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Report of Investigations 114

GRAIN-SIZE ANALYSIS OF POST-CRETACEOUS SAND AND GRAVEL UNITS IN SOUTHEASTERN SOUTH DAKOTA

by

THOMAS N. HAGGAR
KELLI A. MCCORMICK
SARAH A. CHADIMA
LAYNE D. SCHULZ

Science Center
University of South Dakota
Vermillion, South Dakota

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INTRODUCTION

Several quartz-rich sand and gravel bodies located in southeastern South Dakota have been described in outcrop, drill holes, and cores as being “western derived” in origin (i.e., having a Rocky Mountain or Black Hills source). These sand and gravel bodies typically occur, or are preserved in areas, where the local bedrock forms a high beneath glacial sediments in southeastern South Dakota. The deposits are typically clean (having a low clay content), quartz-rich, feldspar-bearing sand and gravel. They appear to be similar to deposits belonging to the Ogallala Group, Bon Homme gravels, and Herrick gravels that have a western source.

This report is the first part of a multi-phase investigation to classify the geologic age and provenance of “western derived” sediments. In this initial phase, 44 grain-size analyses are presented, from which statistical parameters were derived and compared. Other planned phases of this investigation include x-ray diffraction analyses and modal mineralogical determinations of samples analyzed in this initial phase.

Sampling Methods

Sample locations are presented in figure 1. Map location numbers (fig. 1), sample formation names (if known), collection dates, sample names and numbers, sample source, sample depths, sample legal locations, and county are summarized in table 1.

Samples are one of three types: 1) spot samples from outcrops, 2) composite samples from drill cuttings, or 3) spot samples from previously collected cores. For samples collected from outcrops, the area was cleared of recent debris until a fresh exposure could be seen and a representative sample could be collected. Samples obtained by drilling methods were collected as cuttings from mud rotary methods, auger flights, or a hand-auger bucket, and are composite samples over 5-foot intervals (10-foot intervals for mud rotary samples). Samples were also collected from cores available at the South Dakota Geological Survey. First, spot samples were taken from the cores and analyzed. Then, for each individual core, split samples of these spot samples were combined and analyzed as a composite of the entire sand unit sampled.

Laboratory Methods

Grain-size analyses were conducted according to the methods described by Folk and Ward (1957). The samples were first allowed to air dry in aluminum pans. As a significant amount of moisture was retained on the samples collected by drilling methods, these samples were placed in a mechanical oven and heated to 60°C for a period of 3 hours to facilitate drying. After drying, all samples were visually inspected and disaggregated by the use of a mortar and pestle.

The samples were next weighed to the nearest 0.01 gram (g). Samples that contained grain sizes larger than 2 millimeters (mm) in diameter were sieved by hand through the -1.0 phi (ϕ) sieve to separate the gravel size fraction. The gravel fraction was then sieved through the -4ϕ,

-3ϕ, -2ϕ, -1.75ϕ, -1.25ϕ, and -1.0ϕ sieves and the individual weight retained by each sieve was recorded.

Using a riffle box, the sand fractions (<2 mm in diameter) of the samples were split and weighed to the nearest 0.01 g. Next, the samples were sieved for 10 minutes through a standard series of 8-inch diameter sieves using a Ro-Tap machine. The individual weight of sediment retained on each sieve was then weighed to the nearest 0.01 g and recorded. The masses were multiplied by the splitting factor (the total weight of sand in the entire sample divided by the total weight of sand in the split sample) to obtain the corrected weights of each size fraction**.**

Following sieving of the sample, each of the size fractions was observed under a binocular microscope in an effort to correctly estimate the percentage of aggregates still present. By placing the sediments on a plastic weighing pan and viewing them with transmitted light, the aggregates were easily identifiable. If aggregates were present, their mass (based on visual percentage estimations) was subtracted from the corrected weights to obtain an estimate of the true mass of each size fraction (Folk and Ward, 1957). Significant volumes of aggregates were only present in samples of cemented formations, such as the Spencer quarry sample of Sioux Quartzite.

GRAIN-SIZE DATA ANALYSIS

Histograms

Histograms present a factual picture of the abundance of grains in each grade size, and they cannot be used directly for numerical summaries of the data (Krumbein and Sloss, 1963). Histograms displaying individual weight percents for each size fraction are presented in appendix A for each sample analyzed. Several of the samples, mainly those from the Ogallala Group and Turkey Ridge cores, have large pan fractions. A pipette analysis is required for a true determination of modality for these samples. The laboratory was not set up for such an analysis at the time of this investigation and the analyses for these samples are incomplete.

Cumulative Curves

Cumulative curves can be used as graphic devices for determining average particle size and other properties (Krumbein and Sloss, 1963). Cumulative frequency curves were prepared by adding the percentages in succeeding size grades and drawing a smooth curve through the points (app. B).

Statistical Analysis

Statistical measures are used to compare sedimentary environments in a quantitative manner. Properties such as average size, sorting, and frequency distributions may be determined either graphically (Folk and Ward, 1957) by reading selected percentiles off cumulative curves or mathematically by the method of moments (Boggs, 1995).

Graphical Treatment of Grain-Size Data

Cumulative frequency curves using a semi-logarithmic scale (app. B) were constructed to determine the graphical mean, standard deviation, skewness, and kurtosis for each sample. By applying the appropriate phi values (compiled in app. C) from the cumulative frequency curves to the formulas listed in table 2, statistical parameters of mean, skewness, kurtosis, and standard deviation were calculated (app. D).

Mathematical Treatment of Grain-Size Data

Statistical parameters were also calculated using the method of moments by applying formulas listed in table 3. The results of the statistical analyses are given in appendix D. As stated previously, many of the samples have large pan fractions and as Lindholm (1987) notes, “when employing moment methods, kurtosis and skewness are greatly affected by the size and mass of the sediment in the pan. As the size is inaccurate, owing itself solely to the diameter of the finest sieve, skewness and kurtosis cannot be accurately determined unless the pan fraction is analyzed further” (i.e., pipette analysis). Thus, the statistical parameters calculated using the method of moments should not be used to characterize those samples with large pan fractions.

REFERENCES

Boggs, S., Jr., 1995, Principles of sedimentology and stratigraphy: Prentice-Hall, Inc., 774 p.

Folk, R.L., and Ward, W.C., 1957, Brazos River Bar: A study in the significance of grain size parameters: Journal of Sedimentary Petrology, v. 27, no. 1, p. 3-26.

Krumbein, W.C., and Sloss, L.L., 1963, Stratigraphy and sedimentation: W.H. Freeman and Company, 660 p.

Lindholm, R.C., 1987, A practical approach to sedimentology: Allen and Unwin, Inc., 276 p.

Figure 1. Locations of collected samples.

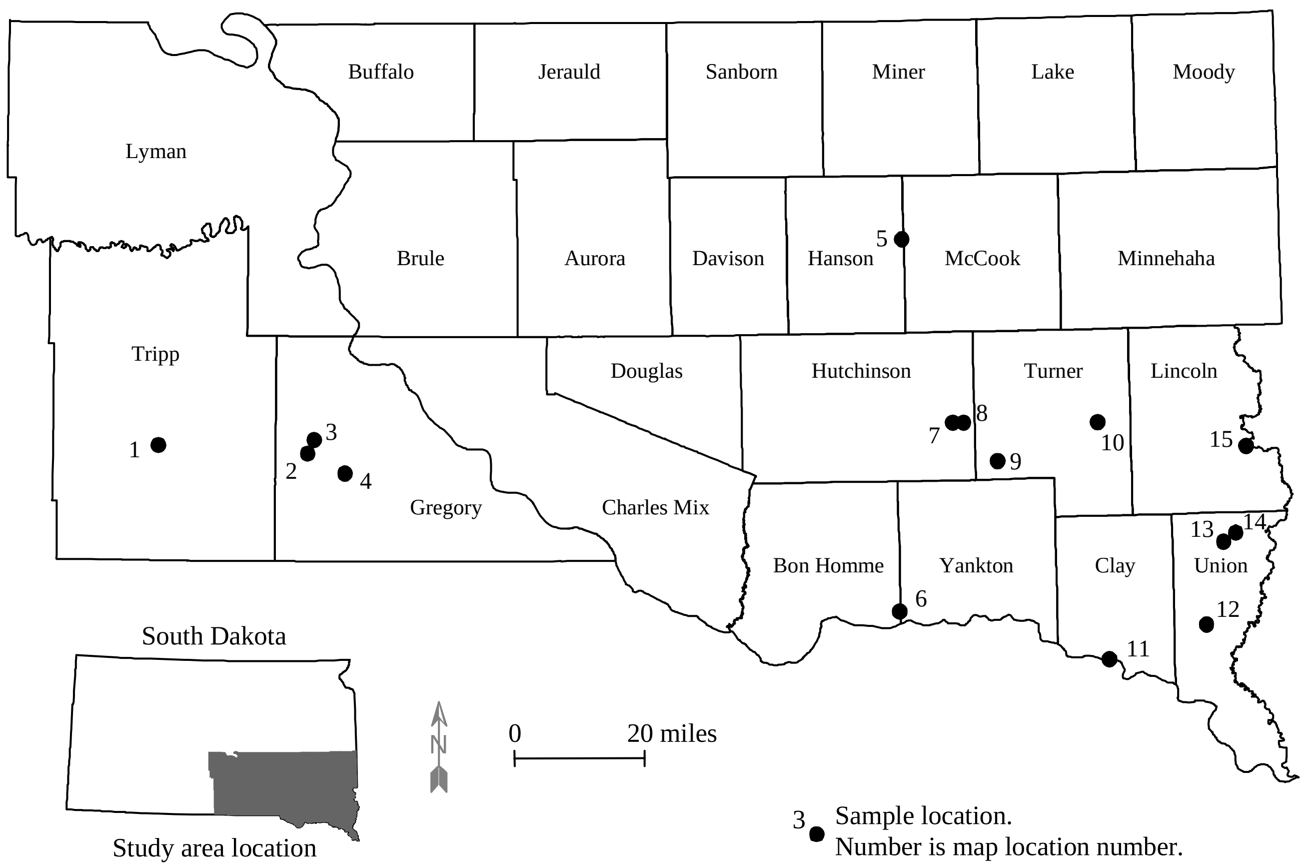


Table 1. Sample collection and location data

Map location number[1]	Geologic group or formation	Collection date	Sample name and number	Sample source	Sample depth (in feet)[2]	Legal location	County
13	uncertain – “western derived”? sand	06-01-01	Alcester 6-1-2	auger cuttings	surface	SE SE NE NE sec. 29, T. 95 N., R. 49 W.	Union
14	uncertain – “western derived”? sand	06-01-01	Alcester 6-1-7	auger cuttings	surface	NE NW NE NE sec. 22, T. 95 N., R. 49 W.	Union
15	uncertain – “western derived”? sand	05-24-01	Newton Hills 5-24-2	outcrop	surface	NE SW NE SE sec. 12, T. 97 N., R. 49 W.	Lincoln
8	uncertain – “western derived”? sand	05-01-01	Turkey Ridge R20-01-2	mud rotary cuttings	40-50	SW SW SW SW sec. 14, T. 98 N., R. 56 W.	Hutchinson
7	uncertain – Ogallala?	04-24-01	Turkey Ridge R20-01-1	core	105-110 117 127 141-145 151 160-161 173-174 180-185 composite	SW SW SW SW sec. 15, T. 98 N., R. 56 W.	Hutchinson
9	uncertain – Ogallala?	06-25-01	Turkey Ridge R20-87-14	core	200-205 205-210 210-215 225-230 230-235 composite	NW NE NE NW sec. 22, T. 97 N., R. 55 W.	Turner
12	“western derived” sand	06-25-01	Heeren core	core	27.5-28.25 30-35 35-40 40-45 45-50 50-55 55-60 60-65 65-70 composite	SW SW SW SW sec. 25, T. 93 N., R. 50 W.	Union

Table 1 – continued

Map location number[1]	Geologic group or formation	Collection date	Sample name and number	Sample source	Sample depth (in feet)[2]	Legal location	County
6	"western derived" sand	05-22-01	Bon Homme 5-22-2	sand pit	surface	SE SE SE SE sec. 12, T. 93 N., R. 58 W.	Bon Homme
4	"western derived" sand	05-23-01	Herrick gravel 5-23-3	sand pit	surface	NW NE NE NE sec. 26, T. 97 N., R. 72 W.	Gregory
3	Ogallala – Ash Hollow Member	05-23-01	Ash Hollow 5-23-4	Road cut/ outcrop	surface	NW NW NW NW sec. 31, T. 98 N., R. 72 W.	Gregory
2	Ogallala – Ash Hollow Member?	05-23-01	Gregory City 5-23-5	outcrop	surface	SW NW NW NW sec. 12, T. 97 N., R. 73 W.	Gregory
2	Ogallala – Ash Hollow or Valentine Member	05-23-01	Gregory City 5-23-6	outcrop	surface	SW NW NW NW sec. 12, T. 97 N., R. 73 W.	Gregory
1	Ogallala	06-04-01	R20-01-5	core	27-28 40-41 58.5-59.5 67-68 75-76 88-89 composite	SW SW SW SW sec. 31, T. 98 N., R. 76 W.	Tripp
10	Glacial outwash	05-22-01	Hurley 5-22-5	small gravel pit	surface	NW NW NW SW sec. 20, T. 98 N., R. 52 W.	Turner
11	Recent sand and gravel	05-21-01	Missouri 5-21-1	outcrop	surface	SW NE sec. 7, T. 32 N., R. 4 E.	Clay
5	Sioux Quartzite	05-10-01	Spencer quarry 5-10-1	quarry	surface	NE sec. 24, T. 103 N., R. 57 W.	Hanson

[1] See figure 1.
[2] Samples were collected and analyzed from each depth or depth interval listed. For each core sampled, a separate composite sample was made and analyzed by combining samples from each depth.

Table 2. Formulas for graphical determination of statistical measures

Graphic mean	$\frac{\phi 16 + \phi 50 + \phi 84}{3}$
Inclusive graphic skewness	$\left[\frac{(\phi 84 + \phi 16 - 2\phi 50)}{2(\phi 84 - \phi 16)}\right] + \left[\frac{(\phi 95 + \phi 5 - 2\phi 50)}{2(\phi 95 - \phi 5)}\right]$
Inclusive graphic standard deviation	$\left[\frac{\phi 84 - \phi 16}{4}\right] + \left[\frac{\phi 95 - \phi 5}{6.6}\right]$
Graphic kurtosis	$\frac{(\phi 95 - \phi 5)}{2.44(\phi 75 - \phi 25)}$

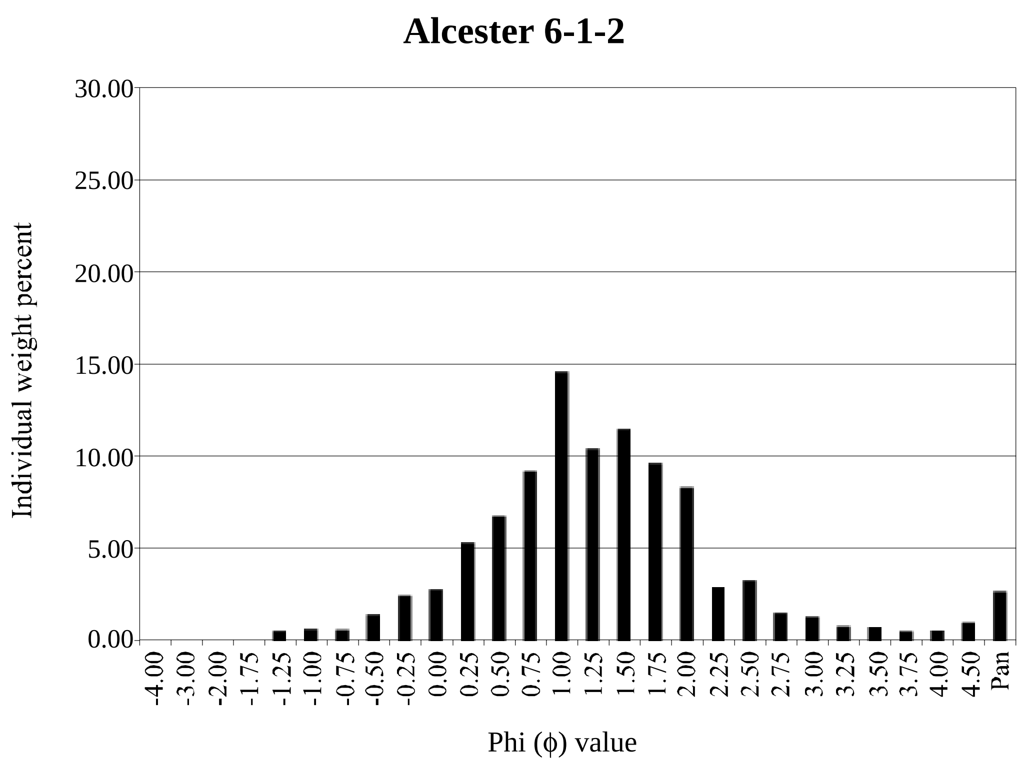
Information from Folk and Ward (1957).

