

The Depositional History of Three Freshwater Lakes in North Central Florida:

Brooklyn Lake, Levys Prairie, and Cowpen Lake

by

Nancy T. DeWitt

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Master of Science
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University of South Florida

Major Professor: Albert C. Hine, Ph.D.
Jack L. Kindinger, M.S.
Gregg R. Brooks, Ph.D.
Stanley D. Locker, Ph.D.

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The Depositional History of Three Freshwater Lakes in North-Central Florida: Brooklyn Lake,
Levys Prairie, and Cowpen Lake

Nancy T. DeWitt

ABSTRACT

Florida has approximately 7800 lakes that are heavily concentrated in the north-central part of the state—a mantled karst terrain. Although much research has been conducted in Florida's lakes, there is not much information on the sedimentary infill. The focus of this research is to define the sedimentary infill of three closely spaced lakes (Brooklyn Lake, Levys Prairie, and Cowpen Lake) in north-central Florida and determine the relative importance of the various sedimentary inputs and their associated processes. Interlake lithostratigraphy comparison helped determine if they experienced a similar depositional infilling history or a unique one.

Twenty-three vibracores were taken (12 in Brooklyn Lake; 8 in Levys Prairie; 3 in Cowpen Lake) from which 331 sub-samples were analyzed for grain size, carbonate content, LOI index for total organic content, pollen content, mineralogy, and internal structures. Five sedimentary facies were defined in Brooklyn Lake, four in Levys Prairie, and three in Cowpen Lake. Using lithologic cross sections a depositional scenario was developed for each lake. Subaqueous and subaerial environments in conjunction with groundwater fluctuation and subsidence activity are key factors in lake development. The comparison of sediment infill of these three lakes reveals that Brooklyn Lake and Cowpen Lake are most similar in sediment facies content, basin morphology and the extent of subsidence depicted in the developmental scenarios, whereas, Levys Prairie is much different in sediment facies and basin morphology.

A doubling in pine pollen from Brooklyn Lake and Levys Prairie indicate a change from drier to a wetter environment. This change is present in Sheelar Lake and Mud Lake and

carbon14 dated at 7200 yrs BP and 5070 $\pm$ 150 yrs BP (Watts and Stuiver, 1980, Watts, 1969 respectively). This suggests that Brooklyn Lake and Levys Prairie are older than 7200 yrs BP.

Sediment infill from Brooklyn Lake, Levys Prairie and Cowpen Lake is conducive to understanding the depositional processes and environments that contributed to their development. Based on results and evidence presented in this study, it can be expected that lake development in a karst terrain will include subaqueous and subaerial intervals, and times of subsidence that can be recorded in the lake sediment.

INTRODUCTION

Florida has approximately 7800 lakes (~6% of the landscape), mostly shallow lakes (<5 m deep) (Brenner et al., 1990) that are heavily concentrated in the north-central part of the state—a mantled karst terrain. Although much research has been conducted in Florida's lakes, there is not much information on the sedimentary infill. Therefore, the focus of this research is to define the sedimentary infill of three closely spaced lakes (Brooklyn Lake, Levys Prairie, and Cowpen Lake -- Figure 1) in north-central Florida and determine the relative importance of the various sedimentary inputs and their associated processes. Basically, with what type of sediment are the lake basins filled and how do these sediments find their way into the basins? This project compares the lithostratigraphy among the lakes to determine if they have experienced a similar depositional infilling history or a unique infilling history.

There are external and internal sediment sources and processes that contribute to the composition and infilling of a lake basin (Figure 2). The external sources include wind blown particles both inorganic, such as terrigenous dust, and organic, such as pollen, sediments transported by surficial runoff, the sediment loads from rivers and streams entering the lake, and groundwater entering the lake. Internal sedimentary sources and processes include organic debris from remains of pelagic and benthic biological organisms (phytoplankton, zooplankton, algae, and macrophytes), waves causing shoreline erosion and sediment redistribution, slumping and failing of the basin sides redistributing sediments to deeper areas, and chemically precipitated sediments such as carbonates, iron and manganese oxides, and hydroxides (Cohen, 2003). Additionally, lake-level fluctuations occur in many lakes in north-central Florida on a scale of one to several meters while other lake levels remain relatively constant. Similarly, paleo lake-level fluctuations are speculated to have occurred. As a result, the lake basins would have experienced subaqueous emergence and subaerial exposure or desiccation (Brenner et al., 1990) forming soil horizons which may be buried later once lake sedimentation resumes.

Rock dissolution is a critical mechanism responsible for lake origin and subsequent basin morphologic development of freshwater lakes in Florida. This is important because Peninsular Florida consists of thick limestone bedrock overlain in many areas by a thin veneer of unconsolidated sediments. Slightly acidic groundwater dissolves the rock leaving a void that can

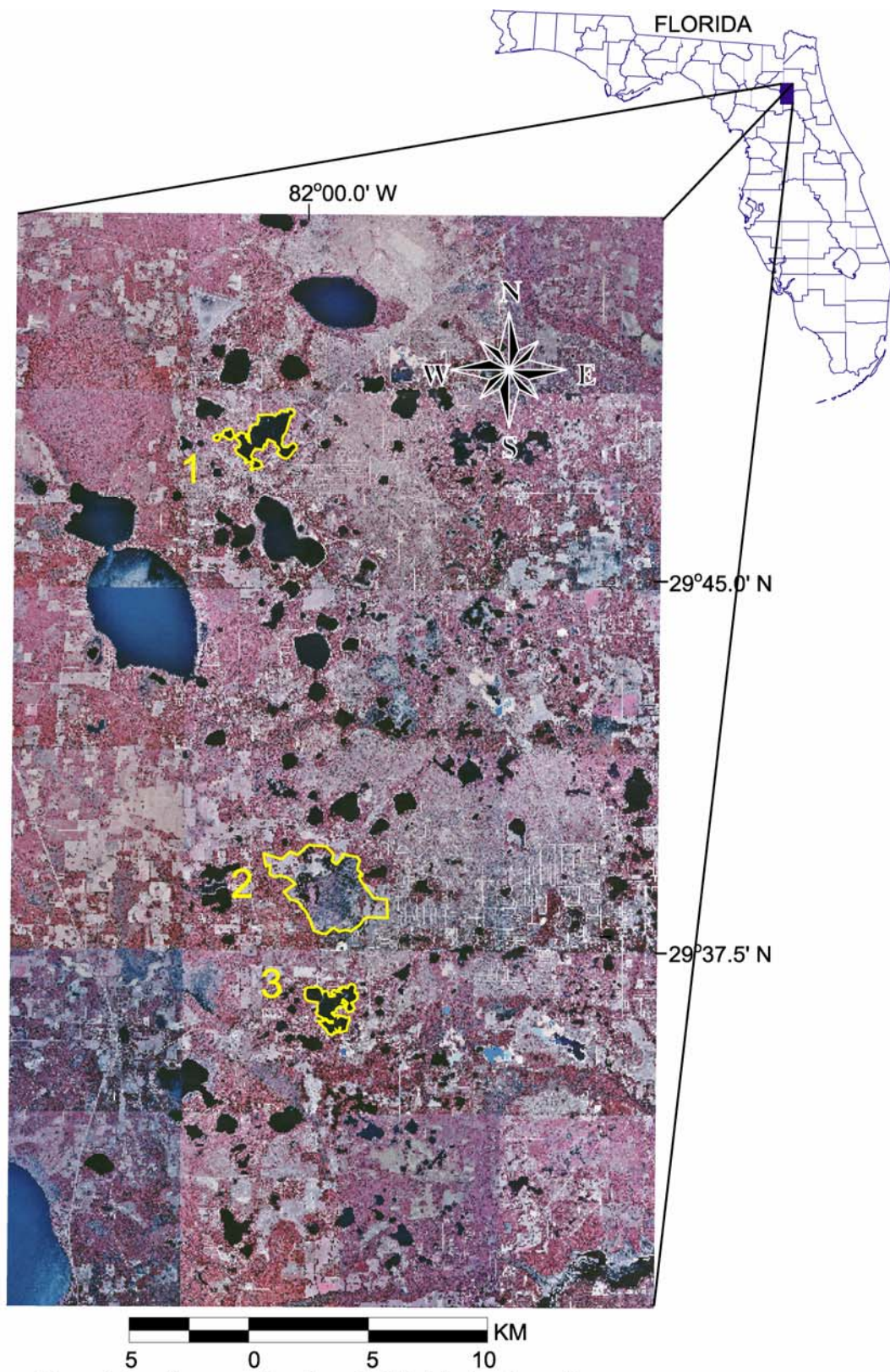


Figure 1. Location map of north-central Florida showing outlines of the lakes in this study; Brooklyn Lake (1), Levys Prairie (2), and Cowpen Lake (3).

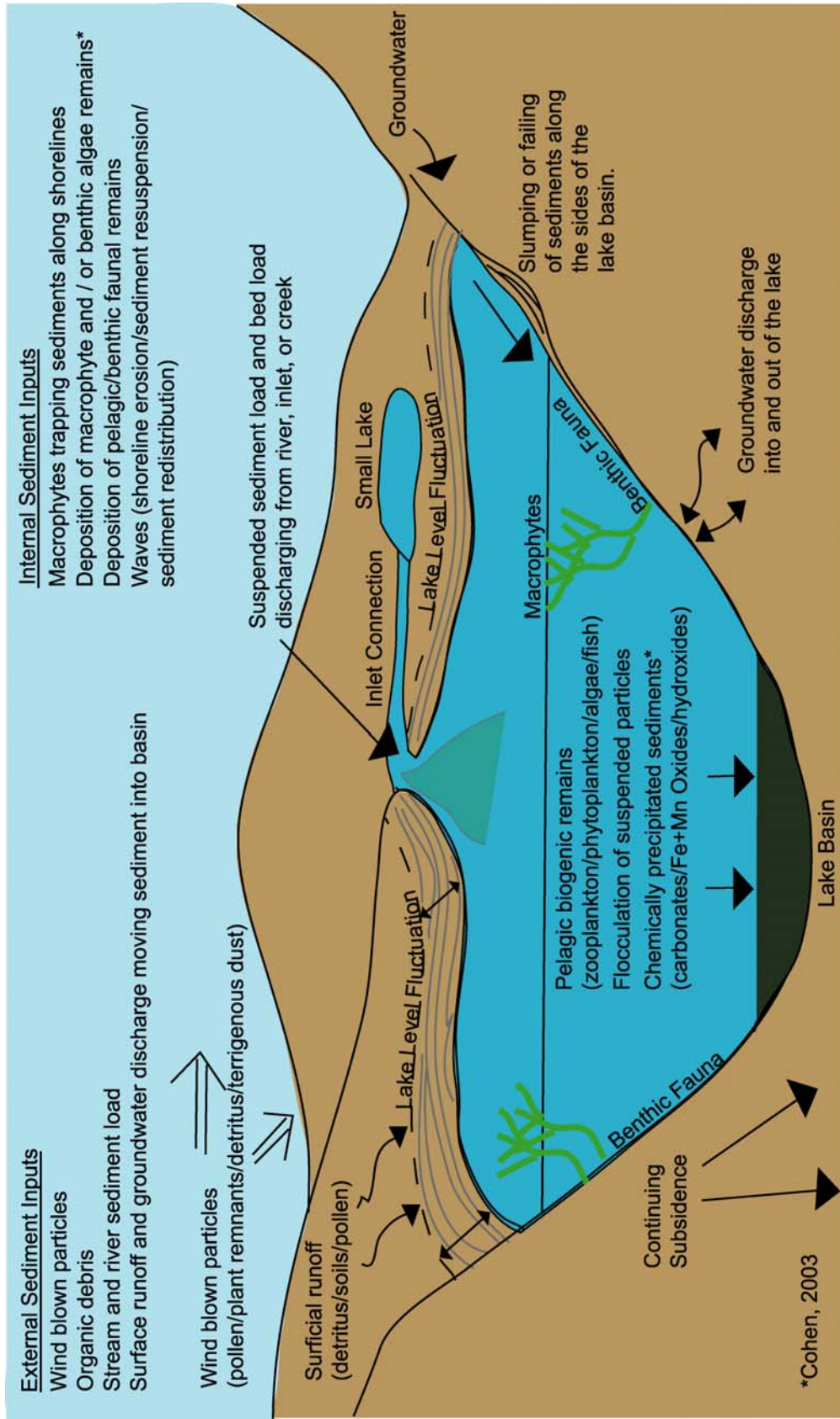


Figure 2. Schematic depicting a freshwater lake basin and the potential external and internal sources of sediment and processes that contribute to the sediment infill.

become enlarged forming a cavern. Eventually, the cavern becomes so enlarged that the weight of the overburden can no longer be supported and a subsidence event occurs leaving a sinkhole depression that fills with water forming a lake. After lake formation, sediment deposition transpires and the lake basin infill is established. Based upon the sediment facies successions and relative placement within the cores from these three lakes an interpretative depositional scenario is developed for each lake to help understand and illustrate depositional infill history and lake development.

INDIVIDUAL LAKES

Brooklyn Lake

Brooklyn Lake is located in the southeastern corner of Clay County, north-east from the center of the city of Keystone Heights, Florida at an elevation of ~35 m National Geodetic Vertical Datum (NGVD) above mean sea level (MSL) (Yobbi and Chappell, 1979) (Figure 1, 3, and 4). It resides in the Interlachen Sand Hills physiographic subdivision of the Central Lake District where the lakes are at or above the potentiometric surface and surrounded by long leaf pine and turkey oak (Brooks and Merritt, 1981). The lake level is highly variable and considered to be an unstable lake having had lake-level fluctuations over 6.1 m (Motz and Heaney, 1991). The lake basin is composed of ten sinkholes that have grown large enough to intersect one another. This becomes evident at the lowest lake level stage when the lake transforms from one large lake at its highest stage into ten individual pools (Clark et al., 1963, Motz and Heaney, 1991, Merritt, 2001). The instability of this lake was obvious during the course of this study when lake levels fell from ~35 m NGVD in 1998 to a low of ~27 m NGVD in 2003. Brooklyn Lake is considered a clear soft water, slightly acidic (median pH 5.56) lake that is oligotrophic, having low nutritional value and low productivity (Shannon and Brezonik, 1972).

Brooklyn Lake is the fourth lake in the Blue Pond chain of lakes within the Upper Etonia Creek Basin (UECB). To the north-east, Brooklyn Lake is connected to Lake Magnolia (third lake in the chain) via Alligator Creek. Alligator Creek exits Brooklyn Lake on the south-east side and then flows into Lake Keystone (fifth lake in the chain). The section of Alligator Creek from Lake Magnolia into Brooklyn Lake is winding ~2.4 km with steep sides ~ 9.0 m and a small wetland in the middle. A three year study (1994-1997) by the United States Geological Survey (USGS) and the Saint Johns River Water Management District (SJRWMD) of stream gauges placed in Alligator Creek concluded that the capacity of stream flow from Lake Magnolia into Brooklyn Lake did not vary greatly, however water backflow from Brooklyn Lake into this section of Alligator Creek was observed during early 1998 (Merritt, 2001). Brooklyn Lake appears to be a pivot point in the chain of lakes because the upper three lakes are documented as outflowing a majority of the time, however, this flow is intermittent from Brooklyn Lake on down through the lower portion of the chain. This could be attributed to the fact that the surface elevation of Brooklyn Lake is lower than the elevation of the outlet stream of Alligator Creek located in the southwestern corner

of Brooklyn Lake; hence outflow can be intermittent to none at time of normal to low lake water levels (Yobbi and Chappell, 1979).

Levys Prairie

Levys Prairie is located in Putnam County, Florida (Figure 1, 3, and 4). In December 1995 the lake-level elevation was ~26 m NGVD above MSL, having a perimeter of 0.82 km and an area of 0.05 km² (Kindinger et al., 2000). The elevation on the western portion of the prairie is ~3.4 m lower than the elevation on the eastern side (Pirkle and Brooks, 1959). Levys Prairie resides in the Interlachen Sand Hills physiographic subdivision of the Central Lake District in which the lakes are at or above the potentiometric surface and surrounded by long leaf pine and turkey oak (Brooks, 1981). The origin of Levys Prairie is a result of the solution and slumping of the Ocala Limestone and the carbonate rocks and sediments of the Hawthorn Formation (Pirkle and Brooks, 1959). There are two sinkhole lakes that formed in the 1950's on the western side of the prairie (Pirkle and Brooks, 1959). The northern-most sinkhole has dried up since, but the southern-most sinkhole contains water and is thought to be plugged. Lake levels are constantly fluctuating with recharge provided when there is sufficient rain for run-off from the Sandhills surrounding the prairie (Pirkle and Brooks, 1959). During this study, Levys Prairie was dry except for two sinkholes that still held water. Limnology characteristics for this lake are unknown.

Cowpen Lake

Cowpen Lake is located in Putnam County Florida (Figure 1, 3, and 4). In December of 1995 the lake-level elevation was 26 m NGVD above MSL having a perimeter of 11.5 km with an area of 2.80 km² (Kindinger et al, 2000). It resides at the intersection of the Perched Lakes and Prairies, the Interlachen Sand Hills, and the St. Johns Offset physiographic sub-divisions of the Central Lake District (Brooks, 1981), and is also just beyond the southern perimeter of the UECB. The lake is complex consisting of five circular sinkholes that formed and grew to intersect one another giving the lake an irregular shoreline (Shannon and Brezonik, 1972). According to a ~14 yr dataset from a hydron measuring the lake level, Cowpen Lake appears to fluctuate within ~ 2.1 m which is much more stable compared to Brooklyn Lake. Cowpen Lake is considered a clear soft water, slightly acidic lake (median pH 5.56) that is oligotrophic, having low nutritional value and low productivity (Shannon and Brezonik, 1972). The lake is a closed basin not having any surficial streams entering or exiting. The lake perimeter is primarily residential housing having some private docks and one public concrete boat ramp.

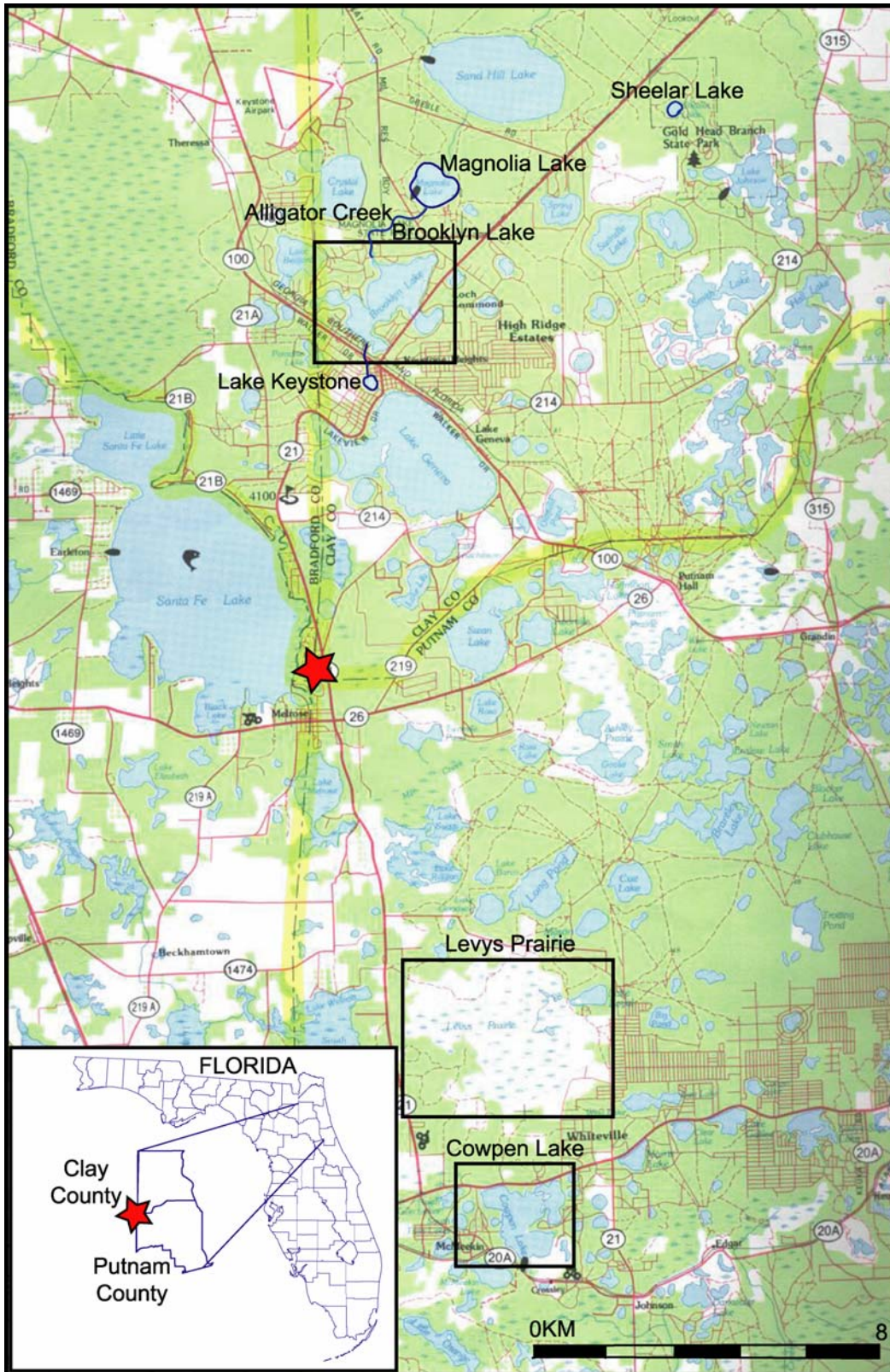


Figure 3. Topographic map showing the location of Brooklyn Lake, Levys Prairie, and Cowpen Lake with respect to the boundaries of Clay and Putnam Counties.



Brooklyn Lake



Levys Prairie



Cowpen Lake

Figure 4. Photographs from Brooklyn Lake, Levys Prairie, and Cowpen Lake. Each set of photographs was taken when the lake-level elevation was lower than the normal lake-level elevation.

REGIONAL GEOLOGY

The Florida Platform

Florida has been described as the emergent portion of a large broad shallow sloping platform. The platform's eastern side is narrow extending from Florida's eastern shoreline out to 164 m water depth; whereas, the western side broader having a shallower slope extending from Florida's western shoreline out to ~1000 m water depth (Puri and Vernon, 1964, Schmidt, 1997--Figure 5).

The Florida platform is a Mesozoic / Cenozoic carbonate platform situated atop basement rock. Tectonic movement of landmasses during the Paleozoic resulted with portions of northwest African and North American basement rock forming a complex unconformable surface (Klitgord and Popenoe, 1984, Lane, 1994). By the late Cretaceous a passive margin setting persisted (Randazzo, 1997) allowing encroachment of shallow seas and establishment of a carbonate-producing environment. The deposition of thick carbonate limestone units persisted into the Paleogene and were facilitated by the presence of the Suwannee Straits, a structural low on the platform's northern margin. A current that flowed through the Straits during high sea level intercepted siliciclastic sediments from northern sources and excess nutrients from reaching and suppressing the carbonate-producing environment (Hine, 1997). These thick (~7 km) carbonate limestone units are the premise for the potted karst surface distinct to Florida's topography and the formation of its freshwater lakes.

Lower sea level during the mid to late Oligocene diminished the current that ran through the Suwannee Straits. Combined with a possible tectonic uplift of the Appalachian Mountains provided a greater source of sediment for erosion (Schlee et al., 1988). This combination of events progressively filled in the seaway with siliciclastic sediments closing it permanently. Once the seaway infilled, the siliciclastic sediments encroached onto the carbonate platform blanketing the carbonate limestone accumulations and partially stifling carbonate production (Huddleston, 1993, Lane, 1994, Scott, 1997). This influx of siliciclastic sediments occurred from the Miocene into the Pliocene during which the carbonate producing environments became less prominent and the siliciclastic materials of sands and clays become prevalent.

During the Quaternary the sea-level fluctuations associated with interglacial and glacial periods contributed to the development of paleoshorelines present in the Florida peninsula today.

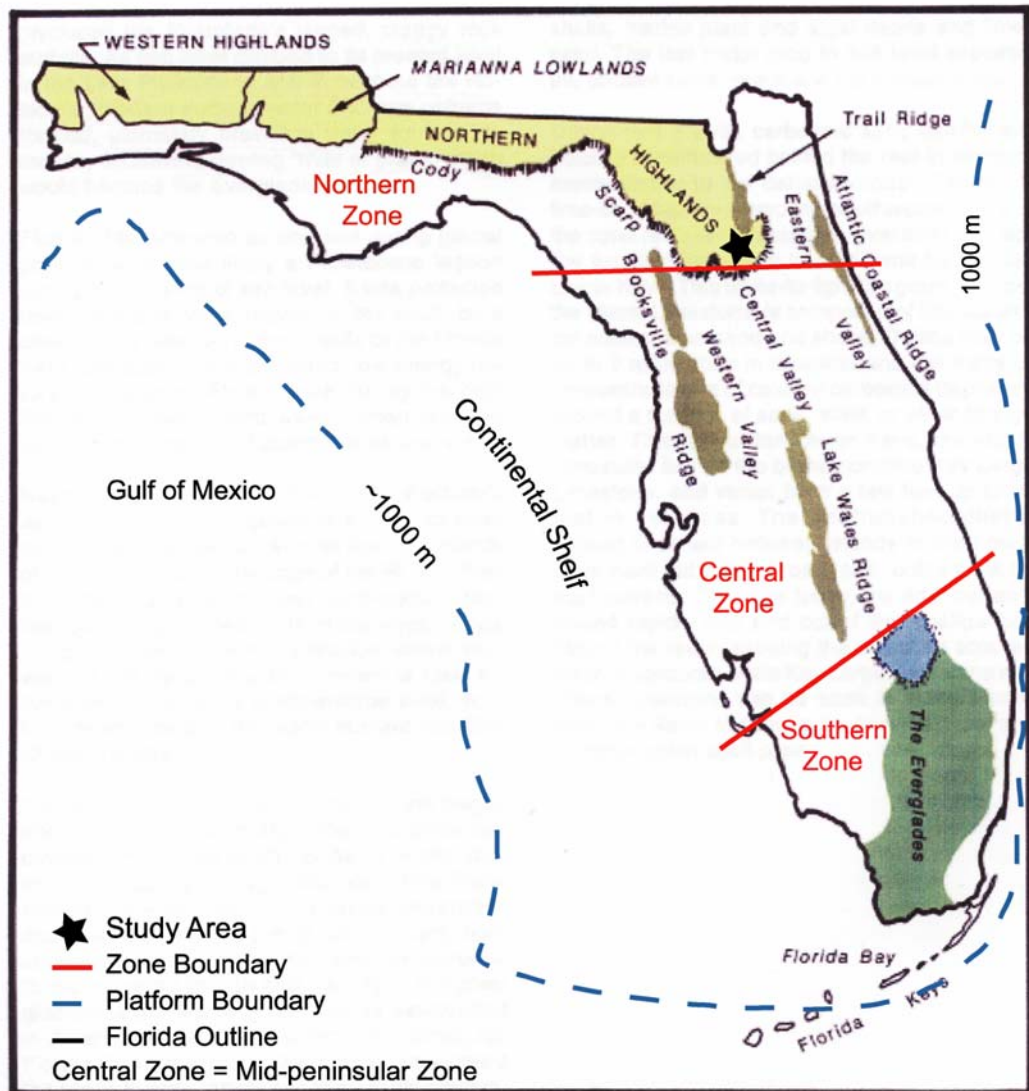


Figure 5. A figure showing the extent of the Florida Platform (blue dotted line), the physiographic zone divisions of Florida (in red) and several physiographic features including the Trail Ridge and the Lake Wales Ridge. Figure modified from Puri and Vernon (1964) and Lane (1994).

Increased sediment accumulation during this time (Poag and Valentine, 1988) and cyclic paleoclimate lead to different erosional and depositional processes controlling in the lateral and vertical distribution and accumulation of sediments (Riggs and Belknap, 1988, Lane, 1994, Scott, 1997). Much of the landscape was sculpted from higher sea levels partially eroding the physiographic landforms and redistributing the sediments. Longshore currents sculpted paleoshoreline and paleodune by moving and redistributing sediments along the paleoshoreline. The Cody Scarp, the Trail Ridge, the Atlantic Coastal Ridge, the Brooksville Ridge, and the Lake Wales Ridge are all examples of topographic features in Florida that resulted from the Pleistocene sea-level fluctuations (Figure 5) (Lane, 1994, Scott, 1997).

Stratigraphy

The geologic units that underlie the study area include limestones of Paleogene age (Figure 6). From oldest to youngest they are the Cedar Keys Formation of the Paleocene, the Oldsmar Formation, the Avon Park Formation, the Ocala Formation of Eocene age, and the Suwannee Formation of Oligocene age. Overlying these limestone units is the Hawthorn Group of Miocene age that has various lithologic formations throughout the state. It is represented in central Florida, from oldest to youngest, as the Penny Farms Formation, Marks Head Formation, and the Coosawhatchie Formation, which includes the Statenville Member, and the Charlton Member (Scott, 1988, Lane, 1994). Unconformably blanketing the Hawthorn Group sediments is the Cypresshead Formation of Pliocene age (Scott, 1988, Lane, 1994, Scott, 2001). The Trail Ridge Sands of Pleistocene age are also in close proximity to the study area and may contribute to the sediments within the lakes (Figures 5 and 6).

The Penny Farms Formation (~47 m thick) is the basal unit of the Hawthorn Group and consists of carbonate sands that are quartz, phosphatic, clayey dolostones overlain by siliciclastic material with interbedded carbonates (Scott, 1988). The Marks Head Formation (~40 m thick) consists of interbedded sands, clays, and dolostones and is considered to be the most lithologically variable formation of the Hawthorn (Scott, 1988); clay beds exist, some as pure clay, otherwise it is found to have quartz, dolomite and phosphates.

The Coosawhatchie Formation (~ 68 m thick) has an informal upper and lower member and the Charlton Member. It contains quartz sand, phosphate, and clayey dolostones all of which can have molds of fossils. The clay layers have variations of quartz sand, silts, dolomite, and sand size phosphates that are amber to brown or black (Scott, 1988). The Charlton Member (~ 12 m thick) is present in the very western side of Clay County to the east of Brooklyn Lake as seen from cross sections of well data (Figure 7). The Charlton Member contains less sand than the upper informal member. Rather, it is interbedded carbonates and clays (Scott, 1988).

There are sediments in the Hawthorn Group referred to as undifferentiated, they are at or near the surface on the southern part of the Ocala Platform, but their relation to the Hawthorn found to the east is unknown. These sediments are characterized as clayey sands, silty clays, or pure clays lacking in fossils and phosphates, having colors of light olive gray to blue gray if unweathered, to reddish brown where exposed, and are the sediments that compose the intermediate aquifer (Scott, 2001).

The Plio/Pleistocene lithostratigraphy in central Florida is complex and not clearly defined or understood. The complexity and difficulties stem from issues such as unclear lithologic boundaries, unconformable surfaces, lack of fossil assemblages within geological units, post-

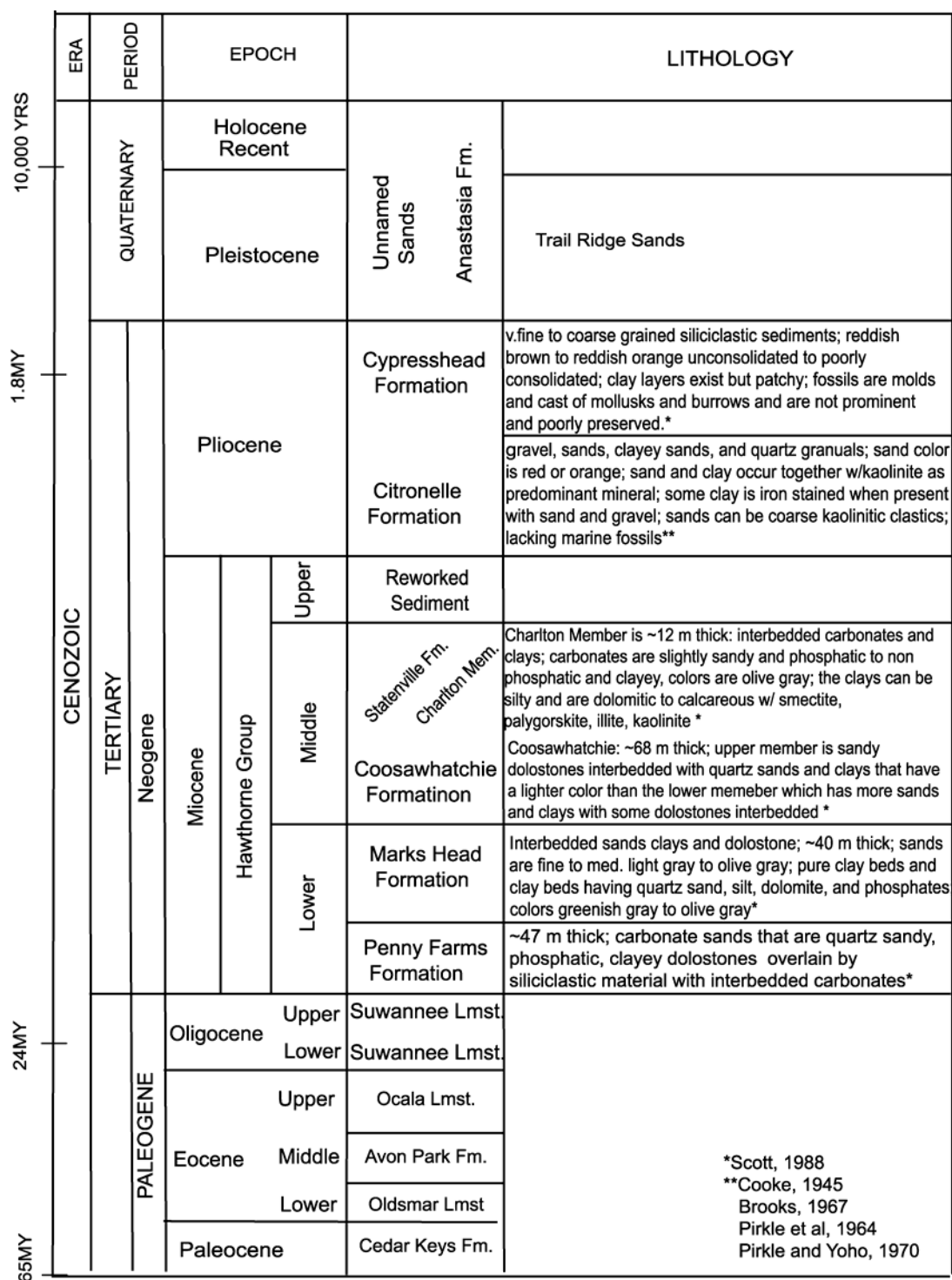


Figure 6. Cenozoic stratigraphic column of north-central Florida modified from Lane (1994) including lithologic descriptions from other authors.

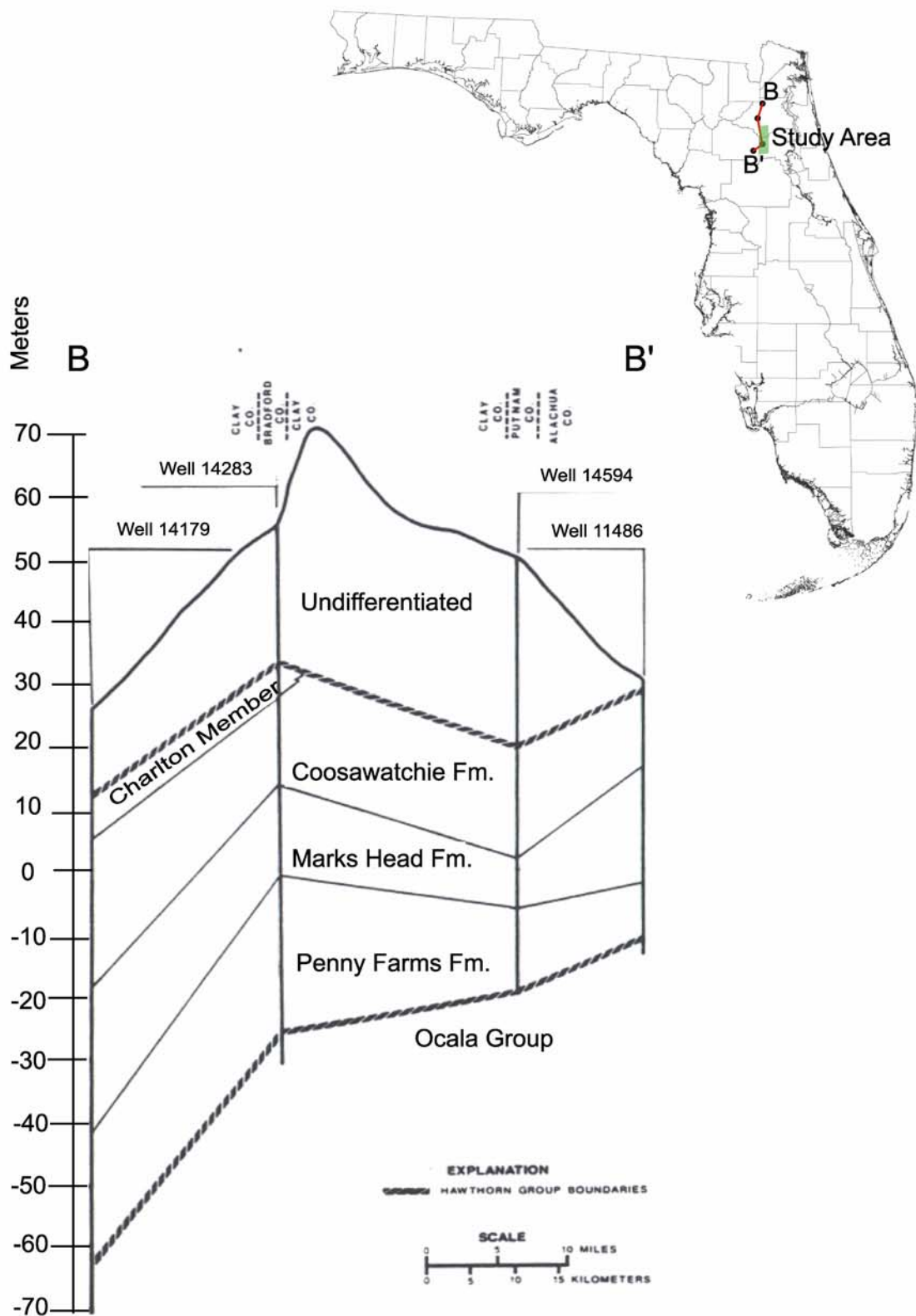


Figure 7. Cross section B-B' from Scott (1988) of four wells representing the distribution of the Hawthorn Group Miocene age within the study area.

depositional erosion that has removed entire lithologic units or left behind partial units, varying amounts of gravels, sands, silts, and clays lacking defining qualities that would permit a distinctive lithologic classification and unclear identification and recognition of reworked sediments from established lithologic units.

The undifferentiated sediments of Pliocene age in the study area are part of the Cypresshead Formation. The Citronelle Formation sediments described by Cooke (1945) Pirkle (1960), Pirkle et al., (1964) are now referred to as the Cypresshead Formation sediments (Scott, 1997, Scott, 2001). The difference being that the Citronelle Formation is composed of deltaic sediments, where the Cypresshead Formation sediments are shallow marine nearshore deposits that form the peninsular highlands of north-central Florida. Scott (1997) states, "The Cypresshead Formation is the Citronelle-Miccosukee time-equivalent in the peninsula. The sediments contain very fine to coarse grained siliciclastic sediments including discoid quartz pebbles". The sand can be red or orange. Sand and clay occur together with kaolinite as the predominant clay mineral acting as a binder between larger sand grains, as well as lenses, and stringers in the sediments; some clay can be iron stained when present with sand and gravel (Cooke, 1945, Pirkle et al., 1964, Pirkle and Yoho, 1970); and sands can be coarse, kaolinitic clastics (Brooks, 1967). Generally there is a lack of marine fossils, but peculiar clay tubes, thought to be fossils, are identified within the sediments. The clay tubes have a 0.59 cm diameter with smooth interior and rough bumpy exterior and thought to be made by a marine organism possibly an extinct crayfish (Marsh, 1963). Post-depositional reworking of the Cypresshead Formation is a lithologic layer characterized as fine to coarse quartz sands, scattered quartz gravel and varying percentage of clay matrix (Scott, 1997 and 2001). Based upon data from a well transect and the current kaolin mining pits at the time in northern Putnam County, Pirkle (1960) identified three zones within this area. 1) the uppermost layer is loose sands, 2) the second layer referred to as the "Red Zone" are red and / or yellow clayey sands that the color is thought to be from oxidation, and 3) the "Kaolin Zone" containing high percentages (average of 20%, but found higher than 30%) of clay predominantly white clayey sands; the amount of clay is inconsistent throughout this zone and varies from area to area; some kaolinite is present as lenses (~ 0.3 m by 1.0 m long) or small balls (0.59 cm). Below the "Kaolin Zone" there is an unconformity, which is believed to separate the Cypresshead Formation from the Hawthorn Formation (Pirkle, 1960).

Physiographic Zones and Features

Peninsular Florida is divided into three physiographic zones, the northern zone, the central or mid-peninsular zone, and the southern zone. The study area is located on the border

between the northern zone and the mid peninsular zone; therefore, review will be limited to these two physiographic zones (Figure 5) (Puri and Vernon, 1964, White, 1970).

The northern zone contains the panhandle and extends southward to the approximate latitude of 29° 39' or the equivalent locations of the cities of Palatka, Hawthorn and Gainesville. The northern zone contains the northern highlands, a portion of the coastal lowlands, and a portion of the central highlands. It is predominantly a broad upland high in which the ground surface is higher than the peizometric surface, in which accumulated water does not remain for long periods generating dry highland characteristics such as dry stream channels and prairies, intermittent lakes, and first generation dry, steep walled sinks (Puri and Vernon, 1964, White, 1970). The northern highlands are well drained by streams and are bordered on the south and a portion of the east by the Cody Scarp and on the northeast by the Trail Ridge (Figure 5) (Puri and Vernon, 1964, White, 1970).

The Trail Ridge is a long (~201 km), broad paleo sand ridge that runs north-south from southern Georgia into north-central Florida and ends near Keystone Heights in Clay County (Figure 5). The sand hills within the Trail Ridge have an elevation range from ~ 45.7 m to ~ 76.2 m above MSL. From the southern tip of the Trail Ridge (the highest point), the ridge quickly loses elevation and pans out toward the south eventually becoming relatively flat in Putnam County (Clark et al., 1963, Pirkle and Yoho, 1970).

There are two theories for the origin of the Trail Ridge. One theory considers that the Trail Ridge and the Lake Wales Ridge were once part of the same ridge. The other theory considers that the Trail Ridge is a relic shoreline from a past highstand. There is evidence from surface sampling and drill holes suggesting that the Trail Ridge is actually separate from the Lake Wales Ridge. However, evidence suggests that the Lake Wales Ridge had an influential part in shaping the Trail Ridge (Pirkle and Yoho, 1970).

A more recent study by Opdyke et al., (1984) suggests that a highstand alone cannot account for the significantly high elevation of the Trail Ridge in comparison with surrounding relic shorelines. The elevation height is accounted for by an epeirogenic isostatic uplift resulting from dissolution of limestone within the Floridan Aquifer that is carried removed as dissolved solids via springs to the surface and then by rivers, hence yielding a lighter landmass (Opdyke et al., 1984). The Trail Ridge sediments are described by Scott (2001) as undifferentiated Quaternary sediments light gray, tan, and brown to black in color, unconsolidated to poorly consolidated siliciclastics, unfossiliferous, and sandy-silty-clays that are poorly to moderately consolidated and can be blue green to olive green in color.

The mid-peninsular zone (Figure 5) contains a large portion of the central highlands and a large portion of the coastal lowlands and can be characterized as having discontinuous upland high areas or ridges separated by valley lowlands. The highlands are above the peizometric

surface, but the lowlands are below this surface allowing shallow broad lakes, and small deep lakes to persist (Puri and Vernon, 1964, White, 1970).

The Lake Wales Ridge (Figure 5) is a prominent elongate paleo-ridge in the central highlands of the mid-peninsular physiographic zone. It is approximately 161 km long and trends northwest to southeast extending from the center of Lake County southeast into Highlands County north of the town Venus. The ridge can be up to 91.5 m high in some areas, and has an irregular surface potted with several lakes and solution features. This ridge is thought to be a remnant of a longer ridge that extended into Clay County. It is bordered on the eastern side by a consistent series of sand dunes that extend from the southern end of the ridge in Highlands County north to the vicinity of the Oklawaha River in northern Marion County. The high clay content and the coarse clastic material of the Cypresshead Formation (Pliocene Age) may have played a role in the preservation of the higher parts of the Lake Wales Ridge (White, 1958; White, 1970). The Lake Wales Ridge is composed of surface sands, sands and clayey sands of the Cypresshead Formation overlying older limestones of the Hawthorn (Pirkle et al., 1964).

Karst

Florida is predominantly a karst terrain. The thick cemented limestone units of the Tertiary age in Florida become brittle with age, allowing the formation of fractures or weak zones along interfaces of different sediment layers. Slightly acidic water traveled along these weak zones in the limestone leaching out the carbonate ions. This process, known as dissolution, may leach out other minerals, which can then be deposited elsewhere via underground streams, sinkholes, and floods. Through time the chemical and mechanical weathering modifies the landscape creating features characteristic of karst terrain like sinkholes, caverns, swales, and solution valleys.

Sinkholes in Florida are affected both by surface water and groundwater and generally exist in undifferentiated sediments that overly carbonate limestone. Precipitation and surficial runoff can percolate downward through the overburden sediments toward the water table and become incorporated into the groundwater within the aquifers. Groundwater also travels along pathways of least resistance particularly at the interface between the unconsolidated sediments and the underlying carbonate rock eroding the rock and eventually forming a cavity underground. The cavity can become so large that the weight of the overlying sediment can no longer be supported and it collapses on itself (Lane, 1986). Sometimes the collapse is more of a gradual event in which the overburden slumps into the cavity forming a swale. After collapse, the sinkhole can fill with rainwater or groundwater to form a freshwater lake. If the sinkhole cavity is below the water table, it would be filled with groundwater that may act to buoy the overburden therefore preventing or prolonging collapse.

Upper Etonia Creek Basin (UECB)

The study area resides within the UECB (Figure 8) covering approximately 265 km encompassing Clay, Putnam, Bradford, and Alachua Counties and part of the St. Johns River Basin. It contains approximately 100 small, landlocked lakes and several shallow solution depressions with the two largest being Putnam Prairie, and Levys Prairie (Clark et al, 1964, Yobbi and Chappell, 1979, Motz and Heaney, 1991). Located within the UECB is the Blue Pond Chain of lakes (Figure 8) containing eight lakes connected by intermittent streams of which the top three lakes and streams combined produce more flow than the lower five lakes and streams. The change in elevation across the chain of lakes decreases dramatically over a short distance (~ 24 m elevation within ~23 km—Figure 9). The lakes are listed from the beginning of the chain to the end including their respective outlet elevation (NGVD) shown in meters: 1) Blue Pond in the Camp Blanding area at 52.7 m, 2) Sand Hill Lake also called Lake Lowry at 39.9 m, 3) Lake Magnolia at 37.8 m, 4) Brooklyn Lake 35.1 m, 5) Lake Keystone at 32.4 m, 6) Lake Geneva 32.3 m, 7) Oldfield Pond at 29.8 m, 8) Halfmoon Lake at 28.3 m, and 4) the headwater to Putnam Prairie at ~27.4 m (Yobbi and Chappell 1979).

The Melrose Chain of Lakes located at the southern end of the UECB contains more prairies with open water bodies than lakes. Putnam Prairie within this chain is documented to have water flow across the prairie (Yobbi and Chappell, 1979). Levys Prairie is not a part of this chain but located just south adjacent to the chain, and Levys Prairie has similar descriptive qualities to Putnam Prairie. It would be within reason to suggest that some areas of Levys Prairie may experience water flow across the Prairie similar to Putnam Prairie while in other areas of the Prairie may experience water discharge through sinkholes.

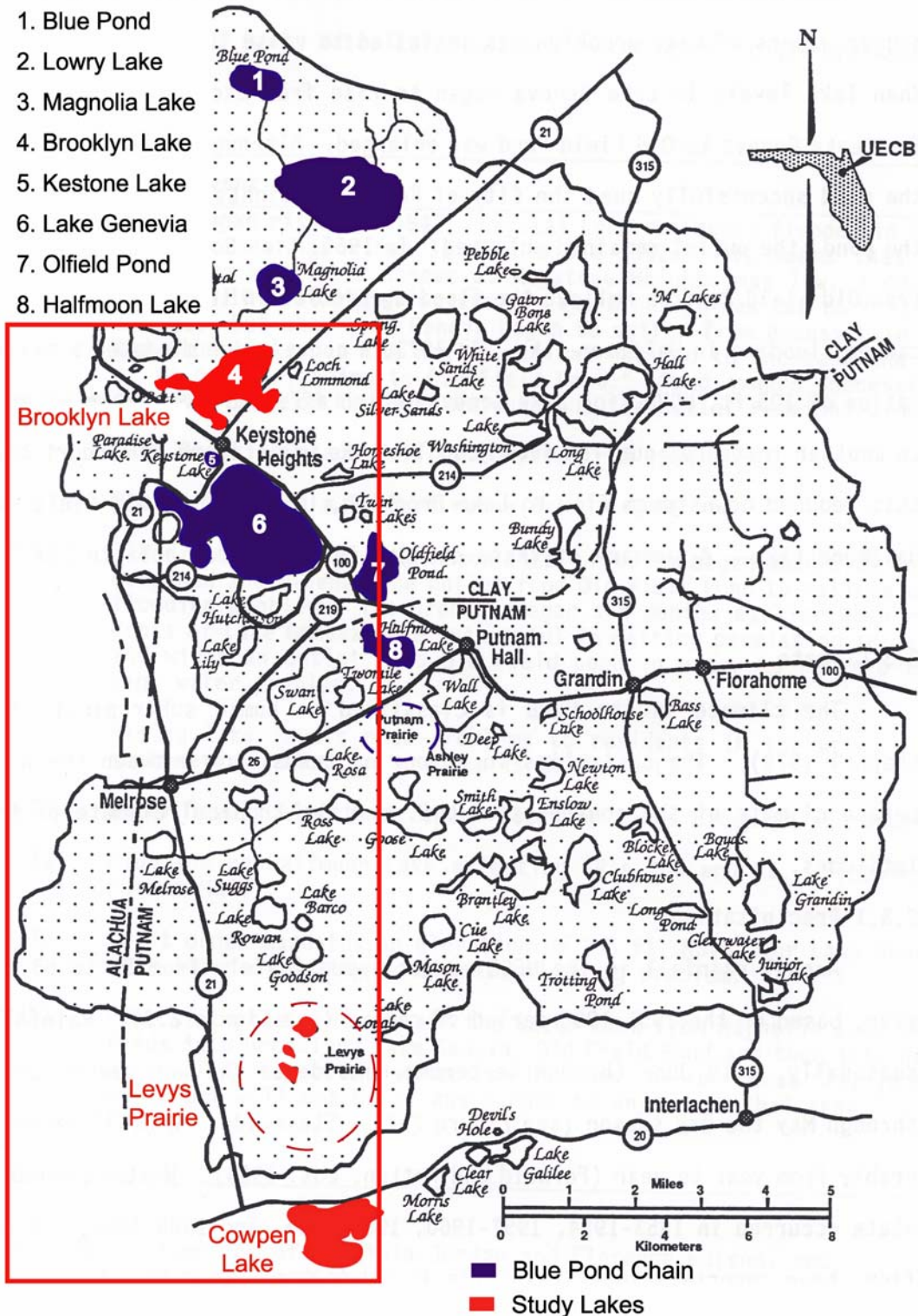


Figure 8. Boundary of the UECB modified from Motz and Heaney (1991); showing the study area and the study lakes (red) and the Blue Pond Chain of Lakes (blue).

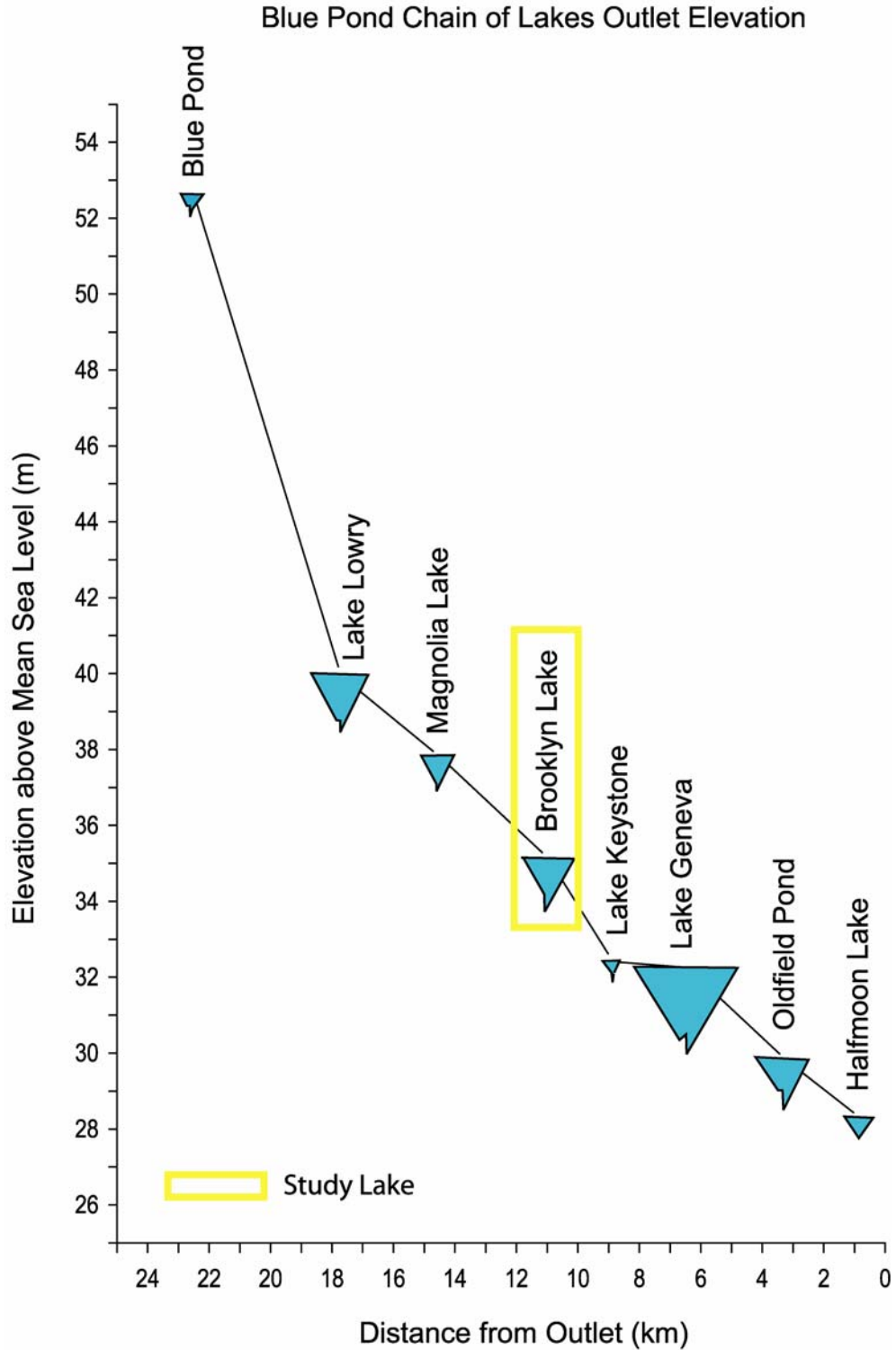


Figure 9. Diagram showing elevation change versus distance through the Blue Pond Chain of Lakes (from Yobbi and Chappell, 1979).

PREVIOUS WORKS

Hydrology

The freshwater lakes in this study, Brooklyn Lake, Levys Prairie, and Cowpen Lake have experienced lake-level fluctuations documented from data collected from hydrons within the lake (Figure 10). Figure 10 is a simplified compilation showing a general comparison of the lake-level fluctuations. Data sets include Brooklyn Lake (~46 yrs) from July 1957 to January 2003, Levys Prairie (~12 yrs) from February 1988 to November 2000, and Cowpen Lake (~ 14 yrs) from March 1989 to April 2003 and indicate during these times each lake has undergone some major and many minor lake-level fluctuations. The lake-level fluctuation range is greatest for Brooklyn Lake over 6.1 m versus approximately 2.4 m for Levys Prairie and Cowpen Lake.

The lakes are located within the UECB drainage basin in which two hydrological studies were conducted. One study by Clark et al. (1963) focused specifically on the hydrology of Brooklyn Lake. The other study by Motz and Heaney (1991) focused on several lakes within the UECB. The study by Motz and Heaney (1991) utilized 33 years of the lake-level data 1957 to 1999 which classified the stability of 121 lakes based on their range of lake-level fluctuation through time. Lakes were assigned a rank from 1 to 121 in which one was the lowest range of fluctuation and 121 the highest range of fluctuation. The lake-level fluctuation range for Brooklyn Lake was 6.79 m and ranked 117 out of 121 and classified as an 'unstable' lake. In comparison a 'stable' lake would fluctuate from 0.61 m to 1.83 m and a 'typical' lake would fluctuate 1.83 m to 2.31 m (Motz and Heaney, 1991). The highest recorded lake levels for Brooklyn Lake are 36.04 m NGVD in 1948 and 35.80 m NGVD in 1960, and the lowest recorded stages are 29.60 m NGVD in 1958 and 29.00 m NGVD in 1989 (Clark et al, 1963, Motz and Heaney, 1991, respectively).

At the lowest lake levels, Brooklyn Lake splits into ten separate pools (Figure 11) that vary in depth (Clark et al., 1963). Levys Prairie and Cowpen Lake were not included in this study of 121 lakes. The data obtained from SJRWMD (Figure 10), indicate similar fluctuation pattern in Brooklyn Lake from 1999 to 2003 in which there was a maximum lake water stage at 35.01 m NGVD and a minimum lake stage at 26.80 m NGVD. For Levys Prairie there is a minimum stage of 25.10 m NGVD and maximum of 27.30 m NGVD in February 1998 and August 1995

respectively, and a minimum of 26.30 m NGVD and a maximum of 26.70 m NGVD for Cowpen Lake in April 1989 and March 2003 respectively.

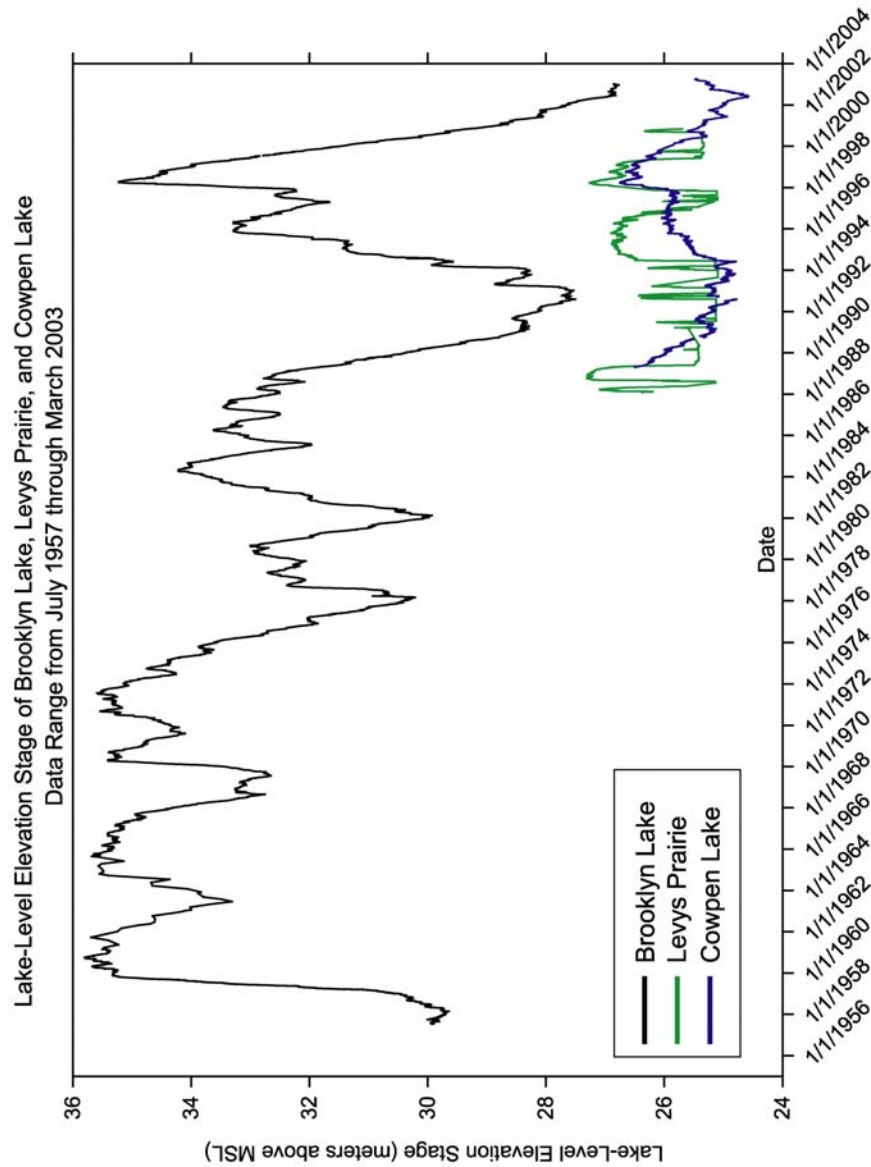


Figure 10. Graph of the daily median lake-level values (meters above MSL) for Brooklyn Lake (black; 3,510 data points over 46 yrs), Levys Prairie (green; 2,399 data points over 12 yrs), and Cowpen Lake (blue; 3,685 data points over 14 yrs). Data furnished from SJRWMD (pers. comm. Humbert, 2003). This data is formerly published in monthly hydrologic conditions reports located at the SJRWMD website (<http://sjrwmd.com/programs/data.html>).

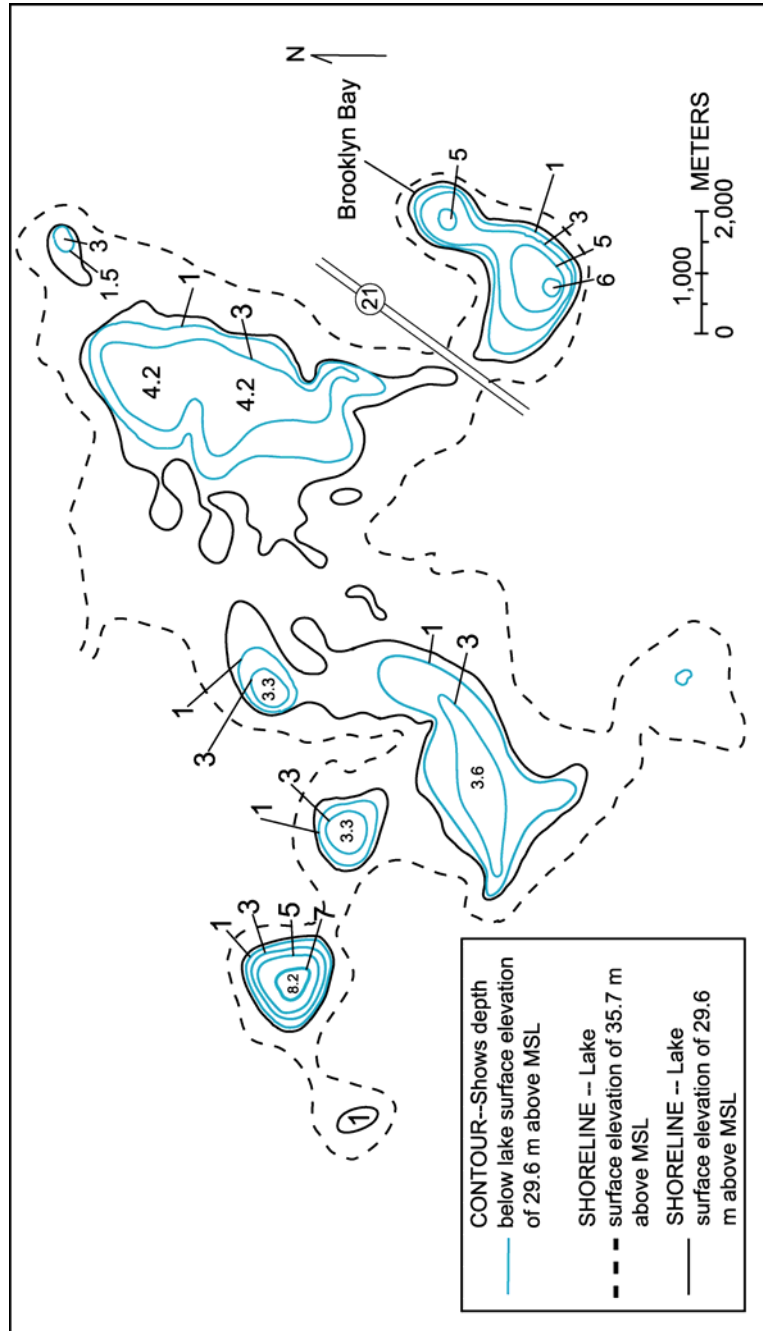


Figure 11. A diagram of Brooklyn Lake at its lowest lake level, showing the ten pools that remain. The dotted gray line indicates the shoreline when the lake is full. Figure modified from Merritt (2001) showing lines of equal depth at a lake level elevation of 29.60 m measured in February 1958 (modified from Clark et al., 1963).

The water in Brooklyn Lake is replenished through direct rainfall, inflow of surficial groundwater, and surficial drainage from Alligator Creek (Clark et al., 1963, Motz and Heaney, 1991). The minimum and maximum lake stage levels can be attributed to one or all of these. Motz and Heaney (1991) documented that Brooklyn Lake surface water levels are influenced by groundwater changes recorded in the Floridan Aquifer as well as the amount of precipitation (Figure 12). The surface drainage into Brooklyn Lake via Alligator Creek comes from three lakes that precede it in the UECB "chain of lakes", but drainage is normally low (Clark et al., 1963). Although largely affected by the below normal rainfall of the four year drought (1954 to 1958), Brooklyn Lake maintained high values of seepage outflow into the surrounding surficial water table (Clark et al., 1963). A study by Hirsch (1998) focused on quantifying the empirical seepage aspects in Brooklyn Lake, and concluded that overall, seepage flow is outgoing from Brooklyn Lake to the surrounding aquifers, however, seepage inflow and outflow is highly variable within the lake. Groundwater flow through the surficial aquifer at Brooklyn Lake is rather complex, but generally moves from the northwest area toward the lake and away from the lake on the southeastern side (Clark et al., 1963).

A brief project by the SJRWMD took measurements in the sinkholes of Levys Prairie to estimate the recharge rate to the Floridan Aquifer. Recharge rates were 0.197 cubic meters per second in one sinkhole and 0.167 cubic meters per second in the terminal sink (pers. comm. Davis, 2003).

Limnology

One research study (Shannon and Brezonik, 1972) sampled 55 freshwater lakes in central Florida over one year period in an effort to obtain basic detailed limnology characteristics and attempt to catalog these lakes according to trophic state. A subset of 16 lakes was chosen from the Trail Ridge region, which included Brooklyn Lake and Cowpen Lake. Based upon cluster analysis of six chemical parameters (pH, alkalinity, acidity, conductivity, color, and calcium) and results indicated four groups, 1) acid colored lakes, 1) alkaline colored lakes, 3) alkaline (hard water) clear lakes, and 4) slightly acid (soft water) clear lakes. In this study color is associated with high organic matter such as pine litter. Cluster analysis was then performed separately on each lake group using seven trophic indicators (primary production, chlorophyll a, Secchi disk depth, total phosphate, total organic nitrogen, specific conductivity, and cation ratio). Results indicate that Brooklyn Lake and Cowpen Lake fall into the slightly acidic (soft water) clear lake group and found to be oligotrophic. The majority of lakes having similar classification to Brooklyn Lake and Cowpen Lake are located within the Trail Ridge region (Shannon and Brezonik, 1972).

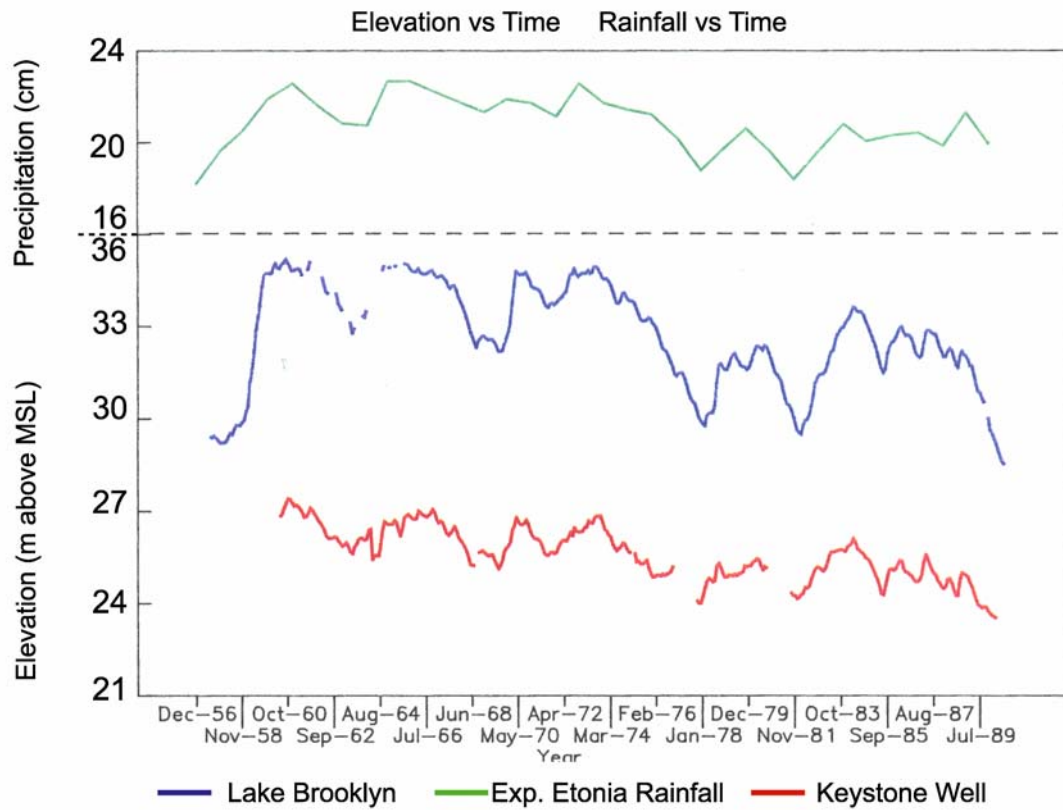


Figure 12. Graph depicting the relationship between precipitation (green), elevation of groundwater in the Floridan (red), and lake-level elevation of Brooklyn Lake (blue) versus time. Figure borrowed from Motz and Heaney, 1991.

A later study by Canfield et al. (1984) sampled 165 freshwater lakes in various physiographic divisions to clarify the relationship between color and some limnological properties (pH, total alkalinity, specific conductance, calcium, chloride, silica concentrations, and total iron, nitrogen, and phosphorous concentration) in order to justify the classification of clear lakes and colored lakes. Color was found to have the greatest variations in lakes of central Florida; yet, overall, low color values were measured in lakes in areas of well-drained soil, and higher color values were measured in lakes in areas of poorly drained soils. In this study the total iron content had a strong positive correlation to color. Overall the statistical relationships between color and limnological properties had weak correlations and were not definitive enough to separate the lakes by color (Canfield et al., 1984). This conclusion is contrary to the work mentioned earlier by Shannon and Brezonik (1972) grouping lakes as clear and colored.

Seismic Investigations

In the SJRWMD, emphasis and interest were placed on the freshwater lakes and their interaction and / or connection with the surrounding aquifers as well as how the lakes developed. A detailed high-resolution seismic stratigraphy study in Orange Lake (Figure 13) identified it as a shallow flooded plain having three separate divisions each owing to specific karst type features including cover subsidence, cover-collapse, and buried sinkholes (Kindinger et al., 1994). Subsequent geophysical studies encompassed more than 40 lakes that were surveyed including Brooklyn Lake, Levys Prairie, and Cowpen Lake. A subset of these surveyed lakes was selected to create and publish an atlas of the subsurface features of freshwater lakes in the SJRWMD boundaries (Kindinger et al., 2000).

Natural gamma logs from wells in the areas were used to help correlate seismic reflections with that of geologic units. Results concluded that these lakes were formed initially as a result of chemical dissolution of the underlying limestone and then mechanically influenced by collapse, subsidence, slumping or converging sinkholes of the limestone and sediment overburden. However, the more definitive characteristics such as size, depth, shape and presence of subsurface features tend to be the function of the overburden thickness, the overburden sediment content, and the magnitude of collapse or subsidence. The overburden is considered as unconsolidated material but detailed information pertaining to sediment character of the overburden is unknown (Kindinger et al, 2000).

Tihansky et al. (1996) performed seismic investigations of four lakes (Lake Wales, Blue Lake, Lake Letta, and Lake Apthorp) (Figure 13) located in the Lake Wales Ridge and established that subsidence activity was the primary mechanism controlling lake origin. Several subsidence features were identified below Lake Wales that have breached the confining units of the Hawthorn Group sediments. Seismic data from Blue Lake represent a more complex situation including the presence of breaches, subsidence, sagging of overlying units and infilled subsidence features. These subsidence events are now covered by sediments suggesting that the relationship between the unconsolidated material and the subsidence features below Blue Lake have reached some degree of stabilization. Lake Letta contains paleobasins created by cover collapse paleosinkholes that later have sagged into the underlying strata. In Lake Apthorp there is evidence of subsidence but the type of subsidence feature is unclear. Generally this seismic study reveals that several subsidence features may contribute to the existence of these lakes rather than one large subsidence feature (Tihansky et al., 1996).

Crooked Lake located in Central Florida (Figure 13) resides within a thickly mantled karst terrain and is composed of several circular basins. Seismic data collected within Crooked Lake indicate that the basins are rimmed with small-scale piping subsidence features that have formed during the late Paleogene through the Quaternary. Larger-scale collapse zones are present

below the lake and have contributed to the deformation of younger Quaternary sediments. (Evans et al., 1994).

Borehole Geology

Much of the information about lithology around the lakes comes from descriptions and interpretations of water wells, test wells, private water wells, well cuttings, and drill holes. These water wells are on the perimeter of the lakes, or within the general vicinity, but not directly within the lake basin. The southern tip of the Trail Ridge just north-east of the lakes contains a concentrated source of minerals called the Trail Ridge Ore Body (~27.40 km long by 1.60-3.20 km wide). Two drill holes from the Trail Ridge Sands provide detailed descriptions of several lithologic units with the upper most layers containing heavy minerals, principally zircon and titanium (ilmenite, leucoxene, and rutile). Below this the lithology consists of alternating layers of peat, quartz sands, and organic sapropelic (Pirkle and Yoho, 1970).

Hirsch (1998), in conjunction with seepage meter analysis, took eleven short cores in Brooklyn Lake (0.064 m diameter by 0.61 m- 0.76 m long) and tested for sediment characteristics including grain size, percent total solids, percent volatile organic solids, and determined their relationship to seepage and vertical permeability. He found that, overall sediments were poorly sorted and were variable throughout the lake. He concluded that sediment characteristics do have an effect on seepage and permeability, which is also variable throughout the lake (Hirsch, 1998).

As mentioned earlier, the Interlachen Highlands have an abundance of well-developed karst features such as sinkholes that developed within a thick mantle of clastic sediments. The thick mantle of sediments was thought to be an inhibitor to karst formation. Arrington and Lindquist (1987) investigated the Interlachen Highlands karst and the role that the thick mantle of unconsolidated material contributed to their development. It was suggested by Arrington and Lindquist (1987) that the nature of the thick overlying mantle sediments, being unconsolidated and well saturated, can act as the primary control on the formation of surficial karst features. To form karst features in this thick mantle of unconsolidated sediments, the sediment must go somewhere. The thought is the limestone acts as the secondary control in the formation of surficial karst features in which the open conduits, fracture zones, and caverns in the limestone that resulted from dissolution now serve as catchments and pathways for the unconsolidated mantle sediments. Therefore, the surficial karst features are formed by large scale piping processes operating through a thick mantle of clastic sediment (Arrington and Lindquist, 1987).

Pollen

Several Pleistocene / Holocene pollen sequences have been reported from Florida lake sediments, but it is difficult to find continuous pollen sequences because of lowered water tables and lake desiccation in the past (Grimm et al., 1993). Reports of cores taken for pollen in five Florida lakes include Lake Tulane in the northwest corner of Highlands County, Lake Annie in the middle-southern Highlands County, Sheelar Lake in south eastern Clay County, and Camel Lake, west of Tallahassee on the west side of the Apalachicola Forest, and Mud Lake in Marion County (Figure 13). In Lake Tulane an 18.52 m core taken in 22.67 m water depth is thought to be the only continuous Pleistocene pollen sequence. This core revealed several oscillations between abundances of *Pinus* indicating wetter periods and abundances of *Quercus* and *Ambrosia* indicating drier times. Radiocarbon dating was used to get geologic ages (Figure 14). The oldest date reported was 39,600 +/- 500 yrs BP at 16.10 m down core (Grimm et al., 1993). Lake Annie was thought to have continuous sedimentation from Pleistocene until Recent. The 11.00 m core taken in Lake Annie in 18.30 m water depth revealed three pollen zones dating back to 37,000 BP (Watts, 1975). Camel Lake is at an elevation 20.00 m above sea level, is 500 m across and resides in a poorly drained pine forest. A 40,000 yr pollen and radiocarbon record was established from a 13.00 m core taken in 4.40 m water depth (Watts et al., 1992).

Sheelar Lake is in close proximity to Brooklyn Lake located ~9.7 km to the northeast. It is a sinkhole lake that has a pollen record (Figure 15) beginning in the late Pleistocene at 23,880 yrs BP extending through the late Holocene. Six pollen zones are represented by approximately 16.00 m of core in Sheelar Lake. These zones indicate shifts and changes in vegetation from dryer windier colder climate in the late Pleistocene, with a shift to wetter conditions around 14,000 yrs BP, then decline of mesic or wetter forests around 12,000 yrs BP that marks the beginning of the Holocene, and finally the change to modern vegetation at 7200 yrs BP (Watts and Stuiver, 1980). Similarly, a 13.60 m core from Mud Lake in Marion County Florida also has six pollen zones representing wet periods and dry periods (Watts, 1969).

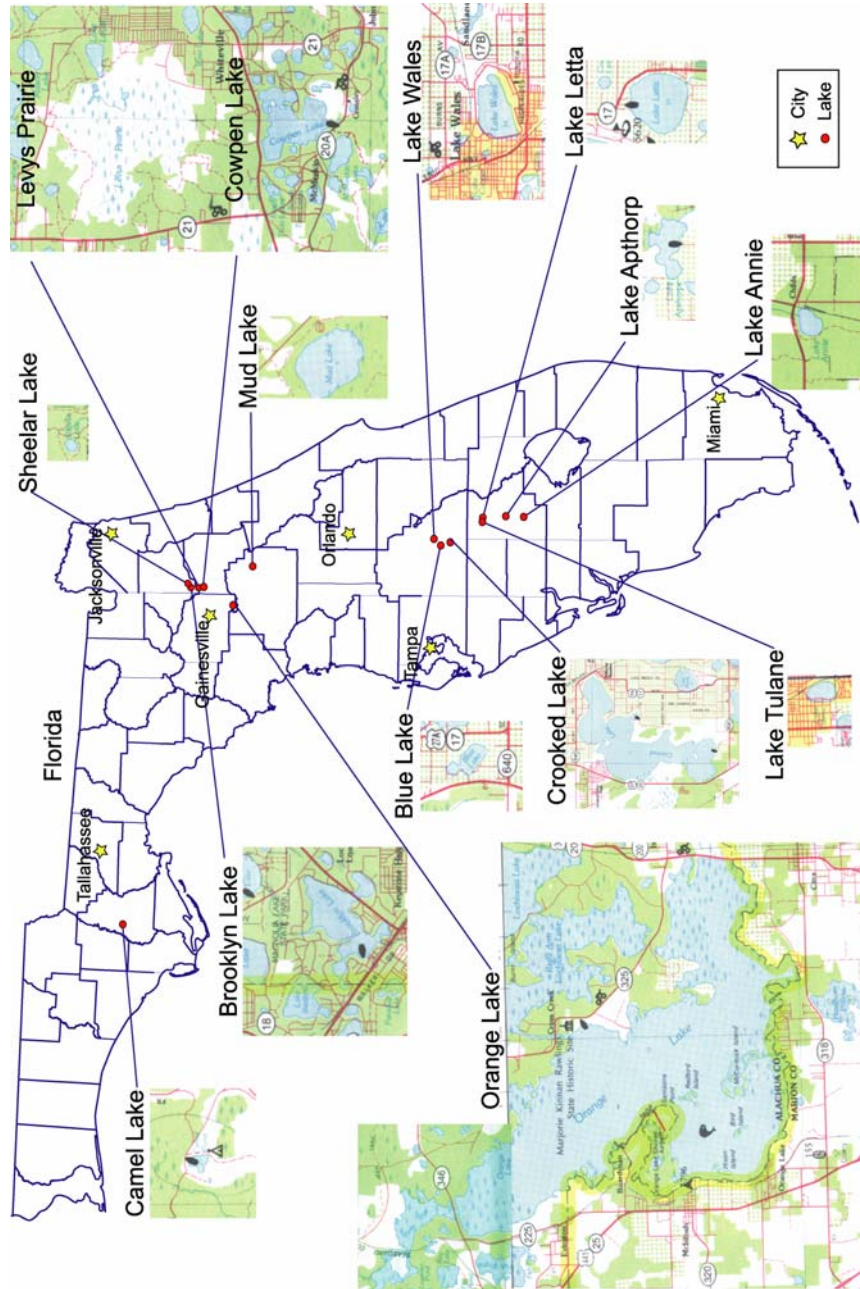


Figure 13. Map showing location of lakes mentioned in previous works

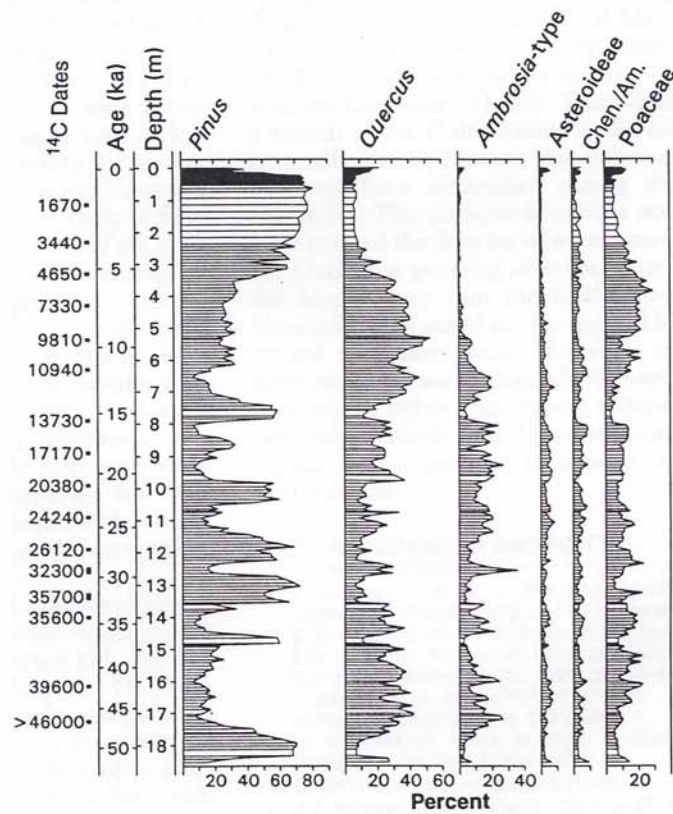


Figure 14. Pollen diagram from Lake Tulane (Grimm et al., 1993).

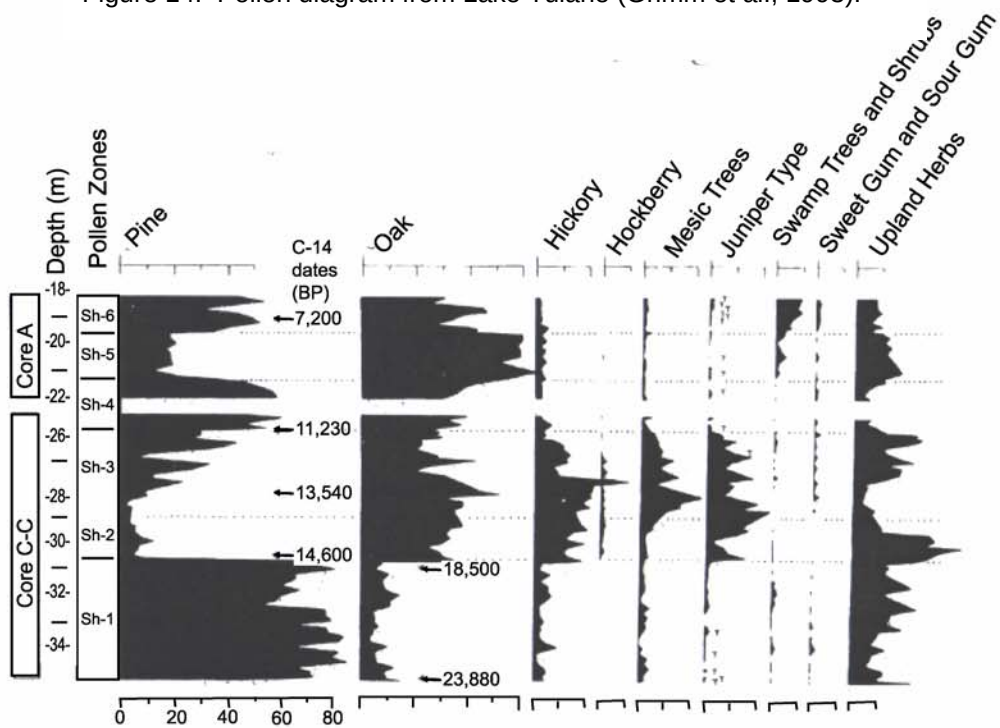


Figure 15. Pollen diagram from Sheelar Lake (Watts and Stuiver, 1980)

METHODS

Vibracoring

A total of 23 vibracores were collected; 12 from Brooklyn Lake, 8 from Levys Prairie, and 3 from Cowpen Lake using a gasoline powered concrete vibrator (Figure 16a and 16b). Sediment recovery ranged from a minimum of 0.43 m to a maximum of 5.88 m cores averaged 2.74 m. The initial sampling trip was in 1998 when the lake levels were at or close to their “full-stage” of lake level elevation, however, during subsequent sampling periods, the lake water levels had declined considerably, therefore both land and underwater vibracoring methods (Lanesky et al., 1979) were implemented. As a result of an extremely low water level in Brooklyn Lake and a lack of water in Levys Prairie (Figure 17), land vibracoring was the predominant method used, whereas, the water level in Cowpen Lake remained deep enough during field operations to facilitate underwater vibracoring.

Land vibracoring was used along the shoreline or in areas of the lakebed that were previously underwater but were exposed as a result of a decreasing lake water level. An all terrain vehicle (ATV) was used to transport equipment at the lake sites and doubled as a winch for extracting cores (Figure 16c).

For underwater vibracoring, a work surface-support platform was assembled to facilitate mobility, safety of coring, and could be independent of a boat when needed. The platform consisted of sections of floating docks and outfitted for diving and vibracoring operations in these freshwater lakes. The platform had several functional and flexible aspects, such as portability and easy assemblage / disassemblage on land or in water in a maximum of 30 minutes by a three person team. If low lake-levels restricted boat launching, the platform was portaged to the shoreline, assembled, and paddled or motored to the sample site (Figure 16d). The pre-established sites were located with a GPS unit and marked with a buoy, so the platform could anchor over the site. Once the coring operation was set upon the lake bed, a GPS reading was taken at the surface, directly above the tripod/barrel setup, and water depth was measured using a metric tape. When the vibracore penetrated to refusal, the divers capped the top of the barrel to provide a seal, and extracted the vibracore. Once the core was fully extracted, the base of the core was capped and safely guided to the surface where the core was recapped properly and secured for transport to the laboratory.

In both coring situations, a tripod was used for stability during coring, and for counter support when extracting the core using a hand winch. Prior to extraction, measurements were taken from the top of the barrel to the sediment surface both inside the barrel and outside the barrel for calculating penetration and compaction. The only fundamental difference between the coring operations was that the core seemed to penetrate faster when underwater.



Figure 16a

Figure 16a. The clamp used to attach the barrel to the vibracore head.

Figure 16b. Vibracore motor and forty-foot shaft

Figure 16c. Land vibracoring, the northern side of Brooklyn Lake in an area that was recently exposed after the lake water level dropped showing transportation mode via ATV

Figure 16d. The work surface-support platform with the Jon boat docked alongside and divers at the surface.

