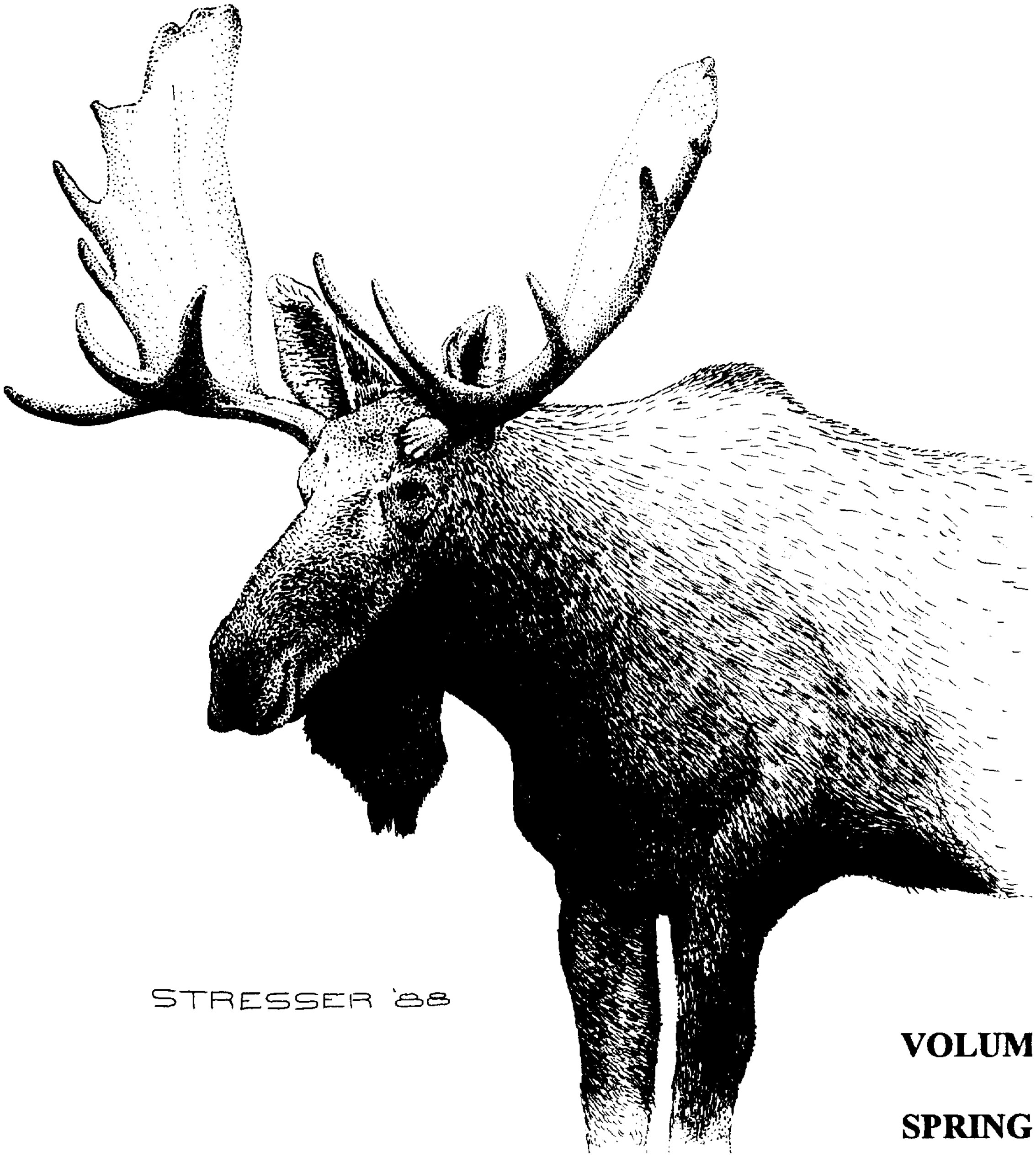
THE MAINE ARCHAEOLOGICAL SOCIETY INC. BULLETIN



VOLUME 35:1

SPRING 1995

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The cover picture was drawn by Dr. David Stresser.

MAINE ARCHEOLOGICAL SOCIETY BULLETIN

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VOLUME 35 NUMBER 1

SPRING 1995

PALEO-ENVIRONMENTAL RECONSTRUCTION USING EARLY HOLOCENE FAUNAL ASSEMBLAGES AND THE BIOLOGICAL PARAMETERS OF SPECIES THEREIN

Harbour Mitchell, 111

INTRODUCTION

Utilizing faunal remains recovered from dated Early Holocene archaeological sites in Maine and New Hampshire, this effort reconstructs the riverine and terrestrial environments of the period 9000-6000 B.P. The biological parameters of the species present in these faunal assemblages define Early Holocene river, marsh, and adjacent terrestrial systems, as being analogous to those currently in existence.

As early as 1941, anadromous fish were identified in prehistoric faunal assemblages recovered from archaeological excavations in Maine (Hadlock 1941 :23). Until recently, however, anadromous species of fish and other species associated with a riverine environment have not been recognized for their enormous potential to contribute to reconstructing Early Holocene riverine and terrestrial environments.

In the past, the lack of a viable archaeological sample has resulted in the development of models for Early Holocene human occupation in the Northeast predicated on underdeveloped forest biomes and speculative, undocumented reliances on large terrestrial mammals (Fitting 1968:442, 444). However, it is now clear that not only do Middle and Early Archaic sites exist in Maine, though deeply buried, they also possess well preserved faunal assemblages.

One consequence of using limited data in past research efforts in the Northeast is a dependence on abstractions to define human occupation and subsistence capabilities. Gross paleo-environmental data recovered from deep sea cores, palynological analyses (Doyle er ***al.*** 1985:4), and lithic assemblages (Doyle ***et al. 1985)*** are appropriate in the absence of any other empirical samples. However, their use often result in gross oversimplifications.

While it is near impossible to define discrete environments from a small sample of lithic technol~gies, pollen, or analogous human adaptations, it is quite possible to define environment from a small but accurate sample of faunal remains. This paper utilizes biological parameters for five species: American shad ***(Alosa sapidissima);*** American eel ***(Anguilla rostrata);*** beaver ***(Castor canadensis);*** common snapping turtle ***(Che/ydra serpentine serpentine);*** and muskrat ***(Ondatra zibethicus).*** These species, present in three archaeological faunal assemblages associated with the Early Holocene in Maine and New Hampshire, represent one anadromous species of fish, one catadromous species of fish, one amphibious reptile, and two river utilizing terrestrial mammals.

THE ASSEMBLAGE

Much of the problem of associating anadromous species of fish, and other riverine related species, with early cultural developments in Maine has been the paucity of sites dating prior to the Late Archaic period. Until recently, the sites themselves proved elusive. Models of human occupation tended to view the Gulf of Maine as subsistence poor. As a result, models of human occupation developed that explicitly stated a reliance on terrestrial species, especially large ones, in a young, underdeveloped forest biomes (Fitting 1968, Petersen and Putnam 1992, Robinson and Petersen 1992).

The Maine Archaeological Socie& Bulletin 34:1:1-1 I (1995)

An increased awareness of deeply stratified sites throughout the Gulf of Maine has illustrated that these early sites are not only present, but that they also contain well preserved fauna] assemblages (Table 1). The data used here are derived from work done at deeply stratified sites: the Sharrow (90.2D) and Brigham sites (90.2C) in Mile, Maine; and the Wadleigh Falls site (NH39. 1) in New Hampshire .

At the Sharrow Site, beaver and turtle are among the identified calcined faunal remains recovered from Early Archaic period strata and features (Petersen 1992: Tables 19- 22; Spiess 1992: Table C-10). Turtle is also represented in the Early Archaic period levels at the Brigham site (Spiess 1992: Table B-l).

In addition to beaver and turtle, muskrat, American eel and shad remains have also been recovered from Early Holocene contexts (Spiess 1992:183-185; Petersen 1991:135-139). Eel is present in the Shamow Site in the Late, Middle, and Early Archaic periods, while shad is present in the Sharrow, Brigham, and Wadleigh Falls sites (Maymon and Bolian 1992:130- 131). At the Sharrow Site calcined shad remains are associated with the Middle, and possibly, Early Archaic periods (Spiess 1992 Table C-1). And, at the Wadleigh Falls site, calcined shad remains are stratigraphically associated with the "upper component" dated to between 6500-7900 B.P. (Maymon and Bolian 1992:123, 127). In the following section the biological parameters for these five species are reviewed with the ultimate goal of isolating and contrasting their habitat requirements.

SPECIES DATA

This section deals solely with illustrating the biological parameters associated with beaver (Castor canadensis), common snapping turtle ***(Che/ydra serpentine serpentine),*** muskrat ***(Ondatra zibethicus),*** American eel ***(Anguilla rostrata)*** and American shad ***(Alosa sapidissima).*** Special attention has been paid to seasonal activity such as spawning, prey or food requirements, limiting factors such as temperature and water velocity, and any inter- relationships that may exist among or between the species (for example, American eels prey on juvenile American shad).

Shad

Shad ***(Alosa sapidissima),*** also known as the American, Atlantic, or common shad, is an anadromous fish species found along the entire length of the Atlantic seaboard of the North American continent, i.e., Newfoundland to Florida (Wiess-Glanz ***et al.*** 1986: 1; Squires 1988:14). They are found in greatest numbers from Connecticut to North Carolina. Being anadromous, mature shad utilize river systems to spawn. "'The species [shad] probably has spawned in virtually every accessible river and tributary along the Atlantic coast." (Wiess-Glanz ***et al.*** 1986:3).

Generally, young individuals remain at sea growing and maturing for approximately 2-5 years (Squires 1988: 14). By 6 years of age most shad have spawned at least once (Wiess-Glanz et al. 1986:3). Squires notes that although individuals of 12 pounds and more have been recorded, most spawning shad range from 3-4 pounds in weight (Squires 1988: 14). While shad suffer virtually a 100% post spawning mortality rate within their southern-most range, the percentage of return spawners in their northern-most range, the area of interest to this paper, is greater than 70°/0 (Wiess-Glanz ***et al.*** 1986:4).

In the Northeast, specifically the Gulf of Maine and further north, shad begin their up-river spawning migrations in mid-May through June (Wiess-Glanz, ***et al. 1986:5,*** Squires 1988: 14). Generally, shad move into rivers in the northeast when water temperatures are between 13-20°C (Wiess-Glanz e{ ***al.*** 1986:5 citing Walburg and Nichols 1967). In New Brunswick, spawning runs crest during June and July. When water temperatures reach levels greater than 20°C the shad "tend to discontinue upstream .." (Wiess-Glanz, ***et al. 1986:5*** citing Kuzmeskus 1977). The tolerable water temperature range for shad appears very specific. Water temperatures below 2°C are lethal, at 5°C impair function, and below 8°C are avoided (Wiess-Glanz, er ***al.*** 1986:10).

BWGHAM SITE			
SPECIES	5000-6000 B.P.	6000-8000 B.P.	8000-9000 BP.
American shad		XX	
Turtle	XX	XX ‘	XX
Beaver	XX	XX	XX
Muskrat		XX	XX
SHARROW SITE			
SPECIES	5000-6000 B.P,	6000-8000 B.P.	8000-9000 B.P.
American shad	XX	XX	??
Turtle	XX	XX	XX
Beaver	XX	XX	XX
American eel	XX	XX	XX
Muskrat	XX	XX	XX
WADLEIGH FALLS SITE			
SPECIES	5000-6000 B.P.	6000-8000 B.P.	8000-9000 B.P.
American shad		XX	
Snapping Turtle		XX	
Beaver		XX	
Muskrat		XX	

Table 1. Temporal association of faunal remains from the Brigham, Sharrow and Wadleigh Falls sites.

Shad spawning takes place in the same river every year, “.. at night, usually in shallow water with moderate currents in the main stem of rivers.” (Wiess-Glanz, et al. 1986:3 citing Marcy 1972). The species ability to return precisely to its natal river is attributed to a keen sense of smell and the ability to “read” tidal and river currents (Wiess-Glanz, ***et al.*** 1986: 5,6).

A water current velocity of 1-3 feet per sec. and a depth range of 3-20 feet are needed at the time of spawning (Squires 1988: 14). No specific substrate requirements are necessary for shad to spawn due to their habit of releasing and fertilizing eggs within the water column (Wiess-Glanz, ***et al. 1986:11).*** Of a critical nature, however, is the apparent need for spawning adults to be far enough up-stream in order to ensure enough time for eggs to hatch while drifting downstream prior to reaching saline environs. Hatching of eggs occurs within 8-12 days as the fertilized eggs drift downstream (Wiess-Glanz, ***et al.*** 1986:4). After hatching, in the fall of the same year, when river temperatures drop to approximately 12°C, juvenile shad begin a general down stream migration first to areas of brackish water and later to the open sea (Wiess-Glanz, ***et al. 1986:5).*** By this time, the juveniles have attained a length of approximately 75- 125mm. This out-migration continues into the Gulf of Maine and the Bay of Fundy where immature, and spawned-out individuals from "north of Chesapeake Bay", congregate in preparation for a southern migration along the Atlantic seaboard (Wiess-Glanz, ***et al.*** 1986:5).

Commercial shad catches tend to occur at ocean bottom temperatures of 7- 13°C (Wiess-Glanz, ***et al. 1986:*** 11). Juvenile shad are not bottom feeders, preferring to feed within the water column on insects and crustaceans (Wiess- Glanz, ***et al. 1986:9).*** Having said that, however, it is noteworthy that shad are found primarily on the bottom (ocean and river) during the day and at the surface or throughout the water column at night.

Although the primary food of adult shad in the ocean is zooplankton, they also eat crustaceans, and small fishes (Wiess-Glanz, ***et a/.*** 1986:9). Predators take large numbers of American shad in both the river and ocean, Juvenile shad in rivers are eaten by juvenile bass ***(Morone saatilis),*** American eels ***(~nguilla rostrata)*** and birds (Wiess-Glanz ***et al.*** 1986:10).

American Eel

The American eel ***(Anguilla rostrata),*** also known as the yellow, silver, green, black, bronze, little, glass, and river eel (Van Den Avyle 1984:1), is a hardy species. It can be found in lakes, rivers, streams, and ocean habitats from Southern Greenland ail along the North American Atlantic coastline as far south as Panama. It is abundant from Maine to Mexico (Van Den Avyle 1984:1). The American eel can be found in warm fresh stream and/or brackish streams as well as cold mountain streams and landlocked ponds and lakes.

The American eel is classified as catadromous, spawning in salt water and spending its life primarily in rivers, lakes, and estuaries (Van Den Avyle 1984:4). Although the American eel is quite capable of living in open ocean levels of salinity during at least its first year of development (Van Den Avyle 1984:4), generally, once it has reached the "elver stage". the American eel is headed toward its freshwater home (Van Den Avyle 1984:4). Elvers are likely to be found moving into estuarine environments in New England waters in spring (Van Den Avyle 1984:4). They first inhabit brackish environs prior to moving up-river (Van Den Avyle 1984:7). However, it is unclear if this is a transitional "stage" or simply a natural consequence of having to enter brackish waters in order to reach rivers. Once there, the American eel will remain in the river system for 3-7+ years until it reaches maturity (Van Den Avyle 1984:12).

The American eel is believed to have a temperature tolerance range of approximately 6°C-300C with a preference for water temperatures in the 16°C range (Van Den Avyle 1984:12 citing Bari la and Stauffer 1980). It is noted that American eels will cease feeding at water temperatures below 14°C.

The American eel is nocturnal, and feeds at night. Its ".. diet is diverse, and generally includes nearly all types of aquatic fauna that occupy the same habitats. Eels in fresh water feed on insects, worms, crayfish and other crustatea, frogs, and fish.." ((Van Den Avyle 1984: 11).

Predators include Largemouth Bass ***(Micropterus sa!moides),*** Striped Bass ***(Morone saatilis),*** **"** ..other species of eels, ..gulls, bald eagles, and other fish eating birds." (Van Den Avyle 1984:12 citing Sihna and Jones 1967; Seymour 1974).

The data are ambiguous with regard to American eels' preferred freshwater habitat. However, studies suggest that small eels, less than 30cm in length, inhabit "..narrow, soft bottomed, upper ..creeks, whereas those longer than 30cm predominated in wider, ..lower creeks having mud and sand bottoms." (Van Den Avyle 1984: 13). They appear to inhabit relatively small areas of the stream/river and may in fact, establish territories (Van Den Avyie 1984: 13). Van Den Avyle notes that in study efforts, American eels rarely moved more than 100m from the point at which they were initially caught (1984: 13). Also, it is noteworthy that American eels will generally utilize the bottom habitat and the substrate itself for shelter and feeding. Of significant importance is the need of migrating elvers to have sofi, undisturbed bottom sediments for use as shelter (Van Den Avyle 1984: 13).

Beaver

The beaver ***(Castor canadensis) is,*** as most are aware, one of nature's most conspicuous overachievers. It has the natural propensi~ to build and maintain dams across virtually any stream it encounters in order to develop a pond in which to live. The effect of this dam/pond building is the natural development and enhancement of broad and complex environmental niches. Hilton outlines some of the benefits as follows:

> "The benefits [of dam building] come from the development of new vegetation and soil conditions. Low- growing shrubs appear around the new pond and serve as food for deer and small mammals; earthworms increase and provide food for woodcock; grouse (partridge) and many nongame birds feed on the fruit-and nut-bearing shrubs; raccoon, mink, and otter thrive on the fish and invertebrates; waterfowl are provided vital nesting and brood rearing sites." (1986:644)

An additional benefit is seen after a beaver colony ceases to utilize a specific area; dams fall into disrepair, the pond eventually drains, and "revitalized" land emerges (Hilton 1986:644).

Beavers generally adopt social structures defined by family groups; the male, weighing approximately 40 lbs, and female, weighing slightly less, will mate for life (Hilton 1986:644). These family groups are part of larger groups known as colonies. The young beaver, approximately two years old, tend to expand the colony by pairing during the summer and establishing a home in the fall (Hilton 1986:644). Their habits are to burrow into an existing bank and build a winter supply of brush nearby. In lieu of an existing pond, they may build a new dam and develop a pond of their own.

New family groups generally consist of a male, a female, and two "kits" or young. Breeding occurs during the winter, generally February, and the kits are born in May (Hilton 1986:645). At any given point, a fully developed group will be comprised of the male and female pair, several two year old or "yearlings" (individuals born the previous year), and the new kits (those born that spring). During the spring and summer, the male beaver, along with any yearlings in the group, will go out and actively forage, returning to the den infrequently (Hilton 1986:645). As fall begins, the male will return to his mate, begin harvesting food stuffs for the winter, and the "yearlings" will pair outside the group and form new groups (Hilton 1986:645).

Of greatest interest to this study is the beaver's diet. As the beaver eats tree bark and leaves exclusively, its diet is an excellent reflection of the terrestrial habitat available, Not only do they utilize trees and their stmcture for dam and den construction, but they also utilize the bark and leaves for food. Hilton (1986:645-6), in his brief review, notes that beavers generally utilize alders for construction because of their abundance near water, while other species are utiIized for food. He states that Aspen (Populus ***tremuloides)*** is the beaver's preferred food, using it almost exclusively when it is available. Although the beavers prefer aspen, they will utilize other hardwood species for food as well.