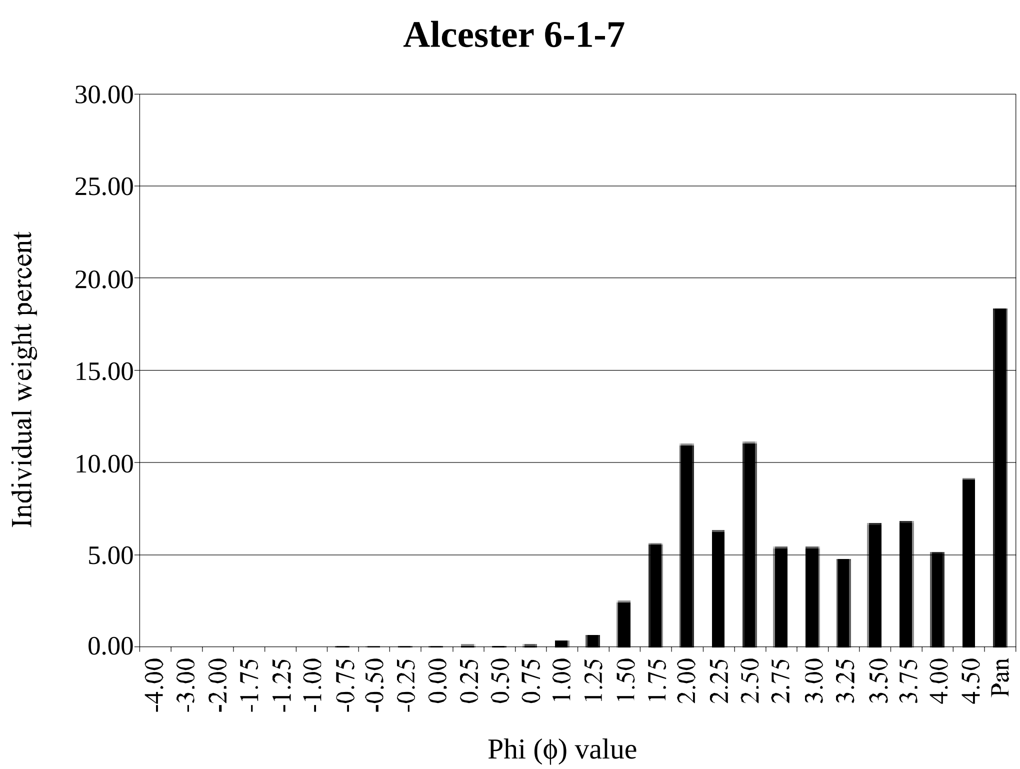
Table 3. Formulas for determination of statistical measures by method of moments

Mean 1st moment	$\boldsymbol{x}\phi = \frac{\Sigma fm}{n}$
Standard deviation 2nd moment	$\boldsymbol{\sigma}\phi = \sqrt{\frac{(\Sigma f\,(m - x\phi)^2)}{n}}$
Skewness 3rd moment	$\boldsymbol{Sk}\phi = \frac{\Sigma f\,(m - x\phi)^3}{n\sigma\phi^3}$
Kurtosis 4th moment	$\boldsymbol{K}\phi = \frac{\Sigma f\,(m - x\phi)^4}{n\sigma\phi^4}$
f = weight percent present per size grade ***m*** = midpoint of each size grade (ϕ) ***n*** = number of samples ***x*** = mean	

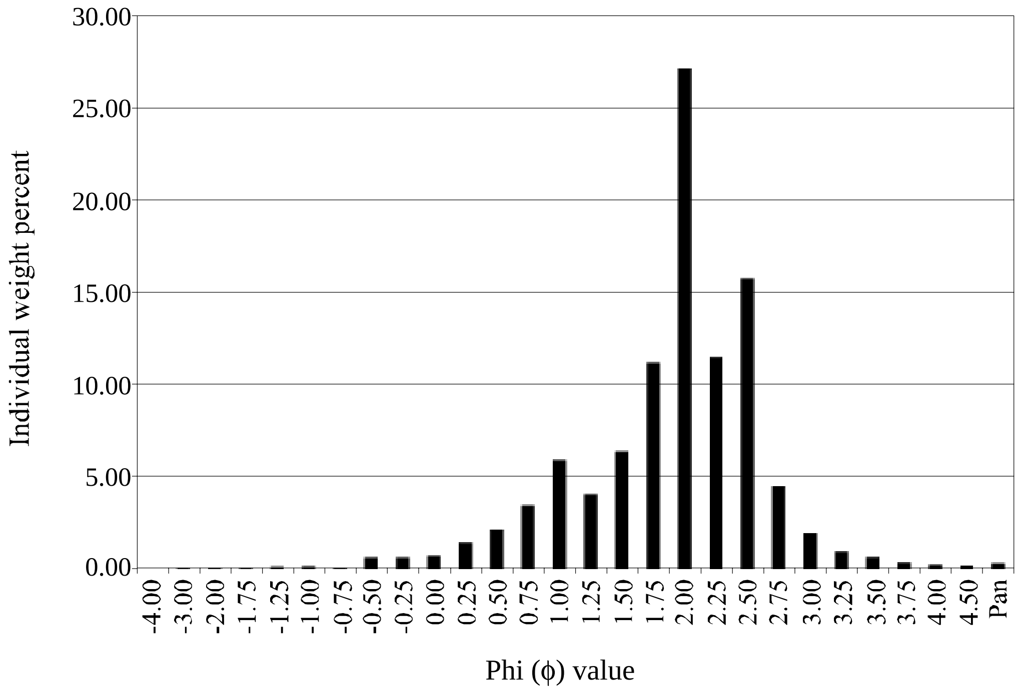
Information from Boggs (1995).

Appendix A. Histograms of individual weight percent by sieve size

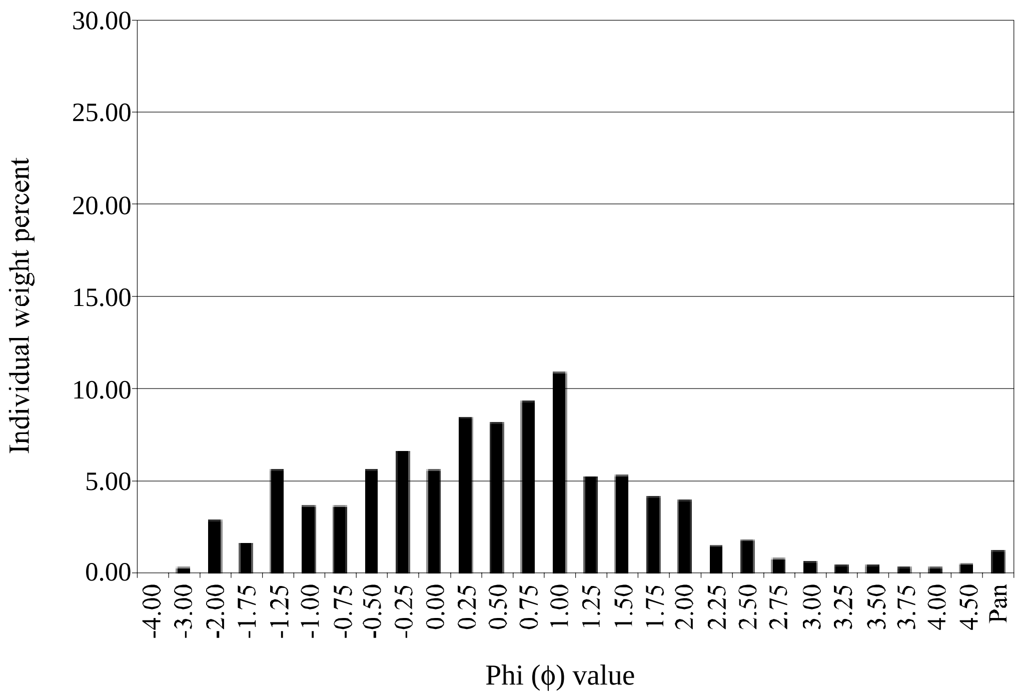


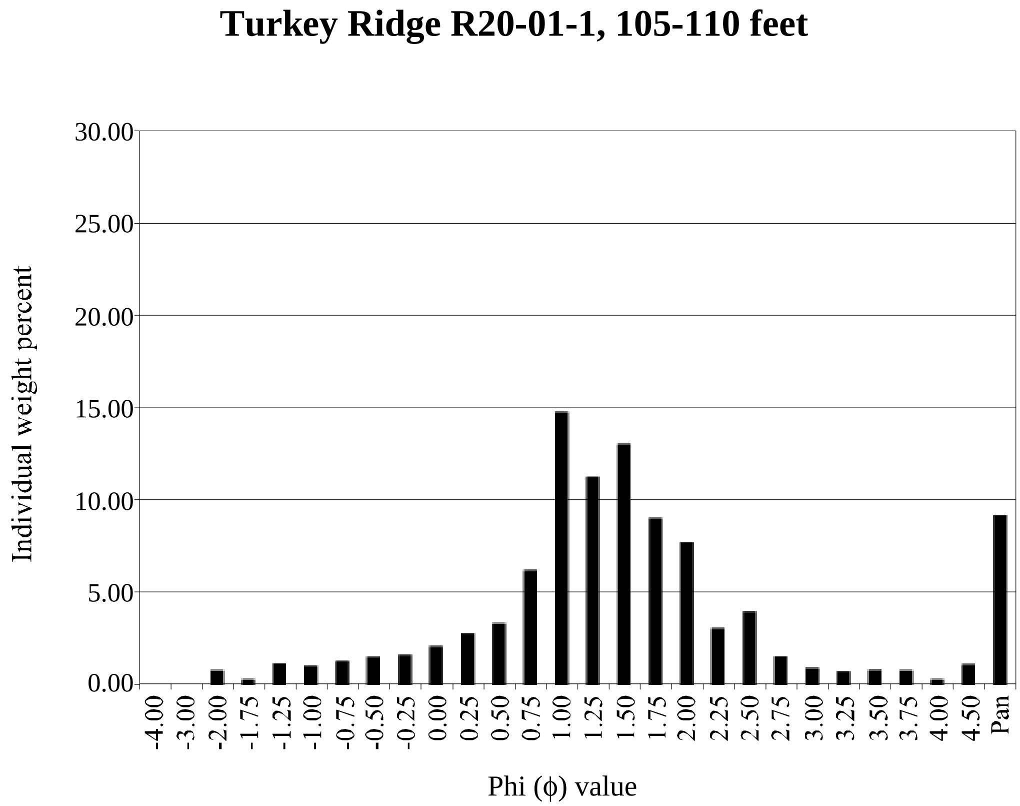


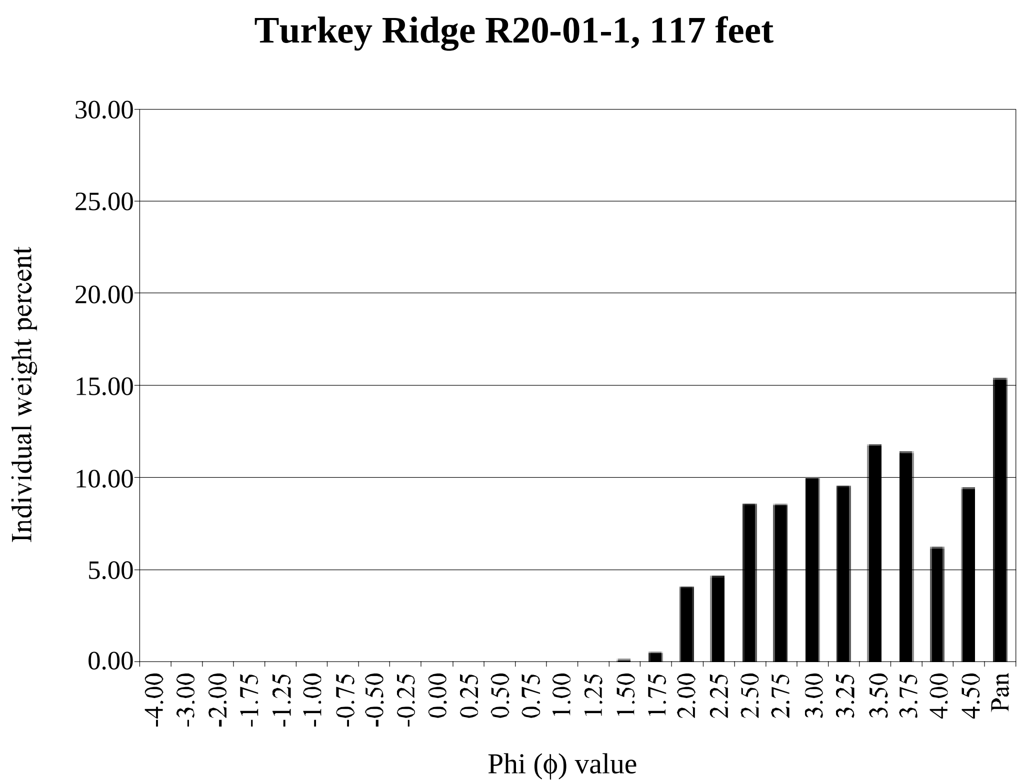
Newton Hills 5-24-2



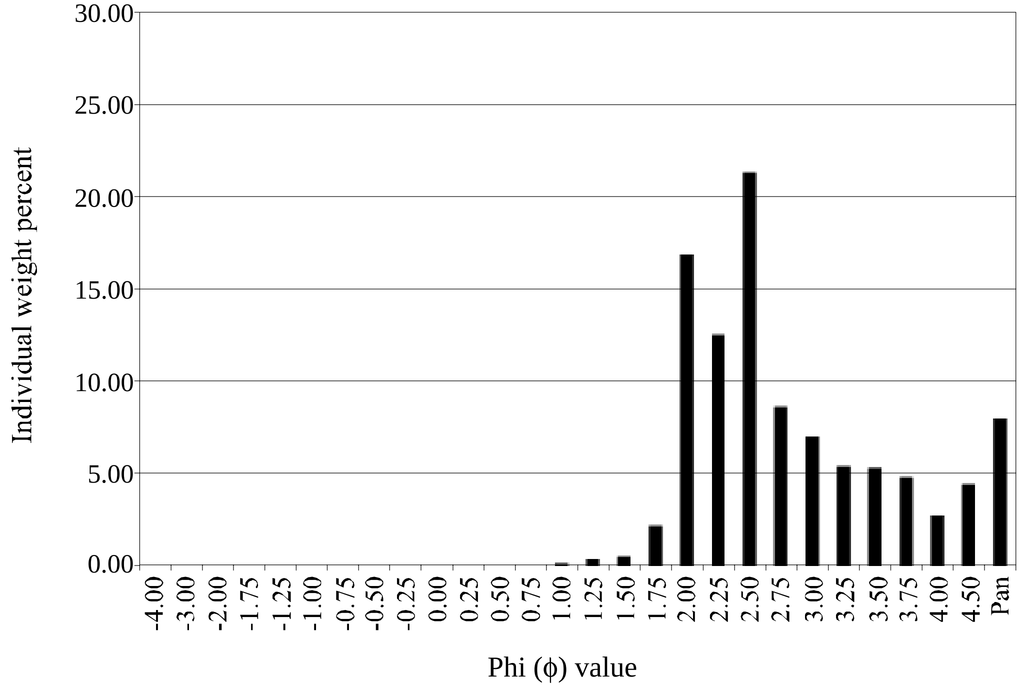
Turkey Ridge R20-01-2



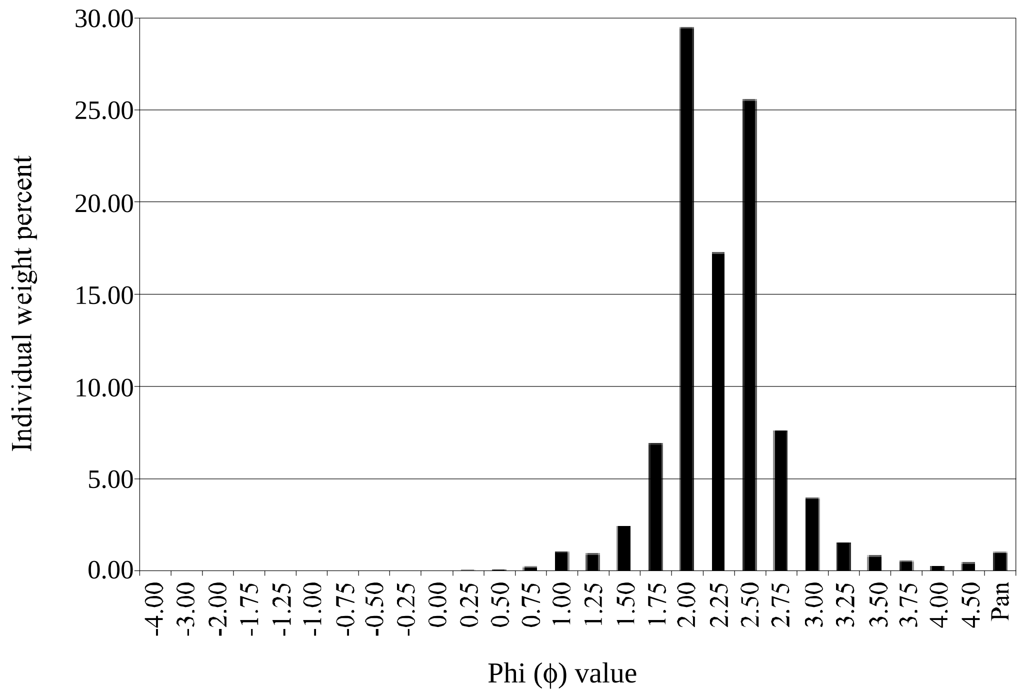

Turkey Ridge R20-01-1, 105-110 feet
Individual weight percent
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-4.00
-3.00
-2.00
-1.75
-1.25
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.50
Pan
Phi (ϕ) value


Turkey Ridge R20-01-1, 117 feet
Individual weight percent
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-4.00
-3.00
-2.00
-1.75
-1.25
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.50
Pan
Phi (ϕ) value

