APPENDIX D:

GEOARCHEOLOGICAL INVESTIGATIONS

Geoarcheological Investigations at the Black Diamond Site (7NC-J-225), SR 1 Smyrna to Pine Tree Corners, New Castle County, Delaware

Prepared for
Parsons Engineering Science, Inc.
Fairfax, Virginia

By
Joseph Schuldenrein, Ph.D and Suanna Selby, M.A.
Geoarcheology Research Associates
5912 Spencer Avenue
Riverdale, NY 10471

May 11, 2004

Table of Contents

Introduction and Objectives 1

Research Design and Field Methods 3

Physiographic and Geological Setting 6

Stratigraphy 8
General Considerations
Allostratigraphy
Radiocarbon Dates

Depositional Environments: Sand Grain Analysis 15
Methods and Sampling
Texture, Sorting and Sphericity
Roundness
Surface Texture
Analysis
Samples from North of N244
Samples from South of N244
Samples from Additional Proveniences
Interpretations
Texture and Sorting
Sphericity
Roundness
Frosting
Comparisons with the Frederick Lodge Site Complex
Overview

Feature Studies 34

Site Formation Modeling 35

References

List of Tables

Table 1. Black Diamond Radiocarbon Dates
Table 2. Summary of Observations from Black Diamond and Control Samples
Table 3. Statistical Analysis of Sand Study and Control Samples
Table 4. Summary of Statistical Analyses for Sand Grain Transformation Study
Table 5. Comparison of Roundness, Polish, and Frosting Between Black Diamond and the Frederick Lodge Site Complex

List of Figures

Figure 1. Site Location
Figure 2. Location of Transects A and B
Figure 3. AU Profile, Transect A
Figure 4. AU Profile, Transect B
Figure 5. Profile Sections
Figure 6. Sphericity Comparison
Figure 7a. Summary of Grain Morphology Comparisons
Figure 7b. Summary of N244 to N252 Rounding Index Comparison
Figure 7c. Summary of N236 to N244 Rounding Index Comparison
Figure 7d. Summary of Additional Proveniences Rounding Index Comparison
Figure 8. Grain Morphology Comparison
Figure 9. Surface Texture Comparison
Figure 10. Comparison of Frosting Percentages
Figure 11. Black Diamond and the Frederick Lodge Site Complex Grain Roundness Comparison
Figure 12. Comparison of Surface Texture Observations from Black Diamond and the Frederick Lodge Site Complex
Figure 13. Comparison of Frosting Percentages Between Black Diamond and the Frederick Lodge Site Complex
Figure 14. Phosphate Fractionation Tertiary Diagram
Figure 15. Diachronic Site Formation Model: Site 7NC-J-225

List of Plates

Plate 1. Land-Use Aerial Photographs

Geoarcheological Investigations at the Black Diamond Site (7NC-J-225), SR 1 Smyrna to Pine Tree Corners, New Castle County, Delaware

J. Schuldenrein and Suanna Selby, GRA

May 11, 2004

Introduction and Objectives

This report summarizes the results of geoarcheological investigations at the Black Diamond Site (7NC-J-225). These investigations were performed under contract to Parsons Engineering Science, Inc. as part of the DelDOT SR-1 project. Phase II studies were completed in the fall of 1999 and identified key environmental and site formation problems at the site complex (Schuldenrein 1999a). A formal research design was then prepared for the Phase III investigations (Schuldenrein 1999b), with the following general objectives:

- Development of a stratigraphic framework to establish the dominant aolian context of the Black Diamond site terrain and to distinguish that landform from the surrounding landscape that extends southward to the Frederick Lodge site complex;
- Reconstruction of pedogenic and sedimentological trends preserved in the depositional sequences;
- Modeling site formation histories for the dune terrain, its southern and western slopes and the flanking and basin landforms;

This study begins by examining contemporary landform relationships and utilizes subsurface chronologies and stratigraphies to formulate localized model of landscape history. Standard earth science terminologies are utilized for characterizing landform segments and especially slopes (Summerfield 1991 and references). Subsurface sequences are described in terms of soil development (after Birkeland 1999; Buol et al. 1997) and lithostratigraphy (after ISG 1994), depending on degree of subsurface weathering of deposits.

It is noted that 7NC-225 is part of the same meso-environment as the Frederick Lodge sites (Knepper et al. 2003). The northernmost perimeter of that prehistoric site complex--7NC-J-97, 7NC-J-98 and 7NC-J-99—begins only 500 ft. (0.15 km) to the south (see Figure 1). They are part of a separate landform segment, spanning crest to midslope interfluves grading down to two Bay Basins at the base of the landform. 7NC-225 is a crescentic dune overlooking the Frederick Lodge slopes. The drainage catchment to the north and west of Black Diamond is part of the Sandom Branch basin.

Depositional and chrono-stratigraphic contexts at Black Diamond are unique and vary from those established at Frederick Lodge (Schuldenrein 2003). The key occupation of the site is considered to be late Archaic, despite the proliferation of radiocarbon determinations post-dating the occupation by a millennium or more. Prehistoric cultural material and activity areas are dispersed with variable degrees of integrity within the dune and, more significantly, when excavated they were identified within both leached and mineral horizons ("E" and "Bw" horizons) of an upbuilding soil profile, or solum. Whereas the temporal ranges and sedimentological contexts of the Frederick Lodge sites are varied--the product of colluvial, aeolian and alluvial deposition—the Black Diamond site occupies two basic landform segments and preserves one major occupation. The Late Archaic materials were housed either within the dune and its margins, or along the slopes grading into slope basins. Several features were identified. As in much of Delaware, pits and areas of staining were the result of geogenic or biogenic as well as anthropogenic site formation processes. At Black Diamond, the classic podsol profile--Ap-E-EB-Bw—is registered in a dune setting that has been stabilized by evergreen overgrowth. Locally, some weakly developed profile exposures point to disruption of pedogenesis and intervals of active sedimentation at the site. Deposition is related to primary occupations as well as to localized site abandonment within the immediate dune setting and destabilization of the slopes. Charcoal was poorly preserved, often in secondary contexts, and did not always correspond to ages of the occupations. Examination of the archeological assemblages in conjunction with the site stratigraphies has nevertheless provided results which can be advanced to test hypotheses about Holocene landscape history and regional environmental change as well as the taphonomy and site formation chronologies of the various site loci.

Research Design and Field Methods

A formal Research Design was developed from a provisional stratigraphic model developed over the course of Phase II testing (Schuldenrein 1999a, 1999b). Initial field inspections suggested that artifacts were housed within the upper 0.2-0.4 m of moderately weathered aeolian sands. The sands appeared to have been sealed by a forest podsol, although the extent of leaching was difficult to determine visually because of the lack of sharp and abrupt soil horizonation within the ostensible zone of eluviation ("E" horizon). It was hypothesized that a series of short-term cycles of aeolian activity and limited stabilily were responsible for the preservation of a sustained cumulic "E" horizon extending across the greater dune profile.

The Phase III field effort proceeded in December, 1999. Inspections were made of continuous East-West and North South profiles that optimally exposed the central portions of the dune and the primary artifact and feature contexts. To obtain a comprehensive profile of the dune and surrounding slope and basin segments, two (2) stratigraphic transects were run across the site (Figure 2). The transects consist of a series of strategically emplaced borings and (archeologically) excavated field units. They are referred to as Transects A and B respectively. Radiocarbon specimens were obtained from critical exposures. As inspection of the excavation units and cores proceeded and archeological contexts became apparent the orientations of the transects were modified to accommodate key landform or stratigraphic breaks and/or loci of archeological significance. The transects ran from the slope-basin terrain across the heart of the dune as follows:

(1) W-ENE transect from N241 E371 to N252 E417;

(2) S-NNE transect between N222 E400 and N252 E417;

Principal exposures are identified as stations 1 through 7 in Figure 2. For both transects, the section between stations 4 and 7 marks the central dune segment, also referred to as aeolian/hummock terrain. Stations 1, 2, and 3 in Transect (1) and stations 5 and 6 in Transect 2 preserve the stratigraphy of slope and basin terrain.

In addition to the 7 coring and excavation stations, supplementary observations were made of the continuous block excavation profiles. These typically extended to the upper depths of the Columbia Gravels (up to 0.3 m within that formation). Core borings were excavated to depths of up to 3 m and

four backhoe trenches were viewed (A-D) and described in varying detail (for safety reasons). The latter were emplaced in the flanking basins to obtain a generalized overview of the pattern of anaerobic sedimentation and hydrography within these enclosures. Figure 2 shows the locations of all subsurface units.

At the conclusion of the subsurface investigations it was possible to separate broad landform/sediment complexes across the Black Diamond site. Aeolian deposition was the dominant sedimentary process across the highest portion of the landform. Relatively limited colluviation and erosion was in evidence along the upper slopes of the hummock terrain and basin sedimentation, characterized by gleying and waterlogging, typified profiles at the eastern and southern ends of Transects and A and B respectively. Seasonally anaerobic conditions are present within 0.5 m of the surface at Locations 5 (Transect B) and 1 (Transect A).

The following primary stratigraphic units were recognized:

- Columbia Gravels
- Slope Basins or minor Bay Basins (sands, silts and clays)
- Colluviated margins (at minor basin edges)
- Aeolian cap (rarely in excess of 0.5 thick)
- Cultural loci
    - Archaic
    - Woodland

The field effort involved micro-stratigraphic mapping and soil-sediment sampling along the transects. The specific field and laboratory tasks performed included:

- Description of stratigraphic exposures at select aeolian/hummock and slope basin exposures.

- Radiometric sampling for absolute dates;

- Sediment and soil sampling and laboratory analysis to identify primary depositional (colluvial, aeolian, etc.) and soil environments as well as post-depositional perturbation. Emphasis was placed on testing procedures that would isolate aeolian process from all

others, since Black Diamond provided the most unequivocal example of an aeolian site in the entire SR 1 project area.

- Chemical analysis to identify cultural features and to frame the archeological interpretation of the prehistoric activities that may have produced them.

In the field, soil-stratigraphies following the criteria in Soil Survey Staff (1984, 1993, 1997) were used for field recording purposes only. As at Frederick Lodge, it was recognized that facies variation, landform complexity, and subtle archeological horizonation accounted for considerable micro-stratigraphic variability. To develop a comprehensive site formation model and to allow for integration with the Frederick Lodge site complex, an allostratigraphic scheme was developed subsequent to all analysis and site interpretations (see subsequent discussion).

The sediment texture of each horizon was recorded in classes such as silt loam, fine sandy loam, silty clay loam, etc. (Birkeland 1999:10-11; Soil Survey Staff 1993). Color was recorded moist using the Munsell chart. The structure of each soil horizon was characterized in terms of the shape and size of peds (Birkeland 1999:12). Where structure was poorly developed or not present, more attention was paid to sedimentological attributes such as bedforms and depositional sorting within a horizon (Reineck and Singh 1986). Boundaries between horizons were characterized in terms of both distinctness and topography (Birkeland 1999:356), with particular attention focused on boundaries that defined the tops of buried soils in each profile.

The profiles sampled for sedimentological analysis emphasized the coarse to fine sand fractions in order to separate aeolian from other depositional processes as carefully as possible. Sediments were taken from 40 samples of fine to coarse sands at 23 localities across the site. As discussed subsequently, additional control samples were taken from modern alluvial and aeolian settings. These controls were acquired from the Frederick Lodge sites as well as another study location in North Carolina. Only sands from the C horizons in any of the stratigraphic exposures were analyzed. Feature samples and sands from the A, B or E horizons were eliminated in order to limit the physical or chemical influence of human or pedogenic factors on the morphology of the sand grains.

Physiographic and Geological Setting

The Black Diamond site is at the margins of the Mid-Drainage and Drainage Divide zones. This portion of the Delaware Coastal Plain is underlain by the Columbia Formation, which is dominated by unconsolidated and heavily reworked sands and gravels of Pleistocene age (Groot and Jordan 1999). Surface soils along the higher portion of the site area have been mapped as the Sassafras Series sandy loam, a classification applied to surfaces with 2-5% slopes. The soils descending into the bay/basin to the west (Figure 2) and grading more gently to the north and northeast, are classified as Fallingston Series Sandy Loam (Mathews and Lavoie 1970).

Hydrographically, Black Diamond straddles the drainage divide between two Delaware Bay watersheds. The catchments to the south and east drain into the headwaters of Sawmill Branch, which empties into Smyrna Creek. Sandom Branch is a first order tributary of Blackbird Creek and drains to the north. Blackbird Creek, in turn, feeds into Delaware Bay approximately eight kilometers east of the confluence with Sandom Branch. The mouths of both trunk streams are embayments, consistent with the coastal drainageways dominant across central and lower Delaware.

Site elevations at the Black Diamond site are on the order of 55 to 60 feet above mean sea level. Thus topo-stratigraphic relations for all landscape segments north of the Bay Basins themselves reflect local dispositions of the Columbia Formation. The subtle hummocky topography, which is effectively a micro-environmental expression of the Bay Basins across the greater landscape, reflects the complex interaction of a variety of geomorphic processes, chiefly aeolian deposition, but also colluviation, erosion, and limited sheetflow. Erosion has resulted in gullying and the sustained backwearing of slopes into the Bay Basins.

The relief across the site is subdued, although two knolls comprise discrete loci of dune sedimentation (Figure 2). To the east and south of the saddle separating the two peaks, localized seeps were noted. These are suggestive of formerly active spring seeps during moister intervals of the Holocene. The primary site landform is a crescentic dune. Its developmental history is linked to the Frederick Lodge site complex. The dune represents the most pronounced aeolian feature in this part of the SR 1 study corridor.

The terrain in the immediate vicinity of the dune (Figure 2) has been sub-divided into two landscape segments. The Bay Basin to the west is considered to

occupy a "slope basin" setting, since slope grades and contours vary laterally as a result of the shifting margins of episodic deflation. Over the course of the Holocene and even during the historic period the extent of that landscape segment oscillated in response to the dynamism of the dune micro-environment. The second landform segment straddles "aeolian hummock" terrain. This component of the landscape reflects net dune aggradation through time. In Figure 2, the slope-terrain segments slope away from the dune center ("aeolian hummocks" are the locations of the block excavations) in Transects A and B.

The more prominent Bay Basin flanking the project area to the west is a small surface depression that retains surface water. It is about 100 m wide (east to west) and has been overridden by deep (>2 m) of medium sands. Heavy rains result in ponding of sediments within the depression. The extent of historic disturbance and reuse of the feature is unclear, as no subsurface probing was undertaken in the feature. It is part of a series of localized basin depressions that range from 2 to 3 meters deep.

Plate 1 illustrates the magnitude and extent of historic land use on the integrity of the site landscape. Plate 1a shows that in the early 20th century the center of the dune was bisected by a row of conifers while the property was part of an agricultural field (70% by area). Nearly 70 years later the mixed hardwood-pine forest encroached upon the fields reversing the ratio of forest to farmland. These edaphic changes have critical ramifications in assessing the archaeological integrity of the site, since nearly a century of podsol weathering has resulted in the accelerated weathering of the upper solum and the deepening of the A-E-EB-Bw profiles in which the cultural materials—artifact distributions as well as features—are preserved. As discussed, at Black Diamond the soil profile provides the key for reconstructing the taphonomic history of Black Diamond's evolution as an archaeological site.

At Black Diamond as at Frederick Lodge, it is critical to note that a very thin mantle of aeolian, colluvial and sheetwash sediment capped the eroded Early Holocene surfaces of the glacial landscape. Depths of Holocene deposit rarely exceeded 1.0 m. Thus the pimary topo-stratigraphic relations across the site environment are underlain by the Columbia Formation gravels. Net sedimentation for the archaeological and historic sediments at Black Diamond is even less than that registered for Frederick Lodge; Holocene deposition is on the order of 0.5-1.0 m.

The lithostratigraphy of the Columbia Formation has been described in detail by Jordan (1964) and its identification was critical to indexing the depth of archeological sensitivity across the project area. Accordingly, field profiles were examined to see to what degree sedimentary structures, composition, texture and stratification conformed to criteria widely recognized for the Columbia Formation. Facies were recognized as being "...essentially unconsolidated although locally there may be considerable differences in the degree of induration due to interstitial clay and/or iron oxides. Heavy bands of limonite-cemented conglomerate are common, especially towards the north. Colors range from white through yellow, tan and brown to reddish brown" (Jordan 1964: 2). While only broad and generic descriptions have been invoked to isolate fluvial from shoreline estuarine facies, mapping and sedimentology verify that 7-NC-J-225 is largely underlain by a fluvial facies of the Columbia Formation (see Jordan 1964).

This study verified that archaeological contexts were found either within weathered podzols or at the base of the soil parent material, the upper portion of the Columbia gravels. The criteria invoked to isolate the Holocene paleosol from the older Columbia Formation is detailed below. Generally, the finer soils weather into Cambic profiles in the aeolian hummock, while even thinner profiles that are archeologically more diffuse are characteristic of the preservation contexts in the Slope Basin. The thin Holocene sediment accumulations render locus-specific identification of the Columbia facies doubly significant for tracking weathering and archeological preservation patterns in the Holocene matrices.

Stratigraphy

General Considerations

The depth of Quaternary sediments at the 7NC-J-225 on the order of 0.2-0.7 m. The only exception to this context is the Bay Basins, which preserved soft sediment accumulations to depths of ±3m. Bay Basin deposits are typically admixtures fo reworked slopewash and slackwater clays. The sediment contain winnowed Columbia Formation sands and silts as well as poorly sorted sands from the aeolian cap at Black Diamond.

The dominant soil profiles on dominant Aeolian-Hummock terrain are Spodosols that formed under boreal forest covers with vegetation that supplies mobile and sesquioxide-mobilizing organic compounds (Buol et al 1997). Classic profiles feature O-A-E-Bs-Cox succession (Birkeland 1999), but Bs horizons

(containing amorphous organic concentrations) can be replaced by Cambic profiles (Bw horizons) representing a more extensive weathering regime. This was a typical succession for the Frederick Lodge columns.

The overriding aspect of the Black Diamond soil profiles is an overthickened "EB" horizon, which in many cases preserved archeological materials. The EB represents a transitional horizon incorporating aspects of leaching and mineralization. Accordingly, the long-term weathering of the column is the dominant pedogenic process over the course of Holocene time. The overthickened EB horizon is registered by strong to weakly rubefied chromas (10YR5/6 to 10YR5/4) that reflect variable rates of mineralization. Generally, higher chromas signify greater leaching (E-horizonation) while lower chromas evidence mineral accumulation or weathering (Bw-horizonation). The fact that most profiles displayed variants of this horizon is indicative of sustained buildup of a continually weathered podsol that also sustained ongoing aeolian accretion. Effectively over the course of the Holocene, rates of weathering were in dynamic equilibrium with net deposition.

Specifically, most artifact distributions were housed within the Ap or EB. It is noteworthy, however, that features were often excavated into the underlying Bw horizon. On the Aeolian-Hummock landscape segment a single Holocene solum was in evidence at the excavation blocks and core locations that were examined. In the Slope Basin the stratigraphy was somewhat different, since the accumumlation of post-Columbia deposits was minimal (< 0.3 m). Here subtle soil horizonation coupled with the strongly weathered fabric of the Columbia sands and gravels provided evidence of a weak Holocene solum above the erosional Pleistocene surface; a basal 2Bw soil may actually register Holocene weathering within the older Pleistocene soil (bisequal horizonation; see Buol 1999).

Archaeological contexts at Black Diamond were somewhat more straightforward than at Frederick Lodge. Effectively, a single (Late Archaic) component was the signature occupation. Accordingly, a prehistoric time frame of 5000 years (Middle to Late Holocene) was preserved at the site. As noted, stratification was compressed within the upper 0.3-0.7 meters of sediment. While sedimentation rates were minimal, separation of components was not as problematic. Nevertheless an array of radiocarbon determination post-dating the Late Archaic required careful microstratigraphic resolution and the development of a site formation sequence that accommodated the variability in the radiometric

record and the unique preservation of artifact distributions and features within soils developed within aeolian sediments. The lateral and vertical dispositions of sediment complexes, soil horizons, and archeological assemblages serve as the basis for the stratigraphic framework.

