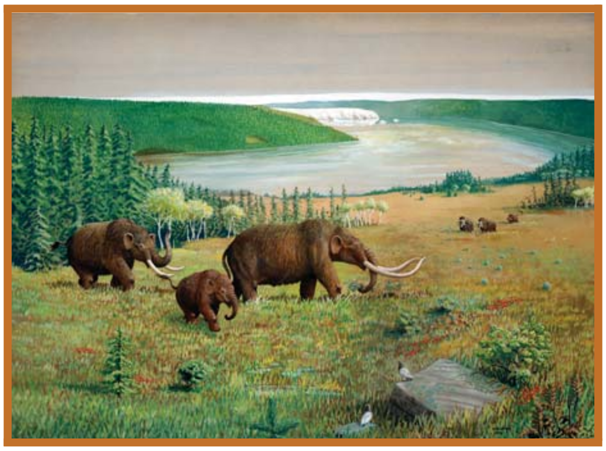

Mastodon Paleobiology, Taphonomy, and Paleoenvironment in the Late Pleistocene of New York State: Studies on the Hyde Park, Chemung, and North Java Sites

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THE HYDE PARK MASTODON MATRIX PROJECT, WITH PARTICULAR REFERENCE TO THE MOLLUSKS AND SEEDS

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ABSTRACT

The "Mastodon Matrix Project" has been a nearly all-volunteer project to collect and describe biotic components from late Quaternary freshwater sediments at several New York State mastodon excavation sites, including sample collection and processing, sorting, and specimen identification. At the Hyde Park site, large bulk sediment samples (in five-gallon buckets) from above and around the bones of a mastodon were used for a scientist-public research partnership. Nonspecialist groups such as K-12 school audiences participated in sorting small fossils from one-kilogram bulk samples, and adult volunteers and interns provided additional sorting, identification, and curation. The project was undertaken (1) to improve public and student understanding of science involved in the process of research, (2), to provide a taxonomic reference collection of late Pleistocene materials, and (3) to generate additional scientific data on biotic materials, including a broader inventory of flora and fauna than would have been available otherwise. Data is analyzed in this study to estimate the degree of noise and bias in the data and to determine the degree to which such data reflect "true" natural patterns. The samples are also analyzed for (a) the degree to which the molluscan data are consistent with expected stratigraphic position of the samples, (b) similarity in results of seed and molluscan data to "expert" data from cores at the site, and (c) internal consistency in assemblage composition among samples from the site and from the same buckets. It is readily apparent that teachers and students participate enthusiastically and that large reference collections can be generated. After samples are returned, however, additional sorting and curation is necessary for consistency in sorting among participating groups. Total abundances of categories of components (total mollusks, twigs, seeds, etc.) vary depending on student recognition of specimens as objects of interest, thoroughness with which students pick out specimens from the sediment, and probably sample processing techniques. Relative abundance of taxa within a particular taxonomic group, such as freshwater mollusks and seeds, however, does seem consistent among samples from the site. Seed types were identified that have not been identified from other studies; many specimens of various other taxa remain unstudied by specialists.

Chapter 9, in *Mastodon Paleobiology, Taphonomy, and Paleoenvironment in the Late Pleistocene of New York State: Studies on the Hyde Park, Chemung, and North Java Sites*, edited by Warren D. Allmon and Peter L. Nester, *Palaeontographica Americana*, 2008, (61): 111-134.

INTRODUCTION

The Mastodon Matrix Project was initiated in 2000 as a collaboration between the Paleontological Research Institution (PRI) and the Department of Earth and Atmospheric Sciences at Cornell University to engage K-12 students and other members of the general public in actual scientific research via distribution of samples of mud "matrix" collected at three late Pleistocene sites in upstate New York at which skeletons of mastodons [*Mammut americanum* (Kerr, 1792)] were excavated between 1999 and 2001 (Ross *et al.*, 2003, 2004). As an attempted "research partnership" between scientists and the general public (see, *e. g.*, Barstow *et al.*, 1996; Harnik & Ross, 2003b; Ross & Harnik, 2003), the goals of this type of project are (1) to improve public and student understanding of science through involvement in open-ended activities connected to ongoing scientific research for which the exact "answers" are not known in advance, (2) to provide a taxonomic reference collection of late Pleistocene materials, and (3) to generate scientifically useful data on biotic materials associated with these mastodons that might provide a more comprehensive, albeit less stratigraphically constrained, inventory of flora and fauna than would be available from core samples and smaller trench samples alone (see Miller, 2008; Robinson & Burney, 2008; Karrow & Mackie, 2008; Miklus *et al.*, 2008; Sokal & Hall, 2008). A fourth goal of this exploratory study, and the primary purpose of this paper, is to assess the degree to which goal 3 can be and has been achieved, having used primarily volunteer support and based on a subset of materials from the Hyde Park excavation. Assessing the data that emerges from the project has broader applicability because of the number of individuals implementing versions of the project in a variety of educational contexts (*e. g.*, Ross *et al.*, 2003; Slattery *et al.*, 2004; Underwood *et al.*, 2007; Wasserman & Ross, 2004; Jarrow, 2008) and the number of other mammoth and mastodon excavation projects undertaking research partnerships and associated outreach (*e. g.*, Magruder & Agenbroad, 2001; Ford & Gummer, 2003; Treworgy *et al.*, 2004).

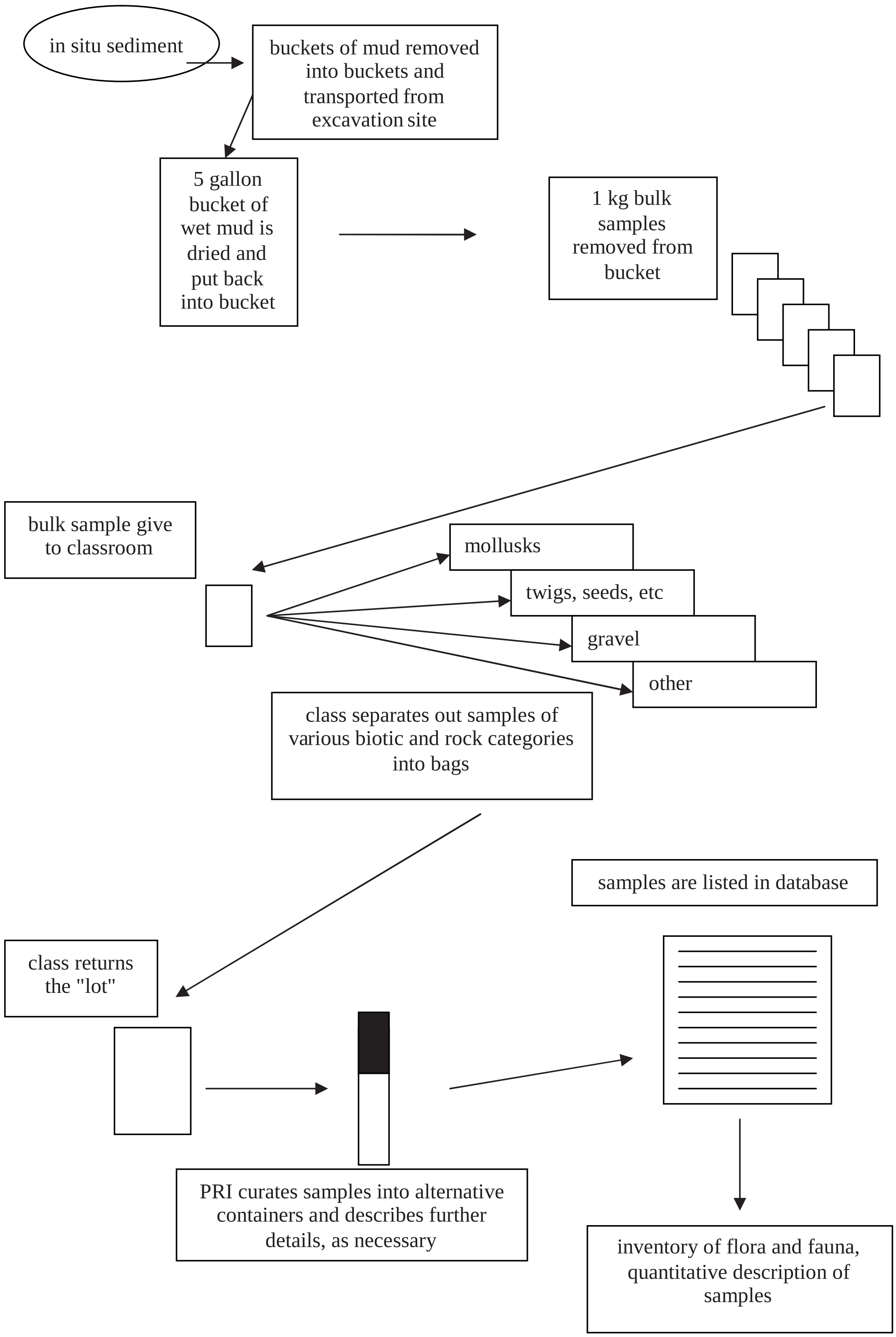
Overview of the Matrix Project

Since 2000, the Mastodon Matrix Project has distributed more than 3,000 samples of dried mud matrix from three PRI excavations (*ca.* two-thirds from Chemung, most of the rest from Hyde Park, and a few from North Java) to school classes and other groups from 49 US states and four other countries. Sediment was divided into samples of *ca.* 1 kg and sent to groups who requested them (Text-fig. 1). General instructions accompanying each sample described objects to sort from the matrix and activities connected with their interpretation, and also encouraged participants to return sorted samples (Ross *et al.*, 2003). The open-ended nature of the directions encouraged teachers and group leaders to tailor the activity to the age of the participants, their own curricula, the availability of resources and equipment, and the amount of time they could devote to it. In many cases, teachers were able to use analysis of the samples as a springboard for introducing subjects such as natural and Earth history, archaeology, and biology. In addition to K-16 groups taking part, groups such as Boy Scouts of America, after-school science groups, gifted programs, and enrichment programs have also participated; this paper, however, concentrates on results from schools.

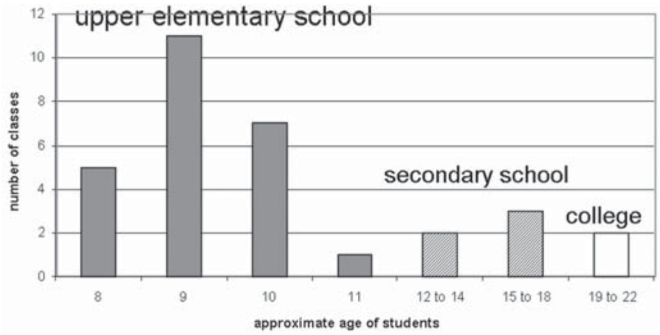
An earlier paper (Ross *et al.*, 2003) focused on the educational impact of the Matrix Project, based on results with sediments from the Chemung excavation. It documented the wide variety of participants and concluded that individuals of a wide range of ages and backgrounds do get excited about science if they are given access to "authentic" materials, have a feeling of sharing in the process of scientific discovery, and can develop deep personal interest in the topics being considered. Ross *et al.* (2003) did not evaluate the nature of the resulting data, but suggested that the principal scientific contribution of project participants consisted of creating substantial museum research collections, rather than producing specific data that could be used to test particular hypotheses.

