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CHAPTER 6

THE LOWER ACHERON RIVER VALLEY: ANCIENT ACCOUNTS AND THE CHANGING LANDSCAPE

by Mark R. Besonen, George (Rip) Rapp, and Zhichun Jing

INTRODUCTION

Recognizing that the earth's coastal systems have undergone profound change since the end of the Pleistocene (about 10,000 years ago), the Nikopolis Project set as one of its objectives the interpretation and understanding of the changing geomorphology, topography, and paleoenvironments in the lower Acheron River valley from the middle Holocene through the present (Fig. 6.1).[1] Archaeological remains in the valley are abundant, and literary and historical references go back at least to the 8th century B.C., when Homer and his contemporaries considered the Acheron to be an infernal river and held that the valley was an entrance to the Underworld (*Od.* 10.508–515).

Various other ancient literary and historical sources also make reference to the valley, and provide details of a landscape configuration that is inconsistent with the current physiography. The inconsistencies pose a problem for archaeologists trying to equate ruins in the valley with particular settlements mentioned in ancient accounts. Are these ancient authors mistaken in their descriptions of the valley, or can a natural sequence of landscape evolution account for these discrepancies? There are three conspicuous inconsistencies whose explanation and resolution have provided a focus for this component of the Nikopolis Project: 1) the size of the Glykys Limen (modern Phanari Bay); 2) the nature, geometry, and evolution of the Acherousian lake; and 3) the course of the Acheron River with respect to Kastri during the classical period.

THE SIZE OF THE GLYKYS LIMEN (MODERN PHANARI BAY)

The small marine harbor located at the mouth of the Acheron River is known today as Phanari Bay (Fig. 6.2). Well protected by a series of high limestone cliffs, and continuously flushed out by the high discharge of the Acheron River and its tributaries, the bay has characteristics that make for an ideal marine harbor. Unfortunately, it is very small, measuring only 700 x 350 m, with a depth of less than 10 m. In ancient times, the embayment

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[1] This chapter is summarized and updated from Besonen 1997, a Masters thesis completed by the senior author at the University of Minnesota, Duluth. An electronic version of Besonen 1997 in Adobe Acrobat PDF format is freely available over the Internet at http://www.paleoenvironment.org, or by requesting a copy from the author via e-mail (besonen@geo.umass.edu).

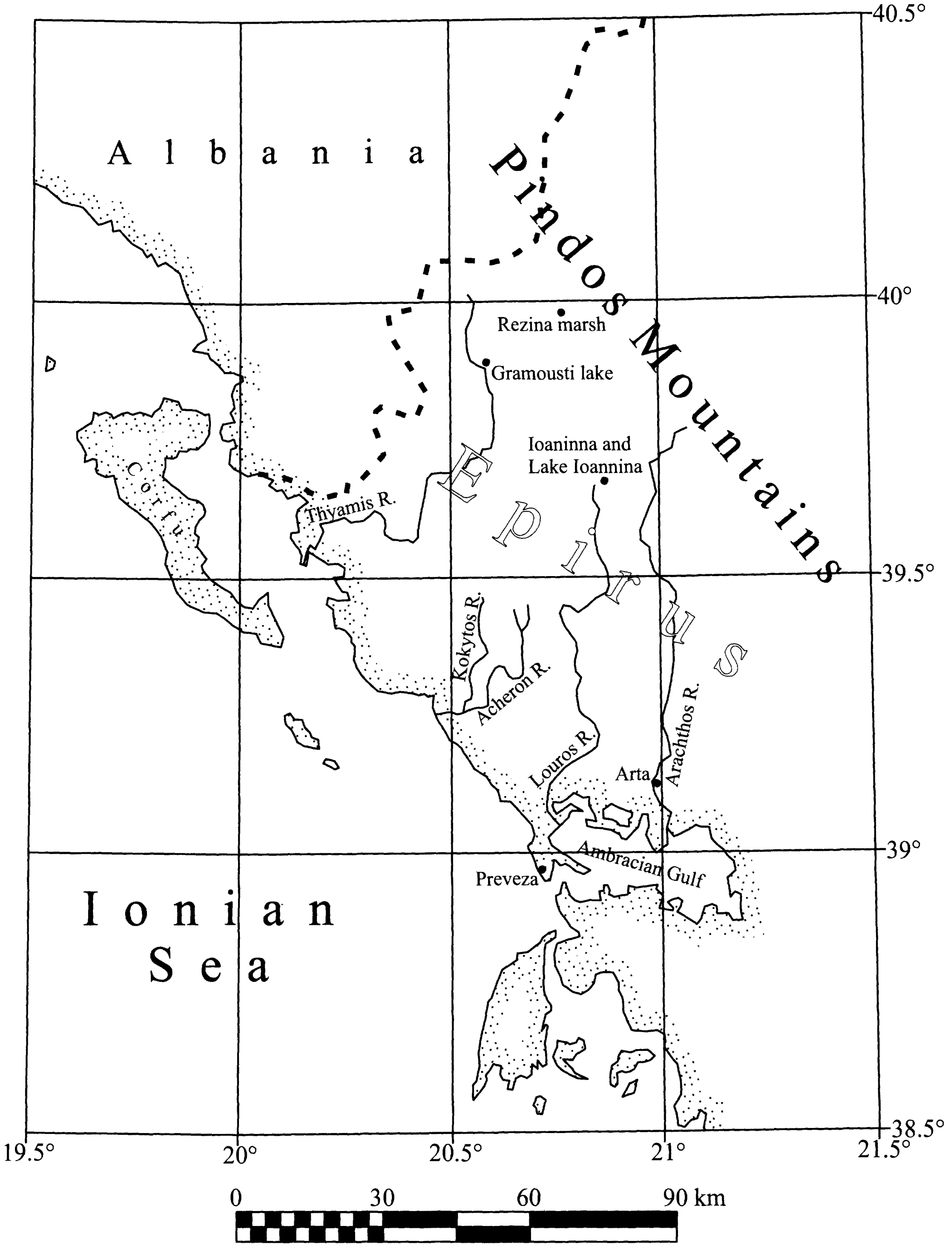

Figure 6.1. Area map of Epirus

was known as the Glykys Limen ("Sweet Harbor"). According to the Greek geographer and historian Strabo (7.7.5 [C 324]), who lived through A.D. 21, this was because the influx of fresh water from the Acheron and its tributaries caused a dilution of the marine water filling the bay.

Strabo's account is not singular; many other ancient authors also mention the Glykys Limen, indicating that it was a well-known feature along the Epirote coastline. Three of these authors provide evidence for a discrepancy between the ancient and modern landscape: while the modern harbor is quite small, the ancient harbor was apparently quite large. The late-5th-century B.C. Greek historian Thucydides (1.46.1–5) wrote in his

Figure 6.2. Area map of the lower Acheron valley

history of the Peloponnesian War that the Corinthians and their allies anchored 150 of their ships in the Glykys Limen before the Battle of Sybota in 433 B.C. Dio Cassius (50.12.2), another Greek historian and Roman official of the 2nd and 3rd centuries A.C., reported that in the summer of 31 B.C., Octavian moored 250 of his ships in the harbor a few days before his confrontation with Mark Anthony and Cleopatra in the Battle of Actium. Finally, Anna Komnena (*Alexiad* 4.3) recorded in the 12th century A.C. that in A.D. 1081/1082, nearly 1,100 years after the Battle of Actium, the Norman Robert Guiscard and his large fleet wintered over at the Acheron delta. Modern Phanari Bay could not possibly accommodate such large naval fleets.

In his account of his travels through the region, the British historian Nicholas Hammond briefly suggested that the bay had silted up since ancient times.[2] Sotirios Dakaris, an archaeologist who did extensive work in the area, addressed the topic more thoroughly. Motivated by the accounts of Thucydides, Dio Cassius, and Anna Komnena, he supplied two further lines of geologic evidence that definitively indicate the harbor was once much larger. Dakaris noted the existence of a strip of ancient beach sand, similar to the white sand beach that surrounds Phanari Bay today, ca. 1.5 km east (inland) of the village of Ammoudia (Fig. 6.3).[3] This strip of sand, in conjunction with "a boring near the confluence of the Cocytus and the Acheron [that] brought to light a layer of sand with sea shells at a depth of 17.5 m from the present surface,"[4] provides unequivocal geologic evidence

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[2] Hammond 1967, p. 69.
[3] Dakaris 1971, p. 5.
[4] Dakaris 1971, p. 5.

Figure 6.3. View of concentric accretionary beach ridges surrounding Phanari Bay, looking south. This photograph was taken from the bedrock highlands on the north side of the valley; see Figure 6.2 for the location of the observation point. The Acheron River is delineated by the faint dark band of trees visible in the background. Photo M. Besonen

that the Glykys Limen formerly extended further inland at some unknown point in time.

Dakaris's observations are significant, but they lack chronological control and thus cannot be used to verify the accuracy of the ancient literary and historical accounts. They provide only a snapshot of the landscape configuration at an unknown moment in time, and do not afford the archaeologist an understanding of the changing landscape. Therefore, our first objective was to develop a detailed picture and absolute chronology for the evolution of the Glykys Limen.

THE NATURE, GEOMETRY, AND EVOLUTION OF THE ACHEROUSIAN LAKE

A second significant discrepancy between ancient references to the valley and the observable modern landscape concerns the nature, geometry, and evolution of the extinct Acherousian lake (Fig. 6.4). The existence of the lake is not in question, for its final swampy remnants persisted until just after the First World War, at which time they were drained and backfilled for agriculture.[5] During Greek and Roman times, the lake was apparently a conspicuous feature given that many authors make reference to it (Thuc. 1.46.3–4; Pseudo-Scylax 30; Strab. 7.7.5 [C 324]; Plin., *HN* 4.1.4; Livy 8.24; Paus. 1.17.5). By medieval times, it was referred to as the Acherousian swamp, apparently reflecting a natural infilling.[6] Though the number of references to the lake-swamp is significant, few provide any detailed topographic information that is useful in determining its location and nature.

Several modern authors have considered the existence of the lake in the valley. William Leake, who traveled through the region in 1809, left a fairly detailed description of the marshy valley bottom with its few, shallow, isolated pools.[7] He concluded that the marsh-lake present below the hill of Kastri was the Acherousian swamp known from antiquity, seemingly not considering the possibility that it might previously have had a different nature or proportions (Fig. 6.4, upper left). Alfred Philippson and Ernst Kirsten presented a different scenario in their survey of the Greek landscape, suggesting that the swampy, marshy ground which rep-

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[5] Hammond 1967, p. 68.

[6] Hammond 1967; Dakaris 1971.

[7] Leake 1835, I, p. 232; IV, pp. 51–54.

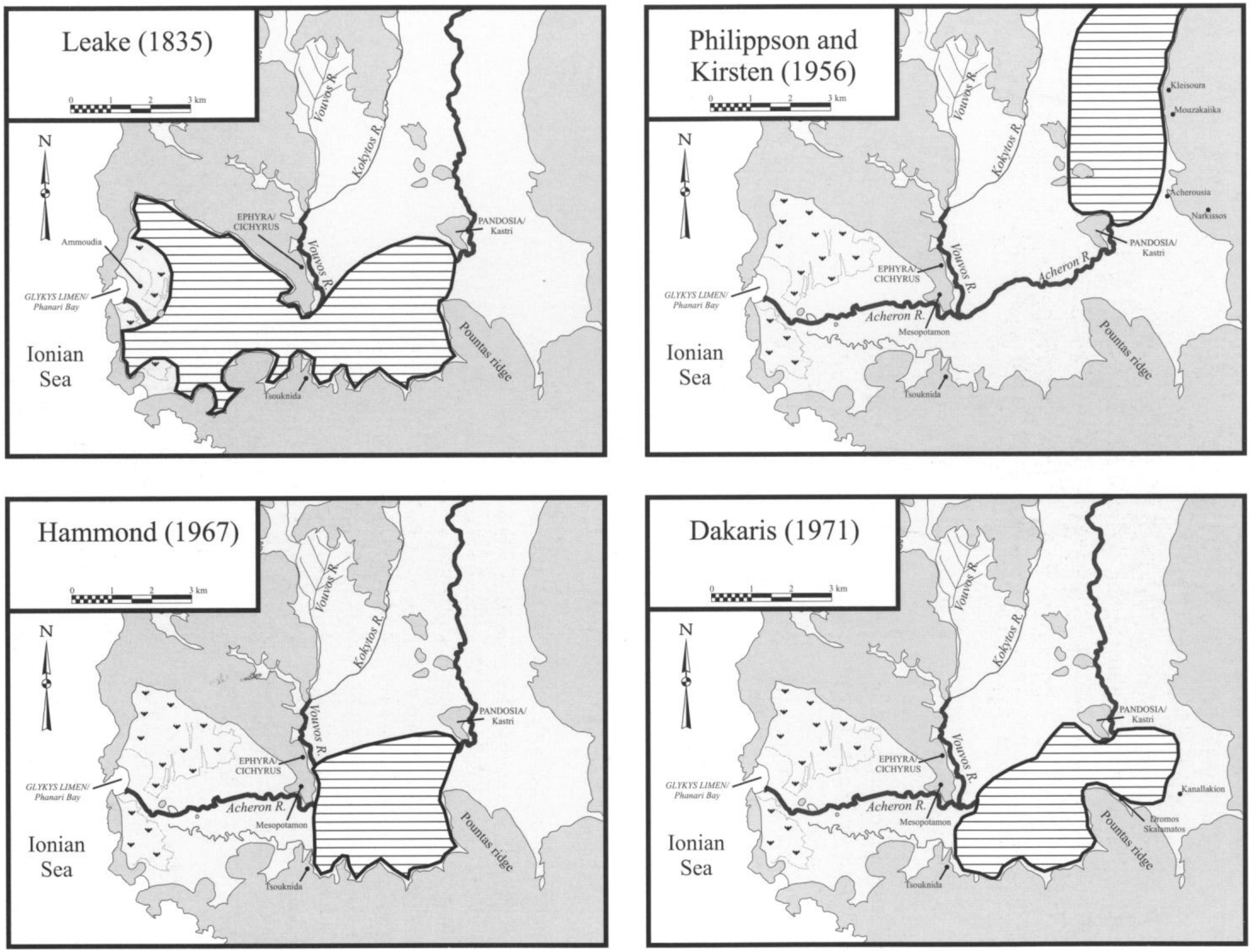

Figure 6.4. Suggested locations of the Acherousian lake in the lower Acheron valley

resented the lake had expanded areally, but become shallower, since ancient times.[8] One of their maps shows a dotted outline of what is presumably the Acherousian lake (the Acheron River enters one side and exits the other). This lake stretches north from Kastri up the valley almost to the point where the Acheron River exits from the bedrock uplands that bound the valley to the east (Fig. 6.4, upper right).

By the time Hammond passed through the valley in the middle of the 20th century, the final remnants of the lake had been filled in. He indicated more definitive boundaries for the Acherousian lake based on ancient literary and historical references, the descriptions of Leake, and some earlier work by Dakaris.[9] The boundaries he indicated are the Mesopotamon/Tsouknida valley constriction to the west, the bedrock highlands to the south, and the Pountas ridge and Kastri to the east (Fig. 6.4, lower left).

Dakaris presented the most careful consideration of the subject, basing his theory on ancient literary and historical references as well as his own observations. His reconstruction of the lake's size and location is similar to that given by Hammond, but he extended the eastern boundary of the lake past the Pountas ridge and Kastri toward Kanallakion (Fig. 6.4, lower right).[10] The basis for this eastward extension was the chance find of ten wooden beams during the excavation of a drainage canal east of Pountas ridge and southwest of Kanallakion. Dakaris interpreted these beams as part of the keel of an ancient boat that had once plied the lake; he also noted that a spot on the eastern side of Pountas ridge is still referred to as "Dromos Skalamatos," which means "port" or "place of embarkation" (Fig. 6.2).[11]

Dakaris, Hammond, and others based their reconstructions primarily on indirect evidence, but were also greatly influenced by their observations of the modern landscape in the valley. Their reconstructions overestimate the size of the lake at least as an open body of water, and lack definitive chronological control. They provide no information about the lake during pre-classical times, an item of interest to the Nikopolis Project. A complete and detailed chronology of the lake's development and evolution based on geologic evidence has never been prepared. Particularly important issues to resolve include when the lake came into existence, the mechanism by which this occurred, the nature of the lake, and its geometry and dimensions through time. These questions framed our second objective.

THE COURSE OF THE ACHERON RIVER WITH RESPECT TO KASTRI DURING THE CLASSICAL PERIOD

The course of the Acheron River, like that of most rivers in their lower stretches, is constantly shifting. Our third objective was to determine the location of the course of the Acheron River with respect to the hillock Kastri during the first millennium B.C. (Fig. 6.2). This is particularly important to help resolve the long-standing problem of identifying the ruins on that hillock with those of Pandosia, a fortified urban settlement often referenced in ancient literary and historical sources (Dem. 7.32; Justin 12.2; Livy 8.24; Plin. *HN* 4.1.4; Strab. 7.7.5 [C 324]). The major discrepancy

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[8] Philippson and Kirsten 1956, II, p. 105.

[9] Hammond 1967, p. 69.

[10] Dakaris 1971, pp. 4–5 and fig. 7.

[11] Dakaris 1971, p. 57.

frustrating this identification has been that Kastri is located to the north of the Acheron River, but ancient sources indicate Pandosia was located to its south (Dem. 7.32; Strab. 7.7.5 [C 324]); hence the difficulty in equating the two.

In ancient times, the Acheron River served as a political boundary dividing the territory of Thesprotia to the north from the territory of Cassopaia to the south (Fig. 6.2). Ancient sources indicate that, in addition to Pandosia, a fortified urban settlement named Ephyra also existed in the valley. Geographic references situate Ephyra north of the Acheron River in the territory of Thesprotia, close to the sea, and near the Acherousian lake (Paus. 1.17.4-5; Strab. 7.7.5 [C 324]; Thuc. 1.46.4). Pandosia, in turn, was located further inland, and within the territory of Cassopaia (Dem. 7.32; Strab. 7.7.5 [C 324]).

Besides the ruins at Kastri, the remains of a second fortified urban settlement can be found in the valley today. This second site is located just north of Mesopotamon on the ridge known as Xylokastro (Fig. 6.2). Since the Xylokastro site is closer to the sea, and the Kastri site is further inland, one might immediately suggest the first site should be identified with Ephyra, and the second site with Pandosia. Combined with simple differences of opinion, however, the issue of the river course has prevented consensus about the identification of the ruins in the valley. For example, Hammond did not consider the Kastri/Pandosia identification as appropriate, suggesting instead that the ruins at Gourana, much further upvalley, were actually those of Pandosia.[12] Dakaris did prefer the Kastri/Pandosia identification, and he reconciled the issue of the river course by suggesting that the river had shifted since ancient times.

> Wherever the river banks are not supported, or when the river overflows, it could result in a change in course. . . . The slight inclination of the Acheron plain, the swamps, and the lake, formed by the river to the south of Kastri hill, contributed to the change in the river bed, which, in ancient times, had the hill with the ruins to its south, at *[sic]* Cassopaia.[13]

While Dakaris's suggestions concerning the dynamic nature of the river course are correct, he did not provide any geologic evidence to show that the river had indeed shifted its course from the northern to the southern side of Kastri since the first millennium B.C. Hence, our third objective was to examine the changing course of the Acheron River with respect to Kastri during the past 2,000 years, and either confirm or deny the shift proposed by Dakaris.

GEOLOGY AND THE NEOTECTONICS OF THE ACHERON VALLEY AREA

Jean Aubouin presented two detailed studies interpreting the stratigraphy and tectonics of Epirus which have served as the foundation for subsequent work.[14] These studies were followed by *Étude géologique*,[15] another major monograph on the geology of Epirus, which resulted from petro-

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[12] Hammond 1967, p. 478.

[13] Dakaris 1971, pp. 136–137.

[14] Aubouin 1959 and 1965.

[15] *Étude géologique*.

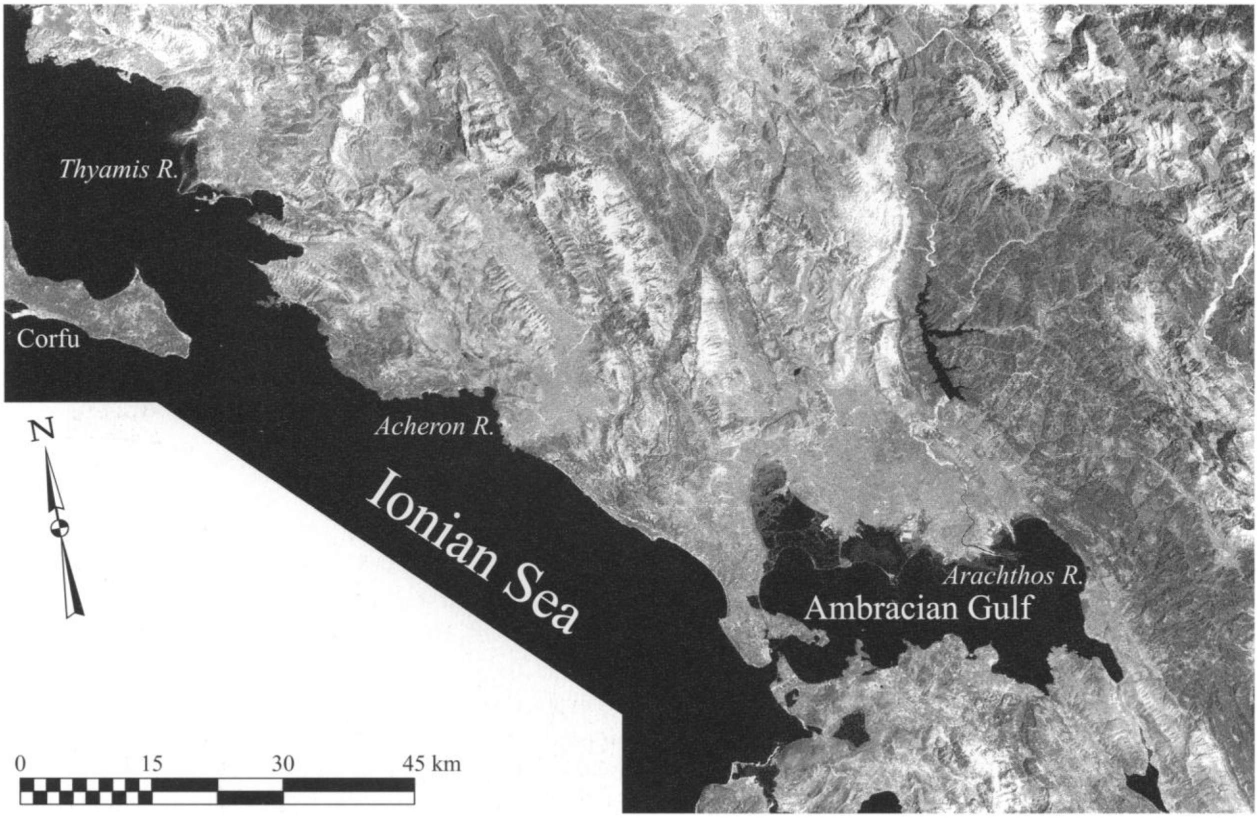

Figure 6.5. Satellite image of Epirus. North of the Acheron valley, the structural configuration of the region is delineated by a series of parallel limestone mountain ranges (trending north-northwest to south-southeast) with intervening flysch basins. Note the elongate geometry of the Thyamis and Arachthos river deltas with fringing delta top/front "barrier" beaches.

leum exploration work. The major features of the landscape of Epirus are structural in origin. The region consists of a series of north-northwest/south-southeast trending folds and thrust fault blocks that have been formed in a sequence of compressional orogenic events since the Late Jurassic period.[16] These folds and fault blocks form a series of parallel limestone mountain ranges with intervening flysch basins that can be delineated in a satellite image of the region (Fig. 6.5). Some of the ranges reach over 2,000 m in elevation, but on average range from 1,200 to 1,700 m.[17] The marked and varied relief noted between the ranges and basins is a direct function of the structure and contrasting lithologic properties of the limestone and flysch.[18] Relief is even more spectacular along the coasts, where bedrock cliffs rise directly from the sea, or very flat coastal river plains give way in abrupt topographic discontinuity to carbonate bedrock valley walls.

A map of the simplified geology of the lower Acheron valley is shown in Figure 6.6. Recent alluvium floors the flat valley bottom, which is flanked by the steep, carbonate bedrock valley walls. These valley walls are composed, for the most part, of Mesozoic and some Eocene limestones. The limestones are cherty, range from fine-grained to sublithographic, are usually fossiliferous (with the remains of calcareous algae, radiolarians, rudist clams, ammonite cephalopods, and globigerinid and other foraminifera), and in places are dolomitized and/or brecciated. Upper Eocene to Lower Miocene (Aquitanien) flysch crops out at the base of the eastern valley wall. The flysch is composed primarily of alternating soft micaceous sandstones and shales with intercalated, thinly bedded biogenic limestones and

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[16] *Étude géologique.*

[17] King, Sturdy, and Whitney 1993.

[18] *Étude géologique.*

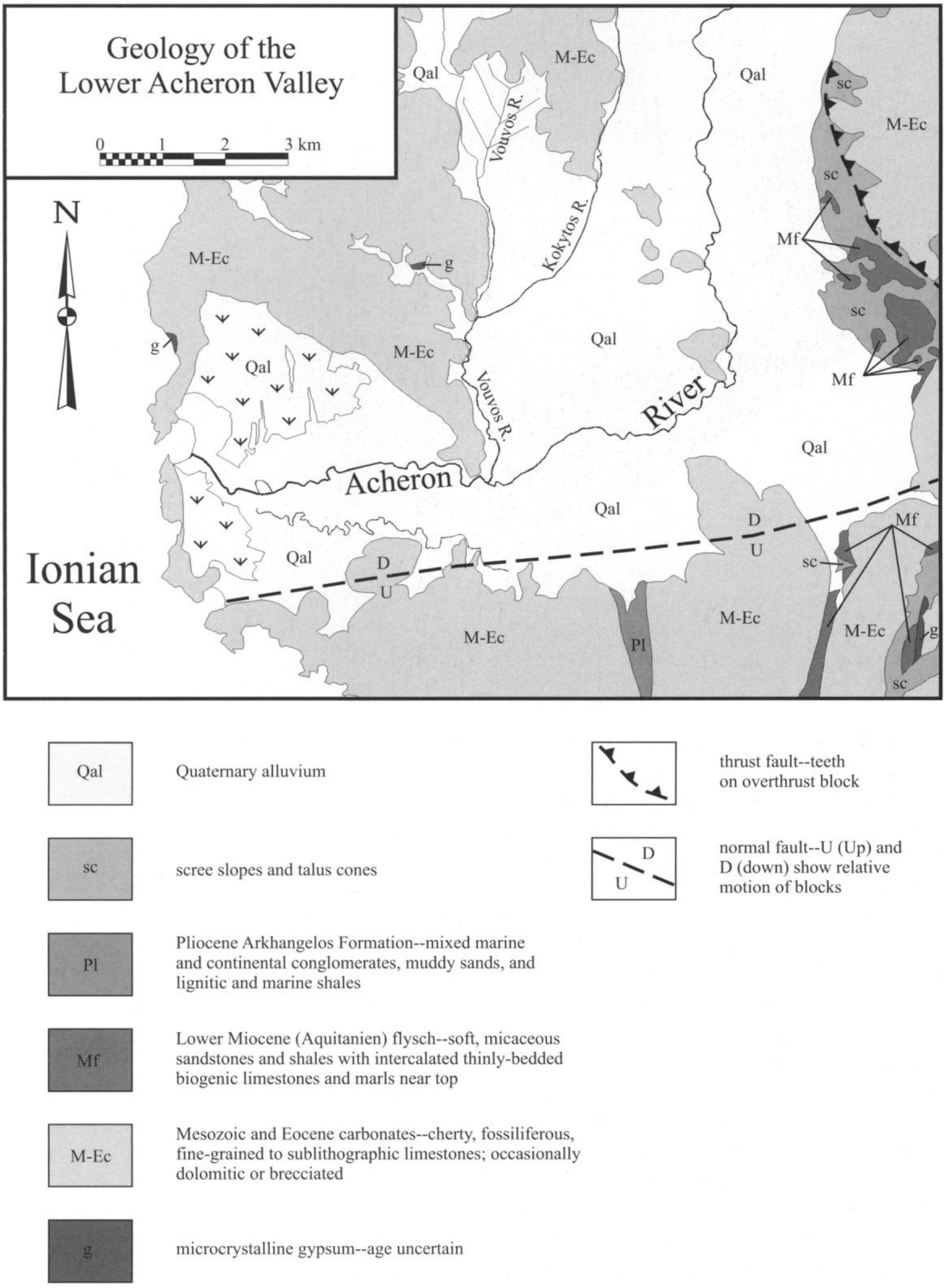

Figure 6.6. Simplified geology of the lower Acheron valley

marls near the top. The top of this flysch unit effectively marks a large shallow thrust fault over which the more competent Mesozoic limestone has ridden to create one of the limestone ranges seen in Figure 6.5. Recent talus and scree slopes cover the contact and most of the flysch unit. A small strip of the Pliocene Arkhangelos Formation crops out in the southern valley wall to the east of Pountas ridge. This formation is a mixed marine and continental unit that consists of conglomerates, muddy sands, and lignitic and marine shales. Finally, an inferred active, east/west-trending normal fault exists along the south valley wall,[19] though this fault was not recognized by earlier work.[20]

While *Étude géologique* is comprehensive through the Pliocene, the tectonic history of the Pleistocene and more recent periods was not included. Fortunately, a recent dissertation by David Waters fills the gap.[21] Waters provides an inventory of geologic evidence (e.g., incised river gorges, wave-cut notches, and raised shell burrows) that suggests mainland Epirus and much of the coast has been undergoing uplift since the Pliocene. At the same time, the evidence suggests that certain areas, such as the Ambracian Gulf, lower Acheron valley, and lower Thyamis valley (Figs. 6.1, 6.5), are subsiding; very thick deposits of Quaternary sediments are found at these locations. Subsidence also seems to be occurring along the northwest coast of the mainland opposite Corfu, a process indicated by the steep, rocky shorelines (with numerous small coves and islets) and the lack of beach platforms.[22]

Waters attributes modern subsidence of the lower Acheron valley bottom to movement on the inferred active normal fault along the southern valley wall (hanging wall to the north) (Fig. 6.6).[23] The existence of this fault would make the valley configuration that of a half-graben, though Waters never explicitly describes it as such. While the alluvial valley bottom appears to be subsiding, there is some evidence to indicate uplift of the carbonate valley walls; Waters identified a wave-cut platform, 1.7 masl, on the north side of Phanari Bay.

