Reconstruction of the Late Glacial and Holocene Paleoenvironmental Setting at 20SA596, and the Saginaw Basin, Michigan

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This is to certify that I have examined this bound copy of a master's thesis by

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and have found that it is complete and satisfactory in all respects,
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examining committee have been made.

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Abstract

An archaic archaeological site, 20SA596, located within the Saginaw basin, Michigan, is preserved in a sedimentary sequence of Late and post Glacial lacustrine and eolian sediments. The Nipissing transgression around 5,000 years BP resulted in an increased wetness at the site with a transition to bog vegetation and peat accumulation. This bog was periodically inundated by minor transgressions. Ultimate regression of Lake Nipissing exposed the site to a period of eolian activity, prior to the development of a stable plant community.

A survey of surficial sediments within the surrounding area supports the established history of the basin and enhances on-site conclusions. During the Archaic Period, people were occupying the Lake Nipissing shorelines. Because of fluctuations in the level of Lake Nipissing, nearshore archaeological sites are scattered over broad areas in a thick accumulation of sediment, rather than being concentrated near traditionally mapped beaches.

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Acknowledgments

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Preface

The archaeological site hereafter identified as 20SA596 was excavated by the Institute of Minnesota Archaeology (IMA) during the 1991 summer season. Funding for this project and the following study was provided by the Great Lakes Gas Transmission Company, because the site was situated in the proposed corridor of a new pipeline. IMA hired Professor Howard Mooers at the University of Minnesota-Duluth to evaluate the on-site stratigraphy.

As the excavation progressed, the archaeologists discovered the site consisted of a well-preserved, relatively complete stratigraphic record spanning from the Late Glacial to post Glacial time period. The presence of a peat layer of Lake Nipissing age in direct association with a cultural horizon added to the intrigue. Since this time period is poorly understood in eastern Michigan by archaeologists, the site provided a unique opportunity to reconstruct the regional and local paleoenvironment in relation to human occupation.

At this point, Professor Mooers and Clark Dobbs, of IMA, agreed that assessment of the site could be most (cost) effectively accomplished by a graduate research assistant. Duties proposed for this graduate student included the completion of lab analyses, literature reviews, geomorphic mapping, and overall synthesis of the information. A final report would then be prepared jointly by Dr. Mooers and the mystery student, who would use the knowledge and information gained to construct a thesis.

I met Professor Mooers in the Fall of the 1991-92 academic year. He outlined the 20SA596 project to me (over beer and foosball at the Reef). A week and a half later I boarded a plane for Saginaw, Michigan, to see the site in its' final stages of excavation. While in Michigan, I was introduced to the aspects of the site and the geomorphology of the surrounding area. The excavation of the pipeline trench had been recently completed, providing an'opportunity to view the stratigraphic profile down into Late Glacial clays for miles to the east and west of the site. We decided the project had a 'now or never' feel to it, and approximately 36 hours after my return to Duluth I boarded a plane to Saginaw once again, with my new advisor in tow.

Introduction

Saginaw Bay represents an extension of modern Lake Huron into a geographic low (Figure 1). An arcuate shaped area, the Saginaw basin, gradually extends upward from the shoreline and conducts drainage water from eastern central Michigan toward the bay. The land rises gently from the shoreline and, initially, differences in relief are minimal. Progressing further inland from the flat-lying lowland results in an increase in relief. Elevational differences are greatest near the basin perimeter. The archaeological site, 20SA596, lies in the Saginaw basin at an elevation of 181 m (594 ft) above sea level.

During Late Glacial and Holocene time, the Saginaw basin underwent a complex geomorphic evolution related to glacial advance and retreat. A dynamic sequence of glacial lakes was created along the southern margin of the Laurentide ice sheet. Lake level changes within the Saginaw and Huron drainage basins were regulated by outlet elevation and climatically induced fluctuations. These changes had a direct influence on the preservation of cultural material during the geologic evolution of 20SA596.

Superimposed upon the physical changes of the landscape, vegetation assemblages changed in response to large-scale climatic variations, shifting from arctic tundra to a northern boreal forest, to the modern deciduous forests characteristic of the region. Changing climates controlled to a great degree the availability of resources associated with the Late and post Glacial vegetational succession and provided a dynamic landscape to which emerging societies were continuously adapting. Paleoenvironmental reconstructions of archaeological sites, like 20SA596, within eastern Michigan therefore provide a framework in which to examine human adaptation.

Sediments and botanical remains preserved within the stratigraphic sequence record the complex geomorphic and vegetational history of the site and provide paleoenvironmental evidence from the time of human occupation to the present. The general geomorphology of the Saginaw basin reflects processes associated with a series of glacial lakes. Early lakes were confined to the Saginaw basin while later lakes were connected with the Huron Basin. These basins were intimately linked with the Lake Michigan basin as well. Therefore, a complete paleoenvironmental reconstruction of the site requires a synthesis of information concerning bedrock geology, Late Glacial and Holocene lake level fluctuations within the Huron, Michigan and Saginaw basins, shifting regional and local vegetation patterns, sedimentological characteristics of regional landform assemblages, and details preserved within the on-site stratigraphy.

The potential contribution of archaeological sediments, aspects of the underlying geology, and the Late Glacial and post Glacial geologic history and vegetational succession

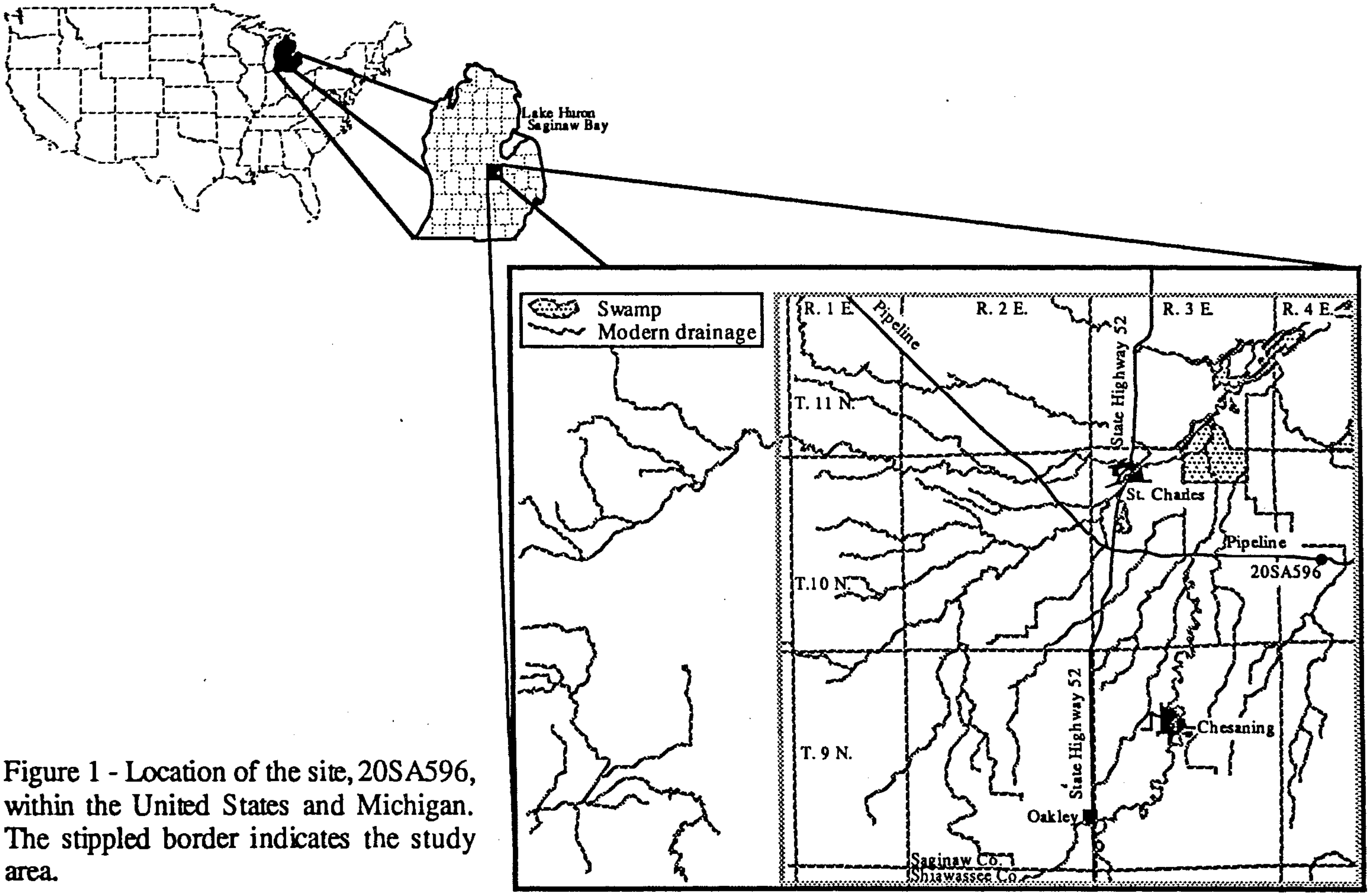


Figure 1 - Location of the site, 20SA596, within the United States and Michigan. The stippled border indicates the study area.

of the region are presented below. Details of the site's stratigraphy are outlined and a regional and local record of vegetation fluctuations is reconstructed from macro- and microfossil analyses of organic-rich units.

Extrapolation of on-site geology to other areas in the Saginaw Basin provides a basis to analyze regional-scale geomorphic influences during the development of local landform assemblages. Conversely, correlation of sediments from 20SA596 with characteristics of off-site surface deposits enhances the on-site interpretation. The success of this approach is found in the mutual enhancement of on- and off-site conclusions. The geomorphic history and distribution of microenvironments in the Saginaw basin provides information disputing the "perceived rarity of Early and Middle Archaic archaeological sites" (Larsen 1985a, p. 91) in eastern Michigan. Archaeological surveying techniques can be modified to fit a more current assessment of deposits in eastern Michigan.

Results of the on-site investigation indicate that at approximately 4,700 radiocarbon years before present (years BP), 5,400 calendar years ago, 20SA596 consisted of a bog located near the margin of a lake that occupied the Huron, Michigan, Saginaw, and Superior lake basins, identified as post Glacial Lake Nipissing. This lake attained a maximum elevation of approximately 183 to 184 meters (600 to 603 ft) (Larsen 1985a). The bog was periodically inundated by minor fluctuations in the level of Lake Nipissing over seasonal to yearly or decadal time periods. The instability of the shoreline created a patchwork of unique microenvironments within a limited area; 20SA596 records evidence of regional geomorphic events as well as a unique environmental niche.

Application of on-site conclusions to the Late and post Glacial lake succession reveals an intimate connection between surficial sediments, geologic processes, and landform development. The landform assemblages within the Saginaw Basin include drainage networks, strandlines, dunes, and paleo lake plains.

Sediments trend from relatively coarse to fine mean grain sizes, progressing from higher beach elevations to the former offshore areas of the earliest water bodies. In general, sand dunes do not occur in association with beach and nearshore sands. Isolated dune occurrences are found at elevations just below prominent strandlines. Dunes are abundant only below 200 meters (656 ft) in elevation, corresponding to the area formerly occupied by offshore environments, where fine to very fine sands accumulated. This suggests that beach and nearshore deposits were too coarse to be significantly affected by eolian processes. Exposure of fine-grained sands provided a sediment source accessible to wind transport, prior to stabilization of the land surface by vegetation. A significant Holocene stratigraphic record is preserved in the Saginaw Basin.

Geologic Context of Archaeological Sites

The role of the environment with respect to archaeological reconstructions has become increasingly important (Butzer 1960; Butzer 1980; Coe and Flannery 1964; Davidson 1985; Hassan 1978; Hassan 1985; Gardner 1977; Kraft et al. 1985; Larsen 1985a; Stein and Rapp 1984; Stoltman and Baerreis 1983). With this realization has come a revision of the false assumption of environmental context as being an unchanging phenomenon (Butzer 1980). Instead, the environment is now seen as a dynamic sequence of fluctuations on many spatial and temporal scales, to which past cultures continually interacted and adapted (Butzer 1980; Childe 1951; Davidson 1985; Gladfelter 1977; Hassan 1985; Larsen 1985a; Stoltman and Baerreis 1983).

Paleoenvironmental reconstructions have primarily resulted in the identification of climatically-induced regional trends (Coe and Flannery 1964) while archaeological endeavors have tended to focus on site-specific locations (Hassan 1985). There is a direct relationship between geomorphology and the geographic distribution of archaeological sites (Larsen 1985a). For this reason, archaeological excavations are now generally accompanied by detailed geologic investigations; examples include Butzer (1960), Gardner (1977), Kraft and Erol (1982), Kraft et al. (1985), Larsen (1985a), Stein (1983), and Stein and Rapp (1984). Archaeology provides a highly controlled context for sediment sampling and places temporal constraints on geologic deposits in direct association with a cultural horizon (Davidson 1985; Gladfelter 1977; Hassan 1985). Cooperation between the archaeologist and geomorphologist yields a body of information that can provide insight to the regional and local geography and vegetation present at the time of occupation (Butzer 1960; Davidson 1985; Gladfelter 1977; Hassan 1978; Stein and Rapp 1984).

Studies must address changes in vegetation, landform assemblages, geologic factors, and climate over time to integrate cultural interaction with available resources (Butzer 1960). Alterations in the physical environment would have affected subsistence and settlement patterns and site depositional processes and preservation (Davidson 1985; Hassan 1985).

Understanding the geologic context is also important in evaluating post-occupational influences, since the interaction of vegetative cover and geologic processes work to preserve, disrupt, or destroy site integrity (Davidson 1985). For this reason there is a need to evaluate an entire stratigraphic profile, rather than focusing solely on cultural horizons (Hassan 1985). A realistic evaluation of a site's context is only complete when the geologic and vegetational history is assessed for the time prior to and following occupation (Hassan 1985).

Especially attractive dynamic geomorphic areas include coastal, shoreline, and river systems. The relationship between coastal geomorphology and archaeological sites has been studied by researchers like Kraft, Rapp, Aschenbrenner, Lovis, and Larsen and many others (Kraft and Erol 1982; Kraft et al. 1975; Kraft et al. 1977; Kraft et al. 1980; Kraft et al. 1985; Lovis 1986, Larsen 1985a). Lovis (1986a), Monaghan et al. (1986), and Larsen (1985a; b) have focused on the eastern Great Lakes, which are influenced by processes similar to those in marine settings. Findings of these works are comparable to coastal studies and illustrate the environmental diversity created by the influence of a large body of water.

Transgressions and regressions caused by changes in the base level force a geomorphic response in nearshore areas and fluvial processes. With sites located in areas subjected to such extensive reworking, a seemingly obvious assumption is that the majority of sites were destroyed (Butzer 1960). It is possible to have good preservation of localized areas within a region dominated by erosional processes (Butzer 1960; Davidson 1985; Larsen 1985a). However, sites located in such areas may be deeply buried beneath the modern land surface and difficult to locate with contemporary surveying procedures (Kraft et al. 1985; Larsen 1985a).

The combination of climatic, isostatic, and geomorphic factors in Michigan at the beginning of the post Glacial time period resulted in diverse microenvironments (Davidson 1985; Larsen 1985a). Variety in microhabitats and resources within relatively restricted areas adjacent to large freshwater lakes, yielded a direct advantage for individuals dependent upon subsistence techniques (Butzer 1960; Coe and Flannery 1964; Davidson 1985; Larsen 1985a). For this reason, archaeological investigations within the vicinity of a fluctuating shoreline demand reconstruction of both regional and local aspects of paleoenvironment (Davidson 1985; Gladfelter 1977; Larsen 1985a).

Upon regression, sediments associated with abandoned beach complexes dry out and are exposed to eolian processes (Milstein 1987a; Reading 1978). Given sufficient time, dune forms will become stabilized by vegetation (Bloom 1991; Davidson 1985; Esterbrook 1993; Hill 1987; Milstein 1987a; Reading 1978; Ritter 1978). Transgression causes erosion and inundation of dune structures (Davidson 1985; Milstein 1987a).

Larsen (1985 a, b) has suggested that relatively minor fluctuations in water level occur within a seasonal to yearly or decadal time frame (micro- to meso-scale), superimposed on macro-scale climatic fluctuations over hundreds to thousands of years (Figure 2). Application of this model of multiple transgressive/ regressive cycles, suggests that sites located in the areas directly affected by small scale fluctuations would contain a well-

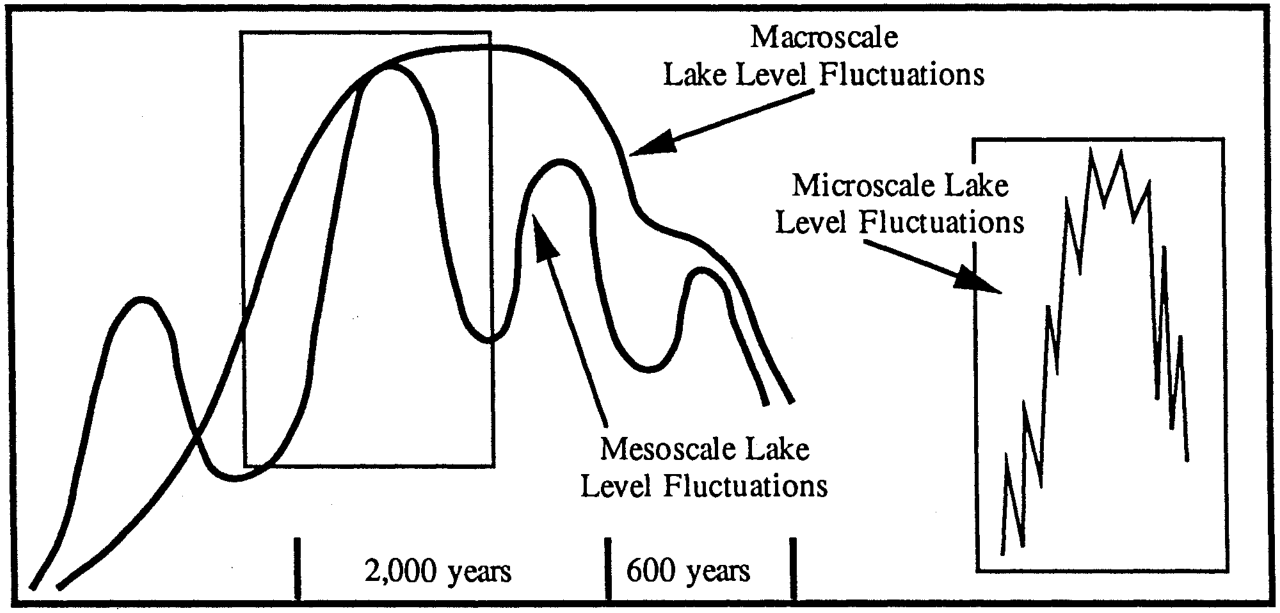


Figure 2 - Magnitude of micro- (seasonal changes to 10's of years) and meso-scale (10's to 100's of years) lake level variations superimposed on macro-scale (100's to 1,000's of years) fluctuations (modified from Larsen, 1978; Larsen, 1985; and Lovis, 1986).

developed stratigraphic profile of reworked sediments (Kraft et al. 1985; Larsen 1985a; Reading 1975; Milstein 1987a).

If a reconstruction is to reflect the true nature of a past environment, aspects of macro-, meso- and micro-scales must be addressed (Butzer 1960; Butzer 1980). Studies which focus on cultural adaptations to macroscopic climatic fluctuations are insufficient because resources are found in microenvironments dispersed throughout a region (Coe and Flannery 1964). Additionally, a site-specific evaluation can not be complete unless considered within a regional context (Davidson 1985). Evidence of human activity may be concentrated within the boundaries of a specific site, but occupants were constantly required to interact with macro-scale aspects of the environment like regional geomorphologic processes and climate (Butzer 1980; Hassan 1985).

Butzer (1960) outlines relevant questions concerning the local geologic and geographic setting of a site and the relationships of such a setting to surficial deposits. Aspects of cultural interaction with potentially attractive geographic features, and the geomorphic bias of a site toward preservation or destruction are emphasized. Finally, Butzer addresses the subject of the spatial distribution of sites within a region and the ratio of known sites to potential sites. Davidson (1985, p. 35) furthers this point by realizing "the stratigraphic and spatial occurrence of archaeological sites is intimately associated with Holocene landform development."

An interdisciplinary approach is needed to accurately reconstruct the context of a site. Archaeologic, geomorphic, geologic, sedimentologic, paleoclimatic, botanical, and zoological studies are some of the information sources which must be considered (Coe and Flannery 1964; Gardner 1977; Hassan 1985; Larsen 1985a; Stein and Rapp 1984; Stoltman and Baerreis 1983). Many details are required to characterize the information preserved, including landform assemblages, stratigraphy, grain size distribution, grain morphology, microfossils, macrofossils, and carbon content, among other things (Hassan 1978; Hassan 1985; Gardner 1977; Gladfelter 1977). Independent data sets define variables which influenced the availability of resources within an area over time (Butzer 1980; Hassan 1985).

Geomorphic Mapping

A map of surficial geomorphology, including landforms and drainage patterns, is beneficial when making initial generalizations about the nature of surficial sediments, tectonic activity, and geomorphology (Davidson 1985). A regional landform assemblage map can provide a good indication of the overall geologic history of an area, while a more localized map is useful for studying the distribution of microenvironments (Coe and

Flannery 1964). Such maps may serve as an analog for the diversity of vegetation and resources at the time of occupation (Coe and Flannery 1964; Davidson 1985; Hassan 1985), and can help recreate the geographic context of an area over time and assist in interpreting on-site artifact distributions (Davidson 1985; Gladfelter 1977).

Knowledge of detailed stratigraphy gained from a site-specific excavation will lend plausibility to the interpretation of landform genesis and strengthen the evaluation of the history of an area (Davidson 1985; Hassan 1985; Larsen 1985a). Superimposing the localities of known archaeologic sites on a geomorphic map may yield a distinctive pattern of site distribution in association with particular landforms (Davidson 1985; Hassan 1985; Larsen 1985a).

The utility of geomorphic investigations in conjunction with archaeological excavations has been demonstrated by many individuals for a number of years. Butzer's (1960) work in Egypt included maps showing the relationship between regional landform distribution and archaeological sites. A topographic cross-section of microenvironmental niches is utilized by Coe and Flannery (1964). Davidson (1985) and Hassan (1985) outline many examples of potential applications of mapping landform assemblages and the work by Kraft, Rapp, and Aschenbrenner in Greece is detailed and extensive (Kraft and Erol 1982; Kraft et al. 1975; Kraft et al. 1977; Kraft et al. 1980; Kraft et al. 1985).

Geomorphic mapping must be carefully conducted. The creation of a single map containing all aspects of the physical setting, such as drainage, landforms, and micro- and macro-scales, may result in a compilation that is too cluttered to clearly delineate geomorphic and cultural interrelationships (Davidson 1985). Also, a landform assemblage map implies a genetic description of an area, not necessarily useful for assessing land-use factors (Davidson 1985). However, properly applied, a geomorphic map can yield information about the spatial distribution of resources (Davidson 1985; Kraft et al. 1985).

Although the Late Glacial and Holocene history of Michigan has been defined primarily by occurrences of landforms like strandlines and terraces (Eschman and Karrow 1985; Hansel et al. 1985; Leverett and Taylor 1915; Mickelson et al. 1983), there is a lack of geomorphic mapping at an intermediate (regional to local) scale. Geologic trends associated with the retreat of the Laurentide ice sheet have been defined on the basis of regional landform assemblages (Eschman and Karrow 1985; Hansel et al. 1985; Leverett and Taylor 1915; Mickelson et al. 1983). Studies like Hill (1987), Milstein (1987a; c), and Monahgan (1986) address the geomorphology of specialized localities.

Refining regional-scale geologic interpretations by applying site-specific details to landform assemblages in the immediate area has been limited to unique areas like the large dune complexes near the lake Michigan shoreline (Milstein 1987a; Hill 1987). There is a need to conduct these types of studies throughout Michigan. Other locations may not exhibit impressive topographic contrasts, but landforms are preserved. Works by Larsen (1985a), Lovis (1986) and Monaghan et al. (1986) have shown that detailed studies can enhance accepted interpretations.

Sediment Analyses

While attempting to reconstruct the history of an on-site stratigraphic assemblage, one must evaluate the site in terms of characteristic geologic structures such as bedding, laminae, dune structures, lenses, etc. (Hassan 1978, 1985; Stein and Rapp 1984). These observations must be followed with careful sampling. Analyses of grain size, grain morphology, organic and inorganic carbon content, and micro- and macrofossil assemblages will provide information about sediment source, depositional processes, and post-depositional history (Gardner 1977; Gifford 1982; Gladfelter 1977; Holliday and Stein 1989; Krinsley and Doornkamp 1973; Larsen 1985a; Hassan 1978; Stein and Rapp 1984).

In general, coarser size fractions indicate high energy environments while fine-grained sediments indicate the influence of a lower energy depositional regime (Reading 1978; Bloom 1991). This is true of a lacustrine environment, where the coarsest sediments are found at the wave front and sediments fine offshore, from nearshore sands to offshore silts and deepwater clays (Bloom 1991; Easterbrook 1993; Reading 1978). However, the source of sediment and its post-depositional history must always be considered. For example, the absence of coarse grains can limit the mean grain size of certain deposits, regardless of the geomorphic environment (Gladfelter 1985; Reineck and Singh 1980; Shackley 1975; Stein 1987).

Transport of sand grains by wind is effectively accomplished by suspension, saltation, or surface creep (Bagnold 1941; Bloom 1991; Easterbrook 1993; Krinsley and McCoy 1978). Smaller particles, below 4 phi, are lifted into suspension and effectively removed from the area (Bagnold 1941; Bloom 1991; Easterbrook 1993). The majority of sand grains, larger than 4 phi, bounce and roll along the ground through saltation, generally traveling as much as a meter with each bounce (Bagnold 1941; Bloom 1991; Easterbrook 1993). Slightly larger grains are dragged along the substrate, traveling a few mm at a time, as surface creep (Bagnold 1941; Bloom 1991; Easterbrook 1993). This combination of processes produces a well-sorted clastic deposit (Bagnold 1941; Bloom 1991; Easterbrook 1993; Folk 1974).

Folk (1974) indicates that a single sediment source affected by a nearshore environment will result in dune sands that are slightly better sorted than the associated beach sands. Eolian sands are usually well sorted, lack a clay component, and range in size from 1 to 2.75 phi (Hassan 1978). Additionally, beach deposits typically lack silt and clay (Hassan 1978). The establishment of a well-developed soil horizon can introduce a clay component to clastic deposits (Bloom 1991; Easterbrook 1993; Reading 1978; Ritter 1978).

The geologic history of an individual site must be taken into consideration. Overlap of grain size characteristics for littoral and eolian deposits (Folk 1974), and input from local parameters, such as climate, soil formation and vegetation (Reading 1978), makes positive identification of the environment of deposition problematic. Surface textures of quartz grains will help identify the previous influence of certain geologic processes (Krinsley and Doornkamp 1973).

The surface characteristics of quartz grains can be used to interpret the geomorphic processes a clast has been subjected to (Gardner 1977; Gladfelter 1977; Hassan 1978; Krinsley and Donahue 1968; Krinsley and Doornkamp 1973; Stein 1987; Stein and Rapp 1984). However, these authors quickly point out that interpretation of grain morphology can be problematic because of the possibility of different processes resulting in similar features, and chemical and physical reworking after deposition (Gardner 1977; Gladfelter 1977; Stein 1987). The reference provided by Krinsley and Doornkamp (1973) has helped to standardize the identification of surface textures. Many researchers have been able to utilize attributes visible under a scanning electron microscope to enhance environmental reconstructions (Bull and Goldberg 1985; Butzer 1968; Hodgson 1970; Krinsley 1970; Tankard 1974). Classic examples of individual textures are shown in Krinsley and Doornkamp (1973).

Textural indicators associated with an eolian environment include rounded grains, a relative abundance of mechanically upturned plates, flat pitted areas, dish-shaped concavities, meandering ridges, and graded arcs (Kuenen and Perdock 1962; Krinsley and Cavallero 1970; Krinsley and Doornkamp 1973; Krinsley and McCoy 1978; Margolis and Krinsley 1971). These characteristics may or may not be present, depending on the geologic environment. Compared with desert conditions, eolian sands associated with a coastal environment are not as well-rounded and do not commonly exhibit dish-shaped concavities (Krinsley and Doornkamp 1973). When viewed with a binocular microscope, quartz grains that have been modified by eolian process are generally dull or opaque in appearance, exhibiting a 'frosted' morphology (Kuenen and Perdock 1962). A scanning electron microscope shows 'frosting' to be a dense occurrence of upturned plates (Margolis and Krinsley 1971).

Action within a littoral environment results in the presence of conchoidal fractures, mechanical V-forms, upturned plates, straight or curved grooves and flat cleavage faces (Krinsley and Doornkamp 1973; Krinsley and Donahue 1968; Margolis and Krinsley 1971). V-shaped indentations, formed by the interaction of abrasive impact and cleavage, are the most common and easily identified of these traits (Ingersoll 1974; Margolis and Krinsley 1971). Mechanically upturned plates formed in a beach environment tend to occupy limited areas of the grain along slightly rounded grain edges (Krinsley and Doornkamp 1973; Margolis and Krinsley 1971)

Sediments derived from glacial environments tend to include a range of conchoidal fracture sizes, flat cleavage faces, mechanically upturned plates, and modifications of these characteristics (Krinsley and Doornkamp 1973), like semi-parallel steps, arc-shaped steps, and high relief, outlined in Krinsley and Cavallero (1970). The overlap of certain glacial and subaqueous textures is caused by influence of both regimes on sediments (Krinsley and Doornkamp 1973). Krinsley and Doornkamp (1973) include a 'glacial and subaqueous' category as a single geologic environment. The influence of chemical processes can mask or destroy any of the previously described textures (Krinsley and Doornkamp 1973).

There is a correlation between grain size and the types of textures found on the surface of quartz grains (Baker 1976; Krinsley and Doornkamp 1973; Margolis 1968; Nordstrom and Margolis 1972). The grain size distribution of a single sample will show a trend, where the outer morphology of smaller and smaller grains are increasingly affected by chemical etching and cleavage (Ingersoll 1974; Krinsley and McCoy 1978; Nordstrom and Margolis 1972; Margolis 1968). Larger grains become increasingly dominated by mechanical features (Baker 1976; Krinsley and Doornkamp 1973; Krinsley and McCoy 1978; Krinsley and Takahashi 1962; Margolis 1968; Nordstrom and Margolis 1972), and grains ranging from 1 to -2 phi tend to show the highest percentage of mechanically formed textures (Ingersoll 1974; Margolis 1968). This is because of differences in mass; larger grains achieve higher momentum than smaller grains and have a higher occurrence of impact during saltation (Bloom 1991; Easterbrook 1993; Nordstrom and Margolis 1972).

The majority of research on quartz grain surface textures has utilized sand sized grains (Krinsley 1978), particularly in the 1-2 phi size range (Folk 1974). Folk (1974) has hypothesized that an individual environment of deposition will produce a range of textural features; river, beach, dune-forming processes will produce frosted, polished, and dull features on quartz grains. He suggests that a lacustrine environment will produce frosted grains at -4 to -2 phi, polished grains of -2 to 0 phi, and dull grains at 0 to 4 phi. An eolian environment will result in frosting from -4 to -1 phi, polished grains at 2 to 3 phi and dull surface textures at approximately 4 phi (Folk, 1974).

According to Folk (1974), the tendency by researchers to study a restricted size range has potentially induced a margin of error in studies aimed at pinpointing the environment of deposition (Folk 1974). However, this hypothesis is applied to the general outward appearance of grains (frosted, polished, dull), rather than precise definitions relating texture and apparent morphology. Experimental studies have shown that the effects of certain processes on quartz grains do create characteristic textural assemblages (Ingersoll 1974; Kaldi et al. 1978; Krinsley 1978; Krinsley and Doornkamp 1973; Krinsley and McCoy 1978; Krinsley and Takahashi 1962; Krinsley and Trusty 1985; Kuenen and Perdock 1962). Kaldi et al. (1978) illustrates that well-formed eolian textures can develop over extremely short periods of time. It is beneficial to compare grains within the same size range (Nordstrom and Margolis 1972) and use a suite of textures to delineate previous geologic environments (Margolis and Krinsley 1971).

Geomorphology, stratigraphy, the concept of facies in a shoreline environment, grain characteristics, lithology, sedimentary structures and preserved micro- and macrofossil remains, will effectively provide a plausible reconstruction (Bloom 1991; Butzer 1960; Easterbrook 1993; Harris 1979; Hassan 1978; Kraft et al. 1985; Reading 1978; Reineck and Singh 1980; Ritter 1978; Stein and Rapp 1984). However, there is a need to consider regional factors which affect geomorphic processes, such as sediment supply, climate, tectonics, changes in water level, biologic activity, and water chemistry (Hassan 1978; Larsen 1985a; Reading 1978; Stein and Rapp 1984).

Regional Setting

Bedrock Geology

Figure 3a shows the bedrock geology of lower Michigan; the associated stratigraphic column can be seen in Figure 3b (Dorr and Eschman 1970). The glacial deposits of central Michigan are primarily underlain by the Early Pennsylvanian Saginaw Formation (Dorr and Eschman 1970; Milstein 1987b). This formation rests unconformably on the Late Mississippian Bayport Limestone and was deposited by alternating transgressions and regressions of the final vestiges of the shallow epicontinental Paleozoic seas. The Saginaw Formation is composed of interbedded fluvial deposits, floodplain silts and clays, shallow water marine shales, swamp deposits, and marines shales and limestones (Dorr and Eschman 1970). The Verne Limestone Member was deposited during a substantial transgression. A significant unconformity, extending to the Pleistocene section, bounds the upper contact of the Saginaw Formation in most areas (Dorr and Eschman 1970; Milstein 1987b).

