Governors Island in New York Bay - Formation of the Island and of Some Historical Archaeological Contexts

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Governors Island is a special place within the New York City metropolis, with a strategic location in New York Bay that has led to military presence on the island throughout much of American history. The island's standing architecture will attract visitors and new residents for many years to come, while beneath their feet remain many historic artifacts and other residues of past human activity. Recent archaeological survey and testing provided an opportunity to employ current earth science methods as well as to compare the new findings with what was already known about the most recent geological period, the Quaternary, in southern New York.

In addition to confirming several previous hypotheses regarding the formation of Governors Island, the present study identifies sediment packages transported onto the island’s surface by specific geological processes. There is some bedrock, particularly beneath the southern end of the island. Above the bedrock is glacial till, a poorly sorted mixture of sand, clay, gravel, and boulders that was deposited in close proximity to glaciers toward the end of the Pleistocene epoch of the Quaternary period. The till rarely extends to the surface, however, and
the intact sediment packages that are immediately below the island's surface are all relatively coarse sand consisting almost entirely of the mineral quartz. These "cover sand" packages contain some significant archaeological contexts and show considerable variation in texture and chemistry depending upon how they were transported to the island, how long they sat beneath forest vegetation on the island, and how much they were disturbed by human activity since the first Americans of European descent arrived at the island.

At the southeast and northwest edges of the original island, particularly well-sorted sand deposits are found in the vicinity of old ("paleo") shorelines. Remnants of these paleoshorelines are also shown on historic maps, some 150 meters inland of the current position of the active shore (Garman and Herbster, 1996). These paleoshorelines promise to yield data that can be compared with the rising sea levels throughout the eastern United States during the past 10,000 years, the Holocene epoch of the geological time scale (Harland et al., 1990).

Toward the top of the original island and adjacent to the large star-shaped fort, Fort Jay, there are "midden" deposits rich in food refuse as well as 19th century historic artifacts. Whereas the midden deposits are concentrated in areas that extend for less than ten meters in any direction, a more extensive package of relatively fine-textured and organic-rich sediment extends across most of the original island and beneath all of the historical archaeological contexts. This is described here as a "paleosol" or soil that was formed on a landscape of the past (Birkeland, 1999, p. 339-346). Because of the extensive landscaping associated with Fort Jay and other buildings on the island, the paleosol is found at varying depths below the present land surface and has also been removed or disturbed in places by those landscaping activities. Radiometric dates and other laboratory results obtained in the present study support the hypothesis that the
paleosol formed at the top of a land surface that preceded the first arrival to the island of Americans of European descent.

Methodology - Geology of Historical Archaeological Contexts

Contributions of earth science figure prominently in the archaeology of Early Man sites (e.g. Farrand, 1975, 2001; Hay, 1976, 1990) and of deeply stratified prehistoric sites (Donahue and Adovasio, 1990; Farrand, 1993; Haynes and Agogino, 1966; Larsen and Schuldenrein, 1990; Waters, 1986). Less attention is typically paid to geological processes by archaeologists who excavate sites that contain buildings which are shown on historic maps or mentioned in written documents. An emphasis on deliberate human design is perhaps to be expected given the significant contributions by architectural and archival research to historical archaeology. From a methodological perspective, however, the excavation and analysis of any archaeological context should be as complete as possible, both in obtaining data from the finds and in explaining those data on the basis of scientific theories. While it may be true that geological processes have less effect on the provenance of artifacts and the composition of cultural sediments from the most recent portion of the archaeological record, this must nonetheless be determined from detailed analysis of archaeological contexts. Analysis of the contexts encountered during archaeological survey and test excavations on Governors Island in New York Bay provides data that further this research objective as well as substantiating several previous hypotheses regarding the formation of the island itself.

In studying the formation of the island and its archaeological contexts, geological and archaeological research problems were inseparably intertwined. Scientific methods from both geology and archaeology were therefore applied in a synthetic manner in order to understand
deposits produced by processes that fall on a continuum between "natural" and "cultural" endmembers (Butzer, 1982; Schiffer, 1987; Stein, 2001). The field investigations themselves involved a collaboration where archaeologists troweled floors, sieved sediments, and identified cultural features within machine-excavated geological trenches (Herbster et al., 1997; Garman et al., 1998). Archaeological test units excavated entirely by hand were also described and sampled by the project geologist. Archaeological analysis of artifacts included as particles in the island's deposits helped to constrain the age of those deposits beyond what could have been achieved through stratigraphy and radiometric dating alone.

Most of the data for the present study come from sixteen small (1 x 5 m) trenches which were excavated mechanically in order to describe and sample the stratigraphy of the original island. Three of these trenches identified paleoshorelines at the southeast and northwest edges of the island. Due to the addition of landfill and other engineering modifications, the paleoshorelines occur up to 150 meters inland of the active shore. Although they are not within the Governors Island National Monument as presently designated, these locations have yielded some data that are relevant to reconstructing local and regional environmental change (e.g. Fairbridge and Newman, 1968; Salwen, 1962; Weiss, 1974).