HOLOCENE RELATIVE SEA LEVEL IN THE REGION OF EPIRUS

Coastal evolution is intimately tied to relative sea level, itself determined by eustatic sea-level changes, isostasy, and vertical tectonic movements. A record of relative sea-level change for a particular region must be compiled from local evidence. A relative sea-level curve for the southwestern Epirote coast is shown in Figure 3.24. Particularly important to note is that, during the last 5,000 years, relative sea-level rise along the southwestern Epirote coast has been less than 2 m. The rate of sedimentation at river mouths, however, has been much greater. A significant implication of this relationship is that the physical sedimentology and microfossil assemblages contained in the stratigraphy are more important indicators for reconstructing shoreline position than the local sea-level curve.

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[19] Waters 1994, figs. 5.7, 5.10.
[20] Cf. *Étude géologique*.
[21] Waters 1994.
[22] Waters 1994, p. 197.
[23] Waters 1994, figs. 5.7, 5.10.

FIELD AND LABORATORY METHODS

Twenty-eight sediment cores were retrieved from various points in the lower Acheron valley during summer field seasons from 1992 to 1994 (Fig. 6.7; Appendix). All cores were retrieved by a hand-operated, 3 cm diameter Eijkelkamp gouge auger with the exception of cores 94-02 and 94-03, which were taken with a 7 cm diameter Edelman auger bit. Cores were described and logged on site using terminology following Folk.[24] Field-observable parameters that were recorded include lithology and approximate grain-size distribution, color when wet,[25] sediment consistency, plant and animal macrofossils, pedogenic characteristics (structure, sesquisoxide/reduction mottling, and calcium carbonate filaments or nodules), and chance finds such as pottery fragments. Sediment samples were collected for laboratory analysis in the U.S. with approximately 300 taken during the 1994 field season, and a much smaller number during the 1992 and 1993 seasons.

Laboratory analyses were focused mostly on sediment samples from the 1994 season. All 1994 samples were analyzed for dual-frequency magnetic susceptibility and anhysteretic magnetization along their length using facilities at the Limnologic Research Center and Institute for Rock Magnetism at the University of Minnesota,Twin Cities. Microfossil assemblages were determined in fifty samples, from ten different cores, all but one of which was collected during the 1994 season. In most cases, the total microfossil population, including ostracods, foraminifera, gastropods, pelecypods, and charophyte oogonia, was picked and identified. Relative percentages of fresh and brackish water microfossils were calculated from species counts to provide an approximation of the salinity of the environment of deposition. Eight cores from the 1994 season were analyzed along their length for organic carbon and carbonate using the method of Dean.[26] Grain-size distribution by pipette analysis was determined for twenty-three samples using the method of Folk[27] to supplement the field-based approximation of grain size. Eight samples of organic material were radiocarbon dated by the accelerator mass spectrometer (AMS) method at either the Radiocarbon Laboratory at the University of California, Riverside, or Beta Analytic Laboratories Inc. of Miami, Florida (Table 6.1).

Results from field observations and laboratory analyses were examined together to determine the probable environments of deposition for each lithostratigraphic unit. A summary of these data for each sediment core can be found in the appendix to this chapter, with the full complement of primary data available in Besonen 1997. A study of early maps of the area, as well as literary and historical references by both ancient and more recent authors (in particular, Homer, Thucydides, Strabo, Anna Komnena, and Leake), was undertaken to supplement and provide a context for the geological data. Finally, three cross sections through the valley were drawn (see Figs. 6.9–6.11), and reconstructions showing the evolution of the landscape in the valley at eight points in time during the past 5,000 years were constructed (see Figs. 6.12–6.15).

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[24] Folk 1980.

[25] Colors were described using the Munsell Soil Color Chart (rev. ed. 1994).

[26] Dean 1974.

[27] Folk 1980.

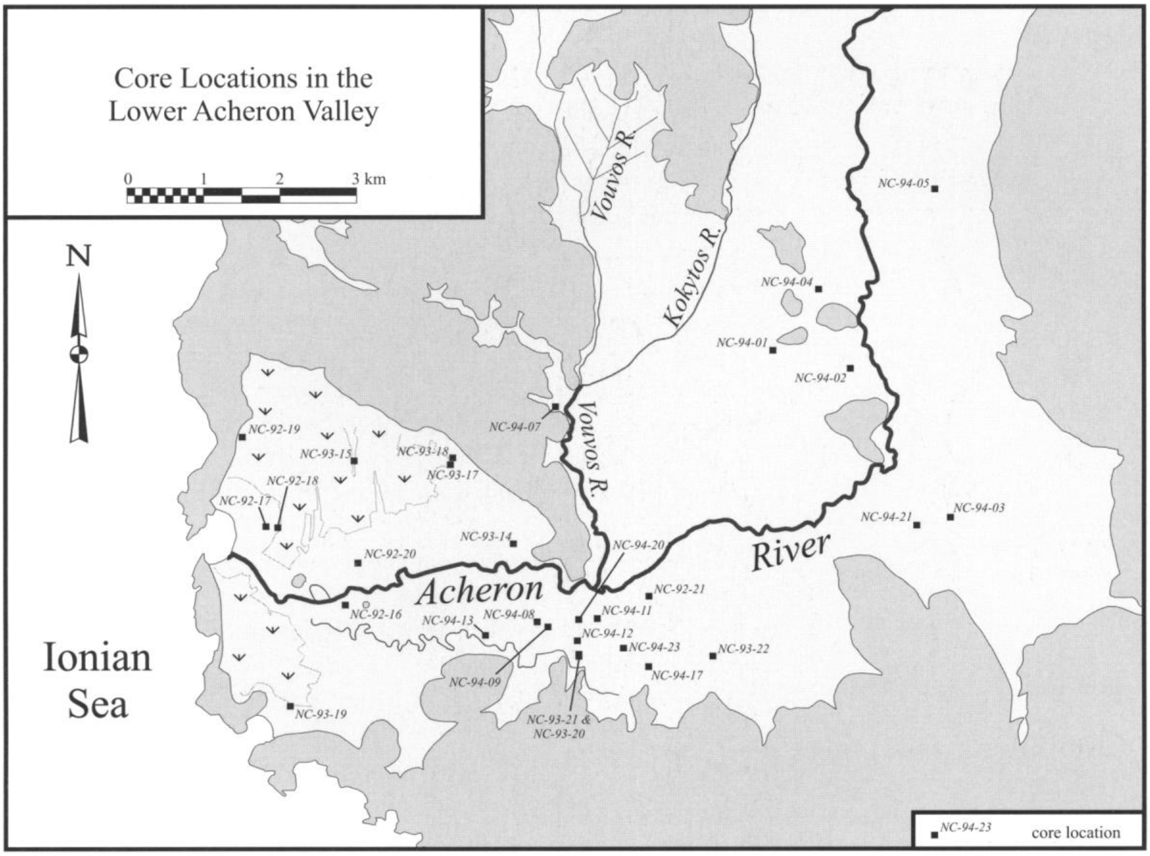

Figure 6.7. Core locations in the lower Acheron valley

TABLE 6.1. RADIOCARBON DATES FROM THE ACHERON RIVER VALLEY

Lab No.[a]	*Core*	*Depth below Surface (m)*	*Material*	$^{13}C/^{12}C$ *Ratio*	*Conventional* ^{14}C *Age (B.P.)*	*Calibrated Age (B.P.)*[b]
UCR-3217	NC92-20	5.30–5.40	charcoal, root fragments	n/a	2470 ± 60	2650 +70/-290
UCR-2695	NC93-18	0.70–0.75	peat with organic material	-27.18‰	2890 ± 40	2980 +90/-30
UCR-2696	NC93-19	7.00–7.20	peat with wood fragments	-20.36‰	4520 ± 60	5140 +160/-100
UCR-2697	NC93-21	5.80–6.10	peat with organic material	-28.24‰	3460 ± 60	3690 +140/-60
Beta-80531	NC94-04	2.95–3.00	wood	-26.0‰	340 ± 50	380 +90/-70
Beta-80532	NC94-13	5.35–5.40	plant material	-23.3‰	950 ± 50	850 +80/-60
Beta-80533	NC94-20	6.05–6.20	wood	-39.9‰	1740 ± 60	1670 +40/-120
Beta-80534	NC94-23	10.35–10.55	plant material	-27.0‰	3700 ± 60	4030 ±100

[a] Dating laboratory: UCR = University of California, Riverside; Beta = Beta Analytic Laboratories Inc. of Miami, Florida.

[b] Calibration from conventional ^{14}C age to calendar years was performed using the CALIB Rev. 3.0.3c computer program available from M. Stuiver and P. Reimer of the Quaternary Research Center at the University of Washington, Seattle. All options were set at their default values. The data set used to make the calibrations was the INT93CAL bidecadal dendrochronologic calibration curve. A decadal calibration is also available, but is meant for use with high-precision dates ($\sigma \leq 40$ years).

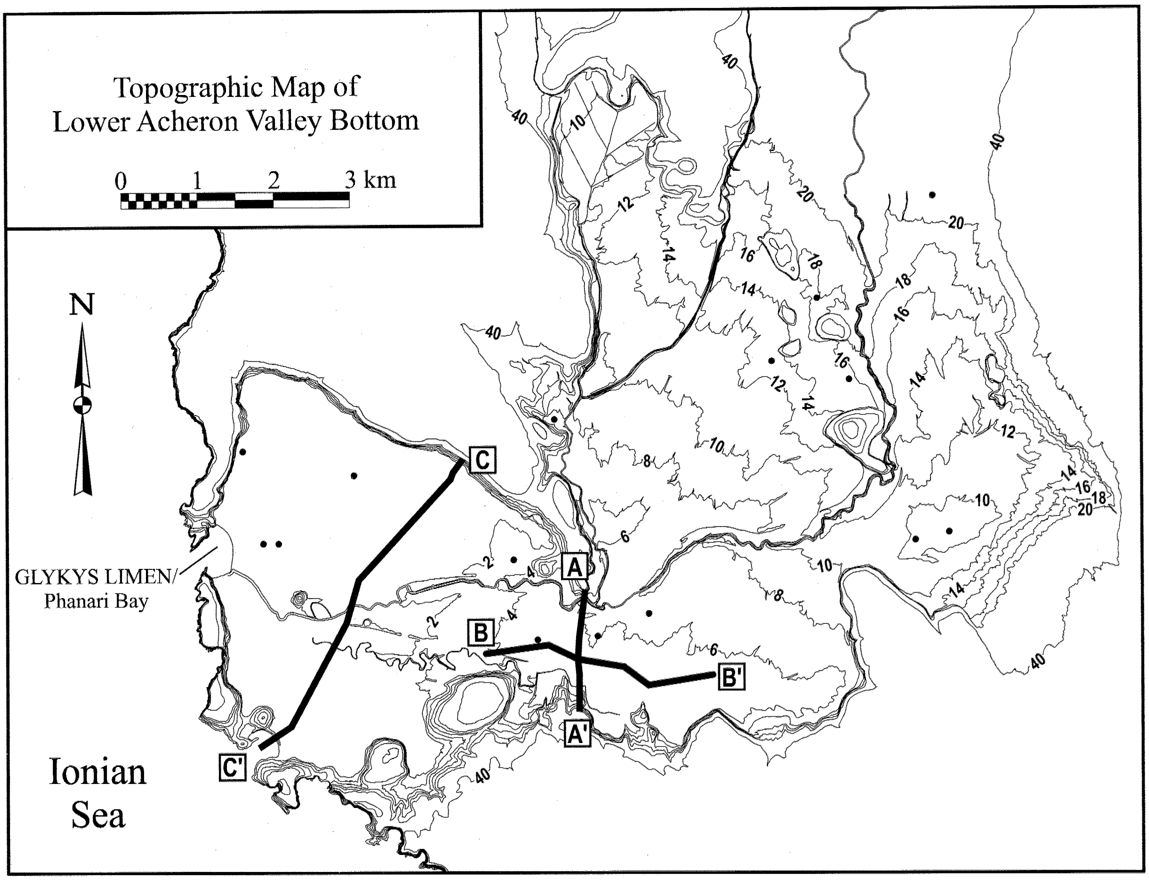

Figure 6.8. Topographic map of the lower Acheron valley bottom. Contour lines may not be continuous at valley edges where they are compressed. Sediment core locations are marked by black dots; see Figure 6.7 for labels. Heavy black lines show the locations of cross sections illustrated in Figures 6.9, 6.10, and 6.11.

Topographic control for all elevations cited in this study was provided by detailed 1:5,000 topographic maps produced by IGME (the Greek Institute of Geology and Mineral Exploration) in 1981. These maps are contoured at 1-m intervals over the flat valley bottom, but shift to 4-m intervals for the steep bedrock valley walls. The maps also record hundreds of individually surveyed point elevations throughout the valley bottom where topography is slight. Figure 6.8 presents a very reduced set of this topographic data, contoured at 2-m intervals to simplify presentation.

MICROFOSSIL ASSEMBLAGES AND RELATED ECOLOGY

Ostracoda and foraminifera have been used with great success as indicators of paleoenvironments in marginal marine systems because they are extremely sensitive to salinity and temperature, among other factors.[28] We examined the microfossil assemblages in fifty sediment samples, paying particular attention to ostracods and foraminifera for paleosalinity information. Identification of the ostracods was achieved down to the species level for twenty-four forms, down to the genus level for one form, and left undetermined for one form. Identification of the foraminifera was less rigorous: down to the species level for three forms, to the genus level for four forms, and to the family level for one larger, well-known group.

[28] Neale 1964; Phleger 1960.

Reference works based generally on Mediterranean localities or similar marginal marine settings were used to identify the microfossils and to gather information about their ecologic and environmental preferences.[29] This allowed us to define two microfossil assemblages indicative of paleoenvironments with differing salinities. The first microfossil assemblage is characteristic of shallow, freshwater environments, while the second assemblage is indicative of shallow, nearshore, brackish to marine waterconditions. Microfossil identifications and paleoecological interpretations based on the assemblages were later confirmed and corrected by micropaleontologist Frederick Swain of the University of Minnesota, Twin Cities.[30]

Whereas microfossils were sparse or absent in some freshwater samples, all shallow, nearshore brackish to marine sediments showed high total abundances. Certain forms were present in nearly all samples from brackish to marine deposits, and in some cases occurred in extreme abundance.

The shallow, freshwater assemblage is comprised of fourteen ostracod species: *Candona albicans*, *Candona* cf. *caudata*, *Candona compressa*, *Candona* cf. *lactea*, *Candona neglecta*, *Candona truncata*, *Cyclocypris* cf. *laevis*, *Darwinula stevensoni*, *Herpetocypris* cf. *reptans*, *Ilyocypris gibba*, *Limnocythere* cf. *inopinata*, *Limnocythere* sp., *Potamocypris* cf. *villosa*, and Ostracod sp. A (possibly *Prionocypris zenkeri)*.

Twelve ostracod species and a series of foraminifera characterize the shallow, nearshore, brackish to marine water assemblage: *Cushmanidea elongata*, *Cyprideis torosa*, *Cytheridea neapolitana*, *Cytheridea* cf. *sorbyana*, *Cytheromorpha fuscata*, *Leptocythere bacescoi*, *Leptocythere* cf. *castanea*, *Loxoconcha elliptica*, *Loxoconcha* cf. *granulata*, *Loxoconcha ovulata*, *Paracytherois* cf. *acuminata*, and *Tyrrhenocythere amnicola*. The foraminifera in the assemblage include *Ammonia beccarii*, *Bolivina* sp., *Bulimina* sp., *Cribrononion translucens*, *Elphidium crispum*, *Fursenkoina* sp., and members of the family *Miliolidae* (including several *Quinqueloculina* spp. and *Triloculina* sp.).

While mixing of fresh and brackish to marine assemblages may be significant, especially in regions with large tidal fluxes,[31] it was minimal in the sediment samples from the Acheron valley. This is not unexpected given the small tidal variation (20 cm) in the region. Cathleen Villas noted some mixing of marine microfossils in the freshwater environments of the Acheloos delta, just 150 km to the south of the Acheron valley,[32] but the Acheloos delta plain is totally unprotected and experiences the unbuffered assault of storm waves. This is not an issue in the Acheron valley where Phanari Bay is enclosed and well sheltered by the large carbonate cliffs.

SEDIMENTOLOGY AND ENVIRONMENTS OF DEPOSITION

The modern sedimentary environments in the lower Acheron River valley are very similar to those found at other spots along the Greek coast.[33] For simplicity, we divide them into two broad depositional systems. The first system, herein referred to as the fluvial depositional system, consists of all the sedimentary environments landward of the shoreline. Six distinct environments can be identified: river channel, natural levee, crevasse splay,

[29] Ascoli 1964; Bhatia 1968; Devoto 1965; Ellis and Messina 1952–2000; Puri, Bonaduce, and Gervasio 1969; Puri, Bonaduce, and Malloy 1964; Sars 1928; Tassos 1975; Tziavos 1977; Villas 1983; Wagner 1957; Yang 1982.

[30] A complete summary of this work, including scanning electron microscope plates of the microfossils encountered in the Acheron valley, is freely available online; see note 1 regarding the availability of Besonen 1997.

[31] Kilenyi 1969.

[32] Villas 1983, p. 54.

[33] Tziavos 1977; Villas 1983.

floodplain, backswamp, and shallow freshwater lake. The second depositional system is a deltaic nearshore association, composed of the environments located seaward of the shoreline and within the marine embayment of the Glykys Limen. Eight distinct environments can be identified in this system: fresh to brackish water delta top marsh, delta distributary channel, distributary channel mouth bar, subaqueous levee, lower delta front, prodelta, interdistributary bay, and accretionary beach.

On the modern landscape, many of these environments grade into one another laterally, making it difficult to place exact boundaries between them. This difficulty is further magnified when attempting to reconstruct paleoenvironments based on a finite number of 3-cm diameter sediment cores. However, Walther's Law of the correlation of facies[34] provides a powerful tool to interpret the subsurface stratigraphy.[35] This is especially true in a marginal marine environment like the lower Acheron valley, when work is grounded in physical sedimentology and the analysis of microfossil assemblages. What follows is a brief sedimentological and geomorphic description for each of the fourteen environments of deposition mentioned above. We begin with the environments of the fluvial depositional system, and then discuss those of the deltaic nearshore association.

River channel deposits are composed of the coarsest sediments found in the fluvial depositional system, and include lag deposits and bars that form directly in the river channel. Deposits are usually tan or buff in color, but may exhibit a reduced color if trapped in an environment such as an oxbow lake. In the lowest reaches of the valley, where the river channel and bar system grades into the deltaic environment, sands and gravels may also have a gray color. Ostracods and other microorganisms do not generally inhabit such environments, and the occasional carapaces of detrital origin that do make it to the river channel are quickly destroyed in the high-energy environment, or are diluted in the abundant clastic material. Reworked microfossils from the local bedrock occur in extreme abundance in deposits of this environment since it is the main transport agent for such material.

Subaerial natural levees are wedge-shaped ridges of sand and muddy sand that are deposited directly adjacent to a river along its length, and thin away from the river. These deposits may form significant topographic highs, and are created when coarse sediments carried overbank by a flooding river are dropped out of suspension. They are generally finer-grained than channel deposits, become increasingly fine away from the river channel, and eventually grade into floodplain or backswamp. Because these deposits are exposed subaerially, they tend to be tan to orange to brown in color, and may exhibit weak pedogenic features such as sesquisoxide mottles and nodules, and carbonate filaments and small nodules. Occasional ostracod carapaces of detrital origin and abundant reworked microfossils liberated from the local bedrock are found in these deposits. Natural levees have played a significant role as agents of geomorphic evolution in the lower Acheron valley through the middle and late Holocene, and their significance will be discussed below.

Crevasse splay deposits form during periods of exceptional flooding, when channels are cut through the natural levee system allowing water and bedload sediment to escape onto the adjacent floodplain or into

[34] Middleton 1973.

[35] See Chapter 5 for a short discussion of Walther's Law.

backswamp or interdistributary bay environments. They occur as lobe-shaped wedges of sand- to mud-sized sediment that thin away from the river channel. A modern lobe-shaped crevasse splay deposit, delineated by the 2-m contour line, can be seen in the floodplain to the southwest of ancient Ephyra (Fig. 6.8). Although these deposits are similar in composition to natural levee deposits, they can be distinguished by their geometry and by the fact that they appear as abrupt pulses of coarser sediment within the mud and silt of floodplain, backswamps, or interdistributary bays. Such deposits contain abundant reworked microfossils from the local bedrock, and relatively small amounts of organic matter.

The floodplain environment consists of the flat, low ground adjacent to a river channel and natural levee system that acts as a settling basin for fine-grained suspended sediment carried over the river's bank during flooding. Floodplain deposits consist mostly of silt and clay with occasional fine sand laminae. This environment is exposed subaerially, so its sediments tend to be tan to orange to brown in color, exhibit slight to moderate pedogenic development, and tend to be more compact and stiffer than sediments from other environments. Occasional modern ostracod carapaces of detrital origin, common fragments of terrestrial gastropod shells, and abundant reworked microfossils from the local bedrock are found in such deposits. These deposits contain moderate amounts of organic carbon.

The backswamp environment represents a transitional step between floodplain and shallow lake environments. It commonly occurs in low, poorly drained areas adjacent to the river channel or valley walls, and consists of nearly perennially saturated swampy and marshy ground. In the Acheron valley, it also occurs in the low swales between the spectacular accretionary beach ridges east and northeast of Phanari Bay (Fig. 6.3). Backswamp deposits are composed of dark gray to brown, organic-rich mud and clays, though sandy intervals may be present depending on the proximity of the river channel. In some cases, vegetation is so abundant that the backswamp is essentially a freshwater marsh, and deposits consist of peat and peaty mud. Such deposits are composed of up to 25% (by weight) organic carbon. Members of the freshwater ostracod genus *Candona* occur in common to abundant quantities in backswamp deposits, while other freshwater forms occur in lesser quantities.

Shallow freshwater lakes and pools are no longer present in the lower Acheron valley because they have been filled in for agriculture, but they occupied a significant portion of the valley bottom in the past. These lakes are commonly transitional with backswamp and marsh environments. Deposits from such lakes are generally gray in color, and extremely rich in clay-sized particles; they have a moderate organic content, ranging from 3 to 8% by weight. Microfossils present in these deposits include relatively sparse numbers of freshwater ostracods and gastropods. Microfossil abundance increases when the deposit is transitional with backswamp and marsh deposits, and this is probably the result of the greater organic content (food supply) of shallower environments. The most significant mechanism for the creation of these shallow lakes in the lower Acheron valley involves the impingement of a river channel and levee system against the bedrock valley walls, as described below. Oxbow lakes, which are very common in other coastal river plain localities,[36] are infrequent in the lower Acheron valley at the present day. The only example that currently exists is the horseshoe-shaped loop immediately north of the Acheron River, ca. 1.25 km to the east-southeast of Phanari Bay (Figs. 6.2, 6.8).

The fresh to brackish water delta top marsh is a thick accumulation of reeds and marsh grasses fringing the shoreline on the delta top, such as that which exists at present on top of the Acheron delta to the south and southeast of Phanari Bay. The marsh is situated at approximately sea level and receives input of water and sediment from the fluvial and marine systems. Deposits consist of peat and peaty mud with occasional sand layers, and are composed of up to 25% (by weight) organic matter. The microfossil assemblages in delta top marsh deposits grade upward from extremely abundant shallow brackish water forms (especially *Cyprideis torosa*, *Leptocythere* cf. *castanea*, *Loxoconcha elliptica*, *Ammonia beccarii*, and *Cribrononion translucens*) to abundant freshwater forms. This distribution of microfossils reflects its location at the transition from the marine to freshwater system during an overall regressive sedimentary regime.

The delta distributary channel, distributary mouth bar, and subaqueous levee are active delta front environments within the marine embayment where the majority of deposition and delta progradation occurs. All three environments are essentially subaqueous continuations of the subaerial fluvial channel and natural levee environments. The coarsest sediments in the system are generally sands and sandy gravels that floor the delta distributary channel. Subaqueous levees border the distributary channel and are composed mostly of sand and silt. As currents in the distributary channel lose competence, sediment is dropped out of suspension and forms a broad sandy apron around the distributary known as the distributary mouth bar. All recognized active delta front deposits from the lower Acheron valley are gray to dark gray in color; however, Villas reports that both gray and tan components exist in the subaqueous levee deposits of the Acheloos River.[37] Microfossils present in such deposits consist primarily of abundant numbers of brackish to marine water organisms, and abundant reworked microfossils from the local bedrock that were carried to the delta by the fluvial system. Deposits from these environments grade basinward into the laminated clays, muds, and fine sands of the lower delta front and prodelta, and laterally into the interdistributary bay environment.

The lower delta front and prodelta environments are located basinward of the active delta front, and act as a settling basin for suspended sediment. Deposits from both environments consist of gray to dark gray laminated clays, muds, and fine sands, but the sediments of the lower delta front are noticeably coarser since they are a distal extension of the active delta front. Deposits from these environments have a low to moderate organic carbon content (3–4% by weight), and their microfossil assemblages consist strictly of abundant brackish to marine water organisms without any freshwater forms.

The interdistributary bay is a shallow open body of water located to the side or partially behind the active delta front. At present, there are no interdistributary bays on top of the Acheron delta because Phanari Bay is almost entirely filled in, but such bays did exist in the past. Deposits from this environment are composed of gray to dark gray silts and clays that

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[36] Russell 1954; Villas 1983.

[37] Villas 1983, p. 75.

settle out of suspension, and sandy material washed in over the natural levees surrounding the fluvial distributary channels of the delta top. Crevasse splay deposits are also commonly found interbedded in deposits of interdistributary bays. Delta top marshes, which surround these bays, contribute to their moderate to high organic carbon content (4–8% by weight). Deposits from this environment also contain extremely abundant brackish to marine water microfossil assemblages, as well as reworked microfossils from the local bedrock in common to abundant quantities.

A spectacular series of concentric accretionary beach ridges and intervening swales surrounds modern Phanari Bay (Fig. 6.3). The Acheron delta top and front provide a constant source of sandy sediment that is reworked by normal wave activity, and then gently piled up over the regular wave base by spring and winter storm waves. Longshore currents that could keep the system in equilibrium by removing excess sand do not exist or are very weak because Phanari Bay is so well sheltered. As a result, these ancient beach ridges have accreted one by one, continuously decreasing the size of Phanari Bay. The sands that comprise these ridges are generally coarse-grained with occasional small pebbles, and are tan to buff in color. The intervening swales are flooded seasonally because of their low elevation, and often accumulate backswamp and marshy deposits. This beach ridge and swale environment is laterally transitional with the delta top and delta front environments.

MIDDLE AND LATE HOLOCENE GEOMORPHIC EVOLUTION OF THE GLYKYS LIMEN

We have documented the relative sequence of geomorphic evolution indicated by subsurface stratigraphy, and supplemented this with eight radiocarbon dates which provide absolute chronological control. Overall, the middle and late Holocene sedimentary record in the valley is regressive in nature reflecting alluviation during a period of very slowly rising relative sea level. Dakaris suggested that the Glykys Limen was formerly much larger, extending back to near the Mesopotamon/Tsouknida valley constriction at "a certain geological period."[38] The suggestion was based on his observation of a fossil beach ridge 1.5 km east of the village of Ammoudia (on Phanari Bay), and the presence of fossil marine macrofauna encountered in a boring near the confluence of the Acheron and Vouvos Rivers. The Mesopotamon/Tsouknida valley constriction is a natural obstruction in the valley both areally and in the subsurface because of shallow bedrock (Figs. 6.9, 6.10), and logically might have served as a natural boundary to transgressing Holocene seas. Our results indicate, however, that marine influence reached even further inland than Dakaris suggested; rising Holocene seas stretched at least to the location of core 94-17 (Fig. 6.7), several hundred meters east of the valley constriction, around 2100 B.C. (see Fig. 6.12). Several radiocarbon dates provide absolute chronological control for this and other shoreline positions during the past 4,000 years.

The reconstructed shorelines we present should be taken only as generalized locations of the shoreline position. Because wave and tidal energy

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[38] Dakaris 1971, p. 5.

are low along the Epirote coast, and even lower in well-protected Phanari Bay, the Acheron delta is dominated by fluvial processes. Such fluvially dominated deltas display an elongate geometry, space permitting. Unfortunately, since Phanari Bay is almost entirely filled in, this elongate geometry is not apparent at present. It can be seen, however, in subsurface cross section C–C′ (Fig. 6.11), as well as in other river deltas in Epirus, such as those of the Thyamis and Arachthos Rivers (Fig. 6.5). Additionally, the Acheron delta may have had multiple distributary channels. These ambiguities preclude the possibility of reconstructing the exact shoreline configuration at any moment in time.

Cores 94-17 and 94-23 (Figs. 6.7, 6.10; Appendix) have a similar stratigraphy and clearly illustrate the overall regressive nature of the sediments laid down in the lower Acheron valley during the middle and late Holocene. Both cores consist of deposits from the following environments given in normal stratigraphic order: 1) delta top to front, 2) brackish water delta top marsh grading upward into freshwater marsh, 3) shallow freshwater lake, and 4) floodplain. A radiocarbon date on peat from the bottom of the brackish water delta top marsh of core 94-23 returns a calibrated 1σ range of ages from 4030 ±100 B.P., or 2080 ±100 B.C. This peat belongs to the extensive subsurface delta top marsh deposit seen in the A–A′ and B–B′ cross sections through the Mesopotamon/Tsouknida valley constriction (Figs. 6.9, 6.10). The radiocarbon date from core 94-23 indicates that the interface between the delta top to front and brackish water delta top marsh environments found today at Phanari Bay has migrated at least 5.3 km seaward at the expense of the Glykys Limen since approximately 2100 B.C. (Fig. 6.12).

Brackish water conditions also existed at the locality of core 94-17, which is located further inland, ca. 5.7 km from Phanari Bay. A radiocarbon date was not obtained from this core, but it is reasonable to assume that the base of the delta top marsh is approximately the same age or slightly older than that of core 94-23. The maximum post-glacial extent of the marine embayment is not known because only a few relatively shallow cores are available east of cores 94-17 and 94-23.

Core 93-21 (Figs. 6.7, 6.9; Appendix) shows a basal stratigraphy that is similar to cores 94-17 and 94-23, and provides another radiocarbon date that further helps to constrain the position of the ancient shoreline. Delta top and front sediments directly overlie bedrock, and are in turn succeeded by a delta top marsh environment. However, since 93-21 is located ca. 0.5 km to the west of the other two cores, within the Mesopotamon/Tsouknida valley constriction where several fluvial systems coalesce, subaerial fluvial deposits dominate the stratigraphy above the delta top marsh. A radiocarbon date from the delta top marsh peat returns a calibrated 1σ range of ages from 3690 +140/-60 B.P. (1740 +140/-60 B.C.). This age is approximately 350 years younger than the ^{14}C date from core 94-23, which is appropriate given that core 93-21 is closer to the modern shoreline.