Allostratigraphy

Because of subtle sediment and archeological stratigraphy and to maintain continuity with the Frederick Lodge sequence (Schuldenrein 2004), an allostratigraphic scheme was developed for Black Diamond. The system is based on tracing individual strata on the basis of bounding discontinuities. It is appropriate for linking sets of grouped archeological, soil, and depositional units across space and time. Since units are defined by boundaries rather than by contents, they allow for explaining the mechanisms that forced changes in stratigraphic ordering (see Ferring 2001). The system is especially flexible for situations in which breaks in deposition are inconsistent across a site and across segments of landforms (ie. Aeolian/Hummock and Slope/Basin terrain). Operationally, the allostratigraphic framework allowed for the expansion of soil-stratigraphies across the site to accommodate depositional breaks and changes across the general site environment.

At Black Diamond, the two transects, A and B (Figure 2), registered the range of stratigraphic variability on site. Archeological information was provided for the key excavation blocks and deep testing units. Sedimentological profiles were integrated within the sequence to highlight co-eval occupation and landscape successions.

Based on field relations and stratigraphy, the Allostratigraphic Units may be grouped and identified by soils and by landform segment as follows (oldest to youngest):

- **AU-1**
  Unweathered to weathered gravels and sands (with lag deposits) of the Columbia Formation [C horizon (Aeolian-Hummock); 2BC/2C horizons (Slope Basin)];

- **AU-2**
  Weathered aeolian with some colluvial sediment of Holocene age; unit is split within the solum and includes horizon interface (EB-

Bw) since this is an overthickened soil. Archeological materials of Late Archaic through Woodland are present [EB-Bw horizons (Aeolian-Hummock); EB-BC-2C horizons (Slope Basin)];

.

- **AU-3**

  Historic soil represented by plowzone but irregularly underlain by thin aeolian or colluvial sediment; includes upper solum [Ap/EB horizons (entire landscape)]

It is emphasized that only slight changes in parent material and slope distinguish the two landscape segments. For this reason the AU units are contemporaneous across both landscape segments while the soil profiles are unique to the individual segments.

AU subdivisions generally articulate with the following archaeological field horizons: Stratum "A" conformed to AU-3; Stratum "B" was equivalent to AU-3 (lower) and AU-2 (upper); Stratum "C" represented AU-2 (lower) and AU-1 (upper); and Stratum "D" is the weathered Columbia gravels, AU-1. Archaeological features were generally sampled in Stratum "I", which is generally within the Bw or upper Columbia gravels (Bw/C interface). In terms of the allostratigraphy, these should be considered AU-2. It is also noted that the EB-Bw succession was often considered a Bw-Bt sequence by excavators. However, since the geoarchaeological investigations identified an overthickened podzol, the field observations were variously adjusted to reflect the continuous pedogenic sequence.

Figures 3 and 4 show the transects and the ordering of the major allostratigraphic units. Principal observation and sampling locations are illustrated for the transects. The sections underscore the subtle differences in the sequences for the two landform segments. Variability is chiefly a function of the unique sedimentation in the Slope Basin. Colluviation is a more prominent depositional process as is the oscillating water table which accounts for permeability of fines through the sandy gravel matrices of the Columbia Gravels in AU-1. It also explains the preservation of a 2Bw horizon in Transect A while the equivalent soil horizon in Transect B is 2AB. Local reworking of basin gravels also explains the succession of coarse grained sands and gravels above the weathered horizons (2AB and 2Bw) in the Basin settings. While AU-1 is of

Pleistocene age there are Holocene veneers of aeolian, colluvial and basin edge sediment (the latter from the Slope Basin) that cap the unit locally.

AU-2 is the most archeologically sensitive unit in the sense that it represents the unit that is time equivalent with human occupation. As discussed, post-occupational disturbances (pedoturbation, soil formation, plowing, land clearance) have resulted in vertical and lateral translocation of artifacts; high densities of cultural materials are therefore preserved in the Ap (Plow Zone) horizon within AU-3.

In the Aeolian-Hummock landform, AU-2 registers a Holocene soil that has weathered on a slightly silty sand parent material. Archaeological materials are either embedded in the firmer Bw silts (as features) or as artifact clusters within the lower EB. The general soil forming sequence extends to the Slope Basin, albeit on a coarser parent material. It is not possible to establish the chronology of soil formation with great specificity, but available radiocarbon dates and the presence of sealed archeological features in the Bw indicate that the soil is at least 5000 years old and, further that the upbuilding of the Late Holocene soil was slow. Within the rubefied clay-silt matrix (7.5 YR hues) of the lower Bw determinations are no younger that 1000 B.P. (see Table 1), suggesting that the active weathering front, which would normally be defined at the E-Bw interface, is rising slowly and that enrichments of aeolian sands are in equilibrium with the soil forming sequence to the present day.

As depicted in Figures 3 and 4, the top of the Bw is offset as an eroded/mineralized surface. In pedogenic terms this is simply a sharp soil boundary to the zone of weathering (EB/Bw transition). However, there are independent indications of a depositional break here, most notably the additions of silts to the otherwise sandy matrix; these are not the product of weathering but appear to be of depositional origin. Further, the dates and the archaeology (some Woodland artifacts intrusive into an otherwise pure Late Archaic occupation) are suggestive of 500-1000 years of landform stability, after which more podsolization proceeded in conjunction with incremental additions of aeolian material. This homeostasis obscures the evidence of the former disruption to landform buildup sometime in the later Holocene. In finer grained sediments the pedogenic record would disclose the break in the form of a bisequal soil, but weathering profiles are considerably more subtle in the sandier parent materials of the Black Diamond site (Buol et al. 1997).

AU-3 represents the plow zone and upper solum (top of EB horizon). It is generally <0.5 m thick. The horizon contains historic debris and prehistoric deposits, irrespective of the landform segment, and it can therefore be difficult to isolate. Prehistoric materials within the upper EB are typically clustered, and in some loci the highest artifact densities are within the leached zone (E horizon) immediately underlying the Ap. The soil boundary is represented by the passage from 10 YR3/6 loamy sands to 7.5 YR4/6 silt to clay-loam sands with structures moving from granular to weak-subangular blocky. Widespread reclamation, plowing, variable forest cover and longer-term erosion account for the diverse distributions of artifacts in that soil-sediment package. It is tempting to link this portion of the sequence to the Woodland-historic succession but the shallowness of the deposit, its loose consistence and exposure are consistent with active sedimentation and redeposition. As opposed to Frederick Lodge, the principal archaeological component is Late Archaic, such that AU-3 represents a post-occupation unit and records the upper weathering sequence extending to the historic period. Beneath the present soil cap artifacts are variously turned over from originally sealed contexts.

Radiocarbon Dates

A total of eight (8) radiocarbon determinations were obtained from site 7 NC-J-225 (Table 1). Five (5) were derived from archaeological features and three (3) were procured from soils. Of the soil carbon samples, two were dated to establish the antiquity of the Bw horizon in the Aeolian/Hummock landform and to assess contemporaneity with the cultural features on that landform. A single sample dated the age of the Slope Basin setting (Beta-150341). Figures 3 and 4 show the stratigraphic contexts of dates along the topostratigraphic transects, underscoring the preservation of features within or immediately above the Bw horizon of the podsol. All of the specimens were taken from AU-2 or the AU-2/3 interface, underscoring the vertically limited associations of cultural materials.

The range of the radiocarbon dates extends from 1900 to 250 B.P. and is consistent with the Late Holocene occupation of the landscape. However, all but one of the determinations—Feature 9 dated to 1870±40 B.P. (Beta-149979)—are of Woodland age and are inconsistent with artifact evidence that points to a single Late Archaic habitation on the site. The considerably more recent ages suggest that a variety of post-occupation processes account for dates that generally cluster within the last millennium.

To determine the sources of variability more carefully, it is necessary to distinguish between the *accuracy* and the *precision* of the set of radiocarbon dates. In the field of radiocarbon dating, *accuracy* refers to the correctness of the age assignment, the degree to which the ^{14}C estimates conform to the period of occupation. *Precision* refers to the degree to which repetitive measurements on specimens conform to a range of values on the set of samples (see Taylor 1987: 106). On this basis, the artifact data independently refute the accuracy of the radiocarbon ages; seven of the eight determinations (87.5% of dated samples) post-date the occupation by nearly a thousand years. However, Table 1 shows a striking consistency within the radiocarbon determinations by spatial locus and stratigraphic context, irrespective of radiocarbon source (ie, cultural carbon vs. humic acid organic assays). Thus, for example, the ages of burnt charcoal from Feature 29 (910±40 B.P.; N253/E421; Beta-149975) and the bulk soil from the Bw horizon (940±40 B.P.; N251/E417; Beta-150342) on the northeast block are contemporaneous. Within the main block, Feature 24 (680±40 B.P.; N244/E412; Beta-149977) and the second Bw sampling locus, N242/E406 (650±40 B.P.; Beta-150343), are only slightly more distant from each other but produced consistent dates as well. In both sets of samples, the dated cultural materials were feature fills and the soil determinations were derived from the Bw horizon within which the features were excavated. It is reasonably concluded that the precision of the dates from the Black Diamond sites is surprisingly high.

The unique precision of the radiocarbon determinations for each of two sets of samples is not readily explained, especially since bulk soil dates typically vary significantly from those produced by more reliable charcoal contexts. Organic matter within soil horizons is subject to churning and decoposition during and after the long period of surface stabilization. As a result the humic materials dated represent the average age of the horizon formed during soil formation, also known as the Apparent Mean Residence Time (AMRT) (Matthews 1985; Scharpenseel and Schiffman 1977; Schuldenrein 2002; Taylor 1987). Thus the probability that any single AMRT determination will correspond, within decades, to a charcoal determination that measures a specific burning event would appear to be low. At Black Diamond, however, the convergence of the AMRT and cultural dates is high for two periods: at 900 B.P. and 650 B.P. More critically, neither of these periods is consistent with the primary occupation of the site. A possible explanation for the Late Holocene radiocarbon determinations may be related to the exposure of the land surface in the general

Frederick Lodge area. A Woodland component was identified in that site complex, AU-2b (Schuldenrein 2003), and it is possible that broader expanses of terrain were available for occupation during the time frames recorded by the specimens sampled at Black Diamond. The periods documented would have been antecedent to more intensive intervals of aeolian sedimentation initiated in historic times.

More generally, the sources of potential contamination for both the cultural and humic specimens are numerous. The radiocarbon ages obtained from the site are well within the range of the weathering profile from which they were procured. This suggests that while localized radiocarbon reworking and adsorption of organic matter may account for both erroneous and reliable dates, the general time frame represented is fully consistent with the duration of AU-2. That the Late Archaic horizon formed within the Bw and was subsequently "overprinted" by sustained and long term weathering is certainly confirmed by the radiocarbon data set and is key to understanding the site formation models discussed subsequently.

Depositional Environments: Sand Grain Analysis

Landform morphology, the uniformity of the sand grain population, and the continuity of the weathering profile offered initial indications of the dominance of aeolian process in fashioning the landscapes at Black Diamond. However, microtopographic variability and the presence of Bay Basins and smaller catchments between the primary sandy knolls indicated that more limited colluviation and ponding were intermittently active. At Frederick Lodge it was possible to develop a detailed and complex depositional history that identified periods of limited aeolian activity, punctuated by soil formation phases and pulses of colluviation and ponding. The entire sequence was indexed chrono-stratigraphically by the archaeological assemblages and the radiocarbon record.

At Black Diamond, the apparent prominence of aeolian activity was tested by undertaking a quantitative analysis of quartz-grain micromorphology of representative samples of the parent material underlying the Aeolian/Hummock terrain. In this way it would be possible to establish a signature of aeolian deposition. For Black Diamond, the isolation of aeolian sedimentation was the key to understanding site formation history.

Methods and Sampling

A central element of the study was the differentiation between fluvial and aeolian transport processes. Facies of both fashioned the Pleistocene landscape—initially registered by the Columbia Formation--and subsequent Holocene sedimentation reflects reworking of basal sediments together with some allochthonous regional sediment contributions (Jordan 1964). Typically, the sediments which underlie the Black Diamond sites are quartz-rich, fine to coarse sands which vary from well to poorly sorted, per their derivation from the Columbia Formation. The homogeneous composition and identifiable texture of these deposits permit morphological analysis on the scale of the individual grain, following a variety of procedures (Butzer and Gladfelter 1968; Holliday 1992; Waters 1992). Analysis of the depositional history of these sediments focuses on characteristics of the sediment grains themselves, grain shape and surface features

Detailed observations of samples were made in comparison with analysis of control samples from known environmental contexts. This facilitated limited correlation with past environments of deposition. Further comparison with samples collected from the Frederick Lodge Site complex allows recognition of aeolian-influenced environmental settings.

There are three elements of the sedimentation process that impact grain shape and surface texture: *entrainment*, *transport* and *abrasion* (Cooke, Warren and Goudie 1993:314; Lancaster 1995:85-88; Livingstone and Warren 1996: 29, 113; Pye and Tsoar 1990). Entrainment is the lifting of grains into the flow medium (water or air); this is expressed mathematically as relationship between the energy required to move a grain of sand and the gravitational, cohesive or other forces which resist that movement. Transport is the mechanism of movement once grains are entrained; it may take many forms including saltation (leaping), creep, suspension or other means. The impact between saltating grains suspended in air has many times more force than the abrasion between grains suspended in water or creeping under the force of gravity. Such forceful collisions distinctly modify grains transported by wind. Finally, abrasion is the impact grains have on each other while in transport; grains may abrade or collide with each other, affecting the shape and texture of individual sands.

In either fluvial or aeolian environments, the reconstructed sedimentation process culminates in the deposition of the sands. The model is idealized, however, and does not exclude the influence of disturbance and reintroduction

into a new sedimentation process, perhaps under very different environmental conditions. As a result, the one-to-one correspondence of certain morphologies or surface textures to a particular sedimentary process may be difficult to establish. Accordingly, there is the possibility for multiple episodes of entrainment, transport and abrasion (Folk and Ward 1957; Wentworth 1922). In general, however, measurement of an array of shape and surface texture features may provide enough evidence to grossly separate depositional histories. Butzer and Gladfelter, in their analysis of nilotic deposits in Nubia, suggest that rounding (morphology) and frosting or polish (surface texture) may indicate the "inherited traits…[of] a complex past history" for Nile River sand deposits (1968:475). Ahlbrant (1979) agrees, noting that texture, grain size, and sorting are also diagnostic for determining depositional history. The key morphometric factors and their utility for this study are summarized as follows:

- *Size* describes the diameter of clastic particles of any composition. Ranging from less than a millimeter to over 2mm, particles are classified as clays, silts, sands or gravels. Sand-sized particles vary from very fine (0.125 mm) to very coarse (2mm) sands. Larger particles are designated pebbles or gravels; smaller particles make up the silt and clay size classes. These designations describe the overall texture of the sand in a deposit.

- *Sorting* measures the similarity in size between particles in a sedimentary unit, ranging from very poorly (heterogeneous sizing) to very well (homogeneous sizing) sorted materials. Samples that exhibit a fewer size classes are considered well sorted. Samples which contain a variety of grain sizes, gravelly sand for instance, are poorly sorted. Sorting is also a general proxy for environment of deposition. Aeolian deposits tend to be winnowed of the largest and smallest

particles, becoming very well sorted during transport. Colluvial sediments may contain clays, silts, sands, and larger materials, exhibiting poor sorting.

- *Sphericity* is the "overall shape" of a single grain and measures the approximation of a grain as compared to a sphere (Livingstone and Warren 1996:113). Grains may vary between oblate (disk-shaped), prolate (roller-shaped) or bladed (thinned) as they approach an equant or spherical morphology. As a grain comes close to approximating a sphere, it is said to have undergone extensive modification through either repeated or long distance transport. Abrasion is a significant influence on the sphericity of grains.

- *Roundness* is a description of the smoothness of the edges and corners on an individual grain (Waters 1992:23-27). Grains are classified as very angular, angular, subangular, subrounded, rounded and well rounded. Repeated episodes of grain-to-grain contact tend to modify, or round, the edges of the particles.

- *Surface texture*, or microrelief, refers to the pitting, scratching, frosting, or polish of a grain surface. Frosting appears as a translucent surface on the grain and may be caused by either physical abrasion during transport or chemical etching after deposition. Surface frosting is most frequently associated with particles transported by wind action. Polishing appears as a transparent surface with a glassy or vitreous luster, and is attributed to contact with other

grains during transport in moving water (Roper 1985:24-24; Livingstone and Warren 1996:115).

Ideally, grains from an aeolian sedimentary context would be similarly sized, well sorted, well rounded sands exhibiting a high degree of sphericity and composed primarily of frosted surfaces. In contrast, alluvial or colluvial contexts exhibit moderate to poor sorting, subangular to angular grains, low sphericity and a low percentage of surface frosting. Based on these assumptions, the following assessment isolates the features in sand samples that distinguish between two ends of the transport spectrum: aeolian and fluvial origins. Colluvial contexts are mixed by definition and would be difficult to differentiate microscopically.

As noted, in this analysis grain sphericity, grain morphology and surface texture were key determinants facies recognition. This analysis measures indices of sphericity, roundness and ratios of frosting to polish on small samples of sand from the sites. Further, this examination hypothesizes that grains influenced by an aeolian environment tend to exhibit higher sphericity, a higher rounding index and a higher percentage of frosted sands, while grains originating in a fluvial environment will tend to be less spherical or rounded and have a higher percentage of polished particles.

Sediments were taken from 40 samples of fine to coarse sands at 23 localities across the site with reference to the master site grid and profiles (Table 2; Figure 5). Two sets of additional samples from modern alluvial (3 samples) and aeolian settings (7 samples) were taken for control. These controls were acquired from the vicinity of the Frederick Lodge, Delaware, sites as well as another study location in North Carolina. Table 2 lists the samples and provenience information. Summaries of the morphological and surface texture observations for both study and control samples are listed as well. Only sands from the C horizons in any of the stratigraphic exposures were analyzed. Feature samples and sands from the A, B or E horizons were eliminated in order to limit the physical or chemical influence of human or pedogenic factors on the micromorphology of the sands.

Tables 3 and 4 summarize the statistical analyses completed for the physical characteristics of roundness, frosting, and polish. The study set from Black Diamond and control samples are included. Major statistical indicators of mean, mode, medium, maximum and minimum values are presented.

Comparison to the data set from Frederick Lodge (Selby and Schuldenrein 2003) provides additional information regarding the overall landscape setting for these Delaware sites.

Texture, Sorting and Sphericity

Sediment samples were removed from storage and prepared for examination. Approximately 10 grams of sand were taken from sample bags and allowed to dry overnight in small plastic cups. Once dry, the sands were loose and easy to observe. First, sand texture was determined without magnification using comparison to a Wentworth sand gauge. Next, an estimate of the relative sorting of grains was determined using a very poorly to very well sorted scale (Waters 1992:24 after Compton 1962), both with and without magnification (Table 2). Third, sphericity was determined on a scale from high to low as follows (Table 2 and Figure 6).

Sphericity	**Sphericity Value**
High	1
Moderate to high	2
Moderate	3
Moderate to low	4
Low	5

Roundness

Random samples of fifty (50) grains from all sand fractions were extracted from the cups and placed in a glass dish. These grains were inspected at 1x and 4x magnification under a binocular microscope. Only quartz grains were observed. Each of the fifty grains was examined for grain morphology (roundness) and predominant surface texture (frosting versus polish). Grain morphology, specifically roundness of grains, was described according to the four-category system used by Butzer and Gladfelter (1968:474).

- *Angular*: Irregular grain surfaces dominated by edges and corners which are sharp.
- *Subangular*: Irregular grain surfaces; edges and corners visible, but less sharp and possibly curved or rounded.

- *Subrounded*: Irregular grain outline, but edges and corners more curved and smoothed.
- *Rounded*: Grain outline smoothed, tending toward an oval or circular shape; edges and corners absent.

Following the model established by Butzer and Gladfelter (1968:475), arbitrary values were assigned to grains of each of these four categories:

Rounding Class	Value (per grain)	Rounding Index (100 grains)
Angular	0	0-250
Subangular	5	250-500
Subrounded	10	500-750
Rounded	15	750-1,250

The rounding index was calculated as a simple total for the 50-grain samples (RI); the rounding index was then doubled and reported as 2RI to obtain a comparable index for the 100-grain samples examined by Butzer and Gladfelter (Tables 2, 3, and 4; Figures 7a, 7b, 7c, 7d, and 8).

Surface Texture

Surface texture, specifically frosting and polish, was also examined. Each of the grains in the 50-grain sample was inspected for evidence of either a transparent, buffed luster (frosting) or a vitreous, brilliant luster (polish). Counts for each category were recorded and a ratio (percentage) of the predominant surface texture to the entire sample was reported. The counts were then qualified with a descriptor.