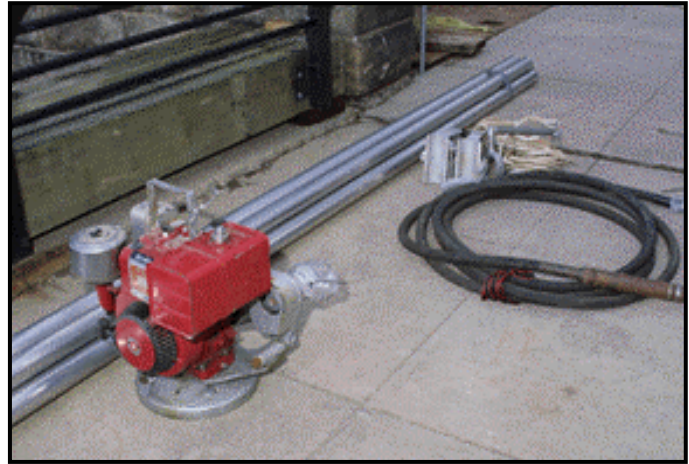


Figure 16b



Figure 16c



Figure 16d

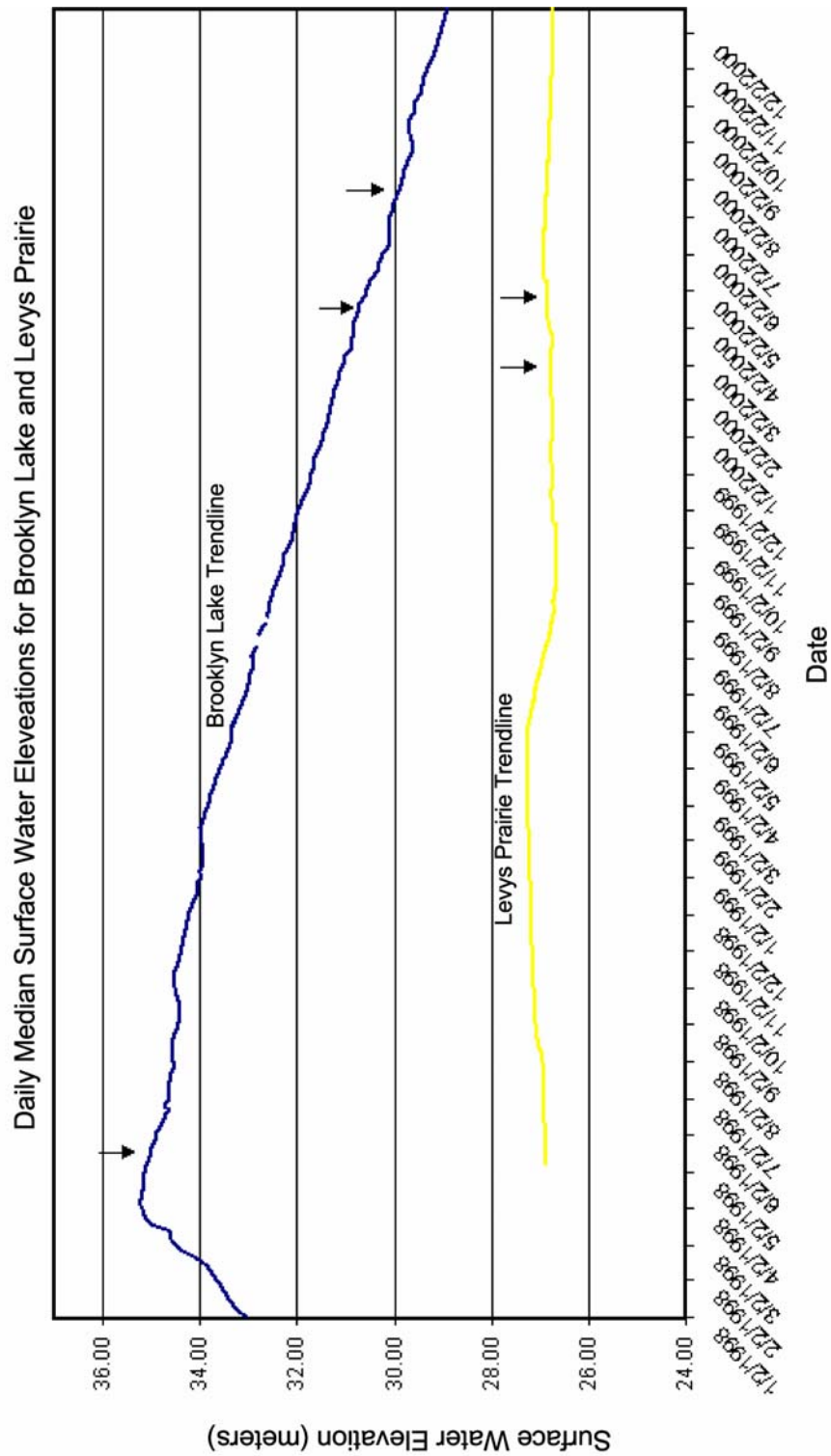


Figure 17. Lake-level elevation trends for 1998, 1999, and 2000 for Brooklyn Lake (normal elevation 35 m) and Levys Prairie (normal elevation 26 m) indicating an overall decrease in lake-level elevation. Arrows indicate time of vibracoring.

Vibracore Visual Description and Sub-Sampling

The vibracores were split in half longitudinally and stored in the sediment core lab facility at the U.S. Geological Center for Coastal and Watershed Studies in St. Petersburg, Florida. The sediment cores were split lengthwise using a specially designed saw that has two sets of horizontally rotating blades. A wire was pulled through the sediment starting from the top of the core and working toward the base to split the sediment into two halves. The core halves were carefully rolled apart and the best half was reserved for the archive and the other half used as the working half.

Immediately after splitting, each core was visually described in detail and logged onto a visual description sheet. To assist in visual description and maintain consistency, three identification aids were implemented, two different sand gauges and rock color chart. Written visual documentation included an interpretative sketch of the core and description of sedimentary textural features that included details about sediment type (i.e., sand, silt, clay, fine sand compactness, etc), sediment grain size, interpretation symbols (i.e. roots, shells, burrows, fossils etc), soil horizons and sediment contacts, all listed at the respected depth of occurrence in the core. Additional detailed worded descriptions were placed in the comments section of the sheet (Appendix 1). In addition, other physical descriptive features were also documented including, structure, color, visual percent organics, visual percent shells, visual percent bioturbation, deformation, bed thickness, and any visual stratification features (i.e., lenticular, flasure, or cross bedding, etc). Samples taken for lab analysis were also indicated.

The archive half was cut into one-meter sections and photographed using a digital camera. The camera was attached to a sliding bar and was plugged into a television monitor allowing the user the flexibility and accuracy for taking various photos of the core.

A total of 331 sub-samples were taken from 23 cores. Sub-samples were taken from the working half in two centimeter intervals, from top to bottom. To prevent contamination, the top layer of the interval was scraped off and only the sediment in the very middle of the interval was taken, avoiding the edges. The sub-samples were stored in labeled plastic bags. Areas of the core that were typically sub-sampled were the following: 1) the top 20 cm and the bottom 20 cm, 2) from each significant sediment layer, 3) from color changes that appeared to have some sediment size differences undecipherable to the naked eye, and from 4) depths of the core that required more than only visual explanation.

Sediment Sample Splitting

To obtain a relatively accurate representative sub-sample split for laboratory analysis, the cone and quartering method (Lewis and McConchie, 1994) was applied to all samples in the lab. This method of rinsing, drying, and splitting helps to break down and homogenize a sample

making it easier to obtain all grain types present. First the sub-sample was rinsed in deionized water and allowed to dry. Second, the sample was gently poured onto a clean piece of paper that is constantly being rotated, this will create a cone. Next the cone was split carefully into two halves using a clean stainless steel spatula and fine material from this was brushed into each split respectfully. One half was split again in the same manner creating a total of four splits (~5-11 grams). One split was used for grain-size analysis, another split was for percent calcium carbonate and percent total organic content, and the remaining two splits were archived.

Grain Size

Initially the first method of grain size was the pipette and dry nested sieving (Folk 1965), however, shortly after analysis began, a Coulter LS200 instrument with a fluid module was purchased, and the remaining grain-size analysis was performed on the Coulter counter. Due to a time constraint, the sample set analyzed using the pipette method was not run through the Coulter counter. For grain-size analysis using the Coulter counter, one sample split as described earlier was placed in a 50 ml beaker, and any samples having grains larger than 1000 μ were sieved to eliminate the larger particles. Several drops of simple sodium-hexametaphosphate (Na_6HPO_4) solution (7.04 g/liter of deionized water) were added to the sieved sample to keep grains from flocculating while they are passing by the laser for measurement. The analysis was monitored and recorded by the computer, which follows a pre-established parameter file created by the user. The volume percent of sample entering the fluid module must be between 8% and 12% to obtain an accurate grain size measurement. After the proper volume percent is added, the fluid module sonicates the sample and measures grains over a 60 s time period after which it graphs the data results of the run. For accuracy, each sample was run three times and all graphs are overlaid for comparison. It was up to the user's discretion to select the best curve. Some samples contained up to three different grain sizes and therefore had to be run through the coulter counter up to eight times in order to get three comparable data curves. A program macro was then used to convert the output statistics into sorting and mean phi sizes.

Percent Calcium Carbonate Content

Calcium carbonate content (CaCO_3) was measured by percent weight difference (Milliman, 1974), using a weak acidic solution ([10% hydrochloric acid (HCL)], as the leaching mechanism. This method was performed under a fume hood for safety. A 250 ml beaker was pre-labeled and pre-weighed, a split portion of the sample added, then weighed again, the difference being the weight of the sediment sample. Next the weak acidic solution was added to the beaker; if there is calcium carbonate present then a reaction began instantaneously. If

necessary, another application of the weak acidic solution was repeated until all calcium carbonate was dissolved. Once all calcium carbonate was dissolved the grains were rinsed by pouring deionized water into the beaker and stirred, waiting until the grains settled out of solution and the remaining liquid carefully decanted without losing sediment. The rinsing step was repeated two more times and then the beaker was placed in a drying oven to be weighed later, when all weights are measured, the percent calcium carbonate content was calculated (Appendix 2).

Care and consistency was taken in each step of this process, but error could still be introduced such as 1) very fine-grained sediments could be lost during the decanting process, therefore altering the initial weight used in the calculations, or 2) if all HCL was not rinsed off it could have altered the weight, and 3) in samples containing peat material, this would float also making decanting difficult, hence, possible weight loss.

Total Organic Content

The index for total organic content was determined through loss on ignition (LOI) (Dean 1974). This method utilized approximately one gram of the residue from the percent calcium carbonate analyses previously described. A crucible was pre-weighed to the fourth decimal place and approximately one gram of the residue from the calcium carbonate analysis was added to the crucible, and then weighed again. The sample was put into a furnace set for 550° Celsius and left for 2 hours and 30 minutes. Immediately after the crucibles were cooled and before they could collect moisture, they were weighed again in the same balance, and then the percent LOI calculated (Appendix 2).

Microscope Photographs

If any sediment in the coarse fraction ($>1000\ \mu$) was sieved out before grain-size analysis it was viewed under a microscope for texture and composition. The samples were viewed in small plastic Petri dishes with a 2 mm grid backdrop. A microscope capable of 20.14X magnification with a digital zoom lens mounted for photographs was used with illuminator for added light. Levys Prairie was the only lake with sediments in this fraction, and only 19 out of 43 sub-samples had very minor amounts of grains $>1000\ \mu$.

X-ray Diffraction Analysis

X-ray diffraction analysis (XRD) was performed on a select group of eleven sub-samples from nine different cores. Selected samples were chosen based upon color, clay content, sediment uniqueness, isolated thin sediment layers, and X-radiograph results. The samples were sieved into a coarse fraction ($>63\ \mu$) and a fine fraction ($<63\ \mu$) and then separately ground into a

powder using a mortar and pestle. The samples were analyzed at 40Kv, 20mA with a 1 s dwell time and each sample was run from 2° 2 θ to 64° 2 θ . The output files were then compared to the Materials Data Incorporated, Jade Pattern processing program for mineral content identification.

Pollen Analysis

Pollen analysis was completed at the U.S. Geological Survey in Reston, Virginia. The samples selected for pollen analysis were determined through exchange and discussion of core photographs (pers. comm. Willard, 2003). Because pollen grains are silt-sized particles, they typically are sparse in sands, which are the predominant lithology in these cores. Therefore, several sub-samples from two cores per lake were selected focusing on the intervals that contained finer-grained material and/or sediments with high organic content. These cores include: LP5, LP6, BK111, and CP5 (sampled throughout their length) and BK108, and CP2, for a total of 50 sub-samples. Samples were taken in two centimeter intervals from the archive half using gloves. The top layer of the interval was scraped off so only unexposed sediment in the middle of the interval was extracted using a melon scoop. Each sample was placed in a plastic bag, labeled, and shipped.

Pollen was isolated from sediments using standard palynological techniques (Traverse, 1988, Willard et al., 2003). One tablet of *Lycopodium* spores was added to 5-7 grams of dried sediment for calculation of pollen concentration (pollen/gram dry sediment). Samples were processed with HCl and HF to remove carbonates and silicates. Samples were acetolyzed (1 part sulfuric acid: 9 parts acetic anhydride) in a boiling water bath for 10 minutes, neutralized, and treated with 10% KOH for 10 minutes in a boiling water bath. After neutralization, residues were sieved with 150 μ m and 10 μ m mesh to remove the coarse and clay fractions respectively. When necessary, samples were swirled in a watch glass to remove mineral matter. After staining with Bismarck Brown, palynomorph residues were mounted on microscope slides in glycerin jelly. At least 300 pollen grains were counted from each sample to determine percent abundance and pollen concentration. The pollen results were displayed in histogram format down core for discussion.

Sediment Core X-radiographs

Five sediment cores were X-rayed to help identify laminations, bedding, contacts or structures, in the cores that could not be seen otherwise. The X-rays were taken using a veterinary portable X-ray unit VR 1020 machine. Only cores BK111, BK108 (partially), LP5, LP6, and CP5 were X-rayed at 56kV and 3.2mA, and promptly developed using an AGFA Processor. Positives of the X-radiographs were then made.

Data Manipulation with Rockworks Software

Two commercial software packages, LogPlot2001 and Rockworks2002, designed by Rockware Incorporated were used for data compilation and statistical review of grain-size analysis. All visual description sheets were converted into digital format using the commercial software package LogPlot 2001 (Appendix 1).

Grain size data were standardized through the use of ternary plots created within the statistical portion of Rockworks2002. The ternary plots were then matched against an accepted ternary plot distribution pattern (Shepard, 1954) to identify sediment types (i.e. sand, sandy-silt, clayey-silt, clay, etc) (Appendix 5).

Sediment Facies

Sediment facies were defined within each lake individually using all measured data components including mean grain size (ϕ), sorting, % sand, % silt, %clay, total organic content, calcium carbonate and sediment color. Facies were defined through an iterative process that involved reviewing ternary plots, scatter plots created in Sigma Plot, and data tables created in Excel of simple statistics such as range of values and averages, then comparing, contrasting and grouping the sediment samples of similar characteristics. Results from the ternary plots did not yield much diversity in grain size distribution; rather the majority of the samples fell into the sand fraction. Because of this, it was in the best interest to review if the samples clustered together within the sand fraction, if so, what other measured data characteristics were similar. Next, scatter plots were created to identify how well other parameters correlated (i.e. mean ϕ verses carbonate content and total organic content). Based upon plots and graphs, a data table with simple statistics was created for samples that grouped well together. Finally, the samples and their assigned facies name were plotted down-core with LogPlot2001 to see how the facies stacked. Outliers or samples that did not cluster together were treated on an individual basis and placed into a facies group based on a combination of the sample location within the core and how closely two or more individual characteristics matched another facies group.

Borehole Geology Comparison

Lithologic descriptions from wells located close to the perimeter of each lake were used for comparison of sediment types outside each lake basin. Descriptions of four wells were obtained from the Florida Geological Survey lithologic database (<http://www.dep.state.fl.us/geology/gisdatamaps/litholog.htm>). Two lithologic wells were used for Brooklyn Lake, well #17252 at an elevation of 48.78 m above MSL located on the northwest side of the lake, and well #C-0442 commonly known as the Moody well at elevation 49.08 m above MSL located on the

south east side of the lake. Well #14594 at an elevation 50.60 m above MSL is used for Levys Prairie. Well #1727 at elevation 29.00 m above MSL was used to for Cowpen Lake.

Sediment Boundary Picks

Several criteria were used when selecting boundary picks. These criteria included 1) any vertical facies boundaries (VFB) that appeared to separate two adjacent layers, 2) any documented boundaries in the visual description sheets, 3) any distinct or unique sediment color changes within the core, 4) any changes in the loss on ignition curve within a sediment facies or at the sediment facies boundary, 5) the presence or absence of root structures and/or other fossils, and the presence of oxidized rhizospheres which represent aquatic plants, and 6) digital photographs. Primarily criteria 3, 4, 5, and 6 were the deciding factors when considering a sediment boundary pick located within a sediment facies.

Every boundary pick does not always coincide with a sediment facies change, rather some boundary picks fall within a sediment facies. If a boundary pick is within a sediment facies it is considered either a very subtle boundary (indicated by S) or it is considered a transitional boundary (indicated by T). Many times the transitional boundary may occur either before or after a sediment facies change.

The sediment boundary picks represent stage boundaries that depict a time when the lake basin underwent a change, for example the basin changing from a subaqueous environment into a subaerial environment. The stage boundaries do not represent chronostratigraphic time, rather relative time based upon proximity to one another. Pollen diagrams from surrounding lakes such as Lake Sheelar and Mud Lake (Figure 13) that had radio carbon dates associated served as the only tool to secure a relative time frame to the cores.

RESULTS

BROOKLYN LAKE

The transect of vibracores that passed through a sinkhole feature within Brooklyn Lake has the broadest range of sediment recovery compared to the cores from Levys Prairie and Cowpen Lake with a minimum of 1.83 m to a maximum of 5.14 m (Figure 18 and Figure 19). A total of 212 sub-samples were taken for laboratory analysis. Table 1 list the vibracore details specific to each core.

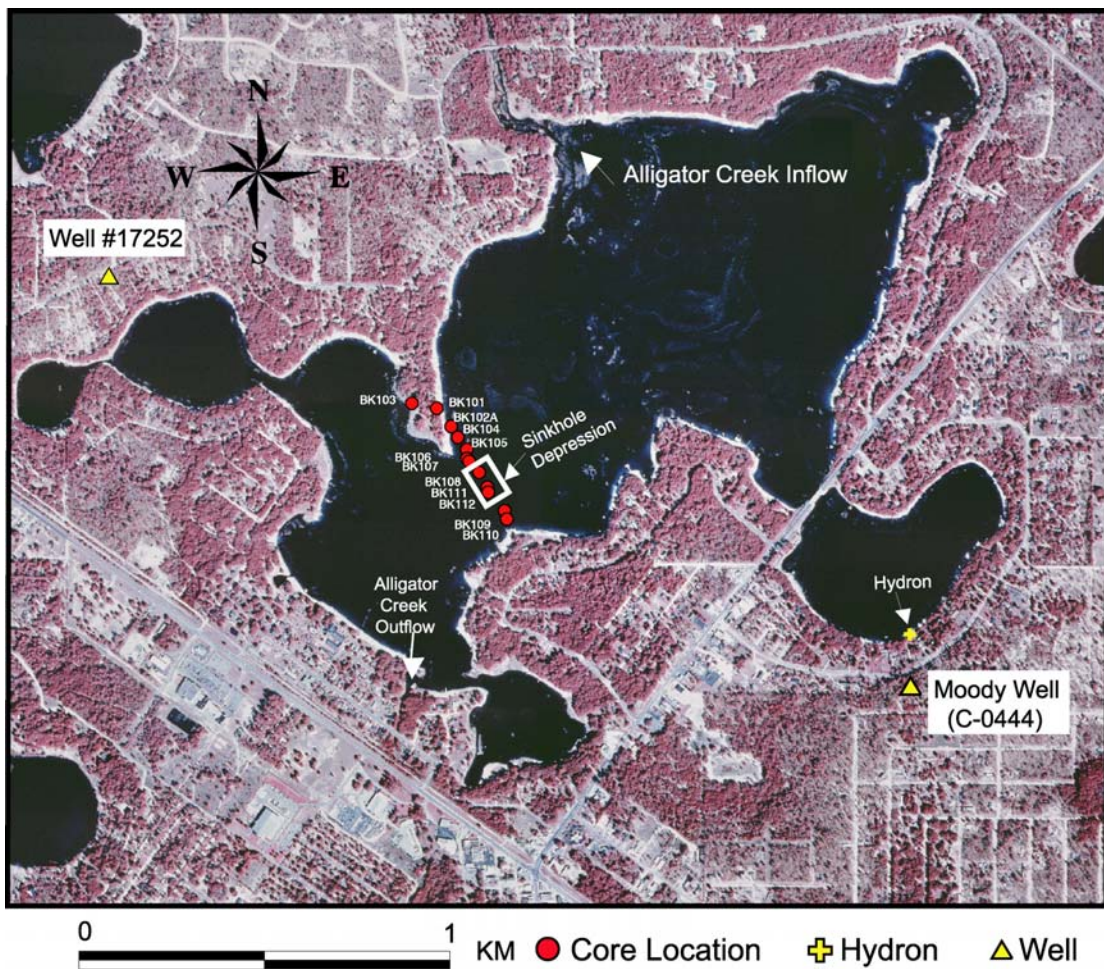


Figure 18. A digital-ortho quarter-quadrangle of Brooklyn Lake in Clay County, Florida showing core locations, well locations, hydron location, estimated sinkhole depression, and Alligator Creek entrance and exit points.

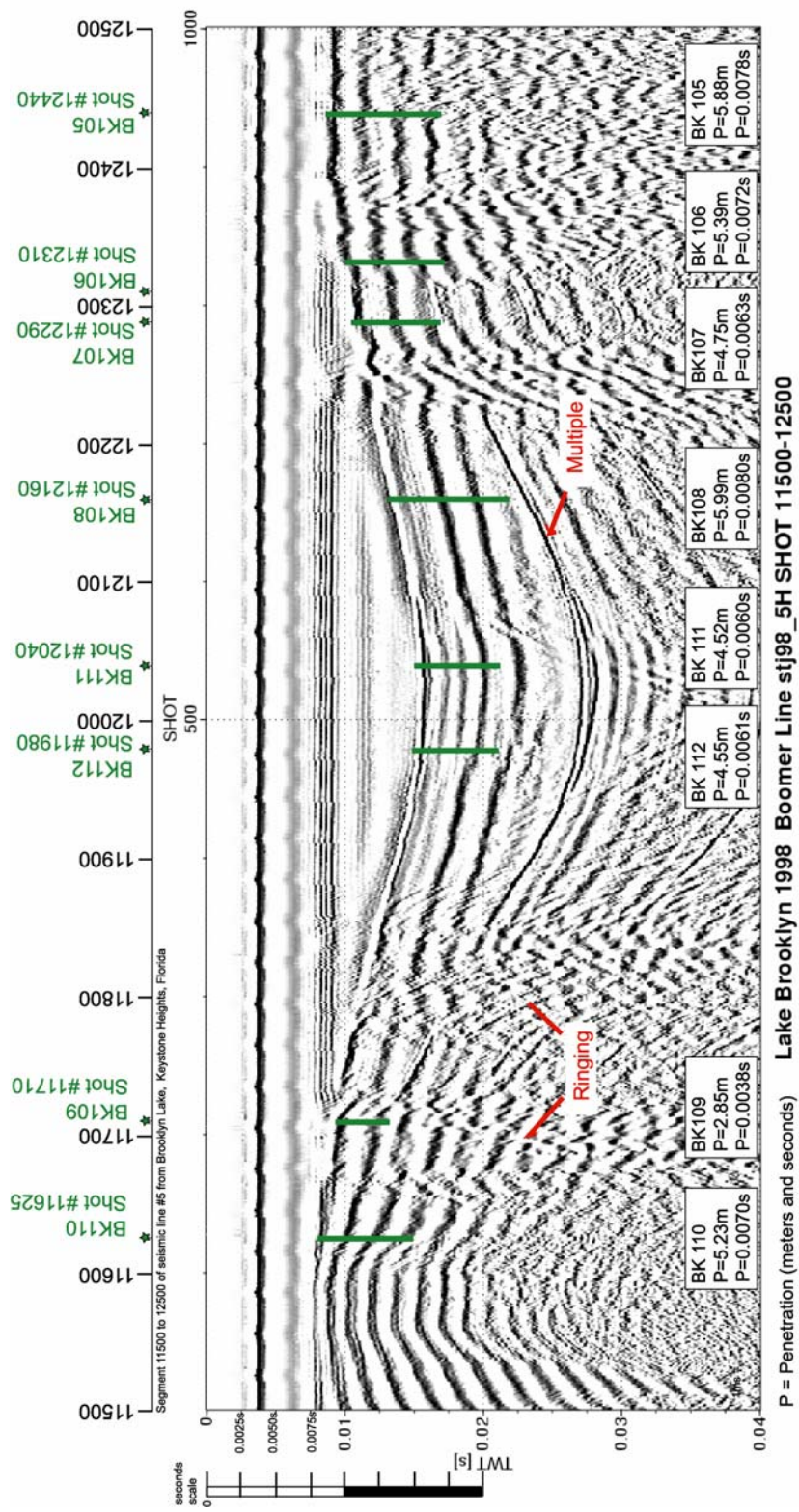


Figure 19. A segment of a seismic line from a 1998 seismic survey shot by the USGS and SJRWMD. Eight of the twelve cores are represented in this figure and cores BK108, BK111, and BK112 are in the sinkhole depression.

Core Name	BK101	BK102A	BK103	BK 104
Latitude	29° 47.933' N	29 47.898' N	29° 47.938' N	29° 47.881' N
Longitude	82° 02.075' W	82° 02.045' W	82° 02.124' W	82° 02.035' W
Easting (X)	400014.285E	400061.219E	399934.895E	400077.046E
Northing (Y)	3296949.590N	3296883.907N	3296958.923N	3296852.365N
Elevation (m)	35.00	34.00*	35.00	34.00*
Water Depth (m)	~0.15	0.00	~0.15	0.00
Penetration (m)	3.20	2.05*	2.56	2.87
Recovery (m)	2.66	2.05	2.16	1.83
%Recovery	83.13	100.00	84.38	63.76
%Compaction	16.01*	0.00	15.63*	23.35
Subsamples	11	10	19	6
Core Name	BK 105	BK 106	BK 107	BK 108
Latitude	29° 47.862' N	29° 47.841' N	29° 47.837' N	29° 47.821' N
Longitude	82° 02.019' W	82° 02.014' W	82° 02.010' W	82° 01.991' W
Easting (X)	400102.505E	400110.212E	400116.589E	400146.93E
Northing (Y)	3296817.043N	3296778.186N	3296770.741N	3296740.916N
Elevation (m)	34.00*	34.00*	30.56	29.07
Water Depth (m)	0.00	0.00	0.26	1.75
Penetration (m)	5.88	5.39? (~-1)	4.75	5.99
Recovery (m)	3.44	3.42	3.26	5.14
%Recovery	58.50	63.45	68.63	85.81
%Compaction	40.88?	24.48	29.68	12.02
Subsamples	25	16	22	27
Core Name	BK 109	BK 110	BK 111	BK 112
Latitude	29° 47.756' N	29° 47.744' N	29° 47.799' N	29° 47.792' N
Longitude	82° 01.943' W	82° 01.936' W	82° 01.978' W	82° 01.977' W
Easting (X)	400223.176E	400234.254E	400167.524E	400169.002E
Northing (Y)	3296620.175N	3296597.911N	3296701.943N	3296687.154N
Elevation (m)	30.69	34.00*	26.11	26.11
Water Depth (m)	0.13	0.00	3.87	3.87
Penetration (m)	2.85	5.23	4.52	4.55
Recovery (m)	2.50	4.61	2.18	3.52
%Recovery	87.72	88.15	48.32	77.36
%Compaction	6.32	11.66	50.66	20.22
Subsamples	12	30	18	16
	*=approximate		?=questionable	

Table 1. Brooklyn Lake vibracore details

Sedimentary Facies

There are five sedimentary facies identified in Brooklyn Lake cores, 1) sand facies, 2) organic sand facies, 3) organic fine sand facies, 4) yellowish-gray organic mud facies, and 5) black organic-rich mud facies. Results indicate that 198 of 213 samples (93%) are sand size 15 of 213 (7%) contain greater amounts of silt and/or clay (Appendix 5). The %CaCO₃ is low (≤ 5.3%) having some variability, but many values below 1%. The %LOI had a wide range of values

(0.0% to 53.2%) (Appendix 2). The five sediment facies are described below and their respective components are summarized in Table 2. A detailed list of the sub-samples and their measured components can be found in Appendix 6. The scatter plot of mean grain size (Phi), versus %CaCO₃, versus %LOI graphically displays the division of sediment facies (Figure 20).

Brooklyn Lake Facies Name	Sand	Organic Sands	Organic Fine Sands	Yellowish - Gray Organic Mud	Black Organic Rich Mud
Mean Grain Size (Phi)	1.23ø - 4.21ø	1.18ø - 2.67ø	2.91ø - 3.88ø	4.19ø - 7.42ø	4.94ø - 6.55ø
Average	1.71ø	1.75ø	3.34ø	5.00ø	5.63ø
Sorting (Phi)	0.45ø - 1.06ø	0.58ø - 1.39ø	0.91ø - 2.00ø	1.77ø - 3.39ø	1.45ø - 1.99ø
Average	0.69ø	0.79ø	1.24ø	2.58ø	1.82
%Sand	79.42% - 100.00%	81.95% - 98.99%	68.47% - 81.09%	10.12% - 74.63%	8.33% - 32.25%
Average	95.04%	90.78%	77.60%	60.71%	20.40%
%Silt	0.00% - 13.67%	0.89% - 15.16%	8.64% - 26.76%	9.41% - 48.47%	59.12% - 75.08%
Average	3.06%	5.01%	14.62%	19.63%	66.07%
%Clay	0.00% - 14.51%	0.09% - 9.62%	2.18% - 11.99%	10.17% - 20.34%	8.66% - 23.78%
Average	1.90%	4.21%	7.76%	19.68%	13.59%
%CaCO₃	0.00% - 3.08%	0.00% - 0.95%	0.00% - 1.35%	0.00% - 0.45%	1.03 - 5.33%
Average	0.27%	0.29%	0.48%	0.45%	2.98%
%LOI	0.06% - 2.25%	2.66% - 7.88%	2.33% - 8.21%	3.23% - 5.79%	28.61% - 53.17%
Average	0.69%	4.16%	4.14%	4.90%	45.40%

Table 2. A summary of the Brooklyn Lake sediment facies characteristics listing the minimum, maximum, and average statistics of seven parameters; mean grain size (Phi), sorting, %sand, %silt, %clay, %CaCO₃, %LOI.

The **sand facies (S)** consists of a well sorted to moderately sorted (0.45 ø – 1.06 ø), quartz sand ~95% usually clean and homogenous, but sometimes has a mottled appearance. This facies is tightly grouped in the scatter plot of mean grain size versus %CaCO₃, versus %LOI (Figure 20). It is found in all the cores (Figure 22), not restricted to a particular depth of the core, and has a wide range of thickness from 6 cm to 321 cm. The %CaCO₃ is extremely low having only a few values ranging from 0.0% - 3.1% with an average low of 0.27%. Similarly the %LOI is very low having only a few values ranging from 0.1% to 2.3% with an average low of 0.7%. It may have roots, root stains, plant material, round brown stains, and burrows or stains. Occasionally a thin (mm scale) clay layer or silt layer may exist and sometimes sandy-clay lenses are found within the sand matrix. There is a wide range of colors having many variations of yellows and browns (Appendix 6). Two samples were analyzed for mineralogy (BK108: 334-336 and BK110: 330-332) and were found to contain quartz in the coarse fraction and quartz and kaolinite in the fine fraction.

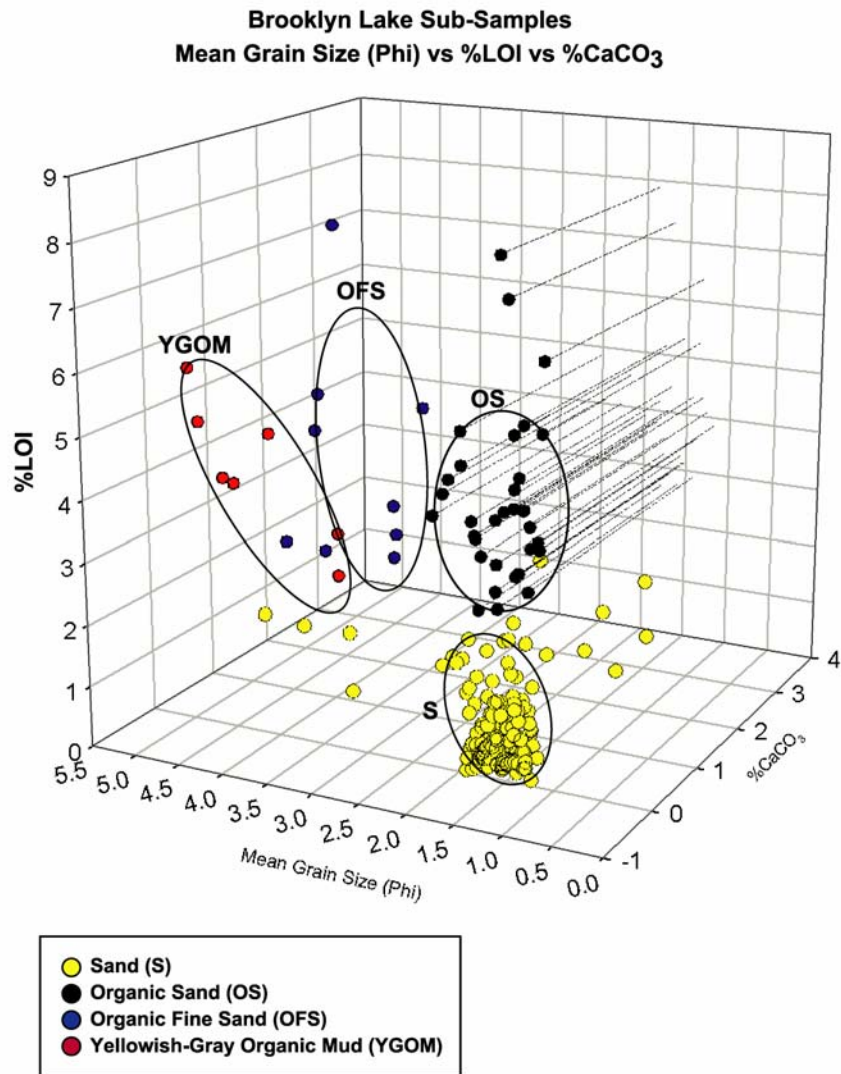


Figure 20. A 3-D scatter plot of the sub-samples from Brooklyn Lake excluding the black organic rich mud facies (BORM). This scatter plot shows four groupings, outlined with ovals for visual effect which represent the sand facies (S--yellow), the organic sand facies (OS--black), the organic fine sand facies (OFS--blue), and the yellowish-gray organic mud facies (YGOM -- red). Samples were grouped based upon proximity and similar values. Outliers were treated individually based upon two conditions 1) how closely two or more defining characteristics (i.e. mean Phi, %LOI, sorting, color, etc.) fit with a facies and 2) the location of the sample within the core.

Five samples from the sand facies of core BK111 were analyzed for pollen. Most of these samples are below 60 cm core depth (61 cm, 92 cm, 131.5 cm, 151 cm, and 191 cm). Two sub-samples were barren (131.5 cm and 191 cm) and *Pinus* and *Quercus* dominated the remaining three samples, with minor abundances of *Poaceae*, *Chenopodiaceae*, *Asteraceae*, *Cyperaceae*, *Polygonum* and *Myriophyllum*. Below 92 cm, *Myrica*, *Liquidambar*, *Chenopods*, *Polygonum* and *Myriophyllum* are absent (Figure 21 and Appendix 4).

The **organic sand facies (OS)** is well sorted to moderately sorted (0.6 ϕ -1.4 ϕ) and found in eight of twelve cores (Figure 22), ranging in thickness from 5 cm to 167 cm and can be found in all areas of the core often times associated with visually noted texture changes, transition areas, or boundaries. It may contain roots, root traces and burrows or stains, and may be stiff and compact. Occasionally there are clay nodules. The organic sand facies has an increased amount of %clay compared to the sand facies, averaging 4.2% vs. 1.9%. The %CaCO₃ is extremely low to absent, whereas the %LOI has increased, averaging 4.2% compared to the 0.6% of the sand facies. One sample (BK109: 160-162 cm) was analyzed for mineralogy and contained quartz in the coarse fraction and quartz and kaolinite in the fine fraction.

The **organic fine sand facies (OFS)** consists of finer grained sediments compared to the organic sand facies (average mean phi 3.3 versus 1.8 respectively). It is moderately to poorly sorted (0.91 ϕ -2.0 ϕ) having more silt content and slightly more clay content than the organic sand facies. It is found in six cores (BK101, BK103, BK105, BK111, BK112, and BK110 - Figure 22) having an approximate range of thickness of 5 cm to 17 cm and is not found having roots but does contain some rounded stains. Four samples from core BK111 (1 cm, 11 cm, 51 cm and 71 cm) analyzed for pollen show similarities to the pollen samples of the sand facies described above (Figure 21 and Appendix 4)

The **yellowish-gray organic mud facies (YGOM)** is distinctly different in color from the organic fine sand facies. It is predominantly yellowish-gray (5Y7/2). Both the silt and the clay content cover the greatest range of values (9.4% - 48.5% and 13.1% - 42.0% respectively) compared to the other facies. It is the most poorly sorted facies (1.8 ϕ - 3.4 ϕ), and is only found in three cores (BK111, BK112, BK110—Figure 22) from the southern side of the lake. The facies is found in the middle to lower depths of the core ranging in thickness from 7 cm to 40 cm thick. The %CaCO₃ is extremely low to absent ($\leq 0.5\%$), whereas, the %LOI is moderate (3.23% - 5.79%) and many times it is found overlain and underlain by the organic sand facies. It is found to be stiff and can have lenses of sand within a clayey-sand matrix. One pollen sample from 214 cm at the base of core BK111 is dominated by ~70% *Pinus* ~15% *Quercus*, ~2% - 5% *Poaceae*, *Asteraceae*, and *Cyperaceae*, and very small amounts of *Carya*, *Liquidambar*, *Myrica* (Figure 21 and Appendix 4). This sample closely resembles the pollen in the upper portion of the core as mentioned earlier within the organic fine sand facies.

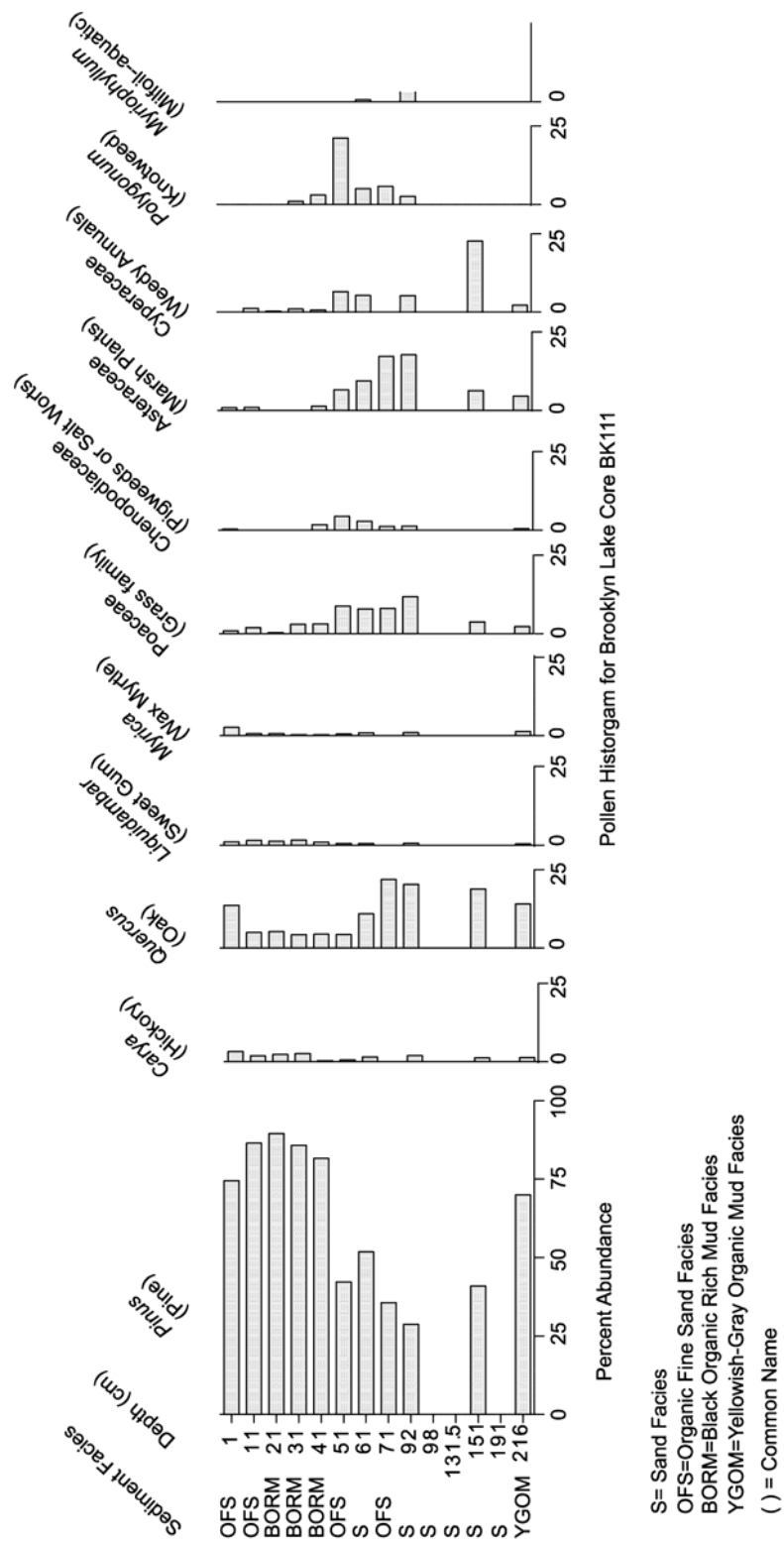


Figure 21. Pollen histogram for core BK111 showing results of pollen content and the respective sediment facies.

The **black organic-rich mud facies (BORM)** is found only in two cores, BK111 and BK112 (Figure 22), which are in the deepest part of the sinkhole depression. Based upon plotted values of mean grain size (Phi), %CaCO₃, and %LOI this facies is distinctly separate from the other facies (Appendix 2). The predominantly black color (N1) and extremely stiff, hardened, and compact sediment texture further emphasize the difference of the BORM facies compared to the other facies described earlier in Brooklyn Lake. This facies is found within the upper meter of the core and is relatively thin ranging in thickness from 27 cm - 30 cm. It contains the highest average %silt content (66.1%) and similarly the widest range and highest average of %LOI (28.6% - 53.2% and 45.4% respectively) of all five sediment facies. It is poorly sorted and rarely contains tiny remnants of plant material.

Three pollen samples from BK111 (1 cm, 31 cm, 41 cm) are dominated by greater than 75% *Pinus*, having between 5% – 10% *Quercus*, and very small amounts of *Carya*, *Liquidambar*, *Myrica*, *Chenopodiaceae*, *Asteraceae*, *Cyperaceae*, and *Polygonum*. There is a lack of *Myriophyllum*. Just below the 41 cm sample, the *Pinus* abundance drops markedly (Figure 21 and Appendix 4).

Sediment Boundary Picks

The current horizontal and vertical positions of the sediment cores in Brooklyn Lake are represented in Figure 22. Each core is hung at its respective elevation (NGVD). This figure was constructed using the sediment facies column and the %LOI curves from the individual down core LogPlot profiles (Figure 23 and Appendix 1). Five sediment boundary picks were identified and expressed by different colors in Figure 22. These five boundary picks represent stages in which the basin developed and will be presented later in the discussion of this paper.

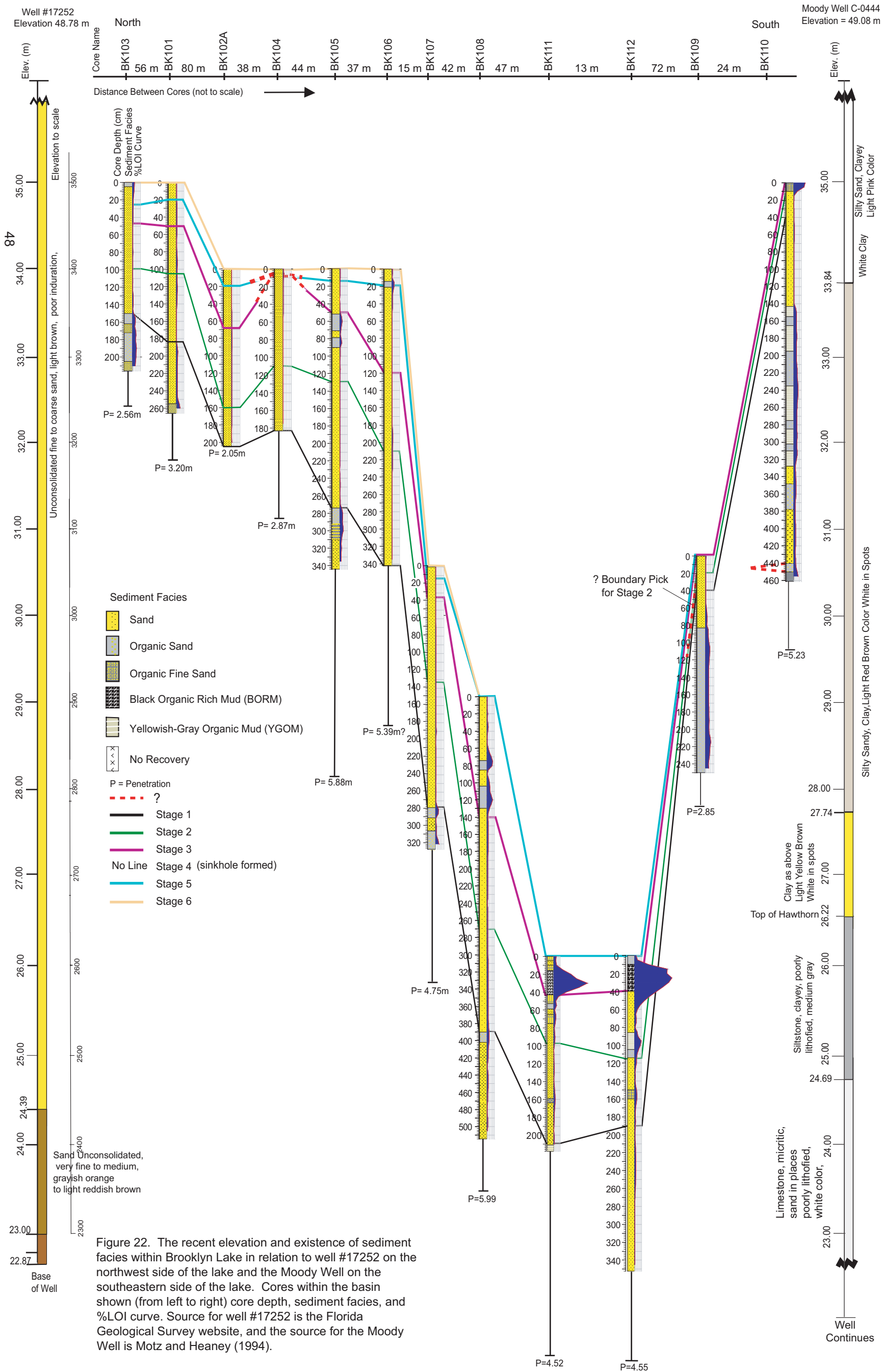
In Brooklyn Lake every boundary pick does not always coincide with a sediment facies change, rather some boundary picks are within a sediment facies. Many times the transitional boundary may occur either before or after a sediment facies change. Two examples of a transitional boundary occurring before a sediment facies change (moving up the core) can be found in cores BK105 and BK111. In BK105 the pick for boundary 2 is at 129 cm, but the sediment facies change is at 90 cm (Figure 22 and BK105 photo in Figure 26, Appendix 1). In BK111 the pick for boundary 2 is at 98 cm, but the sediment facies change is at 75 cm (Figure 22 and BK111 photo in Figure 26, Appendix 1). An example of a transitional boundary occurring after a sediment facies change (moving up the core) is found in BK109 where the sediment facies change is at 83 cm, but the pick for boundary 2 is at 40 cm (Figure 22, BK109 photo in Figure 26, Appendix 1).

Several picks for boundary 1 were primarily associated with a sediment facies change but also consideration of the presence of root structures and changes in %LOI to a lesser degree

(Figure 25). Picks for boundary 2 are principally subtle or transitional within a sediment facies, such as in BK111 as described above, or a coupled transitional change in which there are changes in both sediment color and total organic content (Figure 26). More abrupt VFB can be seen at boundary 3 (Figure 27). The picks for boundary 4 (Figure 28) are not as easy to identify as previous boundaries, rather they are subtle transitions. Cores BK108, BK109 and BK110 do not appear to have boundary picks for boundary 4. Boundary 4 also represents the transition into the cores as they exist in recent geologic time.

Sediment Facies Succession

Sediment facies succession in Brooklyn Lake cores is inconsistent and variable from core to core. In other words, one sediment facies is not consistently found atop or below another sediment facies. However, three generalizations could be applied to these cores. One generalization is that some cores depict a coarsening upward succession. This succession consists of finer sediments and organic sediments thin portions (<1m) in the lower meter of the core overlain by clean coarser sands. Figure 29 represents core BK103 as one example of the coarsening upward succession. Other cores resembling this succession are BK101, BK105, BK107 all of which are on the northern side of the transect. The cores on the southern side of the transect, include BK109 and BK110 except they contain thicker intervals (>1m) of the finer sediments in the lower half of the core. The second generalization encompasses cores in that lack a sediment facies succession and consists primarily of sands. Core BK102A is an example (Figure 29) and other cores similar to this are BK104 and BK106. The third generalization is a fining upward succession that consists of clean coarser sediments overlain by finer sediments and organic sediments. Figure 29 represents core BK112 as one example of the fining upward succession. Other cores similar to this include BK111 and BK108.



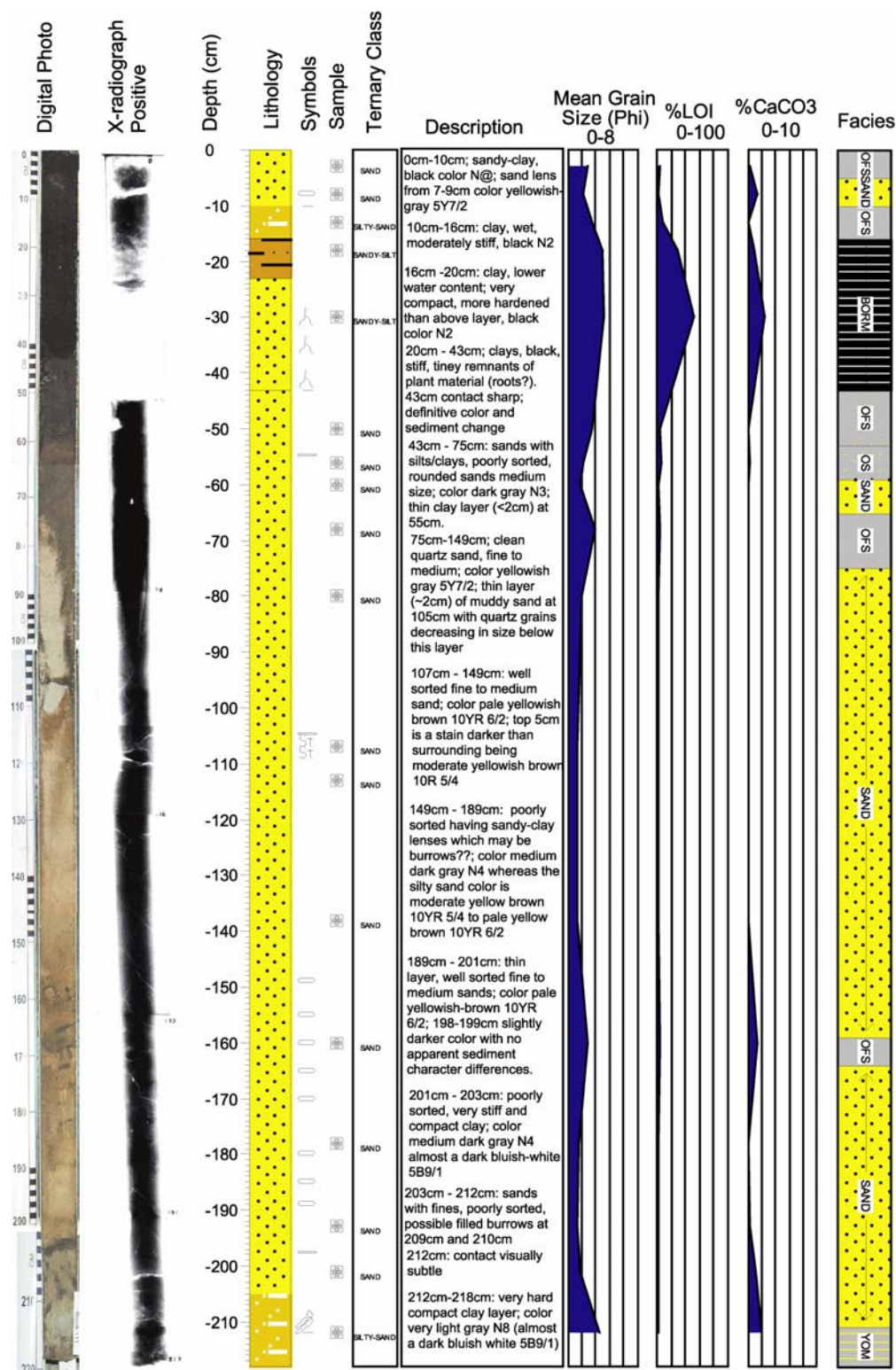


Figure 23. Down core Logplot of core BK111 from Brooklyn Lake, complete with (from left to right) digital photograph, X-radiograph positive, depth (cm), standardized lithology based upon ternary class, symbols, sub-sample depths, description, mean grain size (Phi), %LOI, %CaCO₃, and facies.

Examples of Oxidized Rhyzospheres

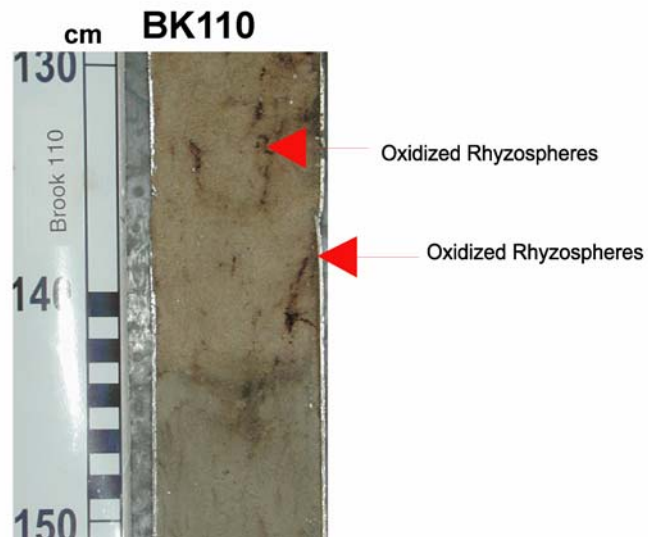
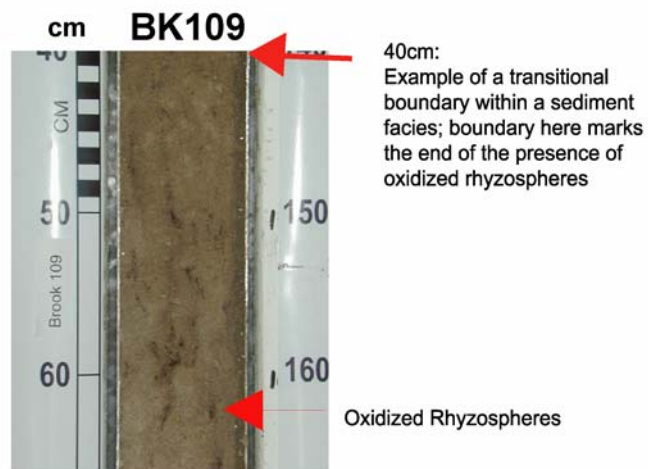
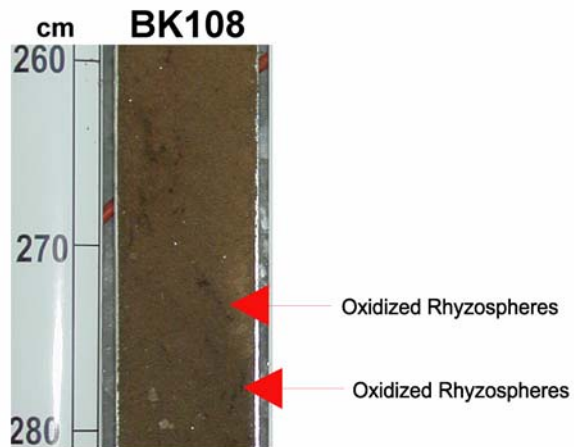


Figure 24. Examples of oxidized rhizospheres in Brooklyn Lake

Picks for Boundary 1

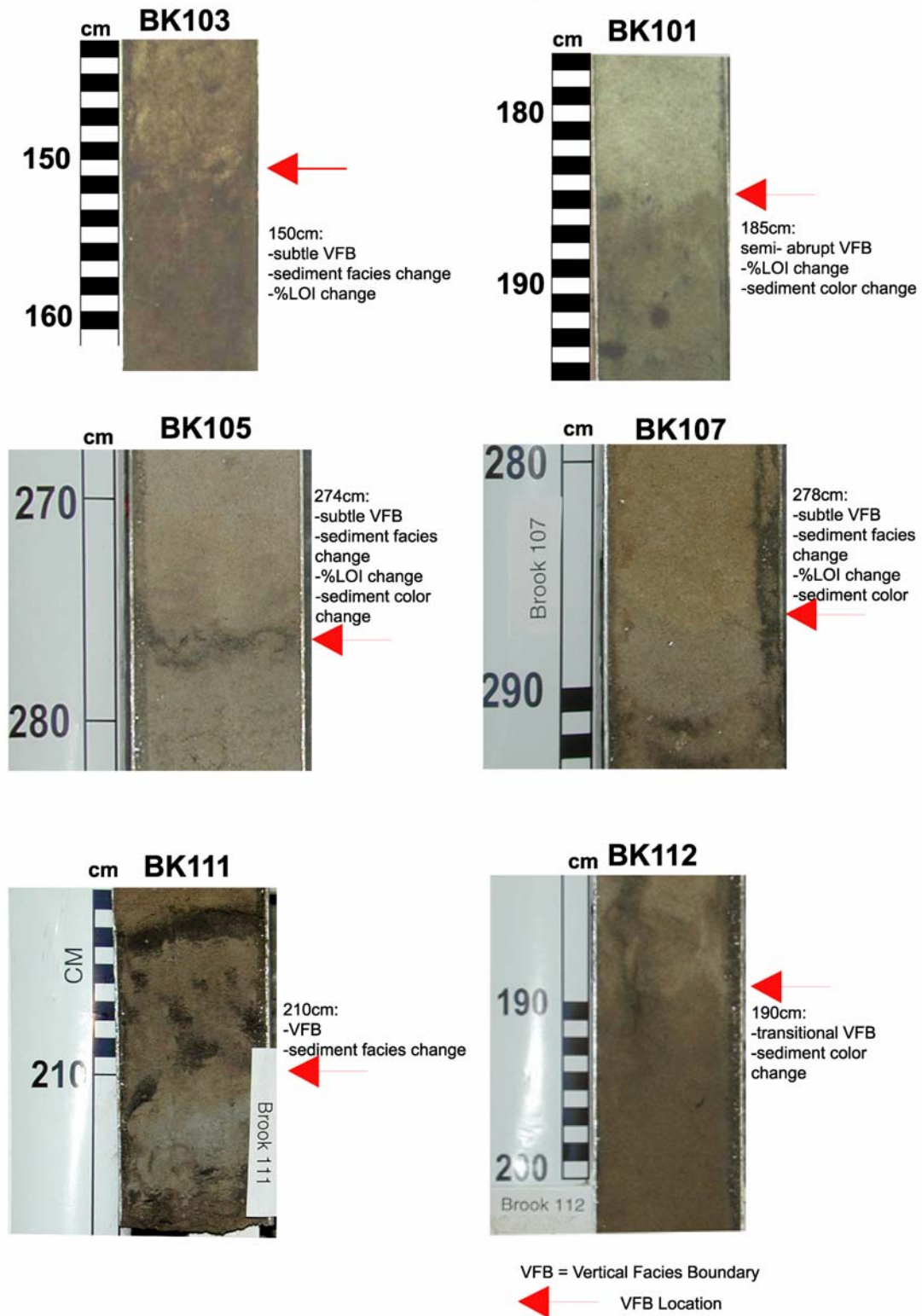


Figure 25. Photographic examples of picks for boundary 1 in Brooklyn Lake

Picks for Boundary 2

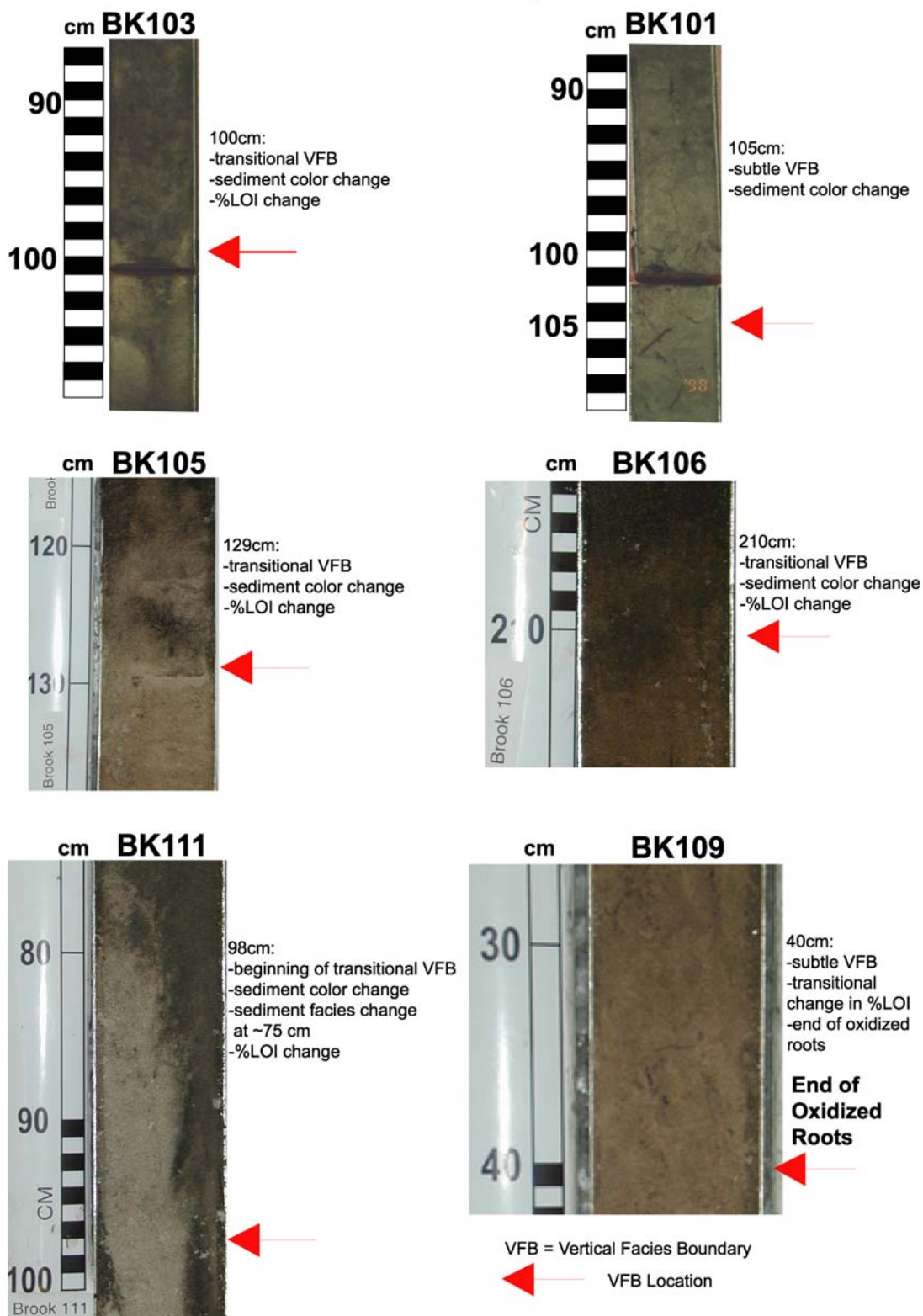


Figure 26. Photographic examples of picks for boundary 2 in Brooklyn Lake.

Picks for Boundary 3

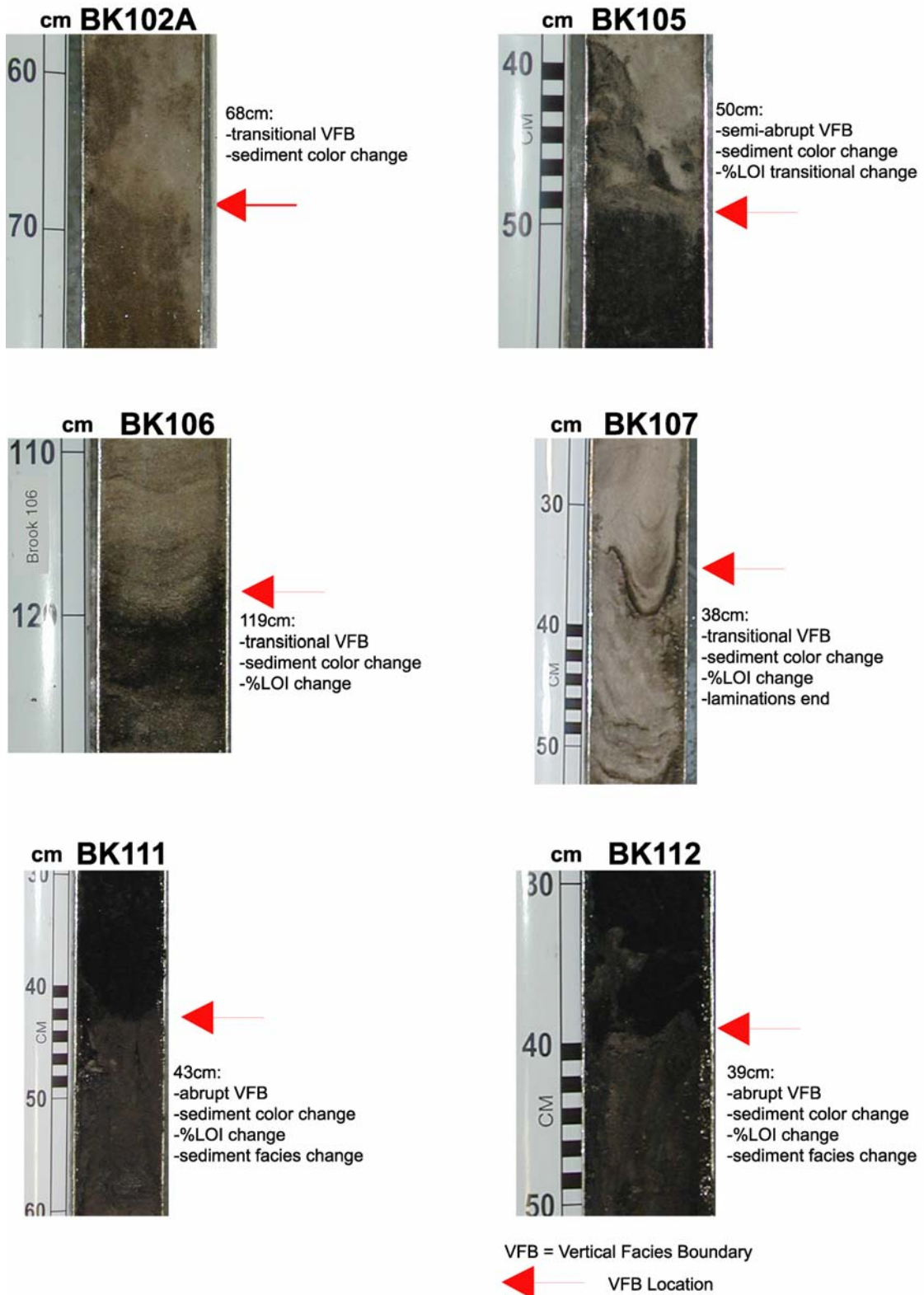


Figure 27. Photographic examples of picks for boundary 3 in Brooklyn Lake.

Picks for Boundary 4

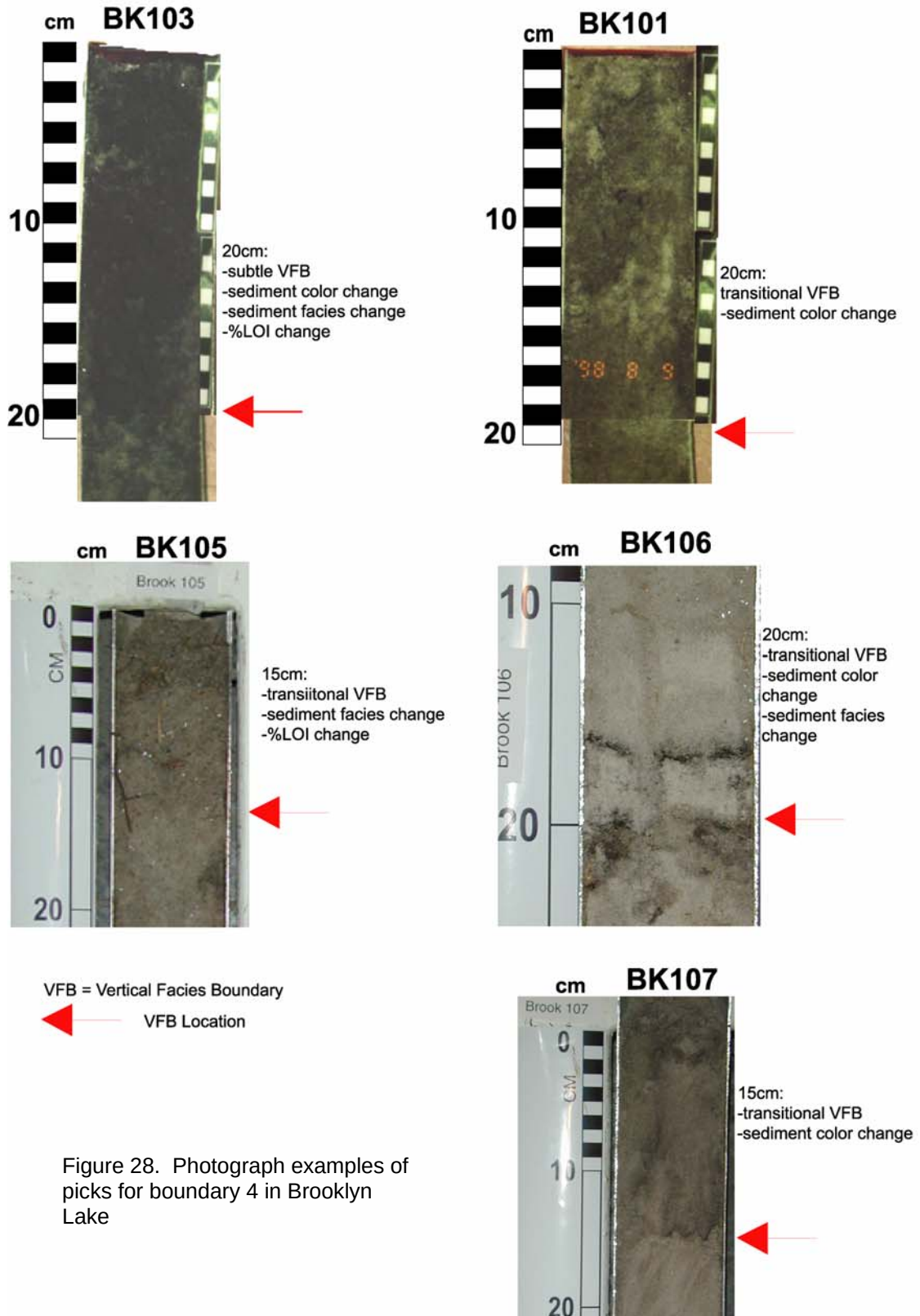


Figure 28. Photograph examples of picks for boundary 4 in Brooklyn Lake

Generalizations of Sediment Facies Successions for Brooklyn Lake

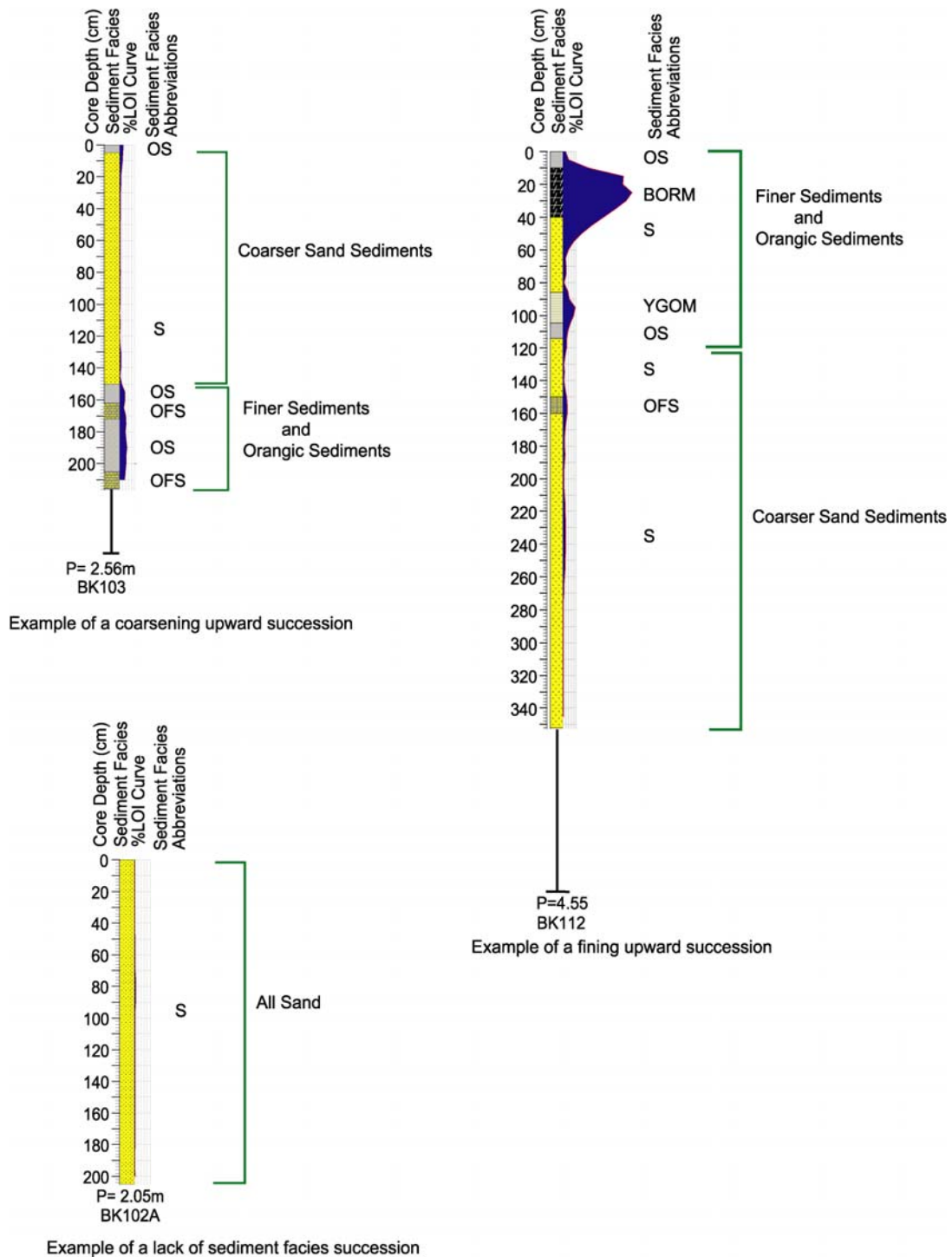


Figure 29. Three generalizations that could be made about the sediment facies succession of the cores within Brooklyn Lake.

LEVYS PRAIRIE

The eight vibracores recovered from a large open water body located in the western portion of Levys Prairie (Figure 30) are the shortest, ranging from 0.43 m to 1.71 m. A set of 43 sub-samples were collected for laboratory analysis. Table 3 lists the vibracore details specific to each core.

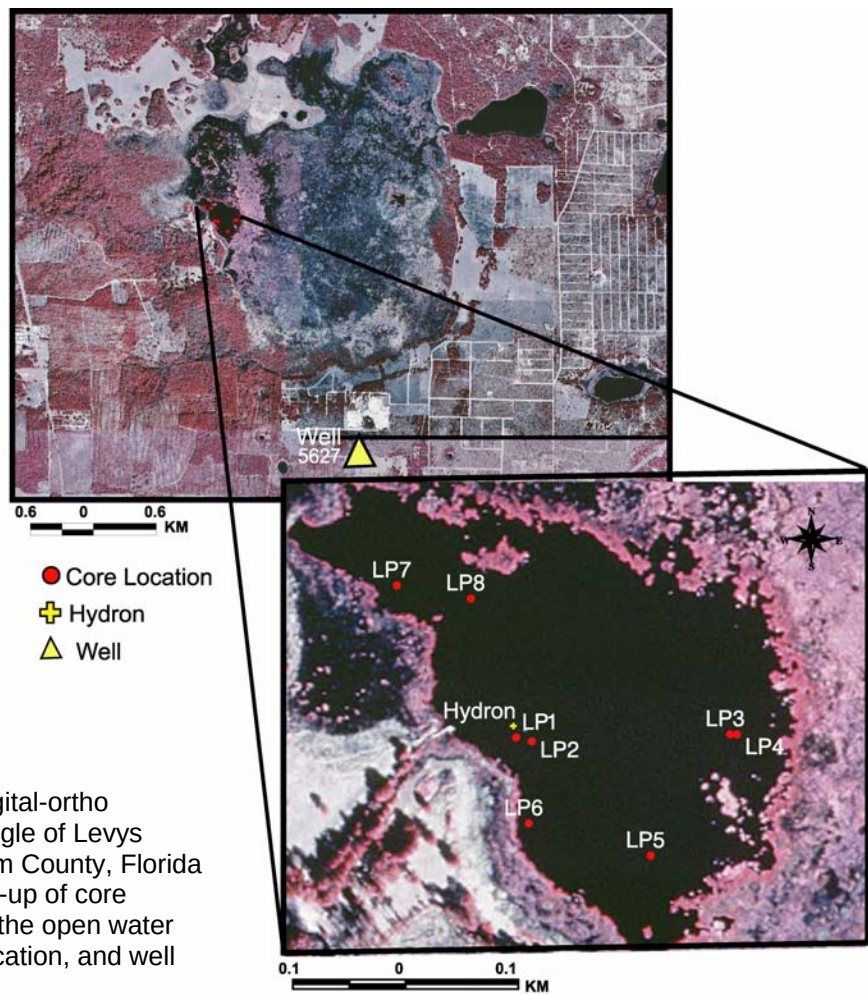


Figure 30. A digital-ortho quarter-quadrangle of Levys Prairie in Putnam County, Florida showing a close-up of core locations within the open water body, hydron location, and well location.

Core Name	LP1	LP2	LP3	LP4
Latitude	29° 38.411' N	29° 38.409' N	29° 38.414' N	29° 38.414' N
Longitude	82° 00.698' W	82° 00.690' W	82° 00.581' W	82° 00.577' W
Easting (X)	402077.363 E	402090.241 E	402266.441 E	402272.894 E
Northing (Y)	3279343.704N	3279340.206 N	3279347.288 N	3279347.232 N
Elevation (m)	25.53	25.53	25.53	25.53
Water Depth (m)	0.00	0.00	0.00	0.00
Penetration (m)	5.00	3.43	4.88	4.02
Recovery (m)	0.46	0.43	1.58	1.51
%Recovery	9.20	12.54	32.42	37.60
%Compaction	90.80*	87.46*	3.07	-9.96?
Subsamples	2	2	5	7
Core Name	LP5	LP6	LP7	LP8
Latitude	29° 38.355' N	29° 38.367' N	29° 38.484' N	29° 38.478' N
Longitude	82° 00.624' W	82° 00.691' W	82° 00.765' W	82° 00.724' W
Easting (X)	402196.116 E	402088.262 E	401970.713 E	402036.763 E
Northing (Y)	3279238.929 N	3279267.575 N	3279479.159 N	3279467.500 N
Elevation (m)	25.53	24.63	25.53	25.38
Water Depth (m)	0.00	0.90	0.00	~0.18
Penetration (m)	1.74	1.89	1.48	1.68
Recovery (m)	1.70	1.33	1.34	1.52
%Recovery	97.59	70.37	90.79	90.37
%Compaction	3.44	24.34	6.78	8.32
Subsamples	6	7	6	8
	*=approximate		?=questionable	

Table 3. Levys Prairie vibracore details

Sedimentary Facies

There are five sedimentary facies identified in the Levys Prairie cores, 1) the peat facies, 2) the sand facies, 3) the organic sand facies, 4) the silty-sand facies, and 5) the organic lime mud facies. Results indicate that the majority of the samples 29 of 43 (67%) are sand size whereas; the remaining 14 of 43 (33%) contain more silt (Appendix 5). However, in this lake, both %CaCO₃ content and the %LOI content show variability versus mean grain size (Phi) as shown in the 3-dimensional scatter plot (Figure 31). The 3D scatter plot indicates four groupings denoted by circles and color that represent four of the five facies. The peat facies is not included on the plot because peat does not have a grain size parameter. Represented in Figure 31 is 1) the sand facies in yellow that exhibits tight grouping over a small value range; 2) the organic sand facies in black, composed of fewer samples that are closely spaced and distinctly set apart from the sand facies; 3) the silty-sand facies in blue which extends over a greater range as shown by the widely spaced, loose groupings, yet separate; and 4) the organic lime mud facies in pink again only few samples, but distinctly separate. The outliers here are many times transitional or

Levys Prairie Facies Name	Peat	Sand	Organic Sand	Silty-Sand	Organic Lime Mud
Mean Grain Size (Phi)	--	1.39ø - 2.41ø	1.28ø - 1.84ø	2.51ø-4.20ø	5.04ø - 6.00ø
Average	--	1.66ø	1.63ø	3.40ø	5.28ø
Sorting (Phi)	--	0.86ø - 1.26ø	0.97ø - 1.06ø	1.15ø - 3.31ø	2.17ø - 3.03ø
Average	--	0.96ø	1.00ø	2.01ø	2.55ø
%Sand	--	83.27% - 97.96%	89.27% - 95.52%	47.60% - 80.88%	19.02%-40.35%
Average	--	93.56%	91.64%	68.68%	30.98%
%Silt	--	1.70% - 14.01%	3.12% - 5.80%	14.56% - 39.56%	41.60%62.70%
Average	--	4.40%	4.43%	25.87%	53.75%
%Clay	--	0.25% - 3.75%	1.37% - 6.03%	2.27% - 12.80%	10.88% - 18.24%
Average	--	1.98%	3.90%	5.45%	15.24%
%CaCO₃	2.33% - 10.13%	1.10% - 6.70%	7.01% - 11.01%	7.41% - 23.40%	13.52% - 26.63%
Average	6.19%	3.38%	9.01%	13.40%	17.20%
%LOI	55.12% - 94.50%	0.33% - 1.43%	3.09% - 5.29%	3.63% - 10.63%	6.89% - 8.74%
Average	77.29%	0.94%	3.93%	5.99%	7.42%

Table 4. Summary of Levys Prairie sedimentary facies characteristics listing the minimum, maximum, and average statistics of seven parameters; mean grain size (Phi), sorting, %sand, %silt, %clay, %CaCO₃, and %LOI.

between facies as identified in their down core profile, however, they are associated with a facies based upon how well two or more of their characteristics matches that facies. The five facies are described below and their respective components are summarized in Table 4, however a detailed listing of the sub-samples that compose the facies can be found in Appendix 6.

The **peat facies (P)** is found in seven of eight cores and ranges in thickness from 25 cm - 89 cm and is characteristic of ~77% LOI and %CaCO₃ between 2.33% and 10.13%. It is stiff and spongy having woody material; occasionally contains small amounts of sand, and may contain thin plant roots. There are three distinct colors brownish-black (5YR2/1), brownish-gray (5YR4/1) and black (N2). It is always underlain by sand with an abrupt sharp contact (Figure 33).

Pollen results from core LP5 (Figure 33 and Appendix 4) for this facies shows *Pinus* as the dominant type in the top 91cm of the core at or close to 75% abundance, with *Carya*, *Quercus*, *Liquidambar*, visually apparent but <12.5%. Poaceae and *Asters* are present at or below 12.5%. The pollen from the peat facies in core LP6 is similar where *Pinus* is the dominant species between 50% and 75% abundance with Chenopodiaceae as the second dominant family having up to ~27% abundance, Asteraceae and *Quercus* have similar amounts both <~15% abundant. Some pollen differences are that core LP6 does not contain *Caraya*, *Liquidambar*, *Ulmus*, *Myrica*, *Alnus*, *Polygonum* or *Nuphar*; LP6 has low to no *Nymphaea*

Levys Prairie Sub-Samples
Mean Grain Size (Phi) vs %LOI vs %CaCO₃

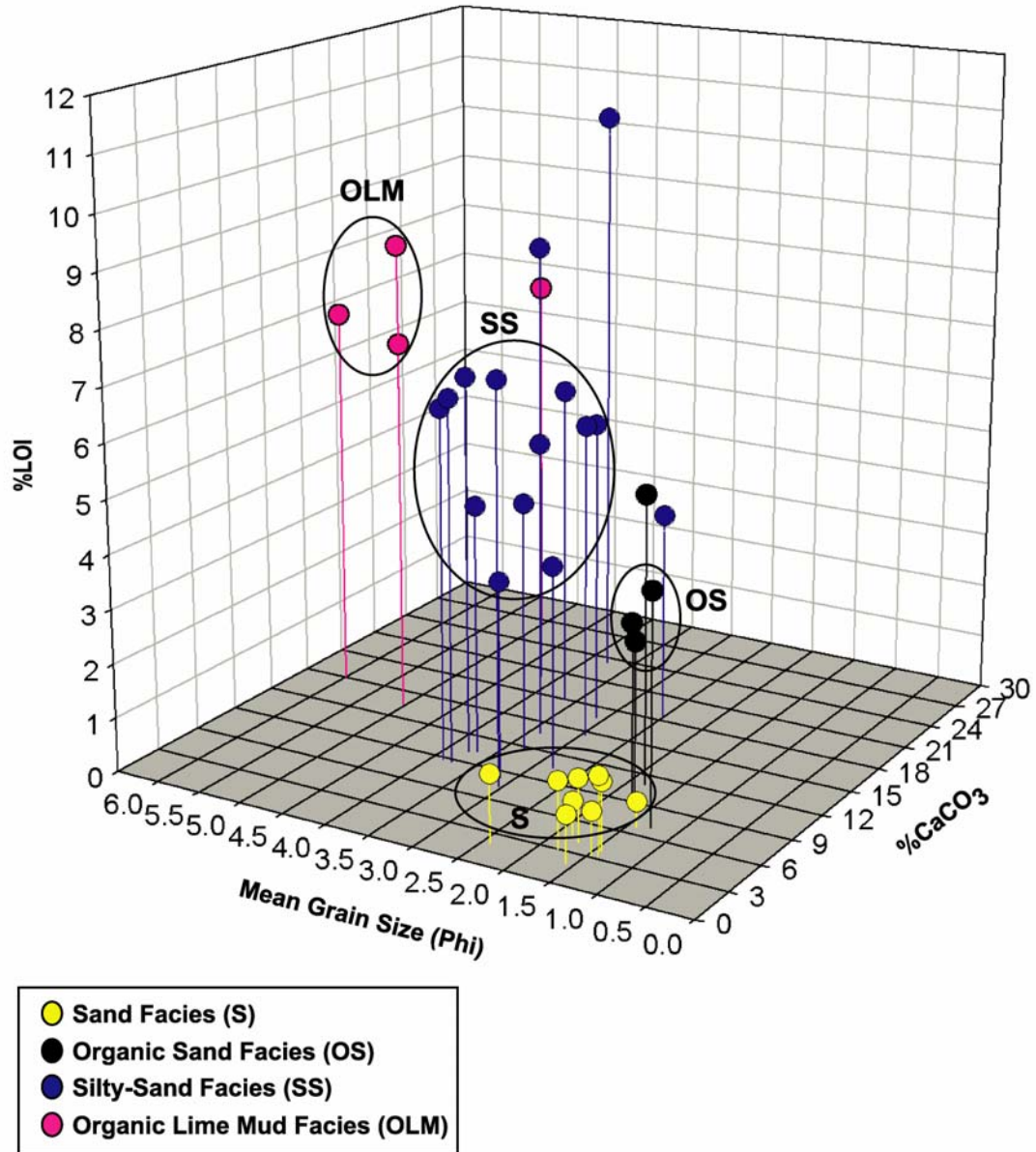


Figure 31. A 3-D scatter plot of the sub-samples from Levys Prairie excluding the peat facies. This scatter plot shows four groupings outlined with ovals for visual effect which represents the sand facies (S--yellow), the organic sand facies (OS--black), the silty-sand facies (SS--blue), and the organic lime mud facies (OLM--pink). Samples were grouped based upon proximity and similar values. Outliers were treated individually based upon two conditions 1) how closely two or more defining characteristics (i.e. mean Phi, %LOI, sorting, color, etc.) fit with a facies and 2) the location of the sample within the core.