The present paper focuses on the nature of the data generated by Project participants using sediment from Hyde Park, and explores to what degree data generated by such "scientist-public partnerships" can be used for genuine scientific research (Harnik & Ross, 2003a). There are several aspects to the "public" components of this particular project. (1) The primary sub-jects were participants in groups that returned specimens sorted from the sediment. These included groups from early elementary school through university level, as well as nonschool community groups. Median and modal age was eight to nine years old, or approximately third grade (Text-fig. 2). (2) Once specimens were returned, they needed further sorting and identification to genus or species level. This was accomplished by a self-trained adult PRI volunteer (Allaby) and a college intern (Gabreski). (3) Dozens of high school to adult volunteers were part of the excavation process at Hyde Park, many of whom filled buckets. (4) Other aspects of the project received adult volunteer support, such as bagging and shipping matrix and databasing information on participants. (5) Mollusks from a set of comparative stratigraphically constrained samples were sorted and analyzed by summer high-school interns (Nancee Kil and Adam Avalos).

In this paper, we explore to what degree robust patterns are retained even in the midst of noise in the data, and infer what biases and data loss can occur in this sort of project. This paper is also the first inventory of the biotic components from the Hyde Park mastodon matrix. We focus here especially on the seeds and mollusks, but the returns also included data on gravel, charcoal, other macrofloral components (twigs, leaves, etc.), and other biotic material (insects, bones), and we comment briefly on these as well. In addition to considering data quality collected by nonspecialists, we also consider the



Text-fig. 1. Simplified overview of processing of mastodon matrix samples, from collection to study by student groups to use in inventorying site flora and fauna.



Text-fig. 2. Relative frequency of participation of different age groups within our subset of 36 returned samples. For simplicity, it was assumed that second grade students are 8 years old, third grade students 9, and so on. The two secondary bars refer to middle school (sixth to eighth grades) and high school (ninth to twelvth grades). Since starting the Mastodon Matrix Project, most participating groups have been of elementary school age, but ages have ranged from pre-K to adults.

degree of lack of stratigraphic constraint arising from the manner in which bulk samples were collected, *i. e.*, as mud removed from above and around the skeleton.

We attempt to address several evident basic questions about the data that students, volunteers, and interns collected. (1) How do the samples compare in range of taxa represented, both in terms of apparent consistency in taxonomic usage between "expert" and nonspecialist, and in terms of finding taxa not known from other scientific studies? (2) How do relative abundances of dominant taxa in Matrix Project samples differ from "expert" data collected by colleagues from the smaller, stratigraphically-constrained samples from trenches and cores? (3) Can the molluscan data, which varies greatly in stratigraphic precision, be used to help stratigraphically position Matrix Project bulk samples? (4) Are replicate samples from within buckets as, or more, similar to each other than samples from between buckets? (5) Assuming internal consistency in identifications (and thus independent of whether species are identified correctly), is there interesting structure to the student data that reveals either scientific insights or potential biases in student processing and sorting?

METHODS: SAMPLE COLLECTING AND PROCESSING

The Hyde Park Site

The sediments were deposited in a low energy abandoned oxbow by the paleo-Fall Kill stream (Miller & Nester, 2006; Nester *et al.*, 2008). From bottom to top, the sediments consist of fluvial overbank silts and clays, shallow-water lacustrine marl, and peat (Nester *et al.*, 2008; Menking *et al.*, 2008). Low energy, acidic swamp conditions led to a very low degree of decomposition and break-up of organic material. A minimum of 2,500 yr at the very end of the Pleistocene is thought to be represented (Miller & Nester, 2006).

Bulk Sample Collection and Processing at Hyde Park

During excavation of the skeleton of the Hyde Park mastodon (August-October 2000), *ca.* 10,000 kg of sediment ("matrix") was recovered from over and around the bones (see Allmon *et al.*, 2008). Although much of the material from the Chemung and North Java sites is highly mixed material removed with construction equipment, most of the sediment from Hyde Park was collected from around the skeleton in individual buckets. In all, *ca.* 800 five-gallon (20-liter) buckets were carried out of the excavation and placed on and under tarps until transported back to PRI. In this sense, the samples are a byproduct of the Hyde Park excavation, collected with the knowledge that some might be used in educational contexts, and not with the expectation that samples would be used for primary scientific work. In most but not necessarily all cases, the sediment collected was from a finite area and range of depths, probably mixing several tens of centimeters of stratigraphic section. Because the sediment was collected from the vicinity of the bones, the samples would have been largely from the lowest detrital peat ("unit 5" of Miller & Nester, 2006), 40 cm of peaty marl ("unit 4," in which bones were especially concentrated), and marly, clayey silt ("unit 3").

The water-logged sediment was spread on tarps and dried, and put back into buckets. Buckets with visible organic materials (fossil-rich peaty marl) were selected for shipping over relatively fossil-poor clay-rich buckets from lower in the section or samples dominated by detrital peat. Bucketed sediment was then packaged into samples of *ca.* 1 kg in resealable plastic bags, usually about half-a-dozen per bucket, which were sent out to Project participants. For the purposes of the study described in this paper, we used a subset of 36 returned samples from 22 different buckets (thus some buckets are represented by more than one returned sample).

Trench Samples

A set of stratigraphically-constrained samples was collected from the edge of a trench dug 10 m southwest of the mastodon excavation pit. Approximately 250 cm^3 samples were collected every 10 cm in the top meter of sediment. These samples were collected in the same fashion as those of the "pit trench" samples used by Miller (2008).

Participant Sample Sorting

Here we focus on 36 samples of Hyde Park matrix that were sent out, returned, curated, and studied between 2001 and 2005.

(Because most of the groups taking part were elementary school classes, we shall generally refer to participating individuals as "students," groups of students as "classes," and group leaders as "teachers.") Each school or organization received one or more 1-kg samples (one per class) of dry matrix with instructions for processing the sample. Each sample contained a set of instructions (Appendix 1), a simple identification guide for expected finds to the level of basic categories (twigs, snails, clams, etc.; Appendix 2), and a data sheet (Appendix 3) for compiling information from each site. The instructions contained general advice for sifting through the matrix in four sessions. Each session used a different method and a different set of requirements, as described below.

Session One

Each class was separated into groups of three to five participants. Each group was given a few tablespoons or chunks of matrix. The peat was broken up using the fingers whereas the marl, which often contained fragile shells and seeds, was broken up using toothpicks to avoid damage to the components. The contents of the matrix were separated according to category: (1) plant material, (2) gravel, (3) mollusks, and (4) everything else (Text-fig. 3). Plant materials were further separated into individual components (*e .g.*, seeds, twigs, leaves, cones, etc.) and weighed when possible. All recovered materials were placed into separate, labeled, resealable bags.

Session Two

Remaining matrix from Session One was processed by wet sieving. Sediment was washed over a homemade sieve of some kind, such as scrim or other mesh stretched over an embroidery hoop. In addition, or alternatively, the sediment could be washed in small "bags" made of scrim or similar fine-weave material. In an alternative version of the instructions (Appendix 1), floatation is used instead of sieving.

Text-fig. 3. A student looks through dried matrix for fossils. Fossils, gravel, and other materials are removed and sorted.

Session Three

The dry material recovered from sieving (Session Two) was sorted, as in Session One, into different categories. Various plant components were again weighed.

Session Four

Gravel was further separated into four categories according to size: B1, gravel larger than 32 mm in maximum dimension; B2, gravel between 8 and 32 mm; B3, gravel between 2 and 8 mm; and B4, all other sediment. Each group of rocks (B1-B3) was then examined for fossils (some area bedrock consists of fossil-bearing shales, sandstones, and limestones of Ordovician-Devonian age). The gravel in each category was weighed.

RESULTS: PROCESSED AND RETURNED SAMPLES

Components Discovered and Sorted by Students

Samples that were returned were curated into their components, and mistakes in sorting were corrected. Several components were consistently recognized and picked out by Project participants; these included twigs and wood, leaves, and snail and clam shells. Seeds were not necessarily separated by participants, but were often in bags labeled "organic matter" or "twigs, leaves, and cones" or "other." Because the degree of sorting of returned materials was inconsistent, project personnel (especially Allaby) did additional sorting of specimens after their return and estimates of all components were quantified. Some specimens were recovered and sorted from returned bags of matrix material ("everything else"). Many returned "rocks" were actually lumps of marl and were removed. Species-level identifications were made for seeds (Allaby, with Gremillion and Buckler) and mollusks (Gabreski) and quantified; other kinds of data from returned data sheets were used selectively after inspection of returned materials, and recounted as necessary (Allaby).

Abundance data for seed types is presented in Tables 1-2, species of mollusks in Tables 3-4, and a variety of other biotic and abiotic data (including charcoal, algal spores, arthropods, bone fragments, and rock fragments) in Table 5. The molluscan data includes actual counts of numbers of specimens, whereas other biotic data, including seeds, was estimated using absent, rare (< 10 specimens), common (10 to < 100 specimens), and abundant (> 100 specimens). Picked and sorted specimens are stored in the Research Partnership Collections of the Paleontological Research Institution, Ithaca, New York.

Table 1. Semiquantitative abundance data for seed taxa. 0 = absent [< 10^0], 1 = rare [< 10^1], 2 = common [< 10^2], 3 = abundant.