West of the Mesopotamon/Tsouknida valley constriction, both geologic evidence and historical documents provide information about the changing size of the Glykys Limen. Core 94-13 (Figs. 6.7, 6.10;

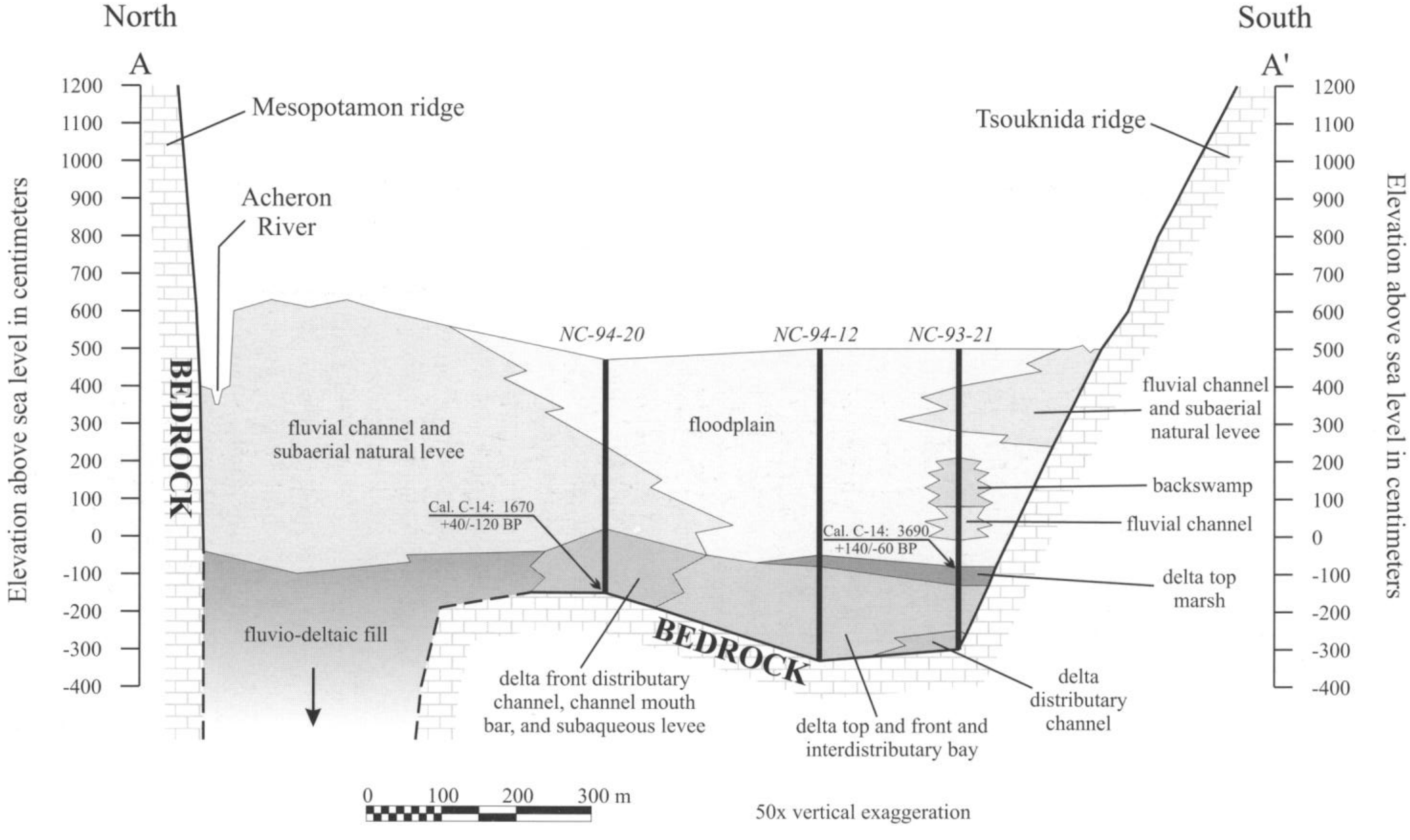

Figure 6.9. North–south cross section through the Mesopotamon/Tsouknida valley constriction

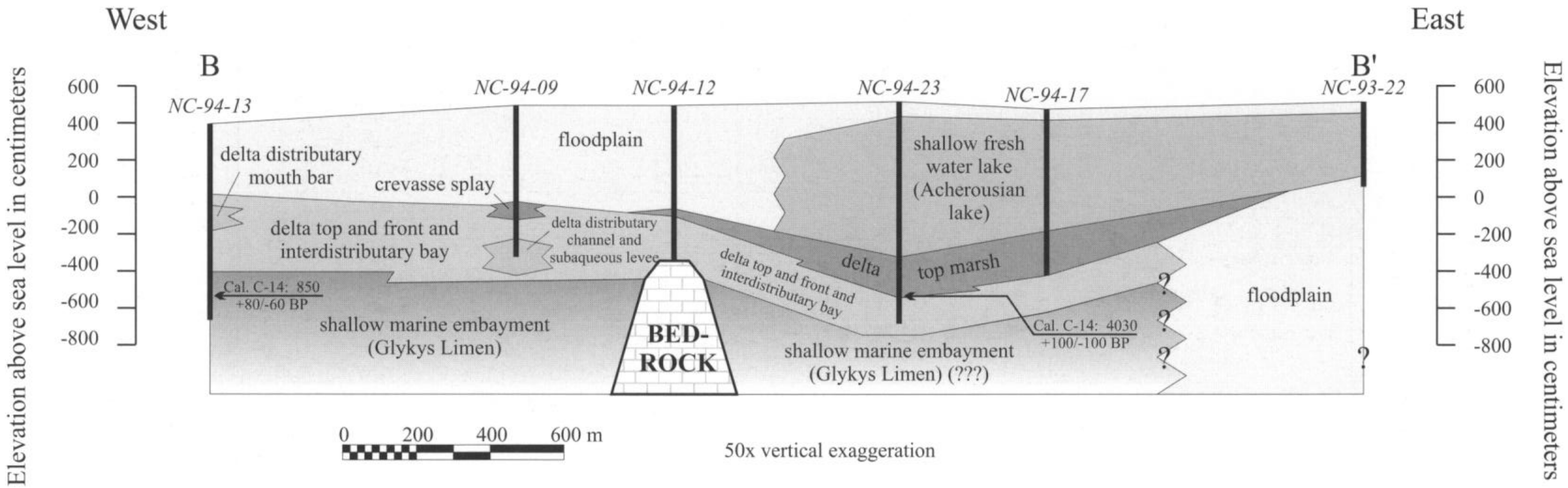

Figure 6.10. East–west cross section through the Mesopotamon/Tsouknida valley constriction

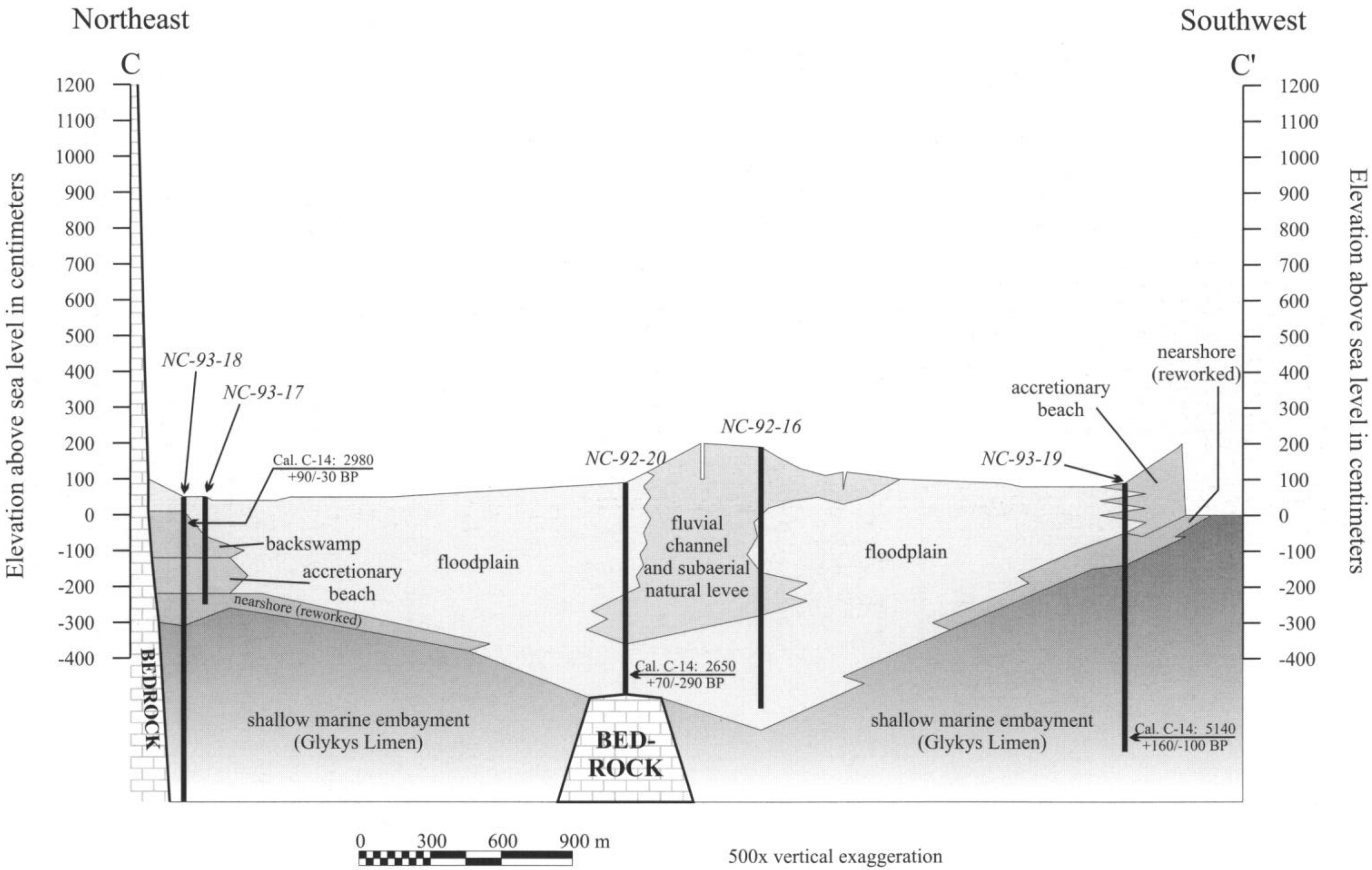

Figure 6.11. Northeast–southwest cross section through the valley bottom (area of former marine embayment)

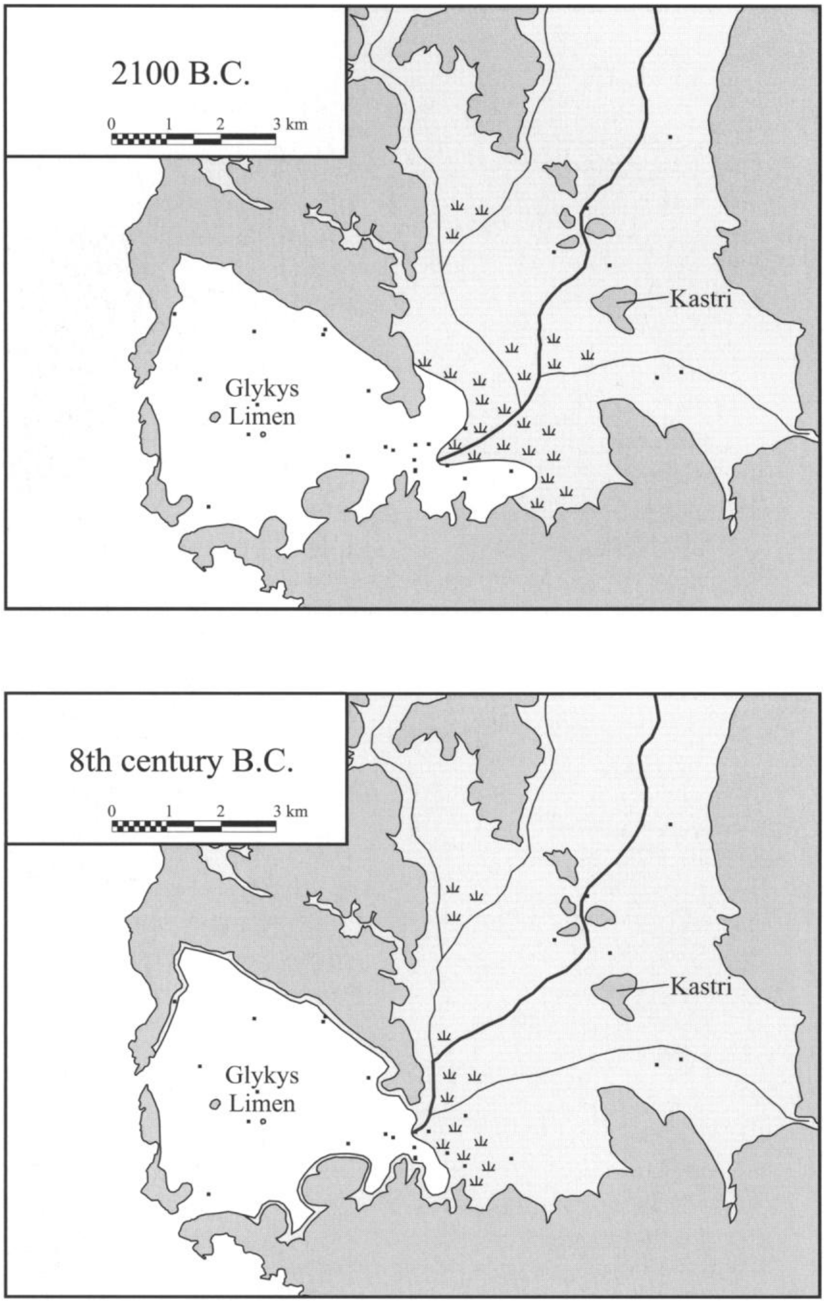

Figure 6.12. Paleogeographic reconstructions of the lower Acheron valley for 2100 B.C. and the 8th century B.C. Small black squares mark core locations; see Figure 6.7 for labels.

Appendix), ca. 3.5 km from modern Phanari Bay, is composed from the base upward of shallow marine deposits of the Glykys Limen which are overlain by delta front sediments. The delta front sediments grade upward into deposits of a distributary mouth bar, and then an interdistributary bay. The sequence is capped by subaerial fluvial sediments. A marsh reed retrieved from the distributary mouth bar deposit was radiocarbon dated and returns a calibrated 1σ range of ages from 850 +80/ -60 B.P. (A.D. 1100 -80/+60). The vertical sequence in this core indicates that it is not directly in front of the prograding delta, but on its flank.

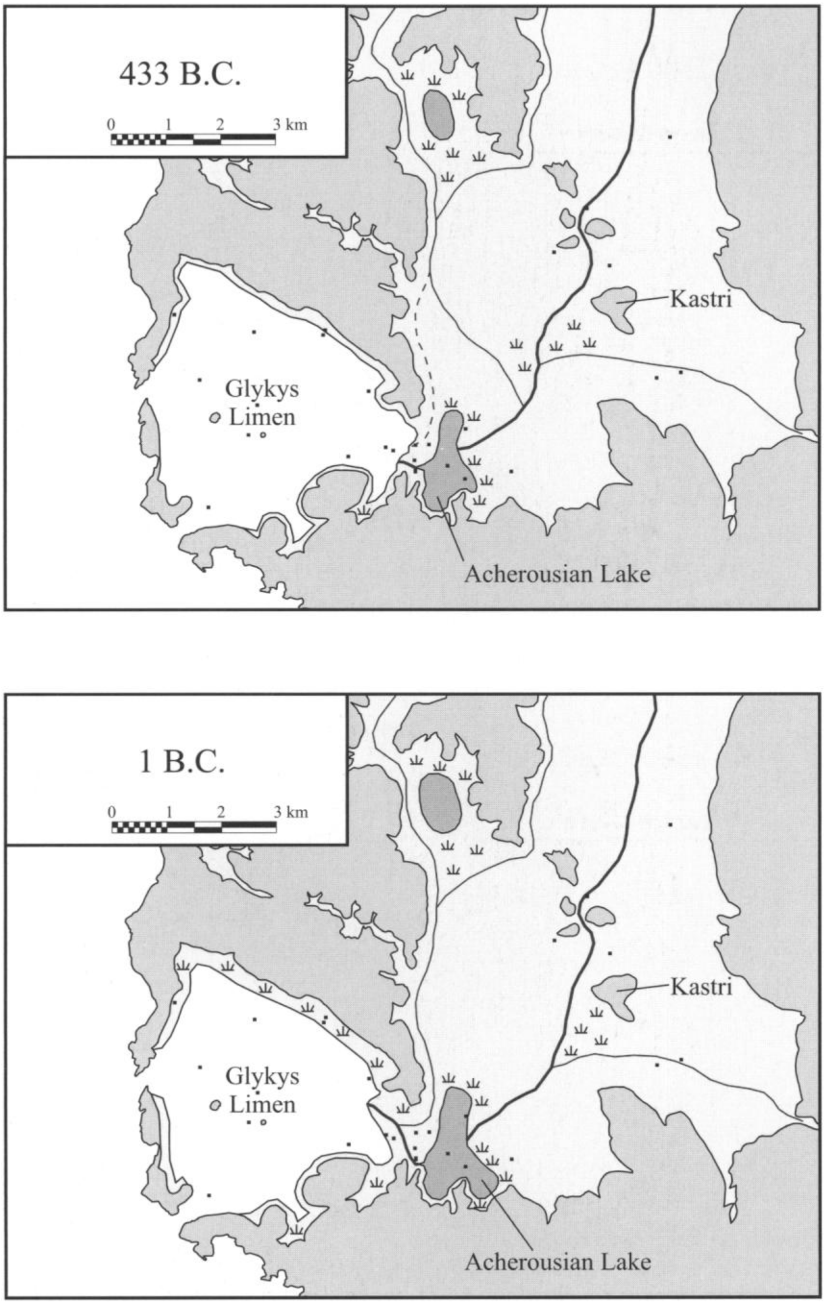

Figure 6.13. Paleogeographic reconstructions of the lower Acheron valley for 433 B.C. and 1 B.C. The dashed line in the 433 B.C. panel indicates a possible alternative course for the Vouvos River. Small black squares mark core locations; see Figure 6.7 for labels.

Therefore, it is not appropriate to use this as an indicator of the actual delta front position, which would have been somewhat seaward of this location. A hypothetical delta front position for this time is illustrated in Figure 6.14.

Several historical documents, in particular early maps of the region, provide information that helps to reconstruct the evolution of the Glykys Limen since A.D. 1100.[39] The maps are clearly not geographically accurate, but they do indicate that the Glykys Limen was still of significant size through the 15th and 16th centuries A.C. Leake's description of the valley as he passed through the region in 1809 provides important infor-

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[39] Besonen 1997 shows 16 maps; see note 1 regarding the availability of Besonen 1997.

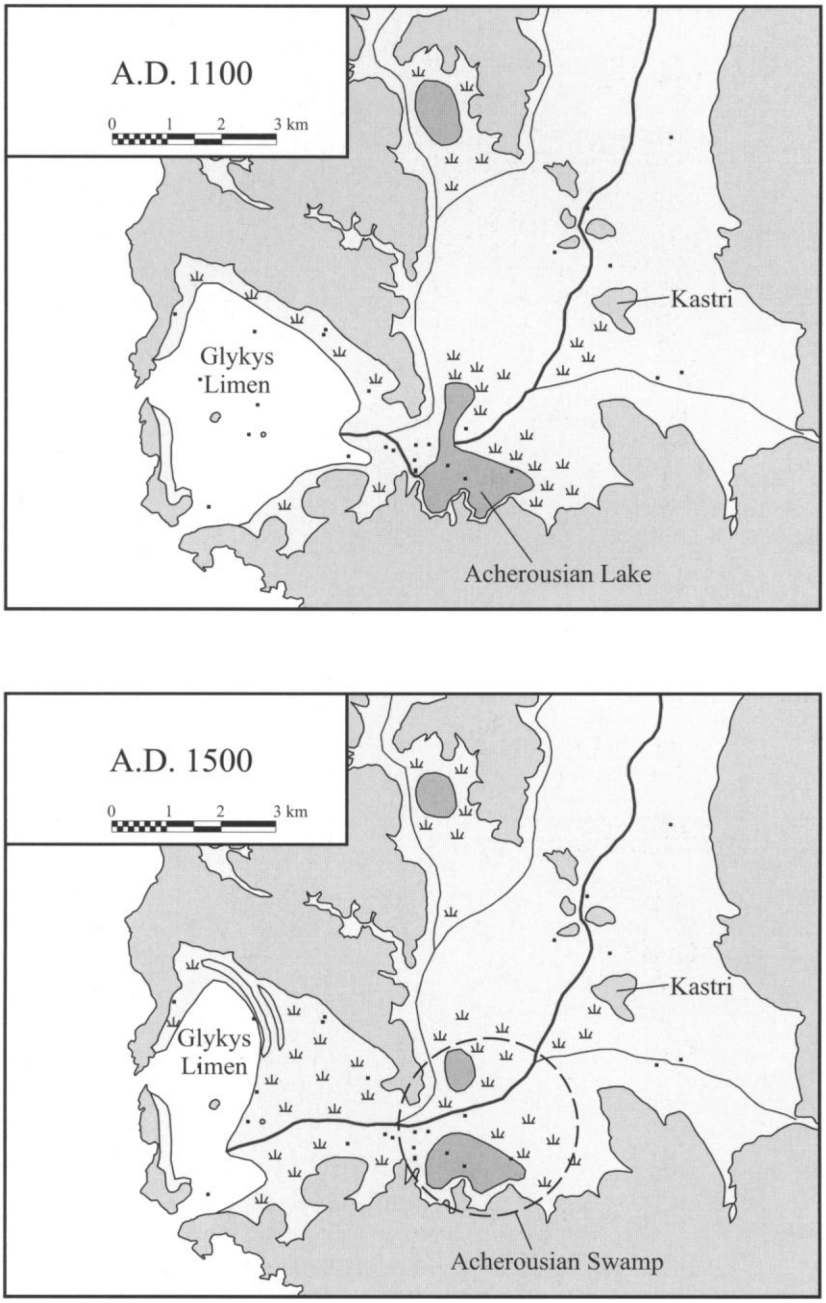

Figure 6.14. Paleogeographic reconstructions of the lower Acheron valley for A.D. 1100 and A.D. 1500. Small black squares mark core locations; see Figure 6.7 for labels.

mation about the landscape configuration east of the Mesopotamon/Tsouknida constriction, but there are few details about the coastline and actual delta front.[40] The modern village of Ammoudia, which surrounds present day Phanari Bay, did not come into existence until after Leake's time, in the early part of the 20th century. Therefore, the position of the shoreline in 1809 must have been a bit further to the east (Fig. 6.15).

There is one radiocarbon date from the area of the Glykys Limen that seems anomalously old, given its location and the type of deposit from which it was obtained. Core 92-20 (Figs. 6.7, 6.11; Appendix) is situated in the middle of the area of the Glykys Limen, ca. 1.6 km from Phanari

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[40] Leake 1835.

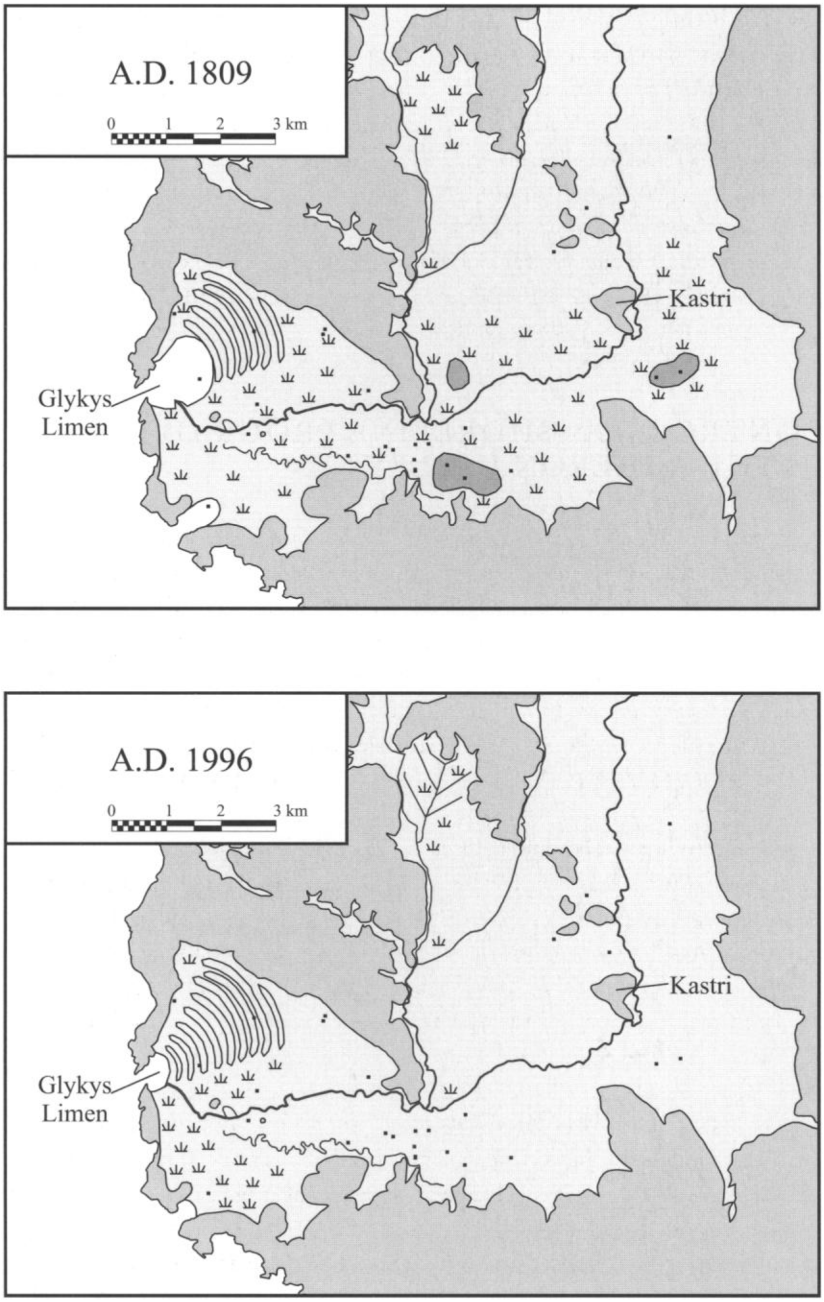

Figure 6.15. Paleogeographic reconstruction of the lower Acheron valley for A.D. 1809 and a map of the modern landscape. Small black squares mark core locations; see Figure 6.7 for labels.

Bay. It consists of inferred floodplain and natural levee deposits that directly overlie either bedrock or gravel. A radiocarbon date on organic material retrieved 50 cm above the base of the core returns a calibrated 1σ range of ages from 2650 +70/-290 B.P., or 700 +70/-290 B.C. Such a date would suggest that the delta top was located here as early as 700 B.C., forcing the delta front position even further basinward. This is problematic since it is in gross contrast with the coherent sequence of coastal evolution documented by the rest of this study.

The anomalously old radiocarbon date from core 92-20 is likely due to reworking of older deposits. The stratigraphy in the core is rather peculiar, and is only similar to that seen in core 92-16, less than 600 m away. Though the deposits in these cores are apparently subaerial (according to their color), they occur up to 5 m below sea level. Bedrock in the area is very shallow, as indicated by limestone knobs that stick up through the alluvium just 500 m to the south, and 700 m to the west (Fig. 6.8). These bedrock knobs are covered with red sediment and vegetation at present, and would have been small islands before the infilling of the Glykys Limen. Consequently, it seems probable that the deposits around the bedrock knobs, such as retrieved in core 92-20, may represent reworked older sediment and material shed off of the islands.

CONTROLS ON SHORELINE PROGRADATION IN THE ACHERON VALLEY

Our data indicate that the rate of shoreline progradation in the lower Acheron valley varied significantly through time; it was slow earlier on, but then much more rapid over the last millennium. In the 3,200 years from 2100 B.C. to A.D. 1100, the shoreline position prograded just 2 km (Figs. 6.12–6.14). In the 850 years from A.D. 1100 to the present, however, almost 3.5 km of shoreline progradation has occurred (Figs. 6.14, 6.15). Rapid recent progradation is also supported by a detailed consideration of the 3-km wide system of beach ridges noted east of modern Phanari Bay (Fig. 6.3). As Waters has shown, the valley bottom is subsiding;[41] if these ridges were accreting slowly over time during subsidence, one would expect to find them at progressively lower elevations moving inland. This is not the case, however. Careful examination of surveyed point elevations on the 1:5,000 topographic maps shows that all the ridges are no higher than 1 masl, and no particular progression of ridge elevations can be noted moving inland. This suggests that the beach ridges have accreted rapidly.

What were the controls on the rates of shoreline progradation? The simple dynamics of basin infilling were probably important factors. Following stabilization of sea level in the middle to late Holocene, sediment deposition would have been directed toward filling the deeper parts of the Glykys Limen. As the basin grew continuously shallower, an increasingly larger proportion of the sediment load could be dedicated to the shoreline, leading to the increased rate of progradation we have documented. A similar phenomenon has been noted for the Spercheios delta on the eastern coast of Greece, where delta growth seems to be occurring at a continuously increasing rate.[42]

One significant local geomorphic control that moderated sediment delivery to the coastline was the formation of the Acherousian lake. As will be discussed below, the lake probably did not come into existence until sometime between the 8th century B.C. and 433 B.C. (Figs. 6.12, 6.13). It then served as an efficient sediment trap, capturing material transported by the Acheron River that would otherwise have been carried to the coast. The lake's ability to trap sediment was further enhanced by a spillway that was built increasingly higher, and subsidence of the lake floor.[43] These

[41] Waters 1994, p. 197.
[42] Tziavos 1977.
[43] Besonen 1997.

factors allowed the lake to accommodate nearly 9 m of sediment infill before being breached, probably after A.D. 1100 but before Turkish times (Fig. 6.14). Once this occurred, the Acheron River was again able to deliver its sediment load directly to the shoreline.