Historical archaeological contexts are particularly rich repositories of stratigraphic detail from the past few centuries of the Quaternary period. However, the questions asked by earth scientists are not typically at the right "scale" for the large volume of deposits associated with relatively brief episodes of human activity on archaeological sites (Stein, 1991). In our studies on Governors Island, geological questions about the formation of the island were at one end of a scale continuum, with the opposite end represented by archaeological questions about the formation and "stratigraphic integrity" of the island's archaeological contexts.
Figure 1: Location of Governors Island in New York Bay
These archaeological research questions were addressed during both the initial "Phase IB" survey (Herbster et al., 1997) and a subsequent "Phase II" testing phase (Garman et al., 1998) by describing and sampling the profiles of excavation units which exposed midden and other contexts from which historic artifacts were recovered. Both the contribution of residues from various human activities and the "integrity" of the layers in which those residues are found were examined using a nested series of laboratory analyses.

Based upon both the stratigraphy and the laboratory results, the island's "cultural" sediments can be distinguished from the relatively coarse sands dominated by quartz which were deposited when the island initially formed at the end of the last ice age. Sediments that are younger than these late Pleistocene sands but older than the first arrival on the island of Americans of European descent were also encountered in a few locations. In particular, an organic-rich deposit identified as a buried paleosol was found to contain sparse lithic debris. This late prehistoric paleosol toward the top of the original island has been intruded and disturbed by historic activity and now extends beneath Fort Jay within the Governors Island National Monument. Preservation and development plans by both the National Park Service (2007) and the Governors Island Preservation and Education Corporation (2007) promise to protect the island's cultural resources and continue to fund scientific research that involves both geologists and archaeologists.

Study Area and Regional Stratigraphic Framework

Governors Island is less than a kilometer south of the southern tip of Manhattan in New York Bay (see Figure 1). The island presently totals nearly 70 hectares (ha), less than 40 ha of which represent the "original" island that existed prior to the beginning of the 20th century.
Figure 2: Cross-section of New York Bay prepared from borings for the Brooklyn-Battery Tunnel (Sandborn, 1950)
Between 1902 and 1911, the southwest end was extended through the addition of material that was removed from Manhattan during the construction of the Lexington Avenue subway. The Governors Island National Monument, the focus of the present study, consists of a mere 8.9 ha surrounding a complex of historic buildings built on the original, geological island (Figure 2). The entire island, both original and artificial, is currently administered by the Governors Island Preservation and Education Corporation (2007).

The most detailed previous description of the bedrock and glacial deposits in this portion of New York Bay comes from studies performed for the Brooklyn-Battery Tunnel (Sanborn, 1950; Schuberth, 1968). The tunnel runs along the northeast side of the island, and a large ventilator shaft for the tunnel can be easily seen from the island shore. On the cross-sections prepared from tunnel borings (Sanborn, 1950), bedrock of "Manhattan schist" is shown beneath less than 15 m of unconsolidated sediment (Figure 2). Although Governors Island cannot be called a bedrock island, schist bedrock does outcrop very near the surface. Schist rock rich in muscovite, a clear or yellowish-brown mineral of the mica group (Dietrich and Skinner, 1979, p. 47-49), was encountered at a depth of two meters below the land surface (2 m bls) in two of the trenches excavated for the present study.

The deposits at the present land surface on Governors Island were mapped by Fullerton et al. (1992) with a unit that includes "lake, ice contact, and outwash deposits," while Cadwell (1989) mapped them as "till." Several layers of till, a poorly sorted mixture of sand, clay, gravel, and boulders deposited immediately in front of a glacial ice sheet, are shown in the Brooklyn-Battery Tunnel cross-sections, primarily in areas north of the ventilator shaft. The till layers are from three to five meters thick, and at least one till was identified in two of the trenches excavated on the island itself in the present study. As described in these trenches (MT-9 and MT-
13), the till contains clasts of granite, diabase, gneiss, and other erratics in a matrix of yellowish brown sand and clay.

In both of the tunnel cross-sections, tills alternate with "drift" (stratified sand and gravel). Stratified sand, silt and clay, probably deposited on the bottom and shores of a glacial lake, are shown primarily on the south side of the island, extending beneath the Buttermilk Channel. Two borings performed for the U. S. Army Corps of Engineers prior to dredging of the Buttermilk Channel (GRA, 2000) also identified stratified sand, silt, and clay. The stratification is in the form of thin "varves" only a few centimeters thick which are inferred to represent annual layers of deposition. Both above and below the varved lake sediment were layers of glacial till that included organic mud. A bulk sample of the organic mud from 4.6 m below the channel floor in one of the borings was submitted for radiocarbon dating to Beta Analytic of Coral Gables, Florida, returning an age of 26,000±300 years before present ("BP"). The material dated was overlain by coarse, poorly sorted sand interbedded with brown clayey silt. This is probably a "flow till" (Hartshorn, 1958) of late Wisconsinan age. Varved silt and clay found at approximately the same depth in the other boring suggests that the ice was melting directly into the lake at this location. Gray-green, sandy "summer" varves alternate with reddish brown "winter" muds in the lake sediment.

No varved sediments were identified in the trenches on the island itself. Sand interbedded with the glacial till does have the same reddish brown color found in the glacial lake mud. The color comes from the Newark group sandstones and mudstones of the present Hackensack and Passaic drainages in northern New Jersey (Schuberth, 1968; Stanford and Harper, 1991). The sediments between the top of the glacial till or stratified drift and the present land surface on Governors Island are mostly sand, coarser in texture than the estuarine mud at the top of borings.
in New York Bay (GRA, 2000; Sanborn, 1950; Weiss, 1974). As noted above, textural and geochemical variation in these "cover sands" on the island were found to be related to how they were transported to the island, how long they sat beneath forest vegetation on the island, and how much they were disturbed by human activity. All of the archaeological contexts on Governors Island are associated with the cover sands or with the paleosol formed in these sands.