The westernmost portion of Saginaw County is underlain by Late Triassic redbeds (Dorr and Eschman 1970; Milstein 1987b). These redbeds are not named and are known only from drill core data. Sandstone, shale, clay deposits, and a few occurrences of limestone and gypsum record the geologic processes involved in the deposition of the redbeds.

Late Glacial and Holocene Geomorphic History

The glacial history of the area encompassed by modern Lakes Michigan and Huron is complex. A generalized summary is presented below; detailed information can be obtained within the works of Hansel et al. (1985), Larsen (1985a, b), Leverett and Taylor (1915), and Mickelson et al. (1983).

The Laurentide ice sheet reached its maximum extent about 18,000 years BP (Mickelson et al. 1985). Influenced by the preexisting topography, major ice lobes advanced down the axes of Lake Michigan, Saginaw Bay, Lake Huron, and Lake Erie (Milstein 1987c). Recession of the Laurentide ice sheet began to expose these lake basins after 18,000 years BP. Retreat occurred in stages and was interrupted by numerous stabilizations and readvances of the ice margin, which led to the formation of a complex system of end moraines (Flint 1959) (Figure 4).

Glacial meltwater was ponded between the ice margin and the region of higher topography located to the south, resulting in the formation of numerous glacial lakes (Milstein 1987c) (Figure 5). These lakes stabilized well above modern elevations and are

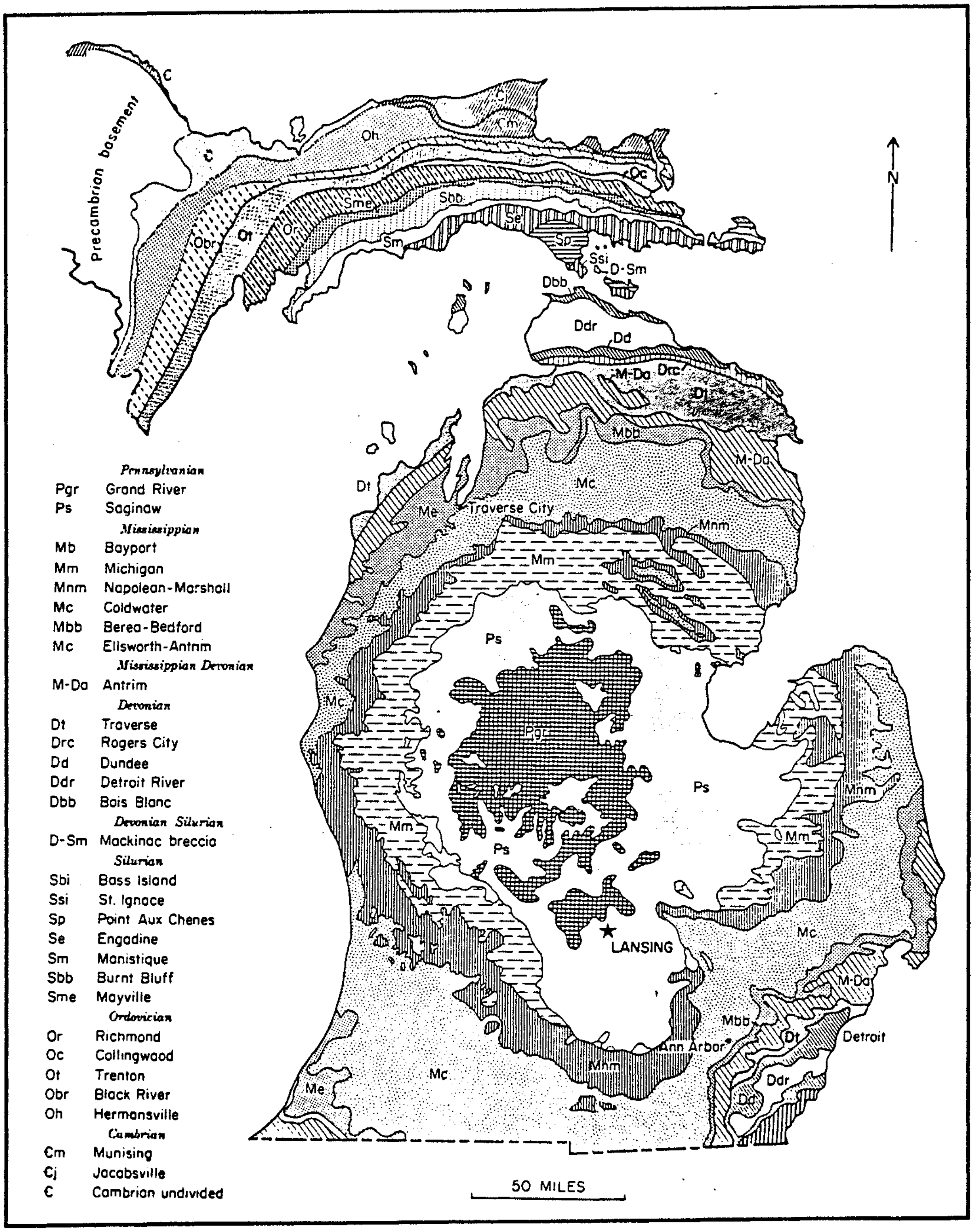


Figure 3a - Map of the bedrock geology of Michigan. Overlying Pleistocene glacial deposits are not shown. Refer to Figure 3b column B, C and D for the stratgraphic profile of lower Michigan; column A, the Upper Penninsula profile, is not shown (Door and Eschman p. 86, 1970).

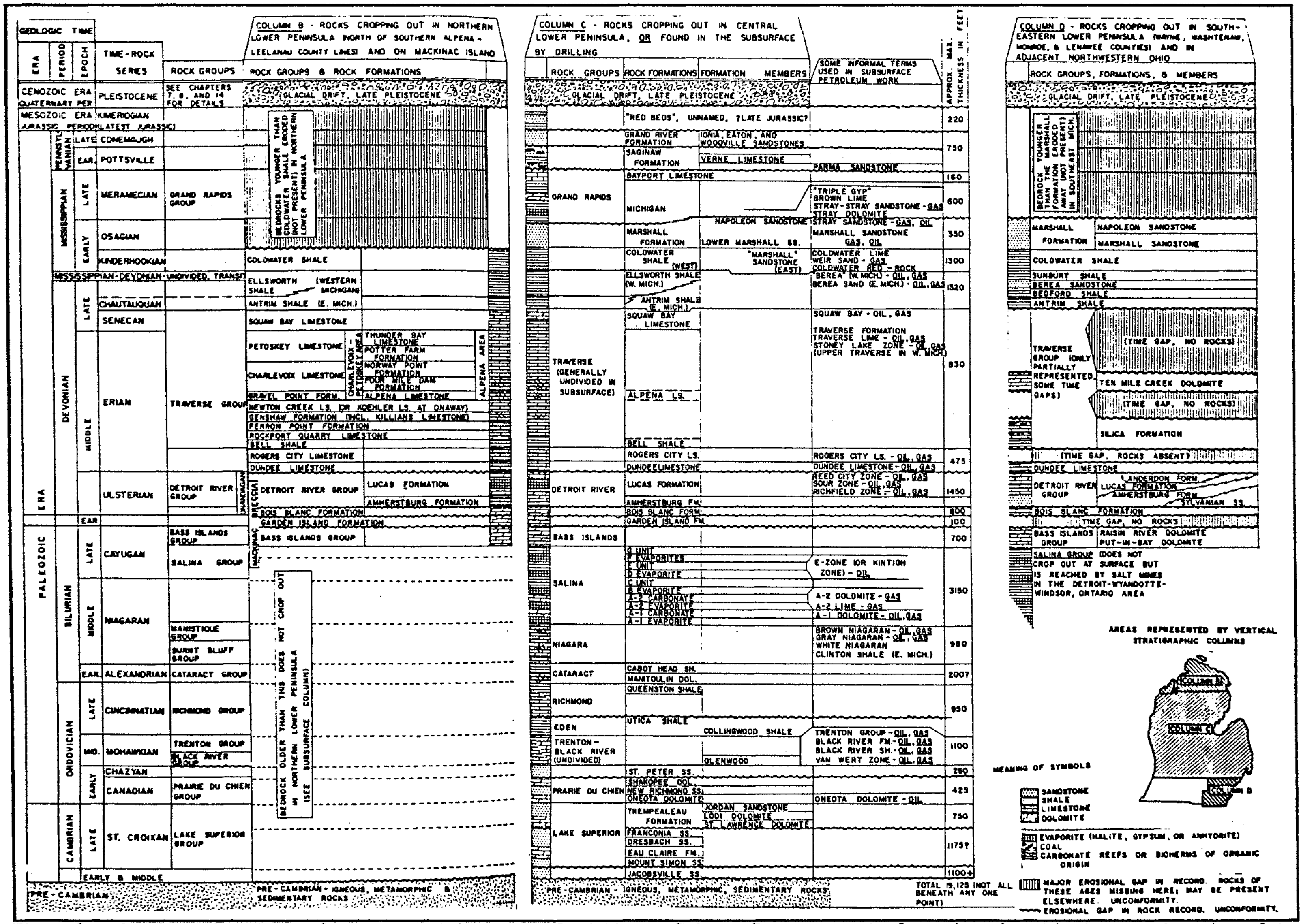


Figure 3b - Stratigraphic column of post-Precambrian rocks of Michigan. Column C represents the formations found in the central portion of the lower Penninsula of Michigan (Dorr and Eschman p. 84-85, 1970).

Figure 4 - Nearshore and morainic deposits and outlet channels for Michigan (modified after Flint, 1959, Hansel et al., 1985, and Kehew, 1992).

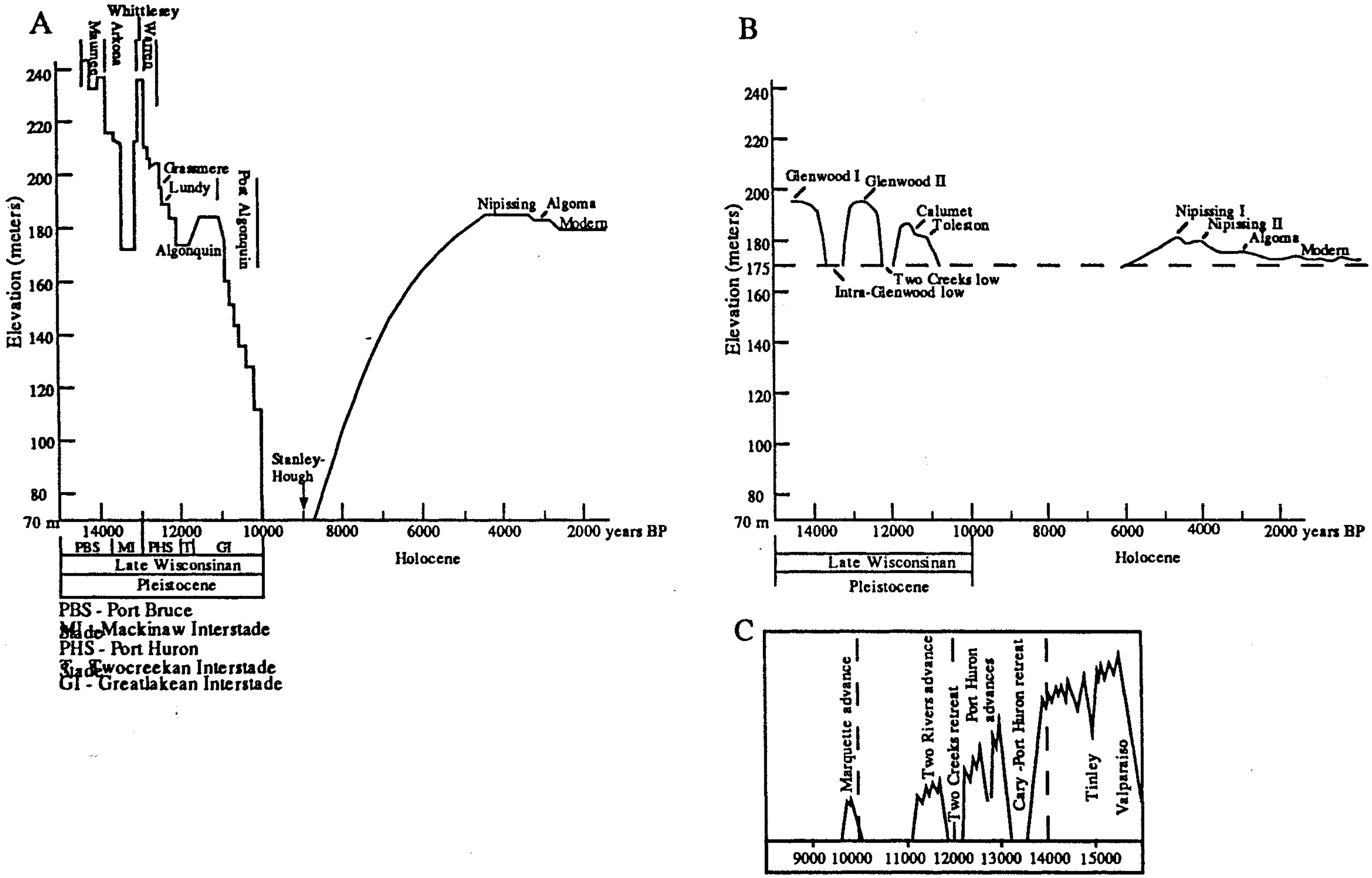


Figure 5 - (a) Glacial Lakes of the Huron Basin over time (modified from Eschman and Karrow 1985). (b) Glacial Lakes of the Michigan basin over time (modified from Hansel et al. 1985). (c) Glacial advances and retreats in the Michigan basin over time (modified from Hansel et al 1985).

marked by abandoned beaches, spits, sand bars, wave-cut terraces, and meltwater spillways (Eschman and Karrow 1985; Hajic 1992; Hansel et al. 1985; Kehew 1992; Milstein, 1987). Ice retreat eventually progressed beyond the northern extent of the lake basins and exposed topographically lower outlets causing water levels to drop well below modern lake elevations (Hansel et al. 1983; Milstein 1987c). The progression of lake stages was complicated by isostatic rebound following the removal of the ice mass. Water levels rose to post Glacial maximums by the mid-Holocene and were subsequently lowered by erosion at the outlets, resulting in the eventual formation of the modern Great Lakes.

Late Glacial History of the Michigan, Huron, and Erie Basins

The Michigan lobe retreated from the Valparaiso moraine (Figure 4) at approximately 15,500 years BP and Glacial Lake Chicago was formed (Hansel et al. 1985; Hill 1987; Larsen 1985b) (Figure 6). Ice retreat was interrupted by several readvances between 15,500 and 11,000 years BP (Figure 5). The Cary, Port Huron and Two Rivers advances were separated by the Cary-Port Huron and Two Creeks interstadials (Hansel et al. 1983) (Figure 5). Eventually the ice margin withdrew to a point to the north of the Lower Peninsula of Michigan. Meltwater which initially drained southward through the Chicago outlet and down the Illinois River Valley (Hajic 1992; Kehew 1992) was rerouted across the Indian River lowland and through the Straits of Mackinac into the Huron basin (Hansel et al. 1985) (Figure 4).

Three distinct shorelines along the southwest margin of Lake Michigan mark the main levels of Lake Chicago. The three phases of the lake include the Glenwood Phase (Figures 6 and 7), which rose to approximately 195 m (636 ft) (Hansel et al. 1985; Larsen 1985b), the Calumet Phase (Figure 8), at an elevation of 189 m (620 ft) (Figure 5), and the Toleston Phase, at an elevation between 183 and 184 m (600 and 603 ft) (Hansel et al. 1985). Lowering of mean lake levels has been attributed to episodic downcutting of the Chicago outlet (Hansel et al. 1985). At times outflow may have occurred catastrophically; the Kankakee Torrent was a series of floods that drained through this area from approximately 16,000 to 15,500 years BP (Hajic 1992).

Meltwater overflowed the southern boundary of Glacial Lake Chicago and began to cut an outlet channel through the glacial deposits (Kehew 1992; Larsen 1985b). Wave-cut terraces and depositional landforms are preserved, marking the Glenwood Stage of Glacial Lake Chicago (Figure 6) (Larsen 1985b) established at approximately 14,500 years BP following ice retreat from the Tinley moraine (Hansel et al. 1985) (Figure 4). The maximum lake level during the Glenwood I Phase was reached just prior to the deglaciation of the Straits of Mackinac as drainage from the Saginaw, Huron, and Erie lobes entered the

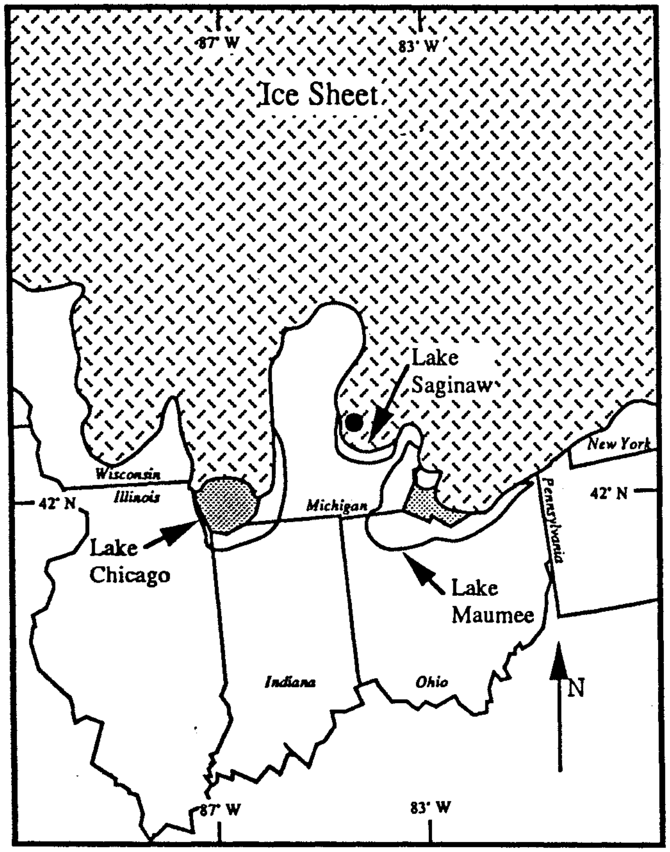


Figure 6 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial Lakes Chicago (Glenwood Stage I), Saginaw, and Maumee, (modified after Leverett and Taylor, 1915, and Hansel et al., 1985).

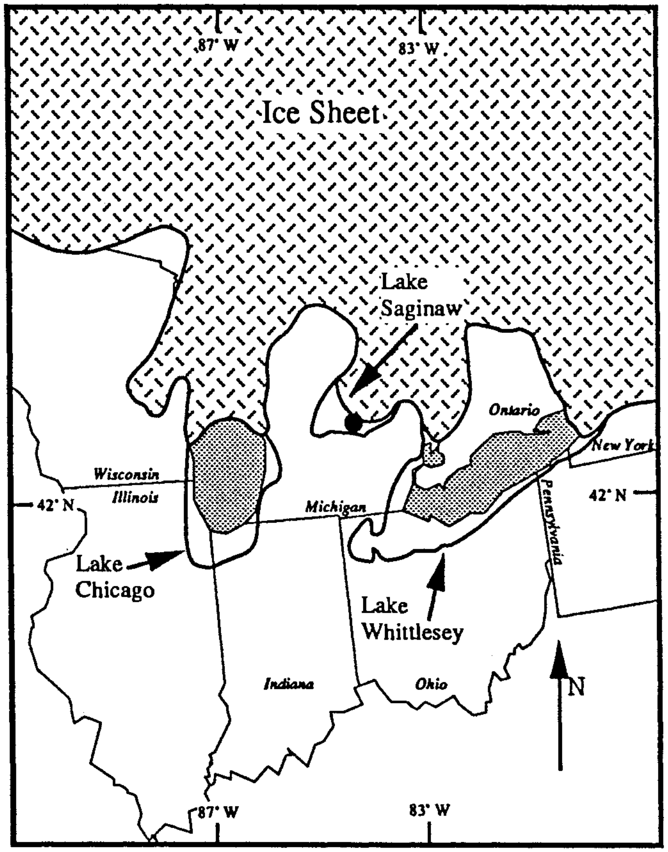


Figure 7 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial Lakes Chicago (Glenwood Stage II), Saginaw and Whittlesey (modified after Eschman and Karrow, 1985, and Hansel et al., 1985).

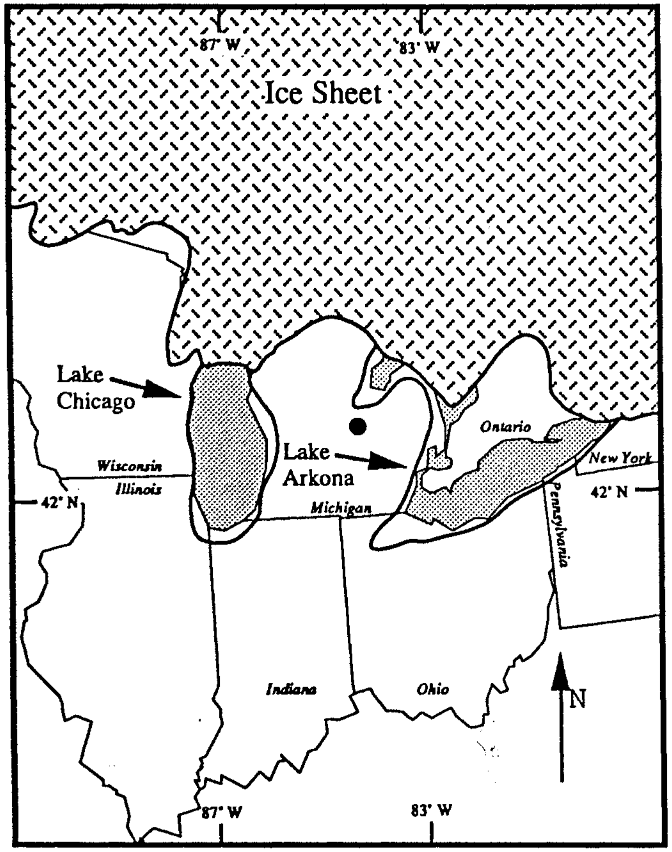


Figure 8 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial Lakes Chicago and Arkona (modified after Kehew, 1992, and Eschman and Karrow, 1985).

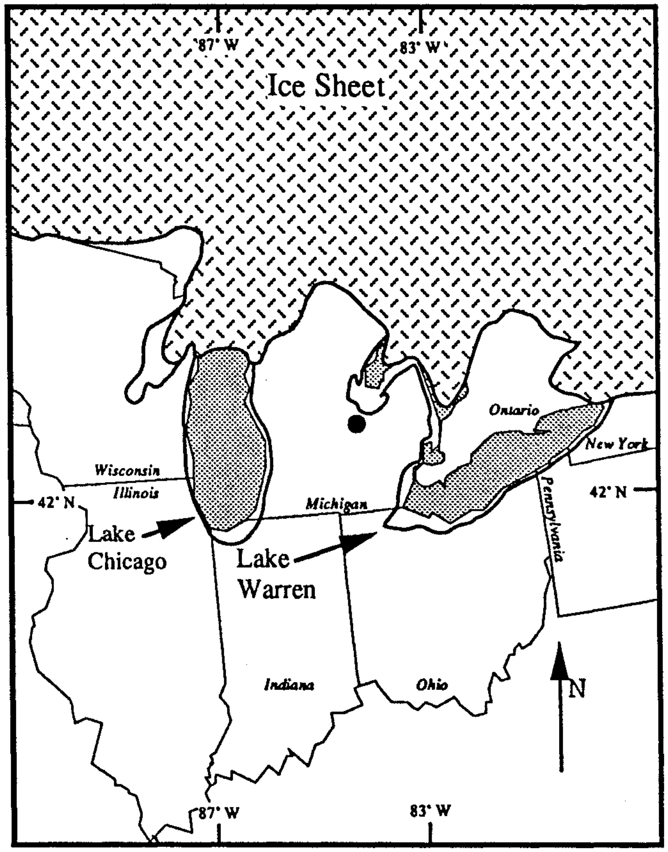


Figure 9 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial Lakes Chicago (Calumet Stage) and Warren (modified after Eschman and Karrow, 1985 and Hansel et al., 1985).

Lake Michigan basin (Larsen 1985b), possibly as a catastrophic inflow (Kehew 1992). The Intra-Glenwood Phase, from 13,500 to 13,000 years BP, corresponds to the Cary-Port Huron Interstade, during which the northern outlet was exposed allowing eastward drainage (Hansel et al. 1985) (Figure 5).

Retreat of ice following the Port Bruce Stade began to expose the Huron basin at 15,000 years BP. The first Glacial lake to form in this area was Lake Maumee contained within the Huron and Erie basins (Figure 6). Lake Maumee initially drained toward the southwest, but eventually drained west across Michigan (Fraser 1992; Kehew 1992). Three separate lake levels have been attributed to Lake Maumee at 244, 232, and 238 m (800, 761, and 781 ft) in elevation.

The majority of the modern lake Huron basin was filled with glacial ice during the three phases of Lake Maumee. Ice retreat uncovered the 'thumb' area of Michigan and stabilized the second Maumee Phase at 232 m (761 ft). Readvance over this area caused lake levels to rise to the Maumee III level of 238 m (781 ft) (Eschman and Burgis 1980). Combined, these three phases lasted approximately 500 years (Eschman and Karrow 1985).

A separate lake confined within the Saginaw basin, Lake Saginaw, came into existence during two separate intervals of the Wisconsinan ice retreat. The first of these lakes gradually expanded in size as the Saginaw Sublobe retreated from the Flint Moraine and drained west along the ice margin into Glacial Lake Chicago through the Grand River Valley (Figure 4). This lake received drainage from the third phase of Lake Maumee (Eschman and Karrow 1985) (Figure 6). Further retreat of the ice during the Mackinaw Interstade allowed a drop in water level in the Erie, Huron and Saginaw basins and the formation of Glacial Lake Arkona (Fullerton 1980) (Figure 9). Three levels of Lake Arkona have been identified at 216, 213 and 212 m (708, 699, and 695 ft) above sea level, though they are blanketed by sediment derived from the readvance of Port Huron ice.

The advance of Port Huron ice resulted once again in the formation of Lake Saginaw in the Saginaw basin and Lake Whittlesy in the Erie and Huron basins at approximately 13,000 years BP (Figure 7). These lakes drained west through the Grand Valley in central Michigan (Hansel et al. 1985; Kehew 1992) (Figure 4). With the Trent lowland outlet blocked by ice, the level of Lake Whittlesy rose to 225 m (738 ft) and drained through the Ulby channel outlet (Figure 4); a delta was deposited where the Ulby channel emptied into the eastern margin of Lake Saginaw (Barnett 1985; Muller and Prest 1985) (Figure 7). At that time, Lake Saginaw was 13 m (43 ft) lower than Lake Whittlesy (Fullerton 1980; Hansel et al. 1985). Lake Whittlesy lasted for approximately 200 years before the retreat of ice from the Port Huron moraine allowed the formation of Glacial Lake Warren within the

Erie, Huron and Saginaw basins, (Figure 9). Lake Warren drained west through the Grand Valley (Figure 4) (Figure 10).

Lake Warren is represented by three strandlines at 210, 206, and 203 m (689, 676, and 666 ft), formed either by the intermittent downcutting of outlets caused by variations in discharge or, according to Larsen (1985a, b), to small-scale climatic fluctuations. These beaches, commonly covered by loess, are most easily identified along the eastern margin of the Huron basin. Glacial Lake Warren was ponded by the ice front that rested immediately to the north of Saginaw Bay and extended in a lobate form into the Huron basin (Eschman and Karrow 1985) (Figure 9).

The sequence of Lake Warren phases was interrupted by a low stand identified by beach remnants at 201 m (659 ft) (Figure 5). This lake, Glacial Lake Wayne, came into existence prior to the lowest of the Warren phases, and is thought to have formed because of a minor retreat of ice near Buffalo, New York which allowed the eastward drainage of Lake Warren waters (Eschman and Karrow 1985; Fullerton 1980; Muller and Prest 1985). Readvance of ice across this eastern outlet allowed the third phase of Lake Warren to form. Combined, the Warren and Wayne phases lasted less than 400 years (Eschman and Karrow 1985).

The final lake phases that formed within the combined Erie and Huron basins were Lakes Grassmere and Lundy (Figure 5). Retreat of the ice margin caused the water level to drop to the Lake Grassmere average elevation of 195 m (636 ft). Several strand lines within a 6 m (20 ft) range have been identified, making the actual level difficult to ascertain; some of these features are tentatively classified as subaqueous sand bars. Lake Grassmere existed for approximately 100 years before further retreat of the Huron Lobe from the Port Huron moraine exposed the Indian River lowland, located just south of the Straits of Mackinac (Figure 4). Northward drainage across this area allowed the formation of Lake Lundy at an elevation of 189 m (620 ft). Like previous lake stages, Lake Lundy strand lines are difficult to identify; the termination of this lake occurred around 12,400 years BP with the formation of an early Algonquin phase that preceded the establishment of the main Lake Algonquin (Eschman and Karrow 1985).

Readvance of the Michigan Lobe caused a rise in lake levels and initiated the Glenwood II Phase of Glacial Lake Chicago (Figure 6), which persisted until the Two Creeks Interstade at 12,200 years BP (Figure 5). Advance of the Two Rivers ice at 11,800 years BP resulted in a rise of water to the Calumet Level at 189 m (620 ft) (Hansel et al. 1985; Larsen 1985b) (Figure 8). The water remained at this level until approximately 11,200 years BP (Figure 5).

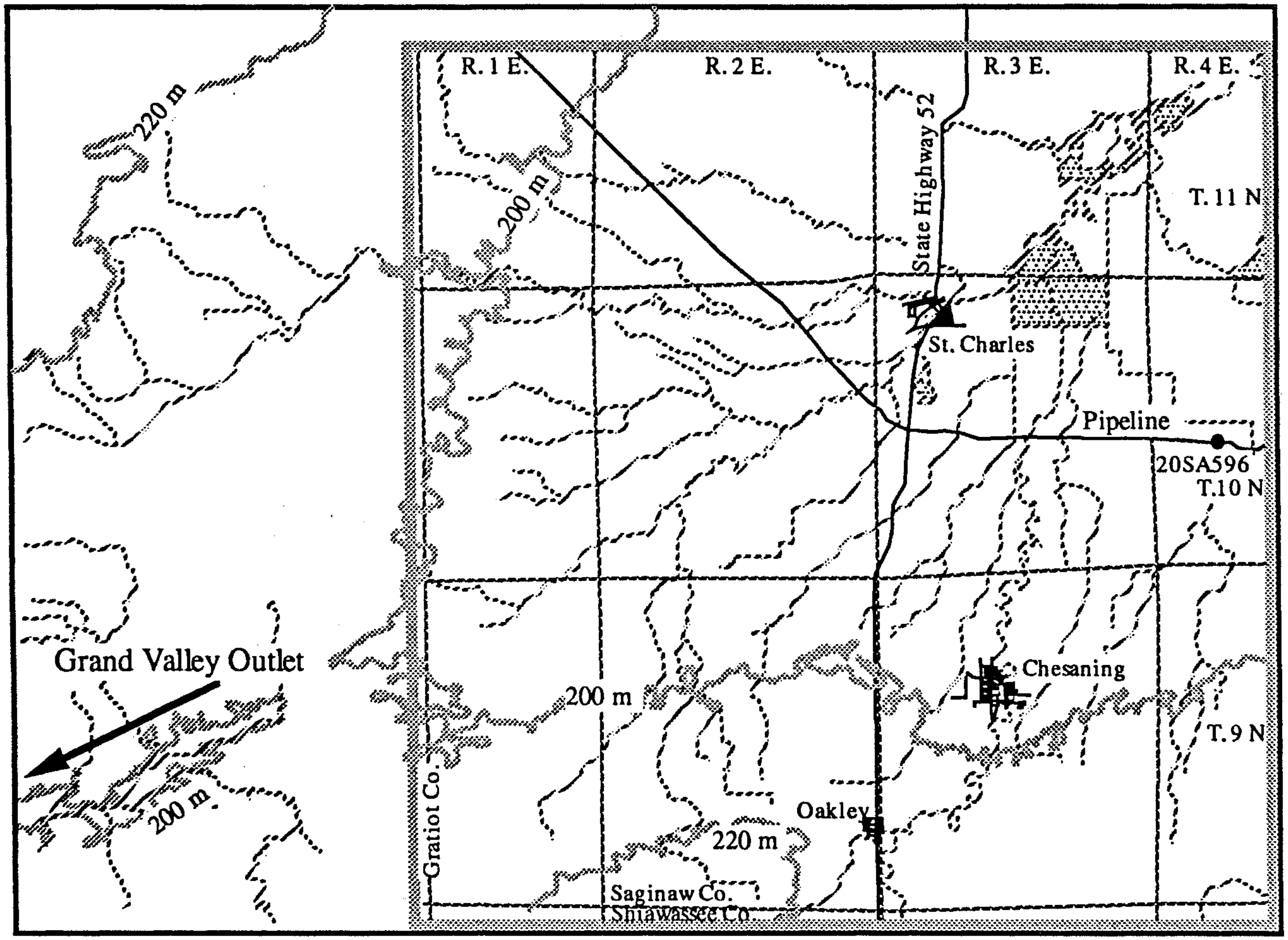


Figure 10 - Perimeter of the Saginaw basin (reconstructed by the modern 220 m contour) and the Grand Valley outlet. Contours are represented by stippled lines and marked by elevation. The 200 m contour is shown for comparison. The study area is outlined by the wide stippled border.

