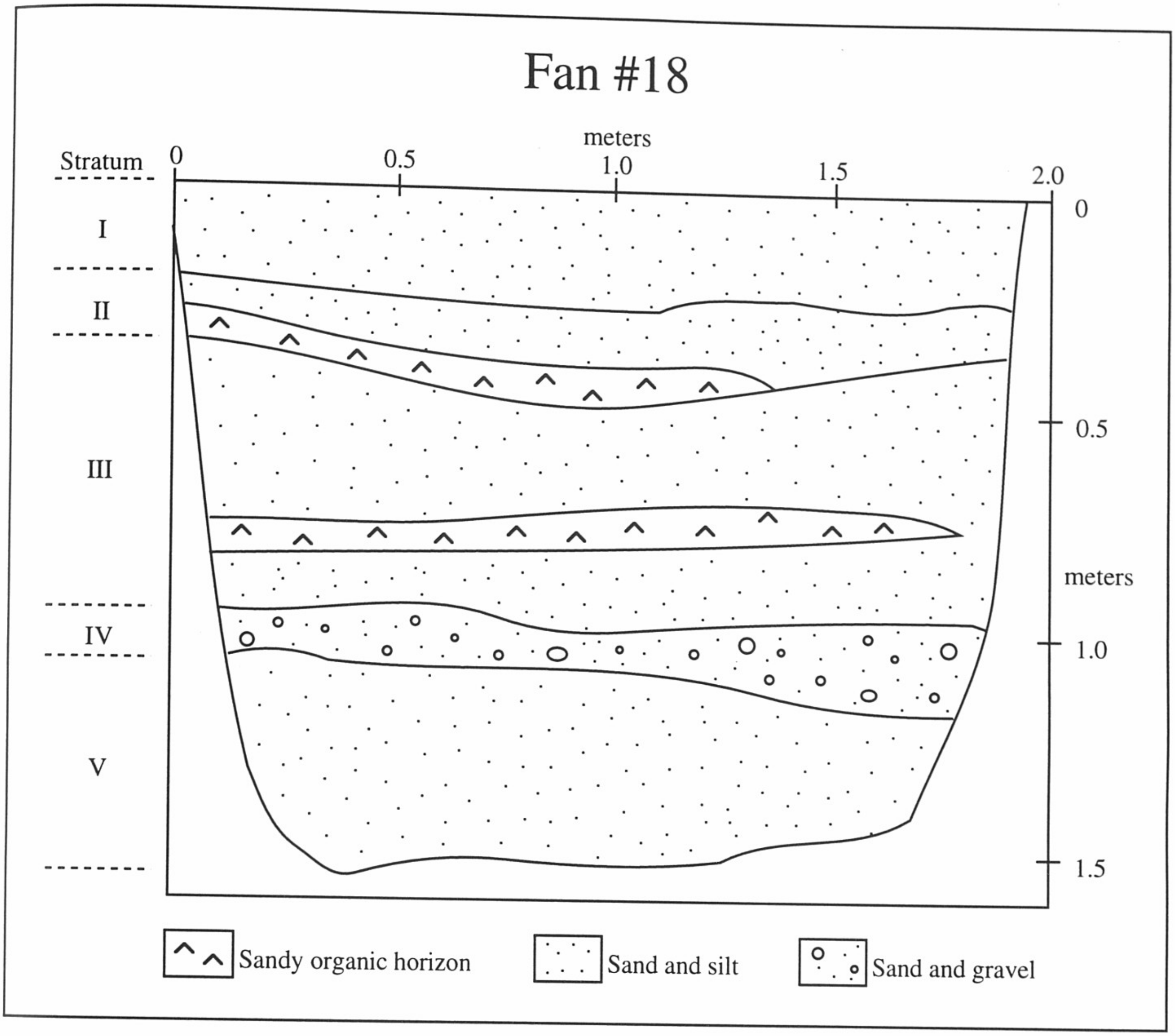

Figure 25. General stratigraphic log for a trench in fan #18. The trench wall is located approximately in the middle of the fan surface and faces away from the apex of the fan. Table 13 provides the descriptions for each stratum.