Surface Texture Percentage	Descriptor
Under 10%	Infrequent
10-28%	Slight and occasional
29-49%	Visible and frequent
50-75%	Dominant and very frequent
Above 76%	Predominant

Basic statistical calculations for the resulting raw data on morphology and surface texture were computed, and are reported in both table and chart formats (Tables 2, 3, and 4; Figures 9 and 10).

Analysis

A total of 56 samples were studied. Of these, 40 (71.4%) are derived from the site proper while 16 (28.6%) were control samples.

For the on-site testing, three discrete segments of the site were sampled on the basis of the site plan . Locales were separated as follows:

- north of the N244 gridline (including excavation Profiles C and F);
- south of the N244 gridline (including excavation Profiles A, B, D, and H);
- supplementary proveniences from various locations across the Black Diamond landform.

The proveniences and numbers of samples taken for the on-site study were as follows:

Black Diamond Proveniences	Total Number of Samples	Sample Numbers
North of N244		
N243-250 E417, N250 E417 - A	3	BD18, BD16, BD19
N243-250 E417, N248 E417 - B	2	BD20, BD17
N243-350 E417, N247 E417 – C	1	BD21
N243-250 E417, N245 E417 - D	2	BD23, BD22
N251 E411-417, N251 E411 - A	3	BD7, BD9, BD6
N251 E411-417, N251 E414 - B	1	BD11
N251 E411-417, N251 E415 - C	2	BD8, BD10
South of N244		
N236-243 E416, N242 E416 - A	1	BD4
N236-243 E416, N238 E416 - B	1	BD5
N236-240 E412, N236 E412 - A	2	BD24, BD25
N236-240 E412, N237 E412 - B	2	BD29, BD28
N236-240 E412, N239 E412 - C	2	BD26, BD27

N237-241 E411, N240 E411 - A	2	BD36, BD37
N237-241 E411, N238 E411 - B	2	BD30, BD31
N237-241 E411, N237 E411 - C	1	BD32
N236 E412-416, N236 E416 - A	2	BD15, BD12
N236 E412-416, N236 E414 - B	2	BD14, BD13
North Wall N243 E412	1	BD40
West Wall N242 E406	2	BD38, BD39
Additional Proveniences		
Trench C	2	BD34, BD35
Trench B West Wall N185 E377	2	BD2, BD1
N222 E400	1	BD33
N242 E397	1	BD3

The controls were taken from several locations including 16 from Frederick Lodge (included in Table 5) (Schuldenrein 2003) and 10 from the Fort Bragg military reservation in North Carolina. The latter were selected because they incorporated settings that were unequivocally aeolian or fluvial and were removed from any unique localized depositional constraints that would have affected sedimentation of the Delaware sites.

Off-site sampling locations were as follows:

Comparative Sample Proveniences	Total Number of Samples	Sample Numbers
7NC-J-97 Block G N218 E647	1	FL15
7NC-J-97 N225 E670	2	FL2, FL3
7NC-J-98 Block B N288 E578	1	FL5
7NC-J-98 Block B N305 E585	1	FL4
7NC-J-98 Block D N305 E545	3	FL6, FL7, FL8
7NC-J-98 NE Edge N296 E620	1	FL17
7NC-J-98 NW Edge N350 E475	1	FL11
7NC-J-99 N185 E715	3	FL12, FL13, FL14
7NC-J-99 Block L N190 E820	2	FL9, FL10
7NC-J-99 N195 E755	1	FL16
Control – Aeolian	7	FB5, FB6, FB7, FB 8, FB9, FB10, FB11

Control – Alluvial	3	FL1, FB15, FB28

Observations for each setting are as follows.

Samples from North of N244

N243-250 E417, N250 E417 – A

The three samples ranged in depth from 50 to 99 cm below surface, and contained medium to very coarse sands. Sphericity varied from low to moderate, while sorting spanned the spectrum from well to poorly sorted. Grain morphology was subrounded, with roundness values falling between 285-335 (2RI of 570-670). Sample BD18 at 50-58 cm below surface presented a frosting ratio of 34%, while the deeper samples BD16 (70-80 cm BS) and BD19 (89-99 cm BS) had frosting percentages of 52% and 54% respectively. It is interesting to note that sample BD19, the deepest collected, was specifically a moderate to well sorted medium sand with moderate sphericity and a rounding index value of 320 (2RI of 640). This sample exhibited the highest observed frosting to polishing ratio of any sample examined at Black Diamond.

N243-250 E417, N248 E417 – B

Both samples contained moderate to very poorly sorted, medium to very coarse sands located between 47 and 69 cm below surface. Sorting was moderate in the upper horizon (BD20), becoming very poor in the lower level (BD17). In BD20, the rounding index was 330 (2RI of 660), indicating subrounded grain morphology, with visible and frequent surface frosting appearing on 34% of the particles. However, sample BD17 showed a higher rounding index value of 465 (2RI of 930), a clearly rounded grain character. A high frosting ratio of 52% (dominant and frequent) complements the high rounding index value for BD17 as well.

N243-350 E417, N247 E417 – C

Sample BD21 from provenience N243-350 E417, N247 E417 – C was a medium to very coarse, very poorly sorted sand with low to moderate sphericity. The sample, taken from 52-59 cm below surface, exhibited a rounding index value of 350, or 700 2RI value, solidly within the value range for rounded grain

morphology. The frosting percentage was 34%, with visibly frosted grains appearing frequently.

N243-250 E417, N245 E417 – D

Samples BD23 and BD22 from provenience N243-250 E417, N245 E417 – D were medium to coarse sands exhibiting moderate to poor sorting and low to moderate sphericity. Sample BD23 (35-44 cm BS) contained a notable fraction of fine subrounded sands with a roundness value of 280, or 560 2RI. Sample BD22 (51-61 cm BS) revealed a high roundness value of 415, or 830 2RI, a clearly rounded sand grain sample. In both cases, the frosting to polishing ratio was high, exceeding 30%, where frosted grains were easily observed and frequent throughout the sample.

N251 E411-417, N251 E411 – A

Three samples ranged from 62-114 cm below surface. BD7, BD9, and BD6 were generally medium to coarse, moderately sorted sands with moderate sphericity. Both BD7 and BD9 exhibited distinct subrounded to rounded grains (2RI values of 640 and 820 respectively), and contained a high proportion of frosted particles, exceeding 44%. However, the deepest specimen, sample BD6, appeared to be a mixed sample, containing fine grains with indications of poor sorting. For BD6, a high roundness value (2RI of 820) contrasted with a low frosting ratio of 24%.

N251 E411-417, N251 E414 – B

A single sample was collected at 54-62 cm below surface. BD11 was a moderately to well sorted, medium sand with moderate to high sphericity. Grains were clearly rounded (2RI of 940), but, like sample BD6, the frosting ratio was rather low. Only 18% of the grains had frosted surfaces, making the occurrence of frosting slight and occasional within the specimen.

N251 E411-417, N251 E415 – C

Two samples were obtained and both BD8 and BD10 (45-68 cm BS) were moderately to poorly sorted, medium sands, with moderate sphericity (S value of 3-4 respectively). Rounding values ranged from 660-700 2RI, indicating the grains were subrounded. The frosting to polishing ratios suggested that these

grains were not heavily frosted (only 22%), with such grains appearing occasionally within the sample.

Samples from South of N244

N236-243 E416, N242 E416 – A

The specimen (BD4), collected between 66-75 cm below surface, was a moderately to poorly sorted medium sand with moderate to low sphericity. Grains were subrounded (2RI of 720). The frosting ratio, under 25%, was also low.

N236-243 E416, N238 E416 – B

BD5 was taken south of BD4 on the B profile. This moderately sorted fine to medium sand contained grains with moderate sphericity (S value of 3). The roundness value suggested a subrounded grain character (2RI of 670). As with BD4, sample BD5 showed a low overall frosting ratio, again under 25%.

N236-240 E412, N236 E412 – A

Samples BD24 and BD25 were between 54 and 72 cm below surface. Samples contained moderately to poorly sorted coarse to medium sands. Sphericity was moderate to low, with a value of 4. Additional, grains tended to be subrounded, with 2RI values for both specimens ranging from 660 to 670. The frosting ratio was split, with BD24 indicating a higher percentage of frosted to polished grains than BD 25. BD24 contained a higher number of coarse sand grains which were visibly frosted in approximately 30% of cases.

N236-240 E412, N237 E412 – B

BD29 (54-62 cm BS) and BD28 (65-72 cm BS) were poorly sorted coarse to medium sands. Sphericity was moderate to low (S value of 4). Grains appeared to be subrounded with 2RI values ranging from 620 to 720. Slight and occasional frosting was observed among 26% of the sampled sand grains.

N236-240 E412, N239 E412 – C

Two samples, BD26 and BD27, came from 66-83 cm below surface. Both were poorly sorted medium sands with moderate to low sphericity. However, the upper sample, BD26 exhibited a subrounded grain character (2RI of 720) with

a low frosting ratio of 28%. In contrast, BD27 showed clearly rounded grain morphology (2RI of 780) and a visible and frequent frosting ratio of 38%.

N237-241 E411, N240 E411 – A

Two samples, BD36 and BD37, contained moderately to poorly sorted coarse to medium sands. Both revealed a moderate to low sphericity value of 4 and a subrounded grain character (2RI of 720 and 580 respectively). The frosting ratios for the samples were identical, reaching only 28%.

N237-241 E411, N238 E411 – B

Samples BD30 and BD31, between 53-79 cm below surface, were moderately sorted medium sands with moderate to low sphericity. Both samples demonstrated two different roundness values and frosting rations. The upper sample, BD30, exhibited a strong overall rounded grain morphology (2RI of 940) with a high frosting ratio (38%). Sample BD31 contained grains of a subrounded morphology (2RI of 670), and a lower frosting ratio of 30%.

N237-241 E411, N237 E411 – C

BD32 (50-59 cm BS) was a moderately sorted, moderately spherical, medium to fine sand. The grain character was subrounded (2RI of 710), while slightly frosted grains appeared occasionally throughout the specimen (24%).

N236 E412-416, N236 E416 – A

Specimens BD15 and BD12 were medium sands with moderate sorting and sphericity. Taken between 53-79 cm below surface, both samples appeared to have a subrounded morphology (2RI of 690-730), and low frosting ratios (24-28%).

N236 E412-416, N236 E414 – B

Provenience N236 E412-416, N236 E414 Column B contained the coarsest materials observed at Black Diamond. Samples BD14 and BD13 (52-73 cm BS) were very poorly to moderately sorted, very coarse to medium sands. Sphericity was low overall. Both samples demonstrated a subrounded character (2RI of 610 and 740 respectively). Further, both samples reflected a slight and occasional occurrence of frosting on grain surfaces, equaling 24%.

North Wall N243 E412

A single sample along the Profile A transect (BD40) was removed at 85-95 cm below surface. This sample was a poorly sorted, medium to fine sand with moderate to low sphericity. Subrounded grains were common (2RI of 710), while the frosting ratio did not exceed 25%.

West Wall N242 E406

Along the I transect profile, BD38 and BD39 consisted of moderately sorted, medium to fine sands with moderate to low sphericity values. The grain morphology indicated a subrounded character in both cases. While texture, sphericity and roundness were similar in both samples, the frosting ratios were divergent. Sample BD38, the upper specimen, indicated only slight and occasional frosting on 22% of the particles. In contrast, sample BD39 was visibly frosted on 36% of the sand grains observed.

Samples from Additional Proveniences

Six samples from four additional proveniences were examined, including Trench C, Trench B West Wall (N184.9 E377), unit N222 E400, and unit N242 E397. These were collected from outside the main excavation area. Generally, these specimens contained coarse to medium sands with moderate sorting. Sphericity was typically moderate to low, and sand grain morphology tended to be subrounded. Three of the five specimens exhibited low frosting ratios (under 28%).

In two cases, BD1 (N184.9 E377) and BD33 (N242 E397), the morphology of the grains was distinct. These samples appeared to be moderately to well sorted medium to fine sands. Further, these specimens showed visible and frequent frosting on 30% or more of grain surfaces.

Control – Aeolian

Seven samples from a modern dune complex near Fort Bragg, North Carolina provided adequate comparative control (FB5, FB6, FB7, FB 8, FB9, FB10, FB11). These moderately to well sorted sands were collected from surface contexts and ranged from coarse to fine textures. Further, these samples tended to have moderate to high sphericity values, and ranged from angular to subangular roundness index values (RI of 220 to 480; 2RI of 440 to 960), with a

mean value of 296 (2RI of 592) (Table 3). Most notably, the ratio of frosted to polished grains indicated a dominant to predominant frequency of frosted surface textures, with percentages exceeding 75%, or greater than 3 to 1 in some samples.

Control – Alluvial

Three samples were used as comparative references for a modern alluvial context. One sample from a Bay Basin at Frederick Lodge (FL1) was used in addition to two alluvial sample taken from extant streams near Fort Bragg, North Carolina (FB15 and FB28). Textures ranged from very coarse to fine. Sorting varied considerably between well to poor, while sphericity remained moderate. Roundness values were low, with a mean value of 275 or 2R1 of 550 (Table 3). Frosted grains from the North Carolina samples were the lowest values observed (14-20%), while the Frederick Lodge reference indicated more visible and frequent frosting (30%).

Interpretations

Tables 2, 3, and 4 report the results of key statistical evaluations of the Frederick Lodge and control samples. Figures 6 through 10 illustrate the important differences between sphericity, roundness and surface texture. Summaries of the physical features are reported below.

Texture and Sorting

Although not evaluated quantitatively, several general observations can be made regarding Wentworth texture and overall sorting patterns with respect to the 23 localities within the Black Diamond site.

In the northeastern corner of excavation, between N244 and N252, the sampled horizons consisted of medium to coarse sands, with only three occurrences of fine sands among the fourteen specimens examined (BD 23, BD6, and BD8). Sediment samples examined from the north-south Profile C reflect the general fining-upward sequence noted during excavation. Samples from east-west Profile F are similarly textured. Horizons from both profiles vary from very poorly to moderately sorted grains. In two notable cases, sample BD19 (89-99 cm below surface) and BD11 (54-62 cm below surface), sediments reflect moderate to excellent soring.

South and west of the N244 grid line, sediments are predominantly medium to very coarse sands, moderately to very poorly sorted. Four instances of fine sands are notable: BD5 (71-80 cm below surface), BD32 (50-59 cm below surface), BD15 (53-62 cm below surface), BD40 (85-89 cm below surface), and BD39 (90-95 cm below surface). These four samples are all moderately sorted, exhibiting a greater aeolian transport imprint than other Black Diamond specimens.

Finally, several additional proveniences demonstrate textures ranging from coarse to fine sands, and are generally moderately to well sorted grains. These samples, particularly BD1 and BD2 from Trench B unit N184.9 E377 (82-117 cm below surface), are well south and west of the main excavation area. Significantly, they demonstrate the finest grain size fractions sampled at the site, as well as the most consistently well-sorted character.

Sphericity

Quantitative evaluations of sphericity ranged from low of 4 to a high of 2, or moderate to high sphericity (Table 2). This limited range of variation for sphericity, for Black Diamond as well as the control samples, does not provide an adequate marker for environments of deposition. Ideally, aeolian environments would produce sand grains with consistently moderate to high (3 to 1) values. Fifteen of the forty samples (37.5%) had sphericity values of 3. One Black Diamond sample, BD11 produced a value of 2, or moderate to high degree of sphericity.

Comparison with the control samples suggests a trend toward an aeolian-influenced environment (Figure 6). Samples in the northeast corner of the excavation area (including BD16, BD19, BD17, BD23, BD9, BD6, BD11, and BD8) featured moderate sphericity values of 3 or higher, comparable to the majority of modern aeolian control samples. These samples taken from Profiles C and F tended to come from depths greater than 60 cm below surface.

Areas to the southwest of the excavation block were similarly distributed. The samples clustered around Profiles B, D and H (samples BD31, BD32, BD15, BD12, and BD14); they trended toward a more spherical morphology and also featured frosting ratios of more than 25%. Collectively, these characteristics indicated an increasingly strong aeolian signature. The two areas are within the Aeolian/Hummock terrain, between the bay/basin lows, and would have formed a collection point for saltating sand grains lifted by local winds.

Outside the main excavation block, further to the south and west, sample sphericity trended toward an alluvial pattern. Samples BD35, BD34, and BD2 in particular exhibited moderate to low sphericity as well as low frosting ratios (around 20%). These samples, taken from topographically low areas or the Slope/Basin terrain would have been more strongly influenced by alluvial or even colluvial processes. A short transport distance combined with the low incidence of abrasion in water would maintain the oblate, prolate, or bladed shapes of individual grains.

Roundness

Examinations of grain roundness were determined by calculating mean, mode, median, maximum, and minimum values established during inspection of the 50-grain samples. Figure 7a reports Black Diamond rounding index (RI) values ranging from 265 to 470 (2RI of 530 to 940) on the Butzer and Gladfelter scale (1968). The average RI value for the Black Diamond samples was 349.8 (2RI of 699.5), with a mode of 335 (2RI of 670) and a median of 340 (2RI of 680) (Tables 3 and 4; Figures 7b, 7c, and 7d). The average values of roundness for Black Diamond most closely resembled the RIs calculated for the aeolian control samples (mean RI: 295.7; mean 2RI: 591.4) than the alluvial control samples (mean RI: 275; mean 2RI: 550).

Samples from the northwest corner of the excavation area indicated 2RI rounding values greater than 600 (Figure 7b). Similarly, samples from the southwest area of the main excavation block showed a 2RI index greater than 600, and in some cases exceeding 750, the transition value to rounded grain morphology (Figure 7c). Notably, samples BD 11 and BD30 reached 2RI values of 960, or clearly rounded grains. Such high roundness values are consistent with the expected pattern of an aeolian influenced environment.

Areas outside the main excavation block, grading from Aeolian/Hummock to Slope-Basin landscape segments, exhibit mixed roundness values (Figure 7d). Four of the six samples (BD34, BD2, BD1 and BD3) converged around a 2RI value of 600, typical of subrounded grain morphology. Sample BD3 had a 2RI value of 530, slightly above the subangular morphology category. These low roundness values suggest an alluvial or perhaps colluvial setting.

Figure 8 reports statistical calculations for the Black Diamond and control sample populations. Of the Black Diamond sample universe, all of the

specimens exceeded a 2RI value of 500, 63% had roundness values greater than 670 and nearly half produced 2RI values above 700. These high rounding index values point toward an aeolian context, consistent with the presence of highly rounded particles. Furthermore, the persistence of these rounded grains on the Aeolian/Hummock landscape segment suggests that wind transport was the likely cause of accumulation.

Frosting

The mean frosting percentage for the Black Diamond samples is 29.9%, indicating that frosted surface textures are distinctly visible and common within a given sand population. Samples BD16 and BD19 from the northeast area of the excavation block have the highest frosting ratios of 52% and 54% respectively. The mean values for the aeolian control samples reach 65%, while the average for the alluvial reference group is 20%. The trend appears to move in the direction of the aeolian group instead of the alluvial sample set.

Figures 9 and 10 demonstrate this trend more distinctly, showing the close statistical relationship between the Black Diamond and aeolian control groups. Samples cluster within a frosting percentage range of 34-54% on the scatter plot, indicating a high degree of similarity between environments of deposition. A second cluster suggests an affinity between selected Black Diamond samples and the alluvial control group, with frosting ratios under 30%. Such low frosting percentages are found at the outer edges of the main excavation block as well as to the south and west of the block where lows and high-to-low topographic transitions are present.

Samples from the northeast corner of the excavation block, in the vicinity of Profiles C and F, contain the strongest indication of aeolian transport. Sands examined from these locations tend to be dominated by frosted surface textures. These samples are from the Aeolian/Hummock segment.

The lowest frosting ratios appeared in the southwestern corner of the main excavation block, particularly from horizons falling between 50 to 80 cm below surface. At least sixteen samples from this region show frosting ratios well below 30%. These samples were collected from the Slope/Basin segment.

Comparisons with the Frederick Lodge Site Complex

Table 5 and Figures 11, 12 and 13 provide comparisons between the Black Diamond data set and that of the Frederick Lodge Site Complex (Schuldenrein

2003; Selby and Schuldenrein 2003). As noted, Black Diamond occupies the northernmost extensions of the Frederick Lodge landform complex.

Table 5 replicates the data sets from Black Diamond and Frederick Lodge. Comparisons of mean roundness and frosting values are very similar. The mean 2RI value for Black Diamond is 699.5 while the mean for Frederick Lodge is 729.3. Overall, the roundness index suggests a dominance of subrounded grains (Figure 11). In some cases, the 2RI value exceeds 900, clearing indicated a trend toward well-rounded sand particles.