Stratigraphy and Archaeology of the Original Island

Prior to the beginning of the 20th century, Governors Island was much smaller, amounting to only approximately 40 hectares of its present total of 70 ha (Garman and Herbster, 1996; Langan, 2005). Five areas shown to have been part of this original island on historic maps and photographs were investigated with stratigraphic trenches during archaeological survey ("Phase IB") and testing ("Phase II") by the Public Archaeology Laboratory (Herbster et al., 1997; Garman et al., 1998). The distribution of trenches within the five areas is summarized in Table 1, and the trench locations are plotted in Figure 3. In addition to the stratigraphic trenches excavated using heavy equipment, several smaller units which the archaeologists excavated with hand tools during the Phase II study were described and sampled as part of the geoarchaeological study.

Linking the profiles for trenches MT-1, MT-16, MT-12B, and MT-13(6), we have a cross-section running from south to north across the original portion of Governors Island (Figure 4). A cross-section running from west to east has been prepared by linking the profiles for trenches MT-7, MT-9, MT-14, MT-5, and one of the archaeological excavation units (EU-5) in Nolan Park (Figure 5). Figure 4 shows that schist bedrock was reached in MT-1 by coring with a hand auger through angular regolith. The same bedrock was also encountered below stratified
Table 1: Distribution of Stratigraphic Trenches within Survey Areas on Governors Island in New York Bay

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>Stratigraphic Trenches</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B)</td>
<td>Fort Jay</td>
<td>MT-4, MT-12A, MT-12B</td>
</tr>
<tr>
<td>(G)</td>
<td>South Battery</td>
<td>MT-1</td>
</tr>
<tr>
<td>(H)</td>
<td>Nolan Park</td>
<td>MT-5, MT-19</td>
</tr>
<tr>
<td>(I)</td>
<td>Golf Course</td>
<td>MT-1, MT-6, MT-13, MT-14, MT-16, MT-17</td>
</tr>
<tr>
<td>(J-1)</td>
<td>Colonel's Row</td>
<td>MT-3, MT-8, MT-9</td>
</tr>
<tr>
<td>(J-2)</td>
<td>Hay Road</td>
<td>MT-7</td>
</tr>
</tbody>
</table>

Figure 3: Map of the original portion of Governors Island showing the locations of stratigraphic trenches.
Table 2: Radiocarbon Dates obtained for samples collected during the archaeological investigations on Governors Island

<table>
<thead>
<tr>
<th>Survey Area</th>
<th>Trench</th>
<th>Horizon</th>
<th>$^{14}$C yr BP</th>
<th>Cal Intercept</th>
<th>Lab No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Fort Jay</td>
<td>MT-12A</td>
<td>2Ab</td>
<td>590±60 AD</td>
<td>1400</td>
</tr>
<tr>
<td>H</td>
<td>Nolan Park</td>
<td>STP</td>
<td>A</td>
<td>460±60 AD</td>
<td>1570-1630</td>
</tr>
<tr>
<td>I</td>
<td>Golf Course</td>
<td>MT-16</td>
<td>II</td>
<td>660±70 AD</td>
<td>1295-1400</td>
</tr>
<tr>
<td>I</td>
<td>Golf Course</td>
<td>MT-6</td>
<td>2Ab</td>
<td>1130±110 AD</td>
<td>785-1015</td>
</tr>
<tr>
<td>J</td>
<td>Colonel's Row</td>
<td>MT-9</td>
<td>2BC</td>
<td>2610±50 BC</td>
<td>BC 800</td>
</tr>
</tbody>
</table>

![Cross-section](image)

Figure 4: Cross-section running north-south across the original portion of Governors Island
Figure 5: Cross-section running east-west across the original portion of Governors Island

glacial deposits approximately 130 m to the west at the base of trench MT-3. The occurrence of Manhattan schist at relatively shallow depths (2-3 m bls) in the southern portion of the original island is consistent with the cross-sections for the Brooklyn-Battery Tunnel (Figure 2). The bedrock is folded up to the south in this part of New York Bay, and this resulted in the emergence of relatively resistant rock as sea level fell during the last glaciation. The bedrock core acted as a "snag" for glacial debris and other sandy detritus, building the island to the north (up ice).
Glacial till on Governors Island could either be an isolated drumlin feature or part of a more extensive recessional moraine that extends beneath New York Bay (Cadwell, 1989; Fullerton et al., 1992; Sirkin, 1986; Stanford, 1997). The till is thickest just west of Fort Jay (see Figure 5), where it was reached within the upper 1.5 m of excavation in trenches MT-14 and MT-9. The till contains clasts of granite, diabase, gneiss, and other erratics in a matrix of yellowish brown sand and clay. Several sets were found interbedded with reddish brown (5YR5/4) sand in an excavation that reached a total depth of over 5 m bls at trench MT-14. The elevation at the top of the till slopes steeply westward between the MT-14 and MT-9 locations at approximately the same grade as the land surface, and this natural relief was evidently exploited for the construction of the western side of Fort Jay. In the MT-9 profile, a relatively well-developed paleosol was found to have formed in sandy outwash that capped the till. A radiocarbon date of 2610±50 BP was obtained on the paleosol sediment, collected at 80-90 cm bls (∼3 m MSL) in trench MT-9 (see Table 2).