Table 13. FAN #18- STRATUM DESCRIPTIONS

Stratum	Description
I	Dark brown, fine sand and silt
II	Medium brown, fine sand and silt. Contains truncated sandy soil horizon. Pebbles to 2 centimeters.
III	Brown, fine sand and silt. Contains charcoal fragments; most abundant in faded, brown soil horizon in middle of unit.
IV	Medium brown, fine to medium sand with pebbles to 3 centimeters.
V	Grey, silty clay with rusty red mottling.

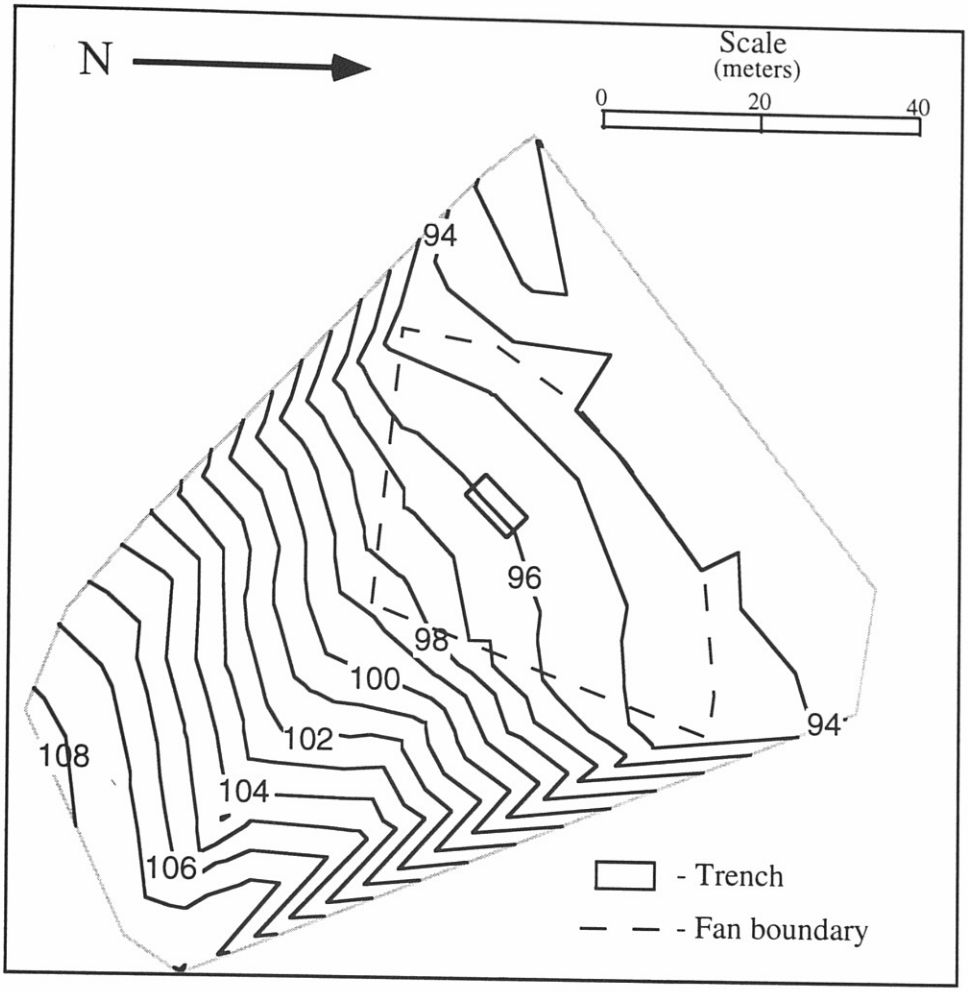

Figure 26. Contour map of fan #19 with elevations relative to an arbitrary benchmark. The approximate location of the trench in Figure 27 is pictured. The fan is 450 sq m in area and contains approximately 1642 cu m of sediment.