Frosting ratios are also analagous, with mean percentages for Black Diamond calculated at 29.9% and Frederick Lodge at 32.9%. For each site, frosted grains are clearly visible and appear frequently within the samples observed. The Figure 12 scatter plot demonstrates how these frosting ratios cluster between 34% and 46%. Figure 13 presents these data in another format. Nine of the forty Black Diamond samples and six of the sixteen Frederick Lodge samples exceeded the 40% level, which tends toward the aeolian control group mean frosting ratio of 65%.

Such quantitative similarities in sand grain morphology underscore similarities in depositional settings and sediment transport. As noted at Frederick Lodge, loci on the crest of the landform (7-NC-J-97 and 7-NC-J-98), exhibited sphericity, roundness, and frosting ratios consistent with an upslope aeolian-influenced setting. Analogous morphological patterns are visible within the main excavation block at Black Diamond, and are especially notable in the northeastern excavation units.

In contrast, the Frederick Lodge site of 7-NC-J-99 demonstrated a mixed assemblage of grain morphologies, consistent with mid and toe-slope settings where colluvial and alluvial processes would have dominated. While no unequivocal evidence of colluviation was tested for at Black Diamond, samples from units south and west of the main excavation area reflected morphological features similar to down-slope topographic positions where ponding and short term fluvial transport would have been active.

Overview

This quantitative assessment of sand grain morphology implicates a landscape that is dominantly of aeolian origin. At Black Diamond the dominant transport mechanism is wind action moving sand grains up and down-slope. Specimens from the various parent materials (C-horizons) sampled in this

experimental study indicate an environment influenced by conditions favorable to mobilization of sand size sediment by wind action.

General and specific observations of sand grain texture, morphology and surface features support the partition of the immediate Black-Diamond landscape into discrete Aeolian/Hummock and Slope/Basin segments. The higher elevations, specifically within the northeast corner of the main excavation block, were dominated by finer and more homogeneous sand sizes, with greater sphericity, rounding and most importantly frosting ratios. Such locations are likely to be loci of peak aeolian sand transport. The sands at the Slope/Basin loci are not distinguished by any one key physical characteristic, but appear to be mixed accumulations of grain sizes, sorting patterns, morphologies and surface textures. At these locations, localized water flow and slope process may recycle aeolian sands.

Feature Studies

The cultural features preserved at Black Diamond were analogous to those at Frederick Lodge, with the caveat that all were presumed to date to the Late Archaic period. It was assumed that patterns of prehistoric human land use would also be similar to those noted for that site. To examine the degree of anthropogenic sedimentation in greater detail, geochemical analyses of feature phosphates were undertaken. The strategy has been effective in sorting out human activity patterns. The extent and performance of specific activities at the site was determined by measuring concentrations of inorganic phosphates and assessing fractionation patterns. The method facilitates reconstructions of the types of activities, duration, and even the relative antiquity of particular feature types. Techniques in this study followed the methodology initially outlined by Eidt (1984) for phosphate fractionation and subsequently refined by Schuldenrein (1995) for North American hunter-gatherer sites.

Phosphate fractionation studies were performed on Features 9, 11, 17, 24, 29, 46, 60, 67, 69, and 71. It is noted that for the SR 1 project generally, the feature analyses were concentrated on the Sandom Branch sites.

Figure 14 shows the results of phosphate fractionation for the Black Diamond sites. The results suggest a strong degree of fit with the Frederick Lodge activity areas. Patterns align almost directly on the Frederick Lodge feature profiles, showing a heavy weighting on Fraction II. Significantly, the Frederick Lodge features may have registered a more extensive time frame.

Occupations ranging from the Middle Archaic to Woodland were recorded at the site. At Black Diamond, the Late Archaic habitation was dominant. However, the feature data suggest that irrespective of the time frame represented at Black Diamond and Frederick Lodge, a limited series of similar activity patterns are represented across the landscape traversed both sites. By contrast, the Sandom Branch sites, which contained a much more limited series of temporal occupations, witnessed a broader array of feature types. The Sandom sites may have supported more complex patterns of site utilization. If Black Diamond was truly a single component occupation, the limited activity record denoted by the phosphate data raises the possibility that a single occupation accounted for the features at Frederick Lodge, or that similar activities were performed at both sites for the duration of landscape use over the course of the Holocene. For example, the relatively low concentrations of total phosphorous may argue for limited seasonal subsistence rounds consistent with short-term occupation. The close match of loadings on time diagnostic Fraction I at Black Diamond and Frederick Lodge may signify coontemporaneity of site use during the Late Archaic (Schuldenrein 1995). Sandom Branch phosphate signature would appear to be partially distinguished by use of a distinctively different landscape, perhaps a more typically riverine habitat. Additional feature sampling and radiocarbon dating are necessary to verify the spatio-temporal trends recorded in the population of features for the SR 1 study area.

Site Formation Modeling

The immediate Black Diamond site environment was utilized by Late Archaic groups approximately 3000-2000 years ago. There is limited evidence for a minor occupation during the Woodland. Field observation, landform relations, limited landscape analysis and sedimentological study have verified that there are two principal landscape segments: the higher Aeolain/Hummock terrain and a series of Slope/Basins. The dominant geomorphic process over the course of the Holocene was aeolian sedimentation. Dune buildups characterized the higher ground. Slopes evolved through limited backwearing, colluviation, and the reworking of sands and silts in evolving depressions. The landscape contours separating the dune covered knolls were established in the Late Holocene and the margins of the basins reflect relandscaping during the historic period.

The evidence indicates the primary agency of deposition prior, during and subsequent to the intervals of human occupation was aeolian. Most significantly,

however, that deposition was episodic. Aeolian activity was periodically punctuated by intervals of soil formation and surface stabilization. It is probable that occupation occurred on stable surfaces. Progressive buildup of the surface through slow and infrequent dune activity resulted in burial of the occupation horizons. Since the immediate native landscape was covered by needle leaf forest communities (conifers) the profiles featured spodic profiles, with classic A-E-Bw horizons typical of the spodosol order. The duration of pedogenic process was such that soil horizon boundaries were diffuse and "EB" horizons were identified in most profiles. Soil formation "overprinted" the organic residues of the primary occupation, such that more diffuse artifact distributions were entrained in the cohesive soil fabric of the weathering B-horizons. More discrete activity areas—hearths, refuse pits, and storage facilities—are recognizable in the sediment matrix because of their concentrated organic fills which tended to resist leaching and mineral mobilization during the weathering process.

Summarily, periodic aeolian sedimentation, semi-continuous weathering, and limited erosion accounted for the preservation context of the archaeological assemblages at the Black Diamond site. The sequence of events and site formation processes can be visualized in a six-stage model as set forth in Figure 15.

The end of the Pleistocene is marked by the erosional surface of the weathered Columbia Gravels (Stage 1). Sometime during the Early Holocene (<10,000 B.P.), bedded aeolian sands accumulated atop the higher elevations of the stripped terrace landscapes of the Delaware's interior Coastal Plain and Piedmont (Stage 2). Rates of sedimentation slowed over the course of Holocene time, giving rise to weathering and promoting a homeostatic balance between aeolian deposition and the emergence of the podsols (Stage 3). The forest cover stabilized the surfaces promoting A-E-Bw horizonation; given that regional climates turned moister after 6000 B.P., it is probable that the spodosols stabilized around this time. By the Middle Holocene incremental aeolian accretion balanced by soil formation resulted in the increased mineralization and deepening of the solum (EB-Bw); weathering also overrode and obscured the bedding planes within the former (now buried) cover sands (Stage 4). At the same time, these stabilized settings became increasingly attractive to Late Archaic populations that were starting to disperse locally. Ongoing soil formation and periodic additions to the aeolian cover caused the weathering front to rise in the profile while the thickness of the solum increased

("upbuilding"). As site topography rose, artifacts of the preceding occupation, were buried by sands (Stage 5) and incorporated into the solum (E, EB, and Bw horizons); features are typically found in the latter two contexts (Stage 6).

Archaeological deposits that are preserved within the Holocene soil generally reflect their initial discard loci. However, in other cases, historic landscaping may have displaced entire assemblages laterally and vertically. At Black Diamond, it is generally possible to isolate pristine archaeological contexts and to reconstruct the key formation processes by understanding this diachronic model of site formation.

References

Ahlbrandt, T. S.
1979 Textural parameters of eolian deposits. In *A Study of Global Sand Seas*, edited by E.D. McKee, pp. 21-51. USGS Professional Paper No. 1052. U.S. Geological Survey, Boulder, Colorado.

Birkeland, P. W.
1999 *Soils and Geomorphology*. 3rd ed. Oxford University Press, New York.

Buol, S. W., F. D. Hole, R. J. McCracken and R. J Southard
1997 *Soil genesis and Classification*. 4th ed. Iowa State University Press, Ames.

Butzer, K. W. and B. G. Gladfelter
1968 Quartz-Grain Micromorphology. In *Desert and River in Nubia: Geomorphology and Prehistoric Environments at the Aswan Reservoir*, edited by Karl W. Butzer and C. L. Hansen, pp. 473-481. The University of Wisconsin Press, Madison.

Compton, R. R.
1962 *Manual of Field Geology*. John Wiley and Sons, New York.

Cooke, R. U., A. Warren, and A. S. Goudie
1993 *Desert Geomorphology*. University College London Press, London.

Eidt, R. C.
1984 *Advances in Abandoned Settlement Analysis: Application to Prehistoric Anthrosols in Columbia, South American*. Center for Latin America, University of Wisconsin, Milwaukee.

Ferring, C. R.
2001 Geoarchaeology in Alluvial Landscapes. In *Earth Sciences and Archaeology*, edited by P. Goldberg, V. T. Holliday and C. R. Ferring, pp. 77-106. Kluwer/Plenum, New York.

Folk, R. L. and W.C. Ward
1957 Brazos River bar: A study in the significance of grain size parameters. *Journal of Sedimentary Petrology* 27:3-26.

Groot, J. J. and R. R. Jordan
1999 *Pliocene and Quaternary Deposits of Delaware: Palynology, Ages, and Paleoenvironments*. Delaware Geological Survey Report of Investigations No. 58, Newark, Delaware.

Holliday, V. T. (editor)
1992 *Soils in Archaeology: Landscape Evolution and Human Occupation*. Smithsonian Institution Press, Washington, D.C.

ISG
1994 *International Stratigraphic Guide*. The Geological Society of America, Inc., Boulder, Colorado

Jordan, R. R.
1964 *Columbia (Pleistocene) Sediments of Delaware*. Delaware Geological Survey Bulletin No. 12, Newark, Delaware.

Knepper, D.
2003 Prehistoric Settlement of Bay/Basin Landscapes in the Archaic and Woodland Periods: Phase II and Phase III Archaeological Investigations at the Frederick Lodge Site Complex, 7NC-J-97, 7NC-J-98, 7NC-J-99, New Castle County, Delaware. A report prepared for Parsons Cultural Resources and Delaware Department of Transportation Archaeology.

Lancaster, N.
1995 *Geomorphology of Desert Dunes*. Routledge, London.

Livingston, I. and A. Warren
1996 *Aeolian Geomorphology: An Introduction*. Addison Wesley Longman Limited, Essex.

Mathews, E. D. and O. L. Lavoie
1970 Soil Survey of New Castle County, Delaware. United States Department of Agriculture, Soil Conservation Service, Washington, D. C.

Matthews, J. A.
1985 Radiocarbon dating of surface and buried soils; principles, problems, and prospects. In *Geomorphology and Soils*, edited by K. S. Richards, R. R. Arnett, and S. Ellis, pp. 269-288. Allen & Unwin, London.

Pye, K. and H. Tsoar
1990 *Aeolian Sand and Sand Dunes*. Unwin Hyman, London.

Reineck, H. E. and I. B. Singh
1986 *Depositional Sedimentary Environments*. Springer Verlag, Berlin.

Roper, D. C. (editor)
1985 *Proto-Historic Pawnee Hunting in the Nebraska Sand Hills: A Report of Archeological Investigations at Two Sites in the Calamus Reservoir*. A report prepared for the U.S. Department of the Interior, Bureau of Reclamation, Lower Missouri Region by Gilbert/Commonwealth, Inc. Jackson, Michigan.

Scharpensee, H. W. and H. Shiffman
1977 Radiocarbon dating of soils, a review. *Zeitschrift Ptlanzanernaehr Bodenkunde* 140:159-174

Schuldenrein, J.

1995 Geochemistry, Phosphate Fractionation, and the Detection of Activity Areas. In *Pedological Perspectives in Archaeological Research*, edited by M. E. Collins, B. J. Carter, B. G. Gladfelter and R. J. Southard, pp. 107-132. Soil Science

1999a Summary Report of Geoarcheological Investigations at DelDOT SR 1: PNC Bank Wetlands Sites. A report prepared for Parsons Engineering Science, Inc.

1999b Research Design for Staged Geoarcheological Investigations at 3 Sites for DelDOT SR 1: Frederick Lodge Site (7NC-J-97/98/99/224); Black Diamond Site (7NC-J-225); and Sandom Branch Site (7NC-J-227/228*)*. A report prepared for Parsons Engineering Science, Inc.

2002 A Geoarcheological Assessment of the Buried Landscape at the Proposed Site of 107-111 Worth Street, New York, New York. A report prepared for URS.

2003 Prehistoric Settlement of Bay/Basin Landscapes in the Archaic and Woodland Periods: Phase II and Phase III Archaeological Investigations at the Frederick Lodge Site Complex, 7NC-J-97, 7NC-J-98, 7NC-J-99, New Castle County, Delaware. A report prepared for Parsons Cultural Resources and Delaware Department of Transportation Archaeology.

Selby, S. C. and J. Schuldenrein

2003 Attachment 1, Appendix H. An Examination of Sand Grain Morphology and Surface Texture to the Identification of Aeolian and Fluvial Sedimentation Processes - Frederick Lodge Site Complex, New Castle County, Delaware. In Prehistoric Settlement of Bay/Basin Landscapes in the Archaic and Woodland Periods: Phase II and Phase III Archaeological Investigations at the Frederick Lodge Site Complex, 7NC-J-97, 7NC-J-98, 7NC-J-99, New Castle County, Delaware. A report prepared for Parsons Cultural Resources and Delaware Department of Transportation Archaeology Series.

Soil Survey Staff

1984 *Procedures for Collecting Soil Samples and Methods of Analysis for Soil Survey*. U.S. Dept. of Agriculture, Washington, D.C.

1993 *Soil Survey Manual*. U.S. Dept. of Agriculture, Washington, D.C.

1997 *Keys to Soil Taxonomy*. 7th ed. U.S. Dept. of Agriculture, Washington, D.C.

Summerfield, M. A.

1991 *Global Geomorphology*. Longman House, London.

Taylor, R. E.

1987 *Radiocarbon Dating. An Archaeological Perspective*. Academic Press, Orlando.

Waters, M. R.

1992 *Principles of Geoarchaeology: A North American Perspective*. University of Arizona Press, Tucson.

Wentworth, C.K.

1922 *The Shape of Beach Pebbles*. US Geological Survey Professional Paper No. 131C.

List of Tables

Table 1. Black Diamond Radiocarbon Dates
Table 2. Summary of Observations from Black Diamond and Control Samples
Table 3. Statistical Analysis of Sand Study and Control Samples
Table 4. Summary of Statistical Analyses for Sand Grain Transformation Study
Table 5. Comparison of Roundness, Polish, and Frosting Between Black Diamond and the Frederick Lodge Site Complex

List of Figures

Figure 1. Site Location
Figure 2. Location of Transects A and B
Figure 3. AU Profile, Transect A
Figure 4. AU Profile, Transect B
Figure 5. Profile Sections
Figure 6. Sphericity Comparison
Figure 7a. Summary of Grain Morphology Comparisons
Figure 7b. Summary of N244 to N252 Rounding Index Comparison
Figure 7c. Summary of N236 to N244 Rounding Index Comparison
Figure 7d. Summary of Additional Proveniences Rounding Index Comparison
Figure 8. Grain Morphology Comparison
Figure 9. Surface Texture Comparison
Figure 10. Comparison of Frosting Percentages
Figure 11. Black Diamond and the Frederick Lodge Site Complex Grain Roundness Comparison
Figure 12. Comparison of Surface Texture Observations from Black Diamond and the Frederick Lodge Site Complex
Figure 13. Comparison of Frosting Percentages Between Black Diamond and the Frederick Lodge Site Complex
Figure 14. Phosphate Fractionation Tertiary Diagram
Figure 15. Diachronic Site Formation Model: Site 7NC-J-225

List of Plates

Plate 1. Land-Use Aerial Photographs

Table 1. Black Diamond Radiocarbon Dates

A. Cultural Contexts

Site	Excavation Sample No.	Sample Material	Provenience	Allostratigraphic Unit	Conventional Radiocarbon Age	Calibrated Results (2 sigma)	Laboratory Sample Number
4	5023	charcoal (unidentified)	N253/E421, Feature 29, Str. I-2	2	910+/-40 BP	AD 1020 - 1220	Beta-149975
2	5003	charcoal (amorphous carbon)	N245/E410, Feature 46, Str. I-2	2	270+/-40 BP	AD 1510 – 1600 and AD 1780 – 1800 and AD 1620 - 1670	Beta-149976
3	5058	charcoal (deciduous taxa)	N244/E412, Feature 24, Str. I-1	3/2	680+/-40 BP	AD 1270-1320 and AD 1340-1390	Beta-149977
5	5004	charcoal (deciduous taxa)	N245/E412-413, Feature 9, Str. I-3	2	1870+/-40 BP	AD 60 - 240	Beta-149979
1	5020	charcoal (unidentified)	N248/E414-415, Feature 11, Str. I-1	3/2	250+/-40 BP	Not Given	Beta-149036

B. Geoarcheological Contexts

Site	Excavation Sample No.	Sample Material	Provenience	Allostratigraphic Unit	Conventional Radiocarbon Age	Calibrated Results (2 sigma)	Laboratory Sample Number
1	5063	bulk soil sample	Trench C, 2AB, 250-300 cm bs.	2/1	370+/-40 BP	AD 1440 - 1640	Beta-150341
2	5065	bulk soil sample	N242/E406, Bw, 50-60 cm bs.	2	650+/-40 BP	AD 1280 - 1400	Beta-150343
3	5064	bulk soil sample	N251/E417, Bw, 45-55 cm bs.	2	940+/-40 BP	AD 1010 - 1190	Beta-150342