West of the MT-9 location on the Figure 5 cross-section is the MT-7 location where the surface organic mat (Ah horizon) rests immediately on top of sediments that were deposited along a paleoshoreline. The sediments deposited in the "shoreface" depositional environment at this location are well-sorted sand and consist primarily of the mineral quartz (quartzose) interbedded with a "hash" of bivalve and gastropod shell fragments. Examined at a scale of a few centimeters, the sand shows ripple bedding caused by waves. The shell hash is found directly above the ripple beds, which have then been truncated by erosion. Sedimentologists refer to this as a "reactivation surface" (Friedman and Sanders, 1978, p. 542-543; Prothero and Schwab, 2004, p. 49-50), found primarily in an intertidal setting where the wave energy is occurring during only one tidal phase.
Beds deeper in the trench MT-7 profile (60-80 cm bls) contain whole shells of the eastern oyster (*Crassostrea virginica*). These beds probably relate to a different tidal phase or to a depositional environment dominated by tides rather than waves (Cooper, 2007, p. 271-274). At 100 cm bls in trench MT-7, beneath these laminar beds, was another reactivation surface marked by a lag of fine shell hash. A hand auger boring in the trench floor showed that laminated sand and sandy mud occur at least 220 cm bls (~ 1 m MSL). The sandy mud represents an estuary environment relatively undisturbed by wave energy. A local relative sea level rise appears to have occurred between the time that this depositional environment was in effect and the deposition of the wave-rippled sands associated with the paleoshoreline.

The trenches in the berm around Fort Jay (Area B) and on the Golf Course (Area I) typically did not reach intact natural sediments of the original island within the upper meter. Human activities subsequent to the purchase of the island by the Dutch in 1637 have here formed a complex sequence which represents the cultural end-member of depositional environments. Construction fill, demolition rubble, and refuse middens are among the deposits present. Radiocarbon dates can only identify these as "modern," so young that their radiocarbon abundance is within the range of the peaks produced by fossil fuel combustion (Aitken, 1990, p. 66-72; Suess, 1955). Ceramics, glass, and other artifacts recovered by the archaeologists provide more definitive age constraints, and time-sensitive artifacts are particularly abundant in the deposits beneath the Fort Jay berm (MT-4, MT-12A, and MT-12B) and in Nolan Park (EU-5, EU-7). In addition to the archaeological data, maps and other documents record the construction of Fort Jay (1806-1809), Castle Williams (1807-1811), and other historic structures on the island (NPS, 2003).
Traces of Native American cultural activity on Governors Island are more sparse, and the prehistoric ceramic and lithic artifacts recovered by the Public Archaeology Laboratory were all from contexts that lack stratigraphic integrity (Herbster et al., 1997). There is potential for better preservation of prehistoric contexts in deposits that underlie the historic fill and refuse on both the north and the south sides of Fort Jay. Radiocarbon dates of 1130±110 BP, 660±70 BP, and 590±60 BP were obtained on scattered wood charcoal from a paleosol found both north of the fort at MT-13(6) and south of the fort at MT-4, MT-12A, MT-12B, and MT-16. Particle size and geochemistry of the sediments from this paleosol are consistent with seasonal settlement by Native Americans during the Middle Woodland and Late Woodland periods of regional prehistory (Ritchie, 1969).

Particle Size Analysis and Sedimentology

Particle size analysis provides key data for reconstructing environments of deposition for archaeological sediments as well as for water-borne or windborne particles (Leigh, 2001; Stein, 2001). In the present study, the percent sand, silt, and clay were determined by hydrometer (Bouyoucos, 1962) for a total of 29 sediment samples from both archaeological contexts and the intact deposits of the original portion of Governors Island. Sand-sized particles make up the bulk of all of the samples studied, but the sediment from archaeological contexts is much finer textured than that from the basal cover sand. The contrast can be clearly seen in a ternary plot comparing samples from middens and pit features in trenches MT-12A, MT-12B, MT-13, MT-16, and two of the archaeological excavation units (EU-5 and EU-7) with samples of basal sand from trenches MT-2, MT-5, MT-7, MT-8, MT-12B, MT-13, and MT-16 (Figure 6). The basal
Figure 6: Ternary plot (lower half) comparing the particle size of samples from archaeological contexts with samples of basal cover sand, Governors Island

Figure 7: Sieve analysis results for 14 samples of basal cover sand from Governors Island
("C" horizon) sand samples are over 90% sand, whereas the archaeological samples all have either sandy loam or loam texture (Birkeland, 1999; Soil Survey Staff, 1997, 2006).

The amount of silt and clay in the archaeological deposits is probably within the range that would be found in a natural topsoil formed under deciduous forest on the island. Soil series recently mapped on Staten Island, for example, have loam or sandy loam textures in the A and B horizons (Hernandez and Galbraith, 1997). The abundance of artifacts and evidence for land modification in all of the deposits investigated on the original island prevented a controlled comparison with natural topsoil. In addition to the artifacts found and the stratigraphic relationships that suggest land modification, however, some of the physical and chemical attributes of the archaeological deposits are diagnostic for that type of deposit. Much of what altered the parent material to make the sediments of these archaeological contexts appears to have been the result of the changing cultural environment on the island.

