Appendix B: Geomorphological Study

Geomorphological Investigations at the Beech Ridge Site, Kent County, Delaware

Prepared by

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Submitted to

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January 26, 2007

1.0 INTRODUCTION

1.1 General

This study involved a geological/geomorphological examination of the Beech Ridge prehistoric archaeological site, Kent County, Delaware. Geoarchaeological investigations at the site were conducted in concert with the recently completed Phase III investigations conducted by Greiner, Inc. for the Delaware State Highway Administration. The principal objective of Greiner's study was too initially to determine eligibility of the site to the National Register of Historic Places. Upon determination of its eligibility, Phase III mitigation of the site was undertaken with the principal goals to determine the vertical and horizontal extent of the cultural traditions present at the site, site function/use over time and the processes of site sedimentation and soil development.

1.2 Location and Description of Project Area

The Beech Ridge site lies along the upper reaches of the Fork Branch of the St. Jones River at a nominal surface elevation of 11 m (35 ft) above mean sea level (Figure B.1). The site proper is situated on a low ridge or spur, which is bound on all sides by a low-lying swampy zone, which borders the active river channel. From the study area, the St. Jones River flows southeast to its confluence with Delaware Bay. The gradient along this reach is approximately 1 meter (3 ft) per mile. Aside from minor, shallow plowing, the site is undisturbed. Presently, the existing vegetative cover consists of small trees (principally

1.3 Purpose of Investigation

The objectives of the geomorphology study was to: 1) identify the various landforms and associated soils present at the site, 2) discuss sediment supply and modes of sediment transport that have and are operating within the study area, 3) determine the age of the soil package present at the Beach Ridge Site and determine the depths to which testing should extend to ensure the recovery of any and all potentially significant cultural resources, 4) assess the effects of paleoclimatic and base level changes on the regime of the local drainage lines and 5) discuss the sources/provenance of the soil mineral suite (e.g., aeolian vs. fluvial).

1.4 Scope of Investigation

This investigation was performed by Dr. Frank J. Vento, Professor, Department of Geography and Geology, Clarion University of Pennsylvania. The study included a review of both general and specific references of the bedrock geology and quaternary history of the project area. In addition, topographic maps, geologic reports, hydrologic information and aerial photographs were reviewed. Field investigations were initiated on 9 July 2003 and included a pedestrian surface reconnaissance of the study area. In addition to the pedestrian walk-over, a number of deep excavation units were examined and deep auger probes were emplaced a the base of several of the test units to determine the thickness of the Holocene sediment package as well as the stratigraphic contact between the aeolian sands and the underlying Columbia Formation.

2.0 PERTINENT ENVIRONMENTAL BACKGROUND INFORMATION

2.1 Physiography and Geomorphology

The Beech Ridge Site is situated in the Embayed Section (Lower Shore of Delaware) of the Atlantic Coastal Plain physiographic province. The Embayed Section extends from north of the Neuse River in North Carolina to a somewhat debatable boundary near Cape Cod, Massachusetts (Thornbury 1965), and is defined by the occurrences of submerged river valleys. From Long Island, south to the James River in Virginia, this embayment reaches inland to the Fall Line, which marks the contact of Coastal Plain sediments with older lithologies of the New England and Piedmont physiographic provinces.

Post-glacial submergence along this reach of the Atlantic Coastal Plain resulted from isostatic adjustments of the crust level due to ice-loading, concomitant with a rise in base level due to ablation of the late Wisconsin ice sheet. The degree of submergence diminishes from north to south as evidenced by a northward decrease in the width of the Coastal Plain and the altitude of its inner edge. North of Cape Cod the Coastal Plain is completely submerged and has become a portion of the continental shelf (Thornbury 1965:36).

2.2 Drainage and Hydrology

The drainage pattern of the Eastern Shore zone of the Embayed section is clearly dendritic with numerous rills and small tributaries supplying the major drainage lines--the

St. Jones River, Issac Branch, Leipsic River and Delaware Bay. The few streams of the region are scarcely incised and are fringed with patches of swampy ground (Glaser 1971:5). In addition, there is a marked asymmetry in stream length within the region, with the east-flowing drainage lines exhibiting a distinctively longer course than those, which flow in a westerly direction. This occurrence is due to the fact that the east-flowing streams follow the east/southeast dip of the bedrock units in the region. Homoclinal shifting of drainage divides on the Eastern and Western Shores occurs along the downdip direction.

As noted above, the Fork Branch of the St. John's River flows southeast to its confluence with Delaware Bay. The Holocene marine transgression, beginning approximately 11,000 years ago and continuing today at a rate of 2 mm per year, was responsible for the drowning of the St. Jones River and Delaware River mouths. All of the first order drainage lines in the region display low gradients (ca. less than 5 ft per mile), relatively narrow, often swampy flood plain conditions along their low bottoms, moderately straight channel courses which lack well-developed meanders and asymetric valley profiles. All of these conditions would support the assignment of a late initial stage of development.

Runoff and subsequent flooding in the study area is dependent upon variations in precipitation. The highest discharges along the Fork Branch and its tributaries occur during the late winter and early spring when there is a water surplus and lowered rates of evapotranspiration, while lowest flow volumes occur during the late summer and fall in association with decreased effective precipitation (see Table 1). Sea level rise during the Holocene and historic deforestation of the study area has allowed for increased surface runoff, higher sediment yields and more frequent overbank discharges along all drainage lines. These conditions allowed for the emplacement of a variably thick package of middle to late Holocene age, vertical-accretionary and colluvial deposits along the valley bottom and lower valley slopes of the Fork Branch and its tributaries.

Table B.1. Peak Annual Streamflow for the St. Jones River at Dover, Delaware

Peak Streamflow for the Nation
USGS 01483700 ST JONES RIVER AT DOVER, DE

Kent County, Delaware
Hydrologic Unit Code 02040207
Latitude 39°09'49.4", Longitude 75°31'08.7" NAD83
Drainage area 31.9 square miles
Gage datum 0.50 feet above sea level NGVD29

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Water Year	Date	Gage Height (feet)	Stream-flow (cfs)	Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1958	Aug. 26, 1958	9.26	1,260[5]	1982	Jun. 16, 1982	4.03	227[5]
1959	Jul. 31, 1959	4.04	217[5]	1983	Apr. 16, 1983	6.30	675[5]
1960	Sep. 13, 1960	9.45	1,900[5]	1984	Mar. 30, 1984	6.10	650[5]
1961	Apr. 13, 1961	5.71	602[5]	1985	Sep. 28, 1985	6.00	634[5]
1962	Mar. 13, 1962	4.18	276[5]	1986	Jan. 27, 1986	4.19	271[5]
1963	Mar. 07, 1963	4.29	285[5]	1987	Dec. 25, 1986	4.80	408[5]
1964	Feb. 19, 1964	5.29	498[5]	1988	Feb. 13, 1988	4.23	280[5]
1965	Mar. 06, 1965	3.48	107[5]	1989	Jun. 22, 1989	6.07	628[5]

2.3 General Geology

The Coastal Plain on the Delaware and Kent County is composed wholly of generally unconsolidated sedimentary deposits ranging in age from Miocene to Holocene. The strike of the deposits is generally northeast-southwest with dips of typically less than 1 degree to the southeast. The mapped outcrop pattern is thus a succession of roughly arcuate bands which become younger to the southeast (the downdip direction). The deposits locally are ascribable to the Chesapeake Group (Calvert, Choptank and St. Mary's Formations). These Tertiary Age deposits consist primarily of sands, shell beds and calcareous clays. The formations are underlain by the Cretaceous Potomac Group and overlain by Pliocene, Pleistocene and Holocene age sands and gravels.

Within the immediate study area a variably thick (less than 1 m) package of Holocene age Aeolian sands are disconformably underlain by coarse sands and gravels of the Pleistocene age Columbia Formation. Locally, the Columbia Formation is then underlain by the Frederica Aquifer. This aquifer facies is an important source of potable water throughout the region (Figure B.2).

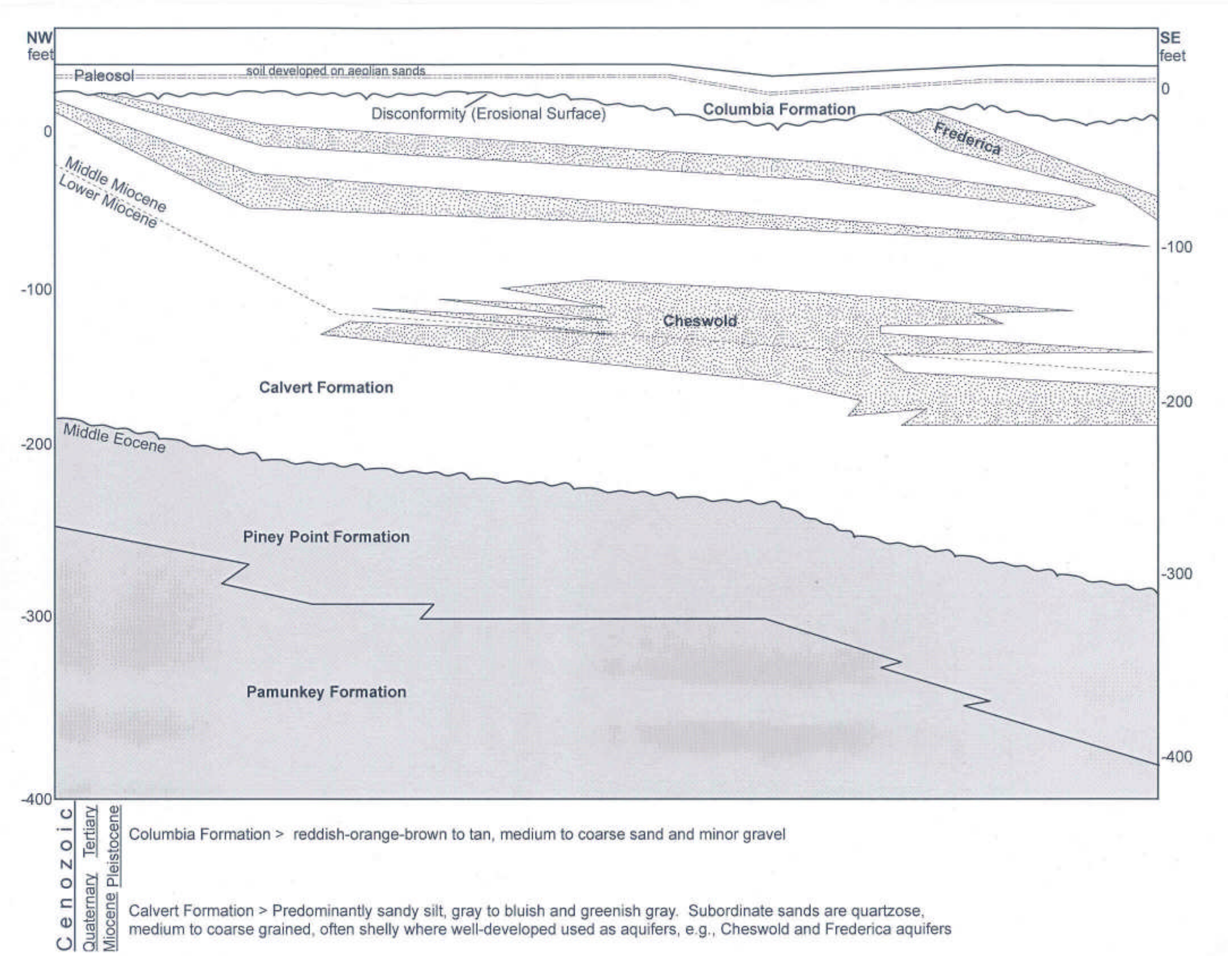


Figure B.2. Stratigraphic cross section showing principal geologic units within general study area. Note the occurrence of the aeolian sands overlying the Columbia Formation.

2.4 Soils

The soils present at the Beech Ridge site are ascribable to the Rumford loam sand series. These soils are developed on a varied assemblage of both alluvial and Aeolian deposits of late Quaternary Age. Throughout the eastern shore the Rumford and Sassafras soils were a preferred locus for prehistoric sites. This occurrence may be due to its well-drained character and mapped association with a high, terrace along the St. Jones River.

2.5 Historic Land Use

Shortly after 1649 with the arrival of Puritan families from Virginia, the lands comprising the general project area were utilized by wealthy merchants as tobacco plantations with a lesser emphasis on corn. In addition, along the coast and in the marshes, fishing, crabbing and clamming were aggressively pursued and developed. By the late 18th century numerous woolen and gristmills were built along streams in the county. Also during this time, crop farming became the dominant practice. The principal crops included: wheat, corn, beans, peas, strawberries, tomatoes, sweet potatoes and cantaloupes. The ability to get these crops to market was greatly enhanced by the advent of improved roads, steamships, and railroad lines during the first and second quarters of the nineteenth century. This change to more diverse crops was due in part to the realization that tobacco farming practices were depleting the soil and that forced black labor force present prior to the Civil War was now gone. It is interesting to note that by 1900's; thousands of farms could be found operating in the general region. Also during this time industries such as canning, box making, chrome and steel factories, seafood and truck farming became important to the economic growth of the area.

2.6 Paleoenvironmental Reconstruction

2.6.1 Late Pleistocene

The major expansion of the Laurentide ice sheet took place beginning in the Late Wisconsin stage at about 23,000 years B.P. In most of the northeastern United States the ice sheet was in full retreat by approximately 14,500 years B.P. Over the next four thousand years, there were several short-lived, small advances or pulses of the Laurentide ice sheet. While Kent County, Delaware was never glaciated, full-glacial and then late-periglacial climatic conditions to the north and west would have had a profound impact on eustatic sea-level changes, rates of weathering and mass-wasting, vegetation patterns and stream regime.

Bloom (1983) has proposed that during the late glacial maximum (18,000 B.P.) sea level was lowered by 120 m +/- 60 m, exposing large portions of the continental shelves. In response to a lowered base level, streams like the St. Jones River and its major tributaries would have rapidly down cut, through temporary base level adjustment, to keep pace with this change. The paired Late Wisconsin age terraces and sharp terrace risers, which occur along the St. Jones River would indicate several episodes of rapid down cutting with minor lateral channel migration during this time. The sandy parent material, greater effective precipitation and heightened stream competence/capacity would have allowed for rapid rates of incision. This is clearly evidenced at the Beech Ridge site were the stream has down cut through more than 11 m (35 ft) of Pleistocene and Tertiary deposits. Given the absence of any ice within Kent County, isostatic adjustments relating to ablation of the Laurentide ice sheet would not have affected late Wisconsin or early Holocene rates of incision.

At the peak of glaciation, changes in radiation and insolation caused the jet stream to split into two portions, with strong easterly winds occurring at the southern margin of the ice sheet (COHMAP 1988; Ebright 1992). As noted by Ebright et al. (1988) these late glacial weather patterns would have resulted in a decrease in seawater temperatures, increase in sea-ice areas, and a decrease in seasonality in eastern North America. Brush (1986) places the average land temperatures at 3 to 8 degrees Centigrade lower than present near the end of the glaciation in the Chesapeake Bay area. Other authors have argued (Webb and Bartlein 1988; Knox 1983; Vento et al. 1992) that it was not until 9,000 - 8,000 yrs. B.P. that the continental ice mass no longer affected continental atmospheric circulation (occurrence of meridional flow) and vegetation patterns.

Late glacial forest-vegetation communities consisted of boreal species dominated by jack pine and spruce, with lesser amounts of birch, fir, hemlock and alder (Brush 1986; Delcourt and Delcourt 1981, Davis 1983; Sirkin et al. 1977). Pleistocene-age peats from eastern Pennsylvania and the Delmarva Peninsula exhibit a diverse spectrum of forest taxa including pine, spruce, birch, alder, willow, oaks, heaths, grasses, and sedges (Sirkin et al. 1977; Crowl and Sevon 1980). Like the flora, Pleistocene fauna was equally diverse including such fauna as mastodon, mammoth, bison, horses and camel (Guilday et al. 1966; Semken 1983; Eschelman and Grady 1986). The cause for the Late Pleistocene extinctions generally follows one of three models: 1.) overkill; 2.) environmental change; and 3.) combined effects of overkill-environmental change. Specific details regarding Pleistocene extinctions are reviewed by Lundelius and others (1983). It might be argued that the late glacial fauna (11,000 - 10,000 yrs. B.P.) of Kent County, Delaware was a mosaic of both megafauna and more modern Carolinian species.

2.6.2 Early Holocene (10,000 - 8,000 B.P.)

By the start of the Holocene (circa. 10,000 yrs. B.P.) the Laurentide ice sheet had ablated to a position just south of present day Hudson Bay. The stagnant ice sheet effectively restricted the mixing of warm-moist air masses from the Gulf with cold Canadian air. In effect, the flow during the early Holocene was clearly zonal or westerly. Prior to 7,000 yrs. B.P. flood intensity in the mid Atlantic States would have been greatly reduced. Also during this time, rapid, eustatic sea-level adjustments along the Atlantic coast caused drowning of numerous river valleys. Kutzbach's (1983) notes that the radiation curves for tilt and precession reinforced each other at 10,000 - 9,000 yrs. B.P. resulting in the global average solar radiation for July being 7% greater than today and that precipitation was 7% greater and temperatures .7 degrees Celsius warmer.

As relates to the drainage lines within the general study area, the early Holocene would have been a time of rapid alluviation-aggradation. Aggradation would have been caused by a base-level adjustment due to eustatic sea level rise. During this time, gradients were much reduced from the earlier late Wisconsinan as were sediment load and overall discharge. The probable braided reaches of these drainage lines changed their channel habit to one of a meandering form. In the interior part of the mid-Atlantic region infrequent large floods during the early Holocene would have been promoted by strong zonal/westerly flow and greater rates of potential evapotranspiration.

Within segments of the Delaware and Susquehanna River basins, the major drainage lines experienced several episodes of rapid, vertical accretion followed by several hundred-year periods of relative flood-plain stability (Figure B.3). The multiple, dated occurrence of a cumulic, buried A horizons from the period 9,000 - 8,000 yrs. B.P., indicates a relatively

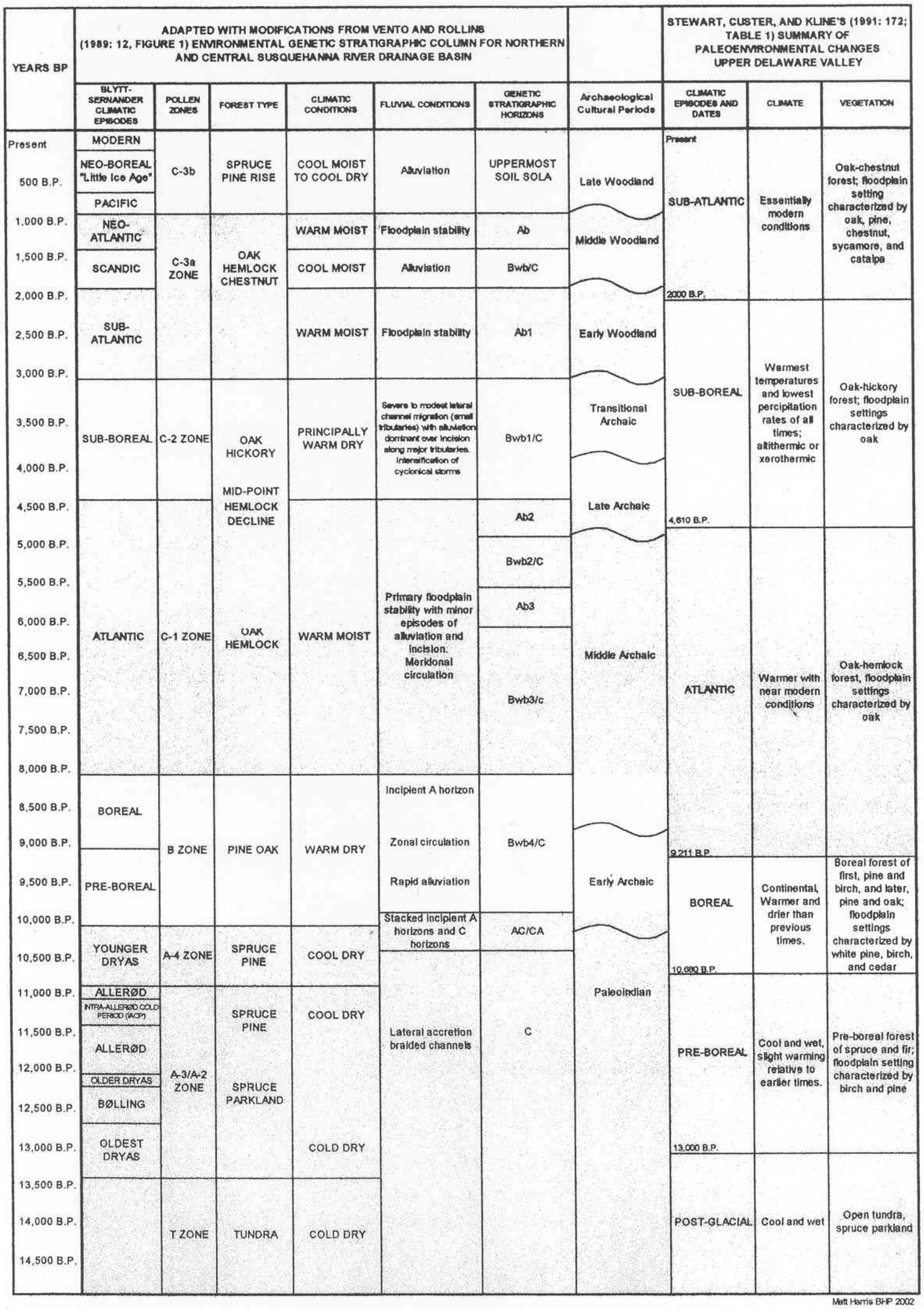


Figure B.3. Genetic stratigraphic framework for the Upper and Central Susquehanna River.

lengthy period of flood plain stability Vento et al. 1992). During the early Holocene, the spruce and pine forest of the late glacial stage was rather quickly replaced by mixed conifers and northern hardwoods (Delcourt and Delcourt 1981; Davis 1983; Brush 1986). Both Brush (1986) and Davis (1983) note oak as occurring within the general study area by 10,000 yrs. B.P. Pollen cores from the southern Chesapeake Bay region document the rapid expansion of mixed deciduous-conifer forests at 10,000 B.P. (Harrison et al. 1965; Whitehead 1972).

2.6.3 Middle Holocene (7,000 - 5,000 B.P.)

The Middle Holocene along the Middle Atlantic coast is a period during which sea level rise rapidly increased (Kraft 1985). The head of the Chesapeake Bay at this time was in the vicinity of Annapolis (Brush 1986). Continued ablation and retreat of the ice sheet by 7,000 - 6,000 yrs. B.P. allowed for the penetration and mixing of warm-moist, maritime-tropical air masses with cold Canadian/arctic air (Knox 1983). This mixing created the potential for large cyclonic storms and, in turn, large floods. At this time there is a rapid shift from zonal to more meridional circulation. In the Delaware and Susquehanna River drainage basins most medium to small-sized streams clearly lack any intact mid- to early-Holocene alluvium. The occurrence may be due to the effects of large floods spawned from cyclonic storms removing these earlier vertical accretionary deposits. Also during this time there is a marked shift from the warm-dry conditions of the late Early Holocene (circa. 9,000 B.P.) period to one of alternating cool-wet and warm-moist conditions. These conditions favored incision and minor active lateral channel migration.

According to Kraft (1985), between 8,000 - 4,000 yrs. B.P. sea level rose at a rate of approximately 0.4 cm per century in the Mid-Atlantic. Joyce (1988) proposes that the warm-dry Hypsithermal Interval prevailed between 9,000 - 5,000 B.P. in the Mid-Atlantic. This period fits well with vegetation shifts observed in the Midwestern Prairie Peninsula and Great Plains. These dates are considerably earlier than estimates based upon pollen core data from Hack Pond which restrict the period of warmth and dryness to the Subboreal (ca. 5100 - 2800 B.P., cf. Carbone 1976; Custer 1984; Custer and Curry 1982). These later dates also conform well to dated soils located on low terraces (Port Huron) within the upper and central Susquehanna and upper Delaware River Valleys (see Figure B.3). Vento et al. (1992) would place the period of warmth and dryness between 4500 - 3000 yrs. B.P.). These dates are based upon dated, buried A horizons which consistently bracket a cambic B horizon which contains Transitional Archaic artifacts (e.g., broad-spear projectile points, steatite). As relates to vegetation, the mixed conifers and northern hardwood forests of the early Holocene were quickly replaced by an oak-hickory-southern pine association that was firmly in place by 5,000 yrs. B.P. in Maryland (Ebright et al. 1992).

2.6.4 Late Holocene (4500 - Present)

The opening of the late Holocene is marked by an episode of extreme warmth and dryness known as the Subboreal climatic phase. The warm-dry conditions are in marked contrast to the generally wet-moist conditions of the preceding Atlantic climatic phase. During this period (4500 - 3000 yrs. B.P.) a persistent mean-westerly atmospheric circulation expanded a mid-continent climatic regime of warmth and aridity (Bryson et al. 1970; Delcourt and Delcourt 1985; Knox 1983; Vento et al. 1992). In the upper and central

Susquehanna River drainage basin, the stratigraphic evidence indicates that in response to these warm-dry conditions, streams entered a phase of active lateral channel migration and along specific reaches, active vertical accretion. These events may relate to a decreased vegetation cover associated with higher sediment yields. The general absence of any buried A horizons at this time on dated terraces would appear to indicate that flood plains were receiving enough sediment from flooding to preclude their development.

Recent fossil pollen data, from Dan's Bog, Prince George's County, Maryland, indicates an increase in herbaceous taxa in the oak-dominated forests between 5,000 and 1770 B.P. (Leedecker and Koldehoff 1991). Davis (1983) and Winkler (1985) note that annual average temperatures may have been as much as 2 degrees Celsius warmer than at present.

Following the end of the Subboreal climatic phase, streams along the eastern shore would have experienced a rather pronounced episode of warm and moist climatic conditions (3,000 - 1750 B.P.) of the SubAtlantic climatic phase. These warm-moist conditions allowed for relative flood plain stability and in places, the development of a thick, surficial A horizon. The SubAtlantic phase was then followed by a period of cool-moist conditions of the Scandic climatic phase (circa. 1750 - 1150 B.P.). Locally, streams would have entered into a phase of active lateral channel migration and incision with more active rates of vertical accretion, which would have precluded A-horizon development. The Scandic phase was then followed by another warm-moist interval termed the NeoAtlantic climatic phase (1100 - 700 B.P.). Warm-moist conditions would have again favored relative flood plain stability. Once again, it might be expected that lower lying terraces should, contain along select reaches buried A horizons from this period. If present along the lower terraces, these A horizons should be overlain by variably thick sola, which have been emplaced during the cool-wet, Pacific climatic phase (700 B.P. - 300 B.P.) and as a result of increased surface runoff/sediment yields to streams from historic deforestation. While the Beech Ridge Site was unaffected by either overbanking events or channel migration, the same climatic conditions which promoted either stability or frequent overbanking events would have promoted either more frequent aeolian processes or stability of the terrace.

According to Brush (1986), sea level continued to rise but at a much slower rate. Chesapeake Bay had essentially attained its present form at ca. 3000 yrs. B.P. The mouth of the St. Jones River was also drowned during this period. Kraft (1985) estimates sea level rise of the last 2000 years at 15 cm per century.

The oak-hickory, southern pine forests typical of early Holocene times remained stable until, as noted above, Euro-American settlement. Brush (1986) notes an especially wet period between 4700 - 3400 yrs. B.P. and an extremely dry period between 1000 -1200 A.D. This latter dry period is based upon the presence of holly, chestnut and ericaceous shrubs. These dates and the associated climatic conditions are exactly the reverse of those proposed for the central and upper Susquehanna River valley (Vento et al. 1992). The high quantities of metallic elements found in cores at this time has led Brush (1986) to postulate that this proposed dry period was characterized by intermittent fires. An alternative hypothesis for the occurrence of abundant free carbon and higher levels of metallic elements might be from aboriginal clearing of land for horticultural/agricultural use.

2.7 Previous Geomorphological and Soil Investigations

The earliest documented geoarchaeological studies undertaken at the site were conducted by Dr. John Foss of the University of Tennessee for HCI Consulting, Inc. in August 2001. Foss conducted limited auguring at the site and collection of samples from auger probes. Foss described the augured soils along two transects at Beech Ridge. In addition, the collected soils were subsequently analyzed for their biogeochemical makeup. In the subsequent report submitted by HCI, Inc., Foss (2001) concluded that the pH vales at the site ranged from 4.2 to 4.8. Soil organic matter ranged from 7.4% near the surface with lows of .5% in the subsoil. Foss (2001) also tested for calcium, iron, potassium and phosphorous. According to Foss (2001), there appears to be a correlation with human activity and higher phosphorus levels at the site. Calcium at the site are higher due to recycling while the higher iron values in some profiles indicating disturbance from the digging of pits and the exhumation and redeposition of soil with a higher iron content.

In his report, Foss (2001) notes that the soils encountered during probing at the site were alluvial in origin. He states that the more sandy horizons may represent deposition in a levee or bank edge position while the silty sediments at the site might represent finer overbank deposition. Given the data at present, it is hard to conceive that the St. Jones River has overbanked the Beech Ridge site in the last 8000 years. Presently the site lies more than 11 m (35 ft) above mean sea level with the channel of the St. Jones River being within 1 m (3 ft) of sea level. Base level control by the ocean, which lies within 3 km of the site would preclude flooding of the site. In addition, prior the beginning of the Holocene marine transgression (circa. 7000 B.P.), the St. Jones River would have been actively incising it s channel during the late Wisconsin.

2.8 Methods: Geomorphological/Geoarchaeological Analyses

The geomorphic field investigations and geological samples collected during the course of the archaeological and archaeogeological investigations at the Beech Ridge site were undertaken to provide additional information regarding late Pleistocene and Holocene physical environments present during the aboriginal occupation of the Coastal Plain in Delaware.

2.8.1 Geological Sample Collection Procedures

Several types of geological or geoarchaeological samples were collected for post-field analyses. The first was a series of vertical sediment samples, which were collected from select excavation units. Bulk samples of 500 grams were collected from each stratigraphic horizon at 5 cm intervals. Where sediment changed composition or color within a 10 cm interval, two samples were taken, one on each side of the change. In addition to the above, geochemical, humic acid, C-14, biogeochemical, detrital grain composition, micromorphology and X-Ray diffraction samples were collected in the same manner from each natural stratigraphic horizon.

2.8.2 Granulometric Analysis Methodology

Sediment samples of 500 grams or more were taken from cultural and non-cultural-bearing stratigraphic levels at 5 cm intervals from select excavation units at the site. All samples were then split into a single 50-gram fraction, using a random sample splitter.

A standard granulometric sieve analysis was performed on the saved 50 gram fraction from each of the sediment columns. Wet sieving was used to determine the distribution of grain sizes within each sediment sample. Whole phi (0) sieve size intervals were used, including those of 4 mm (-2 phi), 2 mm (-1 phi), 1 mm (0 phi), 0.5 mm (1 phi), 0.250 mm (2 phi). 0.125 mm (3 phi), 0.063 mm (4 phi) size classes. Aside from the paleosol horizon, given the small percentage of grains in the silt and clay-sized fraction, no detailed hydrometer, pipette or Coulter Counter analyses were considered warranted. In sum, the percentage of each sieve class was determined by comparing the weight of each dried sieve fraction to that of the initial dry sample weight. The percentage for sediments finer than 0.063 mm (4 phi) is essentially the weight loss from the initial sample weight after wet sieving (Vento, Adovasio and Donahue et al. 1980; 1982).

The dried and weighted fraction for each size class was saved and stored in a sealed vial for detrital grain composition analysis. Statistical formulas used to calculate mean, median, standard deviation; skewness and kurtosis were based on the method of moments and are described below. Histograms, univariate and bivariate plots were completed at the Computer Graphics and GIS Laboratory, Department of Geography and Geology, Clarion University of Pennsylvania 16214. The results of the granulometric analyses are presented in Appendix IB.

According to Friedman and Sanders (1978:78-80) the first moment of the method of moment's calculations is written as follows:

$$firstmoment = \frac{3\ fmø\square x}{100} = \frac{3fm\text{-}ø}{100}$$

Where <u>f</u> is the frequency for each class size and <u>mo</u> is the midpoint of each phi (X) class. The first moment equals the mean, <u>(x)</u>. The second moment is a measure of dispersion about the first moment <u>(x)</u>, and is expresses mathematically as follows:

$$secondmoment = \underline{3\ f\ (mø\text{-}x)_2}$$

$$100$$

This second moment is the numerical value of the standard deviation squared. In order to obtain the numerical value of the standard deviation, we must take the square root of the second moment as follows:

$$\underline{\sigma = 3\ (fm\text{ø}-x)2}\ 1/2$$
$$100$$

The standard deviation gives information on the extent to which sediment particle sizes are clustered about the mean, and hence defines the concept of sorting.

The third moment of the distribution is a measure of the symmetry of the frequency curve about the mean and is written as follows:

$$thirdmoment = 3\ \underline{f\ (m\text{ø}-x)^3}$$
$$100$$

This moment is known as the 100 cubed deviation and, by rating the symmetry of the curves, determines its normality. Since (mo-x) is positive to the right of the mean and negative to the left of the distribution is 0. A positively skewed distribution indicates an excess of fine particles to the left of the mean.

The skewness of the curve is commonly derived by dividing the mean by the cube of the standard deviation. This is expressed as follows:

$$skewness\ (\sigma_3) = \underline{1\ \ x\ 3f\ (m\text{ø}-x)^3}$$
$$1000_{\sigma\text{-}3}$$

Skewness, as the third moment reflects deviation from symmetry of the curve and is sensitive to the presence or absence of the fine or coarse fraction is a sample.

The fourth moment of the distribution is expressed as follows:

$$fourthmoment = \underline{3\ f\ (m\text{ø}-x)^4}$$
$$100$$

The fourth moment is used to calculate the peakedness (e.g., leptokurtic, mesokurtic or platykurtic) or kurtosis of the distribution. Kurtosis is calculated by dividing the fourth moment by the standard deviation raised to the fourth power, thus:

$$kurtosis\ (\sigma_4) = \underline{1\ \ \ x\ 3f\ (m\text{ø}-x)^4}$$
$$1000_{\sigma\text{-}4}$$

Finally, the sand-sized material from each size class was saved and visually scanned for microfaunal (molluscan) elements and to determine the detrital grain composition of the site's sediment suite.

Grain size analysis in concert with the detrietal grain composition study has allowed for determining the various origins of the site's sediment suite. Grain size analysis has proven highly successful for this purpose, not only at closed sites such as Meadowcroft Rockshelter in Pennsylvania and at the Bay Springs Rockshelters in Mississippi, but also at open sites along the Little Platte River in Missouri and the Illinois River in central and southern Illinois.

2.8.3 Detrital Grain Composition

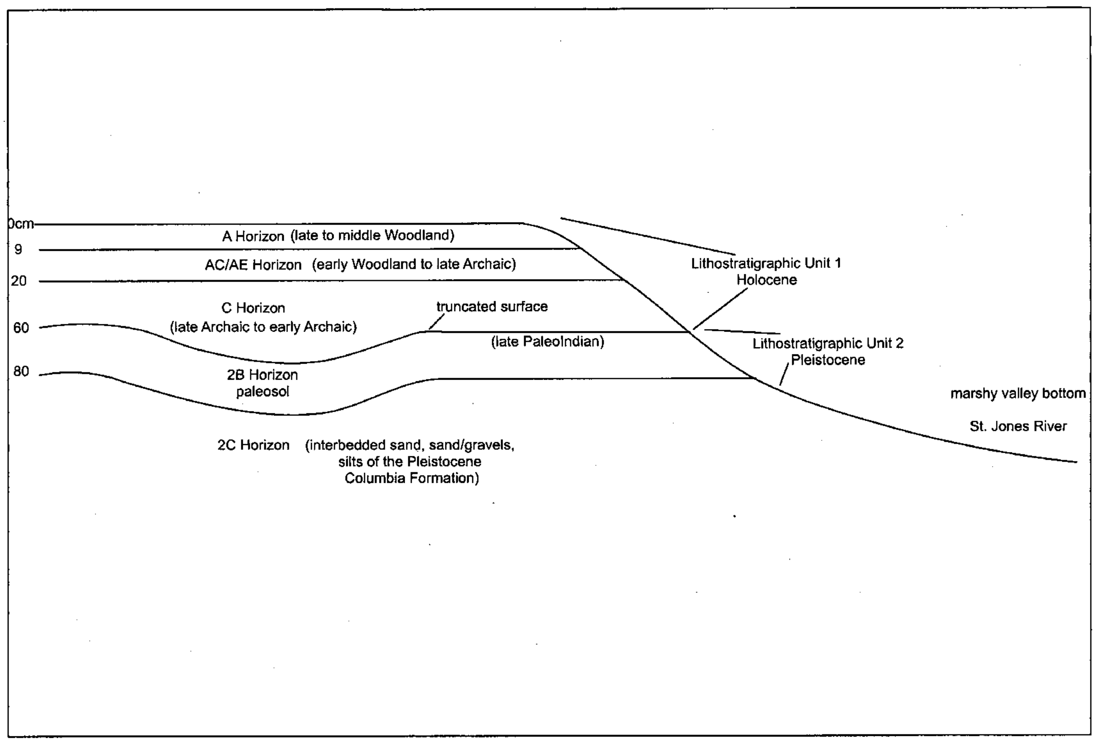
A noted above a visual scan of the sand-sized material was accomplished via a Lietz polarizing microscope attached to a television monitor at CUP geology laboratories to determine the bulk mineralogy of the soils at the Beech Ridge Site. These data coupled with the textural analysis has aided in determining and characterizing the age, depositional emplacement, degree of diagenesis and origin of the sediments at the Beech Ridge Site.