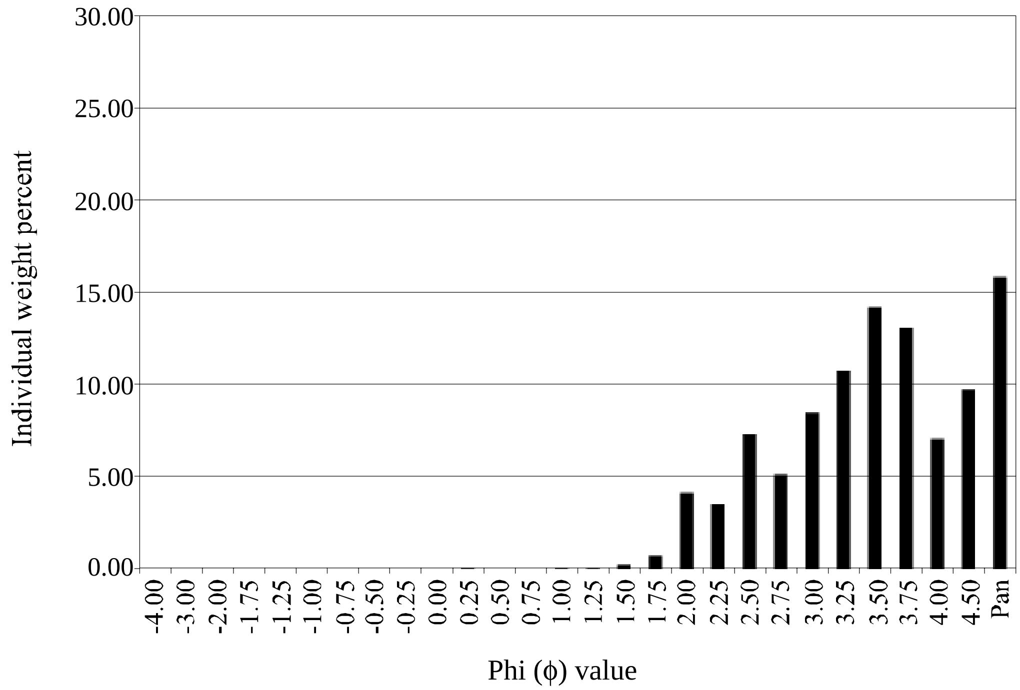
Turkey Ridge R20-01-1, 127 feet



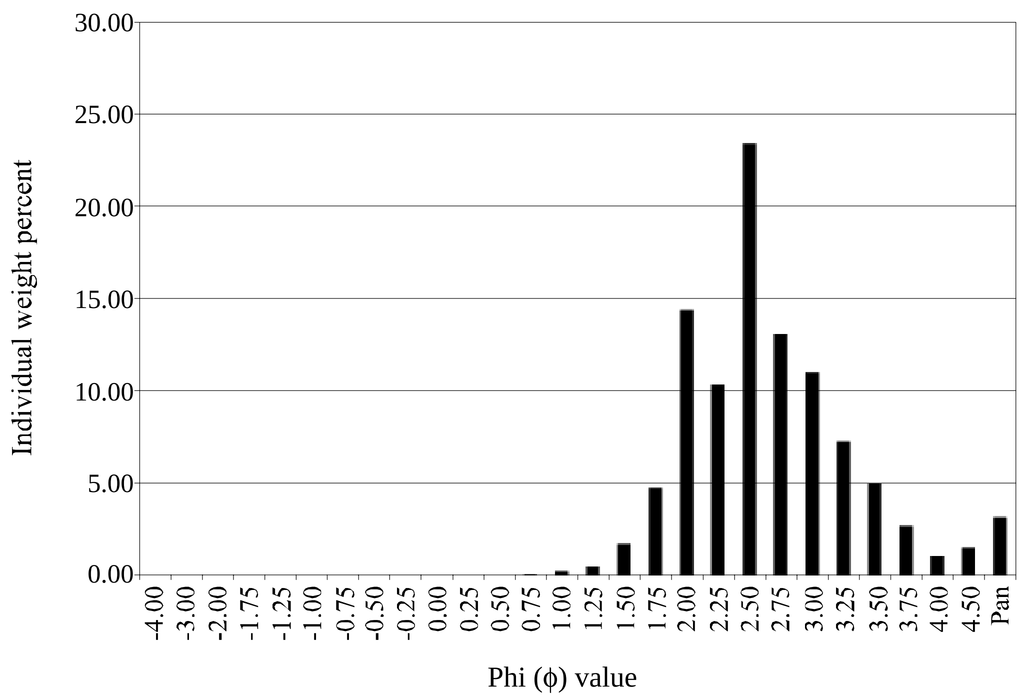
Turkey Ridge R20-01-1, 141-145 feet



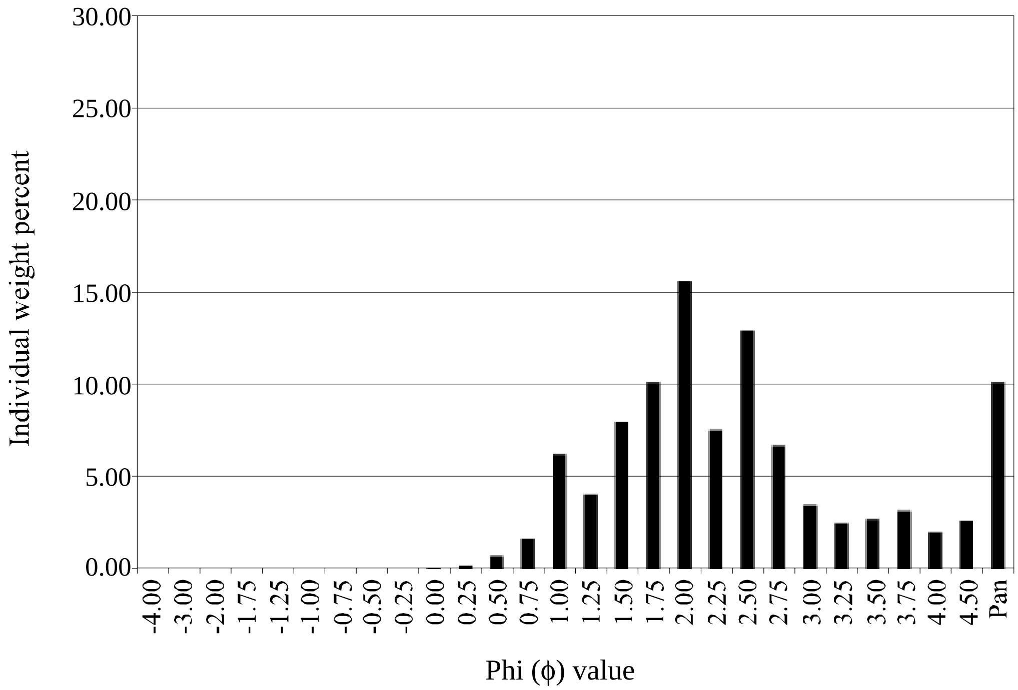
Turkey Ridge R20-01-1, 151 feet



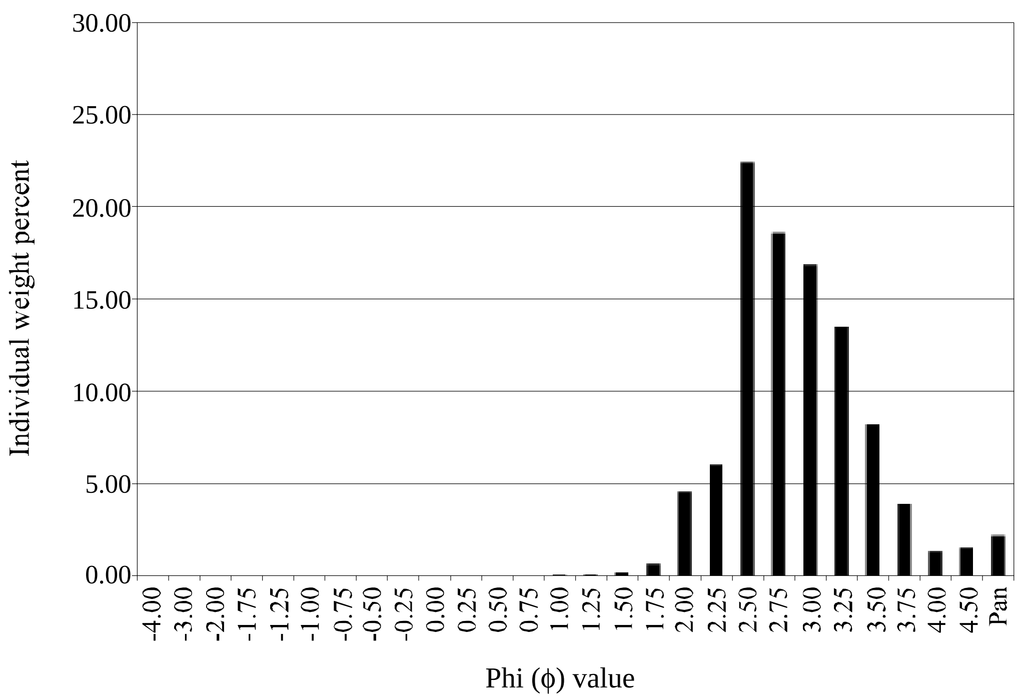
Turkey Ridge R20-01-1, 160-161 feet

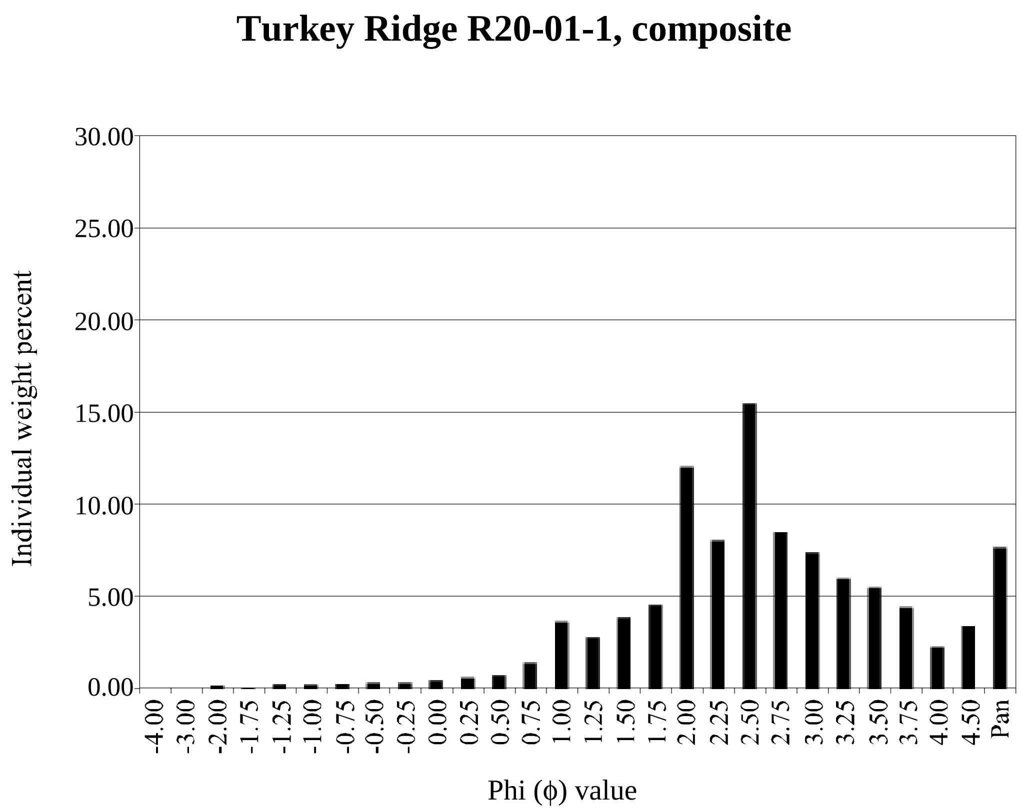


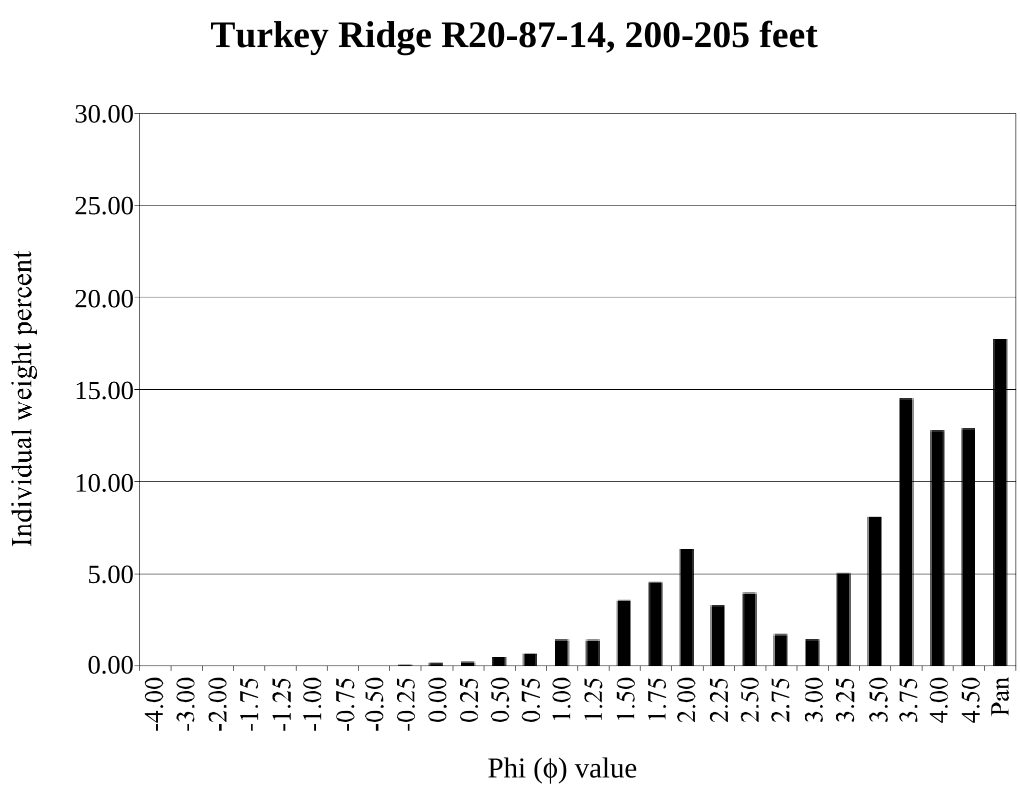
Turkey Ridge R20-01-1, 173-174 feet



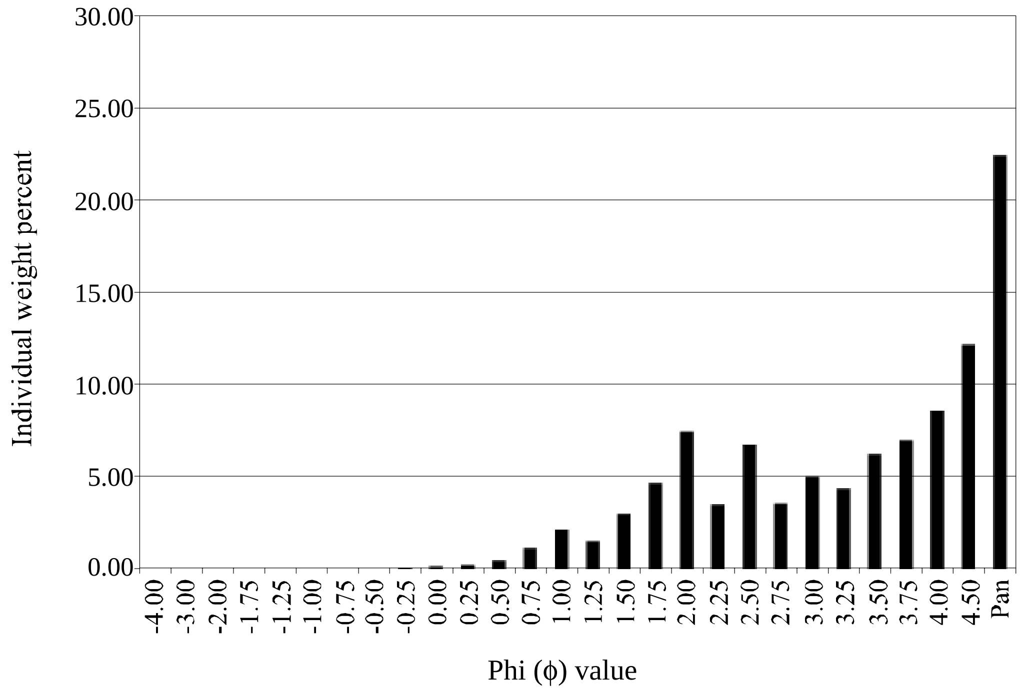
Turkey Ridge R20-01-1, 180-185 feet



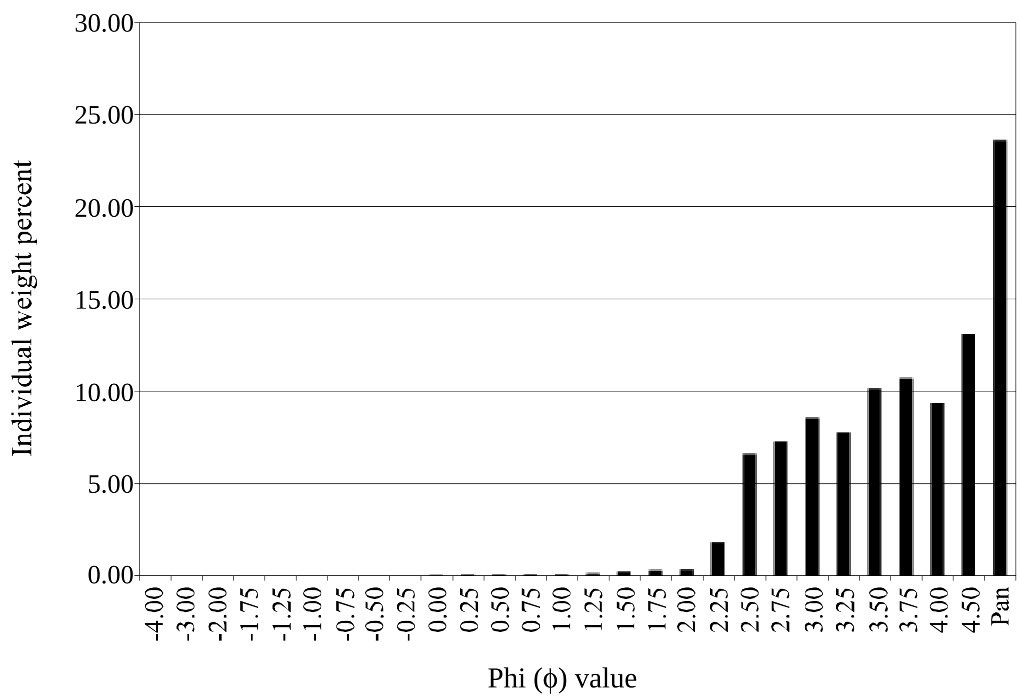

Turkey Ridge R20-01-1, composite
Individual weight percent
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-4.00
-3.00
-2.00
-1.75
-1.25
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.50
Pan
Phi (ϕ) value


Turkey Ridge R20-87-14, 200-205 feet
Individual weight percent
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-4.00
-3.00
-2.00
-1.75
-1.25
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
3.75
4.00
4.50
Pan
Phi (ϕ) value