Fourteen of the 29 samples in the particle size study were from the basal "cover sand" deposits on Governors Island. These basal sands contain mica and other weatherable minerals, in addition to quartz. Mica is particularly abundant in the glacial deposits and in deposits that appear to have been subjected to river (fluvial) transport. River transport is indicated by the results of a sieve analysis using a one "phi" interval (Anderson, 2007; Burt, 2004; Day, 1965; Gee and Bauder, 1986). Five of the fourteen basal cover sand samples analyzed had a distinctive "fine tail" of abundant silt and clay (Folk, 1966; Friedman, 1961, 1967). These are the five with over 20% in phi sizes greater than four ("> 4") on Figure 7 and represent basal sediments from trenches MT-3, MT-12A, MT-12B, and MT-13 as well as the 2BC horizon in MT-12A.

The distribution of particles by phi size for basal sands from Governors Island points to a number of specific depositional environments, not all of which were immediately evident from
Figure 8: Plot of skewness versus sorting for 14 samples of basal cover sand from Governors Island.

Better sorted samples have lower values and plot to the left. The samples with a fluvial "fine tail" are very poorly sorted and positively skewed, plotting in the upper right and inferred to be from a glaciofluvial environment.
All but one of the glaciofluvial samples are from the trenches north and south of Fort Jay, flanking the large till deposit. They underlie contexts from which late Holocene radiocarbon dates were obtained. The channel in this area was either contemporaneous with the till or slightly younger. Another outwash deposit occurred near the base of trench MT-3, 200 m south of Fort Jay in an area that was later submerged by late Holocene sea level rise. The MT-3 sample is extremely poorly sorted, with five percent gravel as well as abundant silt and clay (25%).

The remaining nine samples are moderately sorted, and these are the samples with the high peaks from 1-4 phi in Figure 7. Winnowing of fines by wave action could have occurred either on a bay shore similar to the present (fluviomarine) or on the shore of a glacial lake during the late Pleistocene (glaciolacustrine). The samples from MT-13 and MT-14 are deep in the stratigraphy and probably late Pleistocene. The samples from MT-5, MT-7, and MT-8 are from Holocene paleoshorelines. Two samples were actually sieved from MT-7, one of which is negatively skewed as is typical of an ocean beach in a shoreface depositional environment (Friedman, 1967). Glaciofluvial, fluviomarine, shoreface, and possibly glaciolacustrine depositional energies are thus indicated by particle size distributions in samples of basal sand from Governors Island. The samples from archaeological contexts have more silt and clay than occur in the basal sands, and this is because they contain fines that were contributed by human activity.

Geochemistry of the Archaeological Contexts

Chemical analysis of sediment samples has been used in previous studies to identify archaeological sites, to evaluate their stratigraphic integrity, and even to distinguish residues from particular types of human activity (Barba et al., 1996; Entwistle et al., 1998; Foss et al.,
A "nested" approach was used in the present study. Preliminary identification of samples that contain fine-textured anthropogenic residues was based on the particle size results and measurements of soil pH and percent organic matter for 21 of the 29 samples in the study. The pH was measured on a slurry prepared with a solution of 0.01 N CaCl$_2$ (McClean, 1982; Peters, 2007). Organic matter content was measured by loss-on-ignition (Dean, 1974; Stein, 1984).

Available phosphorus and exchangeable Ca, Mg, and K were measured for sixteen samples from contexts whose formation could be reconstructed independently on the basis of stratigraphy and included artifacts. The extraction was done with 1 M ammonium acetate followed by atomic absorption spectrophotometry (Peters, 2007). Although the procedure is designed to estimate the availability of nutrients for crop plants, it has also been used to identify anthropogenic residues in previous studies (Kolb et al., 1990; Schuldenrein, 1995).

The abundance of Pb and Zn was measured for ten of the samples to evaluate the utility of these two elements in distinguishing residues from specific activities. Atomic absorption spectrophotometry was used once again, but the extraction was done with DTPA (diethylenetriaminepentaacetic acid). Finally, total phosphate and the relative contribution by the three phosphate fractions defined by Eidt (1977, 1985) were measured for five samples from specific archaeological contexts around the perimeter of Fort Jay and in Nolan Park.

Organic matter enrichment associated with human activity is evident in a plot comparing percent silt and clay with percent organic matter for the 21 samples analyzed (Figure 9). Contexts containing fine-textured anthropogenic residues all plot in the upper right of the figure, with at least 30% silt- and clay-sized particles and at least one percent organic matter. The contexts are in three locations. There is a sample from the paleosol which underlies deep fill.
Figure 9: Percent organic matter versus percent silt and clay for 21 samples from the Governors Island geoarchaeological study deposits on the north side of Fort Jay at trench MT-13(6). Prehistoric lithics, marine shell, and historic glass and ceramics were collected from the trench profile, although the paleosol has not yet been sampled by an archaeological excavation. On the south side of Fort Jay (Area B), there is a historic midden which is also deeply buried beneath the berm and in turn rests upon a paleosol that represents the intact late prehistoric land surface. Prehistoric ceramics as well as historic ceramics, glass, buttons, and even a gunflint were recovered from the archaeological test excavations within the three trenches located here (MT-4, MT-12A, and MT-12B). The trench
MT-16 location is on the Golf Course (Area I), approximately ten meters south of the Fort Jay berm trenches and beyond the limits of the midden. The samples from MT-16 can therefore serve as controls against which to compare the samples containing anthropogenic residues.