Preserved at an elevation of 184 m (603 ft), the final phase of Glacial Lake Chicago has been named the Toleston Phase (Hansel et al. 1985; Larsen 1985b). When the ice margin ultimately retreated past the Straits of Mackinac at 11,000 years BP, Glacial Lake Chicago ceased to exist and waters of the Michigan, Huron, and Superior basins merged, forming Lake Algonquin (Figure 11).

Post Glacial History of the Michigan and Huron Basins

Represented by a maximum elevation of 184.5 m (605 ft) (Hansel et al. 1985; Larsen, 1985a; 1985b), Lake Algonquin (Figure 11) was regulated by outlets at Chicago and Port Huron (Karrow 1980; Milstein 1987c). It is hypothesized that former Toleston Phase beaches were reoccupied by this water body, but no stratigraphic evidence has been presented within the southern portions of the Michigan and Huron drainage basins that unequivocally supports this theory (Larsen 1985b).

Between 10,500 and 10,000 years BP recession of the Two Rivers ice exposed the North Bay outlet (Hansel et al. 1985; Karrow et al. 1975; Larsen 1985b) (Figure 4) (Figure 12). Lake Algonquin drained toward the north and east over isostatically depressed terrain. Water levels dropped to the Chippewa and Stanley low stages in the Michigan and Huron basins respectively (Figure 12). These were the lowest water levels recorded since the end of the Glacial period. Beach deposits are located beneath the waters of modern Lake Michigan at 70.2 m (230 ft) and modern Lake Huron at 60 m (197 ft). The Chippewa-Stanley low signals the transition from the Glacial to the post Glacial time period (Larsen 1985b).

As the elevation of the northern outlets increased because of continued isostatic rebound, southern outlets were once again occupied. Regulated by these outlets, water levels returned to the Toleston-Algonquin beach elevations at 184.5 m (605 ft) (Larsen 1985a, b) (Figure 5). This event marks the beginning of the Nipissing Stage I, which spanned from approximately 5,500 to 4,700 years BP in the Huron, Michigan, and Superior lake basins (Hansel et al. 1985; Larsen 1985b) (Figure 13). The Nipissing transgression occurred toward the end of a warm, dry climatic period, the Altithermal, while the region returned to slightly cooler and wetter conditions (Webb et al. 1983). Maximum Nipissing lake levels are recorded at an altitude of 184.5 m (605 ft) (Figure 4).

Continued isostatic uplift eventually caused the North Bay outlet to be abandoned (Larsen 1985b). Drainage was then focused through the Port Huron and Chicago outlets. Downcutting of the southern outlets allowed lake levels to drop to the Nipissing II level, in existence from 4,700 to 3,700 years BP (Larsen 1985a b) with an elevation between 182 m (597 ft) (Larsen 1985b) and 180.5 m (592 ft) (Larsen 1985a) (Figure 5).

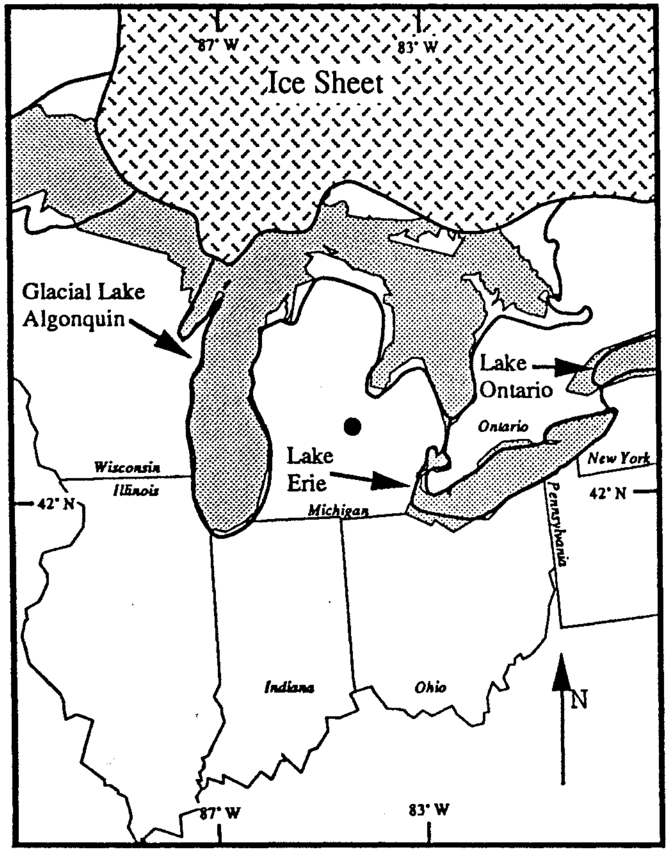


Figure 11 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial Lake Algonquin (modified after Miller, 1985).

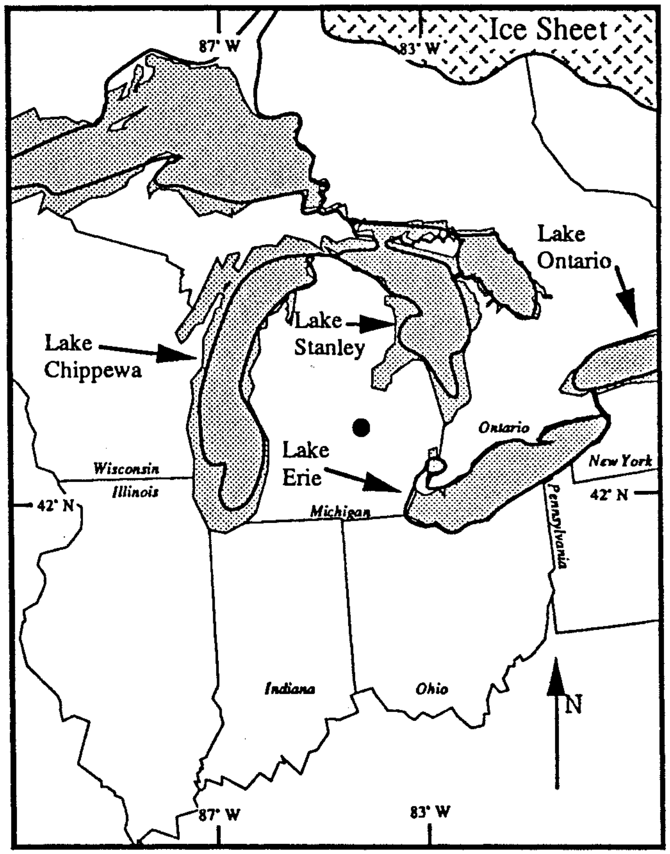


Figure 12 - Perimeter of the Laurentide Ice Sheet and the geographic extent of glacial lakes Chippewa and Stanley (modified after Miller, 1985.)

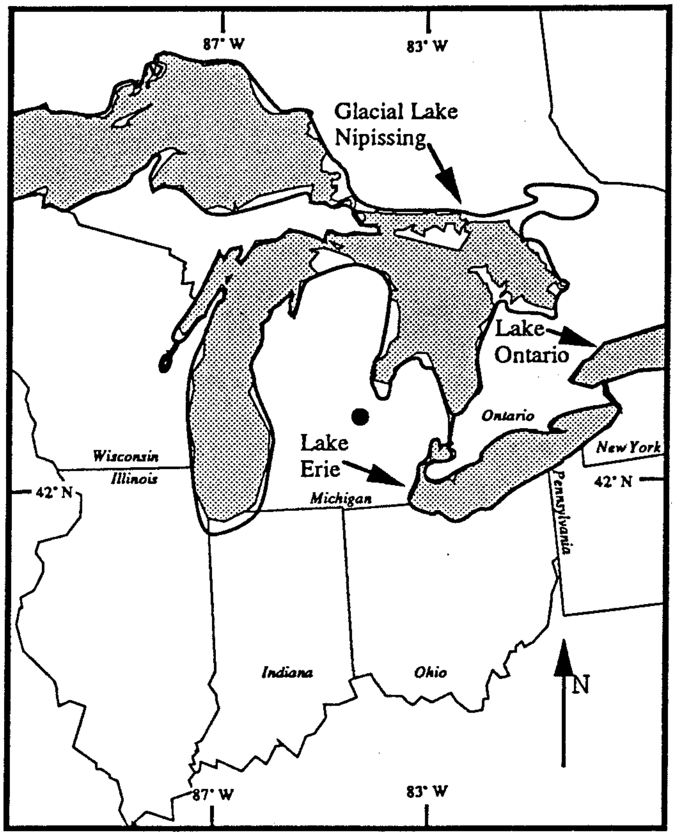


Figure 13 - The geographic extent of Post-Glacial Lake Nipissing (modified after Miller, 1985).

Stream incision into the glacial deposits at the Port Huron outlet allowed Algoma lake level to stabilize at approximately 3,700 years BP (Hansel et al. 1985; Larsen 1985a) (Figure 5). Lake Superior became a separate system from that of the Michigan and Huron basins at this time. The maximum Algoma level of 179 m (587 ft) occurred around 3,200 years BP (Larsen 1985a). The Algoma Phase lasted until 2,500 years BP. Renewed incision at the Port Huron outlet (Hansel et al. 1985; Larsen 1985a) allowed lakes Michigan and Huron to drop to their present elevations of 177 m (581 ft) (Hansel et al. 1985; Larsen 1985a) (Figure 5).

Late Glacial and Holocene Vegetational History

The vegetational history of the upper Midwest is complex, reflecting a transition from the full Glacial climate at 18,000 years BP, to warmer than modern conditions by 6,000 years BP. Ecological changes brought about by the recession of the Laurentide ice sheet resulted in regional-scale migrations of vegetation assemblages. Newly deglaciated landscapes were quickly colonized by pioneer plant communities dominated by arctic species, reflecting the harshness of the Late Glacial climate. Distinct ecotones gradually progressed northward through eastern Michigan as the climate warmed.

By 12,000 years BP the vegetational succession accompanying climatic warming had brought about the establishment of a forest dominated by spruce *(Picea)*, ash *(Fraxinus)*, ironwood *(Ostrya/Carpinus)* and sedge (Cyperaceae) in eastern Michigan. This forest ecosystem was similar in many respects to the modern boreal forest but with a few significant exceptions (Davis 1983; Webb et al. 1983; Jacobson et al. 1987). By 10,000 years BP mixed pine *(Pinus)*, elm *(Ulmus)*, ash, and ironwood forests dominated the region, accompanied by an increasing importance of oak *(Quercus)* by 8,000 years BP (Davis 1983; Webb et al. 1983; Jacobson et al. 1987). By 6,000 years BP pine was much less prevalent and forests were dominated by oak, beech *(Fagus)*, ironwood, ash and elm. Gradual succession led to the diverse modern assemblage including hickory *(Carya)*, pine, oak, beech, hemlock *(Tsuga)*, ironwood, ash, and elm as the key constituents (Jacobson et al. 1987; Webb et al. 1983).

Much of the work concerning Late Glacial and Holocene vegetational changes has been broadly focused on major forest types. Relatively little detail is known about non-arboreal species or the spatial distribution of forest openings and wetlands. An outline of the temporal fluctuations of selected plant taxa is presented to provide a framework for understanding the potential distribution of resources available to humans.

Species Migration

From 18,000 to 14,000 years BP, the Midwest was largely covered by glacial ice. The vegetational record indicates that spruce dominated the vegetation south of the ice margin (Figure 14a). Abundant spruce is taken to be an indicator of a boreal environment and suggests the presence of harsh conditions over broad areas. A pine-dominated region was present within a north-south band situated along the Atlantic Coastal Plain, east of the Appalachians (Figure 14b; c). Ash was restricted to microhabitats south of the ice margin. An oak-hickory deciduous forest gradually expanded northward out of Florida during the Late Glacial time period (Figure 14d) (Figure 14e). Two regions containing high percentages of prairie forbs existed in the Midwestern United States, serving as an indicator of prairie-like vegetation assemblages. The first of these prairie refugia was located in Texas and the other, dominated by sage, was located within the Great Lakes region. This Great Lake forb population may have been a tundra-like rather than a prairie assemblage. Prior to 14,000 years BP the Texas prairie began to expand northward, and was eventually able to interact with the northern forb population (Davis 1983; Jacobson et al. 1987).

From 14,000 to 12,000 years BP the sage-dominated tundra expanded eastward along the southern margin of the retreating ice. At approximately 12,000 years BP, rapid retreat of the Laurentide ice sheet exposed the area of the modern Great Lakes and a treeless, tundra vegetation became dominant. Immediately to the south of the tundra, vegetation consisted of a spruce/ ash/ ironwood forest assemblage (Figure 14a). From 12,000 to 10,000 years BP the sage-dominated tundra present in eastern Michigan was replaced initially by a boreal assemblage and ultimately a deciduous forest (Davis 1983; Webb et al. 1983).

A major shift occurred from 12,000 to 10,000 years BP, when the north-south trending pine population in the eastern United States reoriented to a center of abundance in an east-west band, located south of the retreating ice margin (Figure 14b; c). This pine-dominated forest formed at the expense of spruce and ash woodlands (Bernabo and Webb 1977; Jacobson et al. 1987; Webb et al. 1983). After the expansion of pine, relatively high abundances of spruce were confined to a narrow band of land located immediately south of the ice and ash began to decline within Michigan (Figure 14a). By 10,000 years BP forests covered most of the Midwest (Webb et al. 1983).

As a result of the immigration of pine species into the region surrounding the Great Lakes, two new ecotones came into existence. Central Minnesota, northern Wisconsin, and northern Michigan were covered by spruce-rich forests which also contained moderate levels of birch *(Betula papyrifera)* and jack pine (Figure 14c) (Bernabo and Webb 1977;

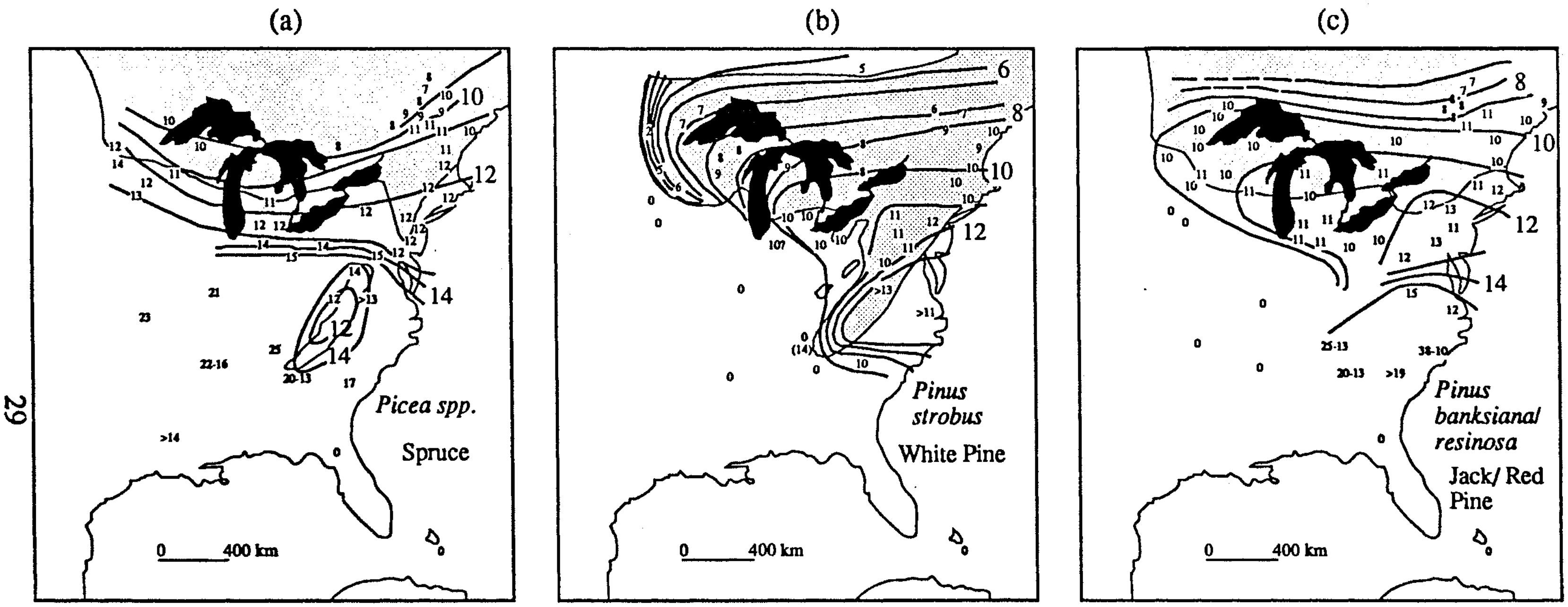


Figure 14 - Migration of (a) spruce, (b) white pine, and (c) jack and red pine in the eastern United States over time. Heavy lines delineate time boundaries in thousands of years. Stippled areas represent the modern ranges of each species (modified after Davis, 1983).

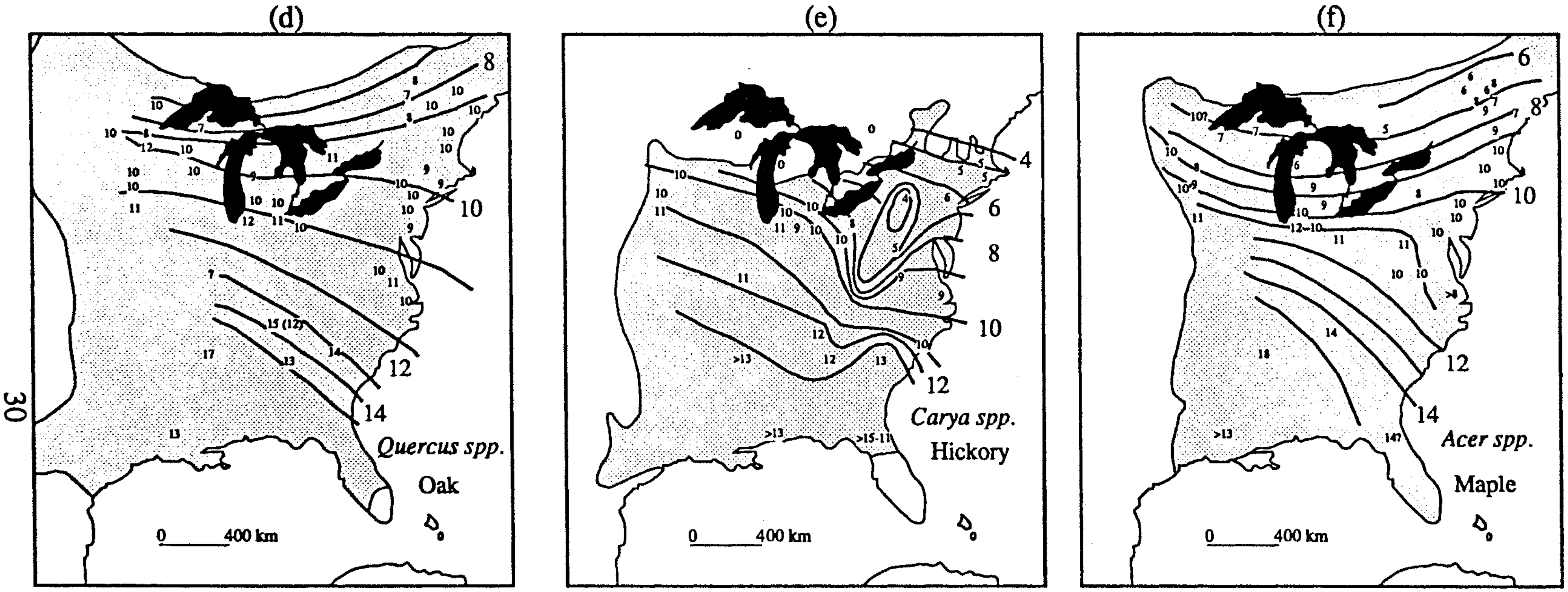


Figure 14 - Migration of (d) oak, (e) hickory, and (f) maple in the eastern United States over time. Heavy lines delineate time boundaries in thousands of years. Stippled areas represent the modern ranges of each species (modified after Davis, 1983).

Jacobson et al. 1987; Webb et al. 1983). In contrast, the extreme southern portions of Iowa, Illinois, Indiana and Ohio were characterized by deciduous forests comprised mainly of oak (Figure 14d), maple *(Acer)* (Figure 14f), elm (Figure 14g), ash, and ironwood (Bernabo and Webb 1977) The northern limit of this ecotone was sharply defined from southern Michigan into Illinois by occurrences of pine and oak species (Figure 14b; c) (Figure 14d); this boundary was increasingly diffuse toward the west. In southern Michigan and Wisconsin, a pine forest was present between the two ecosystems (Webb et al. 1983).

Relatively high percentages of ash and elm were widespread at 10,000 years BP. These species achieved their greatest aerial extent, ranging from southern Michigan into Minnesota (Figure 14g). After 10,000 years BP, moderately high levels of ash and elm began to contract toward the southeast. By 7,000 years BP ash and elm (Figure 14g) were distributed in approximately the same geographic area as beech (Figure 14h) and maple (Figure 14f) (Webb et al. 1983).

At 10,000 years BP, hickory (Figure 14e) had expanded in conjunction with oak (Figure 14d) and other hardwoods, including elm (Figure 14g). Hickory was not significant in abundance in the field area at any time during the Late or post Glacial periods; oak populations were dominant to the southeast and abundant south of the Great Lakes (Figure 14d). At the same time, hemlock expanded in the northeastern United States and became more common within the vicinity of the eastern great lakes, across New England, and into the Canadian Maritimes (Bernabo and Webb, 1977; Jacobson et al. 1987) (Figure 14i).

A boreal forest consisting mainly of spruce (Figure 14a), jack pine (Figure 14c) and birch stretched across northeast Minnesota, northwest Wisconsin, and the western portion of the Upper Peninsula of Michigan just prior to 9,000 years BP. Deciduous forests had extended northward into Wisconsin and lower Michigan. By 9,000 years BP, maximum spruce (Figure 14a) and oak (Figure 14d) assemblages had migrated northward (Webb et al. 1983); maple (Figure 14f) populations had moved into the Midwest, including Wisconsin and Michigan (Webb et al. 1983). By 8,000 years BP there were few centers of spruce remaining (Davis 1983; Jacobson et al. 1987) (Figure 6).

Although relative percentages decreased from 10,000 to 6,000 years BP, the geographic distribution of ash species remained stable. The association of ash with elm (Figure 14g) and ironwood worked to create a mixed deciduous forest in an area south of the Great Lakes, somewhat similar to modern forests. It should be noted that while black

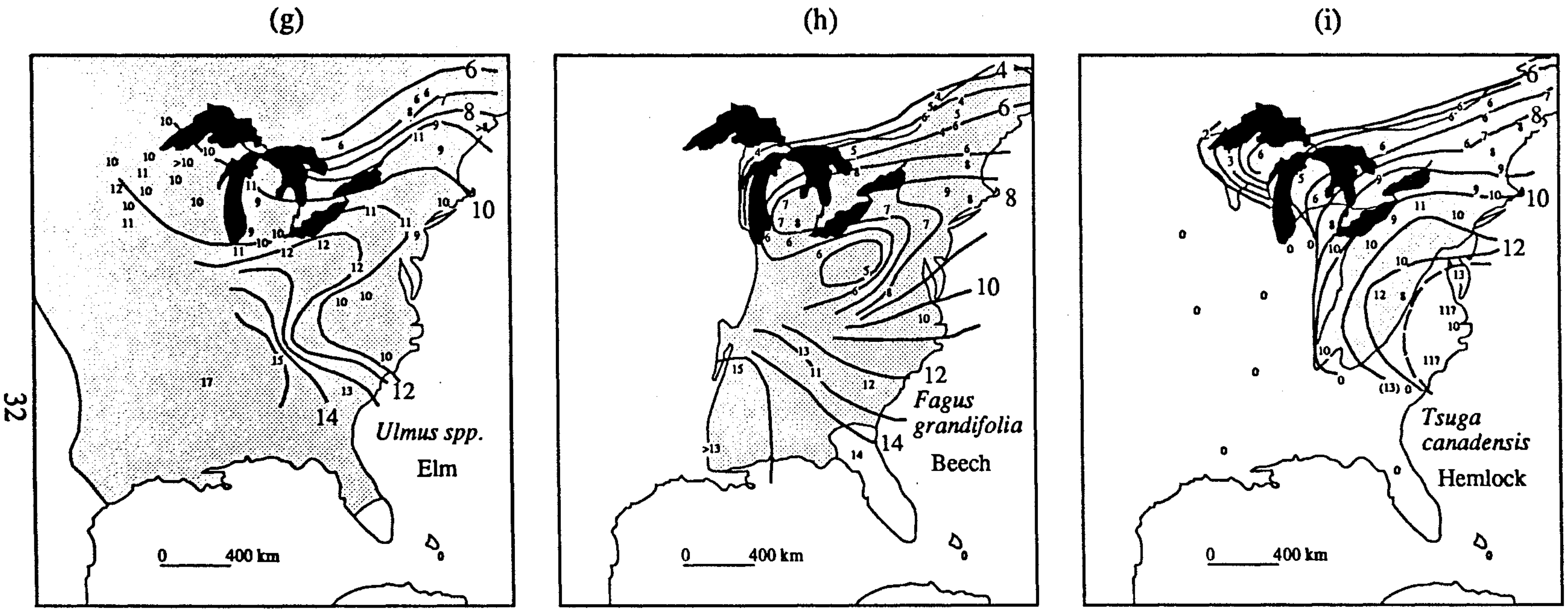


Figure 14 - Migration of (g) elm, (h) beech, and (i) hemlock in the eastern United States over time. Heavy lines delineate time boundaries in thousands of years. Stippled areas represent the modern ranges of each species (modified after Davis, 1983).

ash dominated from 12,000 to 8,000 years BP, progressively modern occurrences have shifted toward an abundance of white and green ash species (Jacobson et al. 1987).

By 8,000 years BP, hemlock had begun to expand north and west (Figure 14i). Maximum abundance occurred around 6,000 years BP (Figure 14i). Hemlock was never present in significant amounts in the Saginaw basin and, in addition to ironwood, has never undergone significant changes in geographic distribution or abundance. The time period of 8,000 years BP also showed little variation of the geographic distribution of oak (Bernabo and Webb 1977; Davis 1983; Jacobson et al. 1987) (Figure 14d).

Maple (Figure 14f) was present throughout southern Michigan and Wisconsin from 9,000 to 6,000 years BP (Webb et al. 1983). This species occurred in significant percentages in southern Michigan, Ohio, and Indiana; beech was initially present and abundant in the same area at 8,500 years BP (Webb et al. 1983).

Prairie was restricted to the Great Plains during the early Holocene until around 8,000 years BP. At this time prairie expanded across the Midwest, and achieved its easternmost extent by 6,000 years BP (Bernabo and Webb 1977; Webb et al. 1983). Deciduous forests were displaced northward and eastward in lower Michigan and Wisconsin. In lower Michigan, deciduous forests included occurrences of oak and moderate amounts of elm, beech, and maple, with ash and hickory also becoming increasingly abundant in southern Michigan and western Ohio.

After 6,000 years BP the prairie retreated westward. Hemlock initially appeared in northwest lower Michigan and gradually extended its range westward into northern Wisconsin, where maple and birch had increased within the forest assemblage (Figure 14i). Beech also extended from northwest lower Michigan into the eastern portion of the Upper Peninsula of Michigan (Webb et al. 1983) (Figure 14h).

From 6,000 to 3,000 years BP, hemlock (Figure 14i), beech (Figure 14h), and maple (Figure 14f) rose in abundance in northern lower Michigan, simultaneously decreasing to the south in Ohio, Indiana and southwest Michigan. This occurrence parallels an increase in herb species throughout central Illinois and Indiana because of an eastward extension of the prairie into Illinois.

Following 3,000 years BP, beech and maple had become more prominent in northeast Indiana, and reversals of many Early Holocene trends had been realized. By this time the ecotone boundary between deciduous and mixed forest type was established in central Michigan. A compositional gradient of hardwood forests existed across northern Michigan, Wisconsin and into Minnesota (Webb et al. 1983).

The post Glacial time period witnessed the establishment of vegetational gradients and mixed assemblages within the Great Lakes region. A patchwork of unique micro-habitats was created, especially in such unstable areas as lake-marginal environments.

Generalized Site Description

Geologic Profile

20SA596 is a multi-component archaeological site (Figure 15) preserved within a 2 m (6.5 ft) sequence of Late Glacial and Holocene lacustrine and eolian deposits overlying a substantial accumulation of varved clays (Figure 16). A 40 cm thick lower sand unit (Figure 16) containing silt and laminated clay inclusions is located above the varves (Figure 17a; b; c; d). No obvious cross-bedding is found within this level however, small-scale dewatering structures are common. This unit becomes progressively organic-rich upward through the sequence and ultimately grades into a peat horizon (Figure 16).

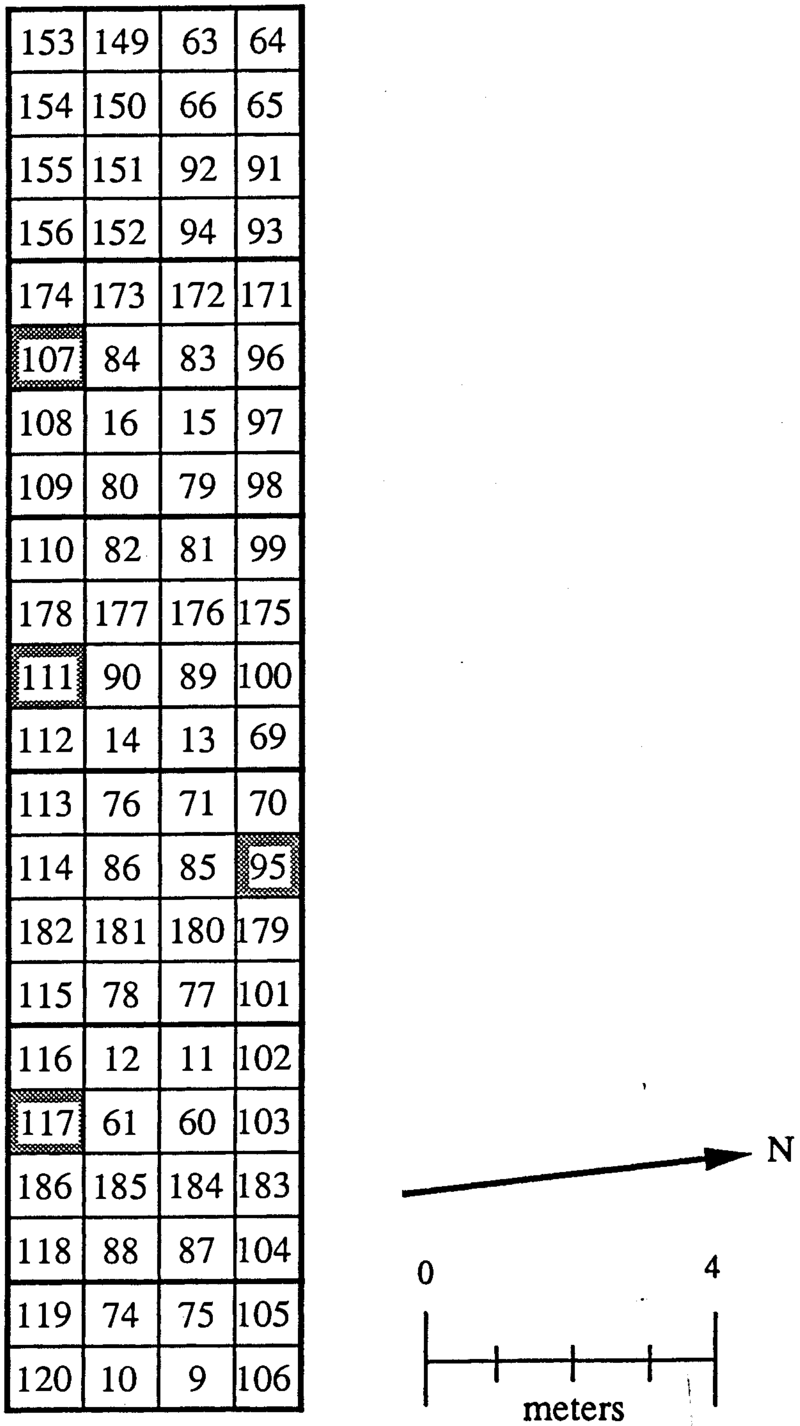
The peat layer is 20 cm thick at its maximum (Figure 17a) and pinches out toward the east and west within the confines of the site (Figure 17b; c), defining the extent of a small depression which allowed preservation of organic materials. Deposits of relatively coarse, light colored sands are found within the thickest portion of this organic-rich unit (Figure 16) (Figure 17d). The peat divides into multiple layers interbedded with clastic sediments at the margins of the shallow basin (Figure 17b). The upper surface is well defined and contains small-scale depressions 30 to 40 cm in diameter and 1 to 3 cm deep (Figure 17a; b; d). Microflakes are concentrated in the central portions of these depressions.

The 50 cm thick accumulation of sediment overlying the peat consists of a sequence of very fine sands intermixed with silt and fine sand layers (Figure 16) (Figure 17b; d). However, medium sands do occur in lenses within the lower portion of this upper sand unit. Some cross-bedded structures with scales of up to 1 meter are preserved with medium sands present in ramp-like lenses separated by finer sediment size fractions (Figure 17b). Forsets are commonly outlined by organic and clay-rich laminae (Figure 17b; c).