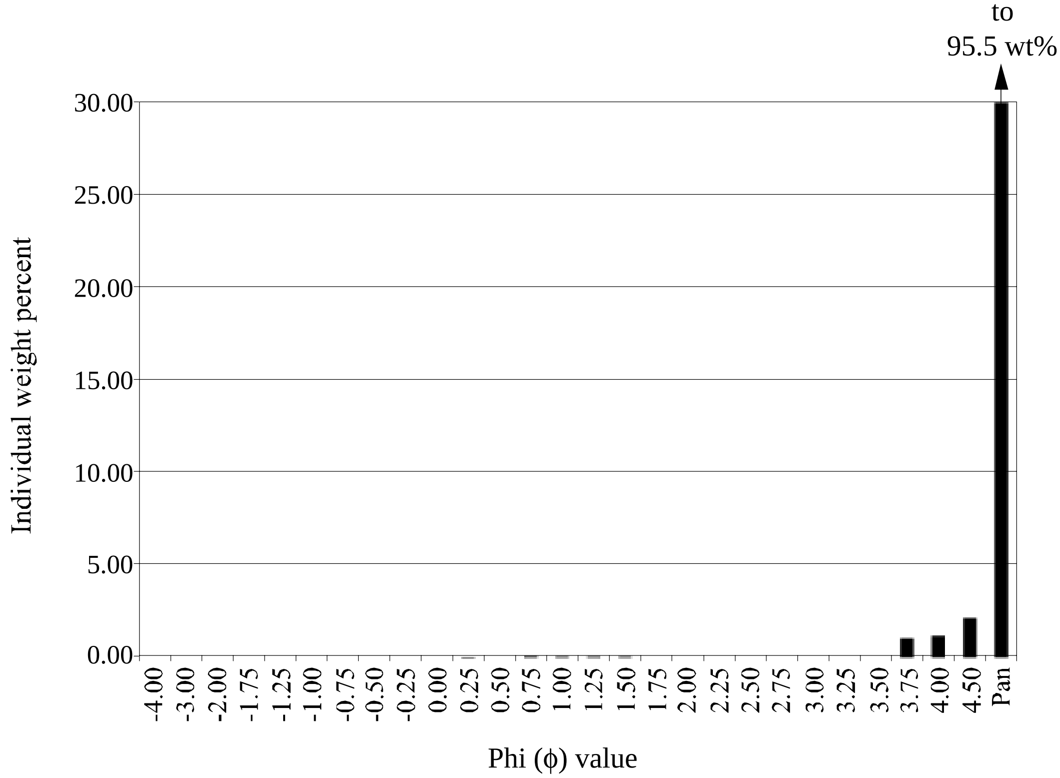
Turkey Ridge R20-87-14, 205-210 feet



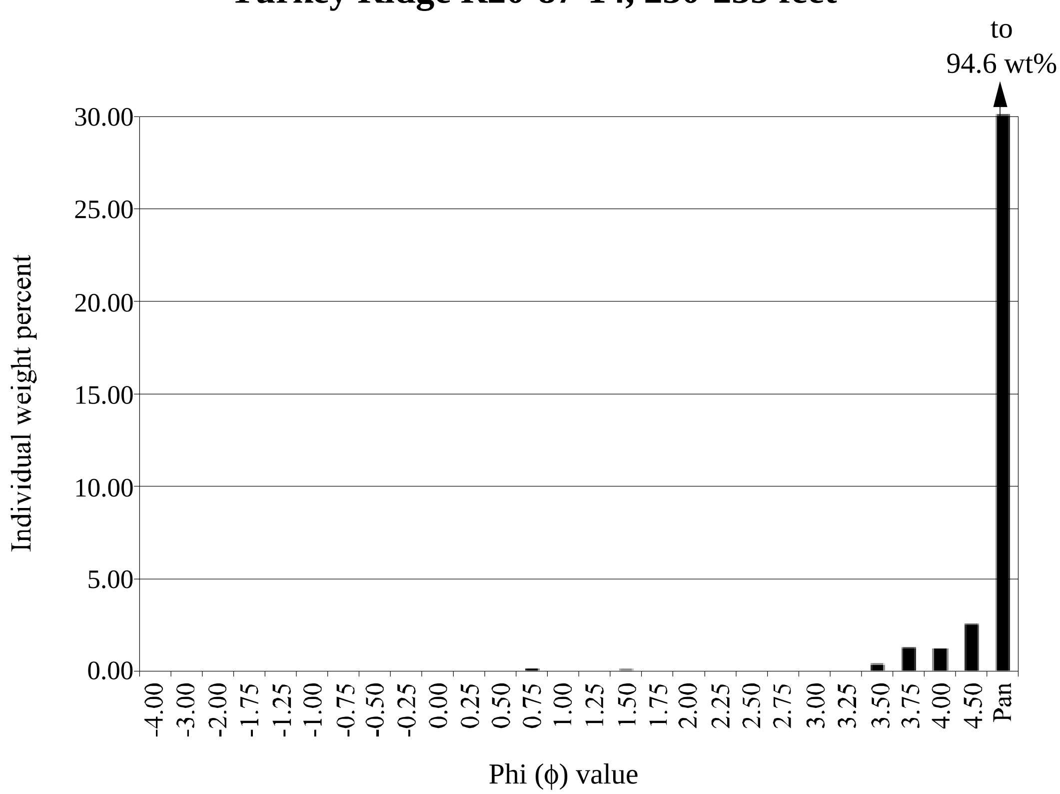
Turkey Ridge R20-87-14, 210-215 feet



Turkey Ridge R20-87-14, 225-230 feet

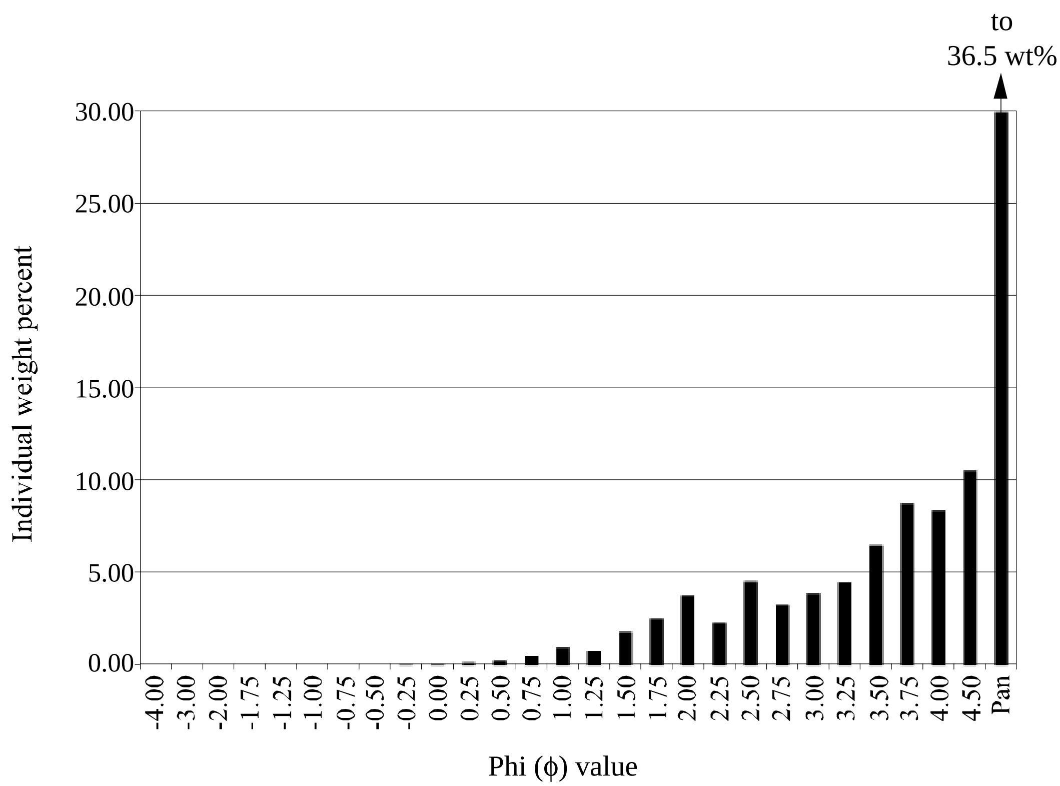


Turkey Ridge R20-87-14, 230-235 feet

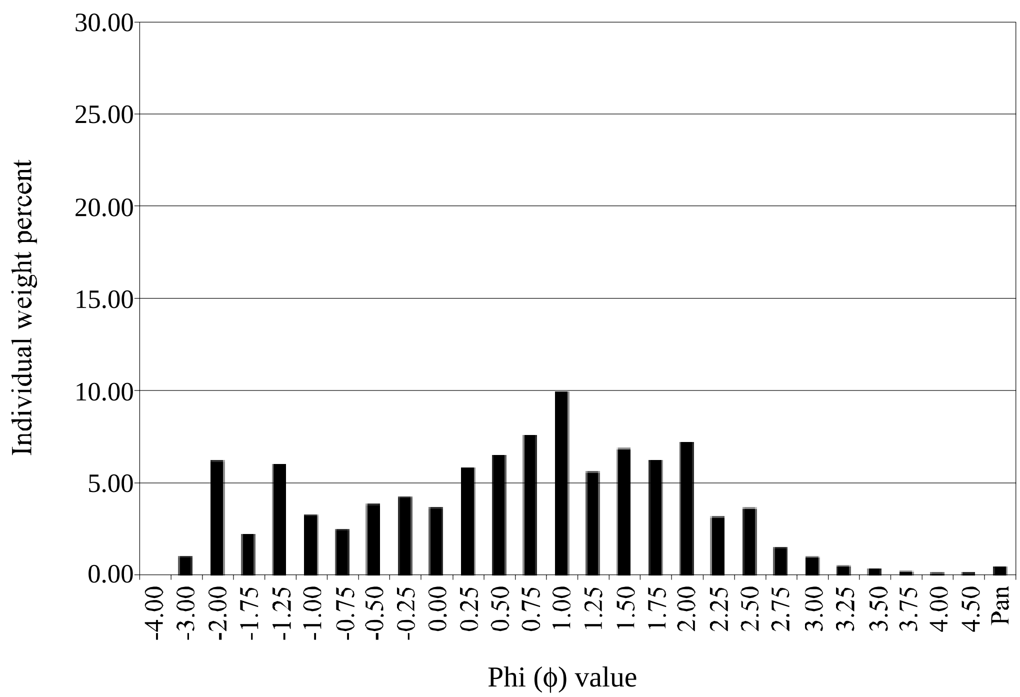


Appendix A – continued

Turkey Ridge R20-87-14, composite



Heeren core, 27.5-28.25 feet



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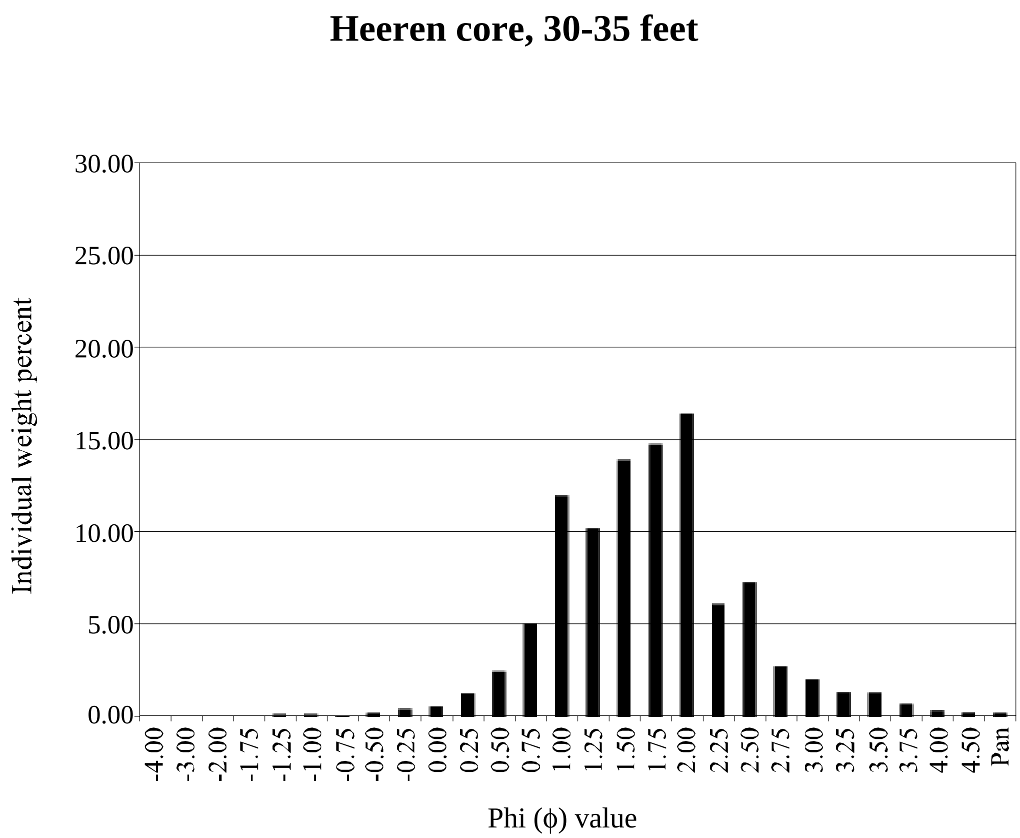
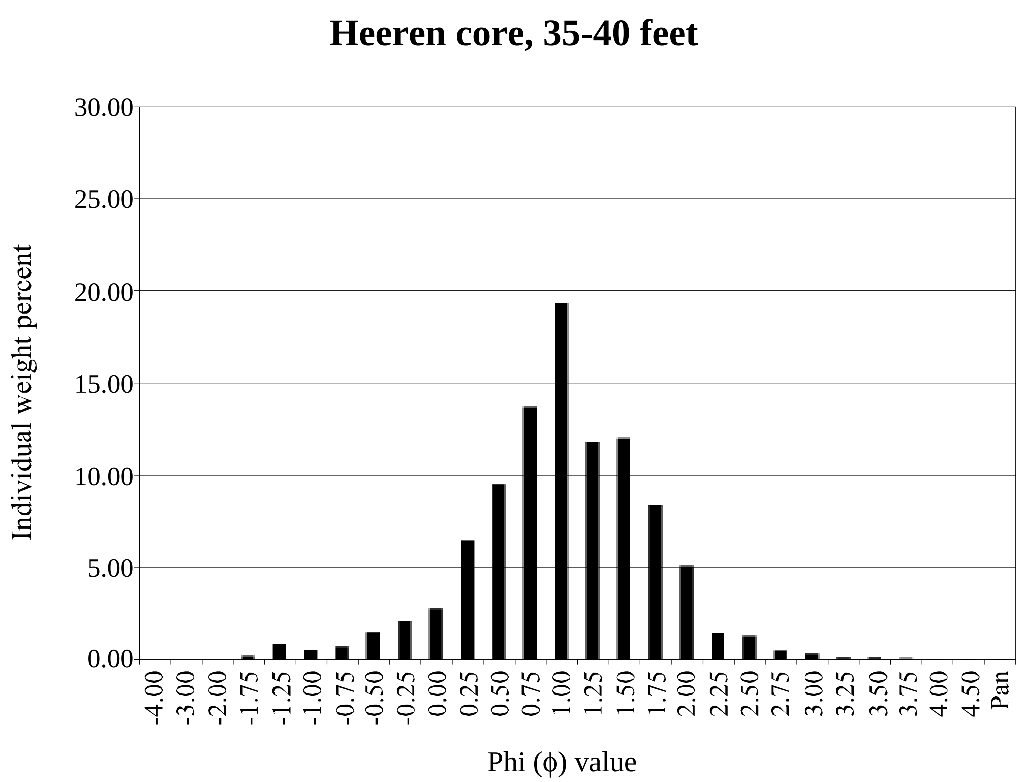
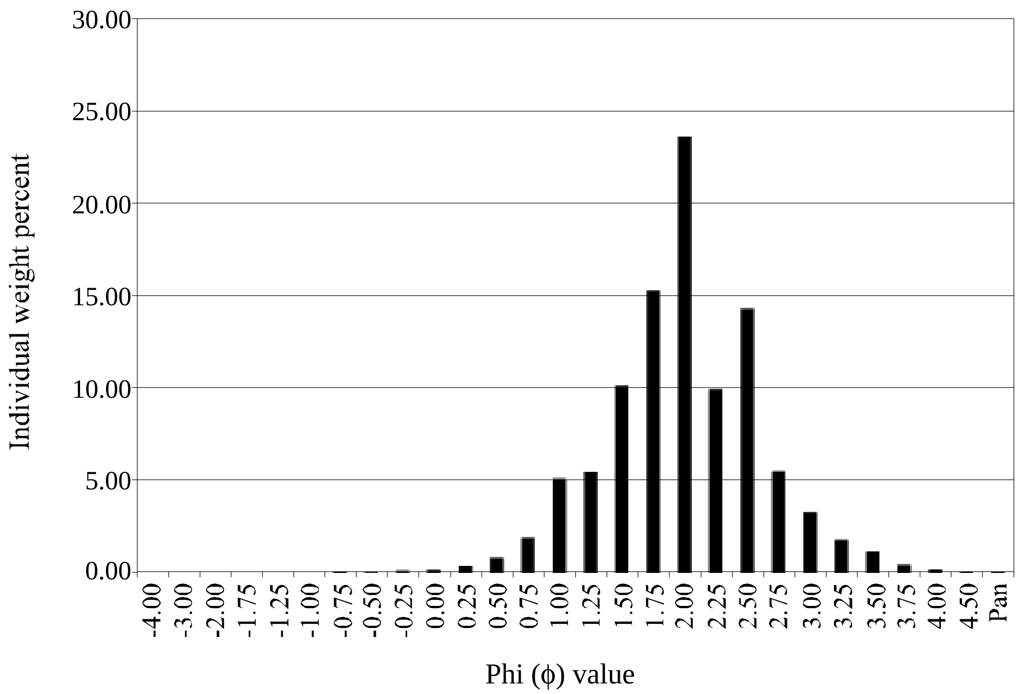
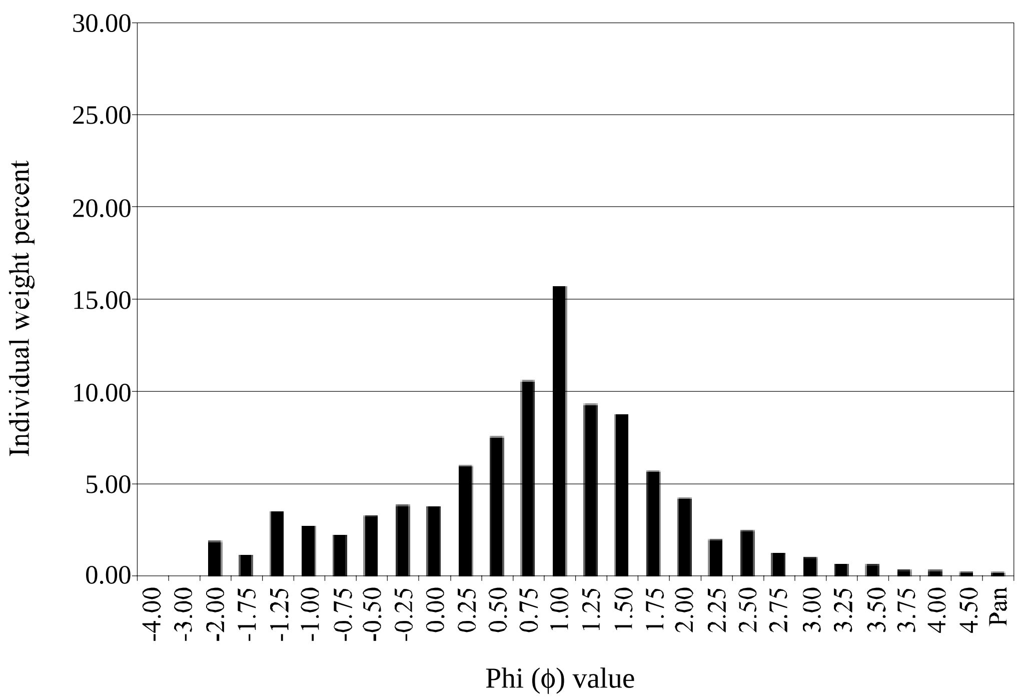