The third location where fine-textured anthropogenic residues appear to occur in association with both prehistoric and historic artifacts is Nolan Park (Area H). Prehistoric ceramic sherds and chipping debris from stone tool manufacture were found at the location sampled by archaeological excavation unit 5 (EU-5). Unfortunately, the excavation of EU-5 did not yield cultural pit features or artifact concentrations that indicate a prehistoric living surface. The geochemical results for the column of six sediment samples collected from the north wall of EU-5 therefore provide key information about the contexts in which prehistoric artifacts occur in Nolan Park. The sediment texture, percent organic matter, and phosphate fraction amounts were also measured for a sample from a historic feature at the base of another archaeological excavation unit in Nolan Park, EU-7. The results tend to confirm the contribution of anthropogenic residues to this sample, as can be seen from Figure 9.

Very large amounts of available phosphorus (>200 mg/kg) in the upper three samples from EU-5 suggest that phosphate was added in recent decades to fertilize the grass in Nolan Park. The samples from the historic midden and the paleosol north and south of Fort Jay have from 50 to 100 mg/kg available phosphorus (see Figure 10). These values fall within the range for topsoil formed under forest vegetation in the eastern United States (Kleinman et al., 2002; Scott et al., 2001). Residual phosphate is thus preserved within the fine fraction of the deeply buried prehistoric and early historic sediments on Governors Island.

The total phosphate was between 250 and 500 mg/kg for the five phosphate fractionation samples (Figure 11), a range that is characteristic of residues from dwelling, gardening,
Figure 10: Available phosphorus (mg/kg) versus percent silt and clay for 16 samples from the Governors Island geoarchaeological study
Figure 11: Ternary plot of phosphate fractionation results for five samples from archaeological contexts on Governors Island
Table 3: Chemistry of MT-12B Profile, Fort Jay Berm, Governors Island

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth bsls</th>
<th>OM</th>
<th>pH</th>
<th>K</th>
<th>Mg</th>
<th>P</th>
<th>Ca</th>
<th>Pb</th>
<th>Zn</th>
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<tr>
<td>Midden</td>
<td>150 cm</td>
<td>1.5</td>
<td>4.9</td>
<td>6</td>
<td>29</td>
<td>82.7</td>
<td>307.0</td>
<td>255.1</td>
<td>0.34</td>
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<tr>
<td>2Ab</td>
<td>200 cm</td>
<td>0.5</td>
<td>5.2</td>
<td>4</td>
<td>30</td>
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<td>150.0</td>
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<td>0.10</td>
</tr>
<tr>
<td>2C1</td>
<td>250 cm</td>
<td>0.4</td>
<td>5.3</td>
<td>5</td>
<td>28</td>
<td>46.5</td>
<td>168.0</td>
<td>0.1</td>
<td>0.12</td>
</tr>
<tr>
<td>2C2</td>
<td>300 cm</td>
<td>0.7</td>
<td>5.2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Table 4: Chemistry of EU-5 Soil Profile in Nolan Park, Governors Island

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth bsls</th>
<th>OM</th>
<th>pH</th>
<th>K</th>
<th>Mg</th>
<th>P</th>
<th>Ca</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>5 cm</td>
<td>6.3</td>
<td>4.9</td>
<td>48</td>
<td>89</td>
<td>426.5</td>
<td>700.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>15 cm</td>
<td>4.7</td>
<td>4.3</td>
<td>44</td>
<td>38</td>
<td>424.2</td>
<td>233.0</td>
<td>354.6</td>
<td>0.12</td>
</tr>
<tr>
<td>AB1</td>
<td>25 cm</td>
<td>2.4</td>
<td>4.3</td>
<td>36</td>
<td>19</td>
<td>250.1</td>
<td>109.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB2</td>
<td>40 cm</td>
<td>2.4</td>
<td>4.2</td>
<td>32</td>
<td>12</td>
<td>107.1</td>
<td>87.0</td>
<td>68.6</td>
<td>0.10</td>
</tr>
<tr>
<td>BC1</td>
<td>55 cm</td>
<td>1.3</td>
<td>4.2</td>
<td>23</td>
<td>16</td>
<td>28.4</td>
<td>89.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC2</td>
<td>65 cm</td>
<td>1.1</td>
<td>4.1</td>
<td>33</td>
<td>19</td>
<td>12.6</td>
<td>95.0</td>
<td>14.3</td>
<td>0.06</td>
</tr>
</tbody>
</table>
manufacturing, and refuse disposal activities (Eidt, 1977; Schuldenrein, 1995). Fraction I, consisting of loosely bound iron and aluminum phosphates, accounts for over half of the total in the samples from trench MT-13, from the AB2 horizon in Nolan Park EU-5, and from the historic post feature in Nolan Park EU-7. The samples from the historic midden and the paleosol in trench MT-12B have much higher loadings on Fraction III (calcium-bound phosphates) but lower loadings on Fraction II (occluded iron and aluminum phosphates). There are two likely sources for calcium-bound phosphates in these contexts, lime mortar in the case of the historic midden and bone or marine shell in the case of both the midden and the paleosol.