The sand upper unit, defined in Figure 16, is approximately a meter thick and is composed of fine sands. Sediments in this upper sand unit are relatively uniform, although a few organic-rich laminae are present (Figure 17a; b; c; d). Iron staining is present at the upper boundary of the water table and a poorly developed A-horizon is present (Figure 16). The modern plow zone caps this sequence (Figure 16) (Figure 17a; b; c; d).

Cultural Assemblage

Artifacts found on site can be separated into two distinct assemblages. The first is associated with the peat and interbedded sediments immediately overlying this layer. Faunal remains, lithic debris, projectile points, cores, and fire cracked rock (FCR) are included in the artifact assemblage. Faunal remains include burnt mammal bone and limited quantities of bird bone and shellfish remains.



153	149	63	64
154	150	66	65
155	151	92	91
156	152	94	93
174	173	172	171
107	84	83	96
108	16	15	97
109	80	79	98
110	82	81	99
178	177	176	175
111	90	89	100
112	14	13	69
113	76	71	70
114	86	85	95
182	181	180	179
115	78	77	101
116	12	11	102
117	61	60	103
186	185	184	183
118	88	87	104
119	74	75	105
120	10	9	106

Figure 15 - Schematic representation of the 20SA596 excavation grid. The site was excavated in 1 by 1 meter squares. Samples were taken from the highlighted units in natural levels and submitted for analysis.

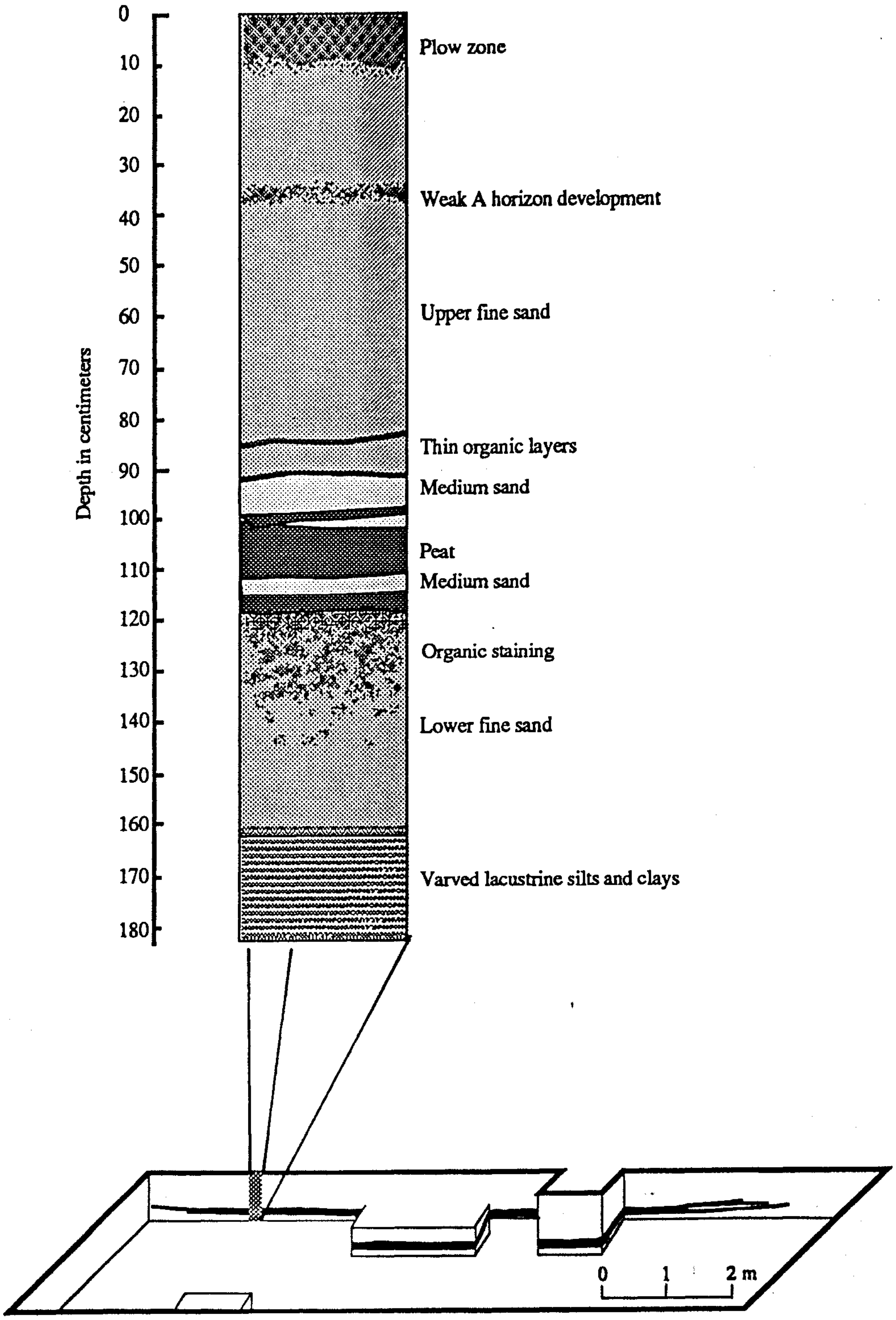


Figure 16 - Illustration of the site and a generalized sedimentary profile.

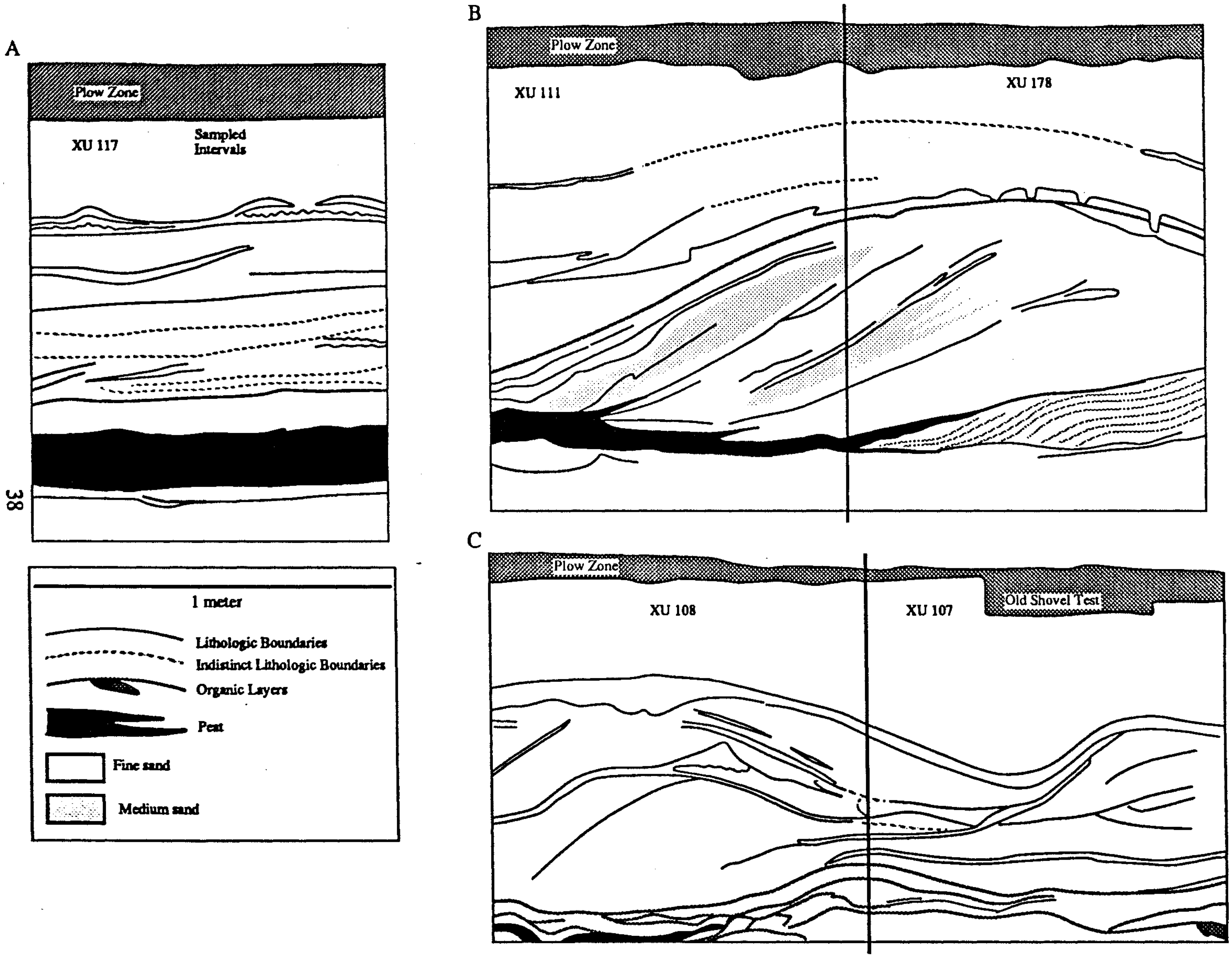


Figure 17- Detailed profile of excavation units (a) 117, (b) 111 and 178, and (c) 108 and 107.

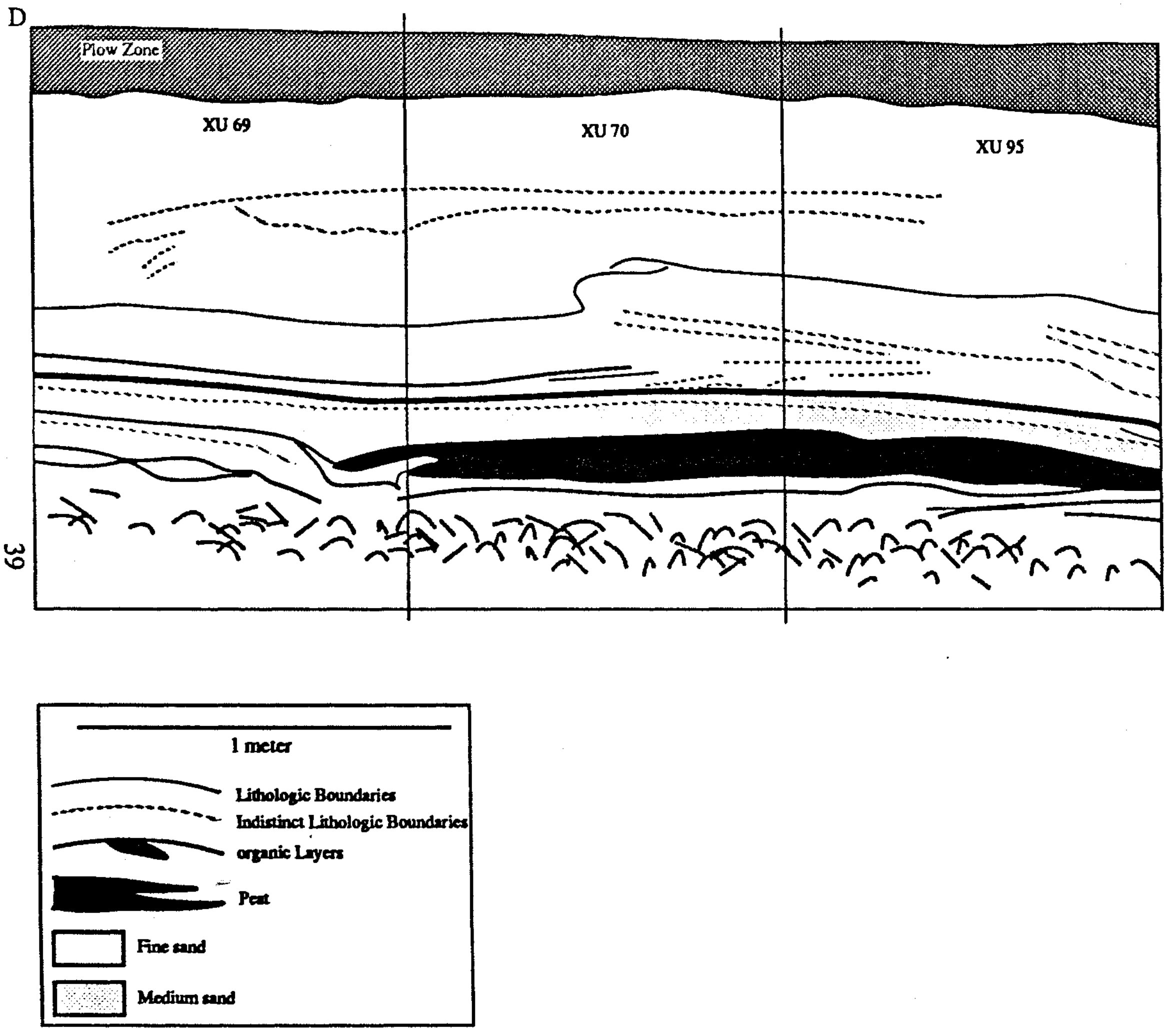


Figure 17- Detailed profile of excavation units (d) 69, 70, and 95.

The second assemblage, contained within the upper sand unit, is comprised of ceramics, four stone beads (made from fossilized crinoid stems), lithic debris, diagnostic tools, cores, and FCR. Only three small pieces of grit-tempered ceramic material were discovered. The toolkit for this cultural component is composed of drills, bifaces, retouched flakes, and projectile points.

The artifacts associated with the peat layer are identified as Archaic. The upper artifact assemblage rests in reworked sediments and also contains Archaic material. The Institute for Minnesota Archaeology has completed a Report of Investigation detailing the artifacts, context, and cultural interpretation of 20SA596.

Methods

On-Site Sampling Methods

A systematic excavation of 20SA596 was conducted by the Institute of Minnesota Archaeology during the 1991 summer season and completed in November. Draw-down wells were emplaced around the perimeter of the site because the majority of artifacts were situated below the water table (Figure 18). Excavation was carried out in 1 by 1 meter squares. Figure 15 illustrates the layout of excavation units within the 4 by 22 m block addressed in this study.

Sediments submitted for geologic interpretation were taken from excavation units 117 (Figure 19a), 111 (Figure 19b), 107 (Figure 19c), 69 and 95 (Figure 19d). These units were chosen because they contained well-defined geomorphic features taken to be representative of the area. Initial hypotheses about the relationships between these factors and preserved sedimentary structures were noted. Unit profiles were sketched (Figure 19a; b; c; d) and described in detail; sedimentary aspects, including color, organic content, and an estimate of grain size, were recorded for each layer. Sampling was conducted in natural levels.

Off-site Field Methods and Observations; 1991

In 1991 the Great Lakes Gas Transmission Company installed a pipeline across central Michigan. In September, a 2-3 m deep pipeline trench existed off-site for many miles to the east and west (Figure 20). Locations of sixteen trench profiles are shown in Figure 20. These profiles were described and samples of sedimentary units were taken.

General information from trench profiles provided insight to the stratigraphy and depositional sequences throughout the area. The Late and post Glacial depositional processes within the Saginaw basin were complex, and sediments include organic-rich laminae, localized peat deposits, glayed clays, dunes, beach sediments, and some fossil-rich units.

Geomorphic Mapping

Geomorphic features within the designated study area were identified on 1: 24,000 scale topographic maps and transferred to a mylar overlay at a scale of 1: 100,000. This was done to present detailed features within a larger geographic context. The map was adapted from the Lakefield, St. Charles, Alicia, Chapin, Chesaning East, Chesaning West, Ovid East, Owosso, and Easton Michigan 7.5 Minute Quadrangles. Figure 21 shows a redrafted version of the landforms and important aspects of the 1; 100,000 topographic map in the study area.

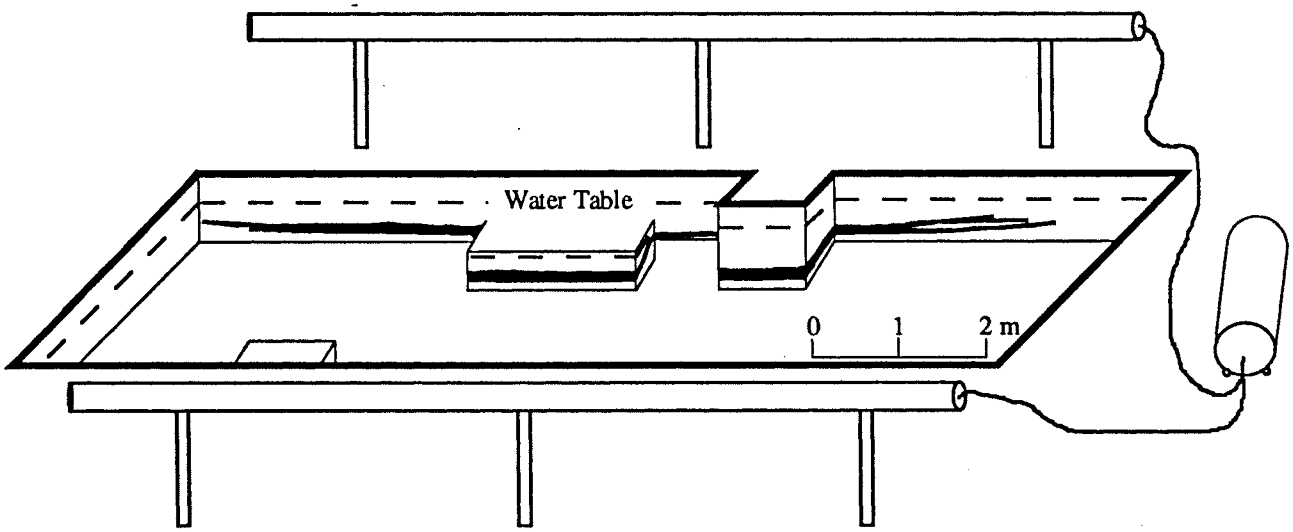


Figure 18 - Illustration of the 20SA596 excavation, including the water table position and the presence of dewatering wells.

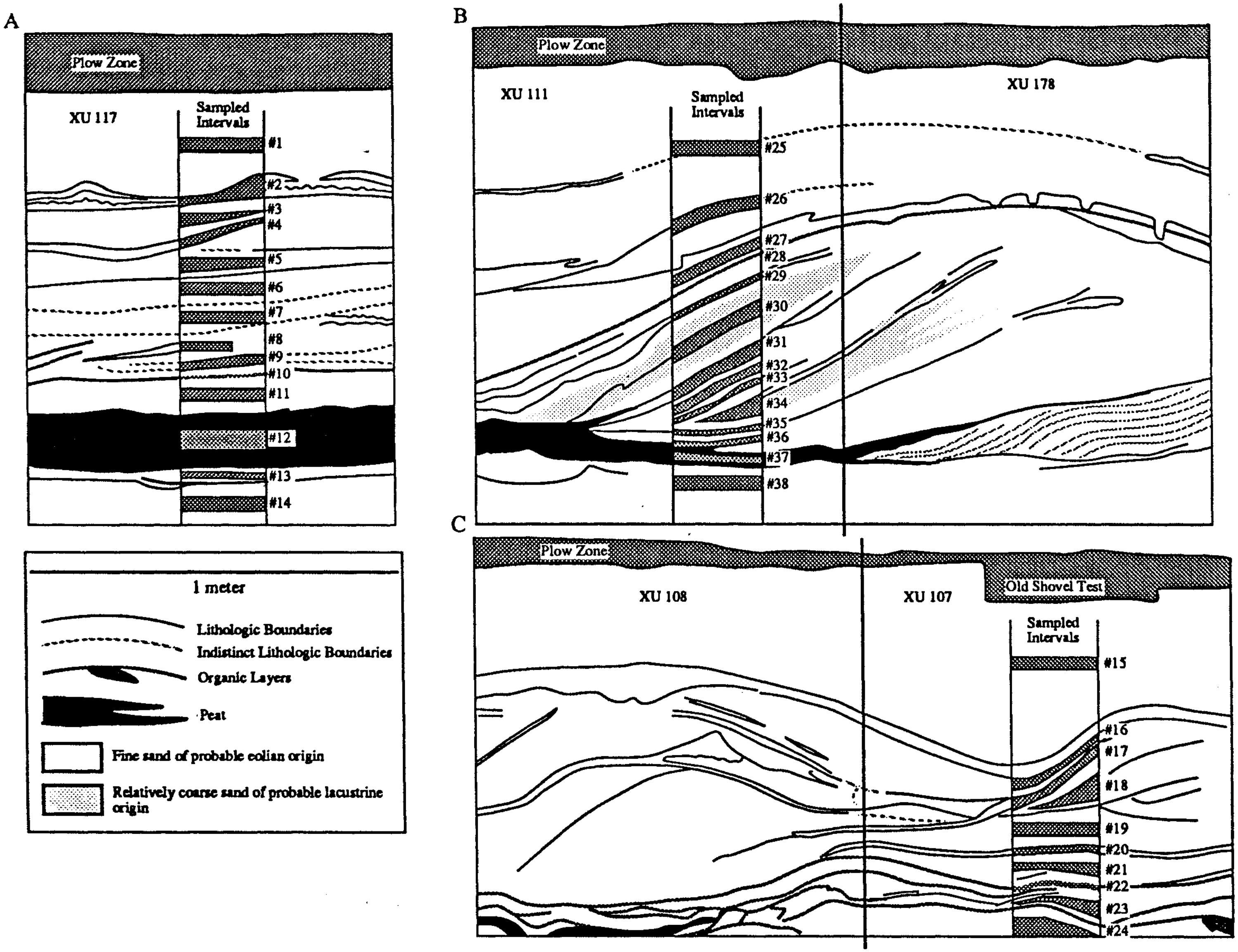


Figure 19- Detailed profile of excavation units (a) 117, (b) 111 and 178, and (c) 108 and 107). Excavation units subsampled in natural levels for sediment analyses.

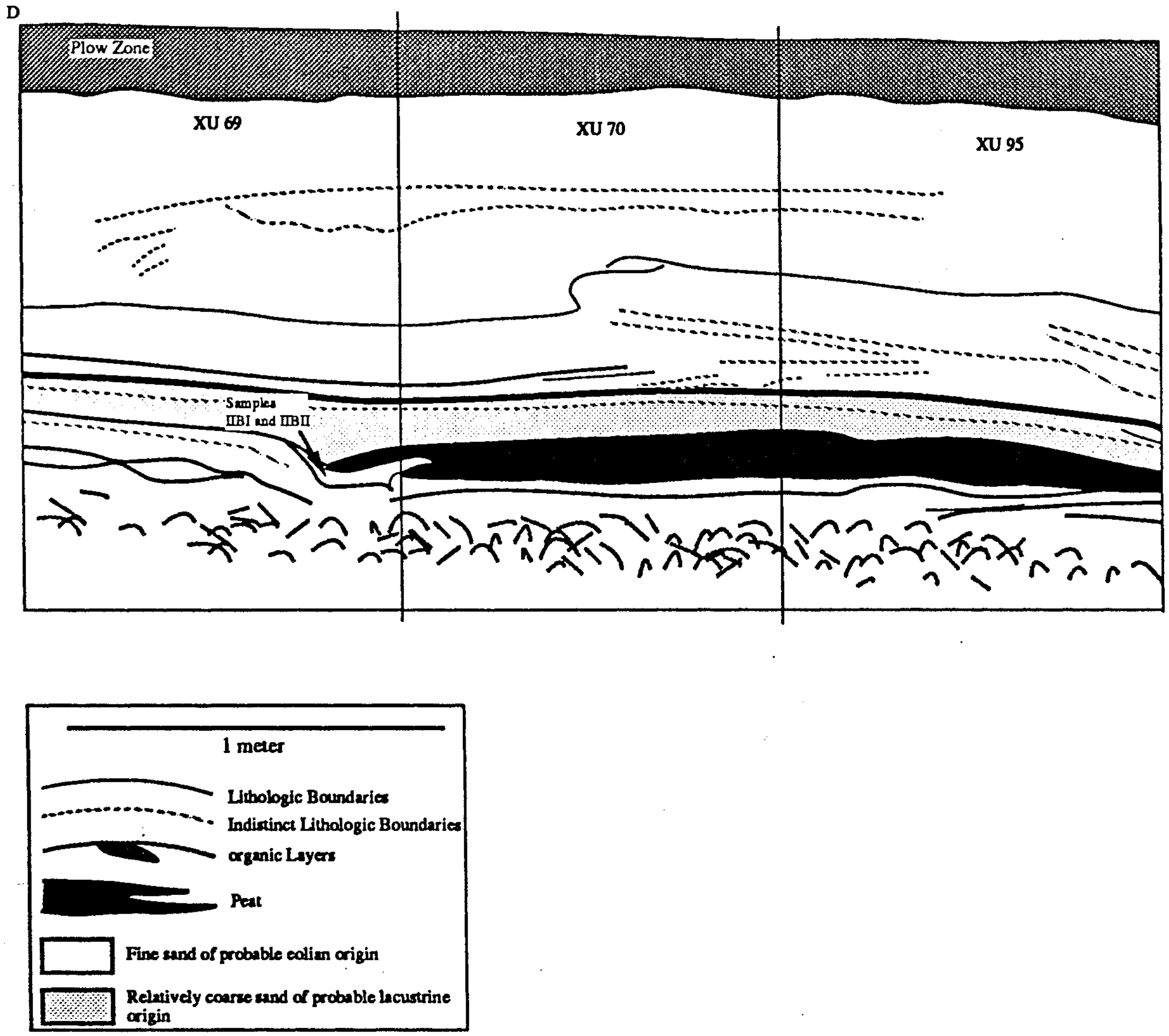


Figure 19 - Detailed profile of excavation units (d) 69, 70, and 95. Excavation units subsampled in natural levels for sediment analyses.

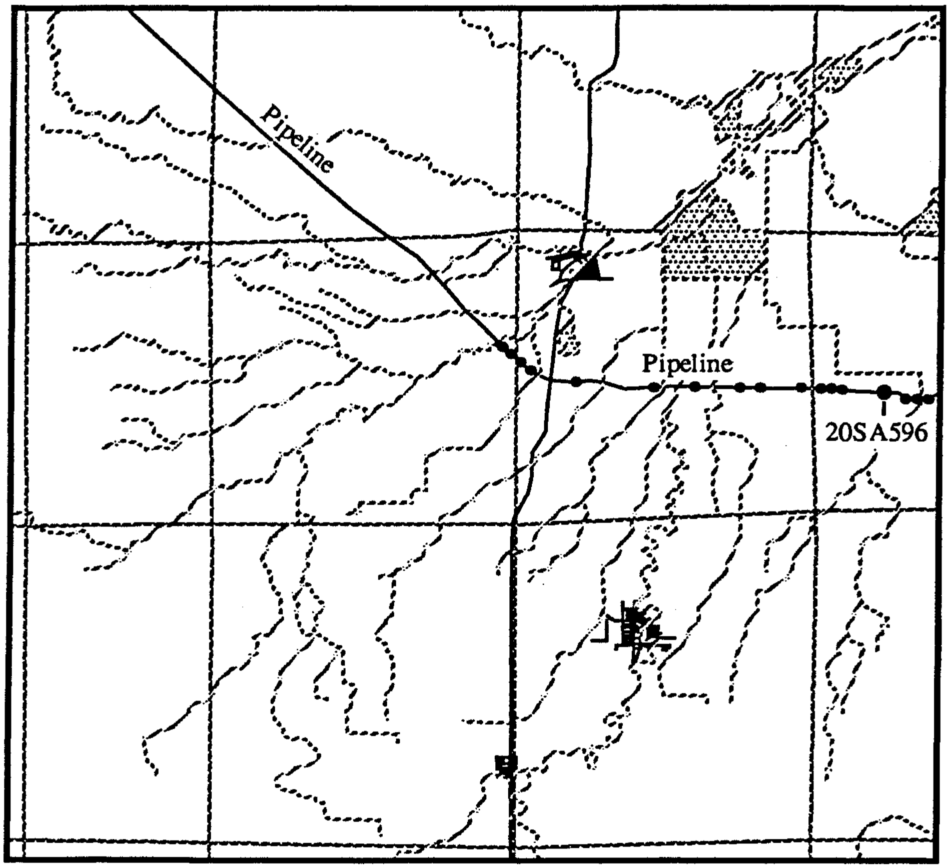


Figure 20 - Map of the study area, indicating 20SA596, and sixteen profile sampling locations along the pipeline corridor.

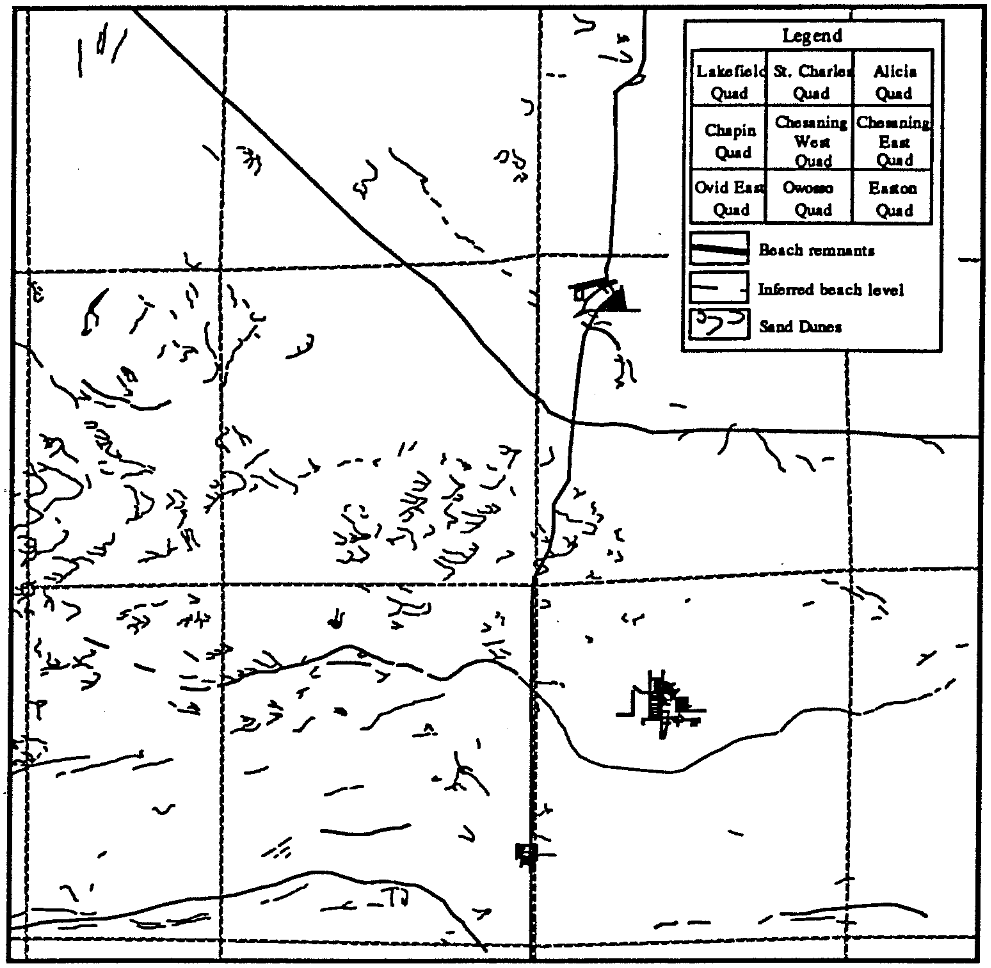


Figure 21 - Geomorphic map showing landforms preserved in the study area.

Off-Site Field Methods; 1992

The 1992 field season was spent surveying the prominent landforms identified in Figure 21. Surface samples were collected from the three transects shown in Figure 22. Transects were designed to traverse prominent geomorphic features delineated during mapping.

Samples were obtained by digging 'shovel tests' and collecting sediment from the surface downward in a combination of natural and 10 cm intervals. A single sample was taken from the modern plow zone, all other samples represent 10 cm intervals below the upper layer. Samples were submitted for grain size analysis and Loss on Ignition, excluding disturbed samples representing the plow zone.

Lab Methods

Grain Size

Determining the grain size distribution of sand- and gravel-sized particles is accomplished by mechanical analyses (Hassan 1978; Holliday and Stein 1989; Stein 1987; Stein and Rapp 1984). Percentages of silt and clay are determined from the setting velocity of each size range within a column of water over time (Hassan 1978; Stein 1987; Stein and Rapp 1984). Interpretation of the grain size distribution is provided by the use of statistical methods (Gardner 1977; Gladfelter 1977; Hassan 1978; Stein 1987).

Grain size procedures followed after Folk (1974). A small portion of each sample was placed in a settling column filled to the 1 liter mark with dispersant. Subsamples were removed with a pipette at the depths and times shown in Table 1, after thorough stirring of the sediment in the column.

Depth	Time
20 cm	20 sec
10 cm	1 m 44 sec
10 cm	6 m 56 sec
10 cm	28 m
10 cm	1 hr 51 m
10 cm	7 hr 25 m

Table 1 - Depths and corresponding times of sample extraction from a settling tube at 24 degrees Celsius (Folk 1974).