Several larger-scale controls, operating over more than just the Acheron valley, may also have had the ability to significantly alter the quantity of sediment delivered to the coast, thereby moderating rates of shoreline progradation. In particular, anthropogenic influence has been implicated as responsible for a profound change in landscape stability and associated erosion/alluviation events over Greece as a whole beginning around 4500 B.P.[44] In Epirus, pollen studies from two sites located ca. 80 km to the north of the Acheron valley also recognized several erosive events during the middle to late Holocene. Using pollen data from Gramousti lake and Rezina marsh (Fig. 6.1), Katherine Willis recognized erosive events from ca. 6300–5000 B.P., 4300–3500 B.P., and finally at 2500 and 2000 B.P.[45] Though both climatic shifts and anthropogenic influence were cited as possible causes for these periods of increased erosion, anthropogenic influence was the more favored explanation, especially for the event dating to 4300–3500 B.P. We do not recognize any of these erosional events in the geomorphic evolution of the Acheron valley, despite its proximity to Willis's study area, but even adjacent regions may have different erosional histories.[46]

A second large-scale control that may have moderated sediment delivery to the coast is a change in climate, in particular, a change in moisture balance. Though the system of responses and feedbacks may be complex, changes in moisture balance affect vegetation cover, and thus could easily alter the effectivity of erosion. Unfortunately, there is little paleoclimatic information available for Greece, and that which does exist is predominantly pollen work.[47] Some effort, however, has been focused on interpreting changes in moisture balance based on lake-level fluctuations.[48] A low-resolution record of interpreted lake-level fluctuations exists for Lake Ioannina, just 55 km to the northeast of the Acheron valley (Fig. 6.1),[49] but the data from the last 5,000 years are too sparse to relate to geomorphic changes in our area. A new record of lake-level fluctuations exists for Lake Xinias,[50] just 160 km to the east of the Acheron valley, but the lake is located on the other side of the Pindos Mountains, a major orographic boundary, and thus a comparison to our area is not appropriate. Furthermore, the data from Lake Xinias—like that from Lake Ioannina—are very sparse for the middle and late Holocene.

While middle and late Holocene paleoclimatic information from Greece may not be the most impressive, there does appear to be increasingly robust evidence for a significant, abrupt aridification event around 4200 B.P. over the eastern half of the Mediterranean and West Asia.[51] Presumably this event would have affected Greece as well, and may have led to a reduction in vegetation cover, thus increasing the effectivity of erosion and resulting in a higher flux of sediment being delivered to the coast. However, this issue cannot be adequately addressed with the present body of Greek paleoclimatic information (e.g., mostly pollen analyses). Furthermore, this event may be impossible to recognize with a proxy like pollen because of the strong overprint of anthropogenic influence that begins

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[44] Davidson 1980; van Andel, Runnels, and Pope 1986; van Andel, Zangger, and Demitrack 1990.

[45] Willis 1992.

[46] In particular, see the comparison of the Southern Argolid and Argive Plain regions examined in van Andel, Zangger, and Demitrack 1990.

[47] See reviews in Roberts and Wright 1993, and Willis 1994.

[48] Harrison and Digerfeldt 1993; Digerfeldt, Olsson, and Sandgren 2000.

[49] Harrison and Digerfeldt 1993.

[50] Digerfeldt, Olsson, and Sandgren 2000.

[51] Weiss et al. 1993; Dalfes, Kukla, and Weiss 1997; Cullen et al. 2000; Weiss 2000.

at this time.[52] To resolve the issue, development of proxy records for moisture balance that are unaffected by human activity (e.g., an oxygen stable isotope record) would be more suitable.

In summary, local factors such as the dynamics of basin infilling and the formation of the Acherousian lake certainly played a role in moderating the progradation of the shoreline in the Acheron valley. Larger-scale factors such as anthropogenic influence and climate change were capable of affecting the amount of sediment delivered to the coast, but the data currently available are not yet sufficient to link either factor to the changing rate of shoreline progradation.

MIDDLE AND LATE HOLOCENE EVOLUTION OF THE ACHEROUSIAN LAKE

We have documented the development and evolution of the Acherousian lake (Fig. 6.4), which until now was most thoroughly considered by Dakaris followed by Hammond.[53] The absolute chronology for our study is based partly on radiocarbon dates, and partly on an analysis of literary and historical references. Unfortunately, the reconstructions of Dakaris and Hammond were based primarily on indirect evidence, the modern landscape configuration in the valley, and the assumption that the lake filled in gradually, becoming shallower and areally less expansive over time. However, the mechanism responsible for the impoundment of the lake was dynamic, and thus it did not experience a typical lacustrine infill sequence and evolution. Instead, the lake maintained a shallow profile but grew continuously larger, spreading upvalley through time. As a result, Dakaris, Hammond, and others overestimated the size of the lake, at least as an open body of water.

The development and evolution of the lake is best recorded by the stratigraphy around and to the east of the Mesopotamon/Tsouknida valley constriction (Fig. 6.2). Sediment cores 94-23 and 94-17 (Fig. 6.7; Appendix) document the overall regressive nature of the middle and late Holocene stratigraphy in the valley, and the entire history of the Acherousian lake. As described above, the cores consist from the base upward of deposits from the following environments: 1) delta top to front, 2) brackish water delta top marsh grading upward into freshwater marsh, 3) shallow freshwater lake, and 4) floodplain. The shallow freshwater lake deposit is from the Acherousian lake. A radiocarbon date on peat from the bottom of the fresh to brackish water delta top marsh of core 94-23 returns a calibrated 1σ range of ages from 4030 ± 100 B.P., or 2080 ± 100 B.C. We therefore conclude that the Acherousian lake came into existence at some point after ca. 2100 B.C.

The stratigraphy in cores 94-23 and 94-17 indicates that the marsh was essentially drowned as the lake came into existence directly on top of it. Some mechanism to the west of these cores was therefore responsible for the impoundment of the lake. Analysis of the stratigraphy in cores 94-20, 94-12, and 93-21 (Fig. 6.7; Appendix), located ca. 600 m to the west in the Mesopotamon/Tsouknida valley constriction, shows what this mechanism might have been.

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[52] See note 44 above.

[53] Dakaris 1971; Hammond 1967.

The A–A′ cross section based on these cores (Fig. 6.9) shows a massive plug of fluvial sediments filling the valley at this point. The stratigraphy in these cores consists of delta top and front sediments that are immediately overlain by fluvial channel, subaerial natural levee, and floodplain sediments. In contrast, core 94-23 consists of the same delta top and front sediments overlain by 7.5 m of sediment from the Acherousian lake. From this relationship, it is clear that the lake was impounded to the east of the Mesopotamon/Tsouknida valley constriction because of fluvial sediments that essentially plugged the constriction.

This fluvial plug records the migration of the channel and levee system of the Acheron River and/or one of its tributaries. As the channel/levee system built south-southwestward from the eastern side of the Mesopotamon ridge, it eventually impinged onto the bedrock promontory near Tsouknida (Figs. 6.12, 6.13). As a result, a shallow, closed depression was pinched off to the east behind this channel/levee/proximal floodplain system and water ponded up, drowning the delta top marsh to form the Acherousian lake (Fig. 6.13).

The stability and longevity of this fluvial plug system are important points to emphasize. Following the initial impoundment of the lake, fluvial sedimentation has dominated in the area of the valley constriction until the present day, as illustrated by cross section A–A′ (Fig. 6.9). Thus, as the channel/levee/proximal floodplain system slowly aggraded through time, it caused a progressive rise in the surface elevation of the lake. Because the lake was also receiving sediment input, this process allowed it to accommodate 9 m of sediment infill while simultaneously maintaining a shallow profile.[54] More information regarding the progressively rising surface elevation of the lake and its areal expansion will be discussed below.

This mechanism of river channel and levee migration is an extremely important agent of geomorphic evolution in the valley, and its effects can be seen in the topography at other points in the valley today. Three excellent examples include the topographic depression to the west of Koroni, the depression between Kastri and Kanallakion, and the small depression to the east-southeast of Ephyra (Fig. 6.8). In these cases, the migrating course of the Kokytos and Acheron Rivers impinged onto a bedrock highland and pinched off a shallow, closed basin upvalley of the constriction. Richard Russell noted a similar process in his study of the Meander River in western Anatolia.[55] In this case, a rapidly prograding delta front/coastal plain built across the entrance to a marine embayment, essentially trapping a standing pool of water within the embayment. He also recognized shallow lakes ("levee-flank depressions") that had formed on the delta top in the area behind/between the intersection of two stream channel/levee systems.[56]

Though the radiocarbon date from core 94-23 indicates that the impoundment of the Acherousian lake must have occurred after ca. 2100 B.C., a more tightly constrained chronology could be determined by another ^{14}C date at the top of the freshwater marsh deposit. Unfortunately, limited resources did not provide this option. Consequently, a closer dating of the lake's inception will be based on an analysis of literary and historical references by ancient authors. Differing opinions about the accu-

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[54] Besonen 1997.

[55] Russell 1954.

[56] Russell 1967, p. 17.

racy and validity of topographic references made by ancient authors are certain. However, if such references, taken in chronological order, present a coherent and logical sequence of events, they may be useful. On the contrary, if they present a sequence of events that is clearly impossible, or if various references contradict one another, one may be inclined to question their validity. This, however, is not the case in the Acheron valley. A detailed analysis of ancient literary and historical references in chronological order presents a logical and coherent picture of the probable evolution and development of the Acherousian lake. That these references fit nicely within the story developed by geological and sedimentological evidence lends them some credence.

The earliest reference to the valley comes from the *Odyssey* of Homer. Current thought suggests that the *Odyssey* may have been written in the 8th century, but describes some events and settings that go back to the 12th century B.C. in the Late Bronze Age. Homer writes:

> And when in your ship you have traversed Oceanos,
> Where the scrubby strand and groves of Persephone are,
> Both tall poplars and willows that lose their fruit,
> Beach your ship there by deep-whirling Oceanos;
> But go on yourself to the moldy hall of Hades.
> There into Acheron flow Puriphlegethon
> And Cocytus, which is a branch of the Styx's water,
> And a rock and a concourse of the two resounding rivers.[57]

Homer makes no mention of the lake; in fact, he strictly describes a scene in which several tributaries feed into the Acheron River. The adage "lack of evidence doesn't constitute evidence for a lack" is applicable here, but it may be suggested that Homer does not mention the lake because it did not exist at the time a contemporary witnessed the topography in the valley. The lake then probably formed at some point between the writing of the *Odyssey* (in the 8th century B.C.) and the time of Thucydides' account of the valley (about 400 years later), when the lake is mentioned for the first time.

Thucydides, who wrote contemporary history, gives a description of a recently nascent Acherousian lake in his account of the Battle of Sybota in 433 B.C.

> It is a harbour, and above it lies a city away from the sea in the Eleatic district of Thesprotia, Ephyra by name. Near it is the outlet into the sea of the Acherusian lake; and the river Acheron runs through Thesprotia and empties into the lake, to which it gives its name.[58]

Of interest here is the fact that Thucydides strictly states "near it is the outlet into the sea of the Acherousian lake," as if the lake empties directly into the sea. This seems to imply that the Acherousian lake and the sea (actually the Glykys Limen) are very close—the two are split by only a very narrow barrier of land on which is situated the lake spillway (Fig. 6.13). This narrow barrier of land is the channel and levee system of the Acheron (or one of its tributaries) that caused the impoundment of

[57] *Od.* 10.508–515, trans. A. Cook, New York, 1967.

[58] Thuc. 1.46.4, trans. C. F. Smith, Cambridge, Mass., [1928] 1956.

the lake, as explained above. Thucydides clearly identifies the Acheron River as flowing into the lake, but says nothing about its exit from the lake.

His account is distinct from all later references in that it suggests the extreme proximity of the Acherousian lake and the sea. Later accounts suggest that more than just a lake spillway is present, and that the channel carrying water from the lake to the sea is long enough to be identified as that of the Acheron River. For example, Strabo writes:

> Then comes Cape Cheimerium, and also Glycys Limen, into which the River Acheron empties. The Acheron flows from the Acherusian Lake and receives several rivers as tributaries, so that it sweetens the waters of the gulf.[59]

It appears that the strip of land separating the lake from the sea had grown sufficiently wide in the 400 years between the accounts of Thucydides and Strabo that the channel draining the Acherousian lake could be identified as that of the Acheron River. Furthermore, several tributaries fed into the Acheron after it exited from the lake.

Based on the radiocarbon date from core 94-23, the Acherousian lake must have formed after 2100 B.C. And, since Homer, Thucydides, and Strabo all present a chronologically coherent picture of the development of the lake in the valley, it is probable that the lake formed sometime after the 8th century B.C. but before 433 B.C. An additional bit of circumstantial evidence supports the notion that the lake did not come into existence until this time. Dakaris noted that the archaeological record from the valley indicated a decrease in population during the Archaic period (ca. 700–500 B.C.),[60] and the data from the diachronic survey of the Nikopolis Project tend to support this conclusion. Dakaris suggested that the population decline might have been related to malaria, which has always been a problem in the low-lying coastal areas of Epirus. Why malaria would have flared up at this particular time was unknown, since Dakaris probably assumed the lake had been present in the valley following the post-glacial rise of sea level. Our analysis seems to indicate, however, that the Acherousian lake came into existence at the same time as the Archaic-period population decline. While the timing of these events may be coincidental, the birth of the lake and associated swampy areas may have given rise to the malarial epidemic postulated by Dakaris.

Because Dakaris and others did not recognize the mechanism responsible for the lake's impoundment, they assumed that it followed a typical lacustrine infill sequence and became increasingly shallower and areally less expansive through time. In contrast, Philippson and Kirsten suggested that the lake had become larger since ancient times,[61] but they did not explain why they considered this to be the case nor did they provide evidence to support their conclusion. They also placed the lake too far upvalley (Fig. 6.4, upper right). The results from our study suggest that their assertion regarding the size of the lake is correct, but we furthermore document the mechanism and details of the lake's evolution as well as its true location.

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[59] Strab. 7.7.5 [C 324], trans. H. L. Jones, Cambridge, Mass., 1960.

[60] Dakaris 1971, p. 12.

[61] Philippson and Kirsten 1956, II, p. 105.

Soon after its formation, the lake existed as a shallow body of open water surrounded by a fringe of marshy ground (Fig. 6.13). Sediment carried by the Acheron would have quickly filled it in were it not for the slowly aggrading spillway mechanism discussed above. This allowed the lake to accommodate an increasingly larger volume of sediment vertically and areally, as the lake expanded upvalley because of its slowly increasing surface elevation.[62]

Evidence for the initial small size of the lake, and for the subsequent expansion of marshy, swampy ground upvalley, can be seen by comparing the stratigraphy in cores 94-23 and 94-17 with that of core 93-22 (Fig. 6.10; Appendix). Cores 94-23 and 94-17 are located just to the east of the fluvial plug in the valley constriction and contain 7.5 and 5.9 m, respectively, of lacustrine mud and clay from the Acherousian lake. These lake deposits begin at 3.1 and 1.7 m below sea level, and run to 4.4 and 4.2 masl, respectively. Core 93-22 is located ca. 1 km east of cores 94-23 and 94-17, in the area considered by Dakaris and others to be the ancient lake. At this locality, however, a much thinner sequence (3.5 m) of mixed lacustrine and marsh deposits occurs between 1.2 and 4.7 masl. The lake deposits in the core are underlain by a very stiff floodplain alluvium with some pedogenic development. Thus, this package of lacustrine and marshy deposits shows stratigraphic onlap upvalley, and its transgressive nature confirms the gradual increase of the lake's surface level and its areal expansion through time. The lake probably never extended much further upvalley than the location of core 93-22 because the mixed lacustrine and marsh deposit in this core is indicative of the lake edge and shore.

This information also helps constrain the size and location of the lake, at least as an open body of water. Mixed lacustrine and marsh sedimentation at the location of core 93-22 could not have begun until the surface level of the lake had reached at least 1.2 masl (i.e., the base of the lacustrine material in that core). When did the lake surface level reach this elevation? By ignoring factors such as subsidence and changes in the rate of sedimentation or spillway aggradation, we can loosely base it on the chronology from core 94-23. Elevationally, 1.2 masl corresponds approximately with the middle of the lacustrine sedimentation sequence of core 94-23. From our preceding analysis of core 94-23, we concluded that the lake probably came into existence after the 8th century B.C., but before 433 B.C. Continuous, uninterrupted deposition occurred there until after the First World War, at which time the final remnants of the swamp were backfilled. Assuming that the surface level of the lake rose at a constant rate, it would have reached 1.2 masl in the middle of this time span, or roughly A.D. 850. Thus, we estimate that the expanding lake and marsh ground reached the locality of core 93-22 around the 9th century A.C.

This evidence suggests that Dakaris, Hammond, and others greatly overestimated the size of the lake (Fig. 6.4), especially considering that their reconstructions are supposed to show the extent of the lake during the classical period.[63] In some of the reconstructions, the shape and location of the lake contradict the modern topography. For example, Dakaris and Hammond suggest that the lake had a northeast/southwest-trending

[62] Besonen 1997.

[63] Dakaris 1971; Hammond 1967; Leake 1835; Philippson and Kirsten 1956.

shore between Mesopotamon and Kastri. However, the topographic lines that would have defined the lake shore in this area have a northwest/southeast trend, exclusive of the elevated subaerial natural levees which flank the Acheron River (Fig. 6.8).

Dakaris's reconstruction also suggests that a branch of the lake extended to the east between Pountas ridge and the villages of Kastri, Kanallakion, and Acherousia, but this is not correct. This area is a closed depression (Fig. 6.8) that came into existence by the same mechanism which caused the impoundment of the Acherousian lake. In this case, the Acheron river channel and levee system pinched off the depression against the tip of the Pountas ridge, which projects up from the south. This depression, therefore, would not have come into existence until the course of the Acheron shifted to the south of Kastri. As we discuss below, this shift probably occurred very recently, perhaps around the end of the 16th century A.C.

There is additional geologic evidence to suggest that the main body of the Acherousian lake to the west of Pountas ridge was not confluent with the water body to the east of the ridge. Laminated lacustrine silts and clays do indeed occur in this small basin, but they form a relatively thin layer and are too high topographically to have been deposited by the Acherousian lake. Core 94-03 (Fig. 6.7; Appendix), taken from the center of this small depression, is composed of a backswamp deposit overlain by a freshwater marsh deposit, which is in turn succeeded by floodplain deposits. Core 94-21 (Fig. 6.7; Appendix), located just 450 m to the west, exhibits identical stratigraphy but bottoms out with a floodplain deposit as well. Though core 94-03 did not penetrate these lower floodplain sediments, its proximity to core 94-21 and the fact that it is shorter support the inference that further penetration of core 94-03 would have encountered the same floodplain deposit.

The Acherousian lake would have necessarily had a surface elevation at or below the elevation of the fluvial plug sediments that impounded it. This fluvial plug was continuously aggrading, but never reached more than 5.0 masl, the present elevation at the Mesopotamon/Tsouknida valley constriction. Thus, sediments from the Acherousian lake could only have been deposited up to this height. But the backswamp and freshwater marsh deposits in cores 94-03 and 94-21 occur between 5.1 and 7.7 masl. Therefore, the body of standing water in which these sediments were deposited could not possibly have been confluent with the Acherousian lake as the standing water had a significantly higher surface elevation. This conclusively proves that the body of ponded water that once existed here was not a branch of the larger lake as Dakaris indicated.

By Turkish times, the Acherousian lake had become a swamp with a few isolated pools of water (Fig. 6.14).[64] Continued growth of the Acheron river channel and levee system split the remains of this swamp. This interpretation is supported by the broad topographic high of the river channel and levee system to the east of Mesopotamon, and by the closed depression directly to the east of Ephyra, created when the channel and levee system impinged against the bedrock ridge (Fig. 6.8). Leake provided an

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[64] Hammond 1967, p. 39.

excellent description of the marshy valley bottom from his travels through the region in the spring of 1809, and he noted that several pools of open water still existed (Fig. 6.15).[65] After the First World War, the final marshy remnants of the former Acherousian lake were filled in for agriculture.[66]

THE CHANGING COURSE OF THE ACHERON WITH RESPECT TO KASTRI

In order to reconcile the archaeological remains in the valley with the accounts of ancient authors, Dakaris suggested that the Acheron River had shifted its course to the south of Kastri since classical times.[67] Unfortunately, he could not provide geologic evidence with chronological control to support his theory. Cores 94-02 and 94-04 provide the evidence to document this shift.

Core 94-02 (Fig. 6.7; Appendix) was retrieved north of Kastri, between it and the larger of the two hillocks named Xirolophos (Fig. 6.2). The core consists from the base upward of deposits from the following environments: 1) floodplain, 2) backswamp, 3) floodplain, 4) fluvial channel, and 5) floodplain. At the interface between the lowest floodplain unit and the backswamp, a small reddish pottery fragment was encountered. The fragment is abraded and lacks diagnostic features, but ceramic specialists on the project have suggested that the texture of the sherd should place it some time in the classical period. Since this pottery fragment occurs below the deposits of a fluvial channel, it provides a *terminus post quem* for the existence of the river channel at that location. Therefore, at some point past the beginning of the classical period, a fluvial channel existed north of Kastri.

Core 94-04 (Fig. 6.7; Appendix) was also retrieved north of Kastri, between the hillock of Koronopoulos and the larger of the two Xirolophos hillocks (Fig. 6.2). From the base upward, deposits from the following environments occur in succession: 1) floodplain, 2) backswamp, 3) fluvial channel, 4) backswamp, and 5) floodplain. The fluvial channel sediment is over 1.5 m thick, and contains gravel clasts up to 1 cm in diameter. This deposit is from a significant river channel, like that of the Acheron, and not from a smaller stream. A radiocarbon date on a piece of wood from the base of the fluvial channel deposit returns a calibrated 1σ range of ages from 380 +90/-70 B.P., or A.D. 1570 +70/-90. For radiocarbon dates this young, however, the calibration curve is relatively irregular and the specimen could date to almost any time during the last 500 years. Nevertheless, the radiocarbon date shows that a river channel, probably that of the Acheron River, was operating to the north of Kastri within the last 500 years. When Leake passed through the region in 1809, he recorded that the Acheron River followed a course to the south of Kastri, as it does today. Therefore, if the fluvial channel sediments in core 94-04 are indeed from the Acheron River, it would suggest that the course of the Acheron shifted from the north of Kastri to its south sometime between ca. 1500 and 1809.

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[65] Leake 1835, I, p. 232; IV, pp. 51–54.

[66] Hammond 1967, p. 68.

[67] Dakaris 1971, pp. 136–137.

CONCLUSIONS

Numerous ancient authors, beginning with Homer in the 8th century B.C., make reference to the lower Acheron valley and indicate a landscape configuration that is significantly different from at present. Three notable discrepancies between the ancient and modern landscape exist. The first problem concerns the size of the Glykys Limen (modern Phanari Bay), which at present is very small, but was much larger in ancient times. The second significant discrepancy concerns the evolution of the extinct Acherousian lake, which ancient sources indicate was a conspicuous feature in the valley. The final discrepancy concerns the course of the Acheron River, which today flows to the south of Kastri but was once located to the north of that site.

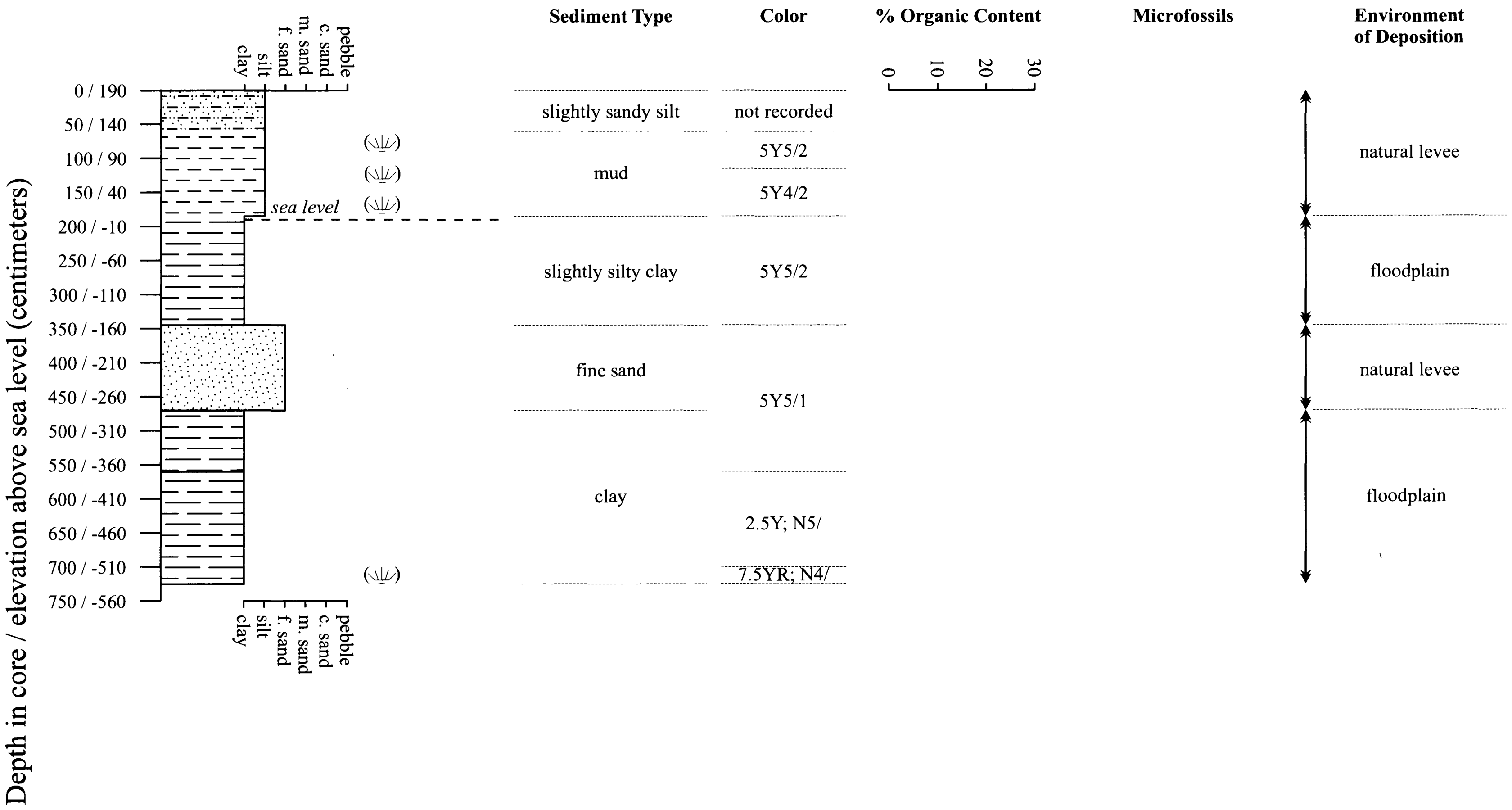
Geologic evidence based on twenty-eight gouge auger sediment cores taken at various locations in the valley indicates that significant geomorphic change has occurred in the valley during the last 4,000 years. The shoreline of the Glykys Limen has prograded nearly 6 km in that time, doing so at varying rates. The Acherousian lake developed relatively late in the Holocene probably between the 8th century B.C. and 433 B.C. Since that time it has been filled in by natural alluvial processes, modified by a constantly aggrading spillway. Finally, the Acheron River appears to have occupied a channel to the north of Kastri, and has only shifted to the south of that hillock in the last 500 years.

It appears that the discrepancies between the ancient accounts and the modern landscape are not due to errors in the ancient sources, but are instead the result of a natural sequence of landscape evolution in the valley. Furthermore, careful examination of the ancient accounts may in some cases provide details and information for paleogeographic and paleoenvironmental reconstructions that are not recoverable from the geologic record. The disciplines of geology and archaeology find a natural interface here, both contributing to, and benefiting from, one another. Indeed, the dynamic geomorphic evolution seen in the Acheron valley during the last 4,000 years reaffirms the need for multidisciplinary archaeological investigations that strive for a broad understanding of the dynamics of environmental change.

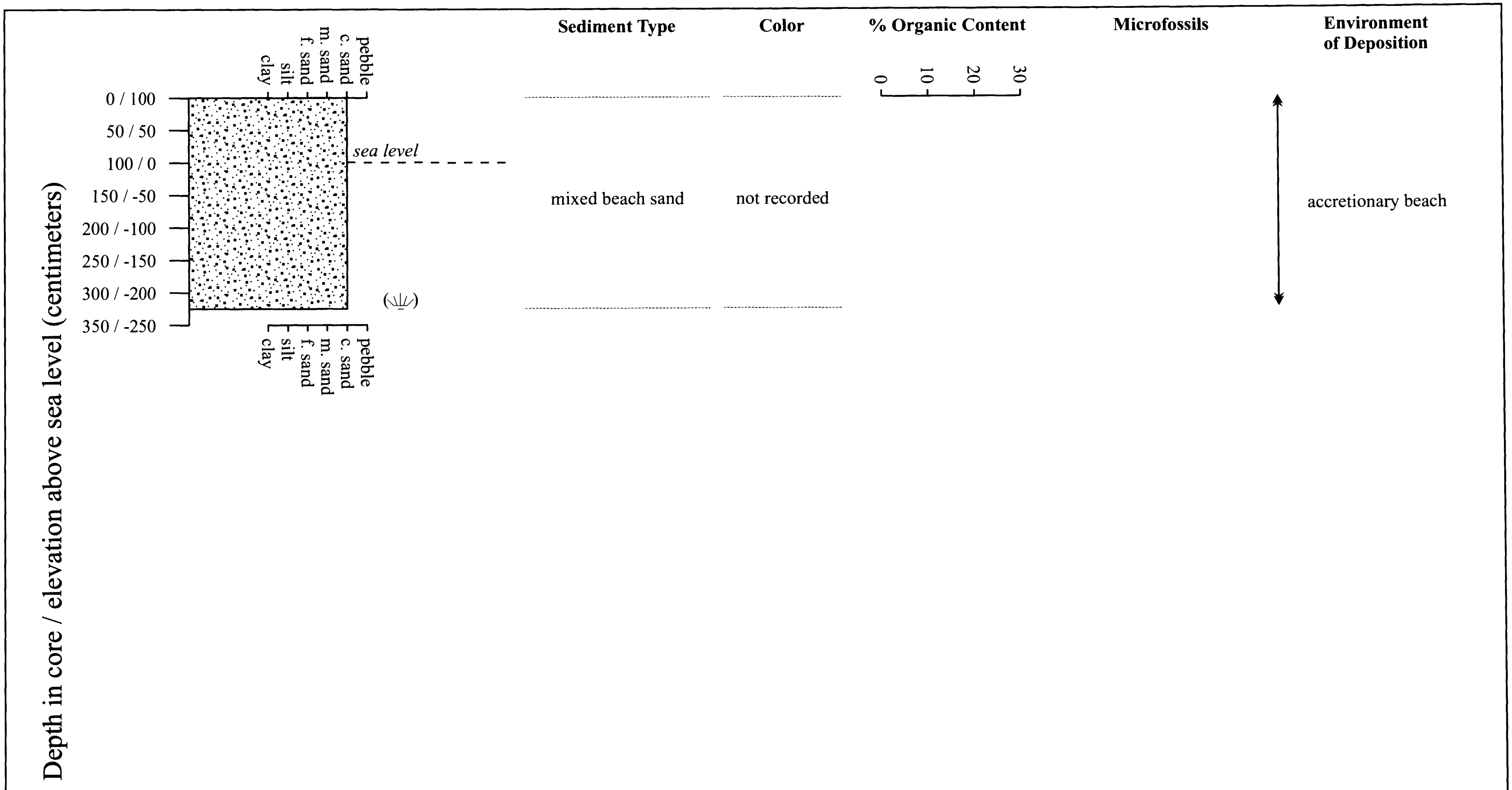
APPENDIX: CORE STRATIGRAPHY AND LITHOLOGY

This appendix contains the sediment core stratigraphy from all twenty-eight cores taken in the Acheron valley. Width of the core, lithologic patterns, and a "Sediment Type" description reflect the grain size and type of sediment based on field and laboratory observations. Organic matter present in the stratigraphy is indicated by one of the symbols in the legend below. Locations of calibrated ^{14}C AMS dates are indicated by arrows. "Color" (according to the Munsell Soil Color Chart), weight percent of organic matter determined by loss on ignition analysis ("% Organic Content"), and results of the microfossil analyses ("Microfossils") are also included (see legend below). The "Environment of Deposition" field represents our interpretation of the stratigraphy based on all available data. All primary data, including results from magnetic analyses, pipette grain-size analysis, microfossil plates and counts, and any data not included here, can be found in Besonen 1997, which is freely available in Adobe Acrobat PDF format (see note 1 for details).