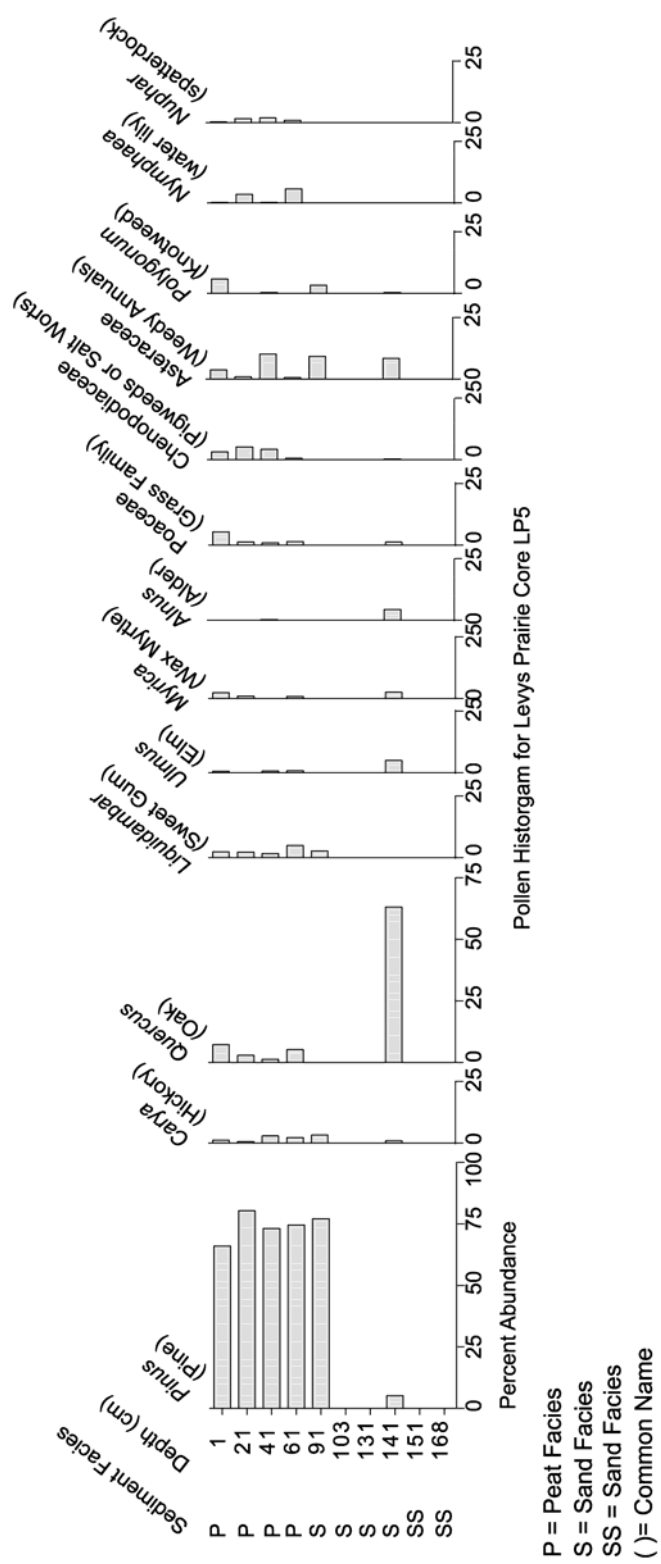


Figure 32. Pollen histogram for core LP5 showing results of pollen content and the respective sediment facies

A close-up image of core LP5 from 70 cm to the base (170 cm) that has examples of the peat facies (P), the sand facies (S), the silty-sand facies (SS), and the organic lime mud facies (OLM) and their respective boundaries. LP5 is considered a good representative of Levys Prairie cores and is the only core with a pollen profile representing the entire core.

In the digital photograph on the right, the P/S boundary appears transitional because of the dark root traces extending into the sand layer, but abruptness is clearly evident in the X-radiograph positive on the left side.

The changes in pollen locations down core from Figure 32 are indicated by the red arrows. Lack of pollen in the sample is represented as barren. The S facies is absent of pollen as is the OLM facies at the base of this core. However, there is a spike in the pollen histogram at 141 cm which has different characteristics from the pollen profile in the top.

Many times a sediment facies contains a small percentage of larger grains. The presence of larger grains is not evident in the digital photo but evident in the X-radiograph as a lack of structure and/or random assortment of grain sizes and shapes.

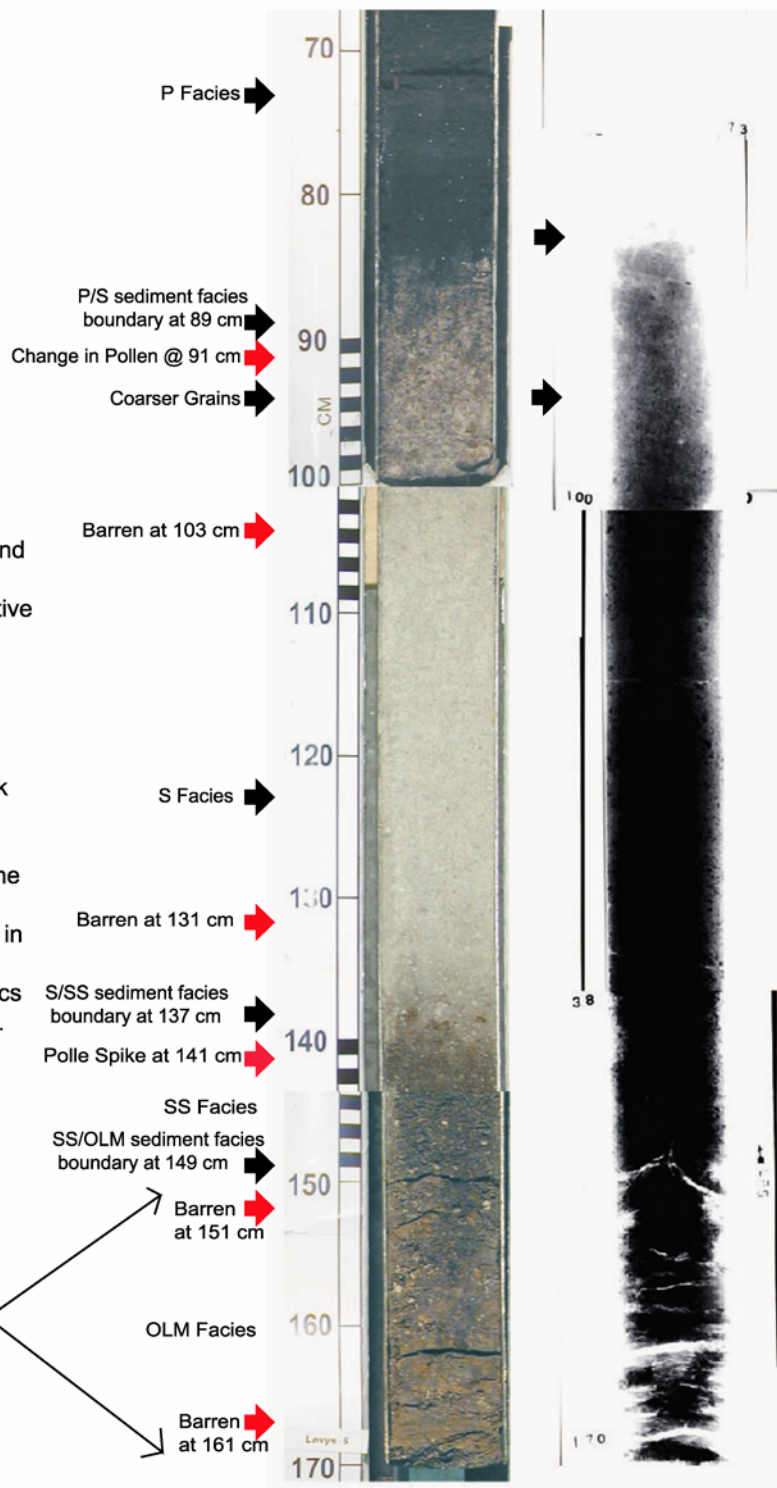


Figure 33. Figure showing a digital photograph and the respective X-radiograph positive of a portion of core LP5 indicating sediment facies boundaries and pollen changes.

compared to LP5, and LP6 has Cyperaceae which is not found in LP5 at all.

The **sand facies (S)** is also found in seven of eight cores and ranges in thickness from 10 cm - 62 cm. It is composed of, moderately sorted medium to fine sands having low %LOI (<1.4%) and comparatively low %CaCO₃ (1.1% - 6.7%) compared to the other facies. There are ~5% - 10% coarser grained material in this layer and the microscope examination of grains >1000µ indicates shell fragments, coral fragments, one sharks tooth, gastropod fragments, and rounded to well rounded quartz grains (Figure 34 and Appendix 3). Other characteristics include roots, root traces, occasional stains or burrows, and occasional pebbles (~5 mm -10 mm). The colors are grayish-brown (5YR 3/2), pale yellowish-brown (10YR6/2) and light olive-gray (5Y6/1).

Pollen results from core LP5 sand facies show a hiatus or lack of pollen from 91 cm-141 cm. However, there is pollen present at 141 cm which is the transition between the base of the sand facies and the top of the silty-sand facies which is characterized by *Quercus* as the dominant species having ~63% abundance, whereas *Pinus* is only a small spike (~<12%). This is the opposite of what is present in the peat facies at the top of the core. *Ulmus*, *Myrica*, *Alnus* are more abundant, and the Asteraceae did not change. *Liquidambar*, *Nymphaea* and *Nuphar* were present in the upper 91 cm, but are absent at the 141 cm sample site (Figure 32 and Appendix 4). One sample from the sand facies in core LP6 at 31 cm (Appendix 4), just below the peat facies, shows a decrease in *Pinus* ~50% abundance but an increase in all other types present, which is slightly opposite that of the pollen in the peat facies of LP6.

The **organic sand facies (OS)** is found in three cores (LP4, LP6, LP7) and is moderately to poorly sorted having higher %LOI, higher %CaCO₃, and higher %clay values (3.0%, 2.8%, 2.0% respectively) than the sand facies. It is a thin layer ranging in thickness from ~12 cm-13 cm, and it is found overlying the silty-sand facies and / or the organic lime mud facies having colors of pale yellowish-brown (10YR6/2) and brownish-gray (5YR4/1). There is ~20% - 25% coarser grained material in this layer and the microscope examination of grains >1000 µ indicates shell fragments, coral fragments, sharks teeth, gastropod fragments, iron stained grains, rounded to well rounded quartz grains (Figure 34 and Appendix 3).

The **silty-sand facies (SS)** is found in six cores excluding LP1 and LP2 and ranges in thickness from 12 cm – 85 cm; it is poorly to very poorly sorted, fine grained (average mean grain size 3.3 ø) solid, stiff, compact sediment sometimes having a mottled appearance (Figure 33). Structures include roots, fine grained sediment filled burrows, nodules of white mud, and lenses of blue-gray clay at the base of LP3. There is ~20% coarser grained material in this layer and the microscope examination of grains >1000 µ indicates shell fragments, coral fragments, sharks teeth, gastropod fragments, iron stained grains, polished grains, rounded to well rounded quartz grains, and white grains (Figure 34 and Appendix 3). Two samples (LP8 140-142 and LP6 110-112) were analyzed for mineralogy and contained quartz, fluorapatite, and kaolinite in the coarse fraction and quartz, fluorapatite, hydroxylapatite, kaolinite and montmorillonite in the fine fraction.

This facies is primarily found at or very close to the base of the core, however it is sometimes found in the middle of the core, and always found either overlain by the organic mud facies or underlain by it. Colors consist of variations in gray, greenish-gray (5Y8/1), yellowish-gray (10YR6/2), brownish-gray (5YR4/1) and this is the only facies which has blue colors including medium bluish-gray (5G6/1), and light bluish-gray (5B7/1). It was observed that some of the blue-gray nodules and lenses oxidized after the core was split indicated by their color change to a rusty appearance. With the exception of the pollen from sample 141 cm described above, the pollen from core LP5 for this facies was barren. However, two samples from core LP6 one barren at 61 cm, the other at 126 cm in which the pollen resembled that of the sample 31 cm from LP6 described earlier (Appendix 4).

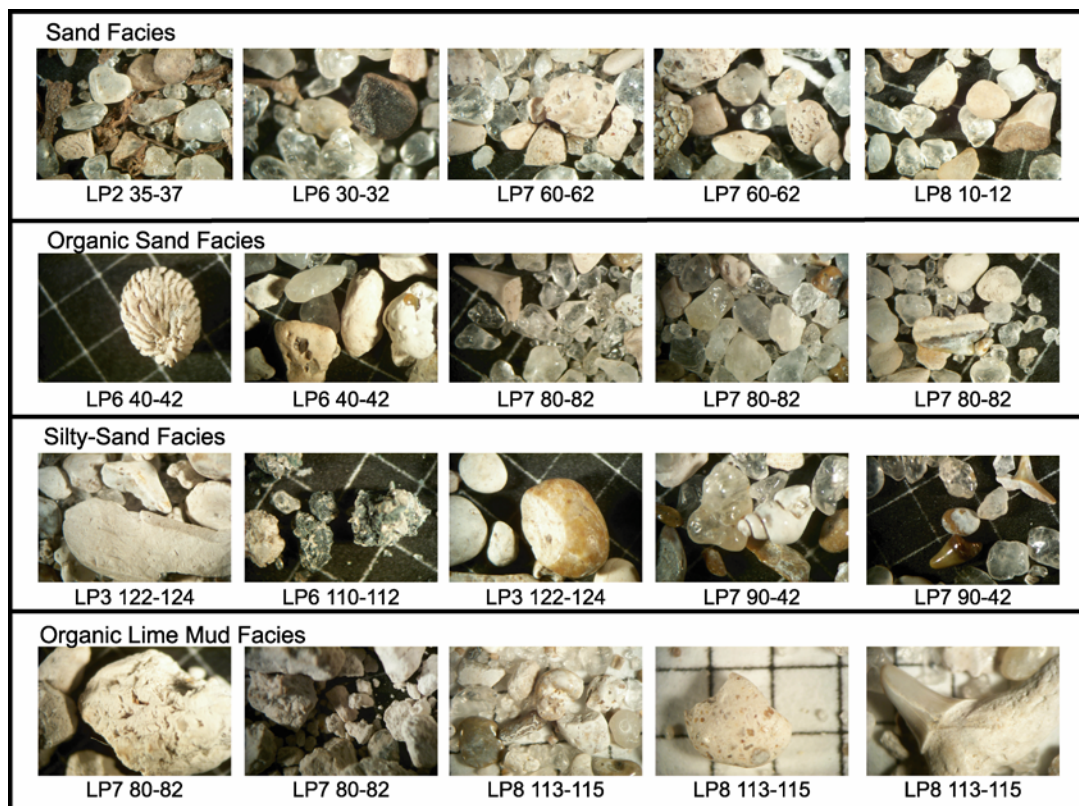


Figure 34. Some examples of the microscope photographs of grains >1000 within the sand facies, organic sand facies, silty-sand facies, and organic lime mud facies. Backdrop scale is 2mm. More photos can be found in Appendix 3.

The **organic lime mud facies (OLM)** is present in three cores (LP4, LP5, and LP8) and ranges in thickness from 14 cm – 41 cm. It consists of a very poorly sorted, very fine-grained mud (average mean grain size 5.28 ϕ) where the average amount of silt and clay is double that of the silty-sand facies (28.6% and 10.0% respectively), and is accompanied by an increase in %CaCO₃ (4.6%), whereas %LOI exhibits a minor increase (1.7%). Structures include nodules of

white mud and occasional burrows (Figure 33). The microscope examination of grains $>1000\ \mu$ indicates sharks teeth and rounded to well rounded quartz grains (Figure 34 and Appendix 3). Two samples (LP5 160-162 and LP8 113-115) were analyzed for mineralogy and contained quartz and fluorapatite in the coarse fraction and quartz, fluorapatite, hydroxylapatite, kaolinite and siderite in the fine fraction. Colors consist of variations in gray, light greenish-gray (5G8/1), yellowish-gray (5Y8/1), brownish-gray (5YR4/1) and greenish-gray (5G6/1). Pollen analysis for the samples from LP5 representative of this facies was barren.

Sediment Boundary Picks

The current horizontal and vertical positions of the sediment cores in Levys Prairie are represented in Figure 35. Each core is hung at its respective elevation (NGVD). This figure was constructed using the sediment facies column and the %LOI curves from the individual down core LogPlot profiles (Figure 36 and Appendix 1). Four sediment boundary picks were identified and expressed by different colors in Figure 35. These four boundary picks represent stages in which the basin developed and will be presented later in the discussion of this paper.

In Levys Prairie, every boundary pick does not coincide with a sediment facies change. Transitional boundaries occur before a sediment facies change or within the middle of a thin sediment facies. For example, the pick for boundary 1 in LP7 is transitional and occurs at 100 cm which is before (moving up the core) the sediment facies change at 88 cm (Figure 35, and 37, Appendix 1). Examples of a transitional boundary within a thin sediment facies can be found at the picks for boundary 2 in LP7 at 82 cm and LP4 at 90 cm both of which are roughly in the middle of the thin OS facies (Figure 35, Figure 38, Appendix 1).

Sediment picks for boundary 1 (Figure 37) and sediment picks for boundary 2 (Figure 38) are half transitional and half associated with sediment facies changes. Sediment picks for boundary 3 (Figure 39) are all associated with a sediment facies change except for one subtle boundary in LP6 at 10 cm. Boundary 3 also represents the transition into the cores as they exist in recent geologic time, in other words, the very top centimeters of the cores.

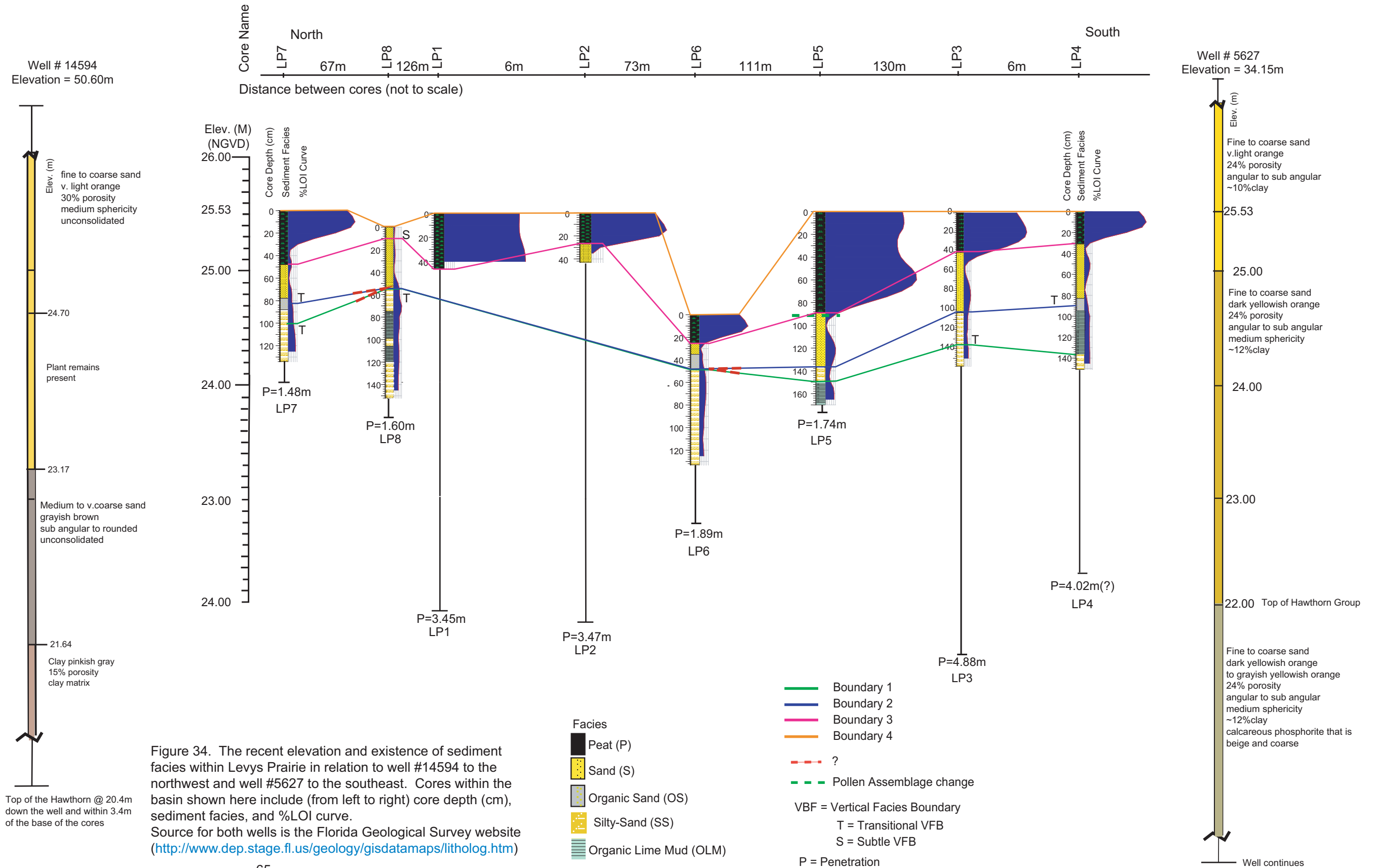


Figure 34. The recent elevation and existence of sediment facies within Levys Prairie in relation to well #14594 to the northwest and well #5627 to the southeast. Cores within the basin shown here include (from left to right) core depth (cm), sediment facies, and %LOI curve. Source for both wells is the Florida Geological Survey website (<http://www.dep.state.fl.us/geology/gisdatamaps/litholog.htm>)

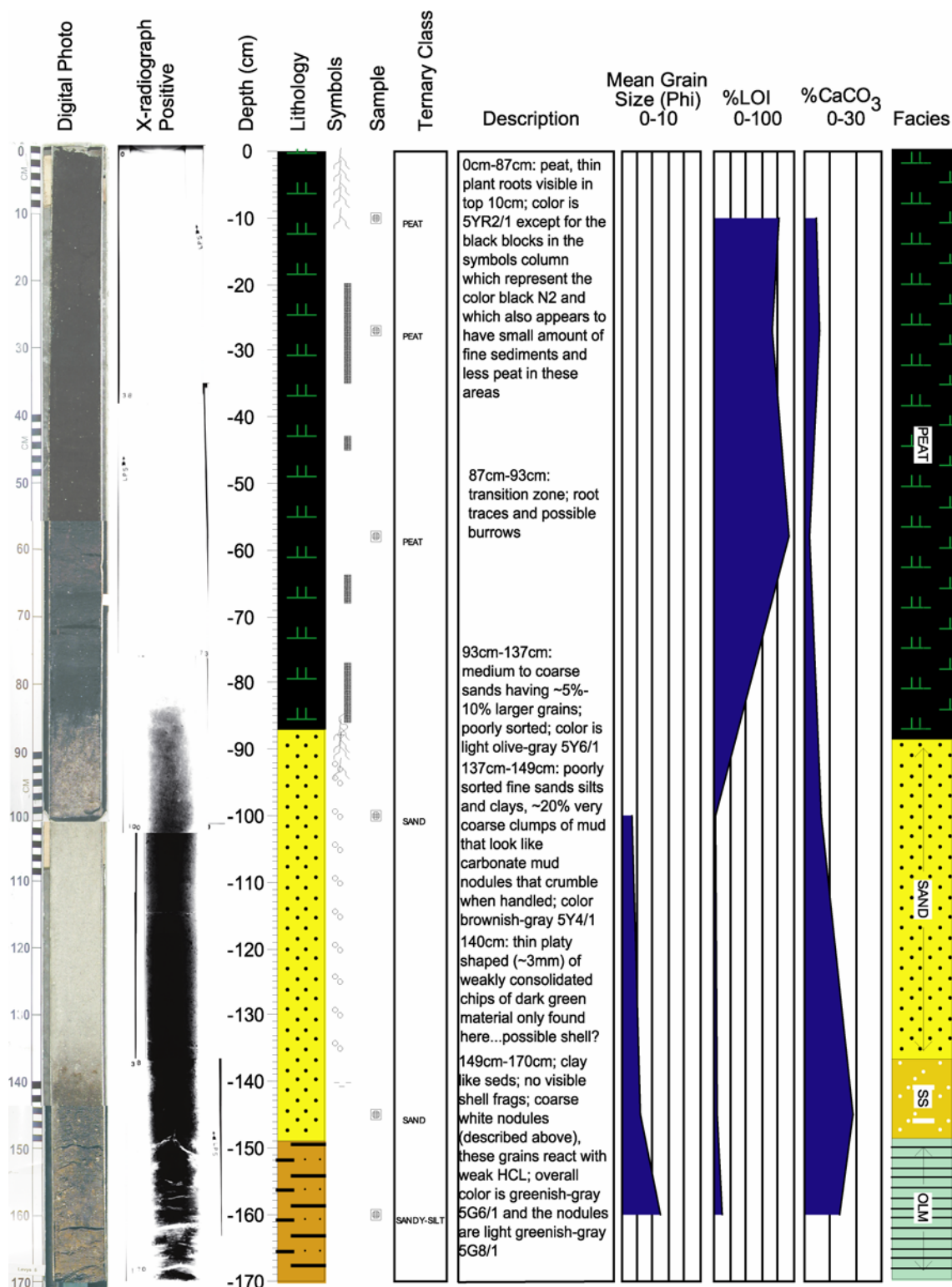


Figure 36. Down core Logplot of core LP5 from Levys Prairie, complete with (from left to right) digital photograph, X-radiograph positive, depth (cm), standardized lithology based upon ternary class, symbols, sub-sample depths, description, mean grain size (Phi), %LOI, %CaCO₃, facies.

Picks for Boundary 1



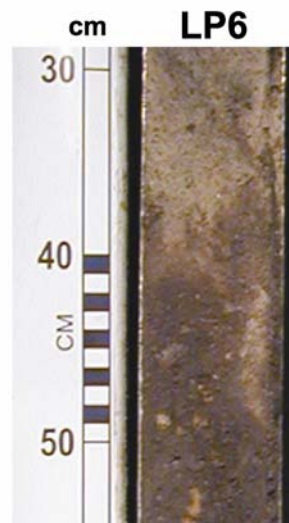
136cm:
-transitional VFB
-%LOI change



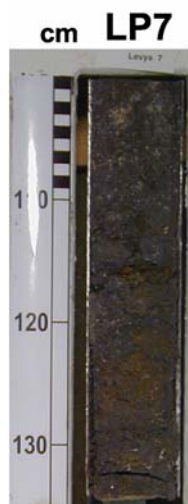
136cm:
-sediment facies change



149cm:
-sediment facies change
-%LOI change



48cm:
-sediment facies change
-%LOI change



100cm:
-Transitional VFB
-visual change
-%LOI change



55cm:
-Transitional VFB
-sediment texture change
-%LOI change

Figure 37. Photographic examples of picks for boundary 1 in Levys Prairie

Picks for Boundary 2

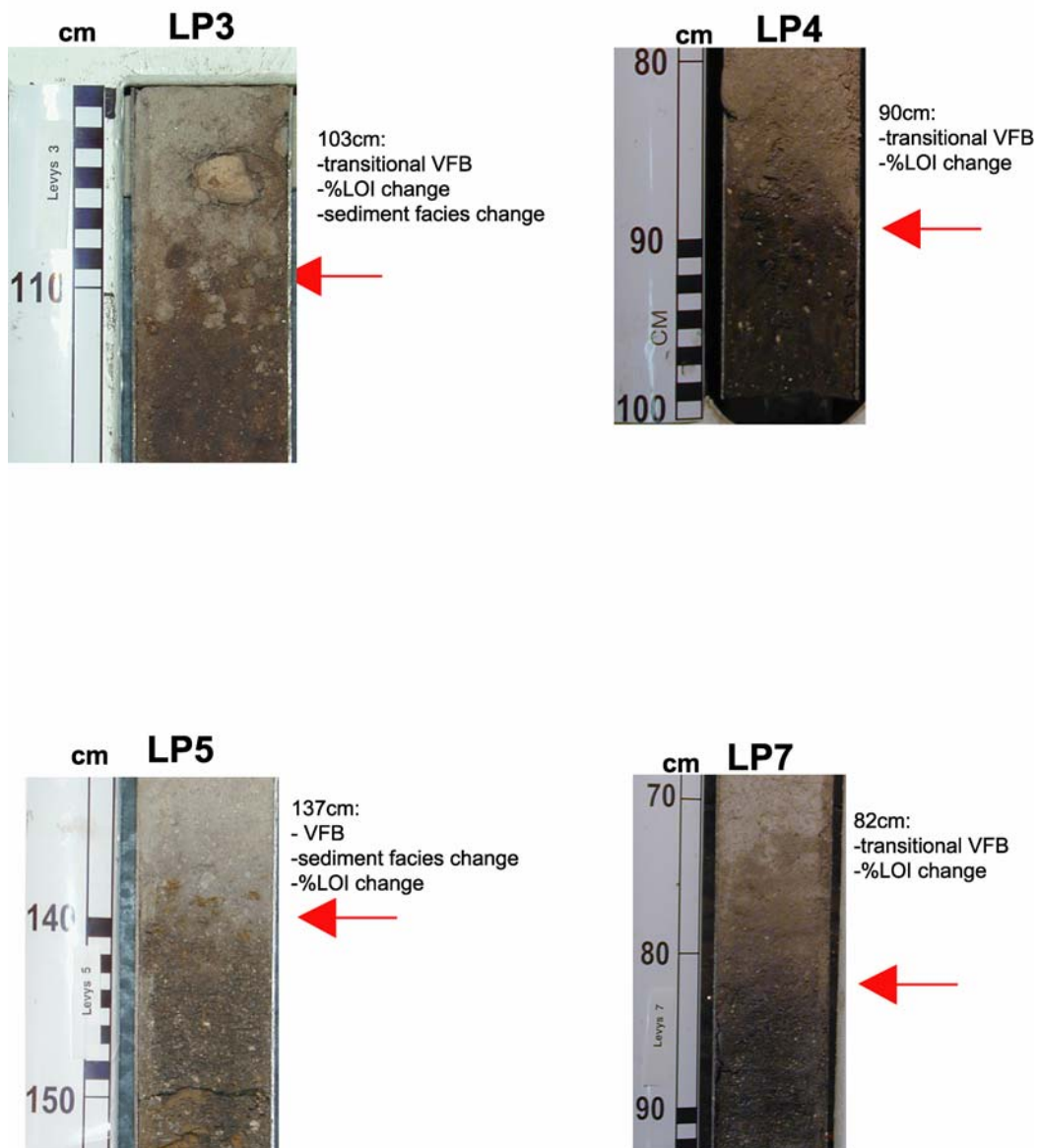


Figure 38. Photographic examples of picks for boundary 2 in Levys Prairie

Picks for Boundary 3

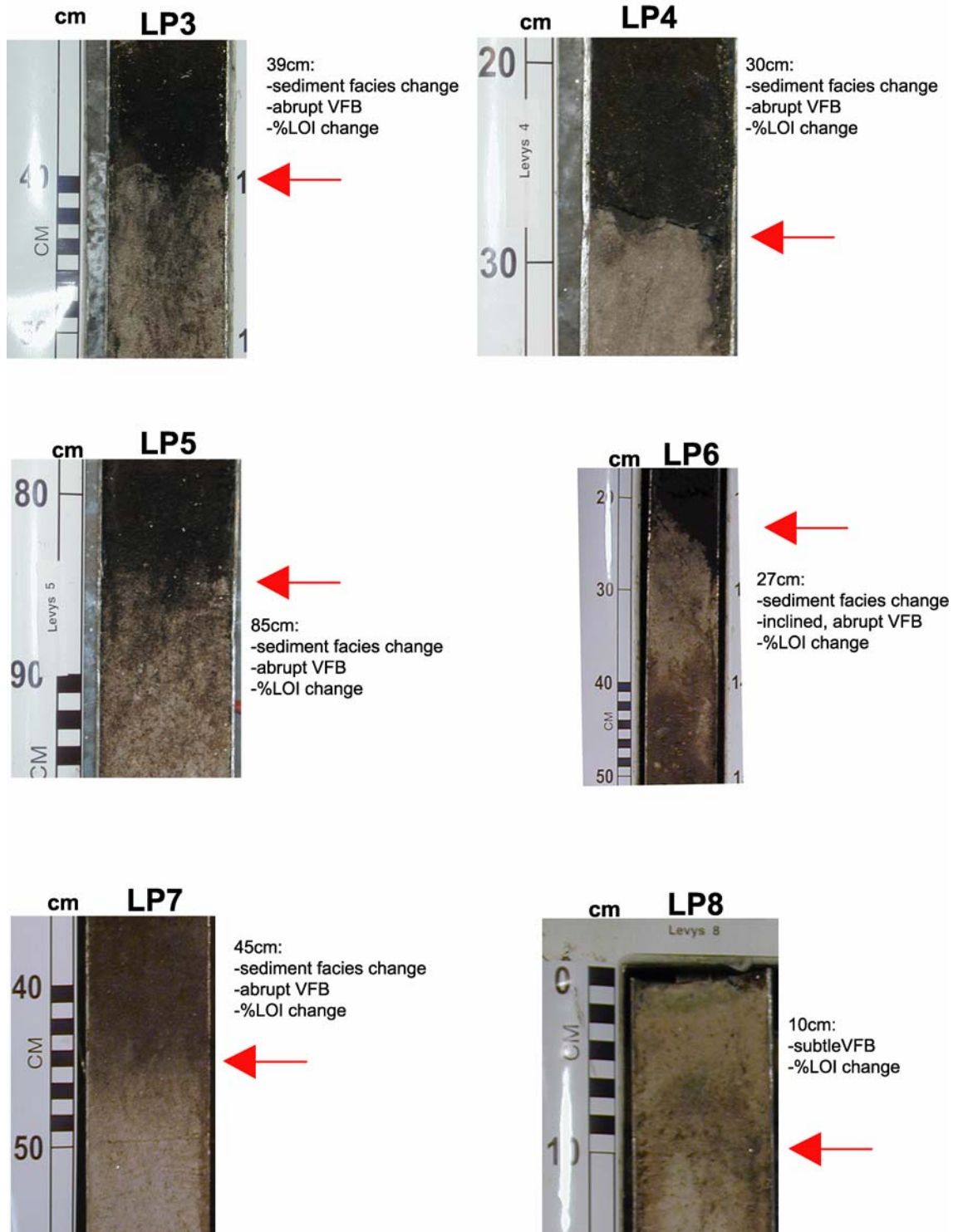
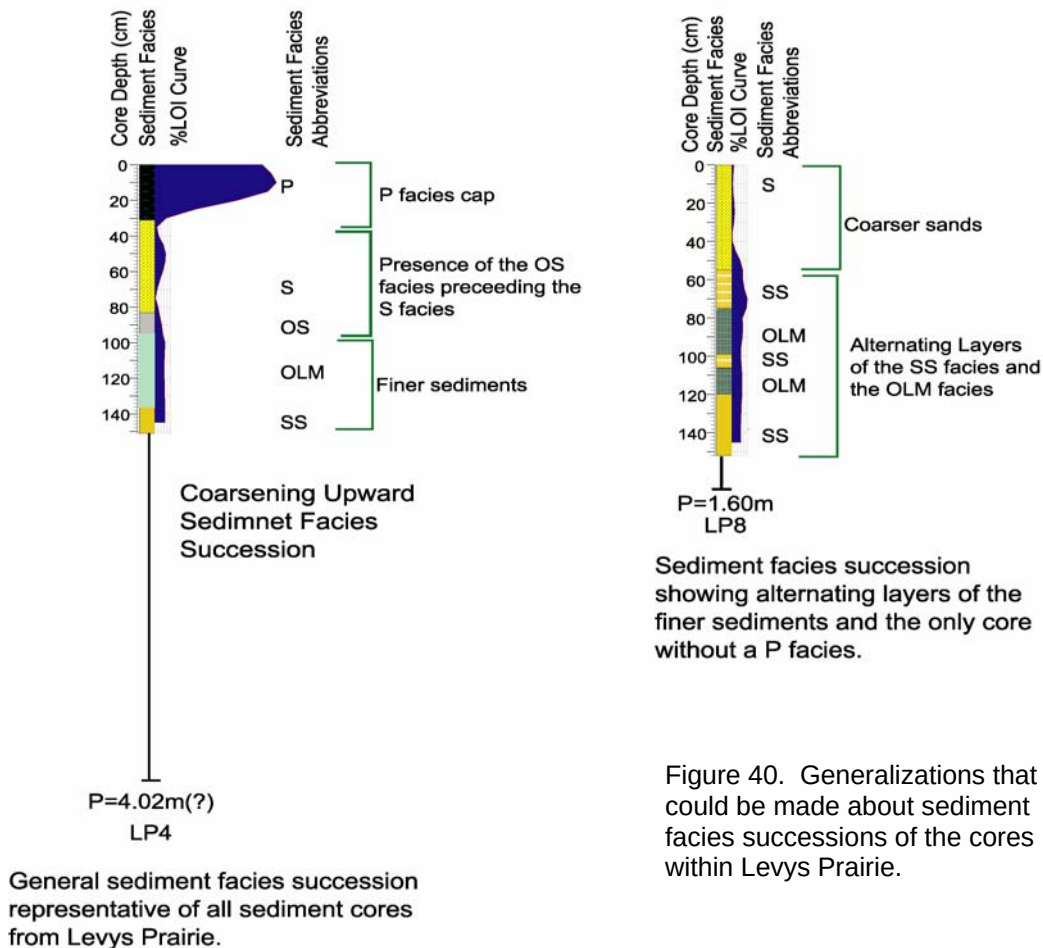


Figure 39. Photographic examples of picks for boundary 3 in Levys Prairie

Sediment Facies Succession

The sediment facies succession in Levys Prairie cores has consistency from core to core, and overall represents a coarsening upward succession that is capped by peat. This general succession is depicted in Figure 40. A photographic example of this facies succession can also be seen in core LP5 (Figure 33). The finer sediments are generally found at the base or in the lowest meter of the core overlain by the coarser sandy sediments and then overlain by peat. The following generalized sediment facies succession may be applied to Levys Prairie cores beginning at the base of the core and moving up: 1) the SS facies is most often found at the base of the cores and is always associated with the OLM most often overlain by the OLM but does occur as alternating layers in core LP8. (Figure 40); 2) the S facies is always overlying the SS facies and the OLM facies, however, when present the OS facies always precedes the S facies (Figures 35 and 40) this is true for cores LP4, LP6, and LP7, and 3) always overlying the S facies is the P facies except for core LP8 which does not have the P facies (Figure 40).

Generalizations of Sediment Facies Successions for Levys Prairie



COWPEN LAKE

The three sediment cores recovered from Cowpen Lake (Figure 41) are the longest of all three lakes having the most sediment recovery ranging from 3.27 m to 4.54 m from which 76 subsamples were taken for laboratory analysis. Table 5 lists the vibracore details specific to each core.

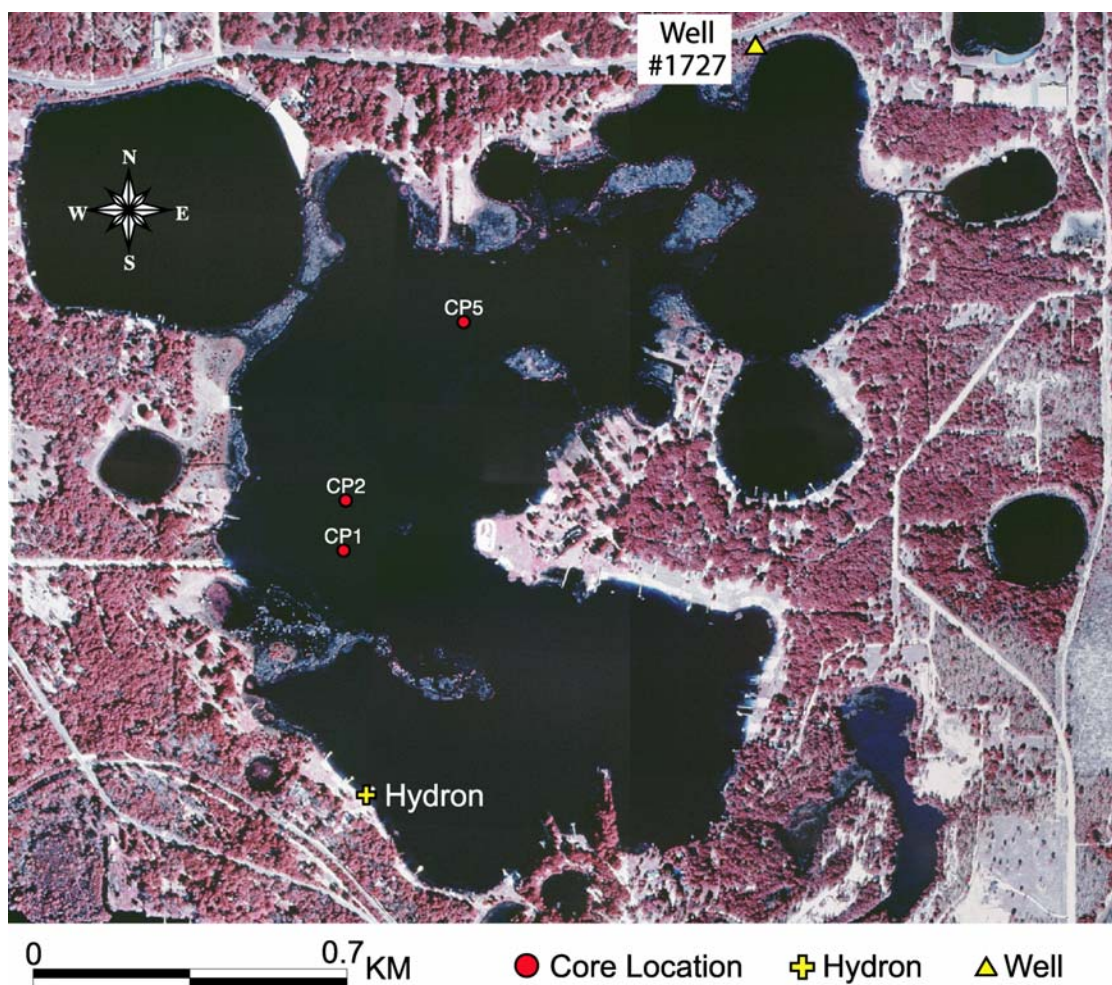


Figure 41. A digital ortho-quarter quadrangle of Cowpen Lake in Putnam County, FL, showing the vibracore locations, hydron location, and well location.

Core Name	CP1	CP2	CP5
Latitude	29° 35.996' N	29° 36.056' N	29° 36.273' N
Longitude	82° 00.184' W	82° 00.182' W	82° 00.021' W
Easting (X)	402868.299E	402872.485E	403135.793E
Northing (Y)	3274876.061N	3274986.844N	3275385.363N
Elevation (m)	24.15	23.47	23.65
Water Depth (m)	1.20	1.88	1.70
Penetration (m)	5.39	5.70	3.47
Recovery (m)	4.38	4.54	3.27
% Recovery (m)	81.26	79.65	94.24
%Compaction	18.37	19.30	4.61
Subsamples	29	29	18

Table 5. Cowpen Lake vibracore details.

Sedimentary Facies

Three sedimentary facies were identified in Cowpen Lake; 1) sand facies, 2) organic sand facies, and 3) organic mud facies. Facies identification were largely dictated by the association of %LOI, and mean grain size (Phi) for two reasons. First, the sub-samples from Cowpen Lake did not have a wide grain size distribution, 71 out of 76 sub-samples (93%) plotted in the sand category of the ternary diagram (Appendix 5). Secondly, %CaCO₃ is extremely low (0.0% - 1.6%) having little to no variability and values below 1% may be a reflection of the error involved with the method. The scatter plot of %LOI versus mean grain size indicates tight grouping of values in the sand facies, and a loose grouping of values within the organic sand facies as well as the organic mud facies (Figure 42). The three facies are described below and their numeric values are summarized in Table 6, however a complete detailed listing of the sub-samples within the facies can be found in Appendix 6.

The **Sand Facies (S)** consists of a very clean, very well-sorted to moderately sorted (0.5 ϕ -1.0 ϕ), medium to fine grained, predominantly quartz sand having greater than 84% sand (1.3 ϕ – 2.5 ϕ) and equal amounts of silt and clay ($\leq$ 8%). It contains extremely low to none %CaCO₃ ($\leq$ 0.52%) and low range of %LOI (0.0% - 2.8%) indicated by the tight group of data points in the lower left hand corner of the scatter plot (Figure 42). Nine different sediment colors are present, the dominant colors being a pale yellowish-brown (10YR 6/2) and yellowish-gray (5Y7/2 and 5Y8/1), whereas, white (N9) and dark gray (N3) occurred the least. This facies is the thickest ranging from 0.13 m to 2.90 m, and is generally found in either the bottom half of the core and / or the upper most portion of the core. It contains roots, small diameter (~1 mm) clay nodules, and stains or burrows that are usually finer grained and darker colored than the sediment immediately surrounding the stain or burrow. Occasionally there may be a very subtle increase in %CaCO₃ associated with the stain or burrow, however no evidence of shells or shell fragments were found. In samples having higher clay content, the sediment is identified as stiff or more compact. One

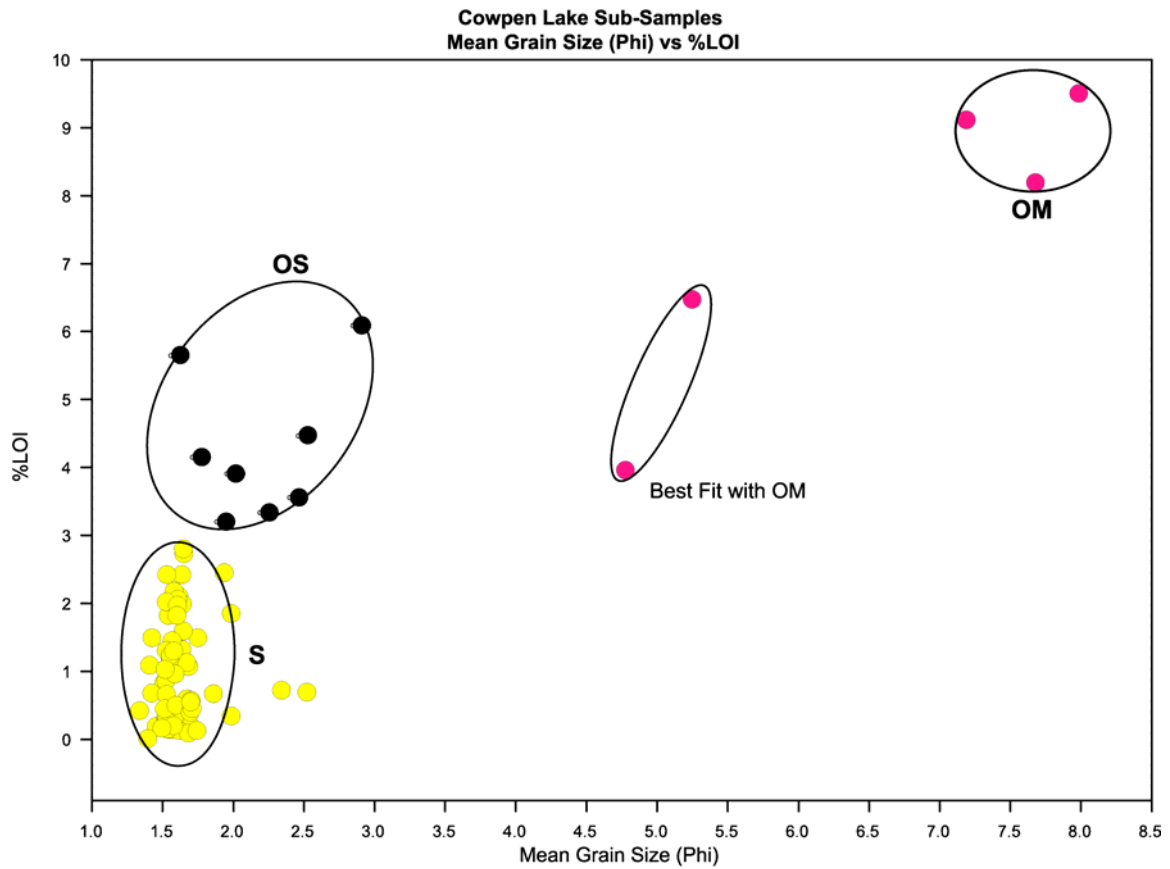


Figure 42. A 2-D scatter plot of the sub-samples in Cowpen Lake. This scatter plot shows three groupings, outlined with ovals for visual effect which represent the sand facies (S—yellow), the organic sand facies (OS—black), and organic mud facies (OM—pink). Samples were grouped based upon proximity and similar values. Outliers were treated individually based upon two conditions 1) how closely two or more characteristics (i.e. mean phi, %LOI, sorting, color, etc.) fit with a facies and 2) the location of the sample within the core.

sample (CP5: 282-284) from this facies was analyzed for mineralogy and contained quartz in the coarse fraction and both quartz and kaolinite in the fine fraction. Seven samples were analyzed for pollen, two from core CP2 and five from core CP5. The samples from core CP2 are considered barren. The three samples from the lower portion of core CP5 are also considered barren of pollen. The two samples from the very top of core CP5 (0 cm and 10 cm) were very abundant in pollen particularly *Pinus* (>50%) with a high abundance of *Poaceae* (Figure 43 and Appendix 4).

The **Organic Sand Facies (OS)** consists of well sorted to moderately sorted (0.5 ϕ to 1.2 ϕ) medium to fine grained sands (1.62 ϕ – 2.91 ϕ) having similar amounts of silts and clays (~5.0%), and low to none %CaCO₃ (0.11% to 0.57%). This facies is loosely grouped on the

scatter plot (Figure 42) and has a higher %LOI (3.2% to 6.1%) than that of the sand facies. This layer is thinner than the sand facies, ranging from ~ 0.09 m to 0.41 m and is absent of roots, stains, and burrows. It is found in the middle to lower portions of the core, is often overlain and underlain by the sand facies, and found associated with the organic mud facies. One sample (CP1: 432-434) from this facies was analyzed for mineralogy and contained quartz in both the coarse fraction and the fine fraction.

The **Organic Mud Facies (OM)** consists of very poorly sorted (2.9 ϕ to 3.6 ϕ), organic-rich mud, highly compact and stiff, predominantly a brownish-gray (5YR4/1) color, with swirl patterns of darker colors which the core X-radiographs did not reveal any internal pattern or structure. Of the three facies, OM consists of all mud (4.78 ϕ – 7.79 ϕ) having the lowest sand content ($\leq 74\%$), the highest clay content (18.6% to 61%), and the highest measured values of %CaCO₃. This facies ranges in thickness from 0.08 m to 0.37 m, contains the highest %LOI (4.0%-9.5%), and includes two outlier samples whose characteristics fit this facies the best (Figure 42). One sample (CP5: 74 cm – 76 cm) was analyzed for mineralogy and contained quartz in the coarse fraction and both quartz and kaolinite in the fine fraction.

Cowpen Lake Facies	Sand	Organic Sands	Organic Mud
Mean Grain Size (Phi)	1.34 ϕ - 2.52 ϕ	1.62 ϕ - 2.91 ϕ	4.78 ϕ - 7.99 ϕ
Average	1.63 ϕ	2.19 ϕ	6.57 ϕ
Sorting (Phi)	0.49 ϕ - 1.02 ϕ	0.51 ϕ - 1.20 ϕ	2.29 ϕ - 3.59 ϕ
Average	0.63 ϕ	0.86 ϕ	3.10 ϕ
%Sand	84.32% - 99.96%	80.31% - 97.09%	9.20% - 73.68%
Average	96.42%	89.09%	32.82%
%Silt	0.01% - 8.05%	0.051% - 11.81%	7.79% - 34.34%
Average	1.78%	5.25%	24.49%
%Clay	0.00% - 7.71%	2.34% - 10.02%	18.58% - 61.02%
Average	1.80%	5.66%	42.69%
%CaCO₃	0.00% - 0.52%	0.00% - 0.57%	0.28% - 1.60%
Average	0.15%	0.25%	1.11%
%LOI	0.01% - 2.80%	3.20% - 6.09%	3.96% - 9.50%
Average	1.00%	4.30%	7.45%

Table 6. Summary of Cowpen Lake facies characteristics listing the minimum, maximum, and average statistics of seven parameters; mean grain size (phi), sorting, %sand, %silt, %clay, %CaCO₃, and %LOI,

Sediment Boundary Picks

The current horizontal and vertical positions of the sediment cores in Cowpen Lake are represented in Figure 44. Each core is hung at its respective elevation (NGVD). This figure was constructed using the sediment facies column and the %LOI curves from the individual down core LogPlot profiles (Figure 45 and Appendix 1). Five boundaries are identified in Cowpen Lake cores. Only one boundary pick coincidences with a sediment facies change and the others are either subtle or transitional. The five boundary picks represent stages through which the basin developed and will be presented later in the discussion of this paper.

For boundary 1 all the picks are transitional and encompass only cores CP5 and CP2 and consist primarily of sediment color changes and %LOI changes (Figure 44 and Figure 46). Boundary 2 is present in all three cores and includes the only boundary pick that coincides with a sediment facies change in CP2 at 177 cm (Figure 44 and Figure 46). Boundary 3 picks are all transitional VFB with distinct sediment color changes (Figure 44 and Figure 47). Boundary 4 also has transitional VFB and only includes cores CP2 and CP1. The primary factor in picking the boundary at 86 cm in core CP1 was the presence and increased frequency of oxidized rhizospheres (Figure 44 and Figure 47). There does not appear to be a pick for boundary 4 in core CP5. Boundary 5 represents the transition into the cores as they exist in recent geologic time, in other words, the very top centimeters of the cores.

Sediment Facies Succession

The sediment facies succession in Cowpen Lake cores is considered to be a coarsening upward facies succession. This succession consists of finer sediments occurring together including the OS facies and the OM facies that is overlain by clean coarser sediments like the S facies. This succession is best represented by core CP1 but is found to occur ~1.5 m up in core CP5 (Figure 48). No consistent sediment facies successions exist in Cowpen Lake cores, rather one facies is not solely found to exist adjacent to another, but the OS facies is found to fringe the OM facies in two out of three cores.

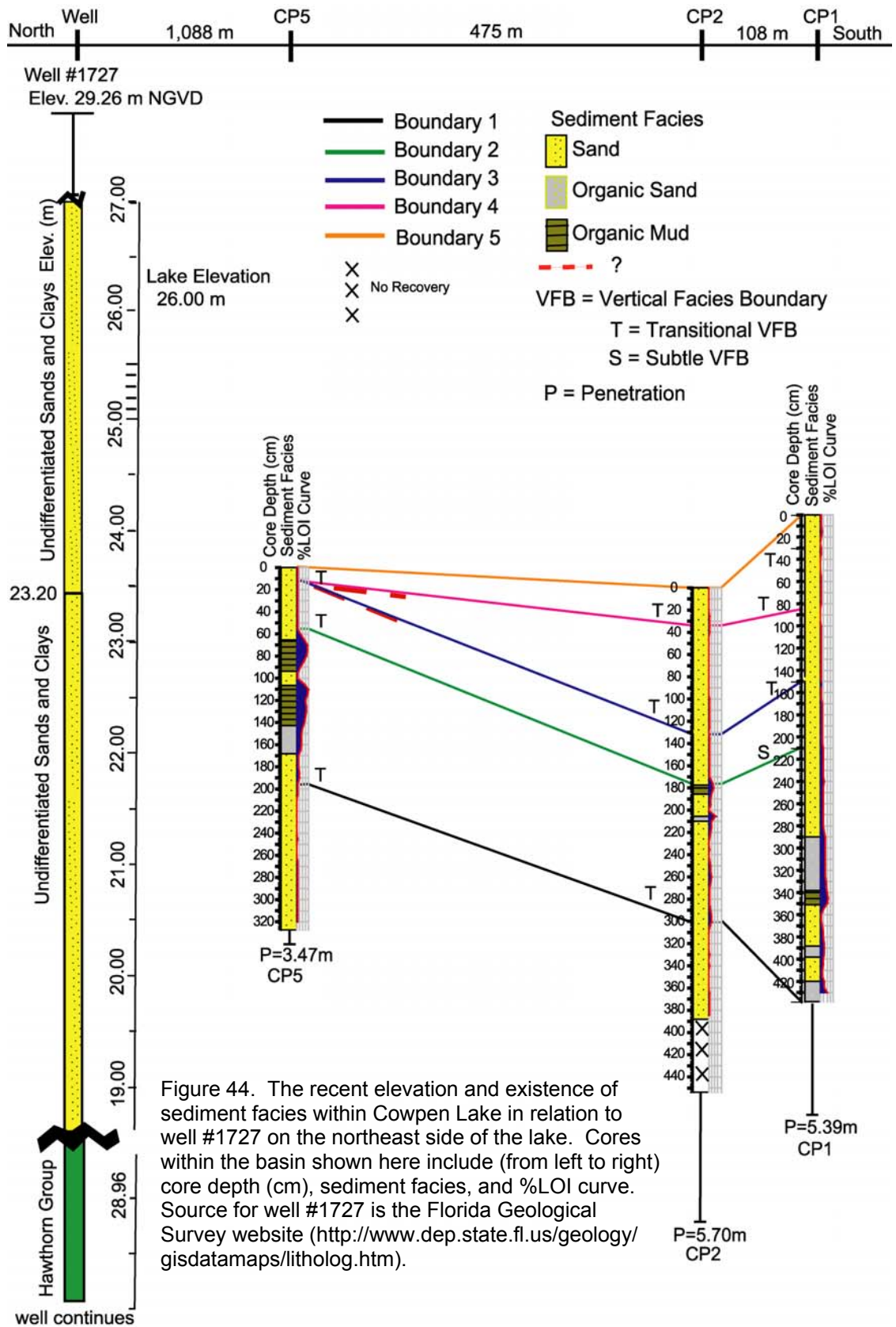


Figure 44. The recent elevation and existence of sediment facies within Cowpen Lake in relation to well #1727 on the northeast side of the lake. Cores within the basin shown here include (from left to right) core depth (cm), sediment facies, and %LOI curve. Source for well #1727 is the Florida Geological Survey website (<http://www.dep.state.fl.us/geology/gisdatamaps/litholog.htm>).

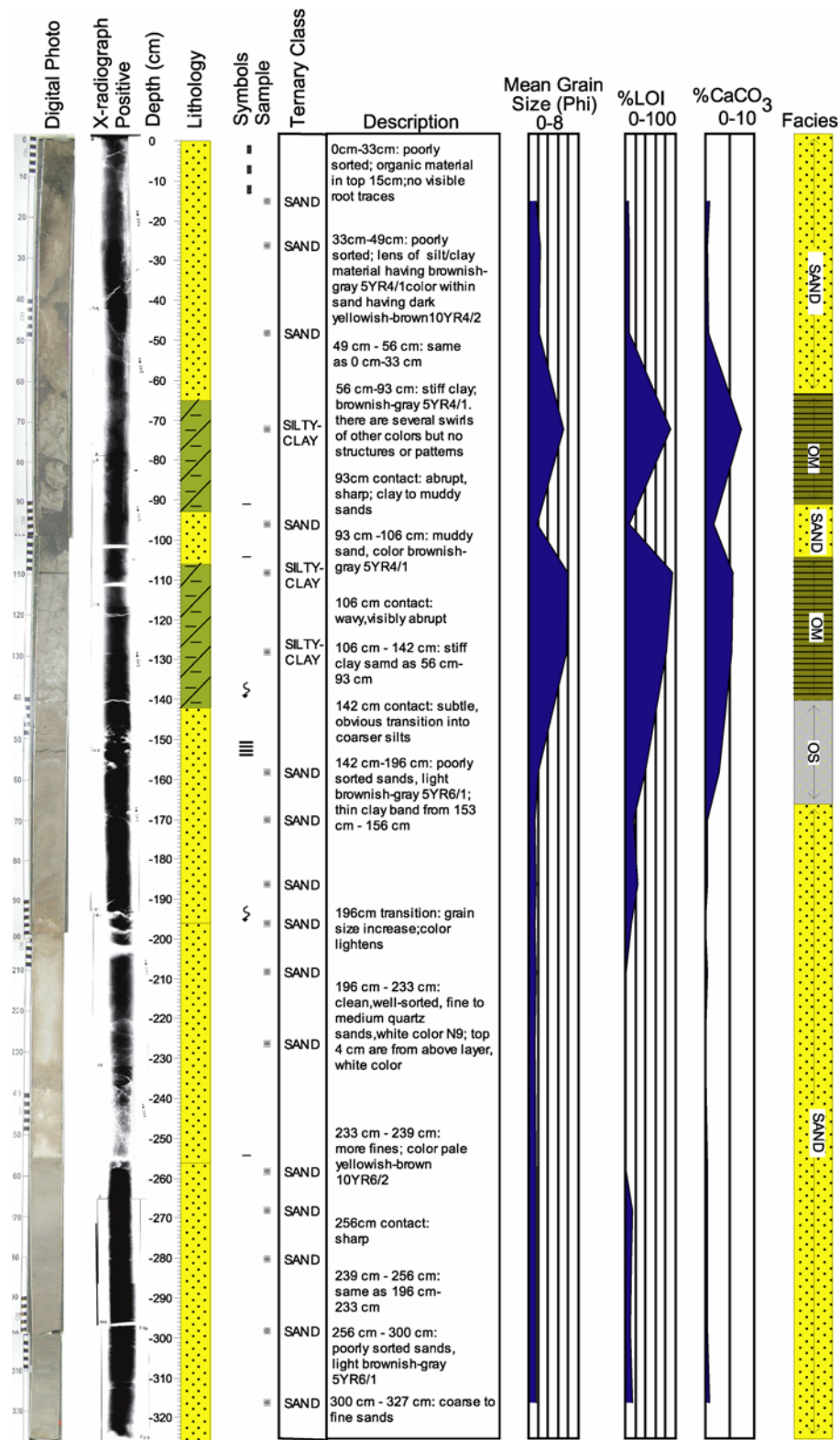
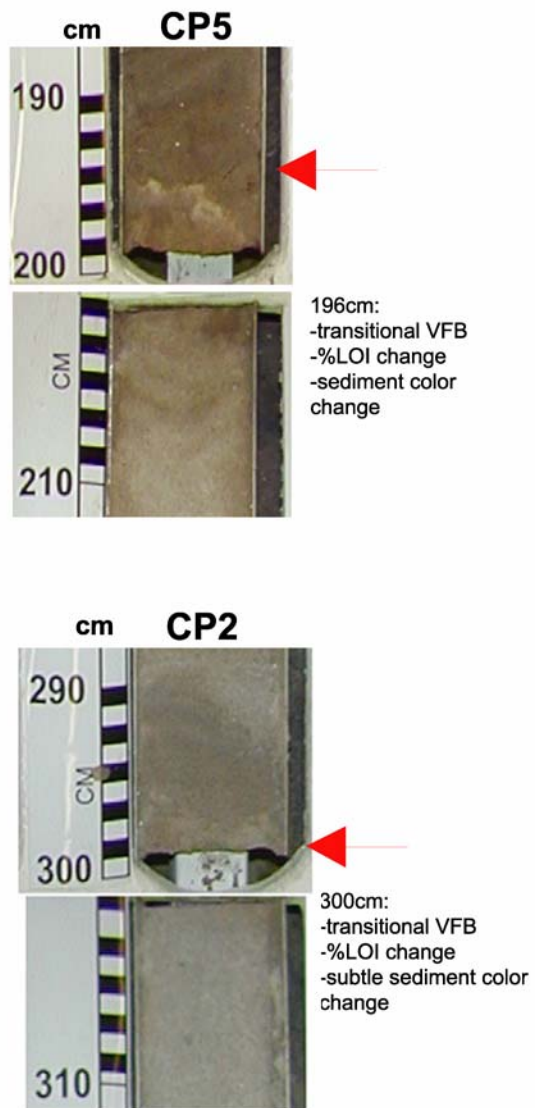


Figure 45. Down-core LogPlot of core CP5 from Cowpen Lake, complete with (from left to right) digital photograph, X-radiograph positive, depth (cm), standardized lithology based upon ternary class, symbols, sub-sample depths, description, mean grain size (Phi), %LOI, %CaCO₃, and sediment facies.

Picks for Boundary 1



VFB = Vertical Facies Boundary

← VFB Location

Picks for Boundary 2

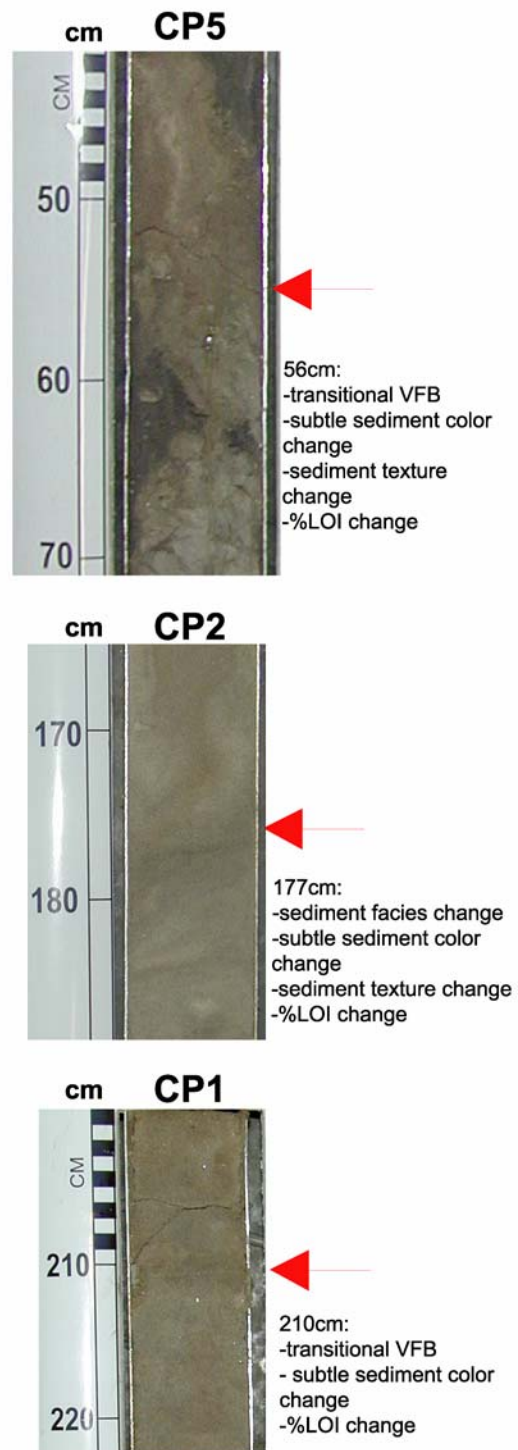
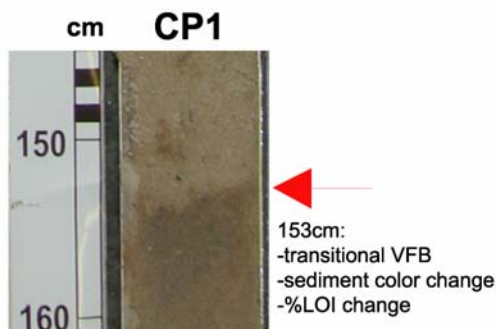
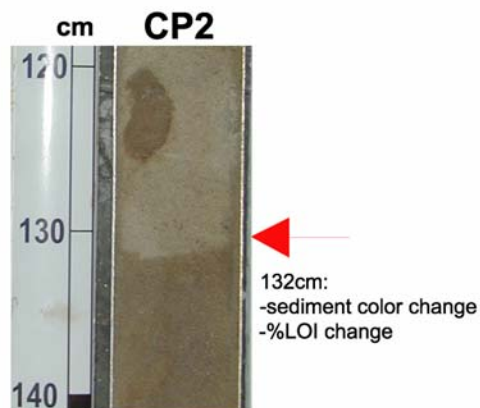
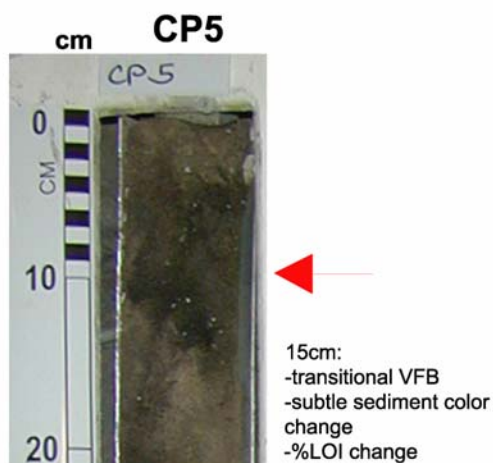
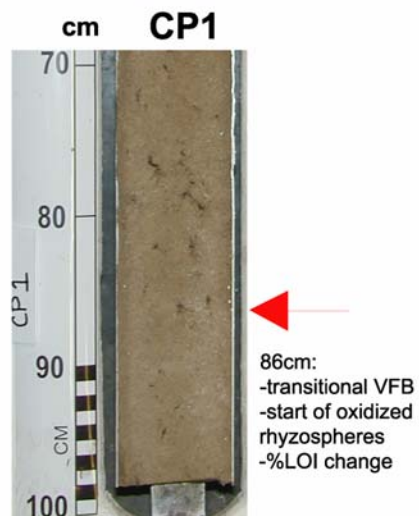
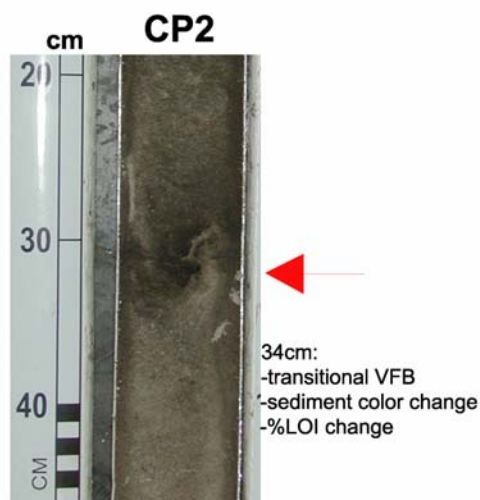


Figure 46. Photographic examples of picks for boundaries 1 and 2 in Cowpen Lake.

Picks for Boundary 3



Picks for Boundary 4



VFB = Vertical Facies Boundary

← VFB Location

Figure 47. Photographic examples of picks for boundaries 3 and 4 in Cowpen Lake.

Generalizations of Sediment Facies Successions for Cowpen Lake

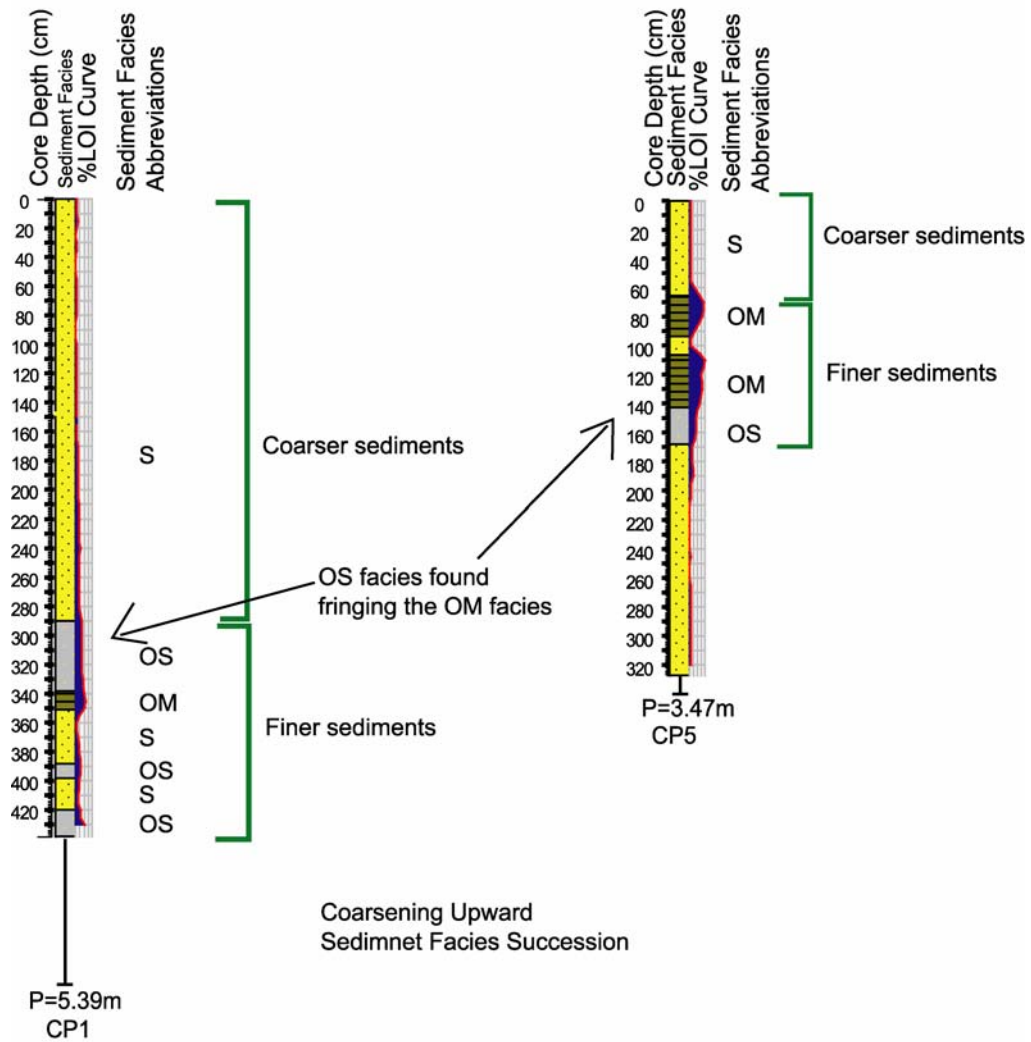


Figure 48. Generalizations that can be made about sediment facies succession in Cowpen Lake cores.

DISCUSSION

INTERLAKE SEDIMENT FACIES COMPARISON

Brooklyn Lake

Sediment infill comparison to Levys Prairie and Cowpen Lake

Brooklyn Lake has a sand facies and an organic sand facies, which are also found in Levys Prairie and Cowpen Lake. The sand facies in Brooklyn Lake is comparable to the texture and sediment characteristics of the sand facies found in Levys Prairie and Cowpen Lake. The averaged characteristics that are almost identical are mean grain size, sorting, %sand, %clay, and %LOI. The %CaCO₃ is similar to Cowpen Lake but is ~3% less than that of Levys Prairie. The %silt is similar to Levys Prairie, but ~1% higher than Cowpen Lake (Table 7).

The organic sand facies in Brooklyn Lake is comparable to the texture and sediment characteristics of the organic sand facies found in Levys Prairie and Cowpen Lake. Organic sand facies characteristics that are almost equivalent include, sorting, %sand, and %LOI. Average mean grain size is comparable to Levys Prairie, but it is ~0.5% coarser than Cowpen Lake and is best noted in the ~1.5% lower clay content. The average %CaCO₃ is comparable to Cowpen Lake, but is ~9% lower than Levys Prairie (Table 7).

Brooklyn Lake contains an organic fine sand facies that is not present in Levys Prairie or Cowpen Lake. It could be considered closest in comparison to the silty-sand facies found in Levys Prairie. Similar averaged characteristics between these facies include grain size, %clay, and %LOI. The larger differences can be seen in the ~10% higher sand and silt content and ~13% lower CaCO₃ content in the organic fine sand facies of Brooklyn Lake versus the silty-sands facies of Levys Prairie (Table 7).

The YGOM exists in Brooklyn Lake, but is not present in either Levys Prairie or Cowpen Lake. The YGOM is only comparable in thickness to the mud facies in Cowpen Lake suggesting a low energy depositional environment. The most distinct attribute is the yellowish-gray color. More peculiar is the preferential location on the southern side of Brooklyn Lake (Table 7). This preferential location of the YGOM facies suggests, 1) that this facies is not present in all areas of the lake basin, 2) the sediment source contributing to the deposition of YGOM is not present in the entire study area, or 3) that a different energy regime existed to deposit finer sediments on the southern side of the lake basin.

Hirsh (1998) also found that two short cores U and Y on the southern side of the lake (Figure 49) contained high values of silt and clay. Hirsh (1998) deduced that the presence of the finer material, even if only present in thin layers, is enough to influence the vertical permeability and act as an aquiclude or aquitard to seepage in that location. A transect of seepage meters from Hirsh (1998) parallels the transect of vibracores from this study (Figure 49). Seepage meter V occupied the same location as core BK112 and seepage meter G occupied the same location as cores BK109 and BK110 (Figure 49). During the course of the seepage meter study no flow was measured in or out of the lake at seepage meters G or V, but flow was measured in seepage meters A and F, which correspond to cores that do not contain the YGOM facies. This observation suggests that the YGOM facies may influence the development of Brooklyn Lake basin in two ways, 1) the presence of the YGOM may retard or divert vertical permeability and seepage on the southern side of the basin, therefore diverting groundwater flow away from this portion of the lake preventing or prolonging groundwater from reaching the limestone and causing dissolution directly below the area of seepage meter G. It is possible that the YGOM facies provided a barrier for groundwater diverting it toward pathways of least resistance or greater permeability such as the sediments below seepage meters F and A (Figure 49) or 2) the YGOM facies was present at the time of lake basin origin and due to the nature of the compact fine grained sediments mechanical erosion and transport has taken longer to erode this portion of the basin, therefore influencing the basin morphology.

The black organic rich mud facies (BORM) is only present in Brooklyn Lake. The sediment characteristics of the BORM facies that make it different from the mud facies in Levys Prairie or Cowpen Lake is the higher (~38.4%) %LOI content, a higher (~12% to ~46%) %silt content, and the extremely black color. It is different from Levys Prairie because it does not contain a high %CaCO₃ value or a peat like texture evident in Levys Prairie cores. Several reasons why the BORM facies exists in Brooklyn Lake and not in Levys Prairie or Cowpen Lake are: 1) the presence of Alligator Creek, a surficial inlet and outlet for Brooklyn Lake, as a mechanism for sediment transport either as suspended load or bed load into the lake. 2) the creek is an intermittent stream (Clark et al., 1963, Motz and Heaney, 1991, Merritt, 2001); therefore the sediment input is variable and limited to when the stream is flowing. When Alligator Creek is not flowing, this may decrease any turbulent circulation caused by the creek and allow fine-grained suspended sediments to be deposited on the lakebed. 3) The high silt content of the BORM facies may reflect a longer sediment suspension time allowing finer sediments to travel further from the outlet into the center of the lake.

Another possible explanation for the BORM facies could be a change in the primary production rate that would be reflected by a change in the amount of organic debris deposited (Cohen, 2003). The high organic content of the BORM facies could be the lakes response to an increased rate of primary production. If the primary production in Lake Brooklyn did not increase

Table 7. A listing of the sediment facies and their averaged sediment characteristics of Brooklyn Lake, Levys Prairie, and Cowpen Lake.

Sediment Facies	Brooklyn Lake	Levys Prairie	Cowpen Lake
Peat Facies (P)			
Average Mean Grain Size	--	--	--
Average Sorting (Phi)	--	--	--
Average %Sand	--	--	--
Average %Silt	--	--	--
Average %Clay	--	--	--
Average %CaCO3	--	6.19	--
Average %TOC	--	77.29	--
Sand Facies (S)			
Average Mean Grain Size	1.71	1.66	1.63
Average Sorting (Phi)	0.69	0.96	0.63
Average %Sand	95.04	93.56	96.42
Average %Silt	3.06	4.40	1.78
Average %Clay	1.90	1.98	1.80
Average %CaCO3	0.27	3.38	0.15
Average %TOC	0.69	0.94	1.00
Organic Sand (OS)			
Average Mean Grain Size	1.75	1.63	2.19
Average Sorting (Phi)	0.79	1.00	0.86
Average %Sand	90.78	91.64	89.09
Average %Silt	5.01	4.43	5.25
Average %Clay	4.21	3.90	5.66
Average %CaCO3	0.29	9.01	0.25
Average %TOC	4.16	3.93	4.30
Organic Fine Sands (OFS)			
Average Mean Grain Size	3.34	--	--
Average Sorting (Phi)	1.24	--	--
Average %Sand	77.60	--	--
Average %Silt	14.62	--	--
Average %Clay	7.76	--	--
Average %CaCO3	0.48	--	--
Average %TOC	4.14	--	--
Silty-Sands (SS)			
Average Mean Grain Size	--	3.43	--
Average Sorting (Phi)	--	2.01	--
Average %Sand	--	68.68	--
Average %Silt	--	25.87	--
Average %Clay	--	5.45	--
Average %CaCO3	--	13.40	--
Average %TOC	--	5.99	--
Organic Mud (OM)			
Average Mean Grain Size	--	--	6.57
Average Sorting (Phi)	--	--	3.10
Average %Sand	--	--	32.82
Average %Silt	--	--	24.49
Average %Clay	--	--	42.69
Average %CaCO3	--	--	1.11
Average %TOC	--	--	7.45
Yellowish-Gray Organic Mud (YGOM)			
Average Mean Grain Size	5.00	--	--
Average Sorting (Phi)	2.58	--	--
Average %Sand	60.71	--	--
Average %Silt	19.63	--	--
Average %Clay	19.68	--	--
Average %CaCO3	0.45	--	--
Average %TOC	4.90	--	--
Organic Lime Mud (OLM)			
Average Mean Grain Size	--	5.28	--
Average Sorting (Phi)	--	2.55	--
Average %Sand	--	30.98	--
Average %Silt	--	53.75	--
Average %Clay	--	15.24	--
Average %CaCO3	--	17.20	--
Average %TOC	--	7.42	--
Black Organic Rich Mud (BORM)			
Average Mean Grain Size	5.63	--	--
Average Sorting (Phi)	1.82	--	--
Average %Sand	20.40	--	--
Average %Silt	66.07	--	--
Average %Clay	13.59	--	--
Average %CaCO3	2.98	--	--
Average %TOC	45.40	--	--

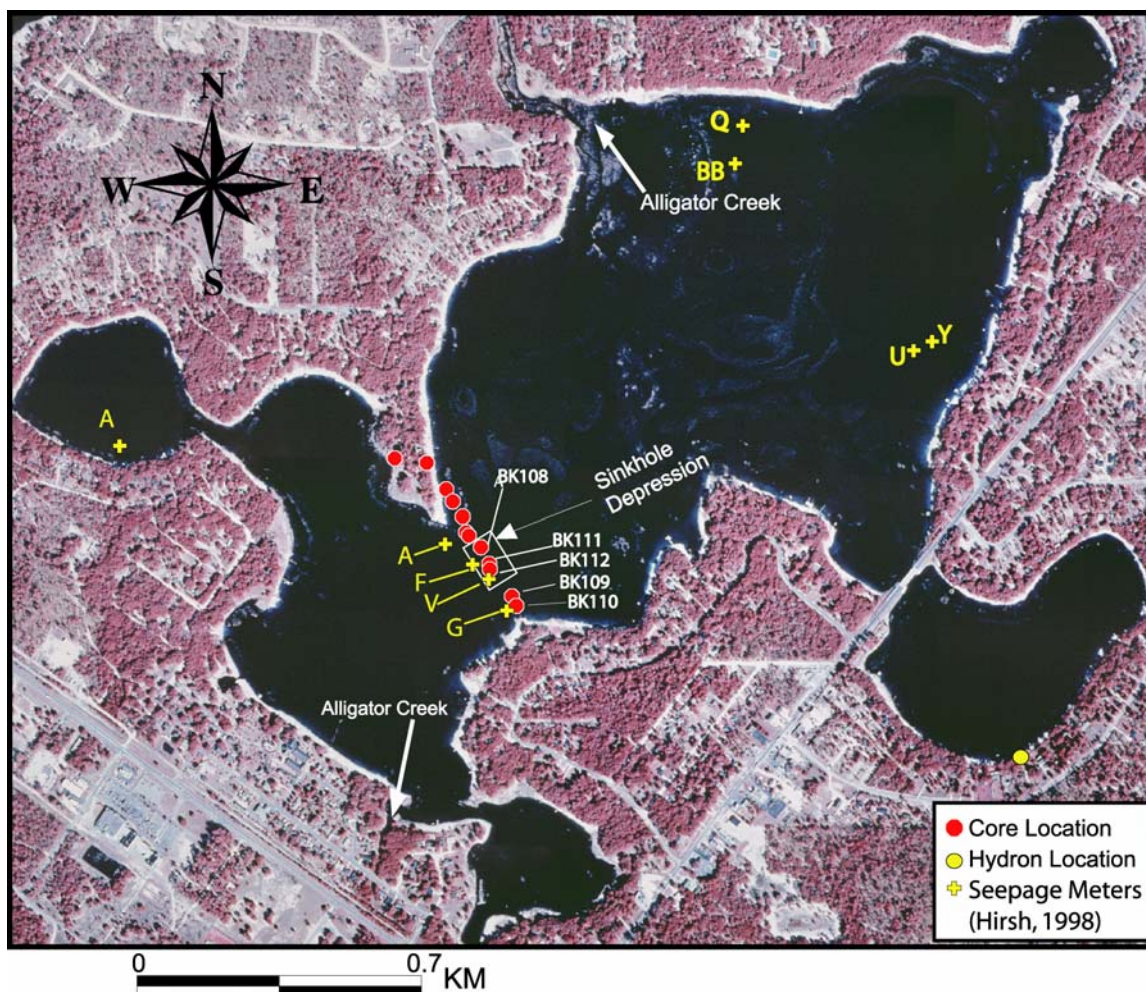


Figure 49. An overlay showing the location of Hirsh's (1998) seepage meter sites with respect to the vibracore transect of this study using a DOQQ backdrop of Brooklyn Lake.

but remained constant, then the presence of the BORM facies may be a reflection of a subsiding and deepening solution feature. A deepening subsidence feature would increase the preservation of organic material by creating sufficient water depth to provide a low energy environment in oxygen deficient waters conducive to organic sediment deposition. It is unclear if these processes could have acted simultaneously or separate.

Levys Prairie

Sediment infill comparison to Brooklyn Lake and Cowpen Lake

Levys Prairie has a thick peat facies that is high in %LOI and present in all the cores except LP8, which was taken in a flowing stream that connects the two sinkholes. This facies is not found in Brooklyn Lake or Cowpen Lake. The %LOI is 45.5% higher in the peat facies of Levys Prairie compared to the %LOI content in the BORM facies found in Brooklyn Lake (Table 7). The thick presence of the peat facies may be a result of the basin topography being a large,

broad shallow depression that intercepts water from the surrounding sand hills during high periods of rainfall, and slowly drains and recharges the aquifer via the sinkhole features at a constant rate (Pirkle and Brooks, 1959). Mud Lake located in Marion County, Florida (Figure 13) is similar to Levys Prairie in that it is a broad shallow lake surrounded by sandy uplands and free of urban development. It is flooded in the rainy season having a maximum depth of 0.85 m and ~0.22 m in the dry season. It occupies a paleo sinkhole in which several meters of saw grass peat accumulated prior to subsidence which occurred ~3000 yrs ago. This peat surface is one to two meters lower, leaving a shallow lake upon which algal ooze now accumulates (Watts, 1969, Bradley and Beard, 1969). The upper two meters of sediment in Mud Lake are considered diatom gyttja and record a pollen assemblage to which the pollen in Levys Prairie can be compared. Gytja is dark gray or dark brown sediment that contains humic material, plant remains, diatoms, algal and zooplankton remains, as well as terrigenous material and is common in shallow depressions ponds or bogs (Cohen, 2003).

The sand facies in Levys Prairie is comparable to the texture and sediment characteristics of the sand facies found in Brooklyn Lake and also with the sand facies found in Cowpen Lake (Table 7). The sand facies characteristic averaged components that are almost identical are mean grain size, sorting, %sand, %clay, and %LOI. The average %silt is highest in Levys Prairie by ~1.3% and ~2.6% over Brooklyn Lake and Cowpen Lake respectively. The average %CaCO₃ is also highest in Levys Prairie by ~3.0% over both Brooklyn Lake and Cowpen Lake, and is most likely a result of the presence of marine fragments (i.e. shell fragments, coral fragments, sharks teeth) identified with the microscope photographs of the grains > 1000 microns (Table 7, Appendix 3).