3.0 RESULTS OF INVESTIGATION

3.1 Site Stratigraphy

During the course of the Phase III investigations at the Beech Ridge Site, two distinct Lithostratigraphic units were encountered. These units can be further subdivided into six distinct pedostratigraphic horizons, which comprise two distinct sola. Figure B.4 is an idealized soil stratigraphic profile, which shows the relationship of the soil horizons at the Beech Ridge Site, while Figure B.5 consists of a series of schematic cross sections showing landform evolution. The following discussion details the soil stratigraphy, age of the deposits, diagenesis and depositional history.

Lithostratigraphic Unit I contains Strata II (Ap), III (CA/CE) and IV (C). Lithostratigraphic Unit I and the pedostratigraphic units contained within it have been emplaced over the last 6000 to 7000 yrs by Aeolian depositional events. The homogenous porous and permeable sands do exhibit extensive leaching (eluviation) of iron and sesquioxides by gravitational waters. The sands also show textural variation which may indicate various episodes of deflation and subsequent deposition. The grain size data plots presented in Appendix A of this report clearly show variations in the soil texture for Lithostratigraphic Unit 1. It should be noted that no distinct, buried cumulic or incipient A horizons can be identified within Unit I. Rather, it appears that the homogenizing effects of frost heaving and bioturbation have removed any potential bedding surfaces, which document discrete depositional events. Furthermore, the absence of any relict A horizons within Unit 1 is not unexpected given the erosive effects of wind deflation to the terrace.



Generalized Soil Stratigraphic Cross Section at the Beech Ridge Site (7K-C-422)
Kent County, DE

Figure B.4. Idealized soil stratigraphic cross section at the Beech Ridge Site (7K-C-422).

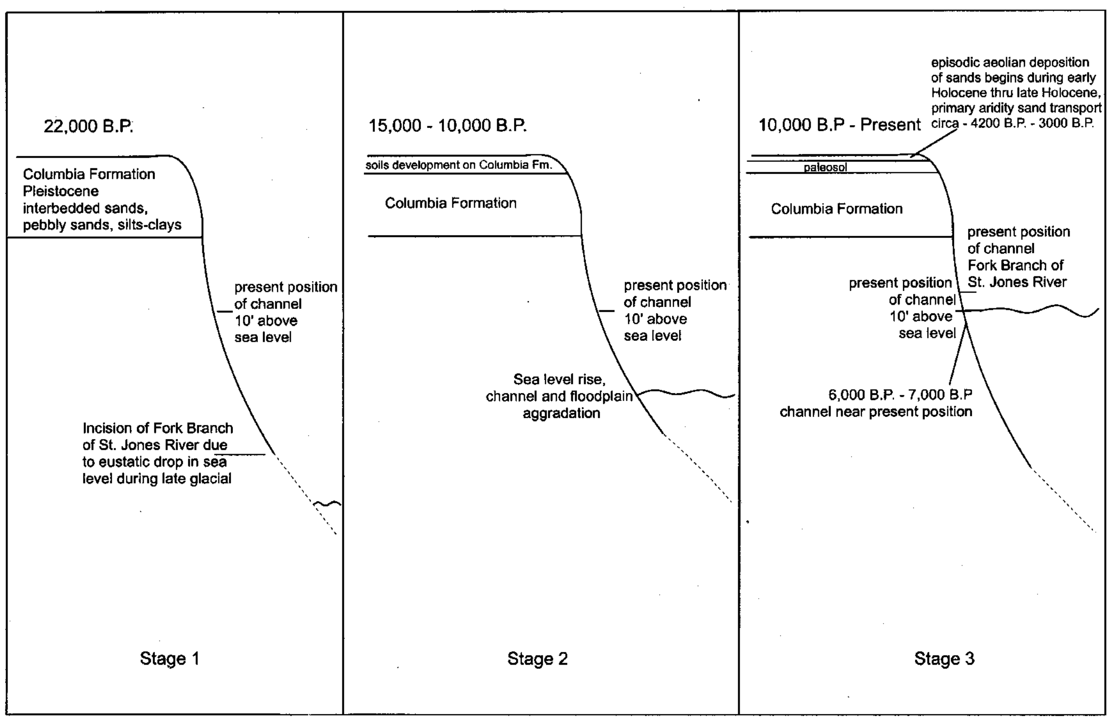


Figure B.5. Schematic diagrams showing landform evolution of the Fork Branch of the St. Jones River from late Pleistocene to Recent.

Stratum I: (Oi, Oe, Oa)

Extent: Stratum I is the surficial stratum at the site and is wholly composed of varying stages of organic decomposition. Stratum I is conformably underlain by Stratum II, a plow zone horizon. Horizontally, Stratum I is continuous across the tested portion of the site. Vertically, Stratum I extend from the ground surface to a nominal depth of 3 cm below ground surface.

Texture: not applicable

Color: dark brown (10YR3/3)

pH: acidic

Organics: leaf litter, pine needles, large roots and rootlets

Bioturbation: extensive, due to root and rodent activity.

Cultural Associations: Historic and Prehistoric

Depositional History: Stratum I is an O horizon comprised entirely of organic debris.

Stratum II : (Ap)

Extent: Stratum II is continuous across the tested site area. The horizon thins along the edge of the hill as it descends onto the flood plain of the river. The truncation of the Ap horizon in these areas is clearly due to mass wasting processes (slopewash, creep, etc). Stratum II is extends essentially from the ground surface to a maximum depth of 10 cm below ground surface.

Texture: organic-rich loam sand. The texture of the A horizon is strongly bimodal with the primary modal peaks occurring in the <4 phi (<.063 mm) size class and the 1 phi (.5 mm) size class. The somewhat coarse texture of the A horizon may be in part due to some organic fragments (pine needles, twigs) in the sample. The A horizon is mesokurtic and is generally poorly sorted. The weighted mean grain size for the horizon is .370 mm (see Appendix A).

Color: dark brown (10YR3/3)

pH: strongly acid

Organics: abundant, fine disseminated roots and rootlets

Bioturbation: extensive

Cultural Associations: historic and prehistoric

Depositional History: Stratum II (Ap) is a plow zone horizon formed in eolian sands of late Holocene age. The horizon is then underlain by a AC/CA horizon.

Stratum III: CA/CE horizon

Extent: Stratum III is continuous across the tested site area. The horizon also thins along the edge of the hill as it descends onto the flood plain of the river. The horizon is conformably overlain by Stratum II and conformably underlain by Stratum IV. Stratum III can best be classified as a CA horizon. The horizon attains a nominal thickness of 10 cm.

Texture: loam sand with moderate organics. Like the A horizon the CA horizon is also strongly bimodal with modal peaks occurring in the <4phi (<.063 mm) and 1 phi (.5 mm) size classes. The horizon is generally poorly sorted, positively skewed and strongly mesokurtic. The weighted mean grain size for the horizon is .377 mm (see Appendix A).

Color: brown (10YR4/3)

pH: strongly acid

Organics: abundant, fine disseminated roots and rootlets

Bioturbation: extensive

Cultural Associations: historic and prehistoric

Depositional History: Stratum III is an intermediate horizon lying between the organic rich Ap horizon and the relatively unweathered, massive sands found in Stratum IV.

Stratum IV: (C1)

Extent: Unit IV is a thick sand horizon (C1), which is continuous across the excavated portion of the site. The Unit is conformably overlain by Stratum III (Ap) and disconformably underlain by a truncated paleosol (Unit V). In areas where there has been erosion and mass wasting the unit is truncated and appreciably thinner. The unit ranges in thickness from cm to cm, with a nominal thickness of cm. The C horizon has been variously assigned an E soil designation by Foss (2001). While the horizon does display extensive eluviation of organics and various sesquioxides and clear post depostional leaching. The C horizon designation used in this report implies deposition of the stratum/horizon under moderate to high energy by Aeolian processes.

Texture: sand to loam sand. The horizon shows a high degree of textural variability and sorting. Once again this is likely due to sand emplacement under varying wind energies as well as episodes of deflation leaving behind a slightly coarser lag of sand grians. The weighted mean grain size for the horizon varies by level from .280 mm to .360 mm (see Appendix A). The horizon varies by level from moderately well sorted to poorly sorted.

Color: gray to whiteish gray

pH: strongly acid

Organics: moderate, disseminated carbon

Bioturbation: moderate

Cultural Associations: prehistoric (lithics)

Depositional History: Stratum IV is comprised of a thick, homogeneous package of well sorted aeolian sand. These sands document that over much of the middle to late Holocene the terrace surface has been intermittently deflated/scoured and subsequently capped by wind deposits. Foss (2001) proposed that the horizon was emplaced by Holocene overbanking of the St. Jones River. It is unlikely that the St. Jones River ever breached the surface of the landform on which the site occurs. Given the fact that the site occurs at 35 ft above seal level, the thalweg of the river is at 0.5 m above sea level, and that the ocean lies only several kilometers to the east, base level control would make Holocene flooding of the site impossible. The well-sorted nature of the sands also argues against fluvial deposition, especially given the temporary base level control on the stream channel by the ocean.

Lithostratigraphic Unit II:

Lithostratigraphic Unit II comprises the basal sola at the site and consists of Strata V and VI. The Unit consist of variably textured alluvial sediments of the Pleistocene age Columbia Formation. The uppermost part of the Unit, designated Stratum V consists of a now buried, strongly weathered paleosol, which had developed on the fluvial deposits of the Columbia Formation (see Figures B.4 and B.5). The thickness of the paleosol and evidence of long-term weathering indicates that Stratum V occurred at or near the ground surface or a very long period of time.

The Unit is disconformably overlain by Unit I. The disconformable contact between the two units lies at the base of the C1 horizon.

Stratum V (Bw/Bt horizon)

Extent: Stratum V is horizontally continuous across the excavated portion of the terrace. Vertically, it occurs disconformably below Stratum IV and conformably above Stratum VI (Columbia Formation). The nominal thickness of Stratum V is 12 cm; however, it varies from less than 5 cm to nearly 20 cm in thickness. Along the margins or edges of the terrace, the unit has been truncated by erosion and mass wasting processes.

Texture: reddish brown sandy loam. The weighted mean grain size for the paleosol (B horizon) is .28 mm. The horizon documents a period of long-term stability and in situ weathering. The red coloration is due to this prolonged period of weathering. The horizon coarsens upward which may indicate translocation of fines downprofile over time. The

Color: reddish brown

pH: strongly acid

Organics: minimal, disseminated carbon

Bioturbation: minimal

Cultural Associations: late Paleoindian, Dalton-Hardaway projectile points have been recovered from the top of the palesol

Depositional History: Stratum V is a buried paleosol having formed on the weathered Pleistocene Columbia Formation. The reddish color, occurrence of clays and moderate structure indicate a soil which has undergone an extended period of in situ weathering. In all likelihood, the unit remained exposed at the ground surface for much of the late Wisconsin Stage subsequently being buried by middle Holocene Aeolian activity. The restricted occurrence of Dalton Hardaway projectile points on the surface of the unit/horizon provides a probable age of 10,000 B.P.

Stratum VI: (Columbia Formation)

Extent: Stratum VI is horizontally continuous across the terrace surface and represents the basal stratum at the Beech Ridge Site. Stratigraphically, Stratum VI occurs conformably below Unit V. The maximum depth to the top of Stratum V is 110 cm below ground surface.

Texture: gravelly pebbly sand. These deposits were emplaced under varying flow velocities during the Pleistocene. In some of the deeper auger probes, silty facies (overbank, slackwater) interfinger with coarse grained (cobbly to pebbly sands) point bar and channel bar deposits. This variation in texture and sorting is clearly shown on select plots in Appendix A.

Color: grayish brown to gray

pH: very strongly acid

Organics: minimal to absent

Bioturbation: minimal

Cultural Associations: None

Depositional History: Stratum VI represents Pleistocene age coarse grained alluvium of the Columbia Formation.

REFERENCES

Bloom, Arthur L.

1983 Sea Level and Coastal Changes. In *Late Quaternary Environments of the United States.* Vol.2 *The Holocene* edited by H.E. Wright, Jr., pp42-51. University of Minnesota Press, Minneapolis

Brush, Grace S.

1986 Geology and Paleoecology of Chesapeake Bay: A Long-Term Monitoring Tool for Management. *Journal of the Washington Academy of Sciences* 76(3):156-160.

Bryson, R.A., Barris, D.A., and R.M. Wendland

1970 The Character of Late-Glacial and Post-Glacial Climatic Changes. In *Pleistocene and Recent Environments of the Central Great Plains*, edited by W. Dort, Jr., and J.K. Jones, Jr., pp.53-74. University of Kansas Press, Lawrence.

Carbone, Victor A.

1976 Environment and Prehistory in the Shenandoah Valley. Ph.D. dissertation, The Catholic University of America, Washington D.C.

COHMAP

1987 Climatic Changes of the Last 18,000 years: Observations and Model Simulations. *Science* 241:1034-1052.

Crowl, G. H., and W. D. Sevon

1980 *Glacial Border Deposits of Late Wisconsinan Age in Northeastern Pennsylvania*. Pennsylvania Geological Survey, Fourth Series, General Geology Report 71. Harrisburg.

Curry, Dennis C., and Jay F. Custer

1982 Holocene Climatic Change in the Middle Atlantic Area: Preliminary Observations from Archaeological Sites. *North American Archaeologist* 3(4): 275-285.

Custer, Jay F.

1984 *Delaware Prehistoric Archaeology, An Ecological Approach*. University of Delaware Press, Newark.

Davis, Margaret B.

1983 Holocene Vegetational History of the Eastern United States. In *Late Quaternary Environment of the United States, Volume 2, The Holocene,* edited by H. E. Wright, Jr., pp. 166-181. University of Minnesota Press, Minneapolis.

Delcourt, Paul A. and Hazel R. Delcourt

1981 Vegetation Maps for Eastern North America: 40,000 Yr. B.P. to the Present. In *Geobotany II*, edited by R.C. Romans, pp.123-165. Plenum Press, New York

1985 Quaternary Palynology and Vegetational History of the Southeastern United States. In *Pollen Records of Late Quaternary North American Sediments*, edited by Vaughn Bryant and R.G. Holloway, pp.1-37. American Association of Stratigraphic Palynologists Foundation.

Ebright, Carol A.

1992 Early Native American Prehistory on the Maryland West Shore: Archaelogical Investigation at the Higgins Site. Volume 1. Maryland State Highway Administration Project Planning Division Environment Evaluation Section Archaeological Report Number 1.

Eschelman, Ralph and F. Grady

1986 Quaternary Vertebrate Locations of Virginia and their Avian and Mammalian Fauna. *Virginia Division of Mineral Resources Publication* 75:43-70

Friedman, G.M. and J.E. Sanders

1978 *Principles of Sedimentology*. John Wiley and Sons, Ltd., New York.

Glaser, John D.

1971 *Geology and Mineral Resources of Southern Maryland. Maryland Geological Survey. Report of Investigations No.15.*

Guilday, John E.

1965 Bone Refuse from the Lamoka Lake Site. In *The Archaeology of New York State* by W. Ritchie.

1967 The Climatic Significance of the Hosterman's Pit Local Fauna, Centre County, Pennsylvania. *American Antiquity* 32(2): 231-232.

1969 Faunal Remains from Dutchess Quarry Cave No. 1. In The Archaeology of Dutchess Quarry Cave, Orange County, New York, by Robert E. Funk, George R. Walters, and William F. Ehlers, Jr., pp. 17-19. *Pennsylvania Archaeologist* 39(1-4): 7-28.

Guilday, J.E. and P.W. Parmalee

1965 Animal Remains from Sheep Rock Shelter. Huntingdon County, Pennsylvania. *Pennsylvania Archaeologist* 35 (1) 34-39.

Guilday, John E., Paul S. Martin, and Allan D. McCrady

1964 New Paris No. 4: A Late Pleistocene Cave Deposit in Bedford County, Pennsylvania. *National Speleological Society Bulletin* 26(4): 121-194.

Guilday, John E.

1971 The Pleistocene History of the Appalachian Mammal Fauna. In *The Distributional History of the Biota of the Southern Appalachians, Part III: Vertebrates*, edited by Perry C. Holt, pp. 233-262. Virginia Polytechnic Institute and State University, Research Division Monograph 4. Blacksburg.

Joyce, Arthur A.
1988 Early/Middle Holocene Environments in the Middle Atlantic Region: A Revised Reconstruction. In *Holocene Human Ecology in Northeastern North America*, edited by George P. Nicholas, pp. 185-214. Plenum Press, New York.

Knox, J.C
1983 Responses of River Systems to Holocene Climates. In *Late-Quaternary Environments of the United States, Vol. 2, The Holocene*, edited by H.E. Wright, Jr., pp. 26-41. University of Minnesota Press, Minneapolis.

Kraft, John C.
1985 Marine Environments: Paleogeographic Reconstructions in the Littoral Region. In *Archaeological Sediments in Context*, edited by Julie K. Stein and William R. Farrand, pp.111-125. University of Maine, Orono.

Kutzbach, J.E. and H.E. Wright, Jr.
1983 Simulation of The Climate of 18,000 Years BP: Results For The North American/North Atlantic/European Sector and Comparison with the Geologic Record of North America. *Quaternary Science Reviews*: 4: 147-187.

LeeDecker, Charles H., and Cheryl A. Holt
1991 Archaic Occupations at the Indian Creek V Site (18PR94) Prince Georges County, Maryland. *Journal of Middle Atlantic Archaeology* 7: 67-90.

Lundelius, E. L., Jr., R. W. Graham, E. Anderson, J. Guilday, J. Holman, A. Steadmand and S. D. Webb
1983 Terrestrial Vertebrate Faunas. In *Late Quaternary Environments of the United States*, Volume 1, *The Late Pleistocene*, edited by S. C. Porter, Jr., pp.311-353. University of Minnesota Press, Minneapolis.

Semken, H.A. Jr.
1974 Micromammal Distribution and Migration during the Holocene. In *American*

1975 *Quaternary Association, Third Biennial Meeting, Abstracts*, p.25. University of Wisconsin, Madison.

Sirkin, Leslie A., C. S. Denny, and M. Rubin
1977 Late Pleistocene Environment of the Central Delmarva Peninsula, Delaware-Maryland. *Geological Society of America* Bulletin 88:139-142.

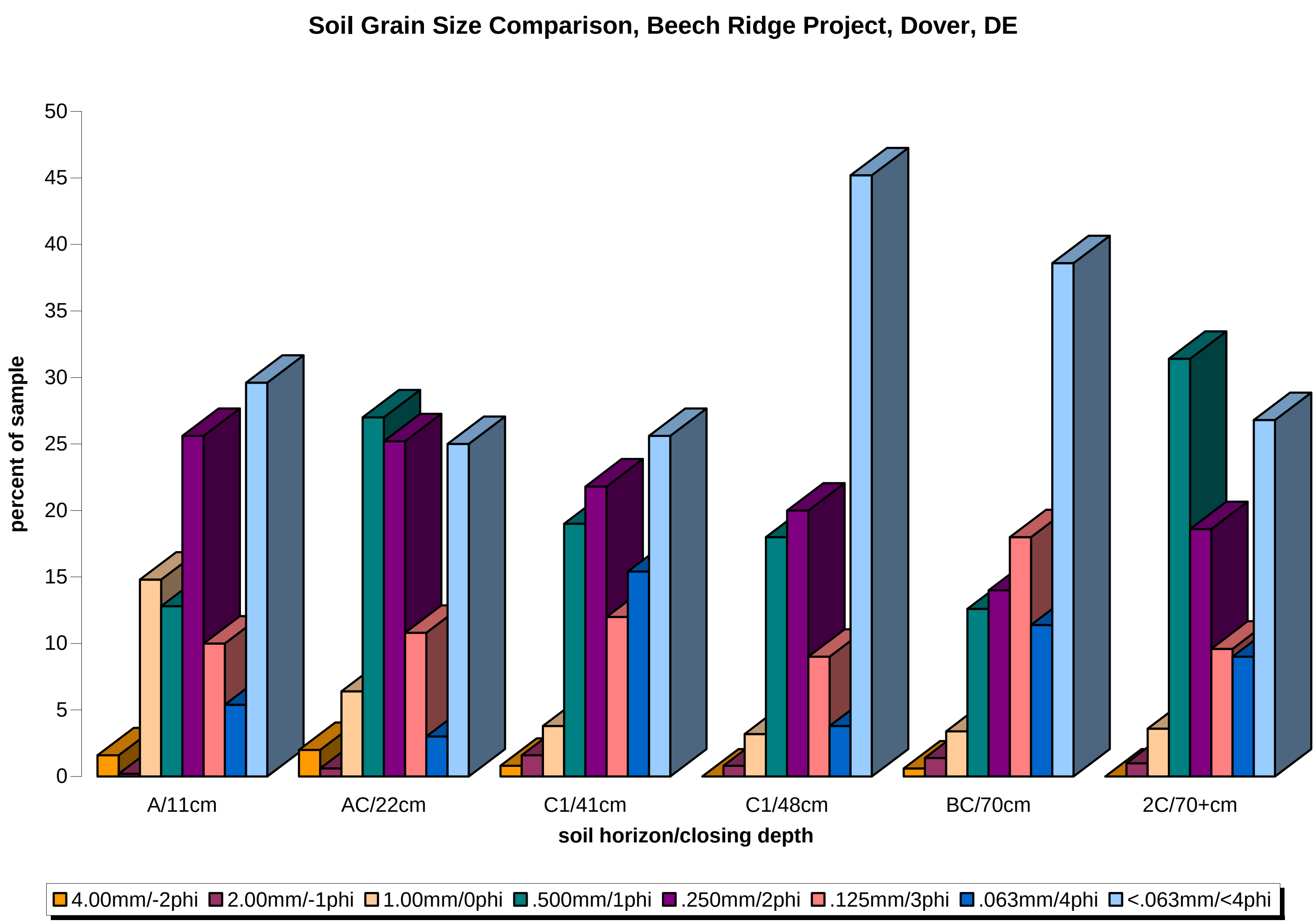
Thornbury, R
1965 *Physiography of the United States*. Wiley and Sons, New York, New York

Vento, Frank J., James M. Adovasio, and Jack Donahue
1980 *Excavations at Dameron Rock Shelter (15JO23A), Johnson County, Kentucky*. Department of Anthropology, University of Pittsburgh, Ethnology Monographs 4. Pittsburgh, Pennsylvania.

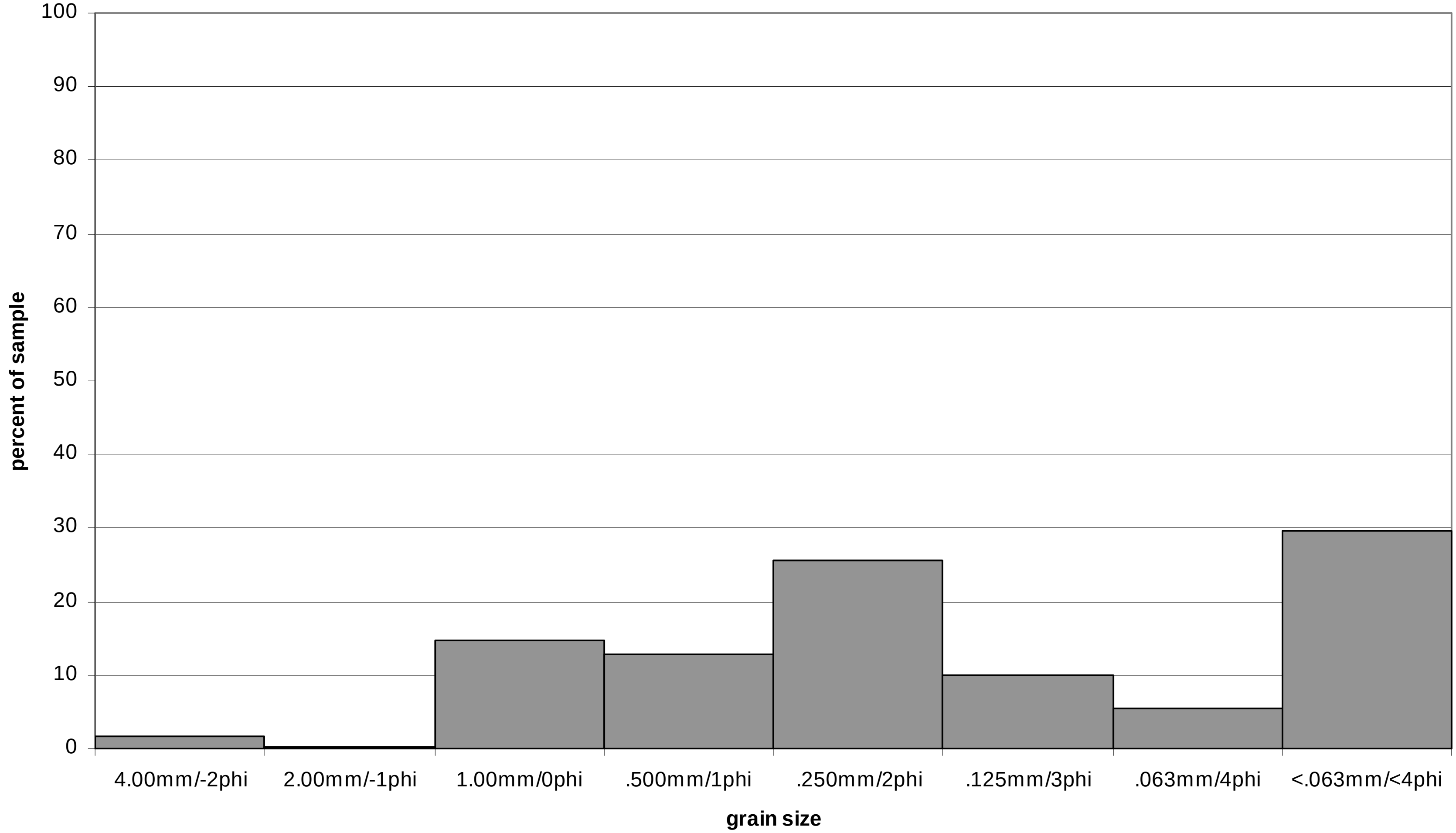
Whitehead, D. R.
1972 Developmental History of Dismal Swamp. *Ecological Monographs* 42:42:301-315.

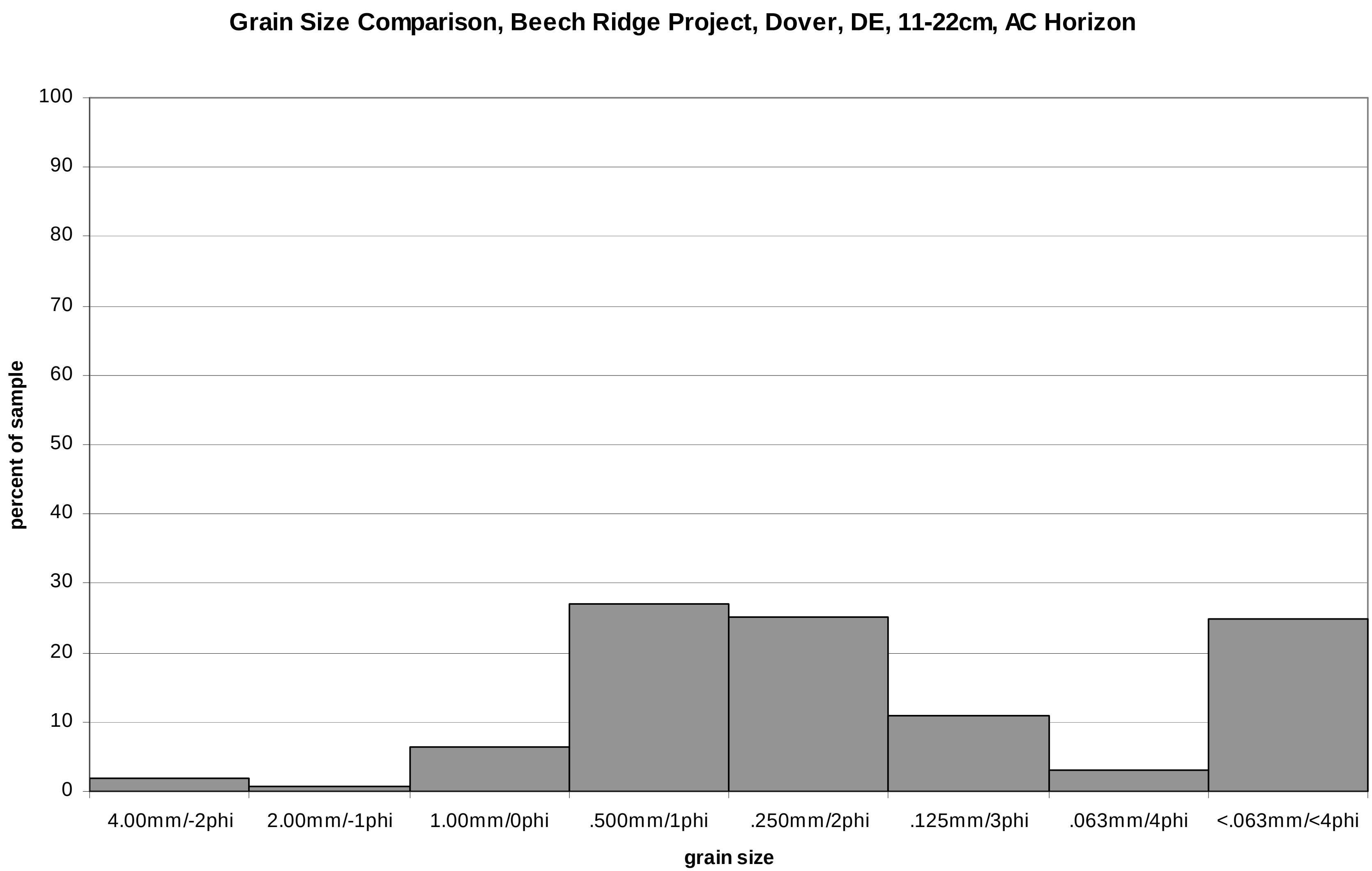
Winkler, M.G.
1985 A 12,000-Year History of Vegetation and Climate for Cape Cod, Massachusetts. *Quaternary Research* 23:301-312

APPENDIX I.B – GRANULOMETRIC RESULTS

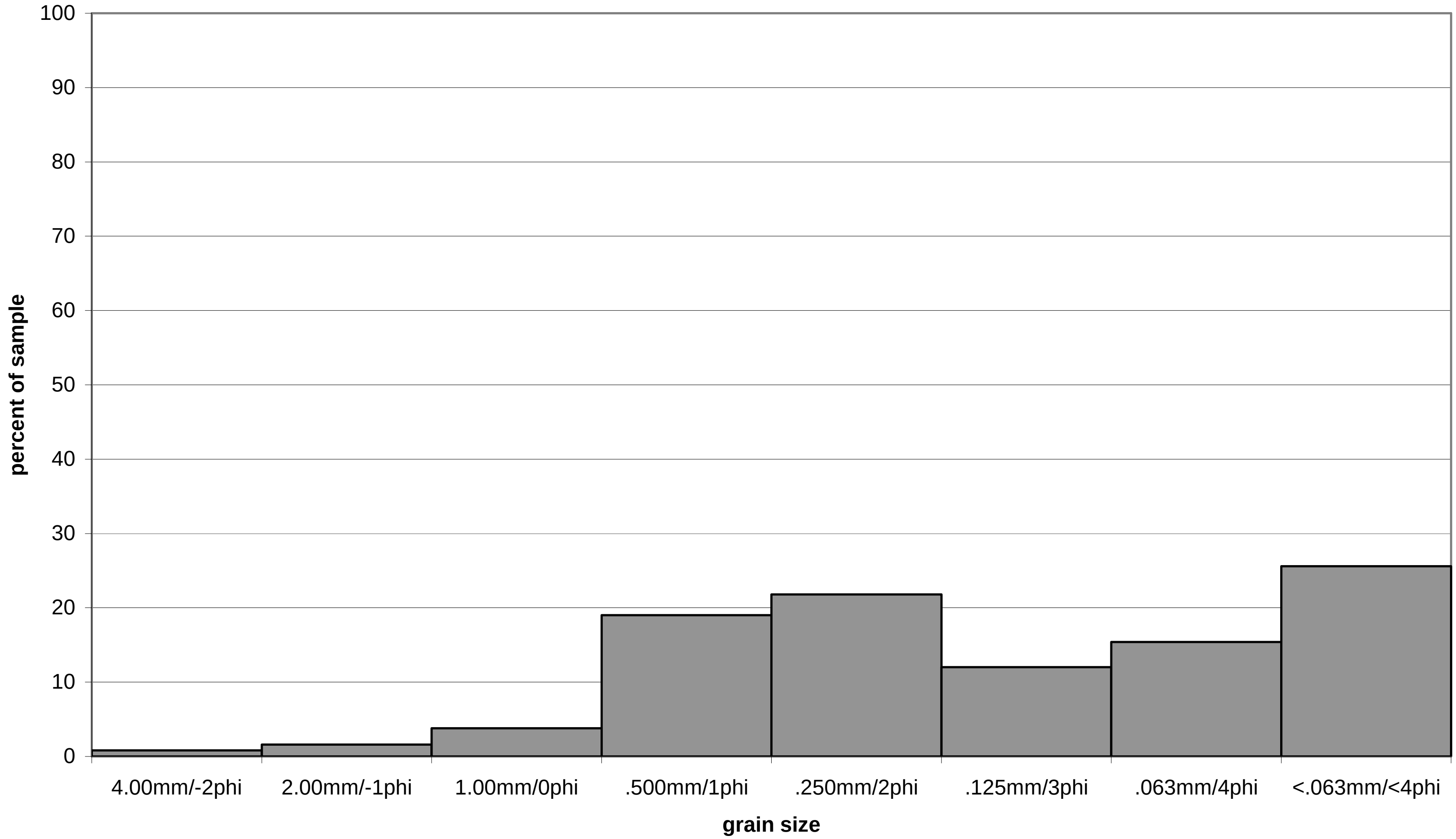

Soil Grain Size Comparison, Beech Ridge Project, Dover, DE
percent of sample
0
5
10
15
20
25
30
35
40
45
50
A/11cm
AC/22cm
C1/41cm
C1/48cm
BC/70cm
2C/70+cm
soil horizon/closing depth
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi

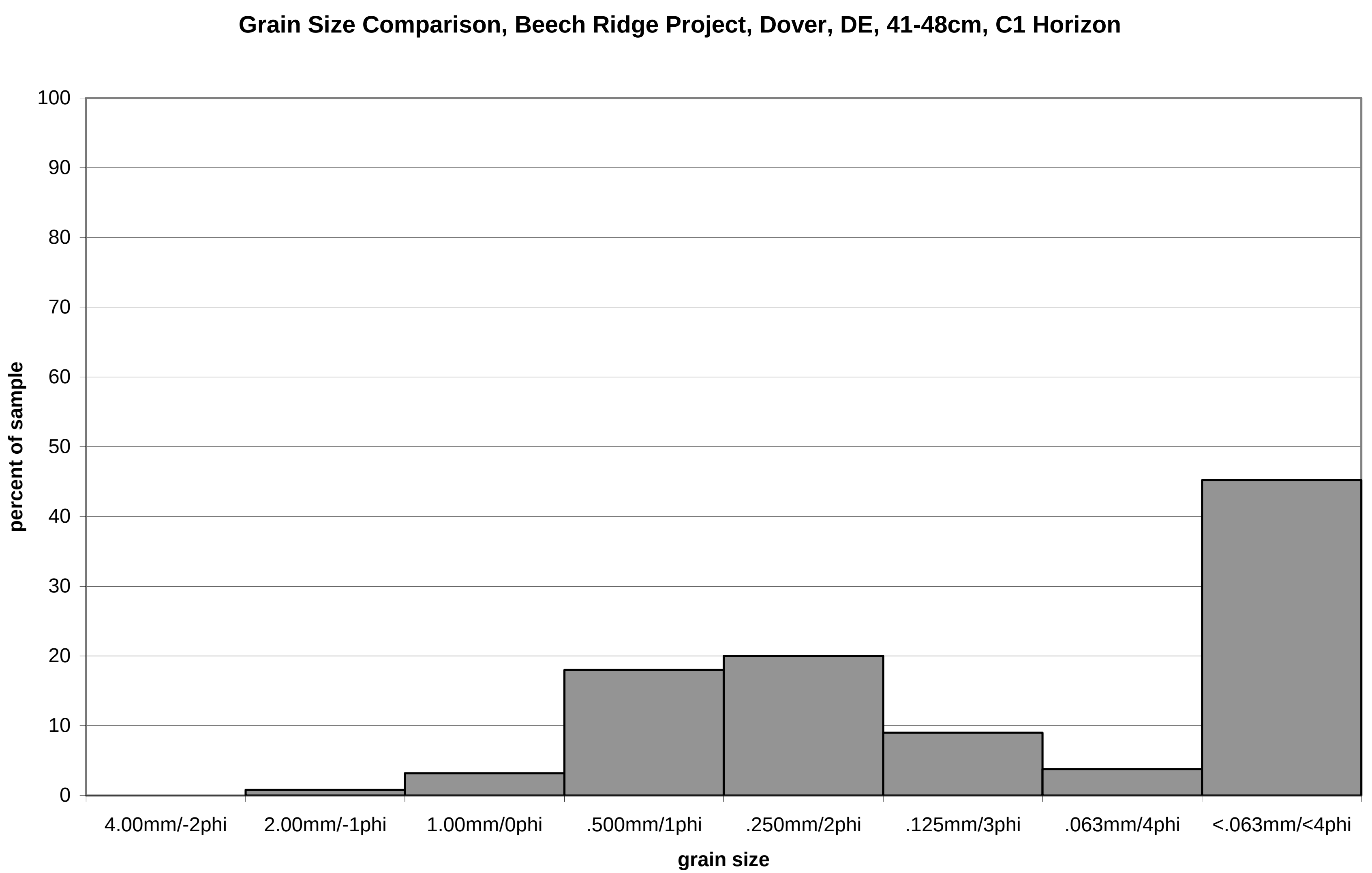
Grain Size Comparison, Beech Ridge Project, Dover, DE, 2-11cm, A Horizon,