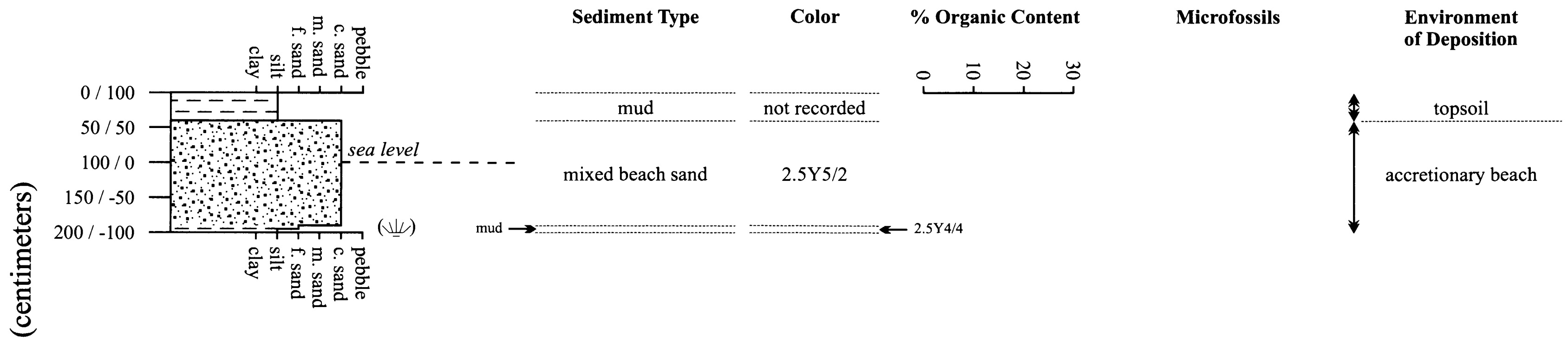
Symbol	***Explanation***
ѱ	common coarse-grained organic matter
ѱ̳	abundant coarse-grained organic matter
(ѱ)	few to trace coarse-grained organic matter
ψ	common fine-grained organic matter
ψ̳	abundant fine-grained organic matter
(ψ)	few to trace fine-grained organic matter
← C-14: 4030 +100/-100 BP	calibrated C-14 AMS date in years B.P.
qty. 615: 1.3% F, 91.4% B, 7.3% R	qty. XXX = quantity/total number of freshwater, brackish to marine water, and reworked microfossils in the sample 1.3% F = percentage of freshwater forms in quantity XXX 91.4% B = percentage of brackish to marine water forms in quantity XXX 7.3% R = percentage of reworked microfauna in quantity XXX


Depth in core / elevation above sea level (centimeters)
0 / 190
50 / 140
100 / 90
150 / 40
200 / -10
250 / -60
300 / -110
350 / -160
400 / -210
450 / -260
500 / -310
550 / -360
600 / -410
650 / -460
700 / -510
750 / -560
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
Sediment Type
slightly sandy silt
mud
slightly silty clay
fine sand
clay
Color
not recorded
5Y5/2
5Y4/2
5Y5/2
5Y5/1
2.5Y; N5/
7.5YR; N4/
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
natural levee
floodplain
natural levee
floodplain

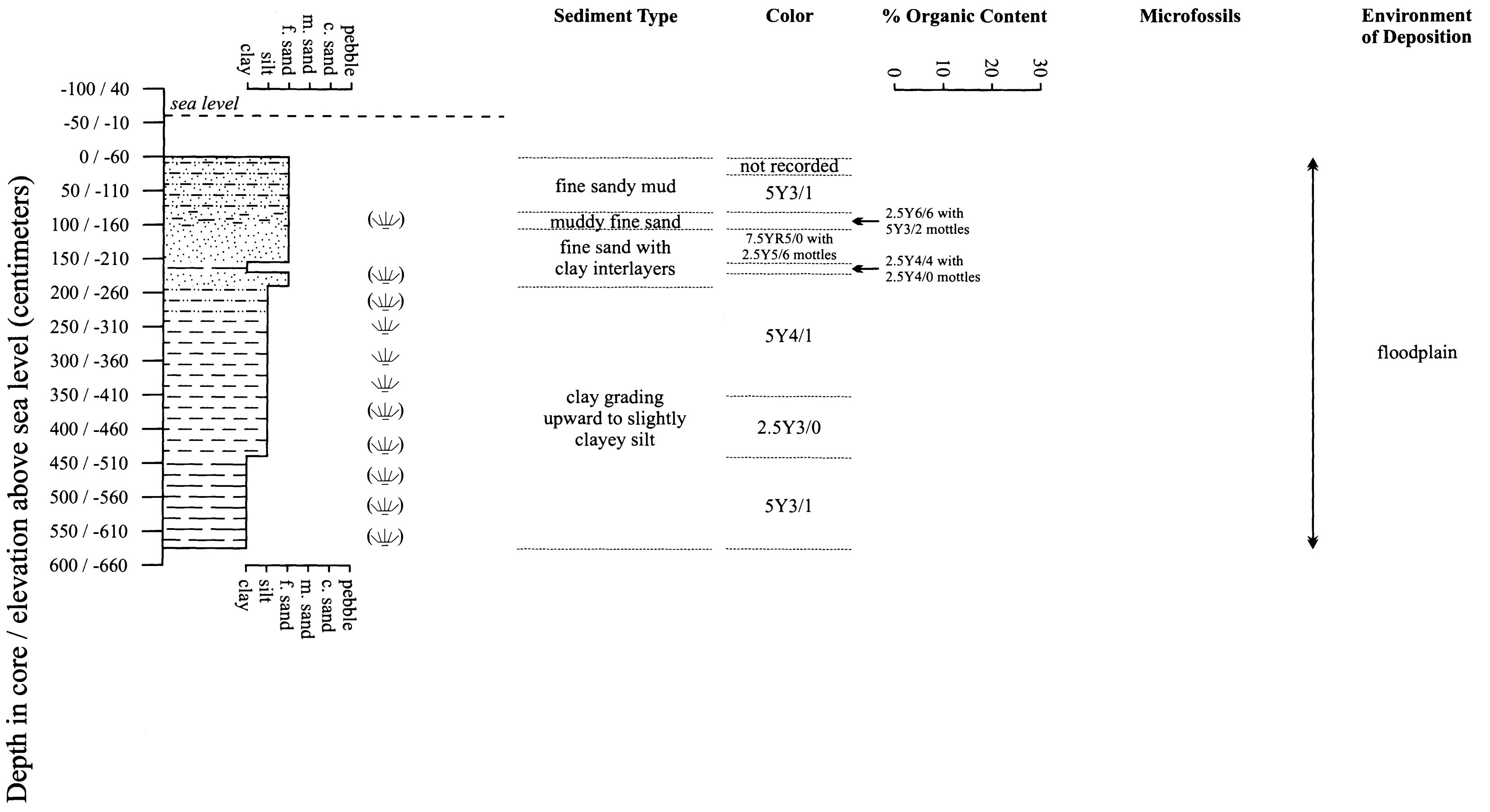
NC-92-16


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
Depth in core / elevation above sea level (centimeters)
0 / 100
50 / 50
100 / 0
150 / -50
200 / -100
250 / -150
300 / -200
350 / -250
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
0
10
20
30
mixed beach sand
not recorded
accretionary beach

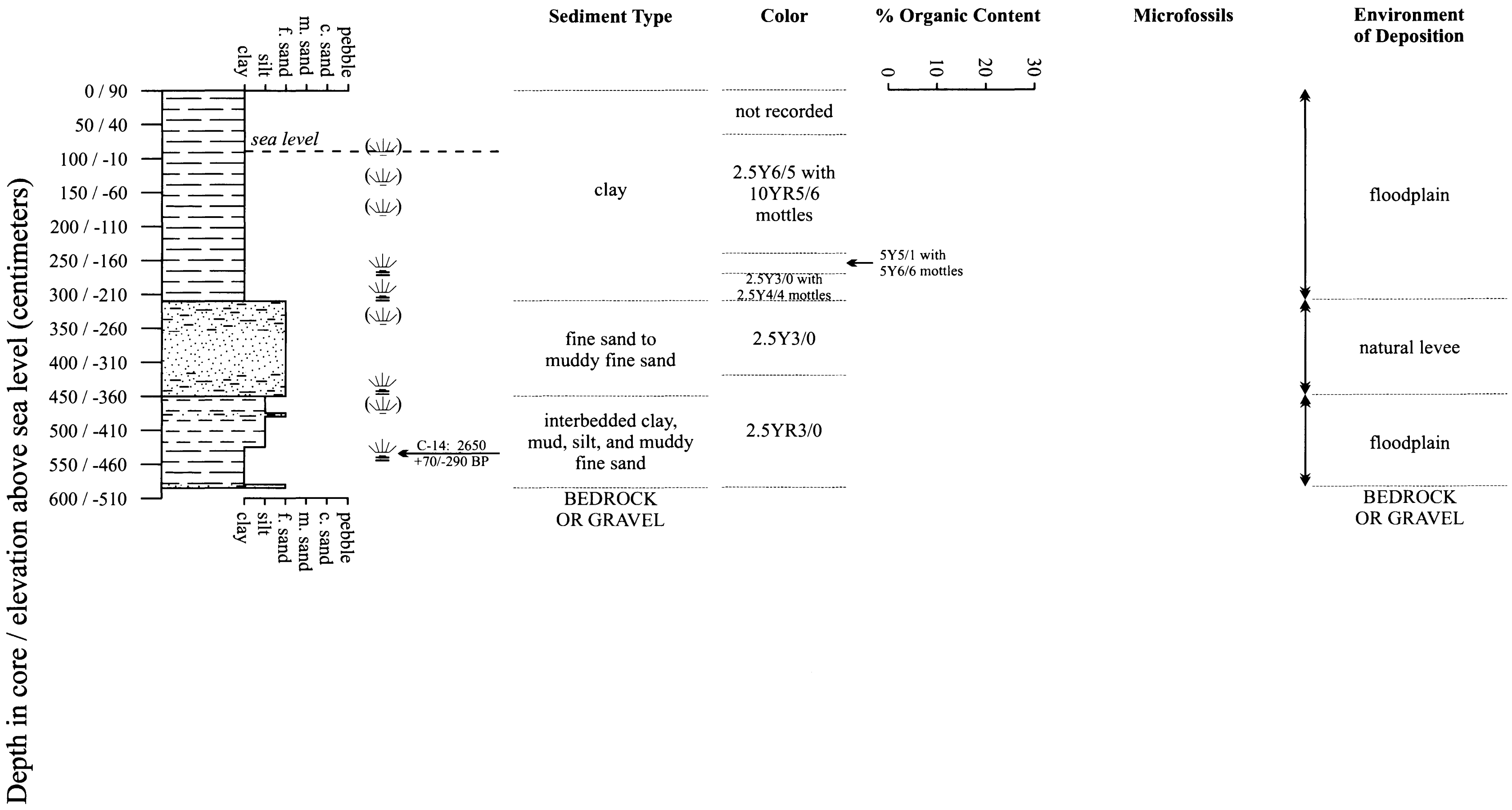
NC-92-17


Depth in core / elevation above sea level (centimeters)
0 / 100
50 / 50
100 / 0
150 / -50
200 / -100
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
mud
Sediment Type
mud
mixed beach sand
Color
not recorded
2.5Y5/2
2.5Y4/4
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
topsoil
accretionary beach

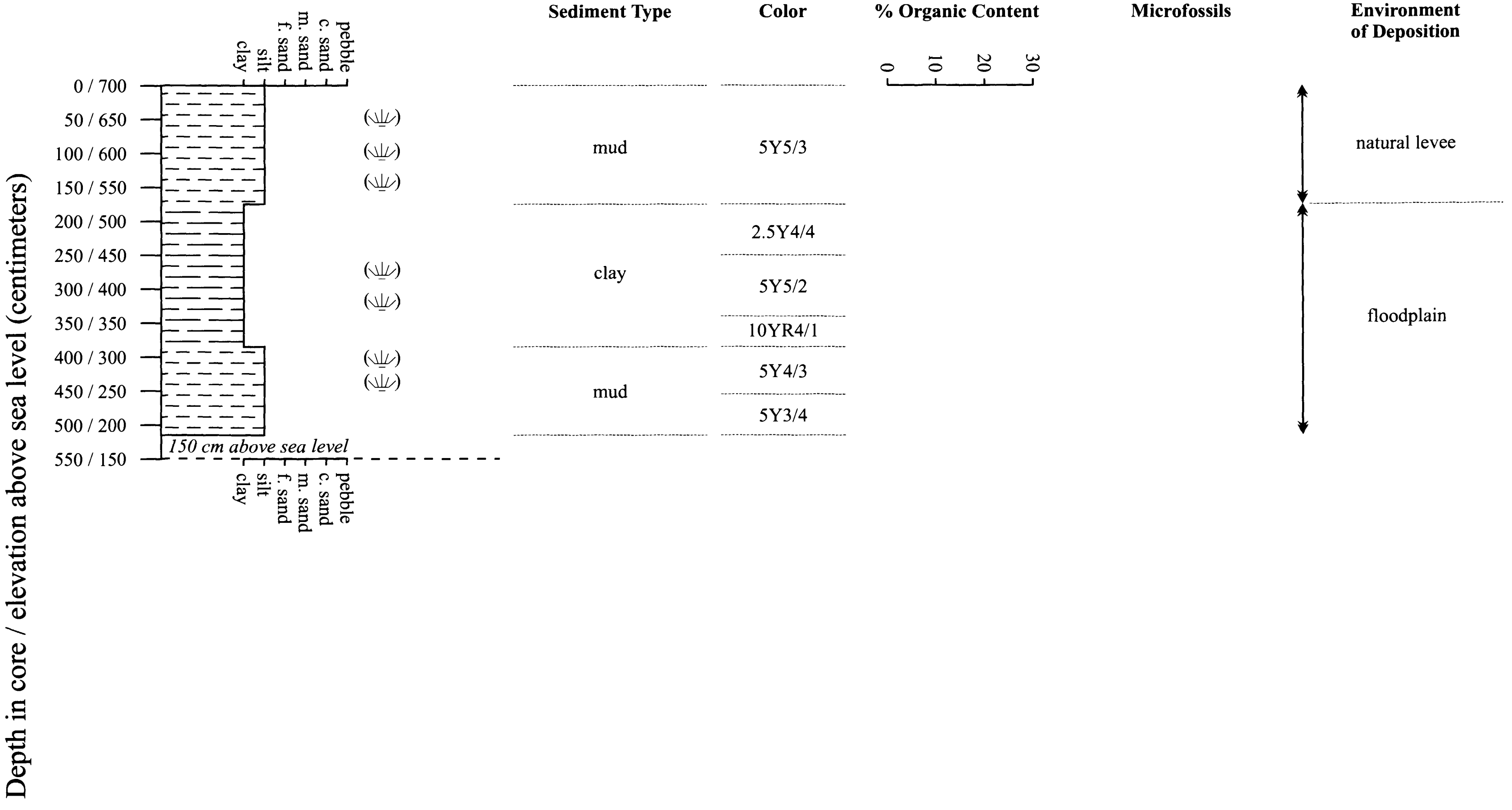
NC-92-18


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
Depth in core / elevation above sea level (centimeters)
-100 / 40
-50 / -10
0 / -60
50 / -110
100 / -160
150 / -210
200 / -260
250 / -310
300 / -360
350 / -410
400 / -460
450 / -510
500 / -560
550 / -610
600 / -660
sea level
clay
silt
f. sand
m. sand
c. sand
pebble
0
10
20
30
fine sandy mud
muddy fine sand
fine sand with clay interlayers
clay grading upward to slightly clayey silt
not recorded
5Y3/1
7.5YR5/0 with 2.5Y5/6 mottles
5Y4/1
2.5Y3/0
5Y3/1
2.5Y6/6 with 5Y3/2 mottles
2.5Y4/4 with 2.5Y4/0 mottles
floodplain

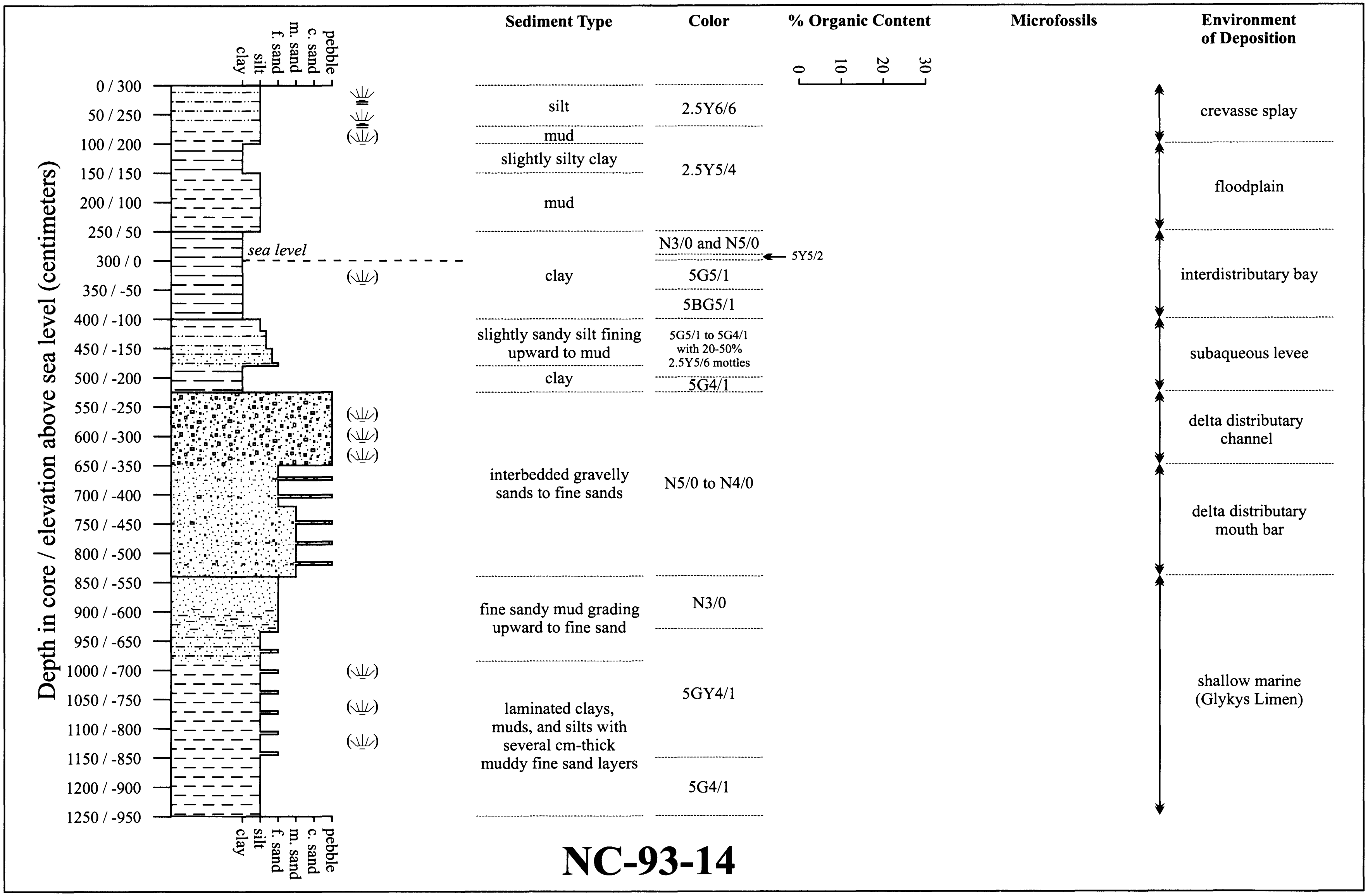
NC-92-19


Depth in core / elevation above sea level (centimeters)
0 / 90
50 / 40
100 / -10
150 / -60
200 / -110
250 / -160
300 / -210
350 / -260
400 / -310
450 / -360
500 / -410
550 / -460
600 / -510
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
C-14: 2650 +70/-290 BP
Sediment Type
clay
fine sand to muddy fine sand
interbedded clay, mud, silt, and muddy fine sand
BEDROCK OR GRAVEL
Color
not recorded
2.5Y6/5 with 10YR5/6 mottles
5Y5/1 with 5Y6/6 mottles
2.5Y3/0 with 2.5Y4/4 mottles
2.5Y3/0
2.5YR3/0
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
floodplain
natural levee
floodplain
BEDROCK OR GRAVEL

NC-92-20

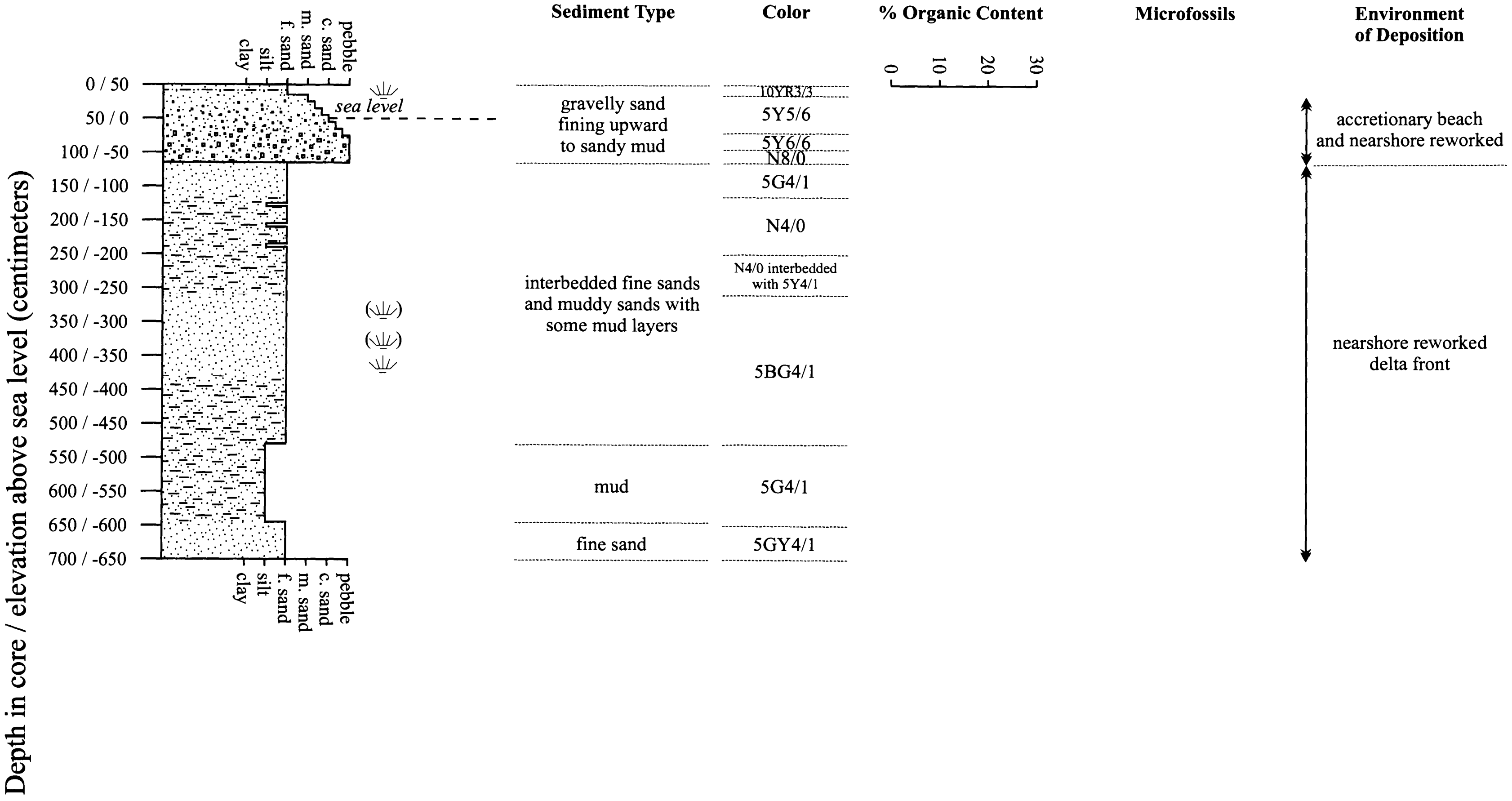

Depth in core / elevation above sea level (centimeters)
0 / 700
50 / 650
100 / 600
150 / 550
200 / 500
250 / 450
300 / 400
350 / 350
400 / 300
450 / 250
500 / 200
550 / 150
pebble
c. sand
m. sand
f. sand
silt
clay
150 cm above sea level
Sediment Type
mud
clay
mud
Color
5Y5/3
2.5Y4/4
5Y5/2
10YR4/1
5Y4/3
5Y3/4
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
natural levee
floodplain

NC-92-21

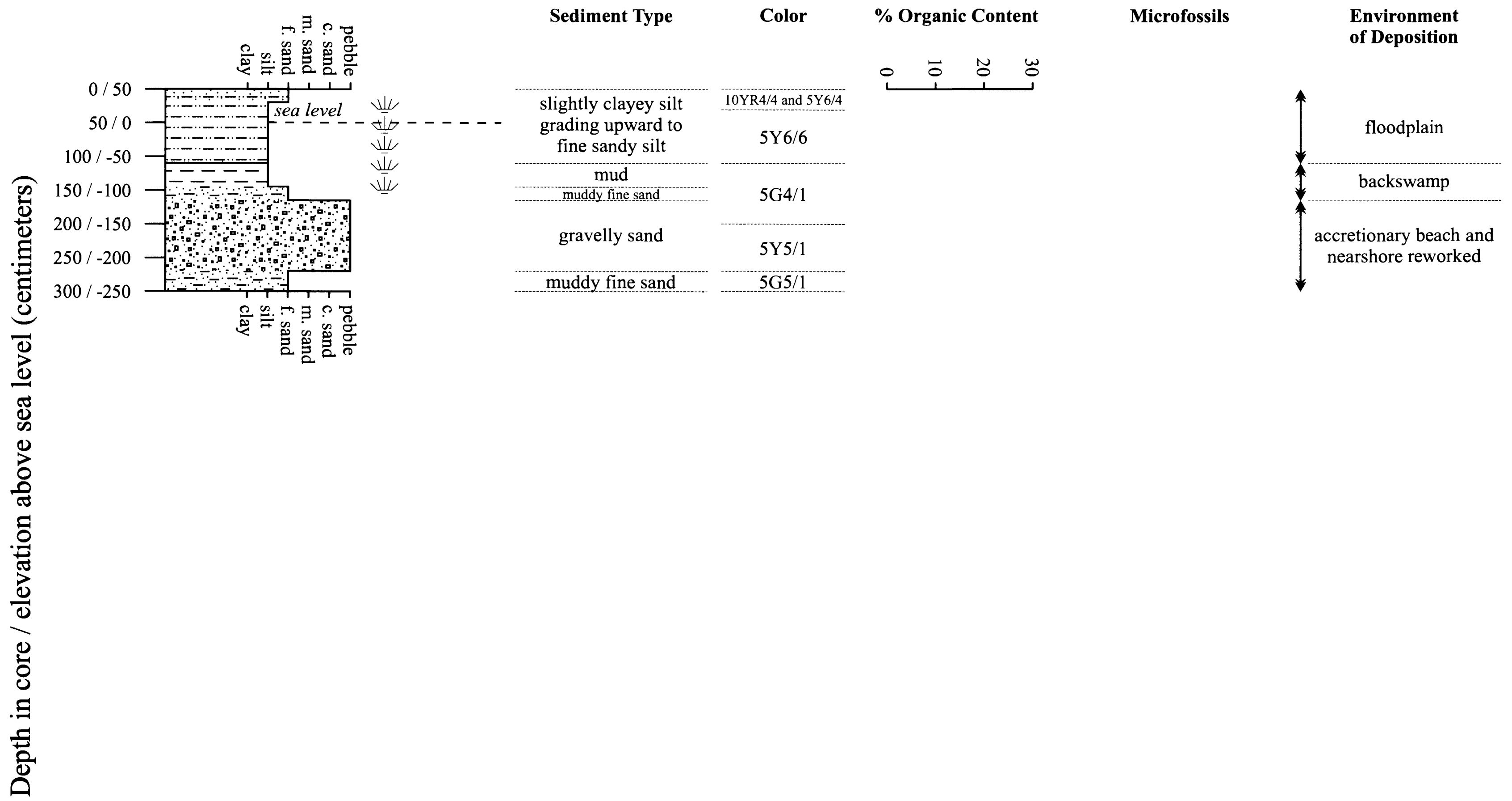


NC-93-14

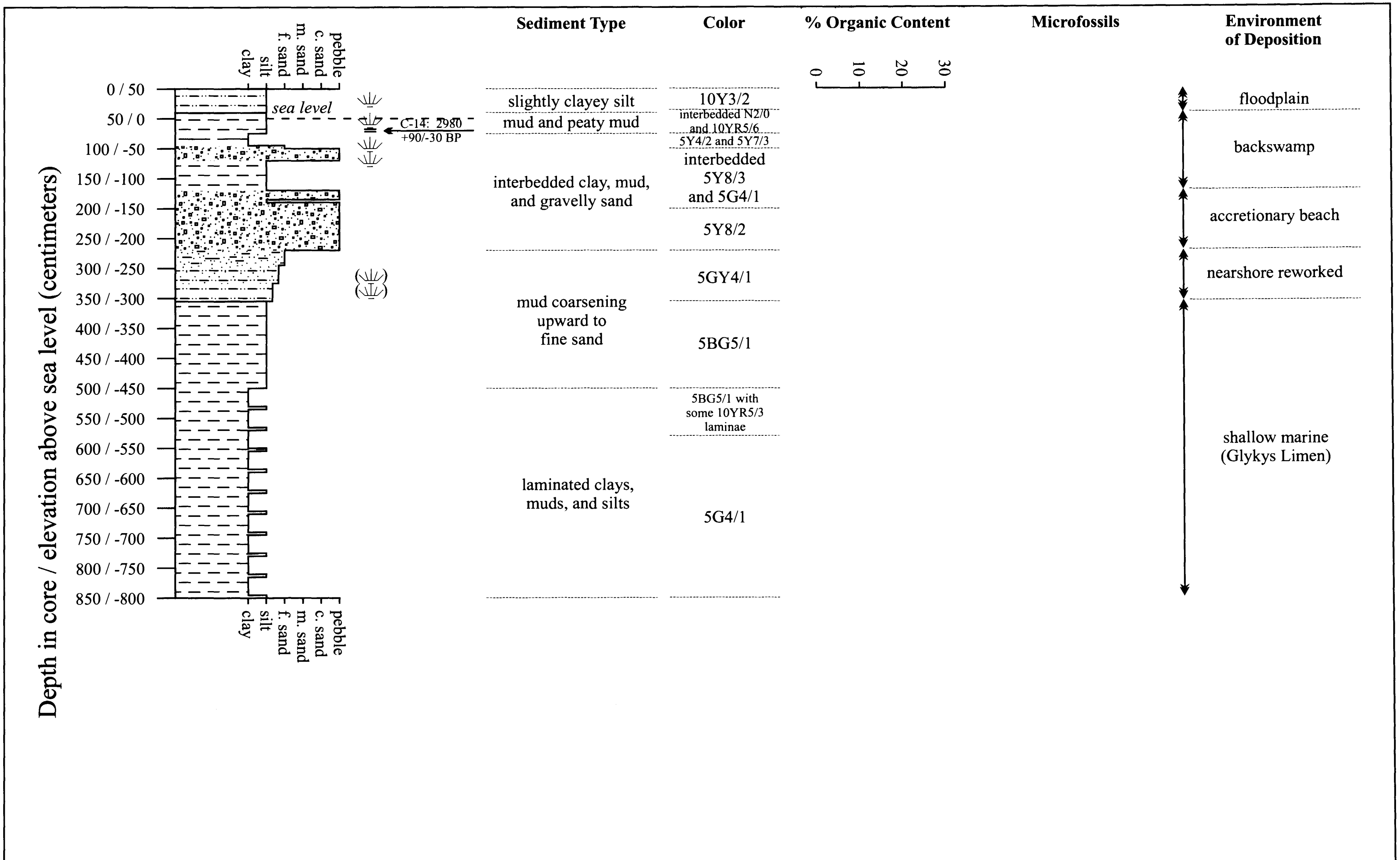
Depth in core / elevation above sea level (centimeters)
0 / 300
50 / 250
100 / 200
150 / 150
200 / 100
250 / 50
300 / 0
350 / -50
400 / -100
450 / -150
500 / -200
550 / -250
600 / -300
650 / -350
700 / -400
750 / -450
800 / -500
850 / -550
900 / -600
950 / -650
1000 / -700
1050 / -750
1100 / -800
1150 / -850
1200 / -900
1250 / -950
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
Sediment Type
silt
mud
slightly silty clay
mud
clay
slightly sandy silt fining upward to mud
clay
interbedded gravelly sands to fine sands
fine sandy mud grading upward to fine sand
laminated clays, muds, and silts with several cm-thick muddy fine sand layers
Color
2.5Y6/6
2.5Y5/4
N3/0 and N5/0
5Y5/2
5G5/1
5BG5/1
5G5/1 to 5G4/1 with 20-50% 2.5Y5/6 mottles
5G4/1
N5/0 to N4/0
N3/0
5GY4/1
5G4/1
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
crevasse splay
floodplain
interdistributary bay
subaqueous levee
delta distributary channel
delta distributary mouth bar
shallow marine (Glykys Limen)