The chemistry of samples collected from beneath the Fort Jay berm at MT-12B (Table 3) indicates discrete, relatively rapid episodes of deposition which produced contexts containing sediments with very different physical and chemical properties. In addition to organic matter and phosphate, calcium, lead, and zinc occur in the historic midden in greater amounts than in the underlying paleosol (2Ab) or its parent material (2C1). Because the midden sediment is actually slightly more acid, with a pH of 4.9 compared to 5.3 for the 2C1 horizon (Table 3), it is unlikely that these elements were precipitated after deposition. Previous studies have found calcium and zinc to be abundant in refuse that contains human excrement, fish bones, and shell (Kolb et al., 1990; Middleton and Price, 1996; Schuldenrein, 1995; Scudder et al., 1995). Lead levels greater than 50 mg/kg are common in residues from societies that practice metallurgy (Foss et al., 1994a, 1994b; Macklin et al., 1992). Lead therefore seems to be particularly suited to distinguishing residues from historic as opposed to prehistoric cultural activity in North America. In addition, lead may be particularly abundant in residues from military garrison areas where lead shot was stored and weapons were cleaned.
Soil chemistry changes much more gradually between the samples collected from EU-5 in Nolan Park. This suggests that here deposition was so gradual that soil development kept up the same pace, mixing the sediment to produce gradual transitions in physical and chemical properties between horizons (Table 4). The Pb values fall off smoothly down profile in EU-5 from over 350 mg/kg in the A1 horizon. There is still 14 mg/kg in the BC2 horizon at 65 cm below surface, an amount which is over twice that in any of the other samples from prehistoric contexts or culturally sterile deposits on the island. The available P falls off smoothly like the Pb while Ca, Mg, and K increase from the AB2 to the BC2 horizon. Lead has moved down profile at least 50 cm since it was first deposited at the land surface. Smooth transitions down profile in all of the elements that were measured indicate that the Nolan Park deposits have been repeatedly mixed by biological organisms and other disturbance as they built up to the level of the present land surface.

Summary of Governors Island Geoarchaeology

Results of earth science investigations have contributed significantly to our knowledge of Governors Island and its archaeological contexts. Due to the artificial extension of the island to the southwest between 1902 and 1911 (Garman and Herbster, 1996; Langan, 2005), contexts over 100 years old are found only on the original, northerly portion of the island. Artifacts and other cultural residues occur there in sediments which overlie and intrude late Quaternary "cover sand" deposits. By sieving fourteen samples of these sands at one phi (Anderson, 2007; Burt, 2004; Day, 1965; Gee and Bauder, 1986), it has been possible to sketch out the complex history of glacial, fluvial, lacustrine, and marine depositional energies which built the island. Additional analyses of particle size for samples from the archaeological contexts show a characteristic
abundance of fine material, and chemical analyses further identify some specific human activities that may be contributing that material.

Results of the particle size analysis indicate that there was lateral variation in the initial texture and chemistry of sediments on the island. Glacial till and drift or outwash deposition appear to be responsible for the tail of fine material found in samples from trenches MT-12A, MT-12B, and MT-13, which plot in the upper right corner of Figure 8. A particularly high and thick deposit of till and stratified drift toward the north end of Governors Island appears to have been chosen as the location of Fort Jay. This location would have already offered natural protection as a fighting position and required minimal earth moving during initial construction of the fort between 1806 and 1809. Relatively coarse sands were later used to construct the berm and other earthen architectural features.

Even in locations found to be devoid of both historic and prehistoric artifacts, the cover sand deposits on Governors Island preserve much unique information about the changing natural environment of New York Bay. Deposits associated with paleoshorelines located at the southeast and northwest edges of the original island, in particular, appear to record a local sea level highstand previously identified in New York Bay by Fairbridge (1960a, 1960b, 1961) and others (e.g. Salwen, 1962). On the northwest edge of the island, the maximum age of the paleoshoreline has been constrained by a radiocarbon date of 2610±50 B.P. for paleosol sediment. In terms of particle size, samples from trenches MT-5, MT-7, and MT-8 typify shoreface deposition with a fine sand to medium sand texture and low index values for sorting (moderate or moderately well sorted). One of the MT-7 samples was also negatively skewed, toward the coarse end of its size distribution, which is very typical of an ocean beach in a shoreface depositional environment (Friedman, 1967).
Both Schiffer (1987) and Stein (2001) have emphasized that natural depositional and postdepositional processes always govern the formation of archaeological contexts, even when people are immediately responsible and even when they document what they have done as is true for many historical sites. For heuristic purposes, it is useful to think of some deposits as more "cultural" and others as more "natural" along a continuum with two extreme end members (Butzer, 1982). The "cultural" sediments that contain artifacts usually do differ in terms of both particle size and geochemistry, as was found in the Governors Island contexts described above.

As has been argued by Stein (1985 p. 7; 2001, p. 21), anthropogenic or "cultural" sediments should always be studied through controlled comparison with sediments from purely natural, "geogenic" deposits. On Governors Island, however, there really are no "offsite" depositional contexts due to extensive disturbance for more than 300 years. The approach taken here is actually one suggested by Stein (1985, p. 7; 2001, p. 21) in which control samples are obtained from strata within an archaeological excavation that are devoid of cultural material. Samples from midden, a possible post feature, and topsoil that contains historic and prehistoric artifacts were studied through comparison to "cover sand" C horizon samples, many of which came from directly beneath archaeological contexts.