Geoarcheology Research Associates
Black Diamond, DE

Table 2. Summary of Observations from Black Diamond and Control Samples

GRA Sample #	Transect	Unit		Col.	Stratum	cm BS	Wentworth Texture	Sorting	Observations at 1x and 4x magnification								
		North	East						Sphericity	S Value	Roundness	RI Value	2RI Value	Polish	P% Value	Frosting	F% Value
BD18	N 243-250, E 417	N250	E417	A	C	50-58	coarse sand	moderate	moderate to low	**4**	subrounded	**335**	**670**	dominant and very frequent	**66**	visible and frequent	**34**
BD16	N 243-250, E 417	N250	E417	A	D-2	70-80	very coarse to coarse sand	poor	moderate	**3**	subrounded	**285**	**570**	visible and frequent	**48**	dominant and very frequent	**52**
BD19	N 243-250, E 417	N250	E417	A	D-3	89-99	medium sand	moderate to well	moderate	**3**	subrounded	**320**	**640**	visible and frequent	**46**	dominant and very frequent	**54**
BD20	N 243-250, E 417	N248	E417	B	C	47-54	coarse to medium sand	moderate to poor	moderate to low	**4**	subrounded	**330**	**660**	dominant and very frequent	**66**	visible and frequent	**34**
BD17	N 243-250, E 417	N248	E417	B	D-2	61-69	very coarse to medium sand	very poor	moderate	**3**	rounded	**465**	**930**	visible and frequent	**48**	dominant and very frequent	**52**
BD21	N 243-250, E 417	N247	E417	C	D	52-59	very coarse to medium sand	very poor	moderate to low	**4**	subrounded	**350**	**700**	dominant and very frequent	**66**	visible and frequent	**34**
BD23	N 243-250, E 417	N245	E417	D	C	35-44	medium to fine sand	moderate	moderate	**3**	subrounded	**280**	**560**	dominant and very frequent	**66**	visible and frequent	**34**
BD22	N 243-250, E 417	N245	E417	D	D	51-61	coarse to medium sand	moderate to poor	moderate to low	**4**	rounded	**415**	**830**	dominant and very frequent	**70**	visible and frequent	**30**
BD7	N 251, E 411-417	N251	E411	A	C-1	62-72	coarse to medium sand	moderate	moderate to low	**4**	subrounded	**320**	**640**	dominant and very frequent	**54**	visible and frequent	**46**
BD9	N 251, E 411-417	N251	E411	A	C-2	84-94	coarse to medium sand	moderate	moderate	**3**	rounded	**395**	**790**	dominant and very frequent	**56**	visible and frequent	**44**
BD6	N 251, E 411-417	N251	E411	A	D	105-114	medium to fine sand	moderate to poor	moderate	**3**	rounded	**410**	**820**	predominant	**76**	slight and occasional	**24**
BD11	N 251, E 411-417	N251	E414	B	C	54-62	medium sand	moderate to well	moderate to high	**2**	rounded	**470**	**940**	predominant	**82**	slight and occasional	**18**
BD8	N 251, E 411-417	N251	E415	C	C	45-55	medium to fine sand	moderate to poor	moderate	**3**	subrounded	**350**	**700**	predominant	**78**	slight and occasional	**22**
BD10	N 251, E 411-417	N251	E415	C	D	59-68	medium sand	moderate to poor	moderate to low	**4**	subrounded	**330**	**660**	predominant	**78**	slight and occasional	**22**
BD4	N 236-243, E 416	N242	E416	A	C-1	66-75	medium sand	moderate to poor	moderate to low	**4**	subrounded	**360**	**720**	predominant	**77**	slight and occasional	**23**
BD5	N 236-243, E 416	N238	E416	B	D-1	71-80	medium to fine sand	moderate	moderate	**3**	subrounded	**335**	**670**	predominant	**78**	slight and occasional	**22**
BD24	N 236-240, E 412	N236	E412	A	C-1	54-62	coarse to medium sand	moderate to poor	moderate to low	**4**	subrounded	**335**	**670**	dominant and very frequent	**70**	visible and frequent	**30**
BD25	N 236-240, E 412	N236	E412	A	C-2	65-72	medium sand	moderate	moderate to low	**4**	subrounded	**330**	**660**	dominant and very frequent	**74**	slight and occasional	**26**
BD29	N 236-240, E 412	N237	E412	B	C-1	54-62	coarse to medium sand	poor	moderate to low	**4**	subrounded	**310**	**620**	dominant and very frequent	**74**	slight and occasional	**26**
BD28	N 236-240, E 412	N237?	E412	B	C-2	65-72	medium sand	poor	moderate to low	**4**	subrounded	**360**	**720**	dominant and very frequent	**74**	slight and occasional	**26**

Geoarcheology Research Associates
Black Diamond, DE

Table 2. Summary of Observations from Black Diamond and Control Samples

GRA Sample #	Transect	Unit		Col.	Stratum	cm BS	Wentworth Texture	Sorting	Observations at 1x and 4x magnification								
		North	East						Sphericity	S Value	Roundness	RI Value	2RI Value	Polish	P% Value	Frosting	F% Value
BD26	N 236-240, E 412	N239	E412	C	C-1	66-73	medium sand	poor	moderate to low	**4**	subrounded	**360**	**720**	dominant and very frequent	**72**	slight and occasional	**28**
BD27	N 236-240, E 412	N239	E412	C	C-2	75-83	medium sand	poor	moderate to low	**4**	rounded	**390**	**780**	dominant and very frequent	**62**	visible and frequent	**38**
BD36	N 237-241, E 411	N240	E411	A	C	51-58	coarse to medium sand	moderate to poor	moderate to low	**4**	subrounded	**360**	**720**	dominant and very frequent	**72**	slight and occasional	**28**
BD37	N 237-241, E 411	N240	E411	A	D	67-76	medium sand	moderate to poor	moderate to low	**4**	subrounded	**290**	**580**	dominant and very frequent	**72**	slight and occasional	**28**
BD30	N 237-241, E 411	N238	E411	B	C	53-62	medium sand	moderate to poor	moderate to low	**4**	rounded	**470**	**940**	dominant and very frequent	**62**	visible and frequent	**38**
BD31	N 237-241, E 411	N238	E411	B	D	70-79	medium sand	moderate	moderate	**3**	subrounded	**335**	**670**	dominant and very frequent	**70**	visible and frequent	**30**
BD32	N 237-241, E 411	N237	E411	C	C	50-59	medium to fine sand	moderate	moderate	**3**	subrounded	**355**	**710**	predominant	**76**	slight and occasional	**24**
BD15	N 236, E 412-416	N236	E416	A	C-1	53-62	medium to fine sand	moderate	moderate	**3**	subrounded	**365**	**730**	predominant	**76**	slight and occasional	**24**
BD12	N 236, E 412-416	N236	E416	A	D	69-79	medium sand	moderate	moderate	**3**	subrounded	**345**	**690**	dominant and very frequent	**72**	slight and occasional	**28**
BD14	N 236, E 412-416	N236	E414	B	C-1	52-60	medium sand	moderate	moderate	**3**	subrounded	**305**	**610**	predominant	**76**	slight and occasional	**24**
BD13	N 236, E 412-416	N236	E414	B	D	65-73	very coarse to medium sand	very poor	moderate to low	**4**	subrounded	**370**	**740**	predominant	**76**	slight and occasional	**24**
BD40	North Wall	N243	E412		C-1	85-95	medium to fine sand	poor	moderate to low	**4**	subrounded	**355**	**710**	predominant	**76**	slight and occasional	**24**
BD38	West Wall	N242	E406		C-1 (#1)	75-85	medium sand	moderate	moderate	**3**	subrounded	**335**	**670**	predominant	**78**	slight and occasional	**22**
BD39	West Wall	N242	E406		C-1 (#2)	90-95	medium to fine sand	moderate	moderate to low	**4**	subrounded	**310**	**620**	dominant and very frequent	**64**	visible and frequent	**36**
BD35	Trench C				C-2	120	coarse to fine sand	moderate	moderate to low	**4**	rounded	**380**	**760**	dominant and very frequent	**72**	visible and frequent	**28**
BD34	Trench C				C-1	80	coarse sand	moderate	moderate to low	**4**	subrounded	**320**	**640**	predominant	**80**	slight and occasional	**20**
BD2	Trench B	N184.9	E377		2C-1	82-90	medium sand	moderate	moderate	**3**	subrounded	**310**	**620**	predominant	**78**	slight and occasional	**22**
BD1	Trench B	N184.9	E377		2C-2	100-117	medium to fine sand	well to moderate	moderate to low	**4**	subrounded	**320**	**640**	dominant and very frequent	**70**	visible and frequent	**30**
BD33		N222	E400		C1	100	medium to fine sand	moderate	moderate to low	**4**	subrounded	**365**	**730**	dominant and very frequent	**64**	visible and frequent	**36**
BD3		N242	E397				fine sand	moderate	moderate to low	**4**	subrounded	**265**	**530**	predominant	**88**	slight and occasional	**12**
FL1	SE Bay/Basin	N185	E665		2C control	165	coarse to medium sand	moderate to poor	moderate to low	**4**	subrounded	**330**	**660**	dominant	**70**	visible and frequent	**30**

Geoarcheology Research Associates
Black Diamond, DE

Table 2. Summary of Observations from Black Diamond and Control Samples

GRA Sample #	Transect	Unit		Col.	Stratum	cm BS	Wentworth Texture	Sorting	Observations at 1x and 4x magnification								
		North	East						Sphericity	S Value	Roundness	RI Value	2RI Value	Polish	P% Value	Frosting	F% Value
FB15	Fort Bragg, NC Lower Little River at Hydro Dam			River Bar	surface control: alluvial	surface	very coarse sand	very poor	moderate	**3**	subrounded	**275**	**550**	predominant	**80**	slight and occasional	**20**
FB28	Fort Bragg, NC Lower Little River below Yucca Ridge			T-0	surface control: alluvial (natural levee)	150cm above river	fine	moderate to well	moderate to low	**4**	subrounded	**220**	**440**	predominant	**86**	slight and occasional	**14**
FB5	Fort Bragg, NC Normandy Drop Zone			Dune Sand #1	surface control aeolian	surface (sparsely vegetated)	coarse to medium sand	moderate to well	moderate	**3**	subrounded to subangular	**250**	**500**	dominant	**58**	visible and frequent	**42**
FB6	Fort Bragg, NC Normandy Drop Zone			Dune Sand #2	surface control aeolian	surface (deflated, armored)	medium to fine sand	moderate	moderate	**3**	subrounded	**255**	**510**	dominant	**50**	dominant and very frequent	**50**
FB7	Fort Bragg, NC Normandy Drop Zone			Dune Sand #3	surface control aeolian	surface (aeolian filling truck tire track)	fine sand	moderate	moderate to high	**3**	subrounded	**255**	**510**	visible and frequent	**34**	dominant and very frequent	**66**
FB8	Fort Bragg, NC Normandy Drop Zone			Dune Sand #4	surface control aeolian	surface (wind deflated)	medium sand	moderate	moderate to low	**4**	subrounded	**265**	**530**	slight and occasional	**16**	predominant	**84**
FB9	Fort Bragg, NC Normandy Drop Zone			Dune Sand #5	surface control aeolian	surface (aeolian deposit in old track?)	medium to coarse sand	moderate to poor	moderate	**3**	subrounded	**305**	**610**	visible and frequent	**48**	dominant and very frequent	**52**
FB10	Fort Bragg, NC Normandy Drop Zone			Dune Sand #6	surface control aeolian	15-20cm note on bag unreadable	medium to coarse sand	moderate to poor	moderate	**3**	rounded	**480**	**960**	slight and occasional	**16**	predominant	**84**
FB11	Fort Bragg, NC Normandy Drop Zone			Dune Sand #7	surface control aeolian	midslope just below surface <5cm	fine sand	moderate to poor	moderate to low	**4**	subrounded	**260**	**520**	slight and occasional	**22**	predominant	**78**

Geoarcheology Research Associates
Black Diamond, DE

Table 3. Statistical Analysis of Sand Study and Control Samples

BLACK DIAMOND

Sample	RI	2RI	Polish %	Frosting %
BD18	335	670	66	34
BD16	285	570	48	52
BD19	320	640	46	54
BD20	330	660	66	34
BD17	465	930	48	52
BD21	350	700	66	34
BD23	280	560	66	34
BD22	415	830	70	30
BD7	320	640	54	46
BD9	395	790	56	44
BD6	410	820	76	24
BD11	470	940	82	18
BD8	350	700	78	22
BD10	330	660	78	22
BD4	360	720	77	23
BD5	335	670	78	22
BD24	335	670	70	30
BD25	330	660	74	26
BD29	310	620	74	26
BD28	360	720	74	26
BD26	360	720	72	28
BD27	390	780	62	38
BD36	360	720	72	28
BD37	290	580	72	28
BD30	470	940	62	38
BD31	335	670	70	30
BD32	355	710	76	24
BD15	365	730	76	24
BD12	345	690	72	28
BD14	305	610	76	24
BD13	370	740	76	24
BD34	320	640	80	20
BD35	380	760	72	28
BD40	355	710	76	24
BD38	335	670	78	22
BD39	310	620	64	36
BD2	310	620	78	22
BD1	320	640	70	30
BD33	365	730	64	36
BD3	265	530	88	12
BD Mean	**349.8**	**699.5**	**70.1**	**29.9**
BD Mode	**335**	**670**	**76**	**24**
BD Median	**340**	**680**	**72**	**28**
BD Max	**470**	**940**	**88**	**54**
BD Min	**265**	**530**	**46**	**12**

CONTROL SAMPLES

Alluvial

Sample	RI	2RI	Polish %	Frosting %
FL1	330	660	70	30
FB15	275	550	80	20
FB28	220	440	86	14
CS Mean	**275.0**	**550.0**	**78.7**	**21.3**
CS Mode	**0**	**0**	**0**	**0**
CS Median	**275**	**550**	**80**	**20**
CS Max	**330**	**660**	**86**	**30**
CS Min	**220**	**440**	**70**	**14**

Aeolian

Sample	RI	2RI	Polish %	Frosting %
FB5	250	500	58	42
FB6	255	510	50	50
FB7	255	510	34	66
FB8	265	530	16	84
FB9	305	610	48	52
FB10	480	960	16	84
FB11	260	520	22	78
CS Mean	**295.7**	**591.4**	**34.9**	**65.1**
CS Mode	**255**	**510**	**16**	**84**
CS Median	**260**	**520**	**34**	**66**
CS Max	**480**	**960**	**58**	**84**
CS Min	**250**	**500**	**16**	**42**

Geoarcheology Research Associates
Black Diamond, DE

Table 4. Summary of Statistical Analyses for Sand Grain Transformation Study

Mean Values for Rounding Index (2RI), Frosting, and Polish

Region	Number of Samples	2RI	Polish %	Frosting %
Black Diamond	40	699.5	70.1	29.9
Control - Alluvial	3	550.0	78.7	21.3
Control - Aeolian	7	591.4	34.9	65.1

Rounding Index (2RI)

Samples	Mean	Mode	Median	Maximum	Minimum
Black Diamond	699.5	670	680	940	530
Control - Alluvial	550.0	0	550	660	440
Control - Aeolian	591.4	510	520	960	500

Mode Values for Rounding Index (2RI), Frosting, and Polish

Region	Number of Samples	2RI	Polish %	Frosting %
Black Diamond	40	670	76	24
Control - Alluvial	3	0	0	0
Control - Aeolian	7	510	16	84

Polish (%)

Samples	Mean	Mode	Median	Maximum	Minimum
Black Diamond	70.1	76	72	88	46
Control - Alluvial	78.7	0	80	86	70
Control - Aeolian	34.9	16	34	58	16

Median Values for Rounding Index (2RI), Frosting, and Polish

Region	Number of Samples	2RI	Polish %	Frosting %
Black Diamond	40	680	72	28
Control - Alluvial	3	550	80	20
Control - Aeolian	7	520	34	66

Frosting (%)

Samples	Mean	Mode	Median	Maximum	Minimum
Black Diamond	29.9	24	28	54	12
Control - Alluvial	21.3	0	20	30	14
Control - Aeolian	65.1	84	66	84	42

Maximum Values for Rounding Index (2RI), Frosting, and Polish

Region	Number of Samples	2RI	Polish %	Frosting %
Black Diamond	40	940	88	54
Control - Alluvial	3	660	86	30
Control - Aeolian	7	960	58	84

Minimum Values for Rounding Index (2RI), Frosting, and Polish

Region	Number of Samples	2RI	Polish %	Frosting %
Black Diamond	40	530	46	12
Control - Alluvial	3	440	70	14
Control - Aeolian	7	500	16	42

Geoarcheology Research Associates
Black Diamond, DE

Table 5. Comparison of Roundness, Polish, and Frosting Between Black Diamond and the Frederick Lodge Site Complex

Black Diamond

Sample	RI	2RI	Polish %	Frosting %
BD18	335	670	66	34
BD16	285	570	48	52
BD19	320	640	46	54
BD20	330	660	66	34
BD17	465	930	48	52
BD21	350	700	66	34
BD23	280	560	66	34
BD22	415	830	70	30
BD7	320	640	54	46
BD9	395	790	56	44
BD6	410	820	76	24
BD11	470	940	82	18
BD8	350	700	78	22
BD10	330	660	78	22
BD4	360	720	77	23
BD5	335	670	78	22
BD24	335	670	70	30
BD25	330	660	74	26
BD29	310	620	74	26
BD28	360	720	74	26
BD26	360	720	72	28
BD27	390	780	62	38
BD36	360	720	72	28
BD37	290	580	72	28
BD30	470	940	62	38
BD31	335	670	70	30
BD32	355	710	76	24
BD15	365	730	76	24
BD12	345	690	72	28
BD14	305	610	76	24
BD13	370	740	76	24
BD34	320	640	80	20
BD35	380	760	72	28
BD40	355	710	76	24
BD38	335	670	78	22
BD39	310	620	64	36
BD2	310	620	78	22
BD1	320	640	70	30
BD33	365	730	64	36
BD3	265	530	88	12
BD Mean	**349.8**	**699.5**	**70.1**	**29.9**
BD Mode	**335**	**670**	**76**	**24**
BD Median	**340**	**680**	**72**	**28**
BD Max	**470**	**940**	**88**	**54**
BD Min	**265**	**530**	**46**	**12**

Frederick Lodge

Sample	RI	2RI	Polish %	Frosting %
FL16	335	670	72	28
FL15	295	590	76	24
FL2	460	920	72	28
FL3	335	670	74	26
FL5	380	760	76	24
FL4	360	720	60	40
FL6	385	770	72	28
FL7	360	720	54	46
FL8	360	720	56	44
FL17	335	670	72	28
FL11	360	720	64	36
FL12	440	880	58	42
FL13	335	670	72	28
FL14	365	730	62	38
FL9	365	730	74	26
FL10	440	880	68	32
FL Mean	**364.6**	**729.3**	**67.6**	**32.9**
FL Mode	**335**	**670**	**72**	**28**
FL Median	**360**	**720**	**72**	**28**
FL Max	**460**	**920**	**76**	**46**
FL Min	**295**	**590**	**54**	**24**