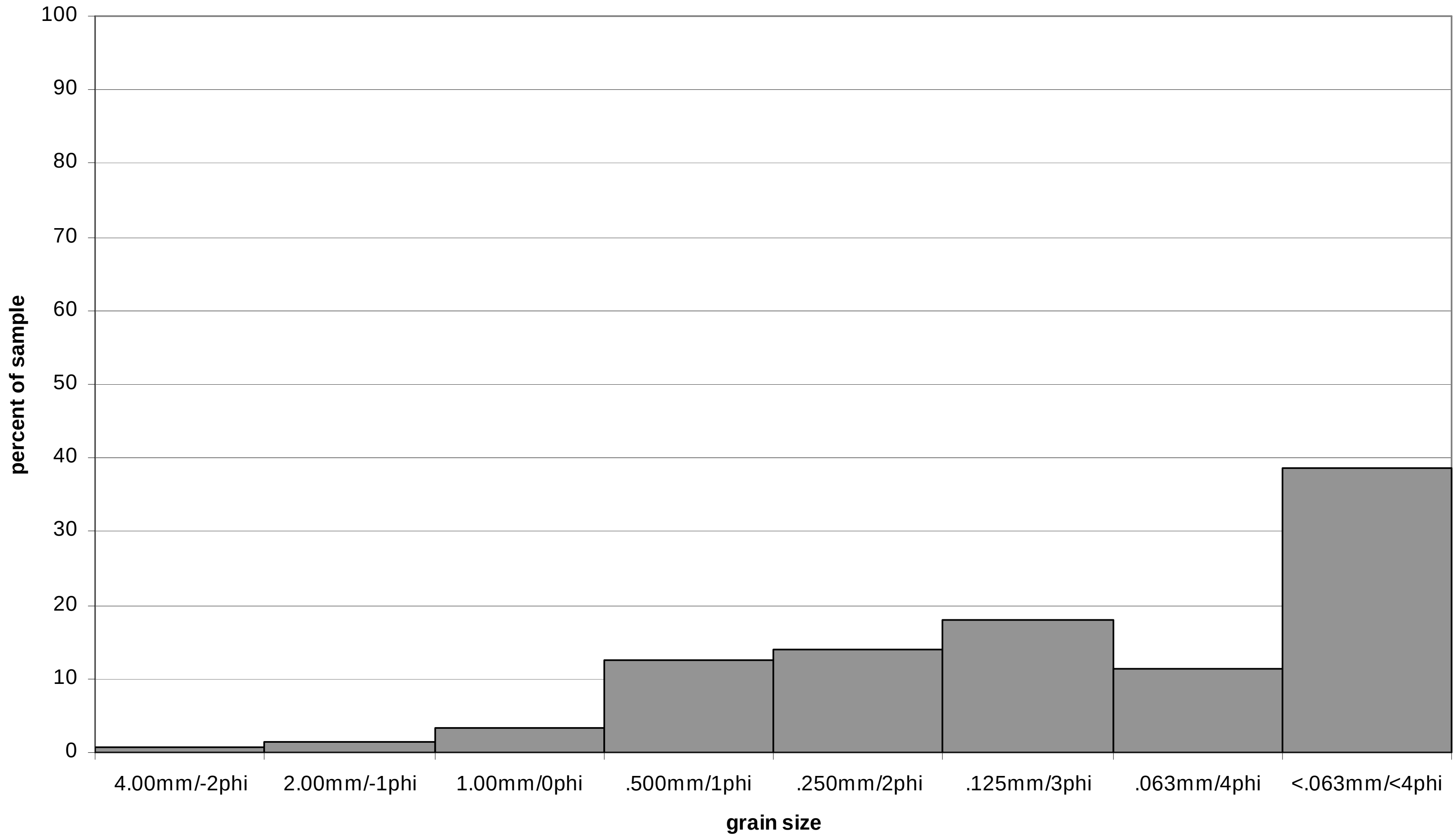

Grain Size Comparison, Beech Ridge Project, Dover, DE, 11-22cm, AC Horizon
100
90
80
70
60
50
40
30
20
10
0
percent of sample
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, 22-41cm, C1 Horizon

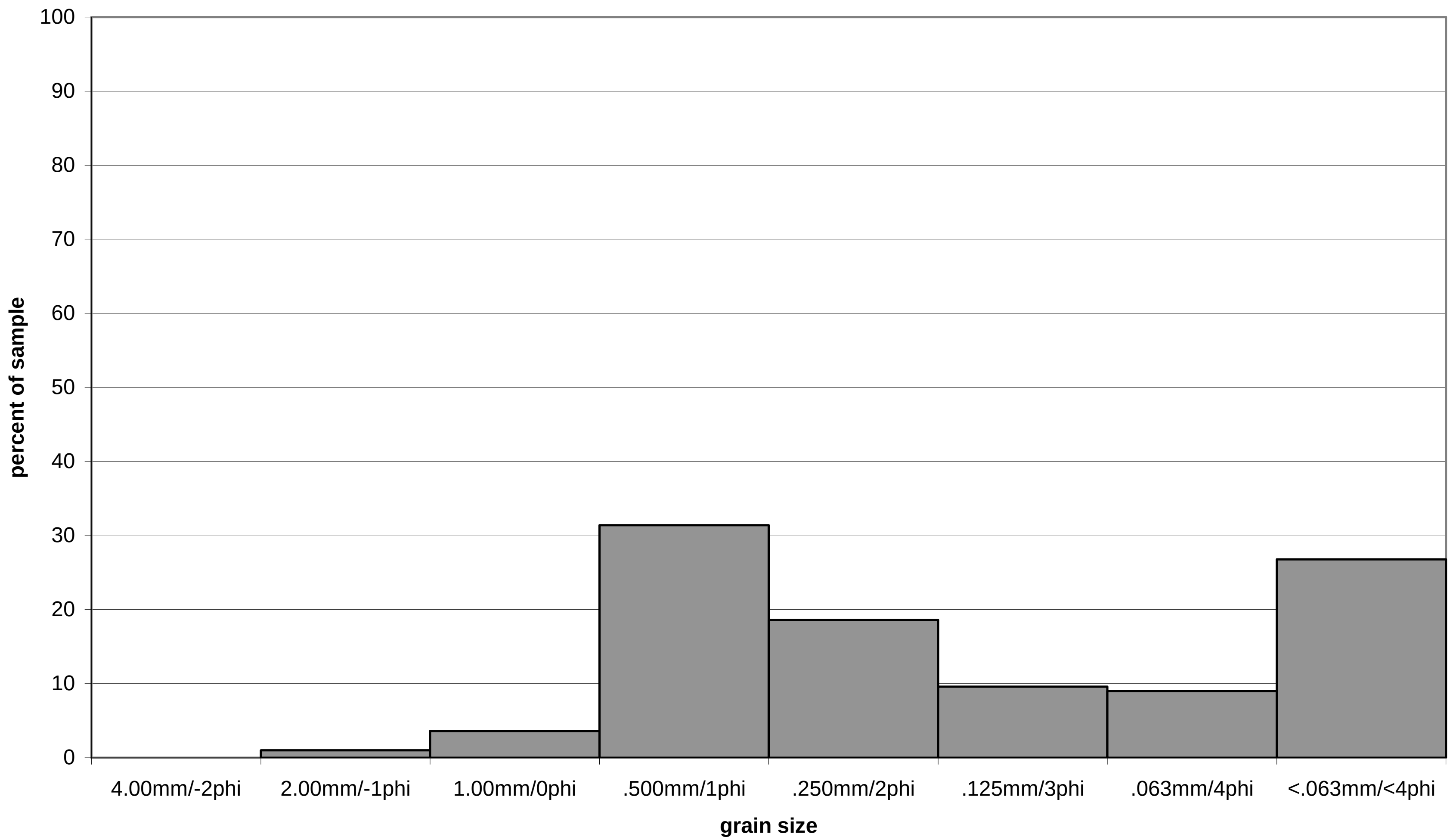



Grain Size Comparison, Beech Ridge Project, Dover, DE, 41-48cm, C1 Horizon
100
90
80
70
60
50
40
30
20
10
0
percent of sample
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

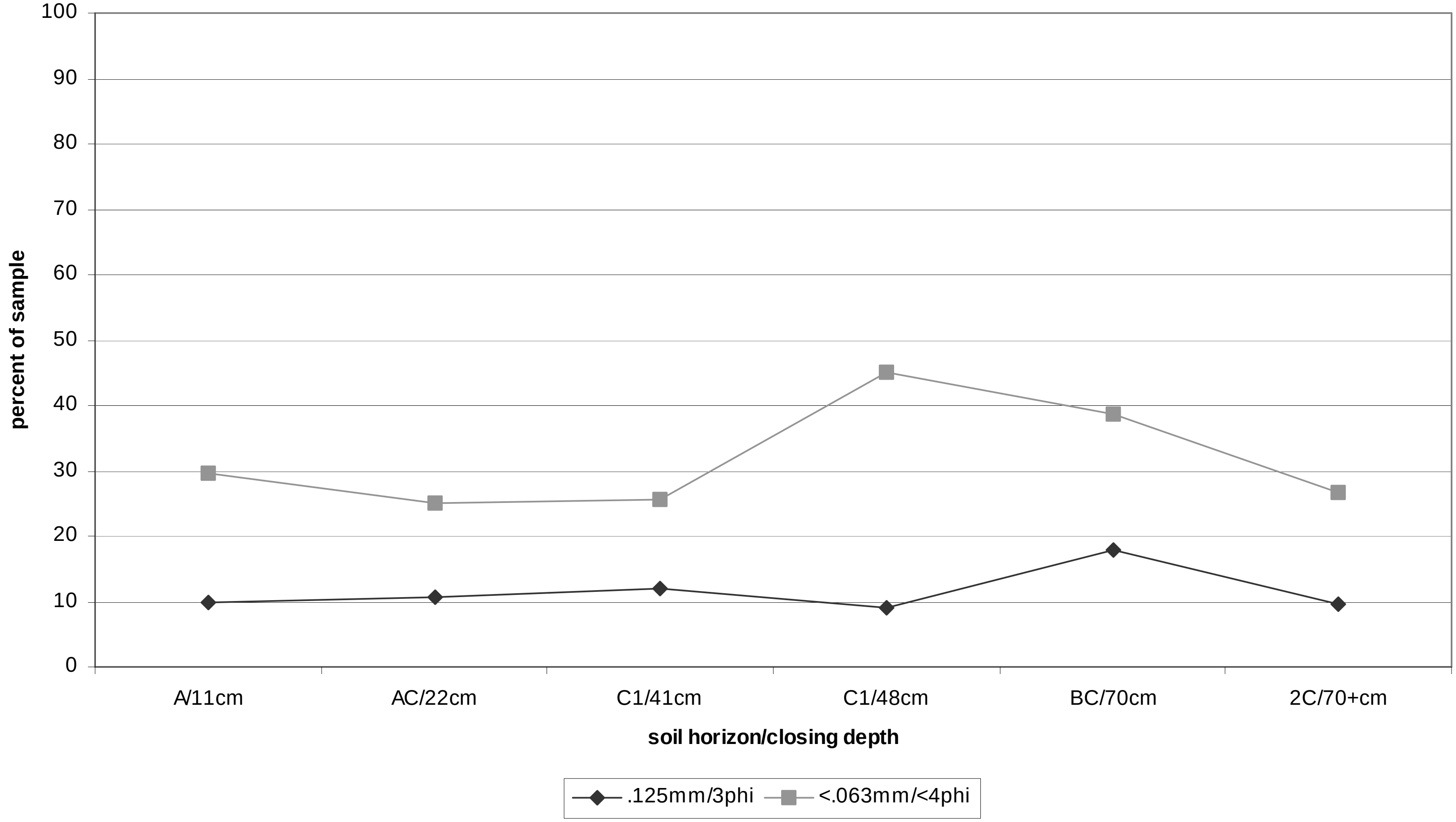
Grain Size Comparison, Beech Ridge Project, Dover, DE, 48-70cm, BC Horizon



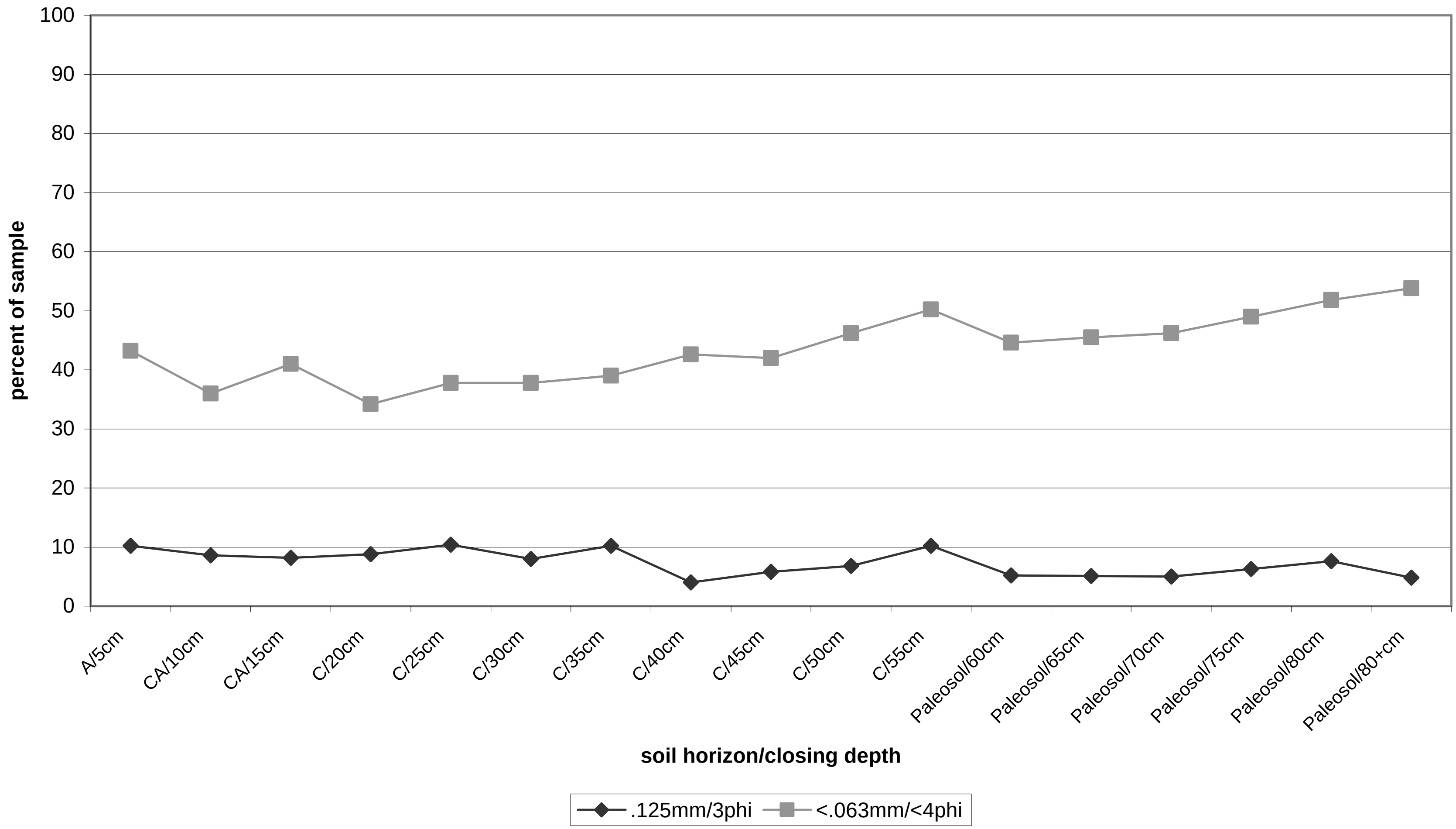
Grain Size Comparison, Beech Ridge Project, Dover, DE, 70+ cm, 2C Horizon

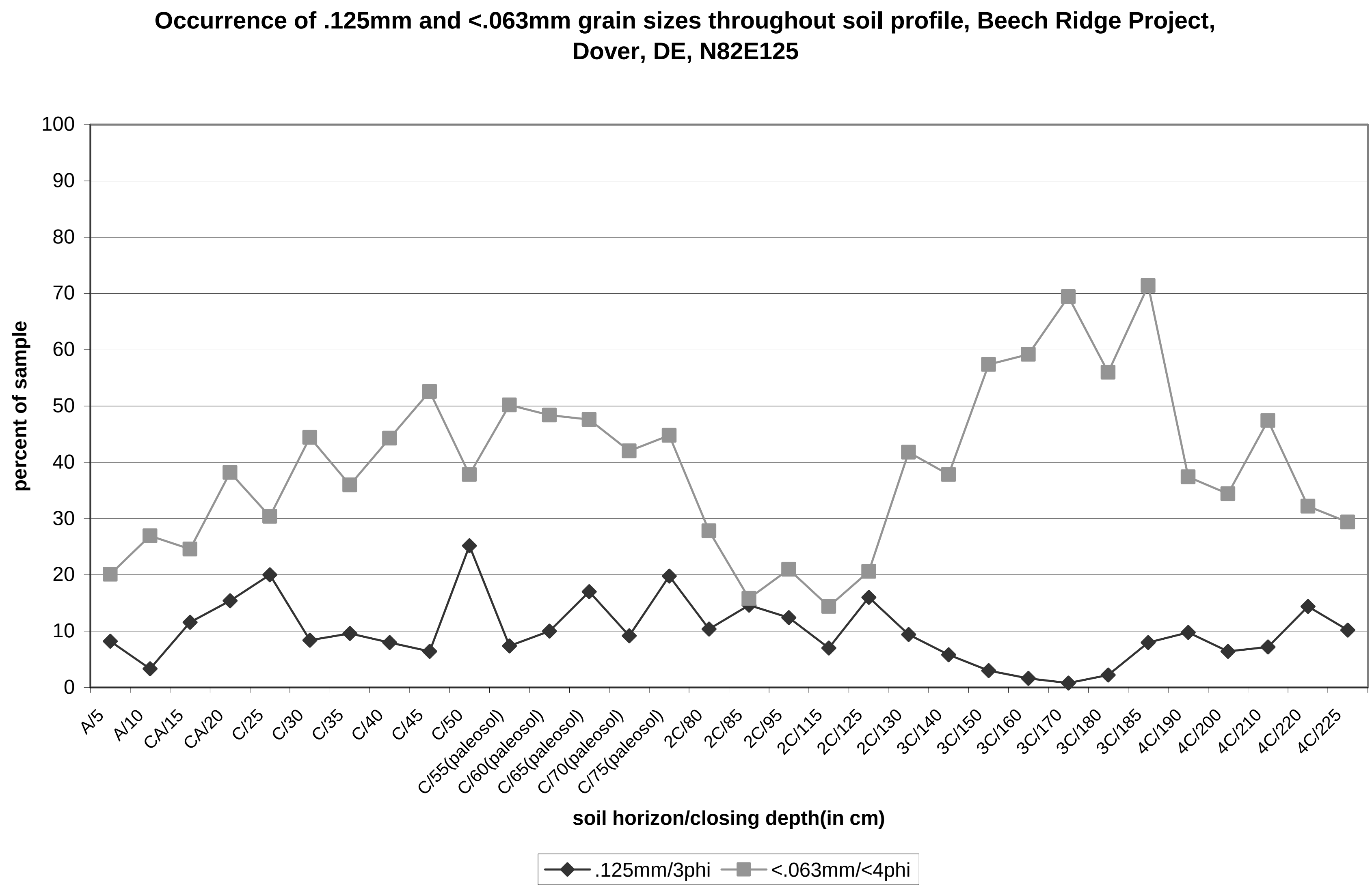


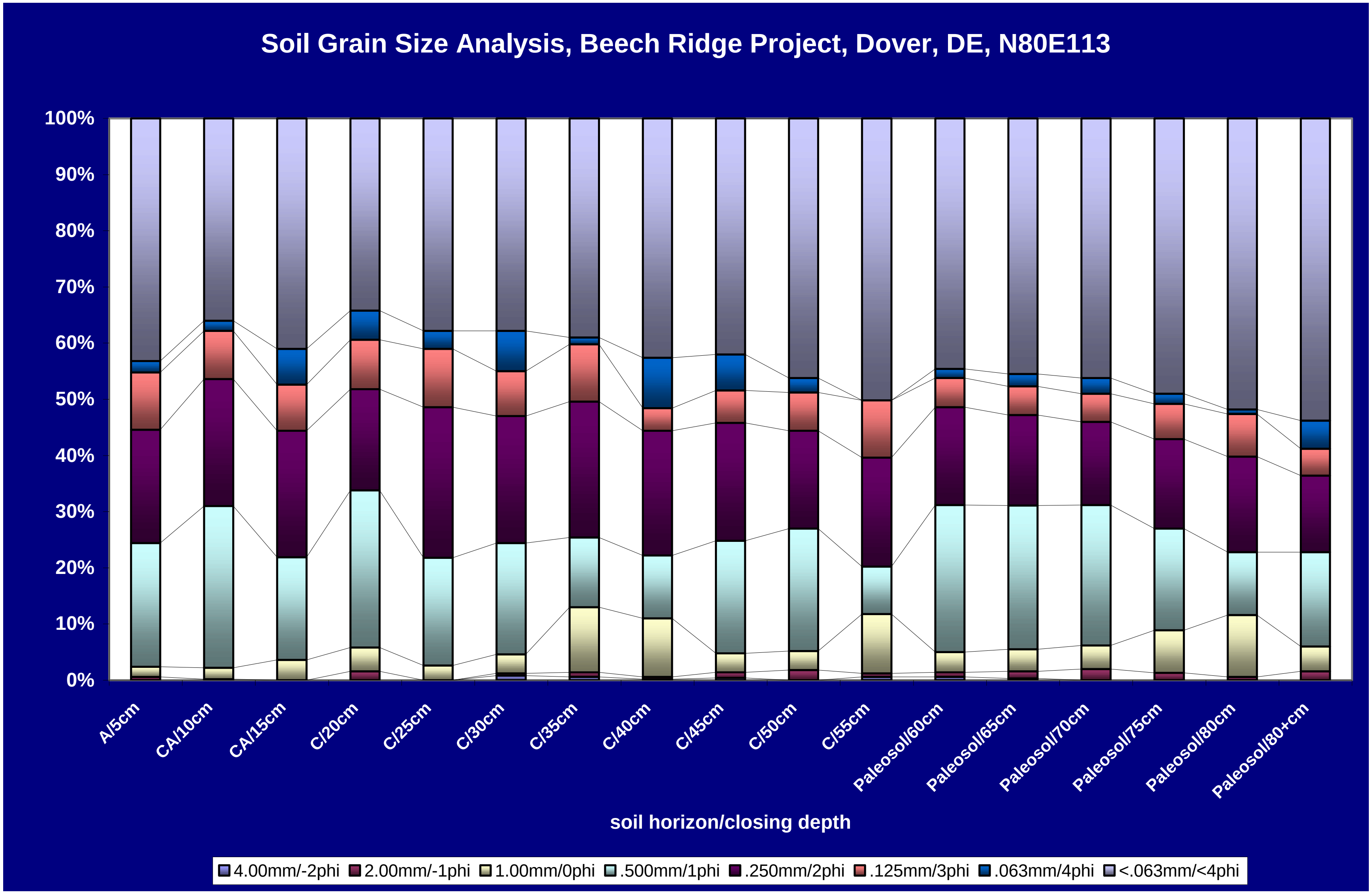
Occurrence of .125mm and <.063mm grain sizes throughout soil profile, Beech Ridge Project, Dover, DE

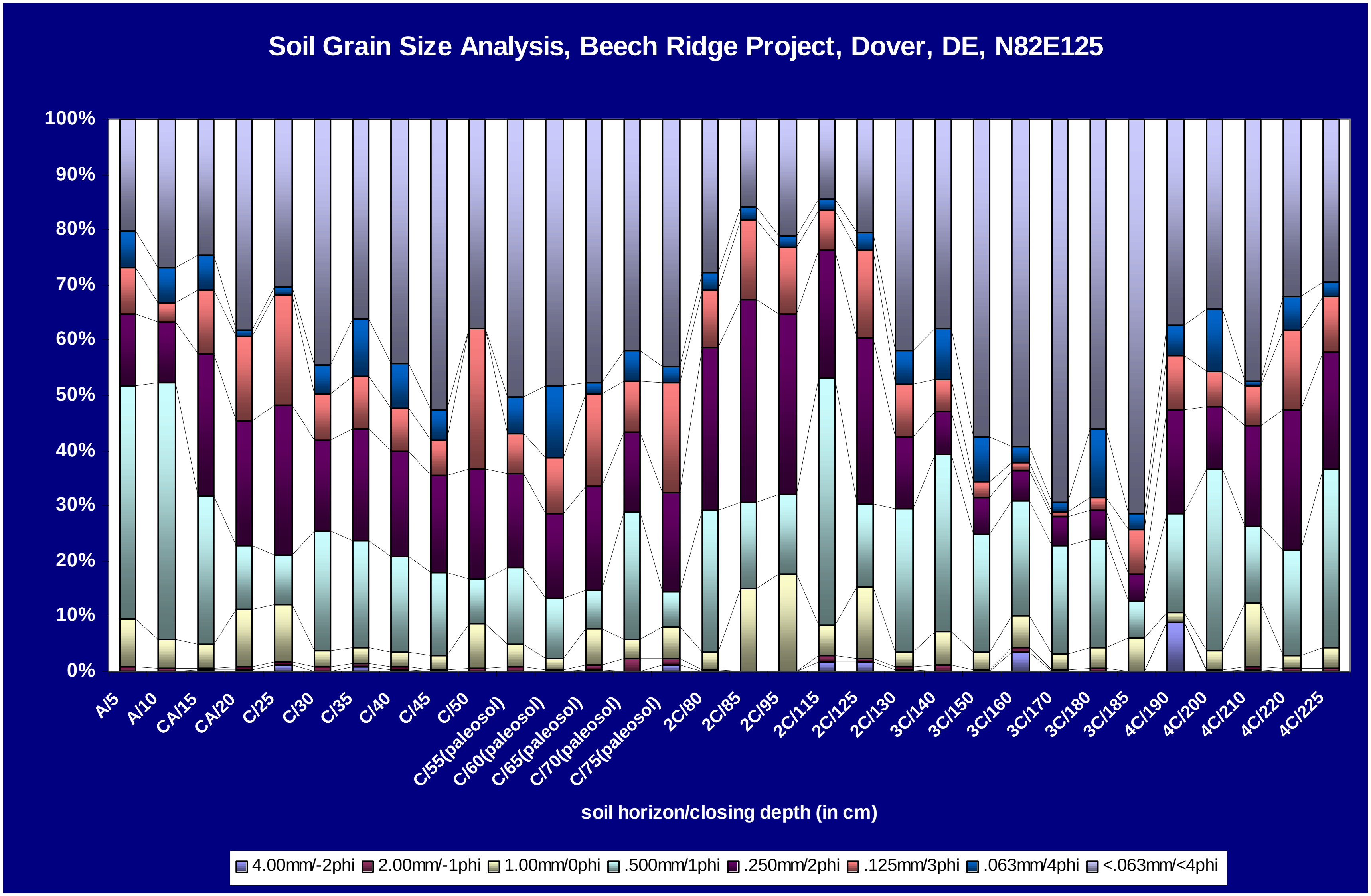


Occurrence of .125mm and <.063mm grain sizes throughout soil profile, Beech Ridge Project, Dover, DE, N80E113

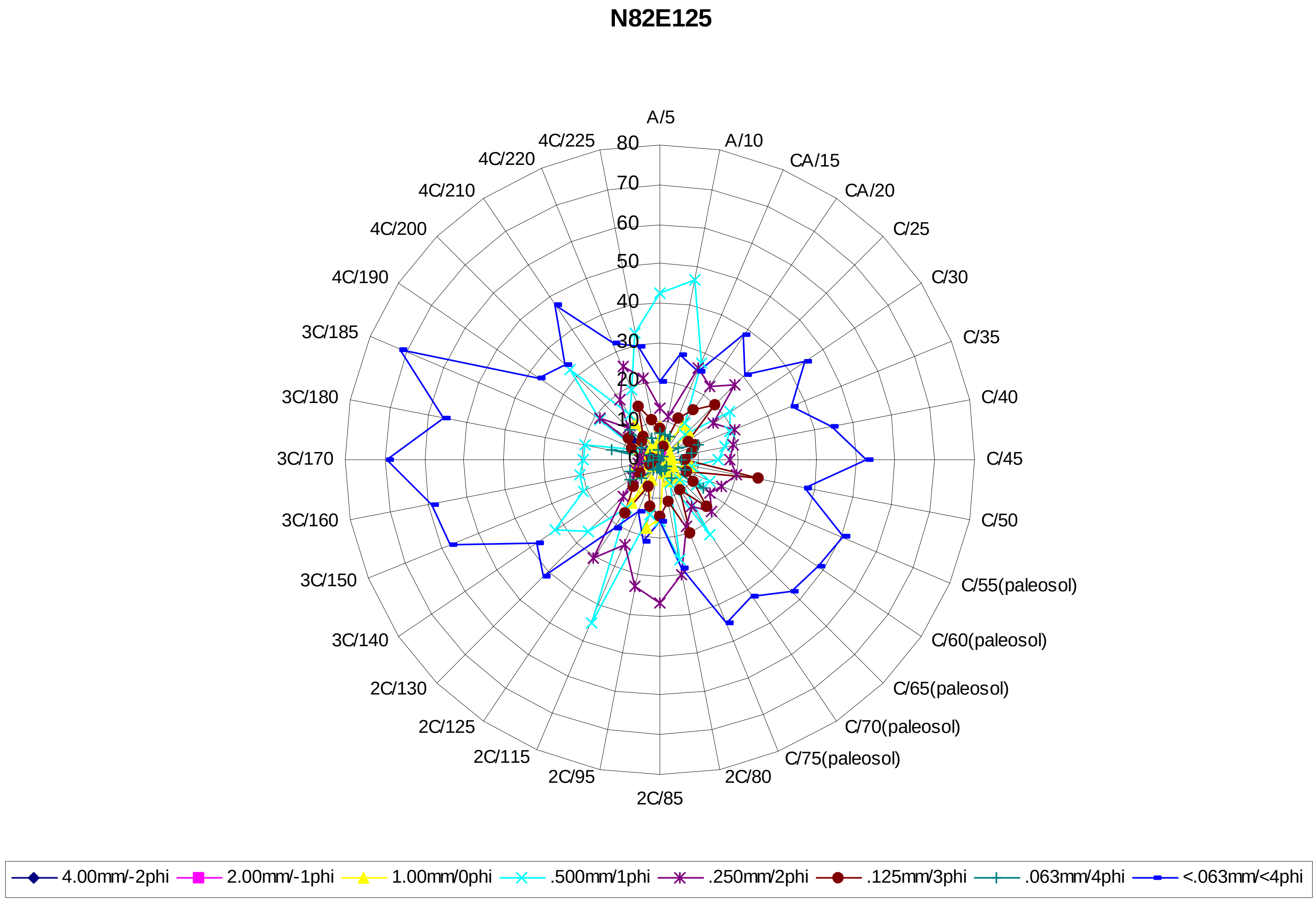



Occurrence of .125mm and <.063mm grain sizes throughout soil profile, Beech Ridge Project, Dover, DE, N82E125
percent of sample
100
90
80
70
60
50
40
30
20
10
0
A/5
A/10
CA/15
CA/20
C/25
C/30
C/35
C/40
C/45
C/50
C/55(paleosol)
C/60(paleosol)
C/65(paleosol)
C/70(paleosol)
C/75(paleosol)
2C/80
2C/85
2C/95
2C/115
2C/125
2C/130
3C/140
3C/150
3C/160
3C/170
3C/180
3C/185
4C/190
4C/200
4C/210
4C/220
4C/225
soil horizon/closing depth(in cm)
.125mm/3phi
<.063mm/<4phi

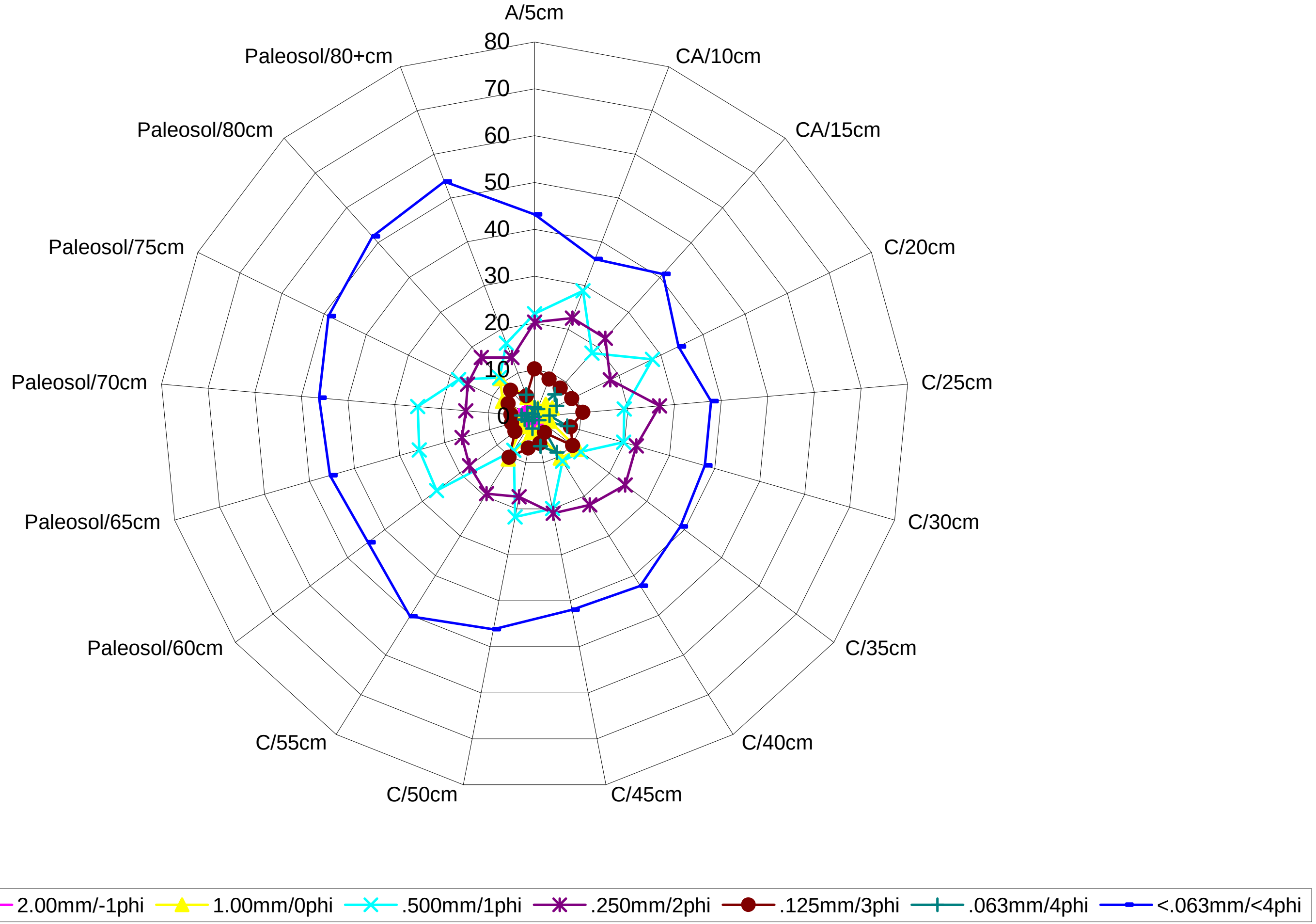

Soil Grain Size Analysis, Beech Ridge Project, Dover, DE, N80E113
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
A/5cm
CA/10cm
CA/15cm
C/20cm
C/25cm
C/30cm
C/35cm
C/40cm
C/45cm
C/50cm
C/55cm
Paleosol/60cm
Paleosol/65cm
Paleosol/70cm
Paleosol/75cm
Paleosol/80cm
Paleosol/80+cm
soil horizon/closing depth
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi



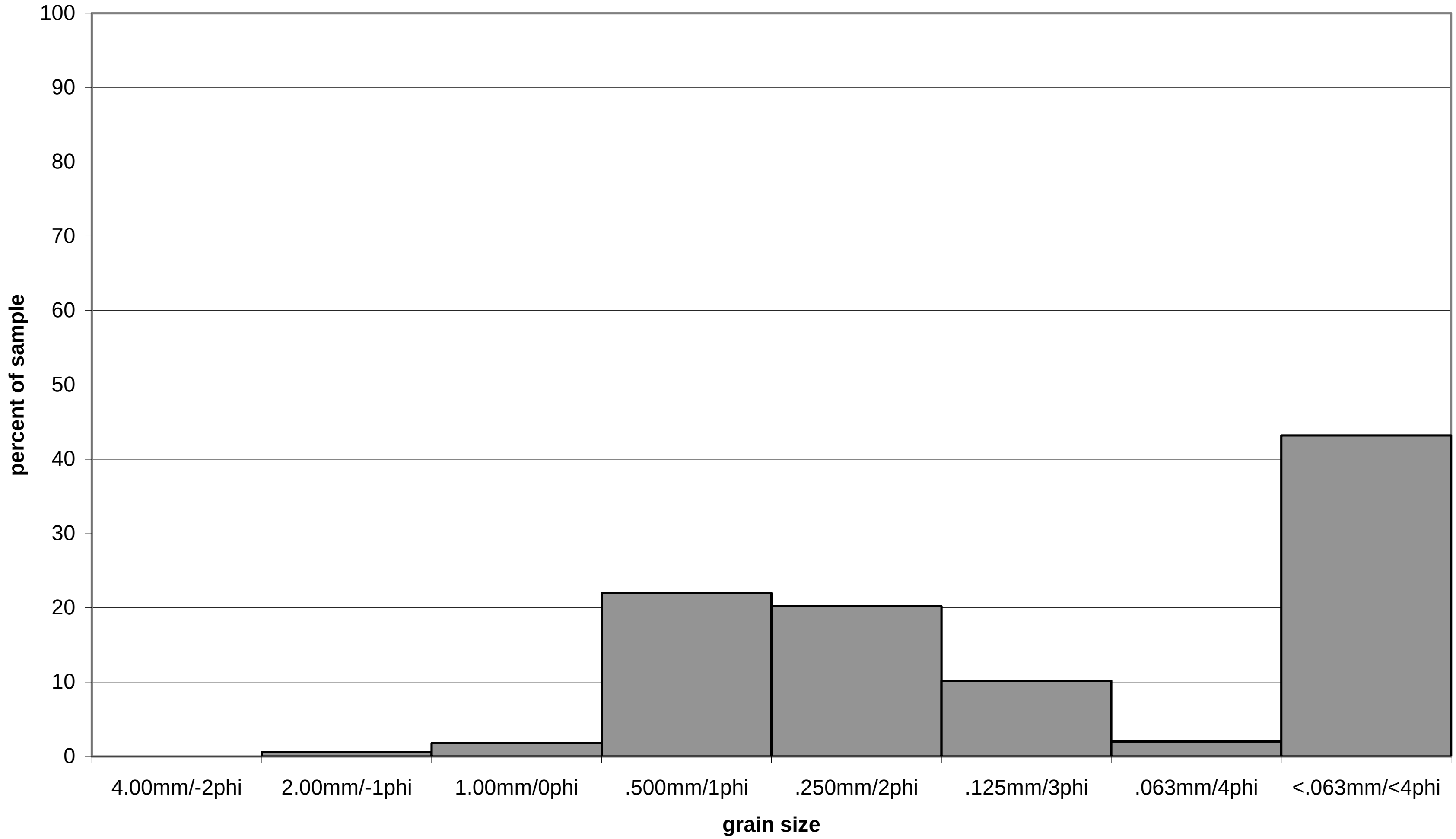
Soil Grain Size Analysis, Beech Ridge Project, Dover, DE, N82E125
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
A/5
A/10
CA/15
CA/20
C/25
C/30
C/35
C/40
C/45
C/50
C/55(paleosol)
C/60(paleosol)
C/65(paleosol)
C/70(paleosol)
C/75(paleosol)
2C/80
2C/85
2C/95
2C/115
2C/125
2C/130
3C/140
3C/150
3C/160
3C/170
3C/180
3C/185
4C/190
4C/200
4C/210
4C/220
4C/225
soil horizon/closing depth (in cm)
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi

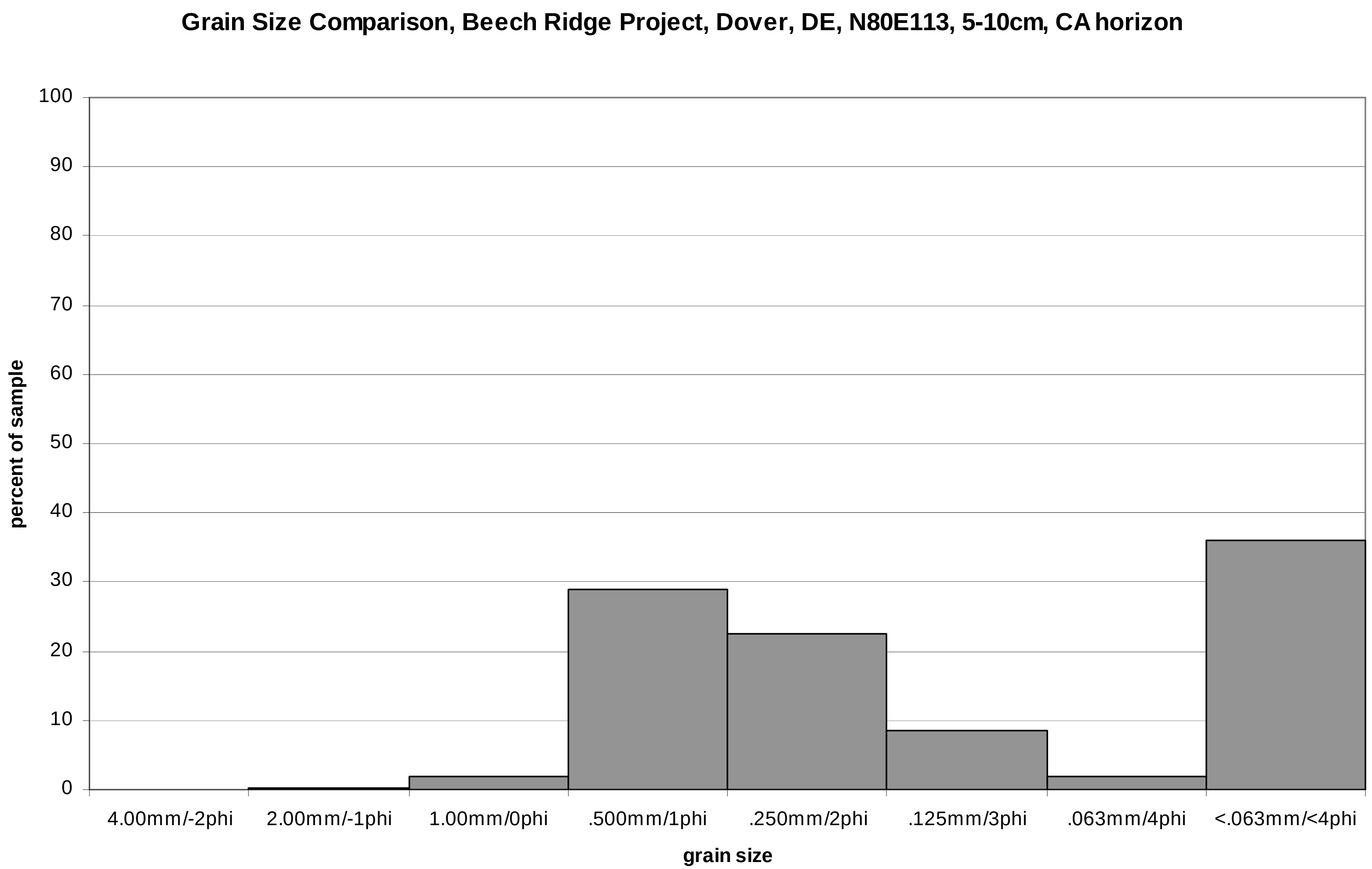

N82E125
A/5
A/10
CA/15
CA/20
C/25
C/30
C/35
C/40
C/45
C/50
C/55(paleosol)
C/60(paleosol)
C/65(paleosol)
C/70(paleosol)
C/75(paleosol)
2C/80
2C/85
2C/95
2C/115
2C/125
2C/130
3C/140
3C/150
3C/160
3C/170
3C/180
3C/185
4C/190
4C/200
4C/210
4C/220
4C/225
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi

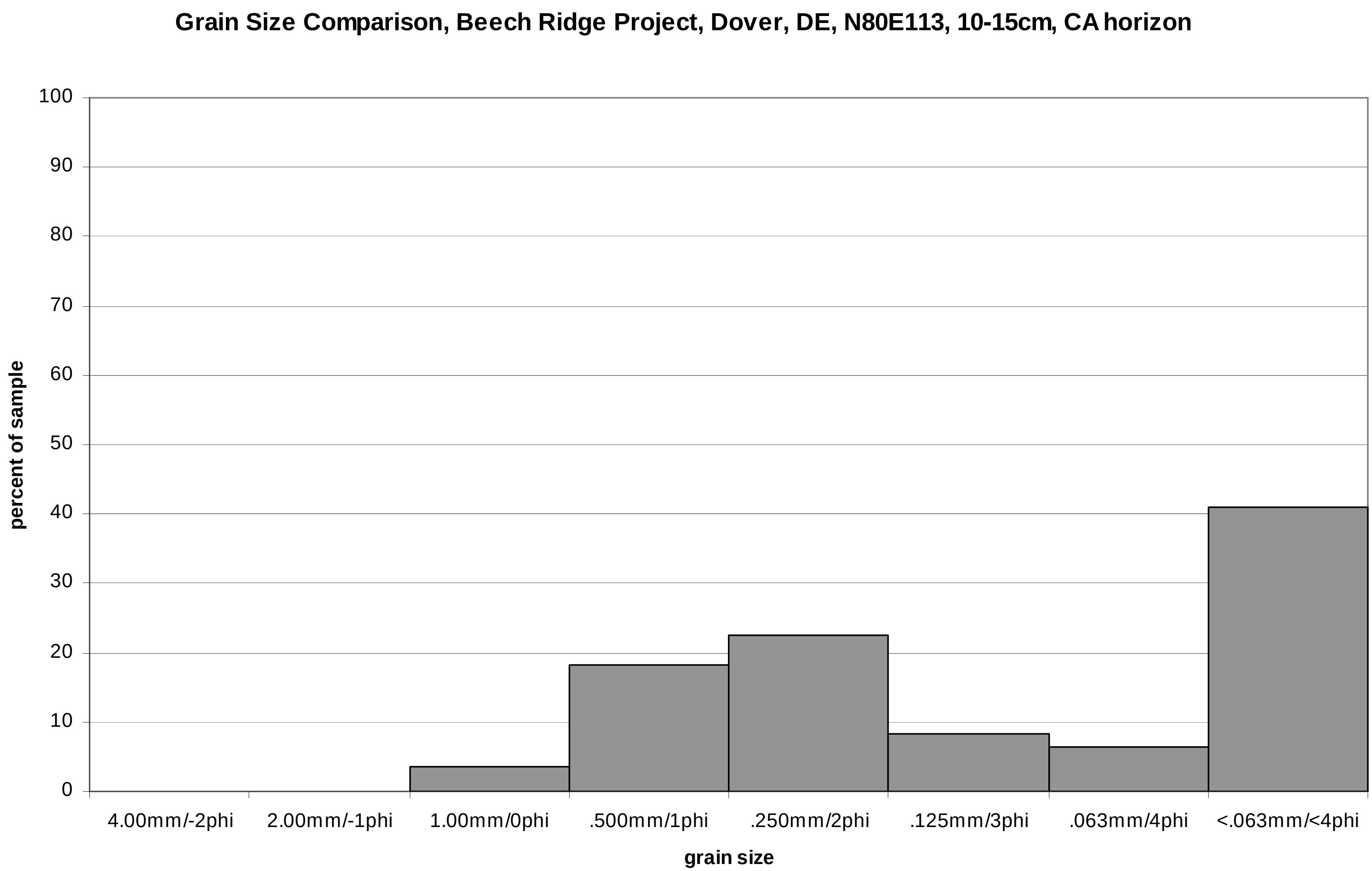
N80E113


A/5cm
CA/10cm
CA/15cm
C/20cm
C/25cm
C/30cm
C/35cm
C/40cm
C/45cm
C/50cm
C/55cm
Paleosol/60cm
Paleosol/65cm
Paleosol/70cm
Paleosol/75cm
Paleosol/80cm
Paleosol/80+cm
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi

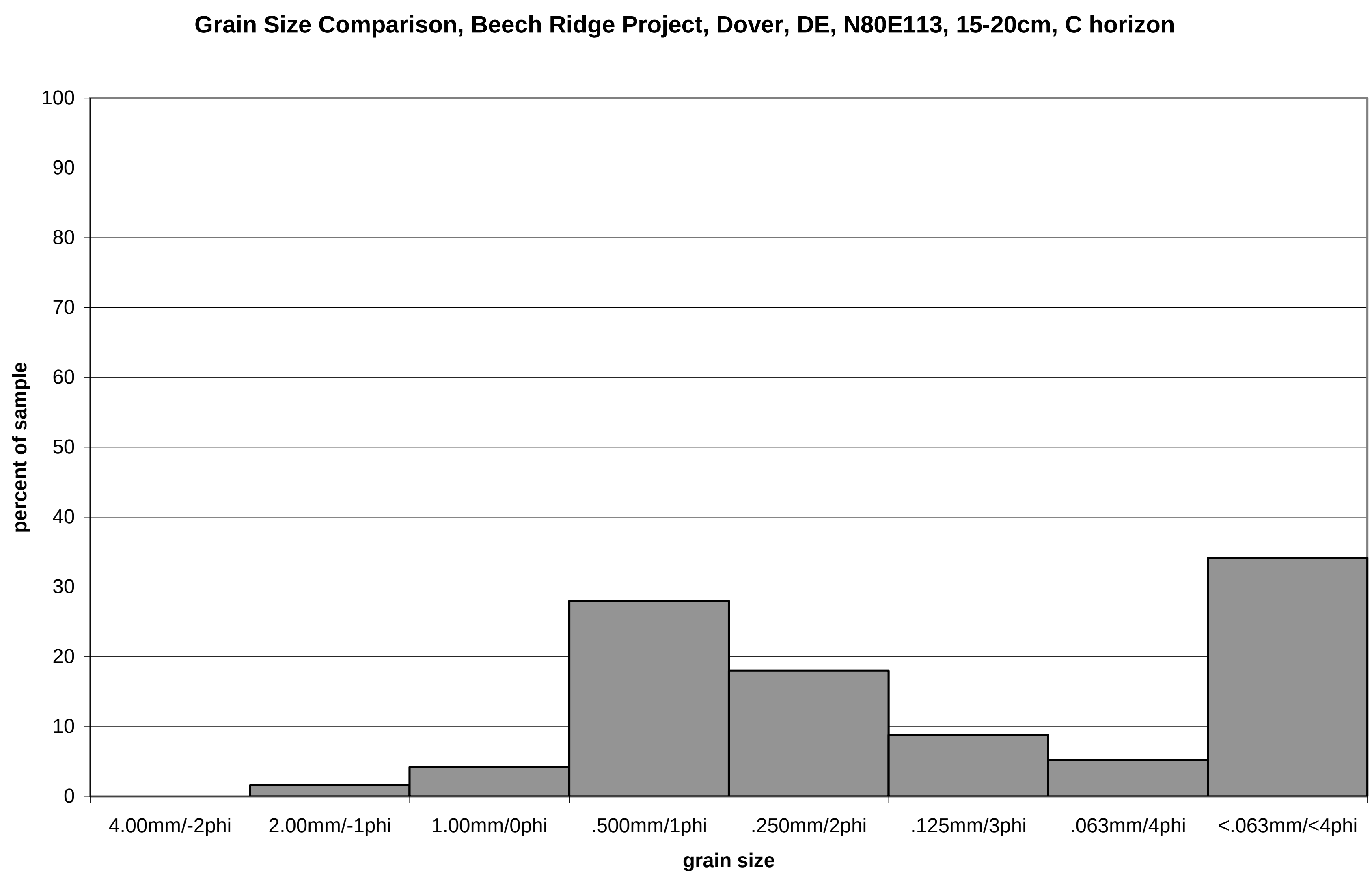
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 0-5cm, A horizon

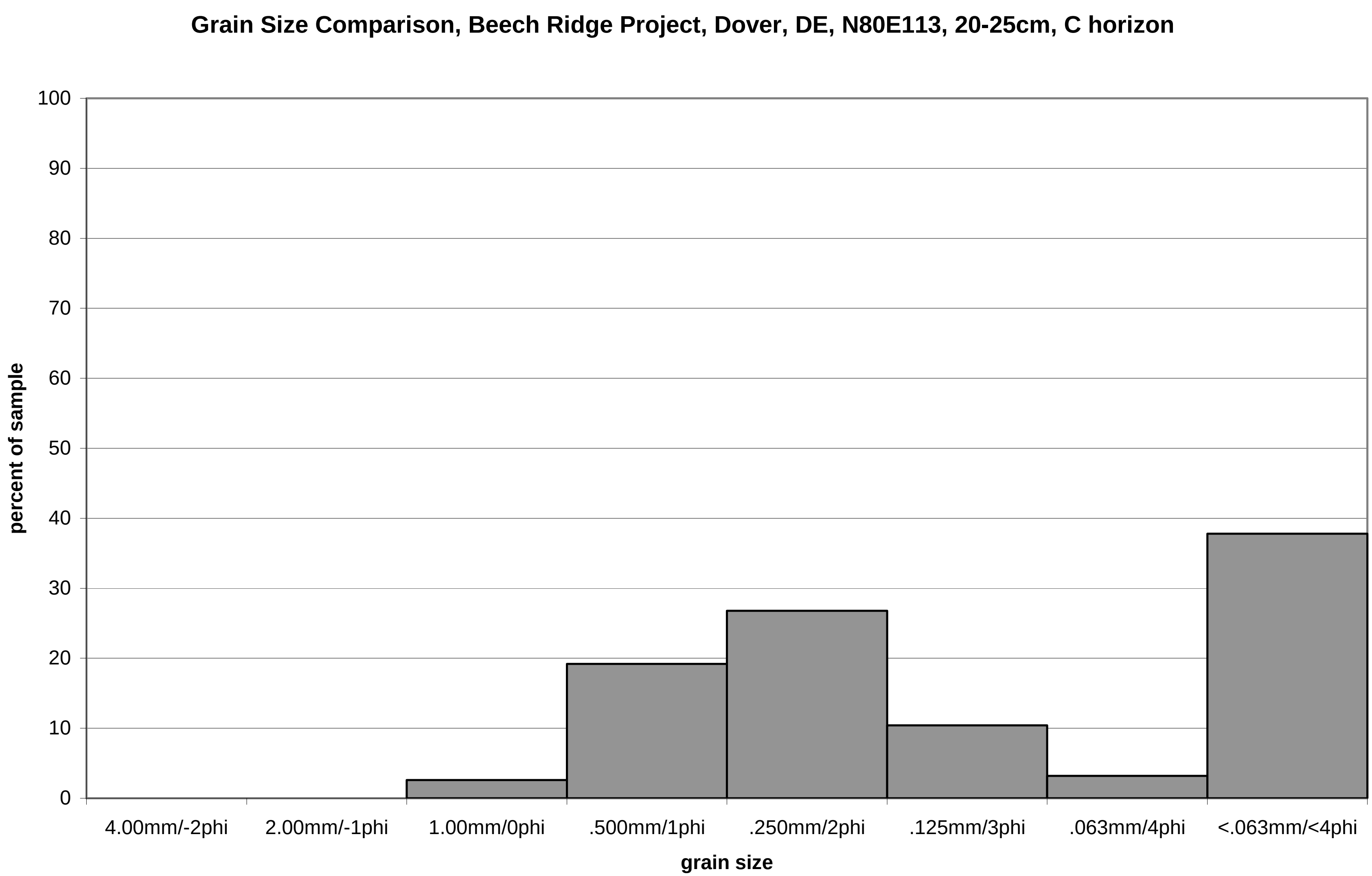



Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 5-10cm, CA horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

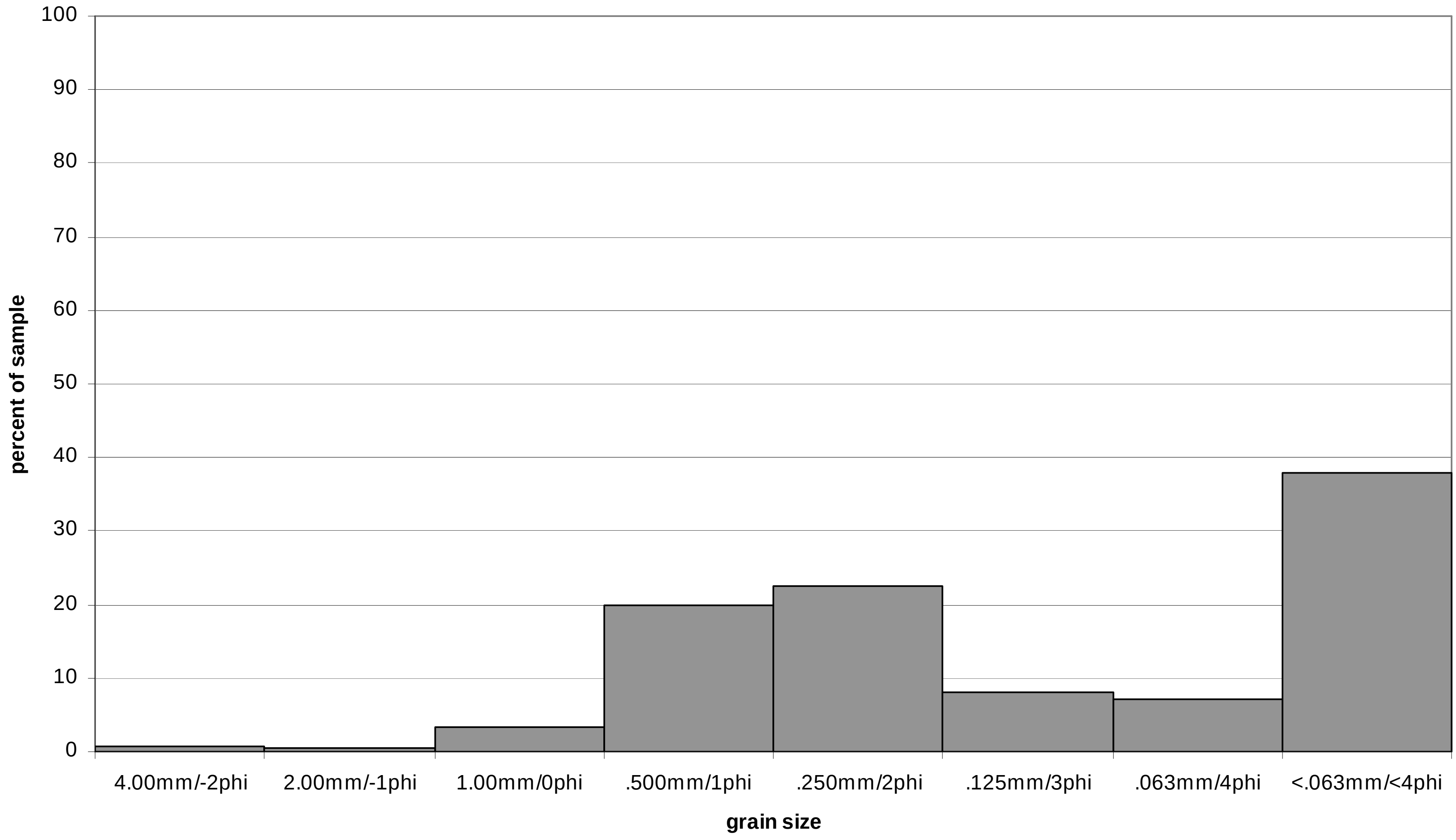


Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 10-15cm, CA horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

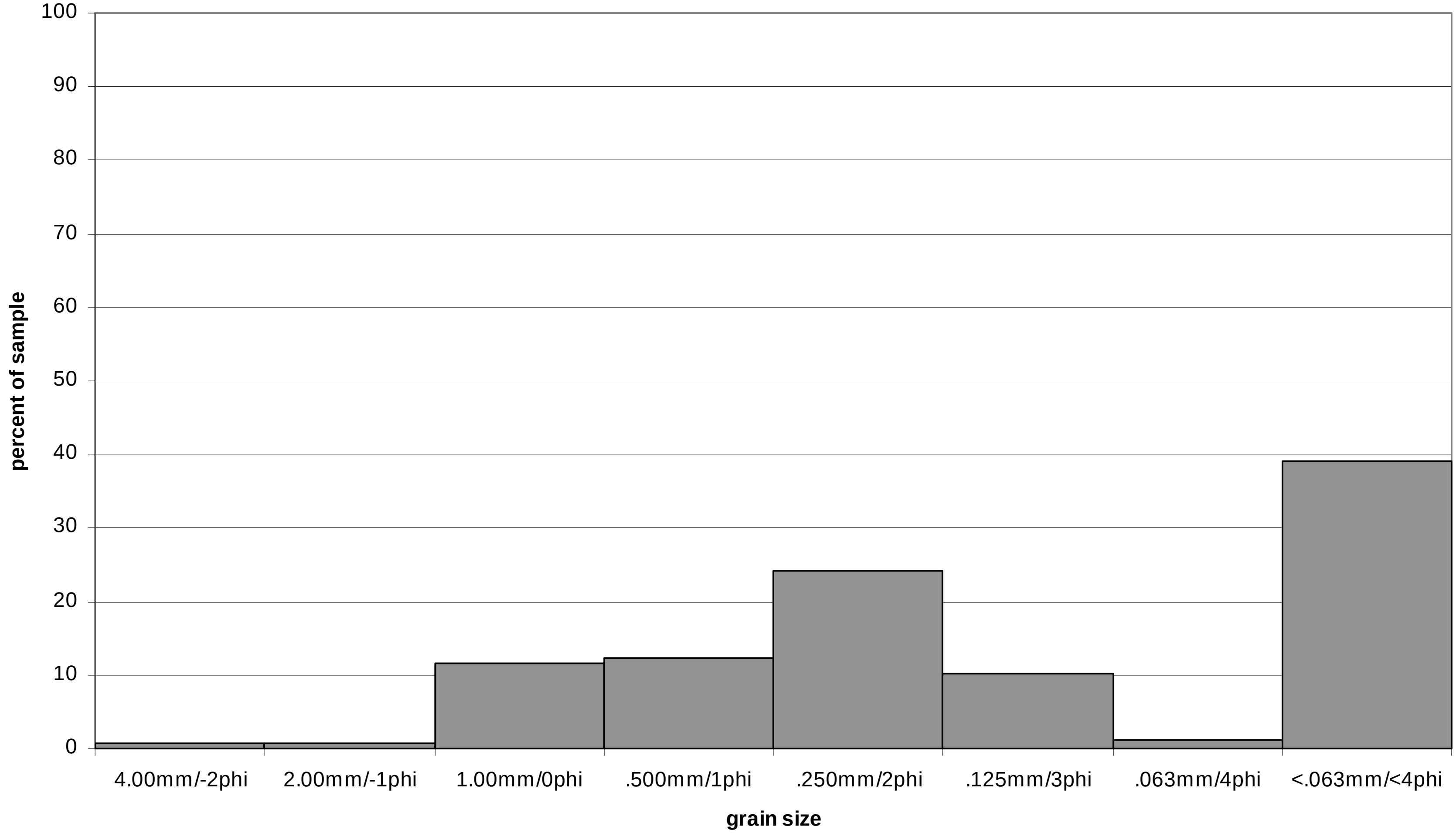

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 15-20cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size


Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 20-25cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

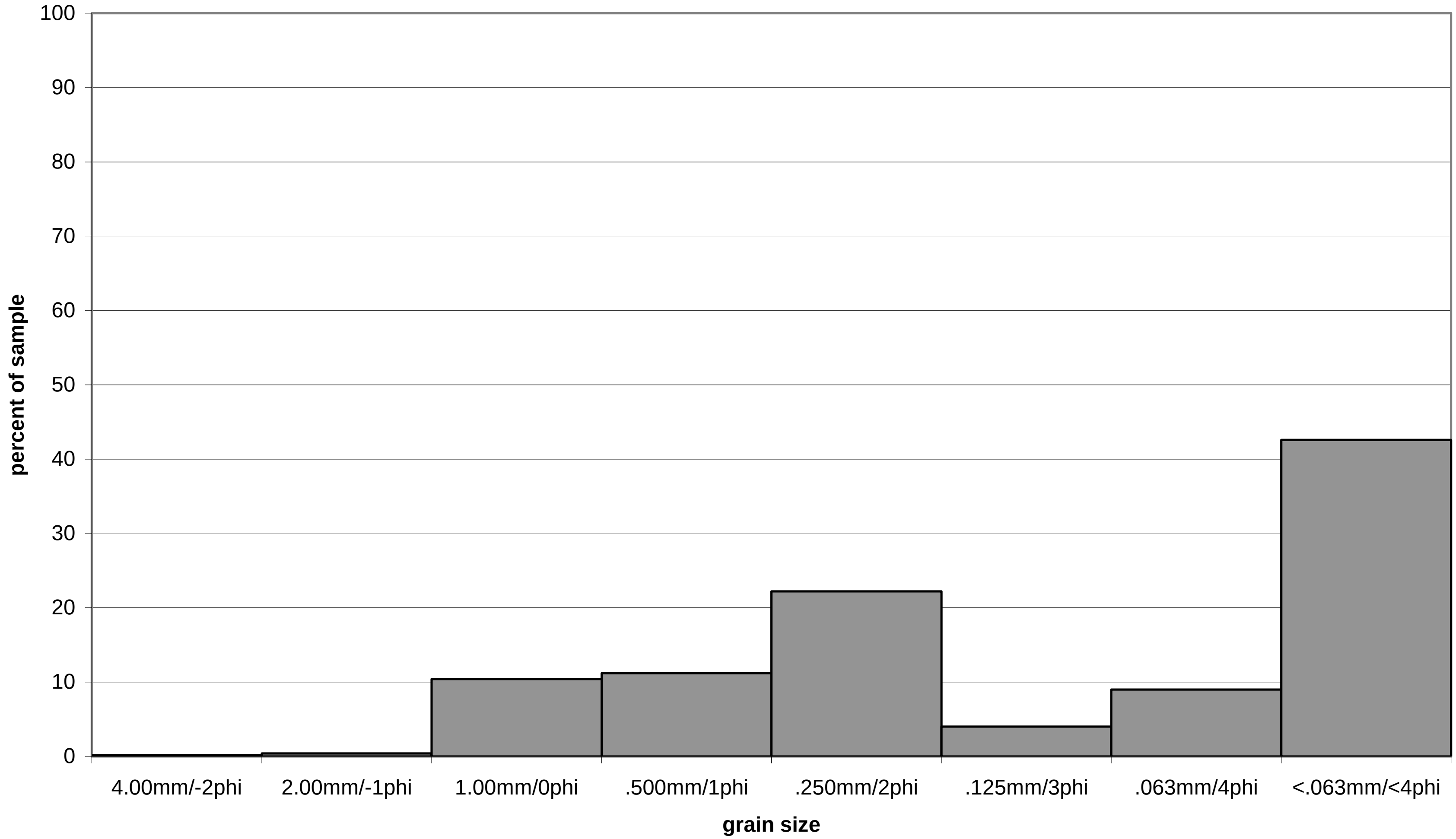
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 25-30cm, C horizon



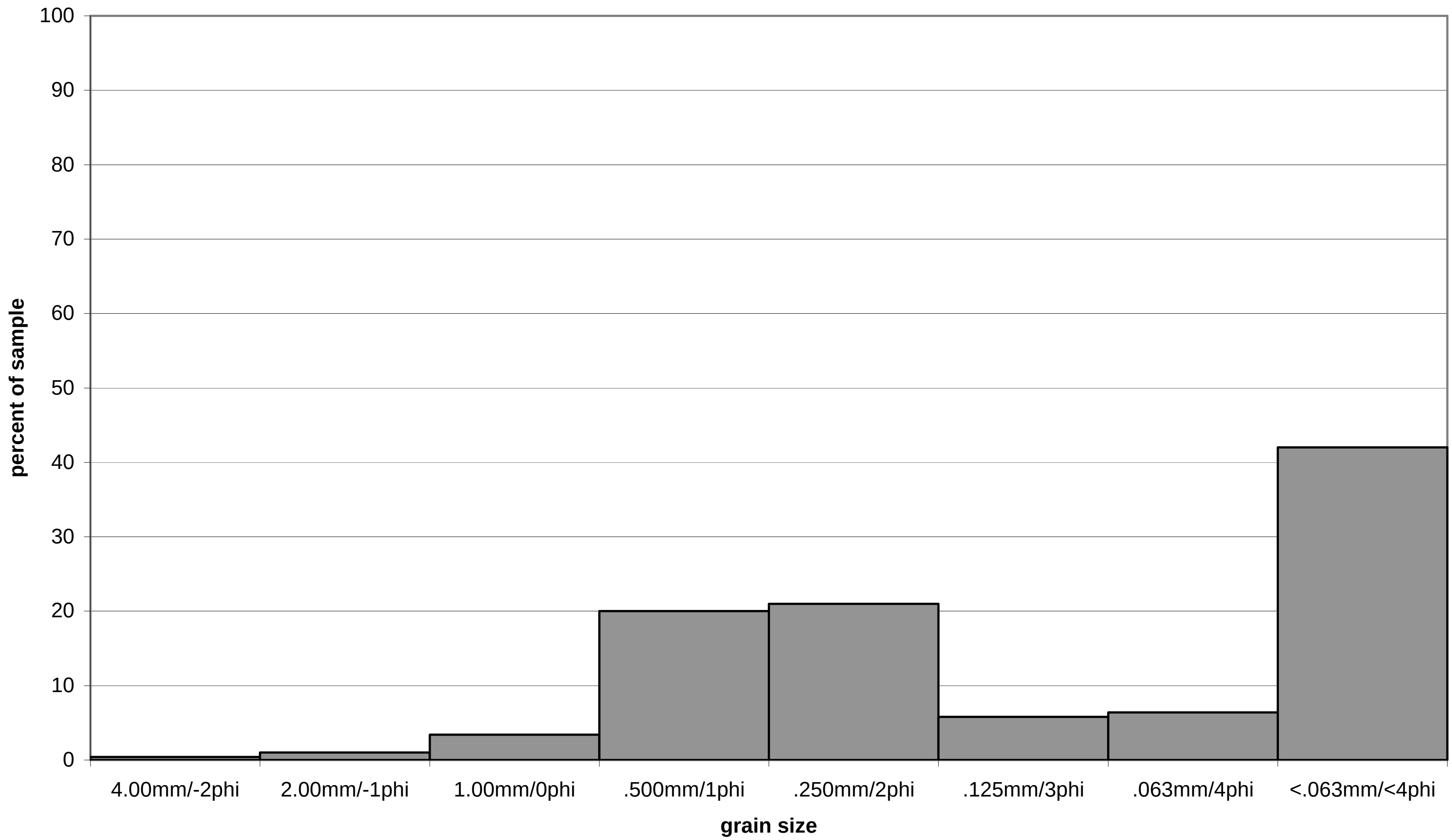
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 30-35cm, C horizon