The sand facies is extremely thin in Levys Prairie (≤ 62 cm) and does not compare with the thickness of the sand facies from Brooklyn Lake or Cowpen Lake. The reason that the sediment is thin in Levys Prairie is not fully known. One explanation could be that the sediment source supplying sand to the local areas was initially low. This seems unlikely though due to the fact that Levys Prairie is surrounded by the Sand Hills which sit at a higher elevation and may provide sediment to Levys basin. The opposite to this would be that there once was a thick sand facies in Levys Prairie, but was subsequently removed by mechanical weathering, or 'piping processes' associated with solution activity as described by Arrington and Lindquist (1987), or a combination of both. The origin of Levys Prairie is a result of solution activity in the Hawthorn and the Ocala Limestone below the prairie (Pirkle and Brooks, 1959). In the 1950s two sinkholes existed, one of which has closed since then, and a more recent study estimated that water flow is still active in the sinkholes that occupy Levys Prairie (Pirkle and Brooks, 1959, pers. comm. Jeff Davis, 2003, respectively). This suggests that solution activity was and most likely still is a prominent mechanism in the development of Levys Prairie today. The presence of well rounded sediment grains and marine fragments indicate that the sediment has been reworked and

transported. These reasons suggest that if thicker sand facies were present in Levys Prairie it is possible that open, unplugged sinkholes, provided a catchment and / or outlet for any unconsolidated sediments.

The organic sand facies in Levys Prairie is comparable to the texture and sediment characteristics of the organic sand facies found in Brooklyn Lake and Cowpen Lake. Organic sand facies characteristics that are almost equivalent include sorting, %sand, %silt, and %LOI. The average grain size is comparable to Brooklyn Lake, but slightly coarser (~0.5%) than Cowpen Lake and is best reflected in the ~1.8% lower clay value. The most notable characteristic difference is that Levys Prairie has ~9.0% higher %CaCO₃ content over Brooklyn Lake and Cowpen Lakes, resulting from the presence of marine fragments (Table 7).

The silty-sand facies is not present in Brooklyn Lake or Cowpen Lake, but could be considered closest in sediment characteristics to that of the organic fine sands of Brooklyn Lake. The averaged characteristics most similar include the mean grain size, sorting, %sand, and %LOI. The %silt and %clay content are (11.3% and 2.3% respectively) higher in the silty-sand facies of Levys Prairie. The most profound difference is the 13% higher CaCO₃ content that is in the silty-sand facies. Similarly the organic lime mud facies is not present in Brooklyn Lake or Cowpen Lake. It could be comparable to the Yellowish-Gray Organic Mud with respect to mean grain size, sorting, %clay, and %LOI, but %CaCO₃ is 17.2 % higher and the colors vary to include a greenish gray (Table 7).

Cowpen Lake

Sediment infill comparison to Brooklyn Lake and Levys Prairie

Cowpen Lake has a sand facies and an organic sand facies which are also found in Brooklyn Lake and Levys Prairie, but the organic mud facies present in Cowpen Lake is not found in the other two lakes. Although the same type of facies is present in one or more lakes, it does not always suggest that their sediment texture characteristics are equivalent as is evident from the data presented in Table 7.

The sand facies in Cowpen Lake is comparable to the texture and sediment characteristics of the sand facies found in Brooklyn Lake and also with the sand facies found in Levys Prairie. The sand facies characteristic averaged components that are almost identical are mean grain size, sorting, %sand, %clay, and % LOI. The average %silt is lowest in Cowpen Lake, approximately 1.0% - 2.0% lower than Brooklyn Lake and Levys Prairie. The average %CaCO₃ is similar in Brooklyn Lake, but ~3% lower than Levys Prairie (Table 7).

The organic sand facies in Cowpen Lake is comparable to the texture and sediment characteristics of the organic sand facies found in Brooklyn Lake and Levys Prairie. Organic sand facies characteristics that are almost equivalent include sorting, %sand, %silt, and %LOI. The average mean grain size is slightly (~0.5%) finer in Cowpen Lake and is best reflected in the

slightly higher %clay value (Table 7). The most notable difference is that Cowpen Lake has ~9.0% lower %CaCO₃ than Levys Prairie

The organic mud facies found in Cowpen is not found in Brooklyn Lake or Levys Prairie. The primary differences of this facies versus the mud facies from the other lakes is that this layer is thinner, has a higher percent silt value, and a predominantly brownish color.

Relation among the Cores, the Lake Basin, and the Geology

A pictorial example of the relative position of Brooklyn Lake, Levys Prairie and Cowpen Lake to the underlying Florida geology is shown in Figure 50. Stated earlier the lakes reside within the post-Miocene undifferentiated sediments of the Cypresshead Formation. The sediment cores in this study only represent the upper few meters of the lake basin infill and do not extend into the Hawthorne Group below. There is no evidence within the cores to suggest that they penetrated the pre-lake sediments. The depth to which the sediment infill extends and where the initial lake basin floor began is unknown.

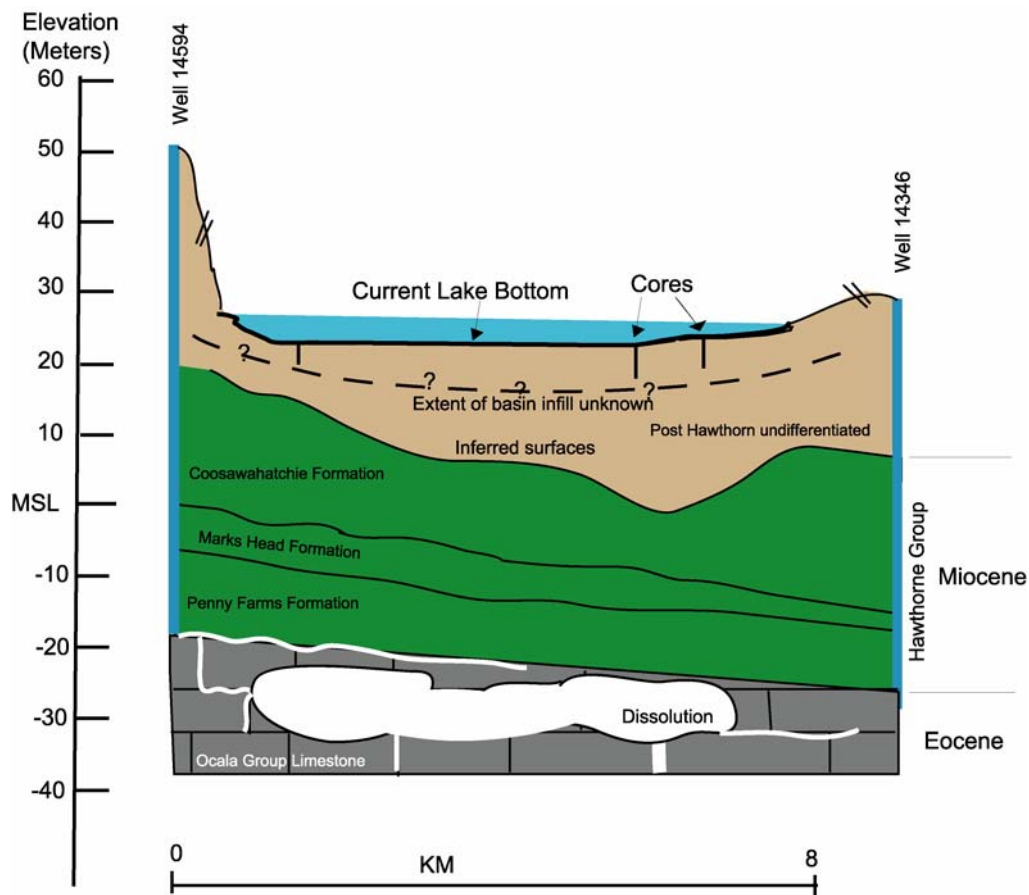


Figure 50. Diagram depicting the relative position of the cores with respect to the lake basin floor and the local Florida geologic formations

BROOKLYN LAKE

Local Borehole Comparison

Sediment infill of cores on the northern side of the transect in Brooklyn Lake are consistent with the lithologic description of a 26 m deep well #17252 located northwest of Brooklyn Lake at an elevation of 48.8 m NGVD (Figure 18). The entire well consists of undifferentiated, poorly indurated sediments having color variations and texture variations with depth. Sediments encountered at a depth equivalent to Brooklyn Lake elevation are from 12.2 m to 24.4 m. These are light brown very fine to medium sands, medium sphericity and a low clay percentage. From 24.4 m to 25.6 m the sand becomes grayish orange to light reddish brown, intergranular, high permeability, very fine to medium, medium sphericity and low clay content. This supports a local source of sediment infill that may have been transported a short distance.

Sediment infill on the southern side of the core transect in Brooklyn Lake is consistent with the lithologic description of a 73 m well #C-0442, also called the Moody Well (Motz and Heaney, 1994), located on the southeast side of Brooklyn Lake (Figure 18). Sediments encountered at a depth equivalent to Brooklyn Lake elevation are from 14.1 m to 21.3 m. The most notable sediments in the well at this depth are the white clay and sandy, clayey silt layers. The YGOM sediment facies in cores BK109 and BK110 strongly reflect these sediment characteristics suggesting a local sediment source as well. The fact that the YGOM facies is restricted to the southern side of the lake is puzzling particularly because one would expect more of a distribution throughout the lake basin because the very fine grained sediment could easily be transported into the lake basin by wind or carried in suspension by waves. This may be a reflection of limited or lack of internal circulation processes. The YGOM facies must have been deposited in a low energy environment which had to persist for some time to account for the thick layers present in the cores (up to 40 cm); or the sediment input for this facies was rapid enough to bury and protect the finer clay material from being redistributed.

The BORM facies is not reflected in the local borehole geology thus supporting two possible sources of input, 1) an external source transported via Alligator Creek most likely suspended load of finer material (biological or detrital) from the upper three basins in the chain of lakes (Kinsley Lake, Blue Pond, or Magnolia Lake) or 2) the biological component established within Brooklyn Lake by benthic and pelagic organisms and macrophytes. To account for the

high amount of finer sediment, this facies most likely was also deposited within a low energy environment.

Pollen

Sediment cores from Brooklyn Lake are abundant in pollen with the exception of two samples from core BK111 that were barren (Figure 21 and Appendix 4). A change in the pollen assemblage was recorded in the top meter (92 cm up to the 1 cm) of core BK111 at 41 cm. *Pinus* (pine) and an abundance of *Quercus* (oak), *Poacea* (grasses), and *Chenopodiaceae* (weedy annuals) represent the pollen assemblage from 92 cm to 51 cm. At 41 cm in BK111 pine doubles and grasses and weedy annuals decrease in abundance. Pollen samples from a portion of core BK108 (77 cm – 136 cm) indicate this same pollen assemblage change between 136 cm and 126 cm (Appendix 4). An abundance of oak is characteristic of drier conditions; an abundance of pine is characteristic of wetter conditions (Grimm et al., 1993). This change in pollen assemblages in which pine increases two fold is documented and carbon 14 dated in two other lakes, Sheelar Lake (~ 8 km northeast of Brooklyn Lake) and Mud Lake (just south of study area) (Figure 13). The shift occurs at 7200 yrs BP in Sheelar Lake and 5070+/- 150 yrs BP in Mud Lake and is considered to represent a drier climate changing into a wetter climate (Watts and Stuiver, 1980, Watts, 1969 respectively). Lake Tulane and Lake Annie, two Lakes further south of the study area (Figure 13) also record this vegetation shift at 5000 yrs BP (Grimm et al., 1993) and 4715+/-95 yrs BP (Watts, 1975) respectively. The vegetation shift observed in Brooklyn Lake is considered to be consistent with the pollen curves from Sheelar Lake and Mud Lake (pers. comm. Willard, 2003). Using Sheelar Lake and Mud Lake as references for geologic age, it can be said that Brooklyn Lake is older than 7200yrs BP.

Lake History and Development

The development of Brooklyn Lake results from sediment deposition in both subaerial and subaqueous environments most likely a result of groundwater fluctuation and subsidence. The literature sites at least four subsidence features such as filled sinks that occur in Brooklyn Lake (Clark et al., 1963, Hirsh, 1998) indicating karst processes are occurring or occurred in the past below this lake basin. The pollen curve from BK111 and a portion of BK108 provides a relative age for placement in the geologic record. A six stage depositional scenario is presented here as an explanation for the development of Brooklyn Lake.

Stage 1

The first stage (Stage 1—Figure 51) is actually the upper boundary of Stage 1 or the end of Stage 1. It was a time when groundwater was higher and a subaqueous environment existed

most likely occupying a shallow depression. The water in the basin may not have been very deep and may have persisted for a short period, represented by thin (~50 cm) sediment facies, primarily the OS facies, the OFS facies and the YGOM. The thin YGOM facies in the base of core BK111 at 151 cm contains pollen abundant in pine and oak with small amounts of marsh plants. This reinforces the presence of water during this time as a mechanism to trap pollen and fine grained sediments as well as providing an environment for the marsh plants. There is no indication that the sediments in the lower portions of cores BK102A, BK104, and BK106 were deposited in a subaqueous environment; therefore, they are not present in this stage. Subsidence must have been ongoing during this stage to create the accommodation space for sediment accumulation in the basin. This would help account for the longer sediment cores on the southern side of the transect.

Stage 1: SUBAQUEOUS Depositional Environment

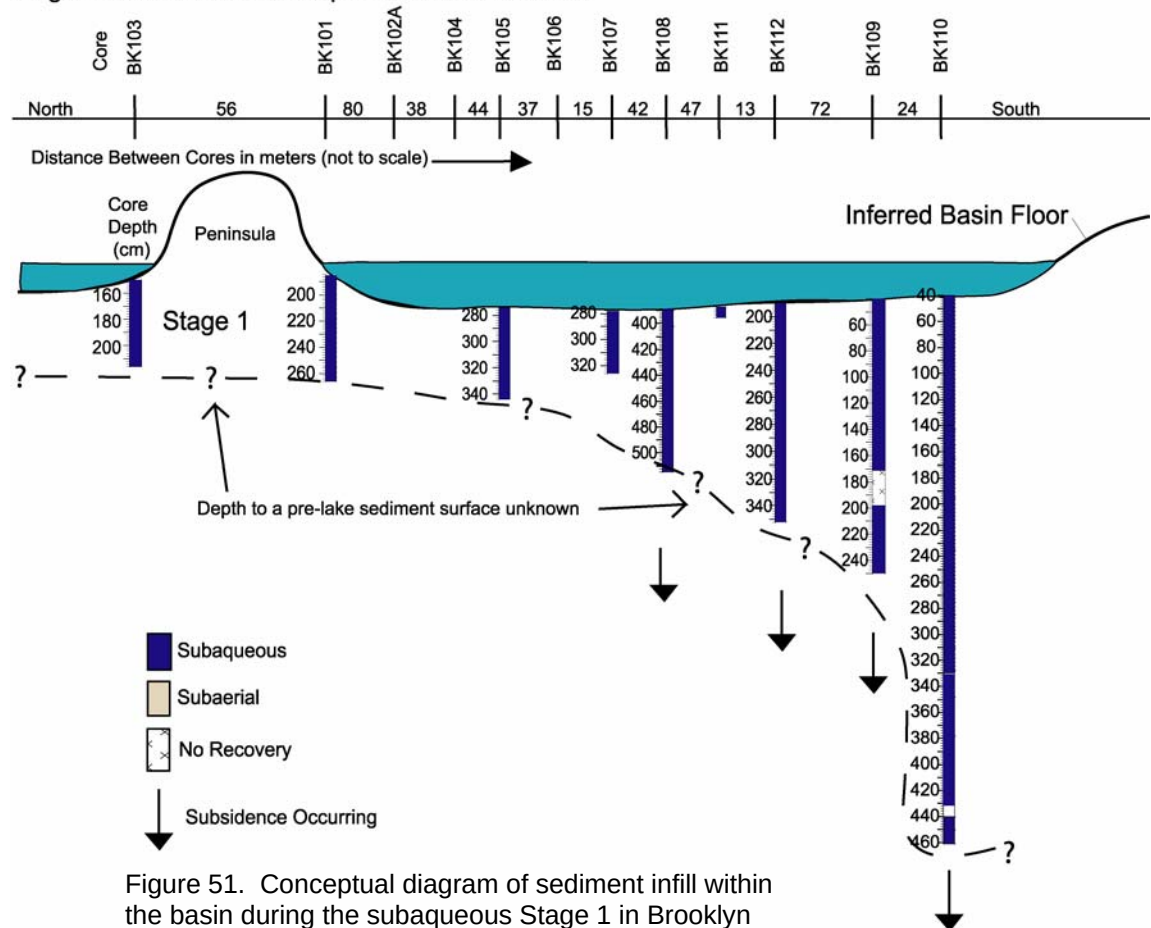
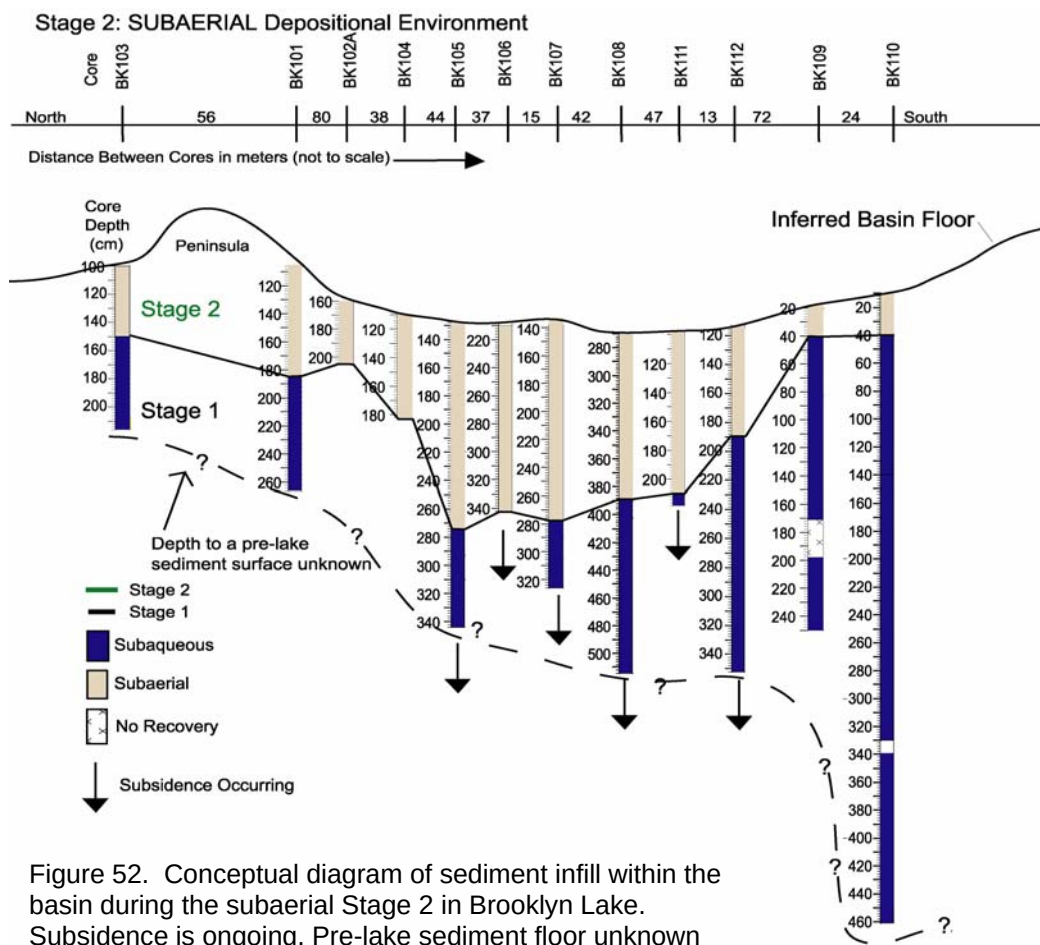


Figure 51. Conceptual diagram of sediment infill within the basin during the subaqueous Stage 1 in Brooklyn Lake. Pre-lake sediment floor unknown.

Stage 2

The second stage (Stage 2--Figure 52) presents a subaerial depositional environment in which groundwater was lower and eolian transport was the dominant mechanism for sediment transport and deposition of the clean sand facies. Pollen samples from BK111 at 191 cm and 131.5 cm are barren (Figure 21 and Appendix 4) supporting the existence of a dry basin and either a windier environment in which silt sized pollen grains were winnowed out, or an absence of pollen producing flora. Sediment cores BK105, BK106, BK107, BK108, BK111, and BK112 have double the thickness of sediment than cores BK103, BK101, BK102A, and BK104 suggesting that subsidence is ongoing during this time, either preferentially or under the entire basin based creating the accommodation space for the sediment. At this time, if solution cavities existed below the Brooklyn Lake depression they would most likely be void of groundwater, and the weight of the overburden that would otherwise be buoyed by the groundwater (Lane, 1994) would no longer be supported and may begin to sag, hence allowing subsidence. The rate of subsidence is unknown, but may have been slow at this point. Sediment deposition begins for cores BK102A, BK104, and BK106.



Stage 3

The third stage (Stage 3--Figure 53) presents a subaqueous depositional environment. Groundwater rises and fills the lake again with subsidence still occurring possibly at an increased rate. Indicators of a subaqueous environment include organic sands, organic fine sands, subtle and abrupt color changes within the sand facies setting it apart from surrounding sediments and the presence of oxidized rhizospheres. Oxidized rhizospheres are intact roots and root traces surrounded by iron stains (Figure 24 and Figure 26). Only aquatic plants produce oxidized rhizospheres by extending their leaves to the surface to obtain CO₂ and expelling oxygen via their roots. The iron stains come from the plant expelling oxygen through its roots and staining the surrounding anoxic sediment a rust color (Lacerda et al., 1993, Jaynes and Carpenter, 1986).

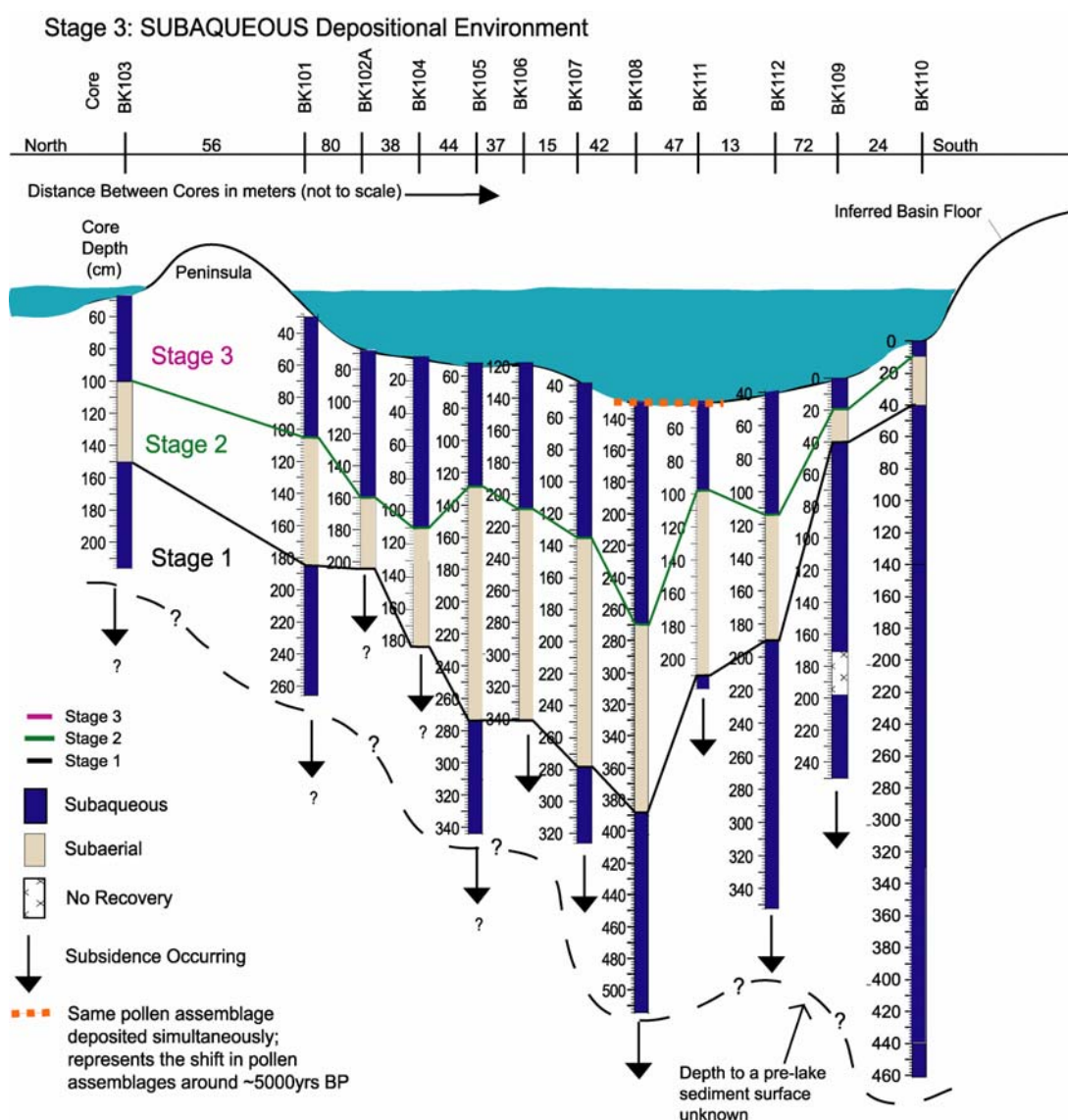


Figure 53. Conceptual diagram of sediment infill within the basin during the subaqueous Stage 3 in Brooklyn Lake.

Stage 4

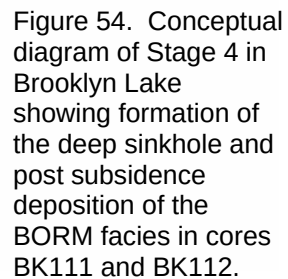
The fourth stage (Stage 4—Figure 54) is still the subaqueous environment from Stage 3, but includes the formation of the deep sinkhole created by rapid subsidence. In this stage any sediment infilling before the subsidence event was minimal and not represented in the diagram. This stage emphasized the subsidence event and post subsidence deposition of the BORM sediment facies in a deeper subaqueous environment. If the deep sinkhole feature previously existed this would then be considered a subsequent rapid subsidence, drastically dropping cores BK111 and BK112. Pollen evidence suggests that the rapid subsidence occurred shortly after the ~5000 yr BP pollen assemblage change.

Evidence of Rapid Subsidence During Stage 4

According to pollen results, the pollen at 136 cm in BK108 is the same pollen assemblage from 91 cm up to 51 cm in core BK111 (orange dotted line Figure 54). Similarly, the pollen at 126 cm in BK108 is the same pollen assemblage at 41 cm in BK111 (red dotted line Figure 54). This indicates that the sediment at these intervals in BK108 and BK111 were deposited simultaneously. Samples at 126 cm and 41 cm respectively having similar pollen signatures also correspond to the ~5000 year BP vegetation shift in which pine doubles and oak decreases. These sediment layers were deposited simultaneously, but are currently offset by ~1.5 m. To explain this offset the solution feature must have subsided shortly after the 5000 yr pollen shift was deposited. The sinkhole opened at depth and the area of the lake encompassing cores BK111 and BK112 subsided approximately two meters.

There are sediment laminations in BK107 and BK108 at this time of subsidence. Preservation of the laminations may be a result of the thick overburden underlying Brooklyn Lake acting more as a swale rather than a catastrophic collapse, which would otherwise destroy the sediment laminations. In core BK108 there are dipping laminations from 102 cm to 84 cm. These dipping laminations, contain more sand, appear in the core directly after deposition of the vegetation shift, and are overlain by parallel laminations that are abundant in pollen (photo in Figure 54). The dipping laminations are interpreted to be a remnant feature of the subsidence event, and the parallel laminations are interpreted to be post subsidence or a settling period in which a more stable depositional environment is regained. This subsidence event created a deeper, lower energy environment conducive for the deposition of finer grained sediments; furthermore, it increased the preservation potential of organics which is reflected in the >80% LOI content in the top 40 cm of cores BK111 and BK112, more specifically the BORM facies. Post subsidence deposition in BK108 and BK111 also occurred simultaneously, although the facies are different in that BK108 has a sand facies and BK111 has the BORM facies, this is primarily due to the fact that BK108 was in shallower water, therefore closer to sand sources and more prone to the process of well mixed oxygenated waters reaching the sediments and degrading any organic content. Data suggest that cores BK111 and BK112 have always been under water or in

Distance Between Cores in meters (not to scale)



the subaqueous stage since the subsidence event occurred. Evidence for this is, 1) the pollen record is abundant and present at the top of the core in BK111, and 2) when Brooklyn Lake is at its lowest lake level, it splits into ten pools (Figure 11), one of which remains over BK111 and BK112. Furthermore, approximately the top 10 cm of both cores contain the coarser organic sand facies and organic fine sand facies and lower %LOI suggesting that coarser material is deposited by wind and a lowered lake surface would mean shallower waters carrying dissolved oxygen to consume organic content. No pollen samples were analyzed for BK112, but it is within meters of BK111 and the sediment facies and contact positions closely mimic that of BK111, therefore it is assumed that the pollen in BK112 would be consistent with that of BK111.

Stage 5

The fifth stage (Stage 5--Figure 55) represents a time in that lake waters only filled a portion of the basin and did not cover all the core sites. The laminations present in BK107 are thought to represent a paleoshoreline where lake level was maintained and only fluctuated < 1 m. The low energy wave action present may concentrate the darker finer material just below wave activity, exposing clean sands along the shoreline, then lake level would rise and the previously exposed sands would be covered in finer darker material (photo in Figure 55). The lake-level fluctuations may have persisted for some time to allow for the thick ~35 cm deposit to form. During this same time, the other portions of the lake were exposed including cores BK101, BK102a, BK103, BK104, BK105, BK106, and BK110 accounting for the subaerial sediment deposition. If any type of flora were present during subaerial deposition it could trap sediments and possibly create sand dunes around the paleoshorelines.

Stage 6

The sixth stage (Stage 6 -- Figure 56) represents a time when the lake transitions into its recent subaqueous stage of today. The boundary or transition from Stage 5 into Stage 6 is not clear in many of the cores. The reason for this could result from erosion mainly caused by the pattern of large lake level fluctuations (>6.1 m) that have been documented in Brooklyn Lake today (Figures 10 and 12) (Clark et al., 1963, Motz and Heaney, 1991). It is possible that these fluctuations may have begun at the end of Stage 5 and continued on into and during Stage 6. During these fluctuation periods eventually all areas of the lake basin would be subjected to shoreline migration causing erosion and redistribution of sediments destroying evidence that would otherwise indicate the depositional environment.

It is speculated that Brooklyn Lake accumulation rates may be low. The deposition of biogenic remains from organisms (algae, zooplankton, phytoplankton, and fish -- Figure 2) is an internal source for lake sediments. Brooklyn Lake is documented as being slightly acidic and oligotrophic, lacking in plant nutrients (Clark et al., 1963, Shannon and Brezonik, 1972). Plants

are a food source in lakes (algae, phytoplankton, macrophytes), if the plant nutrient levels in the lake are low, the food source is low and the amount of biomass (amount of living matter) that the lake is capable of sustaining such as zooplankton and fish will be affected and most likely small. If there are small numbers of plants and animals living in the lake then it is safe to assume that there are low levels of biogenic sediments being deposited on the lake floor. What biogenic remains that are deposited may be present as very thin layers, widely dispersed layers, or deposits concentrated in habitat specific areas.

If accumulation rates are low in Brooklyn Lake and the lake only exists as a full basin (completely full of water) for a period of only a few years, this may not provide enough time for deposition and preservation of fine grained sediments or organic sediments. Any thin layers of fine grained sediments that were deposited could be reworked and redistributed by wave activity of a paleoshoreline as it migrates with the fluctuating lake level. Eventually at some point during these large scale lake-level fluctuations in Brooklyn Lake all surface areas of the basin floor become susceptible to the following circumstances: 1) erosion and redistribution of finer sediments from wave activity along the shoreline, 2) as the lake level fluctuates areas that were once deep enough become shallow enough for oxygenated water to reach the sediments and degrade any thin layers of organic content that was deposited during a higher lake level, and 3) subaerial exposure time allows for eolian sediment transport either into or out of the basin. It is because of one or a combination of these reasons that there is not a clear transitional or abrupt boundary present in the cores between Stage 5 and Stage 6.

Stage 5: Both SUBAQUEOUS and SUBAERIAL Depositional Environments

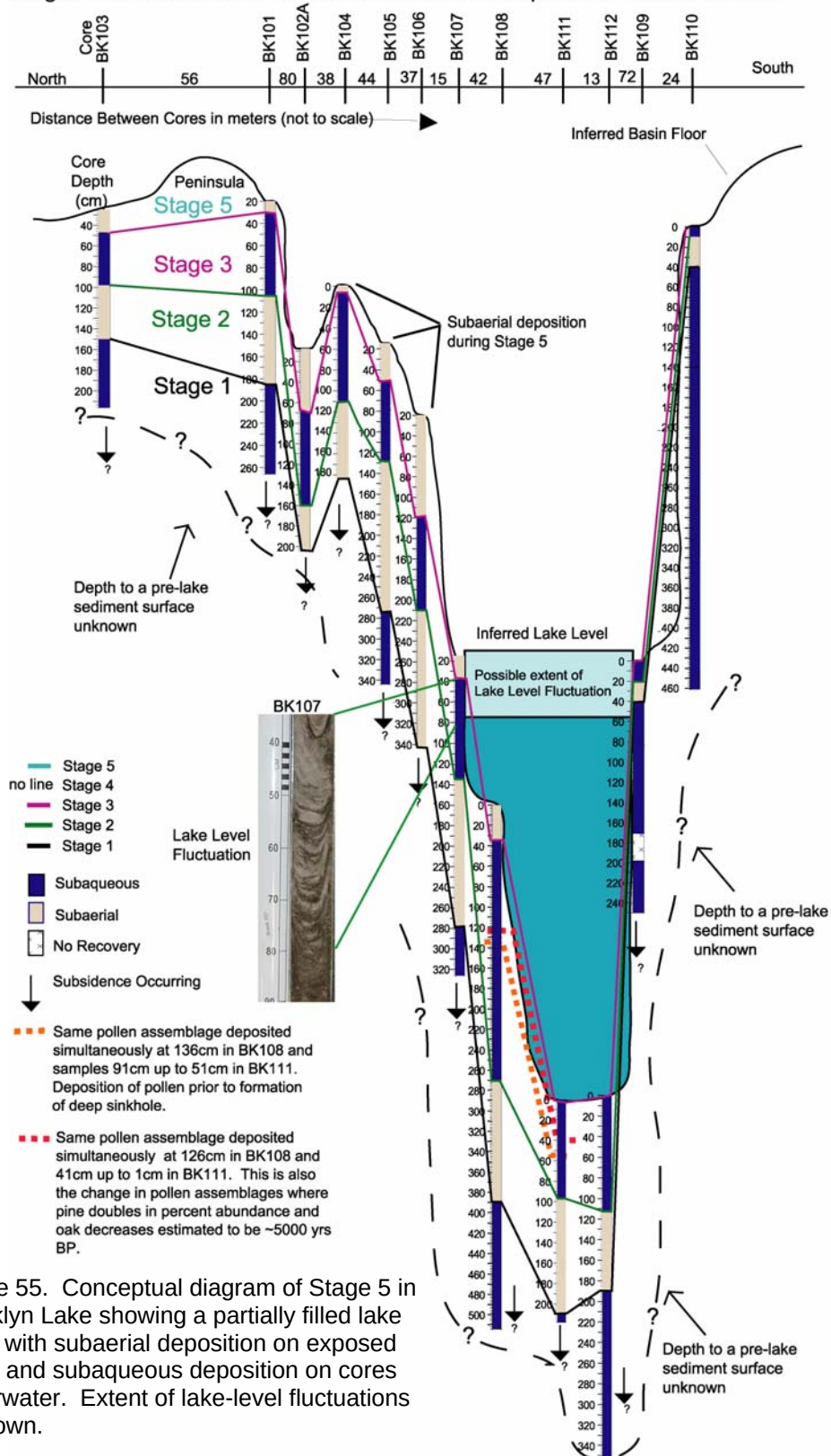


Figure 55. Conceptual diagram of Stage 5 in Brooklyn Lake showing a partially filled lake basin with subaerial deposition on exposed cores and subaqueous deposition on cores underwater. Extent of lake-level fluctuations unknown.

Stage 6: SUBAQUEOUS Depositional Environments--Recent

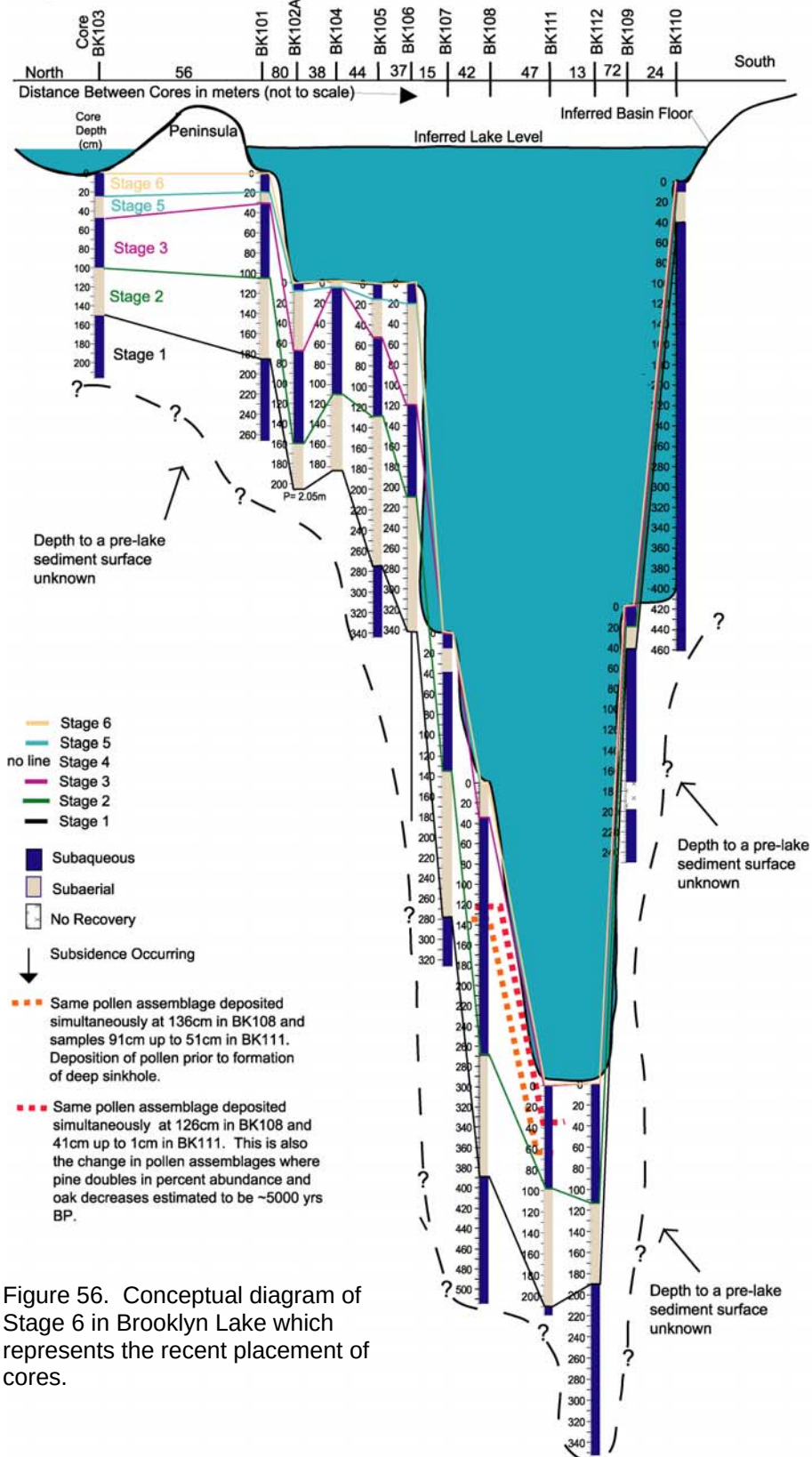


Figure 56. Conceptual diagram of Stage 6 in Brooklyn Lake which represents the recent placement of cores.

LEVYS PRAIRIE

Local Borehole Comparison

The sediment infill in Levys Prairie is partially consistent with the lithologic description of a 70 m deep well #14594 located ~14 km northwest of Levys Prairie at an elevation of 50.60 m. The elevation of Levys Prairie is ~26.00 m above sea level. The sediments in the well that are consistent with this elevation are between ~21.00 m to 25.00 m and consist of very light orange unconsolidated medium sands, having medium sphericity and 30% porosity (Figure 35). This is consistent with the sands found in Levys Prairie. A peat layer is not encountered in well #14594 although plant remains are noted between 26.00 m and 27.00 m. In this well, the top of the Hawthorn Group is located at 20.40 m elevation making it ~2.90 m below the base of the lowest core LP6.

The sediment infill of Levys Prairie is also consistent with the lithologic description of a closer well #5267 located ~3 km to the south of Levys Prairie at an elevation of 34.15 m. The sediments in the well that are consistent with the cores are between ~22.00 m – 25.00 m and consists of fine to coarse sands that are very light orange and dark yellowish orange angular to sub-angular with 24% porosity (Figure 35). These sediments are also consistent with the sands and silty-sands found in Levys Prairie. In the well the top of the Hawthorn Group is located at 22.00 m elevation making it approximately 1.30 m below the base of the lowest core LP6. Natural gamma log data taken in well #P0797 on the western perimeter of Levys Prairie also close to the study area indicate that the top of the Hawthorn is only 12 m below the surface (Kindinger et al., 2000). The sediment consistencies between the wells and that of the cores suggest that the source for sediments within Levys Prairie was derived from the local surrounding geology.

The SS and the OLM sediment facies found within the base of the cores are speculated as being associated with the Hawthorn Group or more likely reworked Hawthorn Group sediments. It is inconclusive that the cores actually penetrated the Hawthorn Group, but the close proximity of the base of the cores to top of Hawthorn support this possibility. Pirkle and Brooks (1959) also note a change in the Hawthorn from clastics to limestones occurs near the surface in the area occupied by Levys Prairie. Furthermore, several similarities between the SS and OLM facies and the lithologic descriptions of the Coosawhatchie and Marks Head Formations

by Scott (1988) that underlie the study (Figures 6 and 7) area make this a plausible suggestion.

For example the OLM facies colors are light greenish-gray (5G8/1) and greenish-gray (5Y8/1). A similar greenish-gray (5GY6/1) color is used by Scott (1988) to describe the sands of the upper informal member of the Coosawhatchie Formation and the clays of the Marks Head Formation. The upper informal member of the Coosawhatchie Formation contains higher amounts of carbonate (5% to 30%). This is also true of the OLM facies (~13 to ~26%) and the SS (~7% to ~23%) facies which are higher values of %CaCO₃ content with respect to the overlying S facies. Marine fossils fragments (sharks teeth, mollusks) are abundant within the OLM and SS facies (Figure 34 and Appendix 3) and most likely contribute to the carbonate content. The presence of marine fragments suggest that the sediments were deposited during the Miocene while sea level covered the Florida platform, but the coarse sand sized fragments and well-rounded quartz grains indicate reworking by erosion and transport, not deposition in situ. Kaolinite is present in both the OLM and the SS facies and is mentioned by Scott (1988) to be present in the Charlton Member which intermingles laterally with the upper informal member of the Coosawhatchie Formation. Sand grains of the upper member of the Coosawhatchie are angular to subangular to subrounded. This is true of the sediment grains in the cores and is evident in the microscope images (Figure 34 and Appendix 3) which show well rounded quartz grains and fragments of mollusks, corals, and broken sharks teeth indicating that they have been reworked and or traveled some distance from their origin.

In contrast to the suggestion that the SS and the OLM facies are derived from the Hawthorn Group, Pirkle (1960) discusses the presence of clay nodules in what he terms the "kaolin zone". According to Pirkle (1960) the "kaolin zone" unconformably overlies the marine Hawthorn Group, and consists of quartz sands that are bound together by the kaolinite clay minerals. It is considered the base of what he refers to as the Citronelle Formation (Pliocene in age), but is more recently called the Cypresshead Formation (Scott, 2001), and it unconformably overlies the Hawthorn Formation. Many times the kaolin is found as stringers (0.3 m by ~1.0 m). Sometimes the stringers were exposed to the atmosphere and portions or all of the stringer would dry out. These hardened lenses would then be fragmented by wave activity resulting in blocks, balls, or nodules of kaolin (Pirkle, 1960). The Coosawhatchie Formation is also noted to contain silicified nodules (Scott, 2001).

Evidence from the cores supporting that the SS and OLM facies originated from the kaolin zone include 1) X-ray diffraction results indicating the presence of kaolinite in both the SS and OLM facies, 2) microscope images of white crumbly grains specifically in core LP8 from the OLM facies (Appendix 3), and 3). the presence of white nodules of clay present in core LP5 (137 cm to base), core LP6 (48 cm to base), core LP7 (82 cm to 100 cm), and core LP8 (64 cm to base), and 4) montmorillonite was detected in the fine fraction of the SS facies in core LP6 at 110 cm and Pirkle (1960) also identified the presence of montmorillonite in the kaolin zone.

Another consideration unrelated to borehole geology, but a possible source of sediment for the SS and the OLM facies are undifferentiated Tertiary/Quaternary Sediments located directly northwest and close to the study area. These sediments are described as gray to blue-green, unconsolidated to poorly consolidated, fine to coarse, unfossiliferous sands, sandy clays, and clays also containing disseminated organic material (Scott, 2001).

Pollen

The pollen diagram of core LP5 (Figure 32) records the similar pollen assemblage change as that described in Brooklyn Lake cores BK108 and BK111. The pollen assemblages from core LP6 do not correlate at all with those of Brooklyn Lake (pers. comm. Willard, 2003). The upper 91cm of core LP5 are high (>70%) in pine pollen, having small amounts of oak, low amounts of grasses and higher amounts of weedy annuals which is representative of a wetter environment. This pollen assemblage change in which pine increases two fold is documented and carbon 14 dated in Lake Sheelar in Clay County and Mud Lake in Marion County. The shift occurs at 7200yrs BP in Sheelar Lake and 5070+/- 150 yrs BP in Mud Lake and considered to represent a drier climate changing into a wetter climate (Watts and Stuiver, 1980, Watts, 1969 respectively). The pollen assemblage change occurs in core LP5 from a barren sample of pollen at 103 cm into a sample abundant in pollen at 91cm. This is different from Brooklyn Lake where the samples both above and below the pollen assemblage boundary are abundant in pollen (51 cm and 41cm in Bk111 respectively--Figure 21 and Appendix 4). Despite this difference, it is possible that this shift in pollen in core LP5 fully documents the pollen assemblage change represented in Sheelar Lake, Mud Lake, and Brooklyn Lake; therefore documenting a shift from drier times to wetter times. To illustrate this point further, the pollen sample at 103 cm in LP5 is from the sand facies and barren of pollen. The pollen sample at 91 cm in LP5 is also from the sand facies but is abundant in pollen. The sample at 61 cm in LP5 is from the peat facies and abundant in pollen. The boundary between the sand facies and the peat facies in LP5 is at 87 cm and is considered a transitional contact, therefore the sample at 91 cm is considered to be in a transitional contact zone between the sand facies and the peat facies (upper part of photo in Figure 33). Hence, the pollen change in LP5 can be considered a real change that is fundamentally similar to the pollen change in Brooklyn Lake. Furthermore, using the dated pollen record from Sheelar Lake and Mud Lake as relative control for geologic age, it can be said that Levys Prairie is older than 7200 yrs BP.

Lake History and Development

The development of Levys Prairie results from the sediment deposition in both subaerial

and subaqueous environments. The literature sites the formation of two sinkholes in the 1950 on the western side of Levys Prairie; the northern-most sinkhole has closed up since (Pirkle and Brooks, 1959), while the southern-most sinkhole still contains water and currently has measured seepage into the Floridan Aquifer (pers. comm. Jeff Davis, 2003). This supports that karst processes occurred under Levys Prairie and most likely are ongoing today. The pollen curve from core LP5 provides a relative age placement for the development of Levys Prairie. A four stage depositional scenario is presented here as an explanation for the development of Levys Prairie.

Stage 1

Stage 1 (Figure 57) indicates pre-existing surface upon which the lake sediments were deposited. The pre existing surface predominantly consists of the SS and the OLM facies. The vertical extent of this layer and whether this is the original lake basin surface cannot be confirmed from these cores, but the sediment characteristics of this surface do not reflect deposition in a lacustrine environment. It is unclear as to what geologic unit or formation this pre-existing surface is associated. The two prominent possibilities discussed above are the Coosawhatchie Formation of the Hawthorn Group or possibly the kaolin zone described by Pirkle (1960) of the base of the Cypresshead Formation. This pre-existing surface is very stiff and compact which suggests deposition some time ago, allowing time for compaction possibly from overburden of other layers that once existed and were possibly reworked and eroded leaving this surface. Cores LP1 and LP2 do not reflect pre-existing surface sediments so they are not present during this stage.

Stage 1: Pre-Existing Surface

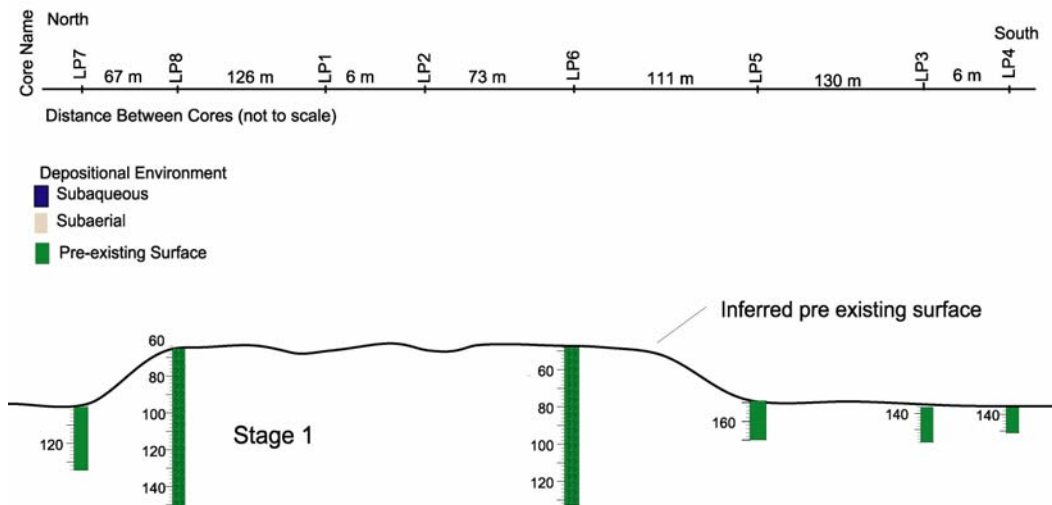


Figure 57. Conceptual diagram of Stage 1 in Levys Prairie representing the pre-existing surface.

Stage 2

The second stage (Stage 2—Figure 58) a subaqueous depositional environment in which the water table was higher and any depressions in the pre-existing surface filled in with water. This subaqueous stage is thin (<50 cm) suggesting that 1) water was present in the basin for a very short time period or 2) if water did persist for a long time period, then sediment accumulation rates may have been low. It is difficult to say whether the sediments deposited here are strictly lacustrine, because of the high amount of calcium carbonate (~10%) that is still present during this time. The calcium carbonate content begins to decline in most cores further up the core away from the pre-existing surface (Figure 36 and Appendix 1). It could be considered that as a lacustrine basin developed, the erosion and transport from wind and primarily wave activity were reworking and redistributing sediments from the pre-existing surface which would help explain the presence of calcium carbonate as well as provide an environment to produce and deposit organic content.

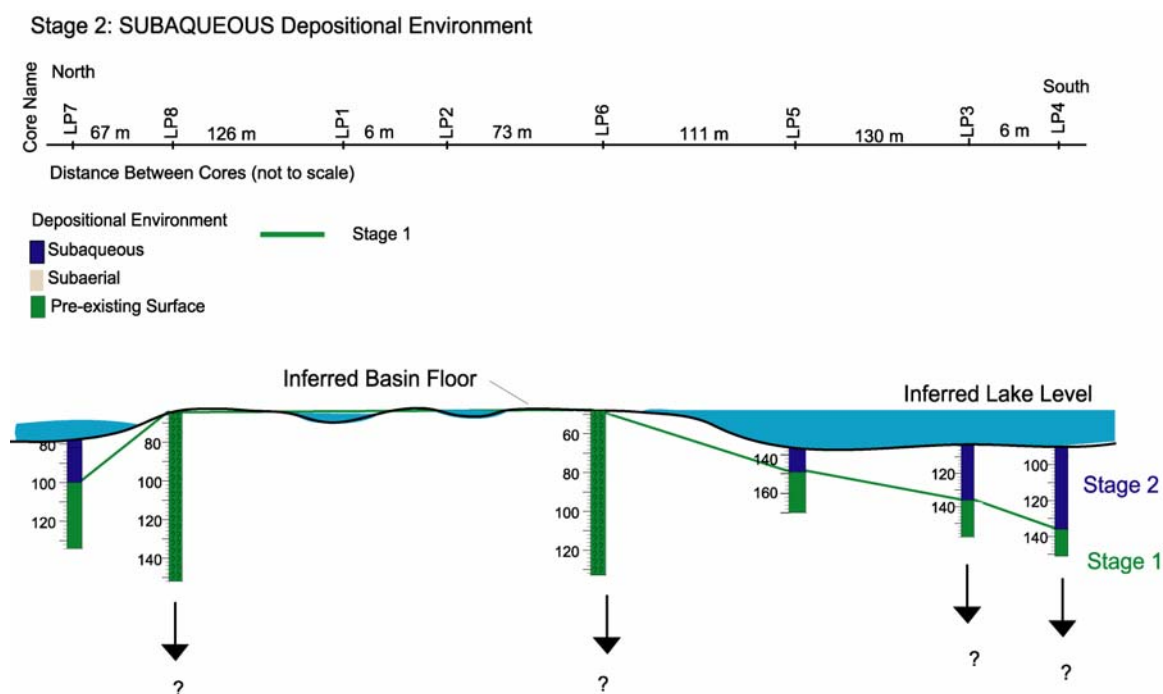


Figure 58. Conceptual diagram of Stage 2 in Levys Prairie representing the subaqueous depositional environment. Also showing multiple depressions with cores LP8 and LP6 on the flanks of the depressions.

Cores LP8 and LP6 lack a clear indication that sediment deposition was occurring during this stage, therefore they are not presented as accumulating sediments. This also suggests that the pre-existing surface was not one large basin, rather possibly having multiple depressions as

suggested in Figure 58. If the pre-existing surface was unconformable or undulating having several shallow depressions cores LP8 and LP6 may have been located on the perimeter of a shallow depressions or on slightly higher ground. As water entered Levys Prairie it would fill the lower depressions first and the encroaching wave activity could slowly work away at the pre-existing surface therefore subjecting the slightly higher areas to mechanical erosion and reworking. Any finer sediment (clays and silts) are now available for transport and deposition in other areas of the basin. Because Levys Prairie does not have any external rivers or streams to carry sediments into the open water bodies, this reworking situation could be thought of as an internal sediment source recycling and redistributing previously deposited sediments.

Cores LP3 and LP4 may have subsided some creating accommodation space for sediment deposition. It is speculated that cores LP6 and LP8 began to subside during Stage 2 which would help to establish the offsets that currently exists (Figure 35) as well as create accommodation space. Cores LP1 and LP2 do are not present during this stage.

Stage 3

The third stage (Stage 3—Figure 59) represents a subaerial depositional environment in which groundwater may have been lower. Deposition of core LP2 begins during this stage. This time is represented by relatively clean sand facies that are barren of pollen grains suggesting that it was a windy and drier time in which silt sized pollen grains may have been winnowed away, or pollen was not deposited at all. This thin sand facies in this scenario suggest two things, 1) that the subaerial period only persisted for a short time, or 2) the sand facies was a much thicker deposit, but was subsequently removed through erosion and subsidence activity in Levys Prairie.

Stage 4

The fourth stage (Stage 4—Figure 60) represents the transition into the recent subaqueous stage of today. Deposition of core LP1 is present in this stage. It is most likely between Stage 3 and Stage 4 that core LP5 and LP6 subsided. The pollen assemblage reflects a transition into a wetter time period.

Core LP6 was taken in a shallow water filled depression that is suspected to be a younger, small solution sink that may have formed. Several pieces of evidence suggest that this is a small solution sinkhole that may have formed in very recent times. The pollen assemblage in core LP6 does not correlate with that of core LP5 (pers. comm. Willard, 2003). This implies a few things, 1) that the pollen was deposited and later removed by erosion, 2) that sediment deposition and accumulation in the vicinity of cores LP5 and LP6 are not occurring simultaneously, or 3) that a pollen assemblage similar to that of LP5 was also deposited in core LP6 and later destroyed or distorted. The peat facies in LP6 is the thinnest of all the cores with the exception of LP8. Core LP6 must have subsided some time during Stage 4 to explain the thinner veneer of peat

compared to the thick peat accumulations of core LP5 which is the closest core in proximity to LP6. The vertical facies boundaries from the Stage 1, Stage 2, and Stage 3 are all dipping. The dipping boundaries are also seen in the X-radiograph positive suggesting that this is not an artifact of coring and may be a small preferential subsidence event such as a piping feature opening below this area. The suggestion that this small depression may be the result of a preferential subsidence event is consistent with evidence of past sinkholes opening and closing in Levys Prairie, also several individual piping events exist on the perimeter of Crooked Lake (Evans et al., 1994). If core LP6 is a representative of a recently formed solution feature then this would imply that subsidence mechanisms are still active in Levys Prairie today.

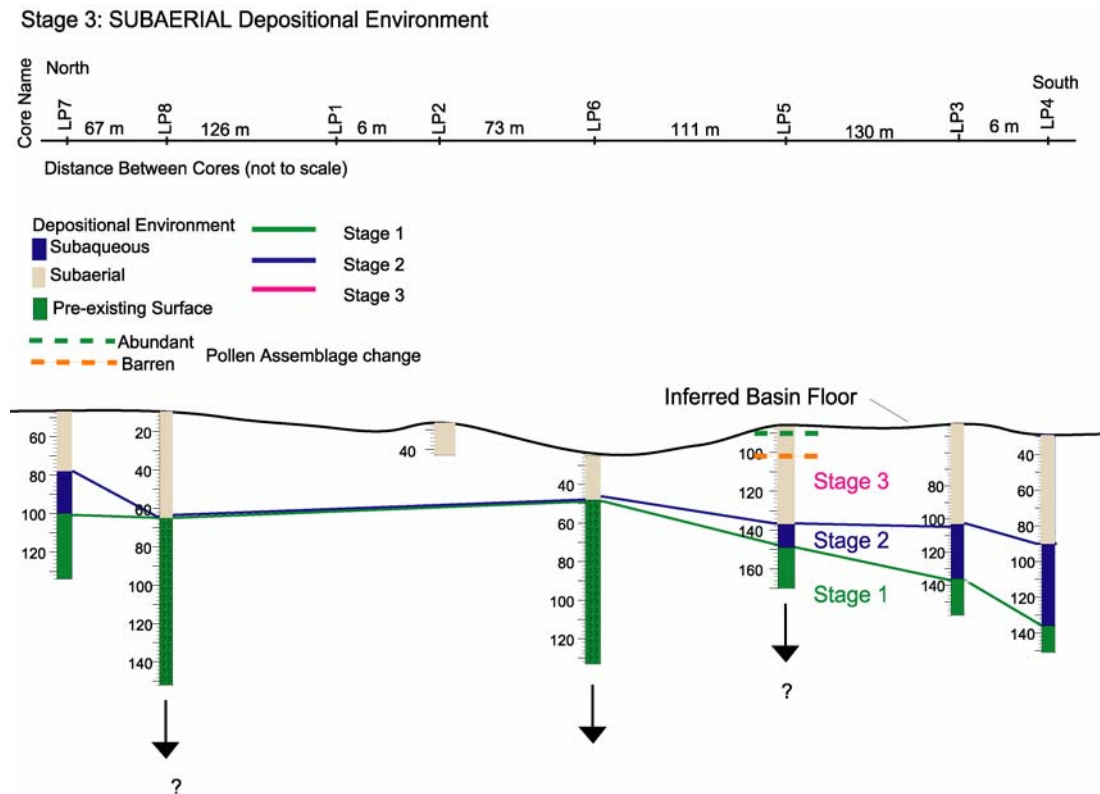


Figure 59. Conceptual diagram of Stage 3 in Levys Prairie representing the subaerial depositional environment. Also showing subsidence of LP6 creating a new depression

Stage 4: SUBAQUEOUS Depositional Environment

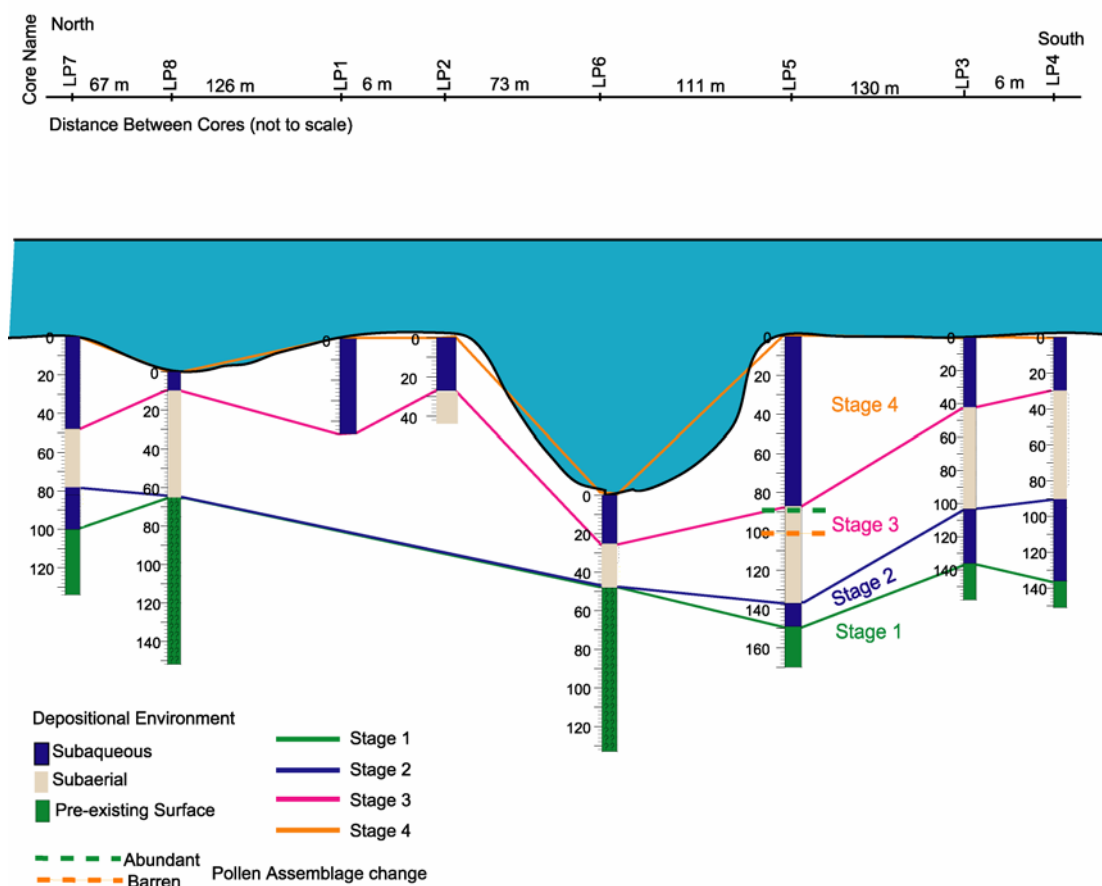


Figure 60. Conceptual diagram of Stage 4 in Levys Prairie representing the subaqueous depositional environment of today.

COWPEN LAKE

Local Borehole Comparison

Sediment infill of Cowpen Lake is consistent with the upper lithologic description of a nearby well #1727 (Figure 44). The upper 29 m of the well consists of undifferentiated sand and clay, predominantly fine to coarse sand, angular to sub-angular and poorly indurated having color variations of pinkish gray and grayish brown. The Hawthorn Group is encountered at 29 m in the well, whereas, the base of the sediment cores from Cowpen Lake are approximately 9 m above this boundary. This supports a local source of sediment infill that was transported a short distance.

Pollen

Sediment cores from Cowpen Lake have extremely low or absent pollen counts and are considered barren; therefore it is not effective in deciphering wet or dry periods that may be a result of changes in climate. The lack of pollen implies that the lake basin may have been dry at one or more times in the past. It is possible that pollen was not deposited or silt sized pollen may have been deposited and winnowed out by wind. This is possible when considering that the sand facies within Cowpen Lake are thick, well sorted, extremely low in silt content and barren of pollen grains. Cowpen Lake is a closed basin making the introduction of pollen grains via a river or stream not possible.

Pollen is abundant in the top 12 cm of core CP5 (Figure 43 and Appendix 4). This indicates that pollen was being deposited ~11 cm down the core and is still being deposited today. The fact that pollen is absent in the lower portions of the core, but abundant in the top 12 cm of core CP5 establishes that the lake basin was dry and became filled with water in the most recent time. This is possible as the water table rose in the Holocene flooding the lakes. Sheelar Lake documents a change at 7200 years B.P. from a drier climate into the modern climate and modern vegetation having an increase in pine species being more abundant than oak (Watts and Stuiver, 1980). This is also the case in core CP5 where the presence of oak is one third the abundance of pine. This later Holocene climate change in Sheelar Lake may be the same change recorded in the upper 11 cm of core CP5 where pollen change from a barren sample (CP5 112 – 114 cm) into an abundant sample (CP5 10 -12 cm). This also suggests that Cowpen

Lake may be older than the Holocene (Figure 43 and Figure 47).

Lake History and Development

The development of Cowpen Lake results from the sediment deposition in both subaerial and subaqueous environments. Cowpen Lake may have undergone a shallowing period in which the basin never completely dried out, but water level decreased significantly. Cowpen Lake is described by Shannon and Brezonik (1972) as having a complex and irregular shoreline. The complexity stems from five sinkholes that have grown together. This indicates that karst processes are occurring below this lake basin. A five stage developmental scenario is presented here as an explanation for the development of Cowpen Lake.

Stage 1

The first stage (Stage 1—Figure 61) presents a subaerial depositional environment. Evidence in cores CP5 from and core CP2 has very clean sands barren of pollen and extremely low in organic content. Sediments in the base of core CP1 do not indicate deposition in a subaerial environment; therefore it is not present during this stage. It is not clear whether the basin was dry because of climate or because of a lower water table. However the lack of pollen may suggest three things: 1) that pollen was present, but because it is smaller than sand, it could be winnowed away by winds therefore leaving clean well sorted sands behind, 2) climate conditions were such that flora could not be sustained, therefore pollen was not produced, or 3) the groundwater table was lower than the lake basin eliminating the presence of water as a mechanism to trap pollen grains.

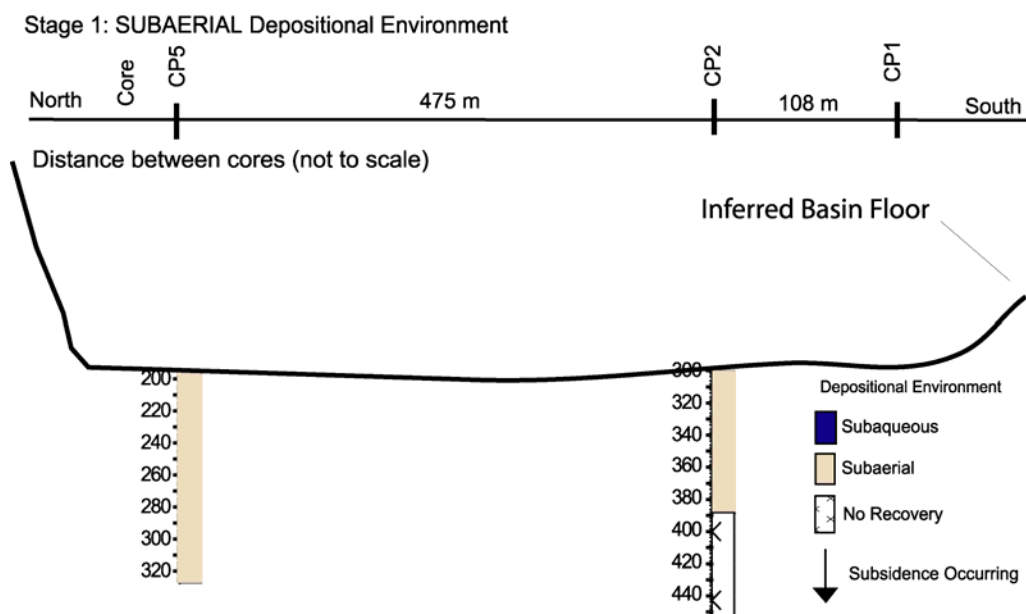
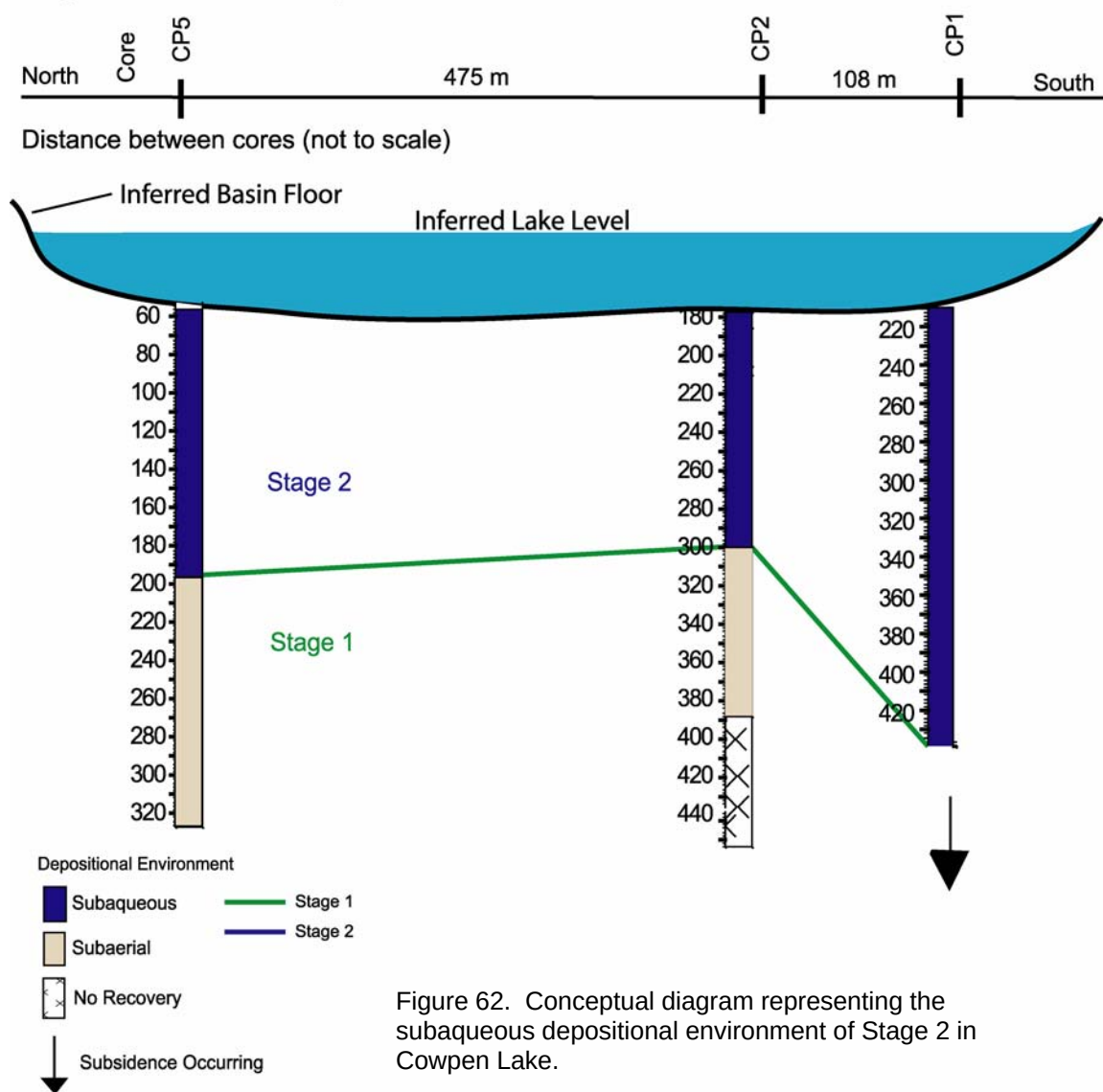


Figure 61. Conceptual diagram representing the subaerial depositional environment of Stage 1 in Cowpen Lake.

Stage 2

The second stage (Stage 2--Figure 62) represents a subaqueous depositional environment. This is documented as a large increase in the LOI index for total organic content and contains several sediment facies including the OS and the OM facies. It is not clear what mechanism introduced water into the basin, but the only reasonable options are a rising groundwater table or a wetter climate introducing water via precipitation and surficial groundwater seepage. The presence of the finer grained facies and the higher organic content also suggest a biological presence possibly of macrophytes and freshwater phytoplankton. The presence of the thin organic mud

Stage 2: SUBAQUEOUS Depositional Environment



facies suggests several potential conditions within the basin during this stage of development: 1) the lake level must have been sufficiently deep to allow quiet, low energy conditions conducive for deposition of the OM facies, 2) the preservation of high organic content (>9%) may also be a result of a deep environment that limits water mass overturn thus retards oxygenation that would otherwise consume organics, and 3) deposition of the organic mud layers may have persisted over a long period of time. This is possible considering Cowpen Lake is a closed basin where sediment sources are limited to biological and detrital material entering the lake via wind or seepage. The waters are considered oligotrophic most likely supporting a small biological community; therefore to obtain a high biological contribution to the sediments deposition must have occurred for a lengthy amount of time. Subsidence of core CP1 during Stage 2 provides a mechanism that would displace or offset sediment layers that were contemporaneously deposited, and allow accommodation space for more deposition. The result being a thicker accumulation of organic rich sediments in core CP1 compared to that of cores CP2 and CP5.

Stage 3

The third stage (Stage 3—Figure 63) represents a time when lake level may have lowered marked by a decrease in %TOC and presence of coarser sediments. By lake level lowering, this would present a situation in which more dissolved oxygen could come in contact with sediments both at the sediment water interface and with sediment resuspension from wave interaction with the lake bed. This would account for the decrease and disappearance of %TOC. Preferential subsidence of core CP1 is still occurring at an unknown rate. It is suggested that core CP2 began to subside during this stage.

Stage 4

The fourth stage (Stage 4—Figure 64) represents a subaerial depositional environment. There is no evidence to indicate that core CP5 was exposed during this stage, if it was emergent, it may have only been for a brief time; otherwise it remained covered by some small amount of water. The lowered lake level or dry basin resulted from a lowered water table. A lack of pollen suggests a drier windier time. A pollen zone located twenty-two meters down core in Sheelar Lake (~26 km north of Cowpen Lake) indicates a drier climate in Northern Florida from 11,230 years BP to 9500 years BP. During this time period mesic trees declined and pine flourished existing with oak possibly a result of fire frequency coupled with drier climate (Watts and Stuiver, 1980). Fire may also explain the lack of pollen in Cowpen Lake, perhaps by eliminating vegetation in close proximity to the lake, eliminating or decreasing the pollen source. According to Watts (1970) pollen was not well preserved during this time and may have been damaged or destroyed by oxidation. Subsidence of core CP1 and CP2 are still occurring at this time, but it is speculated that core CP2 is subsiding at a faster rate than core CP1 or the subsidence rate for

core CP1 may have slowed. This would account for the increased accommodation space for subaerial deposition in core CP2 in comparison to core CP1.

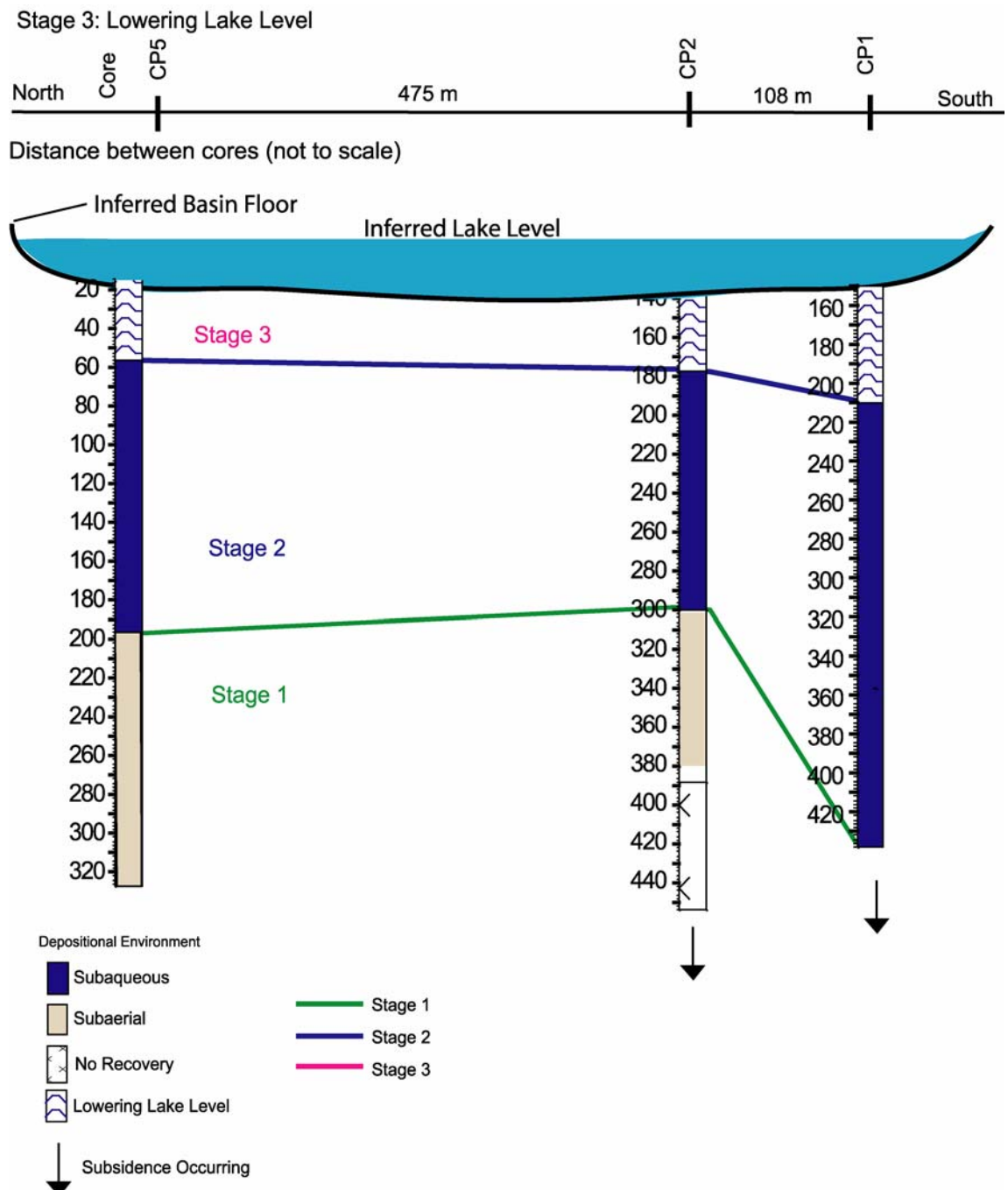


Figure 63. Conceptual diagram representing the lowering lake level of Stage 3 in Cowpen Lake

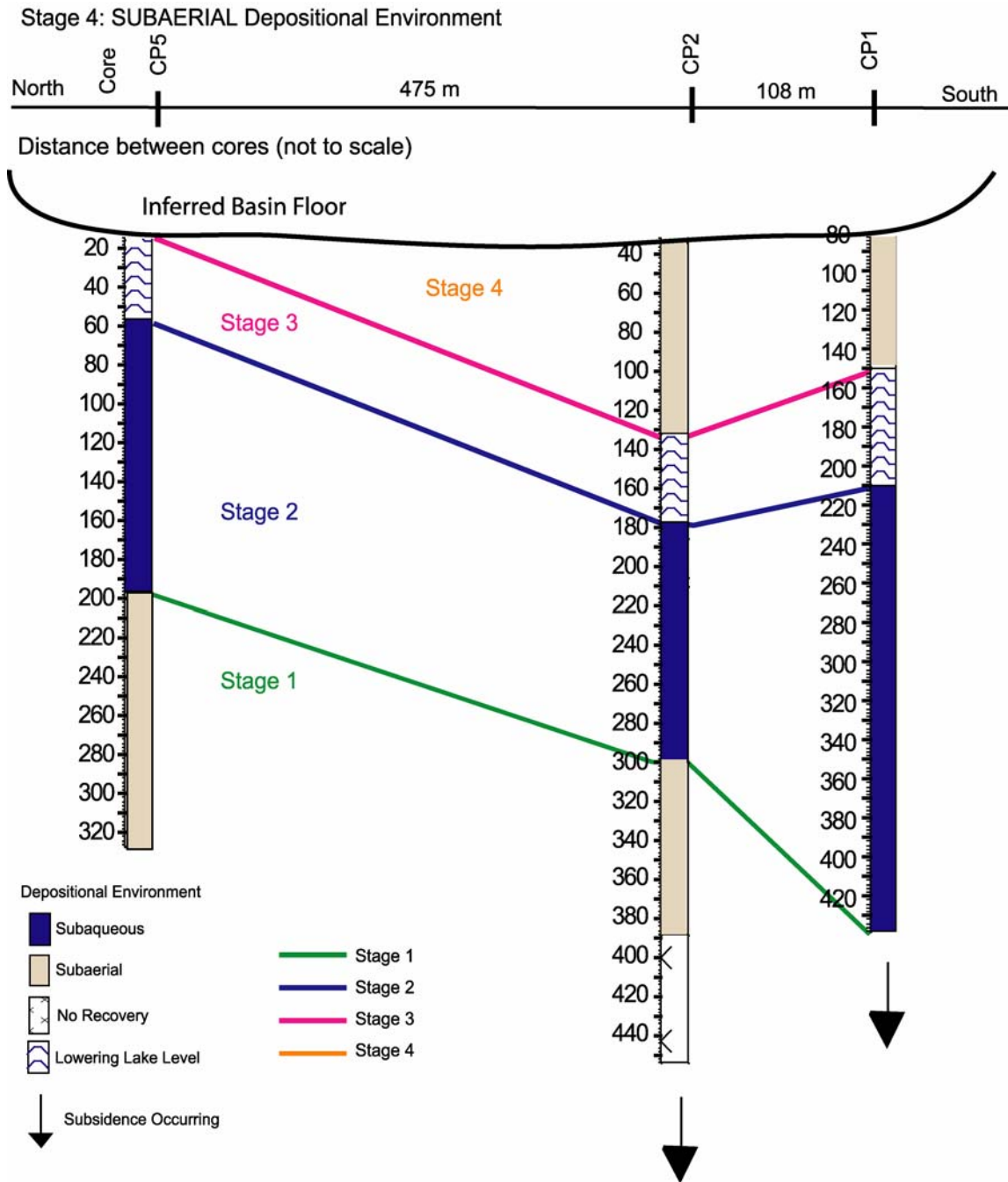


Figure 64. Conceptual diagram representing the subaerial depositional environment of Stage 4 in Cowpen Lake

Stage 5

The fifth stage (Stage 5—Figure 65) represents the recent subaqueous depositional environment of today. Core CP1 most likely stopped subsiding or slowed considerably during this stage, but CP2 has continued to subside into its present position. This is evident by an increase in finer grained sediments and an increase in the LOI index for total organic carbon. Pollen is

abundant in the top 12 cm of core CP5 and indicates that pollen was being deposited and is still being deposited today also the lake has held water in its basin since the end of Stage 4. The presence of pollen is absent in the lower portions of the core, but abundant in the top 12cm of core CP5 establishes that the lake basin was dry and became filled with water in the most recent time. The presence of oxidized rhizospheres in core CP1 (Figure 47) also emphasizes the presence of water.

Stage 5: SUBAQUEOUS Depositional Environment

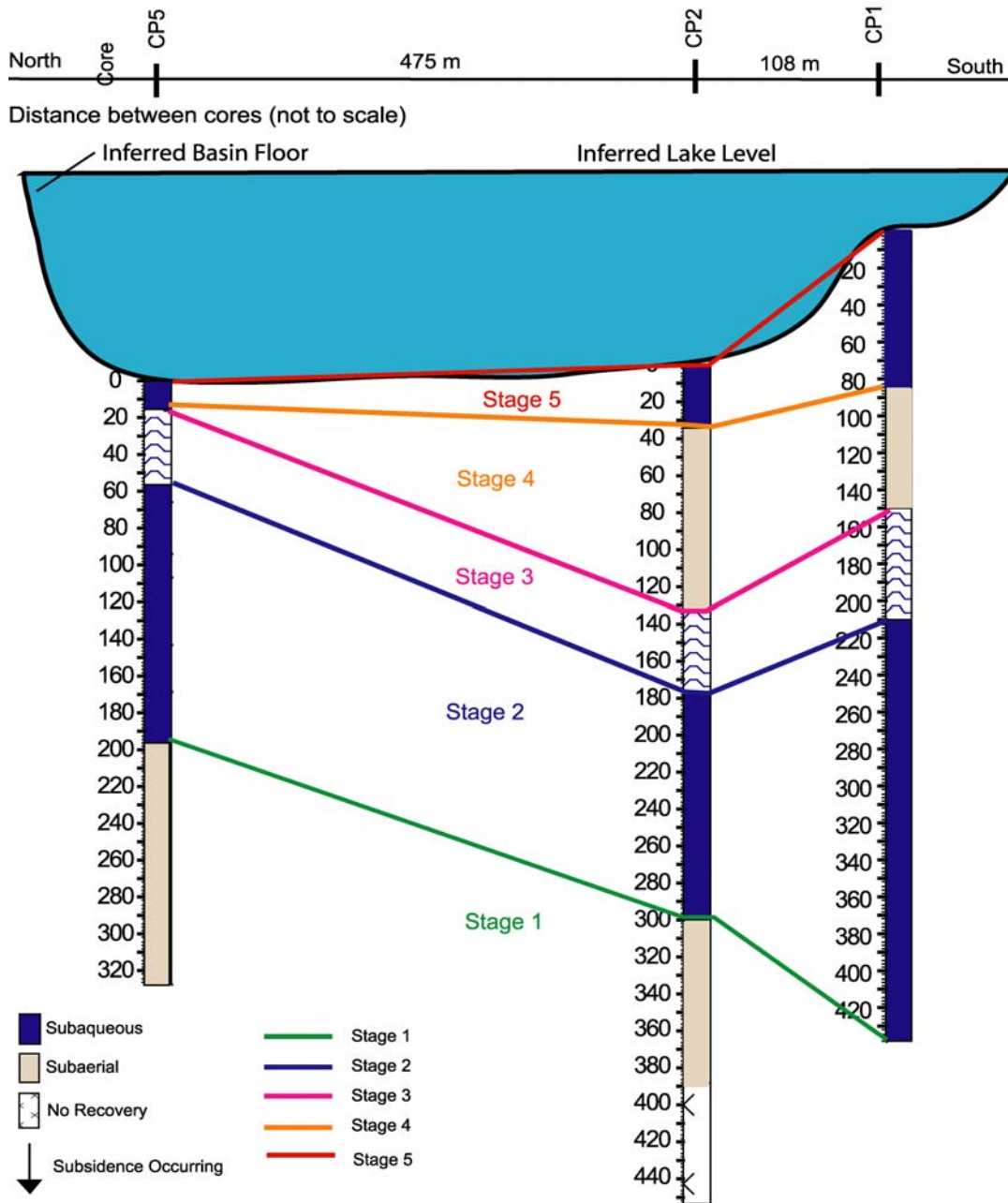


Figure 65. Conceptual diagram representing the recent subaqueous depositional environment of Stage 5 in Cowpen Lake.

SUMMARY AND CONCLUSIONS

This study has focused on defining the sedimentary infill of three closely spaced lakes in north-central Florida (Brooklyn Lake, Levys Prairie, and Cowpen Lake) to determine the various sedimentary inputs and their associated process in an effort to understand the lithology within lake basins in a karst terrain, and offer an explanation for the development of lakes.

The comparison of sediment infill of these three lakes reveal that Brooklyn Lake and Cowpen Lake are most similar in sediment facies content, basin morphology and the extent of subsidence depicted in the developmental scenarios, whereas, Levys Prairie is much different in sediment facies characteristics, basin morphology and less subsidence activity as depicted in the developmental scenario.