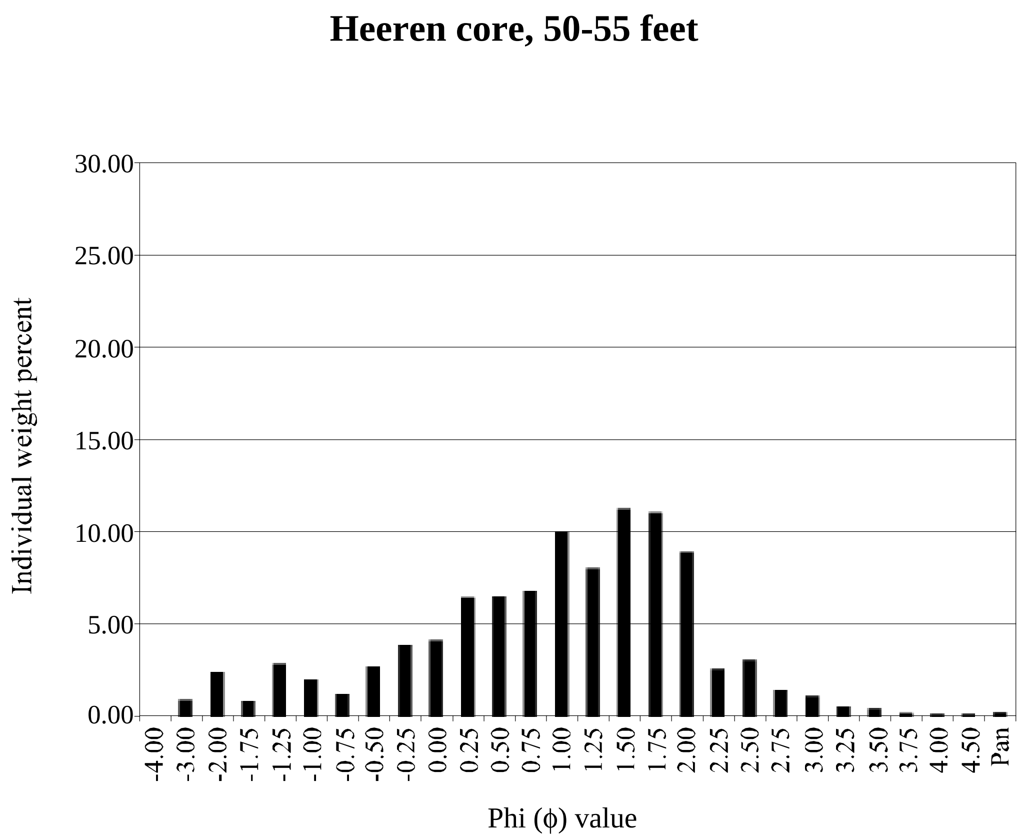
Heeren core, 40-45 feet

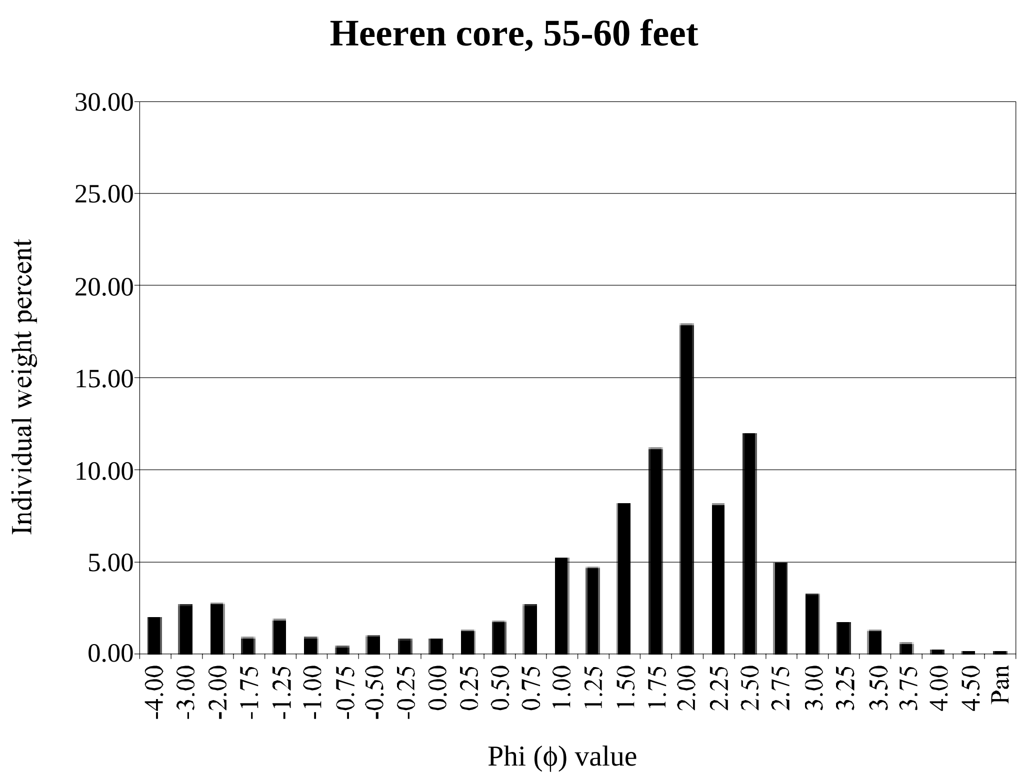


Heeren core, 45-50 feet

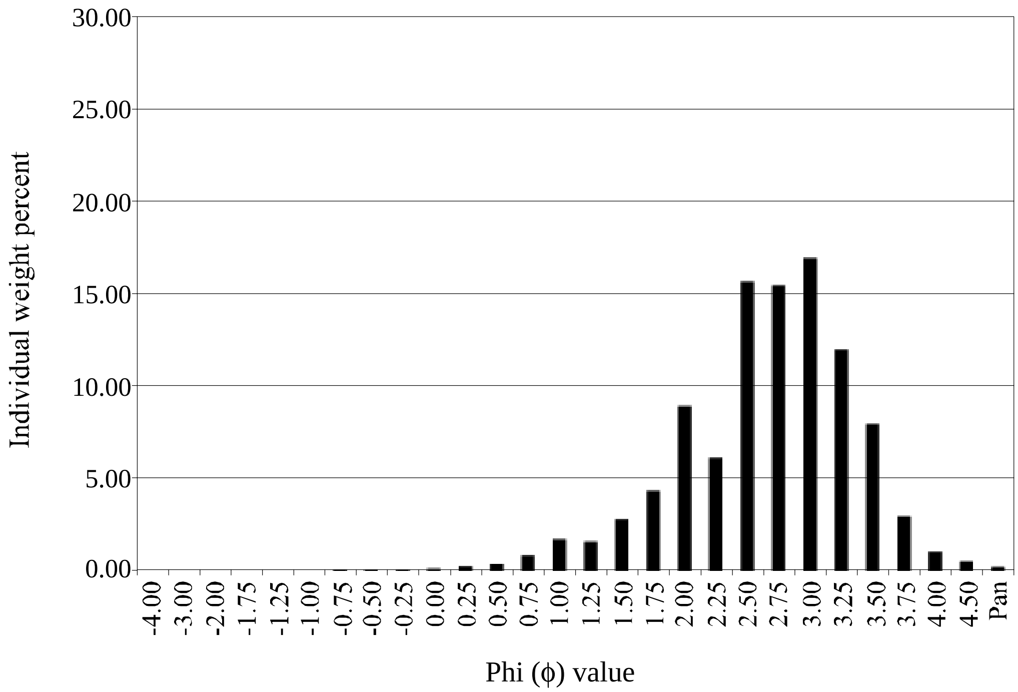


Appendix A – continued

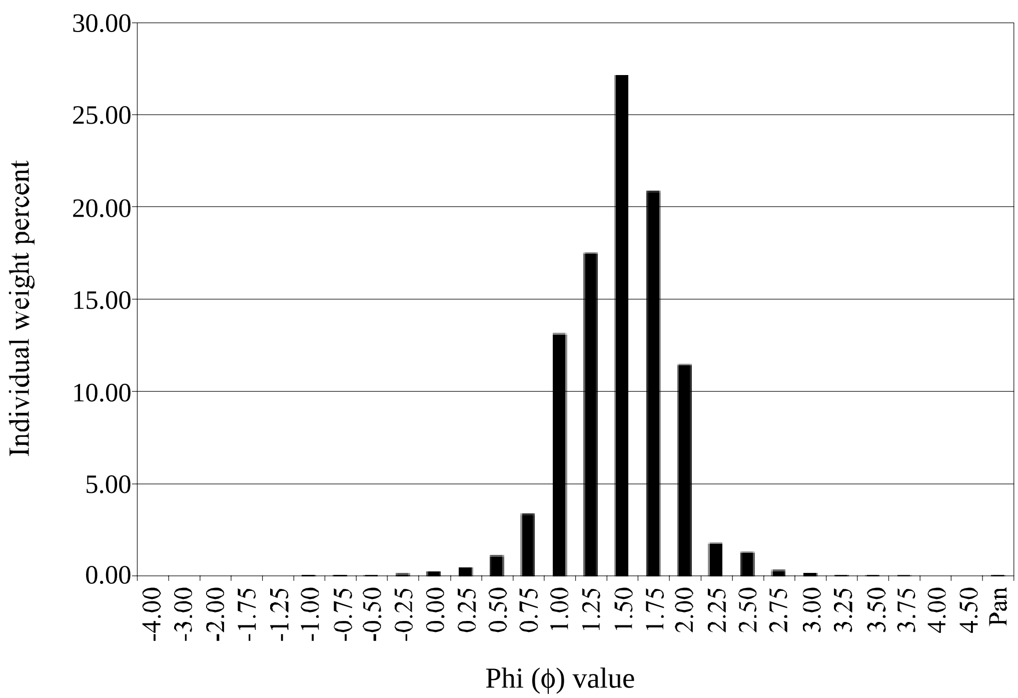




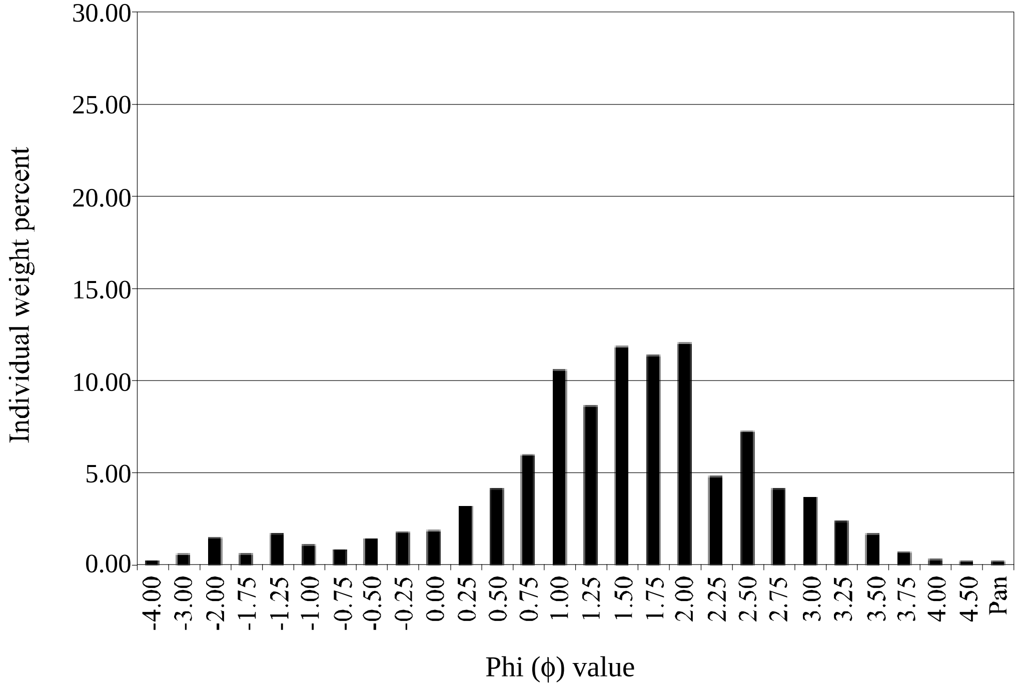
Heeren core, 60-65 feet



Heeren core, 65-70 feet



Heeren core, composite



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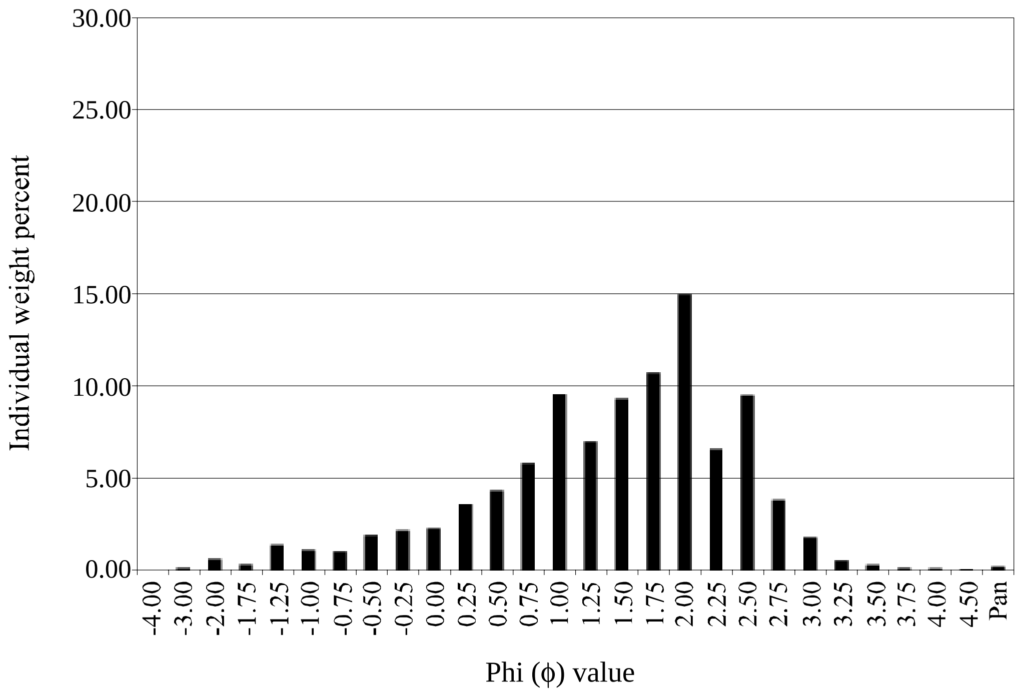
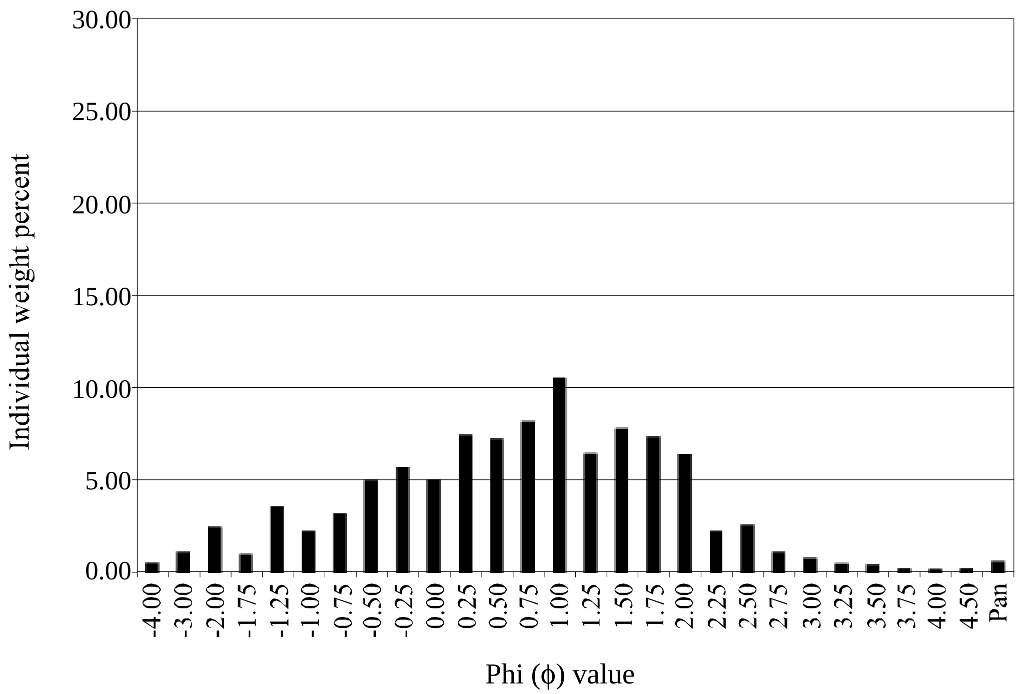
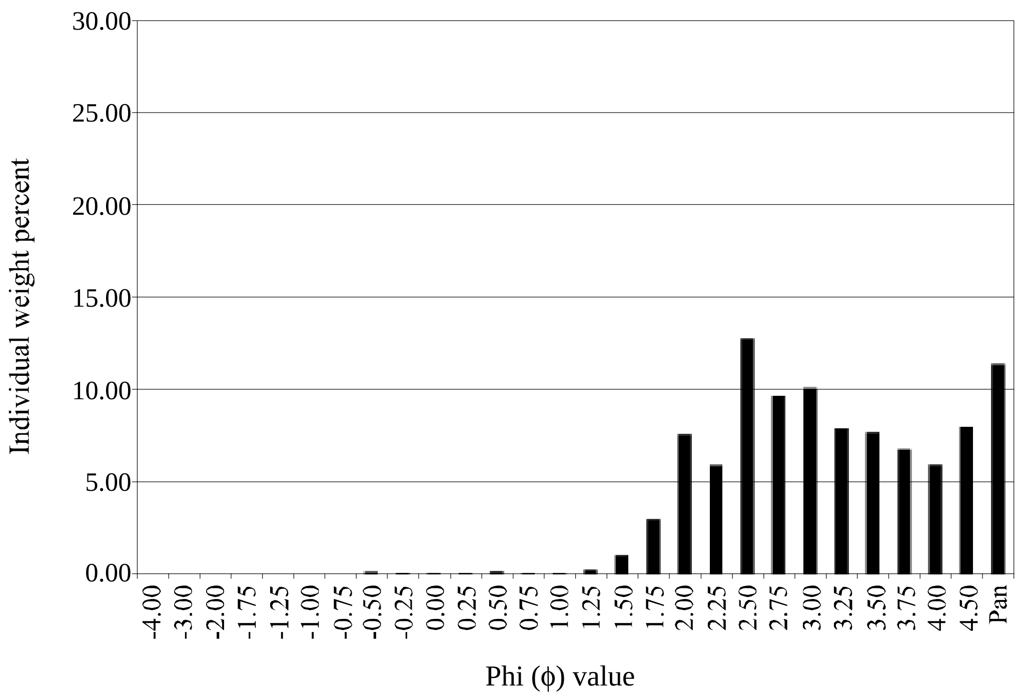