Seed types	*Acer* sp.	*Bidens* sp.	*Bidens cernua*	*Carex* sp.	*Carex comosa*	*Cyperus schweinitzii*	*Monarda didyma*	*Najas flexilis*	*Nymphaea odorata*	*Picea mariana*	*Potemageton* sp. (*pusillus*/*richardsonii*?)	*Rhynchospora alba*	*Rubus* sp.	*Ruppia maritima*	*Scirpus americanus*	*Scirpus* sp.	*Sparganium americanum?*	cf. *N. odorata*
HP 0012P-A	0	0	1	0	1	0	0	2	0	0	1	0	0	0	1	0	0	0
HP 0033P-1	1	0	1	0	0	0	0	2	0	1	2	1	0	0	0	0	0	0
HP 0036P-1	1	0	1	0	1	1	0	2	0	0	2	1	1	0	1	0	0	0
HP 0053C-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HP 0058X-3	1	0	0	0	1	0	0	2	0	1	1	1	0	0	1	0	1	0
HP 0064X-3	0	0	1	1	0	0	1	2	0	0	1	0	0	1	1	0	0	0
HP 0080P-1	1	1	0	1	0	0	1	2	0	1	2	1	0	0	1	0	0	0
HP 0170M-2	0	0	0	1	0	0	1	2	0	1	2	0	0	0	0	0	0	0
HP 0170M-4	0	0	1	0	1	0	1	3	0	2	2	0	0	1	1	0	0	0
HP 0272M	1	1	0	1	0	0	2	2	0	1	2	0	1	0	1	0	1	0
HP 0273M-A	0	0	0	0	1	0	0	2	0	0	2	0	0	1	0	0	0	0
HP 0273M-B	0	0	0	1	0	0	1	1	0	1	2	0	1	0	1	0	0	0
HP 0273M-C	0	0	0	0	0	0	1	2	0	0	2	0	0	0	0	0	0	0
HP 0326X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HP 0326X-A	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0
HP 0326X-B	0	1	0	2	0	0	1	2	0	0	2	0	1	0	1	0	0	0
HP 0332M-10	0	0	1	0	1	0	0	2	0	1	1	0	0	0	0	0	0	0
HP 0332M-5	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
HP 0332M-9	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
HP 0335M-6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
HP 0337M-2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
HP 0337M-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HP 0337M-4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
HP 0339M-1	0	1	0	1	1	0	1	2	0	1	2	0	1	1	2	0	0	0
HP 0352X-1	1	0	0	1	0	0	0	2	0	0	1	0	0	0	1	0	0	0
HP 0352X-2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
HP 0352X-3	0	0	0	1	0	0	0	2	0	0	1	0	0	0	0	0	0	0
HP 0352X-4	1	0	0	1	0	0	0	2	0	0	1	0	0	0	1	0	0	0
HP 0352X-5	1	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
HP 0352X-6	0	0	0	0	0	0	1	2	0	1	2	0	0	1	0	0	0	0
HP 0999A	1	0	0	0	1	0	1	2	0	1	2	0	0	0	2	0	0	0
HP 1	0	0	0	0	0	0	1	2	1	0	1	0	0	0	0	0	0	1
HP 2	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
HP 3	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	0	0
HP 5	0	0	1	0	1	0	0	2	1	0	2	0	1	0	1	0	0	0
HP 9130	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0

Plants

Twigs

Nearly all samples contained an abundance of twigs. The youngest students (grades 2-3) seem to have been more capable of picking this component relative to other materials. According to the data returned by some of the schools, the twigs ranged from 0.5-8 cm, with an average length of 1.5 cm. As yet the species of tree(s) from which the twigs came have not been identified.

Table 2. Comparison of seed taxa identified in expert data (Miller, 2008) and data from the Mastodon Matrix Project (MMP).

	MMP	Miller (2008)
Abies balsamea Miller	-	x
Acer sp.	x	-
Amerlancier sp.	-	-
Bidens sp.	x	-
Bidens cernua Linnaeus	x	-
Carex sp.	x	-
Carex comosa Boott	x	-
Caryophyllaceae	-	x
Celastrus scandens Linnaeus	x	-
Cerastium spp.	-	x
Chenopodium hybridum Linnaeus	-	x
Cornus sericea Linnaeus	-	x
Cruciferae (“*Draba* type”)	-	x
Cyperus schweinitzii Torrey	x	-
Hypericum virginicum Linnaeus	-	x
Juncus sp.	-	x
Monarda didyma Linnaeus	x	-
Myriophyllum sibiricum Komarov	-	x
Najas flexilis Rostkovius & Schmidt	x	x
Nymphaea odorata Aiton	x	-
Picea sp.	-	x
Picea mariana Britton , Sterns & Poggenburg	x	-
Podophyllum peltatum Linnaeus	-	-
Potemageton sp.	x	x
Rhynchospora alba Vahl	x	-
Rubus sp.	x	x
Ruppia maritima Linnaeus	x	-
Saxifraga spp.	-	x
Scirpus americanus Persoon	x	-
Scirpus sp.	x	-
Sparganium americanum Nuttall	x	-
Viola spp.	-	x
Vitis sp.	x	-

Cones

Some whole cones were returned, but more often, the small leaf-like scales that make up the structure of the cone were returned in the “other plant material” category. Most of the scales and whole cones appear to be from hemlock (*Tsuga* sp.).

Other Plant Material

In cases in which a class made a significant return of biotic material, a large amount of non-twig material was found. Most of the plant material included desiccated grass-like strands, possibly of some species of pondweed in view of the frequency and consistency with which they were found in the matrix and given the high number of *Potamogeton* seeds that were found in every sample of the matrix. The dried strands are similar to those of modern *Potamogeton* plants.

Algal Spores

In every sample that included plant material, algal spores were abundant. These appear to be charophytes, possibly *Nitella*.

Seeds

Seeds were present in 33 of the 36 sample returns. A total of 19 seed types were identified (Tables 1-2; Text-fig. 4). By far the most abundantly represented species were *Najas flexilis* (naiad, water-nymph) and *Potamogeton* sp. (pondweed; probably *P. pusillus* Linnaeus or *P. richardsonii* Rydberg). *Najas flexilis* was often sorted into the “everything else” category, suggesting that students recognized them as biotic, but not as seeds. In contrast, *Nymphaea odorata* (waterlily), which was not one of the most common seeds, was relatively frequently picked out and recognized as seeds by students, presumably due to their size and sheen. Likewise, *Acer* sp. (maple) and *Picea* sp. (spruce) seem to have been relatively easy to recognize as seeds by students. Most identifications were made using references by Anderberg (1994), Berggen (1969, 1981), Delorit (1970), Delorit & Gunn (1986), Martin & Barkley (1961), Montgomery (1977), and United States Department of Agriculture (1986).

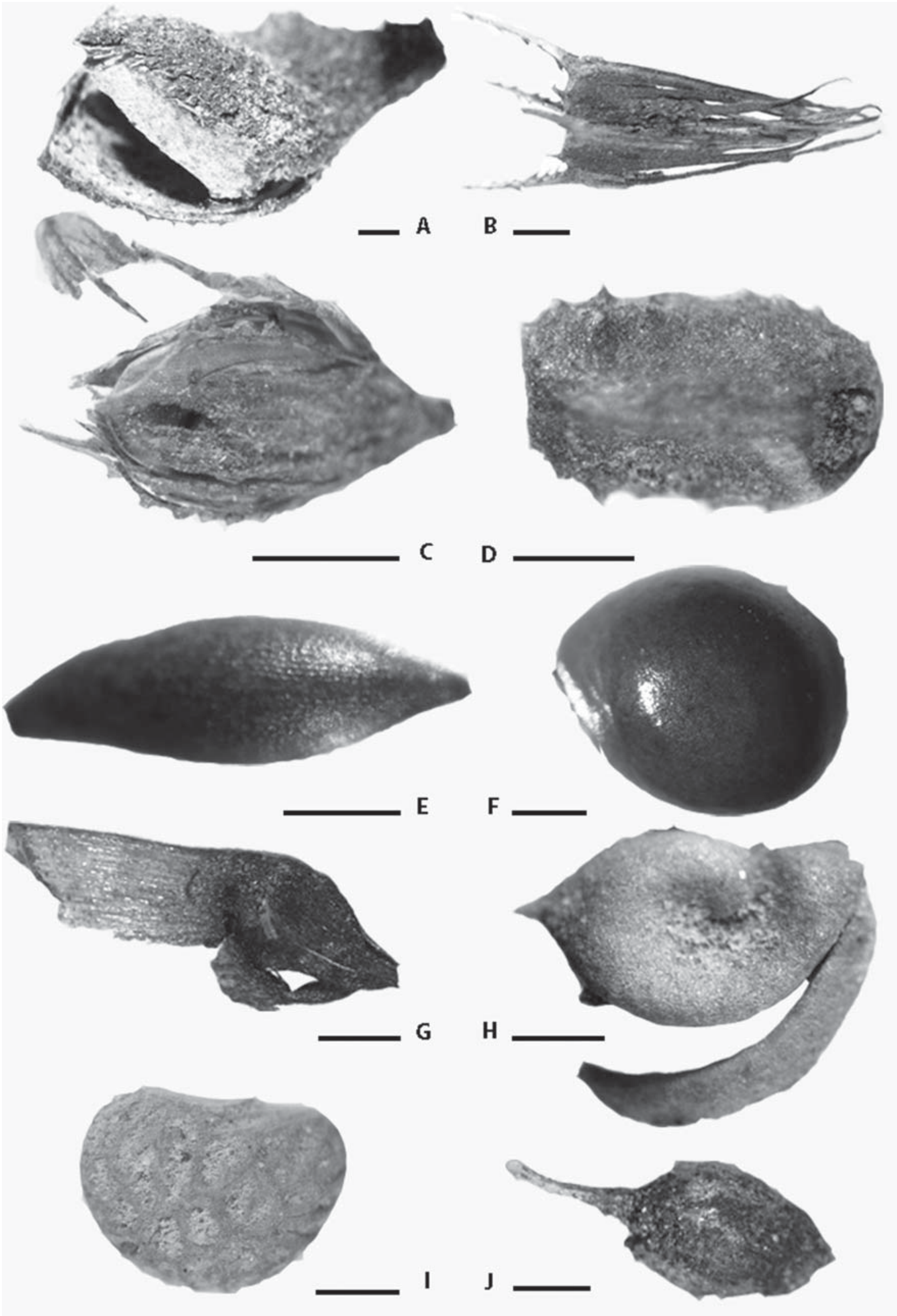
Animals

Mollusks

Mollusks (bivalves and gastropods) were present in all of the returns, but varied widely from fewer than 10 to nearly 200 specimens, and more than 1,500 specimens in total were returned among the 36 samples. Of the mollusks found (Table 3; see also Karrow & Mackie, 2008), most were of freshwater snails (especially planispiral *Gyraulus parvus*, 53% of the mollusk assemblage, and higher-spired *Fossaria parva*, 11%). Freshwater clams were also present (all *Pisidium* spp., especially *P. casertanum*, 29%). A small percentage of the clams was found with both valves articulated.

Insects

Possible insects were present in 16 of the 36 returned samples.



Text-fig. 4. Selected examples of seeds picked out by students. A. *Acer* sp. B. *Bidens cernua*. C. *Carex comosa*. D. *Mondarda didyma*. E. *Najas flexilis*. F. *Nymphaea odorata*. G. *Picea mariana*. H. *Potamogeton* sp. I. *Rubus* sp. J. *Rhynchospora alba*. Scale = 1 mm.

Table 3: Total abundance data for mollusk taxa from bulk samples, picked out by student groups.