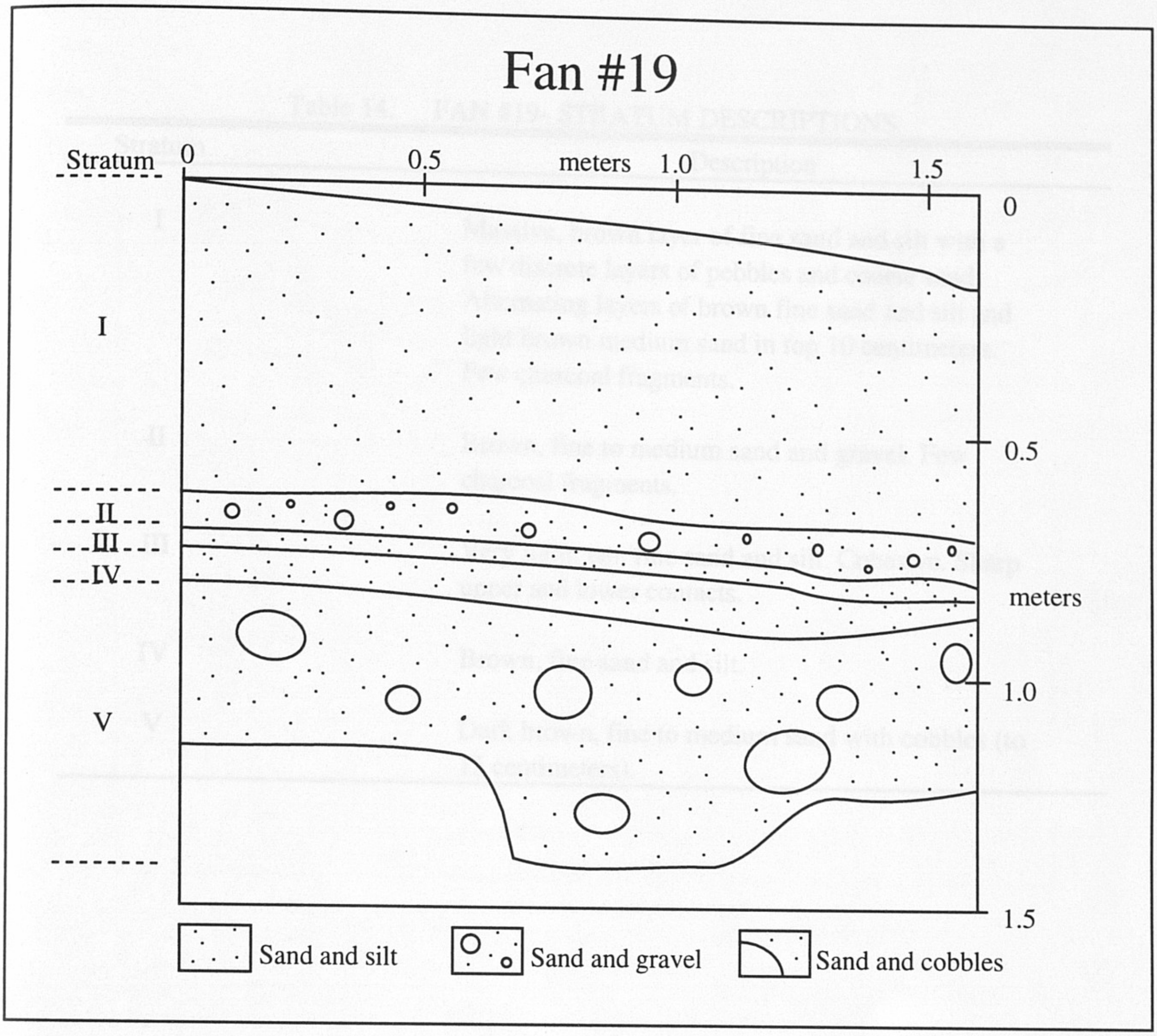

Figure 27. General stratigraphic log for a trench in fan #19. The trench wall faces away from the apex of the fan, and is located on the middle portion of the fan surface.

Table 14. FAN #19- STRATUM DESCRIPTIONS

Stratum	Description
I	Massive, brown layer of fine sand and silt with a few discrete layers of pebbles and coarse sand. Alternating layers of brown fine sand and silt and light brown medium sand in top 10 centimeters. Few charcoal fragments.
II	Brown, fine to medium sand and gravel. Few charcoal fragments.
III	Very light, tan, fine sand and silt. Cohesive. Sharp upper and lower contacts.
IV	Brown, fine sand and silt.
V	Dark brown, fine to medium sand with cobbles (to 15 centimeters).