In a more thorough evaluation of beavers' diets, O'Brien studied several captured Maine specimens. His effort clearly illustrated a prioritization within hardwoods species. Ten species of trees, seen to be utilized by beaver, were given to the captive individuals. They included: Aspen ***(Populus tremuloides*** and ***Populus grandidentata),*** Willow ***(Salix*** sp.), White Birch ***(Betu/apapy~era),*** Gray Birch ***(Betula popul~olia),*** Red Maple (Acer ***rubrum),*** Balsam Fir ***(Abies balsamea),*** White Cedar ***(Thuja occidentals),*** and Hoary Alder ***(Alnus incana)*** (OBrien

1938:27). OBrien fed 10 pounds of each to the beavers every day (OBrian 1938:27). The beavers' eating habits resulted in a use pattern emerging in which

> "The beavers ate all of the aspen bark, leaves, and twigs that were placed in the pen daily. ..willows also seemed to be preferred.. White birch, gray birch and red maple were eaten to a SIight degree.. Alders were eaten by the animals to some extent, although not as much as had been expected. Balsam Fir and white cedar were not eaten at all." (OBrien 1938:28).

OBrien went on to quantify not only the tree species utilized and their frequency of use, but the size of those trees as well. He found that beavers "..rarely peel aspens of diameters greater than 4.5 inches, as they do not like the coarse, woody bark found at such diameters." (1938:39). A 4 inch diameter aspen equates to approximately a twenty year old tree and would be utilized in its entirety. Above 4-5 inches in diameter, waste becomes significant, reaching the 50% level (O'Brien 1938:39).

The inference from these data is that while old growth aspens will support beavers, a young, regenerative aspen stand is the ideal. O'Brien states it is his belief "..that at least two acres moderately stocked with poplar are required to support a pair of adult beavers for one year." (1938:39).

Muskrats

The muskrat ***(Ondatra zibethicus)*** is a small rnarnrnal in the rodent order. Adult muskrats, presumably both males and females, will measure approximately 20 inches in length and weight approximately 3 lbs. (Hunt 1986:739). The female will mate several times per year and produce as many as three litters of 4 to 8 kits each year (Hunt 1986: 739). Their life-span is fairly short. The muskrat is a territorial animal, though they do tend towards "semi-colonial" **groups** (Hunt 1986:740). Hunt notes that, "Disease, parasites, predators (mink primarily), intra-specific fighting and exploitation are the principal causes of mortality." (Hunt 1986:740).

Table 2. Muskrat habitat preference.

Early Spring: none, widespread wandering through the marsh environment.
Late Spring: heavy utili~tion of peripheral margins of the marsh concurrent with the development of lodges and birth of kits.
Summer: With water drawdown, or the drying up of floating type marsh, considerable movement will take place and will involve areas of deeper water and emergent plant forms. Otherwise, movement is stabilized and restricted to floating marsh areas containing potholes and shallow channels.
Fall: Relocation to deeper waters, 18 to 30 inches deep, and areas of heavy emergent plant forms. Winter houses are reutilized or newly constructed.
Winter: Same as fall.
(afier Coulter 1948:90).

Muskrat subsistence is based solely on aquatic vegetation. The primary food species are cattail ***(Typha latfolia),*** sweet flag ***(Acorus calamus),*** wild rice ***(Zizania aquatica),*** sedge (Carex ***Iacustris),*** and arrow leafs ***(Sagittaria latlfolia*** and S. ***cuneata)*** (Takes 1942:2). Thus, the muskrat has a well defined habitat need. It is restricted to marsh or associated peripheral areas. Primarily, it can be found in fresh or salt water marshes, ponds, or slow moving streams (Hunt 1986:739), but can also be found in any suitable body of water, such as ditches or canals (Hunt 1986:739). Although the general character of muskrat habitat can be qualified as being marsh, the reality is that marsh habitat and the needs of the muskrat are both more complex.

Generally, Coulter defines "marsh" to include: shallow marsh (floating mat underlain by rotting vegetation); shallow channels and potholes; and slow moving streams (generally moving through the marsh) (1948:4). Muskrat habitat can also be found adjacent to larger bodies of water such as ponds. Muskrats utilize these habitats seasonally and each tends to have a differing function. In early spring, there appears to be indiscriminate wandering by muskrats that is not confined to a specific habitat. However, by late April or May, females have begun to build and inhabit lodges; from May to August the kits are born (Coulter 1948:53).

The lodges are built along the outer periphery of the marsh area in association with small channels or potholes. (Coulter 1948:55). There is an apparent tendency, and or need, to build these structures on or among a firm footing, ofien a stump or "woody plants" (Coulter 1948:55). Coulter characterizes breeding habitat needs, based on observations, as including: "dense shrubby vegetation affording excellent cover..; potholes or channels where water was between 12 and 30 inches deep..; [and] well established lodges built on stumps, roots, stems of brush, or some other type of fairly stable support. " (1948:58).

During the summer, as water levels in the floating marsh decrease, muskrats tend to move further out toward the deeper water of ponds or lakes and into areas of emergent plants, i.e., pickerel weed, bulrush, and spike rush (Coulter 1948:66). Muskrats are sensitive to water height and will concentrate movement within 200-300 feet of their lodge, closer if possible (Coulter 1948:70). During the fall, muskrats begin their winter lodge development and relocate to wintering areas. With this movement comes an accompanying concentration of animals within a zone along deeper channels bordered by dense growth of submerged and emergent plants (Coulter 1948:71). Coulter notes a preference for areas with abundant emergent plant types, i.e., containing pickerel weed and bulrush, water 18-30 inches deep, and a narrow channel 5-8 feet deep (1948:72). This trend is also noted during the winter (1948:76).

Common Snapping Turtle

Turtles are cold-blooded reptiles. While this may not come as a surprise to most, it may be overlooked with regard to environmental reconstructions. As cold blooded animals, turtles rely solely on solar energy to meet their body temperature needs. It is this reality that makes them excellent environmental "thermometers". They remain active and become dormant within definable thermal limits, they need specific substrate requirements in order to hibernate, and they lay and bury their eggs. All these aspects of turtle behavior and biology act to define the environment in which they live, This section deals with the biological parameters of the common snapping turtle ***(Che/ydra serpentine serpentine).***

The common snapping turtle can be found in all of the eastern two-thirds of the United States and extreme southeastern Canada. This translates into a northern extreme of approximately 48° latitude and a western extreme of 105° It is currently the largest turtle found in the northeastern United States and southeastern Canada.

In captivity, the common snapping turtle has achieved a length in excess of 46cm and a weight greater than 39kg (861bs.) (Alderton 1988:112, 113). The average common snapping turtle in Maine weighs 7.7 - 9 kg (17-18 Ibs.). However, Maine specimens have been collected from the wild weighing 2 1.7kg (481bs.) and measuring 92cm (3ft.) in length from head to tip of tail (Coulter 1992:93).

While the common snapping turtle may be found in fast flowing rivers and streams, it generally prefers calm waters: lakes; shallow marshes; slow moving streams; and even brackish backwaters (Coulter 1992:94; Alderton 1988: 112). One reason for this preference is its feeding habits. The common snapping turtle is opportunistic, lying along the bottom or drifting on the surface waiting for prey (Coulter 1992:94). The common snapping turtle eats both plants and animals (Gorham 1970:14, Coulter 1992:94). Examination of Maine specimens revealed they contained yellow perch, white perch, minnows, suckers, bullheads, pickerel, and other fish. Snails, frogs, grebes, and ducklings provided variety in the diet (Coulter 1992:94). Additionally, cattail and pickerel weed were noted (Coulter 1992: 94).

Because the common snapping turtle relies on external sources to maintain its body temperature, the environment surrounding the animal can be reflected in its temperature needs. To begin with, all turtles have relatively specific temperature ranges within which they will continue to function; the highest extreme represents death for the individual, the lowest represents hibernation. For the common snapping turtle, the lowest temperature at which it can remain active is approximately 6°C. Below this, the turtle will commence a hibernation pattern (Alderton 1992:42). The common snapping turtle is active from May to October. At the point at which temperatures reach approximately 6“C. (43°F), the common snapping turtle submerges to the bottom of the pond, marsh, or stream and burrows into the soft, muddy bottom for the winter (Coulter 1992:94, Gorham 1970: 15). Although this action is often referred to as “hibernation”, this state is not true hibernation. Often, individuals will emerge to feed during the winter or enter this state during other times of the year if food is not plentiful (Alderton 1988:47, 48).

During their active period, spring through summer, the common snapping turtle mates and lays its eggs. Temperature is a critical factor in the development and production of both sperm and eggs. Although no specific data relating to the common snapping turtle has been seen, spermatogenesis generally begins with establishment of a high body temperature.

With regard to the females, the situation is reversed. Vitellogenesis, the development of follicles in the ovary (Alderton 1988:64), generally occurs in late summer and is completed either prior to hibernation or in the early spring just after hibernation (Alderton 1988:65, 66). During June, the female will leave the water and nest digging will commence (Coulter 1992:95), While studies are inconclusive, the female common snapping turtle appears to be site specific with regard to nesting (Coulter 1992:95) and may travel up to 16km (10 mi.), partly overland, to reach her nesting site (Alderton 1988:77). The eggs are laid in nests constructed of “.. gravel, sand, light loams,., or the decaying vegetation in a muskrat house.” (Coulter 1992:95). Gorham notes that eggs are usually laid on sandbars (1970: 14). There they will remain buried and incubate for approximately 3-4 months (Coulter 1992: 95). Nest temperatures in excess of 28°C. (82°F.) will result in producing female offspring, while nest temperatures between 22-28°C. (72-82°F.) will produce male offspring (Coulter 1992:95, Alderton 1988:83).

DISCUSSION

Although the faunal assemblages involved in this study are limited to a maximum of only 5 species, each species, through its habitat requirements and biological parameters, “reflects” one or more aspects of the environment in which it lived.

The dominant habitat represented by these assemblages is the marsh. While marshes are often produced naturally, it is noteworthy that the beaver, an “artificial” marsh builder, is present in the assemblages. It is strongly suggested that marsh habitat was actively being produced as a consequence of the beaver’s activities and biological directives, i.e., colonial expansion.

Given the rate of beaver and muskrat expansion, several family groups every one to two years in the ideal, it is suggested that over a period of a thousand plus years, the Early Holocene river valleys could easily have been at capacity or even overpopulated relative to these two animals. It is critical to note that beaver. muskrat, and common snapping turtle natural ly co-occur within marsh environments and, while not truly symbiotic, do share mutual benefits from each others’ presence. A diverse, and productive combination of streams, small channels, ponds, and marsh types are required to support muskrats and the common snapping turtle. In addition, these habitats provide them not only shelter but fulfill all their food requirements. Both the common snapping turtle and the muskrat utilize like plant species for food, eg., cattail and pickerel weed.

As a result of the beaver’s very specific subsistence requirements, it is concluded that river valleys in the Early Holocene had large expanses of hardwood growth, that included, but were not limited too, poplar, maple, willow, and alder.

The American shad clearly needs the existence of deep streams and rivers, of medium strength, in order to fulfil its spawning needs. As the shad is known to spawn throughout the water column and in channels as shallow as three feet, it is inferred that a fully developed river system, that began at the Gulf of Maine and ended well into the interior, was present (Based on a 3fi. per sec. flow rate, shad eggs will drift as much as 500 miles downstream prior to hatching.) The presence of American eel indicates the development of riverine sub-systems as well; shad and the eel are prey and predator. Like the marsh species, the shad and eel are not symbiotic. However, they co-occur in river systems and share overlapping habitats. Beyond simple riverine or terrestrial reconstructions, there also exists, within these three assemblages, the ability to define the general climate during the Early Holocene as well.

Based on the presence of the common snapping turtle, an animal totally dependent on solar energy to maintain its body temperature and hatch its young, the general statement can be made that during the early Holocene, from May to late August or September, the temperature ranged from 60-80°F. In addition, beaver and muskrat requirements indicate the period from September to November would have maintained cooler, but not freezing temperatures. This would have been followed by a winter of unknown degree. However, it is assumed that if a temperate climate existed during the majority of the year, it is unlikely that anything other than a temperate climate's winter would have prevailed.

Soon after ice out, possibly as early as late March/early April, temperatures would reach a range of 40-50°F and the hibernating snapping turtle, the bdge-bound beavers, and den-bound muskrats would begin to emerge.

Overall, the image of the Early Holocene environment that is produced using these species' biological parameters is one very similar to that which exists today. A mild spring, followed by a warm summer, receding into a temperate fall, and snow bound winter. Visually, the environment would have appeared as a temperate river drainage: mixed hardwood growth (coniferous species have not been ruled out); a main river channel; meandering streams; associated marshes and ponds, either natural or beaver produced; and abundant aquatic vegetation throughout the system.

Three additional conclusions can be drati from this effort, though full development of these topics is outside the scope of the paper. 1) The presence of anadromous and catadromous species suggests that the Gulf of Maine environment may have been more productive during the Early Holocene than previously suspected. Indeed, unless the biological parameters of shad and eel are to be completely dismissed, the implication is of a Gulf of Maine with water temperatures, and species, on the same order as today's. Robinson (1992:3) states that "if aquatic resources provided a critical focus of human exploitation . . . it is a focus that is no longer highly visible." While correct, future models of human adaptation must not overlook the nature of species' interrelationships and their capacity to define the environment in which humans existed. To do so critically limits our ability to develop models of ***potential*** human adaptations in the region. 2) Marsh habitat appears to have been of great significance to Early Holocene human subsistence suggesting that human adaptation in the Northeast was far from limited to large terrestrial mammals. Rather, included a reliance on fish and riverine-associated small- to medium-size mammals: a region-wide, broad-based and generalized subsistence economy. 3) The faunal assemblages cited herein most likely reflect spring through summer site utilization. And, these fauna] assemblages speak to an Early Holocene, warm weather, interior settlement pattern beginning to emerge from the archaeological record. Radiocarbon dates from across the region (Robinson 1992:26) appear to confirm the early region-wide nature of this adaptation.

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FIRE ON THE PLAINS: PALEO-EWIRONMENTAL DATA FROM THE HEDDEN SITE

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~TRODUCTION

This article is a companion piece to Spiess and Mosher (1993), which was published in the last Maine Archaeological Society ***Bulletin.***

Some of our goals during the 1993 excavation at the Hedden site were to increase our understanding of the geological context of the stone tool remains, and to test the deeper portions of the sand dune crest to determine whether stone tools were present there. Consequently, we spent much time examining the profiles of vertical exposures. In going uphill (south) from the Locus 1 stone tool concentration, our strategy was to excavate 1x2 meter testpits, at close intervals. The long axis of these testpits was oriented north-south (i.e., perpendicular to the sand dune crest) so that we could begin to examine the internal structure of the dune by observing microlayering, if present.

An early bonus of the work was confirmation of the hypothesis developed during the 1993 season that the Paleoindian material in Locus 1 was associated with a geological contact between an overlying eolian (windblown) dune sand with almost no gravel (designated C,), and underlying waterlain glacial outwash deposit composed of sand with a little gravel and few pebbles (designated C_z). The Paleoindian stone tools were "associated" with this contact there was a definite vertical concentration of pieces within 5 to 10 cm of the perceived geological contact. How did Paleoindian archaeological materials once lying on a glacial outwash surface come to be buried by an eolian dune? A brief review of the paleoenvironmental context is useful for answering this question, and providing background on Paleoindian occupation at the Hedden site.

HEDDEN SITE PALEOENVIRONMENT

Regional Paleoenvironmental Context

The environment in and around Maine at the time of the Hedden site occupation, circa 10,500 B.P. can be deduced from a variety of types of data: including oxygen isotope composition in ice cores from the Greenland and other ice sheets; underwater topography; sediment characteristics, diatoms (plankton), and isotope composition in sea cores; insect and vertebrate fossils, and plant pollen and plant macrofossils (leaves, needles, twigs, stems), among others. Some computer models have been designed to work with pollen data or geological data (such as the extent of ice sheets), to produce more detailed descriptions of past climates. Dates are almost always expressed in radiocarbon years B. P., although there is now a set of data available (based on radiocarbon measured in series of tree rings) for converting radiocarbon years into calendar years (Stuiver 1986). With the exception of presentation of both radiocarbon and calendar years scales on the accompanying ice core data, all the dates we discuss are radiocarbon years B.P., comparable (within the uncertainty or error associated with radiocarbon dates) to the radiocarbon dates for the Hedden site charcoal.

The latest ice core-based climate data for the North Atlantic, derived from Greenland ice cores, are shown in the accompanying figure (Figure 1). Two graphs measure the air temperature during the time of creation of the snow that fell on the Greenland ice sheet (and which was eventually turned to ice by pressure of further snow accumulation). The air temperature is measured indirectly by an oxygen isotope ratio: down on the graphs indicates colder conditions. The boiling and

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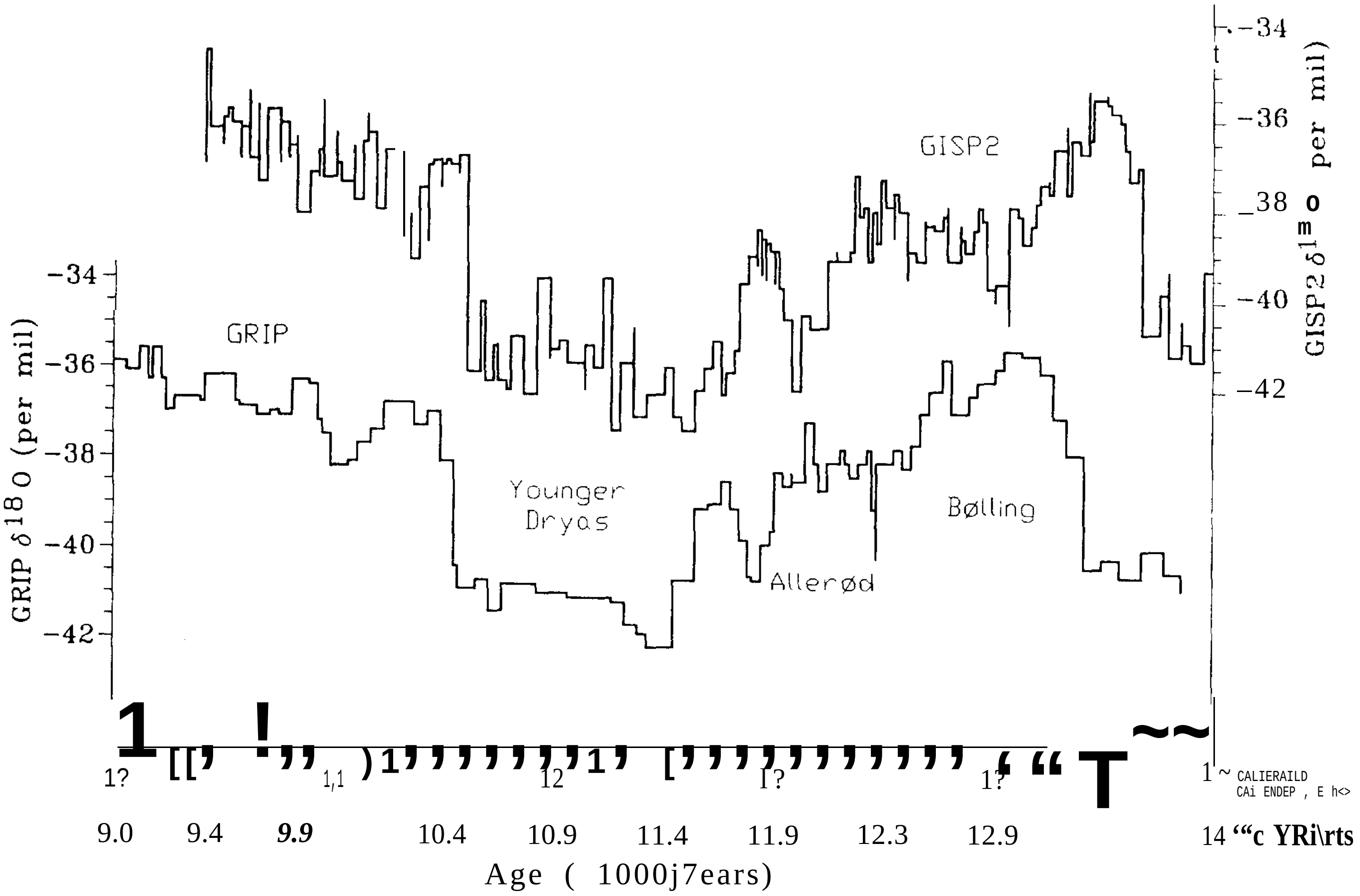
Figure 1. This pair of graphs contains the latest information on late glacial climate in the North Atlantic region, based on the Greenland ice sheet. Lower b ‘^{E}O values (i.e., greater negative numbers, down on the graph) indicate colder conditions for formation of the snowfall. Note the warm spells, named “BOlling” and “AllerOd” lasting from about 14,500 to about 13,000 calendar years ago. These two warmer spells were followed by a 1000 year long colder spell, named the “Younger Dryas.”