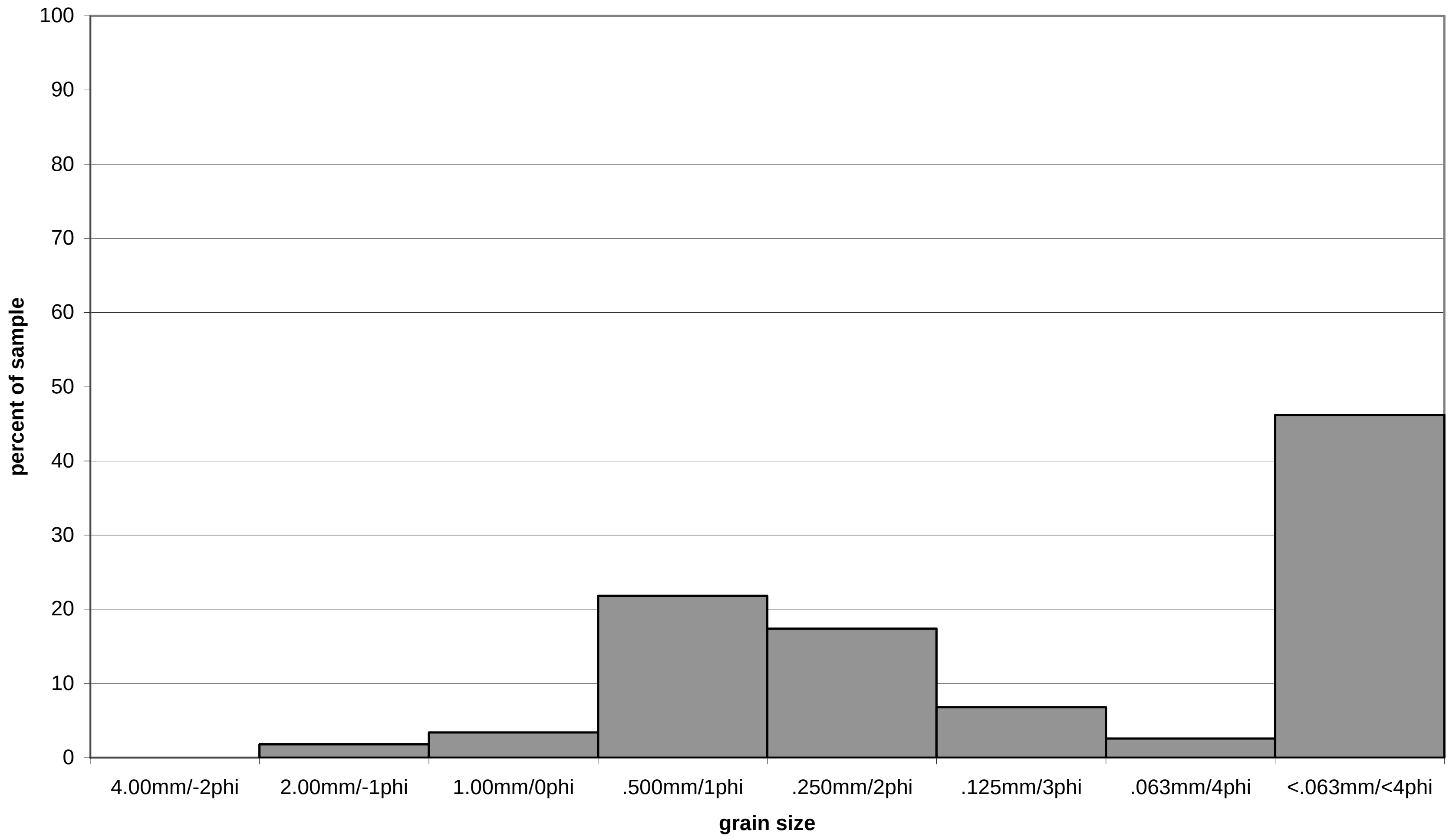
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 35-40cm, C horizon

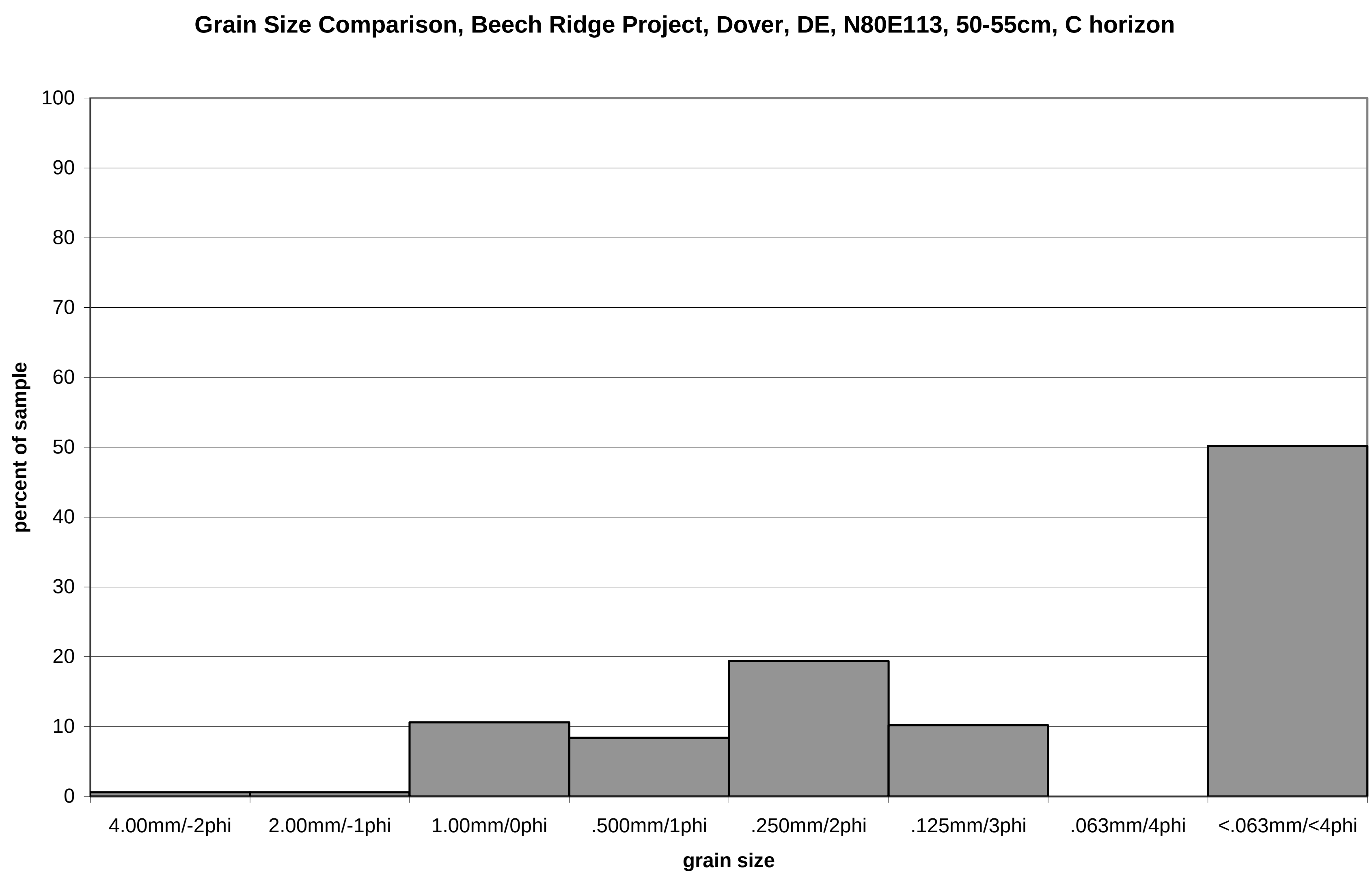


Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 40-45cm, C horizon

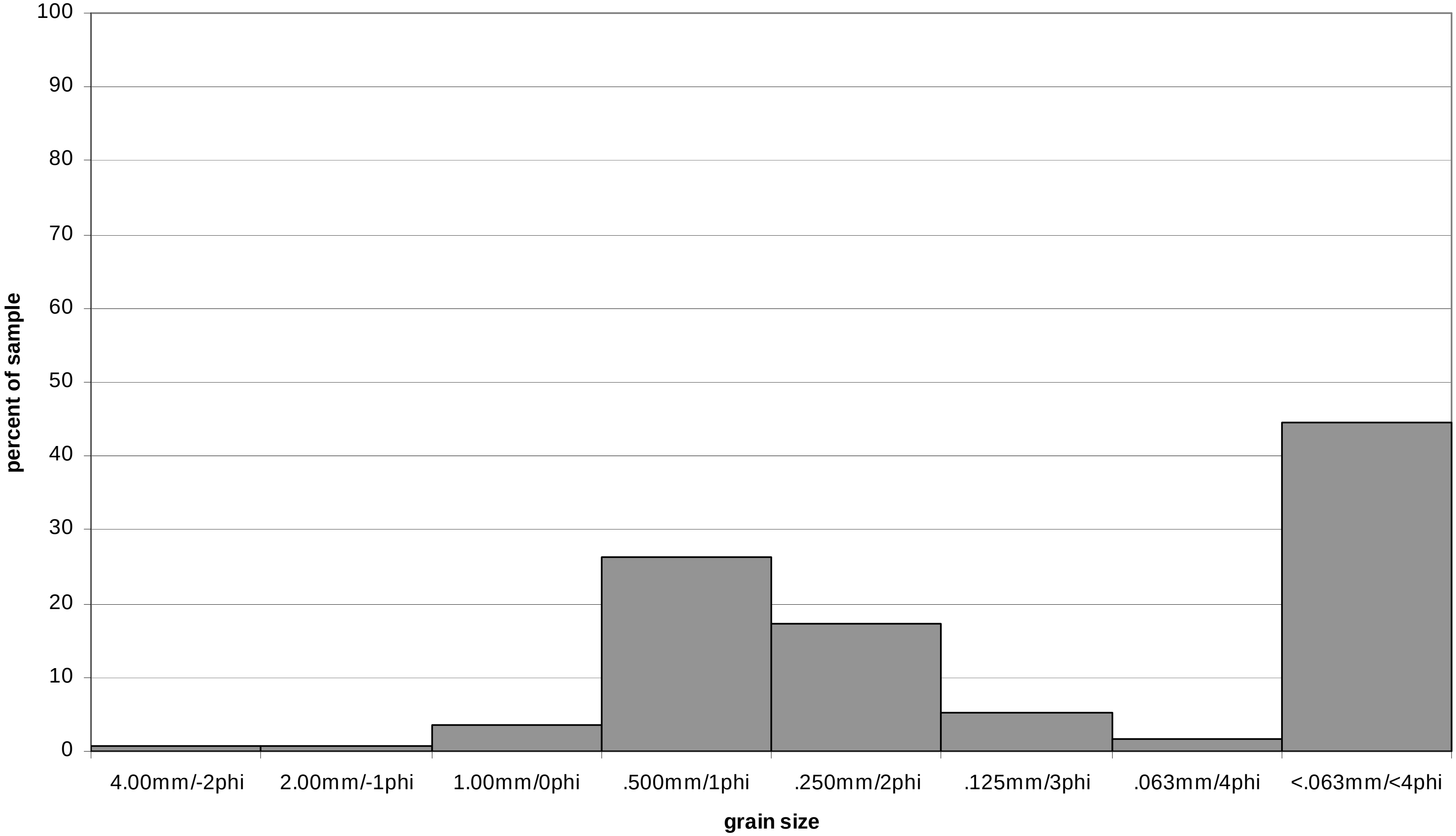


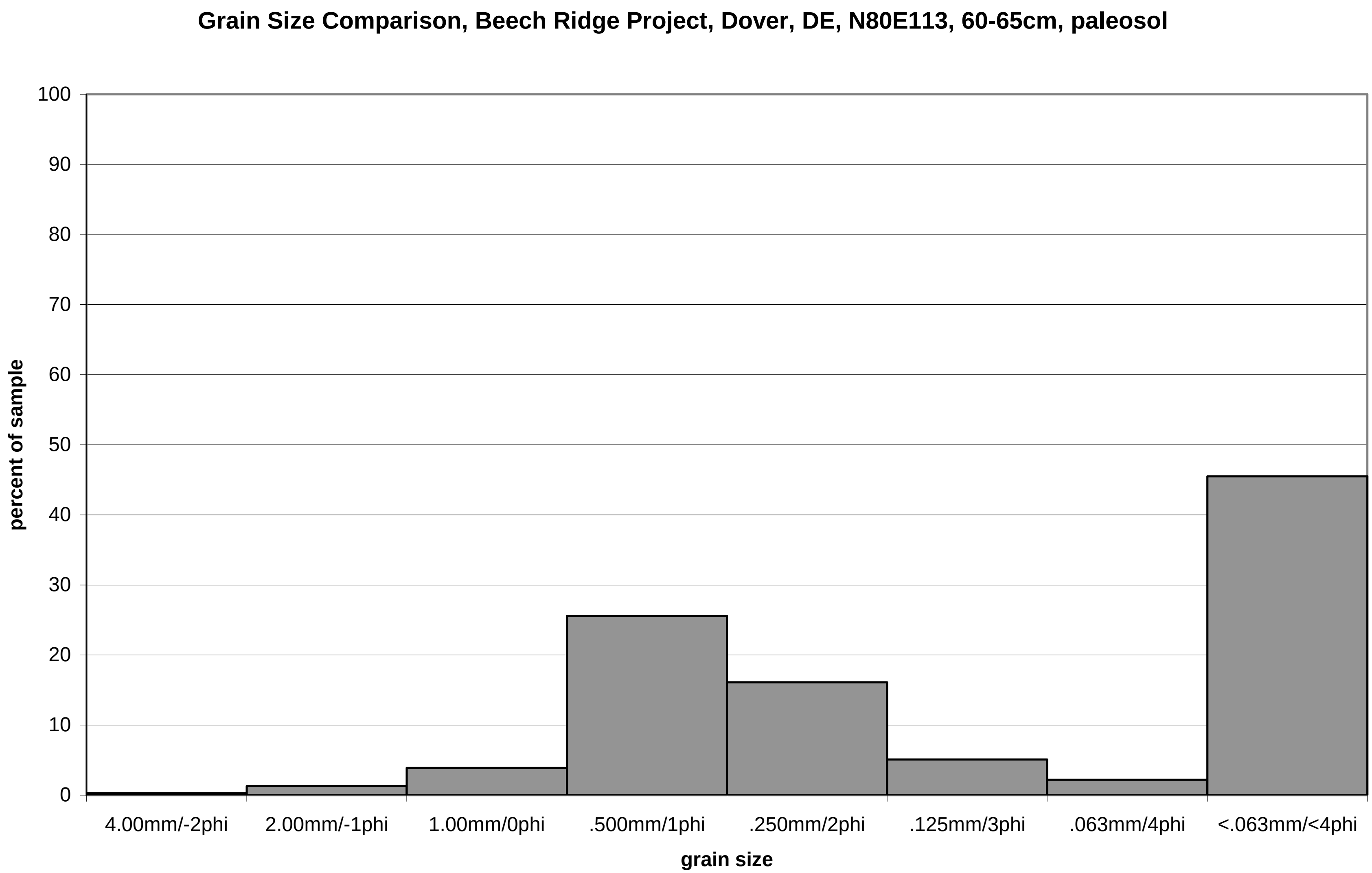
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 45-50cm, C horizon

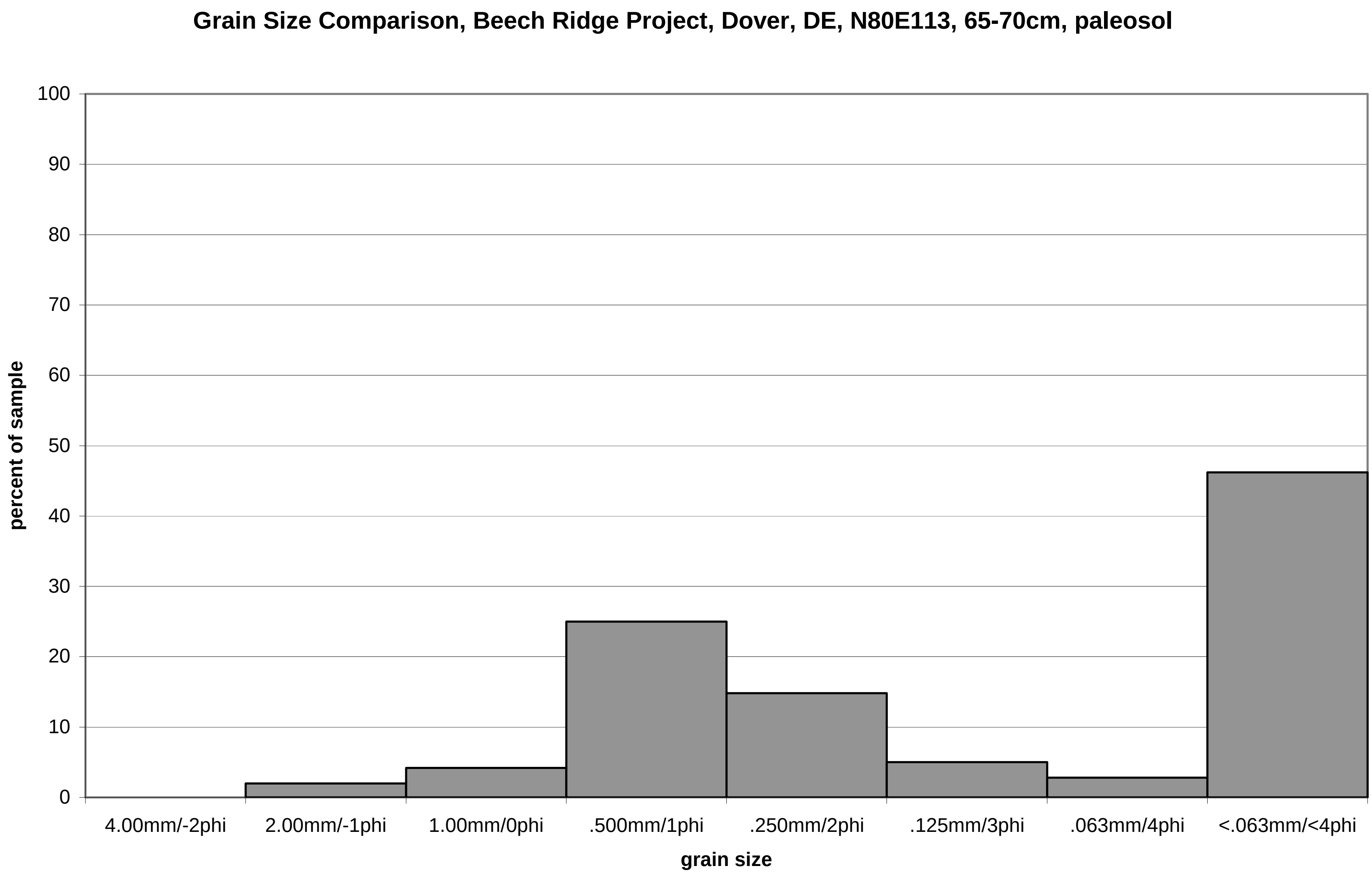


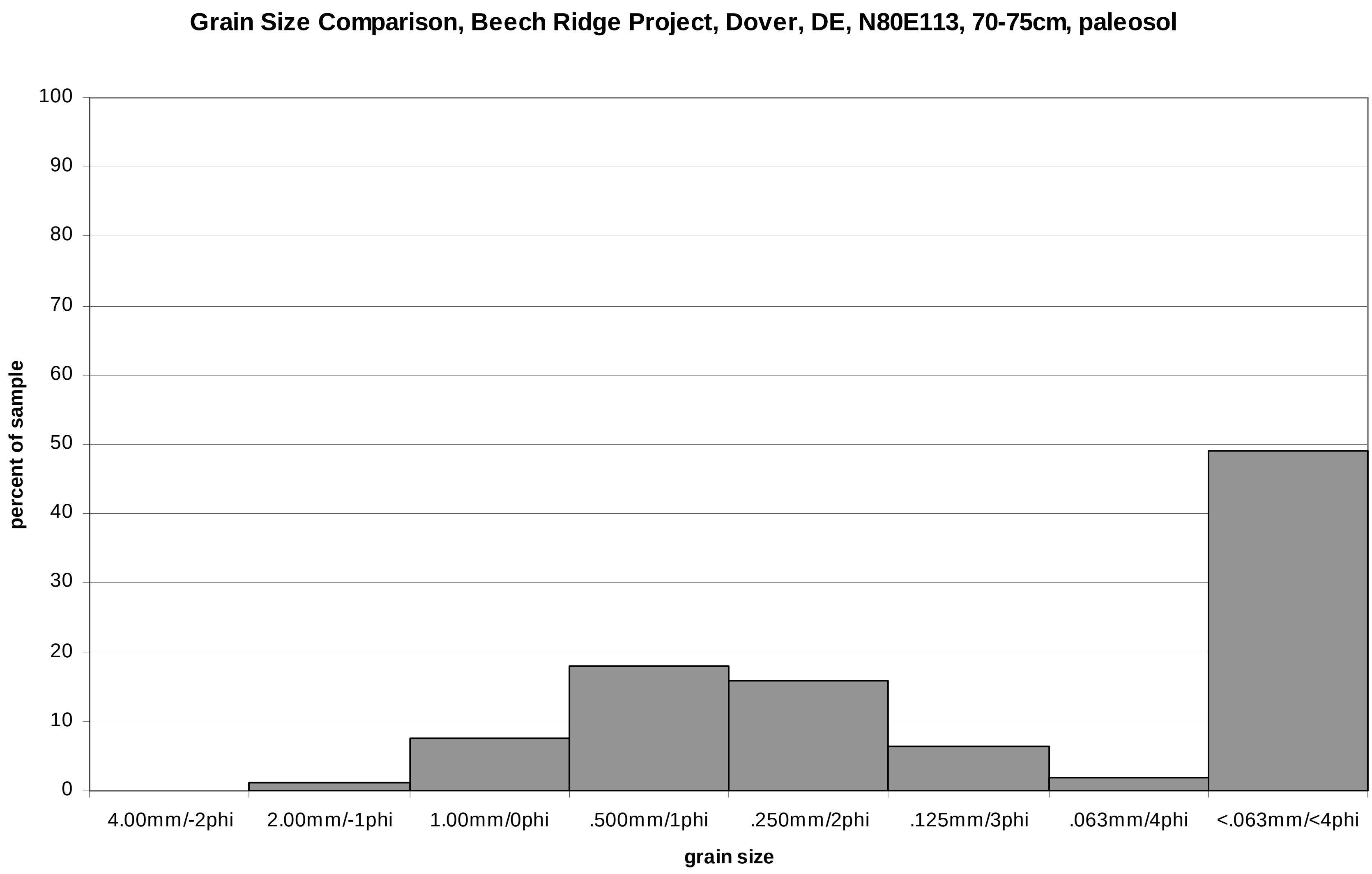

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 50-55cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 55-60cm, paleosol

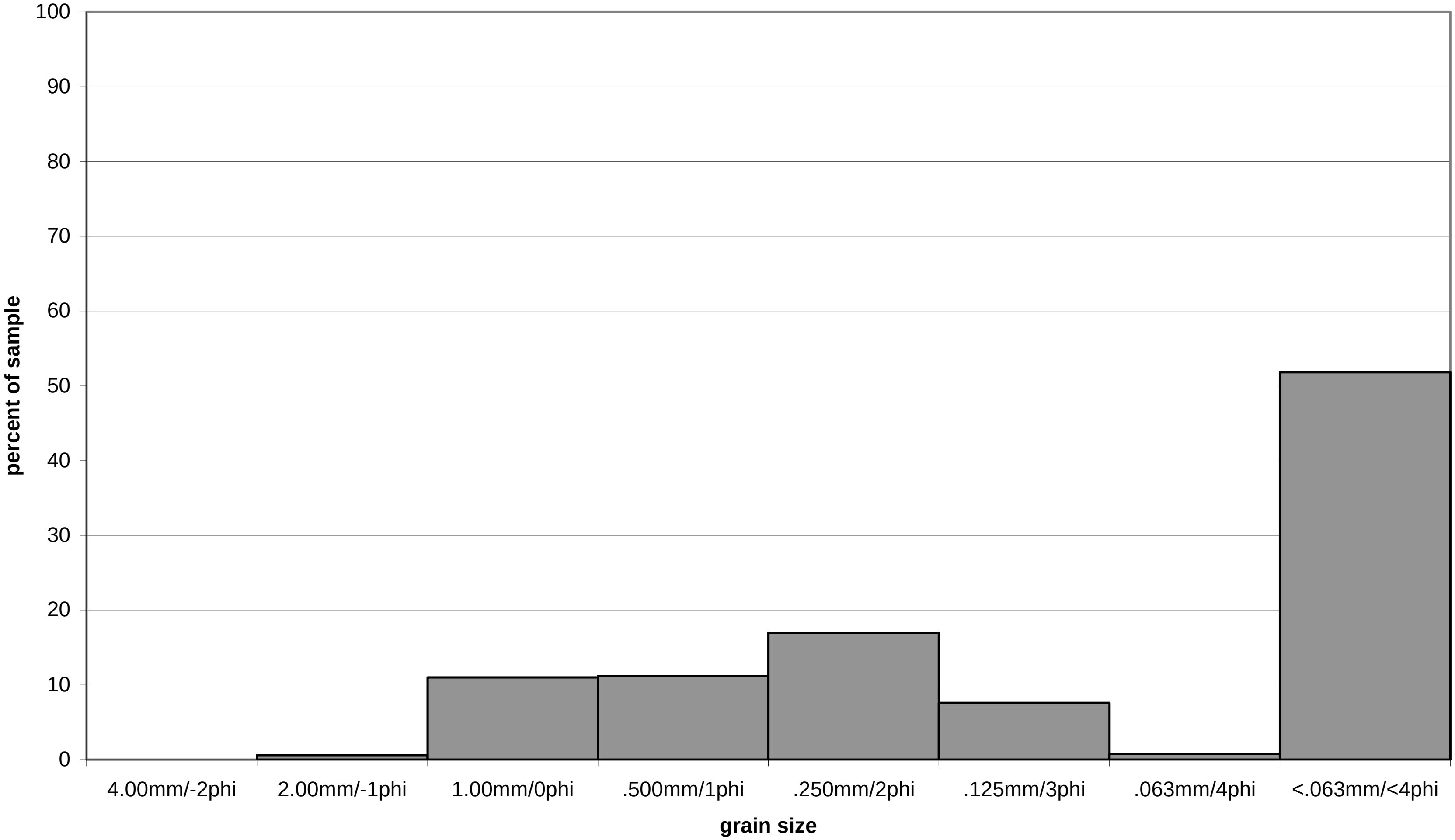


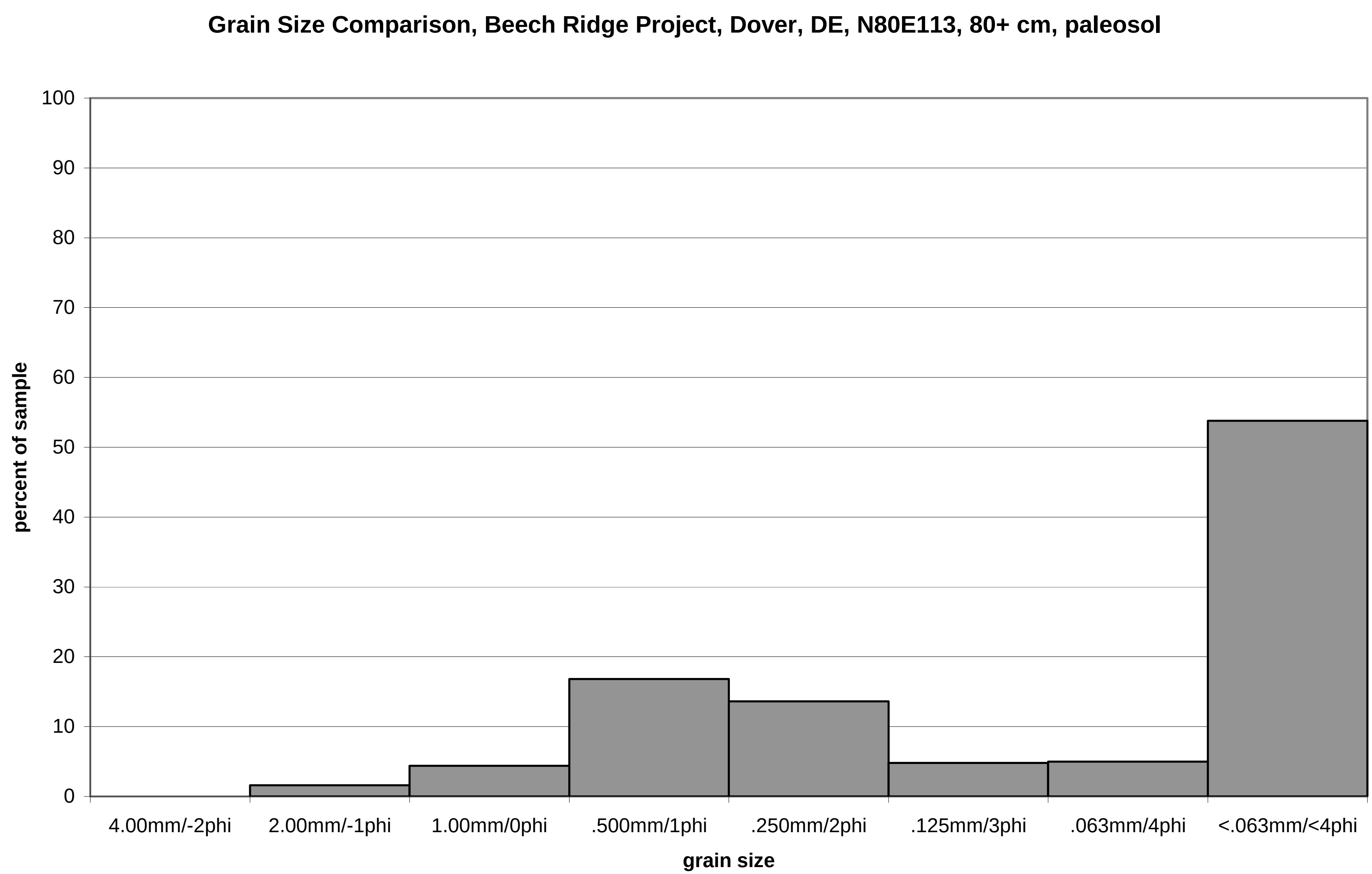

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 60-65cm, paleosol
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size


Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 65-70cm, paleosol
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

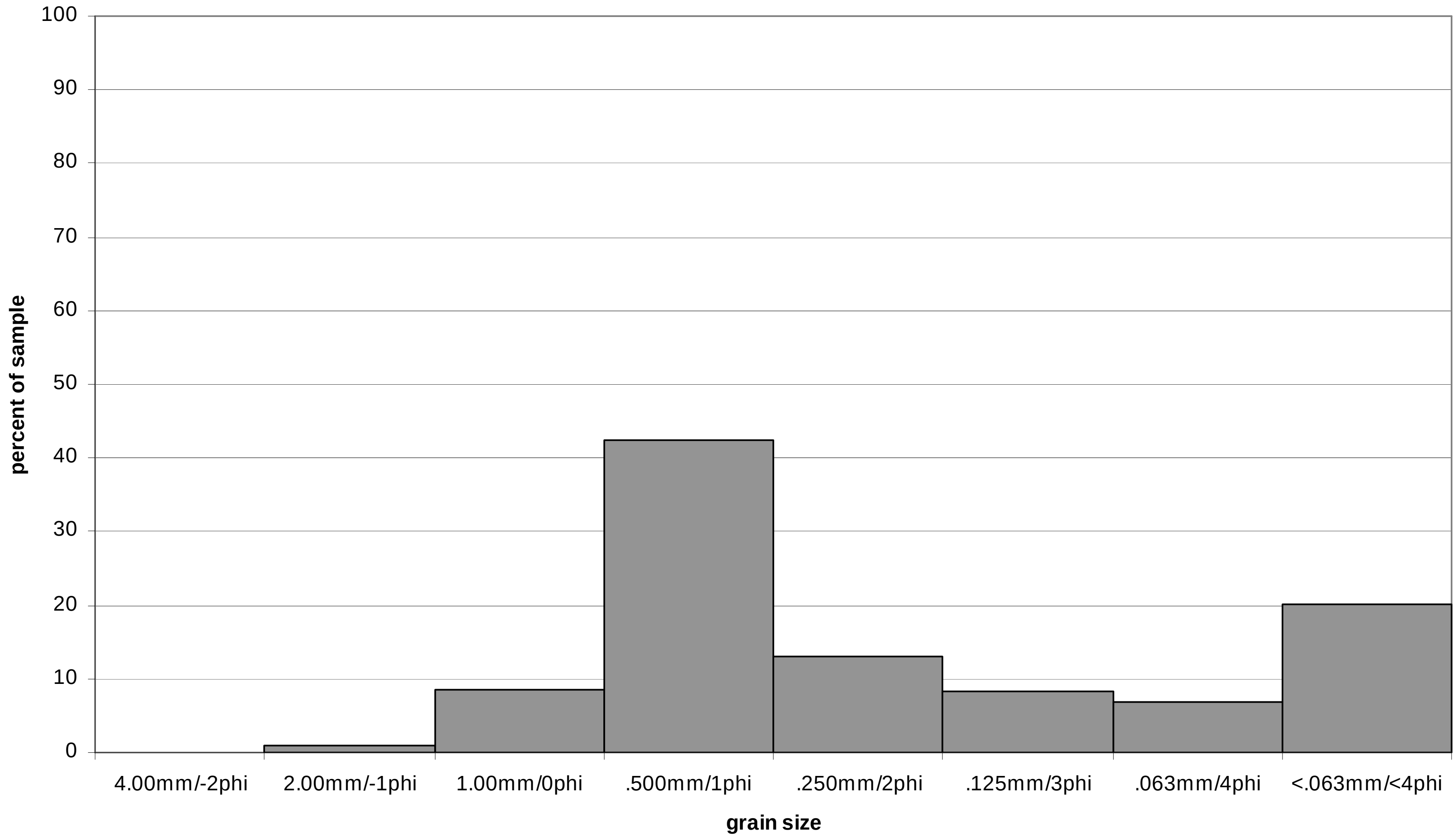

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 70-75cm, paleosol
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

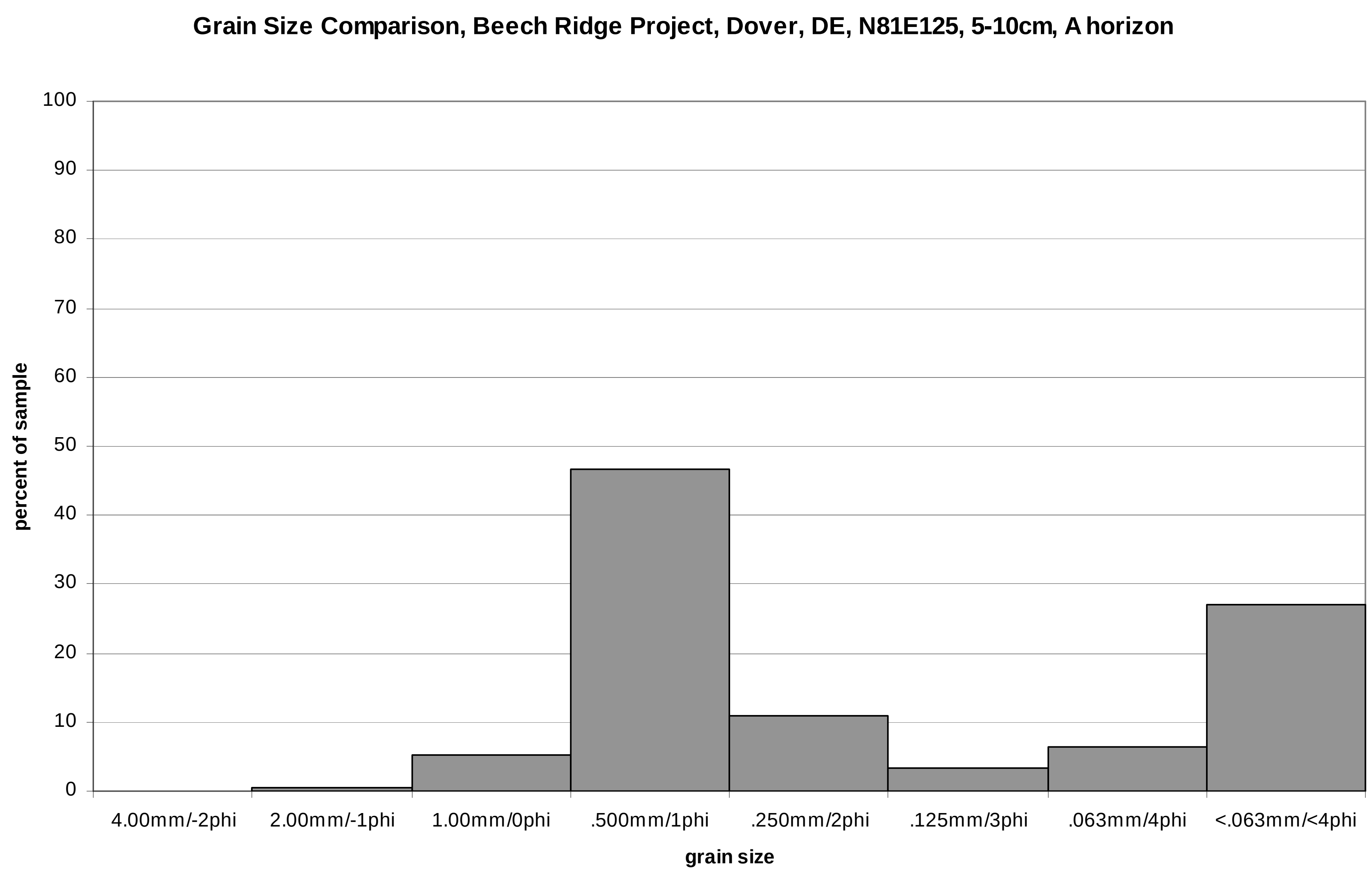
Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 75-80cm, paleosol