The sediment infill from Brooklyn Lake, Levys Prairie and Cowpen Lake are conducive to understanding the depositional environments and geologic process that contributed to their development and continued existence. Based upon the results and evidence presented in this study it can be expected that lake development in a karst terrain will include subaqueous and subaerial times, and that various times of subsidence that can be recorded in the lake sediments.

Sedimentary Facies

Five sedimentary facies were identified within Brooklyn Lake cores and include 1) sand facies (S), 2) organic sand facies (OS), 3) organic fine sand facies (OFS), 4) yellowish-gray organic mud facies (YGOM), and 5) black organic rich mud facies (BORM). Four sedimentary facies were identified in Levys Prairie cores and include 1) peat facies (P), 2) sand facies (S), 3) organic sand facies (OS), 4) silty-sand facies (SS), and 5) organic lime mud facies (OLM). Three sedimentary facies were identified within Cowpen Lake cores include 1) sand facies (S), the organic sand facies (OS), and 3) organic mud facies (OM).

The sediment facies characteristics specific to each basin are in agreement with the lithologic descriptions of local wells located in close proximity to each basin. This suggests that the source of sediment infill in each basin may have a local origin and was not transported far.

Interlake Sediment Facies Similarities

The sedimentary facies that are present in all three lakes are the S and OS facies. The

sediment characteristics of the S and OS facies share the most similarities independent of the basin in which they were deposited. The one exception to this is the presence of sand sized marine fragments within the S facies in Levys Prairie which are thought to be a result of erosion reworking of an older sedimentary unit and not deposition in situ. Sediment erosion and transport processes responsible for the deposition of the S and OS facies in each basin include wind surficial runoff, groundwater discharge into and out of the basin, slumping or failing of sediments, and shoreline wave activity are considered analogous in each basin in this study.

Interlake Sediment Facies Contrasts

Brooklyn Lake is the only lake that contains OFS facies, the BORM facies, and the YOGM facies. The deposition of the BORM facies most likely is a result of suspended sediment load entering Brooklyn Lake via Alligator Creek an intermittent stream. The finer sediments carried into Brooklyn Lake via the creek have a chance to settle out of suspension when the creek is not flowing because of the reduced turbulent flow that would otherwise hinder the deposition of suspended sediments. The presence and preservation of the BORM facies is thought to be a result of the deep subsidence feature that the core transect intersects. The preferential location of the YGOM in the southern side of Brooklyn Lake is not fully understood, but suggests that the sediment source for this facies is not present throughout the study area and / or a different energy regime existed at some point to concentrate deposition of this finer material on this side of the lake.

Levys Prairie is the only lake that contains the P, the SS, and OLM facies. The presence of the thick peat layers may be reflected in the general topography being a large, broad shallow depression that intercepts water from the surrounding hills. Mud Lake's topography is similar and also has a thick gyttja (similar to peat) in the upper two meters. The SS and OLM facies are only present in Levys Prairie and are thought to be part of a pre-existing surface which is not found in Brooklyn Lake or Cowpen Lake. It is inconclusive from this study whether this is the initial lake basin. This surface may be a part of 1) the Hawthorn Group or reworked Hawthorn sediments, or 2) the kaolin zone a basal layer of the Coosawhatchie Formation as described by Pirkle (1960).

Cowpen Lake is the only lake that contains the OM facies. The primary differences of this facies versus the mud facies from the other lakes is that this layer is thinner, has a higher percent silt value, and has a predominantly brownish color attribute.

Lake History and Development

Subaqueous and subaerial environments in conjunction with groundwater fluctuation and subsidence activity are key factors in the development of Brooklyn Lake, Levys Prairie, and Cowpen Lake. The extent and magnitude of these factors appear to be different in each lake;

however, the exact quantification of these factors is beyond the scope of this study. Rather, an interpretation of the depositional environments could be made and it was possible to develop a depositional scenario based upon the sediment infill; therefore contributing to the understanding of lake development in karst terrain.

Brooklyn Lake development is represented by a six stage depositional scenario that includes one subaerial stage, four subaqueous stages, one stage that has both subaqueous and subaerial deposition occurring, and one stage in which a sinkhole formed. The developmental scenario for Brooklyn Lake illustrates that the sinkhole feature within the lake either formed or if it previously existed it went through a rapid subsequent subsidence event shortly after the 5000yr pollen assemblage change. This is strongly supported based upon the presence of the pollen assemblage shift in both BK108 and BK111.

Levys Prairie development is represented by a four stage depositional scenario that includes a pre-existing surface, one subaerial stage, and two subaqueous stages.

Cowpen Lake development is represented by a four stage depositional scenario that includes two subaerial stages, two subaqueous stages, and one lowering lake level stage.

Pollen

Pollen data from Brooklyn Lake records a shift in pollen assemblage in the upper meter of two cores where pine increases two fold, weedy annuals increase and grasses decrease indicating a shift from a dry environment into a wet environment. This shift is reported and carbon 14 dated in pollen records from four other freshwater lakes in Florida. Sheelar Lake and Mud Lake the closest lakes to the study area record this change at 7200yrs BP and 5070+/- 150 yrs BP (Watts and Stuiver, 1980, Watts, 1969 respectively). Lake Tulane and Lake Annie, two Lakes further south of the study area also record a shift at 5000 yrs BP (Grimm et al., 1993) and 4715+/- 95 yrs BP (Watts, 1975) respectively. The vegetation shift observed in Brooklyn Lake is considered to be consistent with the pollen curves from Lake Sheelar and Mud Lake. Based upon the pollen record and the relative thickness of the BORM facies, it can be concluded that Brooklyn Lake is older than 7200yrs.

Pollen data from Levys Prairie records a vegetation shift in the upper meter of the core, and is consistent with that of Brooklyn Lake. Furthermore, this shift is consistent with that of Sheelar Lake, Mud Lake, Lake Tulane and Lake Annie, and suggests that Levys Prairie is older than 7200yrs BP. Cowpen Lake for the most part is barren in pollen except for the top 11 cm in which pollen is very abundant in pine, similar to the high abundance found in Brooklyn Lake and Levys Prairie. If this change recorded in the upper 11 cm of core CP5 is comparable to the pollen change from it would also suggest that Cowpen Lake may be older than 7200yrs BP.

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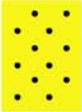
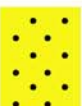
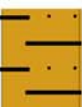
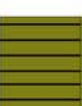
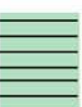
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APPENDIX 1

SEDIMENT CORE LOGPLOTS AND PHOTOGRAPHS

Core Log Description Key

Lithology Patterns	Symbols	Facies	Facies Association
 Sand	 Roots	 Peat	 Subaqueous
 Silty-Sand	 Roots surrounded w/stained sediment	 Sand	 Intermittent Wet/Dry
 Clayey-Sand	 Plan Remains	 Organic Sand (OS)	 Subaral
 Sandy-Silt	 Burrow	 Organic Fine Sand (OFS)	
 Sand-Silt-Clay	 Stain	 Silty-Sand (SS)	
 Sandy-Clay	 Round Brown Stain	 Silty-Sand (SS)	
 Silt	 Thin band of Unique Sediment	 Silty-Sand (SS)	
 Clayey-Silt	 Clay Nodule	 Silty-Sand (SS)	
 Silty-Clay	 Silty/Clay Lenses	 Silty-Sand (SS)	
 Clay	 Platy Material	 Silty-Sand (SS)	
	 Fining Upwards	 Silty-Sand (SS)	
	 Lamination	 Silty-Sand (SS)	
	 Contact	 Silty-Sand (SS)	
	 Transition	 Silty-Sand (SS)	
	 Lenticular	 Silty-Sand (SS)	
	 Color Specific Interval	 Silty-Sand (SS)	
	 Sample	 Silty-Sand (SS)	

BK103 BK101

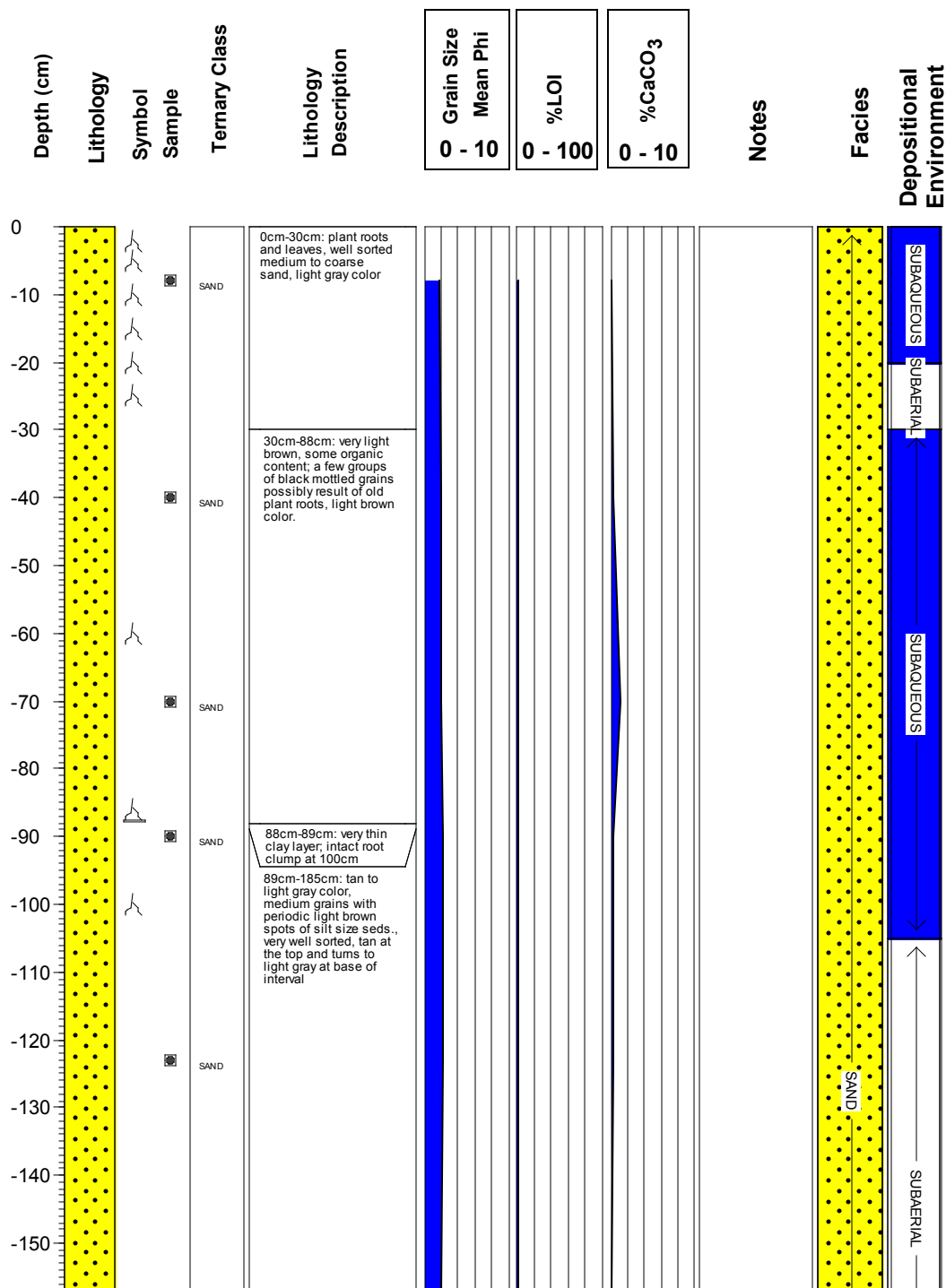


Described by Date/Person: 7-27-98/NTD

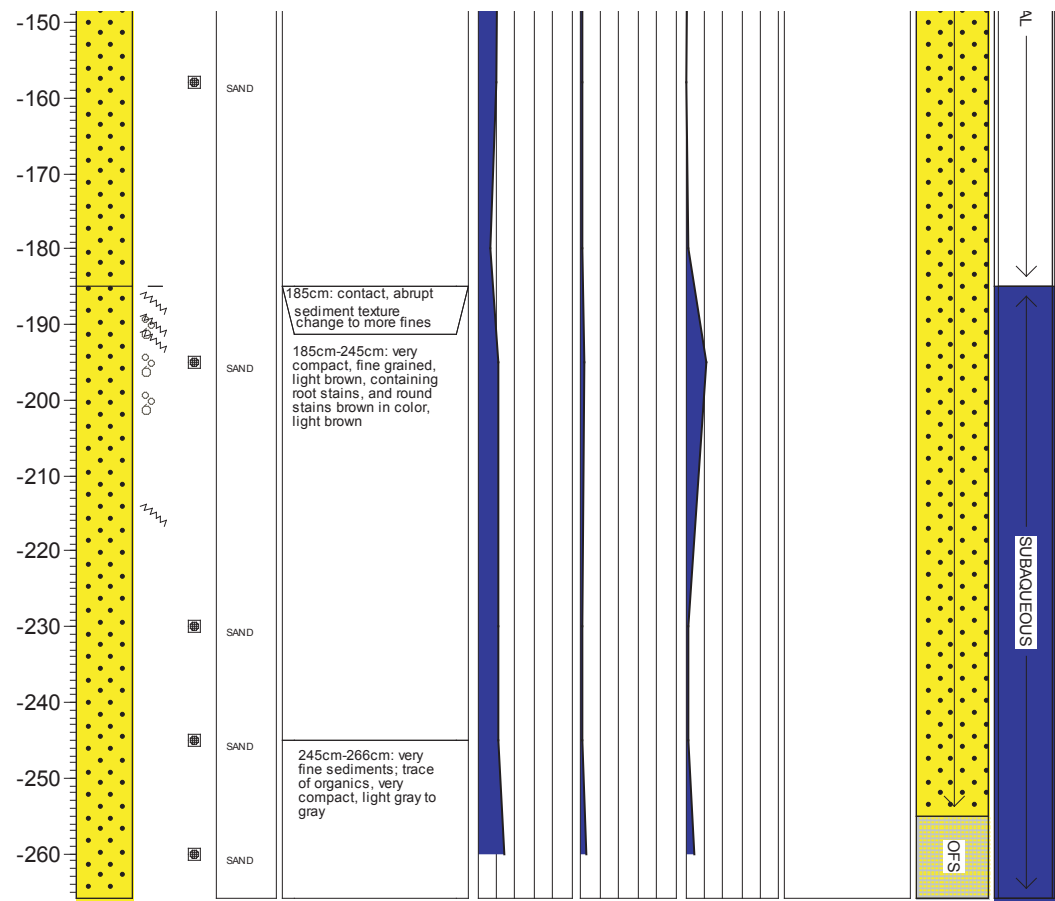
Core Recovery: 2.66m

Core Penetration: 3.20m

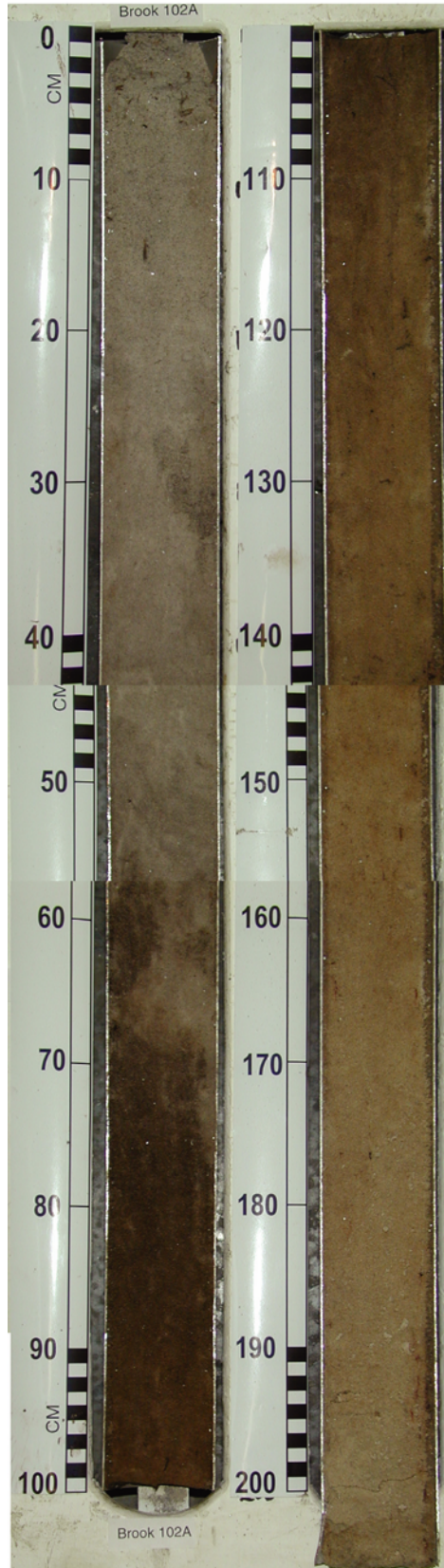
Geographic Location: Brooklyn Lake
Clay County, FL



BK101 Continued



BK102A

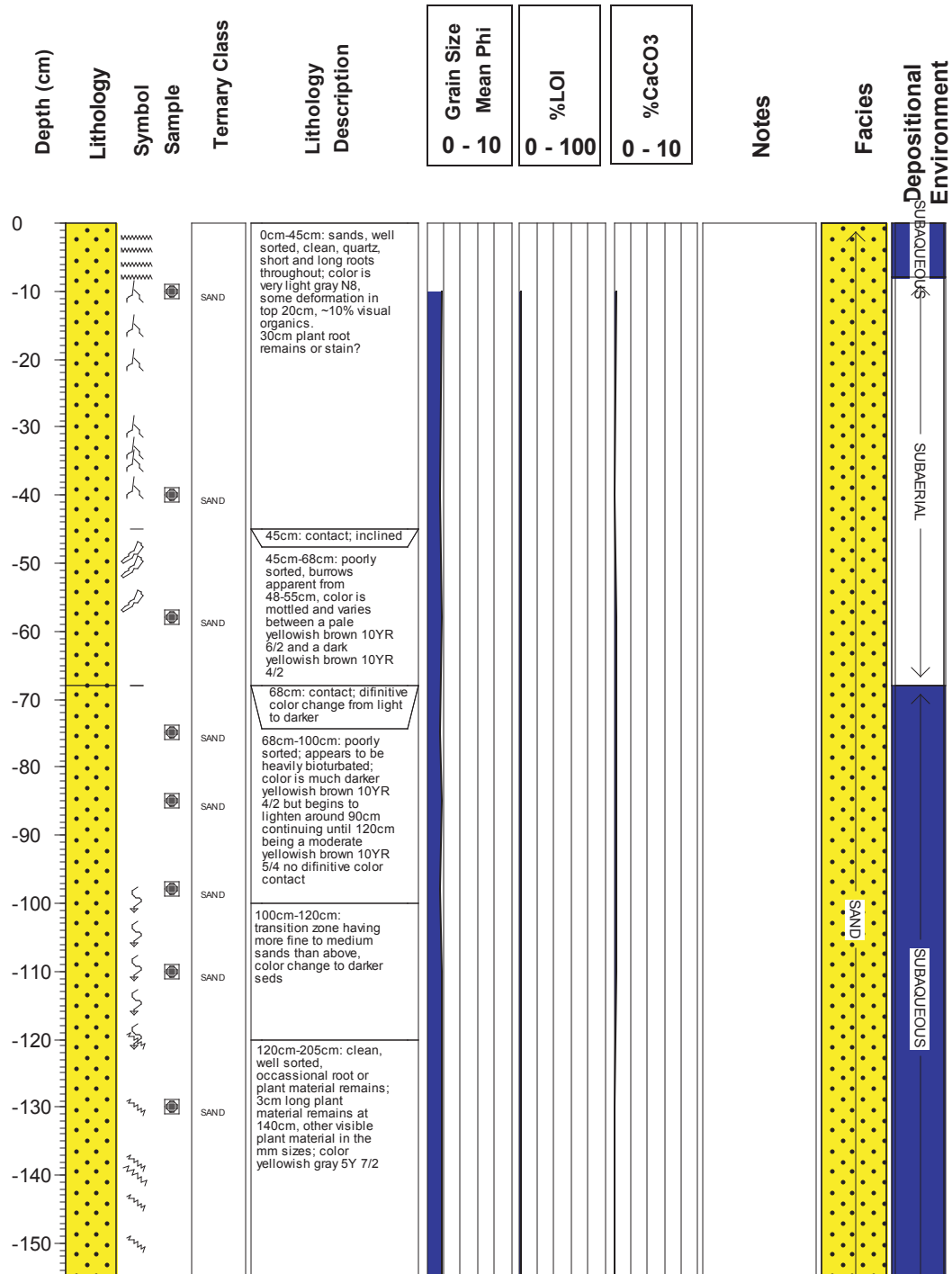


Described by Date/Person: 9-7-02/NTD

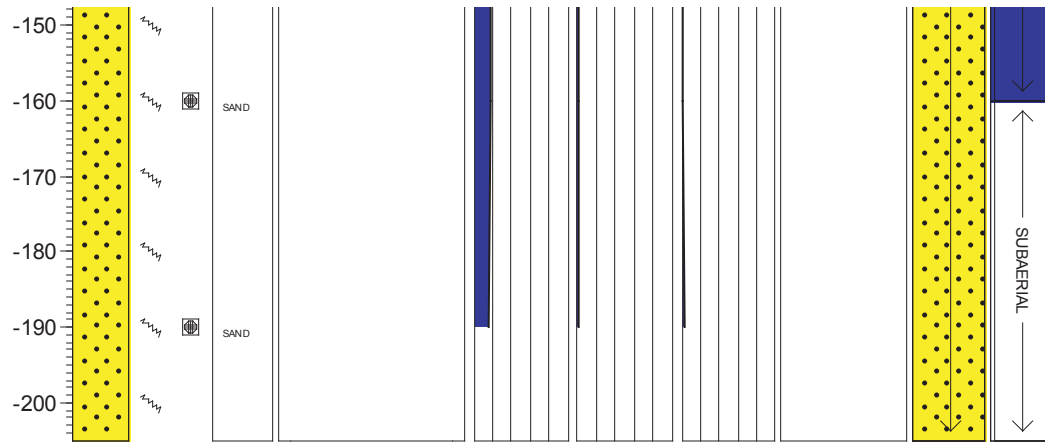
Core Recovery: 2.05 m

Core Penetration: 2.05 m

Geographic Location: Brooklyn Lake
Clay County, FL



BK102a Continued



Core ID: **BK 103**

Described by Date/Person: **7-30-98/NTD**

Latitude: **29d 47.938' N**

Core Recovery: **2.16 m**

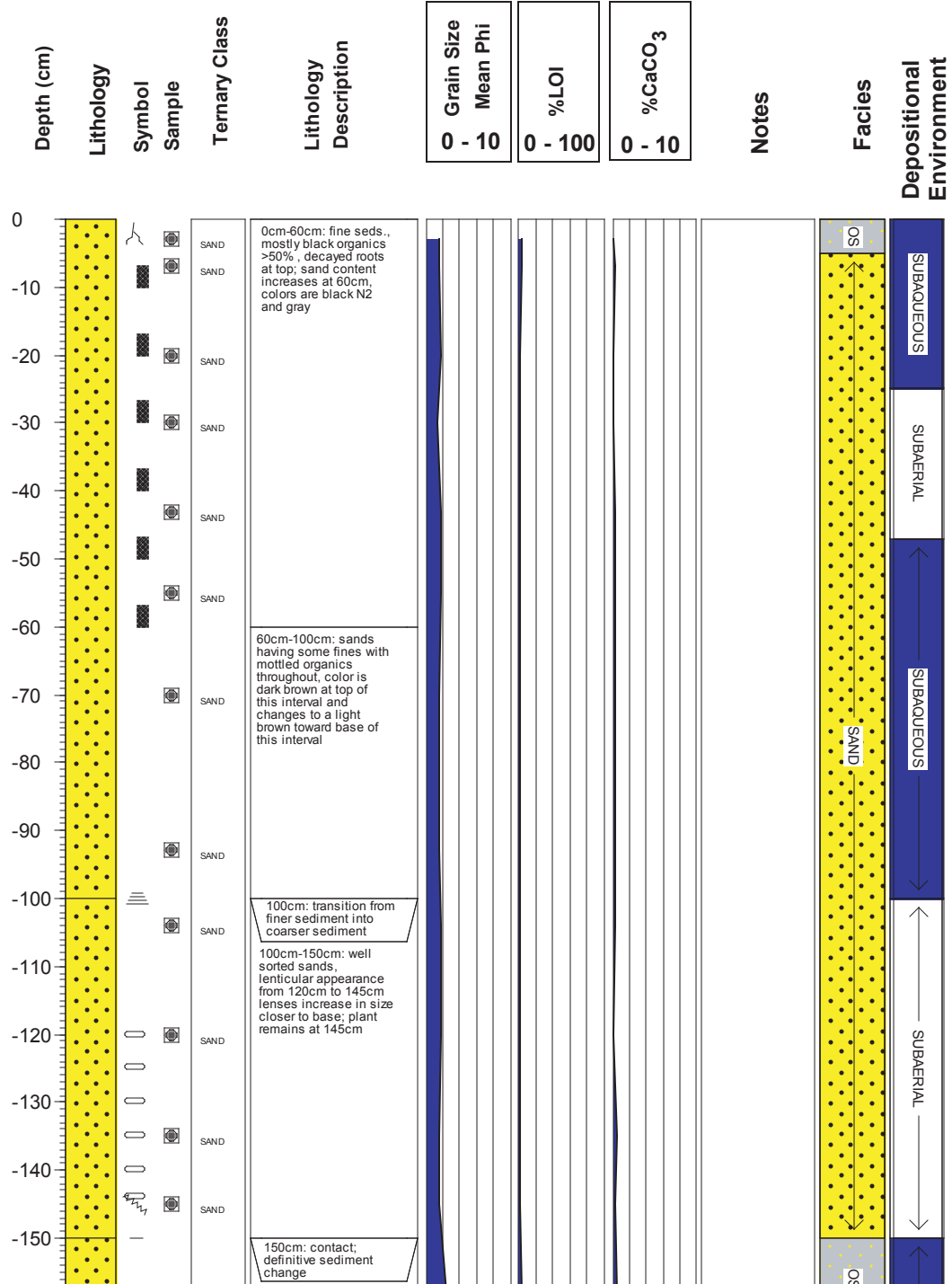
Longitude: **82d 02.124' W**

Core Penetration: **2.56 m**

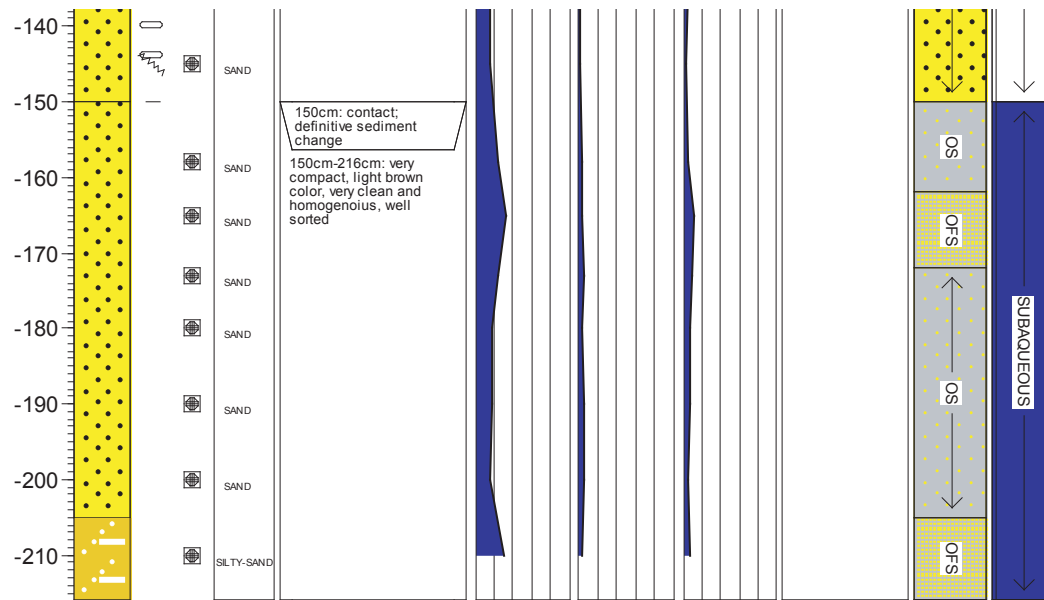
Date Vibracored: **5-20-1998**

Geographic Location: **Brooklyn Lake**

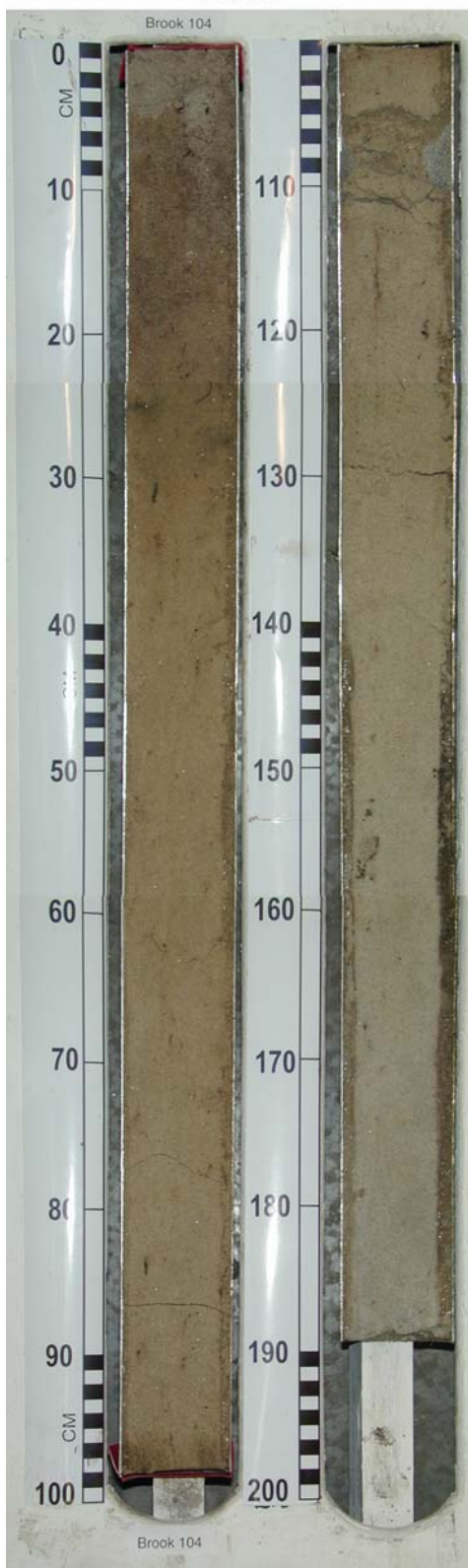
Clay County, FL



BK103 Continued



BK104

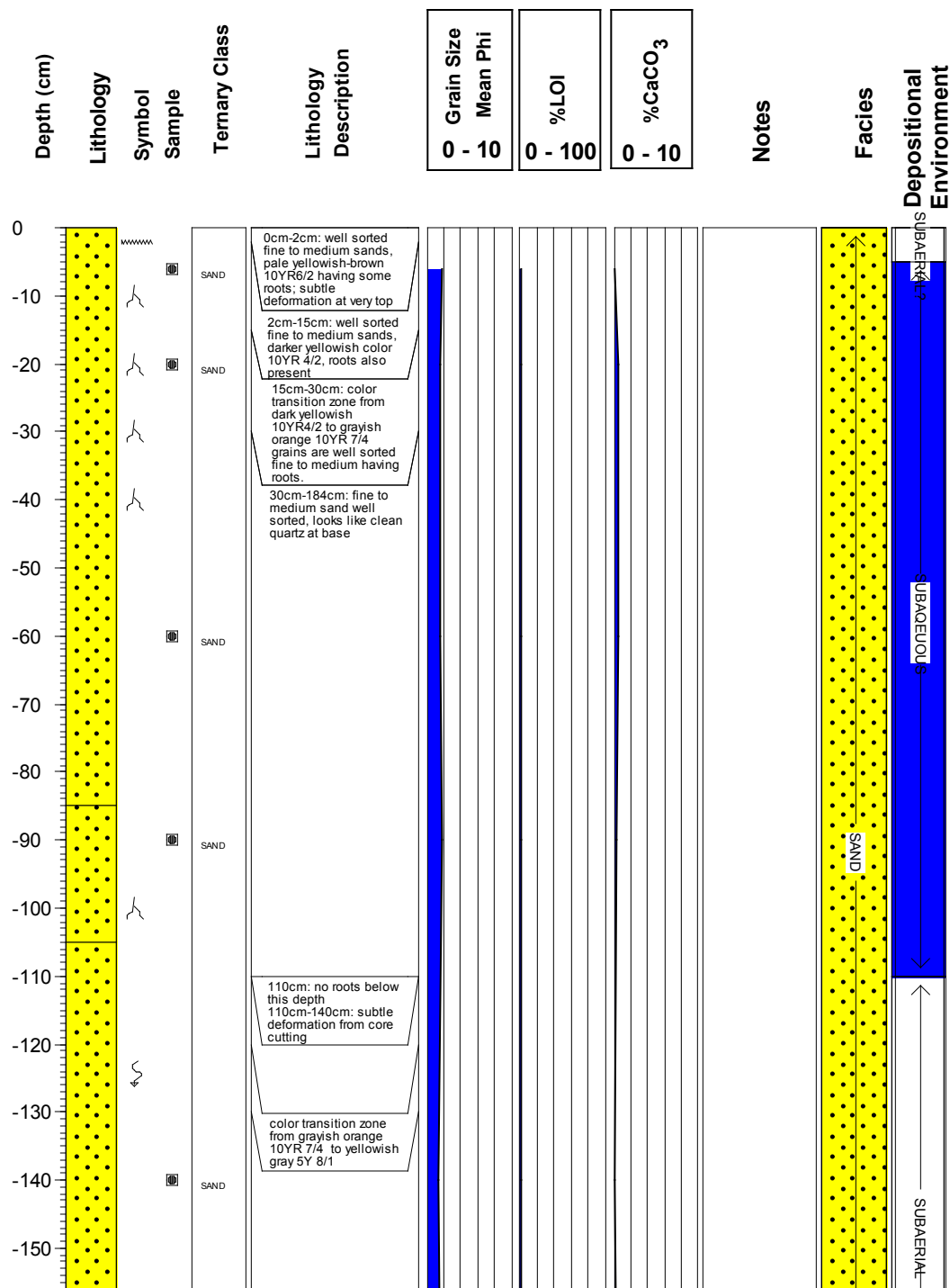


Described by Date/Person: 9-4-02/NTD

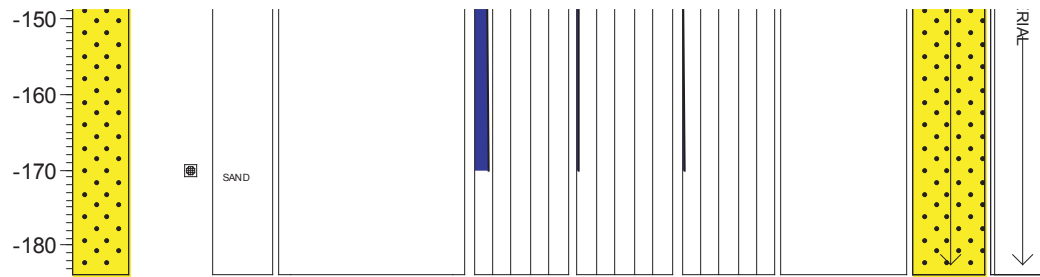
Core Recovery: 1.83 m

Core Penetration: 3.30 m

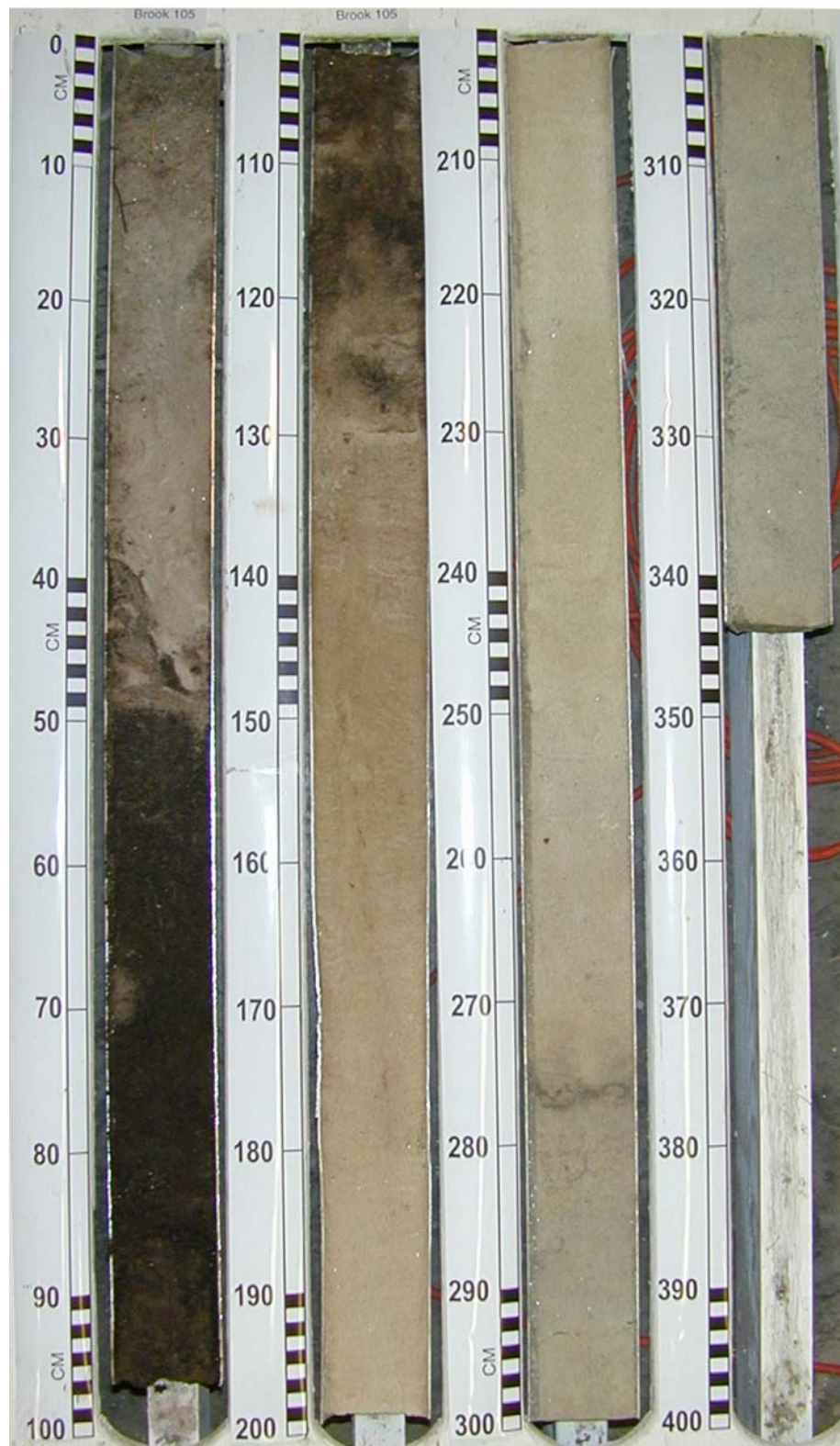
Geographic Location: Brooklyn Lake
Clay County, FL



BK104 Continued



BK105



Core ID: **BK 105**

Described by Date/Person: **9-13-02/NTD**

Latitude: **29d 47.862' N**

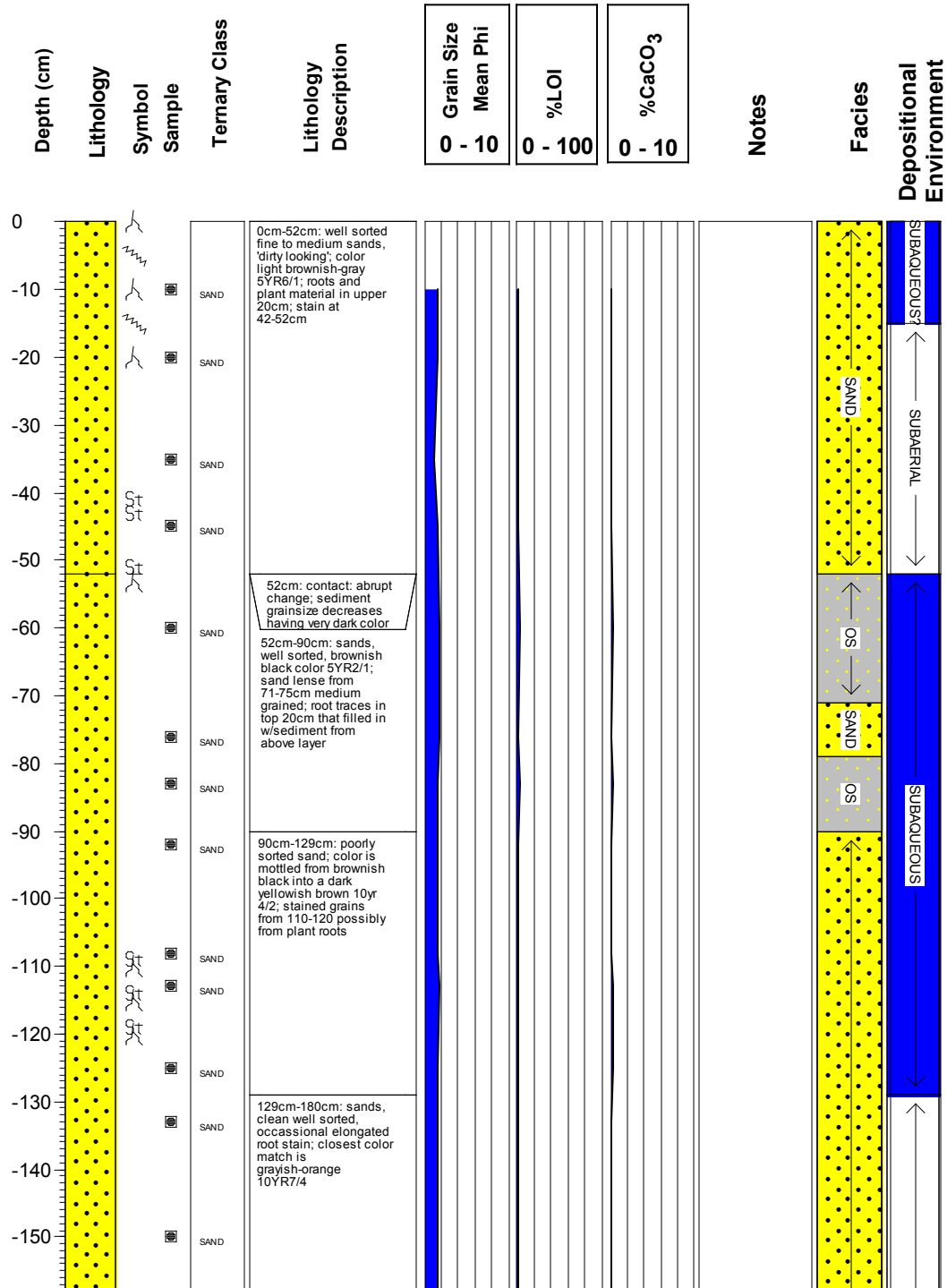
Core Recovery: **3.44 m**

Longitude: **82d 02.019' W**

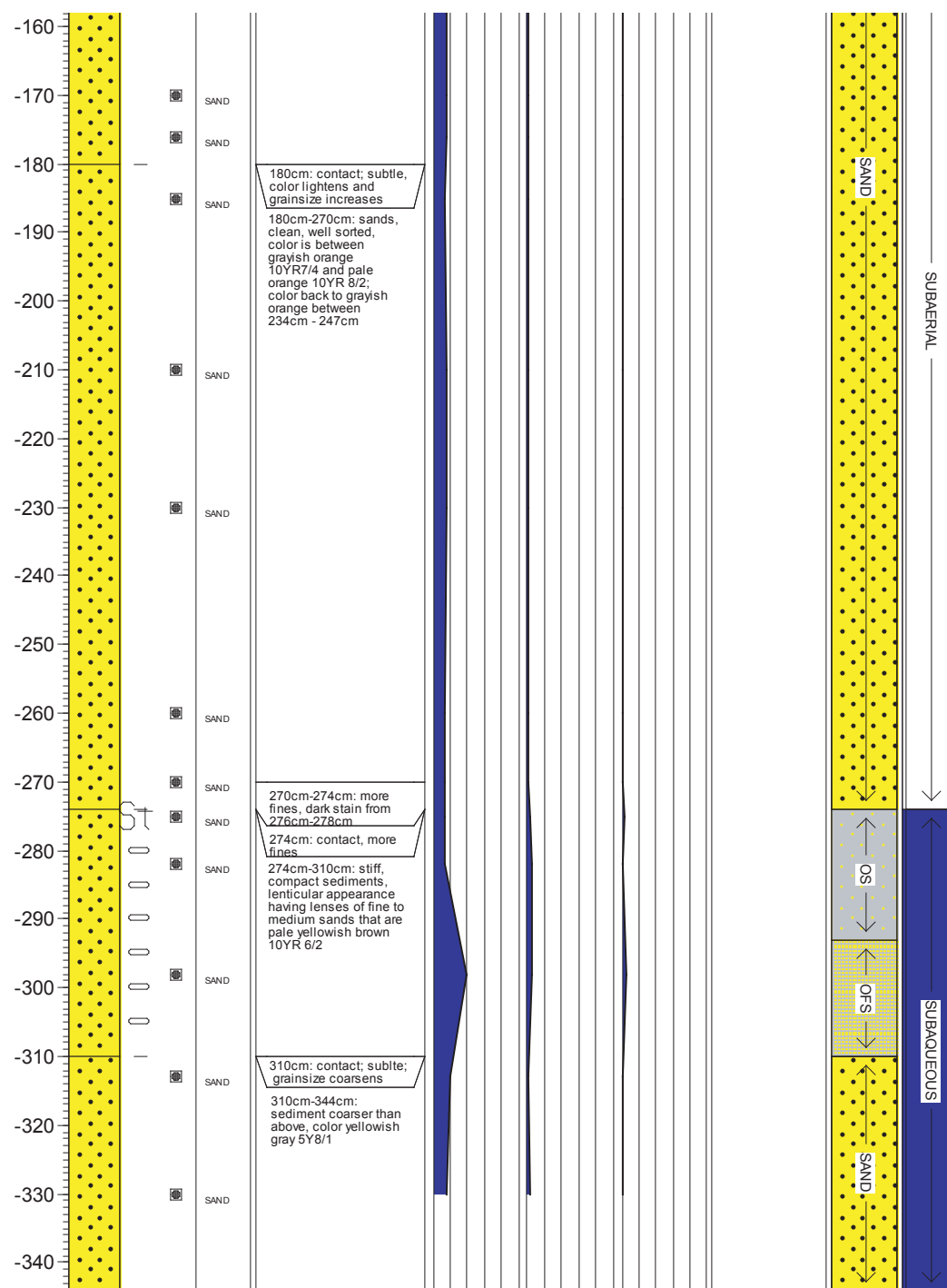
Core Penetration: **5.88 m**

Date Vibracored: **4-4-00**

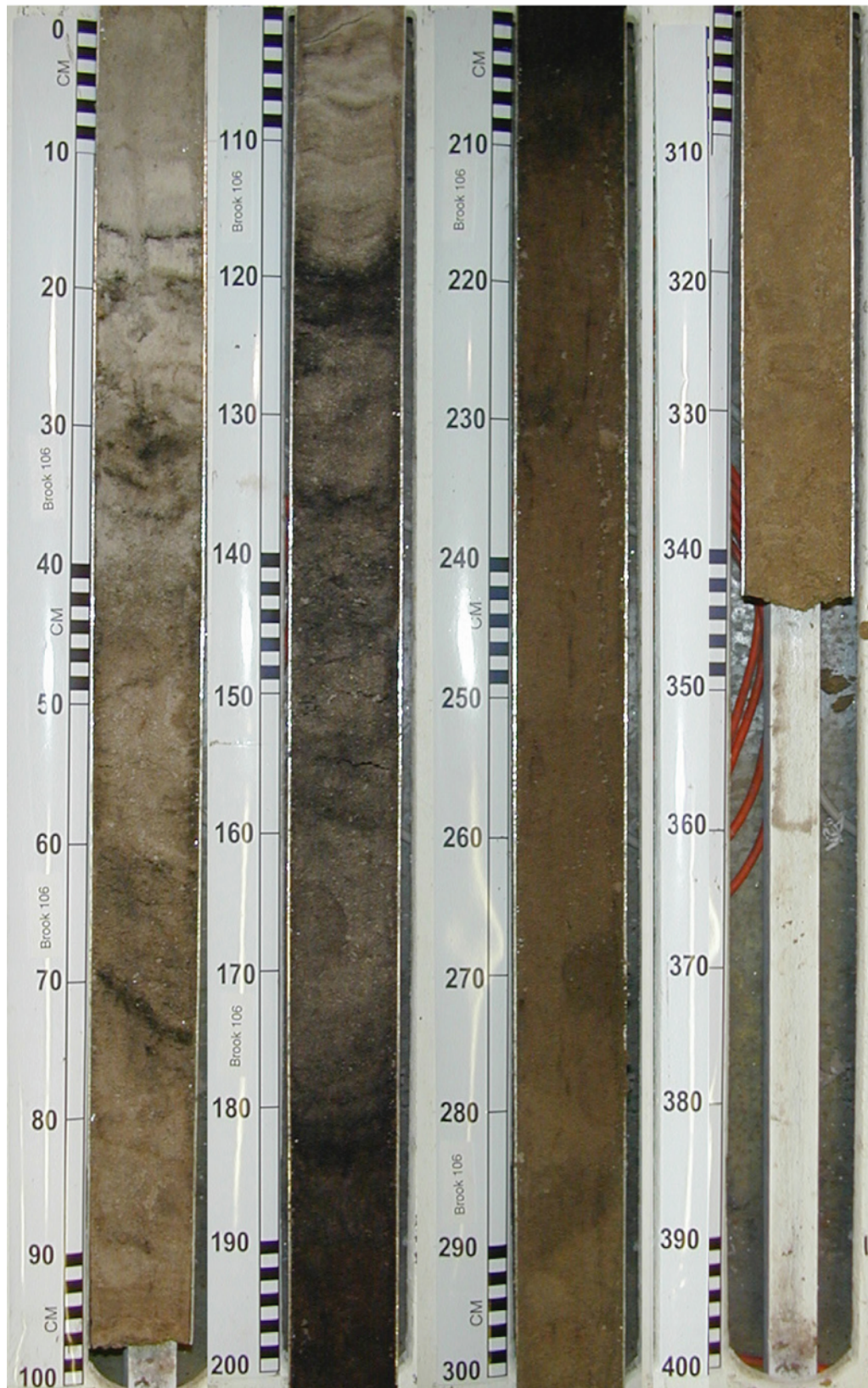
Geographic Location: **Brooklyn Lake**
Clay County, FL



BK105 Continued



BK106



Core ID: **BK 106**

Described by Date/Person: **9-9-02/NTD**

Latitude: **29d 47.841' N**

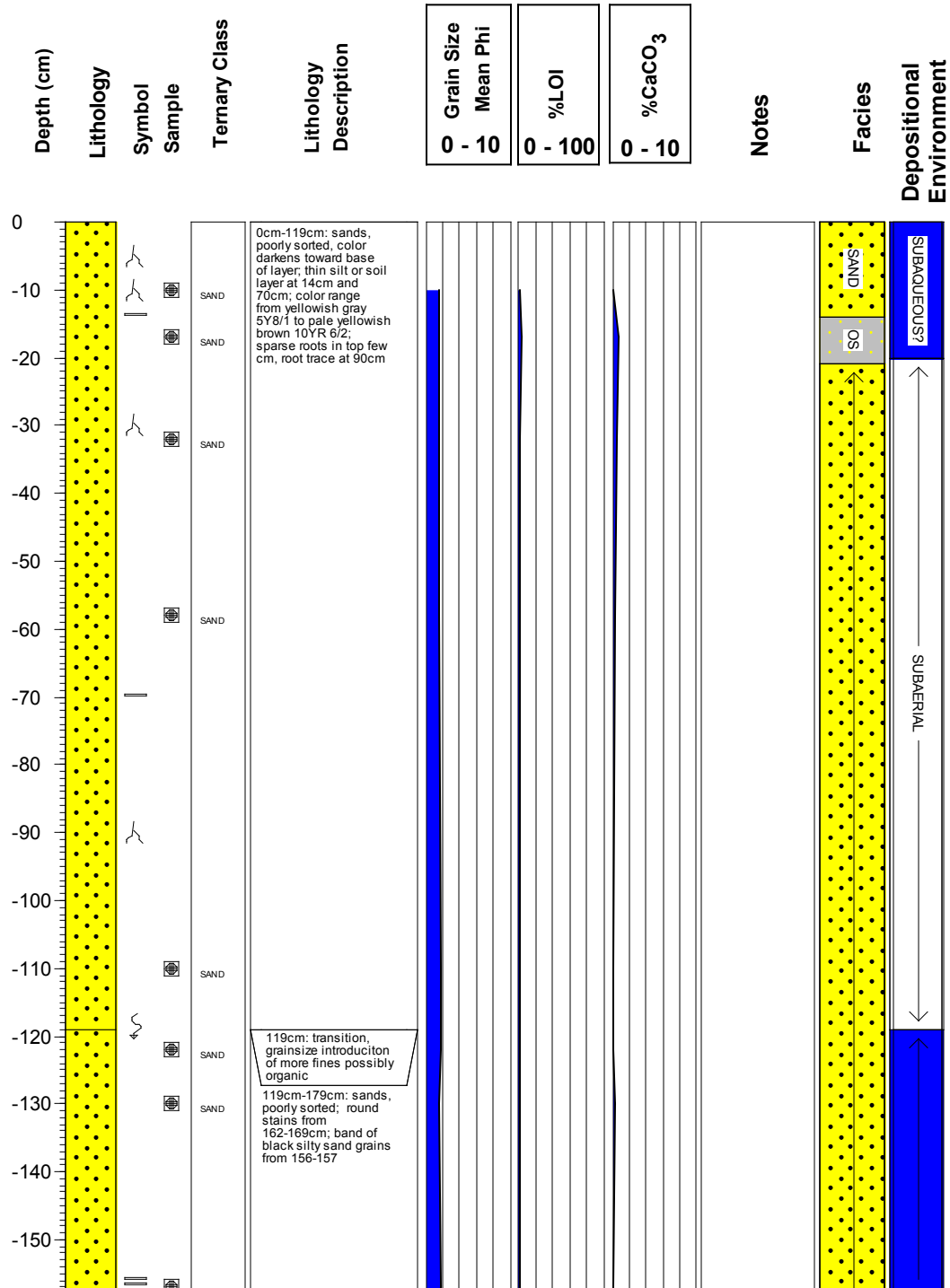
Core Recovery: **3.42 m**

Longitude: **82d 02.014' W**

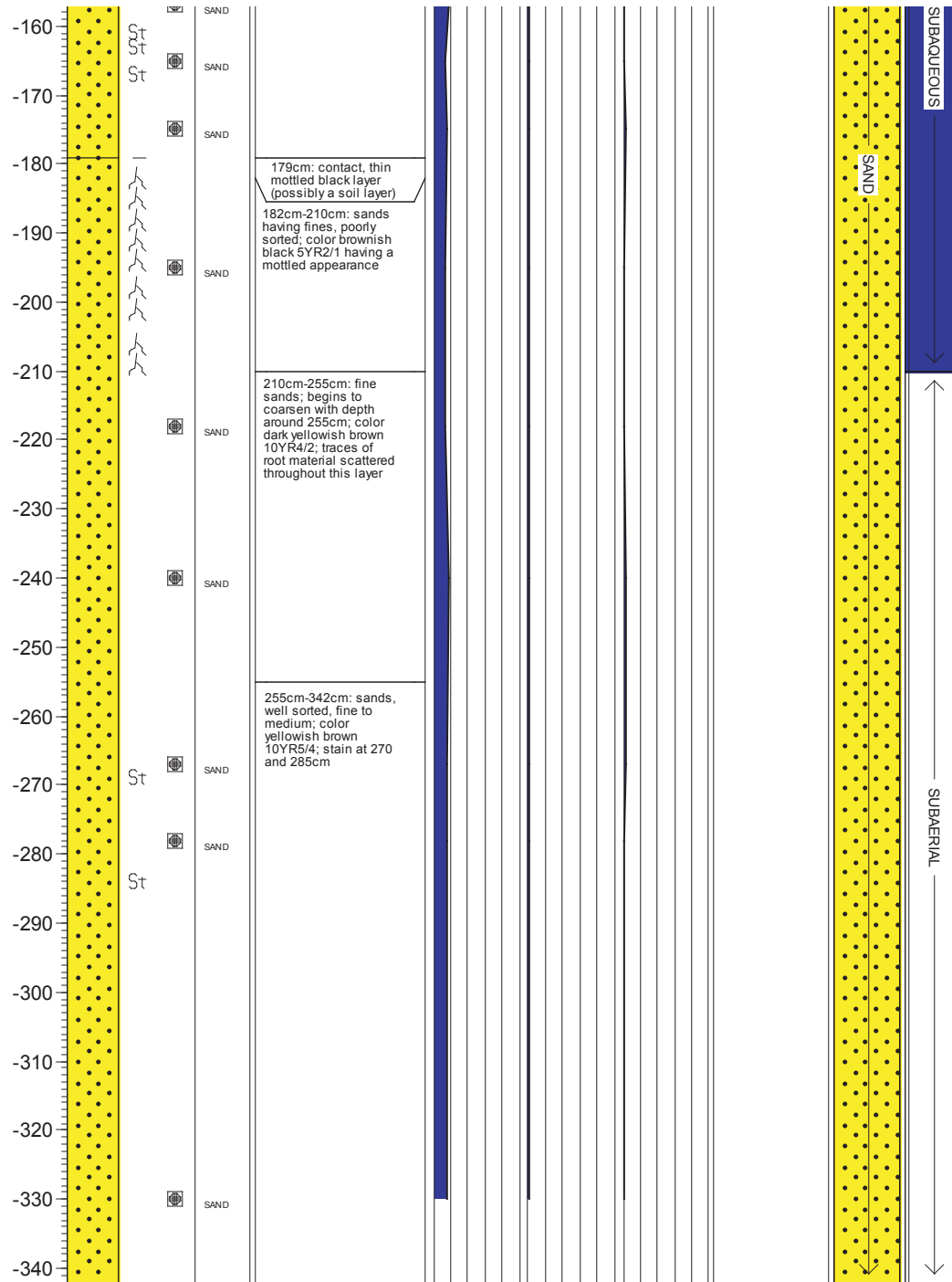
Core Penetration: **5.39 m**

Date Vibracored: **4-4-00**

Geographic Location: **Brooklyn Lake**
Clay County, FL



BK106 Continued



BK107



Core ID: BK 107

Latitude: 29d 47.837' N

Longitude: 82d 02.010' W

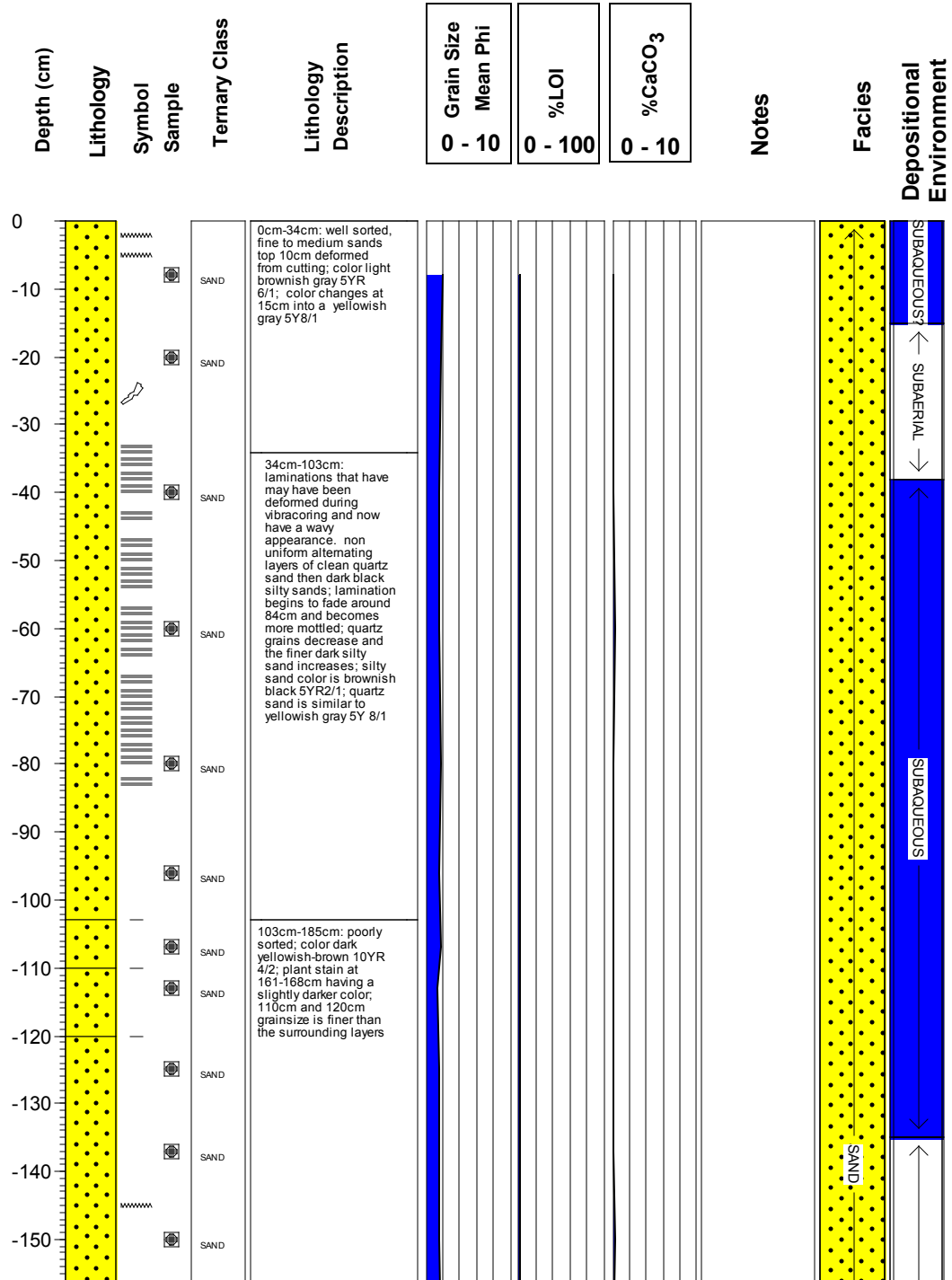
Date Vibracored: 4-6-00

Described by Date/Person: 9-9-02/NTD

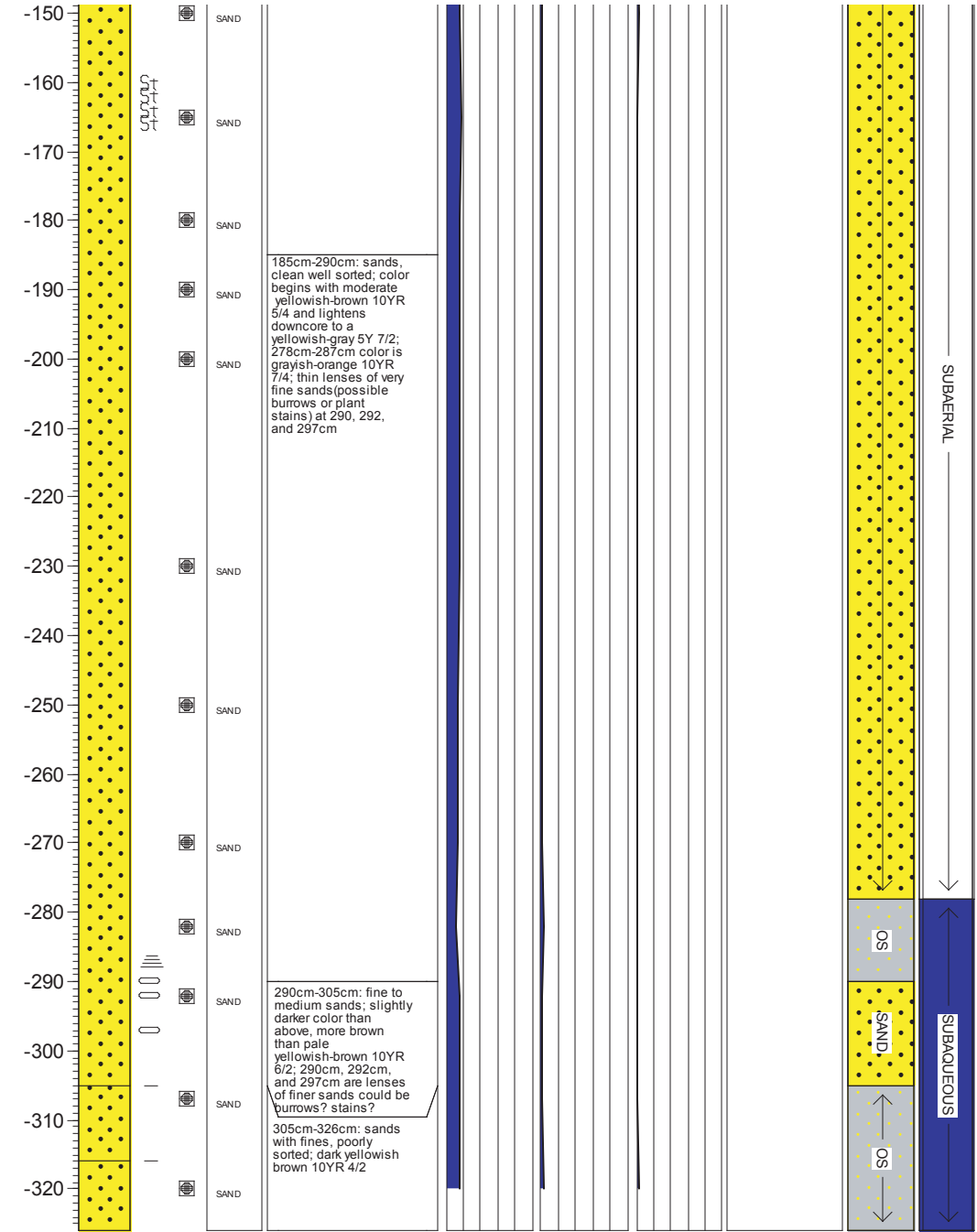
Core Recovery: 3.26 m

Core Penetration: 4.75 m

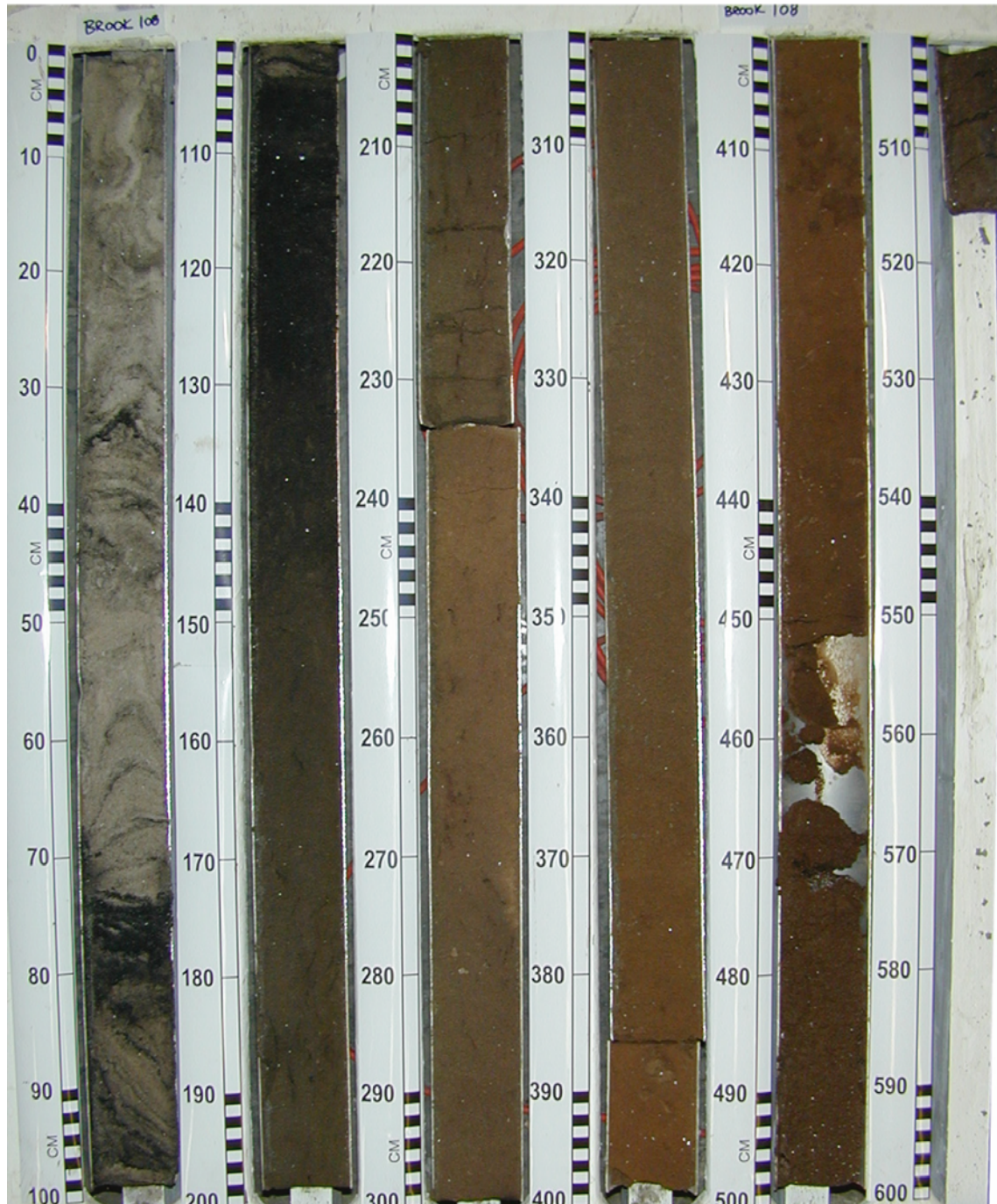
Geographic Location: Brooklyn Lake
Clay County, FL



BK107 Continued



BK108



Core ID: **BK 108**

Described by Date/Person: **9-14-02/NTD**

Latitude: **29d 47.821' N**

Core Recovery: **5.14 m**

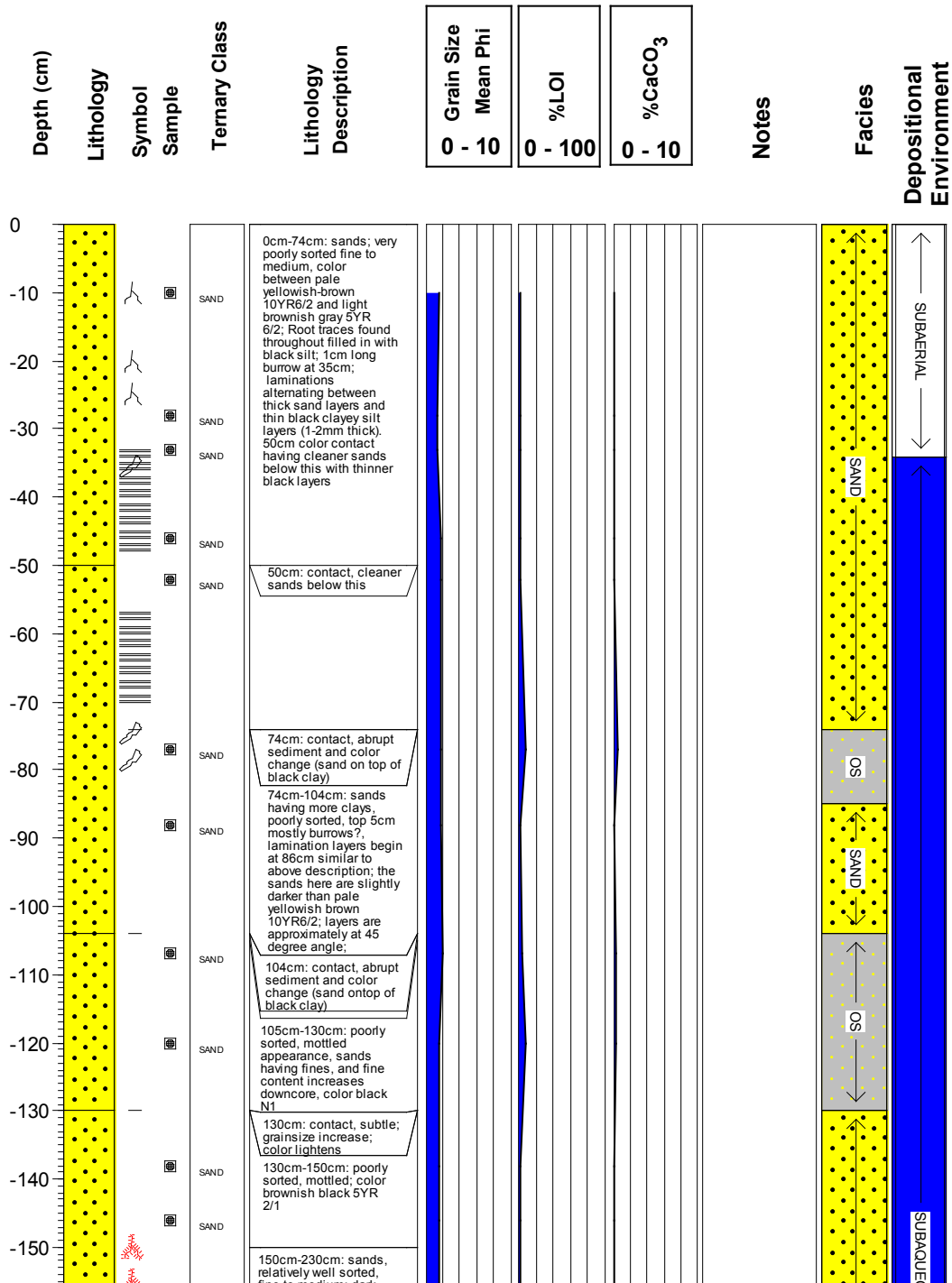
Longitude: **82d 01.991' W**

Core Penetration: **5.99 m**

Date Vibracored: **4-6-00**

Geographic Location: **Brooklyn Lake**

Clay County, FL



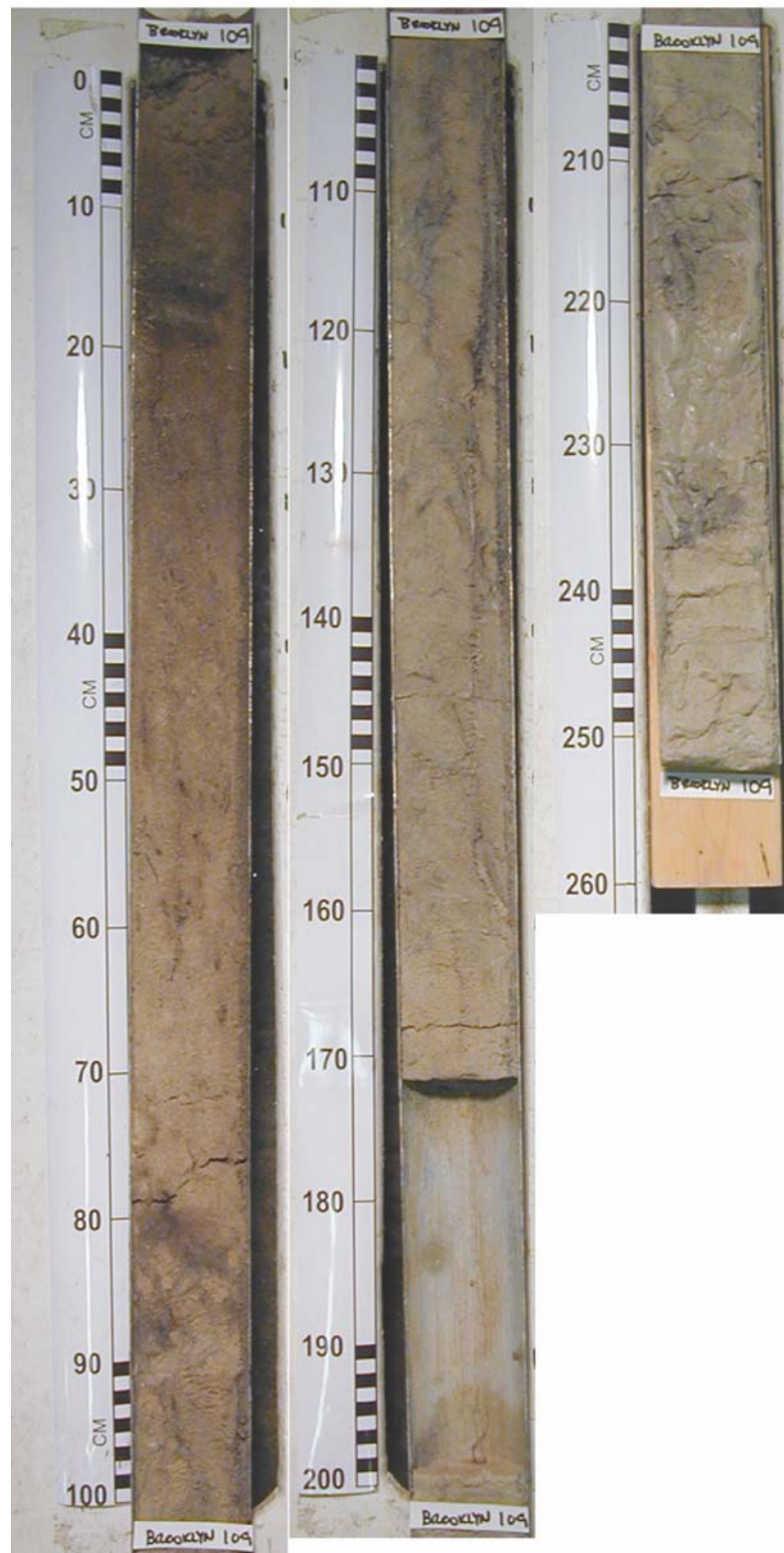
Stratigraphic Column Data:

Depth Range (cm)	Description
-150cm to -230cm	sands, relatively well sorted, fine to medium; dark yellowish brown 10YR 2/2; root traces throughout which have a dark reddish stain surrounding them
-230cm to -270cm	fine sands having coarse silts, color a shade lighter than above layer between dark yellowish brown 10YR 4/2 and moderate yellowish brown 10YR 5/4; same root traces with reddish stain in this layer
-270cm to -275cm	contact visible, angled; color darkens; grain size increases
-275cm to -340cm	sands, fine to medium, clean, relatively well sorted, color dark yellowish brown 10YR 4/2
-340cm to -360cm	contact, subtle, color change and increase in fines moderate brown color 5YR 3/4; from 389 cm to 418 cm there are clay lenses light color, some darker having a red tint

Mineralogy (334cm):
coarse=quartz;
fine=quartz

Geological profile of the 1950s test pit showing depth from -370 to -510 cm. The profile includes a yellow dotted sand layer, a gray subaqueous layer, and a blue contact layer. A scale bar on the left shows depth in centimeters. A legend on the right identifies the layers: SAND (yellow dotted), SUBAQUEOUS (gray), and CONTACT (blue). A note at the bottom states: "500cm: contact subtle; color change only".