Herrick gravel 5-23-3

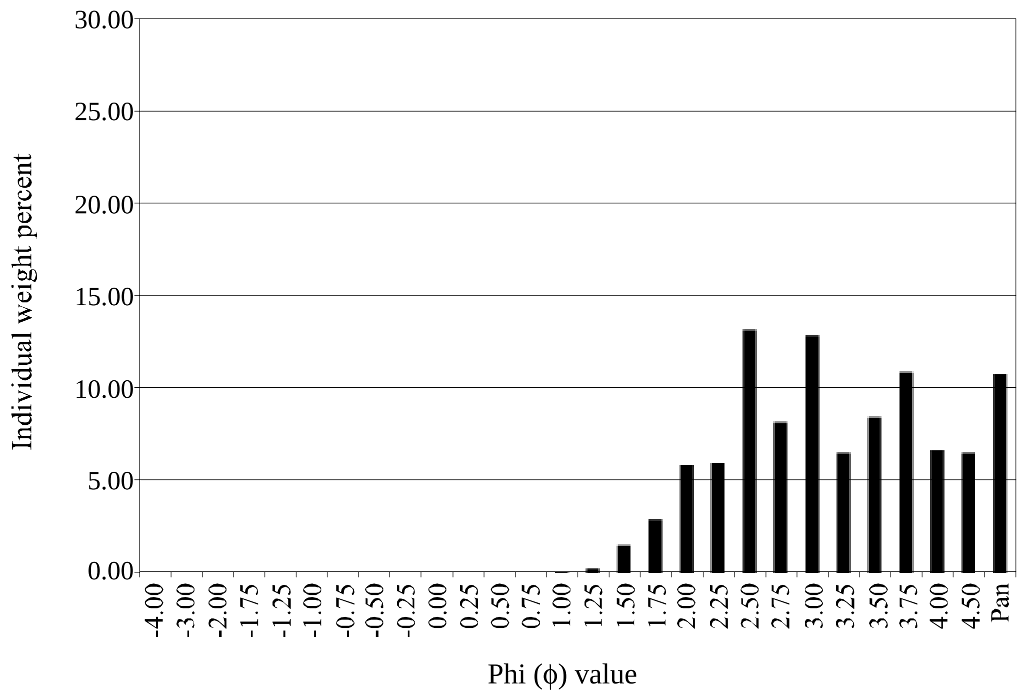


Ash Hollow 5-23-4



Appendix A – continued

Gregory City 5-23-5



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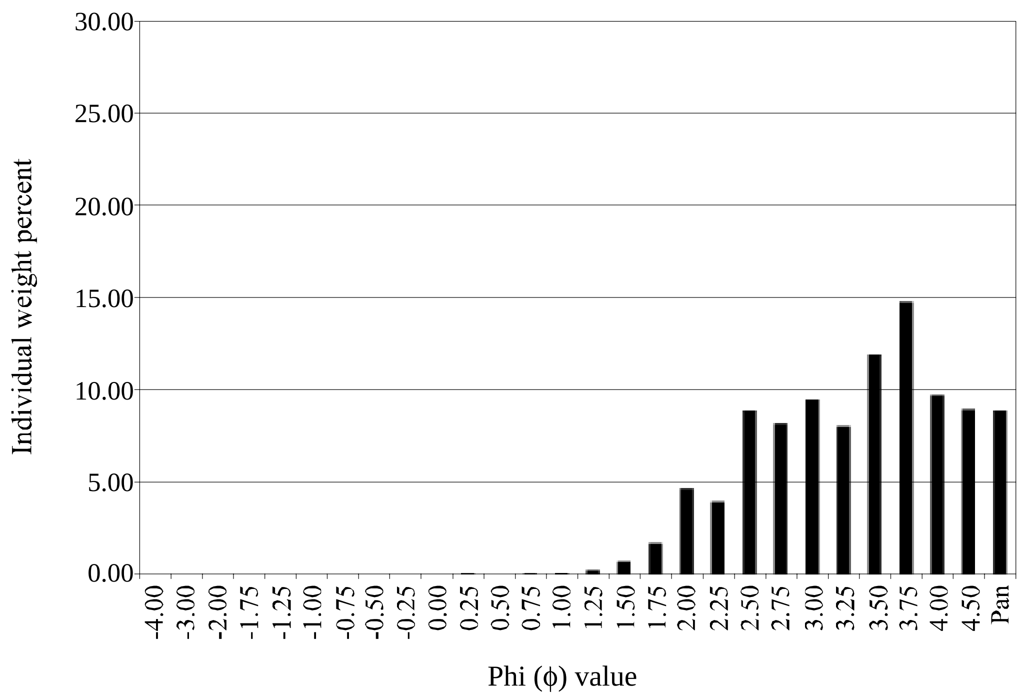
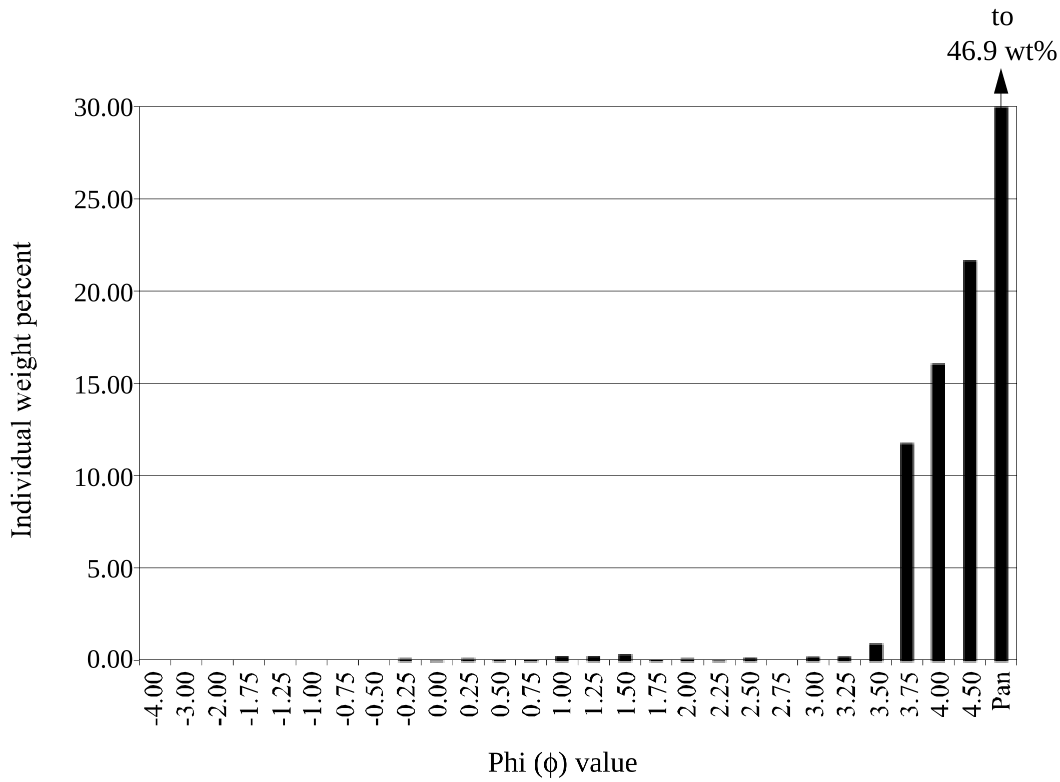
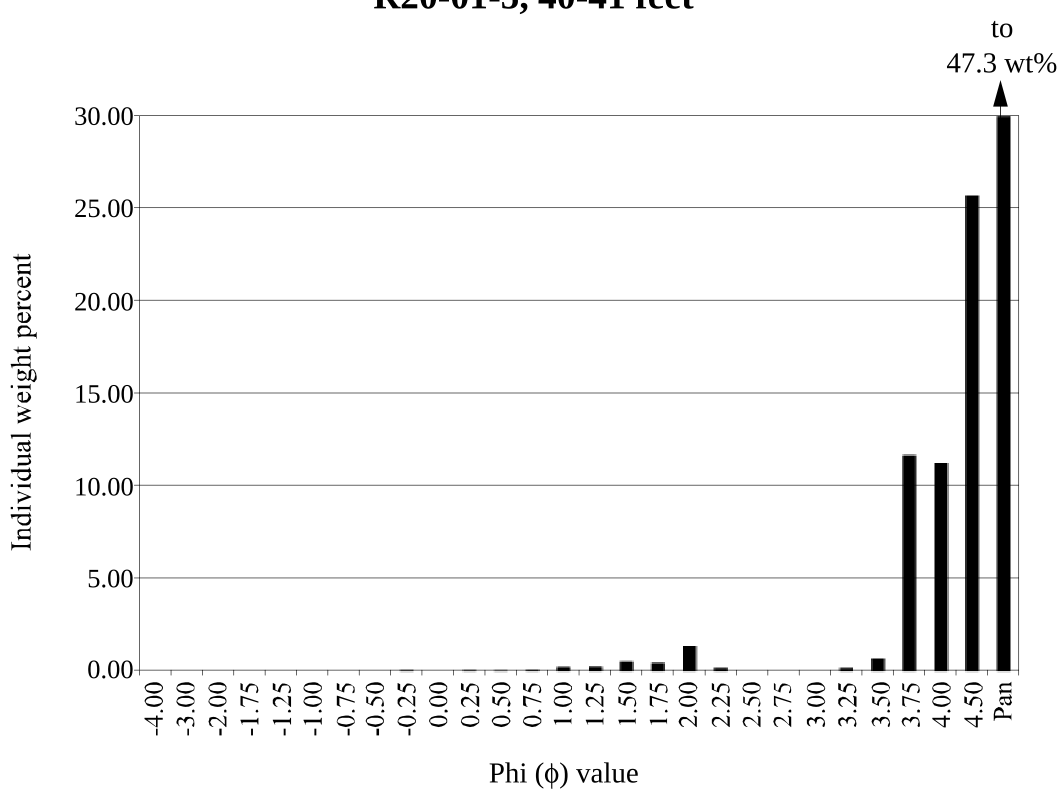