	HP 0012P-A	HP 0033P-1	HP 0036P-1	HP 0053C-1	HP 0058X-3	HP 0064X-3	HP 0080P-1	HP 0170M-2	HP 0170M-4	HP 0272M	HP 0273M-C	HP 0273M-B	HP 0273M-A	HP 0326X	HP 0326X-A	HP 0326X-B	HP 0332M-10	HP 0332M-5
Gyraulus parvus	16	46	5	6	24	25	47	65	73	34	28	31	53	NA	5	39	16	9
Valvata lewisi	0	0	0	0	3	2	3	4	7	1	2	3	1	NA	0	3	0	1
Fossaria parva	3	0	0	0	4	5	8	15	20	2	3	12	9	NA	1	17	0	3
Pisidium casertanum	15	22	6	3	12	10	34	23	88	33	20	18	4	NA	2	22	17	1
Pisidium compressum	0	0	0	0	1	1	0	1	3	2	0	3	7	NA	0	0	3	8
Lymnaea stagnalis	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	0	1	0	0
Helisoma anceps anceps	0	2	0	0	0	0	0	0	0	0	0	0	0	NA	0	0	0	0
total	34	70	11	9	44	43	92	108	191	72	53	67	74	0	8	82	36	22

	HP 0332M-9	HP 0335M-6	HP 0337M-2	HP 0337M-3	HP 0337M-4	HP 0339M-1	HP 0352X-1	HP 0352X-2	HP 0352X-3	HP 0352X-4	HP 0352X-5	HP 0352X-6	HP 0999A	HP 1	HP 2	HP 3	HP 5	HP 9130	TOTAL
Gyraulus parvus	23	1	NA	NA	NA	42	30	14	11	0	13	57	0	17	38	11	9	4	792
Valvata lewisi	0		NA	NA	NA	4	1	1	1	0	3	3	3	3	4	1	4	0	58
Fossaria parva	3		NA	NA	NA	7	10	6	5	0	7	19	0	3	7	0	3	1	173
Pisidium casertanum	10		NA	NA	NA	12	8	7	5	0	4	28	4	8	12	0	7	1	436
Pisidium compressum	2	2	NA	NA	NA	7	1	0	0	0	0	2	0	0	0	0	0	0	43
Lymnaea stagnalis	0	0	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Helisoma anceps anceps	0	0	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	2
total	38	3	0	0	0	72	50	28	22	0	27	109	7	31	61	12	23	6	1505

Table 4. Total nonspecialist abundance data molluscan taxa from constrained samples; selected data from Karrow & Mackie (2008) included for comparison.

	Trench sample data collected by high school and college interns												Karrow & Mackie (2008), expert data								
	Trench 2 #3	Trench 2 #4	Trench 2 #5	Trench 3 #1	Trench 3 #2	Trench 3 #3	Trench 3 #4	Trench 3 #5	Trench 3 #6	Trench 3 #7	Trench 3 #8	Trench 3 #9	Karrow 1	Karrow 2	Karrow 3	Karrow 4	Karrow 5	Karrow 6	Karrow 7	Karrow 8	Karrow 9
Gyraulus parvus (Say, 1817)	16	42	14	118	6	7	4	1	2	4	0	0	929	162	59	6	0	0	0	0	0
Valvata lewisi Cumer, 1868	1	6	0	0	8	1	0	0	0	0	0	0	2	23	10	16	6	0	0	0	0
Fossaria parva (I. Lea, 1841)	3	6	2	8	14	2	0	0	0	1	0	0	60	88	9	3	0	0	0	0	0
Pisidium casertanum (Poli, 1791)	1	30	15	35	66	34	4	2	0	1	0	0	55	175	53	25	10	0	0	0	1
Pisidium compressum Prime, 1852	1	0	0	0	1	1	0	0	0	0	0	0	361	19	0	0	0	0	0	0	0
Lymnaea stagnalis (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helisoma anceps anceps (Menke, 1830)	0	0	0	0	0	0	0	0	0	0	0	0	20	2	0	0	0	0	0	0	0
Total	22	84	31	161	95	45	8	3	2	6	0	0	1427	469	131	50	16	0	0	0	1

Most insect fossils were recognizable as wing casings or fragments of the exoskeleton of various beetles. Occasionally a very small translucent fragment, possibly from an insect wing, was found, and one leg was returned. In a couple of samples, whole beetles were discovered.

Other Materials

Gravel

Most of the gravel picked and returned from the samples consisted of sedimentary rock fragments > 8 mm in diameter. No fossils were found in the gravel clasts. Glacial erratics included primarily quartzite and some chert. Very little gravel larger than 32 mm was found (Table 5).

Charcoal

Charcoal was returned in all but one sample (Table 5), present usually in tiny fragments a few millimeters in diameter, although on one occasion a small twig was discovered that had clearly been partly charred.

METHODS: SAMPLE ASSEMBLAGE ANALYSES

The primary purpose of the assemblage analyses was to seek structure in the data that provides some estimate of (1) the degree to which participant data are a reasonable reflection of the true assemblages in the buckets from which the samples were taken, and (2) the degree to which the composition of the assemblage reflects collection within a finite, recognizable stratigraphic interval. We expect *a priori* that, given variations in picking and processing and/or smearing of assemblages among stratigraphic levels, substantial noise has been added to natural patterns of variation. Such noise might cause samples to vary from each other in ways that bear no relation to natural spatial and stratigraphic variation; alternatively, enough of the original signal might be preserved to justify associating environmental context with interesting recovered specimens or (in the future, in principle) to explore associations among selected variables. If the natural pattern seems to have been destroyed, then there is no point in maintaining data on individual samples, and the primary value of the mastodon matrix project might be pooling specimens into late Pleistocene taxonomic reference collections.

Because we do not have "expert" data from the same samples, to estimate the fidelity of the actual assemblages represented by the student data, we needed to look for other indirect ways of interpreting whether the data reflect expected patterns of variation. Three of these include (1) comparing the samples with "expert" data from other samples from the same site, and (2) looking for internal consistency within the data from (a) among samples from the same bucket, and (b) among the whole group of samples. If the original data structure is

Table 5. Semiquantitative data for all components. 0 = absent [< 10^0], 1 = rare [< 10^1], 2 = common [< 10^2], 3 = abundant.

	plant						animal						gravel			
	twigs	leaves	cones and cone scales	other macroplant material	algal spores	charcoal	planispiral gastropods	high-spired gastropods	bivalves	vertebrate remains	insect remains		gravel 2 - 4 mm	gravel 4-8 mm	gravel 8 - 32 mm	gravel > 32 mm
HP 0012P-A	2	1	0	2	2	2	2	1	2	0	0		1	2	3	2
HP 0033P-1	3	0	0	2	1	2	2	1	2	0	0		0	1	2	1
HP 0036P-1	3	1	2	3	2	2	2	0	2	0	1		0	1	2	2
HP 0053C-1	2	2	0	2	1	1	2	0	2	0	0		0	1	2	2
HP 0058X-3	2	1	1	2	1	1	2	1	2	0	0		1	2	2	2
HP 0064X-3	2	0	1	2	2	1	2	1	2	0	0		1	2	2	1
HP 0080P-1	3	0	2	3	2	2	3	2	2	0	1		0	1	2	2
HP 0170M-2	2	1	1	2	2	1	3	2	2	0	0		1	0	2	1
HP 0170M-4	2	1	2	2	2	2	3	2	2	1	1		0	1	2	1
HP 0272M	2	2	1	2	2	2	2	1	2	1	1		0	1	2	1
HP 0273M-A	2	1	1	2	2	1	2	2	2	0	0		0	0	0	0
HP 0273M-B	2	1	1	2	2	2	2	2	2	0	1		0	1	2	1
HP 0273M-C	2	0	1	3	0	1	2	1	2	0	0		0	0	2	1
HP 0326X	2	1	0	2	0	1	1	0	1	1	0		1	2	2	2
HP 0326X-A	2	1	0	2	1	1	2	1	1	0	0		1	2	2	2
HP 0326X-B	3	2	2	3	2	2	3	2	2	0	1		1	2	3	2
HP 0332M-10	2	2	1	3	2	2	2	1	2	0	1		1	2	2	2
HP 0332M-5	2	1	1	2	1	2	1	1	2	0	0		1	2	3	1
HP 0332M-9	2	0	1	2	0	2	2	1	2	0	0		0	2	2	2
HP 0335M-6	2	0	0	0	1	1	1	0	1	0	0		1	2	2	1
HP 0337M-2	2	1	0	2	1	1	2	0	1	0	0		0	1	2	1
HP 0337M-3	1	0	0	1	0	1	2	0	1	0	0		0	0	1	0
HP 0337M-4	3	1	1	2	1	2	2	1	1	0	0		0	2	2	2
HP 0339M-1	2	1	1	2	2	1	2	1	2	0	0		0	0	1	0
HP 0352X-1	2	2	2	2	2	1	2	2	2	0	1		0	1	2	1
HP 0352X-2	2	1	1	2	2	2	2	1	2	1	1		0	1	1	1
HP 0352X-3	3	0	1	2	1	1	2	1	1	0	1		0	1	2	1
HP 0352X-4	2	1	0	2	2	2	2	2	2	0	0		0	1	1	1
HP 0352X-5	2	2	2	2	0	1	2	1	2	1	0		0	1	2	1
HP 0352X-6	2	2	2	2	2	1	3	2	2	1	1		0	1	1	2
HP 0999A	2	0	2	2	2	2	2	0	1	0	1		0	1	0	2
HP 1	1	0	0	2	0	0	2	1	1	1	1		0	0	0	1
HP 2	2	2	1	1	0	1	2	2	2	0	0		0	0	1	1
HP 3	3	2	1	2	1	1	2	2	1	0	1		0	0	2	0
HP 5	3	3	0	3	0	2	2	1	2	0	1		1	2	1	1
HP 9130	3	2	0	2	0	1	1	1	1	0	1		1	0	0	1

preserved, we would expect that student samples would be generally similar to expert data, particularly to expert data from the stratigraphic level of the mastodon from which most of the bucketed mud came. We would expect that the samples from the same buckets might be more similar to each other than samples between buckets; if samples between buckets vary, we estimate that variation would be similar to what we would expect from small variations in composite stratigraphic intervals represented among buckets.

Analysis of the returned materials involved investigating presence/absence and abundance data. To understand better the similarities among the samples, we chose to use a standard similarity coefficient (Bray-Curtis) and to ordinate the samples using a two-dimensional, nonmetric multidimentionsal scaling analysis (MDS) (*e. g.*, Cheng, 2004).

For the molluscan samples, we used relative abundance data. For other samples, to quantify semiquantitative abundance data, we ascribed log10 estimates [0 = absent (< 10^{0}), 1 = rare (< 10^{1}), 2 = common (< 10^{2}), 3 = abundant]. In this sense we are using coarse-resolution, log-transformed abundance data.