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
0
10
20
30
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
Depth in core / elevation above sea level (centimeters)
0 / 50
50 / 0
100 / -50
150 / -100
200 / -150
250 / -200
300 / -250
350 / -300
400 / -350
450 / -400
500 / -450
550 / -500
600 / -550
650 / -600
700 / -650
gravelly sand fining upward to sandy mud
interbedded fine sands and muddy sands with some mud layers
mud
fine sand
10YR3/3
5Y5/6
5Y6/6
N8/0
5G4/1
N4/0
N4/0 interbedded with 5Y4/1
5BG4/1
5G4/1
5GY4/1
accretionary beach and nearshore reworked
nearshore reworked delta front

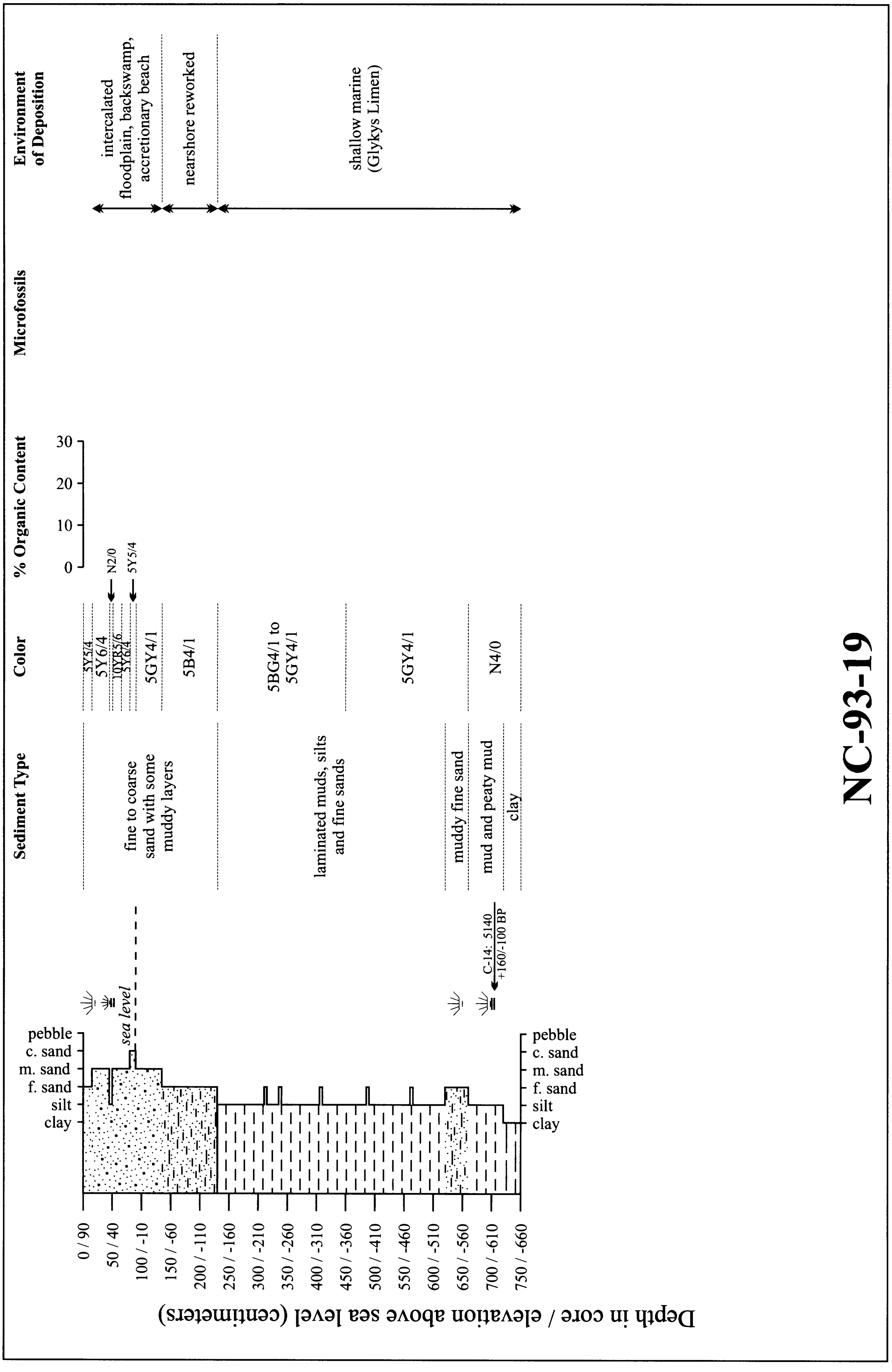
NC-93-15


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
pebble
c. sand
m. sand
f. sand
silt
clay
0 / 50
50 / 0
100 / -50
150 / -100
200 / -150
250 / -200
300 / -250
sea level
0
10
20
30
slightly clayey silt grading upward to fine sandy silt
mud
muddy fine sand
gravelly sand
muddy fine sand
10YR4/4 and 5Y6/4
5Y6/6
5G4/1
5Y5/1
5G5/1
floodplain
backswamp
accretionary beach and nearshore reworked
Depth in core / elevation above sea level (centimeters)

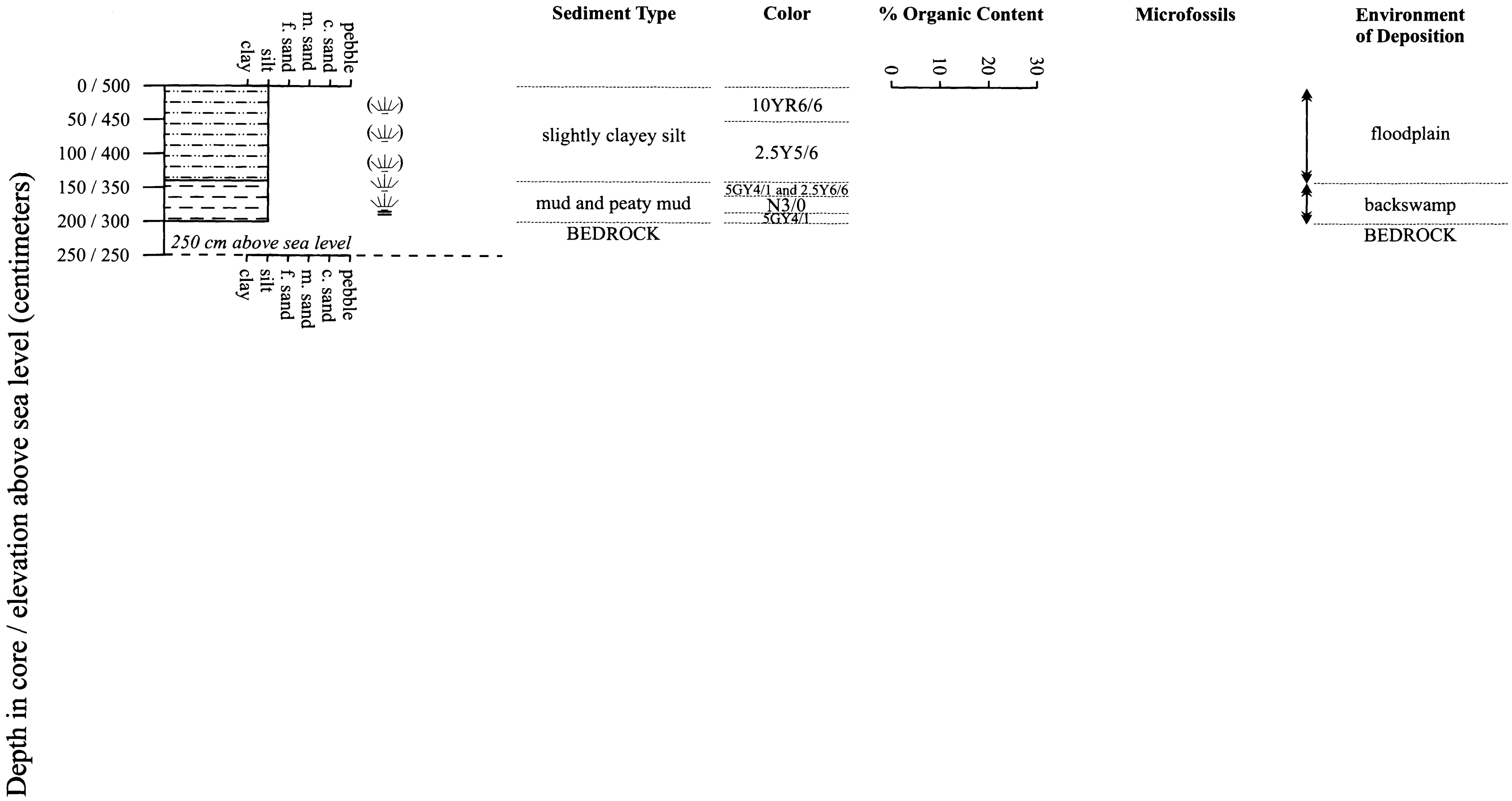
NC-93-17


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
pebble
c. sand
m. sand
f. sand
silt
clay
0
10
20
30
Depth in core / elevation above sea level (centimeters)
0 / 50
50 / 0
100 / -50
150 / -100
200 / -150
250 / -200
300 / -250
350 / -300
400 / -350
450 / -400
500 / -450
550 / -500
600 / -550
650 / -600
700 / -650
750 / -700
800 / -750
850 / -800
sea level
C-14: 2980
+90/-30 BP
slightly clayey silt
mud and peaty mud
interbedded clay, mud, and gravelly sand
mud coarsening upward to fine sand
laminated clays, muds, and silts
10Y3/2
interbedded N2/0 and 10YR5/6
5Y4/2 and 5Y7/3
interbedded 5Y8/3 and 5G4/1
5Y8/2
5GY4/1
5BG5/1
5BG5/1 with some 10YR5/3 laminae
5G4/1
floodplain
backswamp
accretionary beach
nearshore reworked
shallow marine (Glykys Limen)

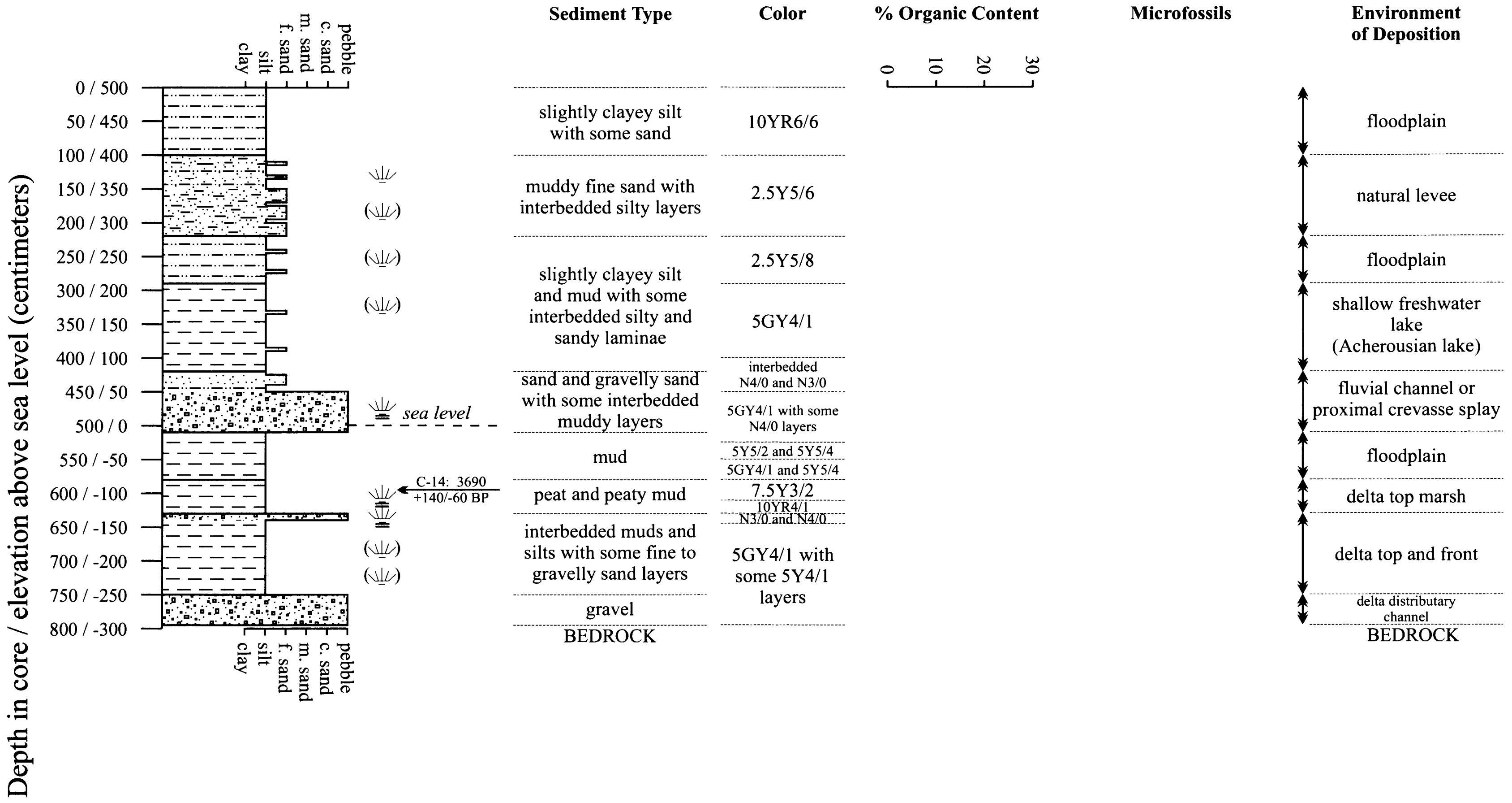
NC-93-18


Depth in core / elevation above sea level (centimeters)
0 / 90
50 / 40
100 / -10
150 / -60
200 / -110
250 / -160
300 / -210
350 / -260
400 / -310
450 / -360
500 / -410
550 / -460
600 / -510
650 / -560
700 / -610
750 / -660
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
C-14: 5140 +160/-100 BP
Sediment Type
fine to coarse sand with some muddy layers
laminated muds, silts and fine sands
muddy fine sand
mud and peaty mud
clay
Color
5Y5/4
5Y6/4
10YR5/6
5Y6/4
5GY4/1
5B4/1
5BG4/1 to 5GY4/1
5GY4/1
N4/0
N2/0
5Y5/4
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
intercalated floodplain, backswamp, accretionary beach
nearshore reworked
shallow marine (Glykys Limen)

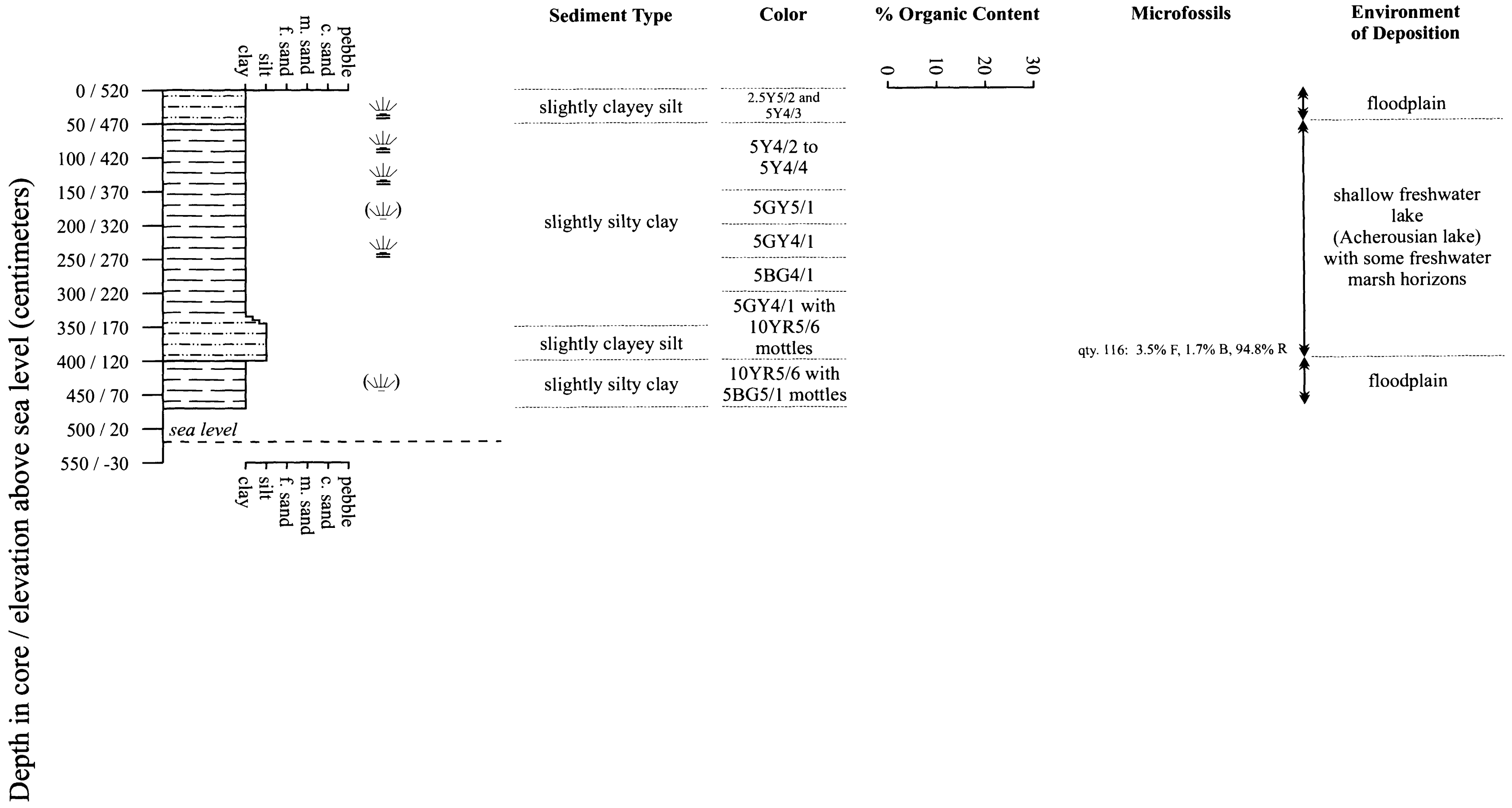
NC-93-19


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
Depth in core / elevation above sea level (centimeters)
0 / 500
50 / 450
100 / 400
150 / 350
200 / 300
250 / 250
pebble
c. sand
m. sand
f. sand
silt
clay
250 cm above sea level
0
10
20
30
slightly clayey silt
mud and peaty mud
BEDROCK
10YR6/6
2.5Y5/6
5GY4/1 and 2.5Y6/6
N3/0
5GY4/1
floodplain
backswamp
BEDROCK

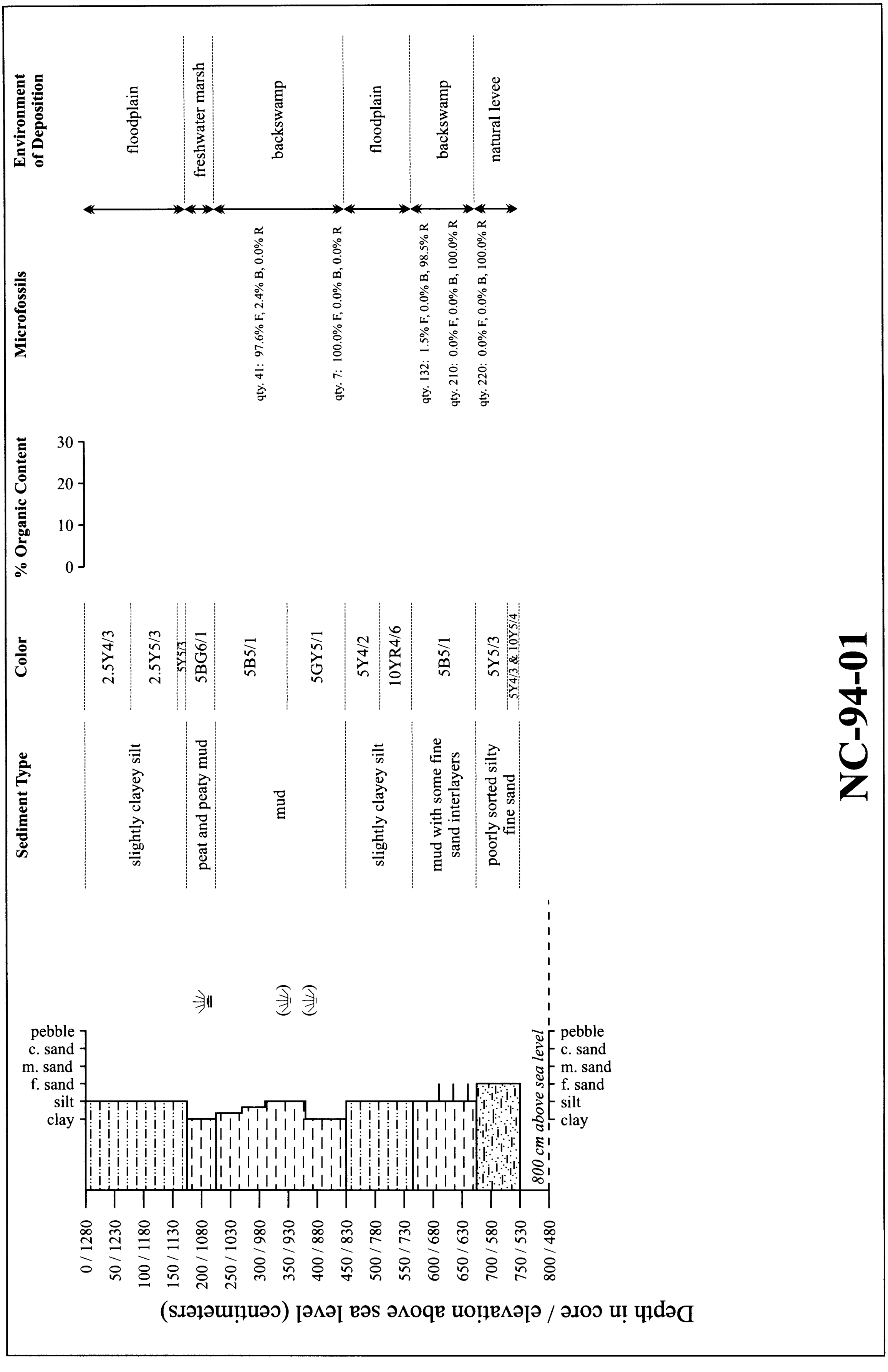
NC-93-20


Depth in core / elevation above sea level (centimeters)
0 / 500
50 / 450
100 / 400
150 / 350
200 / 300
250 / 250
300 / 200
350 / 150
400 / 100
450 / 50
500 / 0
550 / -50
600 / -100
650 / -150
700 / -200
750 / -250
800 / -300
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
C-14: 3690 +140/-60 BP
Sediment Type
slightly clayey silt with some sand
muddy fine sand with interbedded silty layers
slightly clayey silt and mud with some interbedded silty and sandy laminae
sand and gravelly sand with some interbedded muddy layers
mud
peat and peaty mud
interbedded muds and silts with some fine to gravelly sand layers
gravel
BEDROCK
Color
10YR6/6
2.5Y5/6
2.5Y5/8
5GY4/1
interbedded N4/0 and N3/0
5GY4/1 with some N4/0 layers
5Y5/2 and 5Y5/4
5GY4/1 and 5Y5/4
7.5Y3/2
10YR4/1
N3/0 and N4/0
5GY4/1 with some 5Y4/1 layers
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
floodplain
natural levee
floodplain
shallow freshwater lake (Acherousian lake)
fluvial channel or proximal crevasse splay
floodplain
delta top marsh
delta top and front
delta distributary channel
BEDROCK

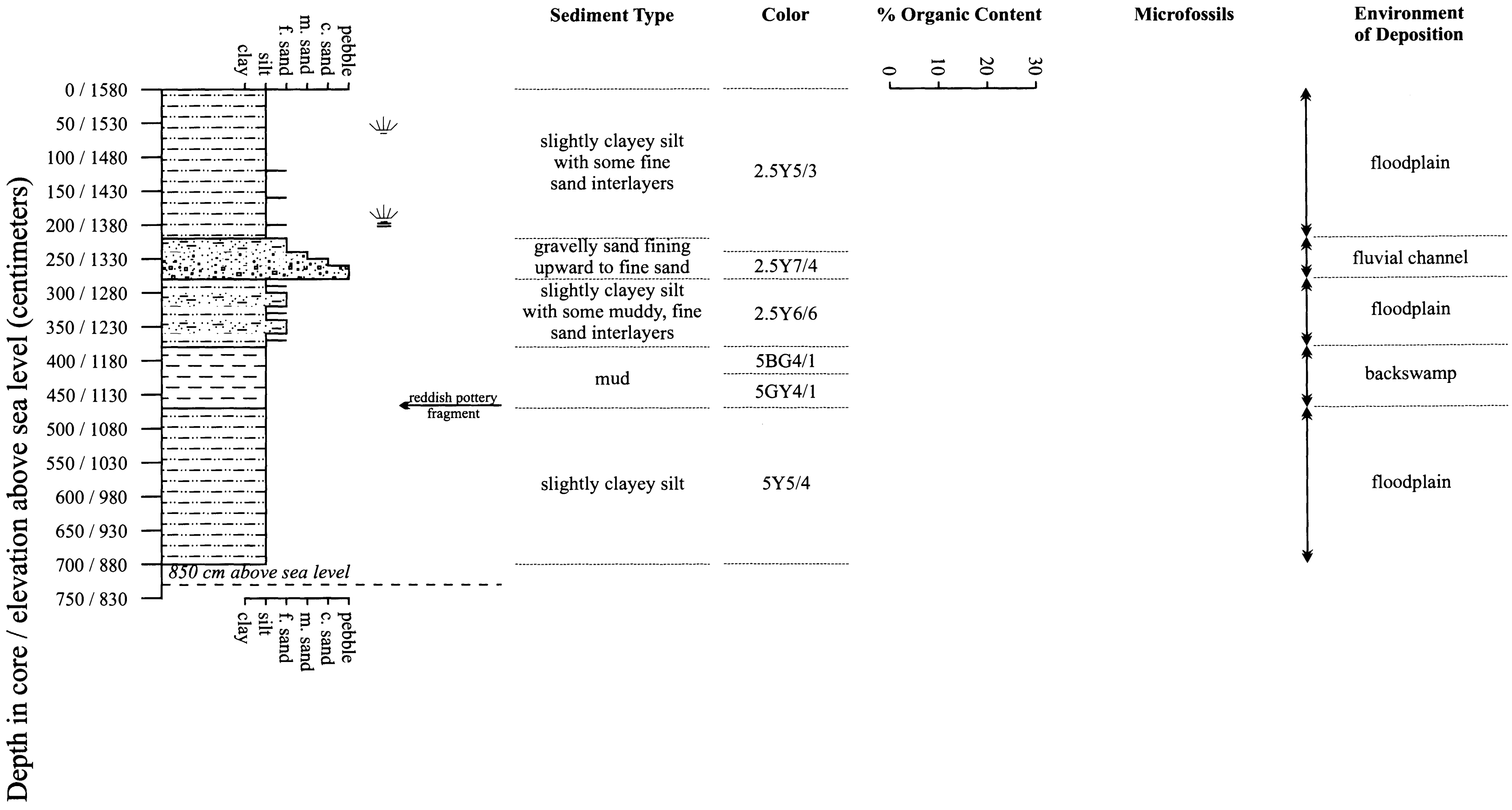
NC-93-21


Depth in core / elevation above sea level (centimeters)
0 / 520
50 / 470
100 / 420
150 / 370
200 / 320
250 / 270
300 / 220
350 / 170
400 / 120
450 / 70
500 / 20
550 / -30
sea level
pebble
c. sand
m. sand
f. sand
silt
clay
Sediment Type
slightly clayey silt
slightly silty clay
slightly clayey silt
slightly silty clay
Color
2.5Y5/2 and 5Y4/3
5Y4/2 to 5Y4/4
5GY5/1
5GY4/1
5BG4/1
5GY4/1 with 10YR5/6 mottles
10YR5/6 with 5BG5/1 mottles
% Organic Content
0
10
20
30
Microfossils
qty. 116: 3.5% F, 1.7% B, 94.8% R
Environment of Deposition
floodplain
shallow freshwater lake (Acherousian lake) with some freshwater marsh horizons
floodplain