BK109



Core ID: **BK 109**

Described by Date/Person: **9-7-02/NTD**

Latitude: **29d 47.756' N**

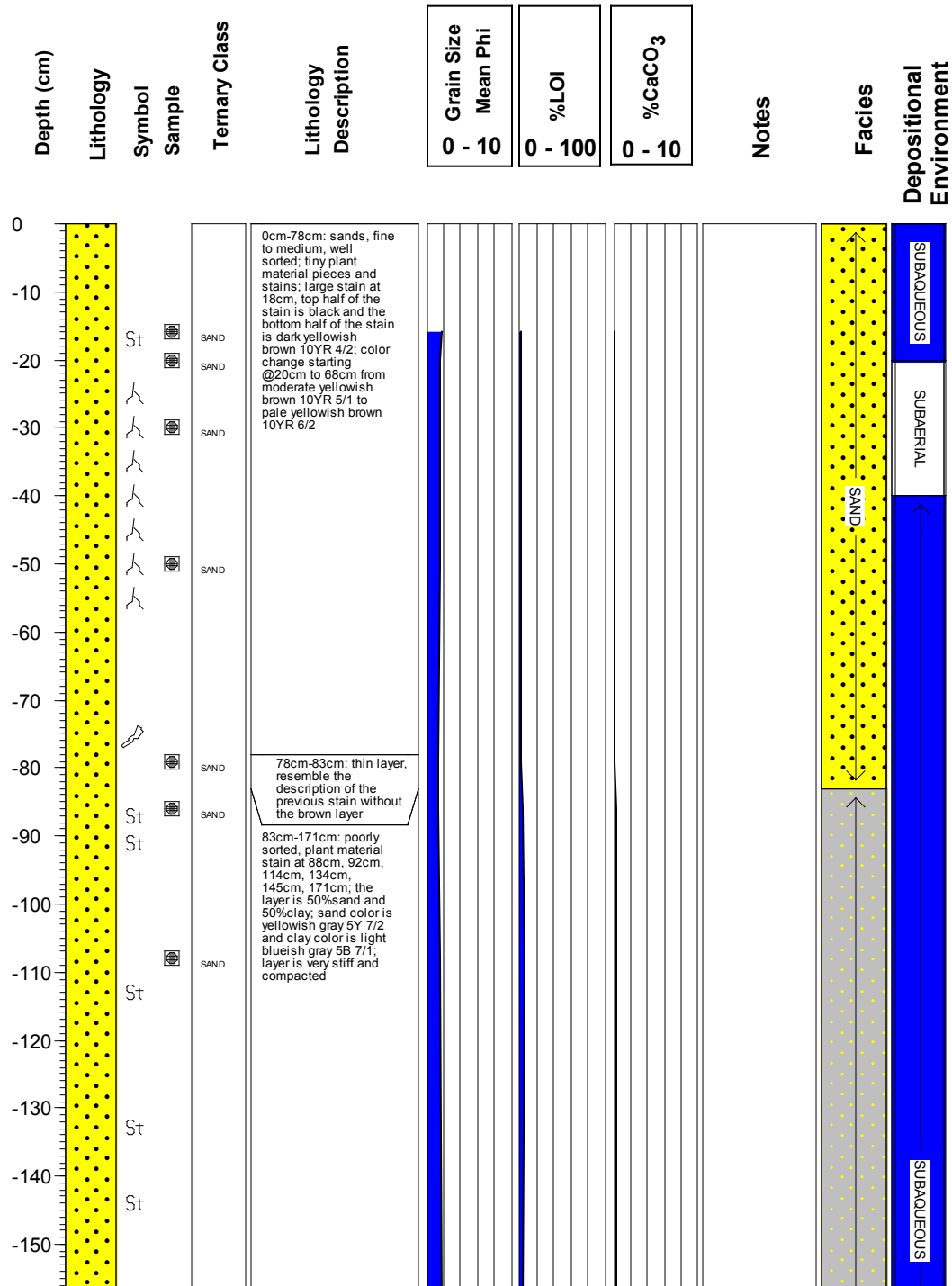
Core Recovery: **2.50 m**

Longitude: **82d 01.943' W**

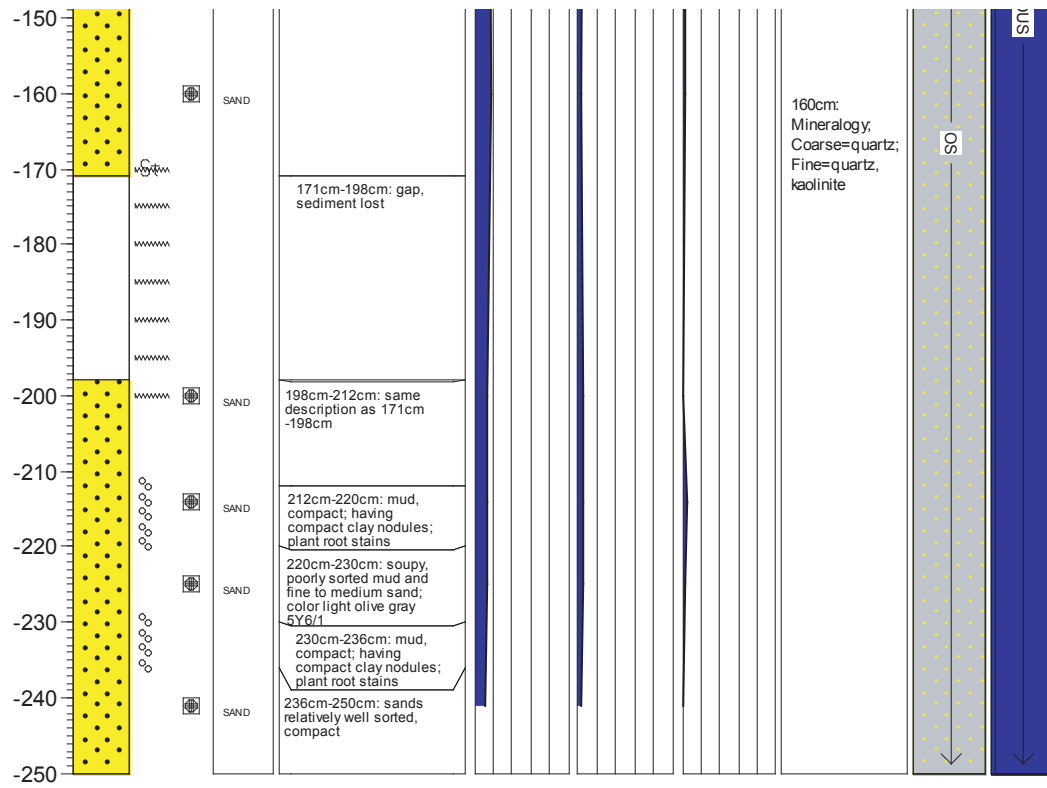
Core Penetration: **2.85 m**

Date Vibracored: **4-6-00**

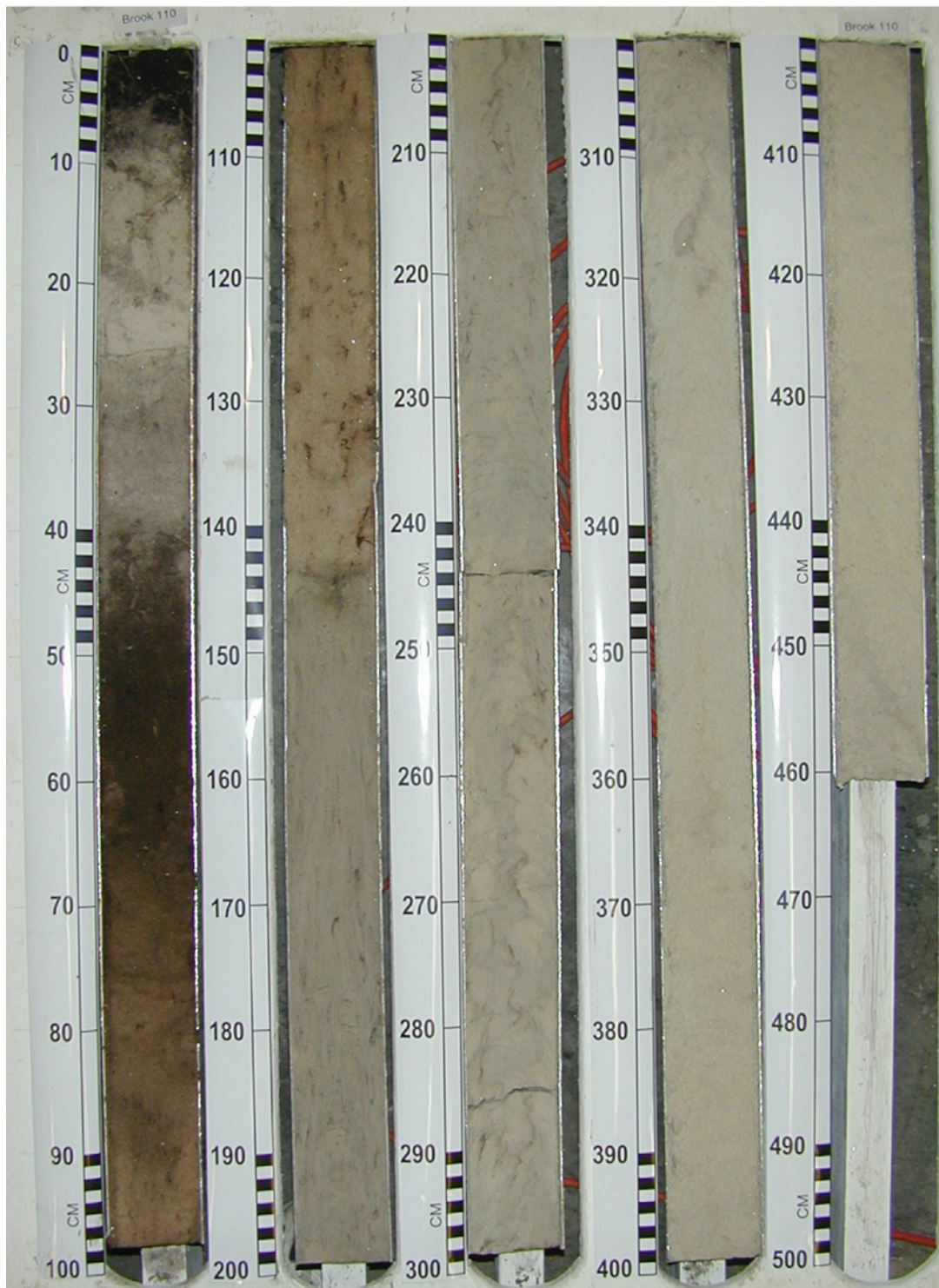
Geographic Location: **Brooklyn Lake**
Clay County, FL



BK109 Continued



BK110



Core ID: BK 110

Described by Date/Person: 9-13-02/NTD

Latitude: 29d 47.744' N

Core Recovery: 4.61 m

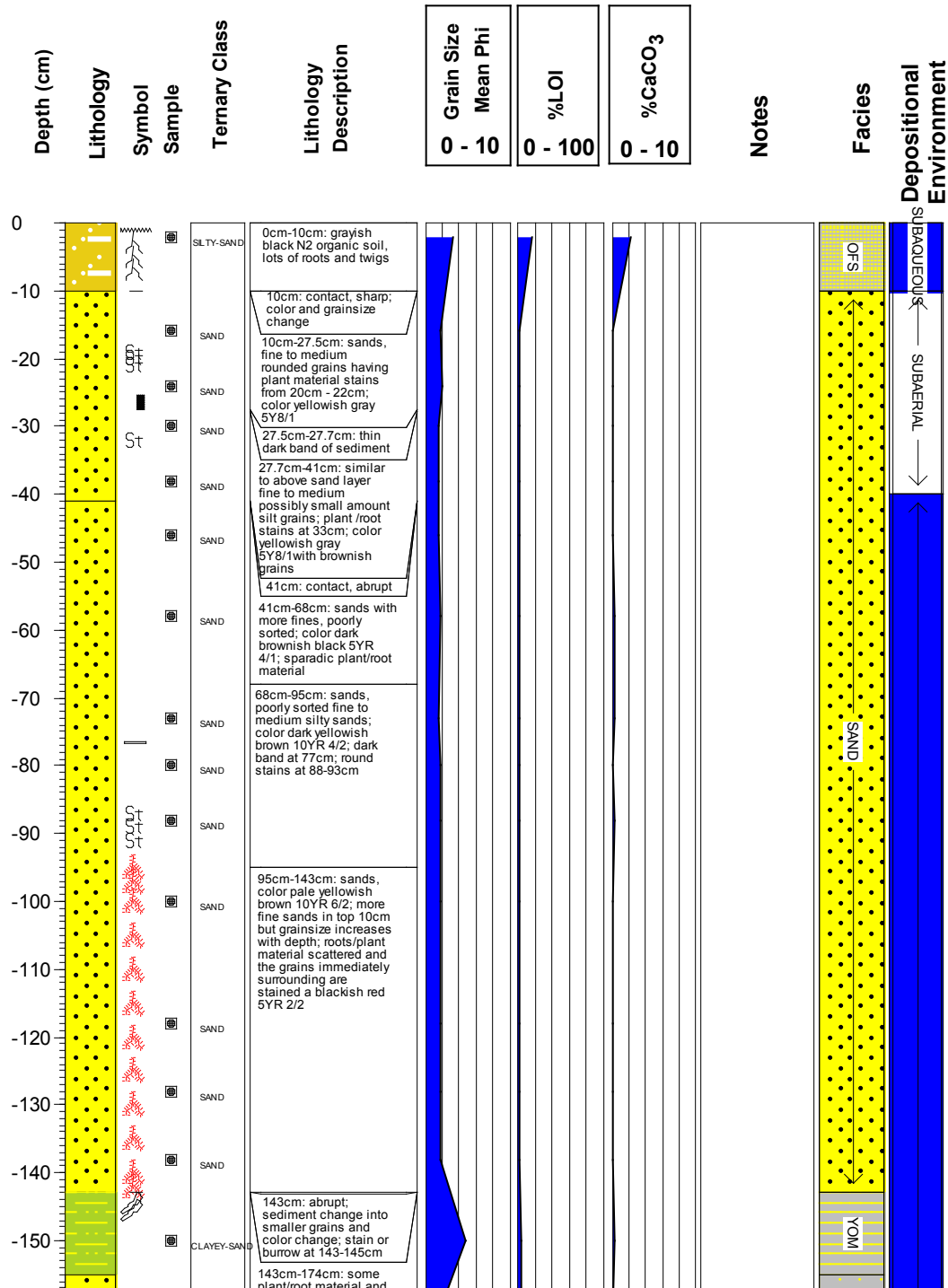
Longitude: 82d 01.936' W

Core Penetration: 5.23 m

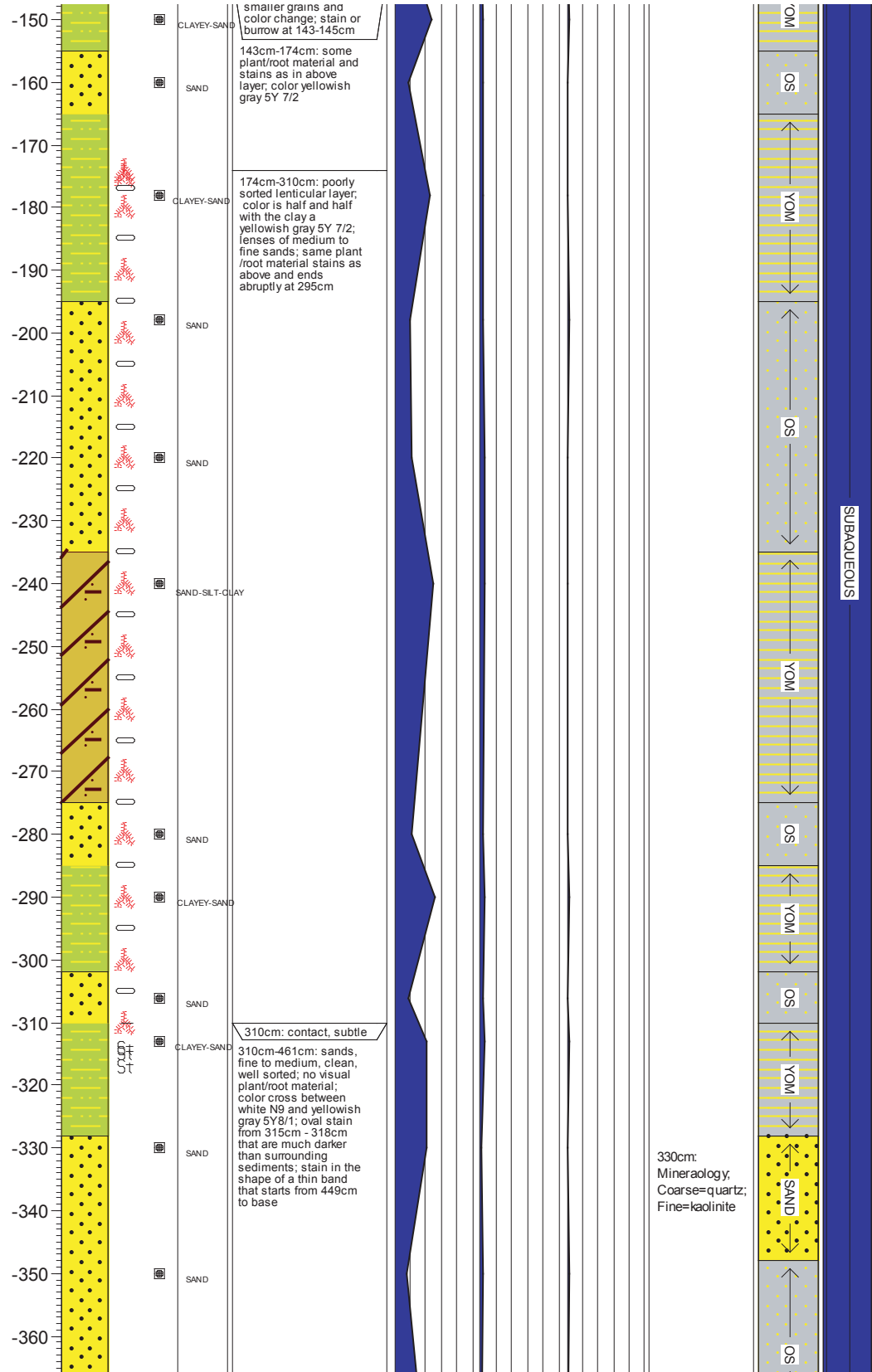
Date Vibracored: 4-6-00

Geographic Location: Brooklyn Lake

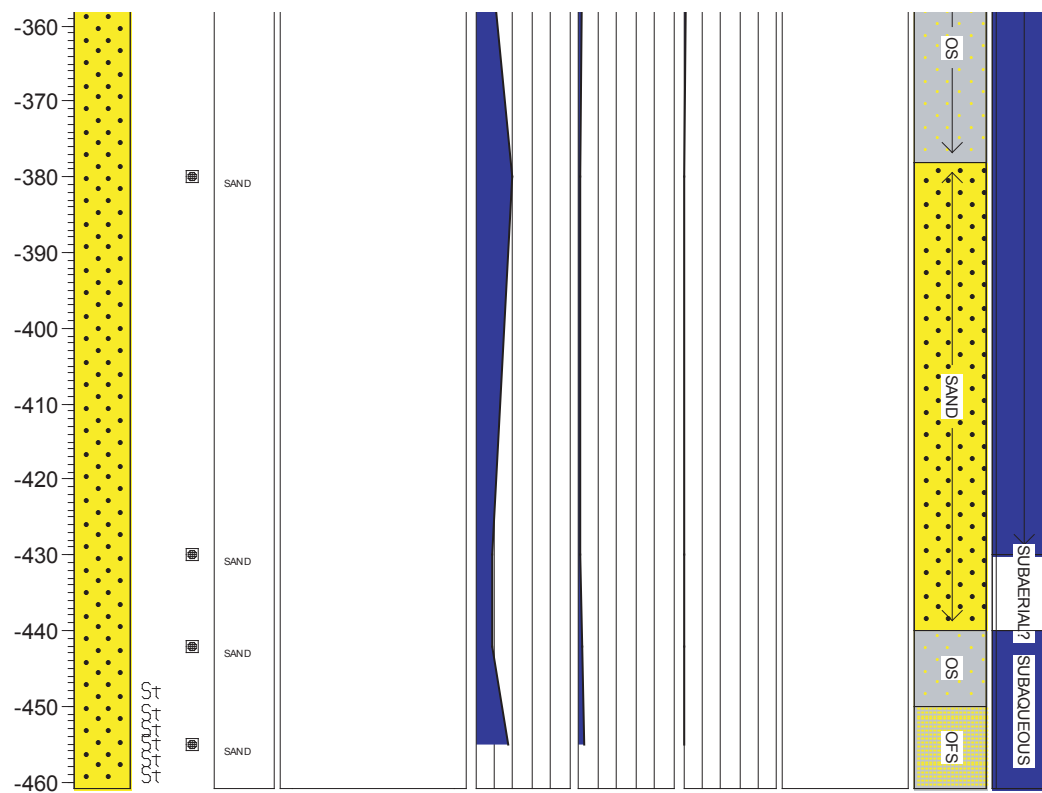
Clay County, FL



BK110 Continued



BK110 Continued



BK 111



Core ID: BK 111

Described by Date/Person: 9-6-02/NTD

Latitude: 29d 47.799' N

Core Recovery: 2.18 m

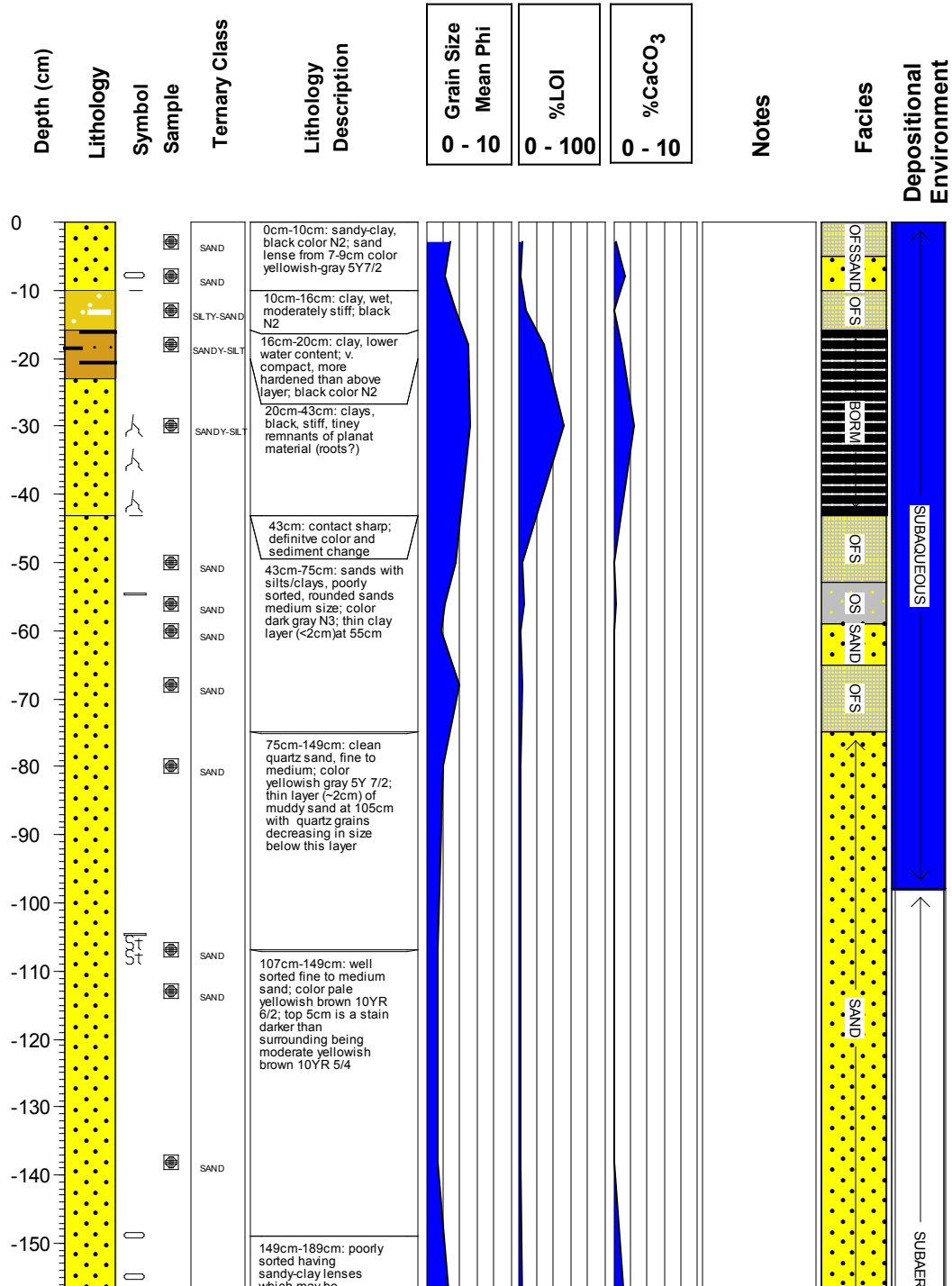
Longitude: 82d 01.978' W

Core Penetration: 4.52 m

Date Vibracored: 7-17-00

Geographic Location: Brooklyn lake

Clay County, FL



149cm-189cm: poorly sorted having sandy-clay lenses which may be burrows?; color medium dark gray N4 whereas the silty sand color is moderate yellow brown 10YR 5/4 to pale yellow brown 10YR 6/2

189cm-201cm: thin layer, well sorted fine to medium sands; color pale yellowish-brown 10YR 6/2; 198-199cm slightly darker color with no apparent sediment character differences

201cm-203cm: poorly sorted, very stiff and compact clay; color medium dark gray N4 almost a dark bluish-white 5B9/1

203cm-212cm: sands with fines, poorly sorted, possible filled burrows at 209 and 210cm

212cm: contact, visually subtle

212cm-218cm: very hard compact clay layer; color very light gray N8 (almost a dark bluish white 5B9/1)

SUBAQUEOUS

BK 112



Core ID: BK 112

Latitude: 29d 47.792' N

Longitude: 82d 01.977' W

Date Vibracored: 7-19-00

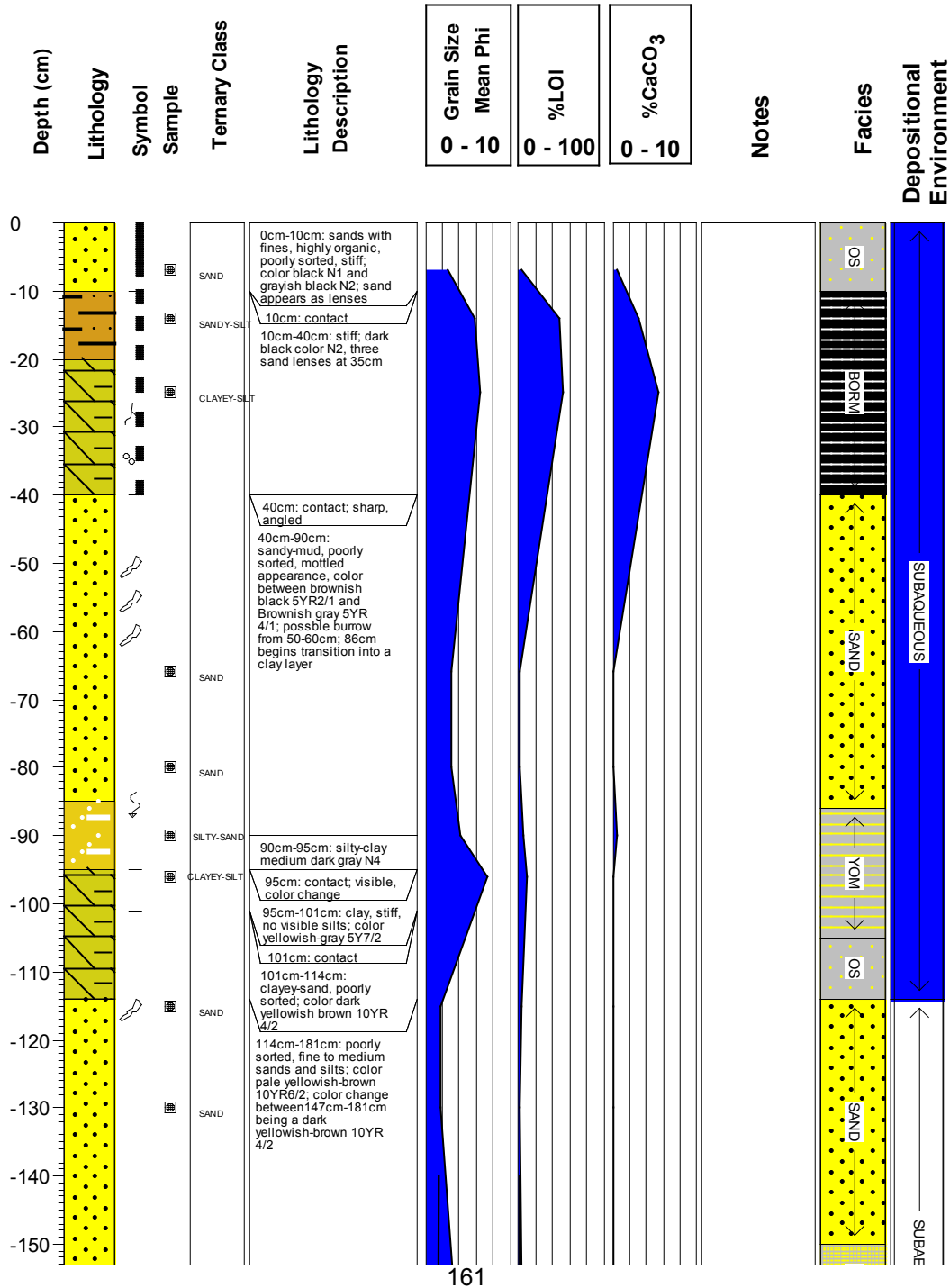
Described by Date/Person: 9-5-02/NTD

Core Recovery: 3.52 m

Core Penetration: 4.55 m

Geographic Location: Brooklyn Lake

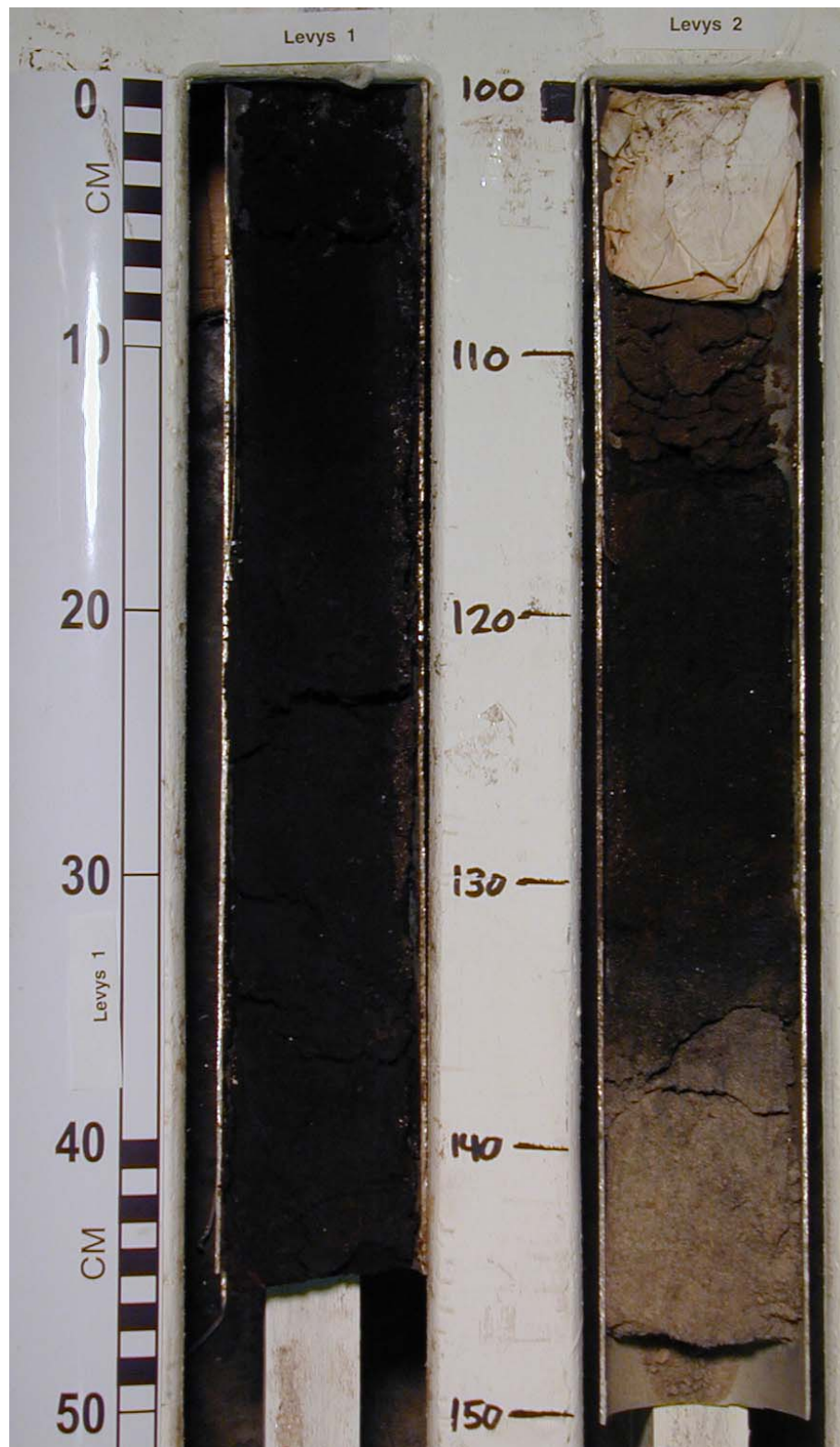
Clay County, FL



181cm-352cm: fine to medium; color moderate yellowish-brown 10YR 5/4 which begins to lighten downcore becoming less brown and more pale yellow (btwn grayish orange 10YR 7/4 and pale yellowish brown 10YR 6/2); Contact at 190cm color change only

SUBAQUEOUS

UBAERIAL



Core ID: **LP1**

Described by Date/Person: **10-18-00/NTD**

Latitude: **29d 38.411' N**

Core Recovery: **0.46 m**

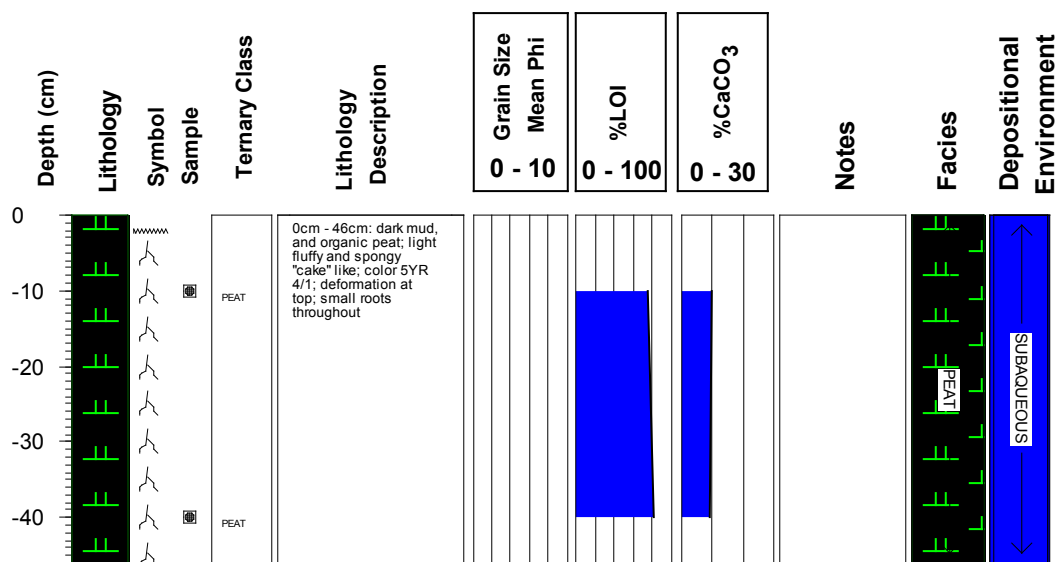
Longitude: **82d 00.698' W**

Core Penetration: **3.45 m**

Date Vibracored: **2-24-00 (pushed)**

Geographic Location: **Levys Prairie**

Putnam County, Florida



Core ID: **LP2**

Described by Date/Person: **10-18-00/NTD**

Latitude: **29d 38.409' N**

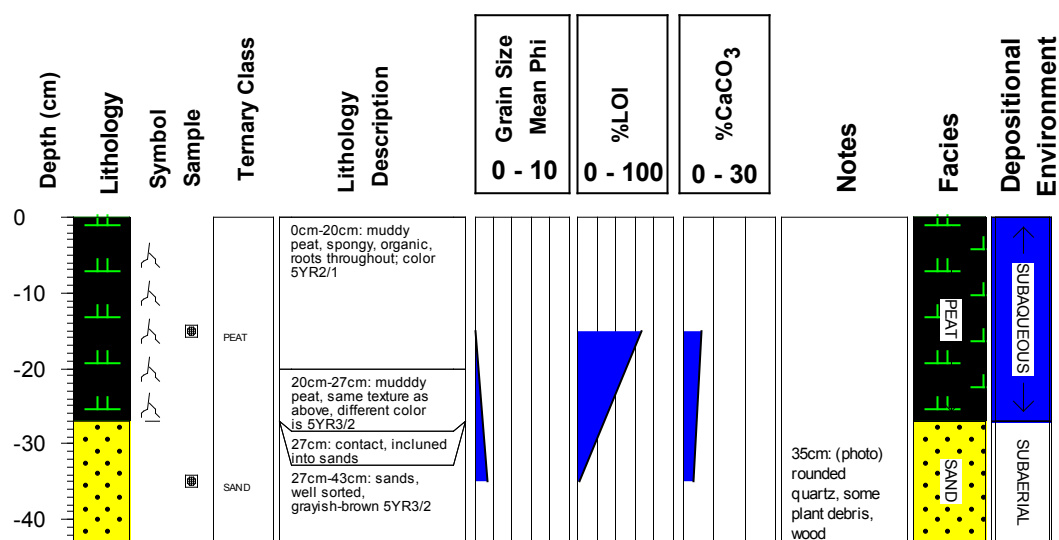
Core Recovery: **0.43 m**

Longitude: **82d 00.690' W**

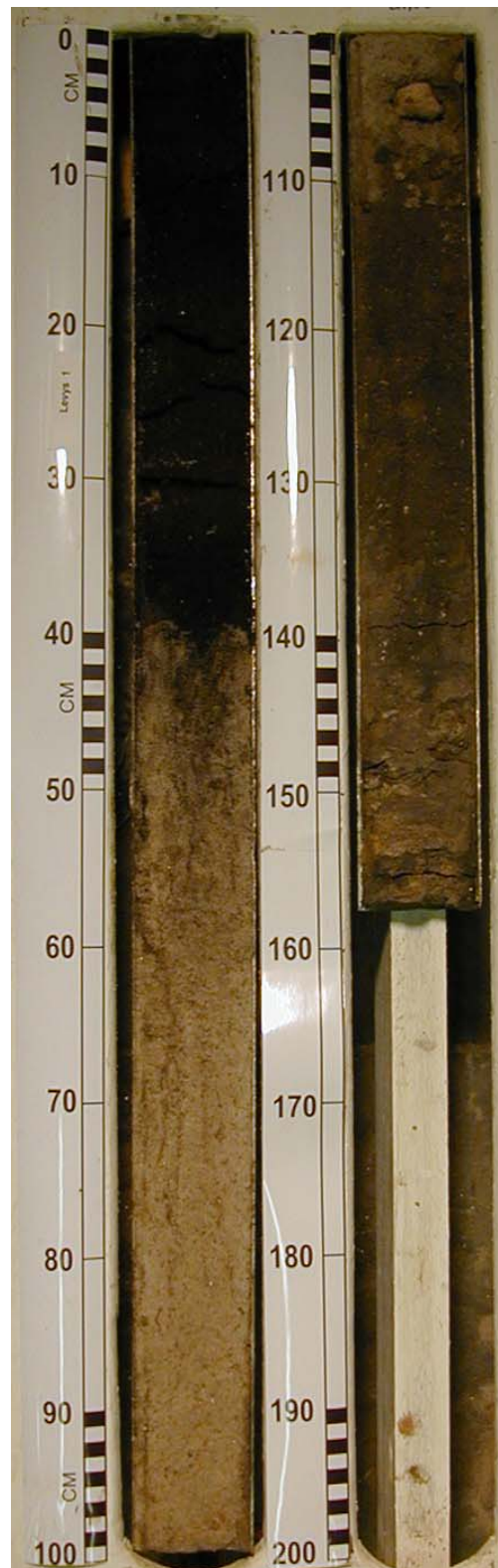
Core Penetration: **3.47 m**

Date Vibracored: **2-24-00 (pushed)**

Geographic Location: **Levys Prairie**



LP3



Core ID: **LP3**

Described by Date/Person: **10-16-00/NTD**

Latitude: **29d 38.414' N**

Core Recovery: **1.582 m**

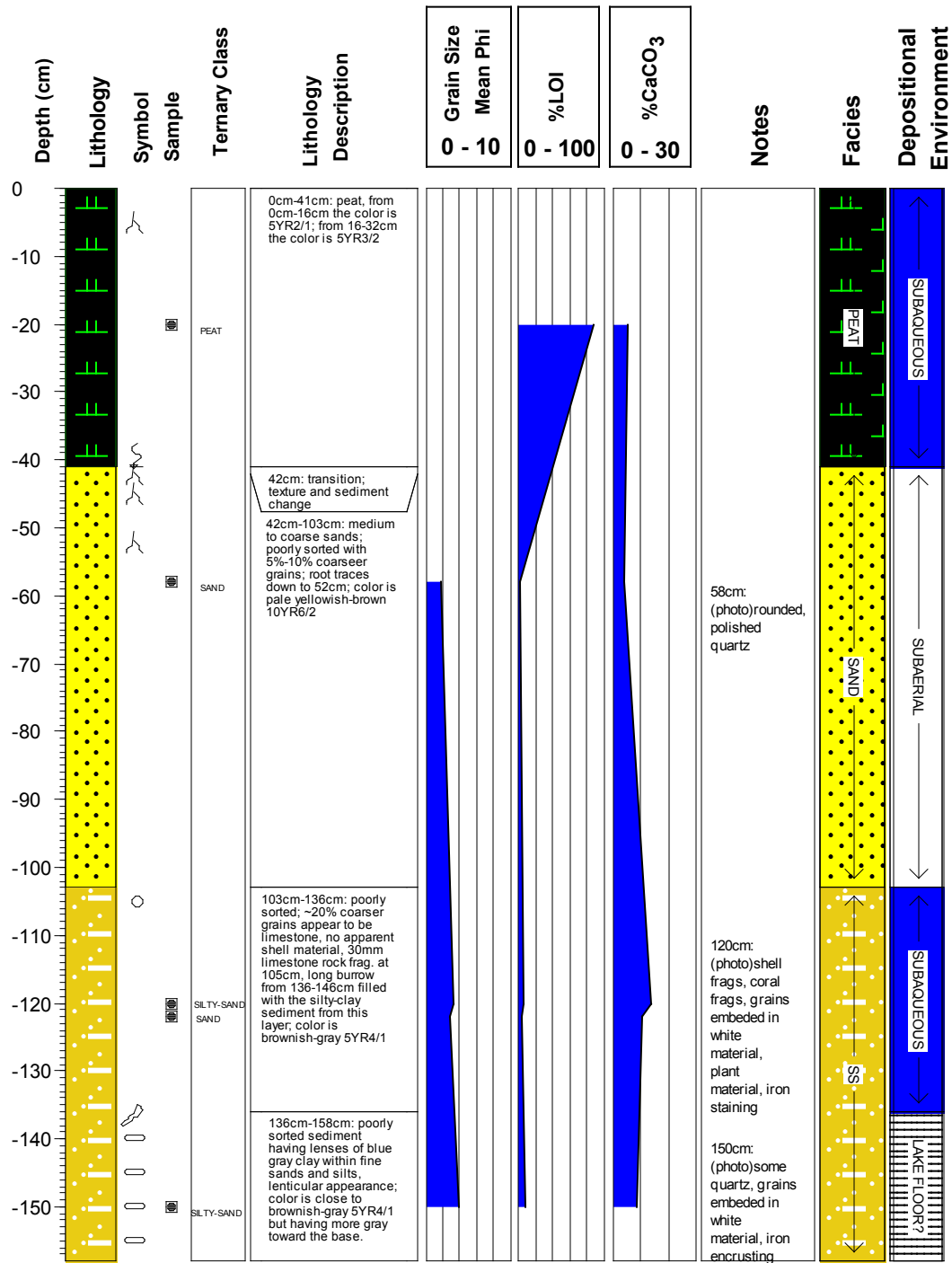
Longitude: **82d 00.581' W**

Core Penetration: **4.88 m**

Date Vibracored: **4-5-00**

Geographic Location: **Levys Prairie**

Putnam County, Florida



LP4



Core ID: **LP4**

Described by Date/Person: **11-16-00/NTD**

Latitude: **29d 38.414' N**

Core Recovery: **1.51 m**

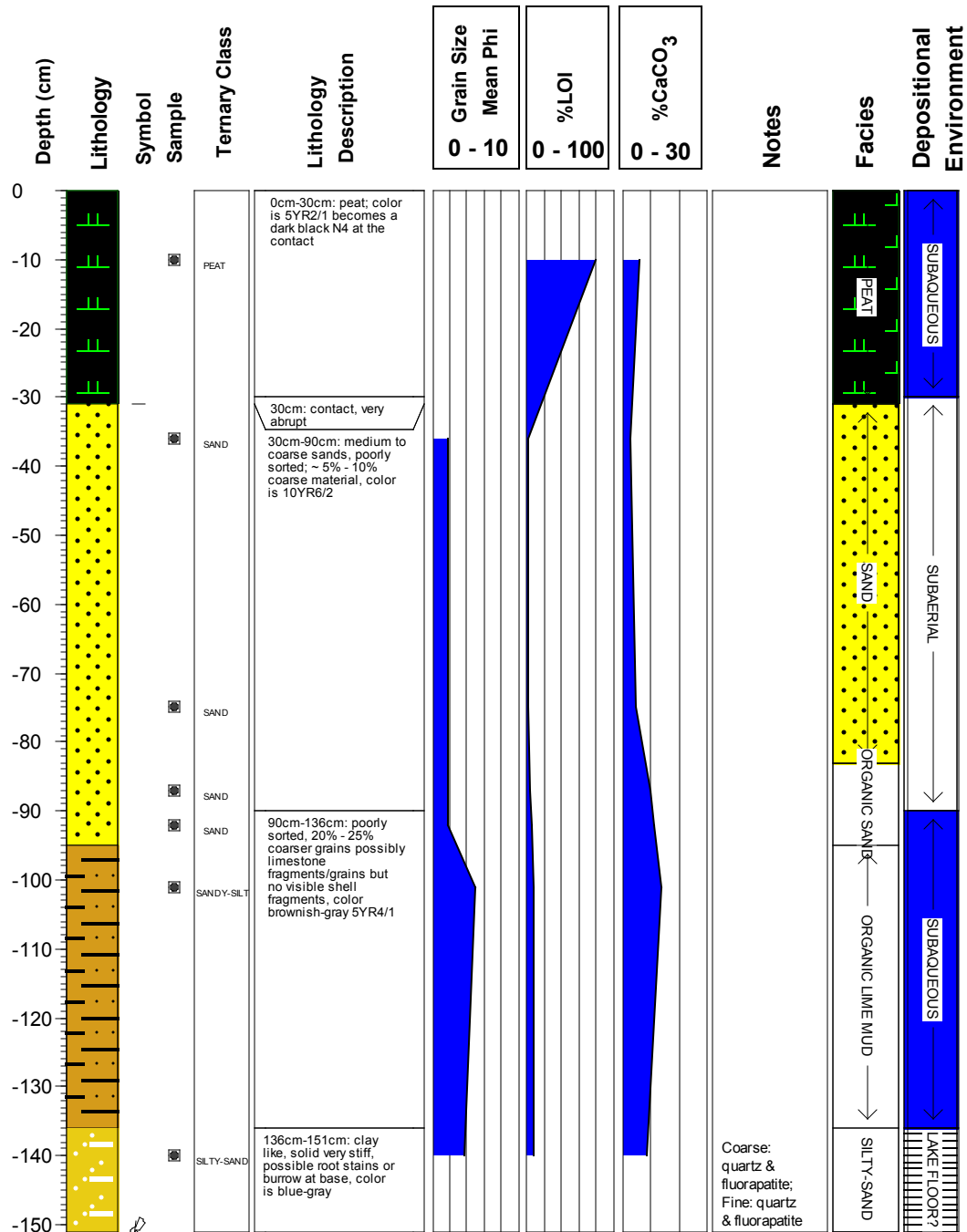
Longitude: **82d 00.577' W**

Core Penetration: **4.016 m**

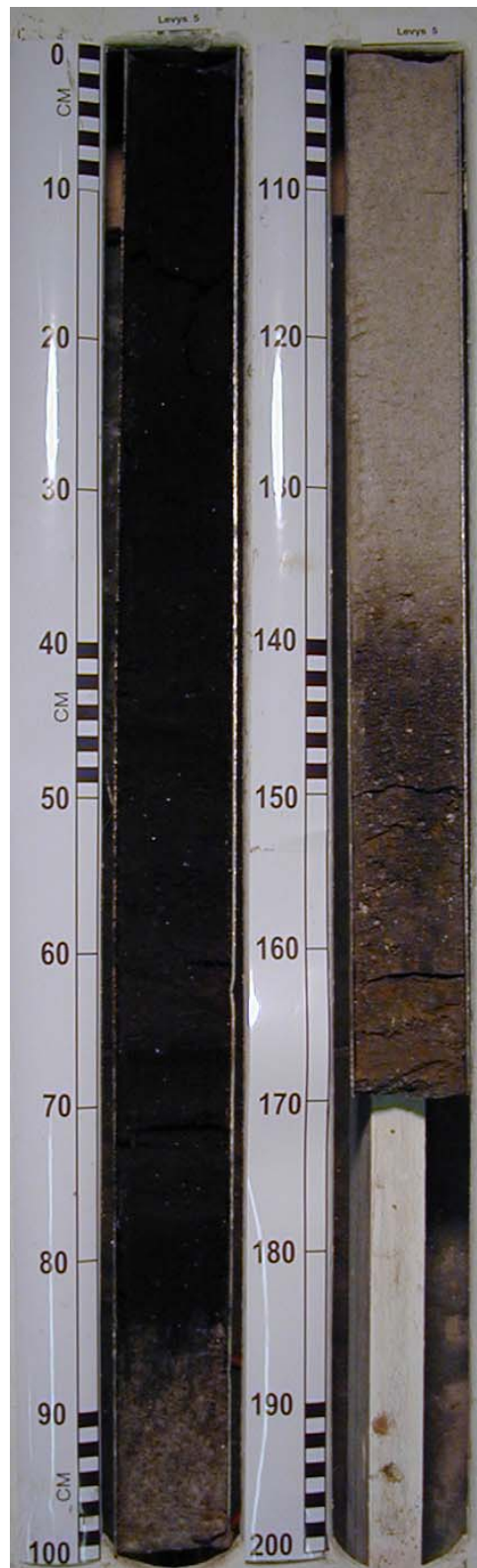
Date Vibracored: **4-5-00**

Geographic Location: **Levy's Prairie**

Putnam County, Florida



LP5



Core ID: **LP5**

Latitude: **29d 38.355' N**

Longitude: **82d 00.624' W**

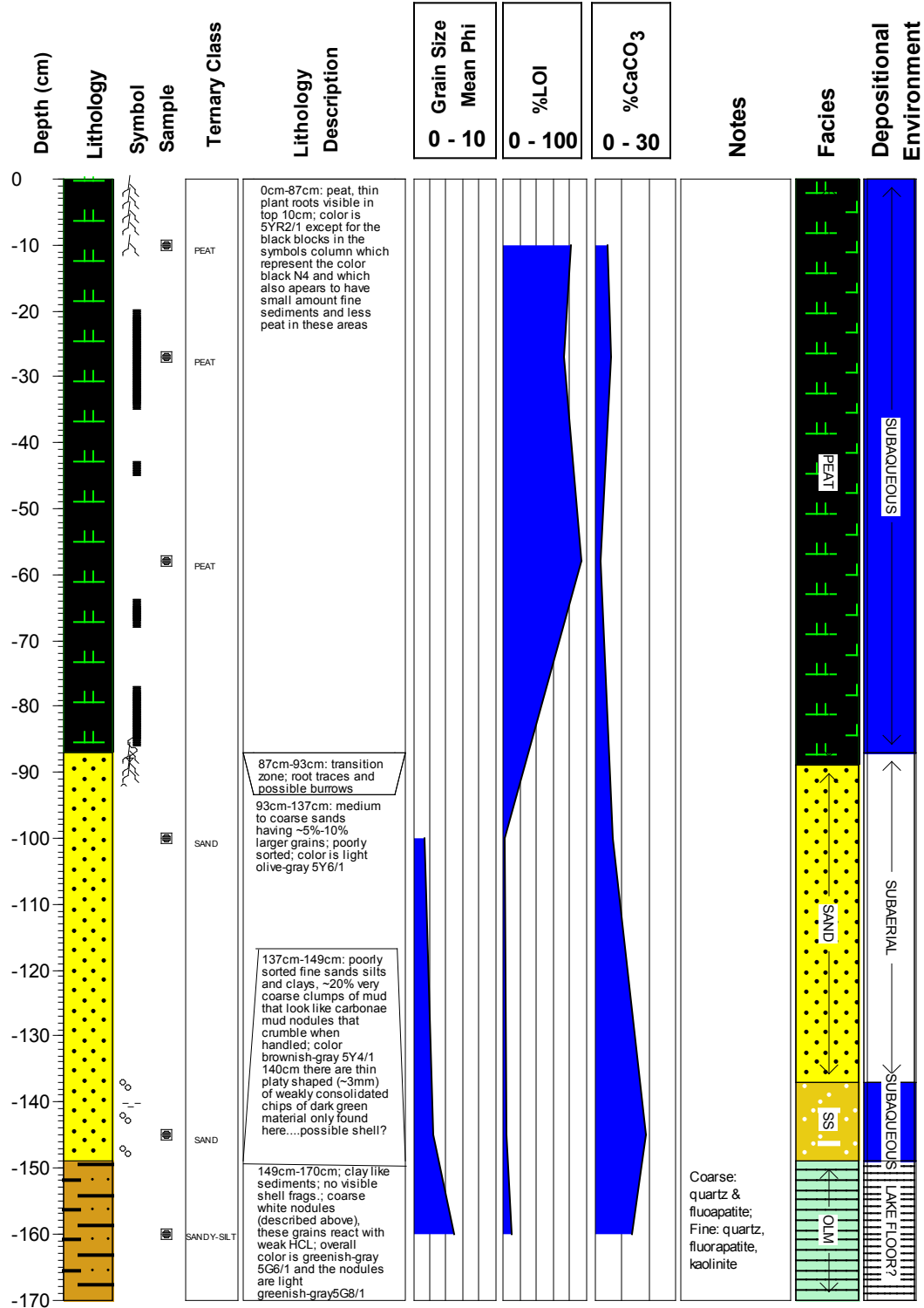
Date Vibracored: **4-5-00**

Described by Date/Person: **11-16-00/NTD**

Core Recovery: **1.70 m**

Core Penetration: **1.742 m**

Geographic Location: **Levys Prairie
Putnam County, Florida**



LP6



Core ID: **LP6**

Described by Date/Person: **11-16-00/NTD**

Latitude: **29d 38.367' N**

Core Recovery: **1.33 m**

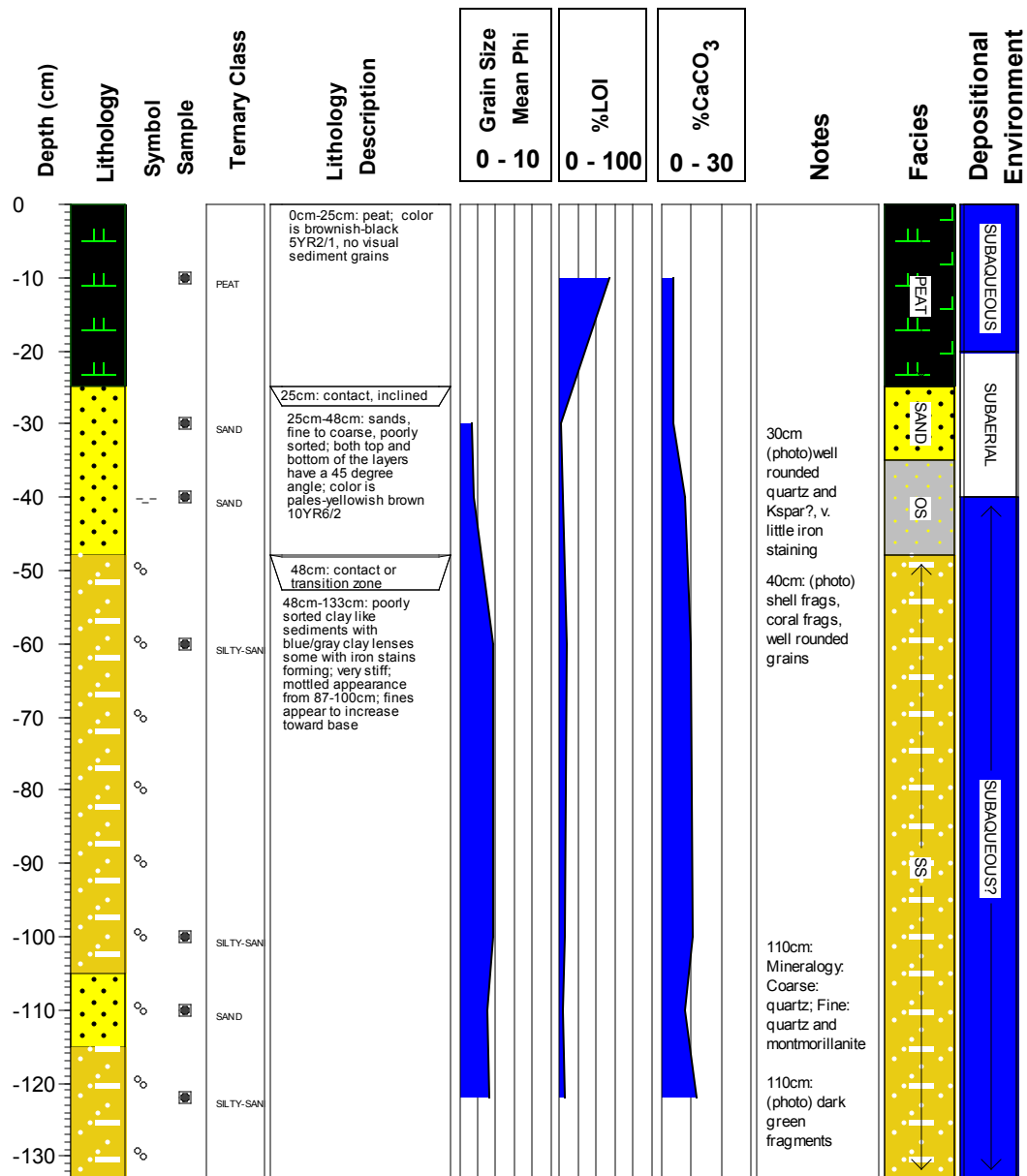
Longitude: **82d 00.691' W**

Core Penetration: **1.89 m**

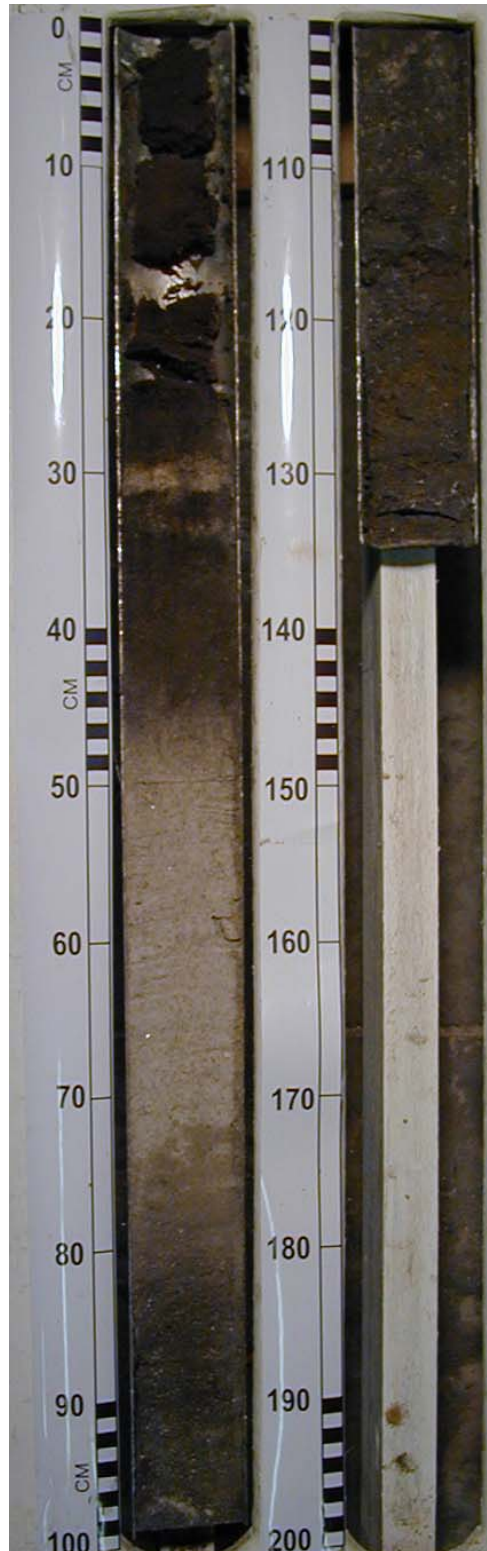
Date Vibracored: **4-5-00**

Geographic Location: **Levys Prairie**

Putnam County, Florida



LP7



Core ID: **LP7**

Described by Date/Person: **11-16-00/NTD**

Latitude: **29d 38.484' N**

Core Recovery: **1.34 m**

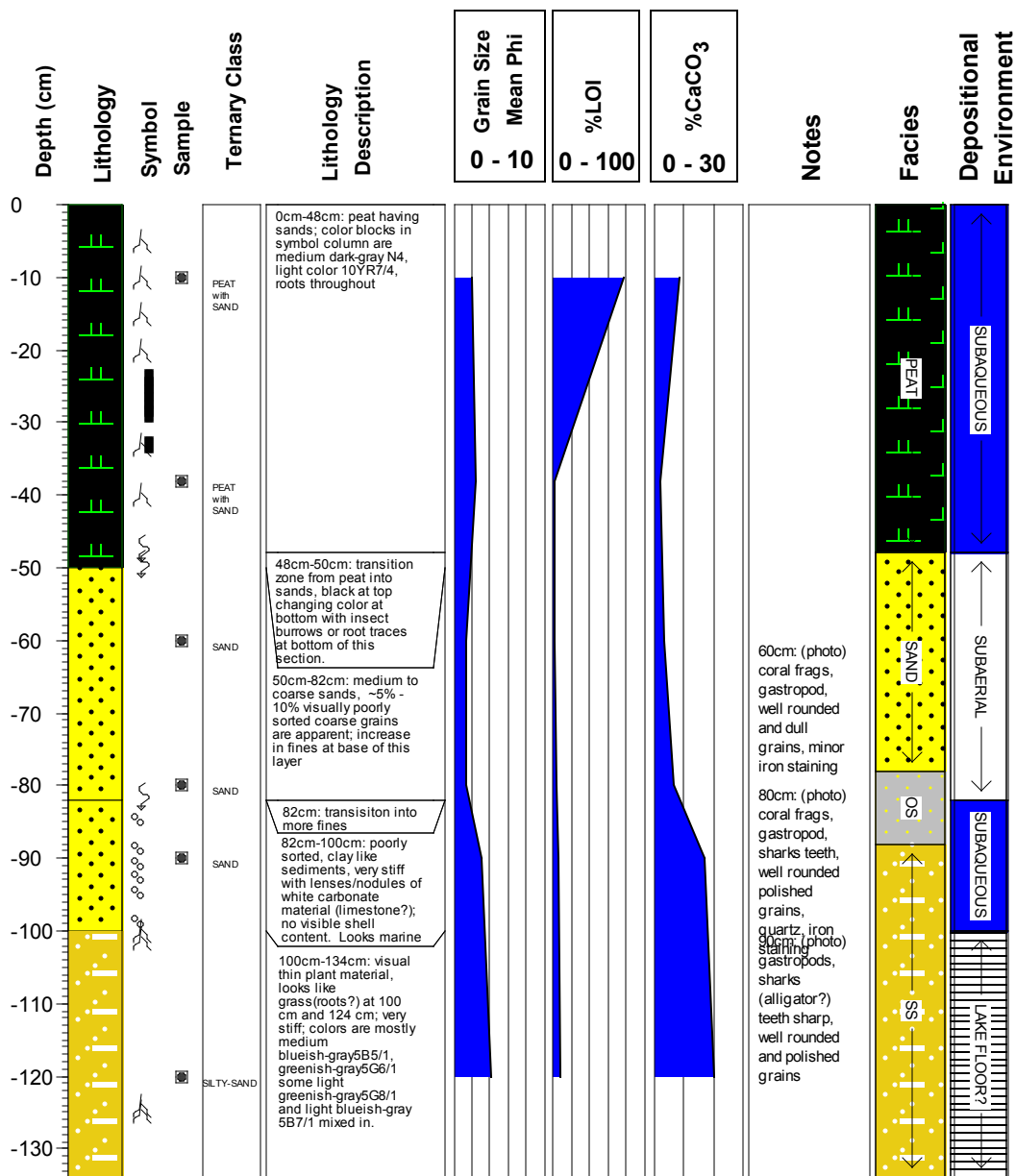
Longitude: **82d 00.765' W**

Core Penetration: **1.476 m**

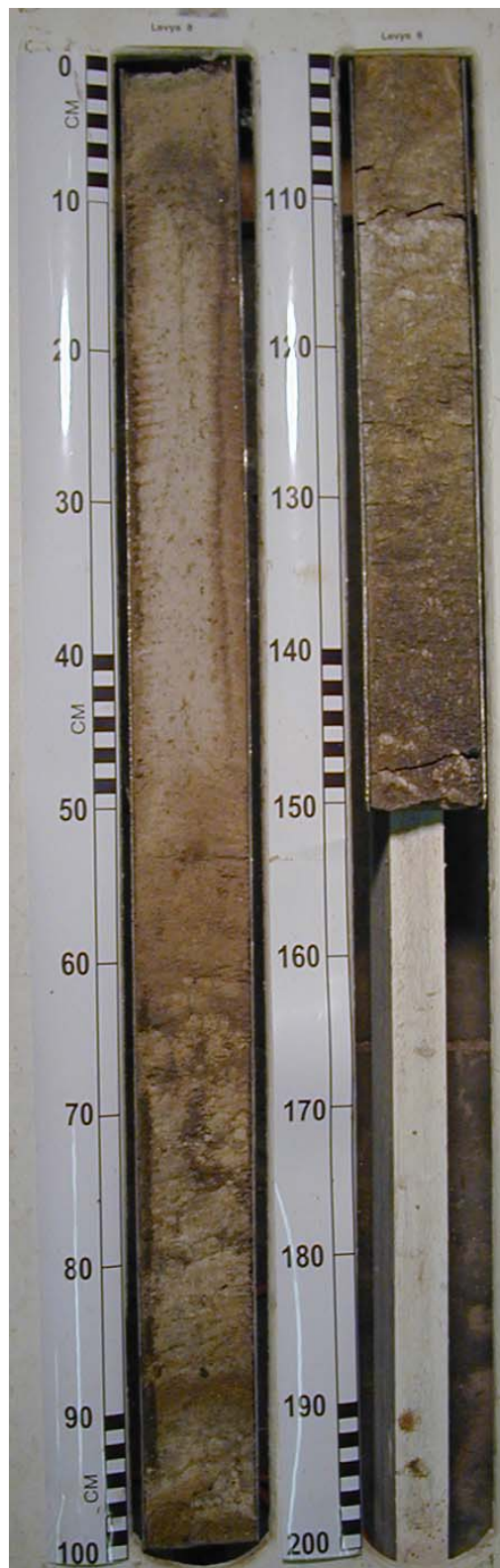
Date Vibracored: **4-5-00**

Geographic Location: **Levys Prairie**

Putnam County, Florida



LP8



Core ID: **LP8**

Described by Date/Person: **11-14-00/NTD**

Latitude: **29d 38.478' N**

Core Recovery: **1.52 m**

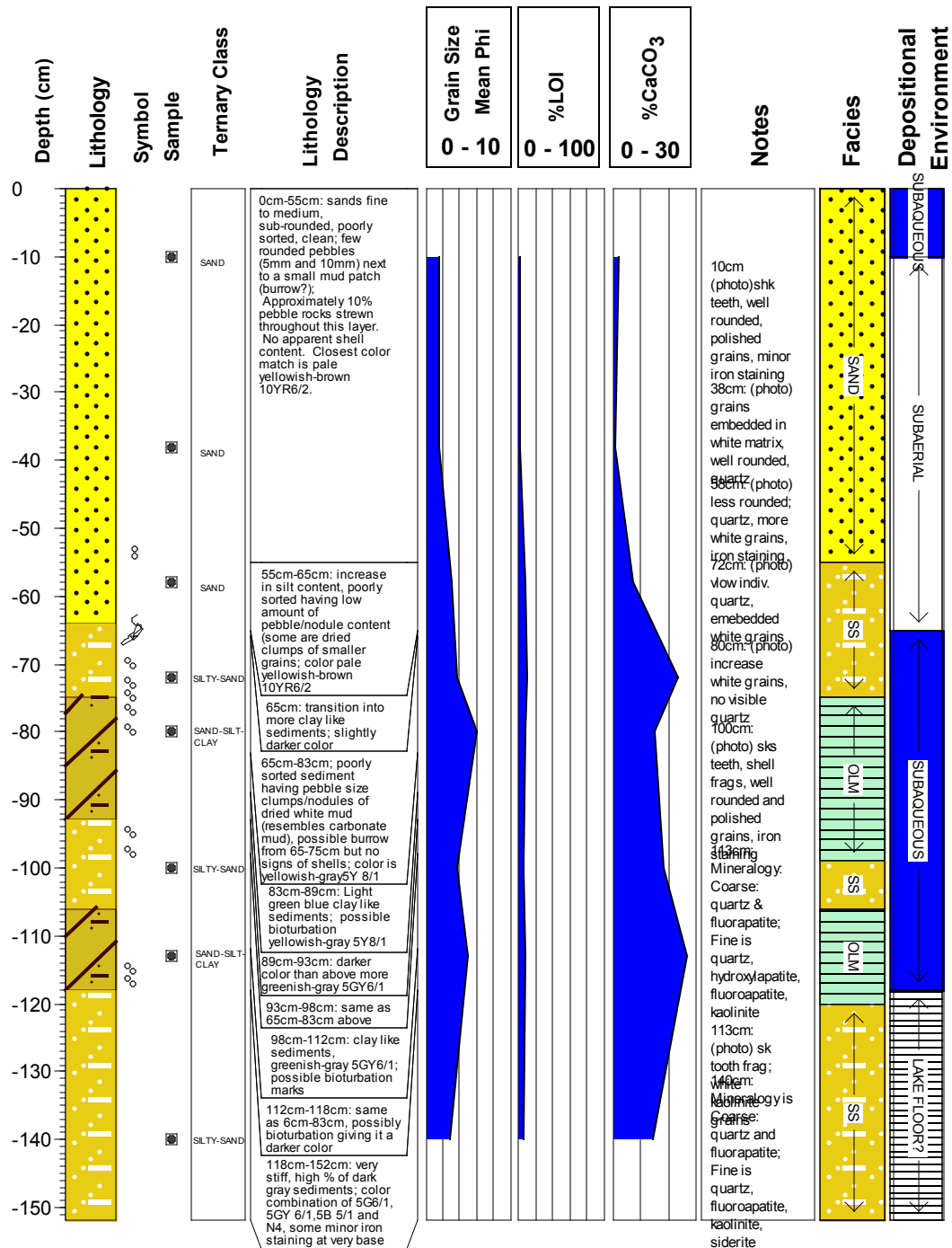
Longitude: **82d 00.724' W**

Core Penetration: **1.682 m**

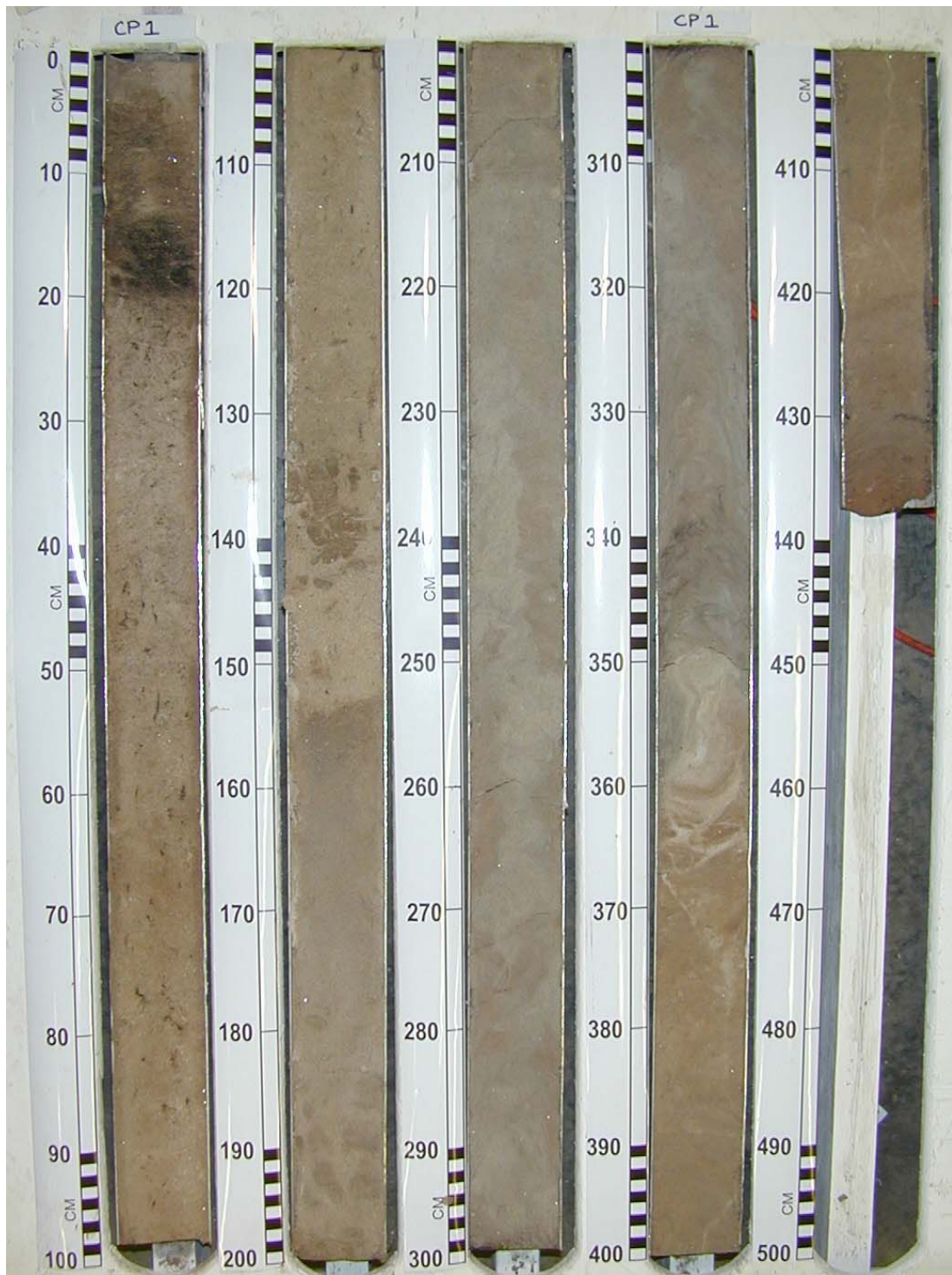
Date Vibracored: **4-5-00**

Geographic Location: **Levys Prairie**

Putnam County, Florida



CP1



Core ID: CP 1

Described by Date/Person: 9-17-02/NTD

Latitude: 29d 35.996' N

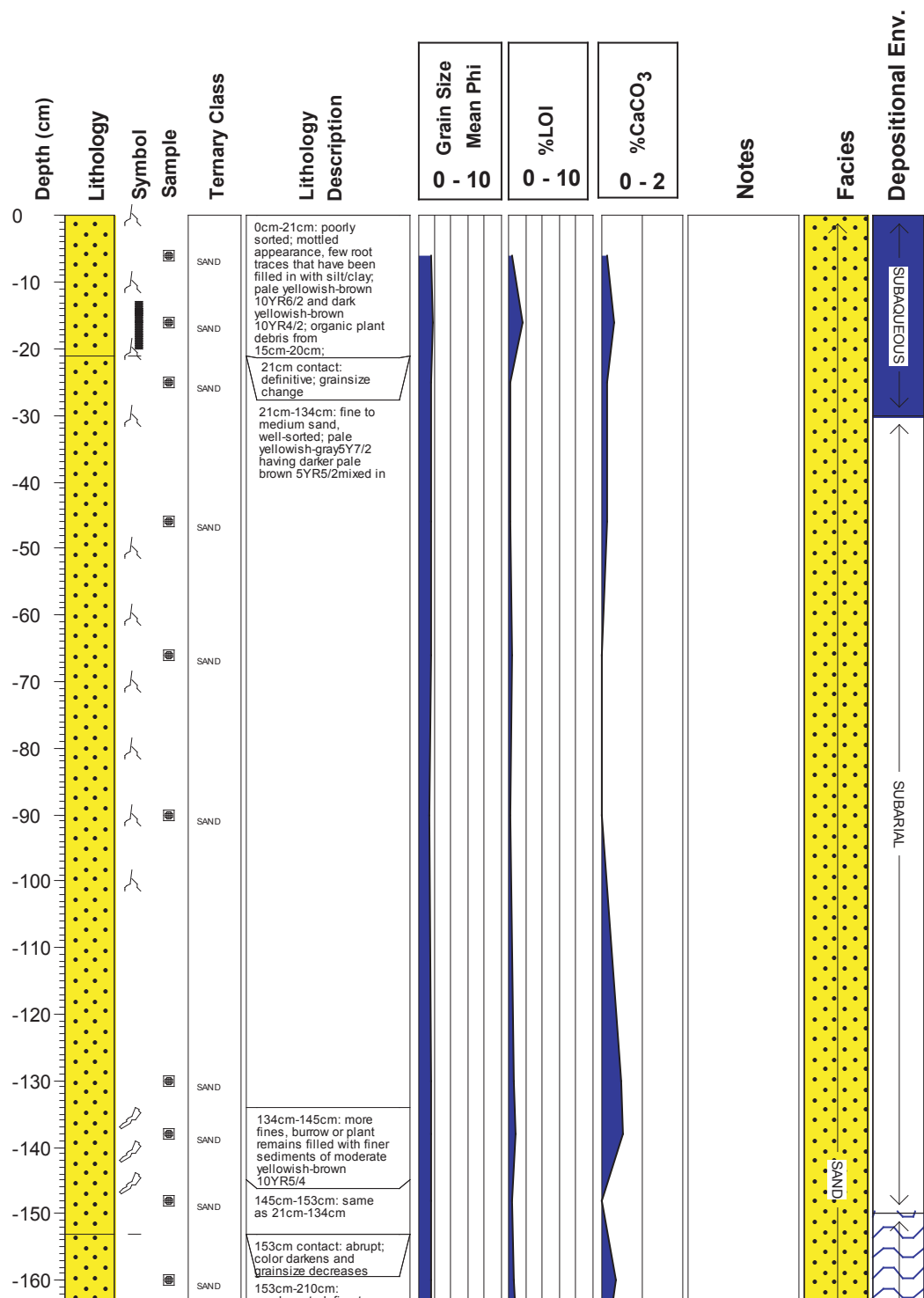
Core Recovery: 4.38 m

Longitude: 82d 00.184' W

Core Penetration: 5.39 m

Date Vibracored: 7-20-00

Geographic Location: Cowpen Lake
Putnam County, FL



153cm-210cm: poorly-sorted, fine to medium sands with fines; pale yellowish-brown 10YR 6/2; clean, no root traces; sediments in the top 5cm of this layer have dark grayish tint; clay lenses or stains from 180cm-200cm increasing desnity at 190cm.

210cm contact: subtle; slightly darker band, grainsize increase

210cm-330cm: poorly sorted muddy sands, clay content increases down core; sands are pale yellowish-brown 10YR6/2 but clays have a yellowish gray 5Y7/2; compact and stiff.

330cm-338cm: same as above, but more clay

338cm-351cm: solid, stiff; mostly clay; brown stains, light brownish-gray 5YR6/1

351cm contact: abrupt, clay stops and fine to medium sands begin

351cm-388cm: fine to silty-sands having a lenticular appearance, no apparent clay or roots; lense color is just lighter than dark yellowish- orange 10YR6/6 and the other is yellowish gray 5y8/1

INTERMITTENT WET/DRY

SUBAQUEOUS

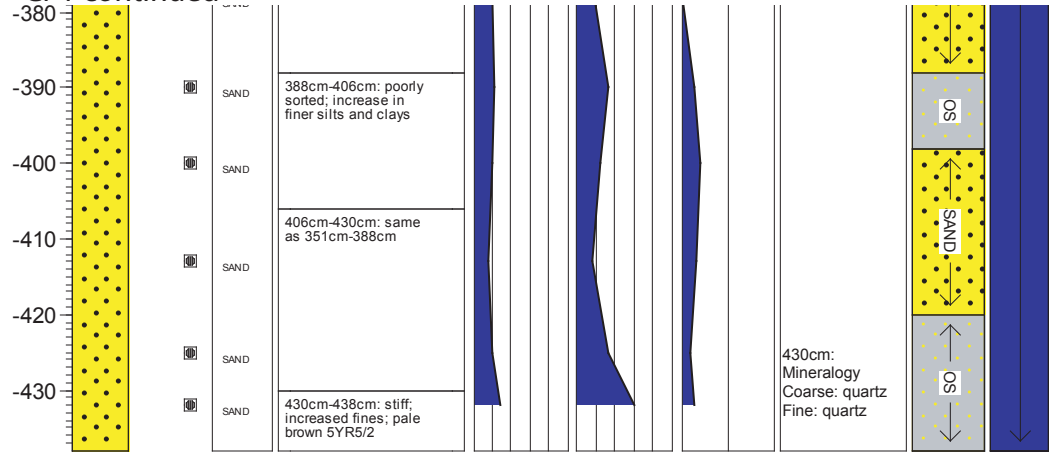
OS

OM

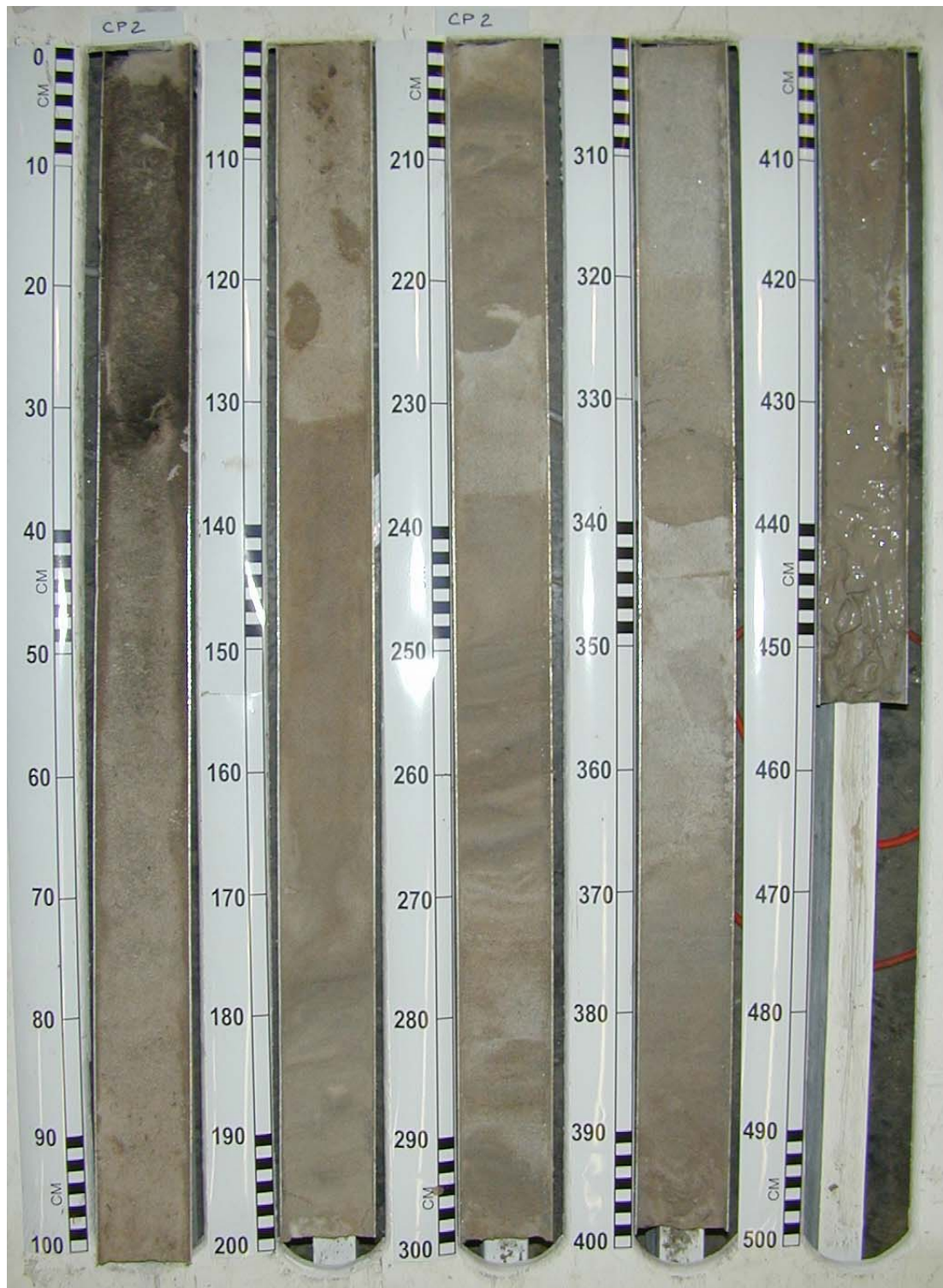
SAND

0 100

CP1 continued



CP2

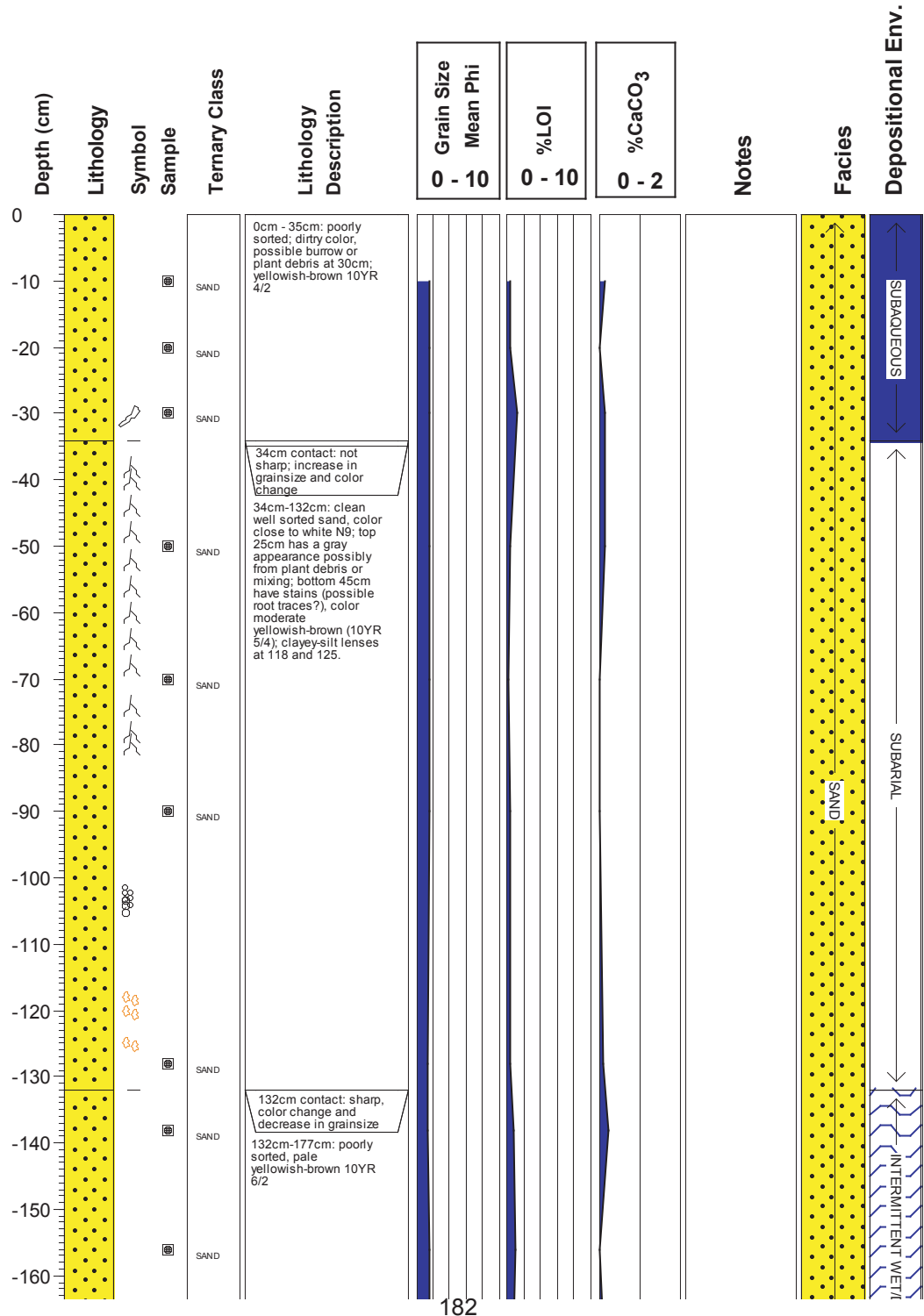


Described by Date/Person: 9-18-02/NTD

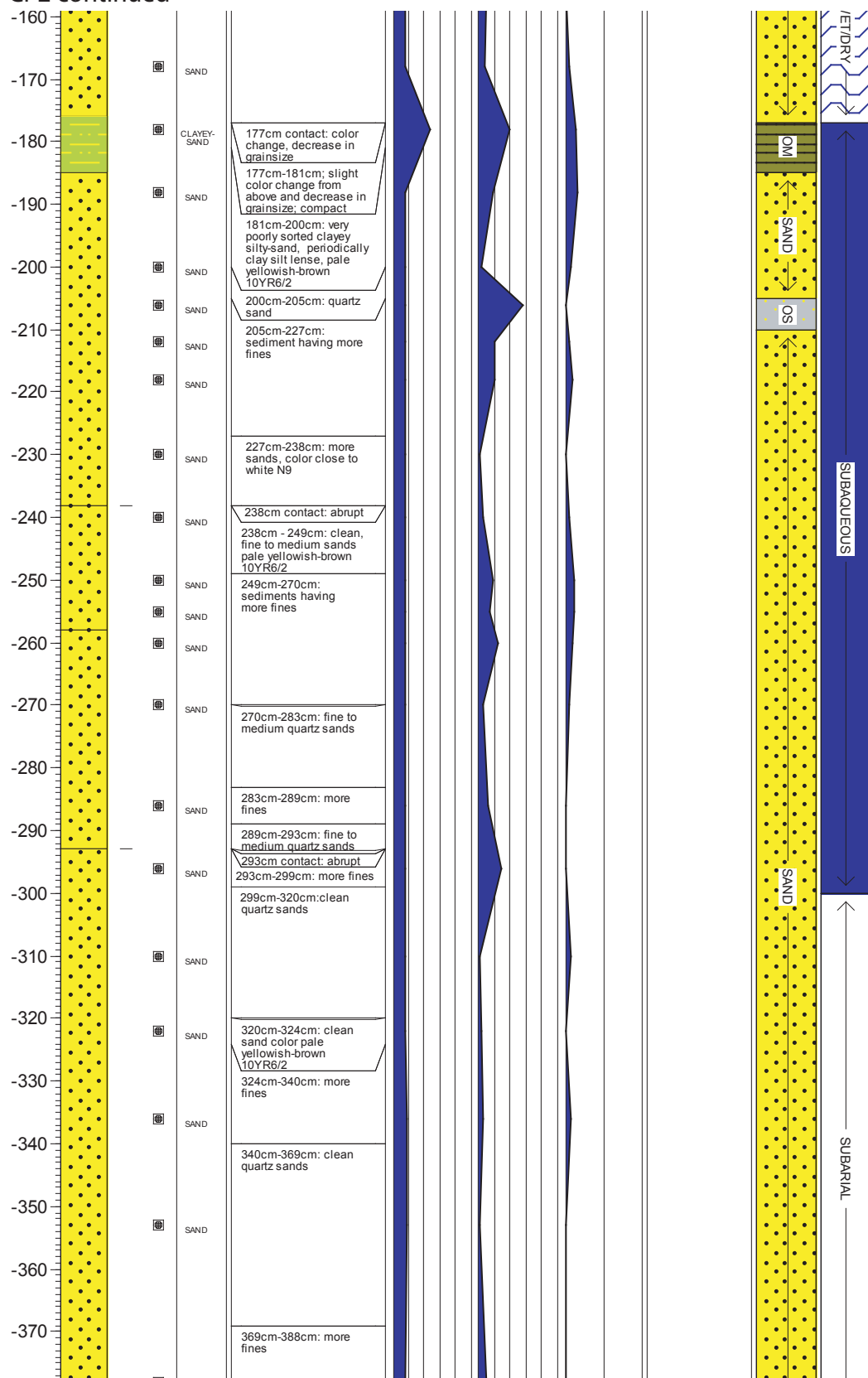
Core Recovery: 4.54 m

Core Penetration: 5.70 m

Geographic Location: Cowpen Lake
Putnam County, FL

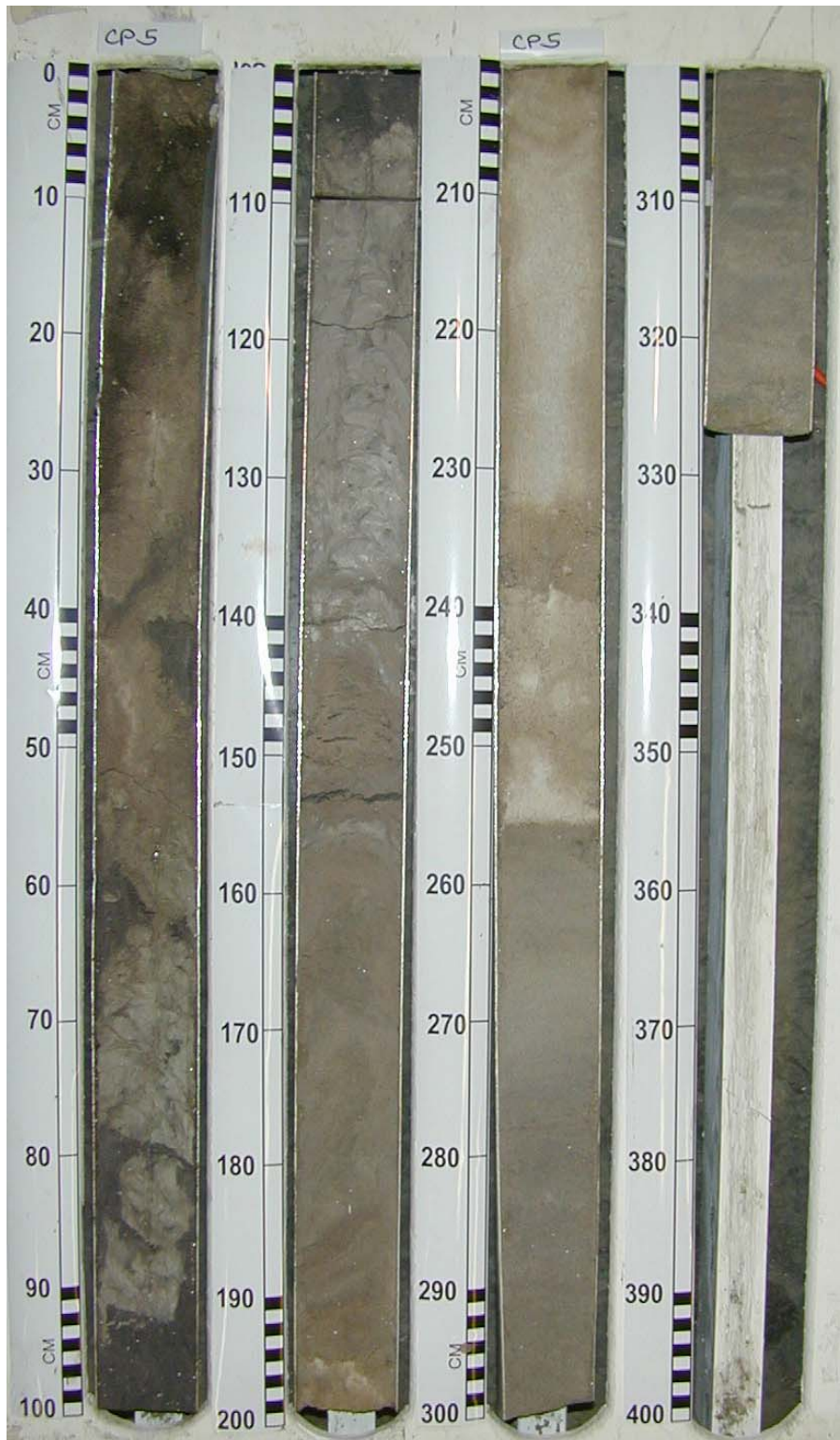


CP2 continued



[illegible]