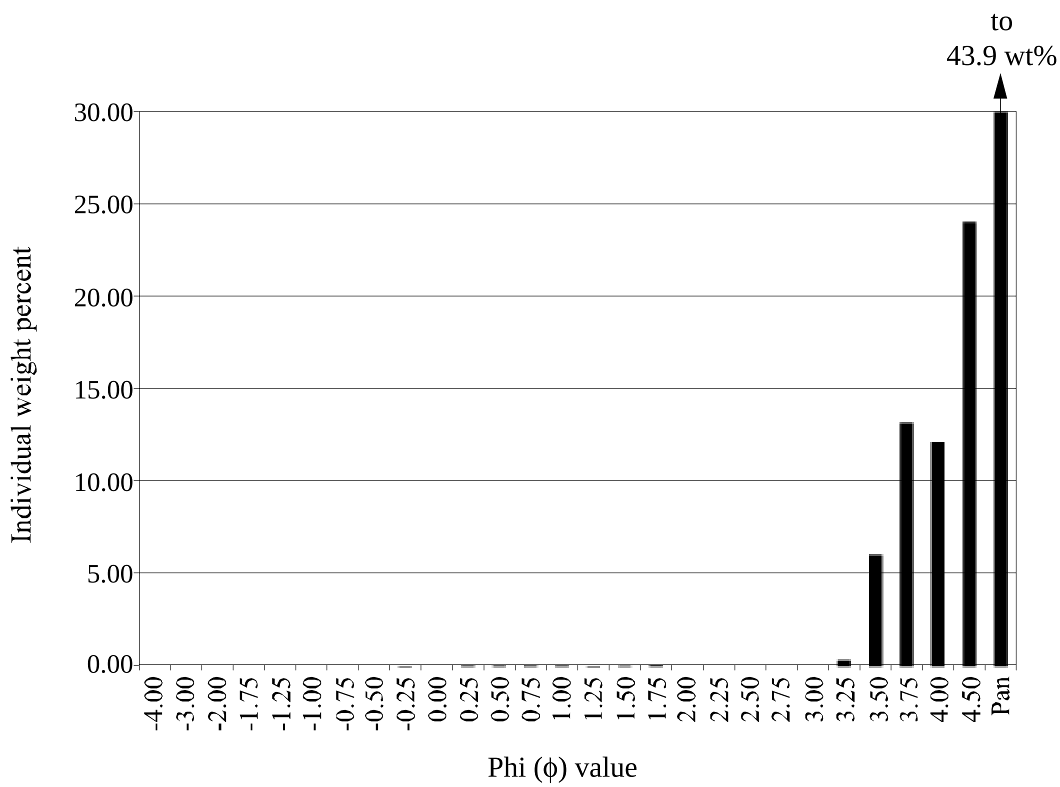
R20-01-5, 27-28 feet



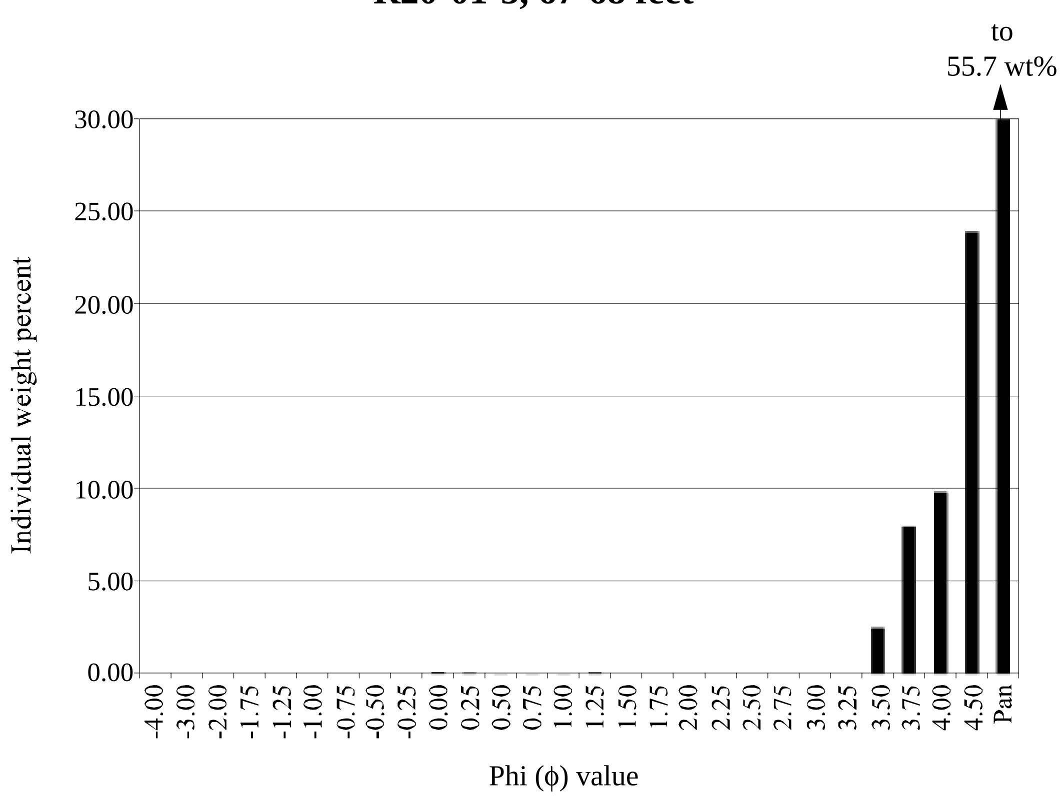
R20-01-5, 40-41 feet



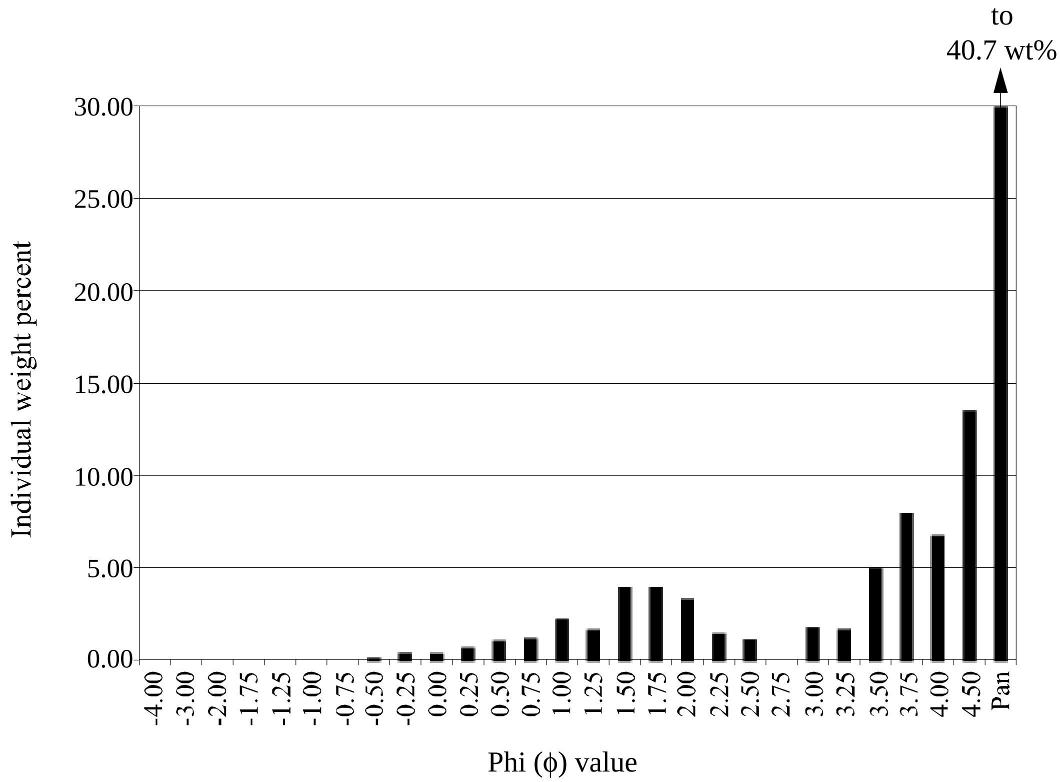
R20-01-5, 58.5-59.5 feet



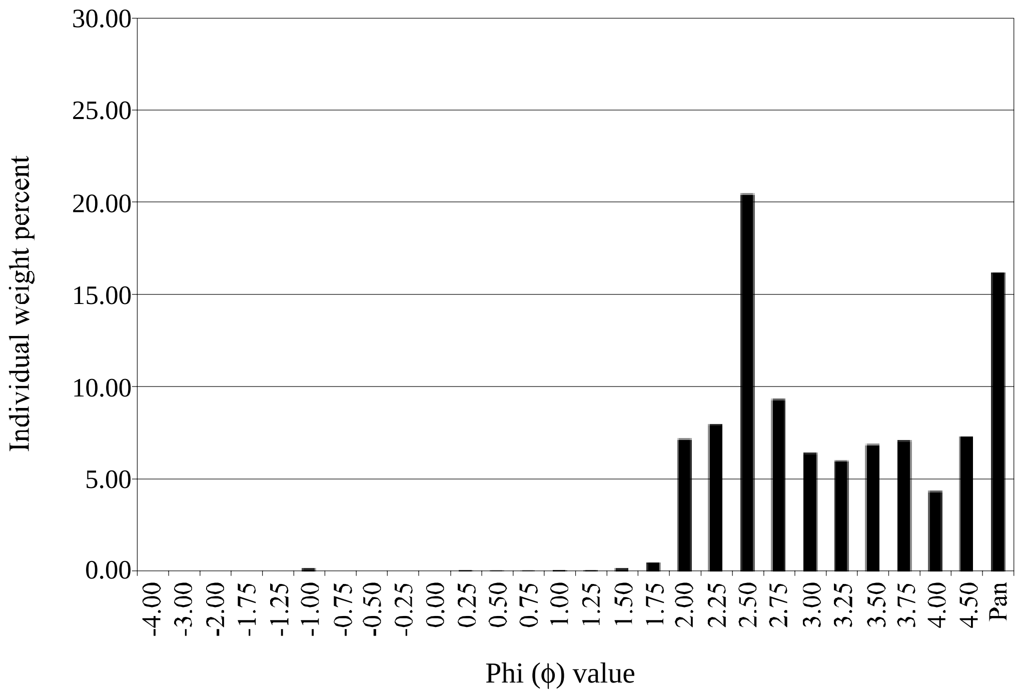
R20-01-5, 67-68 feet



R20-01-5, 75-76 feet

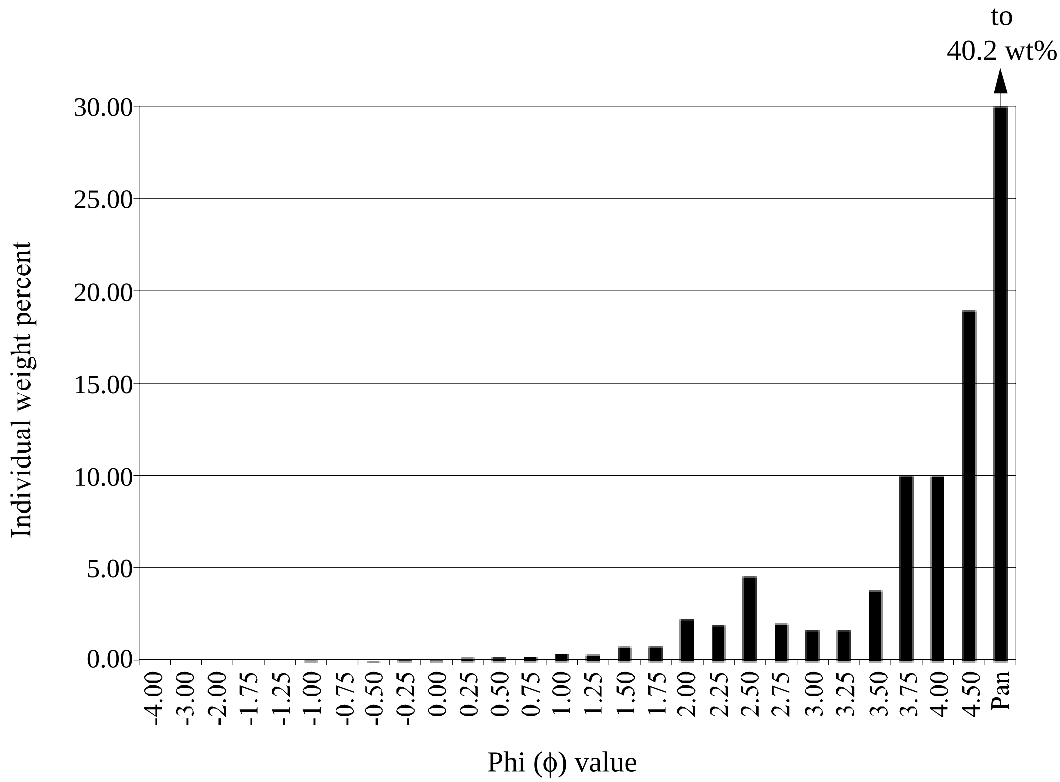


R20-01-5, 88-89 feet

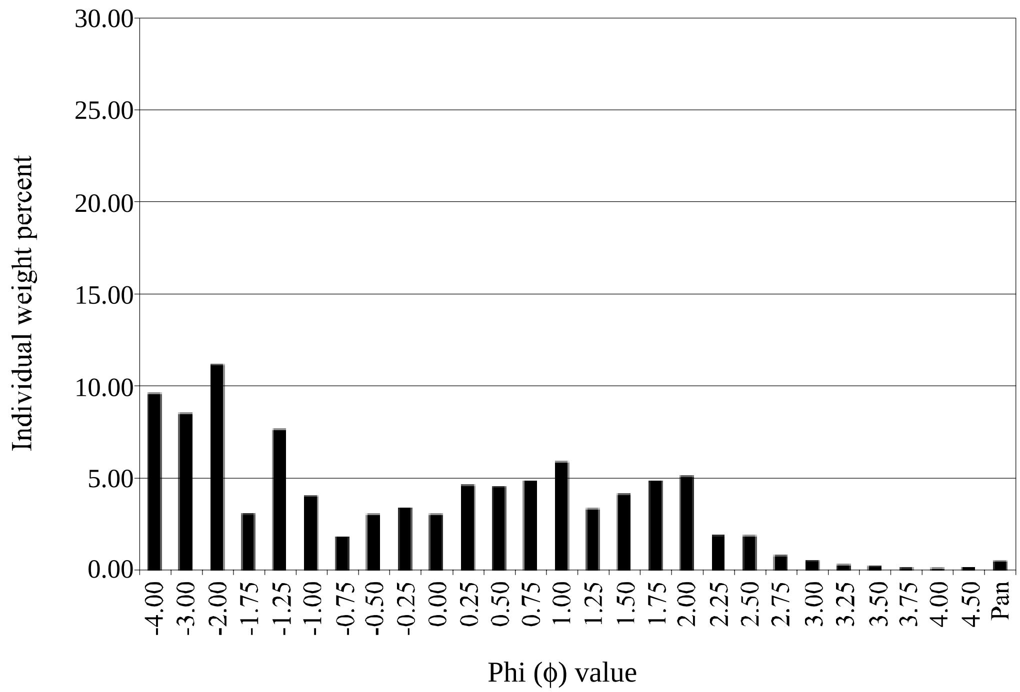


Appendix A – continued

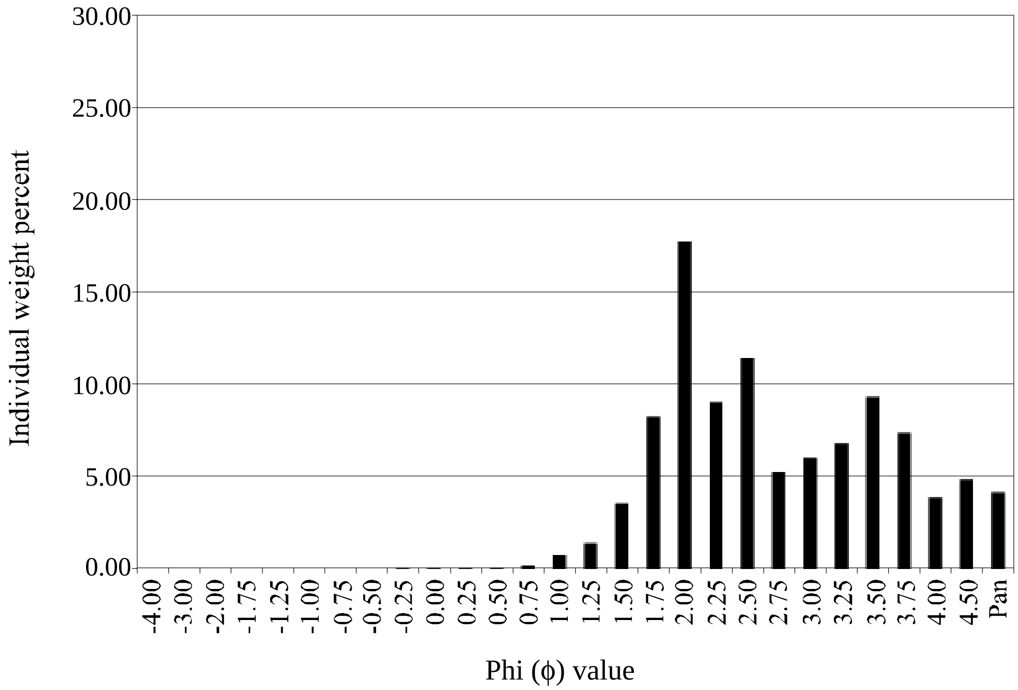
R20-01-5, composite



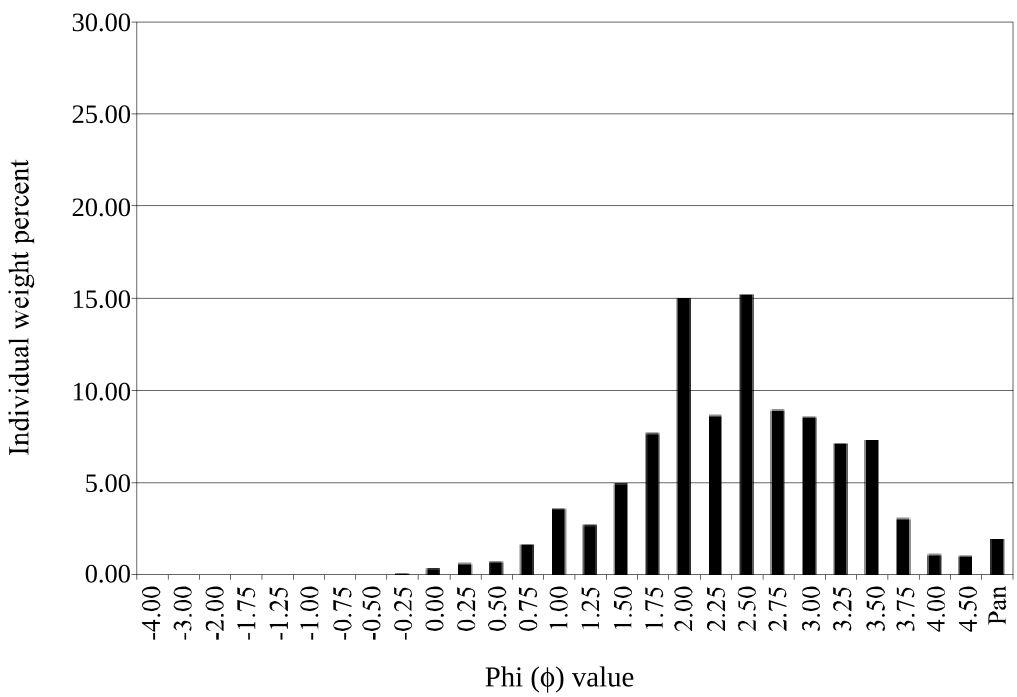
Hurley 5-22-5



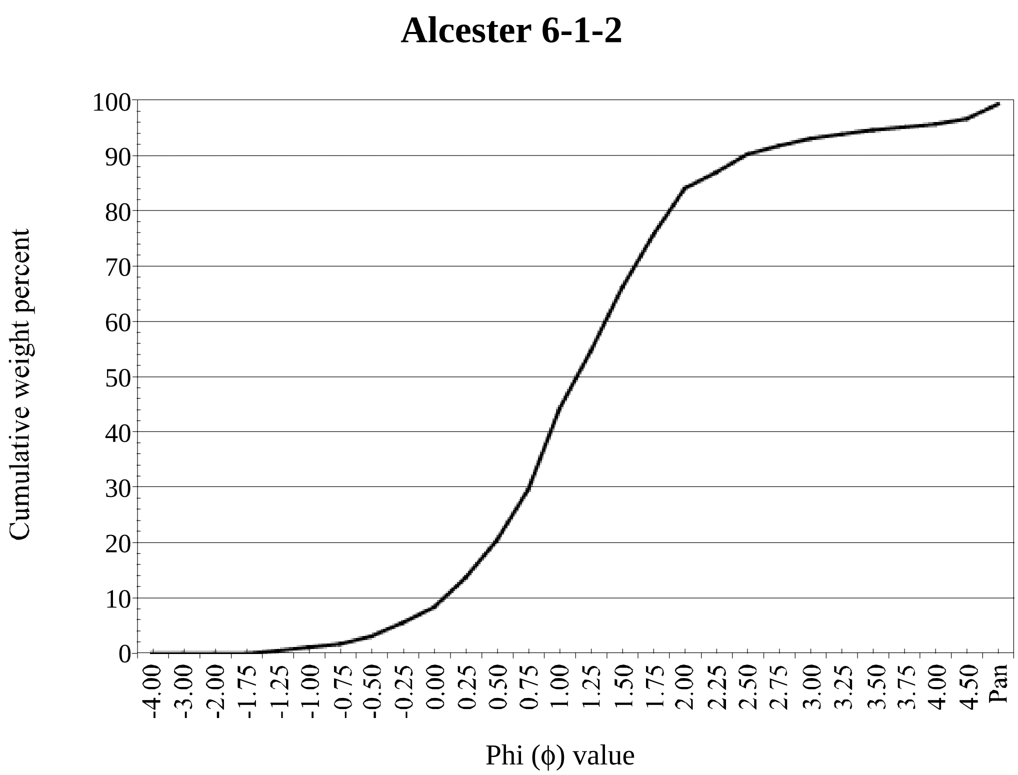
Missouri 5-21-1

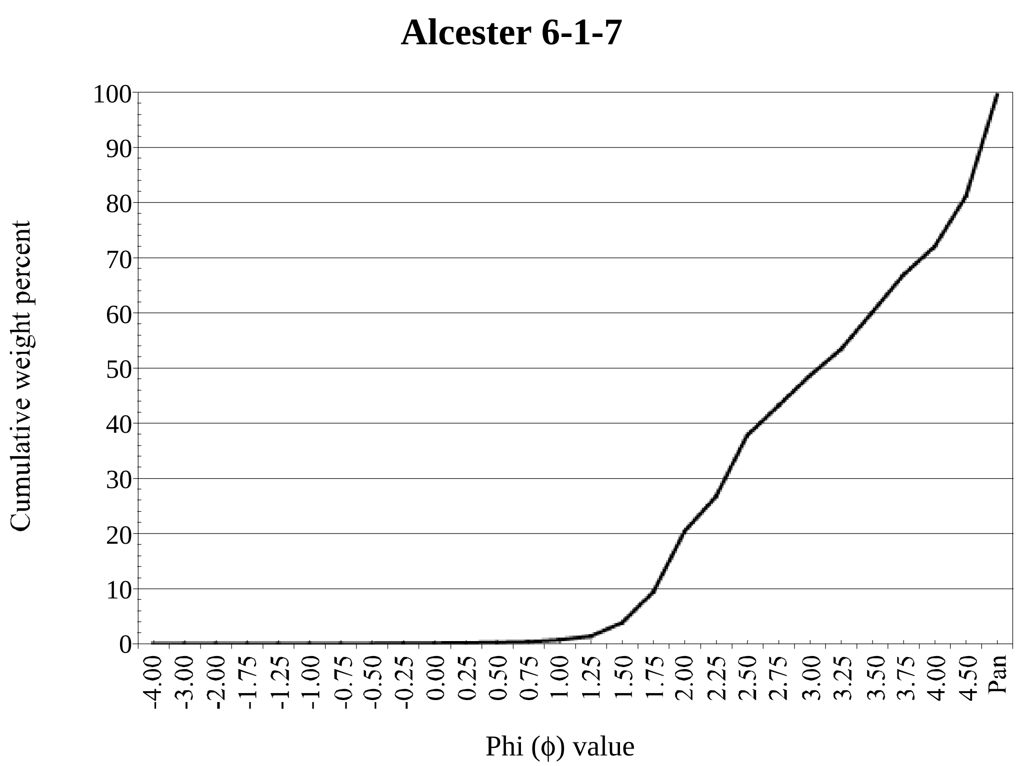


Spencer quarry 5-10-1

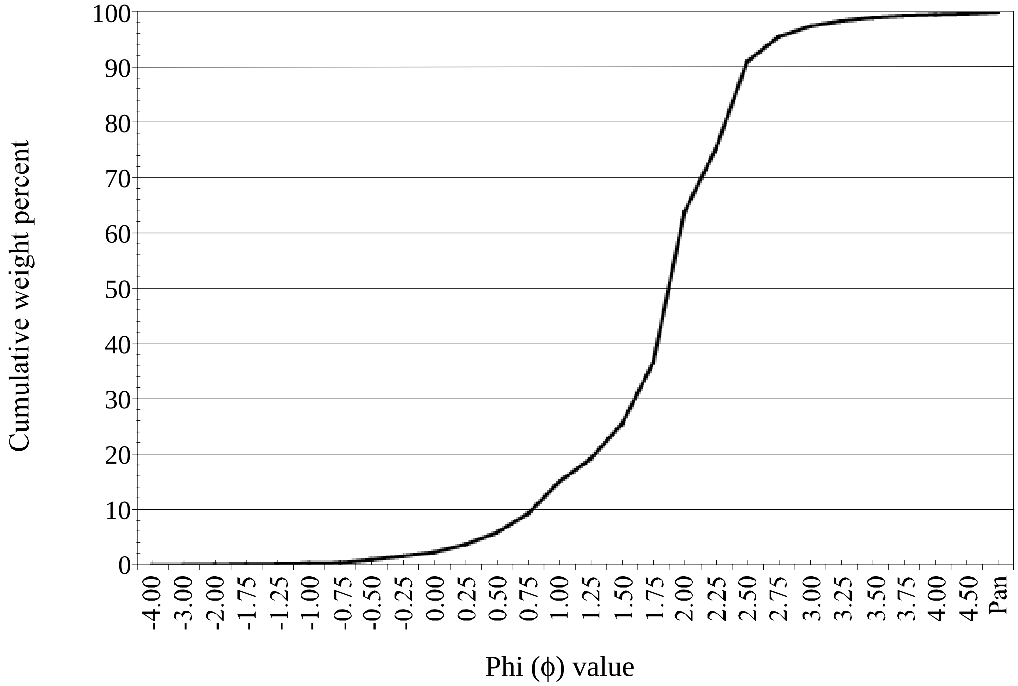


Appendix B. Cumulative frequency curves of weight percent by sieve size