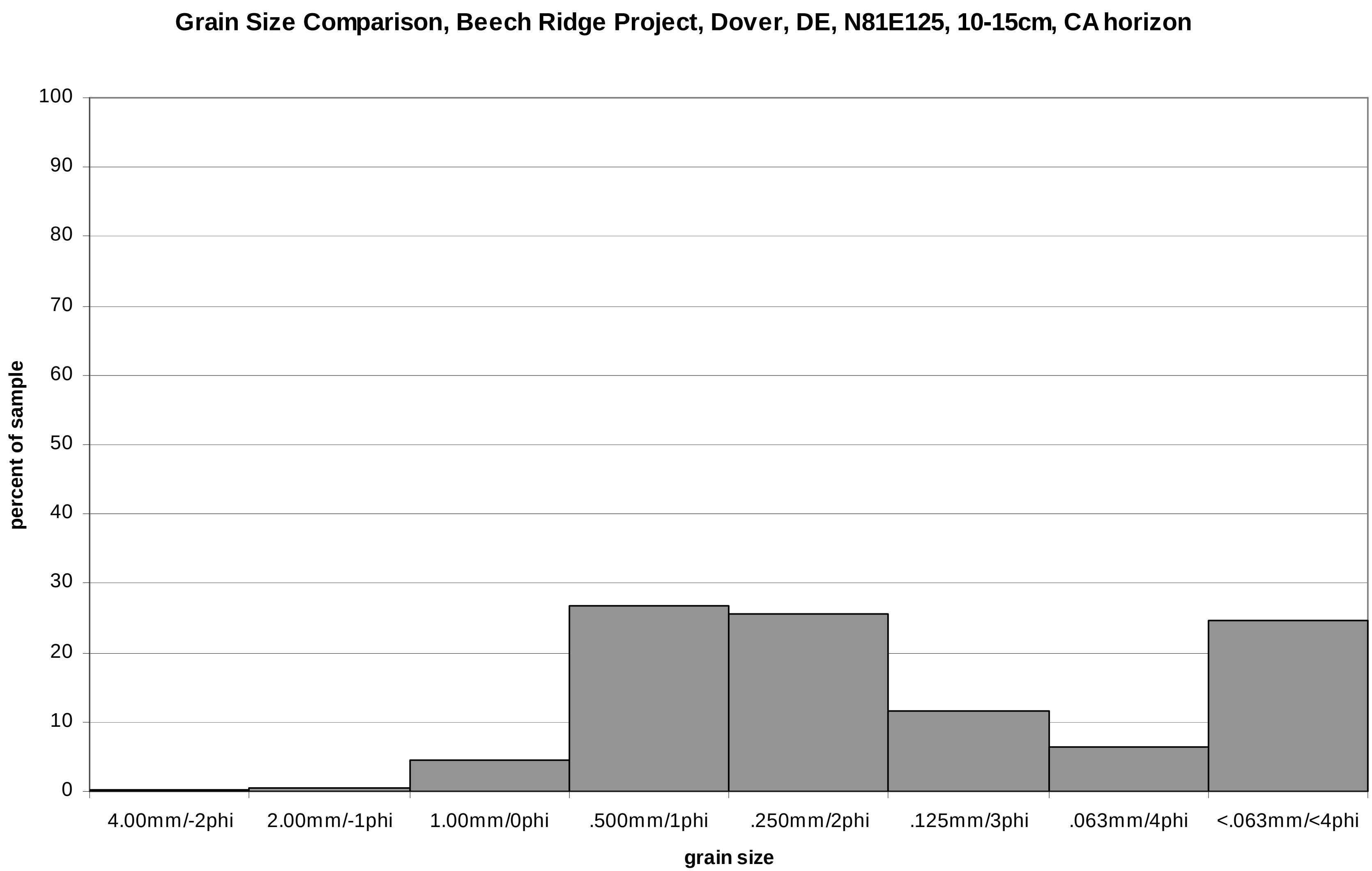

Grain Size Comparison, Beech Ridge Project, Dover, DE, N80E113, 80+ cm, paleosol
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 0-5cm, A horizon



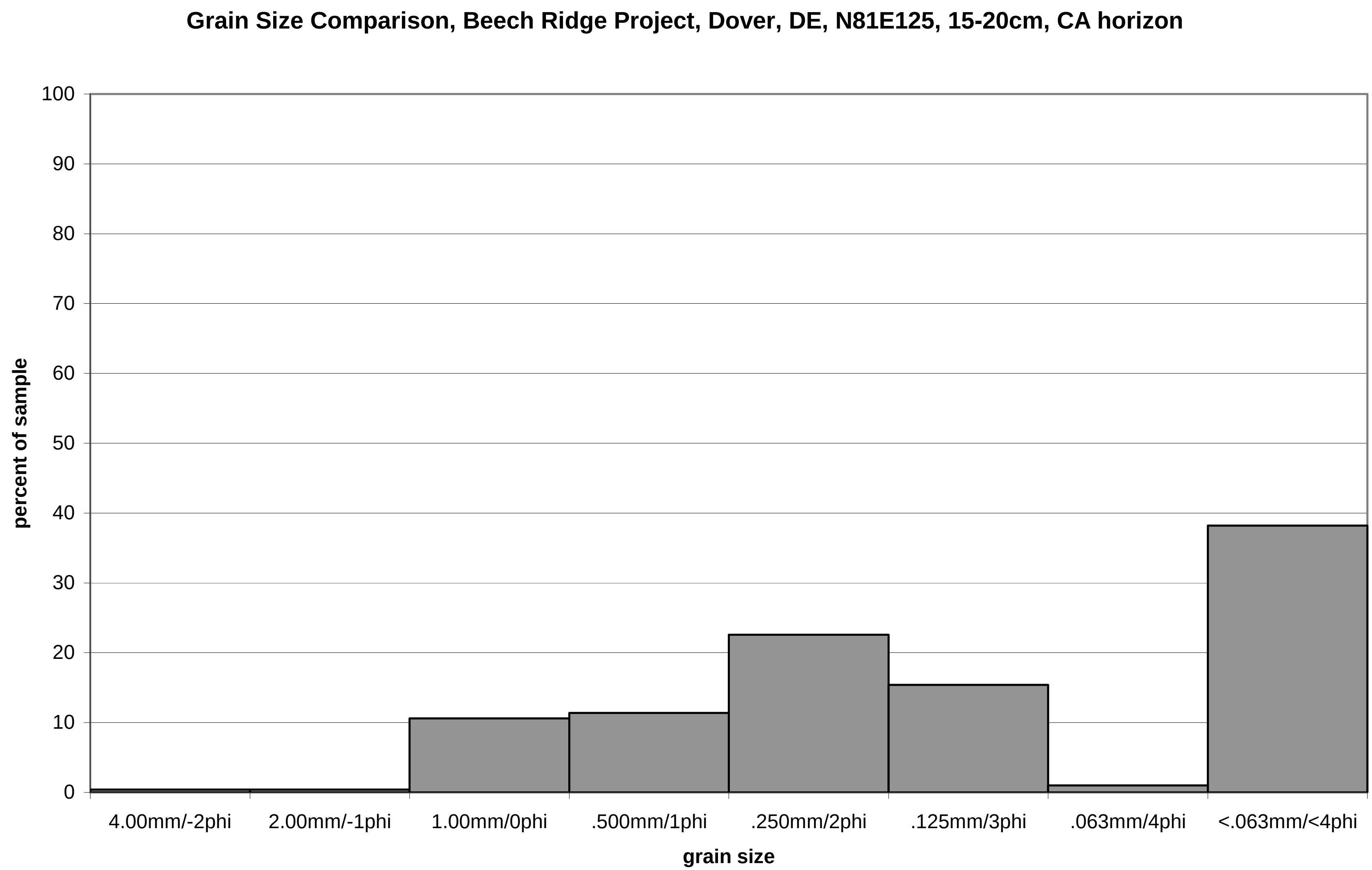


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 5-10cm, A horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

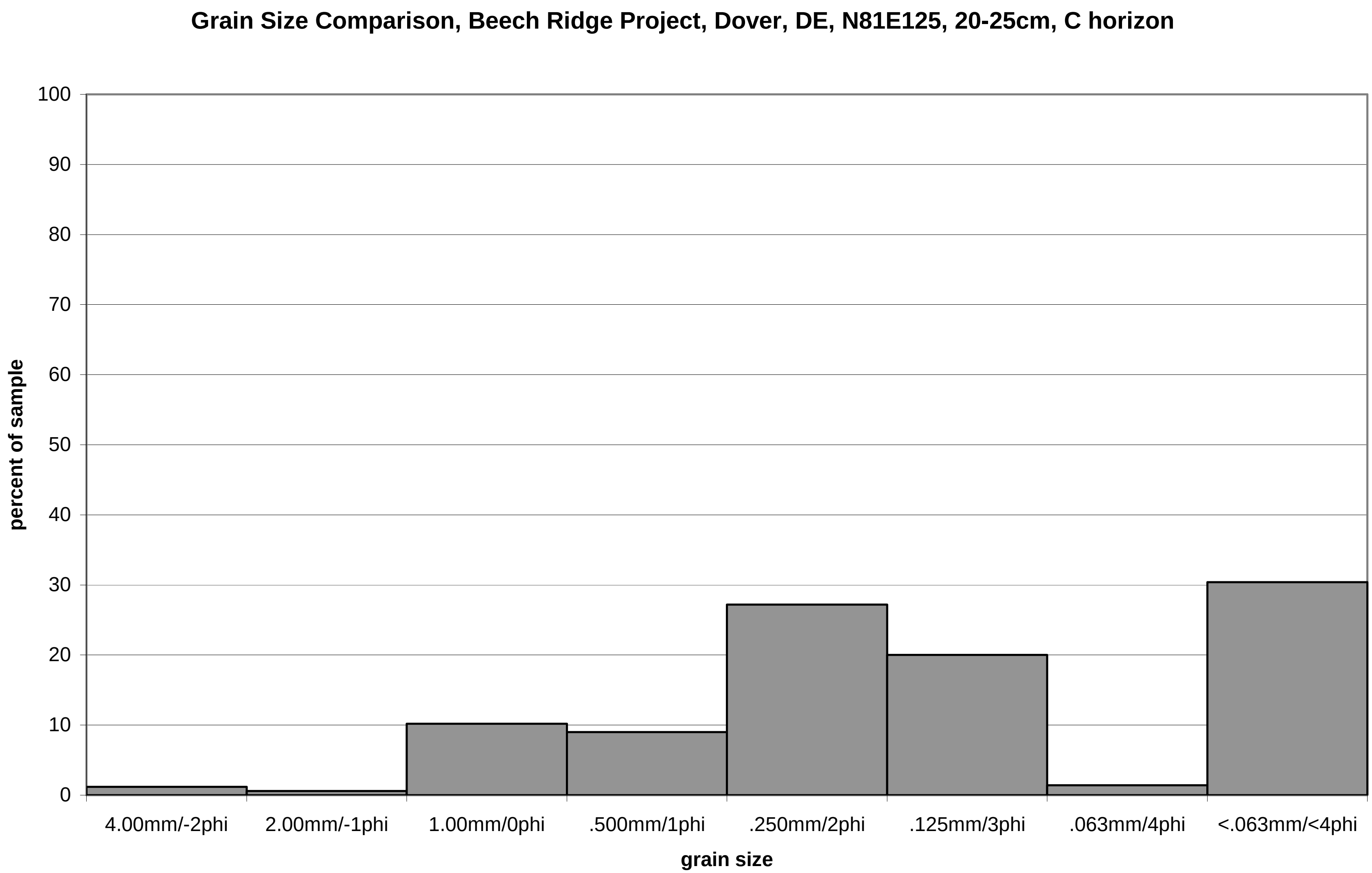


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 10-15cm, CA horizon
100
90
80
70
60
50
40
30
20
10
0
percent of sample
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

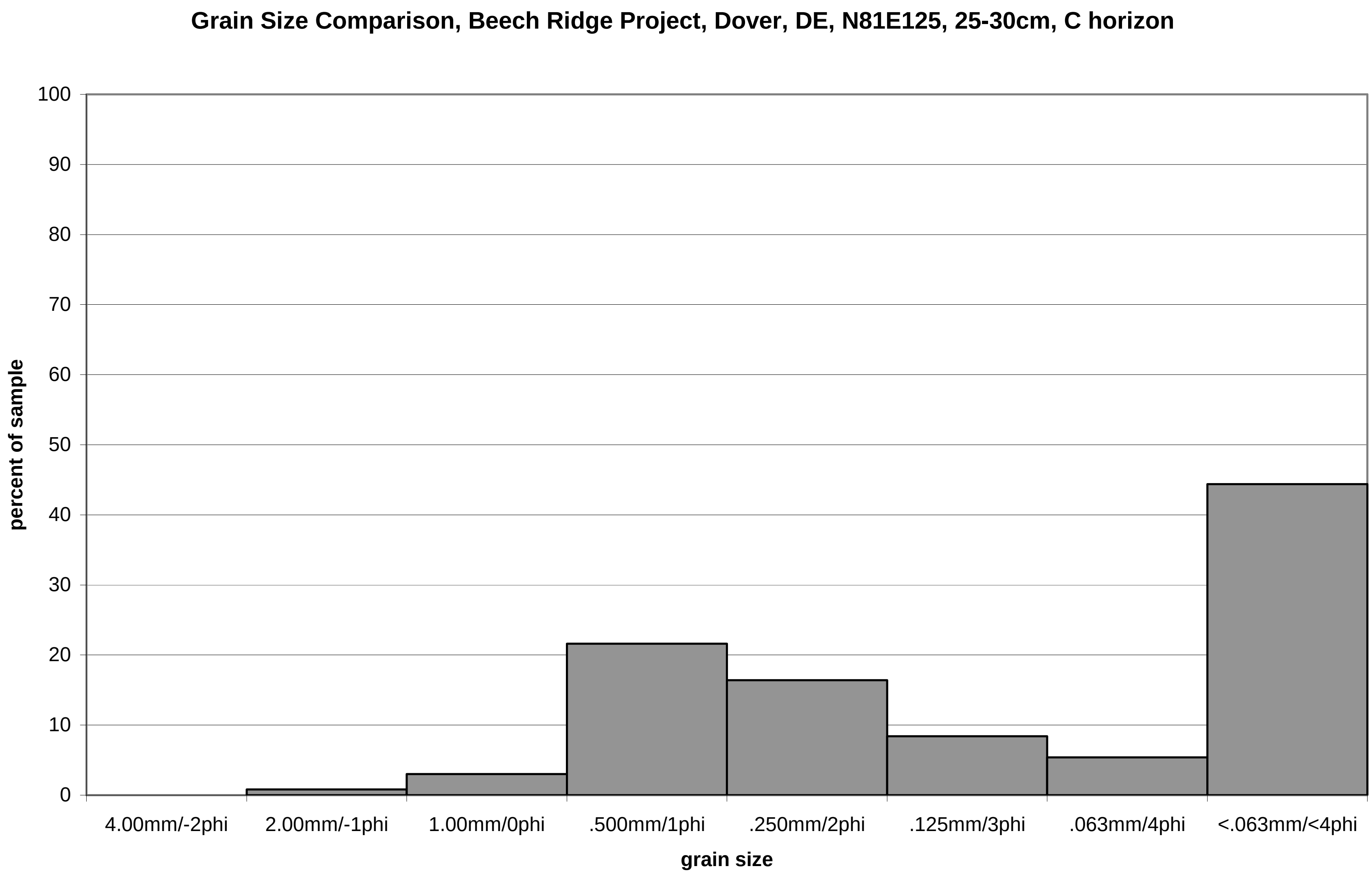
B.70



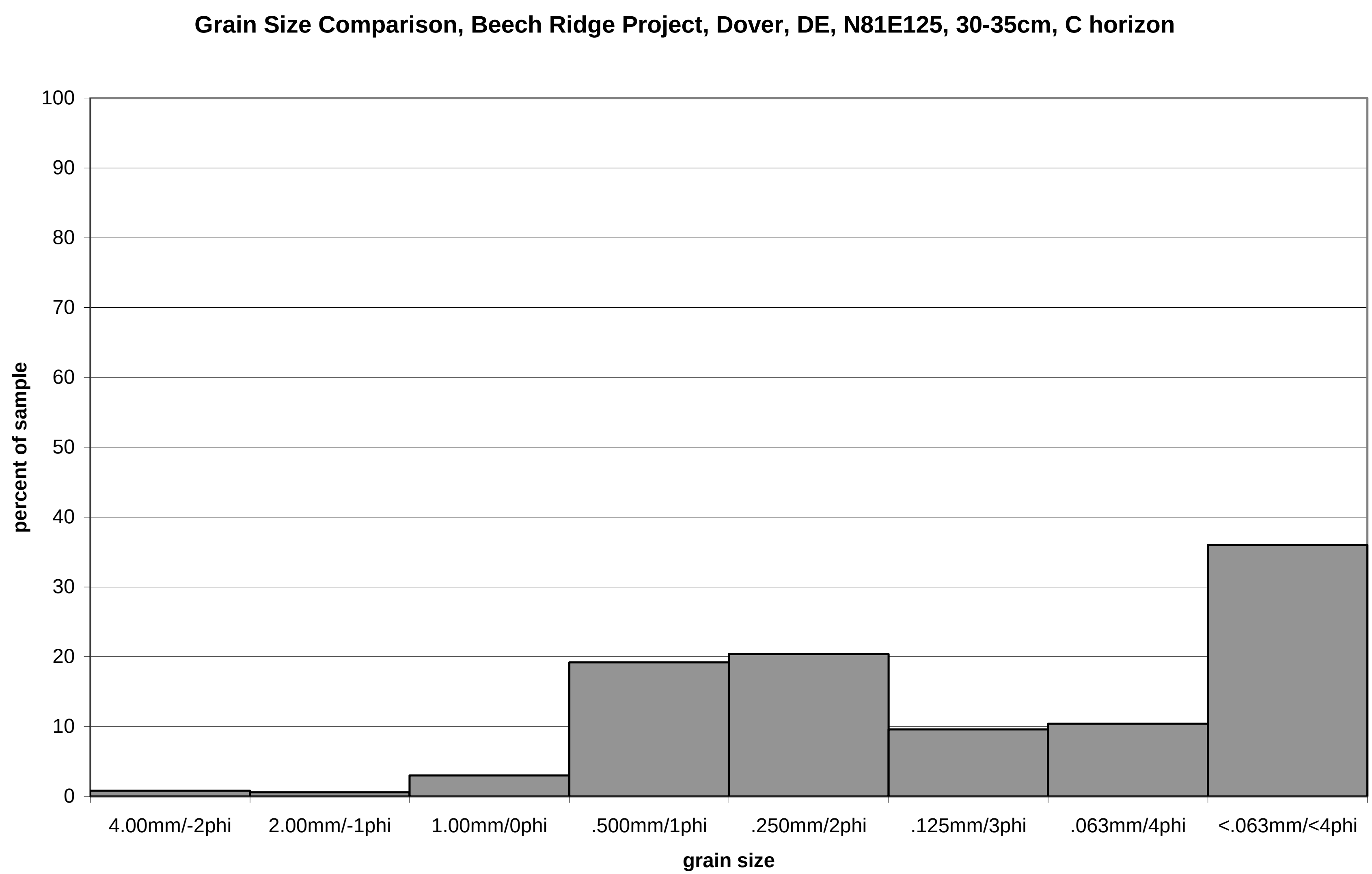
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 15-20cm, CA horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

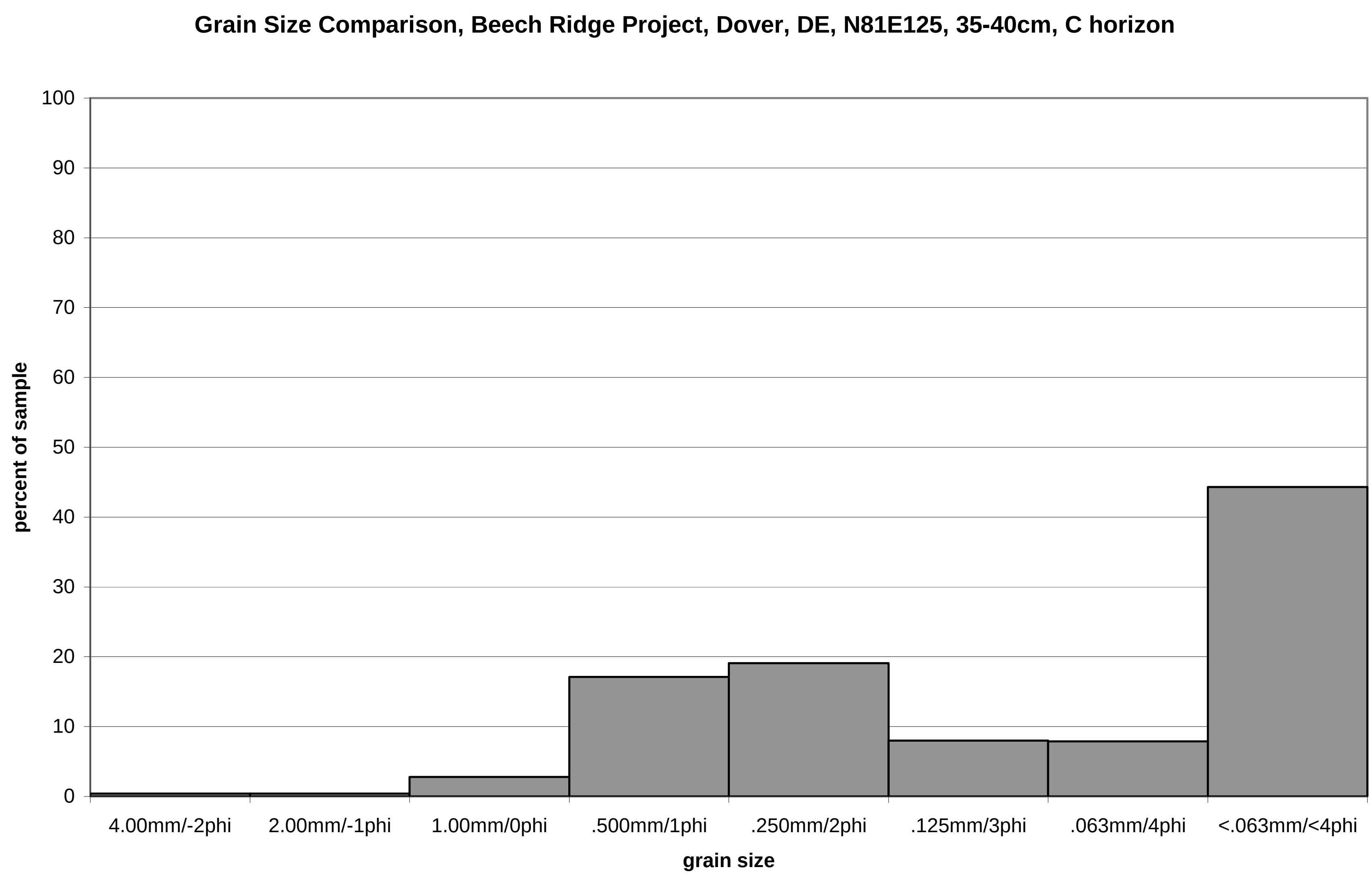

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 20-25cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

B.72



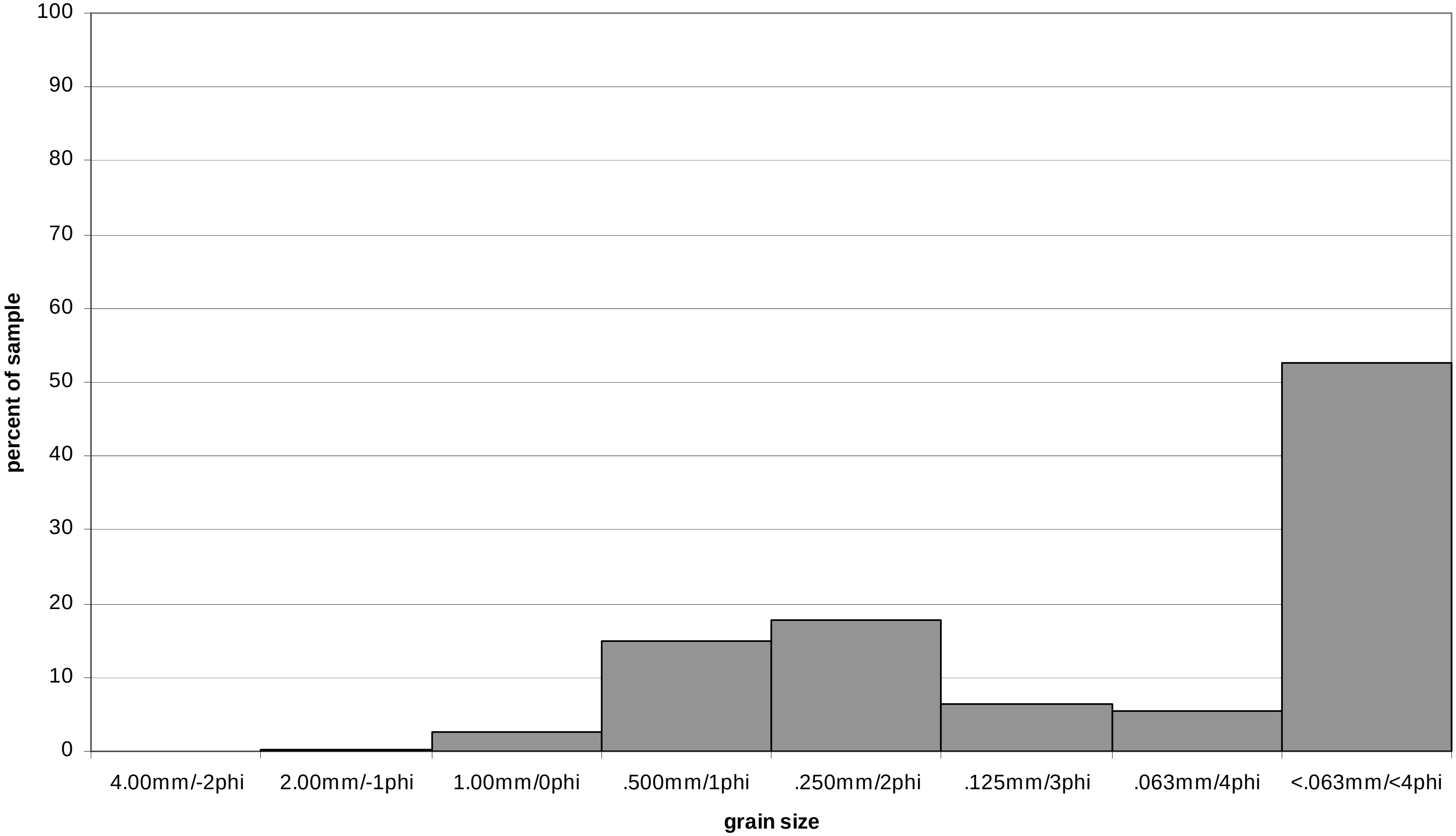
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 25-30cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

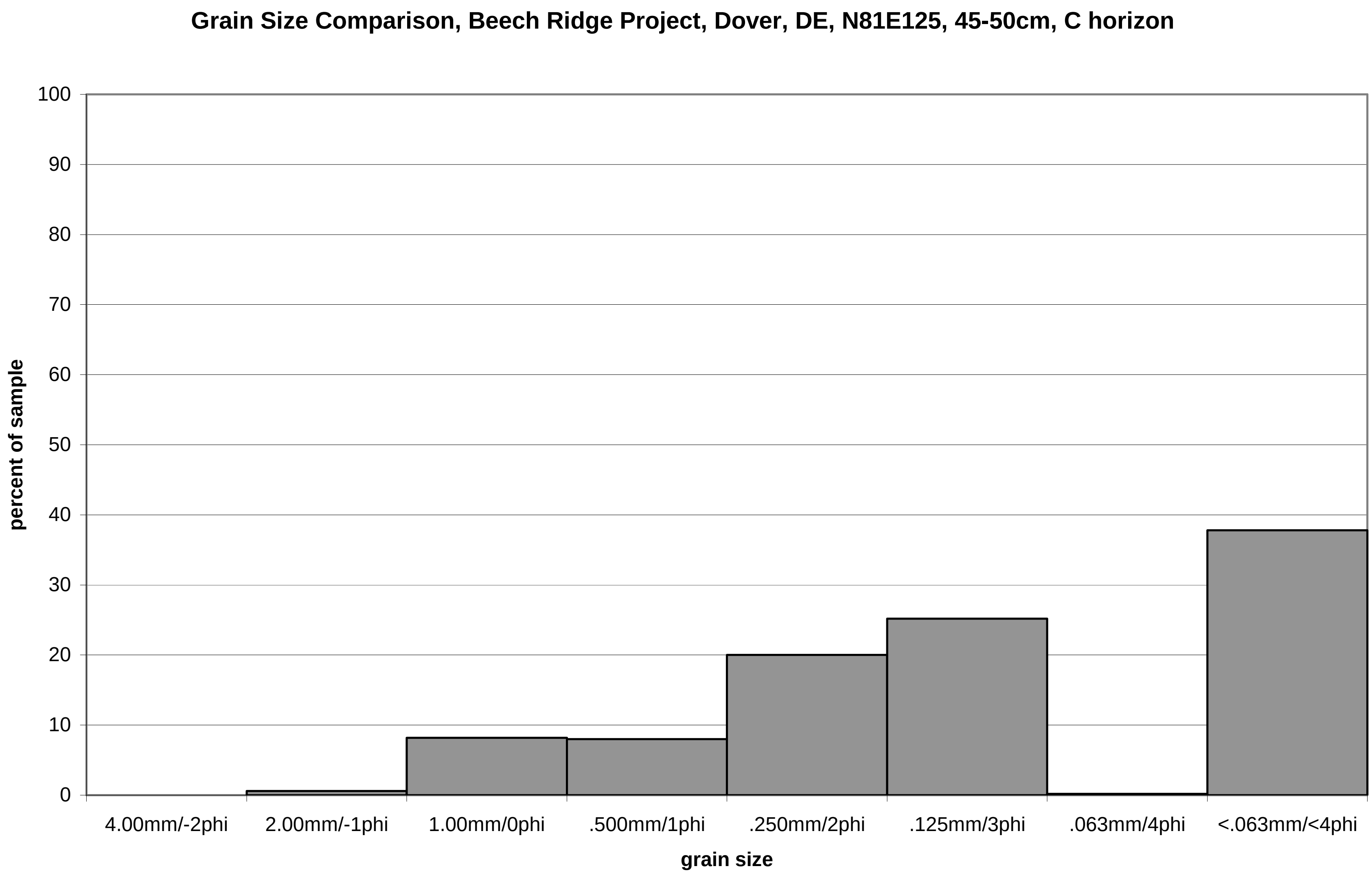

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 30-35cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

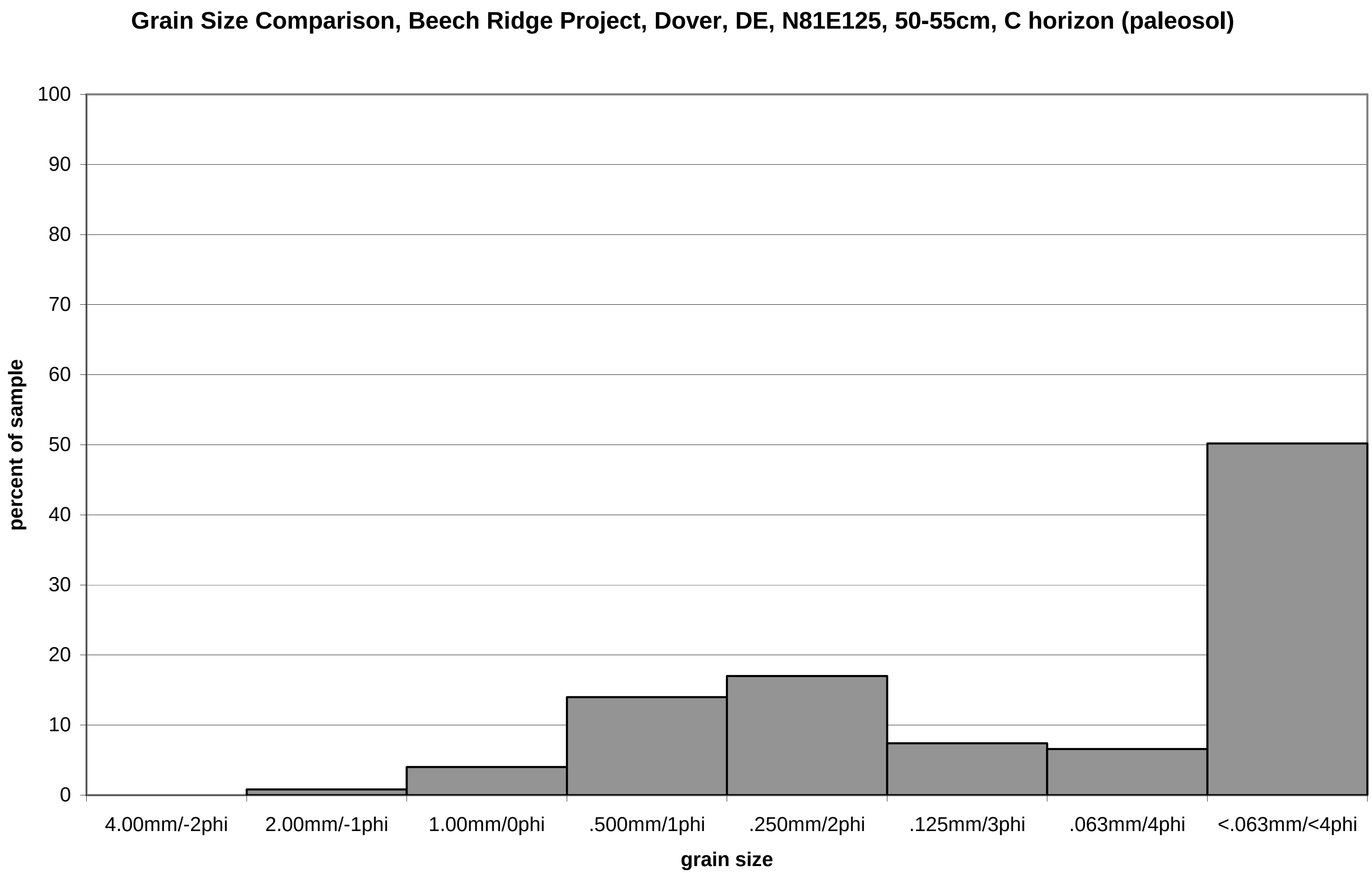


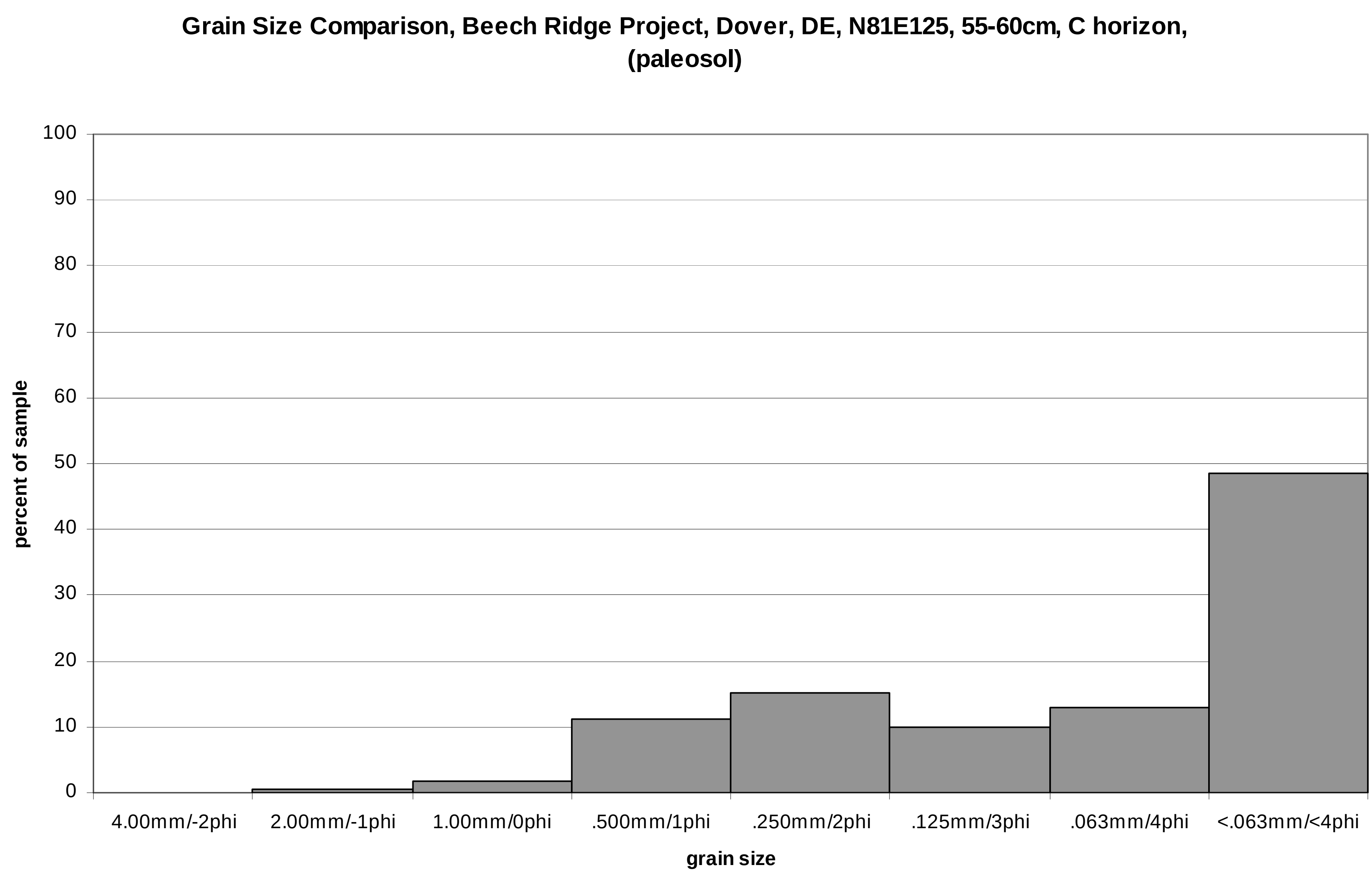
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 35-40cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