Extracted subsamples were placed in beakers to be dried and weighed. Contents remaining in the column were rinsed through a .063 mm screen to separate large size fractions from silt and clay. The sediment was dried and placed in a nest of screens to

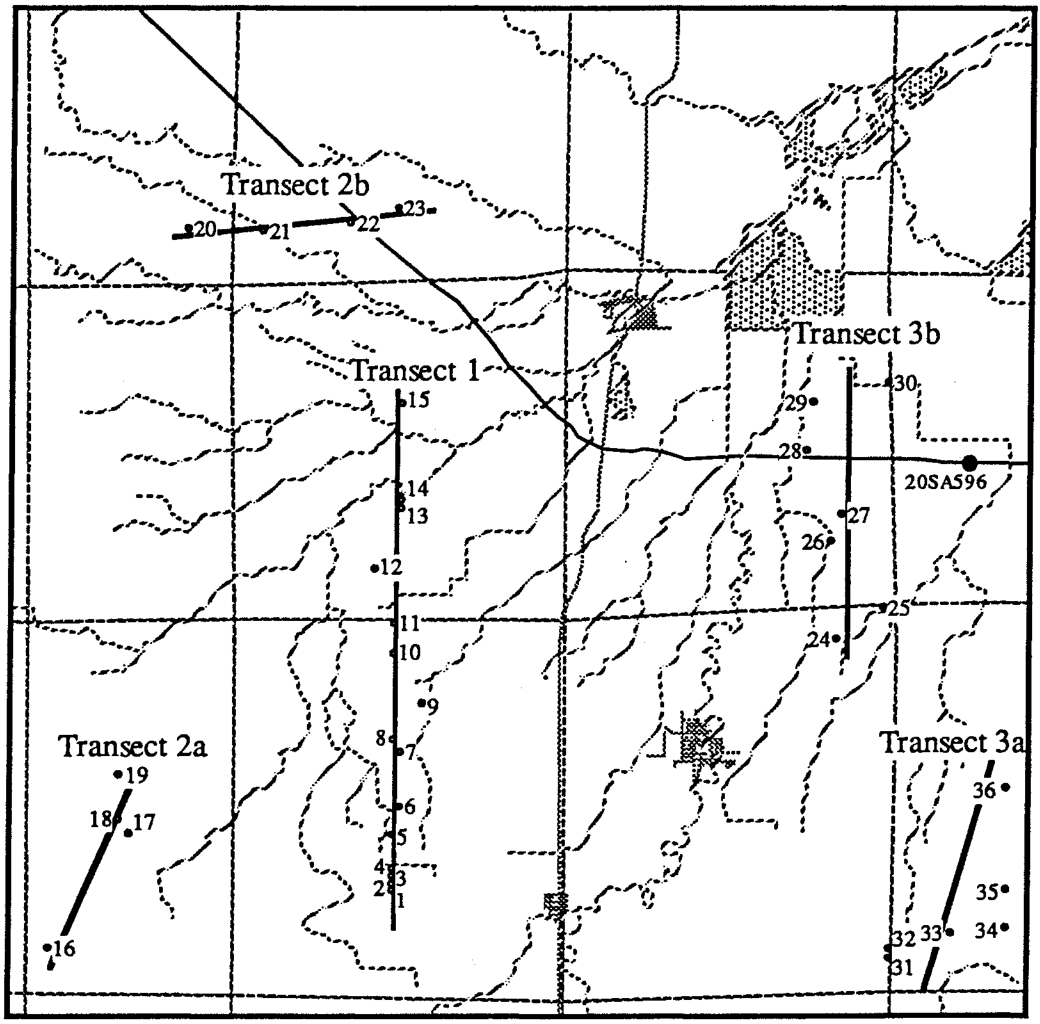


Figure 22 - Map of the study area, indicating transects of surface sediment sampling locations.

isolate the 6, 4, 2, 1, 0.05, 0.25, 0.125, and 0.063 mm fractions for weighing. Grain size analyses were not conducted on layers principally composed of organic material.

Grain Morphology

Samples 2, 13, 29 and 30 from 20SA596 and transect samples 1-B, 3-B, 7-B, 9-B, 12-B, 15-B, 20-B, 23-B and 28-B were washed with water, dried in an oven, and mechanically sieved to isolate the 6, 4, 2, 1, .50, .25, .125, and .063 mm fractions. The 1 to .50, .50 to .25, .25 to .125 and .125 to .0625 mm portions of each sample were individually mounted on metal stubs with a layer of carbon based paint. The mounted samples were coated with gold palladium metal. Representative grains were examined with a scanning electron microscope (SEM) and photographed.

Each photograph was inspected for the presence or absence of certain eolian and subaqueous and glacial surface textures. Surface textures, and the geologic environments they represent, are summarized in Krinsley and Doornkamp (1973).

Various authors (Baker 1976; Krinsley 1978; Krinsley and Cavallero 1970; Margolis and Krinsley 1971; Setlow 1972) have analyzed SEM photographs by identifying the percentage of each occurrence of characteristic geologic features per grain. Baker (1976) emphasizes, however, the inherent subjective bias of this approach. Because of this subjectivity, the presence of those relatively easily identifiable features were simply noted (Baker 1976).

Pollen

Samples 10, 11, 14 (Figure 19a), 20, 22, 24 (Figure 19c), 31, 33, 35 36, 37, and 38 (Figure 19b) were submitted for pollen analyses, along with six 1 cc samples extracted from a 4 by 4 by 20 cm pedestal of peat (at 0-1 cm, 4-5 cm, 5-6 cm, 9-10 cm, 14-15 cm, and 19-20 cm, measuring from top to bottom) from excavation unit 95 (Figure 19d) (Figure 23). Samples were chosen on the basis of organic preservation and many typically contained high percentages of clay. The samples were treated with a technique modified from Faegri and Iverson (1975) (addition of KOH, HCL, HF, and acetolysis), sieved through 7 µm mesh Nitex screens (Cwynar et al. 1979), stained with safranin and stored in silicone oil.

Loss on Ignition

Relative proportions of organic and inorganic carbon were determined for all of the onsite and 1992 field season samples by Loss on Ignition (LOI) following the procedure described by Dean (1974). Specialized sampling was necessary for some sediments, including sub-sampling of large organic fragments submitted for pollen analyses, (samples 10, 20, 22, 36, and 37), and six 1 cc samples from the peat (Figure 23). Sediments were

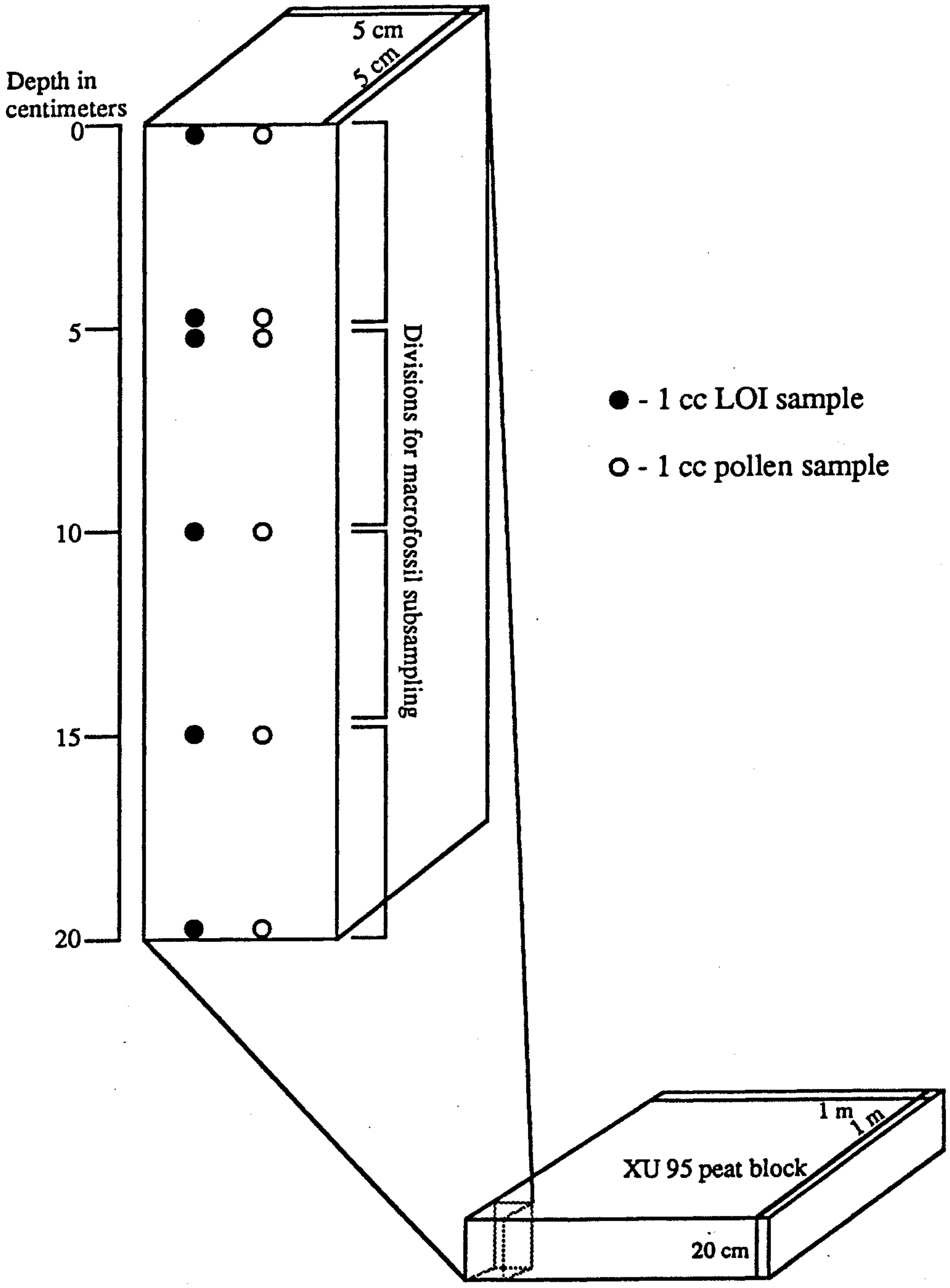


Figure 23 - Schematic representation of LOI, pollen and macrofossil subsamples of the peat block obtained from excavation unit 95.

placed in crucibles and dried. Those samples containing high amounts of clay were disaggregated prior to the firing process. Contents of each crucible were dried at 100 degrees Celsius and weighed, burned for one hour at 550 degrees Celsius, cooled in a desiccator, and re-weighed. Each specimen was then heated for an additional hour at 1,000 degrees Celsius, cooled and weighed.

Macrofossils

After LOI and pollen subsamples were extracted, the peat pedestal (Figure 23) was divided into 5 cm thick sections and presented for macrofossil analysis, along with samples 36 and 37. Dried samples were examined under a binocular microscope.

C-14

Three samples were submitted to Beta Analytic for radiocarbon dating. Excavation unit 12 yielded a charcoal fragment, located in a layer of organically stained sediment immediately above the peat. Wood charcoal was found in an organic-rich layer in the 50 cm of interbedded sediments above the peat in unit 61. The third sample submitted was a portion of an oak log, located at the lower boundary of the peat in excavation unit 69. Refer to Figure 15 for the relative locations of these excavation units.

Results

Regional Geomorphology and Geomorphic Mapping

Figure 21 summarizes the geomorphic features identified within the study area. Landforms include lake plains, beach ridges, longshore bars, eolian dunes, and the head of the Grand Valley outlet. Prominent strandlines occur at 220, 200, and 183 m (722, 656, and 600 ft) in elevation; fragmentary beach remnants and small dune forms are scattered throughout intermediate elevations. The majority of dunes are associated with the 200 m (656 ft) strandline.

A topographic cross section of the drainage basin, shown in Figure 24, helps illustrate the distribution of landforms. The 220 m (722 ft) beaches show the most complete preservation and least post-depositional disturbance. Relief is at its maximum at the basin perimeter. A few scattered beach remnants and isolated occurrences of dune forms are found between the 220 (722 ft) and 200 m (656 ft) elevations. Landforms rest on a slightly inclined, near-horizontal paleo-lake plain.

The 200 m (656 ft) strandline is moderately-preserved in the southern portion of the study area (Figure 21). The northern two thirds of the region show an abundance of dune forms and some scattered beach remnants. Dune forms are abundant below the 200 m (656 ft) elevation. Again, landforms seem to sit on top of a level plane approaching a sub-horizontal incline (Figure 24).

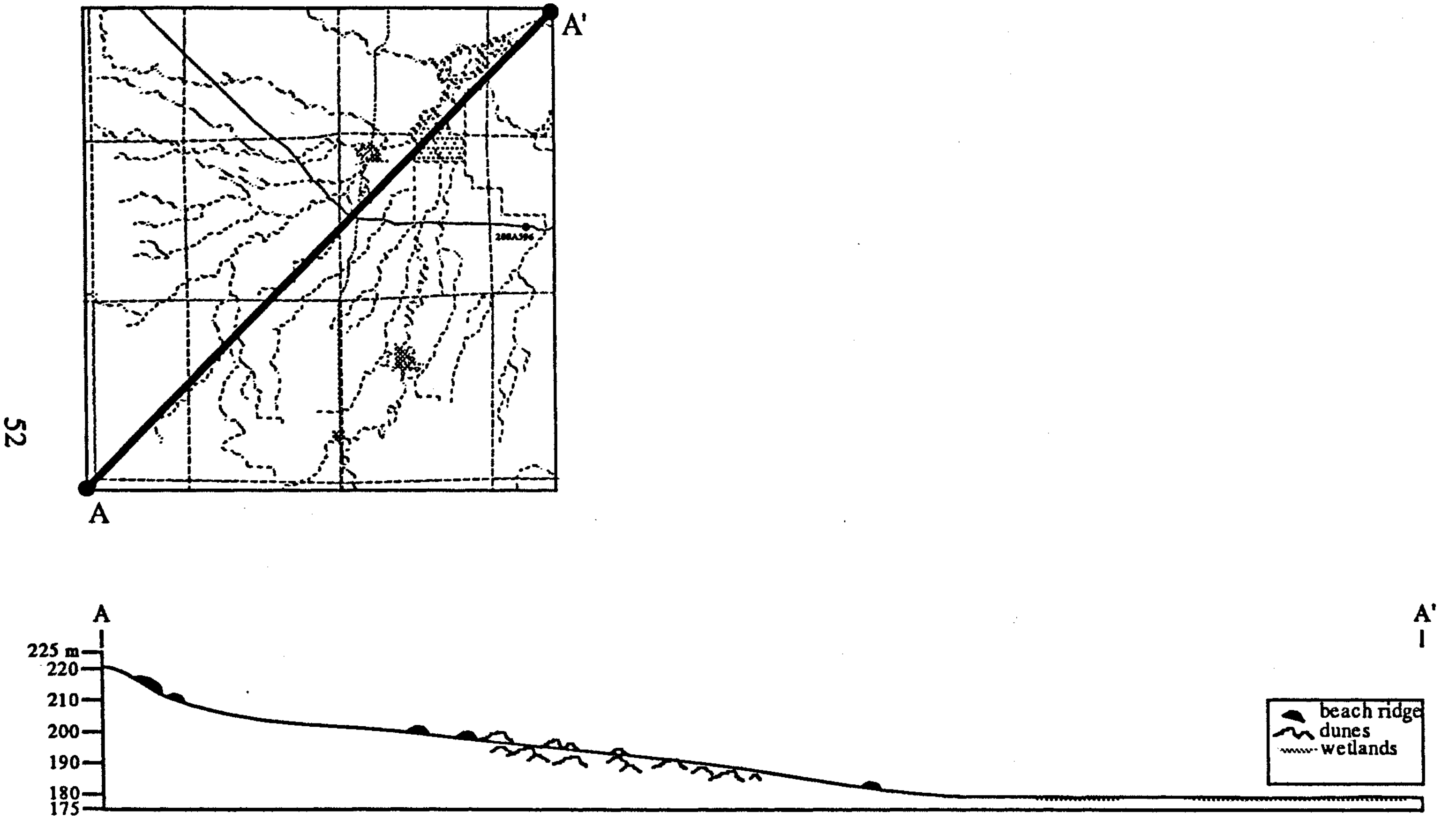


Figure 24 - The topographic cross-section of the Saginaw Basin along the line A-A'. This cross-section illustrates the distribution of landforms in the study area.

Beach remnants at the 183 m (600 ft) contour represent a partially preserved strandline. This strandline is had been cross-cut by the modern drainage pattern in numerous places. Differences in relief are minimal, and a low-lying swampy area is encountered, progressing down-slope toward the direction of Saginaw Bay.

The form of the study area appears as a (relatively) steep-sided drainage basin that gradually levels out (Figure 24). Landform deposits, especially at lower elevations, rest on a large lake plain. The horizontal attitude of this plain is best identified in the northeast portion of the study area by minimal relief and extensive wetlands.

Sedimentary Analyses

Grain size - 20SA596

Results of clastic sediment analyses for 20SA596 are summarized in Table 2. Refer to Figure 19 (a; b; c; d) for visual references and Figure 25 for correlation of the site stratigraphy and generalized grain size results. The sedimentary profile consists of six general zones. These zones include the varved lacustrine silts and clays, a lower sand unit, the peat zone, a 50 cm thick transition zone located directly above the peat, the upper sand unit, and the plow zone. Table 3 shows the conversion from numerical results to grain size categories.

Grain Size (mm)	Grain Size (phi)	Wentworth Size Class
2.00 to 1.00	-1.0 to 0.0	very coarse sand
1.00 to .50	0.0 to 1.0	coarse sand
.50 to .25	1.0 to 2.0	medium sand
.25 to .125	2.0 to 3.0	fine sand
.125 to .0625	3.0 to 4.0	very fine sand
.0625 to .031	4.0 to 5.0	coarse silt
.031 to .0156	5.0 to 6.0	silt
.0156 to .0078	6.0 to 7.0	medium silt
.0078 to .0039	7.0 to 8.0	fine silt
.0039 to .002	8.0 to 9.0	very fine silt
.002 to .00006	9.0 to 14.0	clay

Table 3 - Correlation of mean grain size, reported in mm and phi, and the Wentworth classification system (modified after Folk, 1974).

The lower sand unit (Figure 25), represented by samples 13, 14, 24 and 38, is classified primarily as very fine sand. Sample 13, a fine sand, is the only exception.

Clastic deposits preserved in the peat, such as samples IIBI and IIBII, are medium sands (Figure 25). These and other similarly located deposits occur in lenses. These sands are comparatively well-sorted, and are the coarsest sediments found on site.

sample #	%gravel	%clay	%sand	%silt	% clay<2mm	% sand<2mm	% silt<2mm	mean size	Std. Dev.	skewness	kurtosis
SA596-1	0	2.072546	85.49157	12.43588	2.072546	85.49157	12.43588	3.122571	1.44821	2.266005	7.373673
SA596-2	2.253041	6.7302	76.9468	14.06996	6.885329	78.7204	14.39427	3.383986	2.205192	1.290069	2.143395
SA596-3	0	0	92.349	7.651	0	92.34901	7.651	3.133952	1.060506	2.874409	12.00646
SA596-4	0	2.678498	85.90021	11.4213	2.678498	85.90021	11.4213	3.391287	1.336043	2.882359	10.20718
SA596-5	0	0	92.28498	7.715019	0	92.28498	7.715019	3.076436	.9372694	2.464194	9.122416
SA596-6	0	6.064388	90.50156	3.434051	6.064388	90.50156	3.434051	3.274468	1.714296	2.891866	7.79884
SA596-7	0	3.971842	87.5279	8.500259	3.971842	87.5279	8.500259	3.375093	1.546167	2.763585	7.99462
SA596-8	0	3.349748	88.4007	8.249555	3.349748	88.4007	8.249555	3.367218	1.493121	2.828785	8.587152
SA596-9	0	4.392985	92.29996	3.307057	4.392985	92.29996	3.307057	3.200606	1.512175	3.218549	10.77777
SA596-11	0	4.318671	72.34028	23.34106	4.31867	72.34027	23.34106	3.845871	1.439717	2.635161	7.931559
SA596-13	0	0	92.37654	7.623462	0	92.37654	7.623462	2.961055	.6829914	.5303541	8.43E-03
SA596-14	5.97E-02	6.529523	77.11629	16.29449	6.533423	77.16235	16.30422	3.71068	1.946061	1.869629	2.858775
SA596-15	0	0	94.45538	5.544627	0	94.45537	5.544626	2.712676	.8703452	1.517644	5.695075
SA596-16	0	0	95.90879	4.091214	0	95.90878	4.091214	2.608275	1.016149	1.341533	6.540022
SA596-17	2.799486	2.139207	88.60433	6.456979	2.200818	91.15624	6.642948	2.555099	1.735915	1.128852	4.762197
SA596-18	0	1.089989	96.99477	1.91524	1.089989	96.99477	1.91524	2.455177	1.077417	3.589978	21.10222
SA596-19	0	6.029196	91.13556	2.835251	6.029195	91.13555	2.83525	2.670192	2.021632	2.40007	5.542542
SA596-20	0	11.6131	75.72048	12.66642	11.6131	75.72047	12.66642	3.821887	2.492063	1.424374	.6780288
SA596-21	0	2.296139	96.23756	1.466303	2.296139	96.23756	1.466303	2.735693	1.213765	4.20858	20.54924
SA596-23	0	4.526005	94.31367	1.16032	4.526005	94.31367	1.16032	2.887479	1.582687	3.381947	11.34081
SA596-24	0	4.786895	84.41392	10.79919	4.786895	84.41392	10.79919	3.350677	1.751159	2.376401	5.41573
SA596-25	0	0	95.4625	4.537502	0	95.4625	4.537502	2.623101	1.043955	2.368747	10.4794
SA596-26	0	0	93.75795	6.242062	0	93.75793	0	0	0		
SA596-27	0	5.366773	81.00018	13.63305	5.366773	81.00018	13.63305	3.504423	1.763919	2.339922	5.13391
SA596-29	0	1.41097	94.48021	4.108826	1.410969	94.48019	4.108826	2.535057	1.155194	3.646564	18.52152
SA596-30	0	0	98.22448	1.775521	0	98.22448	1.775521	1.972317	.7273628	.1895125	1.379562
SA596-31	0	5.513215	89.57266	4.914122	5.513215	89.57266	4.914122	2.643336	1.917383	2.565754	6.585162
SA596-32	0	3.882462	95.23728	.8802562	3.882462	95.23728	.8802563	2.089068	1.689508	3.263182	11.90454
SA596-33	0	6.11004	89.16807	4.721896	6.11004	89.16807	4.721896	2.82084	1.987334	2.397673	5.460385
SA596-34	3.56E-02	3.98699	94.91672	1.060688	3.98841	94.95052	1.061066	2.028443	1.792021	2.848848	9.602533
SA596-35	0	5.551027	89.85008	4.598894	5.551027	89.85007	4.598894	2.956706	1.81106	2.837513	7.334811
SA596-38	0	5.642016	79.06262	15.29536	5.642016	79.06262	15.29536	3.518981	1.916861	1.948545	3.38124
S596-IIBI	0	0	98.45293	1.547071	0	98.45292	1.547071	1.853471	.9333606	2.047866	11.11878
S596-IIBII	0	0	98.36645	1.633548	0	98.36646	1.633548	1.750358	.9025328	2.831959	15.93708

Table 2 - Grain size analyses results for 20SA586

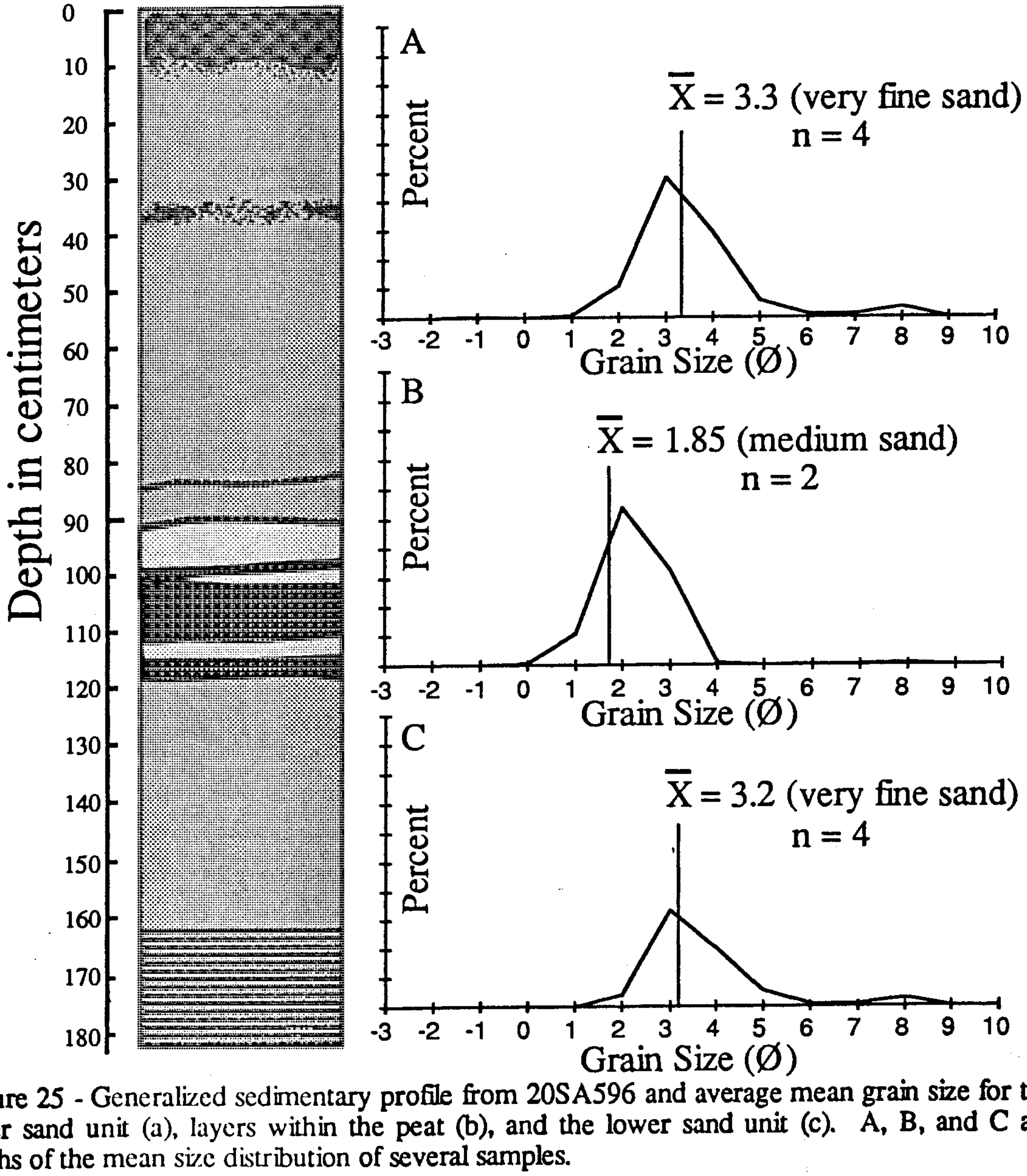


Figure 25 - Generalized sedimentary profile from 20SA596 and average mean grain size for the upper sand unit (a), layers within the peat (b), and the lower sand unit (c). A, B, and C are graphs of the mean size distribution of several samples.

The peat is overlain by approximately 50 cm of stratified sediments. Size fractions for this zone range from very fine and fine sands, to medium sands and also clay-rich organic laminae (samples 10, 12, 22, 36, and 37) (Figure 25). The mean grain size of samples 30 and 34 straddle the boundary between medium and fine sand. Samples 19, 21, 23, 29, 31, 32, 33, and 35 are all fine sands. Samples 8, 9, 11 and 20 are very fine sands and sample 7 lies between very fine sand and coarse silt.

The upper sand unit (Figure 25) is comprised of fine (samples 15, 16, 17, 18, 25, and 26) and very fine (samples 1, 2, 3, 4, 5, 6, and 27) sands. These sediments are partially included in and capped by the modern soil horizon.

Grain size - off site

Grain size results for the transects shown in Figure 22 are summarized in Table 4. Plotting resultant grain sizes against distance from the 220 m (722 ft) contour line, the highest beach, reveals a distinct sedimentary trend (Figure 26).

Transects 1, 2a and 3a (Figure 26) show samples taken from the highest strandline, such as sample sites 1 and 3, to be the coarsest surface deposits within the area. Proceeding from the basin perimeter toward the offshore area shows a steady decrease in mean grain size for sandy sediments. Minor exceptions to this trend can be found in beach deposits and some of the larger dune forms found at the 200 m (656 ft) elevation, sites 9 and 23, which approach the mean grain size distribution found in beach 220 m (722 ft) sediments.

Variations in the trend are also found with sediments in corresponding lows. These areas include localized low points between beach crests, like sites 2 and 8, and broad expanses of low, flat topography situated between prominent landforms, including sites 15, 21, 22, 24, 29 and 30. Sediments from such areas characteristically show the surface exposure of fine-grained, silt and clay-rich sediments which underlie the sand-dominated landforms.

Grain morphology

Samples were classified as having been subjected to primarily eolian processes if the majority of grains were well-rounded and 'frosted'. Examples of grains identified as eolian include Figure 27a, grain 1, and grains 1 and 2 in Figure 27b. Classification of sediment from a littoral environment included angular grains with slightly rounded edges showing a few upturned plates, conchoidal fracture, and the presence of v-forms. Grains 2, 4, and 5 (Figure 27a) and grain 4 (Figure 27b) serve as examples of grains thusly identified.