CP5



Core ID: CP5

Latitude: 82d 00.021' N

Longitude: 29d 36.273' N

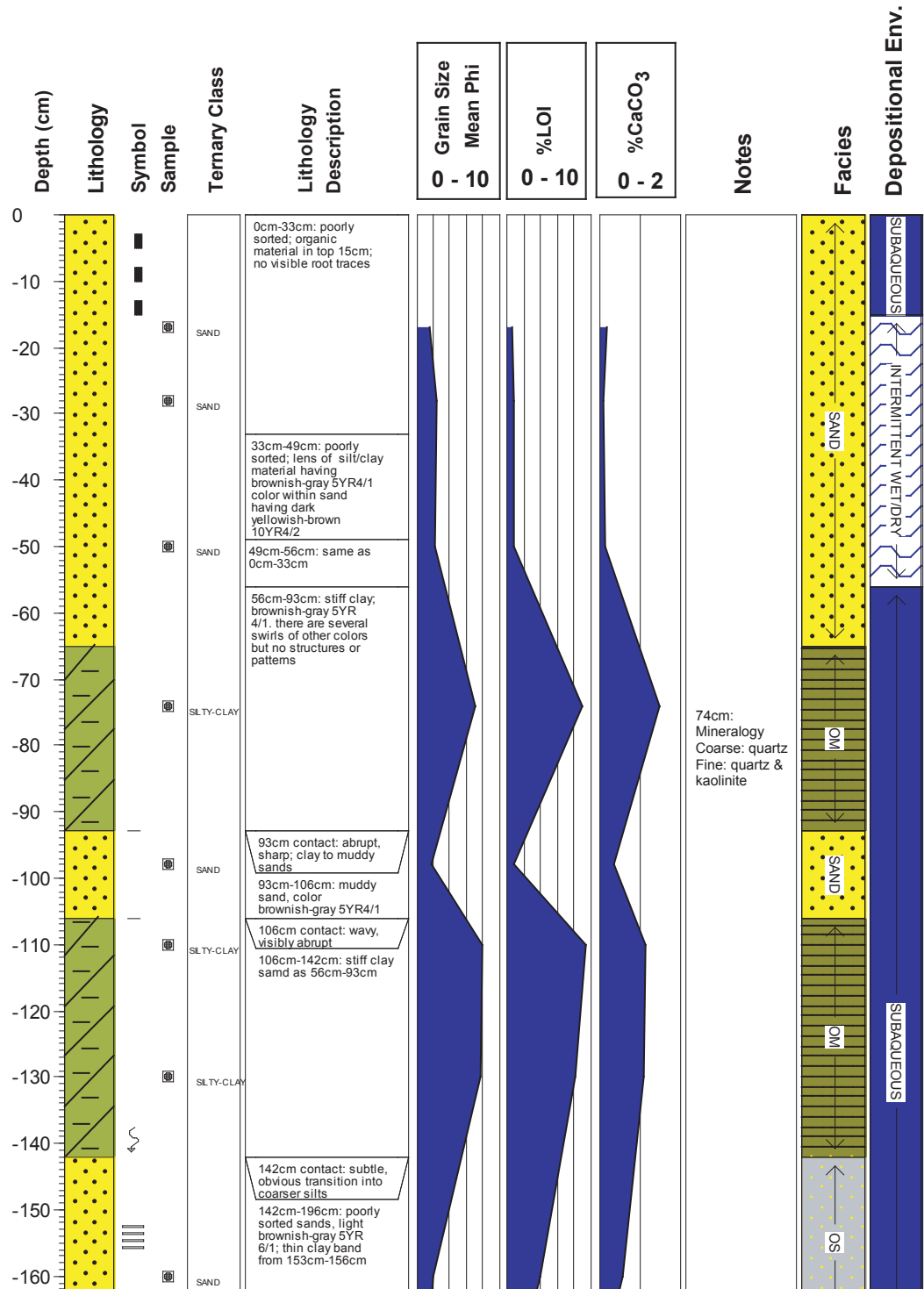
Date Vibracored: 7-21-00

Described by Date/Person: 9-17-02/NTD

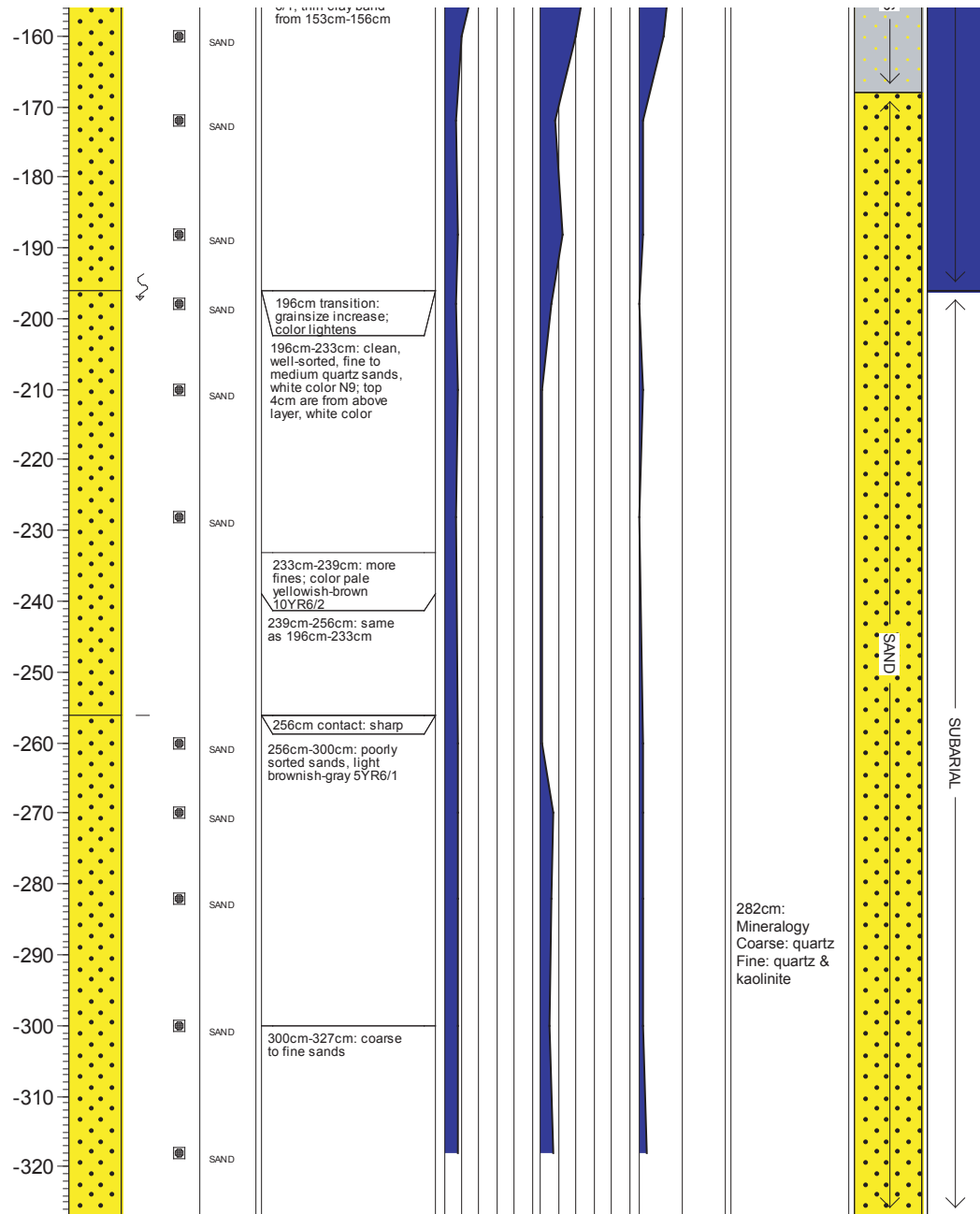
Core Recovery: 3.47 m

Core Penetration: 3.27 m

Geographic Location: Cowpen Lake
Putnam County, FL



CP5 continued



APPENDIX 2
EQUATIONS AND PLOTS

$$\% \text{Total CaCO}_3 = \left[\frac{((\text{Sediment Weight Before HCL}) - (\text{Sediment After HCL}))}{(\text{Sediment Weight Before HCL})} \right] \times 100$$

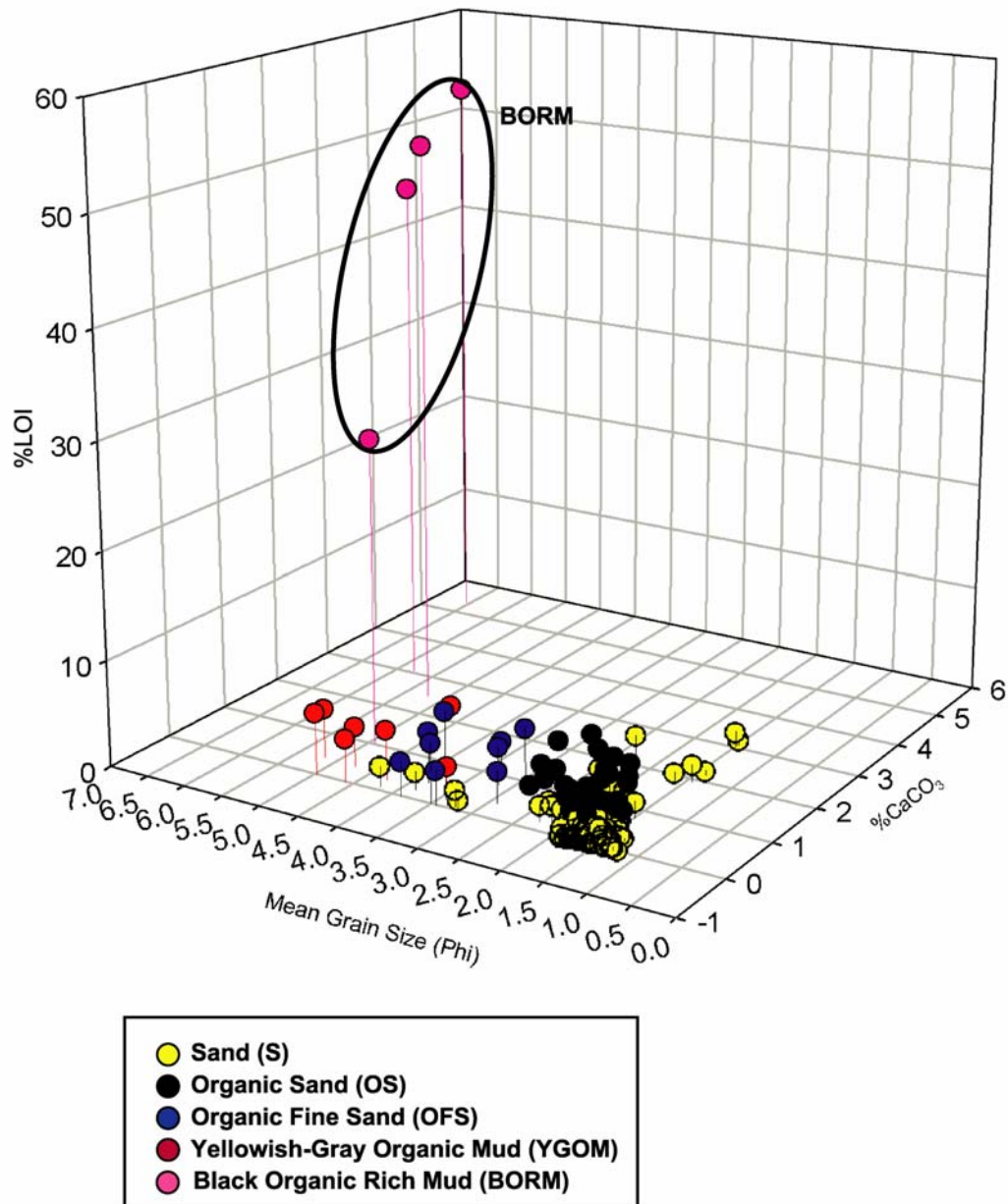
Equation used for Calculating Percent Calcium Carbonate Content

$$\text{LOI Index for Total Organics} = \left[\frac{((\text{Sediment Weight After Furnace}) \times (\text{Sediment Weight After HCL}))}{(\text{Sediment Weight Before Furnace})} \right]$$

$$\% \text{LOI} = \left[\frac{(\text{Loss on Ignition weight})}{(\text{Sediment Weight Before HCL})} \right] \times 100$$

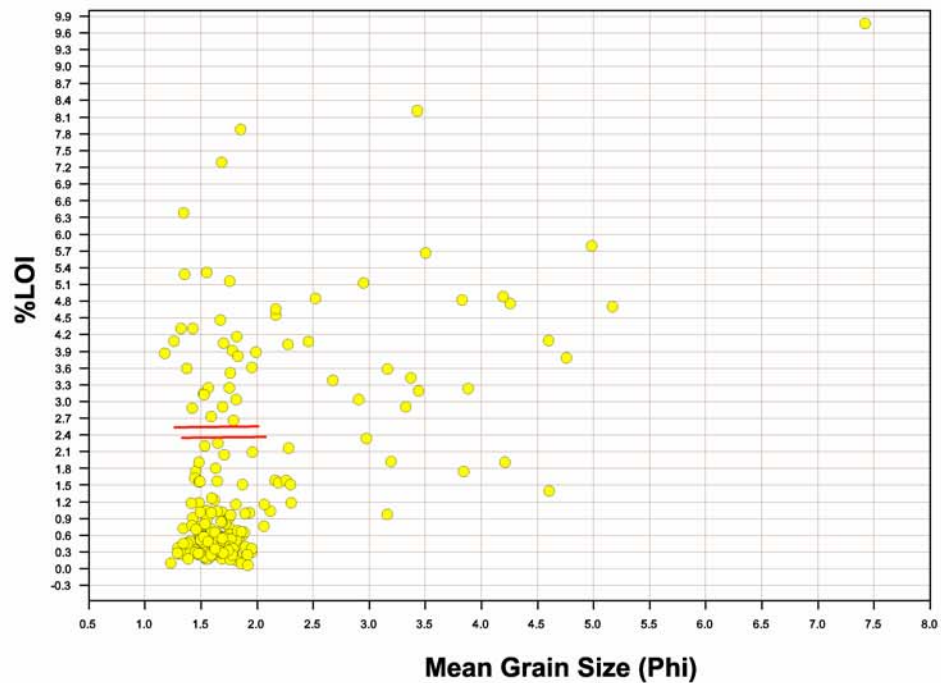
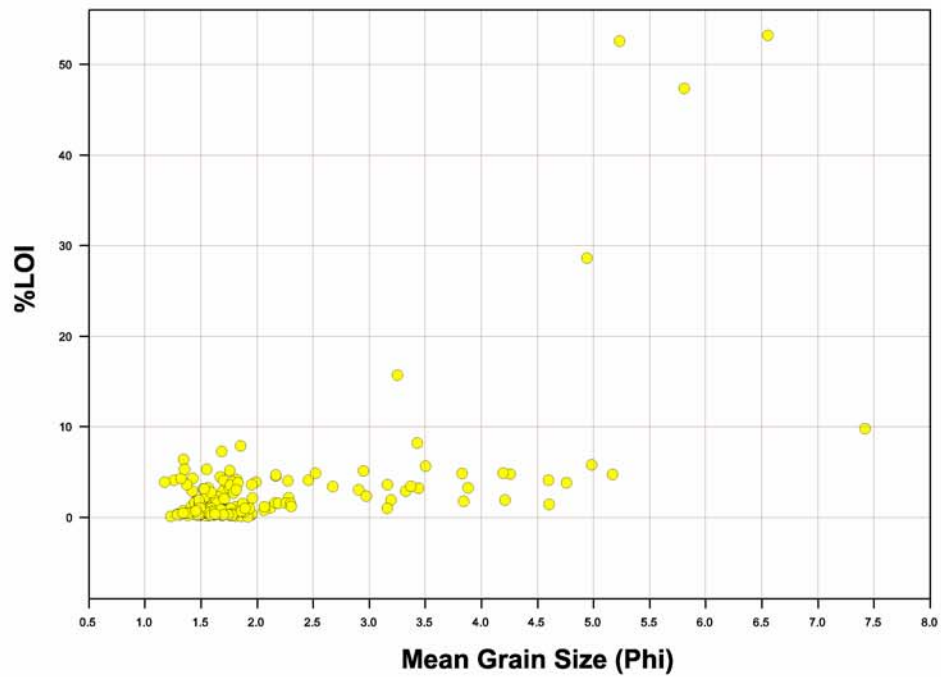
Equations used for Calculating Percent LOI Index for Total Organic Content

Brooklyn Lake Sub-Samples
Mean Grain Size (Phi) vs %LOI vs %CaCO₃



A 3D scatter plot of sub-samples from Brooklyn Lake emphasizing the black organic rich mud (BORM – Pink) facies which is distinctly separate from the other sediment facies in this plot.

Brooklyn Lake Sub-samples of %LOI vs Mean Grain Size (Phi)



Top Graph is a larger scale representing all samples showing that the majority of samples reside between 1% and 10%LOI. The bottom graph is a blow-up of the 0%-10% samples showing that there is a distinct cluster in the bottom corner, and the samples gradually extend from this. Obvious groups, do not exist particularly within the sand sizes, however the only break that does exist is very small ~0.23% indicated by the red lines.

APPENDIX 3

MICROSCOPE PHOTOGRAPHS



Collage of microscope photographs grains >1000 microns from the sand facies in Levys Prairie cores. The core name, sub-sample interval, and respective facies association is on the left and the respective line-up of photos on the right. Backdrop photograph scale is 2mm.



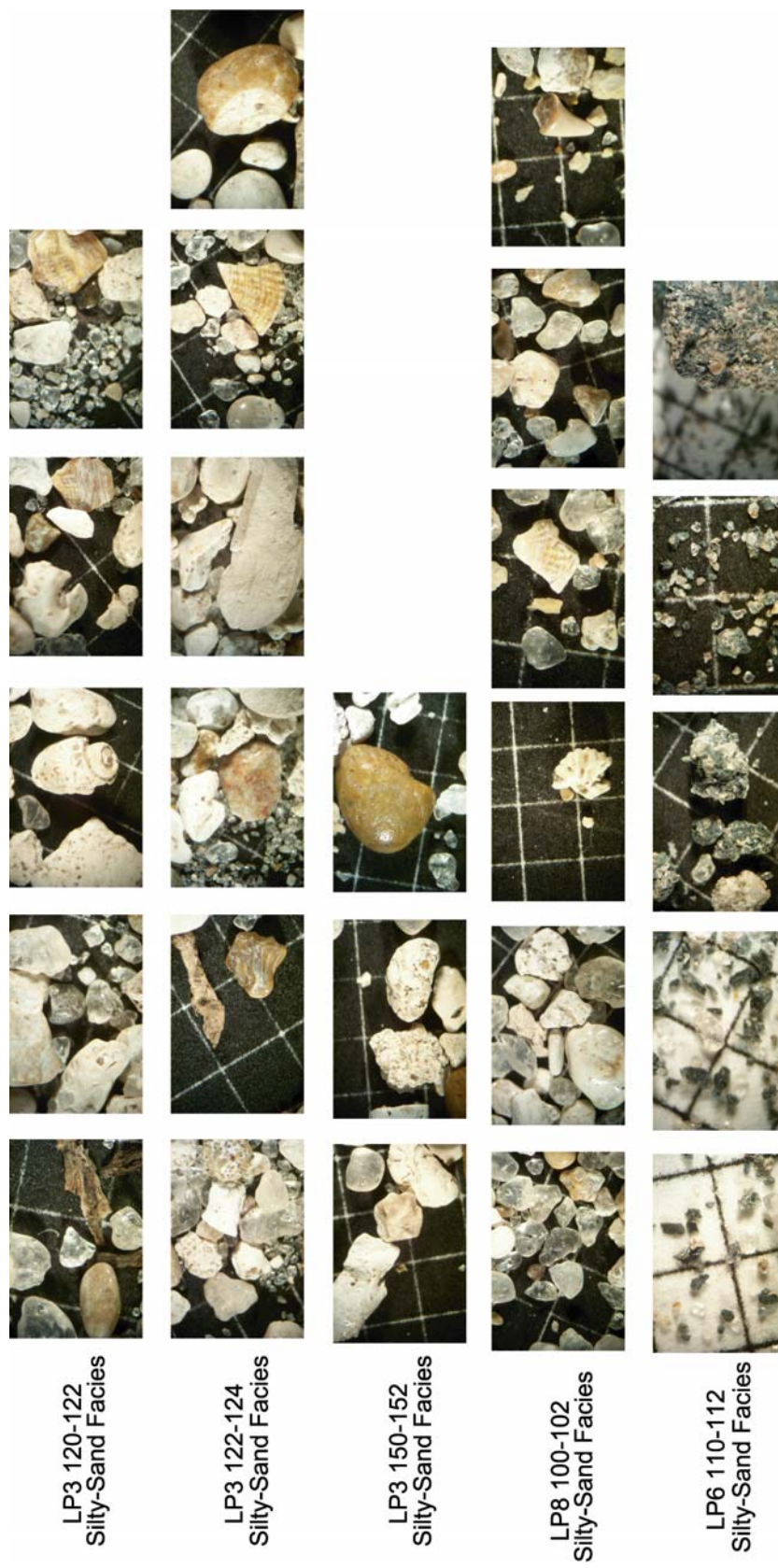
LP6 40-42
Organic Sand Facies

LP7 80-82
Organic Sand Facies

LP7 80-82 (cont.)
Organic Sand Facies

LP7 80-82 (cont.)
Organic Sand Facies

Collage of microscope photographs of grains > 1000 microns from the organic sand facies in Levys Prairie cores. The core name, sub-sample interval, and respective facies association is on the left and the respective line-up of photos on the right. Backdrop photograph scale is 2mm.



LP3 120-122
Silty-Sand Facies

LP3 122-124
Silty-Sand Facies

LP3 150-152
Silty-Sand Facies

LP8 100-102
Silty-Sand Facies

LP6 110-112
Silty-Sand Facies

Collage of microscope photographs of grains >1000 microns from the silty sand facies in Levys Prairie cores. The core name, sub-sample interval, and respective facies association is on the left and the respective line-up of photos on the right. Backdrop photograph scale is 2mm.

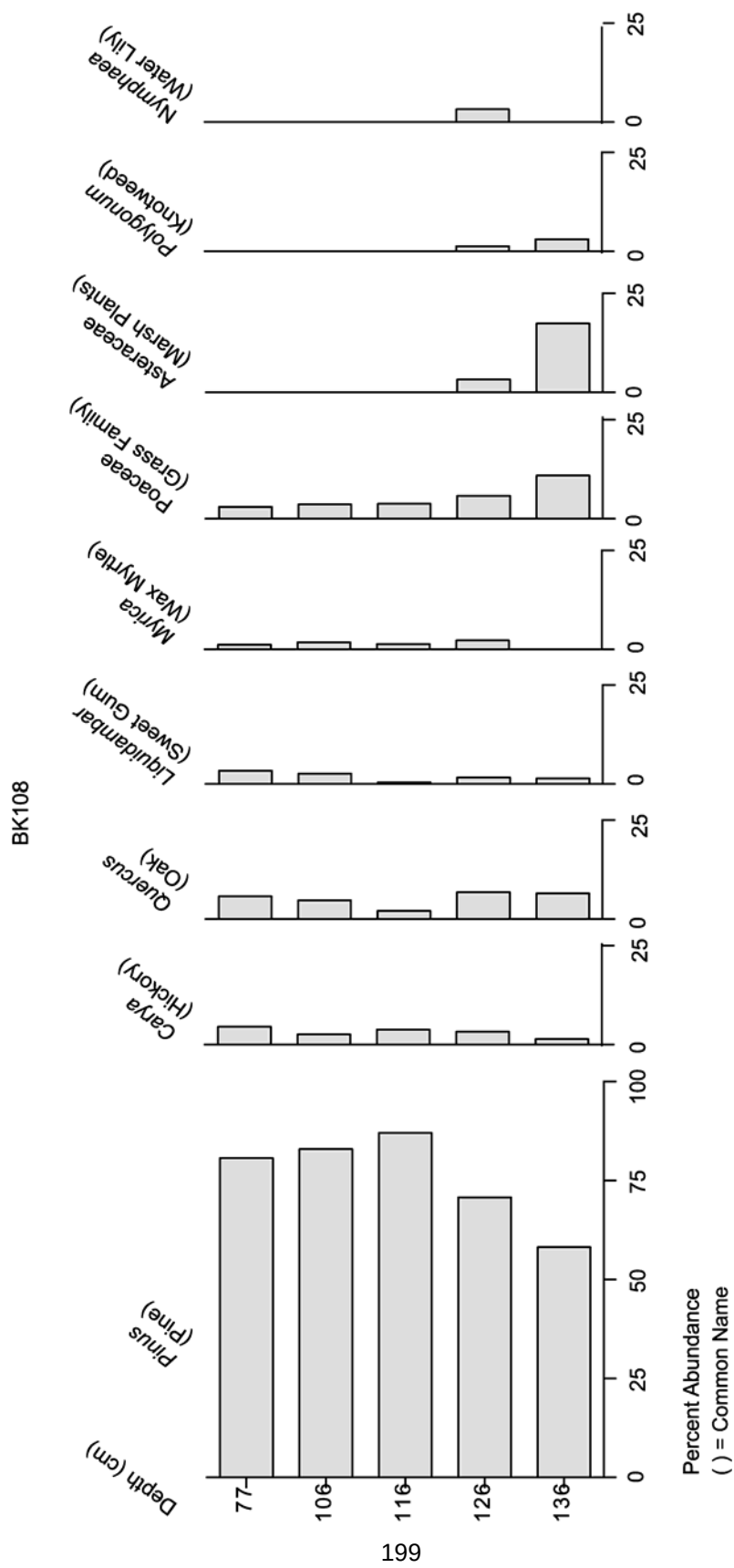


Collage of microscope photographs of grains >1000 microns from silty-sand facies in Levys Prairie cores. The core name, sub-sample interval, and respective facies association is on the left and the respective line-up of photos on the right. Backdrop photograph scale is 2mm.

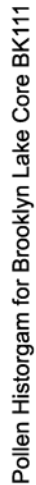


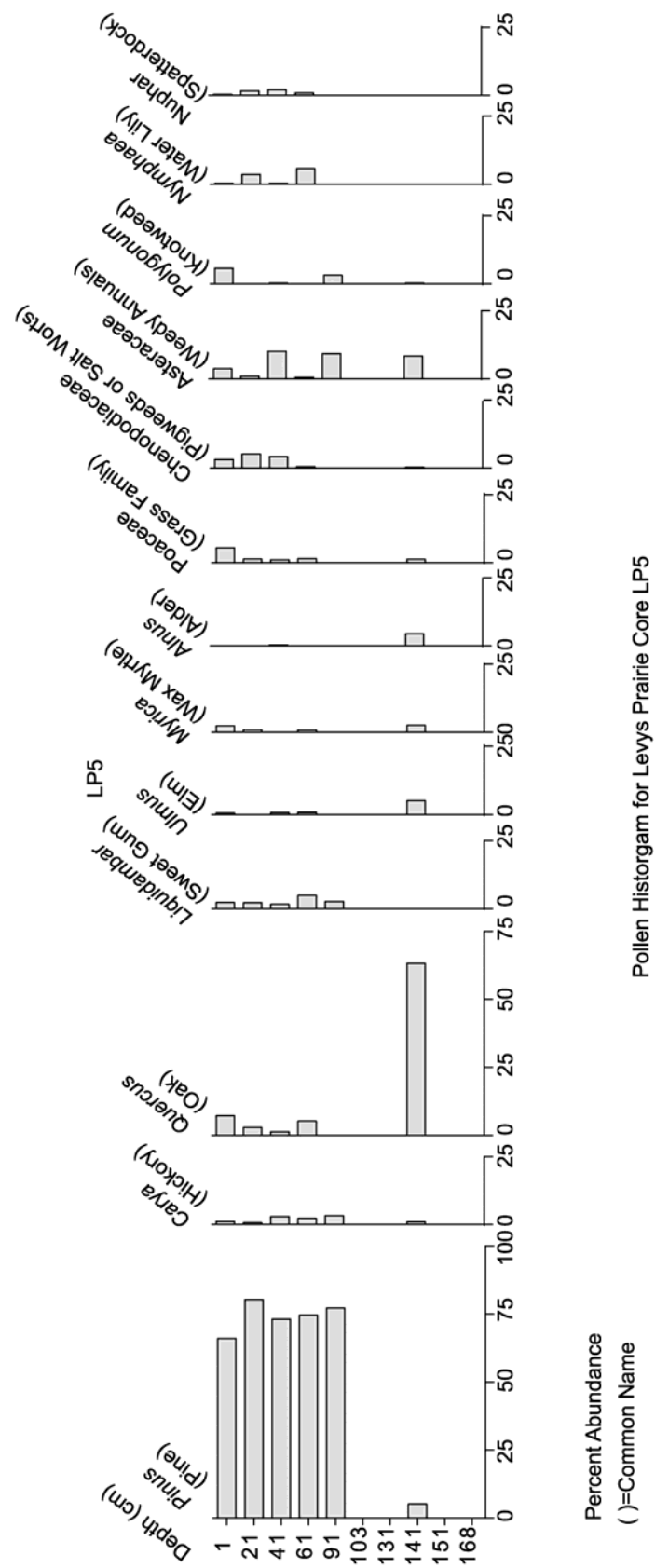
Collage of microscope photographs of grains >1000 microns from the organic lime mud facies in Levys Prairie cores. The core name, sub-sample interval, and respective facies association is on the left and the respective line-up of photos on the right. Backdrop photograph scale is 2mm.