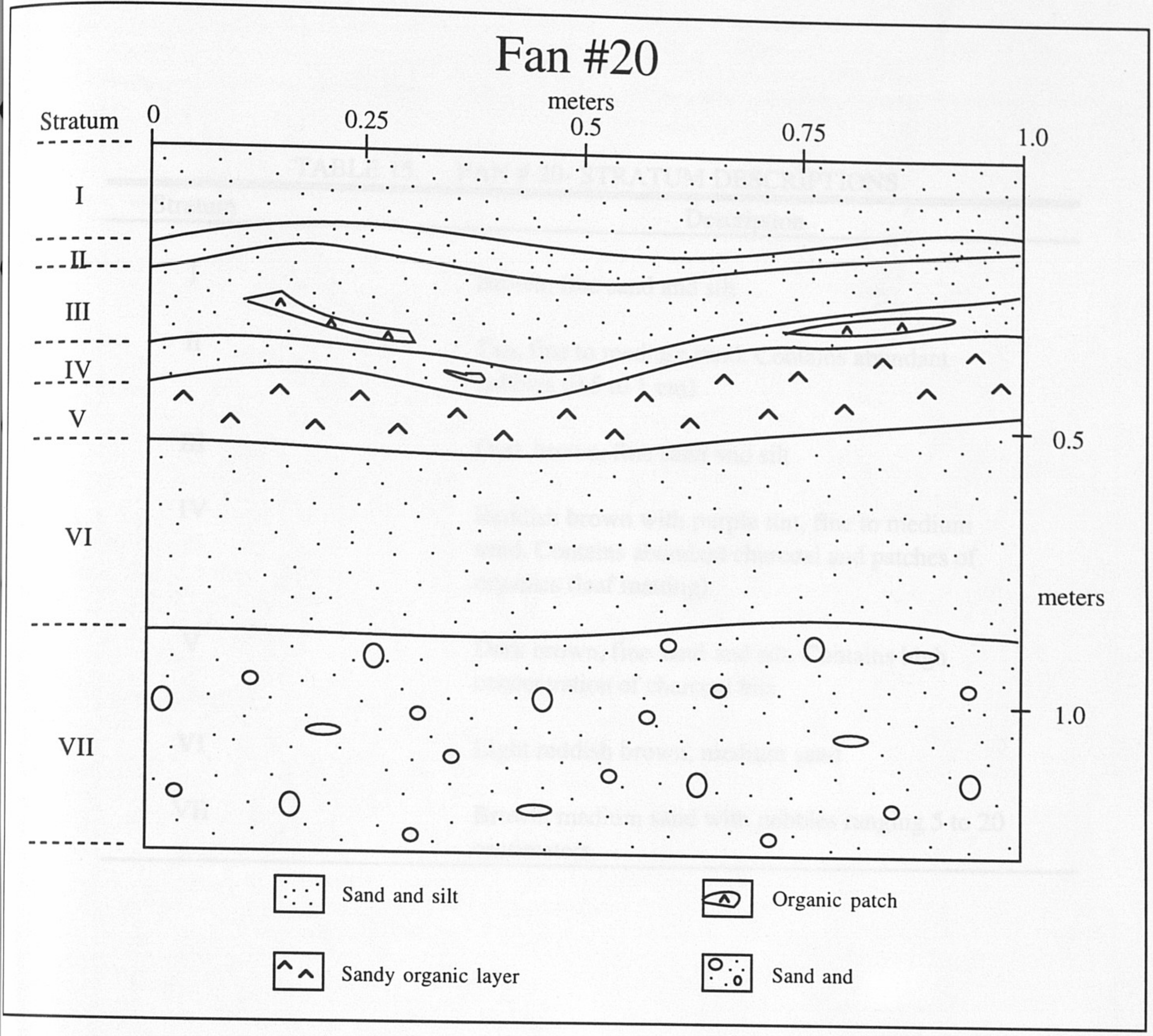

Figure 28. General stratigraphic log for a trench in fan #20. The trench wall is located approximately in the middle of the fan surface and faces away from the apex of the fan. Table 15 provides descriptions for each of the stratum.

TABLE 15. FAN # 20- STRATUM DESCRIPTIONS

Stratum	Description
I	Brown, fine sand and silt
II	Tan, fine to medium sand. Contains abundant pebbles (0.5 to 1 cm)
III	Dark brown, fine sand and silt
IV	Reddish brown with purple tint, fine to medium sand. Contains abundant charcoal and patches of organics (leaf matting)
V	Dark brown, fine sand and silt. Contains high concentration of charcoal bits
VI	Light reddish brown, medium sand
VII	Brown, medium sand with pebbles ranging 5 to 20 centimeters.