Examination of the thirteen samples under a binocular microscope reveals the presence of rock fragment and mineral (muscovite, feldspar, etc.) inclusions. It is difficult to

sample no.	%gravel	%clay	%sand	%silt	% clay (<2mm)	% sand (<2mm)	% silt (<2mm)	mean size	Std. Dev.	skewness	kurtosis
1-B	6.157283	3.306531	81.48949	9.046689	3.523481	86.83624	9.640267	2.115482	2.246644	1.299748	5.679036
1-C	5.224638	4.620352	83.48042	6.674588	4.875056	88.08241	7.042535	2.294081	2.277923	1.5034	6.191841
2-B	31.6067	4.309905	46.40913	17.67427	6.301647	67.85625	25.84211	1.901904	3.06987	.6755553	2.851677
2-C	7.468678	10.72903	47.39671	34.40559	11.59503	51.22233	37.18264	3.955478	3.060308	.2396643	2.38873
3-B	15.66557	2.060762	78.92136	3.352315	2.443559	93.58141	3.975024	1.208456	1.972782	1.701229	8.811181
3-C	12.39759	3.06865	80.8483	3.685456	3.50293	92.29005	4.207026	1.303997	2.1465	1.89033	8.340443
4-B	3.363128	23.35508	38.73088	34.55091	24.16788	40.07878	35.75334	5.08068	3.309454	-1.95E-2	1.818971
5-B	3.283776	.8822604	85.11731	10.71665	.9122155	88.00726	11.08051	2.406039	1.755126	1.395492	7.09335
5-C	2.988366	10.78094	60.22127	26.00943	11.11304	62.07633	26.81063	3.768878	2.830362	.7198627	2.762832
6-B	.5284711	.4162242	87.01894	12.03635	.4184356	87.48127	12.1003	2.416982	1.58797	1.490627	6.91784
6-C	.7084946	1.060804	86.18952	12.04118	1.068374	86.80453	12.1271	2.457442	1.696135	1.620913	7.012065
7-B	.1846084	.1209339	95.4424	4.252059	.1211576	95.61892	4.259923	2.124217	1.037821	1.781311	11.11521
7-C	0	0	98.54315	1.456853	0	98.54314	1.456853	2.043778	.7123588	.6001307	4.375299
8-B	1.100821	21.20981	44.57789	33.11147	21.44589	45.07408	33.48003	5.011306	3.131975	.1924229	1.718071
9-B	0	0	99.4514	.5486084	0	99.45139	.5486083	1.412964	.8243852	.5877056	3.152905
9-C	0	0	99.11178	.8882253	0	99.11178	.8882253	2.058962	.6511807	.6492476	3.716868
10-B	4.567E-02	1.116058	86.9232	11.91508	1.116568	86.96291	11.92052	2.534246	1.551886	2.072314	8.572195
10-C	4.052E-02	1.596909	88.87538	9.487192	1.597556	88.91141	9.491038	2.518712	1.641599	2.209074	8.956794
11-B	3.972682	1.961824	86.83126	7.234229	2.042985	90.4235	7.533511	2.040547	1.824247	2.020336	9.094617
11-C	1.259193	19.7579	21.90966	57.07324	20.00986	22.18907	57.80107	5.84054	2.731574	-.363796	2.451525
12-B	0	0	95.89224	4.107768	0	95.89224	4.107768	1.878564	.9722223	.6599838	3.799195
12-C	0	0	96.21455	3.785443	0	96.21455	3.785443	1.978252	.9559727	.5401598	3.517757
13-B	.153448	29.08284	11.60576	59.15796	29.12753	11.62359	59.24888	6.533964	2.486869	-.435682	2.546504
13-C	0	21.25978	4.560125	74.18008	21.25979	4.560125	74.18009	6.507042	1.978001	-1.53E-2	2.999285
14-B	0	0	93.07971	6.920293	0	93.0797	6.920293	2.210296	.9952623	.6098717	3.433103
14-C	0	0	94.98261	5.01739	0	94.98262	5.01739	1.988954	.9443867	1.000306	4.131941
15-B	1.608993	18.03115	54.94662	25.41323	18.32602	55.84517	25.82882	4.429216	2.917062	.6468622	2.320849
16-B	5.947349	2.28942	76.11505	15.64818	2.43419	80.92813	16.63768	2.329101	2.157707	1.001617	4.953991
16-C	23.01157	1.751857	62.56824	12.66833	2.275481	81.26967	16.45485	1.306828	2.555365	1.206609	4.442538
17-B	1.416696	24.1851	37.03288	37.36533	24.53266	37.56506	37.90229	5.416019	3.049136	9.37E-03	1.830806

Table 4 - Off-site grain size analysis results

sample no.	%gravel	%clay	%sand	%silt	% clay (<2mm)	% sand (<2mm)	% silt (<2mm)	mean size	Std. Dev.	skewness	kurtosis
18-B	.8504861	24.66363	34.17868	40.30721	24.87519	34.47185	40.65295	5.572551	3.066701	-.096728	1.789015
19-B	6.041708	22.26734	33.2329	38.45805	23.69918	35.36985	40.93098	5.064149	3.360878	-.174543	2.015952
20-B	.1362897	1.471049	92.18392	6.208752	1.473056	92.30972	6.217225	2.319987	1.489816	2.547805	11.79383
20-C	0	1.785644	94.18877	4.025578	1.785644	94.18877	4.025578	2.18713	1.352997	3.315632	17.27481
20-D	0	.6257334	94.34048	5.033791	.6257333	94.34048	5.03379	2.373613	1.090895	2.809287	17.24903
21-B	.6018324	17.40625	43.18127	38.81065	17.51164	43.44272	39.04564	4.89854	2.962234	.24343	1.871424
21-C	1.75886	19.24433	40.44061	38.5562	19.58887	41.16464	39.24649	5.00391	3.095656	8.67E-02	1.849319
22-B	.4329549	21.22262	44.81035	33.53407	21.3149	45.0052	33.67989	4.938369	3.169732	.1936659	1.701779
23-B	.244431	.2892419	95.92766	3.538672	.2899506	96.1627	3.547343	1.611109	1.263137	1.762289	10.30512
23-C	2.108E-02	0	98.13914	1.839782	0	98.15984	1.84017	1.453484	.9728505	.6533255	4.217754
24-B	1.974122	27.10774	39.96472	30.95341	27.65366	40.76956	31.57678	5.318218	3.386727	-6.88E-2	1.600147
25-B	.2140507	.9478325	87.7309	11.10723	.9498657	87.91909	11.13105	2.559052	1.463471	2.053982	9.174091
25-C	1.382628	1.481066	84.09443	13.04188	1.501831	85.27345	13.22473	2.999621	1.5061	1.204373	8.809398
25-D	.6650356	15.17456	13.52554	70.63486	15.27615	13.6161	71.10775	6.019361	2.260693	-.213259	2.926802
26-B	.5760453	5.411756	90.16393	3.848269	5.44311	90.68633	3.870565	2.528296	2.032148	2.443074	8.801769
26-C	9.637E-02	19.56453	70.55652	9.782575	19.5834	70.62458	9.792011	4.007495	3.050226	1.018064	2.377816
26-D	0	62.38408	5.874199	31.74173	62.38408	5.874199	31.74173	8.292395	2.074039	-1.90660	5.907655
27-B	0	.4532166	88.61673	10.93006	.4532166	88.61673	10.93006	2.77549	1.413425	2.275889	9.425273
27-C	0	15.08973	75.44836	9.46191	15.08973	75.44836	9.46191	3.802039	2.727638	1.326014	3.222164
28-B	0	3.093493	74.68445	22.22206	3.093493	74.68445	22.22206	3.456921	1.5283	2.026909	8.964735
28-C	.1875661	1.048169	55.03835	43.72592	1.050138	55.14177	43.80809	3.953095	1.052117	1.542378	13.5361
29-B	7.682E-02	17.10078	26.74396	56.07844	17.11393	26.76452	56.12156	5.579835	2.484428	.1362239	2.282546
30-B	.2204188	41.93618	10.60579	47.23762	42.02882	10.62922	47.34197	7.395317	2.44507	-1.02898	3.148604
31-B	23.66688	.7222715	65.48505	10.1258	.9462097	85.78851	13.26527	1.151548	2.288178	1.115045	4.636593
31-C	20.18296	1.012809	66.03035	12.77388	1.268914	82.72713	16.00396	1.398718	2.464969	1.11014	4.208768
32-C	2.475591	12.23742	59.78467	25.50231	12.54806	61.30227	26.14967	3.951661	2.880073	.697308	2.598194
32-B	8.194063	8.650847	60.03706	23.11803	9.422971	65.39562	25.18141	3.371675	2.884602	.5933774	2.971841
33-B	14.53652	6.896877	65.3607	13.20591	8.069969	76.47793	15.45211	2.42046	2.808331	.9229314	3.851667
34-B	3.012046	18.24233	44.29664	34.44898	18.80886	45.67232	35.51883	4.783082	3.165464	.144467	1.928607
35-B	4.511303	5.883707	46.69711	42.90789	6.161678	48.90328	44.93504	3.847512	2.604838	.2621264	2.908403
35-C	5.547021	17.1413	44.55042	32.76127	18.14797	47.16677	34.68526	4.477878	3.212526	.1915495	2.097277
36-B	11.21957	8.515598	51.96827	28.29657	9.591751	58.53572	31.87252	3.304254	3.16092	.4090535	2.435868

Table 4 - continued

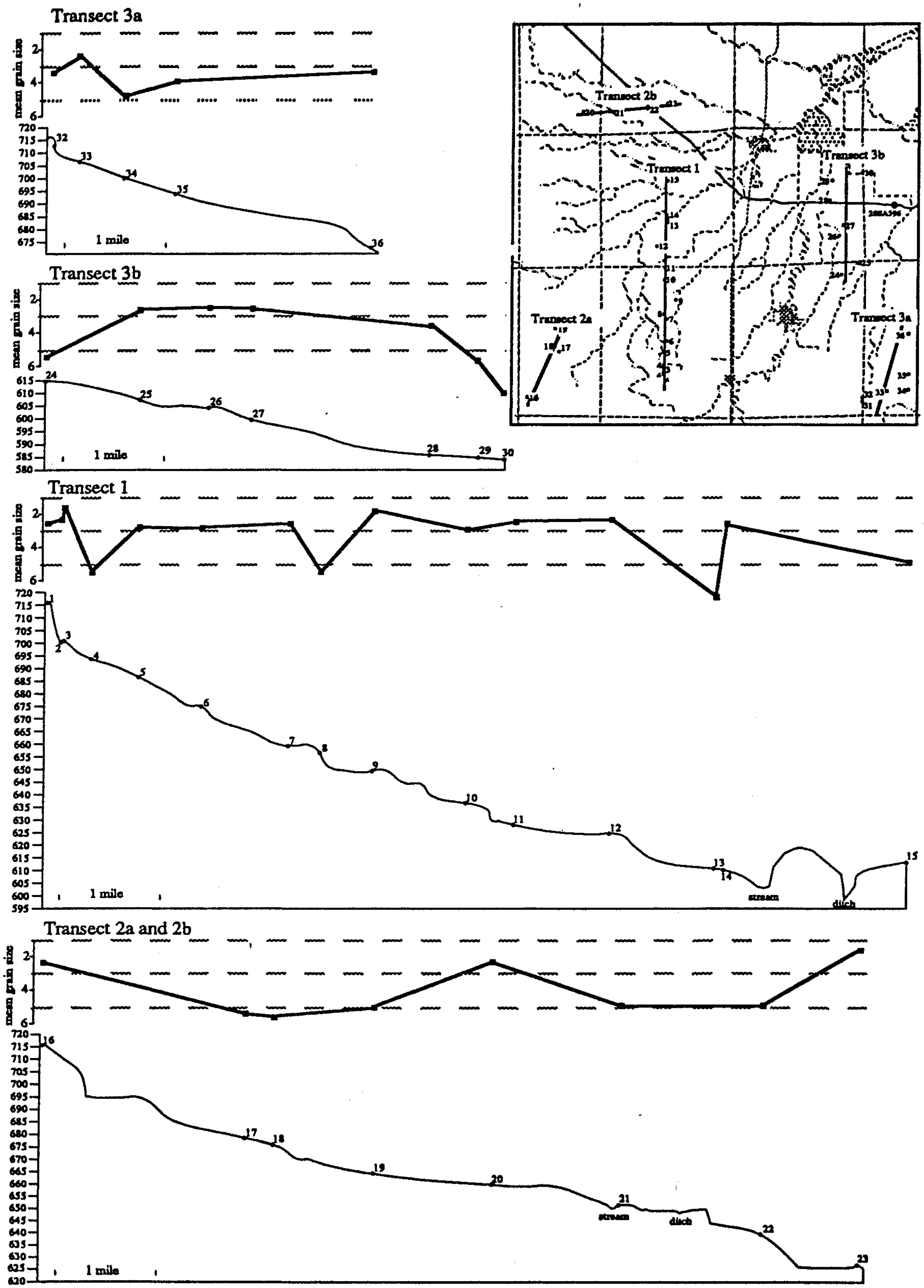
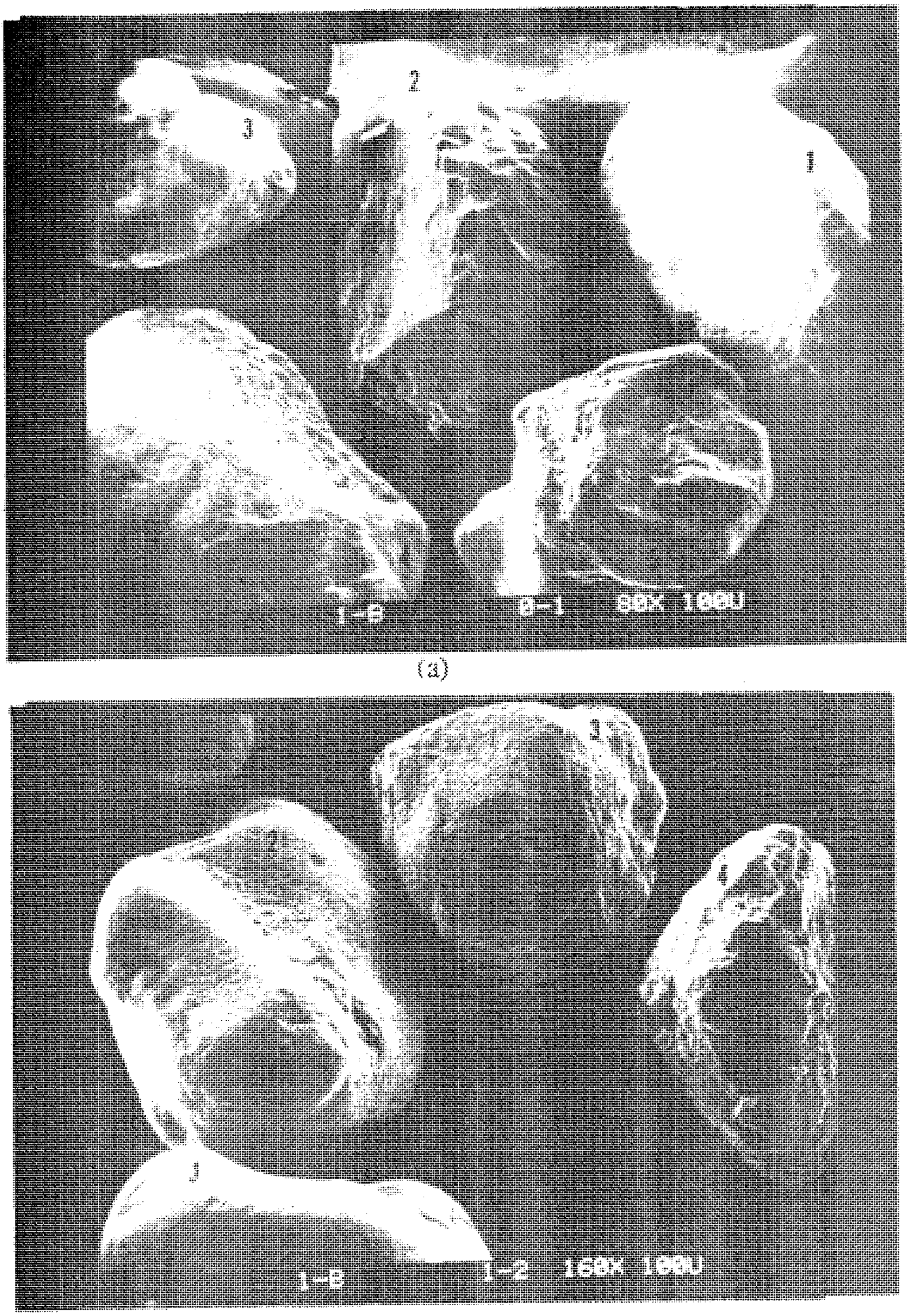


Figure 26 - Correlation of grain size results with a topographic cross-section of transects 1-3. Grain size results represent the -B level of sampling. There is a relationship between elevation and grain size. Excluding clay-rich samples, grain size tends to decrease as elevation decreases, in general.



(a)

(b)

Figure 27 - Photomicrographs of sample set 1-B (a) 0-1 phi and (b) 1-2 phi size fractions.

identify the mineral composition of each grain with a photomicrograph. For this reason, every grain was analyzed for surface textures characteristic of quartz.

Evaluation of the grain morphology for each size distinction within the thirteen sample sets generally revealed similar textural patterns. The 3-4 phi division is an exception. This size fraction includes a lower percentage of well-developed textures on quartz grains and a higher occurrence of rock fragments. Figure 27d is included as an example of this trend.

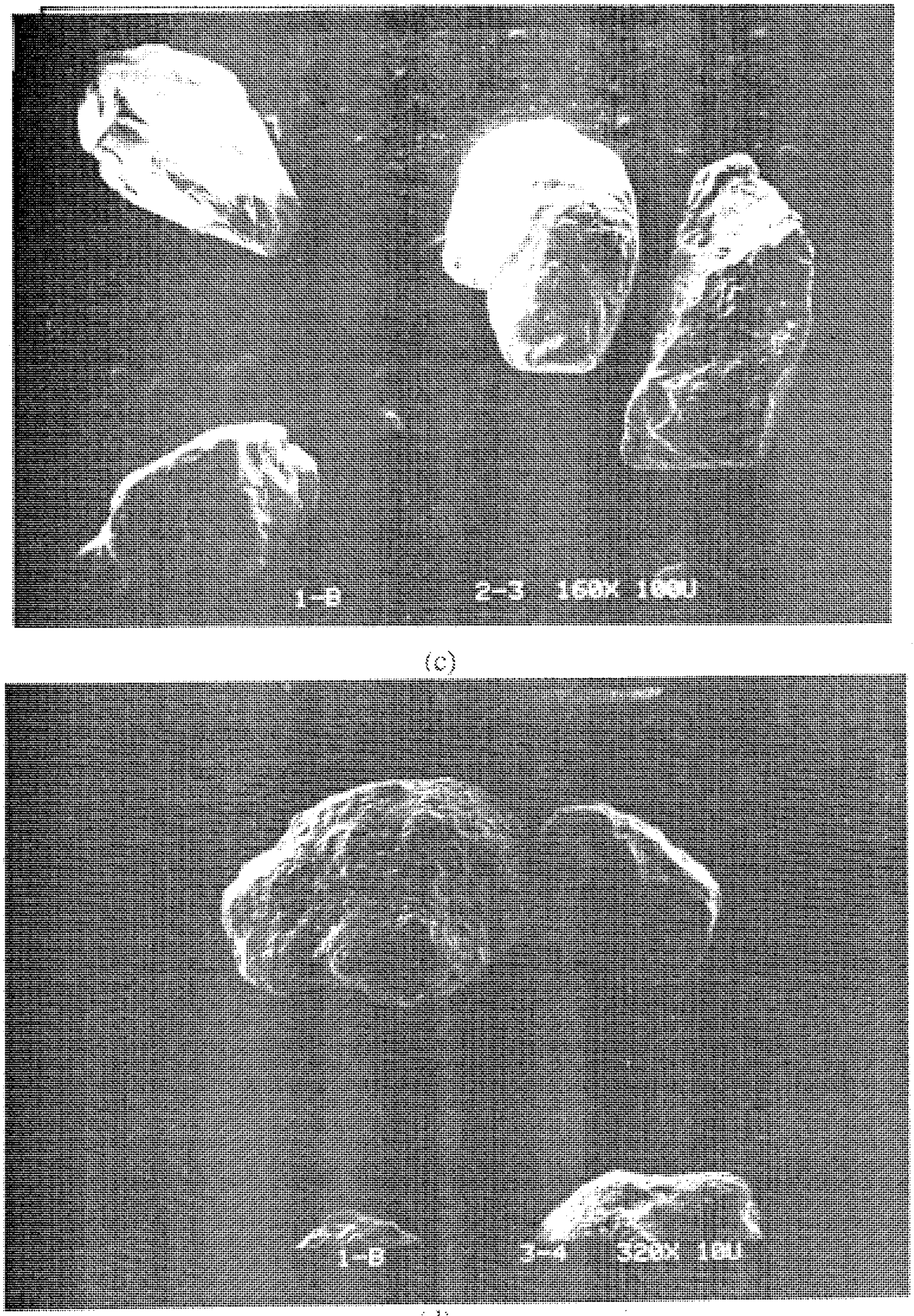
Although environmental indicators were distinguishable in the 2-3 phi range, (Figure 27c) comparison with the 0-1 and 1-2 phi sizes revealed that the coarsest size fractions exhibit the best development of textures. Classification of environmental processes for each sample set was primarily based on the 0-1 and 1-2 size fractions. Photographs of the 1-2 phi size fraction are shown in Figure 28 as representatives of each sample set.

A combination of eolian grains, showing evidence of subaqueous reworking, and angular, fractured grains bearing v-forms is characteristic of samples 1-B (Figure 27a; b; c) and 3-B (Figure 28a). As previously stated, grains 1 and 2 in Figure 27b, are primarily eolian, as is grain 1 of Figure 28a. However, a few v-forms can be seen. Grains 3 and 4 of Figure 27b are more angular and show v-forms. Grain 2 in Figure 28a shows conchoidal fracture and a small percentage of upturned plates on sub-rounded corners. These grains show characteristic features of wave-worked processes (Krinsley and Doornkamp 1973).

Samples 7-B (Figure 28b), 15-B (Figure 28c), 20-B (Figure 28d), and 28-B (Figure 28-e) consist of grains bearing morphologic evidence of both wind and shoreline processes, but none of the textures were well-developed for the most part. Two exceptions are individual eolian grains in samples 15-B (grain 2) and 20-B (grain 5). Otherwise, grains in these four photographs tend to be angular to sub-angular and have variable occurrences of littoral features including conchoidal fracture and v-forms.

Distinctive eolian features were typical of samples 9-B (Figure 28f), 12-B (Figure 28g), and 23-B (Figure 28h). Grains were relatively well-rounded and showed a predominance of upturned plates. Sample 23-B was problematic because a high proportion of the grains were coated with clay particles. However, identification was possible by noting the grain shape and observing textural features in scattered occurrences of surface visibility.

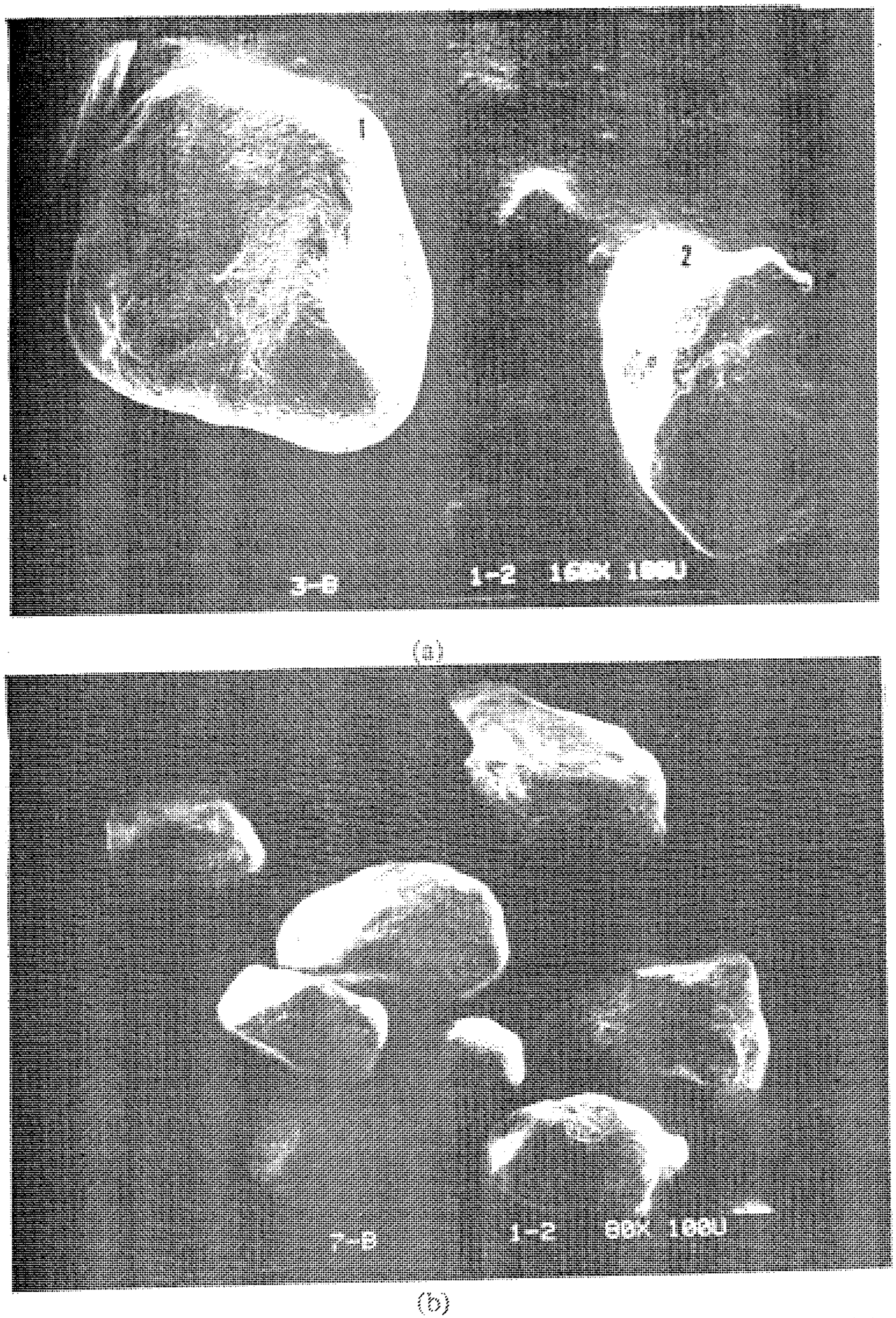
Figure 28i (sample 2) shows a mixture of grains, some of which exhibited eolian characteristics (grains 2 and 5), while others, grains 1 and 4, showed evidence of lacustrine activity. Blocky grains with slightly rounded corners and v-forms implied a nearshore environment for sample 13 (Figure 28j). Sample 29 (Figure 28k) included



(c)

(d)

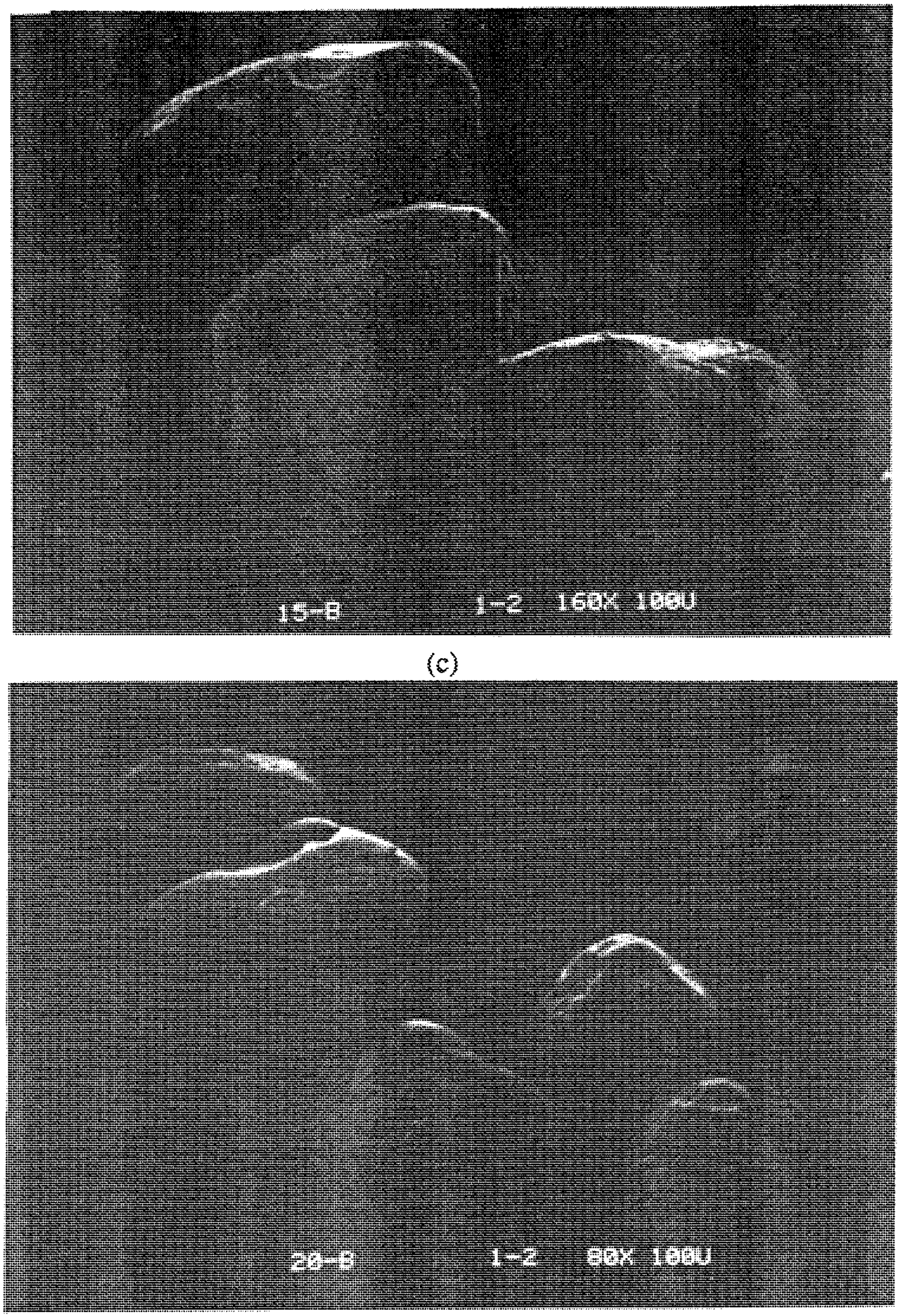
Figure 27 - Photomicrographs of sample set 1-B (c) 2-3 phi and (d) 3-4 phi size fractions.



(a)

(b)

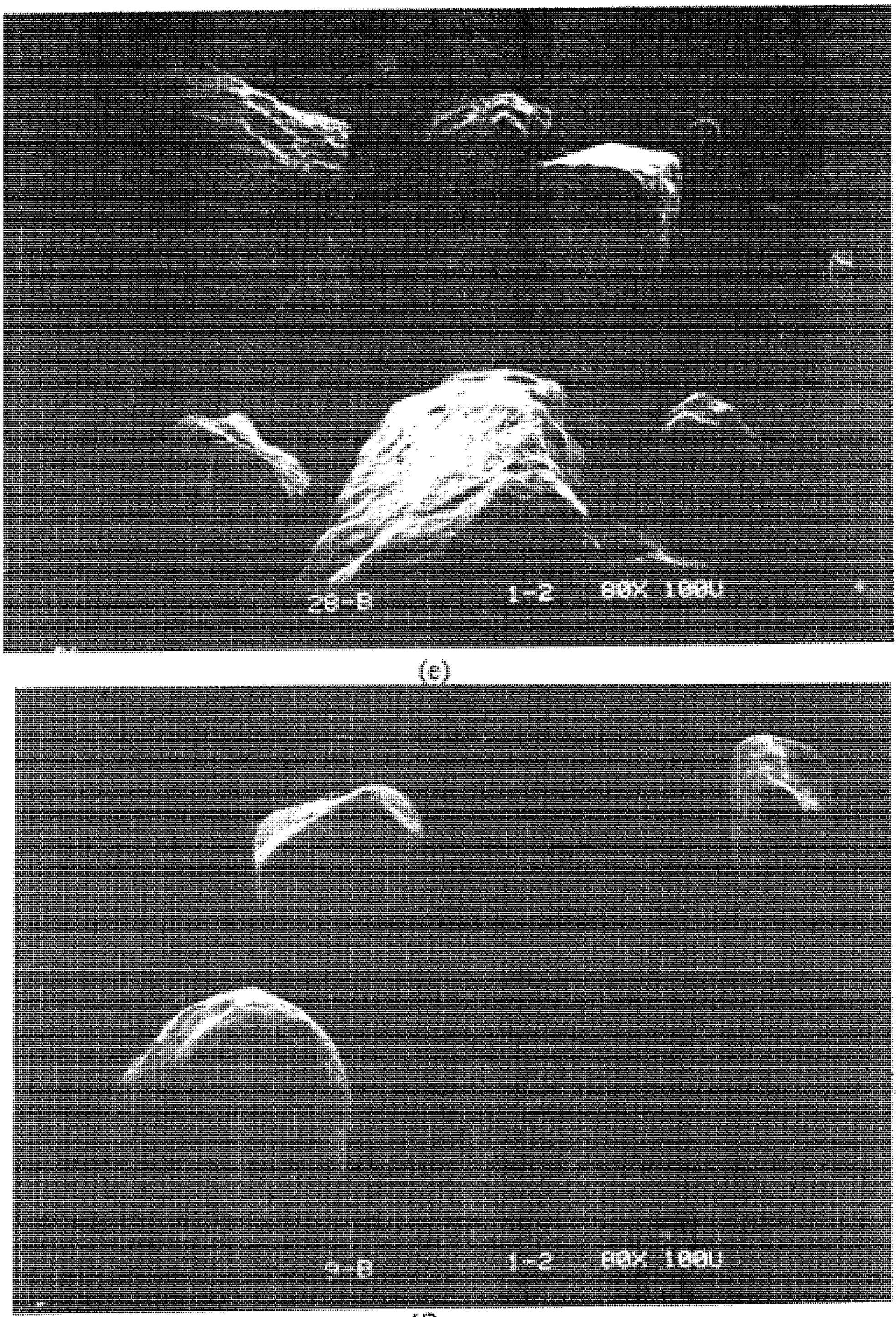
Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (a) 3-B and (b) 7-b.



(c)

(d)

Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (c) 15-B and (d) 20-B.



(e)

(f)

Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (e) 28-B and (f) 9-B.