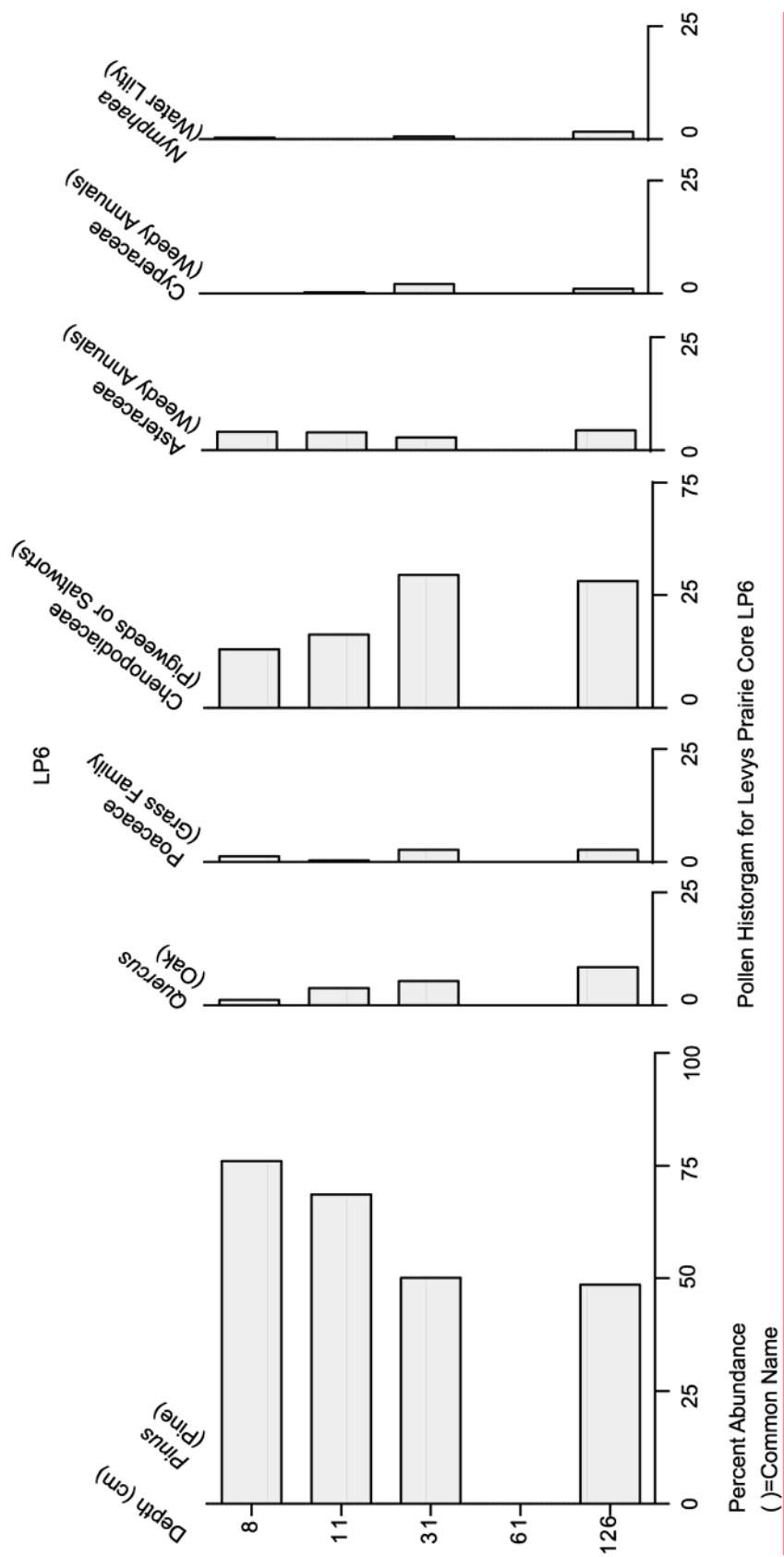
APPENDIX 4
POLLEN HISTOGRAMS

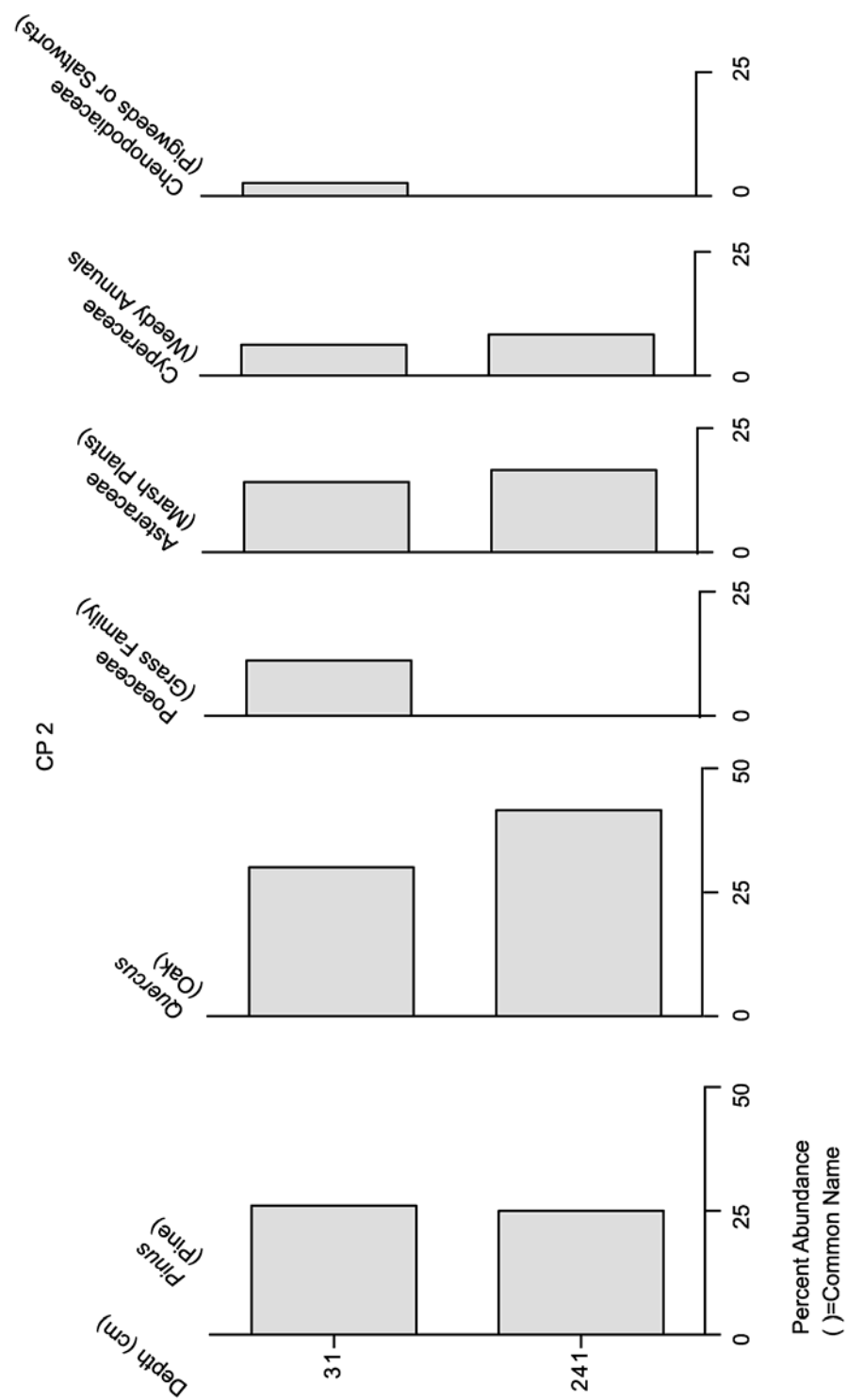


Pollen Histogram for Brooklyn Lake Core BK108

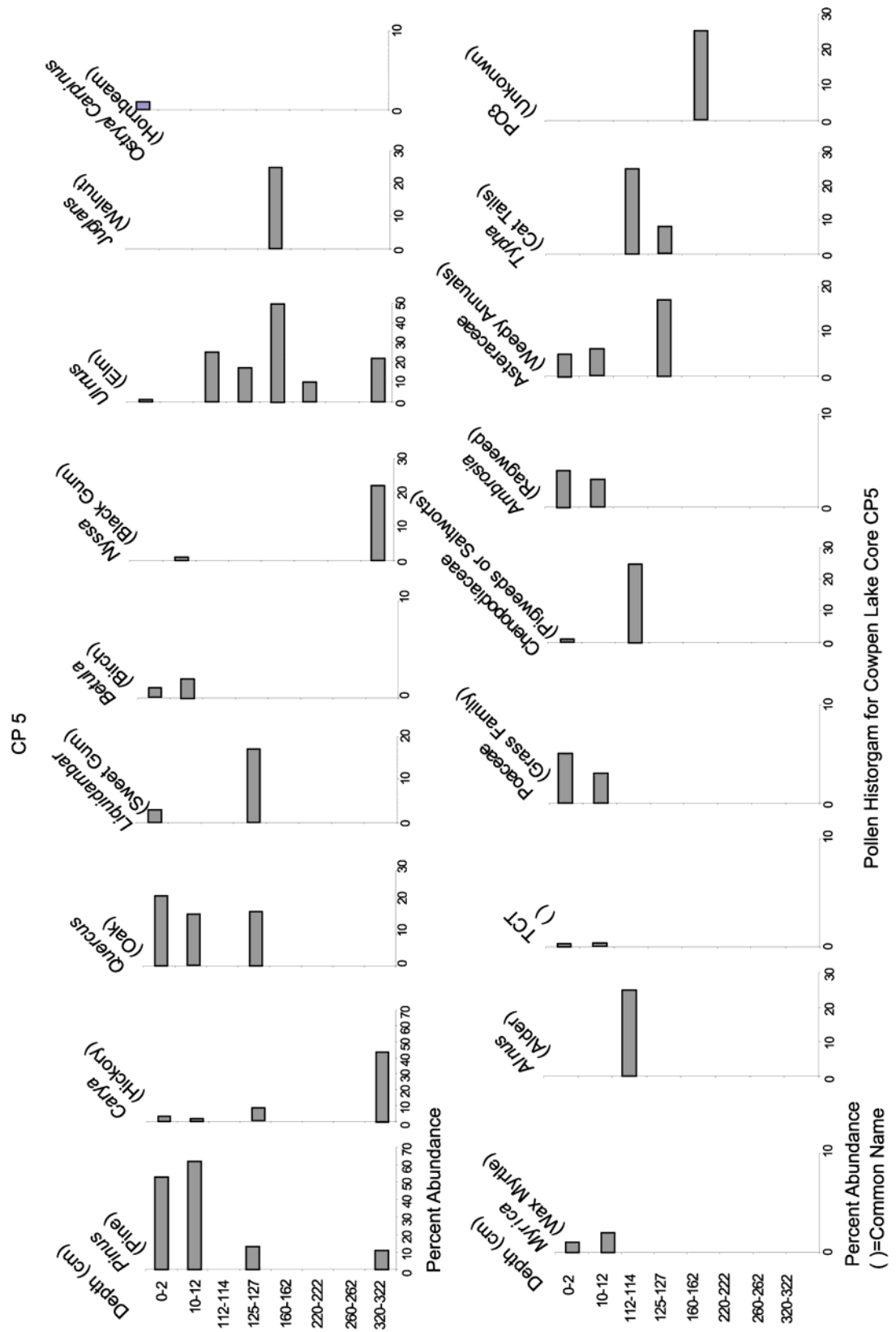




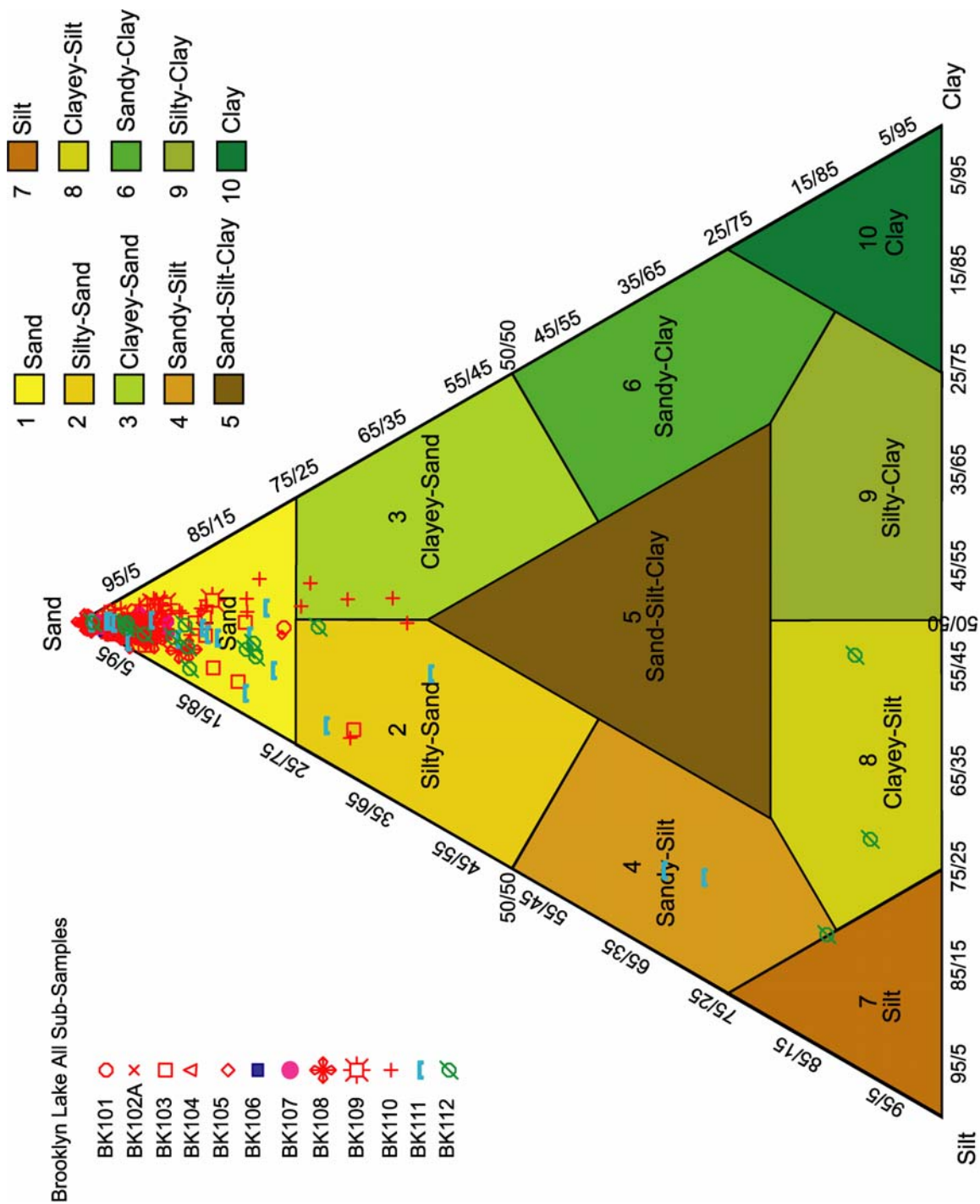


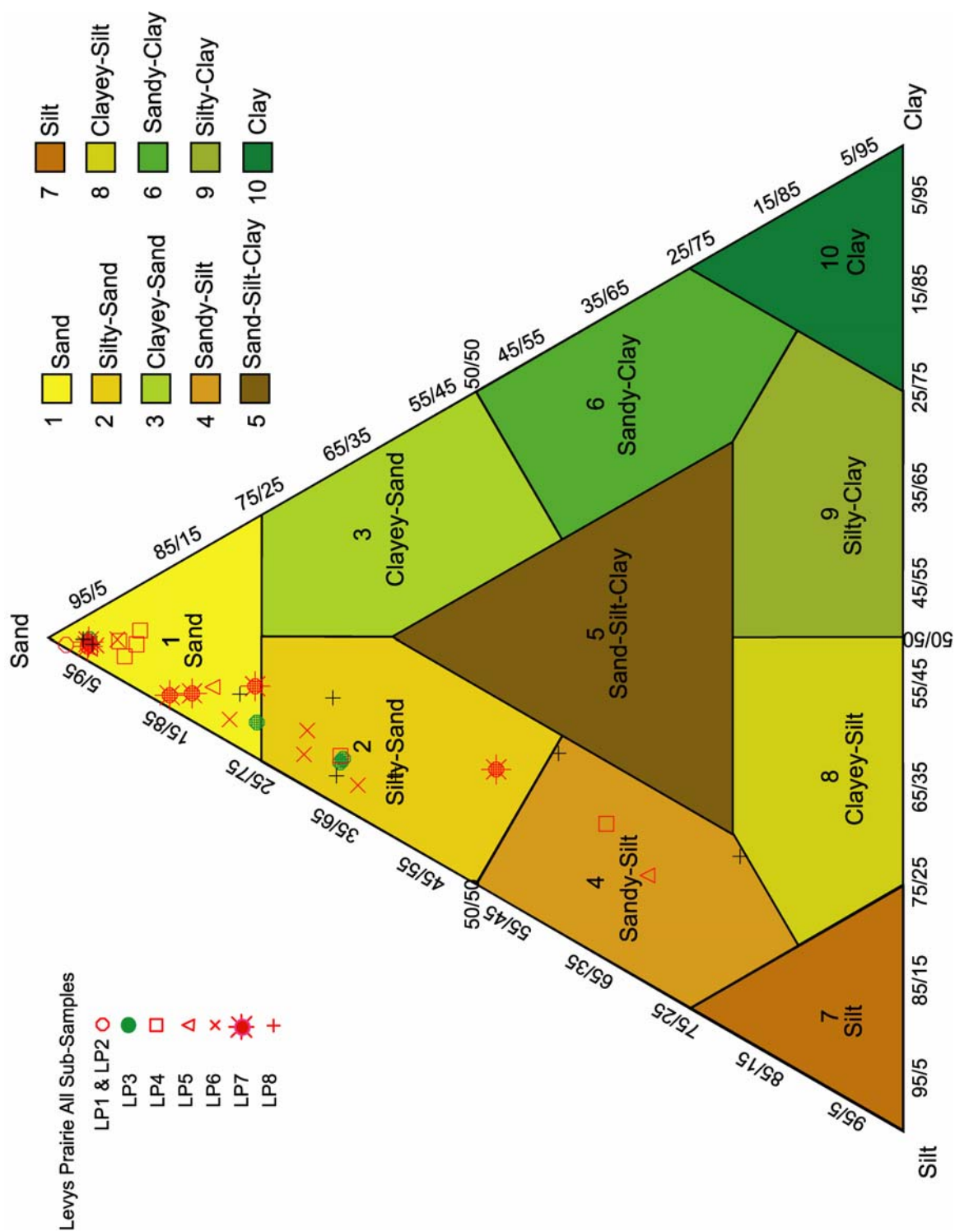


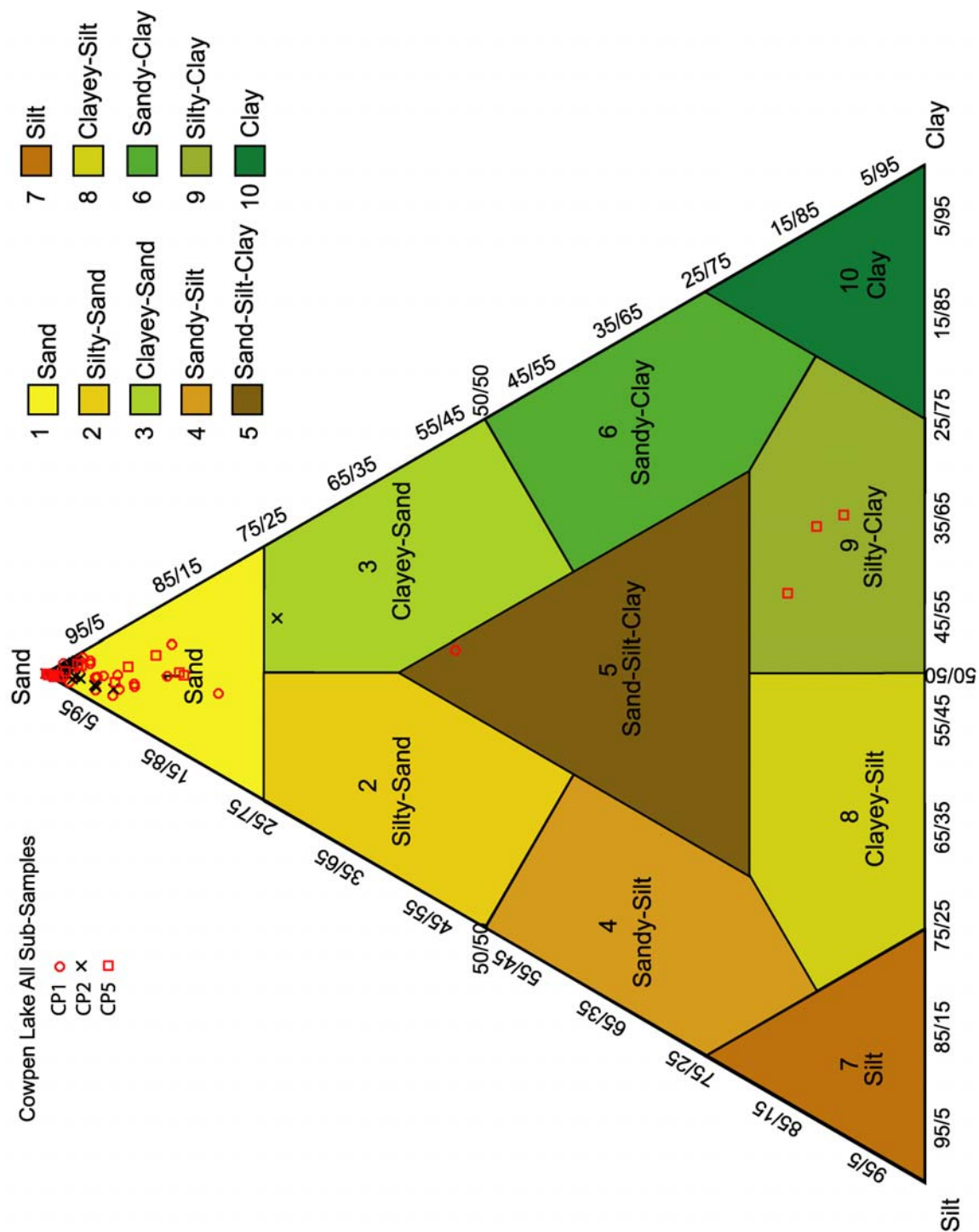
Pollen Histogram for Cowpen Core CP2

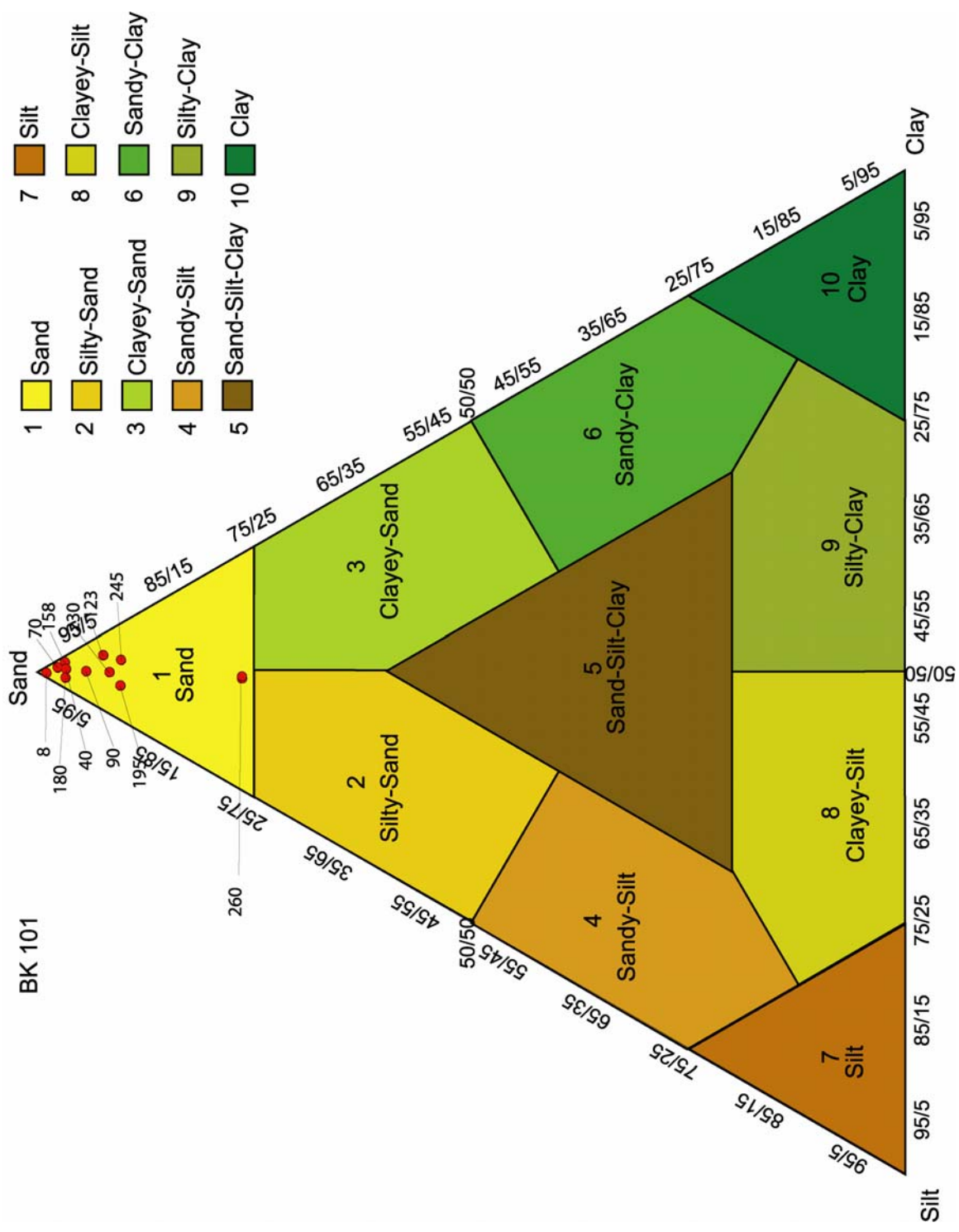


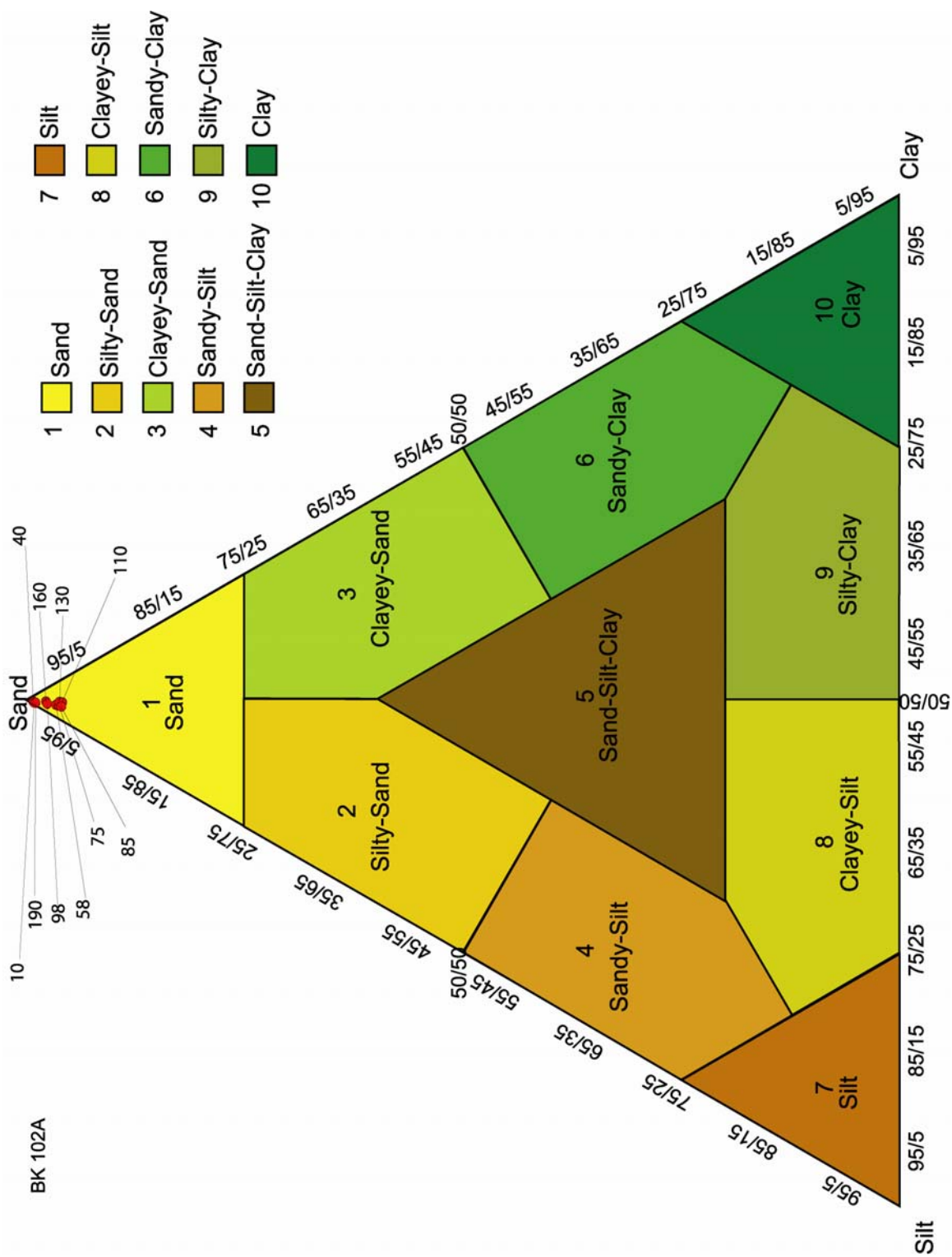
APPENDIX 5
TERNARY PLOTS

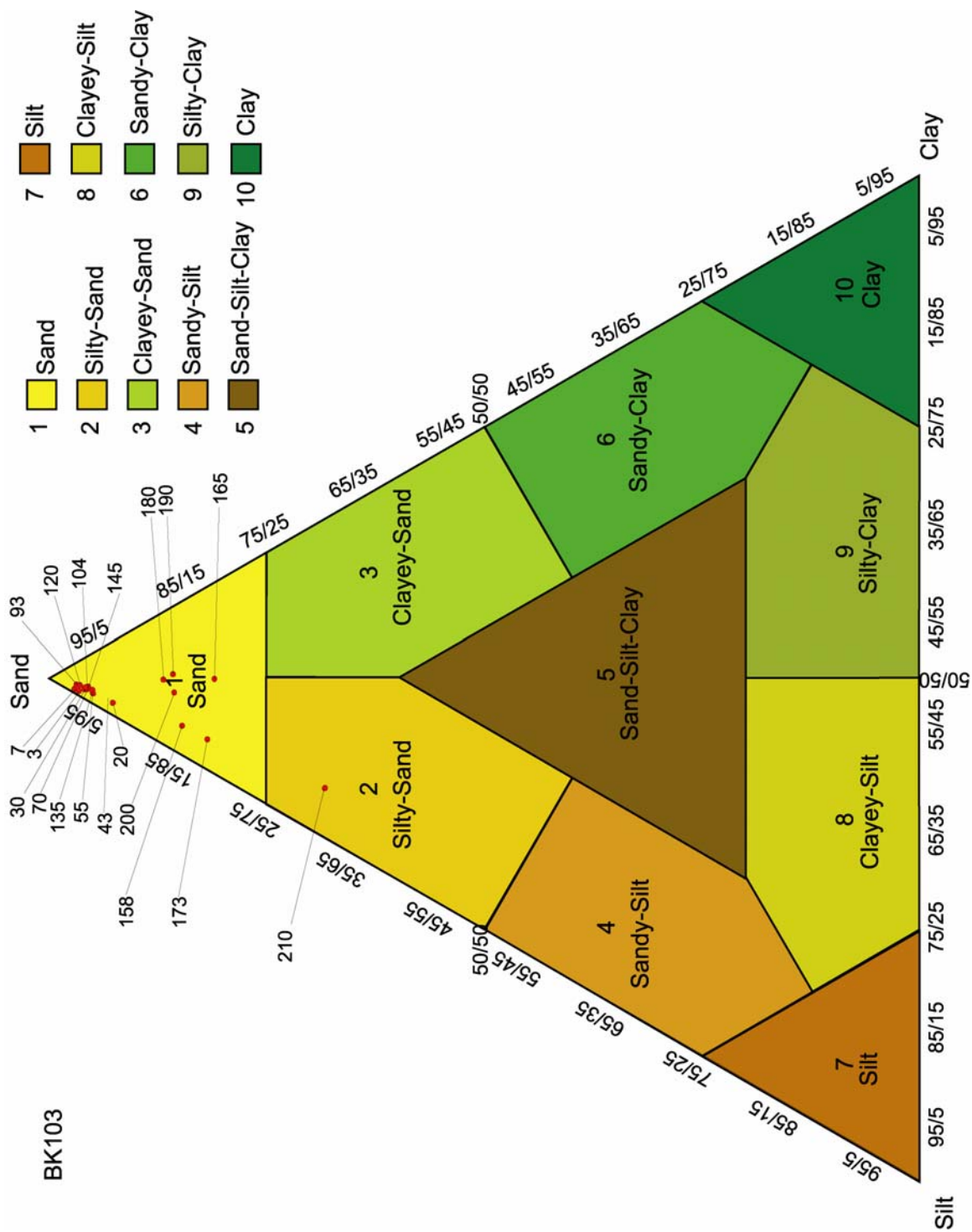


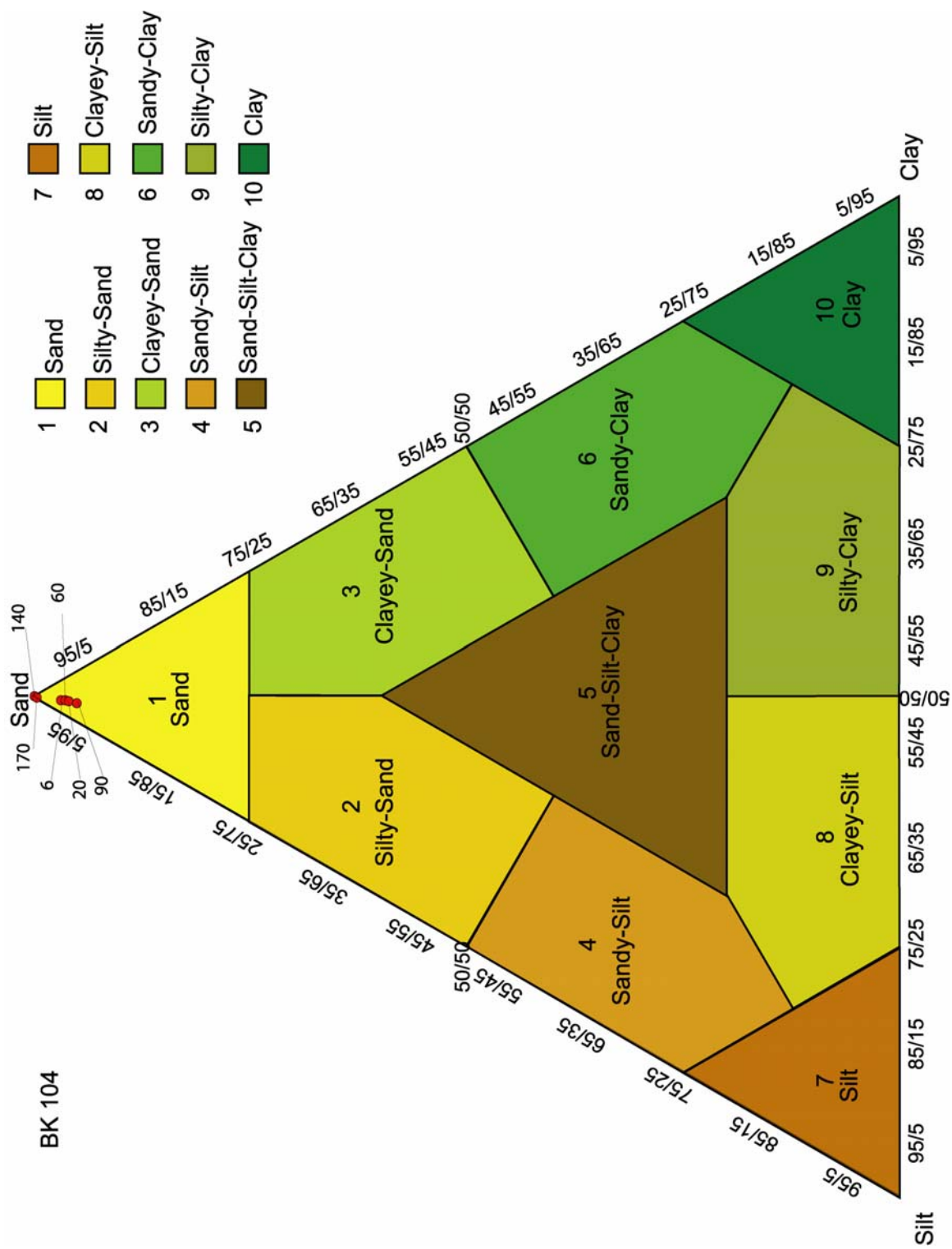


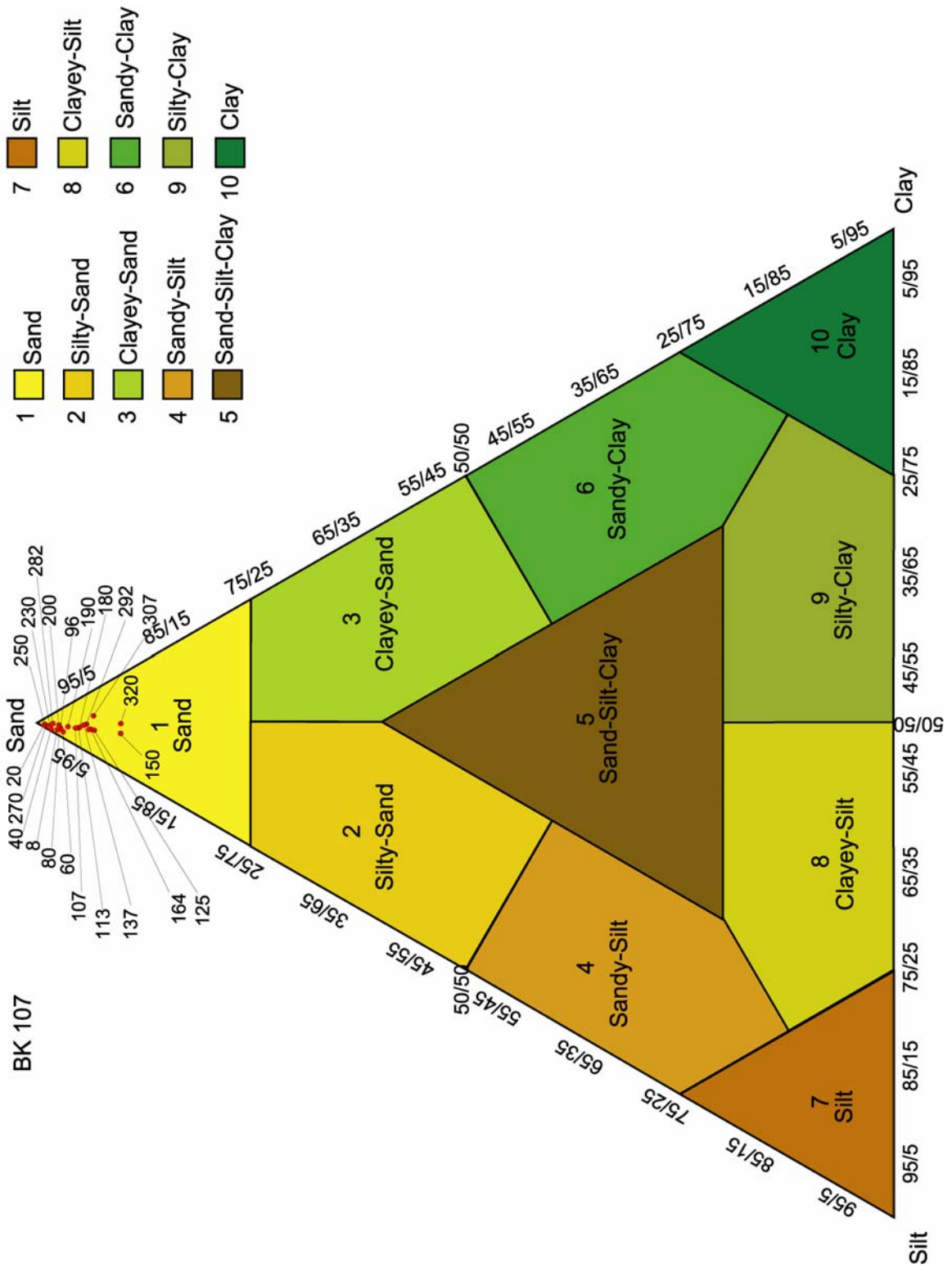




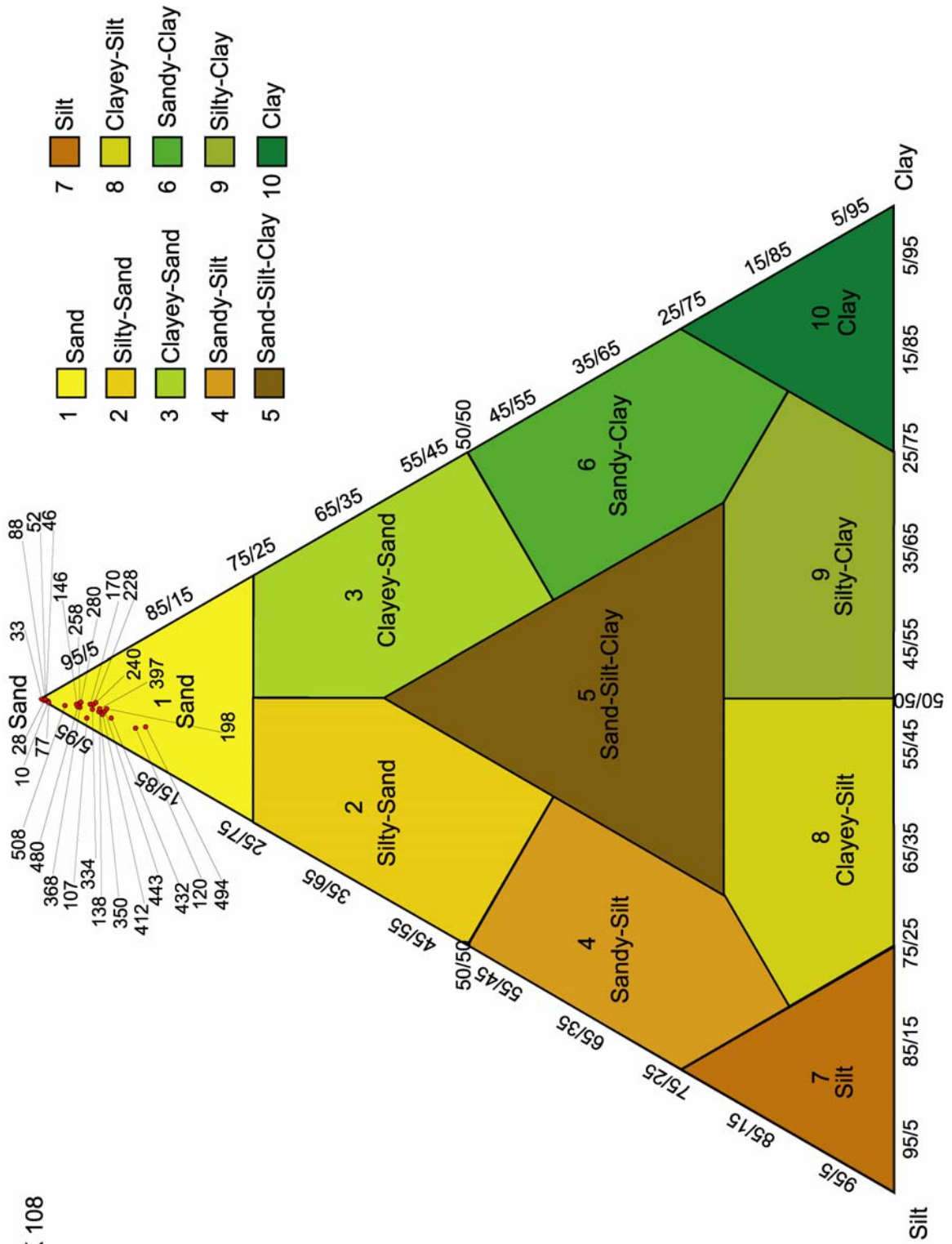


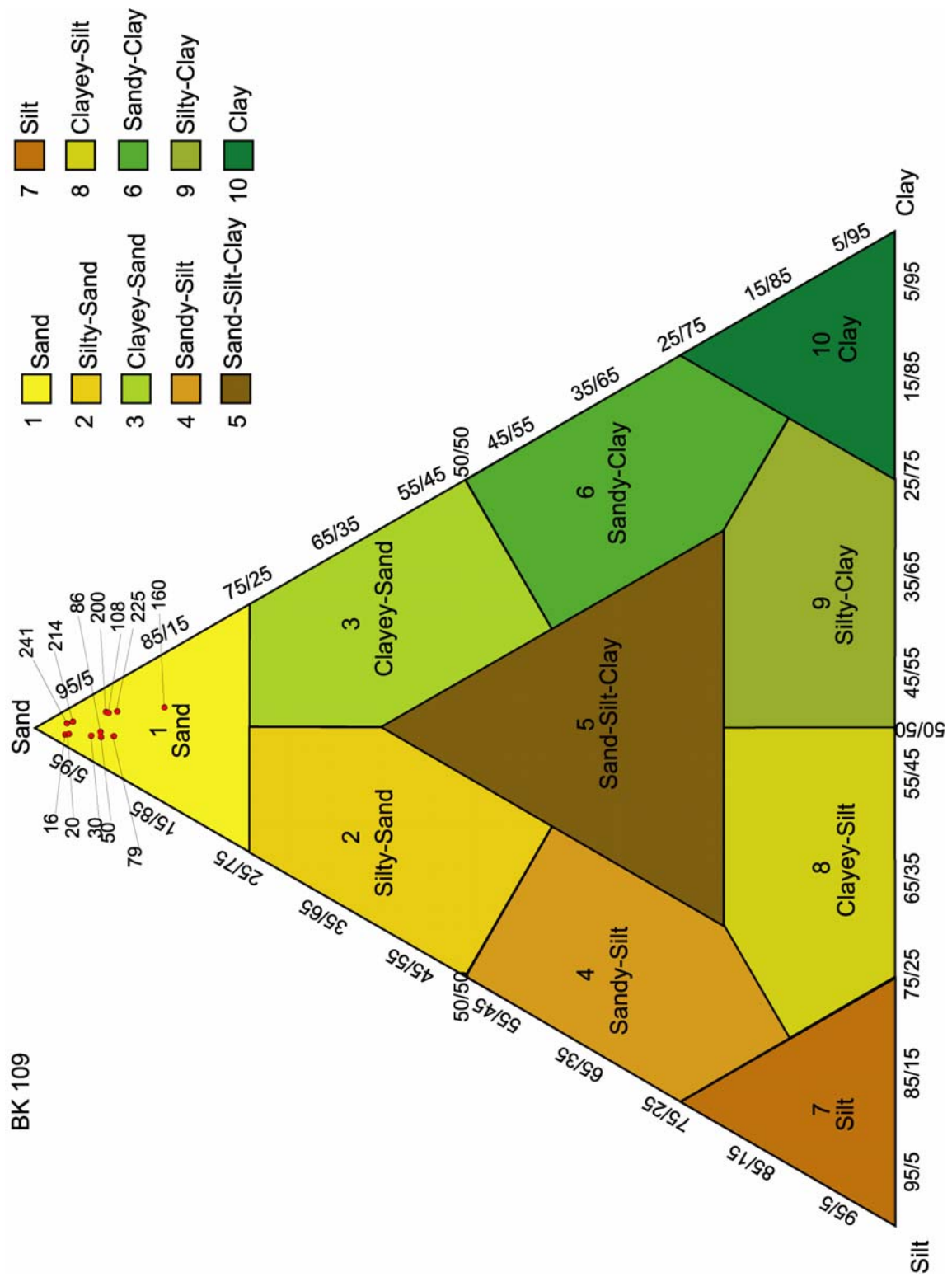


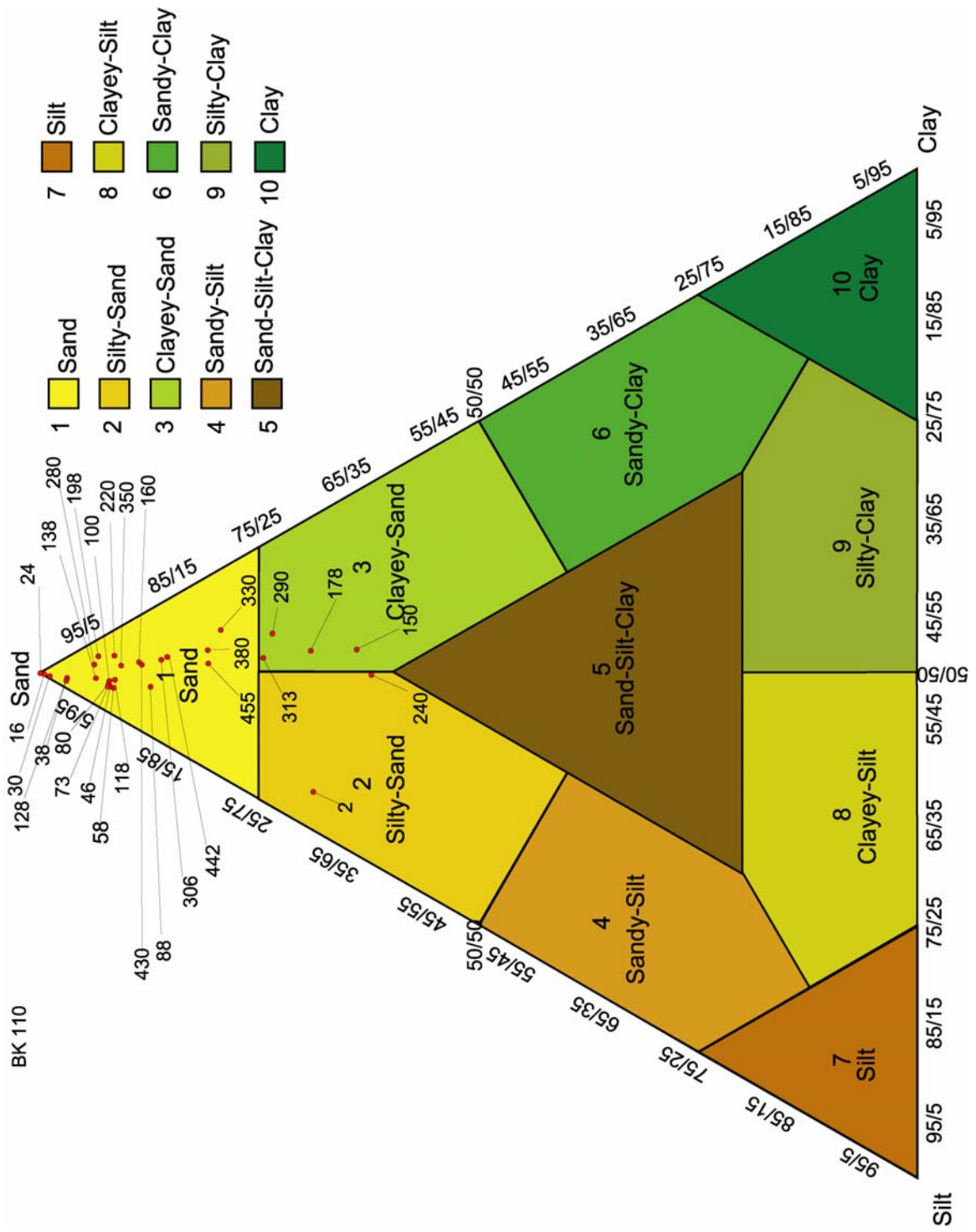


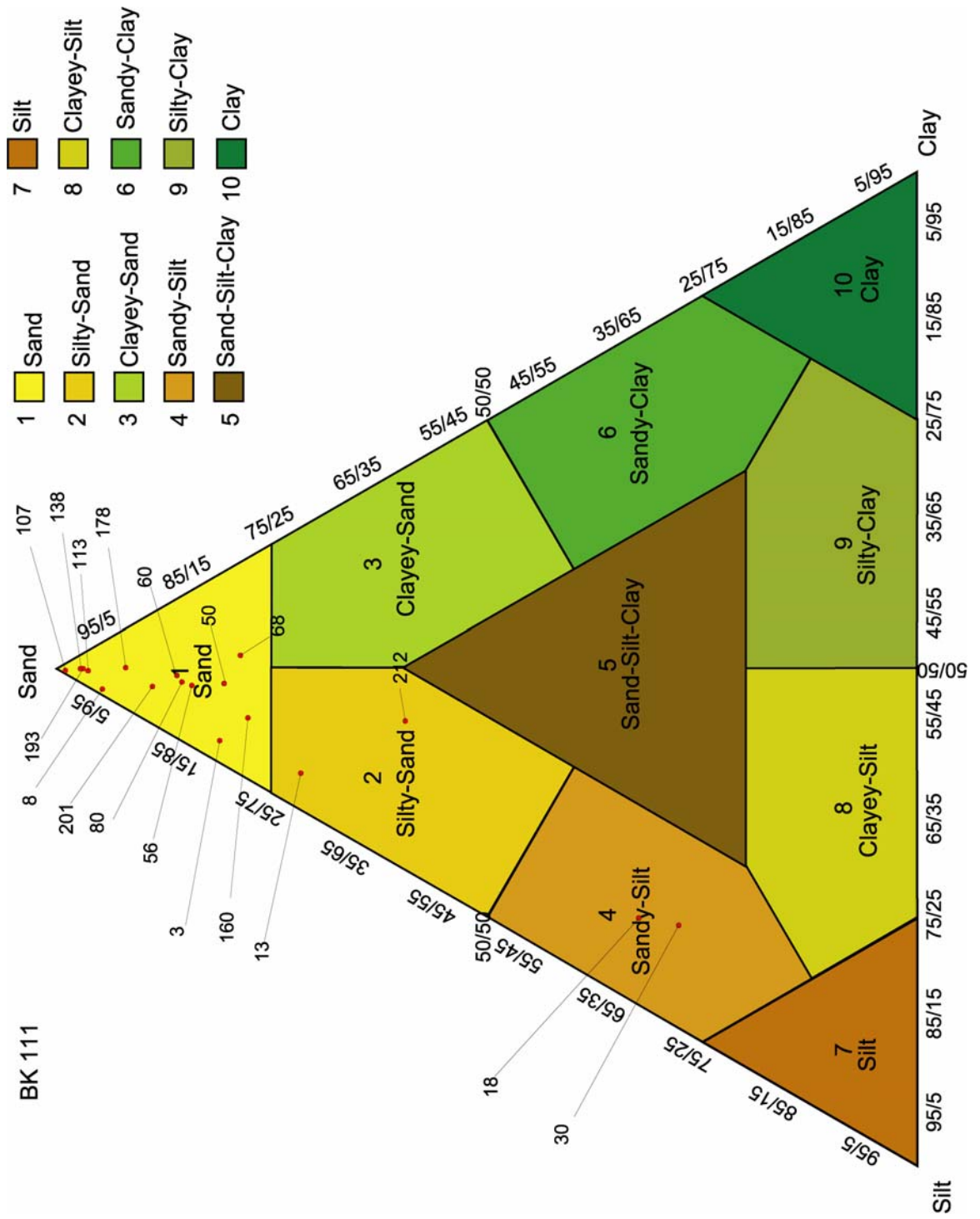


BK 108

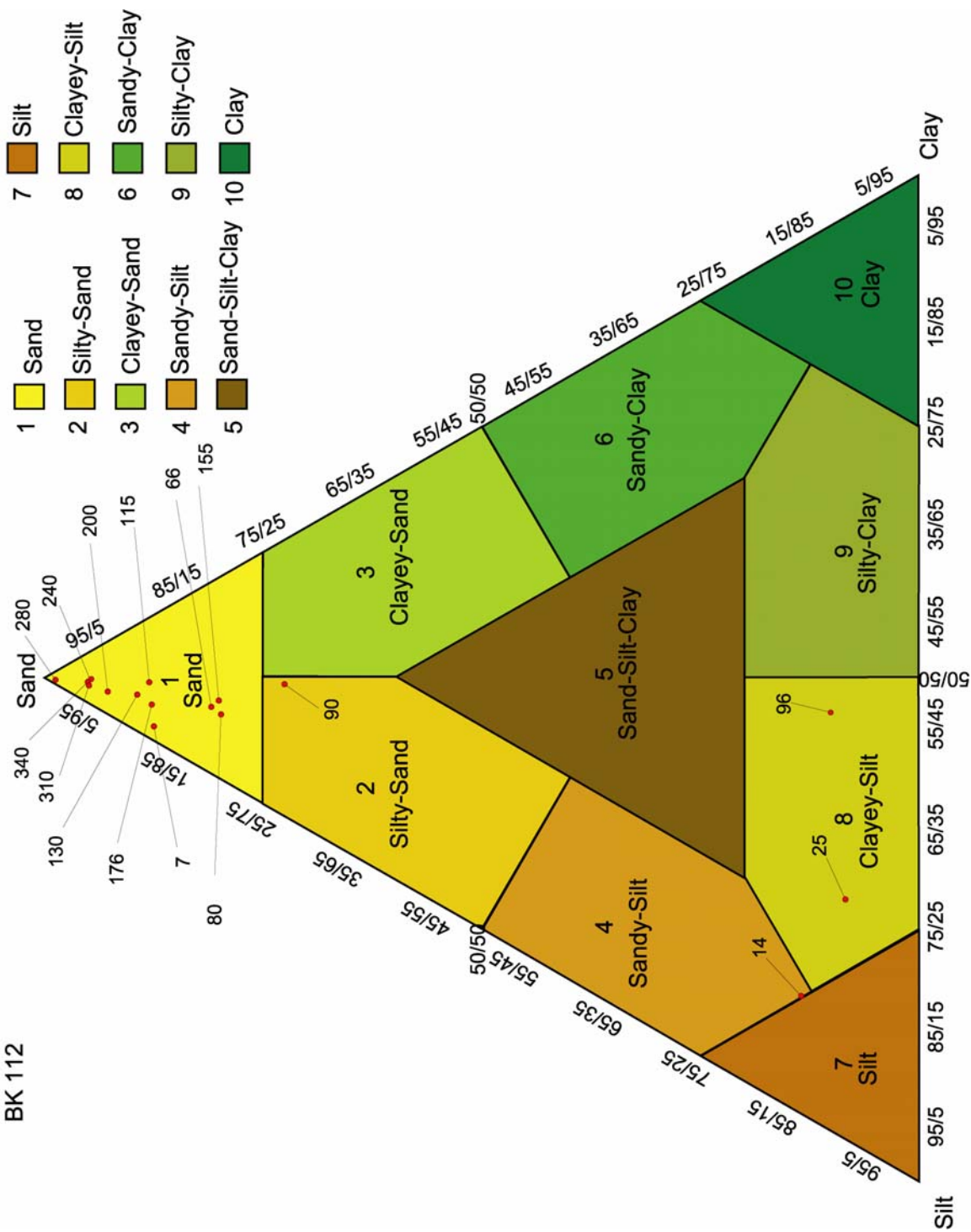


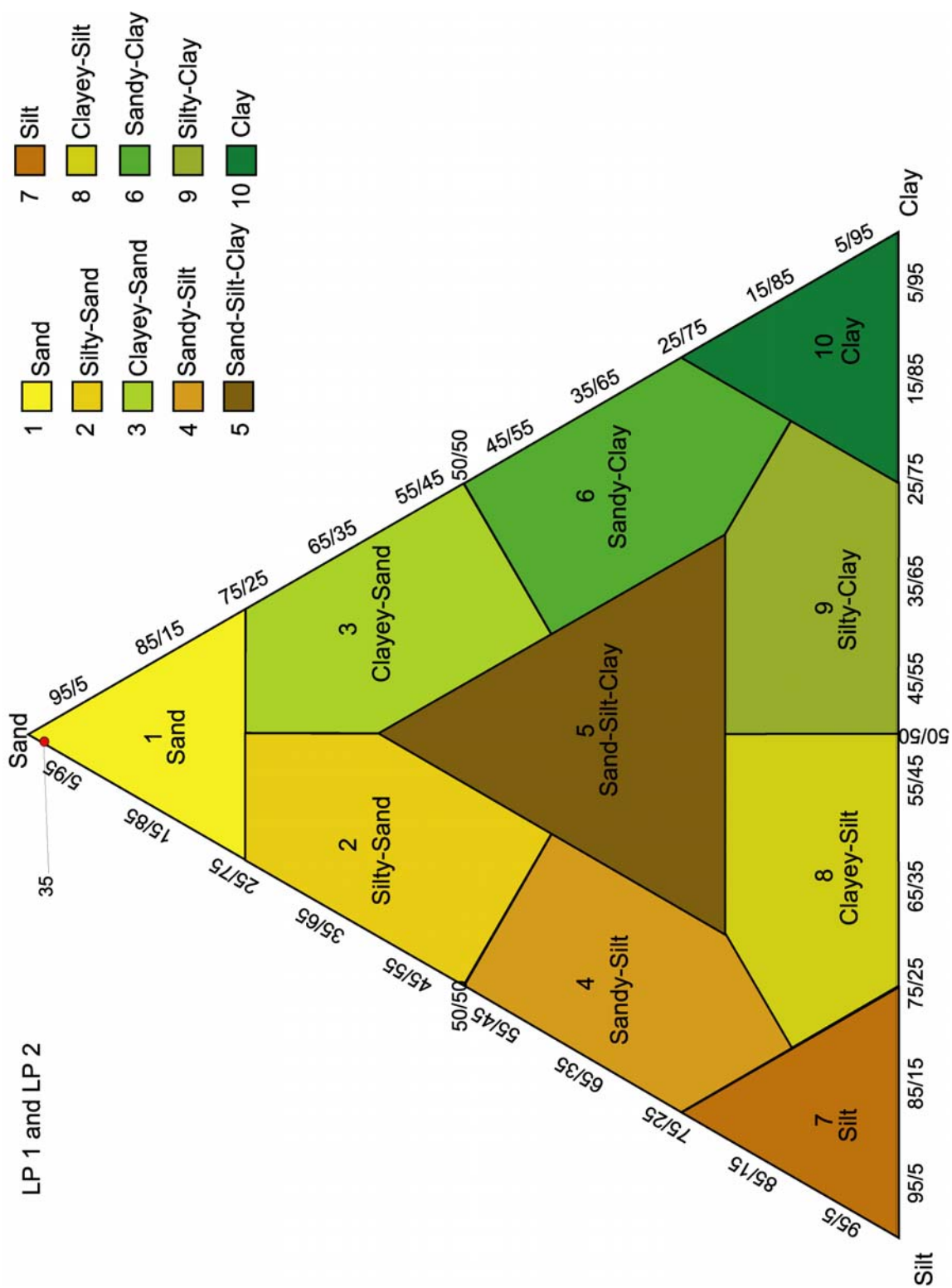


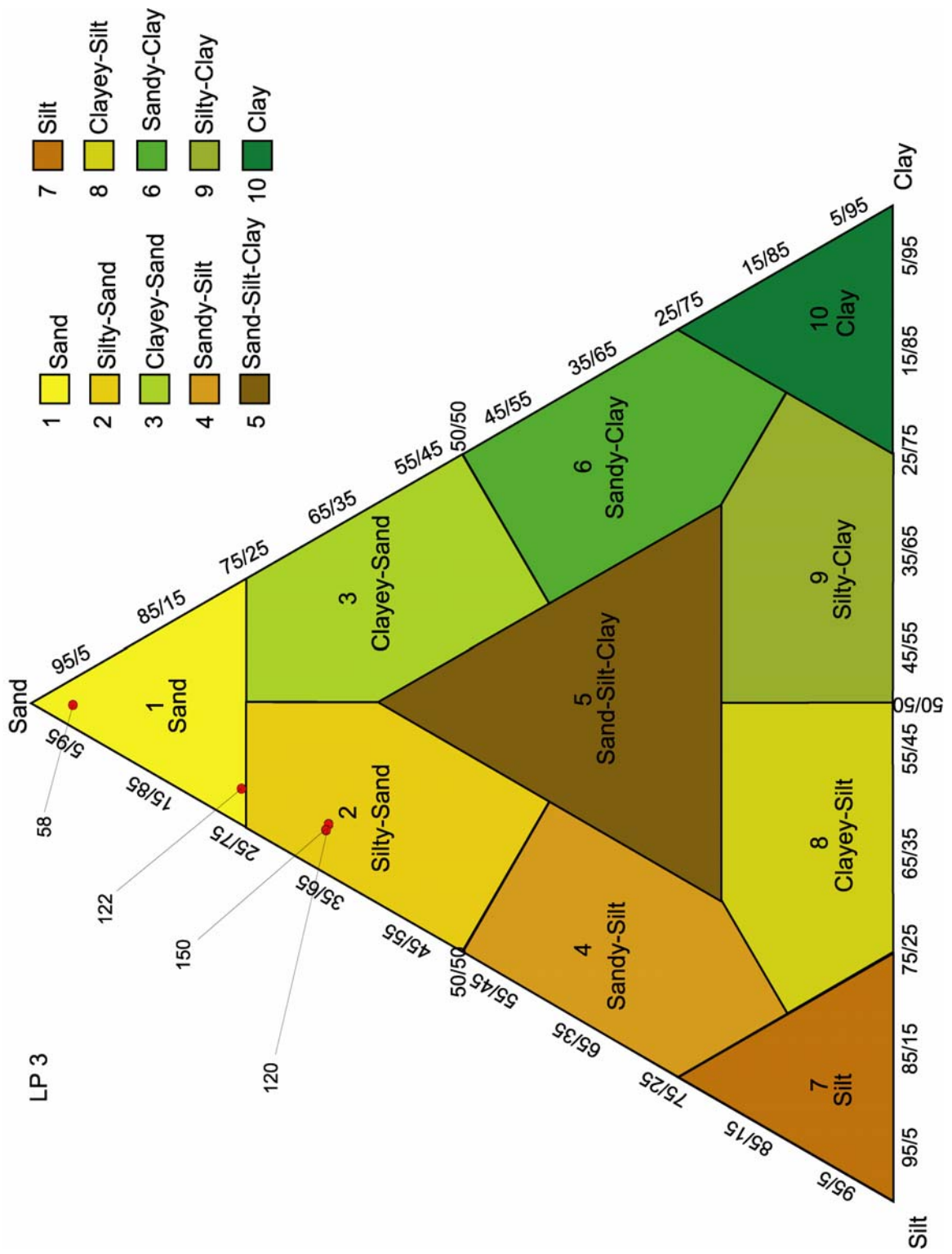


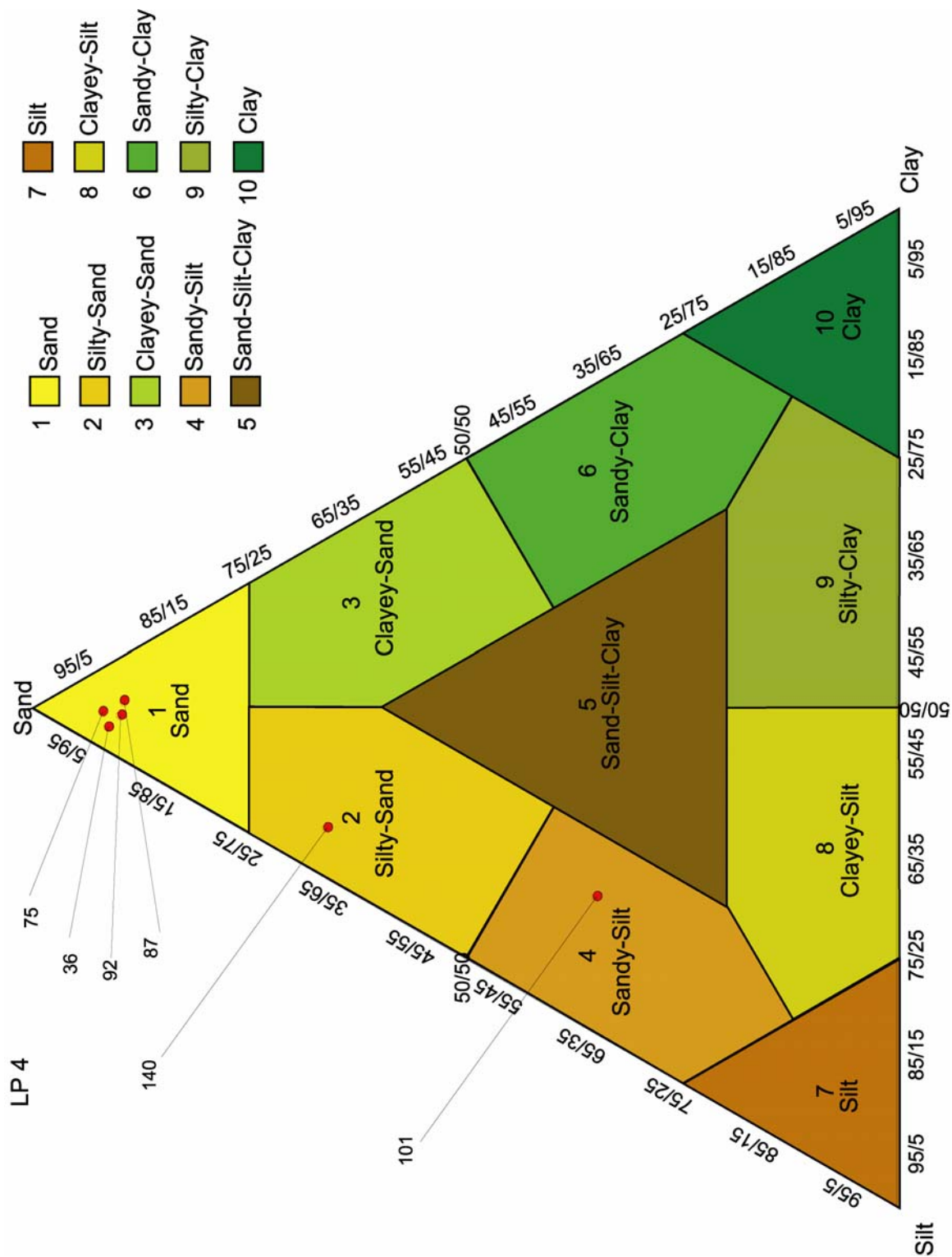


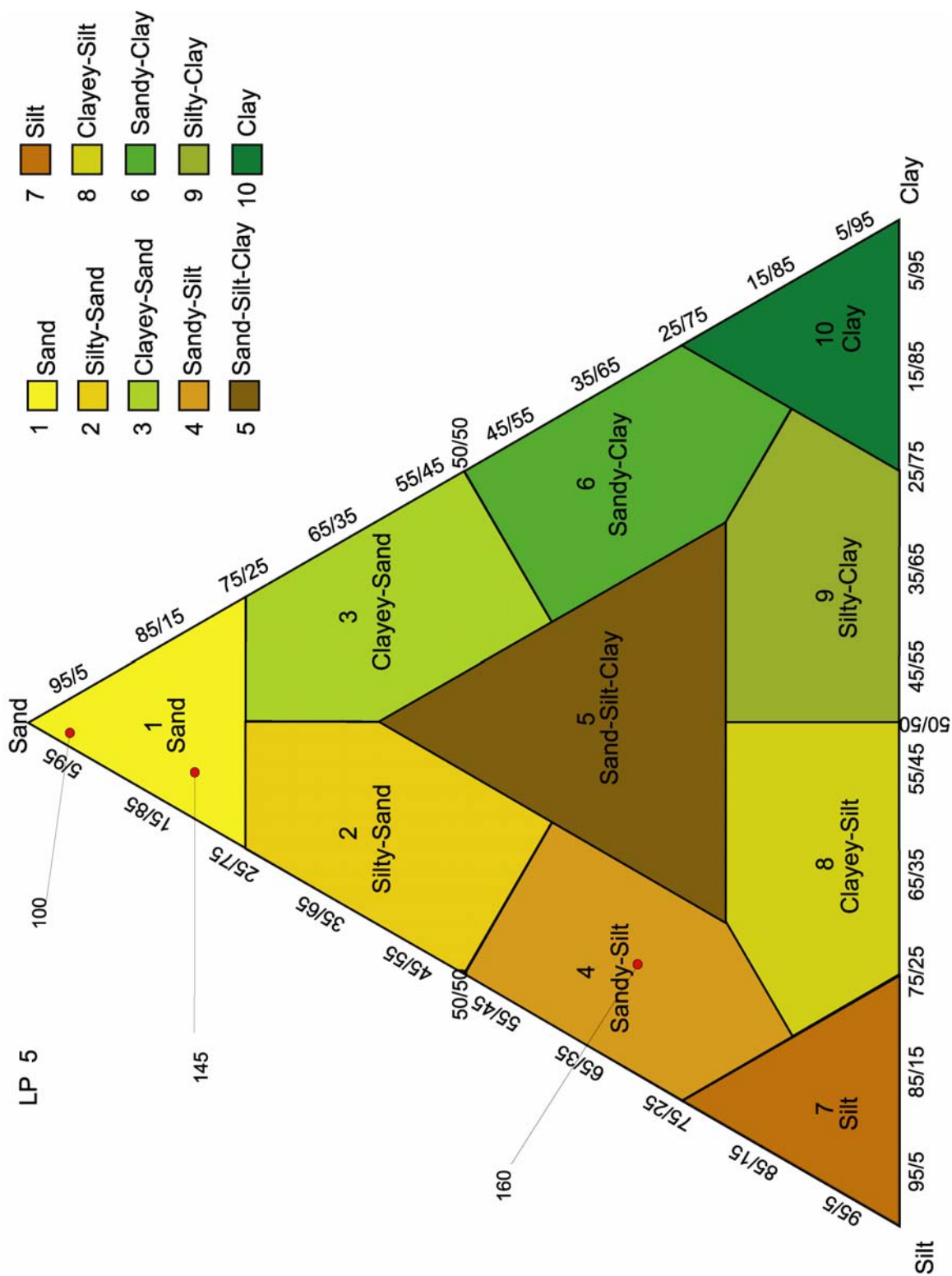
BK 112

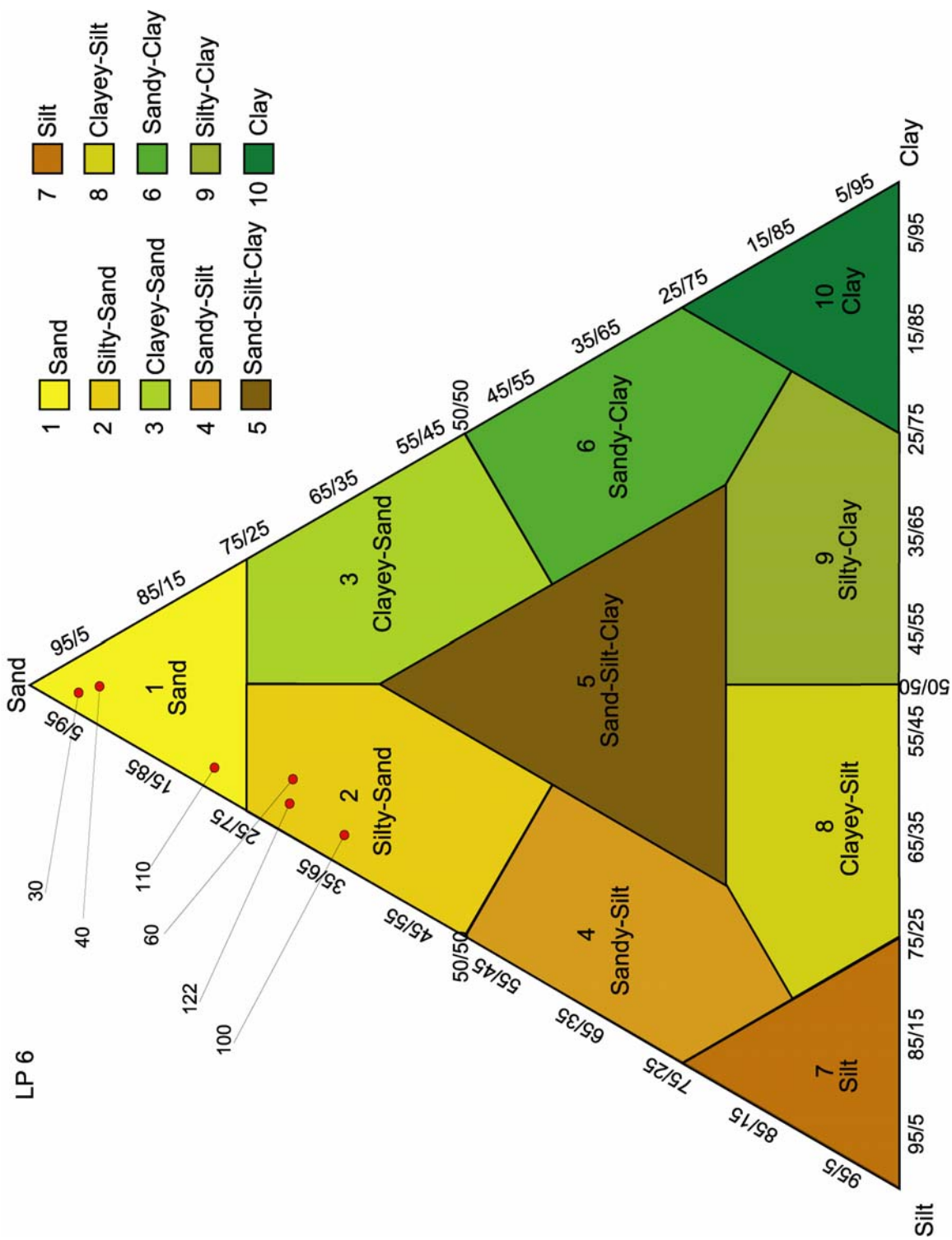


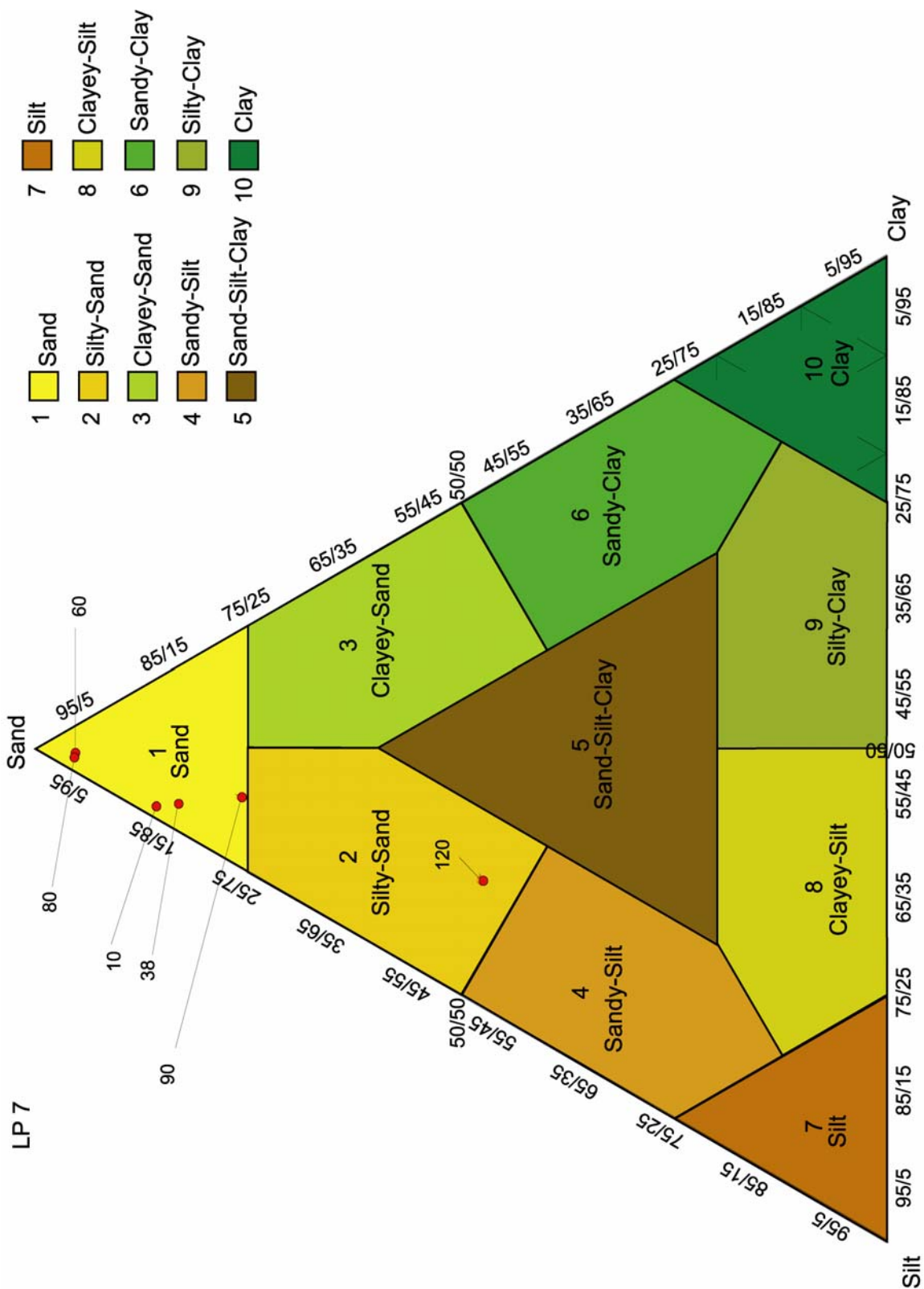


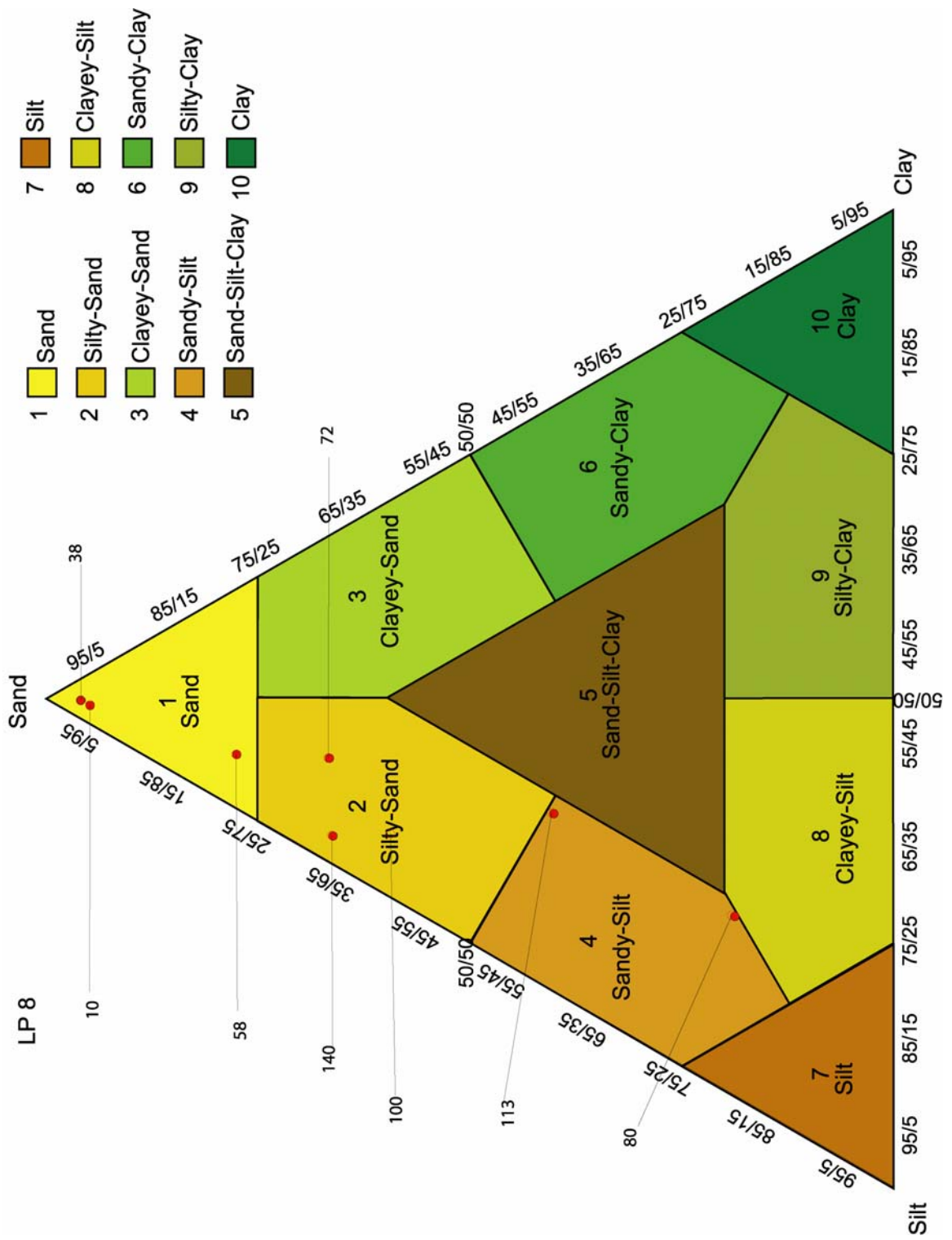


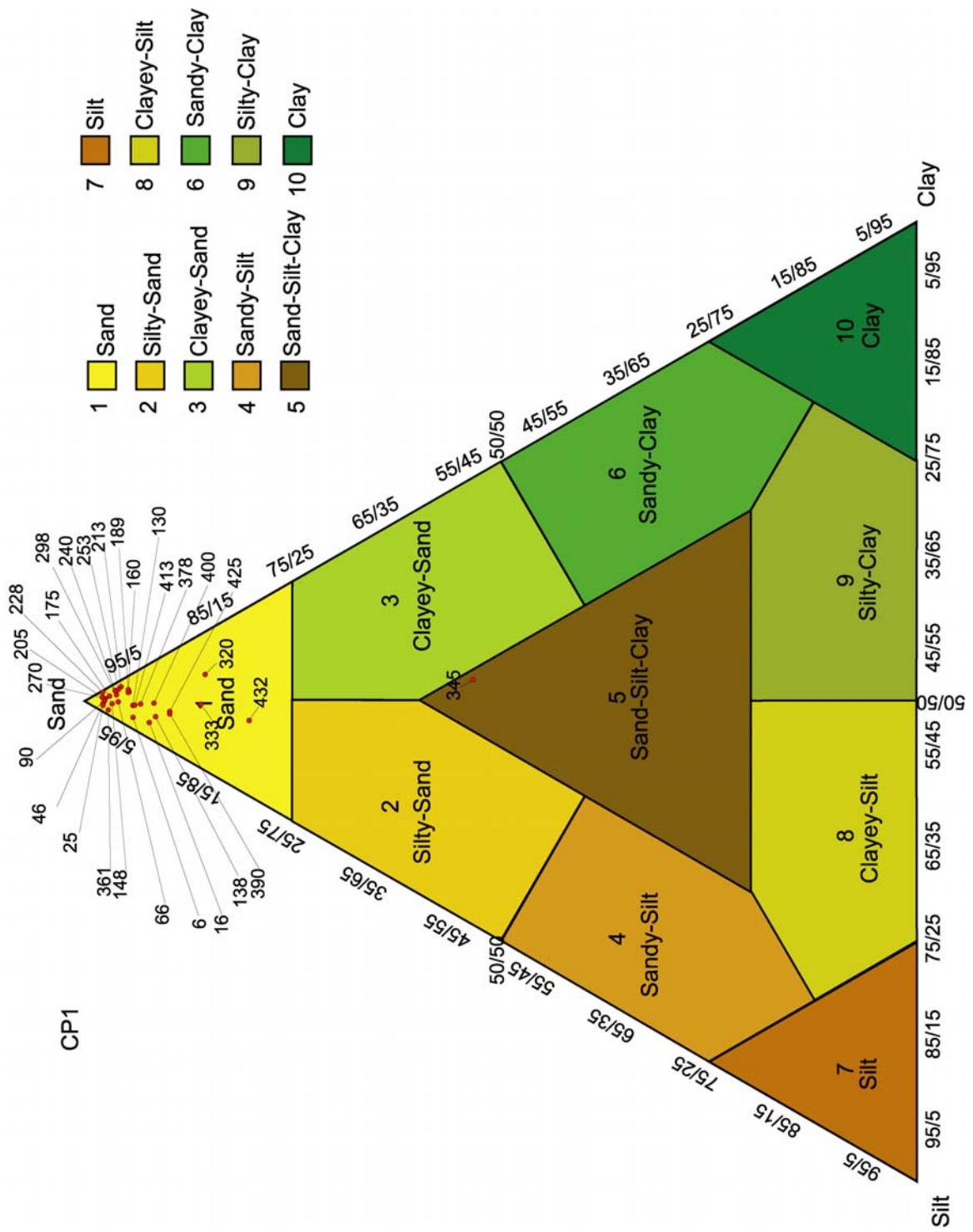


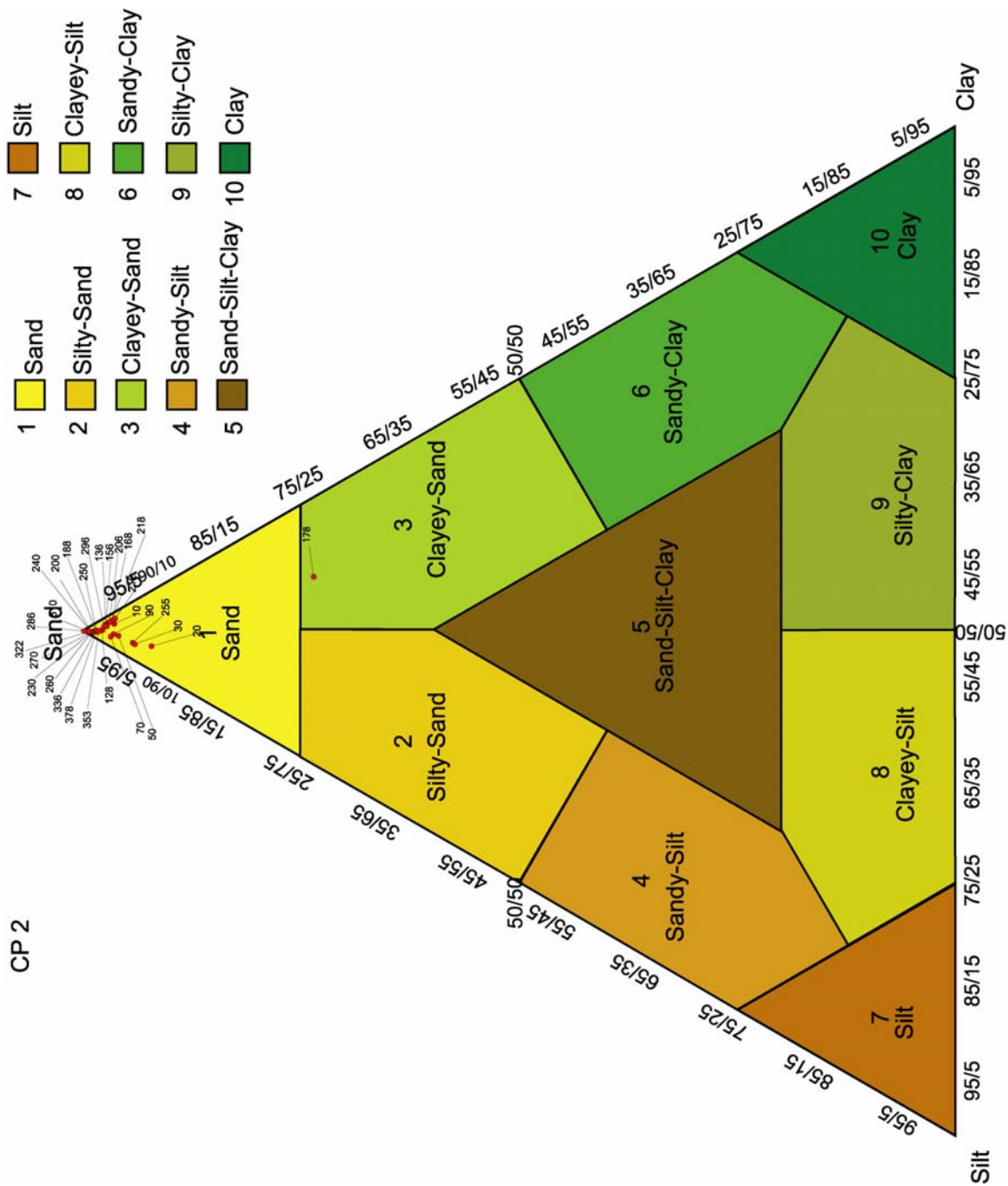


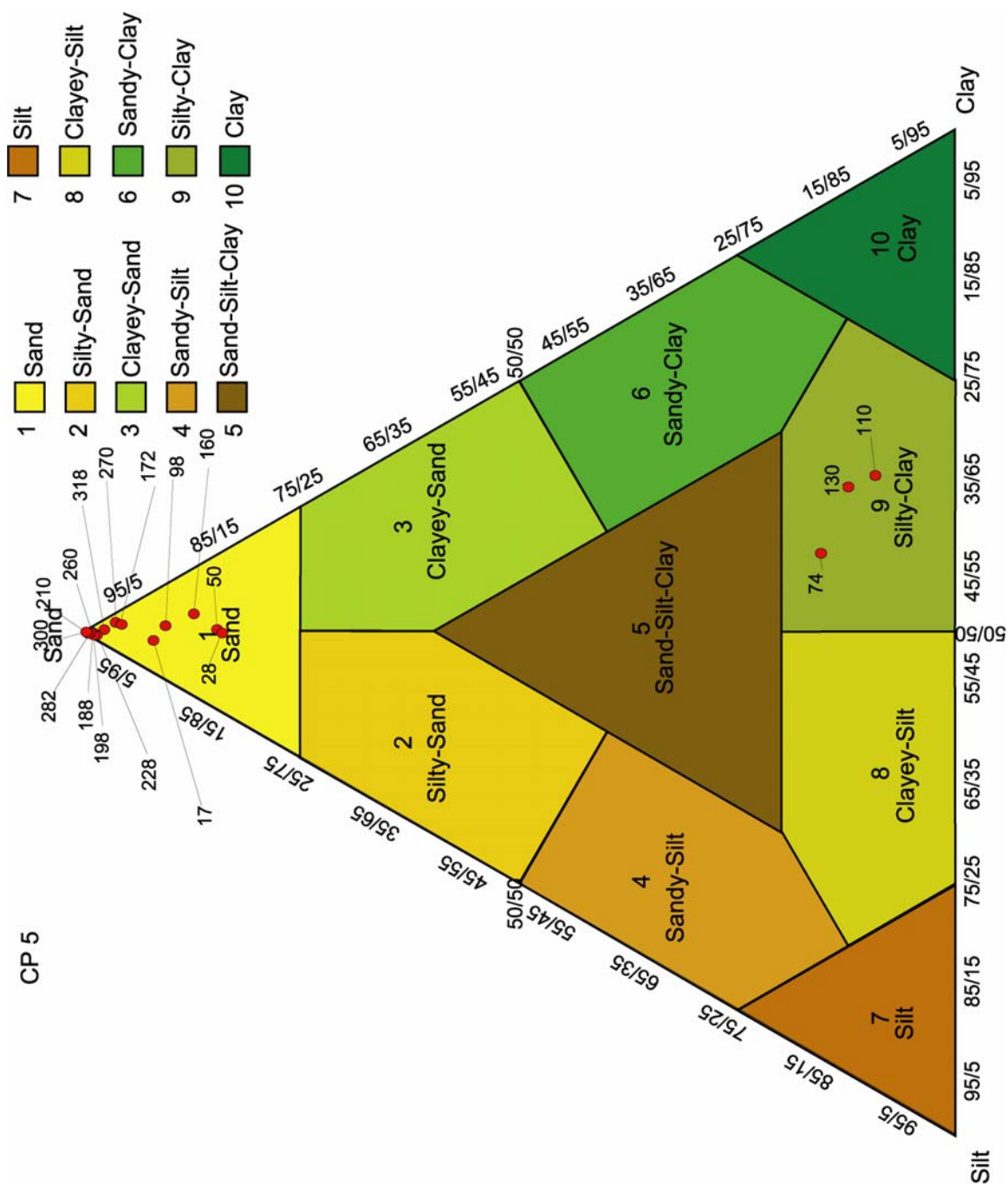












APPENDIX 6
SEDIMENT FACIES SUMMARY

Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Mean Grain Size (Phi)	Sorting (Phi)	%CaCO3	%TOC	Ternary Class	Facies
BK101	8-10	99.09	0.59	0.32	1.87	-	0.10	0.60	Sand	Sand
BK101	40-42	96.80	1.39	1.81	2.12	-	0.36	1.03	Sand	Sand
BK101	70-72	97.76	0.73	1.51	2.06	-	1.24	0.76	Sand	Sand
BK101	90-92	94.51	2.71	2.78	2.16	-	0.35	1.58	Sand	Sand
BK101	123-125	92.55	2.10	5.35	2.19	-	0.28	1.54	Sand	Sand
BK101	158-160	96.96	0.59	2.45	1.95	-	0.12	0.29	Sand	Sand
BK101	180-182	96.96	2.17	0.94	1.31	-	0.25	0.27	Sand	Sand
BK101	195-197	90.49	6.10	3.32	2.28	-	2.18	2.16	Sand	Sand
BK101	230-232	91.83	4.14	4.03	2.26	-	0.35	1.58	Sand	Sand
BK101	245-247	90.41	3.64	5.95	2.30	-	0.22	1.51	Sand	Sand
BK102A	10-12	99.15	0.61	0.18	1.82	0.51	0.38	0.23	Sand	Sand
BK102A	40-42	99.32	0.48	0.22	1.69	0.62	0.00	0.17	Sand	Sand
BK102A	58-60	96.75	2.11	1.22	1.74	0.70	0.24	0.33	Sand	Sand
BK102A	75-77	96.23	2.38	1.32	1.49	0.64	0.27	0.53	Sand	Sand
BK102A	85-87	96.10	2.58	1.34	1.84	0.67	0.31	0.57	Sand	Sand
BK102A	98-100	97.80	1.51	0.80	1.65	0.64	0.23	0.49	Sand	Sand
BK102A	110-112	96.03	2.22	1.73	1.76	0.64	0.27	0.38	Sand	Sand
BK102A	130-131	96.26	2.11	1.61	1.82	0.68	0.12	0.42	Sand	Sand
BK102A	160-162	97.86	1.22	0.94	1.73	0.69	0.00	0.44	Sand	Sand
BK102A	190-192	98.95	0.74	0.23	1.62	0.67	0.27	0.25	Sand	Sand
BK103	7-9	97.06	2.54	0.30	1.65	0.73	0.42	2.25	Sand	Sand
BK103	20-22	92.78	6.08	1.14	1.81	0.74	0.20	1.15	Sand	Sand
BK103	30-32	96.01	3.15	0.82	1.43	0.60	0.11	0.91	Sand	Sand
BK103	43-45	95.02	4.04	0.94	1.76	0.72	0.26	0.71	Sand	Sand
BK103	55-57	95.07	3.90	0.99	1.76	0.73	0.26	0.61	Sand	Sand
BK103	70-72	95.70	3.28	1.00	1.65	0.70	0.41	0.62	Sand	Sand
BK103	93-95	96.91	2.18	0.89	1.51	0.66	0.25	0.50	Sand	Sand
BK103	104-106	95.70	3.01	1.23	1.90	0.76	0.39	0.39	Sand	Sand
BK103	120-122	96.54	2.43	1.02	1.76	0.71	0.00	0.37	Sand	Sand
BK103	135-137	95.05	3.64	1.25	1.69	0.73	0.48	1.01	Sand	Sand
BK103	145-147	95.62	3.09	1.30	1.64	0.75	0.26	0.60	Sand	Sand
BK104	6-7	96.77	2.22	1.03	1.72	0.67	0.13	0.87	Sand	Sand
BK104	20-22	96.09	2.61	1.40	1.54	0.63	0.58	0.43	Sand	Sand
BK104	60-62	96.43	2.36	1.26	1.56	0.65	0.61	0.35	Sand	Sand
BK104	90-92	95.01	3.28	1.66	1.71	0.66	0.36	0.34	Sand	Sand
BK104	140-142	100.00	0.04	0.00	1.29	0.54	0.00	0.37	Sand	Sand
BK104	170-172	99.66	0.32	0.00	1.57	0.58	0.37	0.18	Sand	Sand
BK105	10-12	97.77	2.06	0.19	1.51	0.66	0.14	0.77	Sand	Sand
BK105	20-22	98.13	1.63	0.18	1.70	0.67	0.00	0.49	Sand	Sand
BK105	35-37	99.53	0.46	0.03	1.23	0.55	0.00	0.10	Sand	Sand
BK105	45-47	98.23	1.34	0.37	1.49	0.68	0.10	0.29	Sand	Sand
BK105	76-78	90.15	7.27	2.57	1.75	0.76	0.16	0.91	Sand	Sand
BK105	92-94	92.44	4.89	2.56	1.69	0.67	0.00	0.84	Sand	Sand
BK105	108-110	94.03	3.85	2.14	1.64	0.65	0.00	0.52	Sand	Sand
BK105	113-115	91.03	5.88	3.07	1.72	0.66	0.37	0.80	Sand	Sand
BK105	125-127	94.91	3.39	1.76	1.67	0.67	0.26	0.49	Sand	Sand

BK105	133-135	97.06	1.78	1.25	1.67	0.68	0.00	0.55	Sand	Sand
BK105	150-152	95.21	2.90	1.91	1.60	0.66	0.11	0.44	Sand	Sand
BK105	170-172	98.78	0.77	0.41	1.53	0.63	0.00	0.28	Sand	Sand
BK105	176-178	98.42	0.93	0.52	1.51	0.63	0.00	0.30	Sand	Sand
BK105	185-187	98.46	0.88	0.64	1.48	0.63	0.12	0.25	Sand	Sand
BK105	210-212	98.95	0.75	0.24	1.49	0.64	0.00	0.27	Sand	Sand
BK105	230-232	97.93	1.03	1.09	1.55	0.67	0.00	0.17	Sand	Sand
BK105	260-262	99.10	0.59	0.33	1.31	0.61	0.00	0.26	Sand	Sand
BK105	270-272	96.62	1.42	1.90	1.34	0.62	0.00	0.72	Sand	Sand
BK105	313-315	86.20	5.96	7.81	1.96	0.65	0.11	2.09	Sand	Sand
BK105	330-332	92.46	4.03	3.54	1.53	0.60	0.10	2.20	Sand	Sand
BK106	10-12	99.54	0.49	0.06	1.54	0.54	0.16	0.20	Sand	Sand
BK106	32-34	98.46	1.26	0.20	1.56	0.61	0.56	0.59	Sand	Sand
BK106	58-60	99.07	0.70	0.20	1.55	0.67	0.32	0.17	Sand	Sand
BK106	110-112	99.35	0.55	0.19	1.81	0.78	0.00	0.15	Sand	Sand
BK106	122-124	97.35	2.22	0.43	1.77	0.80	0.15	0.44	Sand	Sand
BK106	130-132	98.04	1.62	0.36	1.50	0.67	0.39	0.24	Sand	Sand
BK106	157-159	98.10	1.67	0.29	1.72	0.73	0.00	0.48	Sand	Sand
BK106	165-167	98.60	1.27	0.14	1.37	0.60	0.00	0.32	Sand	Sand
BK106	175-177	95.91	2.95	1.24	1.58	0.68	0.32	0.49	Sand	Sand
BK106	195-197	92.12	5.63	2.25	1.48	0.64	0.12	1.18	Sand	Sand
BK106	218-220	95.07	2.97	1.85	1.47	0.64	0.11	0.67	Sand	Sand
BK106	240-242	92.99	4.22	2.73	1.80	0.73	0.22	0.54	Sand	Sand
BK106	267-269	92.41	4.45	3.18	1.68	0.67	0.22	0.57	Sand	Sand
BK106	278-280	95.86	2.30	1.83	1.60	0.67	0.00	0.46	Sand	Sand
BK106	330-332	98.85	0.87	0.36	1.53	0.65	0.00	0.34	Sand	Sand
BK107	8-10	97.51	1.81	0.50	1.95	0.80	0.16	0.36	Sand	Sand
BK107	20-22	99.30	0.58	0.17	1.76	0.68	0.10	0.16	Sand	Sand
BK107	40-42	98.42	1.45	0.16	1.53	0.75	0.00	0.21	Sand	Sand
BK107	60-62	96.92	2.37	0.62	1.69	0.75	0.24	0.28	Sand	Sand
BK107	80-82	97.40	1.89	0.69	1.75	0.74	0.00	0.53	Sand	Sand
BK107	96-98	97.34	1.85	0.85	1.54	0.63	0.12	0.45	Sand	Sand
BK107	107-109	95.49	2.70	1.74	1.81	0.72	0.00	0.50	Sand	Sand
BK107	113-115	95.09	2.91	1.91	1.42	0.59	0.00	0.77	Sand	Sand
BK107	125-127	93.39	4.05	2.60	1.65	0.69	0.11	0.58	Sand	Sand
BK107	137-139	94.53	2.92	2.53	1.60	0.65	0.00	0.68	Sand	Sand
BK107	150-152	93.93	3.69	2.33	1.71	0.71	0.32	0.56	Sand	Sand
BK107	164-166	93.75	3.71	2.50	1.77	0.71	0.13	0.53	Sand	Sand
BK107	180-182	95.05	2.89	2.03	1.53	0.65	0.11	0.58	Sand	Sand
BK107	190-192	96.35	2.14	1.42	1.65	0.67	0.00	1.02	Sand	Sand
BK107	200-202	97.45	1.50	1.01	1.60	0.67	0.00	0.25	Sand	Sand
BK107	230-232	98.54	0.97	0.51	1.51	0.62	0.13	0.40	Sand	Sand
BK107	250-252	99.10	0.60	0.27	1.44	0.65	0.00	0.33	Sand	Sand
BK107	270-272	99.01	0.72	0.31	1.29	0.58	0.00	0.28	Sand	Sand
BK107	292-294	94.21	2.98	2.76	1.52	0.66	0.13	0.47	Sand	Sand
BK107	307-309	93.56	2.54	4.02	1.59	0.65	0.19	0.71	Sand	Sand
BK108	10-12	99.10	0.76	0.17	1.67	0.63	0.00	0.31	Sand	Sand
BK108	28-30	99.55	0.43	0.03	1.40	0.63	0.00	0.34	Sand	Sand
BK108	33-35	99.85	0.16	0.00	1.45	0.63	0.00	1.74	Sand	Sand

BK108	46-48	99.41	0.51	0.16	1.79	0.72	0.00	0.28	Sand	Sand
BK108	52-54	99.31	0.49	0.14	1.86	0.68	0.00	0.09	Sand	Sand
BK108	88-90	99.46	0.42	0.16	1.91	0.62	0.00	0.25	Sand	Sand
BK108	138-140	93.19	4.80	2.13	1.56	0.64	0.00	1.04	Sand	Sand
BK108	146-148	95.68	2.75	1.53	1.62	0.63	0.00	1.23	Sand	Sand
BK108	170-172	94.18	3.52	2.33	1.60	0.63	0.00	1.26	Sand	Sand
BK108	198-200	92.20	4.92	2.84	1.69	0.68	0.43	0.82	Sand	Sand
BK108	228-230	93.70	3.72	2.53	1.41	0.66	0.00	1.17	Sand	Sand
BK108	240-242	93.50	3.69	2.78	1.49	0.60	0.47	0.54	Sand	Sand
BK108	258-260	95.48	2.79	1.83	1.55	0.63	0.44	0.90	Sand	Sand
BK108	280-282	95.29	2.77	1.98	1.54	0.66	0.51	0.80	Sand	Sand
BK108	334-336	93.87	4.15	1.95	1.63	0.71	0.63	1.80	Sand	Sand
BK108	350-352	92.99	4.74	2.20	1.64	0.67	0.00	1.57	Sand	Sand
BK108	368-370	95.27	3.21	1.43	1.45	0.62	1.93	1.62	Sand	Sand
BK108	412-414	92.63	5.26	2.03	1.48	0.58	2.99	1.55	Sand	Sand
BK108	432-434	91.72	6.14	2.17	1.50	0.55	3.08	0.52	Sand	Sand
BK108	443-445	92.56	5.08	2.48	1.49	0.51	0.79	1.56	Sand	Sand
BK108	480-482	95.71	3.03	1.35	1.40	0.51	2.15	0.49	Sand	Sand
BK108	494-496	87.74	9.05	3.30	1.59	0.61	1.81	1.00	Sand	Sand
BK108	508-510	97.07	2.17	0.72	1.45	0.61	0.39	0.29	Sand	Sand
BK109	16-18	96.56	2.35	1.15	1.83	0.67	0.13	0.68	Sand	Sand
BK109	20-22	96.25	2.52	1.29	1.59	0.70	0.00	0.64	Sand	Sand
BK109	30-32	93.52	4.02	2.52	1.52	0.73	0.10	0.57	Sand	Sand
BK109	50-52	92.26	4.72	2.96	1.56	0.74	0.11	0.48	Sand	Sand
BK109	79-81	90.86	5.35	3.71	1.48	0.74	0.00	1.91	Sand	Sand
BK110	16-18	99.60	0.36	0.04	1.76	0.55	0.00	0.39	Sand	Sand
BK110	24-26	100.02	0.00	0.00	1.92	0.45	0.00	0.06	Sand	Sand
BK110	30-32	98.97	0.85	0.17	1.49	0.71	0.00	0.28	Sand	Sand
BK110	38-40	96.99	2.24	0.66	1.59	0.66	0.00	0.24	Sand	Sand
BK110	46-48	92.03	5.34	2.60	1.62	0.85	0.00	0.65	Sand	Sand
BK110	58-60	91.63	5.67	2.65	1.77	0.76	0.38	0.96	Sand	Sand
BK110	73-75	92.29	5.22	2.47	1.69	0.83	0.36	0.54	Sand	Sand
BK110	80-82	92.27	4.99	2.75	1.76	0.73	0.00	0.35	Sand	Sand
BK110	100-102	92.16	4.72	3.10	1.79	0.80	0.00	0.36	Sand	Sand
BK110	118-120	91.49	4.92	3.53	1.74	0.84	0.00	0.30	Sand	Sand
BK110	128-130	96.99	2.01	0.99	1.78	0.70	0.00	0.24	Sand	Sand
BK110	138-140	93.70	3.71	2.60	1.74	0.86	0.00	0.32	Sand	Sand
BK110	330-332	79.42	6.03	14.51	4.21	0.91	0.09	1.91	Sand	Sand (?)
BK110	380-382	80.92	7.28	11.77	3.84	0.82	0.21	1.74	Sand	Sand (?)
BK111	8 (sand lens)	94.69	4.75	0.55	2.30	1.06	1.44	1.18	Sand	Sand
BK111	107-109	99.05	0.72	0.28	1.38	0.70	0.00	0.17	Sand	Sand
BK111	113-115	96.35	2.06	1.58	1.36	0.73	0.10	0.45	Sand	Sand
BK111	138-140	97.26	1.43	1.39	1.38	0.73	0.10	0.45	Sand	Sand
BK111	178-180	92.06	3.94	4.08	1.49	0.84	0.21	1.01	Sand	Sand
BK111	193-195	96.83	1.56	1.49	1.48	0.77	0.26	0.27	Sand	Sand
BK112	66-68	81.13	12.39	6.64	3.19	0.89	0.00	1.92	Sand	Sand (?)
BK112	80-82	79.87	13.67	6.44	3.16	0.98	0.00	0.97	Sand	Sand (?)
BK112	200-202	92.85	4.91	2.22	1.46	0.72	0.38	0.70	Sand	Sand
BK112	240-242	94.81	2.75	2.38	1.68	0.64	0.66	0.84	Sand	Sand

BK112	280-282	98.73	0.75	0.39	1.34	0.68	0.25	0.45	Sand	Sand
BK112	310-312	95.10	3.23	1.75	1.70	0.73	0.24	0.28	Sand	Sand
BK112	340-342	95.10	2.81	2.04	1.62	0.65	0.42	0.35	Sand	Sand
BK110	88-90	87.51	7.66	4.87	1.88	0.88	0.24	0.65	Sand	Sand
BK110	430-432	88.53	4.97	6.57	1.71	0.70	0.00	2.04	Sand	Sand
BK111	60-62	86.04	7.70	6.27	1.87	0.83	0.10	1.51	Sand	Sand
BK111	80-82	85.43	8.66	5.90	1.93	0.82	0.18	1.00	Sand	Sand
BK111	201-203	88.83	7.39	3.73	1.86	0.85	1.21	0.66	Sand	Sand
BK112	130-132	89.45	6.90	3.61	1.89	0.75	0.00	0.99	Sand	Sand
BK112	176-178	87.83	8.73	3.45	2.06	0.80	0.31	1.15	Sand	Sand
	Minimum	79.42	0.00	0.00	1.23	0.45	0.00	0.06		
	Maxiumum	100.02	13.67	14.51	4.21	1.06	3.08	2.25		
	Average	95.04	3.06	1.90	1.71	0.69	0.27	0.69		

Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Grain Size (mean phi)	Inman sorting	%CaCO3	%TOC	Ternary Class	Facies
BK103	3-5	96.61	3.00	0.33	1.69	0.69	0.14	2.90	Sand	Organic Sands
BK103	173-175	81.95	15.16	2.90	2.52	1.39	0.95	4.85	Sand	Organic Sands
BK103	158-160	84.84	12.31	2.86	2.46	1.06	0.51	4.07	Sand	Organic Sands
BK103	180-182	86.94	6.70	6.35	1.82	1.06	0.75	4.16	Sand	Organic Sands
BK103	190-192	85.83	6.71	7.44	1.76	1.13	0.81	5.16	Sand	Organic Sands
BK103	200-202	85.76	8.61	5.66	1.67	1.23	0.57	4.46	Sand	Organic Sands
BK105	60-62	92.51	5.76	1.73	1.75	0.74	0.27	3.24	Sand	Organic Sands
BK105	83-85	93.09	4.19	2.65	1.52	0.66	0.28	3.14	Sand	Organic Sands
BK105	275-278	93.34	3.65	3.05	1.42	0.62	0.28	2.88	Sand	Organic Sands
BK105	282-284	90.01	4.20	5.78	1.43	0.65	0.00	4.31	Sand	Organic Sands
BK106	17-19	98.49	1.42	0.09	1.57	0.59	0.78	3.24	Sand	Organic Sands
BK107	282-284	98.10	0.96	0.84	1.26	0.58	0.00	4.08	Sand	Organic Sands
BK107	320-322	90.20	4.92	4.82	1.70	0.68	0.33	4.04	Sand	Organic Sands
BK108	77-79	98.99	0.89	0.09	1.85	0.82	0.52	7.88	Sand	Organic Sands
BK108	107-109	94.51	4.71	0.73	1.99	0.86	0.22	3.88	Sand	Organic Sands
BK108	397-399	93.15	4.53	2.44	1.59	0.60	0.00	2.73	Sand	Organic Sands
BK109	86-88	92.35	4.19	3.43	1.37	0.61	0.24	3.59	Sand	Organic Sands
BK109	108-110	91.47	2.77	5.78	1.55	0.64	0.23	5.31	Sand	Organic Sands
BK109	200-202	91.73	2.50	5.75	1.32	0.62	0.00	4.31	Sand	Organic Sands
BK109	214-216	95.60	1.57	2.85	1.35	0.58	0.44	6.38	Sand	Organic Sands
BK109	225	90.51	3.05	6.44	1.36	0.59	0.42	5.28	Sand	Organic Sands
BK109	241-243	96.20	1.39	2.34	1.18	0.59	0.00	3.86	Sand	Organic Sands
BK110	198-200	93.48	1.65	4.92	1.95	0.81	0.24	3.61	Sand	Organic Sands
BK110	350-352	90.78	3.87	5.30	1.53	0.74	0.23	3.12	Sand	Organic Sands
BK110	442-444	85.56	5.64	8.76	1.79	0.76	0.00	2.66	Sand	Organic Sands
BK108	120-122	88.83	8.58	2.58	1.68	0.69	0.37	7.29	Sand	Organic Sands
BK109	160-162	84.99	5.46	9.62	1.78	0.70	0.30	3.91	Sand	Organic Sands
BK110	160-162	88.77	4.58	6.66	1.76	1.03	0.00	3.51	Sand	Organic Sands
BK110	220-222	91.54	2.51	5.89	2.17	0.74	0.10	4.55	Sand	Organic Sands
BK110	280-282	93.93	2.24	3.87	2.27	0.85	0.00	4.02	Sand	Organic Sands
BK110	306-308	86.31	5.60	8.17	1.83	0.73	0.00	3.81	Sand	Organic Sands
BK111	56-58	84.32	9.59	6.13	2.17	0.85	0.34	4.66	Sand	Organic Sands (?)
BK112	7-9	87.57	11.02	1.40	2.67	1.09	0.50	3.38	Sand	Organic Sands (?)
BK112	115-117	88.12	6.36	5.53	1.81	0.78	0.00	3.03	Sand	Organic Sands
	Minimum	81.95	0.89	0.09	1.18	0.58	0.00	2.66		
	Maxiumum	98.99	15.16	9.62	2.67	1.39	0.95	7.88		
	Average	90.78	5.01	4.21	1.75	0.79	0.29	4.16		

Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Grain Size (mean phi)	Inman sorting	%CaCO3	%TOC	Ternary Class	Facies
BK101	260-262	76.60	12.37	11.03	2.95	--	0.98	5.12	Sand	Organic Fine Sands
BK103	165-167	81.09	9.58	9.31	3.33	1.12	1.10	2.90	Sand	Organic Fine Sands
BK103	210-212	68.47	26.76	4.78	3.16	2.00	0.78	3.58	Silty-Sand	Organic Fine Sands
BK105	298-300	76.87	13.00	10.17	3.83	0.97	0.44	4.82	Sand	Organic Fine Sands
BK110	455-457	80.89	8.64	10.48	3.50	0.91	0.00	5.66	Sand	Organic Fine Sands
BK111	3-5	81.03	16.77	2.18	2.91	1.24	0.36	3.03	Sand	Organic Fine Sands
BK111	13-15	71.62	24.79	3.61	3.43	1.56	0.16	8.21	Silty-Sand	Organic Fine Sands
BK111	50-52	80.51	11.25	8.21	3.44	0.98	0.00	3.19	Sand	Organic Fine Sands
BK111	68-70	78.63	9.38	11.99	3.88	1.15	0.00	3.23	Sand	Organic Fine Sands
BK111	160 (clay ba	77.76	16.12	6.12	2.97	1.47	1.35	2.33	Sand	Organic Fine Sands
BK112	155-157	80.09	12.16	7.69	3.37	0.95	0.10	3.42	Sand	Organic Fine Sands
	Minimum	68.47	8.64	2.18	2.91	0.91	0.00	2.33		
	Maxiumum	81.09	26.76	11.99	3.88	2.00	1.35	8.21		
	Average	77.60	14.62	7.78	3.34	1.24	0.48	4.14		
Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Grain Size (mean phi)	Inman sorting	%CaCO3	%TOC	Ternary Class	Facies
BK110	150-152	63.94	15.73	20.34	4.76	3.39	0.40	3.78	Clayey-Sand	Yellowish-Gray Organic Mud
BK110	178-180	69.17	13.23	17.59	4.60	2.94	0.00	4.09	Clayey-Sand	Yellowish-Gray Organic Mud
BK110	240-242	62.26	19.09	18.66	4.98	3.03	0.00	5.79	Silty-Sand	Yellowish-Gray Organic Mud
BK110	290-292	73.53	9.41	17.06	5.17	1.77	0.41	4.70	Clayey-Sand	Yellowish-Gray Organic Mud
BK110	313-315	74.63	11.22	14.18	4.25	1.88	0.27	4.76	Clayey-Sand	Yellowish-Gray Organic Mud
BK111	212-214	59.43	25.60	14.97	4.60	2.82	2.04	1.39	Silty-Sand	Yellowish-Gray Organic Mud (?)
BK112	90-92	72.60	14.31	13.08	4.19	2.30	0.45	4.88	Silty-Sand	Yellowish-Gray Organic Mud
BK112	96-98	10.12	48.47	41.54	7.42	2.52	0.00	9.77	Clayey-Silt	Yellowish-Gray Organic Mud (?)
	Minimum	10.12	9.41	13.08	4.19	1.77	0.00	1.39		
	Maxiumum	74.63	48.47	41.54	7.42	3.39	2.04	9.77		
	Average	60.71	19.63	19.68	5.00	2.58	0.45	4.90		
Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Grain Size (mean phi)	Inman sorting	%CaCO3	%TOC	Ternary Class	Facies
BK111	18-20	32.25	59.12	8.66	4.94	1.95	1.03	28.61	Sandy-Silt	Black Organic Rich Mud
BK111	30-32	27.63	62.17	10.27	5.23	1.99	2.50	52.54	Sandy-Silt	Black Organic Rich Mud
BK112	14-16	13.41	75.08	11.63	5.81	1.45	3.07	47.29	Sandy-Silt	Black Organic Rich Mud
BK112	25-27	8.33	67.91	23.78	6.55	1.90	5.33	53.17	Clayey-Silt	Black Organic Rich Mud
	Minimum	8.33	59.12	8.66	4.94	1.45	1.03	28.61		
	Maxiumum	32.25	75.08	23.78	6.55	1.99	5.33	53.17		
	Average	20.40	66.07	13.59	5.63	1.82	2.98	45.40		

Core	Depth Interval (cm)	*Color	*Color Number	Mineralogy C=Coarse F=Fine
BK101	8-10	Light Gray		
BK101	40-42	Very Light Brown		
BK101	70-72	Very Light Brown		
BK101	90-92	Very Light Brown		
BK101	123-125	Tan		
BK101	158-160	Tan to Light Gray		
BK101	180-182	Tan to Light Gray		
BK101	195-197	Very Light Brown		
BK101	230-232	Light Brown		
BK101	245-247	Light Brown		
BK102A	10-12			
BK102A	40-42	Very Light-Gray	N8	
BK102A	58-60	BTW:Pale Yellowish-Brown and Dark Yellowish-Brown	10YR6/2 and 10YR4/2	
BK102A	75-77	BTW:Pale Yellowish-Brown and Dark Yellowish-Brown	10YR6/2 and 10YR4/2	
BK102A	85-87	Dark Yellowish-Brown	10YR4/2	
BK102A	98-100	Dark Yellowish-Brown	10YR4/2	
BK102A	110-112	Moderate Yellowish-Brown	10YR5/4	
BK102A	130-131	transition form Moderate Yellowish-Brown into Yellowish-Gray	10YR5/4 - 5Y7/2	
BK102A	160-162	Yellowish-Gray	5Y7/2	
BK102A	190-192	Yellowish-Gray	5Y7/2	
BK103	7-9	Black and Dark Gray	--	
BK103	20-22	Black and Dark Gray	--	
BK103	30-32	Black and Dark Gray	--	
BK103	43-45	Black and Dark Gray	--	
BK103	55-57	Black and Dark Gray	--	
BK103	70-72	Dark Brown - Light Brown	--	
BK103	93-95	Dark Brown - Light Brown	--	
BK103	104-106	Light Brown	--	
BK103	120-122	Light Brown	--	
BK103	135-137	Light Brown	--	
BK103	145-147	Light Brown	--	
BK104	6-7	Pale Yellowish-Brown	10YR6/2	
BK104	20-22	Dark Yellowish-Brown to Grayish Orange	10YR4/2 -10YR7/4	
BK104	60-62	Grayish Orange	10YR7/4	
BK104	90-92	Grayish Orange	10YR7/4	
BK104	140-142	Grayish Orange	10YR7/4	
BK104	170-172	Grayish Orange	10YR7/4	
BK105	10-12	Light Brownish-Gray	5YR 6/1	
BK105	20-22	Light Brownish-Gray	5YR 6/1	
BK105	35-37	Light Brownish-Gray	5YR 6/1	
BK105	45-47	Light Brownish-Gray	5YR 6/1	
BK105	76-78	Brownish-Black	5YR2/1	
BK105	92-94	Brownish-Black to Dark Yellowish-Brown	5YR2/1 to 10YR4/2	
BK105	108-110	Brownish-Black to Dark Yellowish-Brown	5YR2/1 to 10YR4/2	
BK105	113-115	Brownish-Black to Dark Yellowish-Brown	5YR2/1 to 10YR4/2	
BK105	125-127	Brownish-Black to Dark Yellowish-Brown	5YR2/1 to 10YR4/2	

BK105	133-135	Grayish Orange	10YR7/4	
BK105	150-152	Grayish Orange	10YR7/4	
BK105	170-172	Grayish Orange	10YR7/4	
BK105	176-178	Grayish Orange	10YR7/4	
BK105	185-187	BTW: grayish-orange 10YR7/4 and pale-orange 10YR 8/2	10YR7/4 to 10YR 8/2	
BK105	210-212	BTW: grayish-orange 10YR7/4 and pale-orange 10YR 8/2	10YR7/4 to 10YR 8/2	
BK105	230-232	BTW: grayish-orange 10YR7/4 and pale-orange 10YR 8/2	10YR7/4 to 10YR 8/2	
BK105	260-262	BTW: grayish-orange 10YR7/4 and pale-orange 10YR 8/2	10YR7/4 to 10YR 8/2	
BK105	270-272	BTW: grayish-orange 10YR7/4 and pale-orange 10YR 8/2	10YR7/4 to 10YR 8/2 (10YR6/2)	
BK105	313-315	Yellowish-Gray	5Y8/1	
BK105	330-332	Yellowish-Gray	5Y8/1	
BK106	10-12	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	32-34	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	58-60	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	110-112	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	122-124	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	130-132	Yellowish-Gray to pale yellowish brown	5Y8/1 to 10YR 6/2	
BK106	157-159	Black	N2	
BK106	165-167	Black	N2	
BK106	175-177	Black	N2	
BK106	195-197	Brownish-Black	5YR2/1	
BK106	218-220	Dark Yellowish-Brown	10YR4/2	
BK106	240-242	Dark Yellowish-Brown	10YR4/2	
BK106	267-269	Moderate Yellowish-Brown	10YR5/4	
BK106	278-280	Moderate Yellowish-Brown	10YR5/4	
BK106	330-332	Moderate Yellowish-Brown	10YR5/4	
BK107	8-10	Light Brownish gray	5YR 6/1	
BK107	20-22	Yellowish-Gray	5Y8/1	
BK107	40-42	brownish Black; quartz sand is similar to Yellowish-Gray	5YR2/1 and 5Y 8/1	
BK107	60-62	brownish Black; quartz sand is similar to Yellowish-Gray	5YR2/1 and 5Y 8/1	
BK107	80-82	brownish Black; quartz sand is similar to Yellowish-Gray	5YR2/1 and 5Y 8/1	
BK107	96-98	brownish Black; quartz sand is similar to Yellowish-Gray	5YR2/1 and 5Y 8/1	
BK107	107-109	Dark Yellowish-Brown	10YR4/2	
BK107	113-115	Dark Yellowish-Brown	10YR4/2	
BK107	125-127	Dark Yellowish-Brown	10YR4/2	
BK107	137-139	Dark Yellowish-Brown	10YR4/2	
BK107	150-152	Dark Yellowish-Brown	10YR4/2	
BK107	164-166	Dark Yellowish-Brown	10YR4/2	
BK107	180-182	Dark Yellowish-Brown	10YR4/2	
BK107	190-192	moderate yellowish brown	10YR 5/4	
BK107	200-202	moderate yellowish brown	10YR 5/4	
BK107	230-232	moderate yellowish brown	10YR 5/4	
BK107	250-252	Yellowish-Gray	5Y 7/2	
BK107	270-272	Yellowish-Gray	5Y 7/2	
BK107	292-294	darker than Pale Yellowish-Brown	10YR 6/2	
BK107	307-309	Dark Yellowish-Brown	10YR 4/2	
BK108	10-12	BTW: Pale Yellowish-Brown and Light Brownish-gray	10YR6/2 and 5YR 6/2	
BK108	28-30	BTW: Pale Yellowish-Brown and Light Brownish-gray	10YR6/2 and 5YR 6/2	
BK108	33-35	BTW: Pale Yellowish-Brown and Light Brownish-gray	10YR6/2 and 5YR 6/2	

BK108	46-48	BTW: Pale Yellowish-Brown and Light Brownish-gray	10YR6/2 and 5YR 6/2	
BK108	52-54	BTW: Pale Yellowish-Brown and Light Brownish-gray	10YR6/2 and 5YR 6/2	
BK108	88-90	sands are pale yellowish brown	10YR6/2	
BK108	138-140	Black	N1	
BK108	146-148	Black	N1	
BK108	170-172	Black	N1	
BK108	198-200	Black	N1	
BK108	228-230	Black	N1	
BK108	240-242	BTW: Dark Yellowish-Brown and moderate yellowish brown	10YR 4/2 and 10YR 5/4	
BK108	258-260	BTW: Dark Yellowish-Brown and moderate yellowish brown	10YR 4/2 and 10YR 5/4	
BK108	280-282	Dark Yellowish-Brown	10YR4/2	
BK108	334-336	Dark Yellowish-Brown	10YR4/2	Coarse: Quartz Fine: C
BK108	350-352	Moderate Brown	5YR3/4	
BK108	368-370	Moderate Brown	5YR3/4	
BK108	412-414	Moderate Brown	5YR3/4	
BK108	432-434	Moderate Brown	5YR3/4	
BK108	443-445	Dark Yellowish-Brown	10YR4/2	
BK108	480-482	Dark Yellowish-Brown	10YR4/2	
BK108	494-496	Dark Yellowish-Brown	10YR4/2	
BK108	508-510	Light Brownish-Gray	5YR 6/2	
BK109	16-18	Moderate Yellowish-Brown	10YR 5/4	
BK109	20-22	Moderate Yellowish-Brown	10YR 5/4	
BK109	30-32	Moderate Yellowish-Brown	10YR 5/4	
BK109	50-52	Pale Yellowish-Brown	10YR 6/2	
BK109	79-81	Dark Yellowish-Brown	10YR4/2	
BK110	16-18	Yellowish-Gray	5Y8/1	
BK110	24-26	Yellowish-Gray	5Y8/1	
BK110	30-32	Yellowish-Gray	5Y8/1	
BK110	38-40	Yellowish-Gray	5Y8/1	
BK110	46-48	Dark Brownish-Black	5YR 4/1	
BK110	58-60	Dark Brownish-Black	5YR 4/1	
BK110	73-75	Dark Yellowish-Brown	10YR 4/2	
BK110	80-82	Dark Yellowish-Brown	10YR 4/2	
BK110	100-102	Pale Yellowish-Brown	10YR 6/2	
BK110	118-120	Pale Yellowish-Brown	10YR 6/2	
BK110	128-130	Pale Yellowish-Brown	10YR 6/2	
BK110	138-140	Pale Yellowish-Brown	10YR 6/2	
BK110	330-332	BTW: white and Yellowish-Gray	N9 and 5Y8/1	C=Quartz F= Kaolinite
BK110	380-382	BTW: white and Yellowish-Gray	N9 and 5Y8/1	
BK111	8 (sand lens)	Yellowish-Gray	5Y7/2	
BK111	107-109	Pale Yellowish-Brown	10YR 6/2	
BK111	113-115	Pale Yellowish-Brown	10YR 6/2	
BK111	138-140	Pale Yellowish-Brown	10YR 6/2	
BK111	178-180	Moderate Yellowish-Brown to Pale Yellowish-Brown	10YR5/4 to 10YR6/2	
BK111	193-195	Pale Yellowish-Brown	10YR6/2	
BK112	66-68	Brownish-Black and Brownish-Gray	5YR2/1 and 5YR 4/1	
BK112	80-82	Brownish-Black and Brownish-Gray	5YR2/1 and 5YR 4/1	
BK112	200-202	Moderate Yellowish-Brown	10YR 5/4	
BK112	240-242	Moderate Yellowish-Brown	10YR 5/4	

BK112	280-282	BTW: Grayish-Oragne and Pale Yellowish-Brown	10YR7/4 to 10YR6/2	
BK112	310-312	BTW: Grayish-Oragne and Pale Yellowish-Brown	10YR7/4 to 10YR6/2	
BK112	340-342	BTW: Grayish-Oragne and Pale Yellowish-Brown	10YR7/4 to 10YR6/2	
BK110	88-90	Dark Yellowish-Brown	10YR 4/2	
BK110	430-432	BTW: white and Yellowish-Gray	N9 and 5Y8/1	
BK111	60-62	Dark Gray	N3	
BK111	80-82	Yellowish-Gray	5Y 7/2	
BK111	201-203	Medium Dark-Gray	N4	
BK112	130-132	Pale Yellowish-Brown	10YR6/2	
BK112	176-178	Dark Yellowish-Brown	10YR4/2	

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Core	Depth Interval (cm)	Color	GSA Rock Chart Color Number	Mineralogy C=Coarse F=Fine
BK101	260-262	Light Brown	--	
BK103	165-167	Light Brown	--	
BK103	210-212	Light Brown	--	
BK105	298-300	Pale Yellowish-Brown	10YR 6/2	
BK110	455-457	BTW: white and Yellowish-Gray	N9 and 5Y8/1	
BK111	3-5	Black	N2	
BK111	13-15	Black	N2	
BK111	50-52	Medium Dark-Gray N4	N4	
BK111	68-70	Dark Gray	N3	
BK111	160 (clay ba	Medium Dark-Gray N4	N4	
BK112	155-157	Dark Yellowish-Brown	10YR4/2	
Core	Depth Interval (cm)	Color	GSA Rock Chart Color Number	Mineralogy C=Coarse F=Fine
BK110	150-152	Yellowish-Gray	5Y 7/2	
BK110	178-180	Yellowish-Gray	5Y 7/2	
BK110	240-242	Yellowish-Gray	5Y 7/2	
BK110	290-292	Yellowish-Gray	5Y 7/2	
BK110	313-315	BTW: white and Yellowish-Gray	N9 and 5Y8/1	
BK111	212-214	very light-gray almost dark bluish white	N8 almost 5B9/1	
BK112	90-92	medium dark-gray	N4	
BK112	96-98	Yellowish-Gray	5Y7/2	
Core	Depth Interval (cm)	Color	GSA Rock Chart Color Number	Mineralogy C=Coarse F=Fine
BK111	18-20	Black	N2	
BK111	30-32	Black	N2	
BK112	14-16	Black	N2	
BK112	25-27	Black	N2	

Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Mean Grain Size (Phi)	Sorting (Phi)	%CaCO ₃	%TOC	Ternary Class	Facies Name	*Color Name	*Color Number	Mineralogy C=Coarse F=Fine
LP1	10-12	Peat	Peat	Peat	0.00	--	10.13	75.52	--	Peat	Brownish-Gray	5YR4/1	
LP1	40-42	Peat	Peat	Peat	0.00	--	8.99	81.92	--	Peat	Brownish-Gray	5YR4/1	
LP2	15-17	Peat	Peat	Peat	0.00	--	6.29	66.14	--	Peat	Brownish-Black	5YR2/1	
LP3	20-22	Peat	Peat	Peat	0.00	--	5.13	87.72	--	Peat	Brownish-Black	5YR2/1	
LP4	10-12	Peat	Peat	Peat	0.00	--	5.88	79.90	--	Peat	Brownish-Black	5YR2/1	
LP5	10-12	Peat	Peat	Peat	0.00	--	4.50	81.36	--	Peat	Brownish-Black	5YR2/1	
LP5	27-29	Peat	Peat	Peat	0.00	--	5.94	74.00	--	Peat	Black	N4	
LP5	58-60	Peat	Peat	Peat	0.00	--	2.33	94.50	--	Peat	Brownish-Black	5YR2/1	
LP6	10-12	Peat	Peat	Peat	0.00	--	4.35	55.12	--	Peat	Brownish-Black	5YR2/1	
LP7	10-12	85.89	12.89	1.21	2.05	1.48	8.33	76.70	Sand	Peat (?)	Brownish-Black	5YR2/1	
	Minimum						2.33	55.12					
	Maximum						10.13	94.50					
	Average						6.19	77.29					
	Notes:	*	GSA Rock Color Chart										
		--	GSA Rock Color Chart Unavailable										
		(?)	Outlier, but matched the best to the facies										

Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Mean Grain Size (Phi)	Sorting (Phi)	%CaCO ₃	%TOC	Ternary Class	Facies Name	*Color Name	*Color Number	Mineralogy C=Coarse F=Fine
LP3	120-122	65.56	29.51	4.91	3.38	1.86	13.76	5.47	Silty-Sand	Silty-Sand	Brownish-Gray	5YR4/1	
LP3	122-124	75.71	20.76	3.56	2.81	1.68	10.50	3.74	Sand	Silty-Sand	Brownish-Gray	5YR4/1	
LP3	150-152	65.90	29.72	4.39	3.87	1.73	8.77	6.48	Silty-Sand	Silty-Sand	Blue-Gray mixed in w/brownish-Gray	-- / 5YR4/1	
LP4	140-142	65.87	29.05	5.07	3.77	1.54	8.74	6.69	Silty-Sand	Silty-Sand	Blue-Gray	-- / 5YR4/1	
LP5	145-147	80.88	14.56	4.56	2.51	1.34	18.52	3.88	Sand	Silty-Sand(?)	Olive-Gray	5Y4/1	
LP6	60-62	69.77	24.54	5.69	3.76	2.11	10.11	6.94	Silty-Sand	Silty-Sand	Blue-Gray mixed in w/ brownish color	--	
LP6	100-102	63.83	33.07	3.09	3.69	2.22	10.33	4.61	Silty-Sand	Silty-Sand	Blue-Gray mixed in w/ brownish color	--	
LP6	110-112	78.93	18.87	2.27	3.14	1.15	8.29	3.63	Sand	Silty-Sand	Blue-Gray mixed in w/ brownish color	--	C=quartz F=quartz; montmorillonite
LP6	122-124	70.16	26.79	3.07	3.29	2.06	11.61	4.62	Silty-Sand	Silty-Sand	Blue-Gray mixed in w/ brownish color	--	
LP7	90-92	75.87	16.98	7.15	3.10	1.79	16.83	5.60	Sand	Silty-Sand	--	--	
LP7	120-122	47.60	39.56	12.80	4.20	3.31	20.13	8.36	Sandy-Silt	Silty-Sand(?)	Medium Bluish-Gray; Greenish-Gray;Light Greenish-Gray; Light Bluish Gray	5B5/1 and 5G6/1; 5G8/1 and 5B7/1	
LP8	58-60	77.67	16.89	5.44	3.04	1.40	7.41	7.33	Sand	Silty-Sand	Pale Yellowish-Brown	10YR6/2	
LP8	72-74	66.77	22.72	10.52	3.78	2.44	23.40	10.63	Silty-Sand	Silty-Sand	Yellowish-Gray	5Y8/1	
LP8	100-102	59.39	34.17	6.43	3.63	2.93	17.98	5.97	Silty-Sand	Silty-Sand	Greenish-Gray	5GY6/1	
LP8	140-142	66.36	30.87	2.80	2.95	2.51	14.57	5.84	Silty-Sand	Silty-Sand	Greenish-Gray; Greenish-Gray;Medium Bluish-Gray; Medium Dark Gray	5G6/1; 5GY6/1;5B5/1;N4	C=quartz;flourapatite; kaolinite F=quartz,flourapatite, hydrooxylapatite,kaolinite
	Minimum	47.60	14.56	2.27	2.51	1.15	7.41	3.63					
	Maximum	80.88	39.56	12.80	4.20	3.31	23.40	10.63					
	Average	68.68	25.87	5.45	3.40	2.01	13.40	5.99					
	Notes:	*	GSA Rock Color Chart										
		--	GSA Rock Color Chart Unavailable										
		(?)	Outlier, but matched the best to the facies										

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Core	Depth Interval (cm)	% Sand	%Silt	%Clay	Mean Grain Size (Phi)	Sorting (Phi)	%CaCO ₃	%TOC	Ternary Class	Facies Name	*Color Name	*Color Number	Mineralogy C=Coarse F=Fine
CP1	6-8	94.31	4.49	1.20	1.64	0.89	0.16	0.36	Sand	Sand	Pale Yellowish-Brown and Dark Yellowish-Brown	10YR6/2 and 10YR 4/2	--
CP1	16-18	92.36	6.01	1.64	1.75	0.70	0.31	1.49	Sand	Sand	Pale Yellowish-Brown and Dark Yellowish-Brown	10YR6/2 and 10YR 4/2	--
CP1	25-27	97.92	1.42	0.66	1.54	0.64	0.13	0.16	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	46-48	97.93	1.25	0.83	1.56	0.62	0.15	0.14	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	66-68	96.19	1.97	1.94	1.55	0.62	0.00	0.28	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	90-92	97.78	1.07	1.16	1.45	0.65	0.00	0.19	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	130-132	94.35	3.23	2.44	1.67	0.68	0.48	0.59	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	138-140	91.65	5.78	2.63	1.51	0.74	0.52	0.83	Sand	Sand	Yellowish-Gray but stains have Moderate Yellowish-Brown	5Y7/2 and 10YR 5/4	--
CP1	148-150	96.83	1.80	1.36	1.52	0.68	0.00	0.31	Sand	Sand	Yellowish-Gray with Pale-Brown mixed in	5Y7/2 and 5YR 5/2	--
CP1	160-162	94.88	1.60	3.50	1.70	0.62	0.35	0.57	Sand	Sand	Pale Yellowish-Brown	10YR 6/2	--
CP1	175-177	97.24	0.86	2.00	1.56	0.54	0.00	1.17	Sand	Sand	Pale Yellowish-Brown	10YR 6/2	--
CP1	189-191	94.91	1.32	3.79	1.68	0.59	0.00	1.07	Sand	Sand	Pale Yellowish-Brown	10YR 6/2	--
CP1	205-207	97.86	0.59	1.44	1.64	0.62	0.00	1.32	Sand	Sand	Pale Yellowish-Brown	10YR 6/2	--
CP1	213-215	95.71	0.57	3.68	1.61	0.61	0.40	2.10	Sand	Sand	Sands are Pale Yellowish-Brown and Clays are Yellowish-Gray	10YR 6/2 and 5Y 7/2	--
CP1	228-230	97.95	0.04	1.99	1.58	0.58	0.39	2.18	Sand	Sand	Sands are Pale Yellowish-Brown and Clays are Yellowish-Gray	10YR 6/2 and 5Y 7/2	--
CP1	240-242	96.49	0.60	2.92	1.65	0.59	0.00	2.73	Sand	Sand	Sands are Pale Yellowish-Brown and Clays are Yellowish-Gray	10YR 6/2 and 5Y 7/2	--
CP1	253-255	96.00	0.71	3.22	1.64	0.59	0.51	1.99	Sand	Sand	Sands are Pale Yellowish-Brown and Clays are Yellowish-Gray	10YR 6/2 and 5Y 7/2	--
CP1	270-272	97.68	0.85	1.49	1.61	0.59	0.43	2.06	Sand	Sand	Sands are Pale Yellowish-Brown and Clays are Yellowish-Gray	10YR 6/2 and 5Y 7/2	--
CP1	361-363	97.25	2.22	0.49	1.99	0.73	0.11	0.34	Sand	Sand	Sands are Yellowish-Gray and Lighter than Dark Yellowish Orange	5Y8/1 and 10YR6/6	--
CP1	378-380	93.41	3.54	3.06	1.99	0.71	0.00	1.85	Sand	Sand	Yellowish-Gray and Lighter than dark yellowish-orange	5Y8/1 and 10YR6/6	--
CP1	400-402	91.74	4.26	3.94	1.94	0.69	0.42	2.45	Sand	Sand	Yellowish-Gray and Lighter than dark yellowish-orange	5Y8/1 and 10YR6/6	--
CP1	413-414	94.09	3.32	2.59	1.65	0.67	0.32	1.59	Sand	Sand	Sands are Yellowish-Gray and Lighter than dark yellowish-orange	5Y8/1 and 10YR6/6	--
CP2	10-12	96.42	1.03	2.46	1.64	0.52	0.14	0.35	Sand	Sand	Dark Yellowish-Brown	10YR 4/2	--
CP2	20-22	92.27	5.38	2.36	1.63	0.73	0.00	0.40	Sand	Sand	Dark Yellowish-Brown	10YR 4/2	--
CP2	30-32	94.15	4.21	1.58	1.67	0.68	0.15	1.13	Sand	Sand	Dark Yellowish-Brown	10YR 4/2	--
CP2	50-52	96.07	2.47	1.50	1.68	0.70	0.14	0.24	Sand	Sand	Closest to white	N9	--
CP2	70-72	96.89	2.10	0.97	1.61	0.68	0.00	0.13	Sand	Sand	Closest to white	N9	--
CP2	90-92	96.74	2.00	1.38	1.58	0.68	0.00	0.30	Sand	Sand	Sands are white and lenses are Moderate Yellowish-Brown	N9 and 10YR5/4	--
CP2	128-130	97.92	0.95	1.11	1.34	0.73	0.10	0.42	Sand	Sand	Sands are white and lenses are Moderate Yellowish-Brown	N9 and 10YR5/4	--
CP2	136-138	97.46	0.80	1.71	1.42	0.62	0.22	0.68	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	156-158	97.50	0.54	1.98	1.52	0.55	0.00	0.86	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	168-170	96.88	0.68	2.51	1.52	0.60	0.11	0.66	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	188-190	98.65	0.58	0.76	1.54	0.52	0.32	1.82	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--

CP2	200-202	99.23	0.49	0.34	1.52	0.55	0.13	0.28	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	212-214	96.42	0.54	3.05	1.52	0.51	0.11	2.02	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	218-220	96.84	0.52	2.66	1.60	0.51	0.18	1.97	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	230-232	99.17	0.60	0.23	1.54	0.51	0.00	0.15	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	240-242	99.12	0.49	0.32	1.51	0.51	0.12	0.45	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	250-252	98.65	0.66	0.76	1.60	0.51	0.24	1.82	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	255-257	94.48	3.95	1.62	1.57	0.70	0.23	1.45	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	260-262	97.51	0.68	1.79	1.64	0.52	0.21	2.42	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	270-272	99.14	0.53	0.28	1.59	0.52	0.10	0.50	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	286-288	99.96	0.01	0.00	1.55	0.49	0.00	1.19	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	296-298	97.69	0.70	1.58	1.65	0.54	0.00	2.80	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	310-312	99.27	0.42	0.26	1.68	0.54	0.14	0.09	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	322-324	99.58	0.34	0.18	1.69	0.53	0.00	0.40	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	336-338	98.74	0.70	0.63	1.71	0.55	0.17	0.45	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	353-355	98.23	0.84	0.85	1.74	0.58	0.00	0.13	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP2	378-380	98.62	0.80	0.63	1.59	0.52	0.00	0.96	Sand	Sand	Pale Yellowish-Brown	10YR6/2	--
CP5	17-19	92.06	4.83	3.09	1.70	0.94	0.18	0.55	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	28-30	84.32	8.05	7.71	2.52	1.01	0.09	0.69	Sand	Sand(?)	Light Brownish-Gray	5YR 6/1	--
CP5	50-52	84.70	7.53	7.69	2.34	1.02	0.13	0.72	Sand	Sand(?)	Light Brownish-Gray	5YR 6/1	--
CP5	98-100	90.62	4.05	5.35	1.86	0.76	0.37	0.67	Sand	Sand(?)	Dark Gray	N4	--
CP5	172-174	95.87	1.28	2.82	1.42	0.68	0.10	1.49	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	188-190	99.09	0.80	0.14	1.53	0.60	0.11	2.42	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	198-200	98.96	0.63	0.38	1.41	0.62	0.00	1.09	Sand	Sand	White	N9	--
CP5	210-212	99.74	0.32	0.02	1.58	0.61	0.10	0.20	Sand	Sand	White	N9	--
CP5	228-230	98.54	1.08	0.42	1.40	0.62	0.00	0.01	Sand	Sand	White	N9	--
CP5	260-262	99.17	0.56	0.32	1.49	0.61	0.09	0.16	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	270-272	96.29	0.89	2.76	1.53	0.59	0.11	1.31	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	282-284	99.36	0.44	0.19	1.55	0.57	0.10	1.23	Sand	Sand	Light Brownish-Gray	5YR 6/1	C=Quartz F=Quartz/Kaolinite
CP5	300-302	99.91	0.10	0.00	1.52	0.57	0.10	1.03	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
CP5	318-320	97.66	0.94	1.33	1.58	0.60	0.18	1.30	Sand	Sand	Light Brownish-Gray	5YR 6/1	--
	Minimum	84.32	0.01	0.00	1.34	0.49	0.00	0.01					
	Maximum	99.96	8.05	7.71	2.52	1.02	0.52	2.80					
	Average	96.42	1.78	1.80	1.63	0.63	0.15	1.00					
	Notes:	GSA Rock Color Chart											
		Outlier, but matched the best to the facies											