There are two time scales at the bottom of the figure. Bold type shows the radiocarbon chronology. All dates derived from radiocarbon dates can be referred to this scale. The lighter typeface shows an approximate calendar years conversion for the radiocarbon scale, based on various tree-ring and other calibration scales. Most fluted-point Paleoindian occupations in Maine probably date to the last half of the Younger Dryas cold spell, between 10,900 and 10,400 years B.P. on the radiocarbon scale.

Figure was redrawn at MHPC from the Greenland Ice Core Project (GNP) (S. J. Hohnsen et al., ***Nature*** 359:311, 1992), and the Greenland Ice Sheet Project 11 (GISP2) (K. C. Taylor et al., ***Nature361:*** 432(1993). (See also Dansgaard et al. 1982).



birds-eye perspective, the seashore retreated eastward, exposing land across what is now the Gulf of Maine, stopped for a short time, and then began its return movement inland that continues to this day.

Dating relative sea-level changes has been a complex task for geologists for the last three decades or so (Kelley et al 1992). At some point, as sea level rise caught up with and surpassed the rate of land rebound, there was a short period of relative stability, perhaps for a century of so. During that short period when the relative sea level was steady, marine erosion cut recognizable shoreline features which mark the maximum relative exposure of land under what is now the Gulf of Maine. Until recently, the maximum emergence for the central coast of Maine was placed at -65 m (ie. 65 meters underwater on the current coastal chart), and dated at 9200 B.P. by assumptions and a mathematical model (Oldale et al. 1993 with references). Relative sea level retreat in the Isles of Shoals area on the Maine-New Hampshire border definitely reached -55 to -60 m. Oldale et al. (1993) draw a relative sea level curve for northeast Massachusetts of about -45 m retreat, with maximum retreat dated just after 12,000 B.P. By 10,500 B.P. sea level had begun to rise rapidly, and was at about -35 m off Massachusetts. The most recent work off southern and central Maine (Kelley et al. 1992) has provided more bracketing dates for shorelines in the late glacial and early postglacial, and changed the reconstruction slightly. Land rebound (sea retreat) was rapid to a maximum of about -60 meters or so at about 11,000 years B.P. off the mouth of the Kennebec. Subsequent flooding also occurred extremely rapidly, with transgression (inland movement of the sea) probably underway by 10,620 B. P., based on a radiocarbon dated shell. By about 9100 B.P. sea level had risen to -21 m, and the rate of sea level rise had slowed considerably (Kelley et al. 1992).

There are several hints about the nature of the shoreline during the rapid regression and transgression that are relevant to our reconstruction. Sometime about 13,000 B. P., the transgressive sea in central Maine was no longer in direct contact with retreating ice. As land rebounded and the sea retreated a wedge of dry land opened between the sea and retreating ice, A” radiocarbon date of 11,550 B.P. on wood fragments from a core into sediment off Seguin Island indicates deposition in an estuary during sea level retreat (Kelley et al. 1992:32). The wood fragments also indicate that the land was vegetated somewhere upstream, probably nearby. Another core off Cape Elizabeth recovered a ***mya*** (soft-shelled clam) shell dated 10,620 B.P. in what Kelley et al. (1992:32) interpret as transgressive (sea level rising) sediments. Thus, by about 10,600 B. P., communities of soft-shelled clams existed in appropriate near-shore sediments as estuaries formed and rapidly moved inland.

A computer model of the climate conditions in the northwest Atlantic during the Younger Dryas provides more detail on what Maine may have been like (Rind et al. 1986). This model incorporates the fact that the Laurentide Ice Sheet still covered eastern Canada north of the St. Lawrence. It also incorporates the fact that the Earth's tilt and orbit around the sun provided 7°/0 more solar radiation to the latitude of Maine during the summer than it does today, and 7V0 less solar radiation during the winter. A cold and ice-choked North Atlantic, the Laurentide ice sheet, and the solar insolation difference combined to make winter land surface temperatures in the Maine area about 4°C colder on average than they are today. Summer surface air temperatures were between 0° (i.e. no change) and 2C colder than they are today. The model (Rind et al. 1986) predicts ***no change in merage surface wind direction or velociy compared with today,*** although there are some major changes in wind direction and speed elsewhere across North America and the North Atlantic. It seems, then, that summers were not that much different in temperature from our recent experience, but the winters were probably brutal. (See the following references for broader scale models and reconstructions: Bernabo and Webb [1977], CHOMAP Members [1988], Davis [1983], Kutzbach [1987], Ruddiman [1987], Webb [1987], and Webb et al.

[1987].)

Summer, of course, is the season when plants and insects flourish. The record of a fossil insect assemblage, recovered in fragments and identified to genus in some cases, allows recreation of a summer temperature of 66 to 68°F (19° to 20°C) at 10, 100M 150 B.P. at Mount St. Hillaire, just south of Montreal (Morgan 1987). Thus, summer in Maine and northern New England just afier the close of the Younger Dryas may have been quite warm, although not "hot" by modern standards. There are no comparable insect faunas from the Younger Dryas period.

Plant communities are reconstructed from fossil pollen (microfossils), and plant leaves, twigs, and seeds (macrofossils) found in deposits of appropriate age. Pollen data and plant macrofossils Is are extracted for analysis from cores generally taken from small freshwater ponds and bogs with small watersheds. This approach allows palynologists to "read" relatively local environments, and how they changed over time. There is some pollen transported by wind from long distances ("long-distance transport", mostly spruce and pine). Plant macrofossils (leaf and needle parts, stems and twigs) usually reflect local conditions and almost guarantee that the identified species were growing nearby. Pollen data are generated by counting individual grains on microscope slides. They are recorded level-by-level from a core, either in percentages of different taxa, and/or as pollen influx data. (Influx is calculated by taking a carefully measured amount of core material, then calculating how many pollen grains accumulated per square centimeter of pond surface per year.) Chronological control is provided by multiple radiocarbon dates derived from organic matter in the core sediment.

Interpretation of pollen assemblages (pollen from one level in the core) is done by comparing the pollen rain (relative percentages of taxa, influx rates) with modern samples obtained from all over North America. Thus, a pollen assemblage with certain percentages (for example < 100/0 non-arboreal pollen NAP), ie. flowers, grass and sedge) and certain influx rates (for example > 6500 grains/cm^2-yr [Davis et al 1979]) reflect a closed (i.e. dense) forest. The pattern of change over time in a pollen "diagram" for one core is inspected for times of rapid change and the characteristics of different "zones". Within the last couple of decades, as hundreds of well-dated pollen cores have become available for study, the patterns of vegetation change over time across vast areas of North America have been characterized and studied.

Because we are dealing with the end of the ice age in trying to understand the Hedden site environment, and because plant species immigration (mostly via seed transport by wind or animals) characterized the period, it is important to note that those who study pollen (palynologists) use several different methods of analysis to prove arrival of a species in the local area, as opposed to long-distance wind transport of pollen. Some (e.g. Gaudreau 1978) assume that exceeding a critical percentage (usually 1% or 5%, depending on how pollen-prolific the species is) indicates local plant species presence. Other palynologists study individual pollen diagrams and assume that the first rapid rise in pollen percentage or influx' indicates local arrival of a species. (The presence of macrofossils, as in the charcoal at the Hedden site, of course eliminates all argument about the existence of a particular species in a certain area.) There are also professional disagreements in terms of interpreting how much pollen is produced by an "open" (or woodland/parkland) association of trees versus "closed" (boreal forest), and what pollen percentages or influx levels indicate heavy tree cover.

Pollen studies at several lakes in southwestern New Brunswick (Mott 1975, 1977; Mott et al. 1986) show tundra before 11,000 B.P. Between 11,000 and 9500 B.P. a diverse woodland/forest, dominated by spruce, fir, larch, birch and poplar was present. Pine was very rare.

In the Berkshire hills of western Massachusetts, tundra had been replaced by open conifer woodland by 11,500 B. P., and by closed conifer forest by 10,500 B.P. (Whitehead. 1979). The species mix seems to have been dominated by spruce with a little pine at the beginning, changed by a smooth increase in pine from before 11,500 to 10,200 B.P. as measured by pollen influx rates. Early in the pine immigration the pine species seems to have been red pine, with an increase in white pine to a 50-50 mix about 10,000 B,P.

A pollen core from Gould Pond in Dexter, Maine (Anderson et al. 1992) records a sedge and herb tundra with some spruce between 11,300 and roughly 10,800 B.P. Between 10,800 and 10,500 B.P. there is an abrupt pollen percentage increase for tamarack ***(Larix),*** poplar/aspen, fir, birch, oak, pine and alder. Spruce pollen percentages decrease. White pine and tamarack macrofossils are present. A pine pollen maximum occurs after 10,500 B.P. Thus, at this location a change from patchy tundra spruce woodland mosaic to a cover of diverse tree species, probably in an open park/woodland, occurred approximately contemporary with the Hedden site occupation. The rate of change of pollen influx (and vegetation) around Gould Pond is calculated to be highest for the whole 12,000 years or so covered by the pollen core between 10,800 and 9,800 B.P. (Jacobson et al. 1987).

A pollen core from Moulton Pond in Bucksport, Maine (Bradstreet et al 1975, Davis et al. 1975) records a shrubby tundra between approximately 11,700 and approximately 10,500 B. P., with a subsequent change to forest-tundra mosaic or woodland. (The radiocarbon dates are not quite comparable to those marking similar changes at Gould Pond, indicating some caution in interpreting what, exactly, was happening at 10,500 B. P.) The authors (Bradstreet et al. 1975:458) speculate that the earliest postglacial forest may have been a mixture of spruce and white pine; a close parallel to the macrofossil evidence so far recovered from the Hedden site. Closed forest is characterized by less than 10% NAP (non-arboreal pollen), and pollen influx counts of greater than 6500 grains/cm-year (Davis et al 1979). The Moulton Pond core shows a less than 1000 year transition from tundra with 420 grains/cm^2-year to a conifer-hardwood forest with 18,650 grains/cm^2-year. A single sample from within this 1000 year interval is intermediate: 35°/0 NAP and 3000 grains/cm^2-year. Thus, the environmental change from shrub tundra to woodland to forest was comparatively rapid.

At Upper South Branch pond, near Baxter State Park, Anderson et al. (1986) divide the early portion of the record into Zone I (deglaciation to 10,500 B. P.) and Zone 11 (10,500 to 8800 B.P.). Zone I is a mixture of tundra and woodland, with ***Dryas*** (a small flowering herb) and other herbs, sedges, pine (mostly red pine), birch and spruce pollen. After 10,500 B.P. pollen influx increases dramatically, with white pine, birch, oak and ash primarily responsible for the increase. Spruce macrofossils are present about 10,200 B.P. These authors also quantified the charcoal in the core, representative of the frequency of local fires. Charcoal is uncommon until about 9700 B.P., when it increases dramatically. The increased amount of charcoal may represent a much greater amount of fuel available for burning, or drier conditions leading to more frequent fires. Doner (n.d.) shows a sedimentological change at Mud Pond and Conroy Pond in Maine, with an accompanying Younger Dryas-related vegetation change at Nud Pond between 10,000 and 11,000 B.P.

In sum, the vegetation cover of southern Maine about 10,500 B.P. was probably a tundra-woodland (an open, mixed species woodland and tundra mosaic), but the vegetation cover was rapidly moving toward closed forest. The forest had closed-in to the south and west (represented by the Berkshire) by this time, and it may have remained open for a few hundred years more in New Brunswick and Nova Scotia. There were probably also attitudinal delays in tree species immigration into western and northern Maine (Davis and Jacobson 1985).

Multiple pollen cores, and correlation between various species' pollen percentages and soil moisture, have been used to reconstruct soil moisture balance information for New England at 12,000 and 9,000 B.P. (Webb et al 1993). Although the relevant period (1 0,500 B. P.) falls midway between these two reconstructions, the data nonetheless demonstrate a relatively drier environment in the vicinity of the Hedden site than today. Today Maine is characterized by a relatively slow change in moisture balance (excess precipitation over evaporation) geographically across the state: 100 mm in northern Maine to 120 mm at the southwest tip of Maine/New Hampshire border. The Hedden site and the Kennebunk Plains today have about a 115 mm/year moisture balance (surplus). At 12,000 B,P. there was a very steep gradient from 60 mm soil moisture surplus in inland Maine, increasing southward to 80 to 90 mm. at the southwest tip of Maine. The Hedden site area was relatively dry (compared with today) at about 80 mm. By 9000 B.P. the pattern had changed to a rapid decrease from north to south, with about 100 mm. at the Hedden site location, again drier than today. Whatever the meteorological conditions at 10.500, and it is certain that they were changing rapidly on a scale of decades or centuries, it appears that the Hedden site area was generally drier (lower positive moisture balance) than it is today. The well-drained sandy soils of the Kennebunk Plains must have been general ly dry, indeed, during the period of the year when temperature was above freezing, (Seemingly, therefore, the stream channels near the Hedden site were either initially cut during the runoff of the ocean transgression, before 12,000 B. P., or well after the Paleoindian occupation.)

Local Reconstruction of the Hedden Site

The Hedden site occupation, radiocarbon dated at roughly 10,550 years, either falls at the end of the Younger Dryas cold period, or during the time of extraordinarily rapid climatic change to warmer postglacial conditions that occurred in the 200 years immediately afterward. Recent accelerator radiocarbon dates on pollen cores from Nova Scotia and New Brunswick record the effects of the Younger Dryas cold beginning between 10,930 and 10,640 B. P., and ending between 10,120 and 9930 B.P. (Mayle et al. 1993). These dates are significantly later than the estimated dates derived from the Greenland ice cores, and indicate that the Hedden site occupation probably occurred during the local effects of the Younger Dryas climate change.

We don't really know what was happening to the Gulf of Maine shoreline during occupation of the Hedden site circa 10,500 B.P. It is likely that the seashore had just passed its furthermost retreat out into the Gulf of Maine, at a depth now under about 40 to 60 meters of water. The shoreline was 2 to 5 miles further out to sea than it is today, but the adjacent Gulf of Maine was cold and ice-choked for most of the year. The near-shore land had been vegetated with at least some woody plant species for about 1000 years, and communities of clams had established themselves in estuaries. However, the shoreline was transgressing very rapidly, and local sea level was in the process of rising 30 to 40 meters over roughly 1500 years (about 2 cm/year, or 1 meter in a 50-year lifetime)..

The Hedden site, and all other Paleoindian sites in Maine dating between 11,000 and 10,000 B,P. were part of a rapidly changing vegetational scene, with a general decrease in tree cover toward the north and higher in elevation at any one time. Paieoindians living in, or passing through, Maine at the time somehow lived in an "ecotone", or variable boundary between closed forest and tundra/woodland.

Hedden Site Landscape Development

The Hedden site lies buried by a wind-blown (eolian) sand dune. General eolian processes have been presented in a classic text by Bagnold (1941) and recently summarized by Greeley and Iverson (1987). In northeastern North America, sizeable eolian areas are largely restricted to either coastal or "fossil" glacial contexts that boast an abundant sand supply but limited vegetation cover (Katz 1 990). For example, Katz (1990) maps the distribution of a number of environmentally sensitive eolian landscapes in Maine at both coastal and interior contexts. Our review of eolian contexts concentrates on interior eolian areas that may serve as Hedden site analogs with respect to geographic extent, landforrn morphology (and stratigraphy), source material, or formation chronology.

Studies on interior northern North American eolian landscapes are relatively rare. David (1988) examined eolian deposits in the central St. Lawrence Lowlands of Quebec. McKeon (1989, 1972) conducted a detailed investigation of eolian deposits along the Kennebec River near Madison, Maine. Balogh and Gordon (1987) summarize the association of the Paleoindian Michaud site with an eolian landscape near Auburn, Maine.

McKeon (1989) cautions that many terms for eolian Iandforms currently in vogue have developed out of work in modern, warm desert regions. Periglacial eolian deposits are casually mentioned in Embleton and King (1968), and a more thorough bibliography of periglacial eolian features can be found in Neissen and Koster (1984). Koster (1982) refers to eolian ridges under five meters as "undulations". and those over five meters as "dunes". McKeon (1989) contends that the rugged topography (and scale of dune area) is much different than those studied by Koster (1982), and therefore used the term dune to include both types of deposits without reference to height. This study follows the more local example of McKeon (1989) in referring to constructional eolian landforms in the project area as dunes rather than undulations.

It is important to examine each individual dune or dune field carefully, as Flint (1971 :26) cautions that many erroneous interpretations of transverse dunes as longitudinal dunes have beset North American geology. Determination of dune form and paleo~wind direction (i.e. transverse or longitudinal dune orientation to the wind) is usually based on external geomorphology of the dune, internal structures such as foreset dip, relationship to similar dune forms, ventifacts or bedrock striae, or positions of dunes with respect to source material.

David (1988) reports parabolic (simple and elongated) and complex dune forms in the St. Lawrence Lowlands. McKeon (1989, 1972) found longitudinal dunes, wind-shadow dunes, and blanket sands in the Anson, Maine area. Dune forms commonly found in Maine include barchan. barchanoid ridge, transverse ridge, and linear (seif or longitudinal) (Katz 1990). Balogh and Gordon (1987) note the presence of both transverse and longitudinal dunes in the Kennebec and Androscoggin River valleys, but neither Balogh and Gordon (1987) nor Spiess and Wilson (1987:15) attempt to formally classify dune morphology at Michaud; although the latter comment that eolian landforms consisted of "low dune forms with shallow troughs between them. "

Except for McKeon (1989) these cited studies relied primarily on external morphology to classify dunes. Even McKeon had few exposures of internal dune stratigraphy to view, and largely extrapolated paleo-wind directions from surficial morphology. In those dunes where exposures were naturally present, he observed a dominance of tabular bedded or structureless deposits with only a single case of trough cross-bedding (dipping along the dune axis). McKeon also confirmed paleowind directions by contrasting positions of many dune forms, examining ventifacts and bedrock striae, and assessing positions of dunes with respect to source material.

Source material for eolian periglacial sand deposits in Maine is usually attributed to the Embden (upper Presumpscot) Formation (Bloom 1960, Borns and Hagar 1965, McKeon 1989). McKeon (1989) painstakingly compared the sedimentology of eolian deposits in his Kennebec study area to Late Wisconsin till, the fine-grained Presumpscot Formation, and the coarse-grained Embden Formation, before demonstrating that eolian sands were derived from the latter (despite local presence of dunes resting on till surfaces).

Quarternary dune formation chronology in Maine (or northeastern North America) has not received definitive attention. Based on morphology, David (1988) demonstrates dune formation chronologies ranging from late Pleistocene (coeval with Champlain sea occupation of the St. Lawrence Lowlands) into the early Holocene, but comments on some culturally-induced reactivation of dunes during the historic period. Although Bloom (1960) postulated that much of the eolian sand movement in Maine occurred in response to historic period agricultural and timbering deforestation, many later researchers have concurred that most inland Maine dunes are fossilized peri-glacial Iandforms (Balogh and Gordon 1987; Bores and Hagar 1965; Borns et al. 198 1; Katz 1990; and McKeon 1989, 1972). Postglacial dunes in the Androscoggin and Kennebec River valleys were ostensibly formed during strong, prevailing west-northwest winds between 12,900 and 12,200 B.P. Some historic period reactivation of dunes due to deforestation or mechanized disturbance leading to loss of surface vegetation, deflation depressions, and minor dune building has been noted (Balogh and Gordon 1987, McKeon 1972). In particular, Paleoindian occupation of stable dune surfaces at Michaud (Spiess and Wilson 1987) was exposed by historic period eoiian activity related to mechanized disturbance.