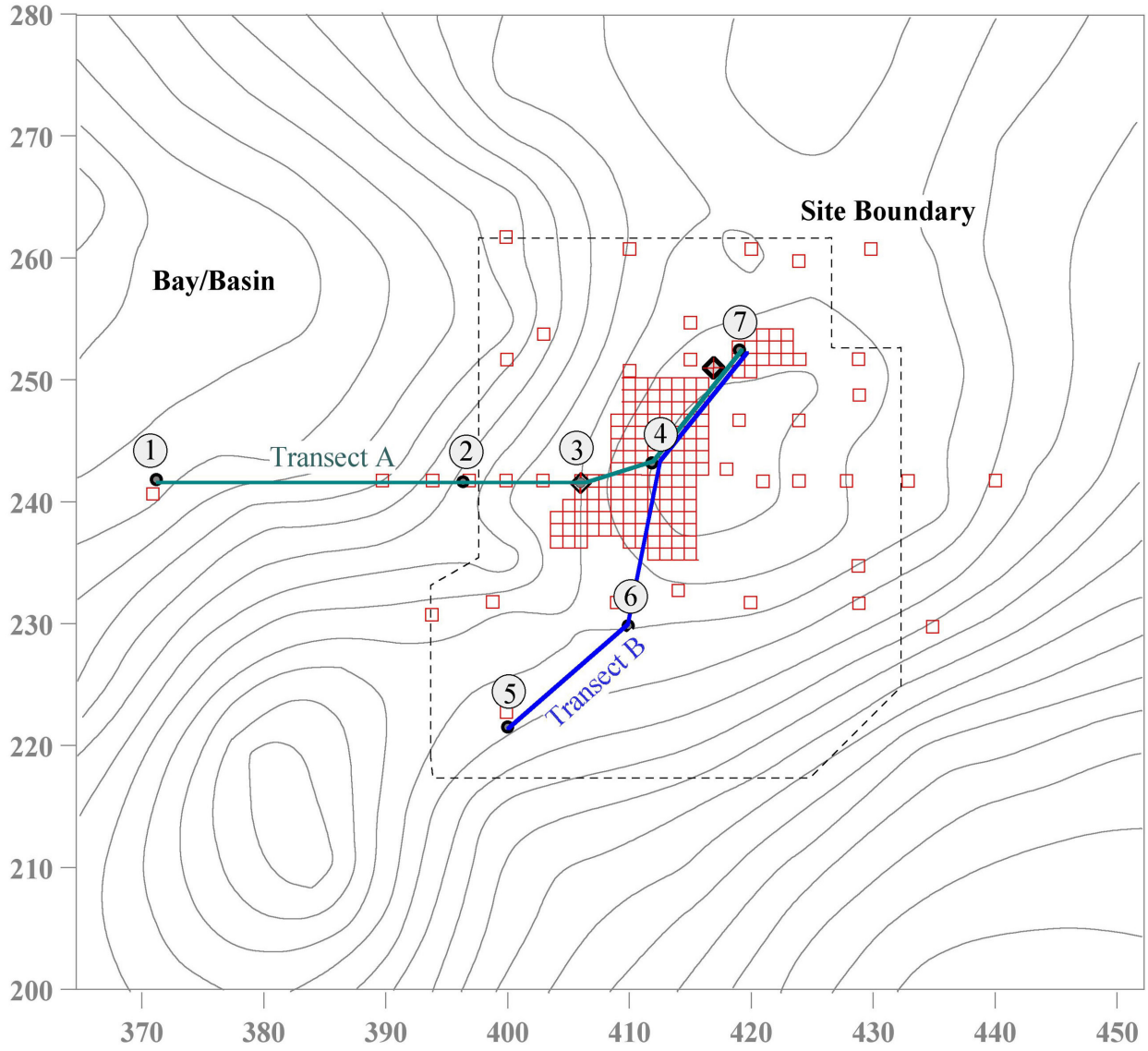


Figure 2. Location of Transects A and B

Ⓧ Profiles on cross section

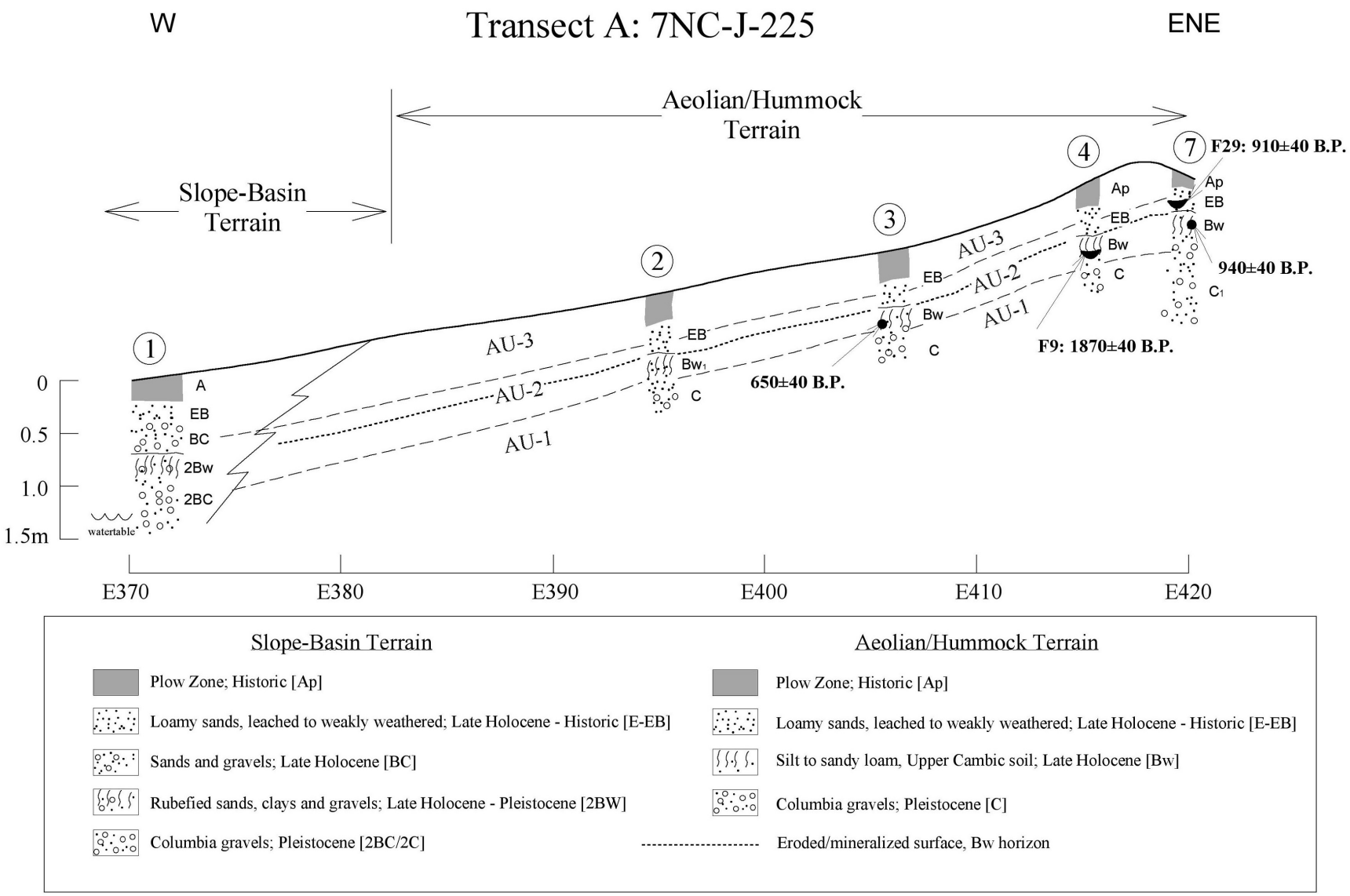
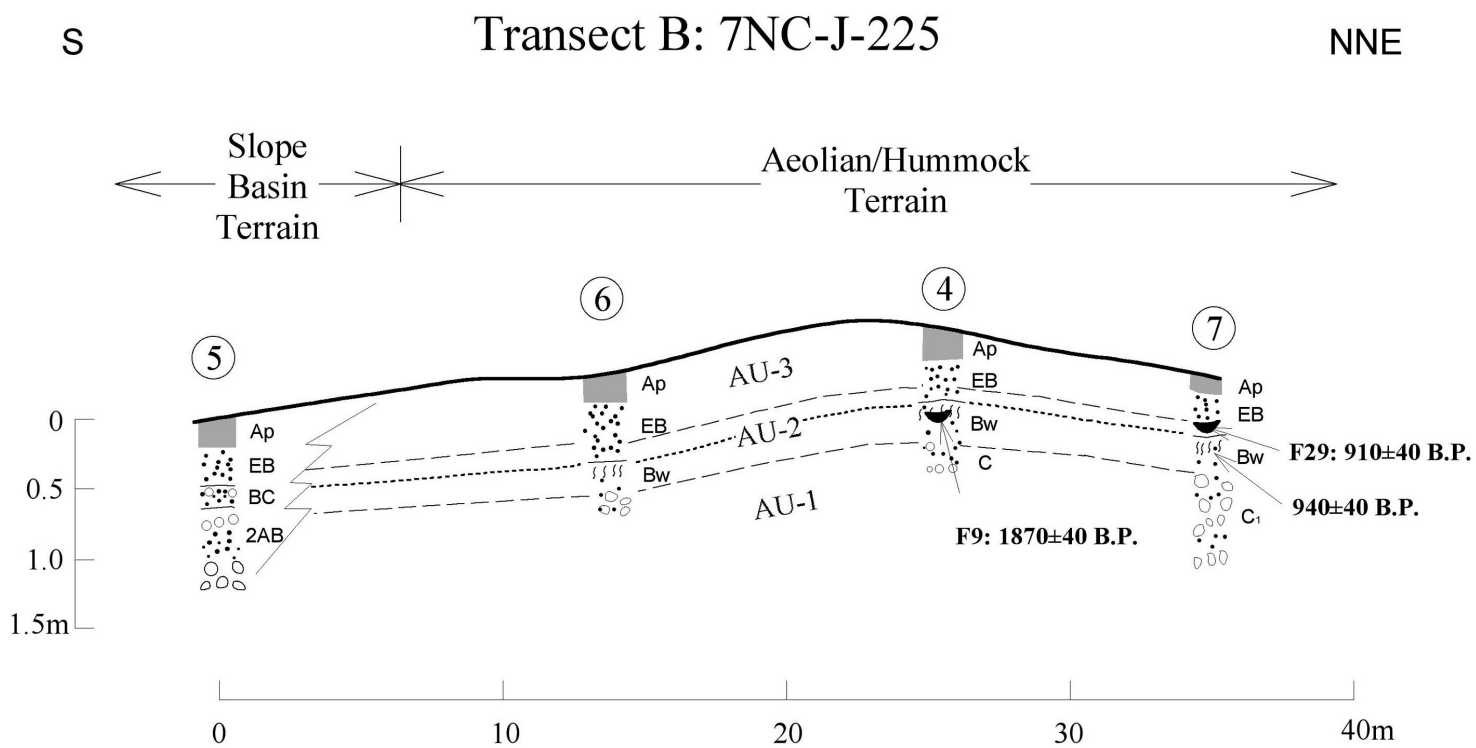


Figure 3. AU Profile, Transect A



Slope-Basin Terrain	Aeolian/Hummock Terrain
Plow Zone; Historic [Ap]	Plow Zone; Historic [Ap]
Loamy sands, leached to weakly weathered; Late Holocene - Historic [E-EB]	Loamy sands, leached to weakly weathered; Late Holocene - Historic [E-EB]
Sands and gravels; Late Holocene [BC]	Silt to sandy loam, Upper Cambic soil; Late Holocene [Bw]
Rubefied sands, clays and gravels; Late Holocene - Pleistocene [2Bw]	Columbia gravels; Pleistocene [C]
Columbia gravels; Pleistocene [2BC/2C]	Eroded/mineralized surface, Bw horizon