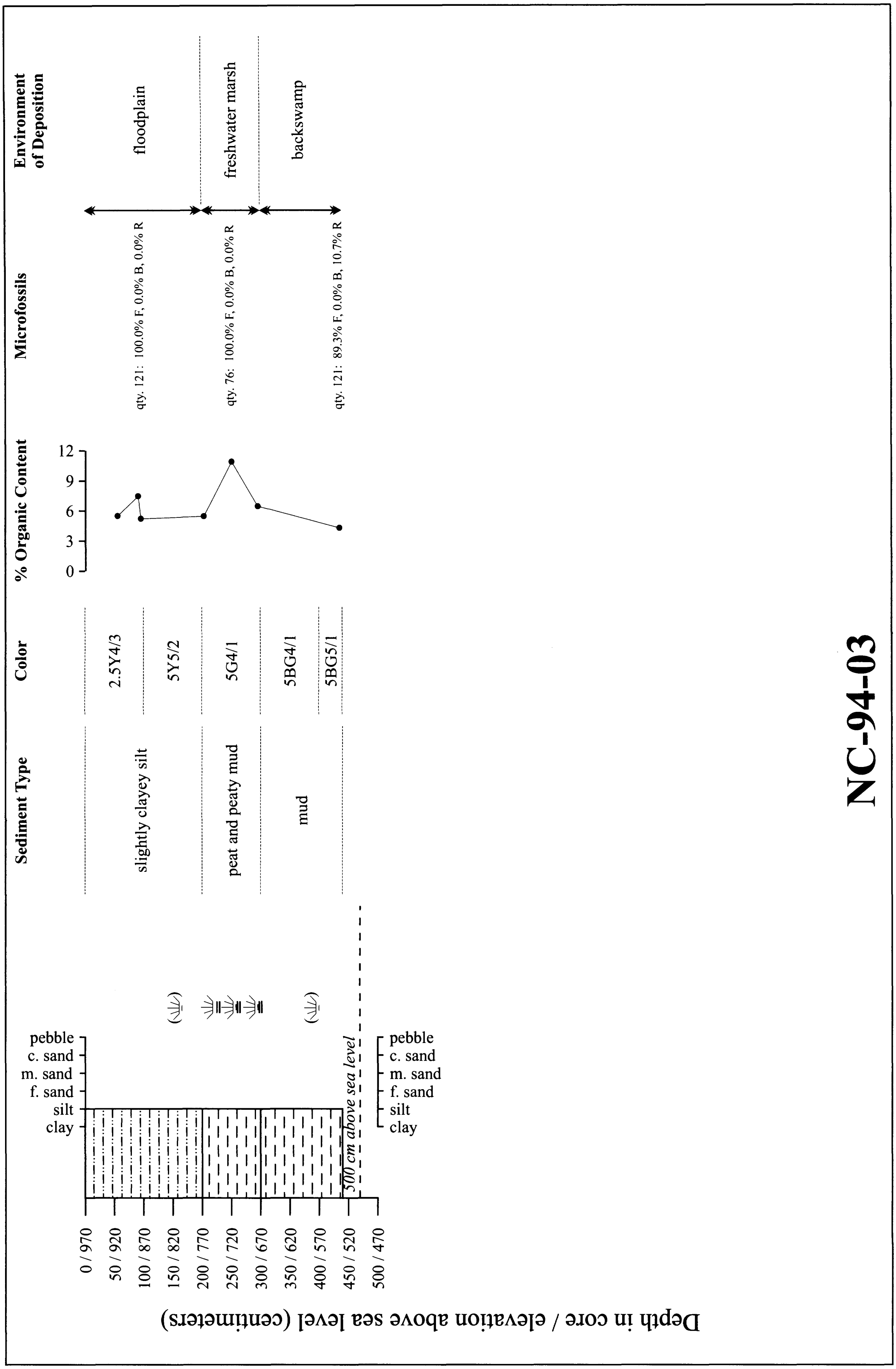
NC-93-22

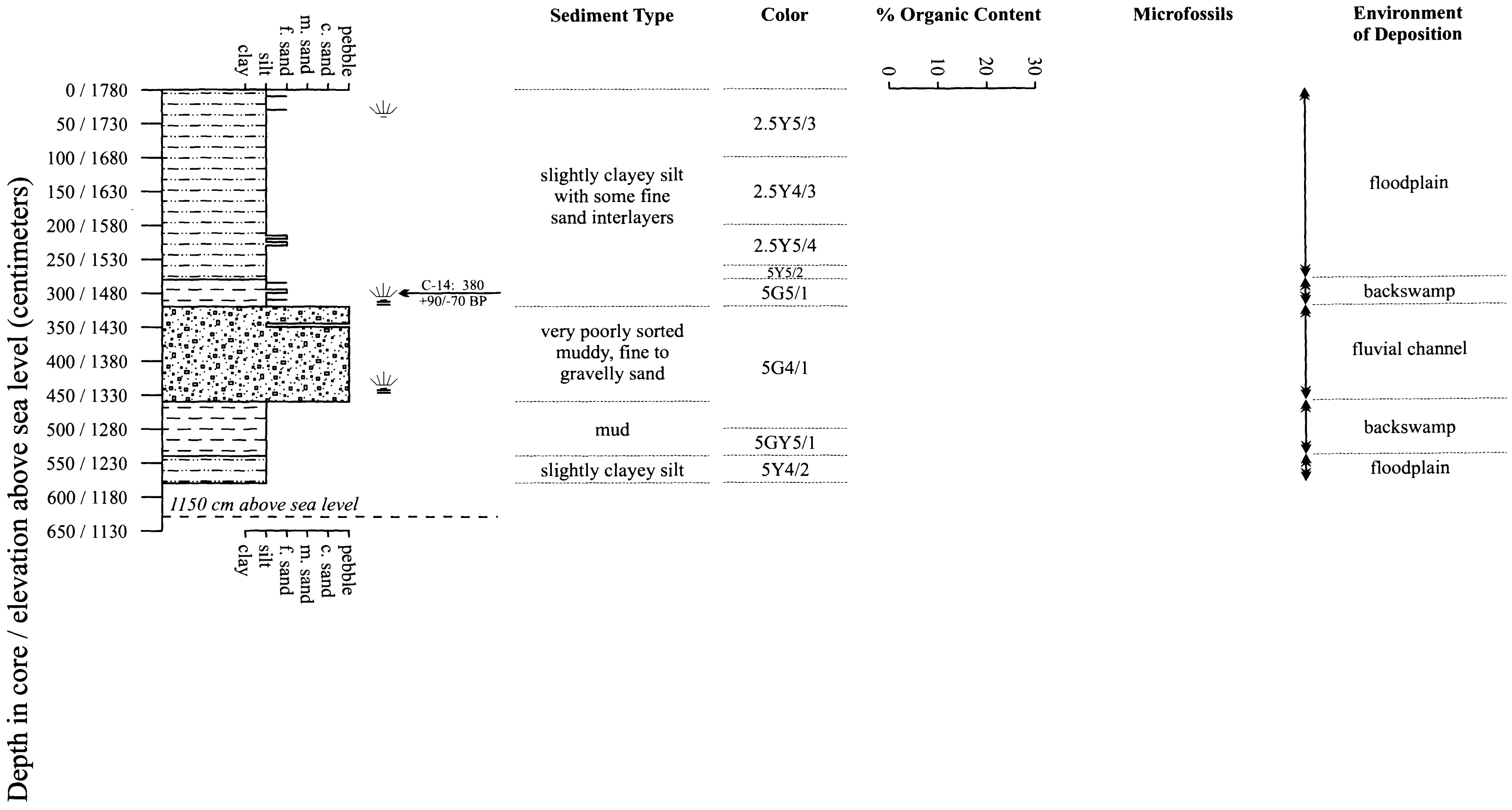

NC-94-01

Depth in core / elevation above sea level (centimeters)
0 / 1280
50 / 1230
100 / 1180
150 / 1130
200 / 1080
250 / 1030
300 / 980
350 / 930
400 / 880
450 / 830
500 / 780
550 / 730
600 / 680
650 / 630
700 / 580
750 / 530
800 / 480
pebble
c. sand
m. sand
f. sand
silt
clay
800 cm above sea level
Sediment Type
slightly clayey silt
peat and peaty mud
mud
slightly clayey silt
mud with some fine sand interlayers
poorly sorted silty fine sand
Color
2.5Y4/3
2.5Y5/3
5Y5/3
5BG6/1
5B5/1
5GY5/1
5Y4/2
10YR4/6
5B5/1
5Y5/3
5Y4/3 & 10Y5/4
% Organic Content
0
10
20
30
Microfossils
qty. 41: 97.6% F, 2.4% B, 0.0% R
qty. 7: 100.0% F, 0.0% B, 0.0% R
qty. 132: 1.5% F, 0.0% B, 98.5% R
qty. 210: 0.0% F, 0.0% B, 100.0% R
qty. 220: 0.0% F, 0.0% B, 100.0% R
Environment of Deposition
floodplain
freshwater marsh
backswamp
floodplain
backswamp
natural levee

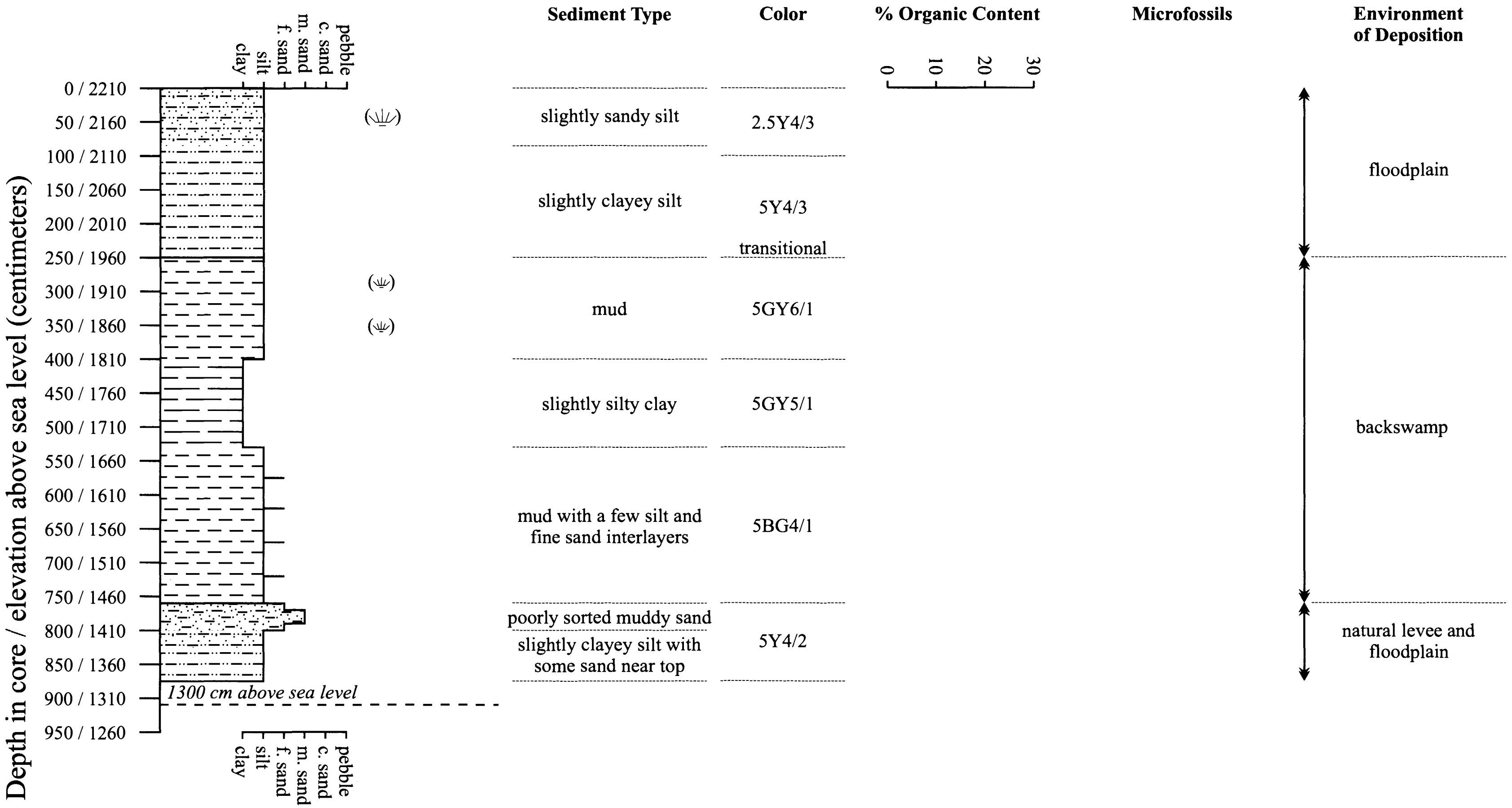

Depth in core / elevation above sea level (centimeters)
0 / 1580
50 / 1530
100 / 1480
150 / 1430
200 / 1380
250 / 1330
300 / 1280
350 / 1230
400 / 1180
450 / 1130
500 / 1080
550 / 1030
600 / 980
650 / 930
700 / 880
750 / 830
clay
silt
f. sand
m. sand
c. sand
pebble
850 cm above sea level
reddish pottery fragment
Sediment Type
slightly clayey silt with some fine sand interlayers
gravelly sand fining upward to fine sand
slightly clayey silt with some muddy, fine sand interlayers
mud
slightly clayey silt
Color
2.5Y5/3
2.5Y7/4
2.5Y6/6
5BG4/1
5GY4/1
5Y5/4
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
floodplain
fluvial channel
floodplain
backswamp
floodplain

NC-94-02

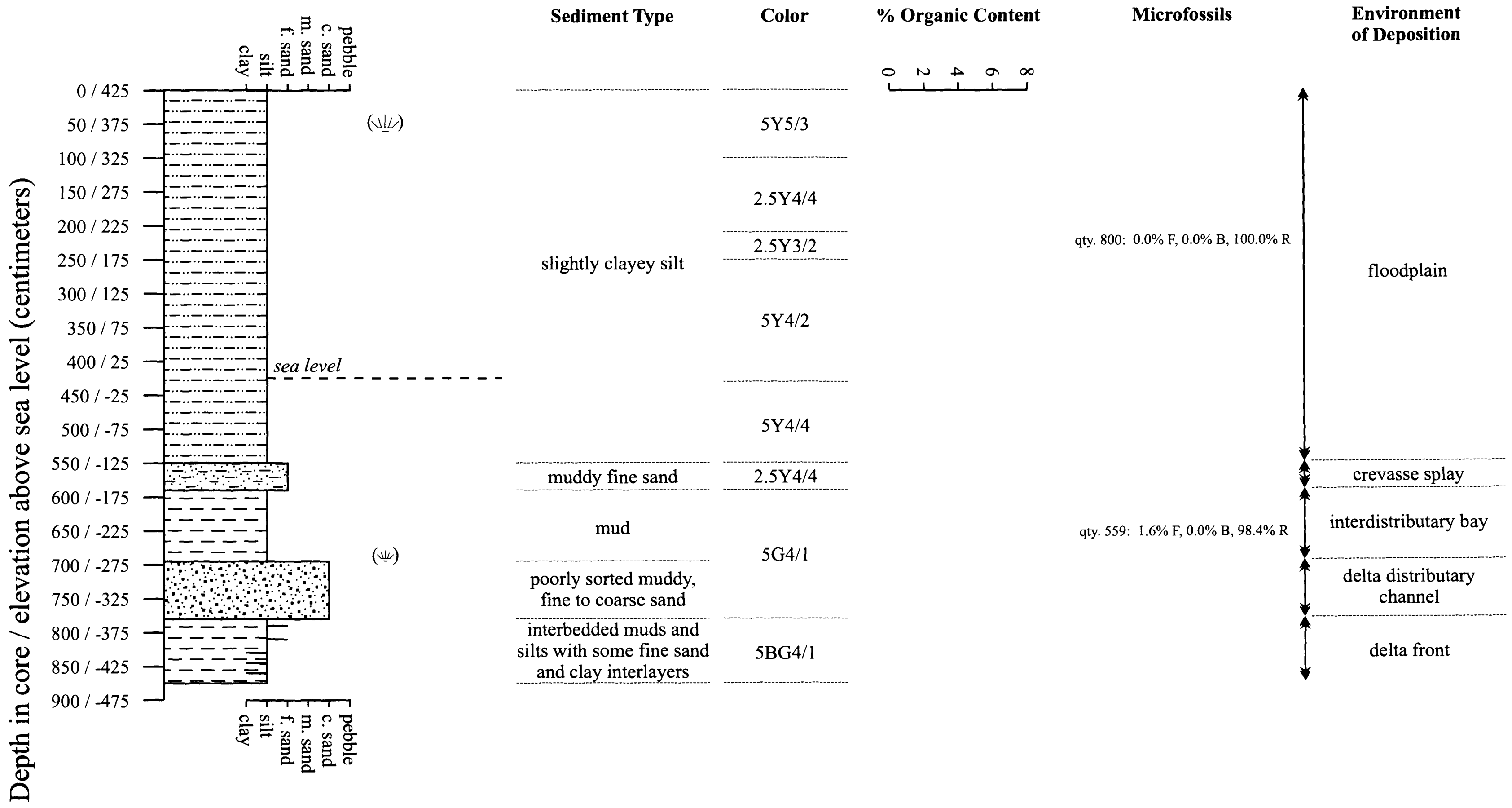

NC-94-03
Depth in core / elevation above sea level (centimeters)
0 / 970
50 / 920
100 / 870
150 / 820
200 / 770
250 / 720
300 / 670
350 / 620
400 / 570
450 / 520
500 / 470
pebble
c. sand
m. sand
f. sand
silt
clay
500 cm above sea level
Sediment Type
slightly clayey silt
peat and peaty mud
mud
Color
2.5Y4/3
5Y5/2
5G4/1
5BG4/1
5BG5/1
% Organic Content
0
3
6
9
12
Microfossils
qty. 121: 100.0% F, 0.0% B, 0.0% R
qty. 76: 100.0% F, 0.0% B, 0.0% R
qty. 121: 89.3% F, 0.0% B, 10.7% R
Environment of Deposition
floodplain
freshwater marsh
backswamp


Depth in core / elevation above sea level (centimeters)
0 / 1780
50 / 1730
100 / 1680
150 / 1630
200 / 1580
250 / 1530
300 / 1480
350 / 1430
400 / 1380
450 / 1330
500 / 1280
550 / 1230
600 / 1180
650 / 1130
pebble
c. sand
m. sand
f. sand
silt
clay
C-14: 380 +90/-70 BP
1150 cm above sea level
Sediment Type
Color
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
slightly clayey silt with some fine sand interlayers
very poorly sorted muddy, fine to gravelly sand
mud
slightly clayey silt
2.5Y5/3
2.5Y4/3
2.5Y5/4
5Y5/2
5G5/1
5G4/1
5GY5/1
5Y4/2
floodplain
backswamp
fluvial channel
backswamp
floodplain

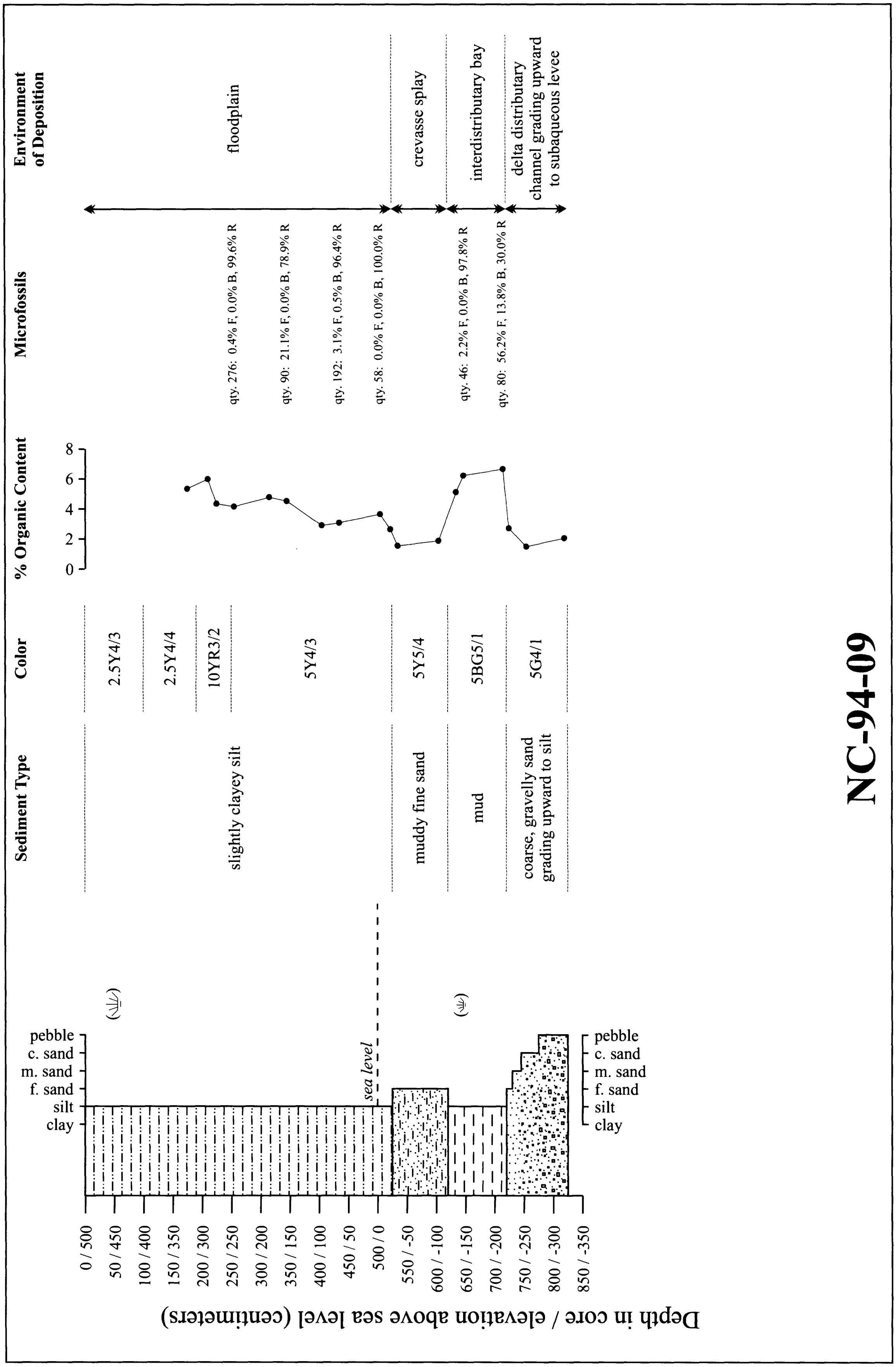
NC-94-04

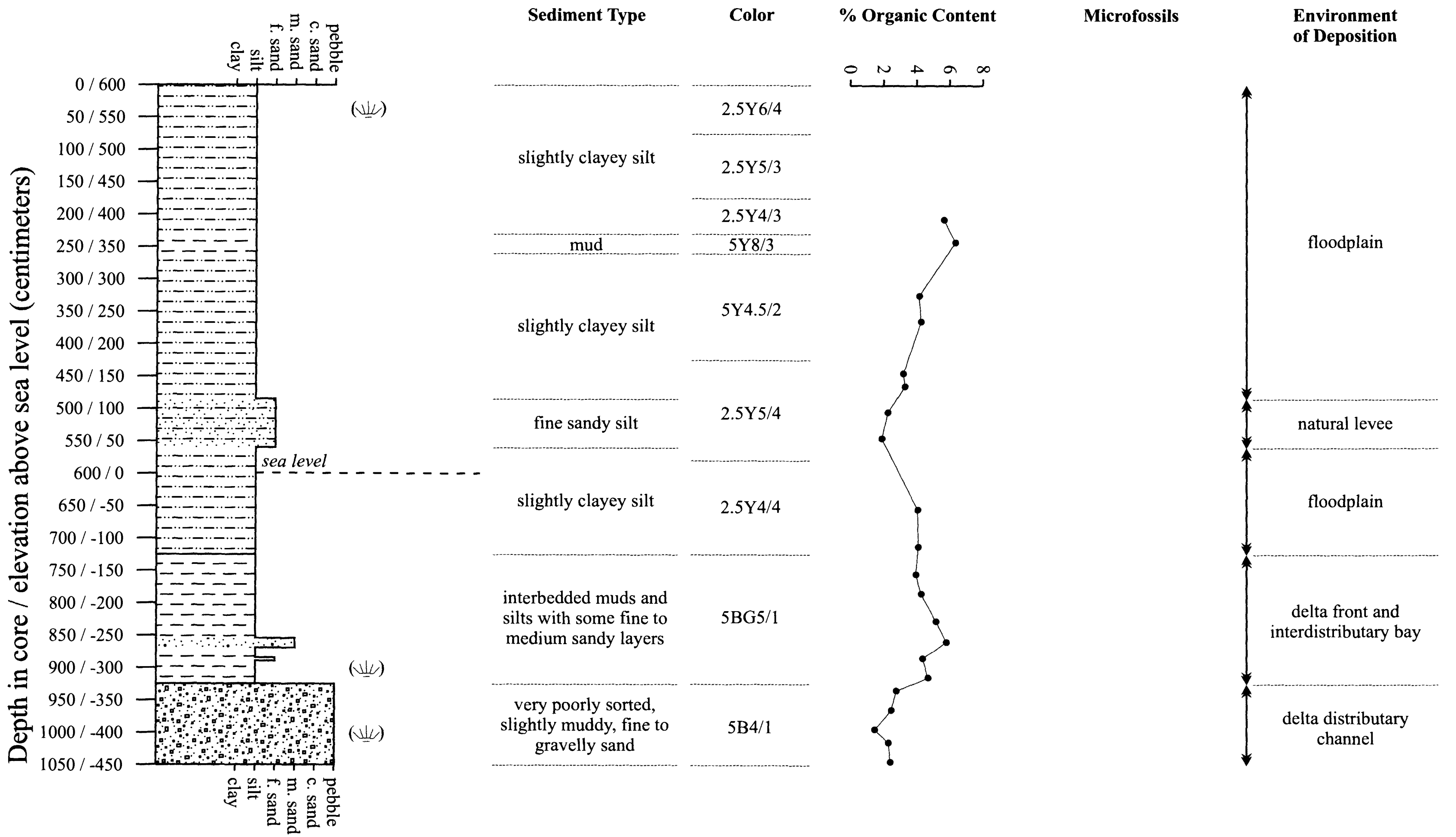

Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
pebble
c. sand
m. sand
f. sand
silt
clay
0
10
20
30
Depth in core / elevation above sea level (centimeters)
0 / 2210
50 / 2160
100 / 2110
150 / 2060
200 / 2010
250 / 1960
300 / 1910
350 / 1860
400 / 1810
450 / 1760
500 / 1710
550 / 1660
600 / 1610
650 / 1560
700 / 1510
750 / 1460
800 / 1410
850 / 1360
900 / 1310
950 / 1260
1300 cm above sea level
slightly sandy silt
2.5Y4/3
slightly clayey silt
5Y4/3
transitional
mud
5GY6/1
slightly silty clay
5GY5/1
mud with a few silt and fine sand interlayers
5BG4/1
poorly sorted muddy sand
slightly clayey silt with some sand near top
5Y4/2
floodplain
backswamp
natural levee and floodplain