Several kinds of inferential evidence were brought to bear on the issue of inland dune formation chronology by previous researchers. Many Quatemary scientists contend that large-scale dune building episodes require strong winds: most researchers rely on periglacial winds coeval with subaerial outwash construction for an explanation of active eolian episodes. Paleoenvironmental reconstructions (e.g. Davis and Jacobson 1985) usually model freshly exposed outwash and eolian surfaces in the northeast becoming quickly stabilized by rapid vegetation migration (Balogh and Gordon 1987, Bloom 1960, McKeon 1972). Michaud site occupation of dunecrests attests to a stable (vegetated) dune (Spiess and Wilson 1987). McKeon (1989) suggests that dunes in the Kennebec basin were stabilized by vegetation by 12,600 B.P. A similar park woodland forest cover existed in the Kennebunk region before the end of the Pleistocene.

In addition, many researchers cite examples of such stabilized surfaces in the northeast and other regions on which soils developed relatively quickly (e.g., Balogh and Gordon 1987), and contend that if later eolian activity remobilized sands, any buried paleosols would be ***easily*** recognized. In particular, McKeon (1972) cites lack of soil development under dunes as evidence for stabilization of dunes during the late glacial. Thus, presence of a stable dune was taken as a given factor during the first seasons of Hedden site investigation (Spiess and Hedden 1990:9). Callum (1993) counters arguments that the stable surface would have developed a recognizable soil profile with the cautionary note that such a surface might not have existed under a suitable climatic regime, that the surface might have only been briefly stable, or that evidence for a paleosol may be difficult to perceive.

Undoubtedly, many of the interior Maine eolian areas did form as a result of the Wisconsin glaciation. However, recent arguments concerning whether intensification of eolian activity in Alaska was related to the Younger Dryas cooling interval (e.g. Bigelow et al 1990; cf. Waythomas and Kaufman 1991) demonstrates that this issue deserves recognizance in northeast North America. Another study in Alaska (Lea and Waythomas 1989) proposed that many surfaces formerly taken to be subaqueosly deposited actually aggraded as eolian sand sheets during the Wisconsin glaciation, and associated prominent surface dunes may have originated subsequently (and therefore do not necessarily reflect full glacial wind conditions). Frink (1993) has employed oxidizable carbon ratio (OCR) dates to argue that (presumably natural) fire episodes were a cyclical process that maintained the pine-oak forests on excessively well-drained (e.g., Adams-Windsor soil association), sandy outwash (or eolian) surfaces in the Northeast. Cyclical fire episodes throughout the Holocene would have cleared sizeable areas of vegetation and promoted periodic sand reactivation.

Eolian reactivation due to deforestation and agricultural use of New England eolian landscapes during the historic period is well-documented (Bloom 1960; Katz 1990); indeed, many early 1900’s reforestation programs date to the recognition of dune reactivation as a problem (e.g., Sobourin and Goldsmith 1986). Initial eolian construction of dunes, or subsequent eolian reactivation of fossilized dunes in Maine may have taken place at any interval during the late Quarternary period. In particular, reactivation of existing

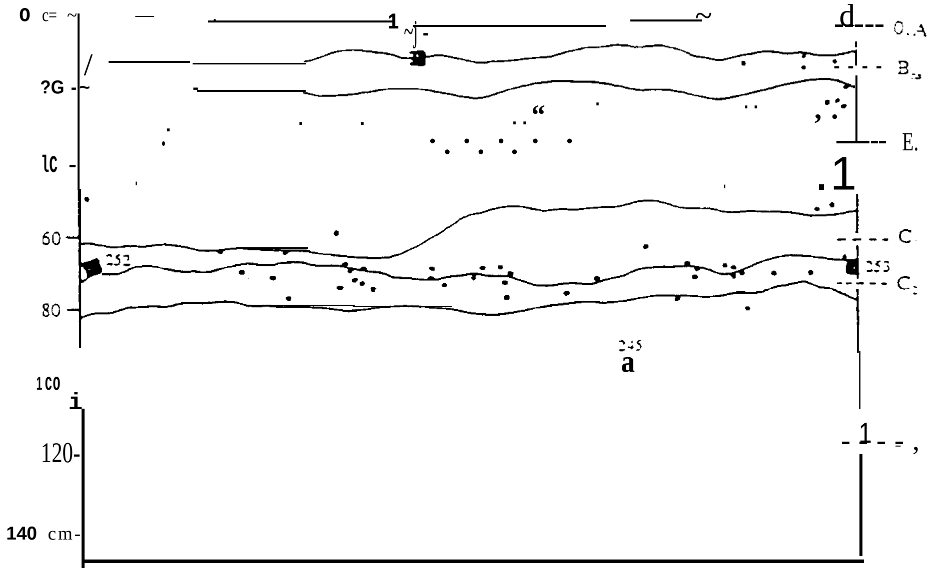


Figure 2. Vertical distribution of flakes and artifacts "projected" onto a soil profile in the excavation area. There is a fairly clear bimodal distribution, with the lower concentration of artifacts associated with the C_1/C_2 interface. Based on 1992 data.

fossilized dunes could have arisen due to loss of vegetational cover, lowering of watertables, or an increase in wind intensity. Any of these occurrences leading to dune construction may have been either local (e.g. fire) or regional (e.g., Younger Dryas climatic change) in scope.

SOILS AND GEOLOGICAL CONTEXT

Vertical Distribution

In Locus 1 at the Hedden site, tools and flakes were unevenly distributed in over 1 meter of sand with the heaviest concentration of artifacts, roughly 330 in all, found between 60 and 80 cm below datum. A second more shallowly buried concentration appears between 25 and 45 cm below datum (Figure 2). This second concentration has a total of 185 tools and flakes. This vertical distribution of artifacts in the sandy soil is indeed bimodal (two frequency peaks), but there is no difference between the peaks in artifact average weights or dimensions, even when corrected by removal of the largest pieces; nor is there a difference in vertical distribution of raw materials as represented in the debitage. Moreover, as discussed above, there are multiple refits of pieces of broken tools that tie both the upper and lower vertical concentrations of artifacts together. It is obvious that the upper and lower concentrations were somehow derived from the ***same original, homogeneous*** artifact assemblage.

In search for a physical mechanism that might have forced such a distribution, we initially thought of eolian sand redeposition. Spiess has seen many examples of eolian "blowout" and redeposition of archaeological sites in Labrador. If eolian redeposition were a primary cause, we would expect some vertical or horizontal sorting of artifacts by size and weight, as smaller pieees get blown firther by a wind. Such a separation is not evident in our data. We then looked for eolian abrasion or "sand-blasting" wear on artifacts. Only five of nearly 810 artifacts show any sign of "sand-blasting".

That only five artifacts out of more than 800 are "sand blasted" suggests that Locus 1 was quickly, and possibly repeatedly, buried. Importantly, each of these eolian abraded specimens was distributed in the midst of the shallowly buried upper concentration between 20 and 40 cm below modem ground surface.

Some wind transport of artifacts did demonstrably occur at Locus 1 where the eoloian deposit is about 1.8 meters deep. In three testpits dug into the dune crest 8 pieces of debitage were recovered from as far as 30 meters south of Locus 1. The depth of some of these finds is equally suggestive. In testpit N130 El 00, a microflake was recovered from level 26 or 1.3 meters below ground surface. In N142 El 100 one microflake was found in level 28, which is some 1.4 meters below the top of the excavation, and another from the same pit was found in level 19 between 90 and 95 cm below ground surface. In each case, the microflakes are located well within the "Cl " horizon. The rest of the artifacts were found in levels associated with the upper distribution between 20 and 40 cm below ground surface or just below it.

Thus, there is no evidence of wind sorting, and only minimal evidence of exposure of the artifacts on a bare surface. Importantly, all five such examples of "sandblasting" appear in the upper vertical concentration, which means that part of the vertical separation involved some exposure on the surface of the ground.

One possibility for the physical mechanism causing this vertical movement and separation is "tree throw", the tipping and vertical sorting of soil around the roots of very large trees when they are blown over. Such tipping usually results in fomation of a broad and shallow, devegetated crater of soil, into which the soil held in the roots slowly falls, or is washed in. Evidence of tree throws occurring sometime in the past at the Hedden site can be seen in the south wall profile of N 164 E98 (see below). In this square a good 2 cubic meters of soil was "tipped over" and redeposited. Other wall profiles along the E1OO line indicate that pockets of disturbed soils, some of them quite large, are numerous, These disturbed areas could be attributed to a number of natural processes that are observable at the Hedden site today. These include the burrowing of rodents and the burning of tree roots to form craters that subsequently get filled by soil (see below).

Another physical mechanism that might have caused the physical separation into two overlapping vertical levels is downslope soil creep. This mechanism is likewise operating on the northern side of the Hedden site dune today (Figure 3). This soil creep appears to occur in highly localized patches on the downslope of the dune, during the spring thaw when the surface soil layer is saturated and the underlying soil is still frozen. To test this hypothesis, *in situ* artifacts were computer plotted in 10 cm increments, and total counts of artifacts were graphed per 1 meter quad south to north. The results of these analyses indicate that a combination of horizontal and vertical displacement, which might be expected with soil creep, was not a critical factor in site formation - at least in terms of redistributing artifacts.

Local Geomorphology

The Hedden site is associated with a linear eolian Iandform, a probable longitudinal dune, that rests uncomfortably upon the glacial outwash comprising the Kennebunk Plains. Previous researchers studying the area either did not note the presence of linear eolian landforms on the' Kennebunk Plains, or misclassified them as glacial moraines. Burial of Paleoindian archaeological materials and the existence of early Holocene or terminal Pleistocene radiocarbon dates associated with the occupation surface attest to large-scale eolian reactivation sometime around 10,500 B .P. Despite the presence of a Paleoindian occupation on the outwash surface, it appears that either this paleo-surface did not exist under a suitable climatic regime for soil formation, or it was not stable long enough for a soil to develop (Callum 1993), because there is no evidence marking an associated paleosol.

During the initial archaeological research at the Hedden site, it was assumed that large Maine dunes have remained relatively stable since the late Pleistocene (McKeon 1989; Spiess and Hedden 1990; e.g., Spiess and Wilson 1987) unless reactivated by historic burning, clearing, or plowing.

Figure 3. Solitluction feature on the north side ofthe Hedden site dune, abou{ 50rri northeast of N 104E 100. When photographed on 9.28.92, the feature was dry and inactive

Research on initial inland peri-glacial context colian Iandforms in the St,, Lawrence drainage (David 1988) and Alaska (lea and Waythornas 1989) has recognized multiple periods of dune formation and reactivation, There has been some discussion on whether the Younger [>~as in Alaska is marked by increased eo]ian activity (Bigelo\\ et al. 1990: cf. Waythomas and Kaufman 199 I). Hedden site context and chronollgy may spur reevaluation of what comprises typical dune bebavior in Maine during the late Pleistocene and Rarly Holocene (Callum I 993).

The Kennebunk Plains consist of Pleistocene outwash deltaic sediments. Slnith (1977) noted that such outwash plains are "usually flat, and deepty dissected by more recent drainage patterns. " ()0 reconnaissance-level maps of the Kennebunk 15' Quadrangle surficial geology, Smith (1977) designated the Kennebunk Plains arezt in which the site is located as "Qgo". "flat outwash deposits comprised of sand and gravel, possessing high pertneability and good drainage. " on more detail led surficial geological maps of the Kennebunk and Alfred 7.5' Quadrangle maps, Smith (1990) mapped the Kennebunk Plains as "Pmdo", or a marine delta comprised of coarse sand and gravel grading to sand and silt.

The deltaic head (marked by "Prndi" or kettled areas) lies further inland on the A Ifred Quadrangle, The distal portions of the delta grade into glacial marine deposits and lie further to the southeast. Smith (1990:4) notes that "these [deltaic] sediments were deposited by glacial meltwater streams in a preglacial setting as the ice retreated and sea-level fell. " Smith and Hunter's (1989) idealized stratigraphic section consists of (in successive order): till, ice-contact stratified drifit, subaqueous outwash, silt and clay of the marine Presumpscot formation, and subaerial outwash. Flewelling and Lisante (1982) confirm designation of the Kennebunk Plains as glacial outwash by mapping the area as Adams loamy sand, a soil series usually associated with deltas and outwash plains. Smith and Hunter (1989) further note that the fine sand, silt, and clay of the Presumpscot formation grades upward to a fine sand that has been locally subjected to eolian activity. The coarse upper (subaerially deposited) section of the Presumpscot Formation is also referred to as the Embden Formation (McKeon 1972).

No eolian deposits have been officially mapped in the vicinity of the Hedden site. However, Smith (1977) initially showed a series of glacial end moraines parallel to the Day Brook drainage in the area. At that time Smith may have been working primarily from aerial photography (Woodrow Thompson, personal communication). In the more detailed maps, Smith (1990) depicted the area as homogeneous marine delta. Flewelling and Lisante (1982: 12) also distinguish between Adams soils with O-8 % slopes (AdC) often occurring toward the edges of deltas but including some areas "which are irregular in shape, and some are elongated. " These latter areas may signal potential dune forms.

Elevations on the Kennebunk Plains near the study area range from approximately 80' (just to the north at the Mousam River) to 230' (along Route 99) above sea level. Average Kennebunk Plains elevations span 190' to 200', with lower elevations resulting from drainage incising. Embden Formation sands on the Kennebunk Plains are underlain by the finer-grained Presumpscot Formation, therefore fluvial dissection has created characteristic steep-sided, flat-bottomed valleys.

Besides fluvial dissection, the flat Kennebunk Plains topography has also been influenced by eolian activity. Two "scales" of eolian features are visible in the study area: prominent linear ridges, and shallow depressions accompanied by low hummocks. The Hedden archaeological site is associated with a linear ridge over 1.1 miles in length, 10-20' in height, with a trend of 103°-2830 (WNW-ESE). The total ridge height is accentuated near the Hedden site due to incising of parallel trending drainages nearby. The trend of this linear ridge bends slightly, to 94°-2740 approximately 0.4 miles WNW of the site. A second, perhaps formerly contiguous, linear ridge lies just north of Route 99, Due to road and residential construction near the intersection of Route 99 with the McGuire Road, any potential former continuity between the two features can not be conclusively traced. The Route 99 linear ridge is over 0.6 miles in length, up to 10' in height, and trends 80°-2600. Both ridges have crests ranging from sharply defined, to broad and sometimes bifurcating. The ridge crest at the Hedden site is 10-15 m in width, while the Route 99 ridge varies from 6 to 20 m in width. The Hedden site ridge is asymmetrical, with a gentle slope on the northern side. and steep on the south side (adjacent to an unnamed dry stream). This asymmetrical surficial morphology may result from either primary depositional (eolian) processes or from secondary fluvial incision. In contrast, the Route 99 ridge is clearly symmetrical in form.

Shallow depressions and low hummocks are also characteristic of the Kennebunk Plains. Elevation of these features varies less than 5'. Erosional depressions are evidenced by the deflationary accumulation of relatively minor amounts of pebble lag (desert pavement). The small depressions and constructional hummocks are generally amorphous in form and are less than 20 to 40' in diameter.

Examination of Kennebunk Plains stratigraphy at a commercial excavation on the north side of the Route 99 linear ridge revealed a characteristic cross-bedded deltaic section (Figures 4 and 5). Strata included trough cross-bedded coarse sands with a gravel lag deposit at the base; well sorted, massive fine sands with ball and pillow soft

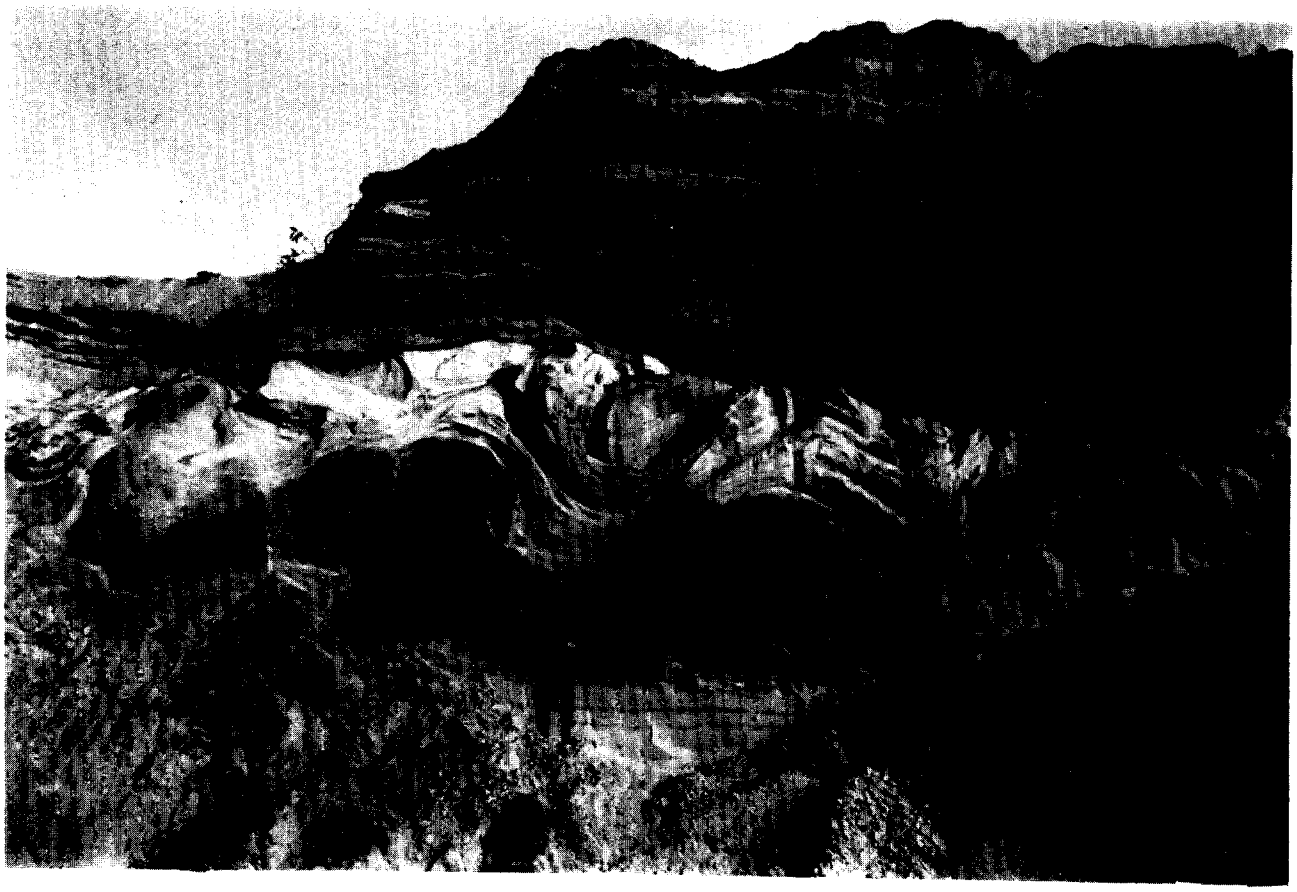


Figure 4. Cross-bedded deltaic section in a commercial borrow pit north of Route 99. Stratigraphy is interpreted in Figure 6 schematic profile. This photograph shows the upper 3/4 of the Figure 5 profile.

sediment dewatering structures and planar coarse sands, A well-developed Spodosol consisting of typical dark A horizon, light E and a reddish B horizon extended to 30 cm from the surface.