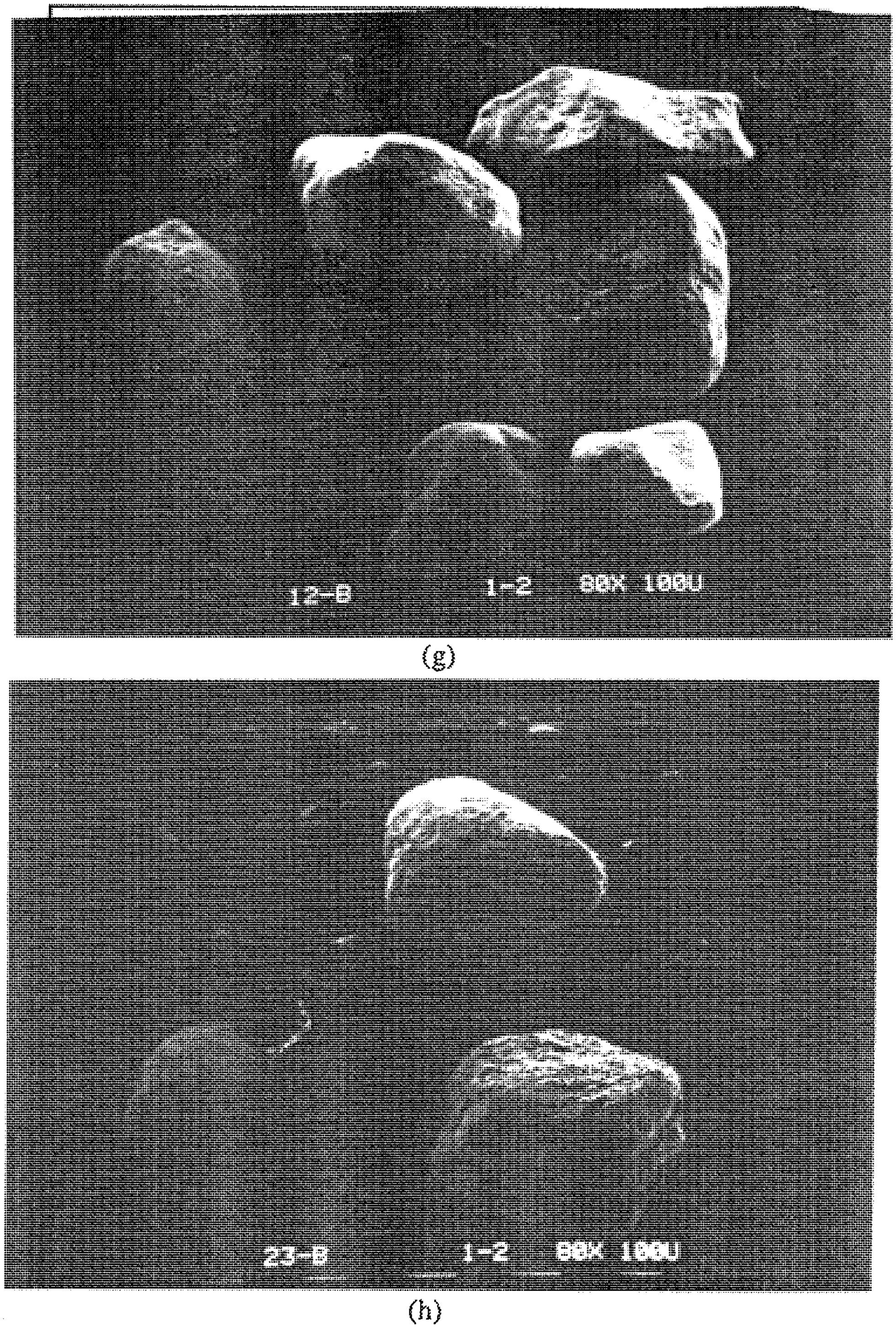
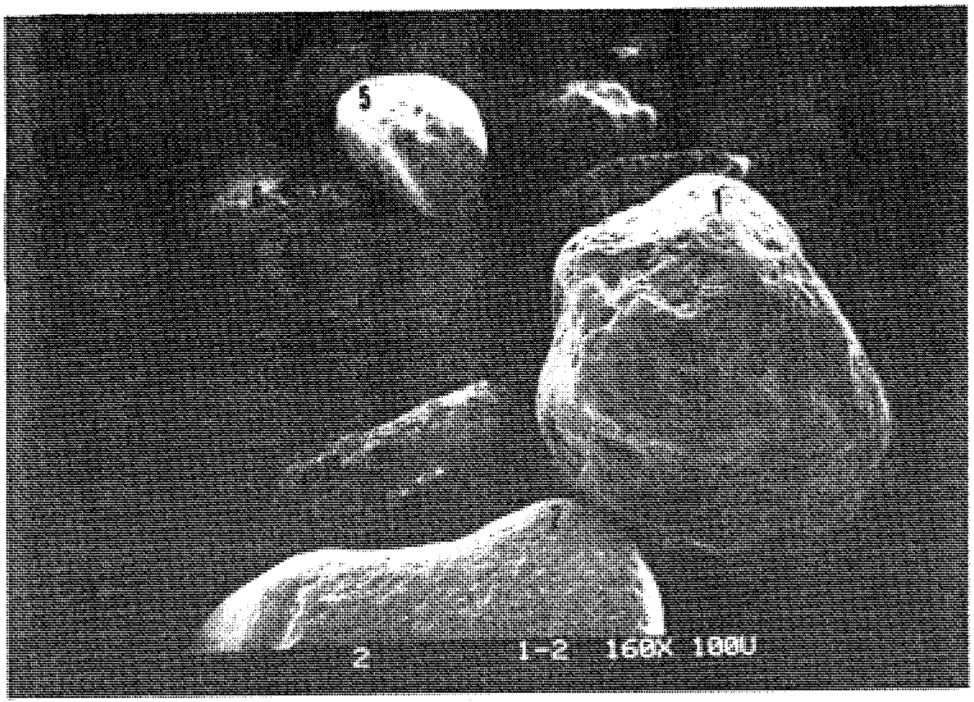
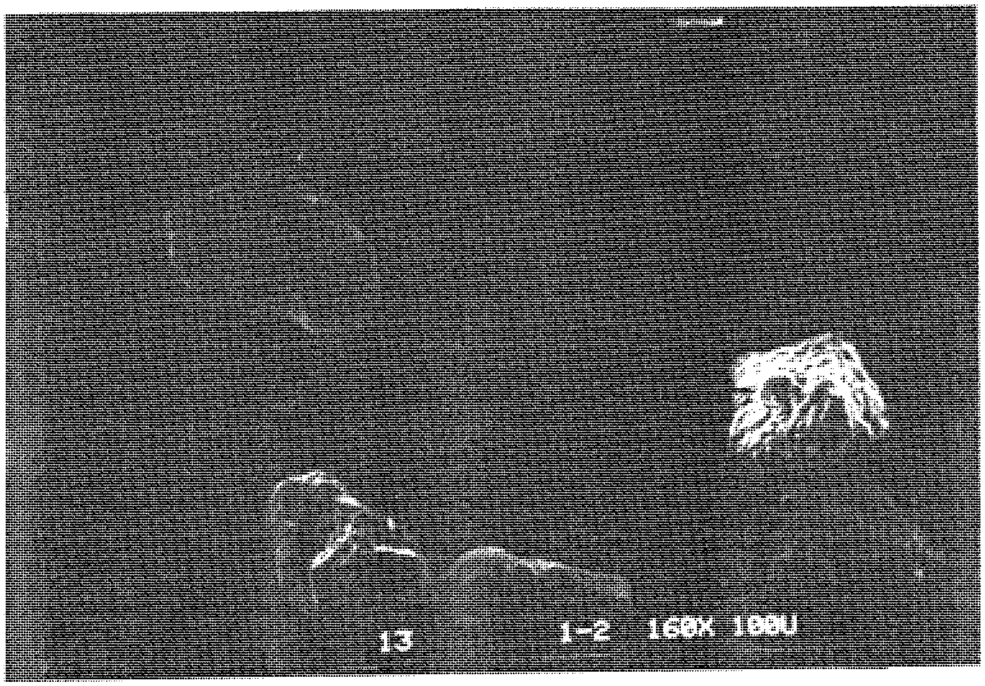


Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (g) 12-B and (h) 23-B.



(i)



(j)

Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (i) 2 and (j) 13.

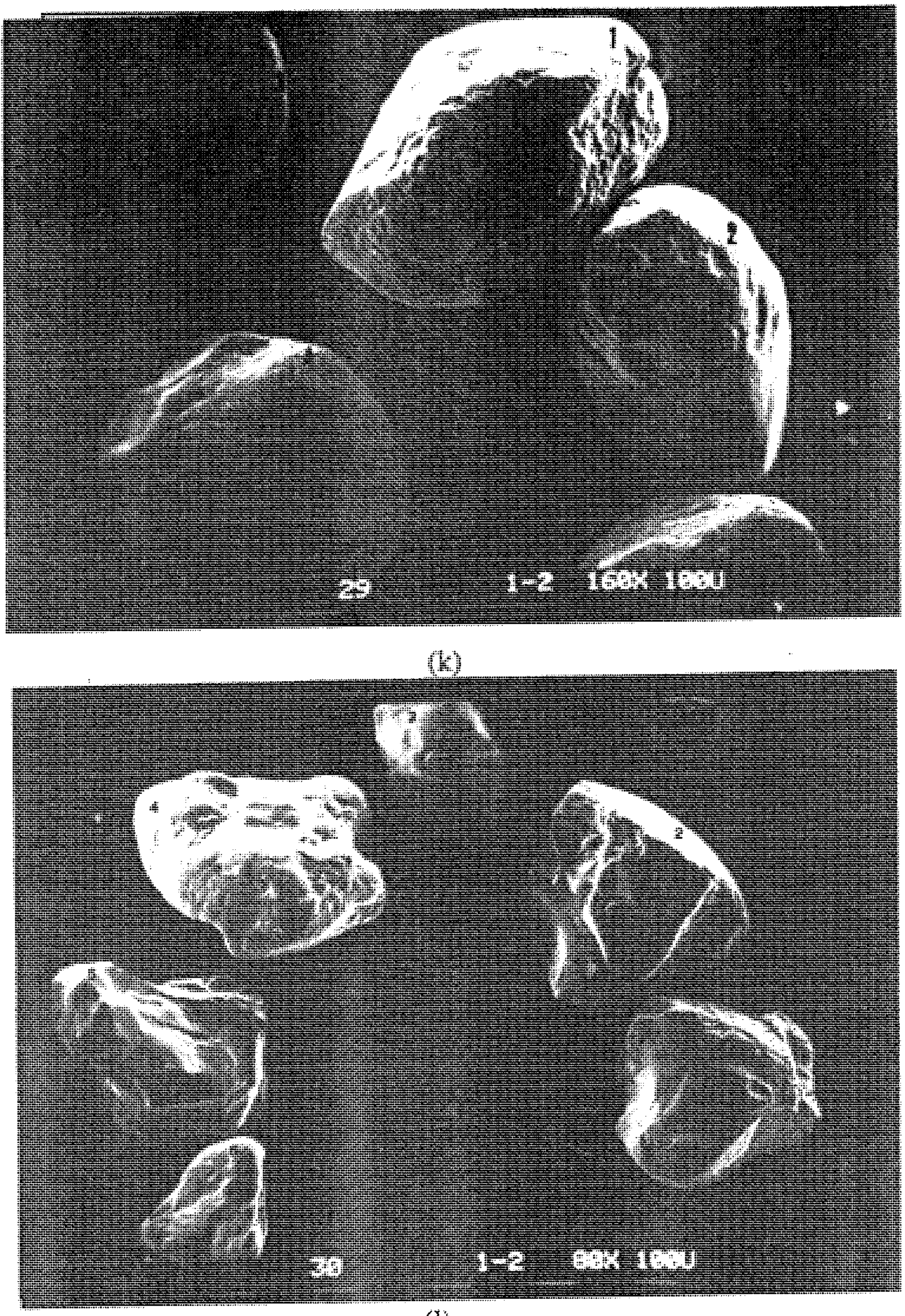


Figure 28 - Photomicrographs of the 1-2 phi size fraction for sample (k) 29 and (l) 30.

characteristically eolian sediment (grain 4) and grains bearing v-forms (1 and 2) and lower distributions of mechanically upturned plates (grains 2 and 3). Grains in Figure 28l (sample 30) were primarily subaqueous in nature (1, 2, 4, 5, and 6) with eolian inclusions, like grain 3.

LOI - 20SA596

Results of Loss on Ignition analyses are reported in Table 5. Total organic and inorganic carbon content of the clastic samples was low. Samples 10, 12, 22, 36, 37 and the six peat samples taken from excavation unit 95 (Figure 23) contained significant organic material. Samples 10 and 22 contained organic averages between 1 and 4 percent loss during the initial firing. Samples, 12, 36 and 37, yielded a range of 8.7 to 21.5 percent loss during the 550 degree burn, and the peat losses ranged from 10.27 to 45.19 percent.

There is a direct correlation between organic-rich samples and higher loss during the 1000 degree burn. A regression plot of percent clay vs. percent loss at 1000 degrees Celsius does not reveal any direct correlations. Therefore, the amount of material lost by the second burn is attributed to incomplete loss during the 500 degree run or organically derived calcium carbonate ($CaCO3$) in the form of marl. Small amounts of $CaCO3$ in clastic samples is attributed to the presence of small shell fragments.

LOI - Off Site

LOI analysis results for the transects are shown in Table 6. Total percentages of organic and inorganic carbon in these samples were relatively low. With the exception of two samples in the 5 to 6.5 percent range, all of the organic carbon ratios plot below 5 percent.

Levels of relatively substantial inorganic carbon, ranging from 5 to 12 percent, are only found in six samples. These samples have mean grain sizes classified as coarse to very fine silt, with the exception of 2-B. However, this sample was taken slightly deeper than other '-B' sediments and sample 2-C also has a high inorganic carbon content. Sample 28-C is included in these six samples and has excellent preservation of gastropods. Each of the six samples showed higher percentages of inorganic than organic carbon, signifying sampling below the leached zone of the soil profile. The remaining samples had inorganic carbon levels of less than 2 percent, many of these approach zero. Material lost during the second heating run is attributed to the presence of small shell fragments and organically derived calcium carbonate ($CaCO3$).

Pollen Stratigraphy and Macrofossil Assemblage

Samples taken for pollen analysis from excavation units 117 and 95 can be combined to provide an overview of the on-site vegetational succession. The reconstructed stratigraphic

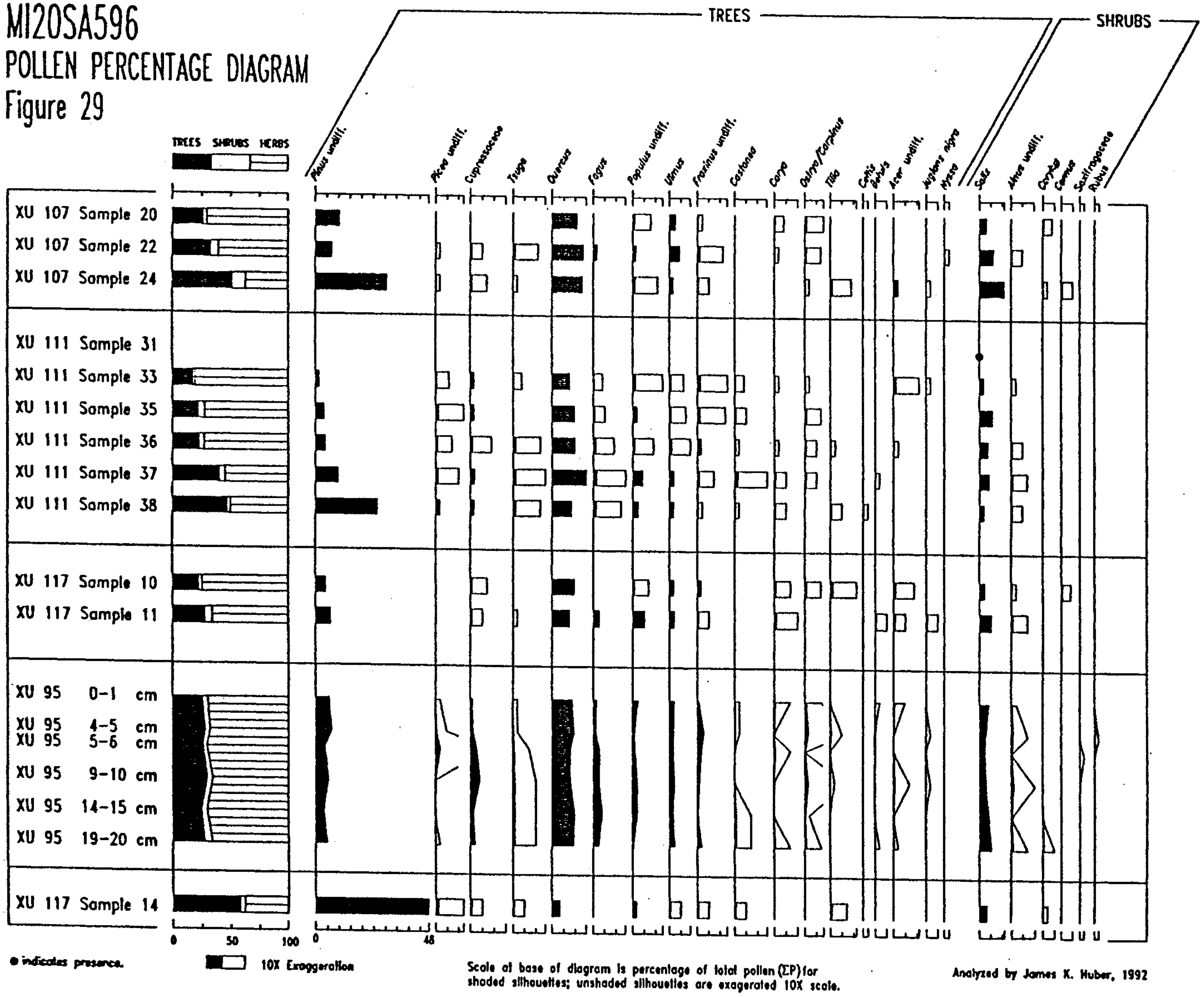
sample no.	LOI 550	LOI 1000	CaCO3
SA596-1	0.37	0.11	0.25
SA596-2	1.14	0.13	0.29
SA596-3	0.47	0.13	0.30
SA596-4	0.74	0.16	0.36
SA596-5	0.49	0.14	0.32
SA596-6	0.79	0.20	0.45
SA596-7	1.05	0.21	0.48
SA596-8	0.72	0.20	0.46
SA596-9	0.69	0.10	0.23
SA596-10	7.68	0.59	1.35
SA596-11	2.42	0.29	0.66
SA596-12	42.55	0.94	2.13
SA596-13	0.42	0.10	0.23
SA596-14	1.68	0.25	0.57
SA596-15	0.29	0.13	0.29
SA596-16	0.34	0.11	0.25
SA596-17	0.72	0.24	0.30
SA596-18	0.30	0.10	0.22
SA596-19	0.91	0.20	0.45
SA596-20	2.81	0.37	0.84
SA596-21	0.36	0.10	0.22
SA596-22	5.35	0.48	1.10
SA596-23	0.95	0.15	0.35
SA596-24	1.68	0.26	0.58
SA596-25	0.36	0.10	0.22
SA596-26	93.76		
SA596-27	1.11	0.18	0.41
SA596-29	0.34	0.09	0.21
SA596-30	0.29	0.10	0.22
SA596-31	0.76	0.18	0.40
SA596-32	0.56	0.16	0.36
SA596-33	1.09	0.23	0.53
SA596-34	0.70	0.16	0.37
SA596-35	1.29	0.21	0.49
SA596-36	31.32	0.93	2.12
SA596-37	17.34	0.50	1.13
SA596-38	7.77	0.26	0.58
SA596-IIBI	0.00	0.26	0.00
SA596-IIBII	0.00	0.26	0.00

Table 5 - Loss on Ignition results for 20SA596

sample no.	LOI 550	LOI 1000	CaCO3
1-B	0.88	0.32	0.73
1-C	0.95	0.72	1.63
2-B	2.64	5.70	12.96
2-C	2.01	8.88	20.18
3-B	1.05	0.44	0.99
3-C	1.40	0.81	1.84
4-B	3.16	0.90	2.04
5-B	0.57	0.20	0.46
5-C	1.60	0.49	1.10
6-B	2.24	0.24	0.54
6-C	0.40	0.15	0.34
7-B	0.86	0.24	0.54
7-C	0.25	0.12	0.27
8-B	3.82	0.89	2.02
9-B	0.28	0.13	0.30
9-C	0.22	0.12	0.28
10-B	2.77	0.25	0.57
10-C	0.92	0.18	0.42
11-B	0.44	0.17	0.39
11-C	2.95	6.07	13.81
12-B	1.05	0.26	0.60
12-C	0.50	0.17	0.40
13-B	3.43	1.14	2.60
13-C	2.97	1.12	2.55
14-B	1.02	0.24	0.56
14-C	0.56	0.16	0.36
15-B	2.23	0.58	1.31
16-B	3.69	0.52	1.19
16-C	3.96	2.82	6.41
17-B	3.18	0.80	1.81
18-B	3.59	0.83	1.89
19-B	4.00	0.85	1.93
20-B	0.50	0.14	0.33
20-C	0.40	0.13	0.29
20-D	0.28	0.12	0.26
21-B	3.54	0.67	1.53
21-C	3.21	0.69	1.56
22-B	2.67	1.47	3.35
23-B	3.61	0.34	0.78
23-C	0.93	0.23	0.53
24-B	3.22	0.28	0.63
25-B	2.26	0.35	0.80
25-C	0.73	0.24	0.55
25-D	1.85	12.58	28.59
26-B	0.85	0.28	0.65
26-C	1.98	0.68	1.55
26-D	4.58	2.41	5.47
27-B	0.40	0.14	0.32
27-C	2.04	0.76	1.72
28-B	0.89	0.54	1.23
28-C	0.70	5.79	13.16
29-B	4.38	1.17	2.65
30-B	5.32	8.43	19.16
31-B	1.82	0.45	1.02
31-C	2.13	0.48	1.08
32-C	2.03	0.98	2.24
32-B	1.78	0.69	1.56
33-B	2.21	1.54	3.50
34-B	2.64	1.02	2.33
35-B	6.43	0.91	2.06
35-C	2.83	0.86	1.96
36-B	2.10	0.73	1.65

Table 6 - Off- site Loss on Ignition results

MI20SA596
POLLEN PERCENTAGE DIAGRAM
Figure 29



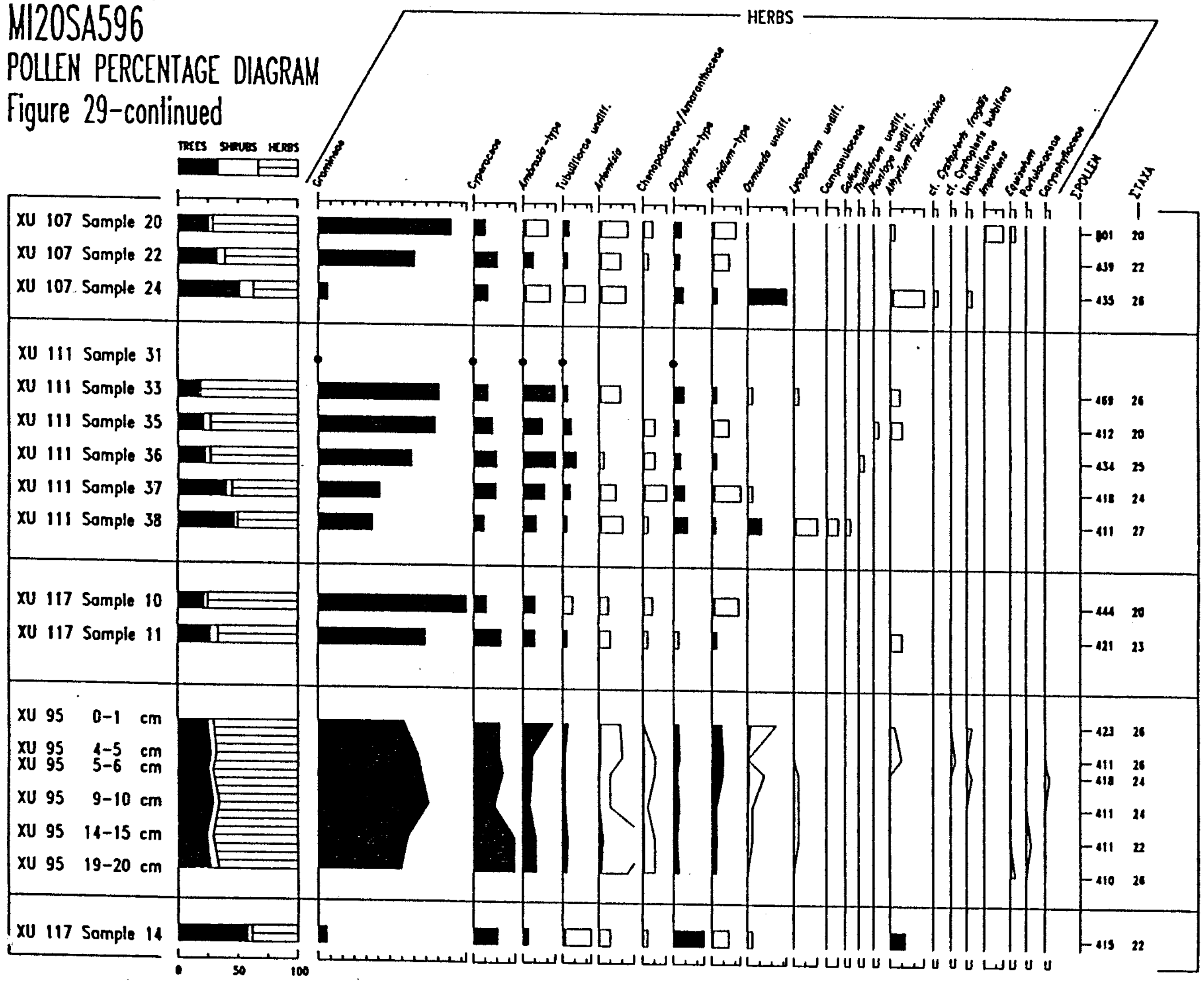
● indicates presence.

10X Exaggeration

Scale at base of diagram is percentage of total pollen (ΣP) for shaded silhouettes; unshaded silhouettes are exagerated 10X scale.

Analyzed by James K. Huber, 1992

MI20SA596
POLLEN PERCENTAGE DIAGRAM
Figure 29-continued



● indicates presence.

10X Exaggeration

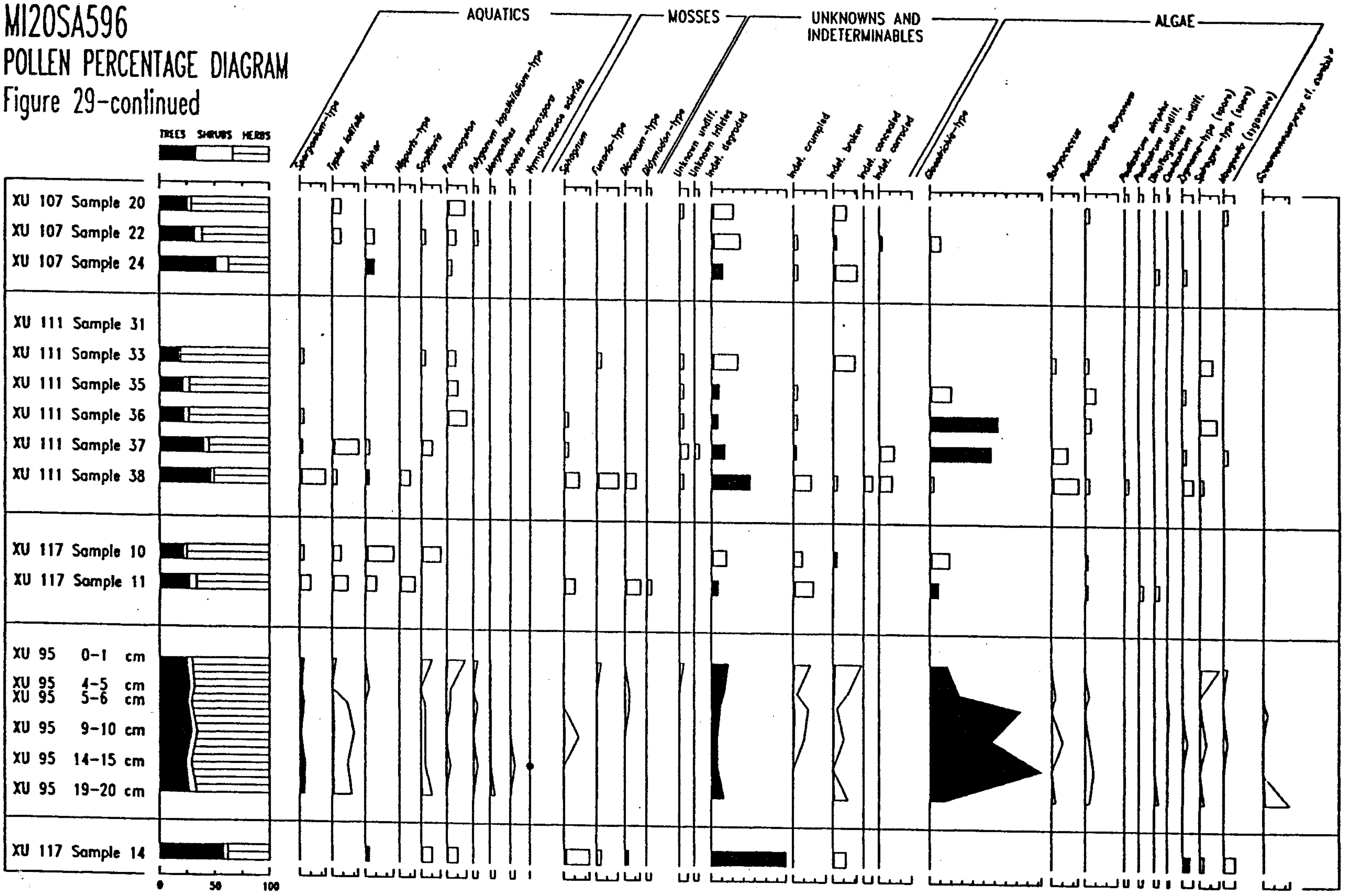
Scale at base of diagram is percentage of total pollen (ΣP) for shaded silhouettes; unshaded silhouettes are exagerated 10X scale.

Analyzed by James K. Huber, 1992

MI20SA596

POLLEN PERCENTAGE DIAGRAM

Figure 29-continued



● indicates presence.

▮▯ 10X Exaggeration

Scale at base of diagram is percentage of total pollen (ΣP) for shaded silhouettes; unshaded silhouettes are exagerated 10X scale.

Analyzed by James K. Huber, 1992

sequence represented in the pollen diagram (Figure 29), includes one sample from below the peat (14), six divisions of the peat layer, and two samples contained within the overlying sediments (10 and 11). Macrofossil analysis results are shown in Figure 30.

Results of pollen analyses are divided into seven sections: trees, shrubs, herbs, aquatics, mosses, unknowns and indeterminables, and algae. Tree species present in the greatest abundances are oak, beech, poplar, elm, ash, hemlock. pine and spruce. Other species include cedar (Cupressaceae), chestnut (Castanea), hickory, ironwood, basswood *(Tilia),* hackberry *(Celtis),* birch, maple, black walnut *(Juglans nigra),* and tupelo *(Nyssa).* The large percentage of pine pollen in sample 11 is attributed to both poor preservation in this clastic sample and easy identification of degraded pine grains (Huber, pers. comm.)

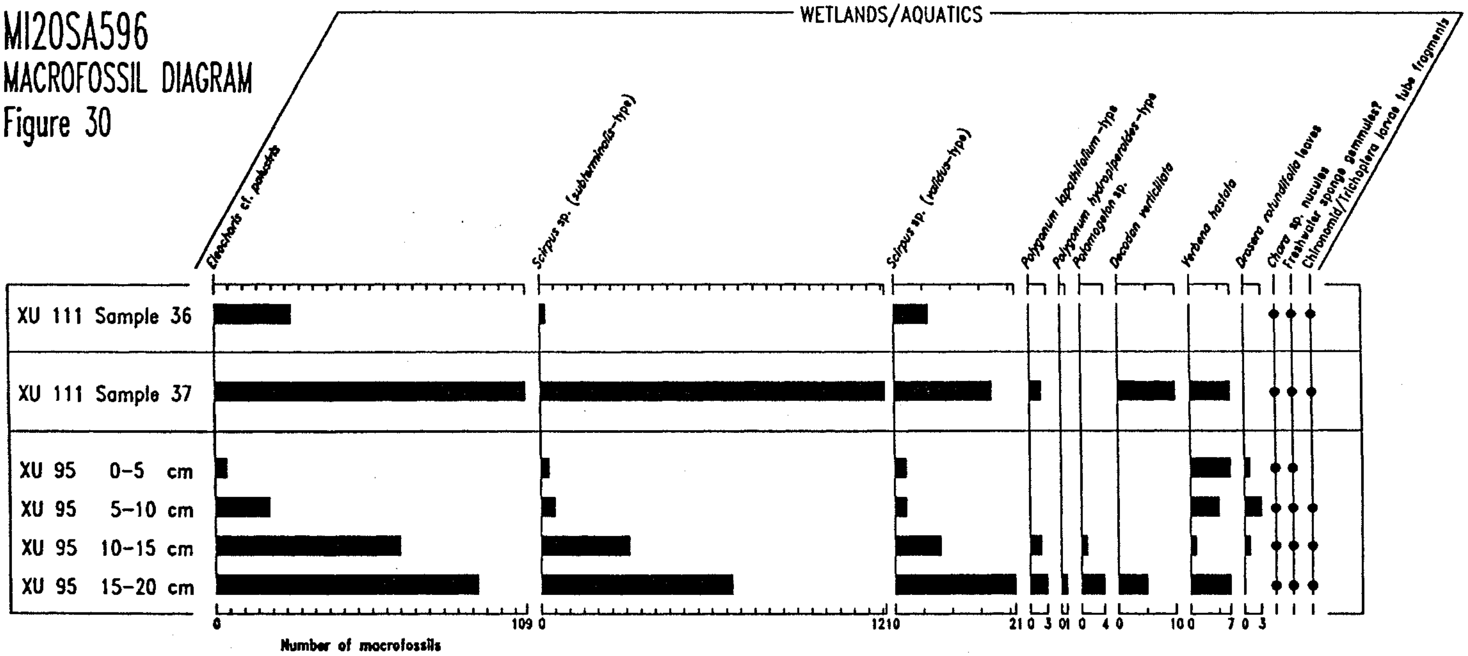
Significant aspects of the local assemblage are shrub species like willow *(Salix)* and alder *(Alnus),* aquatics such as bur-reed (Sparganium-type), and Gloeotrichia-type (blue-green algae). Herb species dominate the local vegetation. Sedge, ragweed *(Ambrosia),* Tubuliflorae, wormwood *(Artemisia),* goosefoot/ amaranth families (Chenopodiaceae/ Amaranthaceae), shield fern (*Dryopteris*-type), bracken fern (*Pteridium*-type), cinnamon fern (*Osmunda*), and especially grasses (Gramineae) are the most abundant species. Approximately 70 percent of the preserved pollen on-site is grass (Figure 17-A, B), but grass glumes, lemmas, and seeds percentages are very low (Figure 30).

C-14

The uncalibrated radiocarbon date for the charcoal fragment in unit 12 was 6,040 ± 110 years BP (BETA-47065) (calibrated to 7,180 - 6,660 calendar years ago). Dating of the wood charcoal sample yielded a date 4,660 ± 90 (BETA-47379) (calibrated to 5,590 - 5,050 calendar years ago). The radiocarbon date of the oak log was 4,720 ± 50 years BP (BETA - 51001) (d ^{13}C -28.7, ^{13}C adjusted age 4,720 ± 50 BP, calibrated to 5,589 - 5,309 calendar years ago).

Comparison of the dates reveals Beta-47379 and Beta-51001 to be roughly similar. The date from the small piece of charcoal (Beta-47065) is much earlier than the other two dates. This difference can not be accounted for by any factor related to the dating process. The disparity may be caused by the sample size, a source of older wood during sediment reworking, or an unidentified post-depositional alteration. The date from the oak log is taken to be most reliable and, when paired with the Beta-47379 date, indicates deposition within the bog during a 300 year period from approximately 5,570 - 5,300 years BP.