NC-94-05

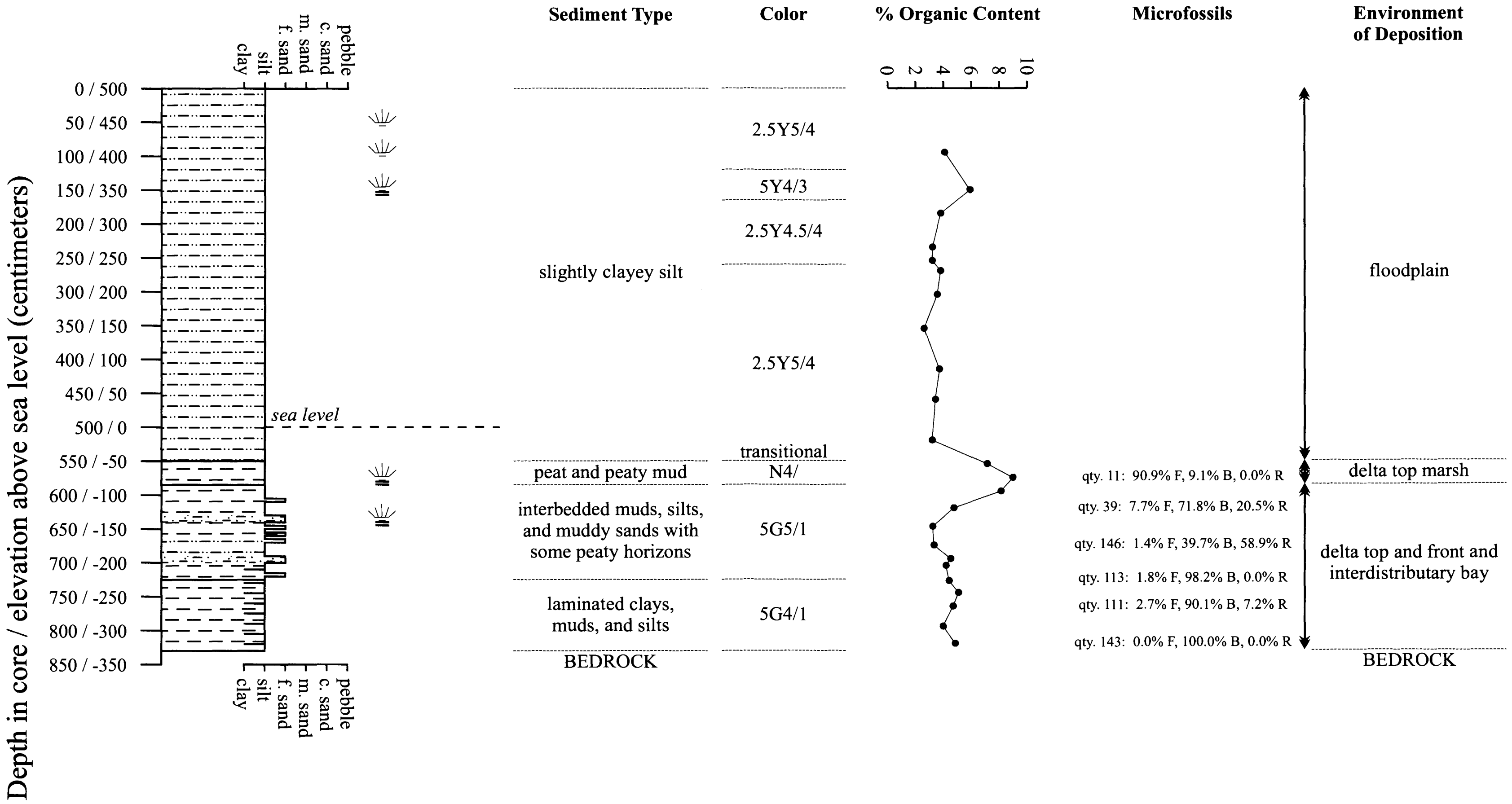

Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
Depth in core / elevation above sea level (centimeters)
clay
silt
f. sand
m. sand
c. sand
pebble
0 / 425
50 / 375
100 / 325
150 / 275
200 / 225
250 / 175
300 / 125
350 / 75
400 / 25
450 / -25
500 / -75
550 / -125
600 / -175
650 / -225
700 / -275
750 / -325
800 / -375
850 / -425
900 / -475
sea level
0
2
4
6
8
slightly clayey silt
muddy fine sand
mud
poorly sorted muddy, fine to coarse sand
interbedded muds and silts with some fine sand and clay interlayers
5Y5/3
2.5Y4/4
2.5Y3/2
5Y4/2
5Y4/4
2.5Y4/4
5G4/1
5BG4/1
qty. 800: 0.0% F, 0.0% B, 100.0% R
qty. 559: 1.6% F, 0.0% B, 98.4% R
floodplain
crevasse splay
interdistributary bay
delta distributary channel
delta front

NC-94-08

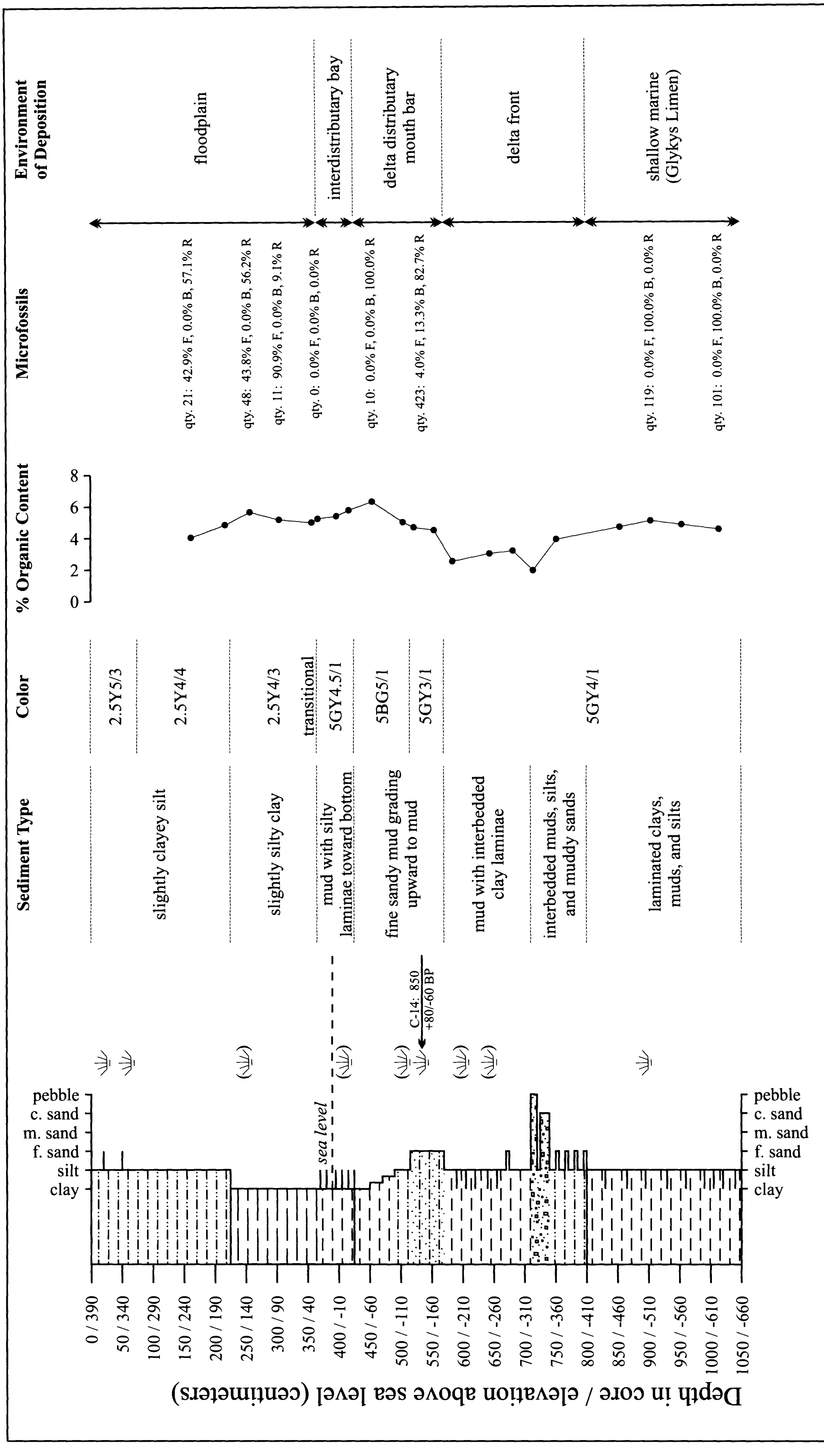

NC-94-09
Depth in core / elevation above sea level (centimeters)
0 / 500
50 / 450
100 / 400
150 / 350
200 / 300
250 / 250
300 / 200
350 / 150
400 / 100
450 / 50
500 / 0
550 / -50
600 / -100
650 / -150
700 / -200
750 / -250
800 / -300
850 / -350
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
Sediment Type
slightly clayey silt
muddy fine sand
mud
coarse, gravelly sand grading upward to silt
Color
2.5Y4/3
2.5Y4/4
10YR3/2
5Y4/3
5Y5/4
5BG5/1
5G4/1
% Organic Content
0
2
4
6
8
Microfossils
qty. 276: 0.4% F, 0.0% B, 99.6% R
qty. 90: 21.1% F, 0.0% B, 78.9% R
qty. 192: 3.1% F, 0.5% B, 96.4% R
qty. 58: 0.0% F, 0.0% B, 100.0% R
qty. 46: 2.2% F, 0.0% B, 97.8% R
qty. 80: 56.2% F, 13.8% B, 30.0% R
Environment of Deposition
floodplain
crevasse splay
interdistributary bay
delta distributary channel grading upward to subaqueous levee


Depth in core / elevation above sea level (centimeters)
0 / 600
50 / 550
100 / 500
150 / 450
200 / 400
250 / 350
300 / 300
350 / 250
400 / 200
450 / 150
500 / 100
550 / 50
600 / 0
650 / -50
700 / -100
750 / -150
800 / -200
850 / -250
900 / -300
950 / -350
1000 / -400
1050 / -450
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
Sediment Type
slightly clayey silt
mud
slightly clayey silt
fine sandy silt
slightly clayey silt
interbedded muds and silts with some fine to medium sandy layers
very poorly sorted, slightly muddy, fine to gravelly sand
Color
2.5Y6/4
2.5Y5/3
2.5Y4/3
5Y8/3
5Y4.5/2
2.5Y5/4
2.5Y4/4
5BG5/1
5B4/1
% Organic Content
0
2
4
6
8
Microfossils
Environment of Deposition
floodplain
natural levee
floodplain
delta front and interdistributary bay
delta distributary channel

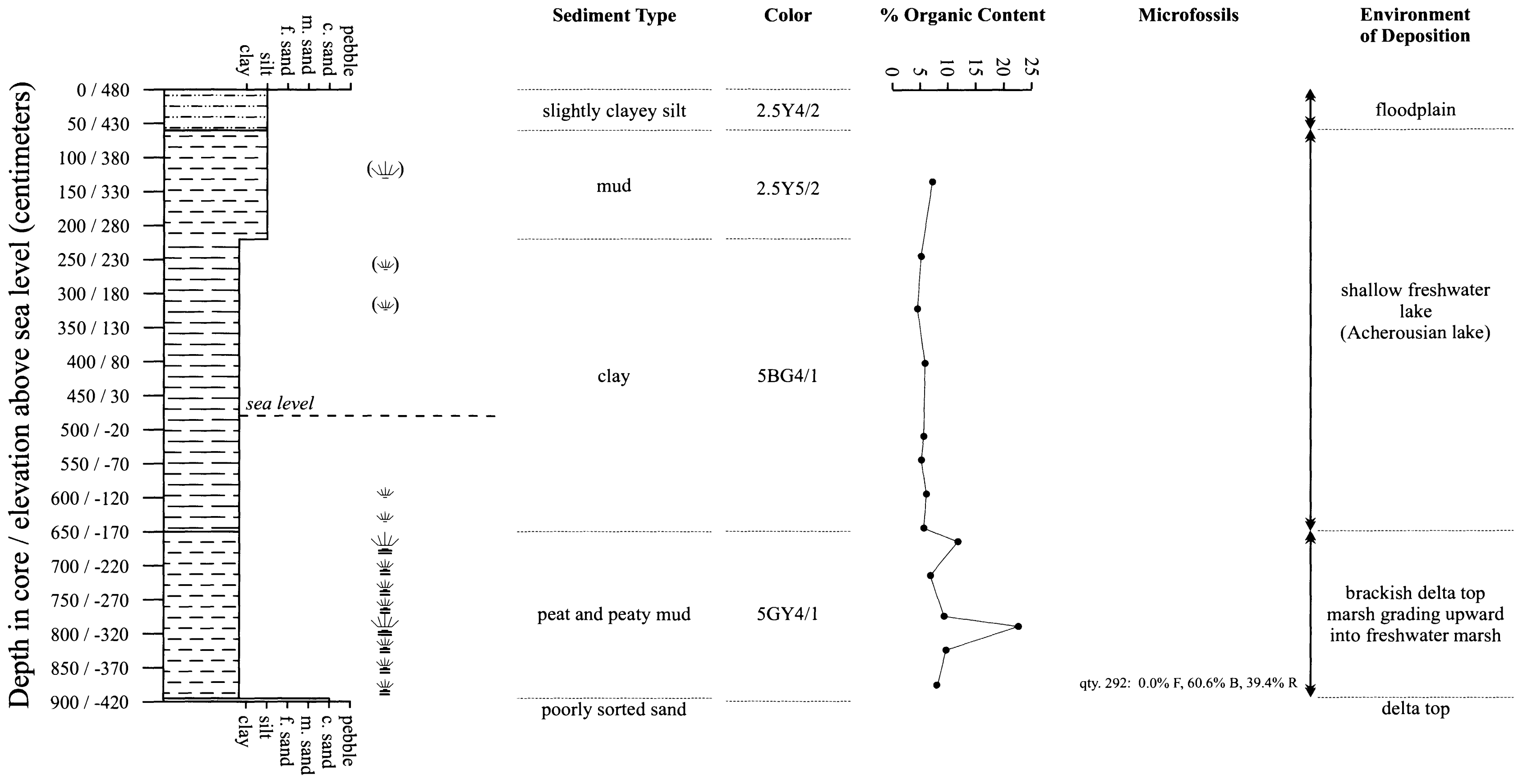
NC-94-11


Depth in core / elevation above sea level (centimeters)
0 / 500
50 / 450
100 / 400
150 / 350
200 / 300
250 / 250
300 / 200
350 / 150
400 / 100
450 / 50
500 / 0
550 / -50
600 / -100
650 / -150
700 / -200
750 / -250
800 / -300
850 / -350
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
Sediment Type
slightly clayey silt
peat and peaty mud
interbedded muds, silts, and muddy sands with some peaty horizons
laminated clays, muds, and silts
BEDROCK
Color
2.5Y5/4
5Y4/3
2.5Y4.5/4
2.5Y5/4
transitional
N4/
5G5/1
5G4/1
% Organic Content
0
2
4
6
8
10
Microfossils
qty. 11: 90.9% F, 9.1% B, 0.0% R
qty. 39: 7.7% F, 71.8% B, 20.5% R
qty. 146: 1.4% F, 39.7% B, 58.9% R
qty. 113: 1.8% F, 98.2% B, 0.0% R
qty. 111: 2.7% F, 90.1% B, 7.2% R
qty. 143: 0.0% F, 100.0% B, 0.0% R
Environment of Deposition
floodplain
delta top marsh
delta top and front and interdistributary bay
BEDROCK

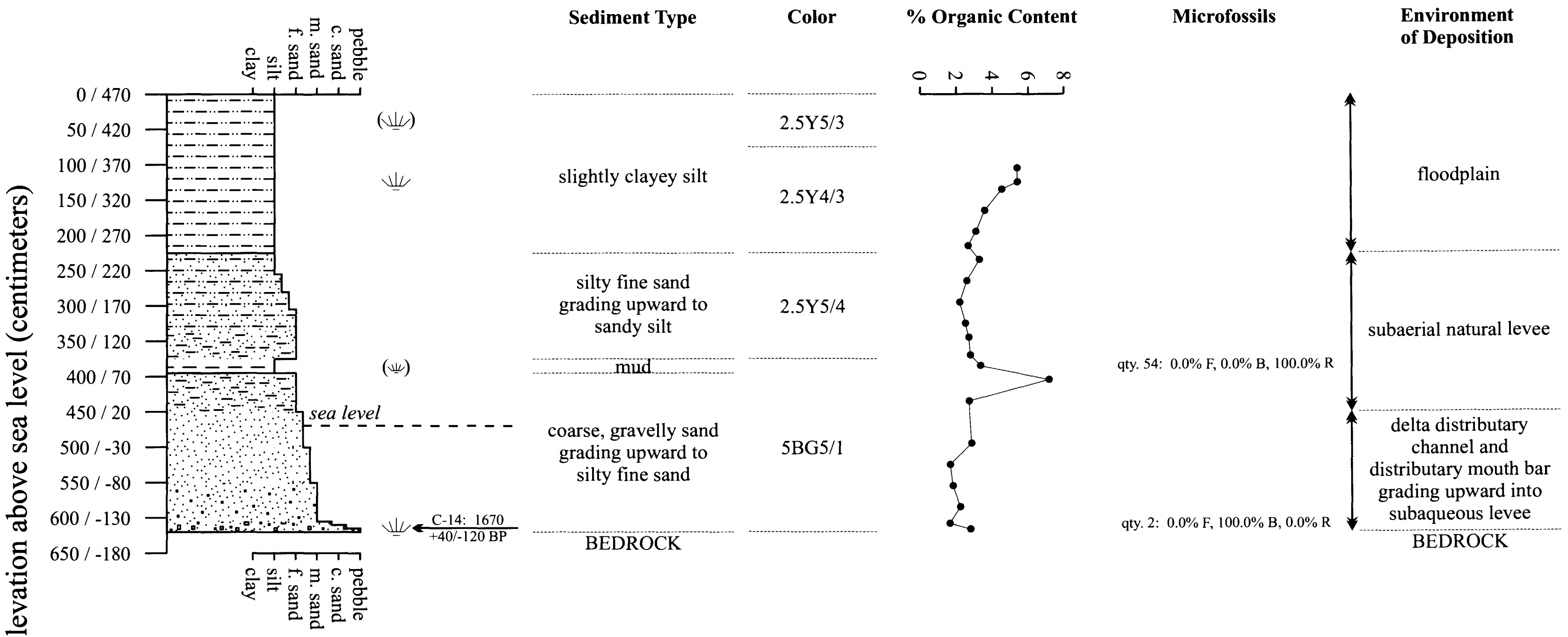
NC-94-12


Depth in core / elevation above sea level (centimeters)
0 / 390
50 / 340
100 / 290
150 / 240
200 / 190
250 / 140
300 / 90
350 / 40
400 / -10
450 / -60
500 / -110
550 / -160
600 / -210
650 / -260
700 / -310
750 / -360
800 / -410
850 / -460
900 / -510
950 / -560
1000 / -610
1050 / -660
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
C-14: 850
+80/-60 BP
Sediment Type
slightly clayey silt
slightly silty clay
mud with silty laminae toward bottom
fine sandy mud grading upward to mud
mud with interbedded clay laminae
interbedded muds, silts, and muddy sands
laminated clays, muds, and silts
Color
2.5Y5/3
2.5Y4/4
2.5Y4/3
transitional
5GY4.5/1
5BG5/1
5GY3/1
5GY4/1
% Organic Content
0
2
4
6
8
Microfossils
qty. 21: 42.9% F, 0.0% B, 57.1% R
qty. 48: 43.8% F, 0.0% B, 56.2% R
qty. 11: 90.9% F, 0.0% B, 9.1% R
qty. 0: 0.0% F, 0.0% B, 0.0% R
qty. 10: 0.0% F, 0.0% B, 100.0% R
qty. 423: 4.0% F, 13.3% B, 82.7% R
qty. 119: 0.0% F, 100.0% B, 0.0% R
qty. 101: 0.0% F, 100.0% B, 0.0% R
Environment of Deposition
floodplain
interdistributary bay
delta distributary mouth bar
delta front
shallow marine (Glykys Limen)

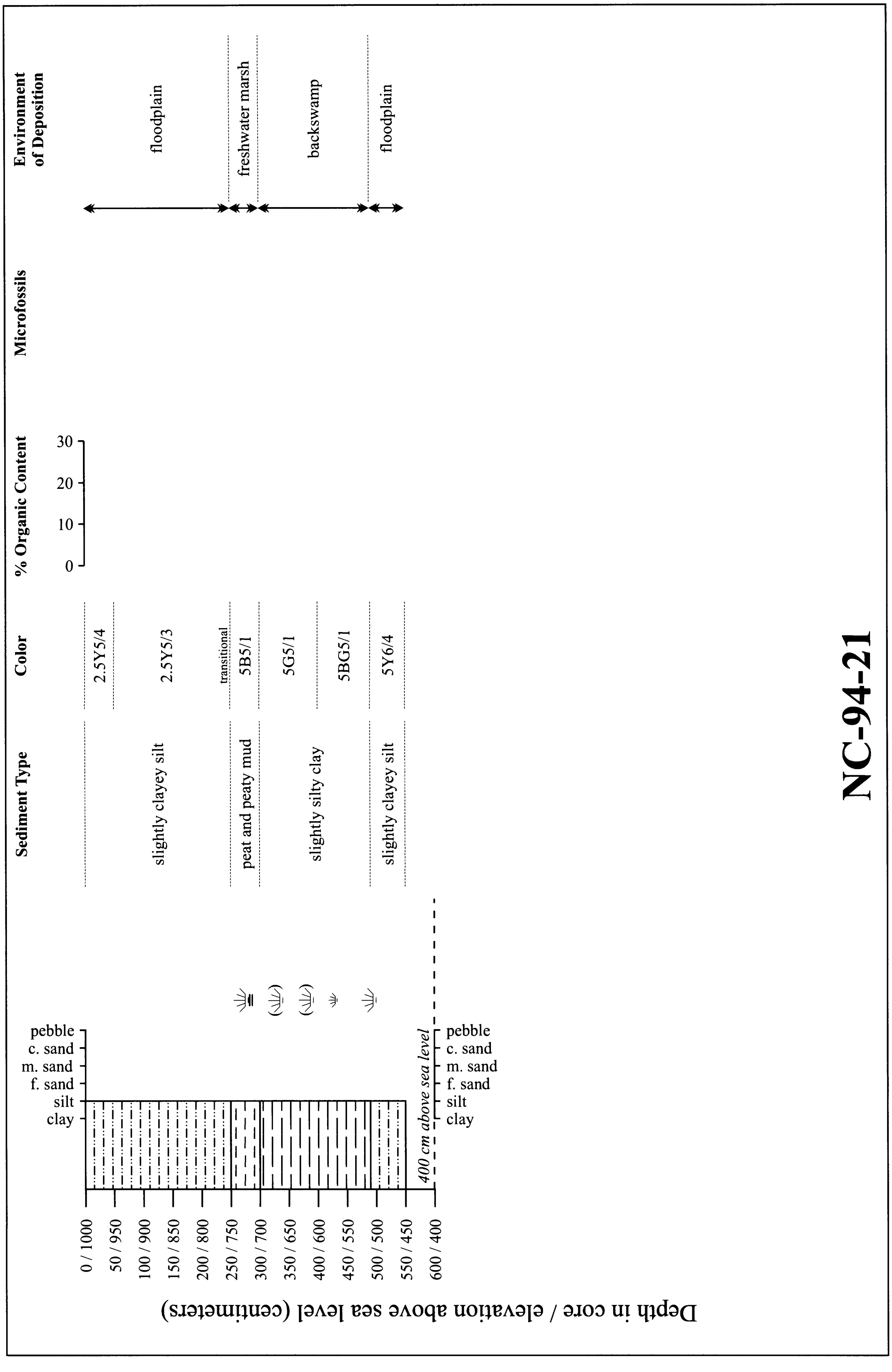
NC-94-13


Depth in core / elevation above sea level (centimeters)
0 / 480
50 / 430
100 / 380
150 / 330
200 / 280
250 / 230
300 / 180
350 / 130
400 / 80
450 / 30
500 / -20
550 / -70
600 / -120
650 / -170
700 / -220
750 / -270
800 / -320
850 / -370
900 / -420
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
Sediment Type
slightly clayey silt
mud
clay
peat and peaty mud
poorly sorted sand
Color
2.5Y4/2
2.5Y5/2
5BG4/1
5GY4/1
% Organic Content
0
5
10
15
20
25
Microfossils
qty. 292: 0.0% F, 60.6% B, 39.4% R
Environment of Deposition
floodplain
shallow freshwater lake (Acherousian lake)
brackish delta top marsh grading upward into freshwater marsh
delta top

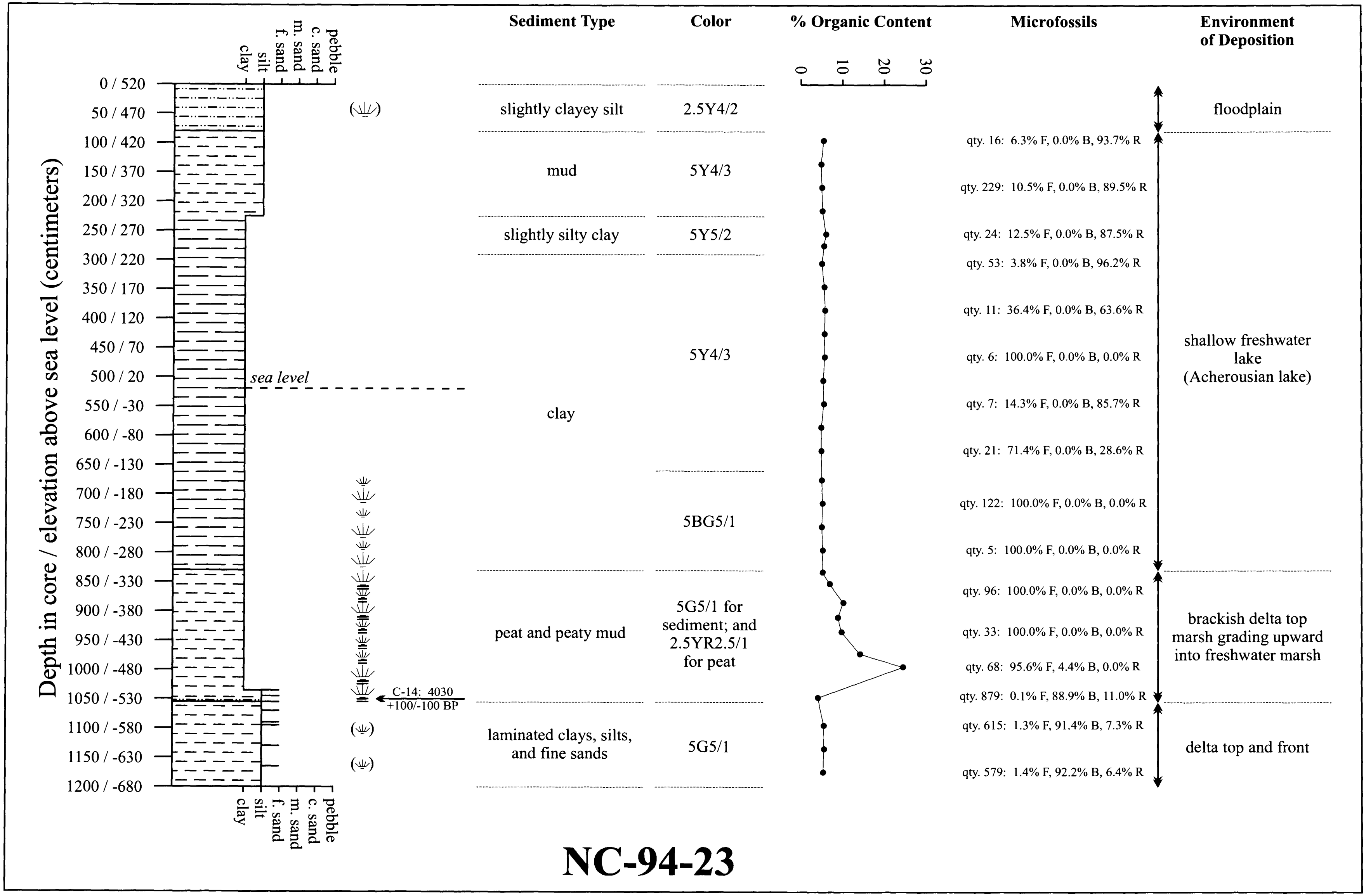
NC-94-17


Sediment Type
Color
% Organic Content
Microfossils
Environment of Deposition
Depth in core / elevation above sea level (centimeters)
0 / 470
50 / 420
100 / 370
150 / 320
200 / 270
250 / 220
300 / 170
350 / 120
400 / 70
450 / 20
500 / -30
550 / -80
600 / -130
650 / -180
pebble
c. sand
m. sand
f. sand
silt
clay
sea level
C-14: 1670 +40/-120 BP
slightly clayey silt
silty fine sand grading upward to sandy silt
mud
coarse, gravelly sand grading upward to silty fine sand
BEDROCK
2.5Y5/3
2.5Y4/3
2.5Y5/4
5BG5/1
0
2
4
6
8
qty. 54: 0.0% F, 0.0% B, 100.0% R
qty. 2: 0.0% F, 100.0% B, 0.0% R
floodplain
subaerial natural levee
delta distributary channel and distributary mouth bar grading upward into subaqueous levee
BEDROCK

NC-94-20


Depth in core / elevation above sea level (centimeters)
0 / 1000
50 / 950
100 / 900
150 / 850
200 / 800
250 / 750
300 / 700
350 / 650
400 / 600
450 / 550
500 / 500
550 / 450
600 / 400
clay
silt
f. sand
m. sand
c. sand
pebble
400 cm above sea level
Sediment Type
slightly clayey silt
peat and peaty mud
slightly silty clay
slightly clayey silt
Color
2.5Y5/4
2.5Y5/3
transitional
5B5/1
5G5/1
5BG5/1
5Y6/4
% Organic Content
0
10
20
30
Microfossils
Environment of Deposition
floodplain
freshwater marsh
backswamp
floodplain

NC-94-21


Depth in core / elevation above sea level (centimeters)
0 / 520
50 / 470
100 / 420
150 / 370
200 / 320
250 / 270
300 / 220
350 / 170
400 / 120
450 / 70
500 / 20
550 / -30
600 / -80
650 / -130
700 / -180
750 / -230
800 / -280
850 / -330
900 / -380
950 / -430
1000 / -480
1050 / -530
1100 / -580
1150 / -630
1200 / -680
clay
silt
f. sand
m. sand
c. sand
pebble
sea level
C-14: 4030 +100/-100 BP
Sediment Type
slightly clayey silt
mud
slightly silty clay
clay
peat and peaty mud
laminated clays, silts, and fine sands
Color
2.5Y4/2
5Y4/3
5Y5/2
5Y4/3
5BG5/1
5G5/1 for sediment; and 2.5YR2.5/1 for peat
5G5/1
% Organic Content
0
10
20
30
Microfossils
qty. 16: 6.3% F, 0.0% B, 93.7% R
qty. 229: 10.5% F, 0.0% B, 89.5% R
qty. 24: 12.5% F, 0.0% B, 87.5% R
qty. 53: 3.8% F, 0.0% B, 96.2% R
qty. 11: 36.4% F, 0.0% B, 63.6% R
qty. 6: 100.0% F, 0.0% B, 0.0% R
qty. 7: 14.3% F, 0.0% B, 85.7% R
qty. 21: 71.4% F, 0.0% B, 28.6% R
qty. 122: 100.0% F, 0.0% B, 0.0% R
qty. 5: 100.0% F, 0.0% B, 0.0% R
qty. 96: 100.0% F, 0.0% B, 0.0% R
qty. 33: 100.0% F, 0.0% B, 0.0% R
qty. 68: 95.6% F, 4.4% B, 0.0% R
qty. 879: 0.1% F, 88.9% B, 11.0% R
qty. 615: 1.3% F, 91.4% B, 7.3% R
qty. 579: 1.4% F, 92.2% B, 6.4% R
Environment of Deposition
floodplain
shallow freshwater lake (Acherousian lake)
brackish delta top marsh grading upward into freshwater marsh
delta top and front

NC-94-23