A systematic search of the Kennebunk Plains revealed little bedrock (or bouldery till) on which striated, eolian abraded surfaces could have occurred. In contrast with an hypothesis espoused by McKeon (1972) for the Madison area, although archaeological excavations exposed wind abraded artifacts, these artifacts were not ventifacted (faceted). Thus, data sets other than dune morphology could not be used to investigate paleo-wind directions. Further assessment of Kennebunk Plains paleo-wind directions awaits detailed topographic mapping of a great number of dunes. including the low-relief forms. A lack of desert pavement on the Kennebunk Plains is presumed to indicat scarcity of coarse fragments from deltaic sediments. rather than a *priori* formation of dunes during deltaic construction.

Likewise, the timing of fluvial incision on the Kennebunk Plains can not be ascertained. The existence of currently dry drainages (e.g., dry tributary parallel to the longitudinal dune) and somewhat underfit deep dtainages suggest that the fluvial incision occurred during a somewhat wetter climate than our current one, and is therefore unrelated to eolian activity on the Kennebunk Plains, Thus, it is possible that the eolian activity coincident with the Younger Dryas predates fluvial incision of adjacent drainages.

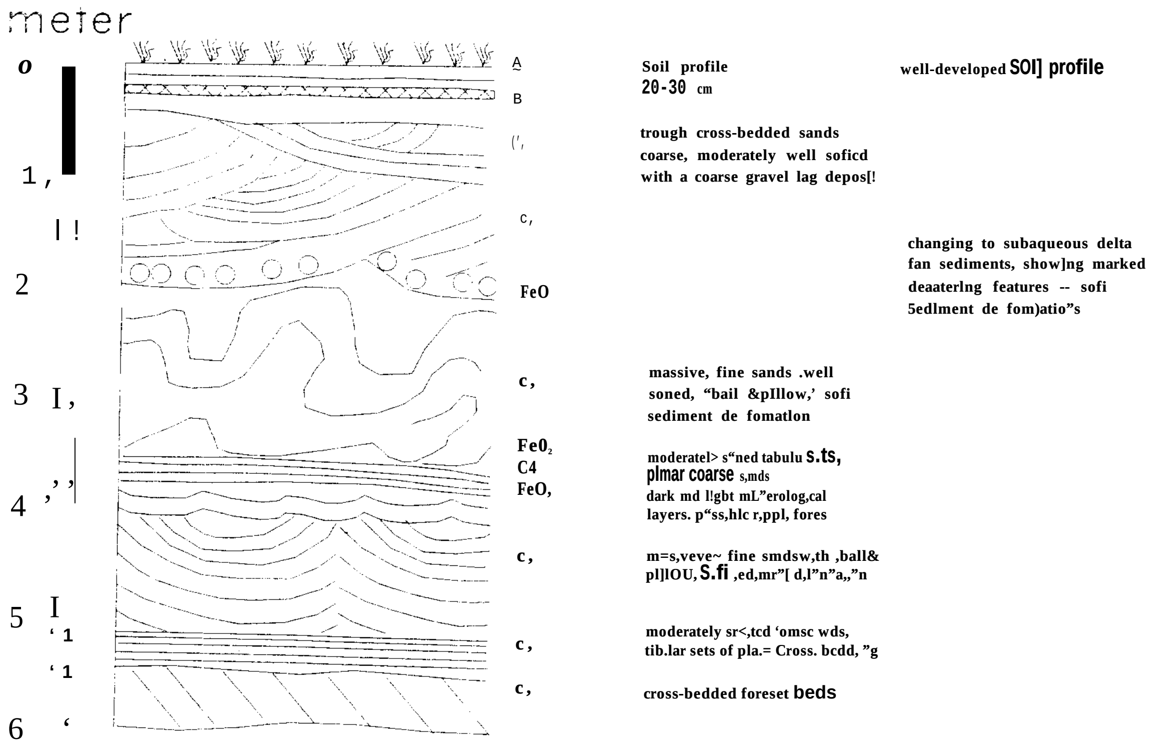


Figure 5. Schematic profile of the borrow pit north of Route 99. Compare photo in Figure 4.

Soils and Sedimentology

During the 1993 field season, complete soil columns from test pit NI42E100 and from square N 168E 100 were removed for geochemical and sedimentological study. Samples were removed in 5 cm increments to the base of the excavation and placed in gallon-size plastic bags with provenience information recorded on the outside of the bag. The volume of each sample was approximately 750 ml. Samples were also saved from bucket auger tests beneath the excavation “floor.” Soils were allowed to air dry in the laboratory prior to analysis.

Since the focus of this study was to differentiate between glacial outwash and eolian regimes (sand dunes), we decided to devote the majority of our laboratory processing efforts on “C” horizon sediments from both on and off-site sources. (“On site” refers to Locus 1 excavation squares and 1x2 test units dug into the dune just south of Locus 1. “Off-site” refers to remote 1x 1 m testpits and auger tests dug elsewhere around the Kennebunk Plains.) We reduced the sample size so that we could concentrate specifically on the off-site samples first, then the column soils from 50-95 cm below ground surface in N 142E 100, followed by the auger samples. and finally with samples from 15 cm intervals below 95 cm.

Grain size analysis methods follow Folk (1980). Approximately 100 grams of soil were removed from each of the sample bags for sedimentological study. These 100 gram samples were placed in beakers or Nalgene bottles to which a solution of 50°/0 commercial chlorox bleach and 50% distilled water was added. The solution covered the sediments generously. Any organic material in each sample was then oxidized in one of two ways - either in a 40° C drying oven over night, or boiled on a hot plate for an hour or so. Surface liquid was decanted and the sediments were washed with disti I led water, decanted, and allowed to air dry.

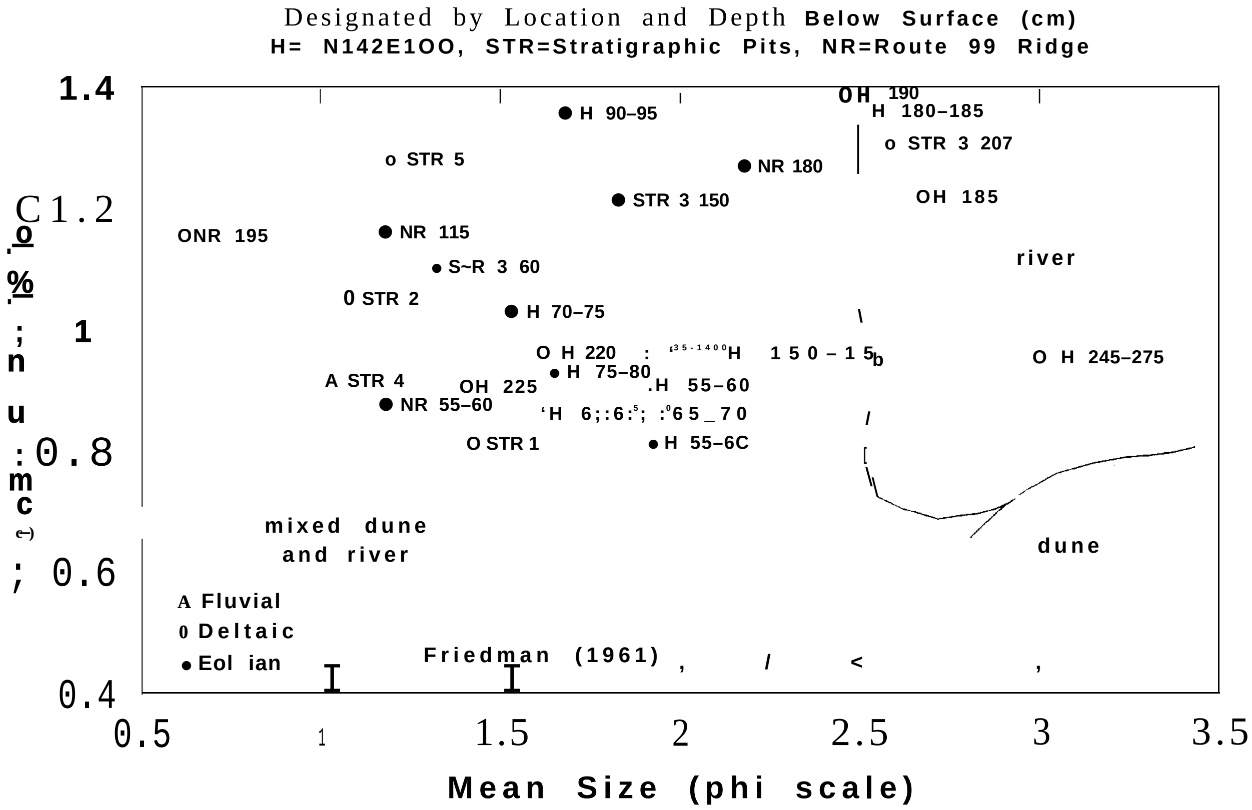


Figure 6. Standard deviation (variability) versus mean size of sand grains in fluvial (river), deltaic (outwash) and eolian (dune) sands.

At the Sedimentology Laboratory at USM Gorham, each sample was weighed to the second decimal place and recorded on a standard form. Next, samples were dry sieved in 1/4 phi intervals on a ROTAP shaker for 15 minutes. Weights for each sieve were determined to the second decimal place and recorded, and all soil was returned to its proper bag for future analysis.

A plot of mean grain size versus skewness can allow delineation between eolian dune sand and alluvial beach sand (Friedman 1961). Such studies suggest that although dune sand can not be as readily distinguished from river (fluvial) sand, a plot of mean size versus standard deviation (Figure 6) can assist with such differentiation (Friedman 1961, Moila and Weiser 1968). On the basis of the mean size versus skewness, it is difficult to specify whether Kennebunk Plains samples were of eolian or fluvial origin. A plot of mean size versus skewness (Figure 7) demonstrates that most of the probable eolian samples are more finely-skewed than the probable deltaic sediments. These statistics lend support to the hypothesis that the linear ridge sand deposits on the Kennebunk Plains are indeed of eolian origin. The analyses closely compare to results obtained by McKeon (1972:66-67) using similar plots.

A transect perpendicular to the linear ridge at the Hedden site allowed interpretation of Kennebunk Plains surficial stratigraphy. Off-site stratigraphic pits (Figure 8) were excavated with a shovel to depths of approximately 1 m, sediments screened through 1/4” (6 mm) mesh (all negative for archaeological material), and then augered to an additional depth of 1.6 m.

Due to the potential for encountering laterally

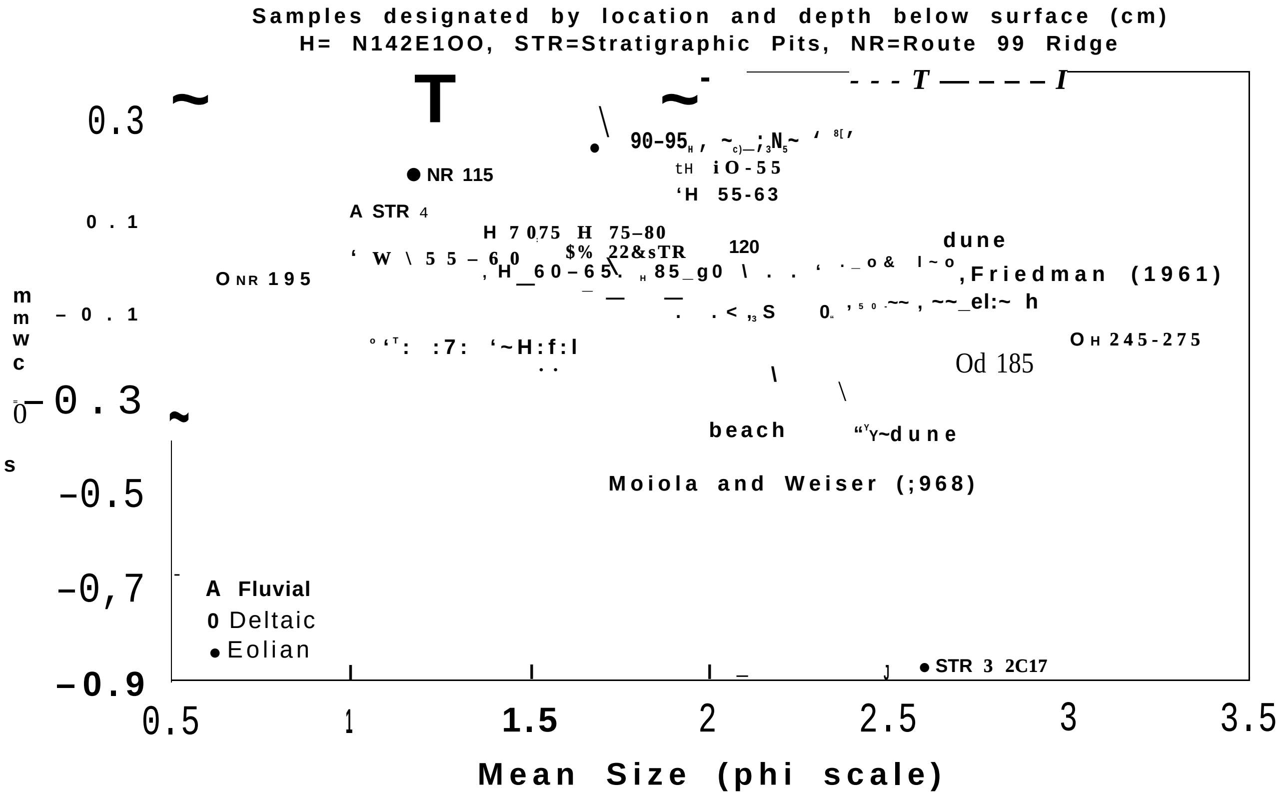
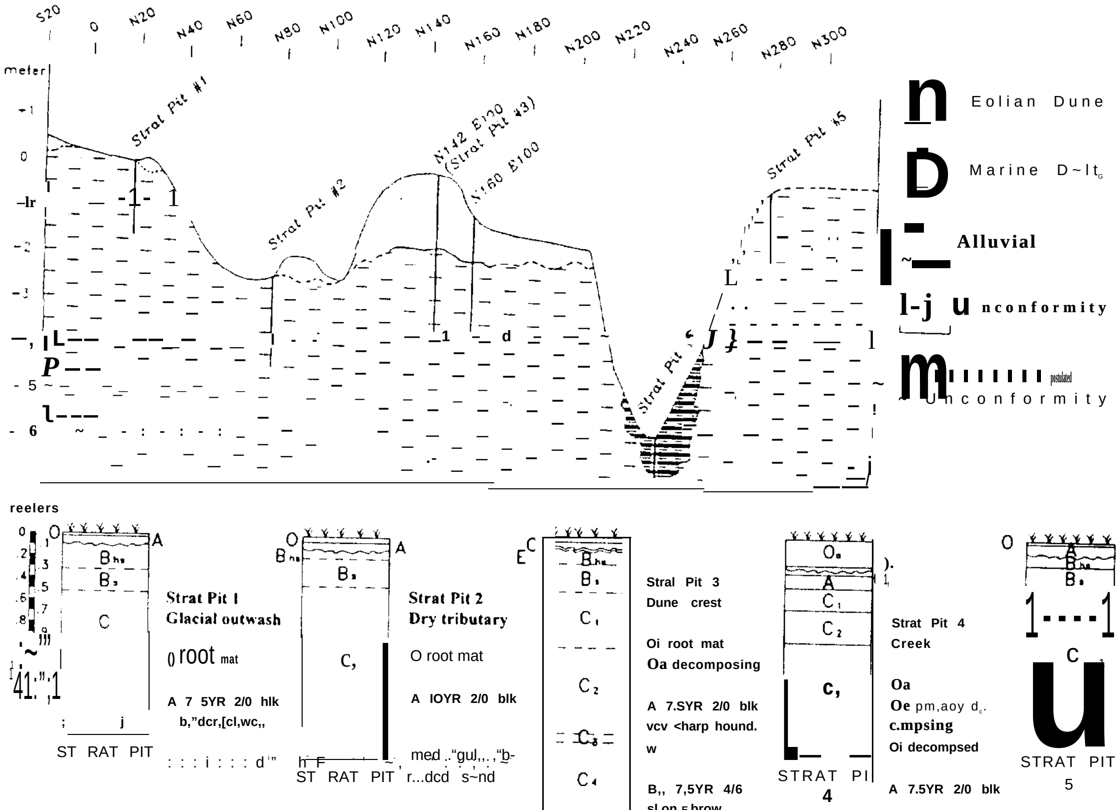


Figure 7. Skewness (lopsidedness of size distribution) versus mean size of sand grains in fluvial (river), deltaic (outwash) and eolian (dune) sands,

variable deltaic stratigraphy on the Kennebunk Plains, general pedological guidelines were utilized for labelling specific natural (geological or pedogenic) stratigraphic layers. For example, an A horizon indicated the top mineral horizon in any given pit, and a C, indicated the first parent material encountered during excavation. Therefore C, horizons do not necessarily designate equivalent parent material strata between stratigraphic profiles. Stratigraphic pit profiles were examined, drawn, and sampled for sedimentological and geochemical analysis.

Off-site stratigraphic pits 1 and 5 possessed parent materials strongly resembling those exposed at the Route 99 commercial excavation. Field analysis showed moderately sorted, dominantly quartz (with some mica, feldspar, and rock fragments) medium to coarse sands, Sands were massive: no stratification was evident. In stratigraphic pit 5, sands become loosely packed with depth and gravels increased, Both geological profiles exhibited B horizons to depths of approximately 50 cm. Stratigraphic pit 2, emplaced in the dry tributary near Locus 1, corresponded more closely with profiles in 1 or 5 than with stratigraphic pit 4 which was dug in wet brook sediments, Based on similarity to the Route 99 commercial excavation sediments, pits 1, 2, and 5 are interpreted as exposing subaqueous deltaic sediments, although upper layers may have been eolian and related diagnostic stratigraphy (if any) subsequently destroyed by pedogenesis. In contrast, stratigraphic pit 4, emplaced in brook sediments, revealed moderately to poorly sorted, compact, silty quartz sand accompanied by organic materials, No soil profile was evident, indicating a very active

Figure 8. Schematic cross section (north-south) through the Kennebunk Plains, sand dune and the Hedden site (N 16OE1OO area). Vertical exaggeration is 20:1. Soil and sedimentological descriptions for the off-site strat pits are below the figure.



E] ~o'i"n o~ne ~~~j'''' 2

m Delta , , " , , , , , , , , O "

= f i : : ~ : l " " " M

Strat Pit I
Glacial outwash

0 root mat

A 7 5YR 2/0 hlk b,"dcr,[cl,wc,,

: : : i : : : d'"

B„ 7 5YR 4/6 .,ro"g b,own

'~fl::';ub ar, gular sa,, d l,r,m.,,1,, q,,afl, with coating. Also feldspar. mica. rock frag. Gradual. wavy boundary.

B, 10YR5/6 yellowish brown. Same as above but including pebble-sized fragments. Gradual, straight boundary.