MI20SA596
MACROFOSSIL DIAGRAM
Figure 30

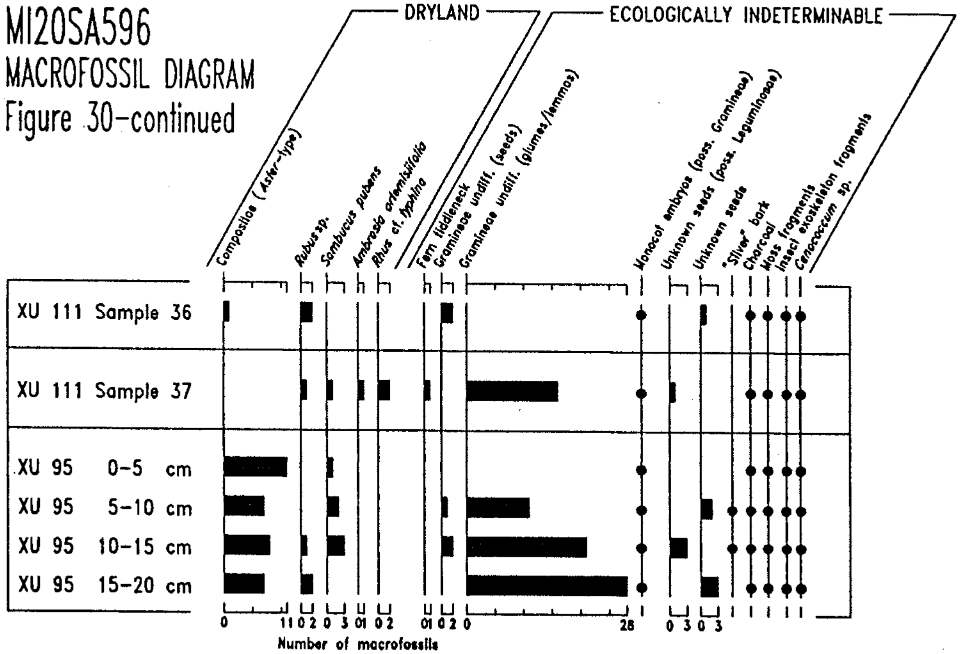


Note--scale differs between taxa

● indicates presence.

Analyzed by Seppo H. Valppu, 1992

MI20SA596
MACROFOSSIL DIAGRAM
Figure 30-continued



Note--scale differs between taxa ● indicates presence. Analyzed by Seppo H. Valppu, 1992

Paleoenvironmental Interpretation

Regional Geomorphology

Synthesis of information concerning the formation of landform assemblages, process-related sediment characteristics, and the Late and post Glacial geologic history of eastern Michigan, reveals a genetic interpretation of deposits in the Saginaw basin. Results of this study support and enhance the accepted sequence of early Holocene lake formation. Macroscopic changes in climatic and geologic processes are represented by sedimentary trends within the basin sediments.

The landforms in the study area generally correspond with prominent contour lines. Thus, a line of equal elevation can be used as a reference to reconstruct the perimeter of paleo lakes (Figure 31). The 220 m (722 ft) strandline is well-preserved and best attributed to early Lake Saginaw (Figure 31); in existence at approximately 14,000 years BP (Eschman and Karrow 1985). Sediments associated with this strandline include the coarsest surficial sediments in the basin (Figure 26). Preserved morphology of quartz grains (Figure 27b) (Figure 28a) shows direct evidence of wave action, including some reworking of previously formed eolian grains.

The Saginaw strandline was abandoned at roughly 13,500 years BP (Eschman and Karrow 1985; Fullerton 1980). Loss of the high-energy wave environment resulted in a retardation of sediment reworking at the 220 (722 ft) m elevation. The relatively well-preserved strandline, lack of dune forms, and the occurrence of characteristically subaqueous surface textures on eolian grains indicate wind velocities were not present at sufficient levels to extensively effect these deposits after abandonment.

Beach remnants located below the 220 m (722 ft) elevation represent Glacial Lake Arkona (Figure 31). Former nearshore deposits of Lake Saginaw were subjected to beach forming processes associated with the rise to the Lake Arkona water level. The slightly lower mean grain size at site 7-B (Figure 26), the occurrence of a few scattered dune forms near the 210 m (689 ft) elevation (Figure 31), and the incorporation of partially-developed eolian grains (Figure 28b) support this interpretation.

Effects of the limited duration of lakes and the increasing instability of shoreline position are seen in the suite of Saginaw, Warren, Wayne, and Grassmere beach remnants ranging in elevation from 210 to 200 m ((689 to 656 ft) (Figure 31) (Eschman and Karrow 1985; Fullerton, 1980; Muller and Prest 1985). The lack of a well-preserved beach comparable to that of Lake Saginaw represents the combined effects of a decrease in relief and lake level fluctuations, in addition to being influenced by modern drainage.

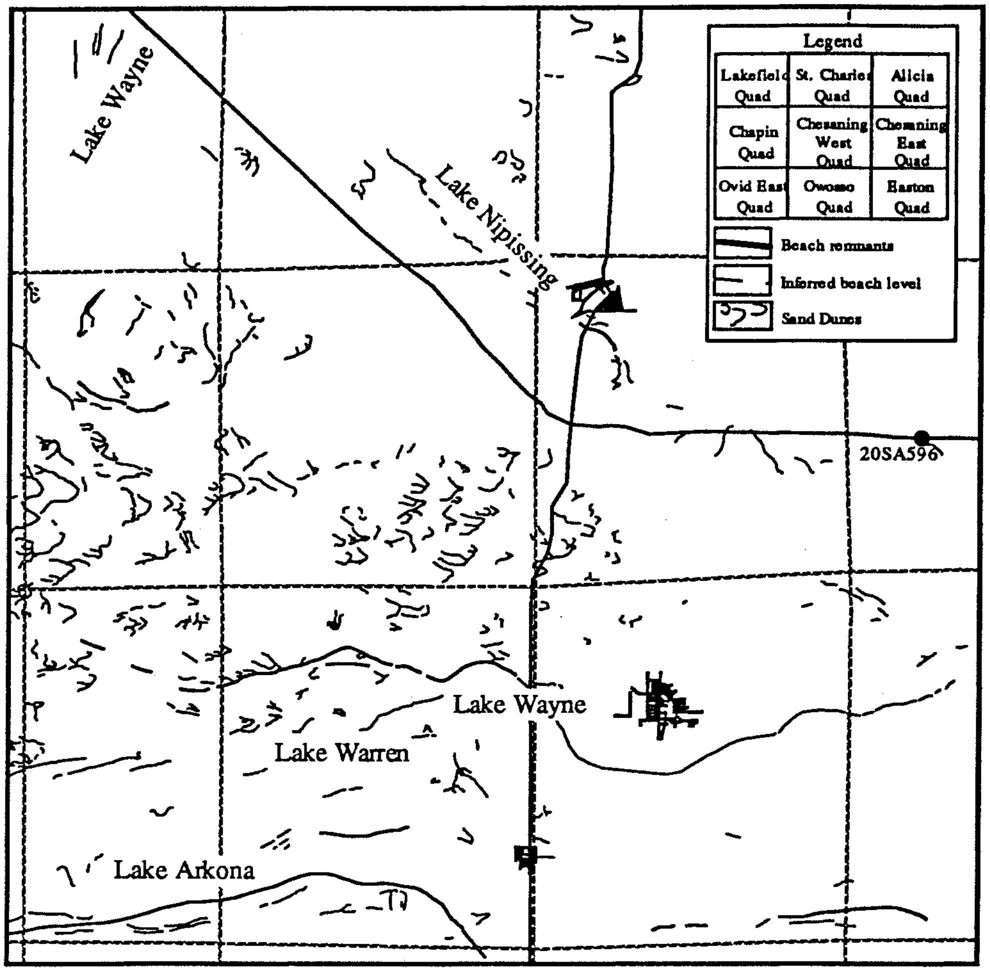


Figure 31 - Correlation of landforms preserved in the study area with the Late and post Glacial geologic history of the Saginaw Basin.

Strandline remnants centered on the 200 m (656 ft) contour (Figure 31) are interpreted to correspond with either the lowest phase of Lake Warren, Lake Wayne, or Glacial Lake Grassmere (Eschman and Karrow 1985). Further lowering of mean grain size (Figure 26) and an increase in dune occurrences (Figure 31) at this elevation indicate exploitation of near- and offshore sediments of previous lakes by littoral processes.

The highest density of dunes occurs below the 200 m (656 ft) strandline (Figure 31). Sediments in large dune forms and reworked strandlines, such as sites 9 and 23 (Figure 26), have mean size fractions which approach those of the Saginaw beaches. Other deposits, like site 12 (Figure 26), show a slight decrease in mean grain size from those sediments from higher elevations. All three of these samples are comparatively well sorted and include quartz grains with developed eolian morphology (Figure 28f; g; h). This represents continued reworking of former near-to offshore sediments, initially by subaqueous and ultimately by eolian processes.

Beaches at 183 m (600 ft) in elevation were occupied twice. Initially by Glacial Lake Algonquin at 11,000 years BP (Hansel et al. 1980; Larsen 1985a; 1985b) and ultimately by the post Glacial Lake Nipissing maximum at 5,500 years BP (Figure 31) (Larsen, 1985a, b). Although the area was exposed during the Lake Stanley phase, there is a lack of dunes near the 183 m (600 ft) strandline. 20SA596 has a well-developed stratigraphic record. These factors indicate the presence of a fluctuating shoreline.

Larsen (1985 a, b) has suggested that relatively minor fluctuations in lake level would have occurred within a seasonal to yearly, or decadal time frame (micro- to meso-scale), superimposed on macro-scale climatic fluctuations over hundreds to thousands of years. Comparisons with modern lake level data from 1900 to the present support his idea (National Oceanic and Atmospheric Administration Ocean Survey 1992). The lake level hydrograph of the Michigan-Huron basin shows water level changes of a little less than a half meter (over 1 foot) occurring within an average year. Decadal fluctuations of over a meter (under 4 feet) are common, and the difference between the lowest and highest recorded values since 1900 is over 3 m (approximately 10 feet).

Figure 32 shows the magnitude of water level fluctuations of Lake Nipissing, Lake Algoma, and modern Lake Huron. 20SA596 lies at an elevation of 181 m (600 ft). For the area surrounding the site, lake level changes shown in Figure 32 imply an alteration of the geographic placement of the shoreline by many kilometers (Figure 33).

Variability in the shoreline location inhibited formation of well-developed landforms; established landforms were periodically 'erased' by the fluctuating water levels. This

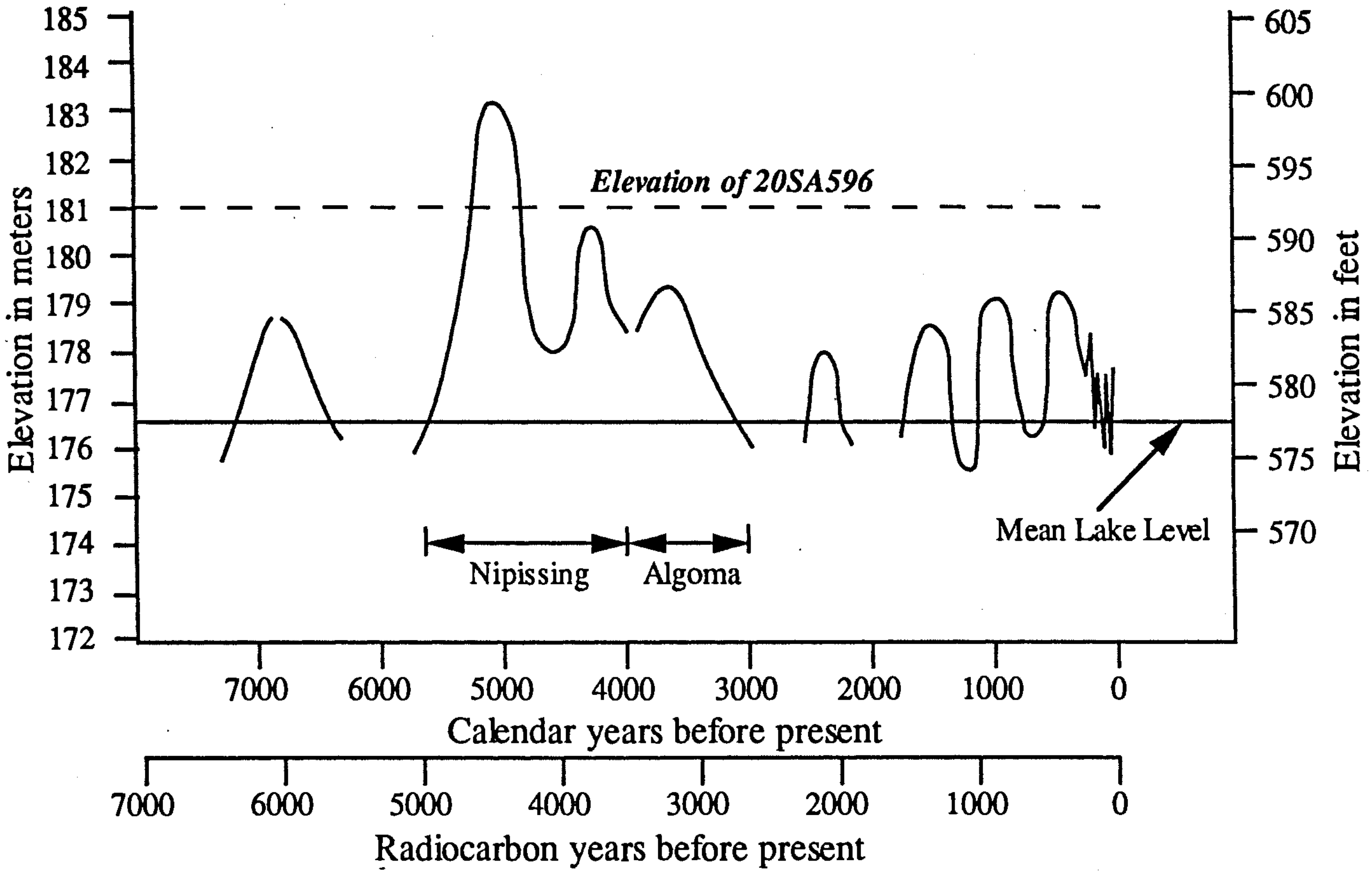


Figure 32 - Graphical representation of Nipissing, Algoma, and modern lake level fluctuations (modified after Larsen 1985). The approximate elevation of 20SA596 is plotted on the diagram with a dashed line.

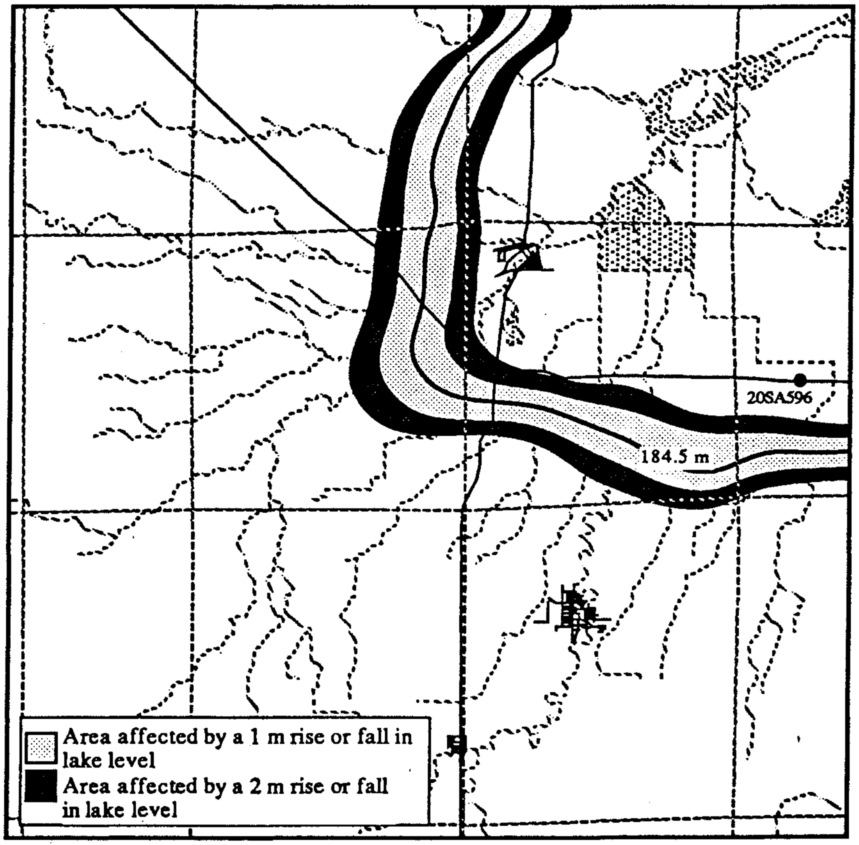


Figure 3 - Implications of a 1 or 2 m variation in the maximum level of Lake Nipissing for the study area.

interpretation is supported by the poorly developed littoral and eolian surface textures in sample 28-B (Figure 28e). Lake Algoma strandlines are not preserved in the study area.

Resulting implications for the completeness of stratigraphic preservation comply with the profile seen at 20SA596. Geologic processes blanketed the area with a thick sequence of sediments and preserved microenvironmental evidence. A few scattered dune forms below the Nipissing level (Figure 31) suggest exposure of the area to wind erosion prior to the development of a stable vegetation assemblage.

Paleobotany

Pollen associated with organic sediments records the regional and local vegetational assemblages. Preserved tree pollen, indicative of the regional forest community, is primarily dominated by oak, beech, poplar *(Populus)*, elm, ash, and hemlock species. Pine and spruce are also present in significant quantities, however, these two genera are not considered to have been abundant in the immediate vicinity. Pine and spruce produce large amounts of pollen which are transported great distances via air currents. Based on the pollen spectra, the peat layer and the overlying organic-rich beds indicate a regional assemblage roughly comparable to the modern forests of this area.

The local component reveals the presence of a wet environment that supported a restricted range of vegetation (Figures 17-A, B). Bulrushes *(Scirpus sp.)* and Chara species are plants that require standing water and imply periodic inundation of the site by water up to 1 to 2 m (3.3 to 6.5 ft) in depth (Hotchkiss 1972). Smartweed *(Polyganum* sp.*)*, pondweed *(Potamogeton sp.)*, and cattail *(Typha latifolia)* are representatives of fresh to brackish water marsh environments. *Sphagnum* (moss), sundew *(Drosera rotundifolia)* and the presence of midges and caddis fly larvae support an interpretation of a bog with local stagnant water (Hotchkiss 1972).

Those shrub and herb species identified on site additionally reflect a wet local environment, especially willow and alder. Willow is relatively abundant, in comparison with analogous forest populations. Cattail *(Typha)* and the presence of *Pediastrum* (a green algae) and other algae indicates the presence of standing water (Hotchkiss 1972).

The peat represents a former wetland ecosystem. A bog existed in a small, shallow low that was periodically inundated with fresh water up to 1 to 2 m (3.3 to 6.5 ft) deep. Remnants of aquatic macrofossils, including bulrushes, smartweed, pondweed, Chara species, freshwater sponge gemmules, and midges and caddis fly larvae, support this interpretation (Figure 30).

A unique aspect of the local vegetation is the inordinately high percentage of grasses. Approximately 70 percent of the preserved pollen is identified as grass species. This is more than double the abundance of grass in typical prairie assemblages. Although grass pollen is abundant (Figure 29), grass seeds, glumes, and lemmas occurrences are uncommon (Figure 30). It is therefore unlikely that grass was growing in the bog.

The evidence suggests that the small bog was surrounded by an expanse of grass-covered open ground. Minor transgressions and regressions, resulting from seasonal and annual variations in the level of the nearby lake periodically inundated the shallow basin. Repeated lake level fluctuations inhibited the establishment of a permanent plant community around the site.

As water levels dropped, grasses quickly colonized the newly exposed portion of the lake bed. Before they could be replaced by more permanent varieties of plants, water would rise and inundate the area. Upon recession, a pioneer plant community, dominated by grasses, once again propagated across the freshly exposed area.

Site Stratigraphy and Sedimentology

20SA596 is underlain by a thick sequence of varved clays, which represent deep water accumulations of silt and clay of an ice marginal lake. The presence of dropstones supports this interpretation. Early Lake Saginaw and Glacial Lake Arkona are the Phases likely to have deposited these sediments (Figure 34a; b); corresponding beach elevations imply a water depth at the site, approximately 30 to 40 m (98 to 131 ft), sufficient for the accumulation of clays.

A massively bedded sand unit primarily consisting of fine to very fine sands overlies the varved clays (Figure 25). These sands correlate with an offshore lake environment related to the Lake Saginaw (Figure 34c) and Lake Warren/ Wayne (Figure 34d) stages, approximately 20 m (66 ft) in depth. Gradual deposition occurred while water levels initially receded to the Lake Grassmere level (Figure 34e). The grain morphology of sample 13 (Figure 28j) indicates deposition in a subaqueous environment. This is supported by the fine nature of this sediment, which suggests a near to offshore setting.

The site was exposed to eolian reworking as the water dropped to the Algonquin (Figure 34f) and Stanley (Figure 34g) levels prior to the establishment of a vegetational community. No bedding is preserved within this lower sand unit; dewatering structures are abundant. Inclusions of laminated clays within the lower portion of this unit suggest further disturbance of the sands and underlying clays by geomorphic and biologic processes such as frost heaving, root growth and tree throws.

The Nipissing transgression raised the water table level, resulting in the creation of an environment capable of supporting a wetland community (Figure 34h). This transgression is recorded by the upward transition of the very fine to fine sands of the lower unit into

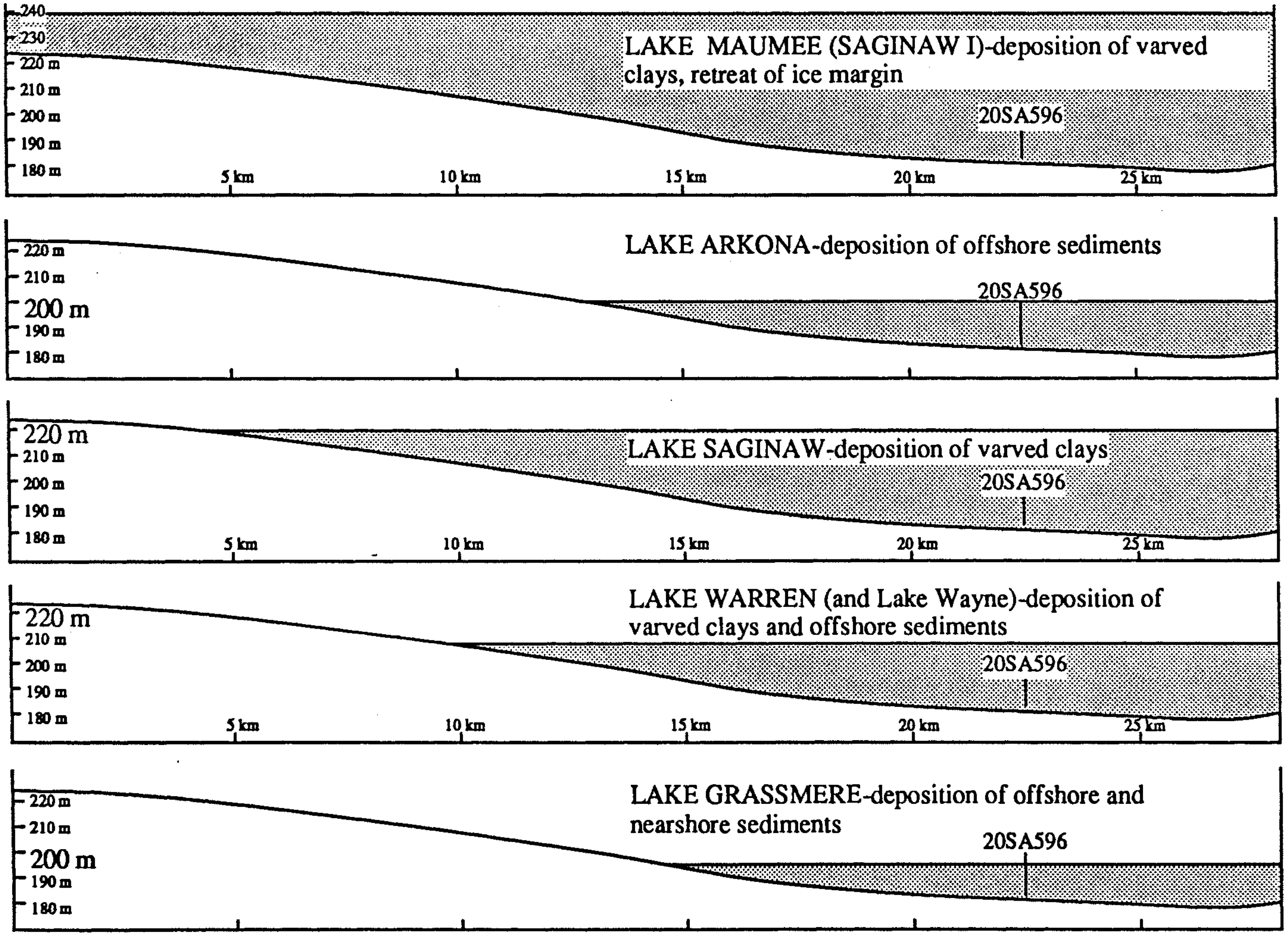


Figure 34 - Environment of deposition for 20SA596 and the study area at the (a) early Lake Saginaw, (b) Lake Arkona, (c) Lake Warren, (d) Lake Wayne, and (e) Lake Grassmere water level.

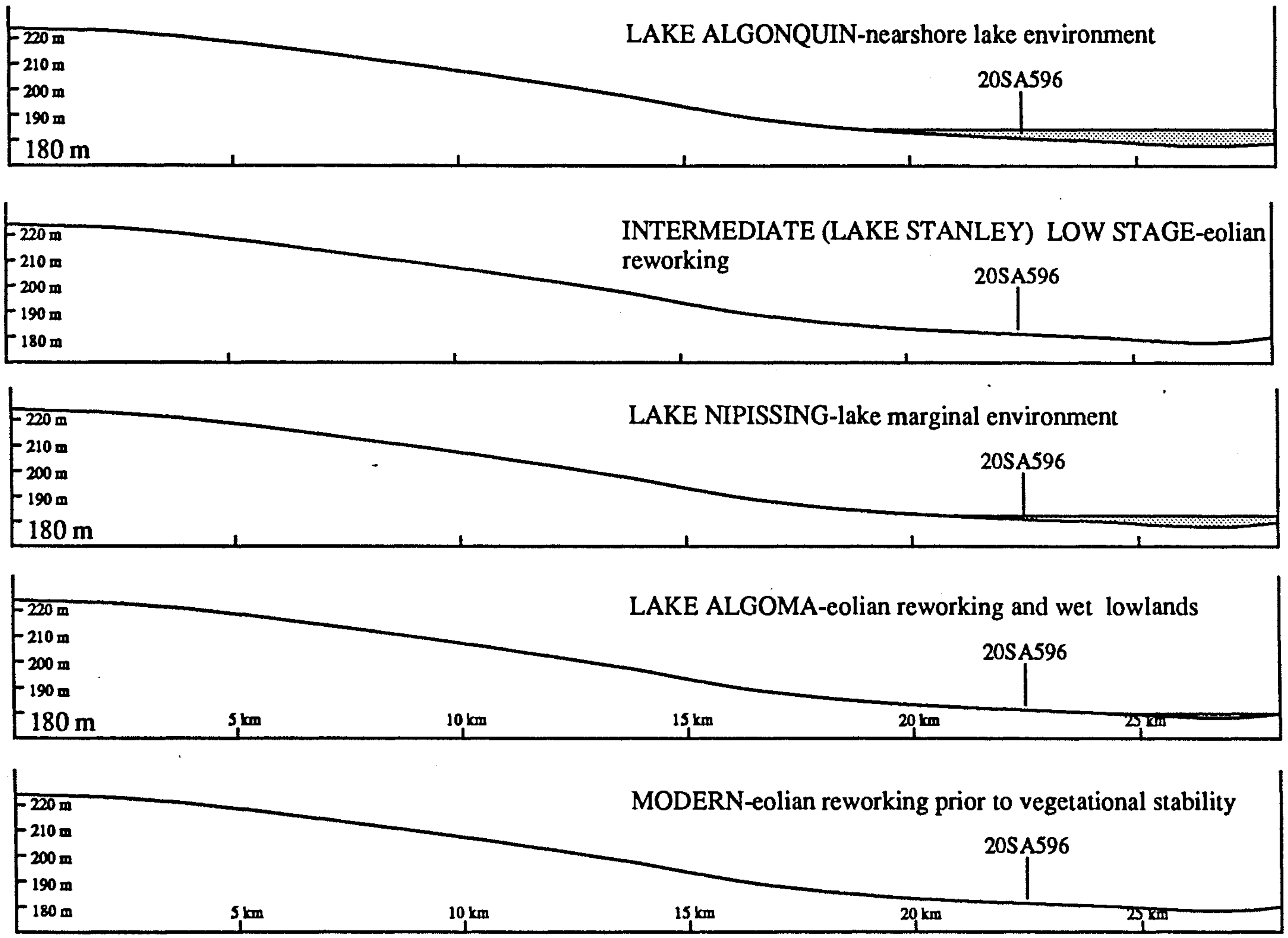


Figure 34 - Environment of deposition for 20SA596 and the study area at the (f) Lake Algonquin, (g) the Lake Stanley low stage, (h) Lake Nipissing, (i) Lake Algoma, and (j) modern Lake Huron water level.

organically stained sediments and ultimately into a peat horizon. Excellent preservation of partially decayed plant material represents a significant period of organic accumulation. The radiocarbon date for the oak log, located at the lower boundary of the 20 cm thick peat, is taken to be the most reliable date because of the correlation with the wood charcoal date and the relatively large amount of material submitted for dating. This date, at 4,780 ± 50 years BP ((BETA - 51001) (d ^{13}C -28.7), ^{13}C adjusted age 4,720 ± 50 BP, calibrated to 5,589 - 5,309 calendar years ago), supports a direct relationship between the formation of the wetland and the Lake Nipissing transgression.

The main body of the peat is interrupted by relatively coarse sands (Figure 25). The peat also splits into multiple layers separated by sand laminae and lenses up to 5 cm in thickness at the margins of the shallow basin defined by the occurrence of preserved organics (Figure 19b; c; d). Sample 30 (Figure 28l) is representative of these coarser deposits and the majority of grains have surface textures which indicate a littoral environment. Some distinctly eolian grains were mixed in with this sample, probably by wave action over dune forms.

Interbedded clastic and organic layers suggest the wetland was being encroached by slowly advancing dunes and was periodically inundated by lake waters. A large dune form can be identified along the margin of the wetland (Figure 19b). Episodes of dune movement were separated by periods of stability when vegetation became established on the dune surface. Fine organic laminae record such events and, where preserved, effectively protected underlying sediments from extensive reworking.

The top of the peat forms an abrupt contact with overlying sediments. Lenses of medium sand are present in the 50 cm directly overlying the peat. Other preserved sedimentary structures consist of small-scale laminations, small eolian features (Figure 19c) and a few larger dunes, as is evident in excavation unit 111 (Figure 19b). This feature (Figure 19b) formed as sand gradually migrated into the periphery of the bog. Ramp-like lenses of medium sand within this dune form suggest an added influx of sediment due to shallow water lacustrine activity. Medium sands are typically associated with strandlines, or partially reworked beach remnants such as sample site 9 and 12 (Figure 22), within the study area.

Additional evidence supporting inundation of the site by Lake Nipissing is the accumulation of lithic materials. These artifacts are concentrated in the lowest part of small depressions found on the upper surface of the peat layer, interpreted to be wave-formed features.

Fine and very fine sediments of the upper sand unit (Figure 25) were introduced to the site by eolian processes. This is supported by the grain morphology of samples 2 (Figure 28i) and 29 (Figure 28k). The final regression of Lake Nipissing and the establishment of Lake Algoma (Figure 34i) allowed site modification by eolian reworking, prior to the stabilization of the surface by vegetation and the establishment of modern Lake Huron (Figure 34j).

Conclusion

Sediments at 20SA596 preserve a record of deposition dating from the Late Glacial to the present. The accumulation of varved clays occurred during the highest phases of the Late Glacial lake sequence. Sands overlying these clays represent a transition from deepwater varve accumulation to the deposition of nearshore and offshore sands. Exposure of the site allowed plant communities to become established. A rising water table associated with the Nipissing transgression resulted in an increased degree of wetness and the initiation of organic accumulation. Preserved macro- and microfossils indicate a bog community periodically inundated by fresh water.

Cultural remains at the site correspond with the post Glacial Lake Nipissing water level, as indicated by the nearby beach remnant, the radiocarbon date, and the accepted maximum of this lake. During the Nipissing stage, seasonal or annual variations in water level periodically inundated the site with water depths of one to two meters. This directly supports the model presented by Larsen (1985a, b), where natural climatic fluctuations and associated lake level changes over years to a few tens of years would cause minor water level fluctuations. Given the extremely low relief of eastern Michigan, a one meter rise or fall in lake level translates into a repositioning of the shoreline by several kilometers. A pioneer community of grasses reclaimed newly exposed territory following each regression.

Over time, small-scale dune structures gradually encroached into the bog. With the ultimate regression of Lake Nipissing, 20SA596 was exposed to a period of eolian activity, resulting in the deposition of the upper sand unit, prior to the development of a stable plant community.

The detailed stratigraphic context provided by 20SA596 can be used to evaluate the geomorphic history of the Saginaw Basin. Synthesis of information provided by geomorphic mapping and sediment analyses provides insight into factors influencing landform distribution, brought about by the characteristics of available sediments.

Shoreline placement for Late and post Glacial water bodies fluctuated about a mean elevation over time. This instability provided the opportunity for the deposition of sediment within a well-defined localized stratigraphic sequence.

While the artifact assemblage is somewhat limited and even shows evidence of post-depositional reworking in some places, it does provide a record of Archaic utilization of resources associated with the lakeshore. Active surveying for temporally specific sites, especially Archaic sites, should not be restricted to identified strandlines preserved upon the contemporary land surface. Such sites will be positioned over a range of area and possibly contained within a thick accumulation of sediment. This study provides insight to the detailed information of the early Holocene geologic record still preserved in eastern Michigan.

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