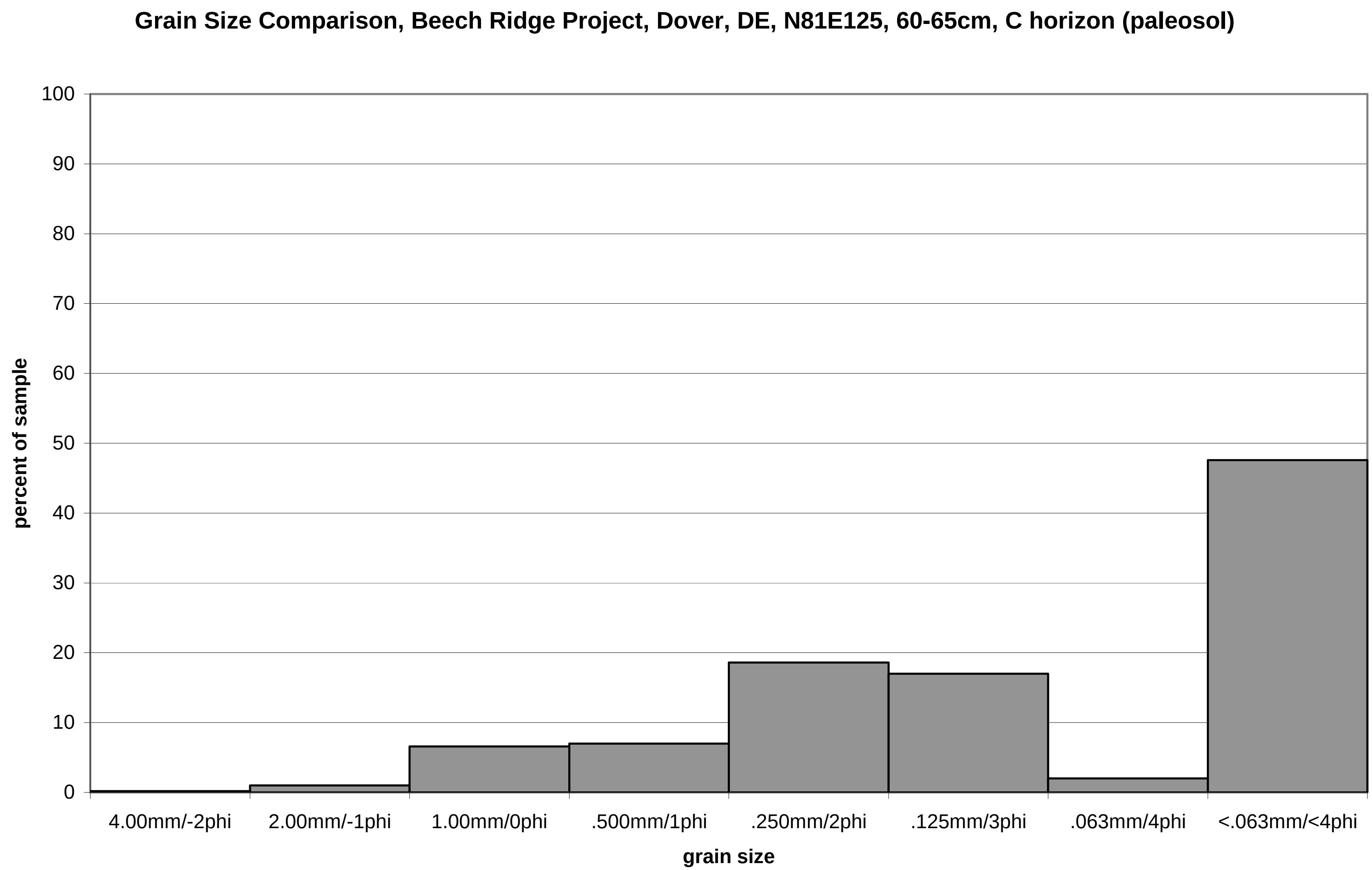
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 40-45cm, C horizon

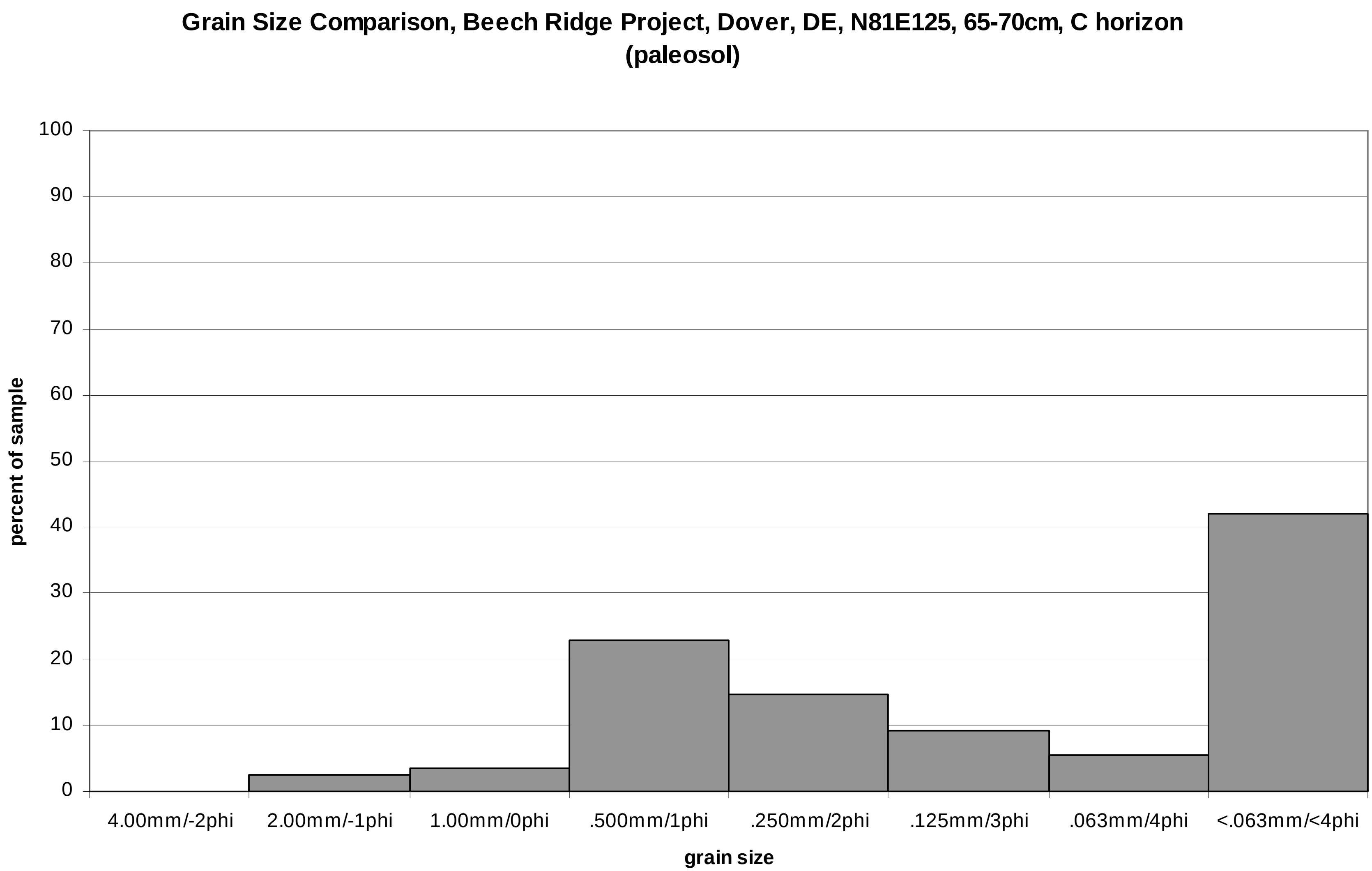



Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 45-50cm, C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

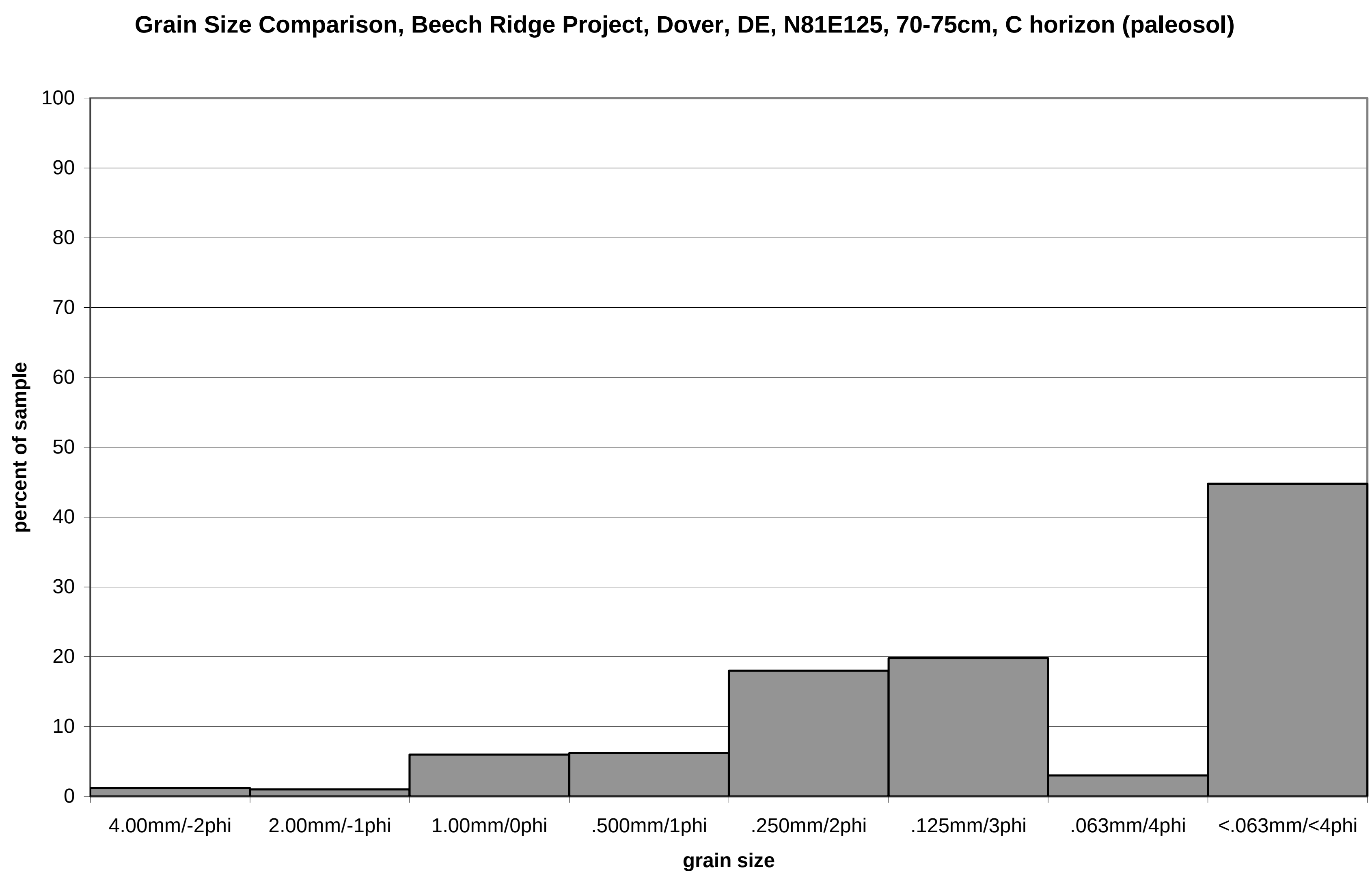

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 50-55cm, C horizon (paleosol)
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

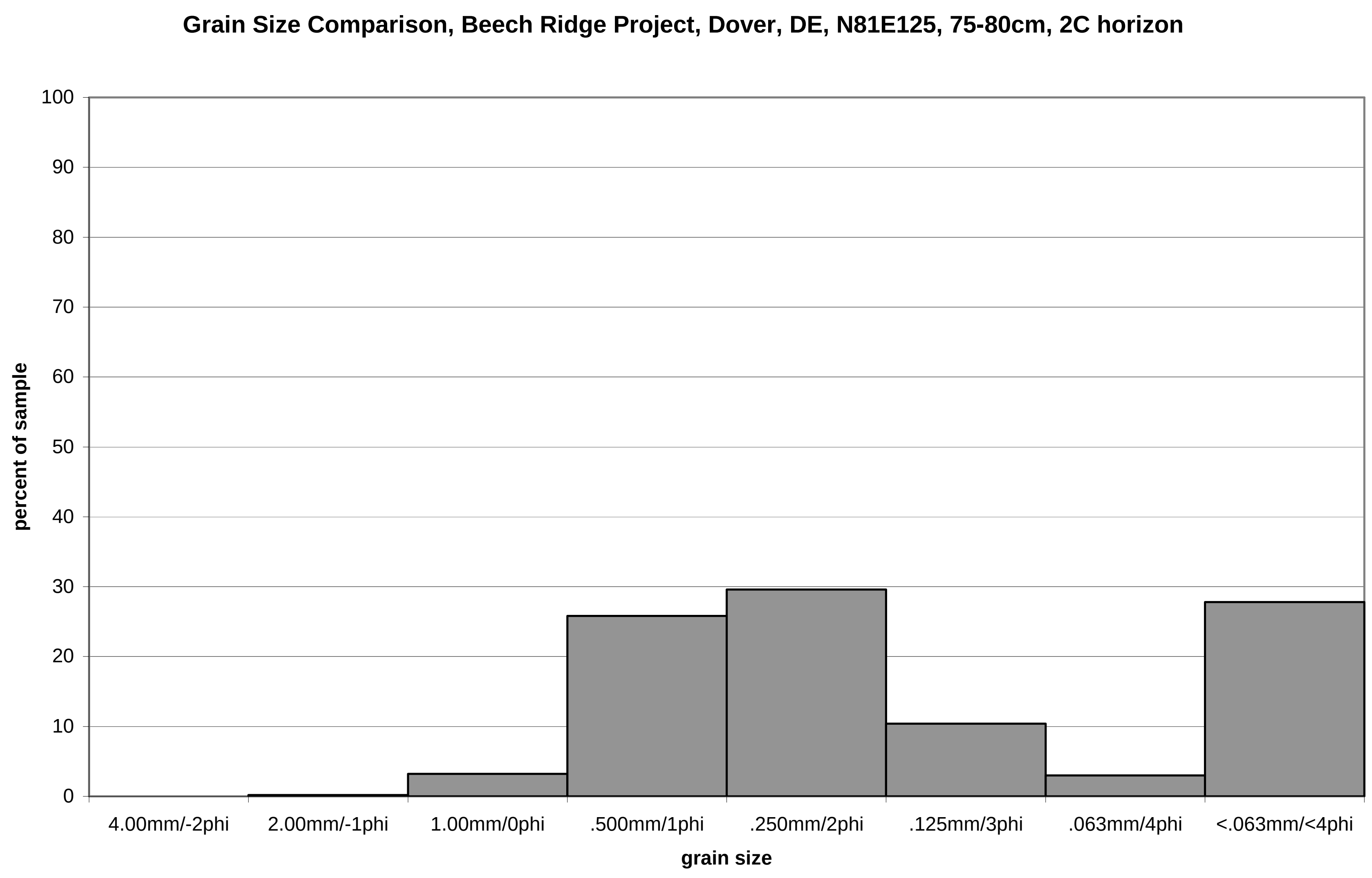

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 55-60cm, C horizon, (paleosol)
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

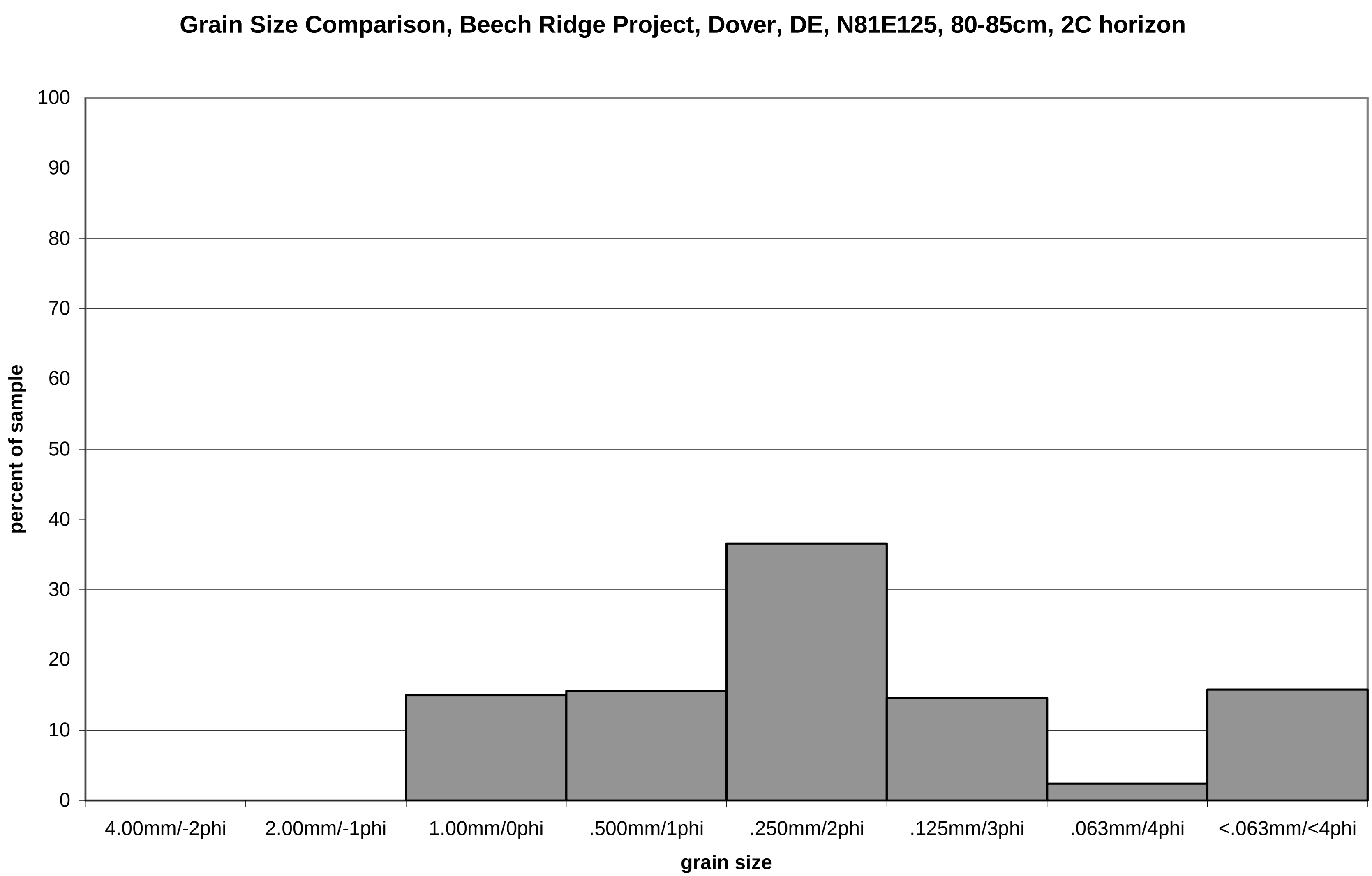

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 60-65cm, C horizon (paleosol)
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size



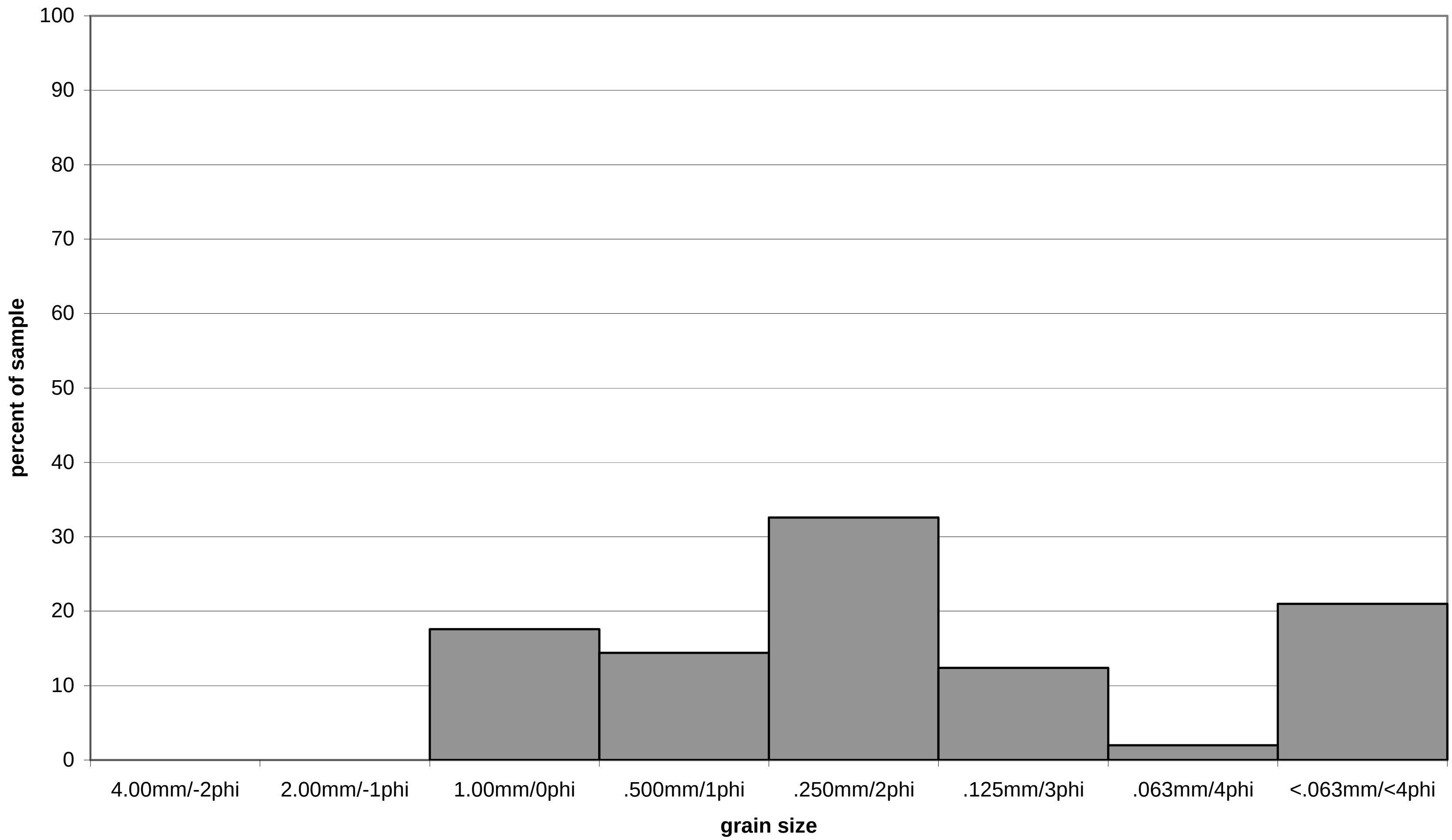
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 65-70cm, C horizon (paleosol)
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 70-75cm, C horizon (paleosol)
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

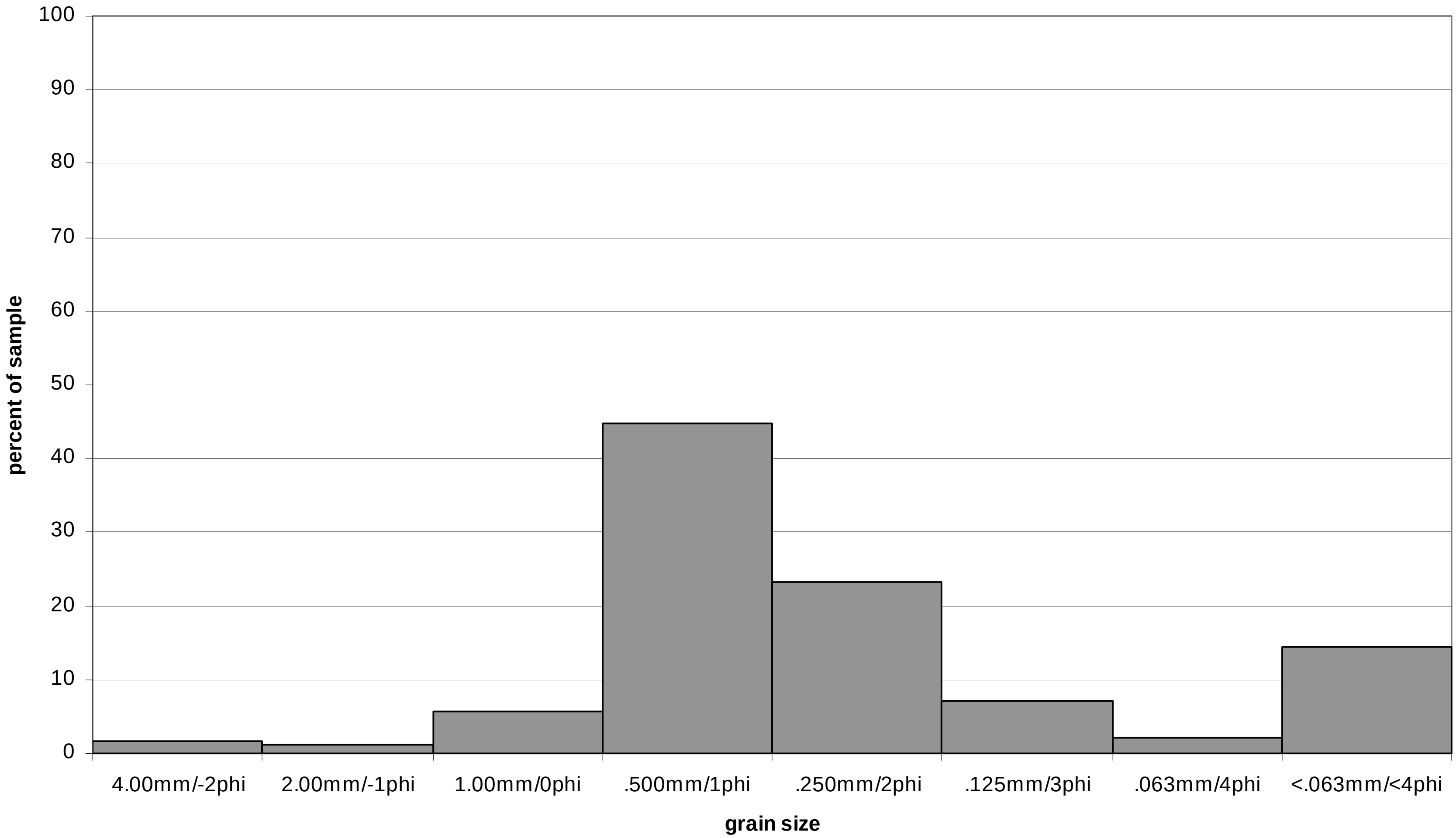

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 75-80cm, 2C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 80-85cm, 2C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

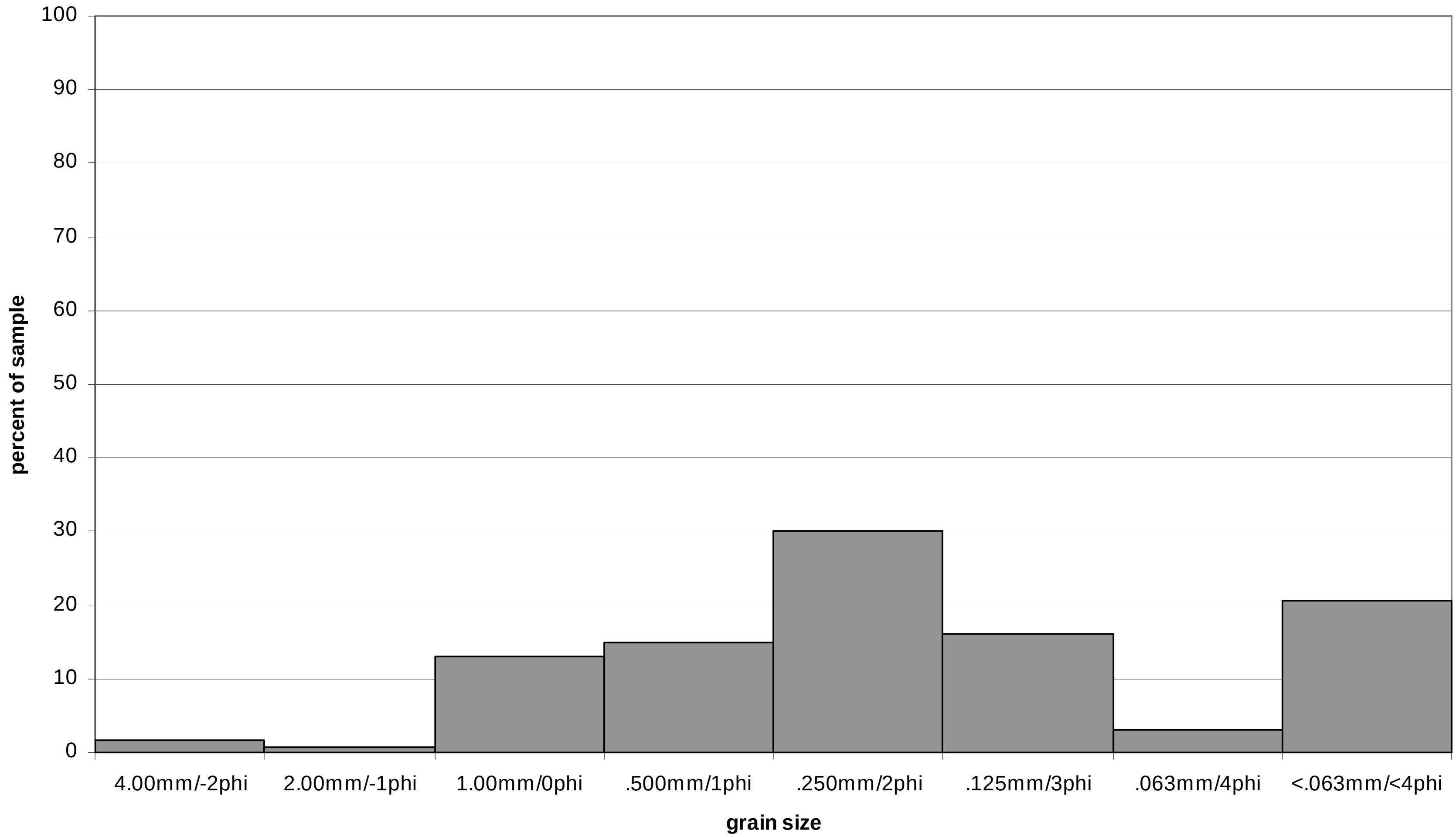
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 85-95cm, 2C horizon



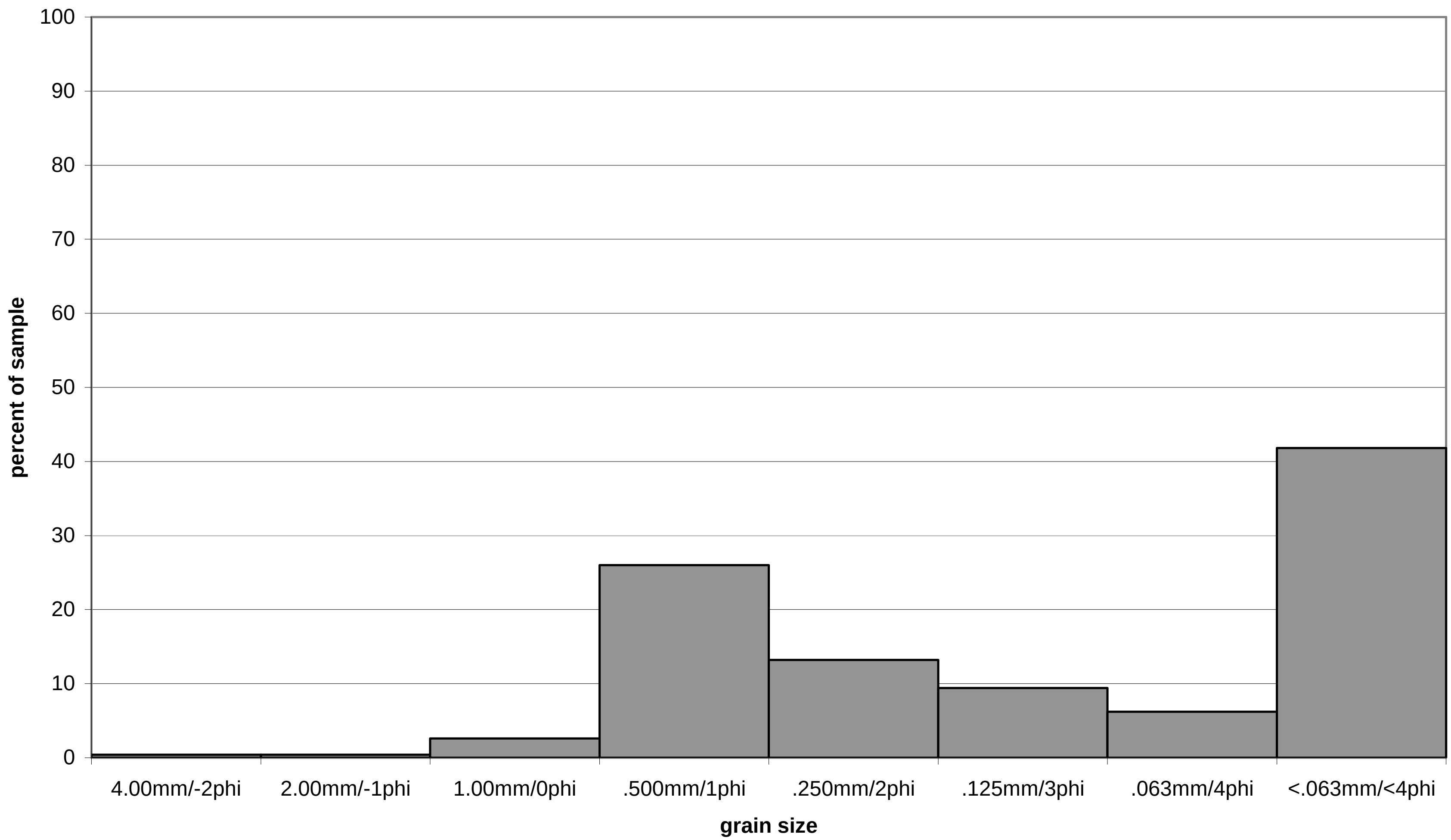
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 95-115cm, 2C horizon