C IOVR7/4 VCT pale br"w" C h,>,,.." pucnt ,,,,,!.,, s1 M,,dcr-fltcly soflcd sands. ,n(,",i~.lc med,.,,,- C""rs. Quafl, 60.6, ,,,1,., rcbl. ,P X,S, l.l.a R r 400,; bla<sivc, "<, ,!,ata ,,"[cd

STRAT PIT #l NIMsive, probable subaerial delta sedlmet]ts. WeO-develo~d soil profile No Ejbor]zon indicates some disturbance

Strat Pit 2
Dry tributary

O root mat

A IOYR 2/0 blk

med ."gul,,.,"b- r...dcd s~nd

B,, 7,5YR 4/6 str,, ng hro,v" M<,d :p,wrly wncd angulm-s"b. r".nded med-Coarst sand w ,lh coat, ngs ad cemcn [cd "od"lcs

B, 8YR4/6 dark yellow brown ,a,"e, b"t 1,ss well mfl.d

Cl 10 VR8/8 yellow sub-round. cd t" sub.angulw mod 10 poorly s,)ncd n,ed 10 C"~rSC, d(,m - lna"tlv coar,c sand

CZ10VR8/8 yellow Bedded Plmar sa"ds~ ouafl~ 60.700/. fcld~pm, r",ca

STRAT PIT #2 Massive, pr"bablc dcbn $cd,mcn(s Well-dcvclo~d so!! profile. No E hor,zo" indicates $..?. disl.rbmce

Stral Pit 3
Dune crest

Oi root mat

Oa decomposing

A 7.SYR 2/0 blk vcv <harp hound. w

B,, 7,5YR 4/6 sl,on E brow. well soncd sub-rok, nded med. coax smd w ,lb coatt.gs

B, 10V RS/8 yellow WCII soticd domin. anlly s"bro."dcd, mcd, un) smd S1ra,ght clc~ boundq

Cl 10 YR7/6 YCOOW mcdtum smd. mod to well soned 859. qu~ mm, ve

.C210VR5/8 br,gb! yellow mast .e

glcycd to reduced layer

C3 fine smds, vc~ compact, well soned

C4 C0U5. rends, loox

STRAT PIT #3 Eolim scdaments wi(h well devcl. o~d SO,) Profile. Chmgc t" sub. acr, al delm sedt. mcnb somcwbcrc in C2, md the" subaqueous delw std. at 174 cm

Strat Pit 4
Creek

Oa

Oe pm,aoy d. c.mpsing

Oi decompsed

A 7.5YR 2/0 blk

Cl 10 YR7/3 "t~ pale brow"

C2 10 YR7/3 vcv pale brow".

C3 10YR7/4 vev pa!e brow"

A, Cl,C2, ~d c3 COmpoxd of mood .POOlv soticd Compac, ~EUIW-rounded smd w,tb mmc silt, quartz 60%

STRAT PIT #4 Prob~bly ~0 ~[l". vial wdimc"ts dcposi(ed by meander, ng strew Poorly dcvclo~d s, l

Strat Pit 5
Glacial o"twash

O root mat

A 7.5VR 2/0 blk

~ 7.5YR 3/4 dwk brown

B, 10YM16 yellowish brow",

C 10YR6/4 very pale brow". fl"~ witi lugc gravels

STRAT PIT #S Mms,vc, Probable s.baer,=l dclm scdimenu well. dcvelo~ mil profile. No E jhorimn tndicates some dzd"rbmce

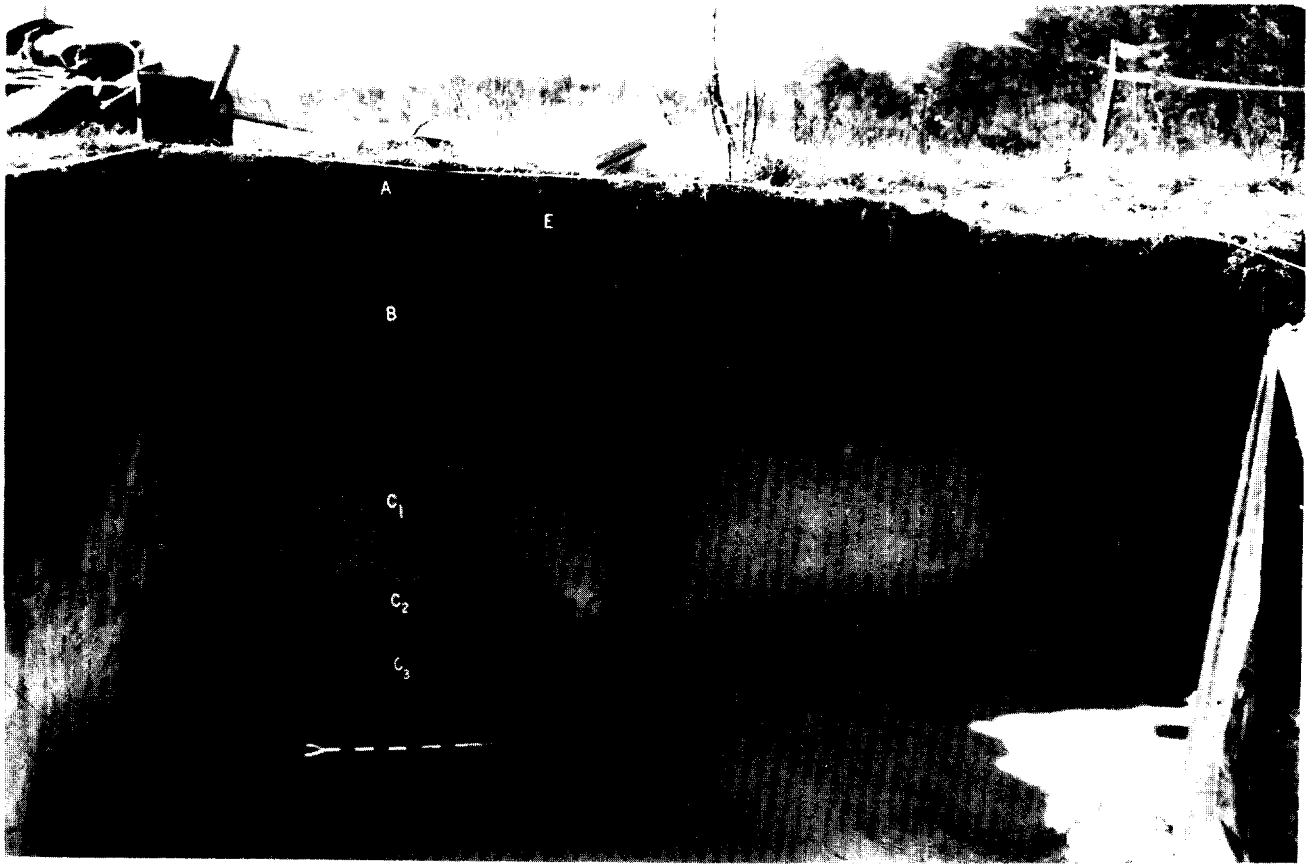
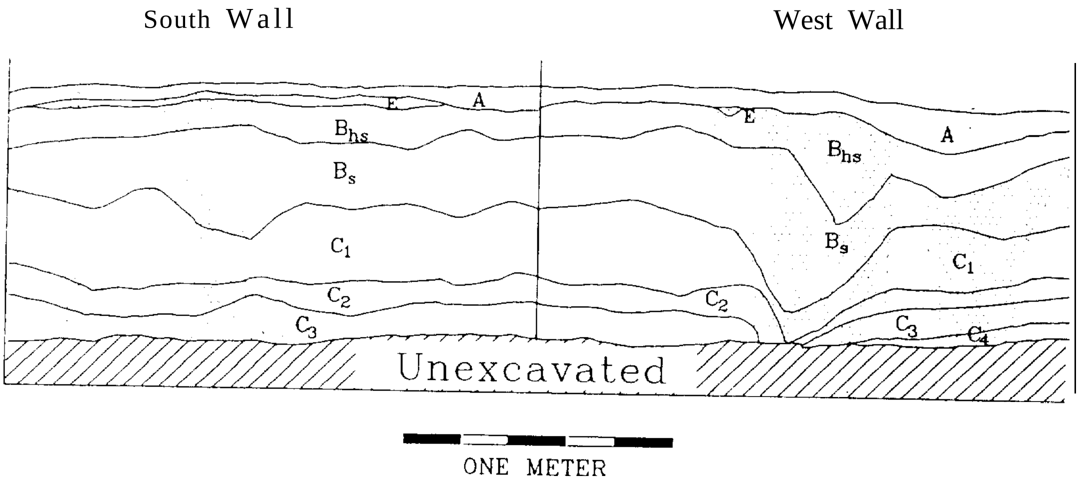


Figure 9. Profile of the west }vall of N 164E98 showing large tree-tthrow feature n **centel of \vall, an~: intense podsol feature at right. Photographed 10123~9:. Compare with** profile drawllng. f'igure **10.**

ererrosional/(~sit~rlal~dep0sitional~ ~siti{~[l:]l e]~vironment I)ue t0 ttlc deeply incised morphology of' the drainage, this pit therefore is interpreted as an exposure Into a (potentially thin) alluvial sediment deposited on the floor of'the brook during historic pcrlod fluvial aggra~lat ion.

Exarnination of the archaeological profile~at l,ocus I and in the 1x2 In tcstpits Into the nearby dune crest showed Spodosot dcvclopment. Atotal of 9 stratigraphic protiles ~were taken from representative walls 0f 1x2 m test J3it~ and locus I excavation squares (Figures 9-16), ['hose frotn the test pils match closely withthcprofites from locus t,, allowing us to generalize about the slratigraphy ot the on-site area. The general soil sequence conslsts of.:a rnoderatcly well-sorted. coarsc. btack organic sand "A" horizori overtying intermittent tnoderatct~ well-sorted, coarse. dark gray "E" horizon sands. Below the "E" is:i~well-sofledd~]rk orange to yellowish brolvn. medium sand ("B". "f3},,''(B)}vt~i; hi.:h exte~ldstos(~mt jocm bet(~~v ground surface lhistypcoffort:~[Spodosol cou]d hate fol-lncd tvilhin thelast collJlleofcetlturiesor" so It i, ctcatJ\ 11(11 Paleoindian in origin even th(~ugb ;I)tl]c artiliicts ~vcre f'ound ill the A and B horizon, (see Vertical I)istribution discussion above)<)vc), ,≶1 Spodosol pedogellcsis, cspecia[ly in the A. E,atld B horizon. ll~~slargcl] des[r~~yedgeological strati graf)ll:v i4ittll[l 60 CIII (Jf'ttle su~face. '1'he C, horizon l:~~rrclatl~ bet~icen a]t ;irchaeologica] pr~)files (III >itu A ty[lical (', horizon parent materiat (NI60F;16(I[li)())l:(>flsist,<(>f loYR7/(~(yelloiv).



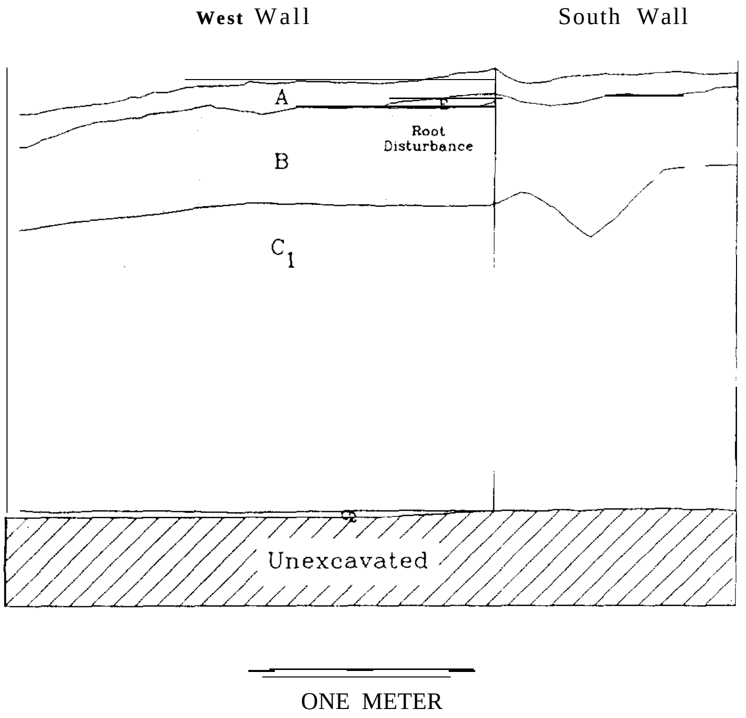
A	7.5 YR2/O Black organic sand, moderately well-sorted coarse sand.
E	10yR7/3 very pale brown, dominantly fine salld.
Bhs	7.5 YR3/4 dark brown moderately we]]-~orted coarse sand.
Bs	10 YR6/4 ligl~t brownist] yellow moderately well–sorted coarse sazld.
C$_1$	10 YR6/4 light yellowish brown moderately well–sorted coarse to medium sand.
C$_2$	10 YR7/3 very pale brow, dominantly fine sand.
C$_3$	^{10y}R5/6 Yellomsh brown, dommantly fine sand.
Disturbed	

Figure 10. Profile of west and south walls of N 168E98, showing tree uprooting features and other disturbances to the stratigraphy.

well sorted, subangular, fine to medium grained, dominantly quartz sand. Lithology also includes 10% mica, feldspars, and rock fragments, Except for cultural materials, coarse fragments were rare in surficial levels, but increased slightly with depth.

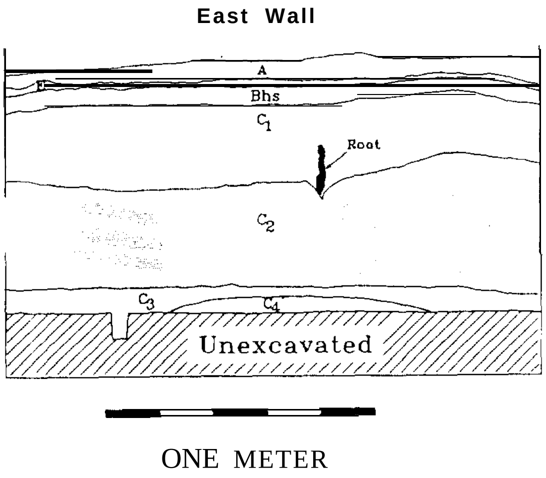
Results of sedimentological studies show that there are differences in grain size composition at different levels in the soil colum$_n$of N 142E1 00 (Table 1, Figure 17). Between 50 cm and 155 cm below ground surface the percentage of silticlay and fine sand ranges from about 4 to 7 percent of the total sample weight. At 180 cm, however, the silticlay and fine sand fractions amount to 34 to 42 percent of the total sample weight. This portion of the column marks the visible boundary between Cl and C$_z$, which is also the boundary between the dune and the glacial outwash. Below 190 cm, the silticlay and fine sand fractions resemble those of the upper soil column until about 240-275 cm where the combined fractions equal 45 percent of total weight. Finer resolution of sediment distributions will be possible with additional sampling from future soil columns.

The contact between the glacial outwash surface and overlying eolian sediments may range from just a few cm to well over 1 m in depth below the surface in the general vicinity of Locus 1. In archaeological exposures (within 25 m or so of Locus 1) this contact ranges from 72 cm ~168E98, west wall) to 154 cm ~ 142E 100, west wall) below surface (b.s.). The typical morphological expression of an Adams series soil (a sandy, mixed, frigid, Typic Haplorthod) extends to approximately 120 cm, with the lower limits of the B horizon around 40 cm (Flewelling and Lisante 1982). Except where disturbed, archaeological profiles at the Hedden site exhibit visual surficial Spodosol development (the B horizon) to depths of 60 cm.



A	**10 YR3/2 Very dark gray brown fine sand, moderately well-sorted.**
F.	**10 YR5,'1** Gray **fine to medium sand tith organlcs.**
n	**10 YR5/6 Yellow~sh bron, moderately weU - sorted sand with pebbles.**
c 1	**10 YR7.6 Yellow, moderately well–sorted to well–sorted, dominantly fine to medium sand, dominantly quartz titi rock fragments feldspar and mica; mth lenses of coarse sand and subparallel laminar - I–5** cm th,ck, **Boundar? to C2 is clear (gradational) and linear.**
c:?	**10~7/L tight gray, moderately sorted, dominantly fine sand ranging from very f~ne to coarse, dominantly quartz with rock fragments and garnets; subangular to surrounded. Boundary to C3 is clear, gradational, and Ilnear. (Auger sample)**

Figure 11. Labeled stratigraphic section of west md south walls of N 142E 100. Cross stratification and disturbances shown with heavy and light stippling, respectively.



A	10 YRZ/O black ~"**ati**, sand w,th O.E,D,C S Bo"nuy to **E is sharp** and ureg?,lar.
E	10 YR8/0 gray flue to med,"m sand wtth a p.tchy **boundary t<,** Bh,.
Bh,	7 5YR3/2 dark brown f,ne to medium sar, d. Bou"duy to Bs clear and waq.
Bs	10 YR5/8 well-sorted, subangular to **subroundcd** dominantly quartz sand tith rock (ra~menti and feldspar. Boundory .to Cl is gradat,ond a"d WOVY.
C1	10 YR7/d yetlow, well–so~d snbsn~ular to aubrounded, domban fly fine to medium qu.rtz ~and mth <1OZ m,ca. rock frmgme"t, feldspar, etc. Dr,es quickly. and has cross-%tratlfic. tlon - lcm lhick. Or*nge and white reflect w~ter bble.
C2	10 YR6/4 light yellomsh brawn, compact, moderately well–sorted, very fine to coar,e h"t dommantly very fine a"bang"lar to surrounded quartz s~d. Gleyed perched water table,
C3	10 YR5/6 light yellow,~h **bro- compact.** moderately well-sortid. very fine to cosrse (dominantly very fine). sub-ang"iar to subro"nded, dom>n=Uy qunrtz sand. Ox~dized perched water tible.
C4	10YR5/6 yellomsb brom, moderately weu-sorted, dom,nantIY .oerse sand r-einE from ve~ fine 10 gravelly. Sub–r'"g,dar to a"bro"nded
▱	Cro3, strmt,f,cntio".
□	Disturbed soil.

Figure 12. Labeled section of east wall of N 160E 100(Wfi), showing cross stratification, disturbances. and a recent root.

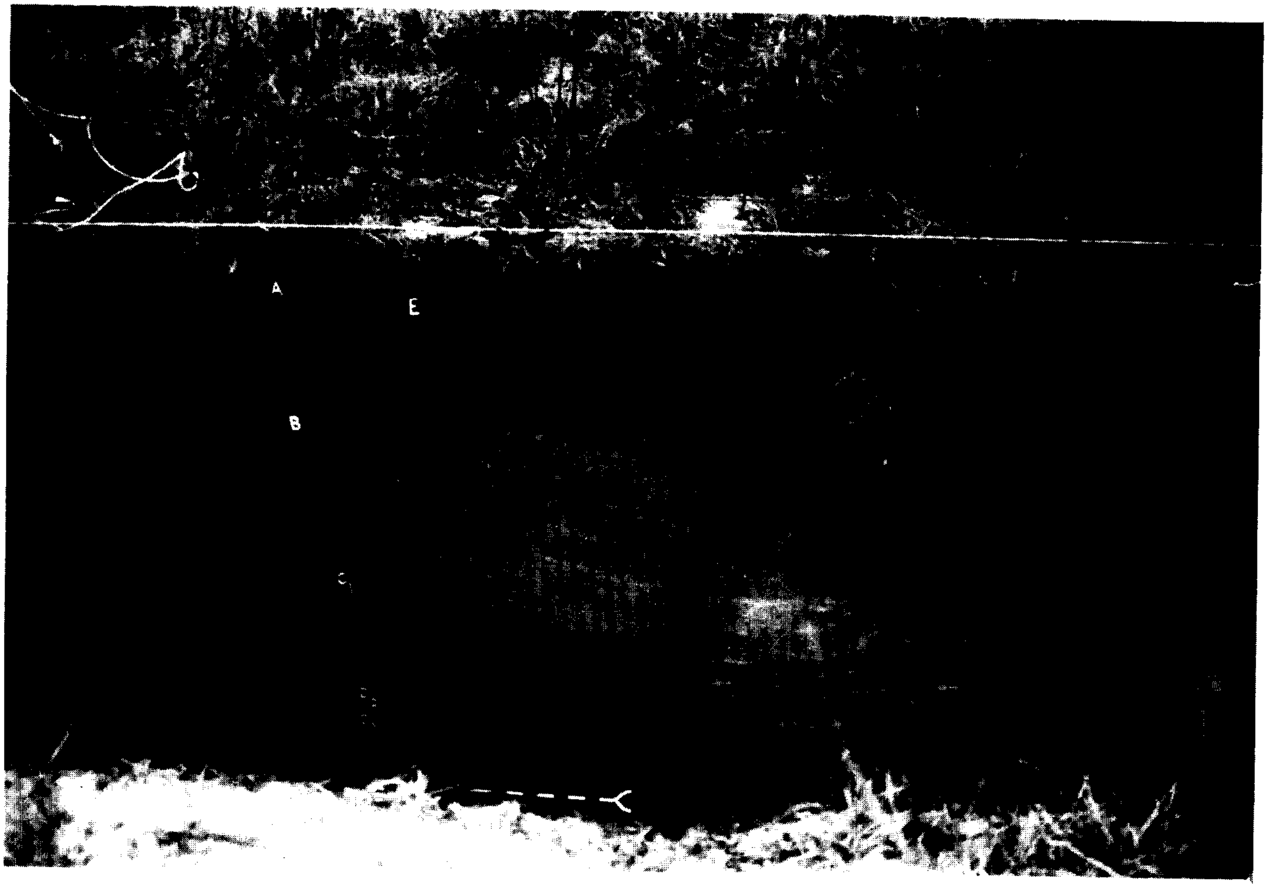


Figure 13. Photograph of the west wall of N154E100, with a major tree root disturbance at the right (north).