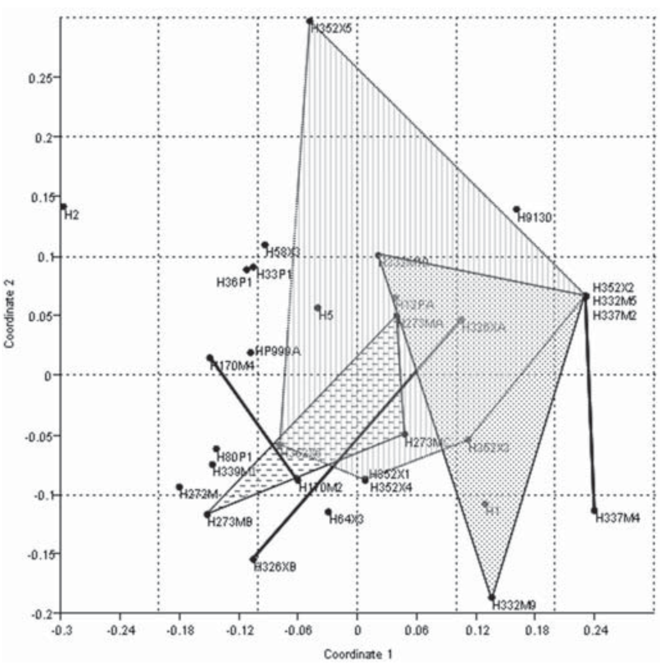
RESULTS: PATTERNS IN SAMPLE ASSEMBLAGES

SEEDS

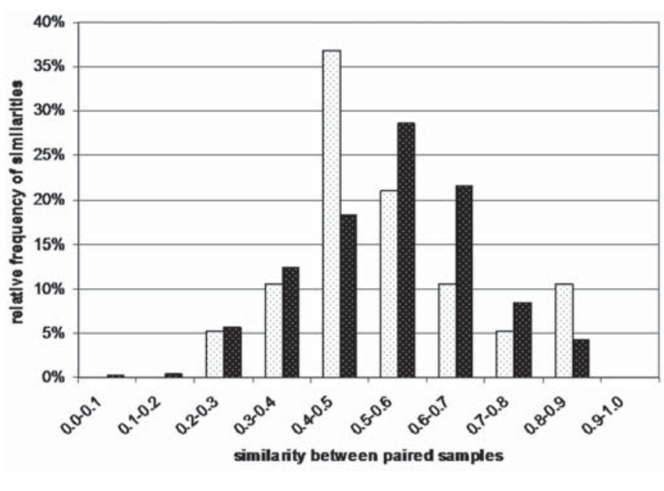
One of the most basic goals of collecting materials from bulk samples was to extend the inventory of species and other materials present at the site beyond that found in the relatively small number of small trench and core samples. Although in principle our intention was to look for any kind of biotic materials, the practical first investigation was to use seeds to extend the known flora.

The most common taxa of seeds, *Najas flexilis* (water-nymph) and *Potemageton* sp. (pondweed), were identified in over 80% our bulk samples and in samples studied by Miller (2008). *Picea* sp. (spruce) was also in the Miller samples and in over one-third of our samples (Table 1). In total, at least 17 taxa we identified from the bulk samples did not show up in those of Miller (2008), including two species of *Carex* (sedge; present in more than one-third of the bulk samples), *Monarda didyma* (beebalm; present in 28%), *Acer* sp. (maple; 28%), and one or two species of *Bidens* (sticktight; 19%). At face value, this suggests that one goal of the project, to more completely inventory the flora from the site, was accomplished. Conversely, Miller (2008) identified at least ten taxa that were not identified in our bulk material, although this could reflect not having been identified rather than not having been found (Table 2), because several other taxa from the bulk samples remain unidentified. It is possible that parts of a spruce assemblage, from overlying early Holocene peat mixed into the bulk samples, could account for some of the species not found in the Miller samples (N. Miller, pers. comm., November 2007).

To explore similarity among samples using the seed data, we created a Bray-Curtis similarity matrix and performed an MDS analysis on semiquantitative abundance data. The similarity of samples between buckets and within buckets is approximately the same (the difference is not statistically



Text-fig 5. Nonmetric multidimensional scaling analysis using Bray-Curtis similarity coefficients on seed data, using semiquantitative order-of-magnitude data. Lines and minimum-area polygons connect points from the same buckets.



Text-fig. 6. Comparison of similarities (using Bray-Curtis similarities on semiquantitative data) in seed assemblages among samples from the same buckets and from different buckets. Median similarities: Hyde Park (HP) within-bucket similarity (white) 0.48; HP between-bucket similarity (black) 0.50; identical = 1. There is no statistically significant difference between the distributions, meaning that seeds really are homogenously distributed within the excavation site or that selective picking homogenized an originally heterogeneous distribution.

significant, based on a Mann-Whitney U-test); this can be observed in the broad scatter of assemblages from the same buckets in the plot (Text-figs 5-6).

This suggests either that seed assemblages are spatially homogeneously distributed (*e. g.*, they are allochthonous and evenly dispersed spatially) or that data noise, from variation in student recognition and selection of seeds, decreased distinctness among samples. Seeds, unlike mollusks, are relatively robust and less likely to vary among samples due to breakage, but are visually less conspicuous than mollusks and might be less likely to be noticed by students of certain age groups.

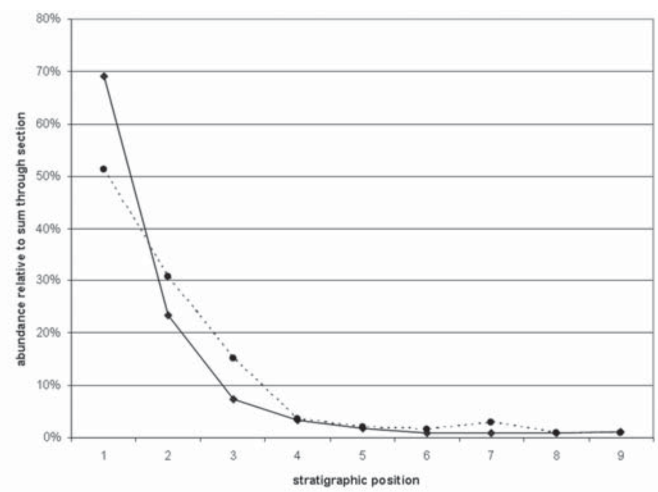
MOLLUSKS

Assemblage Composition

Over 1,500 individual molluscan specimens were identified from our bulk samples. The apparent diversity was low and the vast majority were assigned to species identified in expert data (Karrow & Mackie, 2008).

Using Absolute Abundance as a Stratigraphic Proxy

Based on trench samples, including both expert data by Karrow & Mackie (2008) and student intern data, the number of mollusks increased by almost two orders of magnitude from the samples below 50 cm depth to the topmost sample under the peat (Text-fig. 7). We could use molluscan abundance alone as a measure of bucket sample depth if (1)there were no biases in sample processing and picking by students undertaking the Matrix Project, and (2) the bulk samples are not so mixed across depth and space that they have become uninterpretable. The variation in molluscan total abundance from the bulk samples does happen also to span two orders of magnitude, which we might initially assume reflects stratigraphic variation. Because we know, however, that mollusks are fragile and break easily, the number of mollusks that the students picked out might also be explained simply through biases of processing rather than actual abundance. We therefore need an independent measure of depth that could be based on *relative* abundance of molluscan species, which might be less likely to be influenced as strongly by variation in processing and picking (assuming that biases in abundance of individual species are not well correlated with bias in total molluscan abundance).



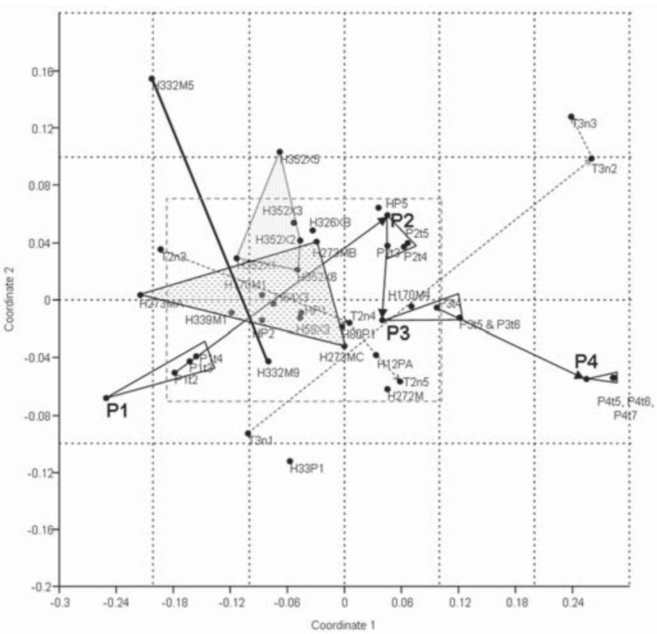
Text-fig. 7. Depth gradient in molluscan abundance per unit volume of sediment, using expert data from “pit trench” samples (Karrow & Mackie, 2008; solid line) and volunteer data from “trench 3” samples (interns; dashed line).

Based on the Karrow & Mackie (2008) data, the relative abundance of several species do show strong depth gradients that could also serve as depth proxies. The planispiral snail *Gyraulus parvus* tends to increase in percentage through time. The snail *Valvata lewisi* and bivalve *Pisidium casertanum* are at their maximum soon after appearing at the pond and, although increasing in abundance until the penultimate sample, decline in *relative* abundance steadily afterward (as *G. parvus* becomes dominant). (The patterns are similar, but not identical, in two additional sets of stratigraphically constrained trench samples studied by high school interns; see Table 4.) If there are no taphonomic biases, in particular if abundance per unit weight of sediment is maintained in student-picked bulk samples, then we should expect stratigraphically lower samples to have smaller absolute abundances of mollusks. One way to test whether this is true (and thus whether total abundance can be used as a stratigraphic proxy) is by observing whether samples with fewer mollusks also have assemblages that are similar to the stratigraphically lower samples studied by Karrow & Mackie (2008; assuming that the Karrow & Mackie data can be generalized spatially to the *ca.* 100 m^2 area around the excavation), which have small relative percentages of *G. parvus* and high percentages of *V. lewisi* and *P. casertanum*. In the student-picked bulk samples, there is very little relationship between total mollusks picked from each sample and relative abundance of these three species. Thus, the number of specimens picked by the students probably does *not* reflect actual abundance in the samples and cannot be easily used as a depth proxy.

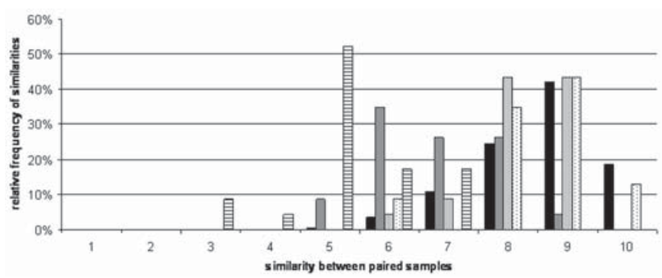
We performed ordination analyses on the molluscan assemblages to search for structure in the relative abundance data in the bulk samples. We observed patterns that indicate that the student-picked samples contain relative proportions of species that (a) were similar to some of those of the Karrow & Mackie (2008) reference samples, and (b) are consistent with what we would expect if the samples were from a limited set of depths. If the samples were strongly mixed and/or the processing caused strong biases, the relative abundances in the resulting assemblages might be expected to strongly differ from the more carefully collected and identified samples of Karrow & Mackie (2008). Further, if the data are problematic, it would be expected to be different in random ways from the depth gradient that we see in the Karrow & Mackie (2008) data.