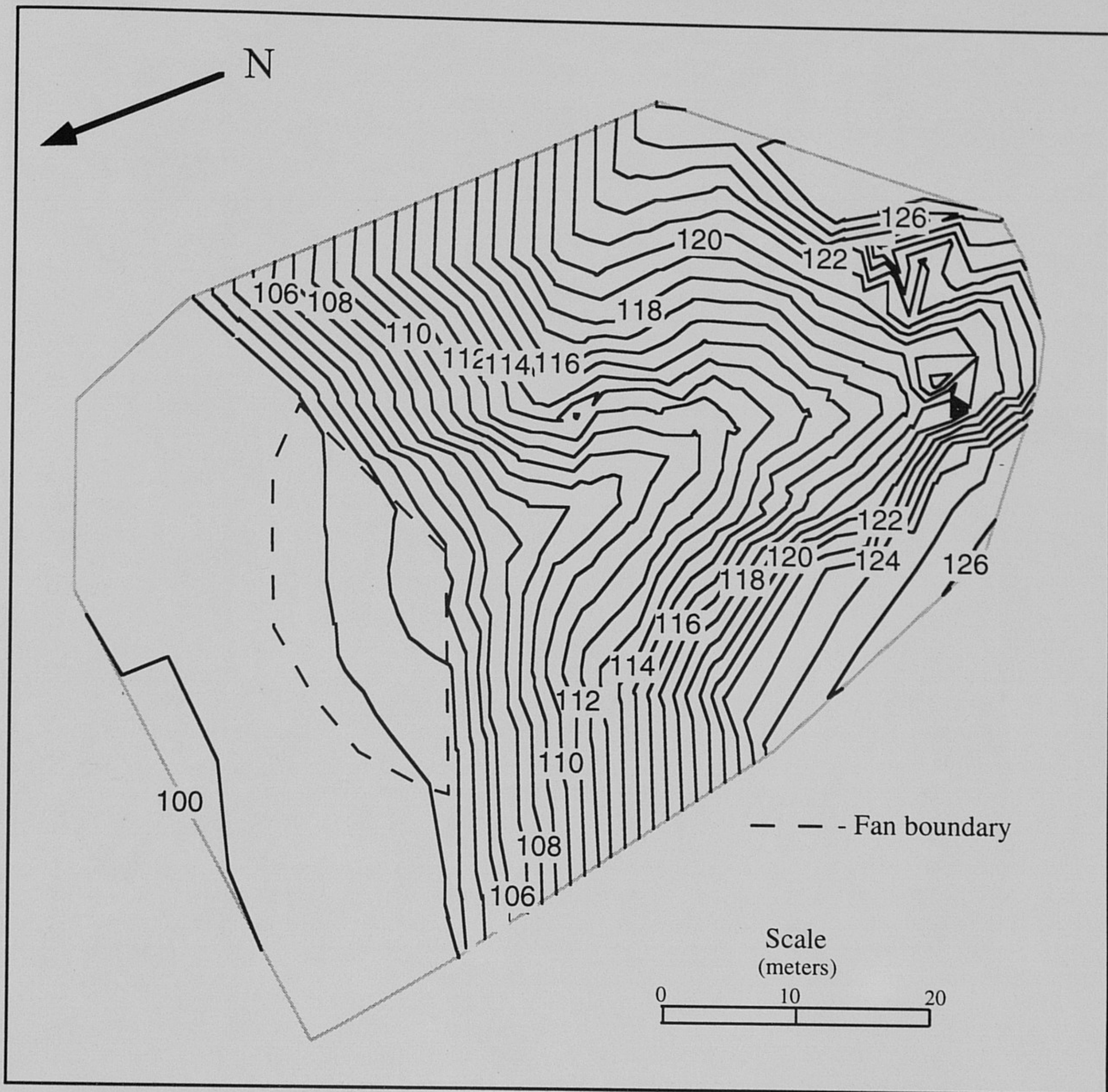

Figure 29. Contour map of fan #13 with elevations relative to an arbitrary benchmark. The fan is 320 sq m in area and contains approximately 1650 cu m of sediment.