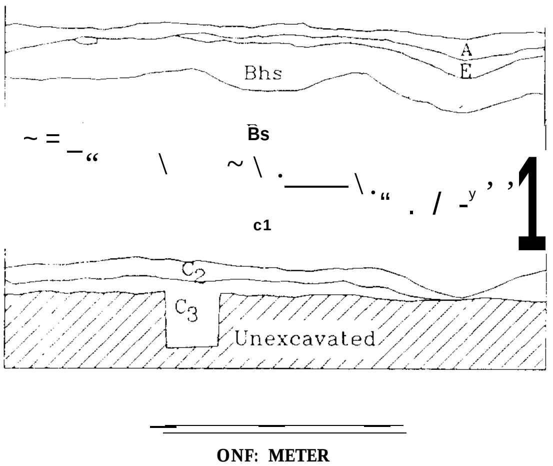


Figure 14. Profile of N 154E 100, west wall, with disturbance and cross-stratification noted,

The boundary between C, and C_z within the archaeological profiles was clear and straight. A characteristic C_z description (from N 160E1 00) consists of 10YR 6/4 (light yellow brown) compact, moderately well-sorted, very fine to coarse, subangular to surrounded, dominantly quartz sand. Perched water table gleying of Cl sediments highlights this contact. (C_1 materials are excessively well-drained, and C_2 sediments are only moderately permeable.) The contact between C, and C_z is taken to be an erosional unconformity separating the overlying subaerial eolian sediments (Cl) from underlying subaqueous deltaic sediments (C,). The C, parent materials are 10YR 5/6 (light yellowish brown) sediments differing primarily in oxidized color, not sedimentology, from the more gleyed C_z sediments. Archaeological exposures at

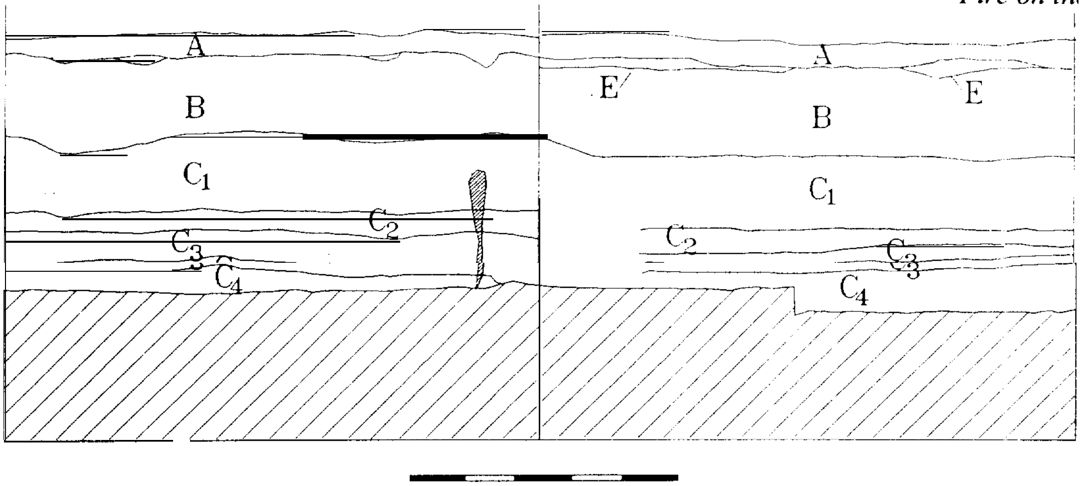


Figure 15. Profile of the west and south walls of N 164E 100 with several disturbances and a modem root stain.

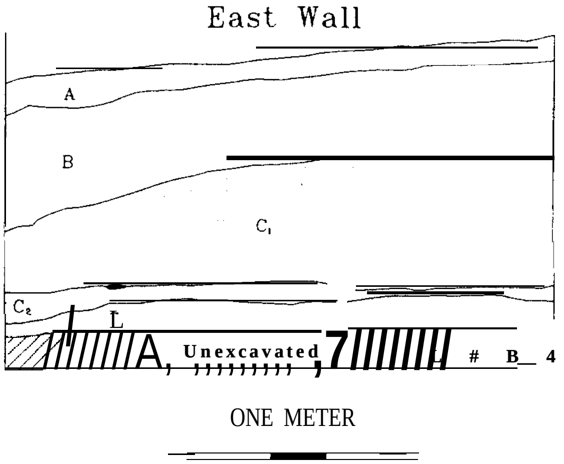


Figure 16. N148E1OO(W%), east wall.

the Hedden site were rarely excavated deeper than the C_j parent materials. Auger coring revealed a varie~ of underlying sediments ranging from sediments as fine-gained and compact as the ball and pillow strata at the Route 99 commercial excavation to very loose, coarse-grained quartz sands.

Evidence of cross-stratification in archaeological profiles at the Hedden site was intermittent due to bioturbation and variable hydrological conditions. Probable grain size variation within Iaminae resulted in microscopically-scaled "perched water tables", accentuating specific Iaminae (Figures 18 and 19). In profiles where laminae consist primarily of coarse-grained sands, however, the excessively well-drained conditions throughout failed to promote visible stratigraphy, and profiles appeared massive and structureless. Intermittently visible Iaminae indicate a linear dune ridge comprised of tabular sets of planar-bedded sands. Foreset dips were visible in only two archaeological profiles: N142E100 (Figure 11) and N 160EI 00 (Figure 12). At the ridge crest, foreset beds on the west wall of N 142E 100 dipped approximately 20° to (grid) north. Off the ridge shoulder in N 160E 100, foreset beds on the east wall dipped approximately 60° to the grid south. Although Embleton and King (1968) advise against extrapolating wind direction, and hence dune morphology, from variable or gentle dips of less than 25°, low angle, multidirectional dips are consistent with inland longitudinal dunes (Brookfield 1984). Longitudinal (sometimes termed linear or seifl dunes ofien form as a net result of deposition from two different wind vectors (Greely and Iversen 1987). This implies a possible net resultant E-W wind direction aligned with the general flow of the broad Mousam River valley.

Figure 17. Bar graph of grain size percentages from the N 142E100 column sample, compared with visual stratigraphy. The contrast between Cl dune sand and underlying glacial outwash sand (Cl, C,, C,) is striking, in that the dune is dominated by sand particles to the near exclusion of silt and very fine sand.

The internal dune stratigraphy exhibited in the archaeological profiles was truncated in a number of places by disturbances related to postdepositional bioturbation. Disturbances were primarily marked by destruction of eolian cross-bedding, tilting of pedogenic stratigraphy, presence of loose fill that exhibited signs of stratigraphic mixing, and/or charcoal fragments clearly associated with root burns. Root penetration loosened and darkened sediments (by contributing organic residue). Root molds were often characteristically V-shaped (e.g., Figures 10 and 14). Tree falls near the surface (e.g., Figure 10) were indicated by warping of the pedogenic stratigraphy. Preferential sorting of sediments by ants was also observed. Where eolian cross-bedding was intact, individual sets of laminae were stiff and brittle, perhaps due to micro-hydrological processes. It is conceivable that these paleo-hydrological processes (gleying and oxidation of sediments along laminae) may have conferred some resistance to bioturbation of longitudinal dune sediments. However, in contrast to many northeastern archaeological sites (especially those in sandy, penetrable sediments), less than half of the dune stratigraphy and the underlying archaeological horizon has been disturbed by such bioturbation, despite the passage of more than 10,000 years, As noted previously, tree throw appears to have been a primary post-deposition process leading to a bimodal separation of artifacts.

Depth below ground surface (cm)	Silt and Clay Fraction %	Sand					Sample Weight (g)
		Very Fine %	Fine %	Medium %	Coarse %	Very Coarse %	
50-55	0.94	6.28	32.14	41.02	17.34	1.72	100.1
55-60	0.63	6.00	31.65	43.47	16.05	1.39	100.59
60-65	0.59	4.12	24.72	40.43	26.01	3.13	101.95
65-70	0.72	5.92	31.95	39.4	19.03	2.16	100.25
70-75	0.64	4.75	26.42	38.76	22.79	5.15	100.29
75-80	1.26	3.96	25.31	39.67	24.5	4.05	103.15
80-85	0.65	5.53	28.87	41.88	20.72	1.73	99.36
85-90	0.58	5.25	28.01	41.64	21.88	1.09	99.7
90-95	0.64	5.34	27.11	39.05	23.76	2.99	100.82
135-140	1.73	9.54	36.46	37.09	11.98	1.75	101.68
150-155	2.83	13.63	43.54	28.59	9.52	1.37	100.96
180-185	16.56	25.43	26.42	16.61	12.02	2.13	
185 (auger)	19.52	26.97	25.28	16.94	9.54	1.23	98.98
190 (auger)	18.01	16.45	23.3	28.58	11.95	1.25	96.48
220 (auger)	3.59	3.93	25.83	42.56	14.31	8.05	101.46
225 (auger)	0.51	0.91	17.21	45.73	27.52	6.57	100.11
245-275 (auger)	13.44	32.41	37.28	10.24	4.46	1.24	

Table 1. Percent grain size information for 5 cm increments from a soil column sample in the wall of N 142E 100, near the crest of the dune to the south of Locus 1.

Solifluction is currently impacting surficial sediments on the steeper slopes of the longitudinal dune near the site (Figure 3). However, no evidence for older solifluction disturbances were recorded within dune profiles. Despite passage of over 10,000 years, much less than half of the *dune strafigraphy* has been disturbed by bioturbation processes. This state of preservation contrasts directly with many other northeastern archaeological sites, especially those in loose, sandy penetrable sediments where the archaeological horizon is more shallowly buried.

Pilot studies conducted in order to assess the viability of geochemical tests for anthropogenic indicators at the Hedden site have focused on pH and qualitative phosphate. The pH tests were accomplished with a 2:1 water to sediment ratio and read with a Piccolo pH meter. The ring phosphate tests followed procedures detailed by Eidt (1984), with some modifications of result interpretation (Callum 1 994).

Both on and off-site pH ranged widely between 3.6 and 6.3, In general, pH measurements were strongly acidic at ground surface and gradually increased to slightly acidic with depth. In dune column samples, the highest pH measurements occurred at about 115 cm b.s. As expected, active creek fluvial sediments (Stratum pit [STR] 4) were close to neutral, indicating the active deposition of recent alluvial materials. Neutral pH measurements

Figure 18. N164E102 south wall. showing microstratification in the C_1 dune sand. See closeup, Figure 19.

in this drainage may also be influenced by residential run-off. In contrast. the dry tributary pH profile (STR 2) most closely resembled glacial outwash sediments (STR 1, 5). Except for the active creek sample. most of the pH readings fall within the suggested ranges for the Adams soil series. Based on results of 1993 laboratory analysis, we had thought that a slight pH decease at the interface between deltaic sediments and overlying eolian sediments may have been a geochemical indicator of this important unconformity. Further testing demonstrated that pH variability (due to equipment capability and natural sediment variation) precluded this possibility. However, it appears that geochemical work confirms fieldwork conclusions that a soil profile did not have time to develop on the outwash surface. or was not under the right climatic conditions for soil development.

Qualitative phosphate readings range from 1.5 (barely reactive) to 4.0 (strong reaction). In general, phosphate profiles start out weak at the surface, increase in intensity in the B horizon, and decrease into the C horizon. Some of the off-site profiles exhibit readings as high as 3.0 and 4.0, suggesting intensive modern phosphate addition to the former commercial blueberry fields. Initially, we had hoped that phosphate tests would highlight the buried archaeological horizon. However, all sediment columns exhibit some degree of qualitative phosphate signature throughout. Alternative geochemical tests such as total phosphate or phosphate fractionation may prove more instructive than qualitative phosphate.

Figure 19. Close-up of micro-strata (horizontal laminae) in the south wall of N 164E 102, 10/23/94,

CHARCOAL AND DATING

Introduction

Repeated careful trowel excavation and shovel skimming with square shovels through meters of dune sand down to and through the contact with the underlying outwash pebbly sand (the C ,/C$_2$ contact) convinced us that we could recognize the contact in profile, and often by a subtle change in grain size when coming “down” onto it. In profile, the Cl/Cl contact is described as “clear, gradational, and linear” or “sharp and linear” (fieldnotes) over a short vertical distance (a few centimeters). Because we were being extremely careful in looking for small stone flaking debris, several excavators (Maxine Collins first) noticed that the frequency of lump wood charcoal increased just above the C ,/C$_2$ contact. Lump wood charcoal is very common in the uppermost soil layer (O and A), since the field was cleared for blueberry cultivation by burning within this century, and the blueberry fields were burned periodically as a regular part of blueberry culture practices. We also noticed an occasional “feature” in the dune sand that contained charcoal, such as the obvious rodent burrows and some evident burned tree roots, Thus, the dune sand did contain a “scatter” (although non-random) of charcoal of multiple and unknown age, from burn events that occurred in the former forest over the last 10,000 years and the recent field preparation.

Thus, we decided to ignore lump wood charcoal from most of the depth of the sand dune deposit as we were troweling down through it. There was a noticeable decrease in charcoal

Table 2. Charred plant remains from the Hedden site 1993 season, identified by Nancy Asch Sidell.

CATALOG NUMBER	694	695	696	697	698	699	700	701	702	703'	704
SAMPLE WEIGHT gr											
> 2 mm fraction	.011	.010	.029	.282	.079	.122	.071	.316	.065	.192	.075
0.5 - 2 mm fraction	.014	.002	.002	-	.005	-	.004	.014	.006	.058	.168
Total	.025	.012	.031	.282	.084	.122	.075	.330	.071	.250	.243
SAMPLE COMPOSITION (> 2 mm) count of fragments											
Wood	2	3	2	8	2	5	7	26	6	27	14
Bark	-	-	-	2	-	-	-	-	2	4	2
Twig	1	-	-	-	1	-	-	-	-	2	-
Pitch	-	-	1	-	2	5	-	3	1	1	3
Seeds	-	-	-	-	-	-	-	-	-	-	(2)
Total	3	3	3	10	5	10	7	29	9	34	19
SEED IDENTIFICATIONS											
Vitis sp., grape	-	-	-	-	-	-	-	-	-	-	1?
Unknown, unidentifiable	-	-	-	-	-	-	-	-	-	-	1
Total	0	0	0	0	0	0	0	0	0	0	2
WOOD IDENTIFICATIONS											
Picea spp., spruce	-	-	-	-	1	-	-	2	-	-	-
Pinus spp., pine	-	-	-	8	-	-	5	-	-	-	-
Coniferous	-	-	-	-	1	5	-	3	-	7	-
Total	0	0	0	8	2	5	5	5	0	7	0

frequency as one dug more than 20 cm below the existing soil surface, so that the increase in charcoal frequency near the C_1/C_2 contact, at great depth in the dune (up to nearly *2* meters in some squares) did eventually make an impression on us.

However, the charcoal lumps near the geological contact were not concentrated horizontally, at least within areas of a few meters scale. With great effort and patience, an excavator could pick up (with trowel tip and fingers) enough for a small, standard radiocarbon date (2-4 grams) over an area of 1 or 2 ml of exposure, over 5-10 cm of depth as one approached the contact. Neither was the charcoal horizontally associated only with the Locus I concentration of stone tools. There appeared to be roughly the same amount of lump charcoal at the C_1/C_2 geological contact inside the locus as there was 25 meters away under the crest of the dune. The only "features" we could recognize, as soil discolorations, appeared to be natural

Catalogue #	Square	Depth	Geological Association	Comment
694	N164 E100	77-80	near contact	gley patch
695	N164 E100	70	false feature	gley patch
696	N164 E100	75-80	false feature	gley patch
697	N160 E100	85-90	C1/C2, or dune/outwash interface	clearly associated with a modern tree root penetrating from the surface, pine charcoal
698	N160 E100	85-90	C1/C2, or dune/outwash interface, associated with "false" gley feature	spruce charcoal present
699	N142 E100	175-180	C1/C2 near interface	
700	N142 E100	165-170 cm.	20 cm. above C1/C2 or dune/outwash contact, which is at 184 cm	pine charcoal
701	N142 E100	170-180 cm	just 5 to 15 cm above C1/C2 dune/outwash contact, which is at 184 cm	just below #700, spruce and unid. coniferous charcoal
702	N148 E100	95-100	C1/C2 interface	from screen
703	N148 /e100	95-100	C1/C2 interface	hand picked *in situ*
704	N164 E100	77-82 cm	false "Fea 10" gley patch	two charred seeds, one probable grape

Tab1e3. **Provenience infomation fortheidentified charcoal samples itl"rable2.**

gleyed sediment (oxidation-reduction) patches associated with a change in water percolation rates at the dune/outwash geological contact, Thus, we knew that the charcoal associated with the contact was not clearly a result of Paleoindian fire-hearth construction and use; it was much more widespread horizontally,

During our work at the site, the Nature Conservancy, which helps manage the Kennebunk Plains. deliberately burned a portion of the Plains within sight of our excavation. This periodical management practice is done to maintain the open character of the vegetation, and to maintain habitat for some rare species of plants and animals. We realized that an analagous fire, whether set by nature or human action, could have burned The Kennebunk Plains just before, during, or after Paleoindian habitation there. Fire would have resulted in widespread, dispersed charcoal generation. Subsequent and rapid dune movement might have preserved the charcoal sample from such a burn, at least locally, without much later contamination. Fire may conceivably have occurred in conjunction with local or regional shifts in hydrological water table, wind intensity, or vegetation stress due to climatic change.

Charcoal Identification

Preliminary examination consisted of sorting the charcoal from I 1 samples by size, then sorting into categories of "wood. bark, twig, pitch, seed". then identifying seeds when possible (two. found in sample 4,1 ().704). Wood species identifications for this season's work were done with low magnification (30x) and hence cannot be species-specific in some cases. Table 2 presents the charcoal identifications, with proven ience information for each sample catalogue number in Table 3. Sample 697 is, most likely, a modern pine root burn. Two of the samples (698. 70 t) contained spruce charcoal at the geological contact. But one sample (700) tocated j to 10 crn above one of the spruce samples *(#70 I)* contained pine charcoal.