A total of 37 samples plus 12 stratigraphically combined samples (Tables 3-4) were ordinated using relative abundance data (Text-fig. 8). These samples included the following. (1) The similarities among 23 (of 36) bulk samples that have a sample size of greater than 20 were used for assemblage analysis. (2) For comparison, expert data from the top four stratigraphically constrained 10-cm samples (P1 = 0 to 10 cm, P2 = 10 to 20 cm, and so on; Karrow & Mackie, 2008) were used; other samples from that study, from lower in the section, had too few specimens for analysis. (3) To simulate mixing of sediments from different layers, as occurred in collection of the buckets of matrix, stratigraphically adjoining samples of the expert data were binned in various combinations: (a) 0-70 cm in intervals of 20 cm (P1t2, 0-20 cm; P2t3, 10-30 cm; P3t4, 20-40 cm, etc.), (b) intervals of 30 cm (*e. g.*, P1t3, 0-30 cm), and (c) intervals of 40 cm. Such combined samples might in principle provide a better match to the bucket samples than any individual 10-cm interval. In total there were 12 of these sample combinations. (4) Six other stratigraphically constrained 10-cm samples from Trench 3 that had sufficient numbers of specimens, which had been studied by nonspecialist high-school and college interns, were also used.

The two-dimensional MDS plot (Text-fig. 8) suggests that in fact the relative abundance data from the bulk samples *do* plot in a way that would be expected if the assemblage data retains original and interpretable structure. First, the Karrow & Mackie (2008) samples, not surprisingly, vary on the plot from the *Gyraulis parvus*-dominated sample in the top 10 cm (P1) to the mollusk-poor samples from 30-40 cm (P4), with samples from 10-20 cm (P2) and 20-30 cm (P3) relatively similar to each other and intermediate with respect to samples P1 and P4. The bulk samples largely fall into the same MDS space as the Karrow & Mackie (2008) samples; the highest similarities are with samples P2, P3, and P2-3 (10-30 cm), confirming their position at roughly the depth of the Hyde Park mastodon skeleton.



Text-fig. 8. Nonmetric multidimensional scaling analysis using Bray-Curtis similarity coefficients on molluscan data, using relative abundance percentages. P1 to P4 are core data from Karrow & Mackie (2008); P#t# refers to mixed theoretical samples, *e. g.,* P1t2 is sample P1 (0-10 cm from top) mixed with sample P2 (10-20 cm). Cones have been drawn from each actual sample to mixed assemblages, and arrows from higher samples to lower. Lines and shaded minimum-area polygons connect points from the same buckets. T#n# refers to trench number, sample number, *e. g.*, other trench samples processed by high school interns. In all three trench sequences, the youngest and oldest samples plot on opposite sides of MDS axis 1. Notice that most samples fall within a rectangle representing the MDS coordinates for Karrow & Mackie (2008) samples mixed from 10-40 cm depth .



Text-fig. 9. Comparison of similarities (using Bray-Curtis similarities on relative abundance data) in molluscan assemblages among samples from expert data (P1-4) and from bulk sample data. Median similarities: Hyde Park (HP) within-bucket similarity 0.88; HP between-bucket similarity 0.82; P1 vs. HP buckets 0.62; P2 vs. HP buckets 0.78; P3 vs. HP buckets 0.81; P4 vs. HP buckets 0.47; identical = 1. Bars include: HP buckets within-sample variability (black); expert data top 10 cm vs. HP buckets (dark gray); expert data top 10-20 cm vs. HP buckets (light gray); expert data top 20-30 cm vs. HP buckets (stippled white); expert data top 30-40 cm vs. HP buckets (hatched). The distribution of samples P1 to P4 reflects the known stratigraphic assemblage gradient from 0 to 40 cm depth reported in Karrow (this volume); the bulk sample data plot most closely to P2 and P3, about the stratigraphic level at which bulk samples were removed as the mastodon was excavated. Unlike the seed data, samples from within the same bucket are more similar on average than samples from different buckets.

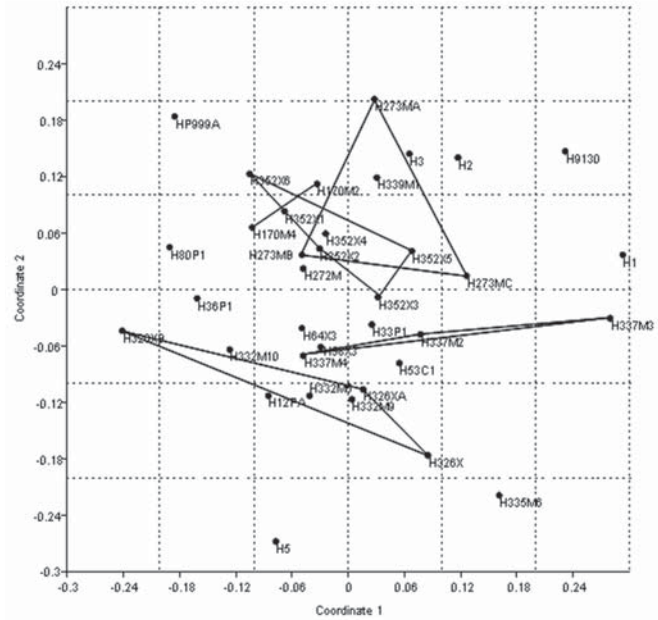
To better understand the distribution of similarities among groups of samples of interest, we plotted histograms and computed median similarities (Text-fig. 9). For example, there is no statistically significant difference between the distribution of similarities within the group of student-picked bulk samples (median Bray-Curtis coefficient 0.82) and the distribution of similarities between expert sample P2 and student samples (median 0.81), and only a weak statistical difference ($p = 0.08$ using a Mann-Whitney U-test) in an analogous comparison using expert sample P3 (median 0.78).

We might then ask whether any natural heterogeneity between buckets (that we would expect if there was a depth gradient and/or spatial heterogeneity in molluscan assemblages) is captured in the data, or if this was wiped out by (1) vertical mixing in the process of collecting bucket samples, and (2) variation in student processing among samples. One way to test this is to observe whether similarity among samples from the same bucket, which serve as replicates (assuming that the samples within any one bucket has become well-mixed), is greater than between buckets. Fifteen "within-bucket" sample pairs (two samples from bucket HP332, three samples from HP273M, and five samples from HP352X) have a median Bray-Curtis coefficient of 0.88, statistically significantly higher ($p = 0.04$) than the median among samples from different buckets (median 0.82, $n = 239$). There is, however, substantial overlap in similarity coefficients within and between buckets, suggesting that although samples do tend to retain modest interbucket differences, different buckets are largely drawing from the same depths and assemblages.

OTHER DATA

Similarities among the 36 samples (Table 5) were compared as a group using mixed quantitative data as described above, using a Euclidean dissimilarity coefficient (Bray-Curtis, designed for biotic assemblages, is less appropriate in this case, because the data include gravel and other inorganic material). This data set includes abundance of macroflora, gravel, charcoal, and twigs, and includes molluscan data compiled into high- and low-spired snails and bivalves. Arthropods and bone fragments were not included because of their rarity and uncertainty in identification.

An MDS plot (Text-fig. 10) suggests some interpretable structure to the data: samples along axis one vary from those with high abundance of most components (left side) to those with poor representative of most components (right); axis two tends to vary from those rich in mollusks and aquatic algal oospores to those richer in macroplant remains and gravel. If that pattern is "real," then we might expect samples from the same bucket to plot together, whereas if that structure is an artifact of how the samples were processed or picked, then



Text-fig. 10. Nonmetric multidimensional scaling analysis using Euclidean similarity coefficients on mixed data, including both biotic and sediment components. Lines and minimum-area polygons connect points from the same buckets. Samples from the same bucket are typically more similar to each other han they are to other buckets.

we might expect samples from the same bucket to be no more similar to each other than samples from different buckets. (Note that in dissimilarity coefficients, lower values indicate greater similarity.) The result is that within-bulk sample distances are shorter (more similar, at 0.76) than between-sample distances (0.90), highly statistically significantly different (Mann-Whitney U-test, $p < 0.001$). This suggests that there are real differences between the buckets, and that the student data, in spite of the "noise," picks up those differences.

To determine whether the age of participants alone might account for some of the differences among samples, quantities of each of the primary components were plotted against student age. This required turning the log-tranformed semiquantitative data into estimated total numbers. There do not appear to be age-distribution differences among the number of specimens reported per sample for any of the primary variables, with the possible exception of mollusks, which on average are more likely to reported in larger numbers by secondary-school and college-aged students. We did not investigate whether sample ordination varies by age participating group, but our expectation is that this effect is small.

CONCLUSIONS

One of the primary limitations in development of sorted collections of paleontological materials is the human labor involved in finding and sorting specimens in sediment or sedimentary rocks. In turn, one of the main reasons that the general public does not understand what scientists study is because they have few opportunities to have direct contact with authentic materials and open-ended questions. One might expect that, with careful planning, these two problems ought to have mutually beneficial solutions, in the involvement of nonspecialists in collecting and sorting fossil materials. The Mastodon Matrix Project was born in this spirit, and the project has been pushed along over the years primarily by a remarkable demand from educators, who found tremendous student interest in working with materials associated with such spectacular fossil finds (Ross *et al.*, 2003). It takes additional human resources to manage both the educational and research aspects of these scientist-public partnerships, and because PRI has had no paid staff over the length of this project with adequate time to oversee logistics of the project and curation of the materials, the project has survived through the dedication of a wide spectrum of volunteers and interns. This study represents a compilation of selected data associated with a nearly entirely volunteer-run project, and so represents documentation of the kind and quality of data that can arise out of this sort of effort.

Some of the most basic objectives were achieved: (1) large numbers of participants were relatively easy to recruit and this resulted in a large amount of returned material, and (2) the material seems to have yielded seed taxa not reported in other Hyde Park studies (and some components still not identified past the most basic categories could yet yield new taxa). A number of components such as insect parts have not yet been studied closely, and since the data for this paper were compiled, many samples have been returned that have yet to be curated and analyzed.