Figure 4. AU Profile, Transect B

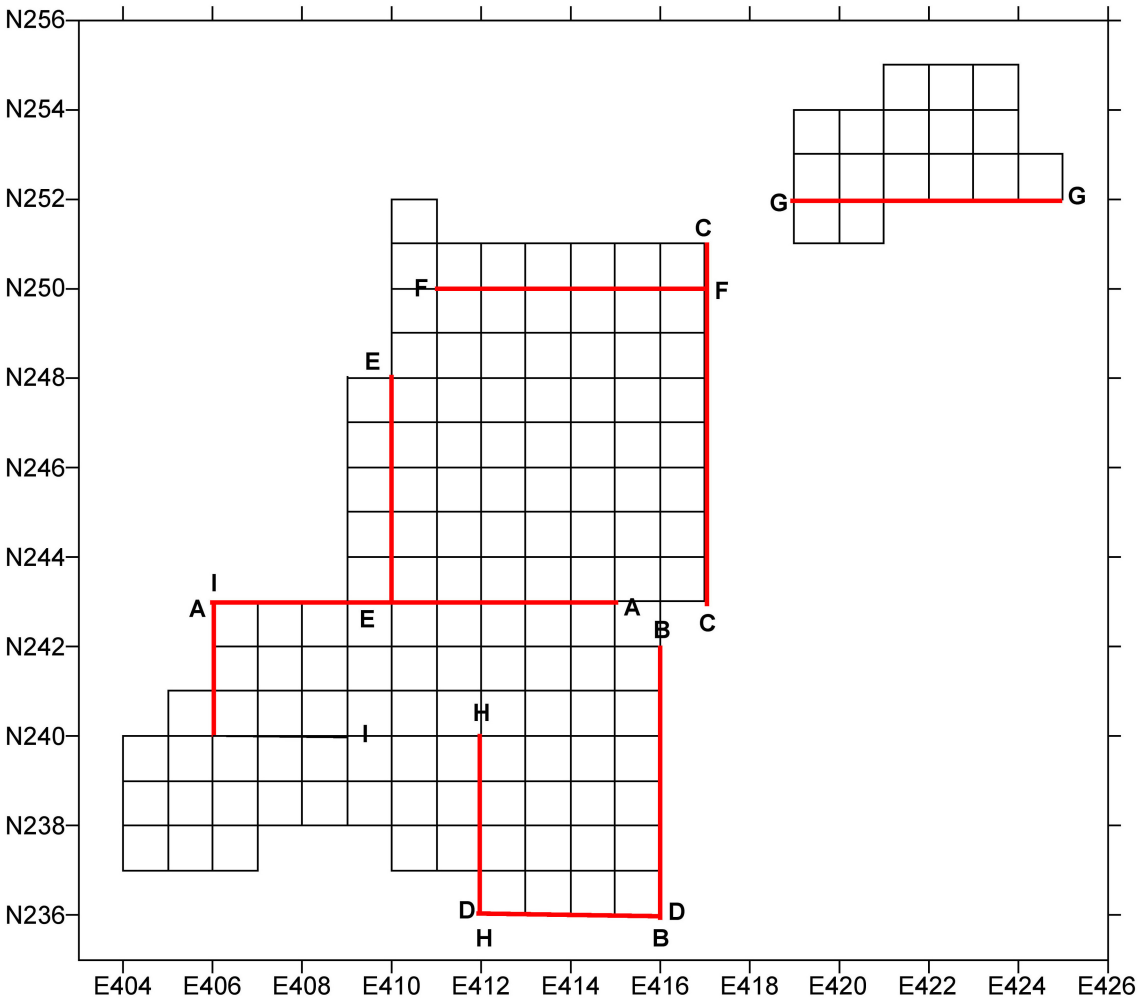


Figure 5: Profile Sections

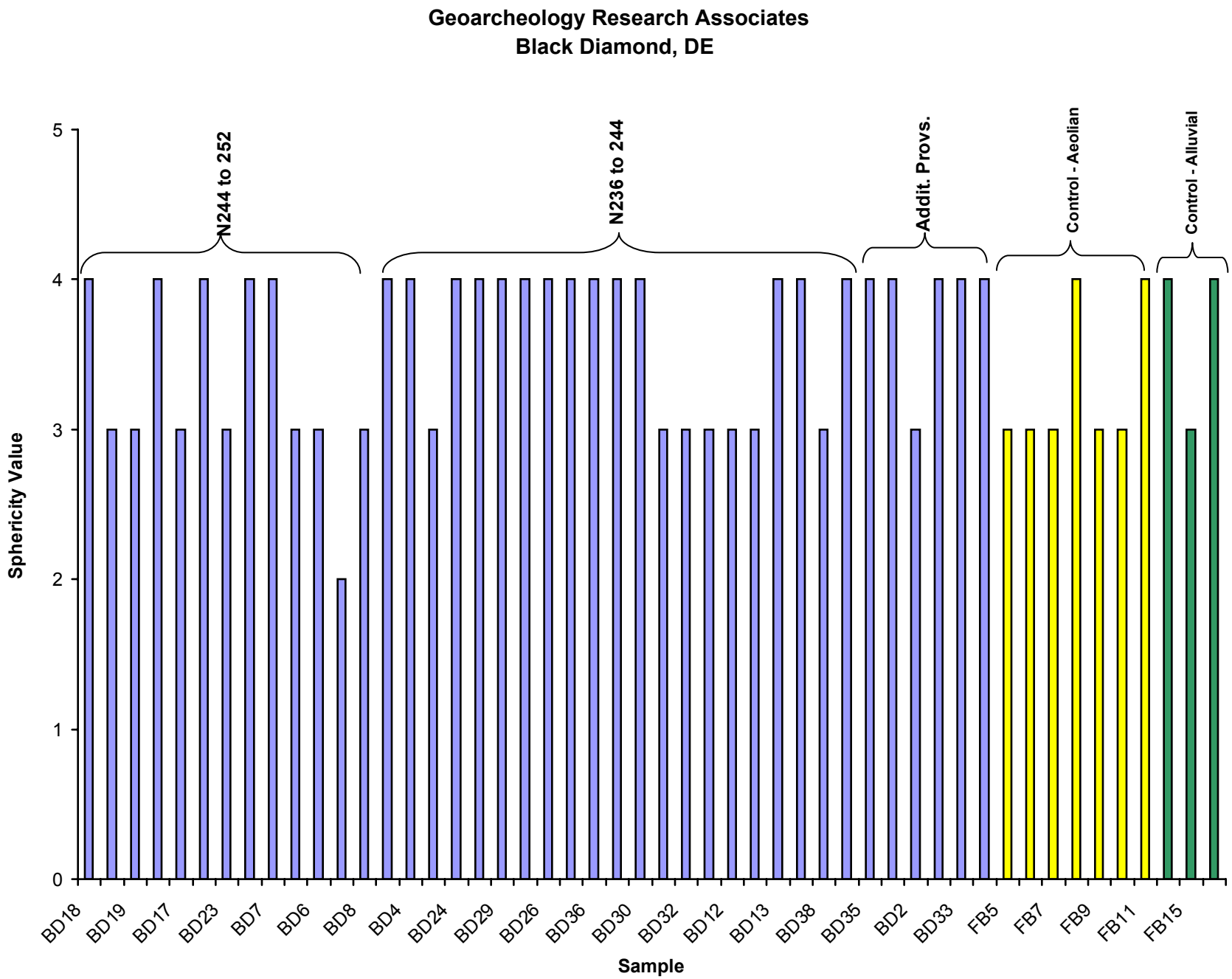


Figure 6. Sphericity Comparison

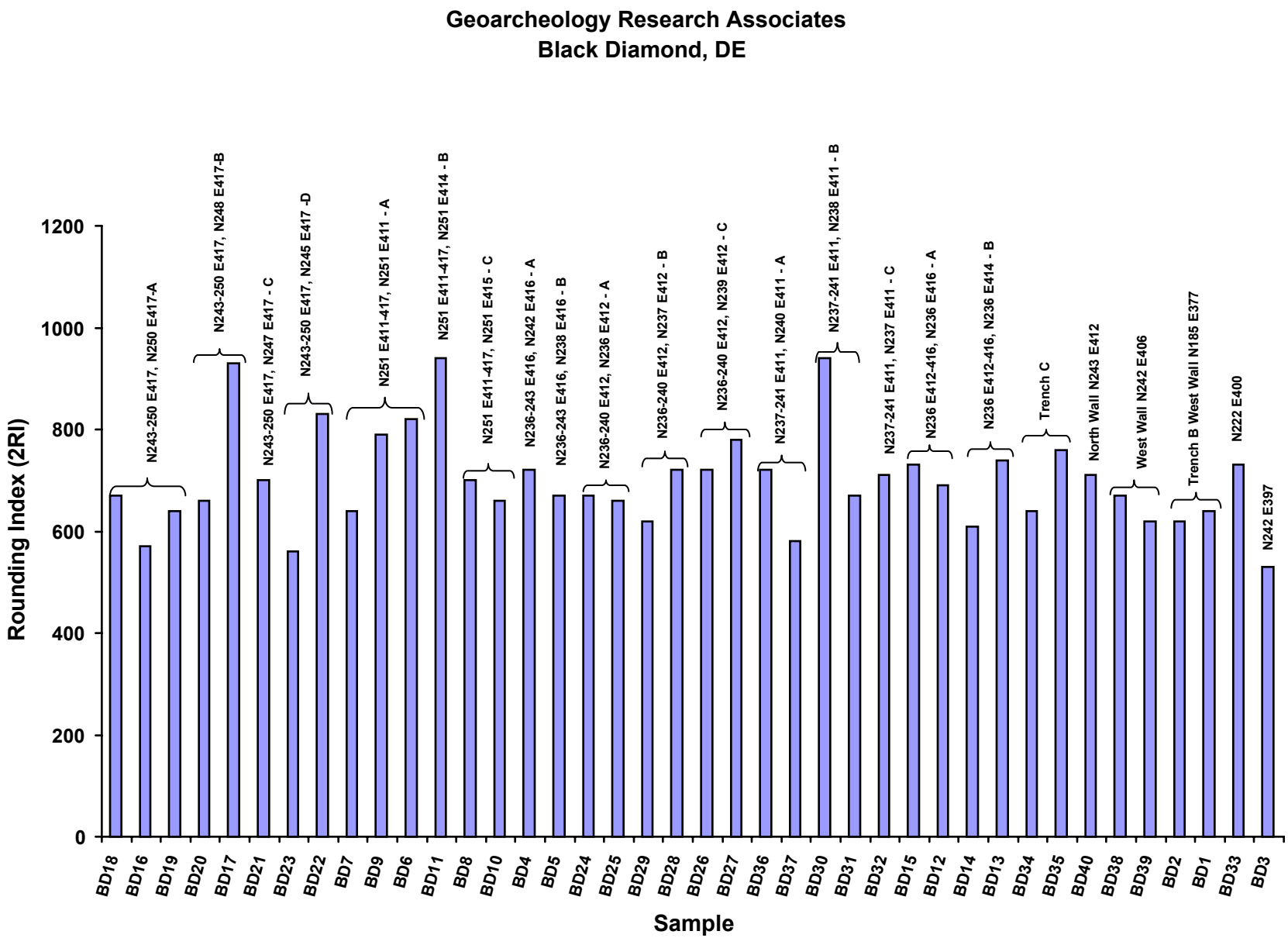


Figure 7a. Summary of Grain Morphology Comparisons

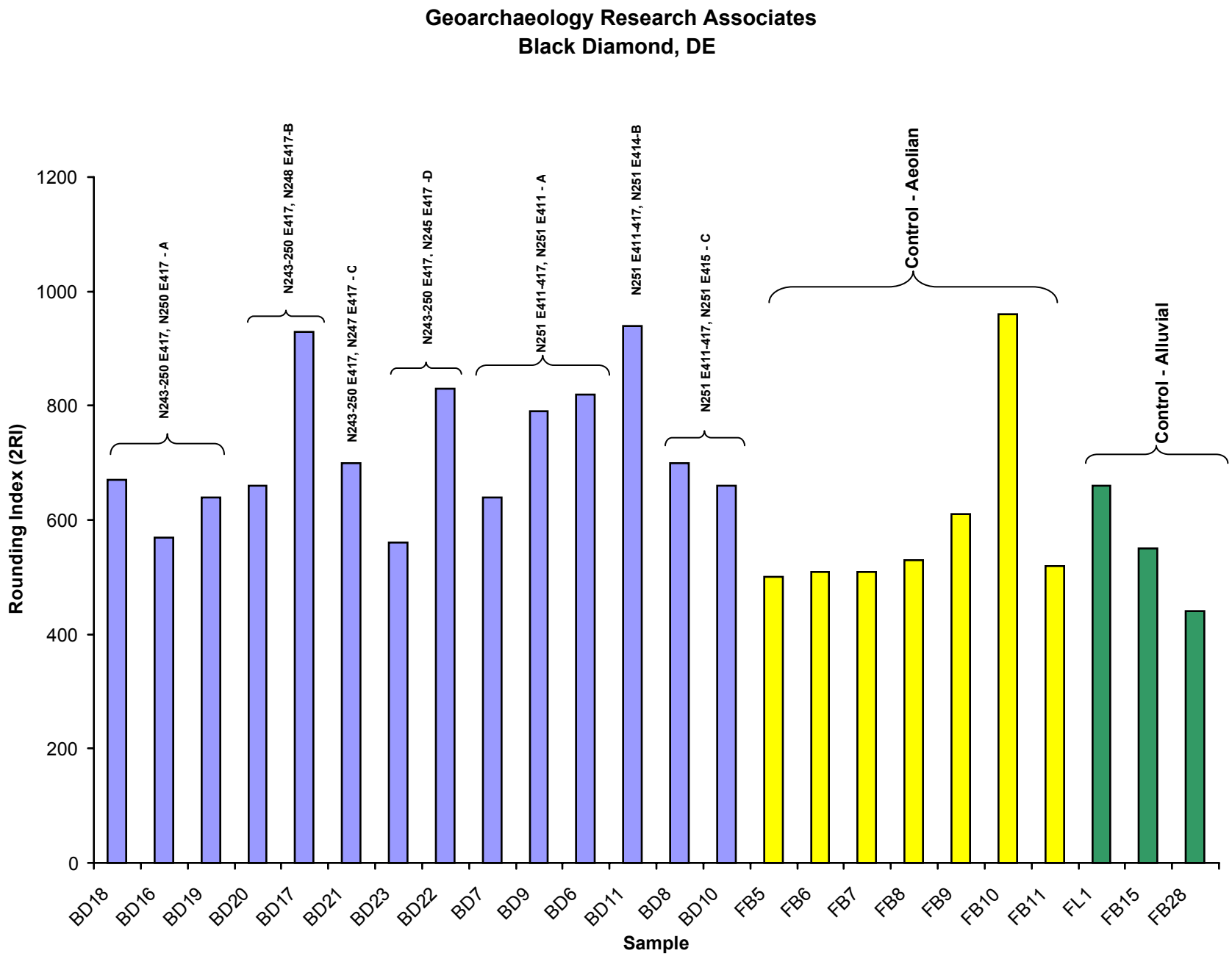


Figure 7b. Summary of N244 to N252 Rounding Index Comparison

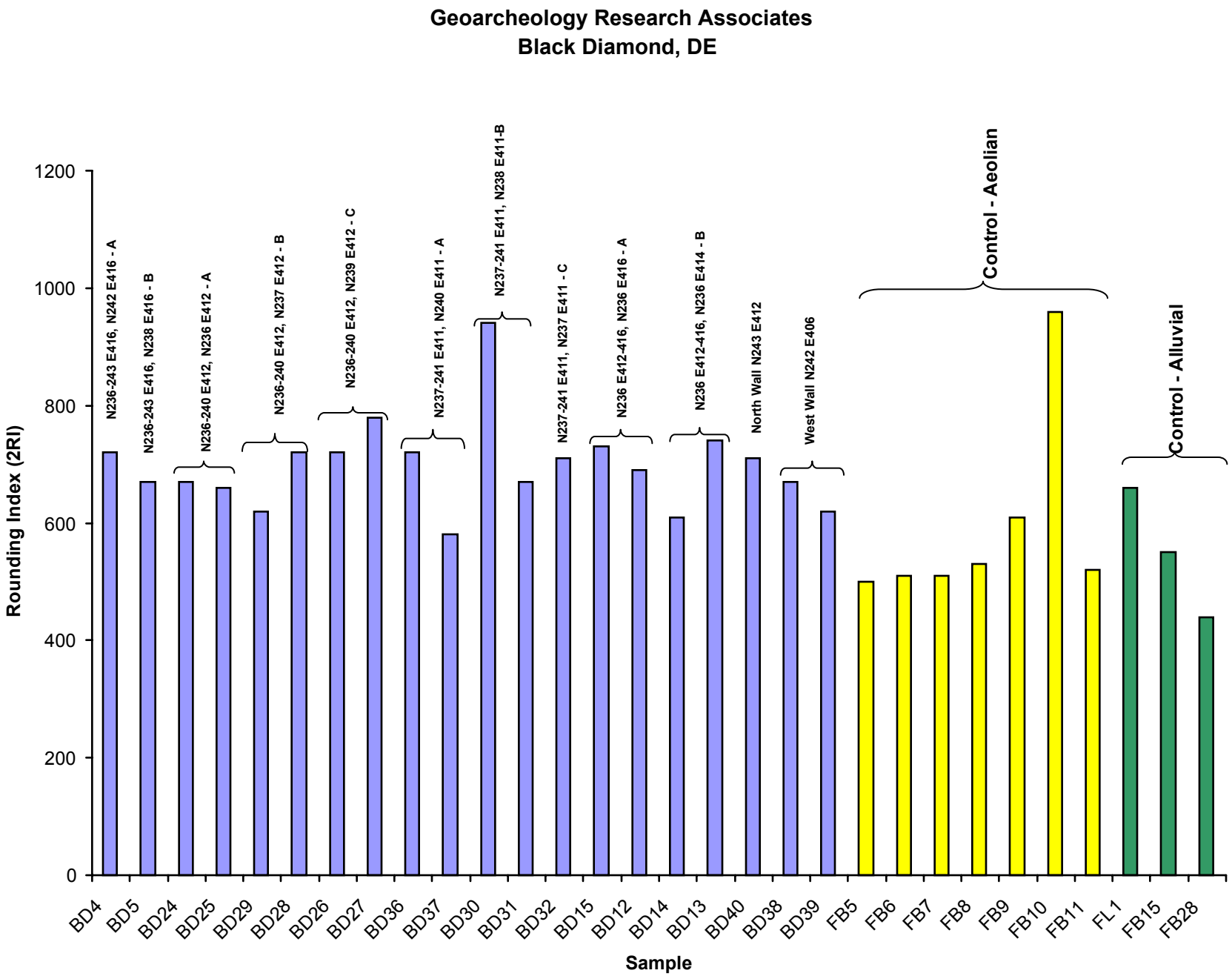


Figure 7c. Summary of N236 to N244 Rounding Index Comparison

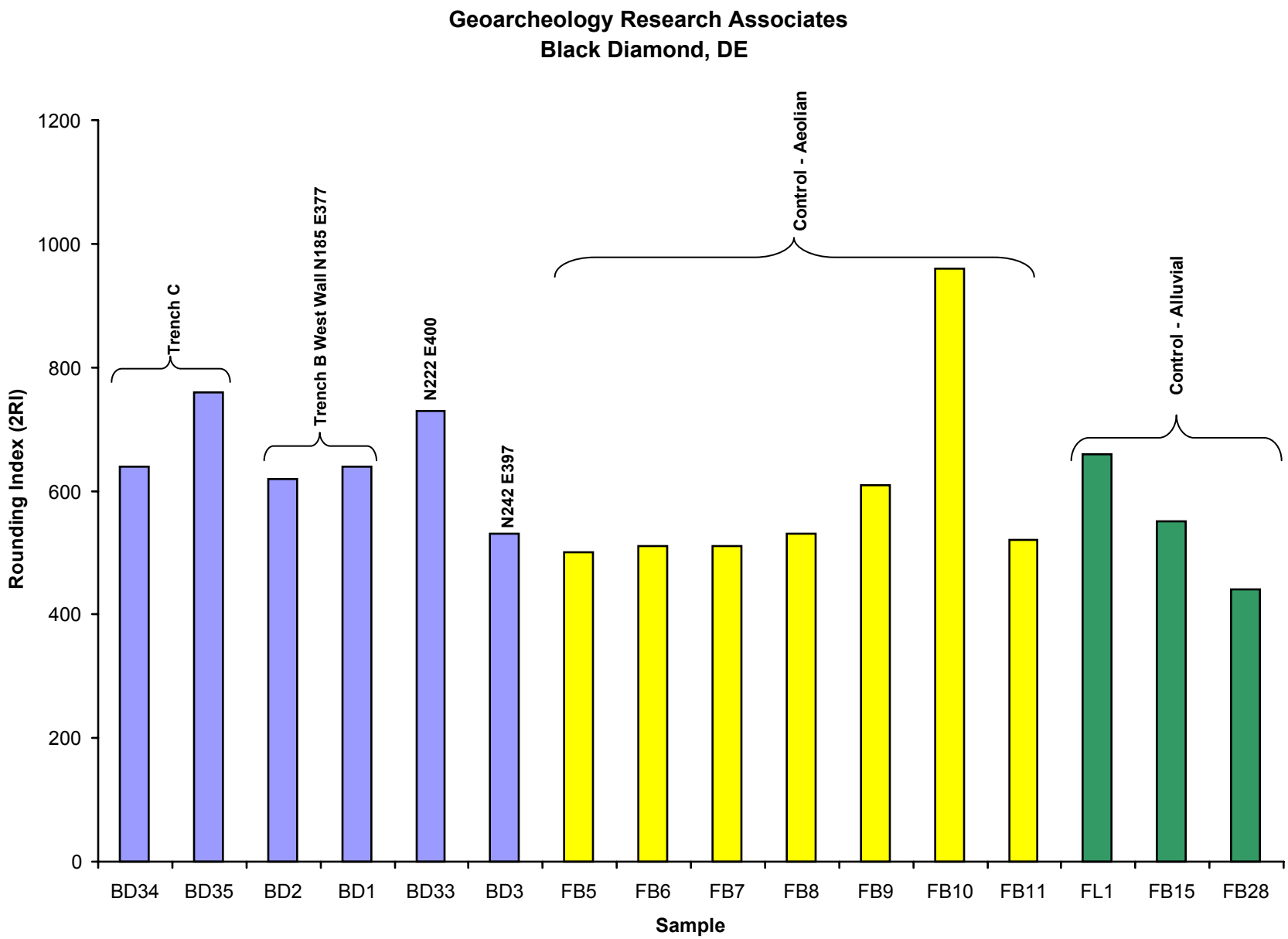


Figure 7d. Summary of Additional Proveniences Rounding Index Comparison

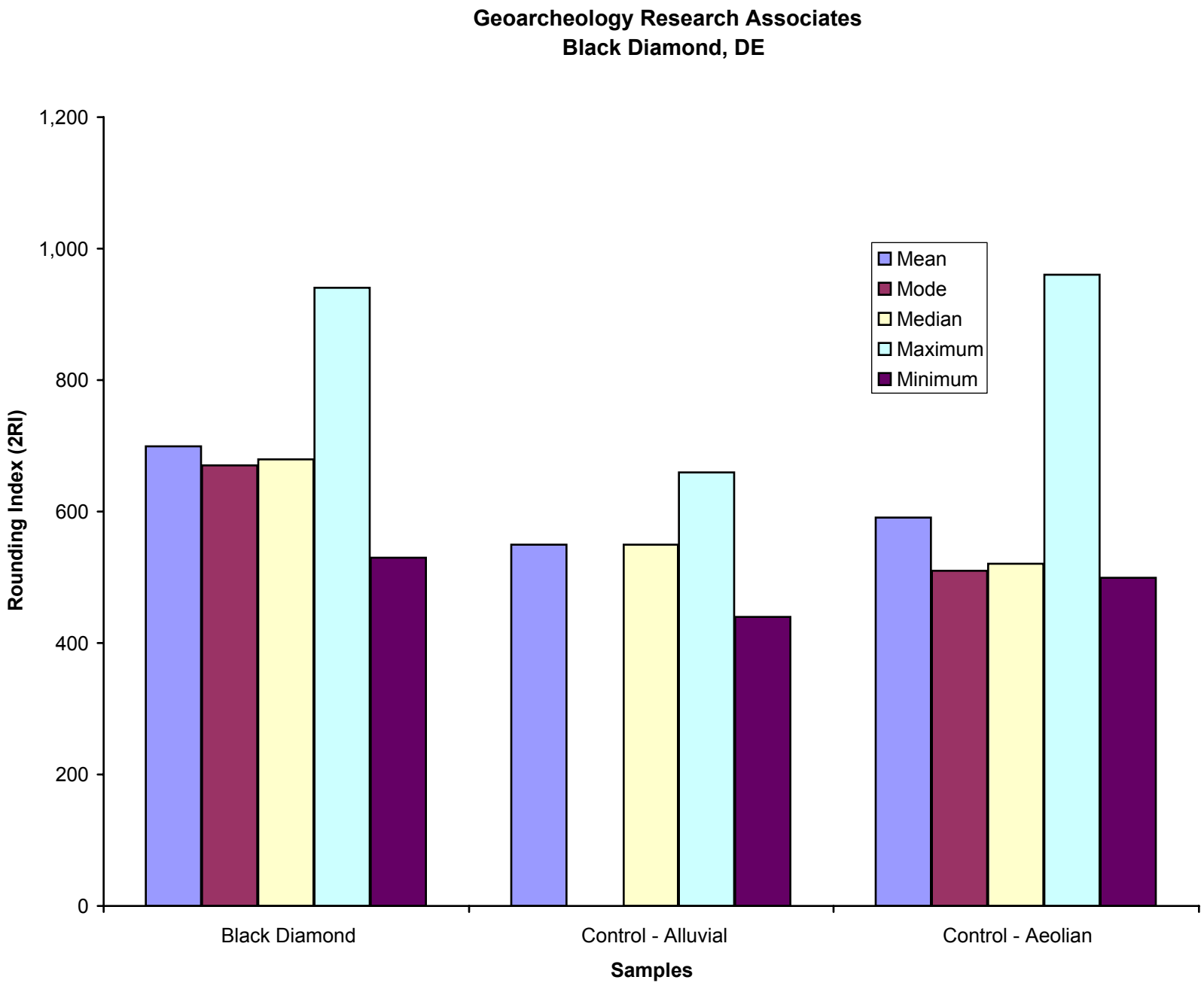


Figure 8. Grain Morphology Comparison

Geoarcheology Research Associates
Black Diamond, DE

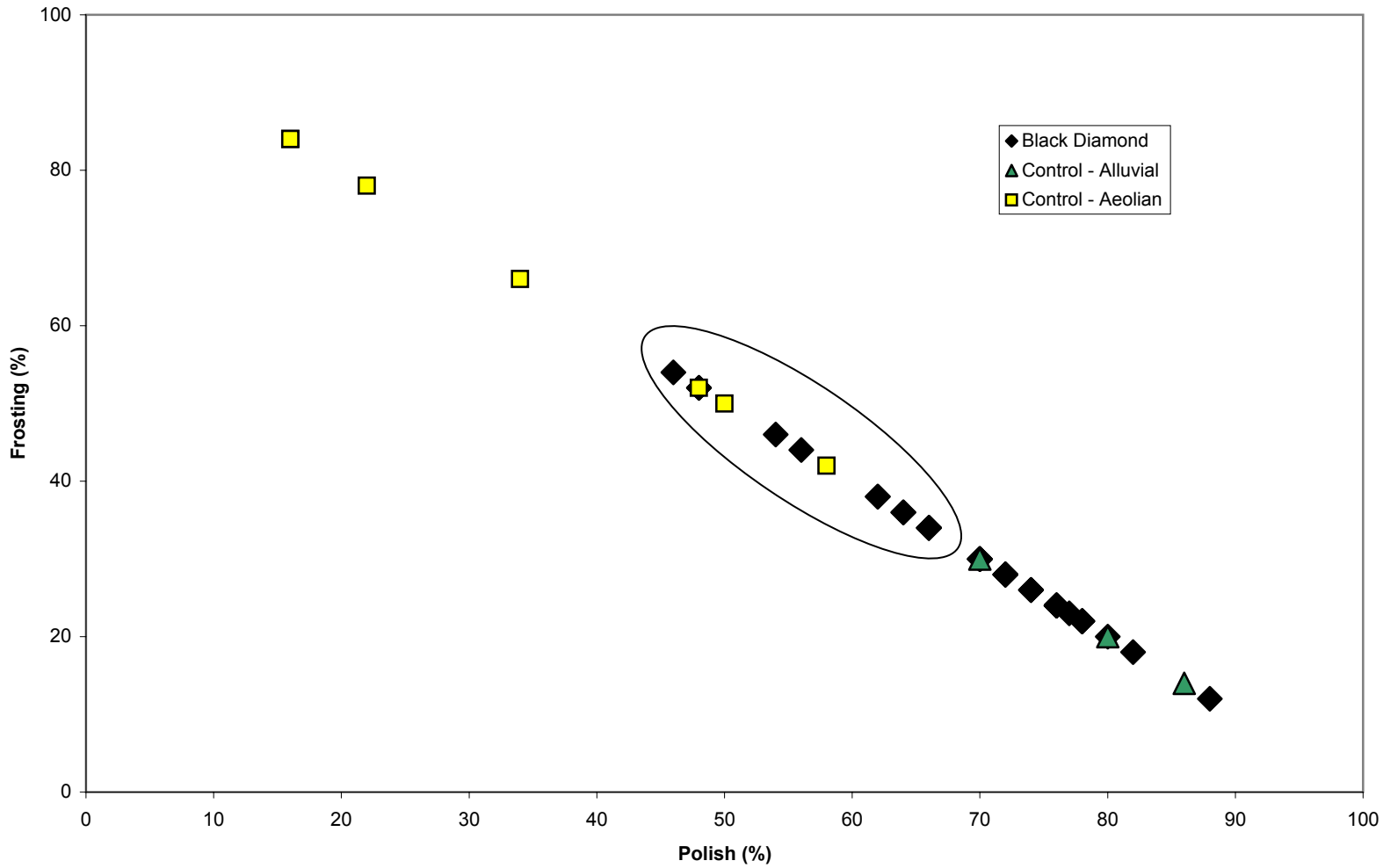