Based on our initial understanding of terminal Pleistocene pollen diagrams, and various models of Paleoindian tife and environment in northern New England, we were expecting an association of the Paleoindian horizon with spruce. or perhaps poplar, charcoat, l-he forest growing on the location at the ~irne ofctearance for btueberry cultivation had been dominated by pine and oak trees (judging from surrounding areas today, and some stitl-visible stumps), Thus, we were expecting pine charcoal to be a marker for Holocene or recent contamination. Spruce is very rare in the total and regional environment of southern-most Maine today, and appears to be absent from the sandy Kennebunk Plains.

On the basis of our assumption that pine was a "modern" inhabitant of the Plains, we did not expect uncontaminated terminat Pleistocene charcoat from near the contact. But we expected that the spruce charcoal. which coutd not be from a completely modern plant association at this location, might hetp date the dune formation. The radiocarbon dates we have obtained changed these assumptions,

Radiocarbon Dates

Assuming that we had a high probability of contamination with the charcoal samples as a combined group, we submitted only the spruce wood charcoal (O. 1 gr) from sample #701 to Beta Analytic, and requested an accelerator radiocarbon date, The date is:

4.10.701, 105 10+60 B.P. (Beta-68806, CAMS-10487), C13/C12 ratio is -25.7 o/oo, giving a C13 adjusted age of 10,500+60 B,P.

This resutt proved to us that at least some of the charcoat from the geological contact did, in fact, date from the terminat Pleistocene, and perhaps somehow dated the Paleoindian occupation. Curious about whether the pine charcoal from sampte #700, just 5-10 cm above # 701, dated to the Holocene, we submitted only the identified pine (<] gram) for an accelerator date. Ttle date is:

4.10.700, 10590+60 B.P. (Beta-70668, CAMS 11530), C13/C12 -25.4 o/oo, C13 adjusted age 10580+60 BP.

Interpretation

Thus, the pine charcoal is contemporaneous with the spruce charcoal lying 5 - 10 cm below it, and both date to the terminal Pleistocene, at the time when we would expect a Paleoindian occupation. They provide a date for some sort of widespread burn event (or multiple burn events), which was fueled by a woodland which contained both pine and spruce trees. The burn event must have occurred when the underlying outwash gravelty sand constituted the mineral soil base of the existing ground surface. Sand dune movement to cover the outwash occurred subsequent to the spruce-pine woodland fire event. Because the Pa]eoindian occupation is demonstrably associated with the same surface, that occupation may have occurred anytime before the surface was covered by dune sand movement. [n sum, we do know that the land surface was available for Paleoindian habitation circa 10,550 B,P. because there were trees growing on it of that age when they were burned,

Away from the Locus 1 concentration of flakes and tools where material has demonstrably been moved verticalt} by biological activity, the only Paleoindian materials we find in the dune sand are microflakes, items that could easily have been blown into the dune during its initial formation or subsequent movement. Within the Locus I concentration, just a few larger Paleoindian stone tools and flakes are "wind-blasted", i.e., had been subjected to light to moderate abrasion by wind-blown sand. Thus, we know that some Paleoindian stone artifacts were available, exposed on the surface for some wind abrasion and movement once the dune sand movement began. However, the vast maiority of the stone tools were either not exposed

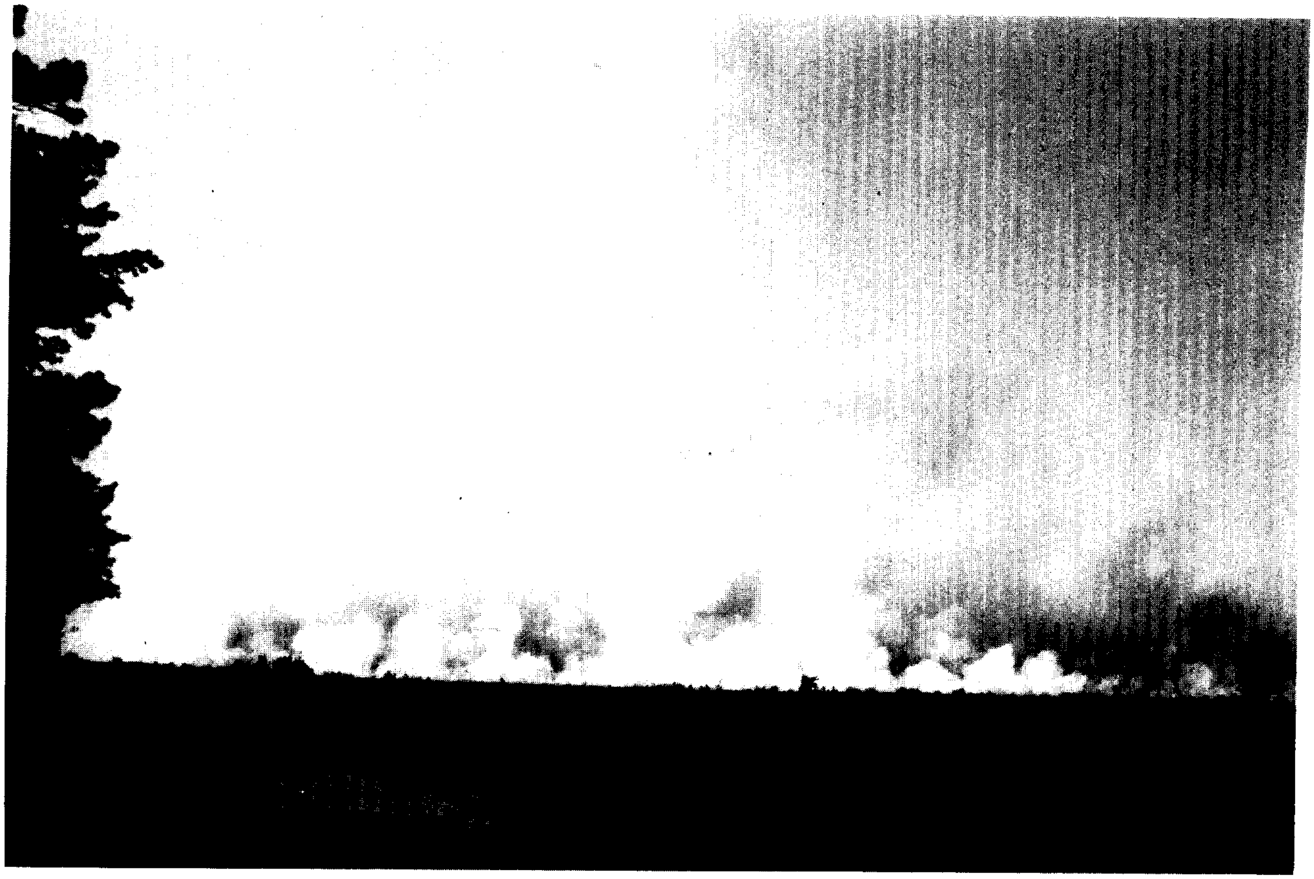


Figure 20. Fire on the Plains, controlled burn in october 1993.

on the surface, or were buried by moving sand too quickly to be wind abraded. In the latter case, the dune formation occurred very soon after the Paleoindian occupation.

One hypothesis, seemingly at present the most likely, is that the Paleoindian occupation and the fire event were very closely linked in time. and that the fire event was lar&e enough in scale to destroy existing vegetation cover and allow sand particle movement and dune formation, It is possible that the Pa]eoindian-fire-event association is causally linked. If the Paleoindian occupation predated the fire and they are causally linked, the fire may have been started by human beings, either on purpose (as in a game drive), or accidentally (escaped campfire). If the Paleoindian occupation postdated the fire, before substantial sand dune movement. then they may have been attracted to the spot by an open vegetation association, or by game attracted to regenerating vegetation. in the latter case. we have to explain wI]J the sand dune moveinent occurred subsequently to the Paleoindian occupation ."~he natural explanations discussed previously (e.g., water table. increase in wind intensity) apply.

Dune fortnation chronology at the [{edden site contrasts strongly vitb that hypothesized by McKeon (1972. 1989) and tnany others. Eolian activity chronot~)gy cc~utd either imply initiat dune construction contemporaneous with or slight!y postdating the Paleoindian occupation. or a reactivation ofpreviousl~' fossllized periglacial dunes. Maxitnal radiocarbon dates (circa 10.500" BP..). and the existence ofa probabty singte Pateoindian cotnponent at the interface bet\\ een gtacial ou[wash and

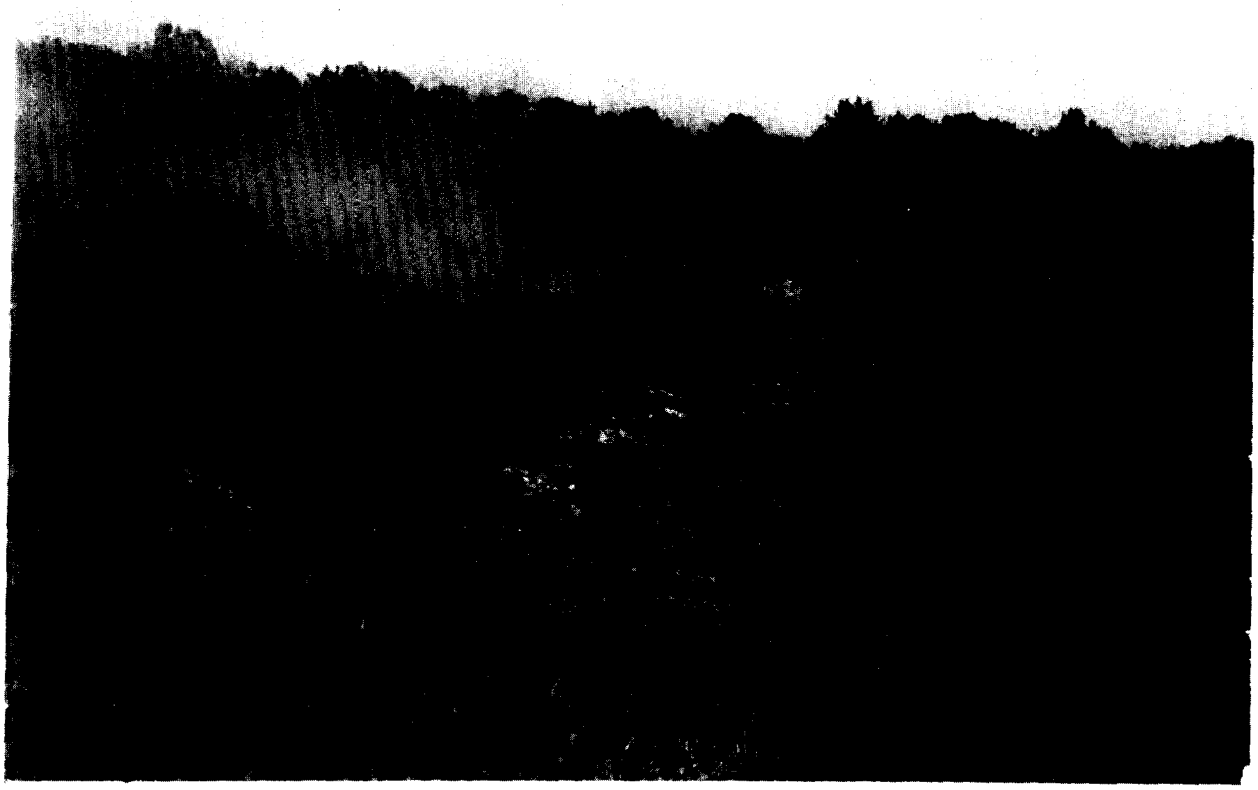


Figure 21. Backfire burning through dry grass, October 1993.

the overlying longitudinal dune, suggest that eolian formation processes were operating sometime contemporary or subsequent to the radiocarbon date.

Fire on the Plains Today

one day during our excavation at the site, the Nature Conservancy burned a 20+ acre portion of The Plains near where we were excavating (Figure 20). In this section we present some of our observations of that fire that may have relevance to the archaeological record on the site. The vegetation cover at the time of the controlled burn was a grassland, with a few shrubs. Repeated burning of the field during blueberry cultivation had removed any dry branches or other accumulation of heavier fuel. The fire spread very rapidly through the grass, even in the absence of wind. Flames were 18“ high on average (Figure 21), to 3’ high at most, Many small pines (<3’ tall) and small birch bushes were not charred or noticeably burnt. Within 10 minutes after the wave of flames passed one spot, Spiess tested the soil with his trowel. There was charred grass/fine charcoal on top, but the base of grass clumps were still green. Pebbles that had been exposed on top of the mineral soil were not altered (i.e. not reddened or heat fractured). At a depth of I/8” (about 0,3 cm) in the sandy soil, the soit was still moist, and its temperature had not been raised to more than 80°F (air temperature that morning had been 50” F.)

Upon arriving at the site the next day, we noticed a few dozen wisps of smoke drifting up from the burned acreage. Investigation showed that

Figure 22. Plume of smoke rising from an underground burning root, 24 hours after the burn.

these were burning tree stump and root fragments, ones that had been cut several decades before and had partially rotted. Most were pine. All the smoke wisps were associated with small (j-25 cm diameter) holes in the soil and/or shallow craters, Spiess excavated one of these burning holes (Figure 22), and found burning root coals at a depth of 35 cm., with the air hole apparently having been caused by the complete oxidation of the root as it burned downward. At a later stage. the sand walls would fail and fall in, causing the formation of craters with a diameter of 30 cm to 1 m. Walking over the field, which was now absolutely clear of vegetation, showed that there were dozens of similarly-sized craters. A few were still smoking. Many, however, probably predated the presenl burn event.

Thus. we learned that a fire event that is not intense causes relatively little alteration of the existing soil surface. but that it might cause localized slumping of soil into shallow craters as tree roots burn and lea\ e voids to at least the depth of the base of the existing B soil horizon. This process probably adds to the churning effect of tree falls and rodent excavation. The anl(~unt of wood charcoal remaining on the surface of the soil away from the burned stump and root locations was nil. Most of the charcoal was so fine that it could probably not be recovered from archaeological context without very fine flotation. t However, the burned stump roots added charcoal to the soil at depths of up to 40 cm,

CONTRIBUTION TO THE STATE PLAN

The State Plan is the document (Spiess 1990) that guides decisions about archaeological site management, including decisions about National Register eligibility, and to a lesser degree, decisions about how much archaeology to do (if any), and with which methods. when faced with a plan for major construction or land modification. Paleoindians sites are relatively rare in the New England-Maritimes region. and almost all of them have been found shallowly buried (surface to 30 cm, or 1 foot) in sandy soils (Spiess and Wilson 1987; Wilson and Spiess 1990), The vast majority of these sites have been discovered by chance, or during planning for a construction project, as some or all of their stone tools have been exposed on the surface. There has been enough soil disturbance for agriculture (plowing), utility and road construction, and building construction across most of the New England-Maritimes region to demonstrate that we typically do not find fluted point Paleoindian sites deeply buried in river alluvium, and rarely do we find them on stony or poorly drained soils derived from glacial till. (However, they are found in river alluvium and other soils south of New England.) l-he vast majority of New England-Maritimes Paieoindian sites are found on sandy glacial outwash, dropped by glacial runoff 1.000 or more years before humans arrived. In many cases, Paieoindian sites are associated with fossilized sand dunes (dunes that had been formed by late glacial period winds and often were stabilized by vegetation before the Paleoindians arrived). After the Paleoindians lived on the land surface, their stone tools became incorporated into the top foot or so of soil by soil formation processes. There usually has been no major deposition of new sediment on top of the old soil surface, and we can often count on the stone tools being shallowly buried, if not exposed on the surface. Sometimes the vegetation cover on these sand dunes has been badly disturbed by 20th century agricultural practices, and the sand dunes have begun to move again after 12,000 years or so of presumed stability.

With the exception of this modern sand movement, we have had no indication previously of Paleoindian sites being deeply buried by ancient sand movement until the discovery of the Hedden site. As stated above, to date, Paleoindian sites in New England seem to be rare. When archaeologists go and look for them on sandy soils (as opposed to a chance find on the surface), we have assumed that digging shallow testpits (to 50 cm or 2 feet depth) is sufficient to either find a site or demonstrate its absence. Especially in the case of construction projects (e.g., a shopping mall or industrial park), anything we miss during an archaeological survey is not I ikely to get noticed when the bulldozers roll.

In contrast to the predictive model of fluted-point Paleoindian sites shallowly buried in eolian sand, the excavation at the Hedden site has demonstrated that the primary (original) occupation level of the one locus we tested was buried between 70 and 110 cm (3 to 4 feet) below the ground surface. Moreover, the site had never been plowed, and the surface layers were intact except for an occasional rodent burrow. The surface layers of the soi I are a distinctive and intact black, gray, and reddish soi I called a Spodosol which shows surficial disturbance quite clearly. Such soils take from a few centuries to over 1000 years to form. So we know that the surface of the site had not been heavily disturbed for the last 1000 years or so.

The deeply buried occupation level at the Hedden site is *noi* associated with any buried soil layer, pH anomaly, or qualitative phosphate concentration that could be detected by visual or chemical test means. The level is subtly marked by a slight change in grain size. The only practical way to detect the occupation is by screening the sand through I/8” or 1/4” mesh hardware cloth and visually identifying the products of stone tool manufacture.

Moreover, the Hedden site occupation occurred on a glacial outwash surface that could be characterized as slightly gravelly sand. The windblown (eolian) sands, which lack gravel, overly the Paleoindian occupation. Until recently our fluted point Paleoindian predictive model was based on searching for fluted point sites associated with eolian sands. Based upon the Hedden site and other recent discoveries in Maine, this exclusive association is no longer tenable. In fact, one fluted-point Paleoindian site (site 39. I) and one later Paleoindian site (22. 10) have recently been discovered on slightly gravelly glacial outwash surfaces similar to the one on which the Hedden site lay. All slightly gravelly glacial outwash sands are now possible candidates for Paleoindian occupation.

A reanalysis of fluted point Paleoindian site locations in southern and central Maine (Spiess, personal observation) indicates a possible association of sites with *sand and withsome sort of a topographic feature characterized by a break-in-slope,* such as the margins of a (dry or still wet) stream or river bank, eolian dune, swamp margin or former pond or lake shore. The water bodies associated with some of these situations cannot be characterized as "canoeable" water, and in fact most of them have been abandoned or seemingly changed in character since the Paleoindian occupation.

Therefore. survey which is designed to test for fluted-point Paleoindian sites must not be confined just to eolian sand, although dunes provide one example of the topographic break that seems to have been attractive. (Sometimes these dune positions may have shifted since Paleoindian occupation). All glacial outwash sand with low ,gravel content must now be surveyed, focussing on areas where there is some minor topographic change, Thus, there is some focus for survey efforts on what may otherwise be huge areas on the flat tops of former outwash deltas.

FinalIy. we can no longer assume that testing through the lower B horizon and into the C horizon in an intact Spodosol on surfaces with eolian sand constitutes an adequate sampling effort. Now that we know sizeable dunes were prone to movement after periglacial times. and not only due to late historic deforestation, we should take care to separate differing surfaces in relatively homogeneous sandy sediments. There must be some effort to identify any contacts between eolian sands and possible underlying outwash surfaces, in case the eolian sand cover postdates the time of possible Paleoindian occupation. Stated in other words, multiple C horizons or a series of contrasting parent materials may be present on these types of sandy deltaic Iandforrns. Of course. there are practical limitations for depth in small hand-dug shovel testpits and excavation units (1,5 to 2 m), and the introduction of mechanized equipment into many project areas is sometimes not practical or possible for a variety of reasons, However, as Hedden stie strati graphic profiles demonstrate, sandy soils can exhibit high integrity archaeological contexts even if they have been vegetated for over 10.000 years.

Obviously. we will continue to refine the Paleoindian predictive model in Maine for some time to come, and , make as prudent and practical an application as we can to "contract archaeology" situations.

ACKNOWLEDGEMENTS

Kathy Callum would like to thank Quarternary researchers of various institutions for their generous advice, including Lisa Doner, George Jacobson, Peter Lea, and Woody Thompson.

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