The relative abundance among molluscan taxa from student-sorted bulk samples is what we would expect of samples collected from near the top of the organic-rich marl at approximately the depth of the mastodon skeleton, in spite of: (1) the mixing of sediment in bucketed samples, and (2) potential processing and sorting biases in student-collected data. The total number of mollusks picked out, however, does not seem to reflect expected natural abundances. In the molluscan data and in "mixed" data, samples from the same bucket are more similar to each other on average than samples between buckets. Interestingly, seed data is more homogeneously distributed than that for mollusks, leading to the question of whether this reflects true differences in meter-scale spatial variation of these two types of materials. In science-public partnerships, it could thus be not just collections of specimens, inventories of species, and tables of data that are important. Even if data are noisy, if large quantities of data retain sufficient "true" information to raise new scientific questions, then they have important additional scientific value.

RECOMMENDATIONS FOR FUTURE INITIATIVES

In 2000, when the samples were collected, we could not have envisioned what future years would bring in terms of volunteer or staff investment of time. Over the years we had several volunteers (Allaby in particular) without whom this compilation of data would not have occurred. Although this study is not a "how to" for running such research partnerships, the process of gathering and analyzing volunteer-collected data leads naturally to suggestions for running similar science-public partnerships.

(1) Authentic samples are intrinsically interesting to the general public, and it is possible to recruit large numbers of teachers and other individuals who, in principle, would like to be involved. It is helpful to maintain steady communication and coordination with groups that are interested in the samples, both because the educational impact is higher and because the likelihood of the samples getting processed and returned is higher. Motivation to continue the project on an annual basis is in part contingent upon a response from a project scientist or coordinator.

(2) The scientific impact, of course, is only as good as the quality of samples that are collected. The samples used in the mastodon matrix project were byproducts of the excavation process at the three sites (Chemung, Hyde Park, and North Java). There was little opportunity to spend significant quantities of time collecting very large quantities of material specifically for this sort of educational outreach; most of the Hyde Park samples happened to be more stratigraphically constrained simply because of the way they were removed. Nevertheless, it would be well worth the time at other excavations to develop a system for removing bulk material, as part of the excavation process, in a way that facilitates collection of bulk samples for which stratigraphic position can be documented and constrained.

(3) It would be helpful early on in a research project to develop outreach in collaboration with other project scientists, who can then lend expertise from the start of the project on how students and volunteers should process and curate samples, and provide feedback on collected data – especially back to classroom teachers and students.

(4) By its nature, such a project involving very large quantities of bulk sediment takes considerable space, for storing, processing, shipping, and curating samples. It is helpful to set aside storage and workspace early in the project that will be stable throughout the course of the project.

(5) Our personal experiences from working directly with students on the Matrix Project is that students from a very

young age can find and sort out small specimens of potential scientific interest. For such a project to have interest beyond merely creating a collection of such specimens, it is of course essential that sample processing occurs according to protocols consistent among participating groups. Although we did send out detailed instructions, it is evident that different teachers carried out the project in somewhat different ways. Balancing what is expedient (especially given classroom limitations) and what is necessary scientifically is an inevitable consideration.

ACKNOWLEDGMENTS

We are grateful to Alan Clapham for assistance with seed identification, Adam Avalos and Nancee Kil (NASA Sharp highschool summer interns at Cornell University) for assistance with sample sorting, Norton Miller for advice on interpreting the seed data, and Andrea Kreuzer for help with the illustrations. Special thanks are due to Peter Nester and Michelle Goman for comments on previous drafts of the manuscript, and to Michelle Goman for assistance with seed photography. PRI volunteers Stu Anderson, Victoria Tesoniero, Andrew Goldman, and interns Amy Patchen (Oberlin College) and Patrick Brennan (Cornell University), provided helpful logistical support. Chris Underwood (University of Tennessee Knoxville), William Slattery (Wright State University), and teacher Sandy Wasserman (Levittown Union Free School District) provided useful insights on their implemention of the project. John Chiment began the Matrix Project in early 2000 using materials from the mastodon excavation in Chemung County, New York, and Jim Sherpa played a large role in developing and managing the Hyde Park Mastodon Matrix Project over several years.

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Appendix 1. Instructions to school groups for carrying out the matrix project. These directions originated with John Chiment for the Matrix Project developed from the Chemung County (New York) mastodon excavation (Ross *et al.*, 2003) and were substantially modified for the Hyde Park project by James Sherpa. This version is simplified from the instructions described in "Methods" above.

The Mastodon Project

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Welcome to the Mastodon Matrix Project,

Allow us to begin by saying that we don't know exactly what is in your bag. This is a research project, not a laboratory exercise. This research is an open-ended educational journey into New York's Ice Age past. We hope that you and your group will learn something exciting, and would love to hear about what you have gained from this exercise.

The only requirements to participate are that you are a careful and observant researcher and that you return the materials you find together with the completed data sheet. We will summarize the data sheets of all the participants and post the results on the web. We would also like to have names, and a photo of the participants, if possible. Any supplementary materials that you feel inspired to contribute are also welcome.

The following pages contain basic instructions to guide your exploration of the matrix collected from around the bones of the Hyde Park Mastodon. Feel free to adapt the materials and approach to better fit the needs of your group. In short, we are asking you to sort organic (once living) from inorganic (never living) things, lithic (rock) from non-lithic things, to examine the different categories that you find, and document anything that appears interesting or extraordinary to you. We also ask that you return all of the materials to the Mastodon Project at the Paleontological Research Institution.

If you would like additional information, please visit the following web sites:

- http://www.priweb.org has online instructions, along with information about the Hyde Park Mastodon excavation (where your sample was collected!)
- http://www.geo.cornell.edu/mastodon has information about the Cornell Gilbert Mastodon Project.

If you would like additional instructions, or have a question, you can also reach the Mastodon Project by email at jms242@cornell.edu.
Some have asked if they can contribute to the Mastodon Project's funding. Contributions to the project are much appreciated, as it is currently funded largely by private donations. Contributions are tax-deductible and should be made to the Mastodon Project.

Remember, by participating in this project, you are playing an important role in an actual scientific study. Thank you for your help in researching New York's Ice Age history, and we hope you enjoy the experience!

Jim M. Sherpa
Matrix Project Coordinator

Matrix Instructions

You have received a 1-kilogram bag of "matrix" from a mastodon site in Dutchess County, New York. Everything in the bag is at least 9,000 years old, though some of the twigs, leaves and shells may not look very old. They have been well preserved by being buried in an acidic bog since the Ice Age. We have found that a kilogram will keep 20 or so students busy for 2-3 sessions of about 30 minutes each. You are encouraged to take more time if required, or to include more students as needed. In your bag there is likely to be a mixture of peat, which is brown, organically rich material, and marl, a gray, clay-like material containing small shells.

Session #1

Required Supplies: newspapers, paper plates, toothpicks, one or more embroidery hoops with a piece of scrim (or other gauzy curtain material), or a clean fine mesh, grease splatter screen, jars with wide mouths and tight fitting lids, and a scale (preferably a beam balance scale, accurate to at least a 10 of a gram).

Recommended Supplies: a magnifying glass, a low-power microscope, an overhead projector, and a black plastic plates.

1. Separate into groups of 3-5 students. Cover workspaces with newspaper. You may want to begin by placing a small amount of matrix on the glass of an overhead projector and identifying different items such as rock and shell material for the whole class to see.

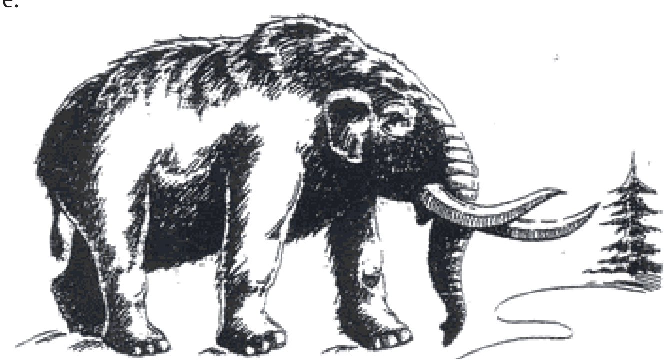
2. Give each group a few tablespoons or chunks of matrix. The peat (brown material) may be broken up with your fingers and looked through. The marl (gray, clay-like material) will have visible shells that should be picked out with toothpicks. The shells are very delicate, so try to be as careful as possible when extracting them. Then place the chunks of marl in a jar of warm water filled to about a 1/2 inch from the rim and put on the lid. Set this aside to soak, occasionally swirling the water and matrix around gently until the material has completely fallen apart. In the meantime, sort the rest of the material into 4 piles.

A. Wood, cones and leaves
B. Rocks
C. Shells
D. Everything else

3. Examine the wood, cones, and leaves. You may find a group of twigs of similar length (1/2"-1 1/2"). Some of these may be crushed on one end and broken on the other. We believe mastodons ate spruce twigs this way, grabbing the short green twigs, and breaking them off. This group of twigs, which you have on your desk, could have passed through the stomach and intestines of a mastodon.

4. Collect the wood, cones and leaves from each group and weigh. Put it in a ziplock bag and return to PRI. Use your tweezers or toothpicks to put the shells into a bag. How many different kinds of snail shells did you find? How many different kinds of clams? Did you find any charophytes (algae spores)? Any ostracodes? Please return these shells to PRI.

5. When the marl in the jar is completely separated, pour it through scrim-lined embroidery hoop or a fine screen. Dry on paper and treat as above.



Session #2

Required Supplies: water to wash rocks, an old toothbrush, paper towels to dry them, coffee filters, a colander or funnel, a magnifying glass, and plastic ziplock bags.

Optional Supplies: beam scale.

6. Separate the rocks into 3 piles.

B1-Big, gray rocks (Big means larger than a 25-cent coin)
B2-Little gray rocks (smaller than B1, but bigger than 2mm)
B3-All other rocks

7. Students may want to wash off their rocks to see the colors. You can simply wash them off under a faucet. You can, if you want, run the wash water through the coffee filter, let the material dry overnight and examine the materials left in the filter with a magnifying glass.

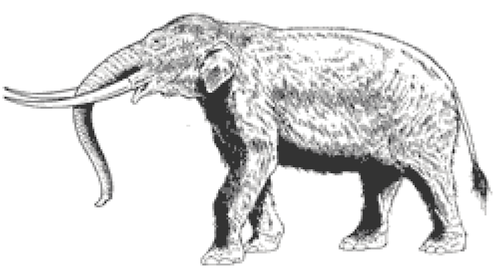
Some of the things you will find in the B3 pile:

Black shiny rocks are probably chert. They are found today in limestone layers between Rochester and Albany, New York. They were carried south to Dutchess County by the glaciers. Chert may be the remains of fossilized sponges that lived over 400,000,000 years ago in a salty ocean. Visit http://www.geo.cornell.edu/glasssponge to find out more. Chert was used by early people in North America to make knives and other tools. Look closely at the edges of these rocks. You may find possible signs of being "worked" by early North Americans!