Figure 9. Surface Texture Comparison

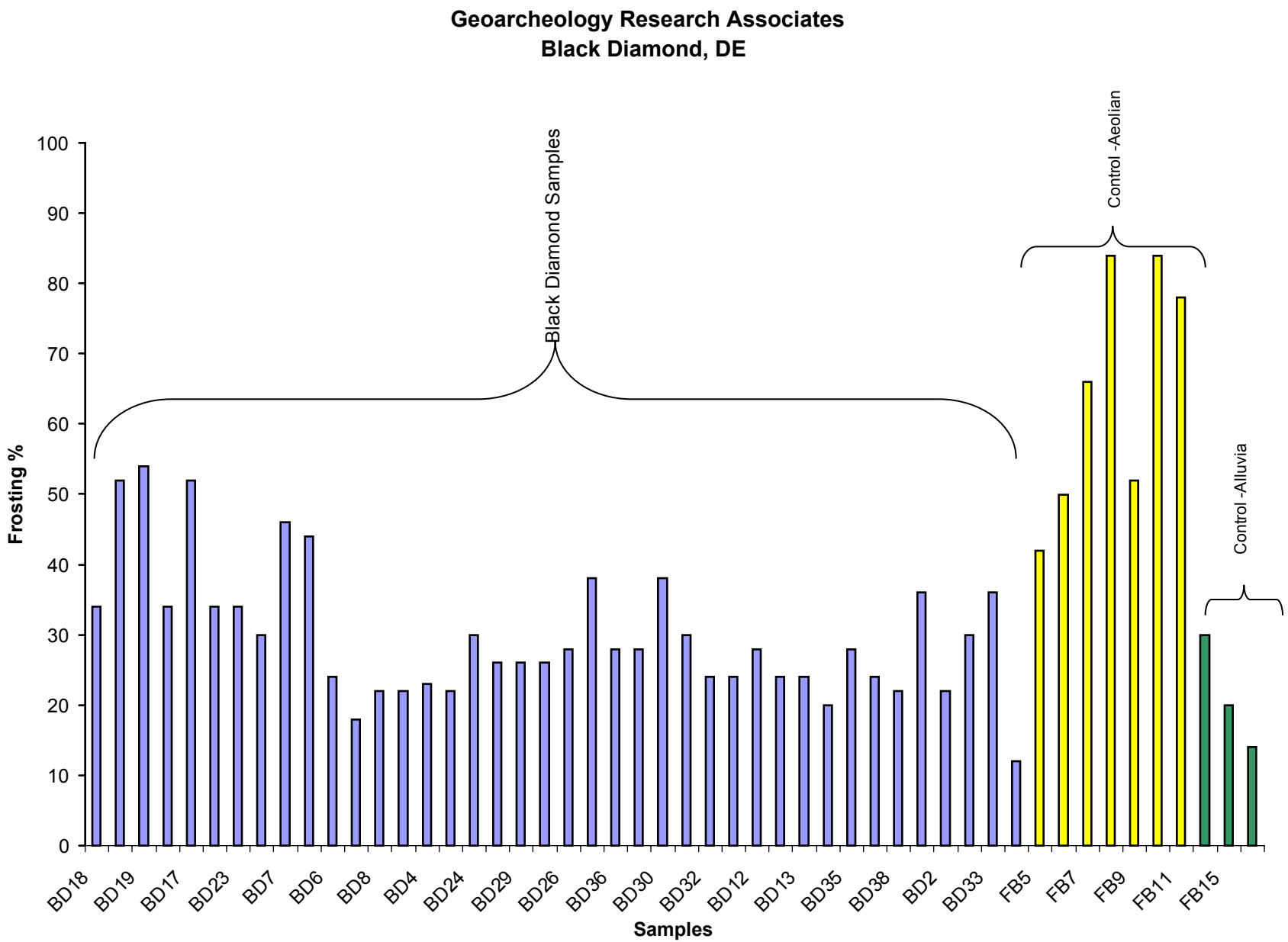


Figure 10. Comparison of Frosting Percentages

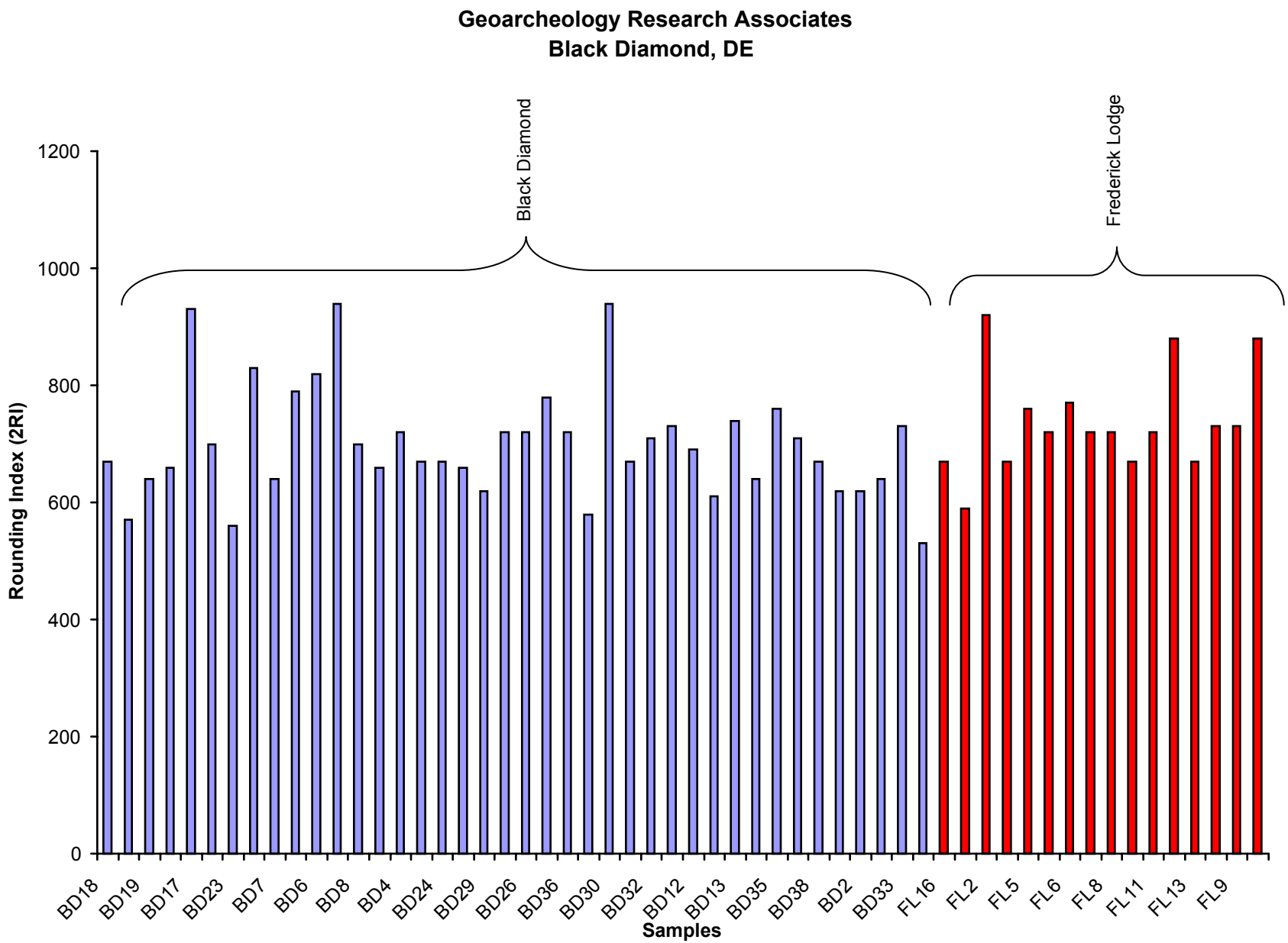


Figure 11. Black Diamond and the Frederick Lodge Site Complex Grain Roundness Comparison

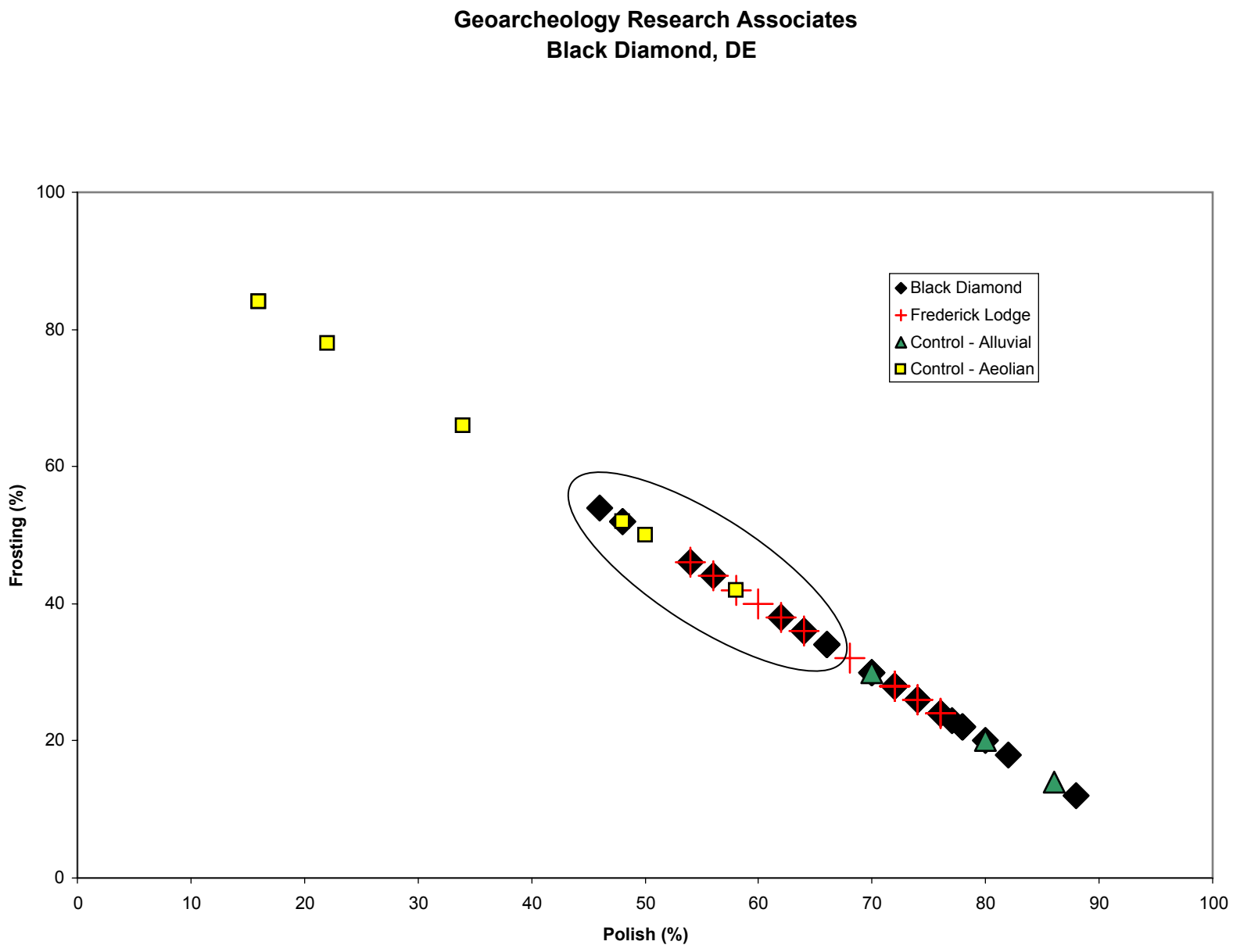


Figure 12. Comparison of Surface Texture Observations from Black Diamond and the Frederick Lodge Site Complex

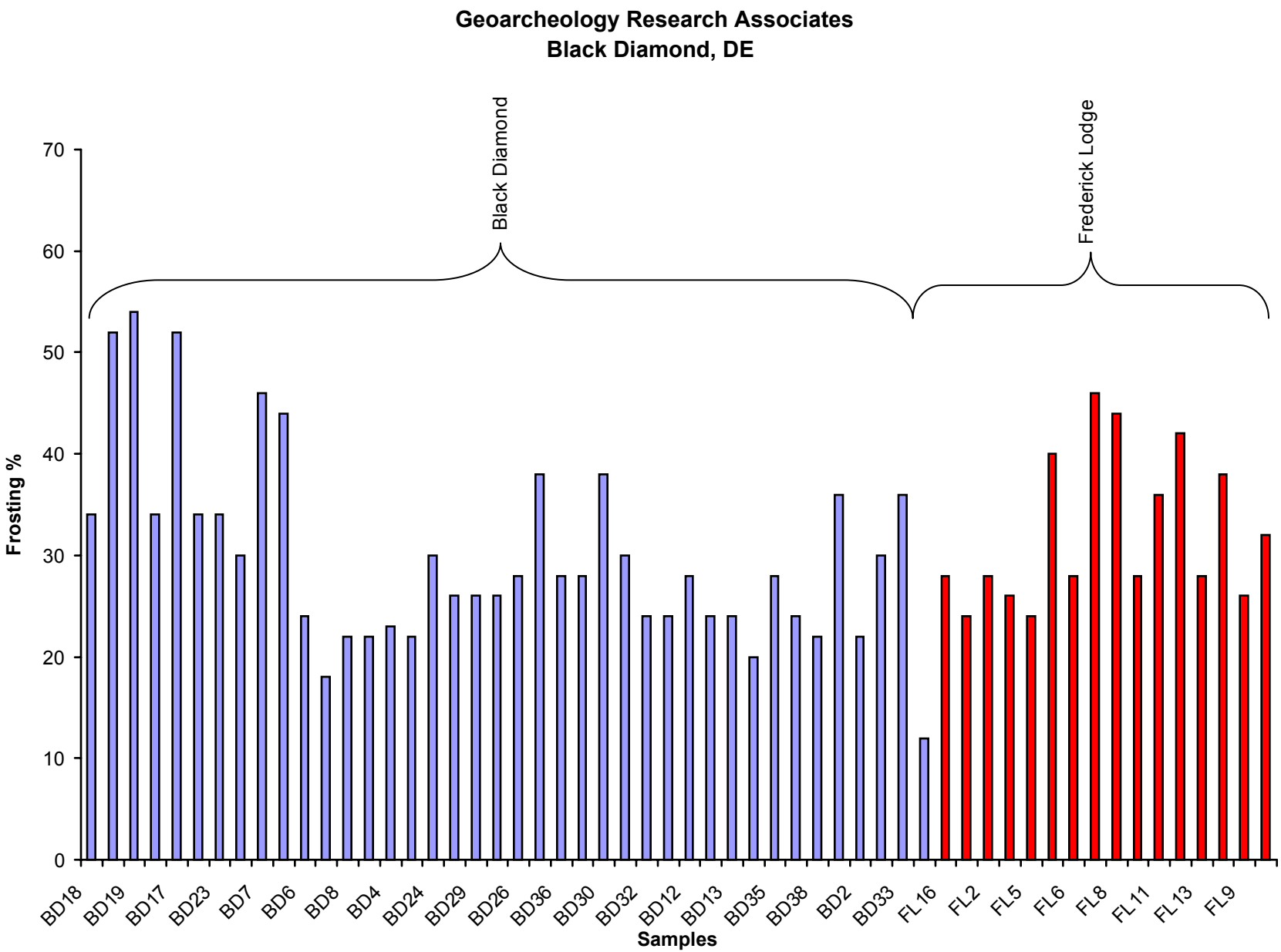


Figure 13. Comparison of Frosting Percentages Between Black Diamond and the Frederick Lodge Site Complex

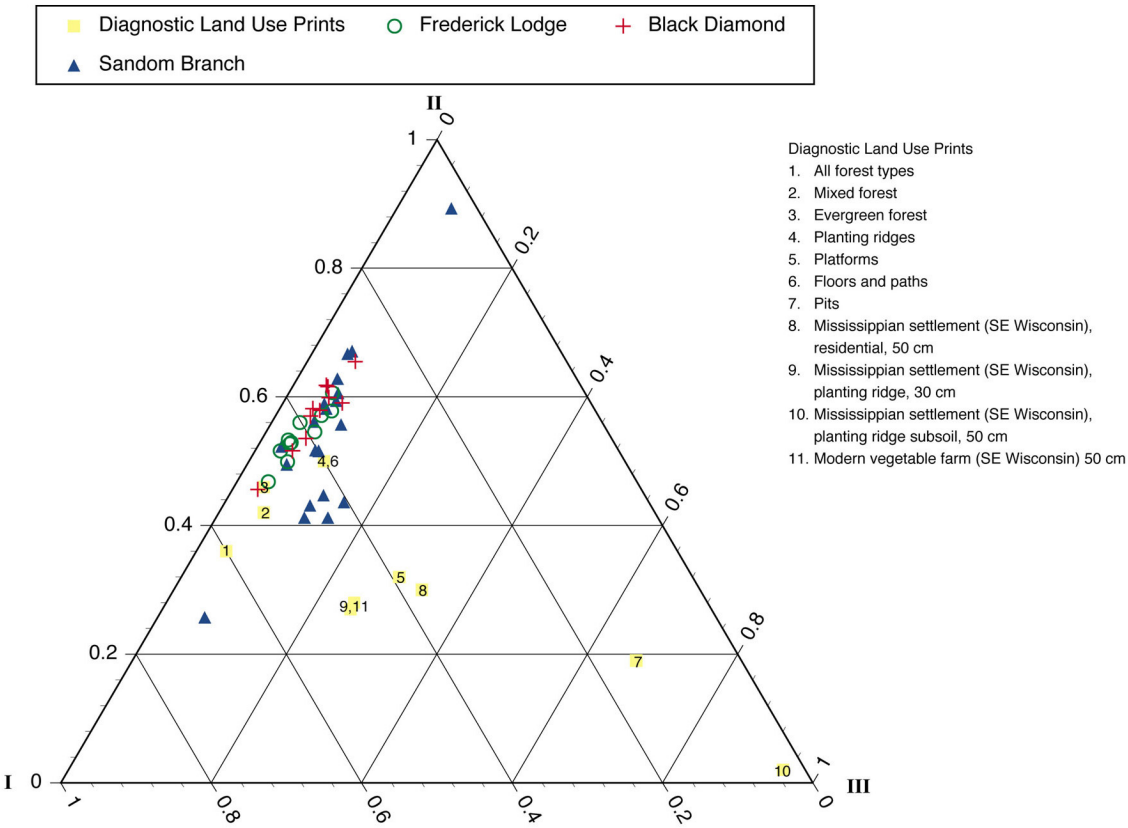


Figure 14. Phosphate Fractionation Tertiary Diagram

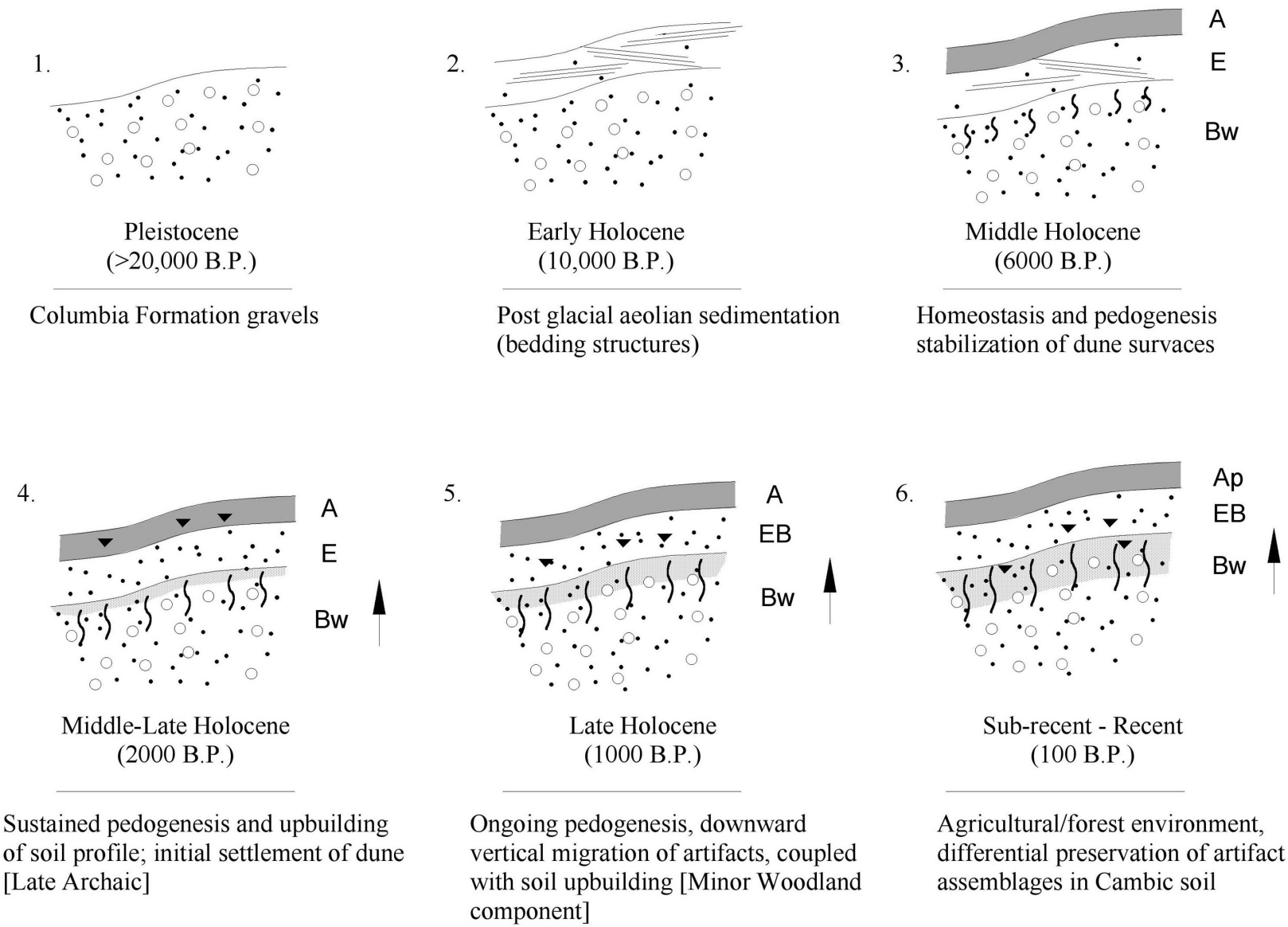


Figure 15. Diachronic Site Formation Model: Site 7NC-J-225