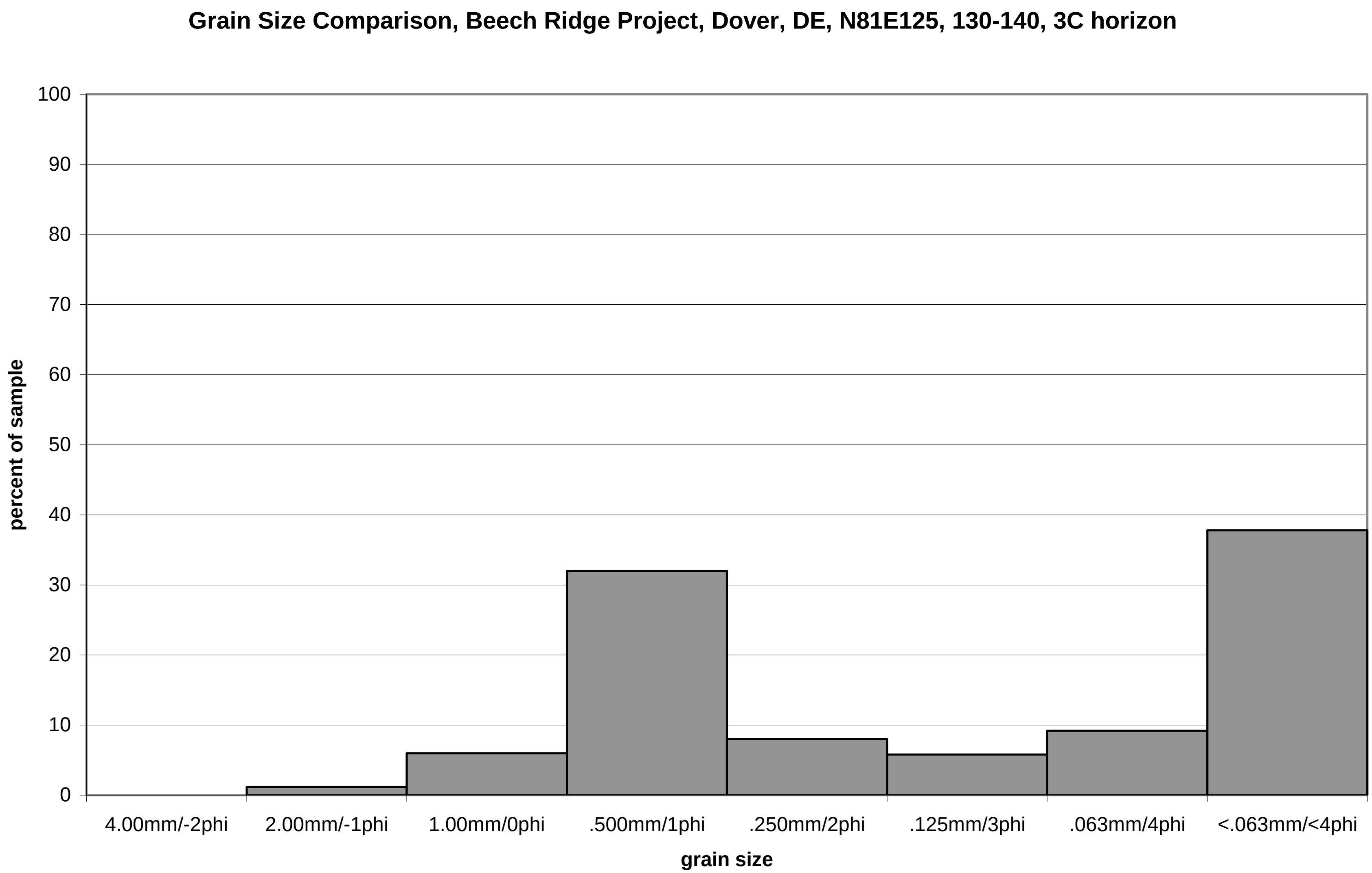


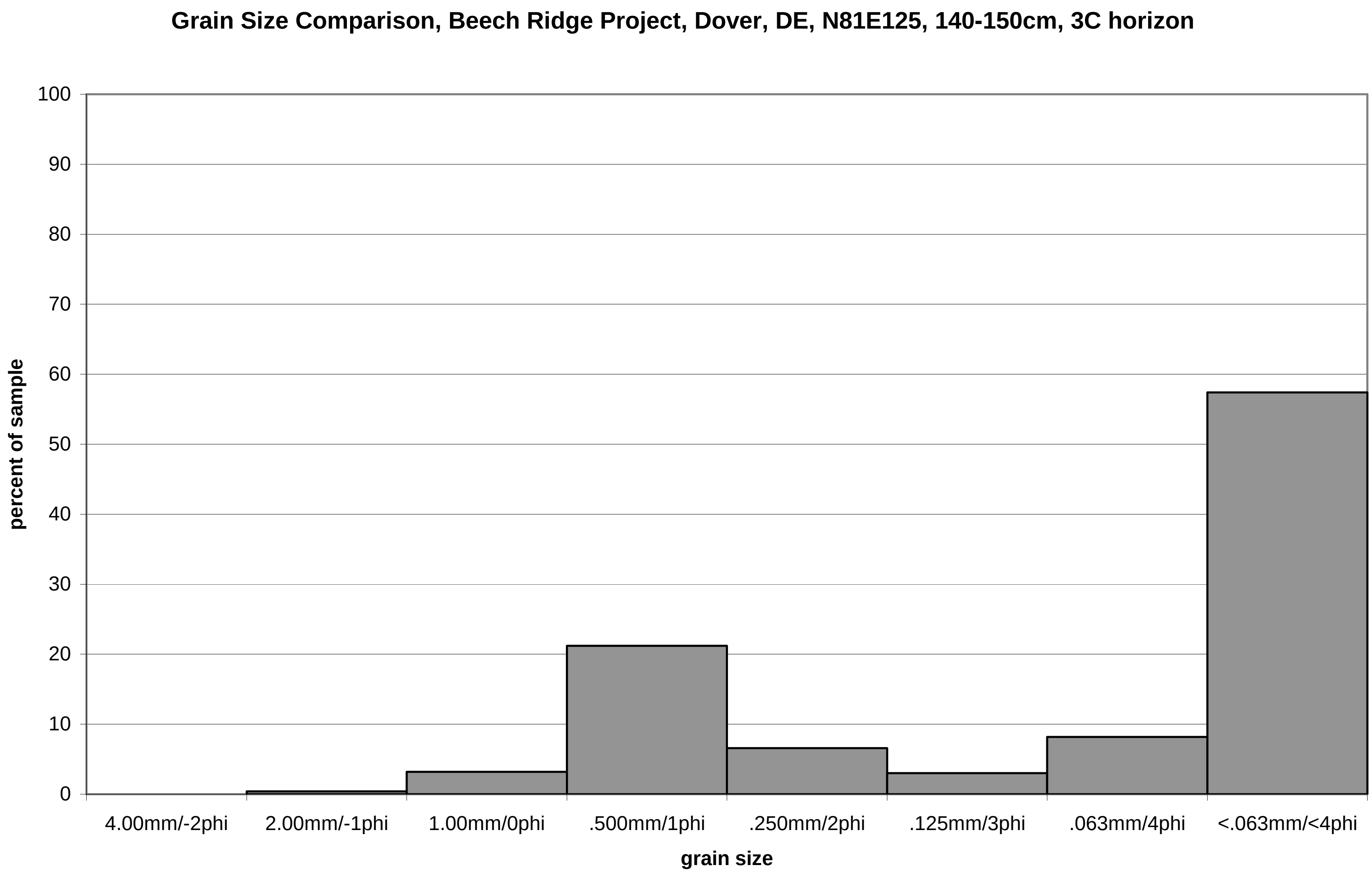
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 115-125cm, 2C horizon

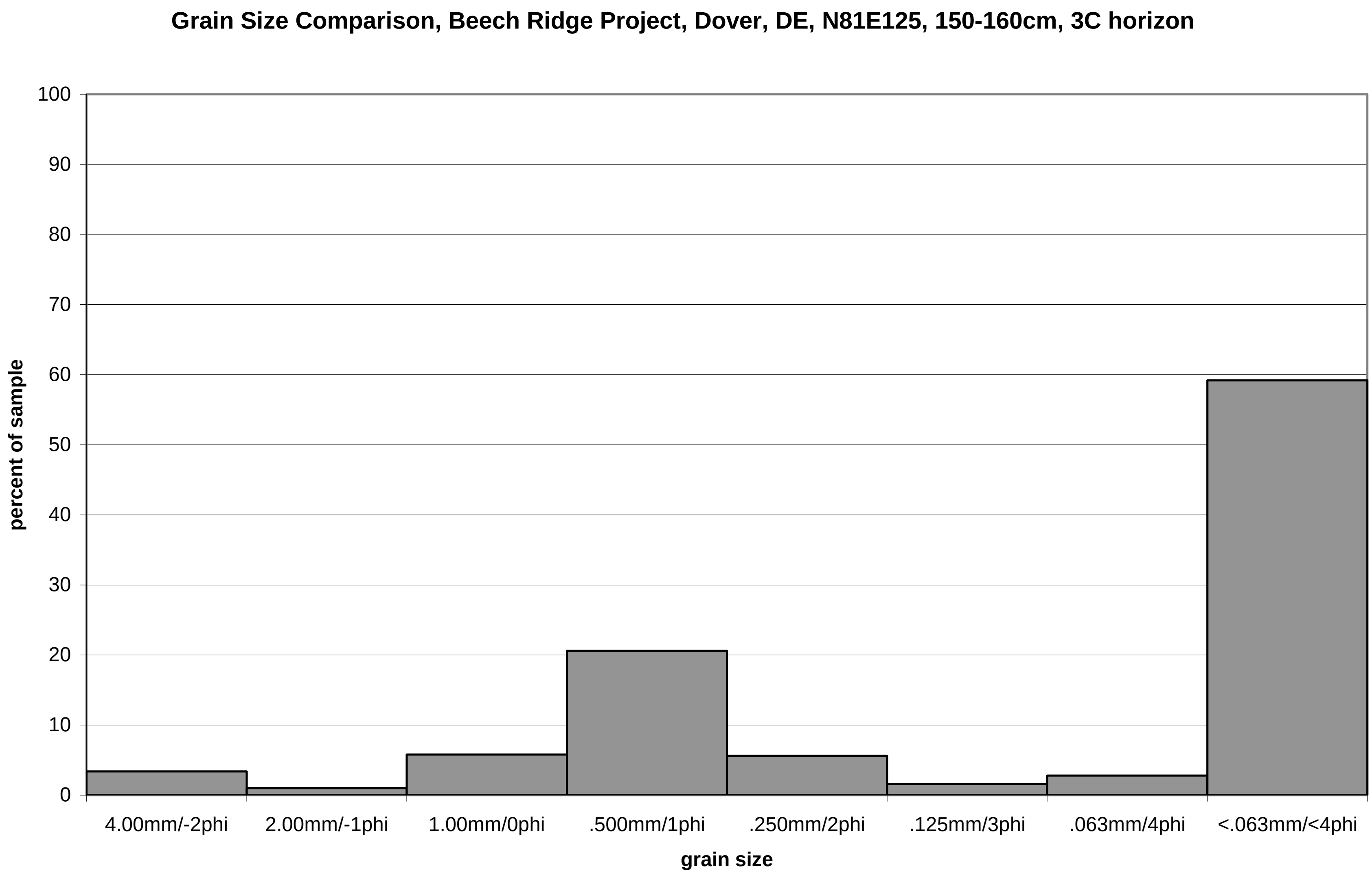


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 125-130cm, 2C horizon

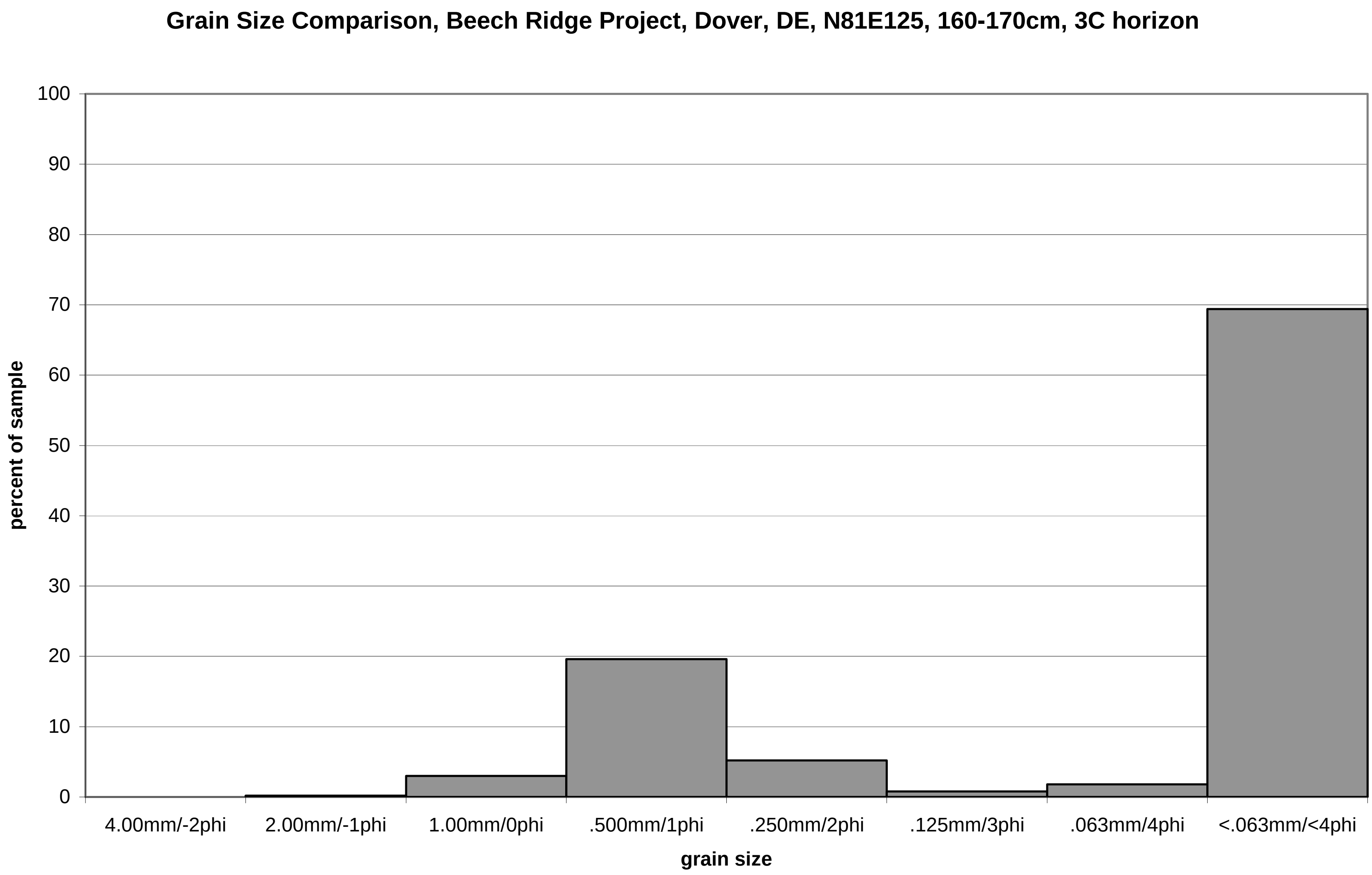



Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 130-140, 3C horizon
100
90
80
70
60
50
40
30
20
10
0
percent of sample
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

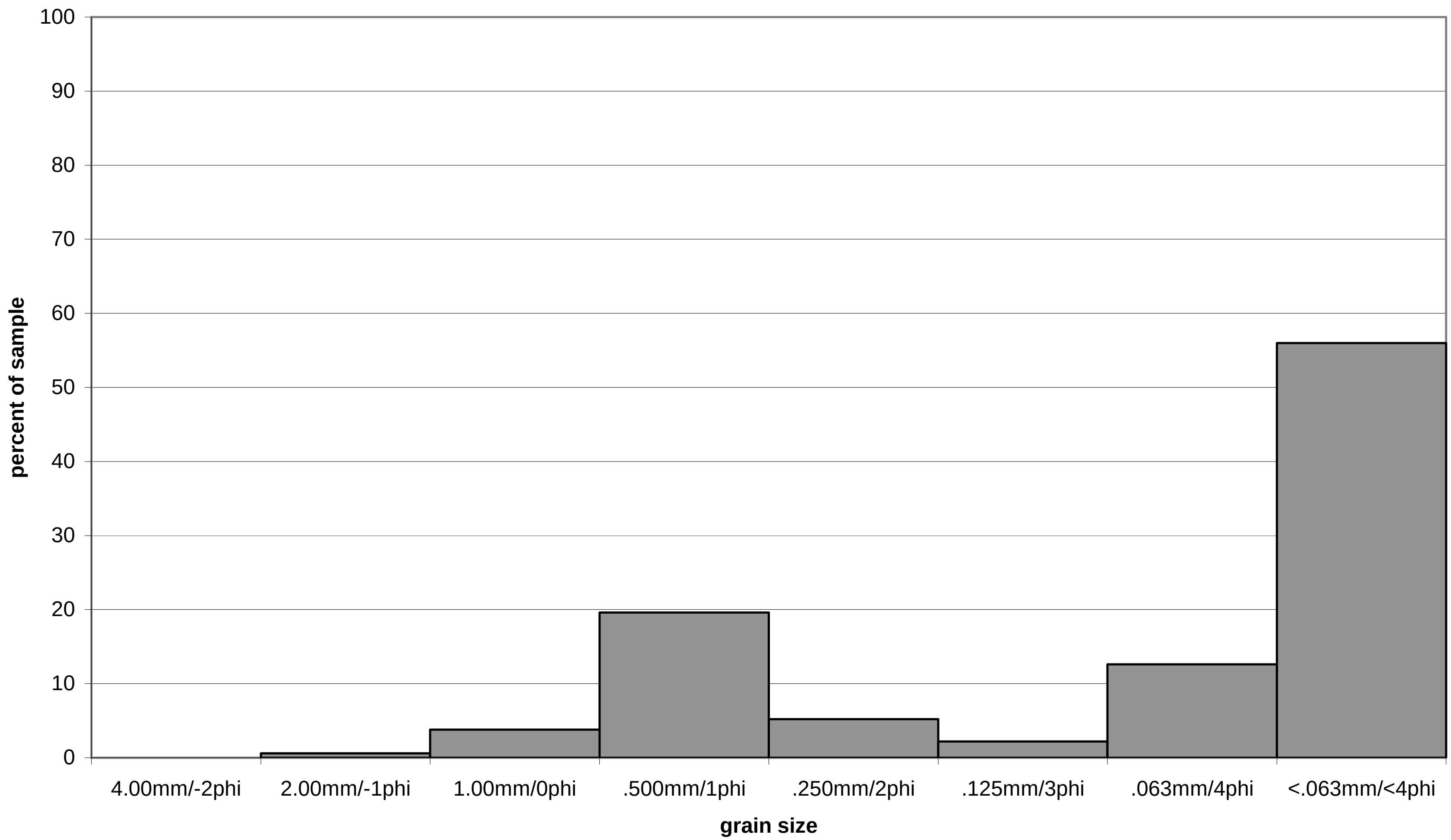

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 140-150cm, 3C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

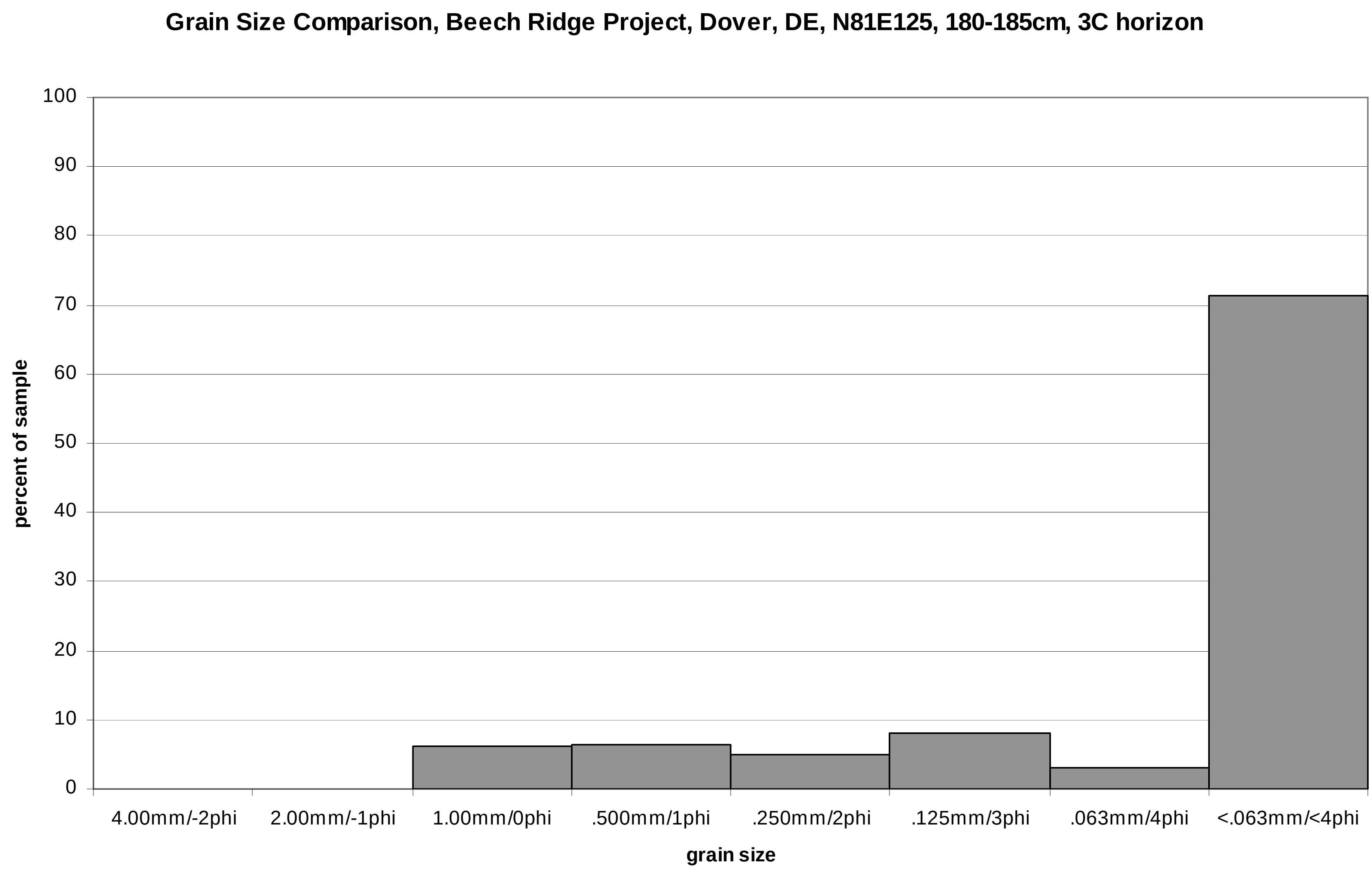


Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 150-160cm, 3C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

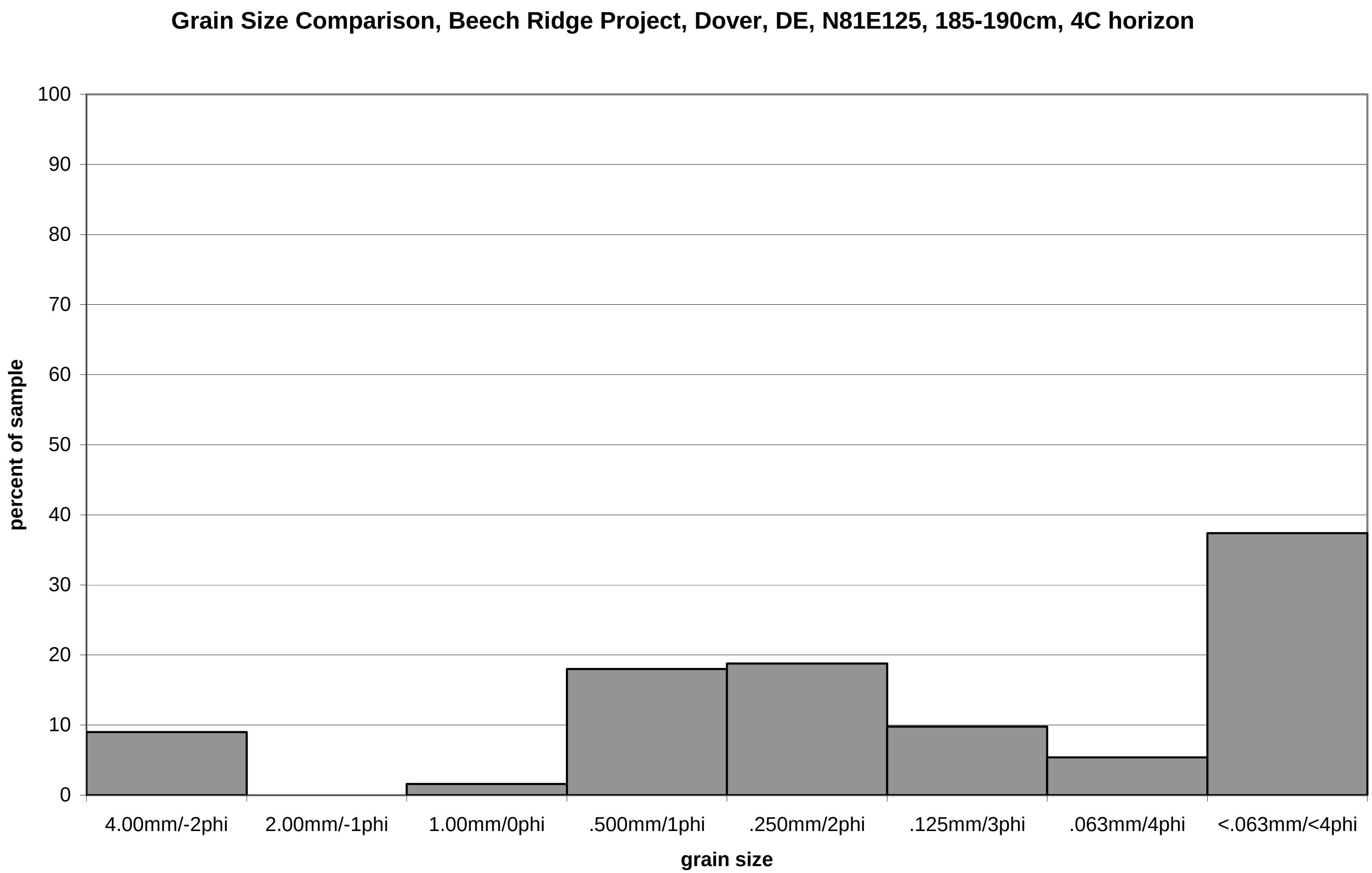

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 160-170cm, 3C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 170-180cm, 3C horizon



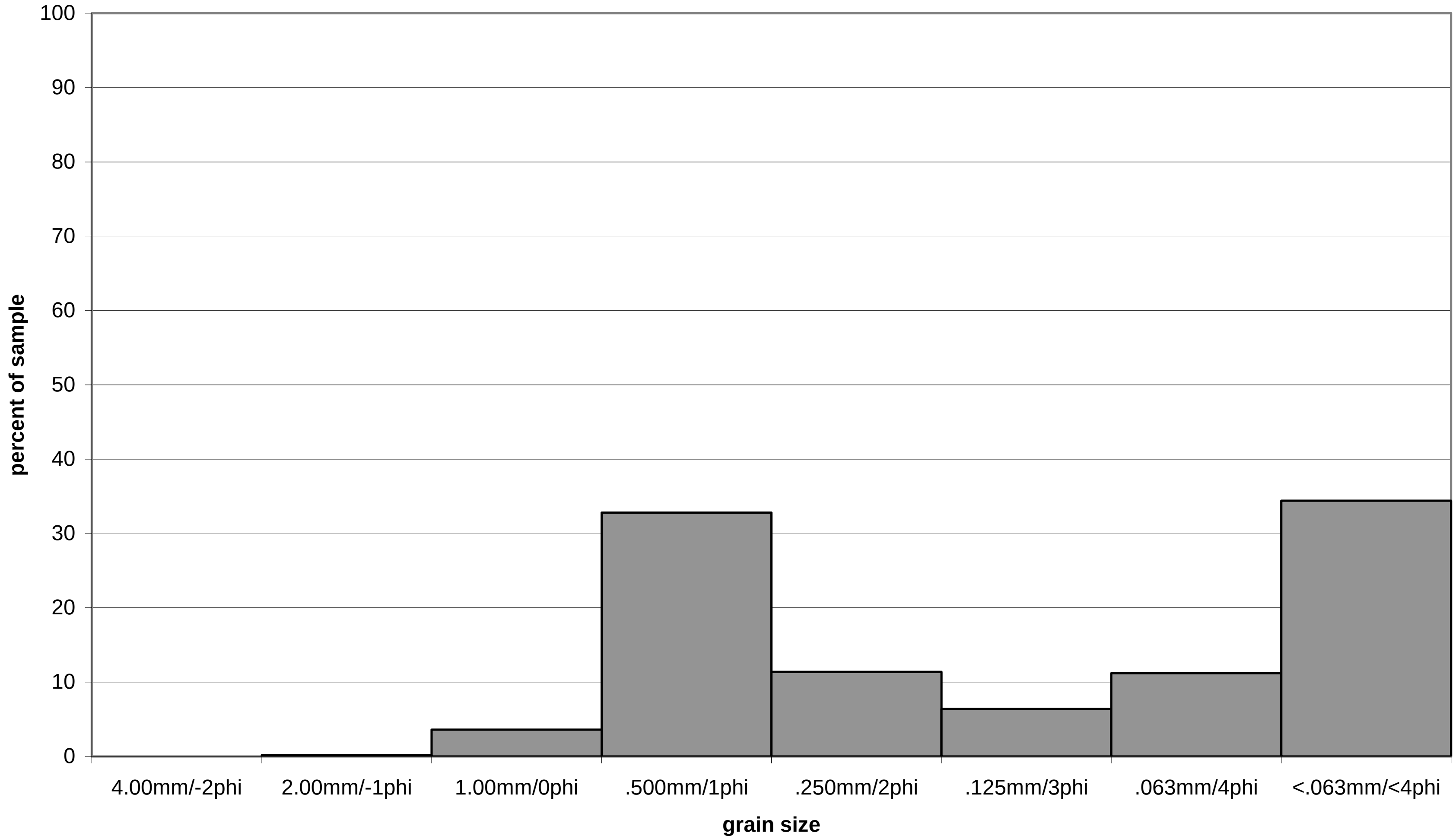

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 180-185cm, 3C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

B.94

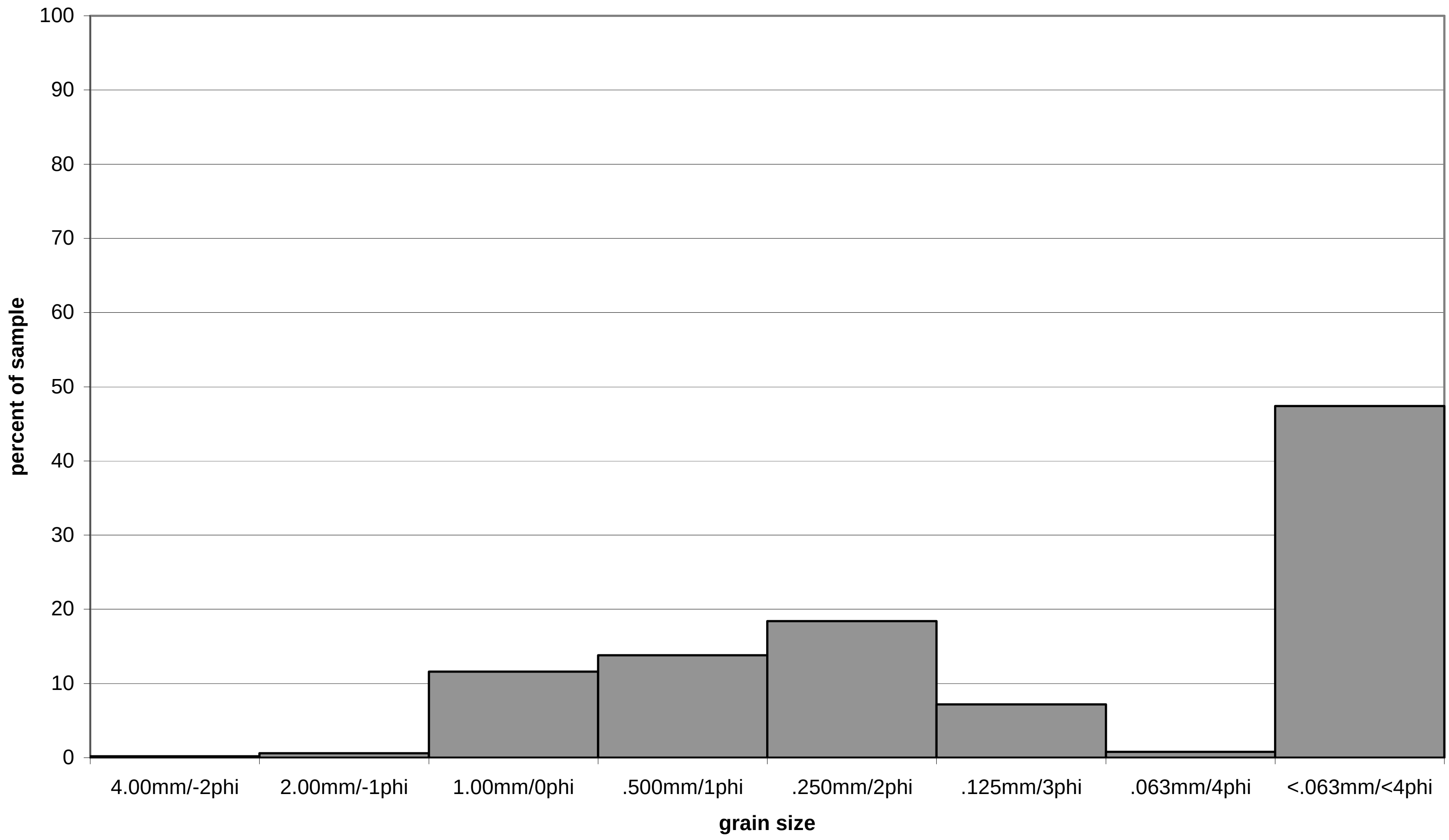


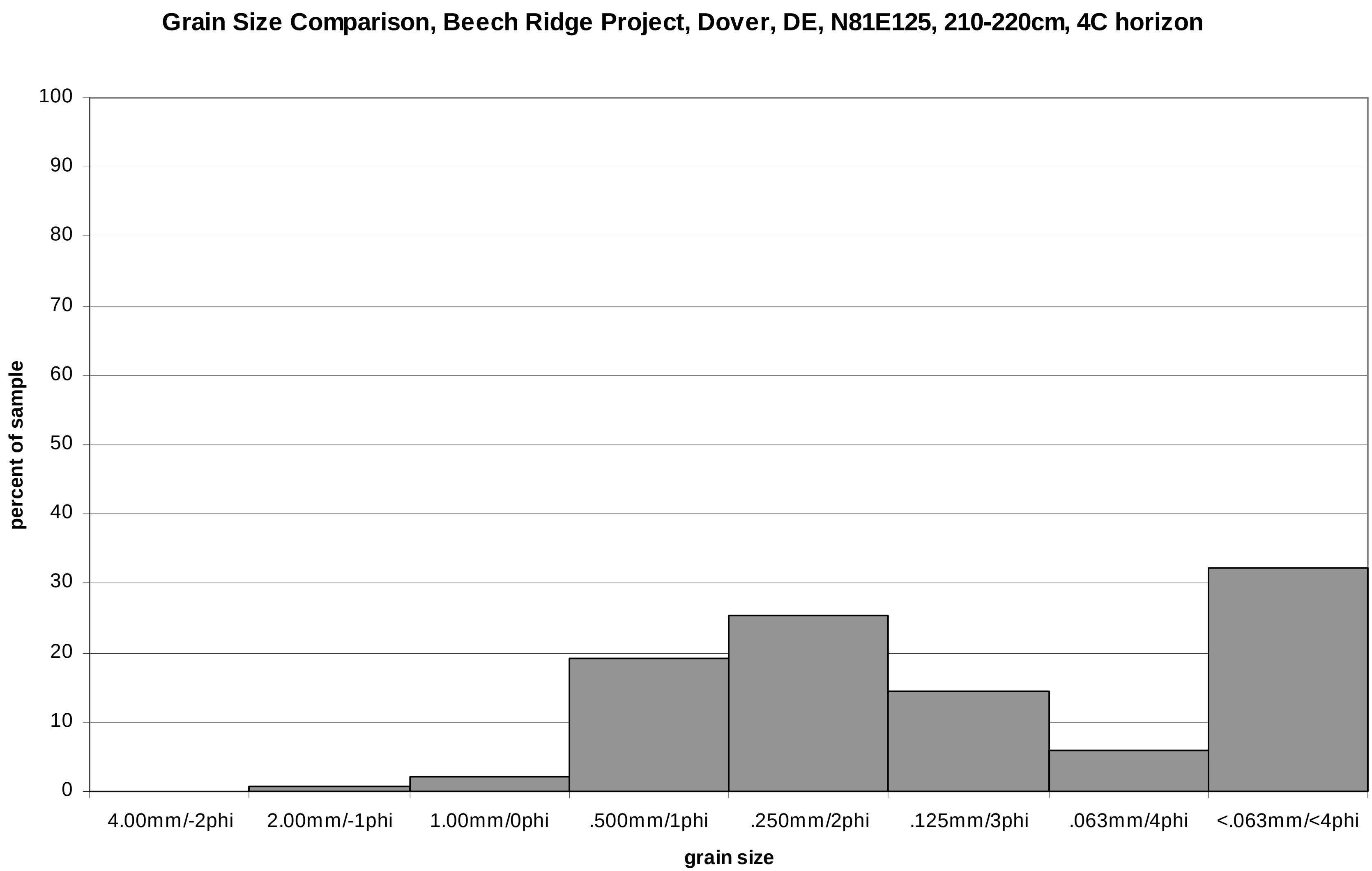
Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 185-190cm, 4C horizon
percent of sample
100
90
80
70
60
50
40
30
20
10
0
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 190-200cm, 4C horizon



Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 200-210cm, 4C horizon




Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 210-220cm, 4C horizon
100
90
80
70
60
50
40
30
20
10
0
percent of sample
4.00mm/-2phi
2.00mm/-1phi
1.00mm/0phi
.500mm/1phi
.250mm/2phi
.125mm/3phi
.063mm/4phi
<.063mm/<4phi
grain size

Grain Size Comparison, Beech Ridge Project, Dover, DE, N81E125, 220-225cm, 4C horizon