Another approach for controlled comparison is to make use of the regional sedimentological and soil geochemical databases which have now been developed for much of the United States. Chemical signatures identified in the present study fall above or in the upper range of reported values for soil series mapped on Staten Island (Hernandez and Galbraith, 1997). In the case of phosphorus, there are also systematic studies of soils formed under forest vegetation in the eastern United States (Kleinman et al., 2002; Scott et al., 2001). The topsoil
samples from Nolan Park do appear to be aberrant, possibly due to recent addition of artificial fertilizer.

In the contexts where fine-textured residues were introduced by human activities, the sediment characteristics result from a combination of geological and cultural processes. Chemical results indicate that human excreta have incremented the percent organic matter, the available phosphorous, the loosely bound iron and aluminum phosphates, and possibly the trace amounts of zinc in sediments from archaeological contexts. Higher zinc values also appear to occur in sediments to which marine shell, animal bone, and other kitchen refuse were added, and these sediments also have abundant exchangeable calcium and calcium bound phosphates. Storing and firing lead shot as well as maintaining military weapons have increased the amount of lead in 19\textsuperscript{th} and 20\textsuperscript{th} century deposits in the original portion of Governors Island. Because lead is only abundant in residues from societies that practice metallurgy (Foss et al., 1994a, 1994b; Macklin et al., 1992), it seems to be particularly suited to distinguishing residues from historic as opposed to prehistoric cultural activity in North America. Values greater than 250 mg/kg, as found in two of the sediment samples in the present study, probably occur only in soils from specific cultural environments, such as the military garrison areas on Governors Island.

The identification of chemical residues associated with specific human activities is useful to archaeologists interpreting a context that contains prehistoric or historic artifacts. At least as important from a management or planning perspective, however, is the use of earth science methods including chemical analysis to assess the stratigraphic integrity of archaeological contexts. On Governors Island, contexts associated with Fort Jay and other features of 19\textsuperscript{th} and 20\textsuperscript{th} century construction and landscaping are easily identified from abrupt changes in the color and texture of associated sediments. In other cases, however, artifact-rich middens and dwelling
areas have been mixed with topsoil material and buried up to four meters below the present land surface. These more deeply buried contexts are challenging to identify and interpret, because they were formed by both natural and cultural processes (Schiffer, 1987; Stein, 2001)

On Governors Island as in other areas mantled by late Quaternary cover sands in the Atlantic Coastal Plain (Leigh, 2001; Michie, 1990; Scudder et al., 1996), physical mixing by small organisms ("pedoturbation") and chemical weathering are important natural processes affecting archaeological contexts and their surrounding matrix. Beyond simply identifying the presence or absence of anthropogenic residues, sedimentological and geochemical results can be used to assess the stratigraphic integrity of archaeological contexts in such deposits. Profiles containing sediments with very different physical and chemical properties, such as that beneath the Fort Jay berm at trench MT-12B, indicate discrete, relatively rapid episodes of deposition. Profiles where deposition was so gradual that soil development kept up the same pace, such as that in Nolan Park EU-5, are considered to be "disturbed" and to lack stratigraphic integrity for archaeological purposes. Prehistoric and historic artifacts and residues need not be entirely mixed within such a profile, however. The Nolan Park contexts do preserve some traces of Middle Woodland and Late Woodland occupations in this portion of the original island.

The Governors Island study illustrates many of the challenges of doing geoarchaeology on historical archaeological sites in that the problems investigated by earth scientists studying the Quaternary period in southern New York are not an immediate concern of the archaeologists who work on historical sites. Geological problems about processes responsible for sediment deposition on the island do become archaeologically relevant, however, when framed as questions about the formation and stratigraphic integrity of the island's archaeological contexts. As noted by Stein (1991), geoarchaeology is very often a matter of bringing earth science
descriptions and interpretations to the right "scale" for the large volume of deposits associated with relatively brief episodes of human activity on archaeological sites. In a similar discussion referring specifically to chronology, Stewart (1999) has recently commended the archaeological focus on a "human" scale of centuries up to millennia, bridging the gap between the documentary archives of historians and the geological archives of Quaternary stratigraphers.

Due in part to the difficulties of scale mentioned above and in part to the management of the island's resources by several government agencies, a number of questions and concerns remain to be addressed by further geoarchaeological investigations on Governors Island. In order to enrich and extend the robust results obtained through chemical analysis of the sediments from archaeological contexts, for example, it would be helpful to take some samples of 20th century contexts to analyze in comparison to the values of lead, phosphorus, and other elements in the 18th and 19th century archaeological contexts. In several areas, particularly on the Golf Course and in Nolan Park, geophysical methods promise to provide information that compliments and enriches the interpretations based upon stratigraphic trenching. In the paleoshoreline locations at the southeast and northwest edge of the original island, it should be possible to more precisely constrain the age of regional sea level highstands by dating shell in the deposits with radiocarbon (Little, 1995) and by using luminescence methods to date the sand grains themselves (Aitken, 1998; Forman et al., 1992; Wallinga et al., 2001). Overall, the results from "Phase I" and "Phase II" summarized above represent a successful synthesis of scientific methods from both geology and archaeology, leading to a new understanding of how Governors Island formed and how people contributed to its present form and the composition of its uppermost sediments.
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