Rocks with colors of red, white, etc. were also carried by glaciers to Dutchess County. Many are igneous or metamorphic rocks, which are common in Canada and the Adirondack Mountains. These rocks are called "glacial erratics." They may tell us the exact path the glacier took on its way from Canada to Dutchess County. Bag these rocks, and send them back to PRI. If you wish, you can weigh all of the rocks together and send back the results.

8. Put all the B1 rocks together. Examine them carefully. These rocks are likely to be sedimentary rocks. They are hardened sediments from the bottom of an ancient ocean. Some may have impressions of shells and other fossils. In New York State, these shale fossils are probably hundreds of millions of years old. Remember, the mastodon and the wood in your bag is "only" 11,500 years old. Note your finds. B1 rocks with fossils should be bagged and returned to PRI. Again, if you wish, you can weigh them and send us the results.

9. Do the same sorting and examination of B2 rocks, which are the same material as the B1 rocks. If any of these small rocks contain what appear to be fossils, bag them separately and return to PRI. Weights are again encouraged, yet not required.



Session #3:

Required Supplies: A bowl of water, a spoon, some coffee filters, colanders or funnels, and paper towels.

Recommended Supplies: You may want to have some small bottles (pill bottles or film canisters are good) to protect small or delicate items, and a black plastic plate.

10. Take about 1/2 teaspoon of "dirt" from bag D and dump into a bowl of water. The material and ivory will sink. Insect fossils, hair and other organic material will float. Use a spoon to skim off the top and place on a black plate. Let this dry and examine with a magnifying glass. Place all interesting materials--seeds, hairs, small shells, insect parts, etc. into the containers, and return to PRI.

11. When all of D has been "wet-sorted," pour the bowl of dirty water through a coffee filter, let the material at the bottom of the filter dry, and examine. Look for brown-colored pieces of bone and creamy-colored pieces of tusk (ivory). Bag up the interesting discoveries and return them to PRI.

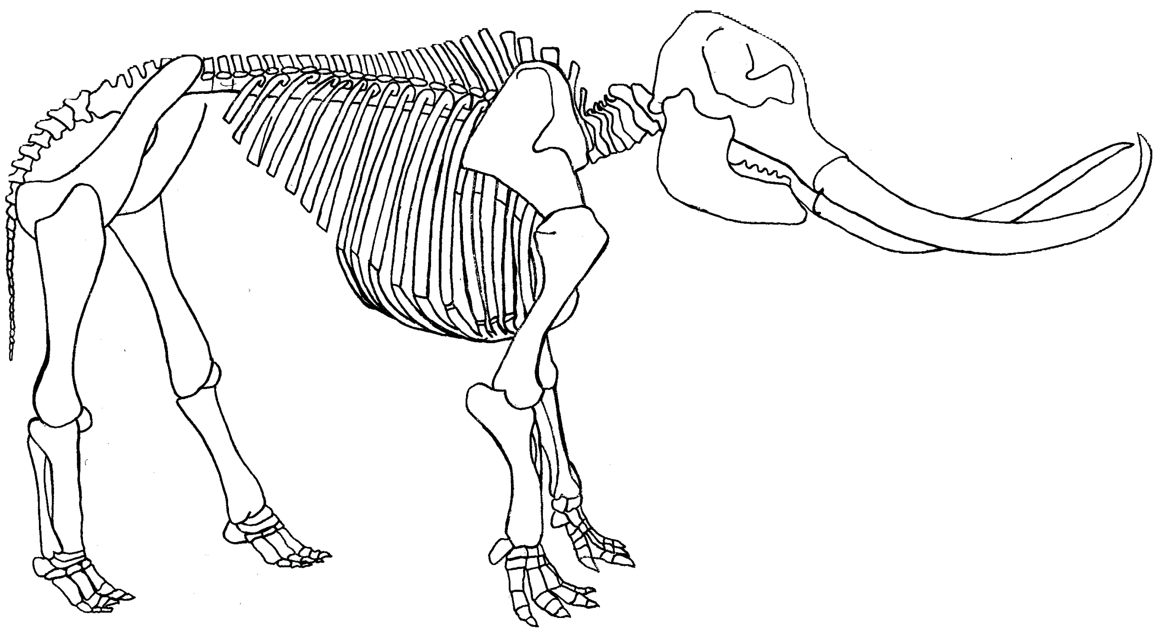
After you have completed this final step you will have some remaining dirt. If you wish, you may keep this dirt and use it for an additional experiment. Try growing some local wild seeds or commercial vegetable or flower seeds. Plant some in the mastodon dirt as well as in dirt from other sources (for example, from your backyard, potting soil, etc.). Compare the results.

Please send to us all sorted material (including twigs, leaves, seeds, all rocks and interesting things you found, hairs, bones, insect parts, etc). You may wish to use the pictures we included and additional information on our web pages to help you identify the items that you have found.

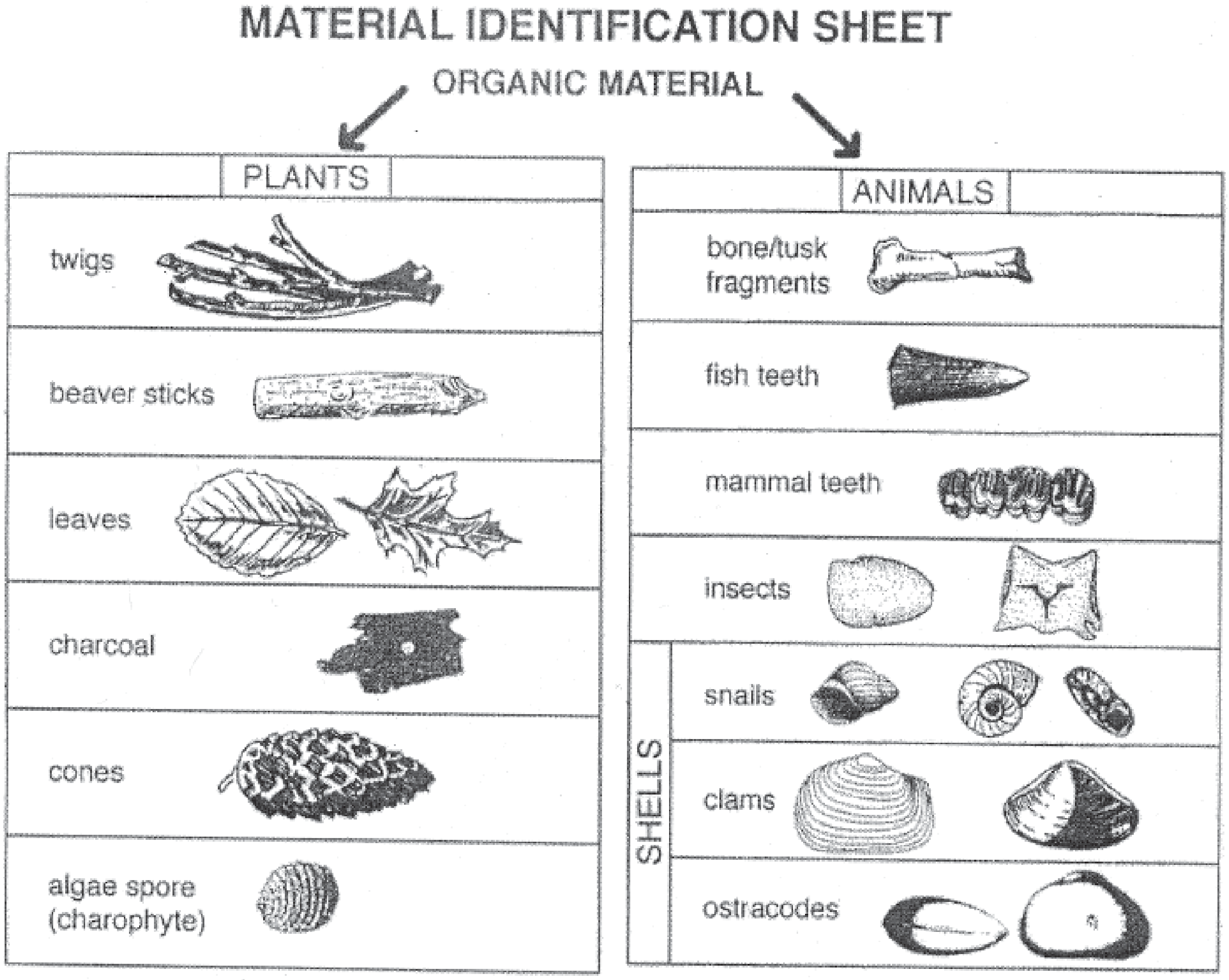
Please enclose materials in their original box as these containers are reused by the project.

Please send us the names of your students/researchers. Material discovered will become part of PRI's research collection. A class photo would also be welcome. Please take a moment to fill out the questionnaire sheet. Also, let us know about the different ways in which you may have expanded on the project (did you use graphs to log finds? Did you describe the finds? Etc.) We would love to have copies of whatever extra items you were inspired to create!

Send materials to:
Hyde Park Matrix Project
Paleontological Research Institution
1259 Trumansburg Rd.
Ithaca, NY 14850



Appendix 2. Identification sheet used by students during sorting phase.



Appendix 3. Data sheet to be filled out and returned to PRI with sorted materials.

Hyde Park Mastodon Worksheet

Name: ______________________________
School or Organization (if applicable) (e.g. Scouts, or other youth group, etc): ______________________________
Mailing Address: ______________________________
Email and Phone Number: ______________________________
Age Range of Participants or Grade Level: ______________________________
Number of Participants: ______________________________
Number Written on Sample Bag (required): ______________________________

What Did You Find in Your Sample?

Put a check mark next to all the things you found in your Plant Material sample. Provide number counts for Rocks and Animal Material.

Rocks

For B1 and B2, we ask that you provide us with counts.

B1
Remember that to qualify as a "Big Gray Rock," it must be greater than 32mm across.

Big Gray Rocks with fossils: _____

Big Gray Rocks without fossils: _____

Weight in grams (optional): ____ g

B2
To qualify as a "Medium Gray Rock," it should be between 8 and 32mm.

Medium Gray Rocks with fossils: _____

Medium Gray Rocks without fossils: _____

Weight in grams (optional): ____ g

B3
To qualify as a "Little Gray Rock," it should be between 2 and 8mm.

Little Gray Rocks with fossils: _____

Little Gray Rocks without fossils: _____

Weight in grams (optional): ____ g

B4
All other rocks (glacial erratics, chert fragments): _____

Animal Material

For animal material, we ask that you provide us with counts.

Bone and/or Tusk Fragments: _______

Hairs: _______

Mammal Teeth: _______

Fish Teeth: _______

Insect Parts: _______

Shells:
- Snail: _______
- Clam: _______
- Ostracode: _______

Plant Material

Beaver-Chewed Sticks: ( )

Bark: ( )

Cones: ( )

Seeds: ( )

Twigs: ( )

Algae Spores: ( )

Average Twig Length (in cm): ____cm