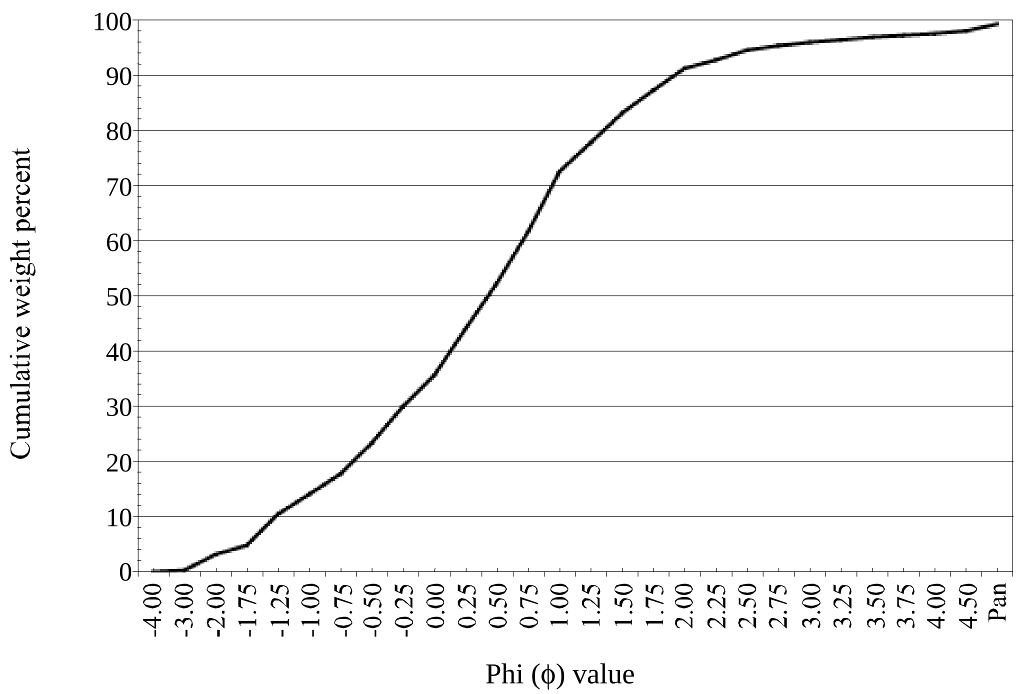




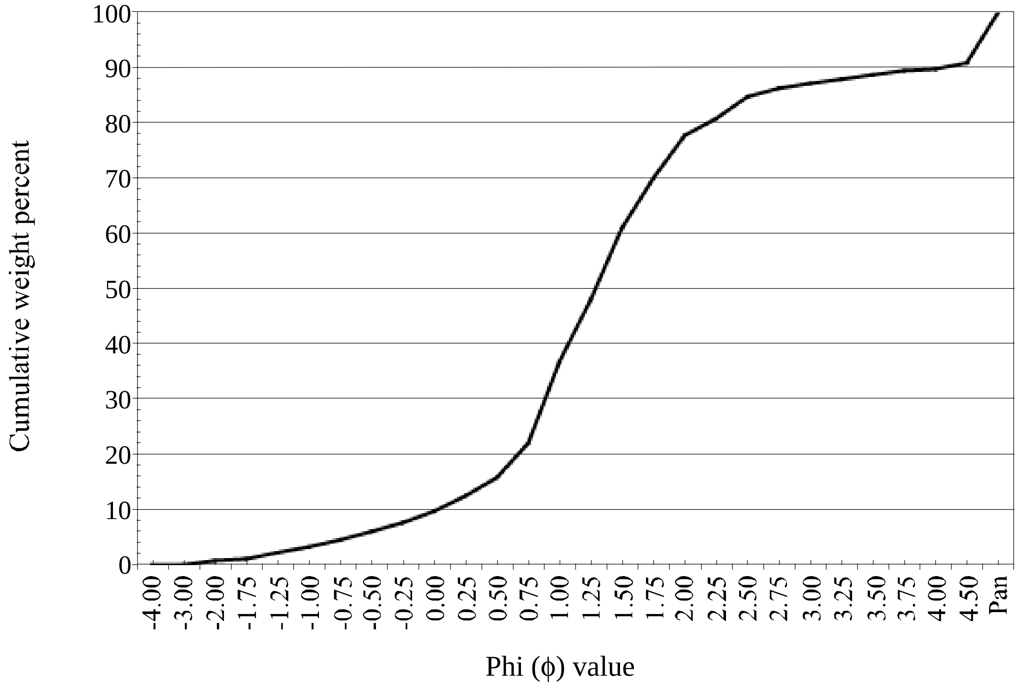
Newton Hills 5-24-2



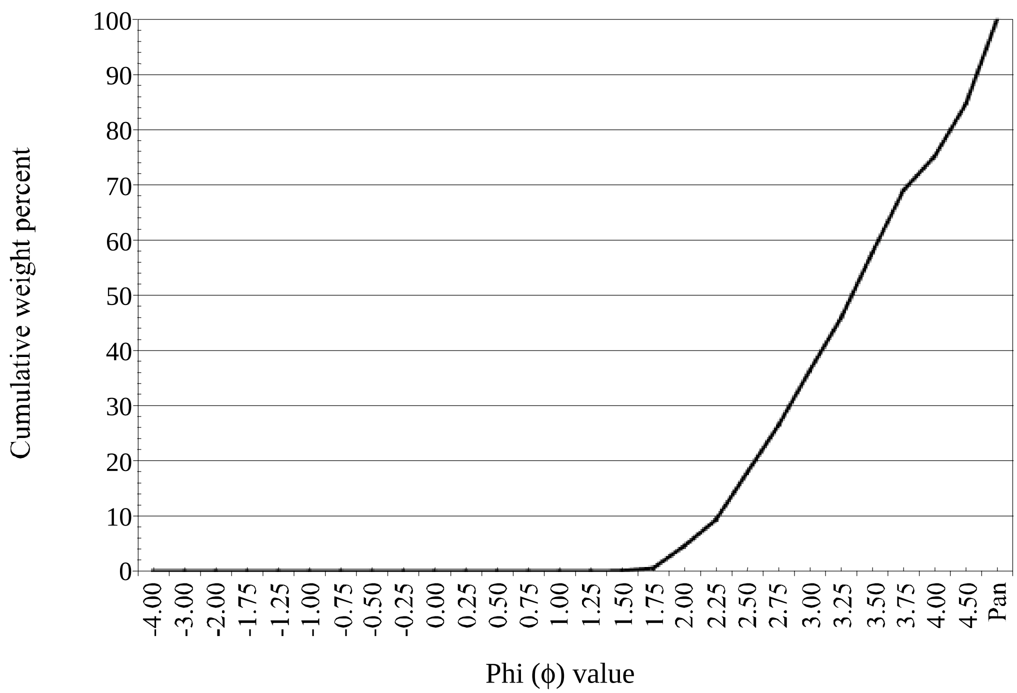
Turkey Ridge R20-01-2



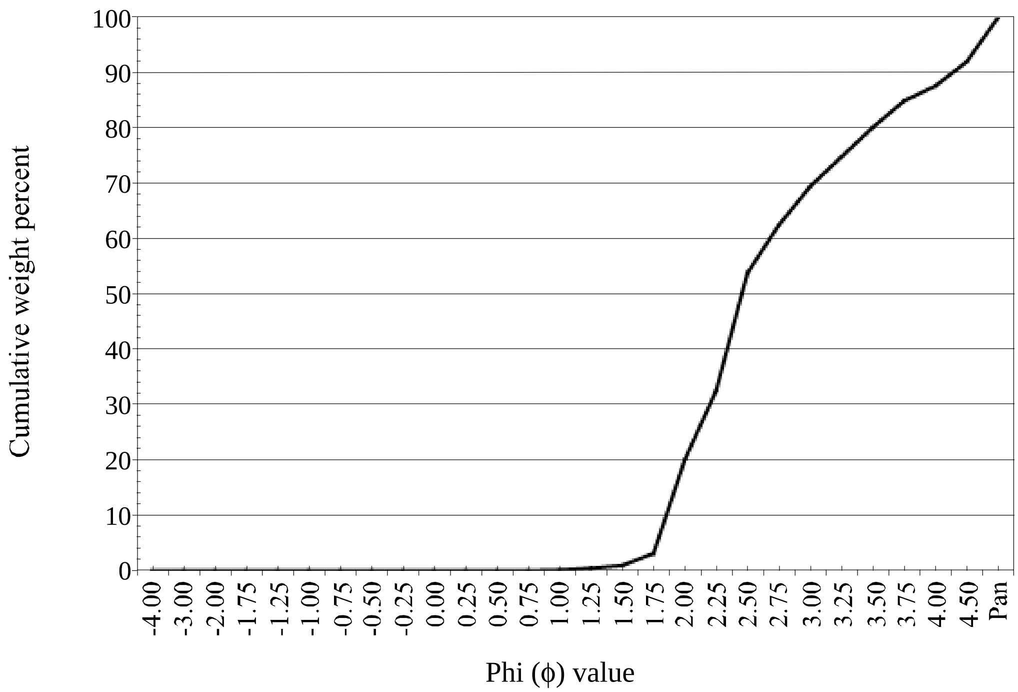
Turkey Ridge R20-01-1, 105-110 feet



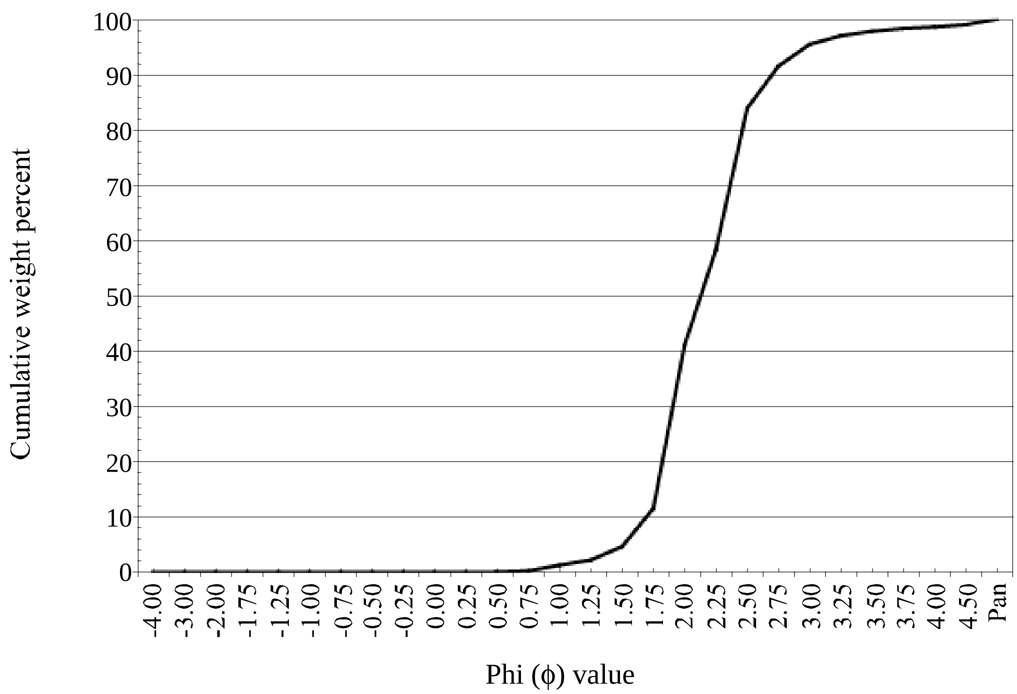
Turkey Ridge R20-01-1, 117 feet



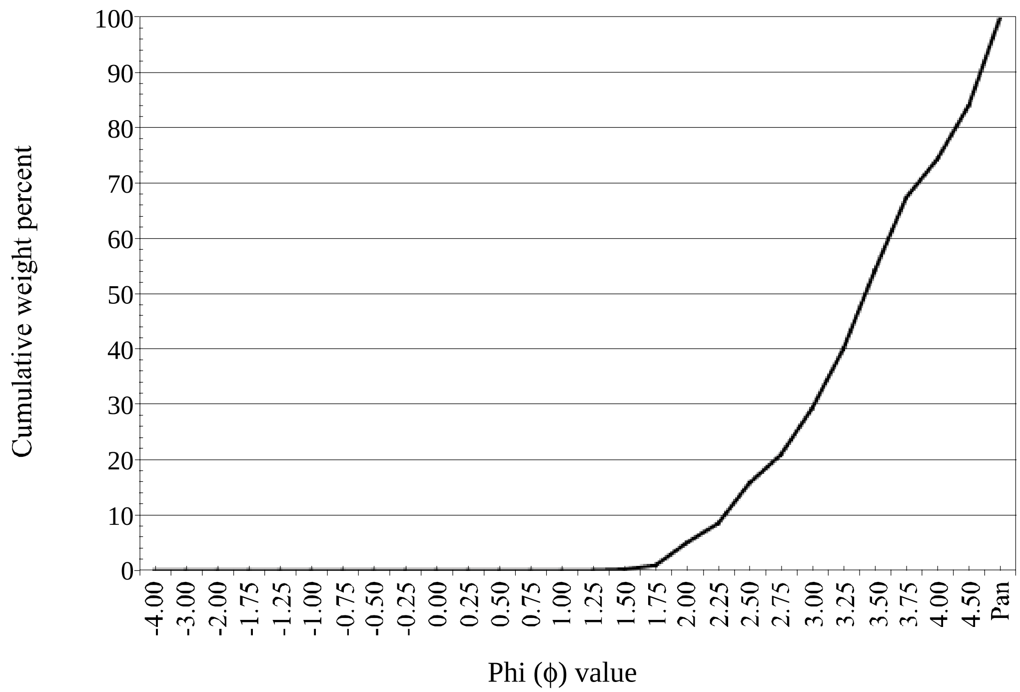
Turkey Ridge R20-01-1, 127 feet



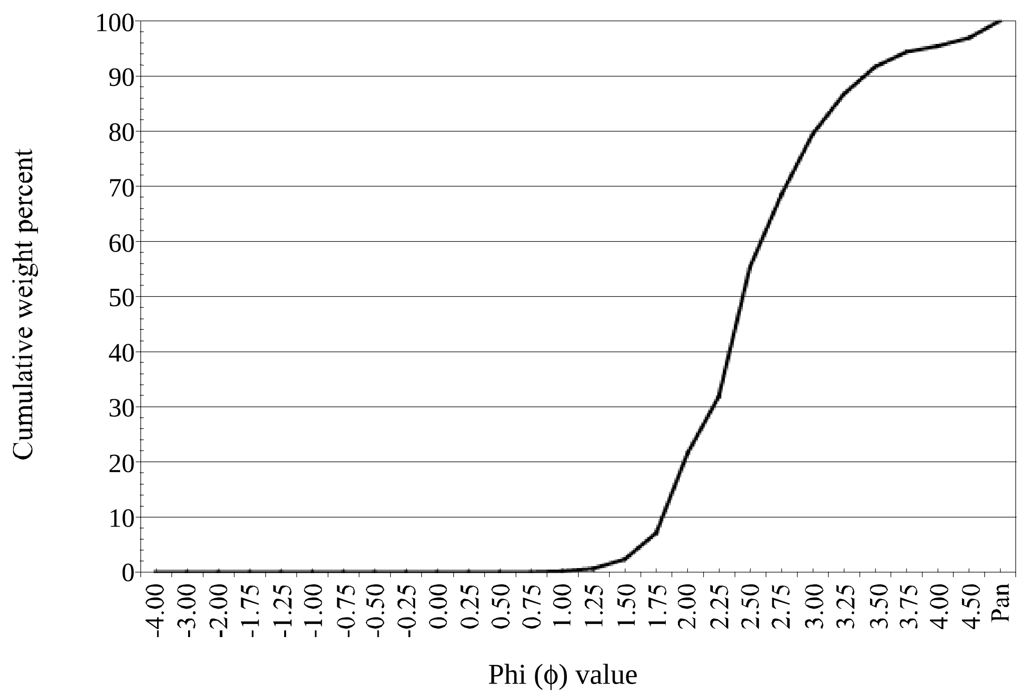
Turkey Ridge R20-01-1, 141-145 feet



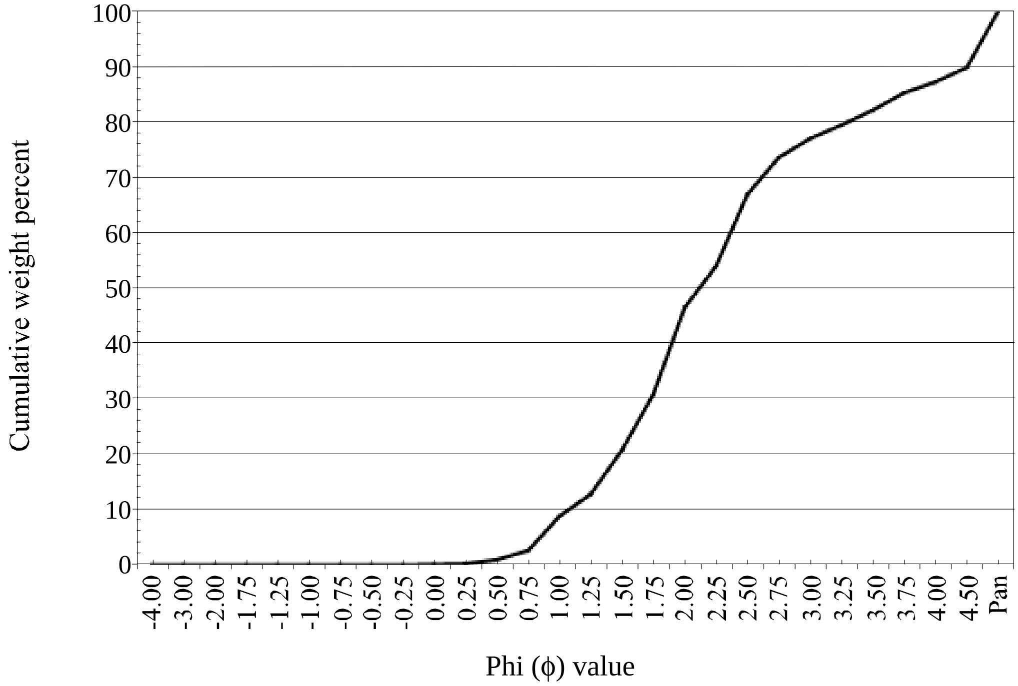
Turkey Ridge R20-01-1, 151 feet



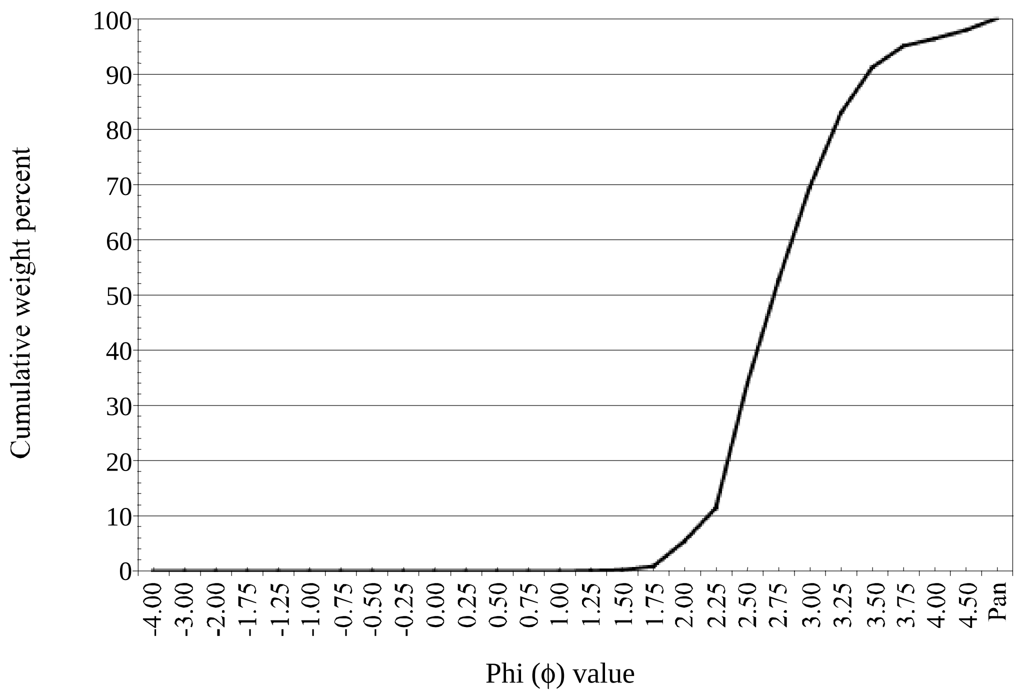
Turkey Ridge R20-01-1, 160-161 feet



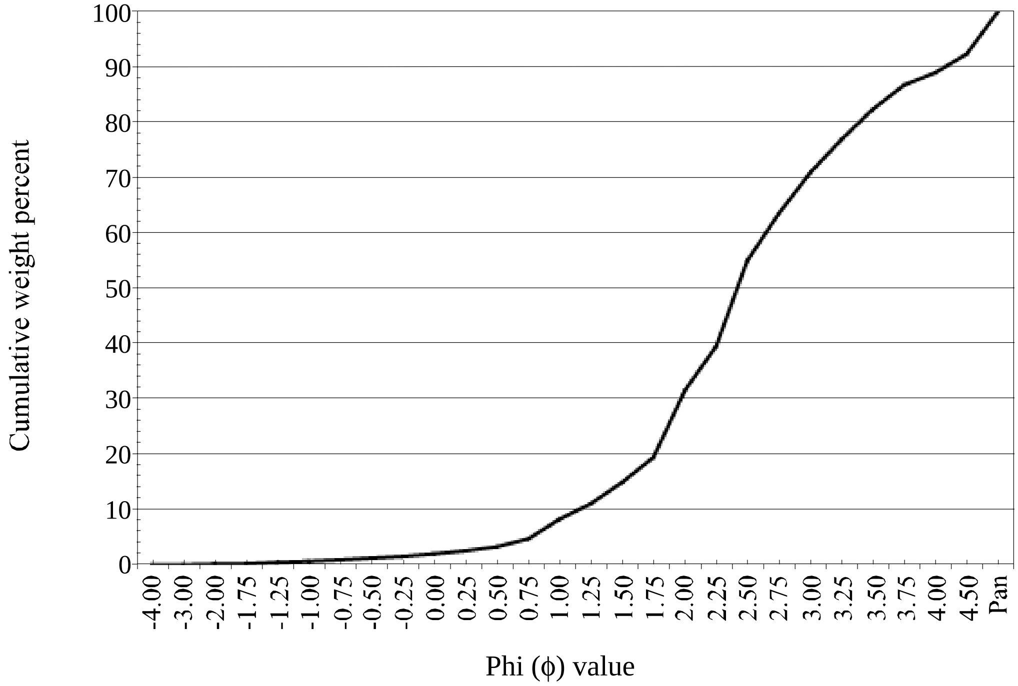
Turkey Ridge R20-01-1, 173-174 feet



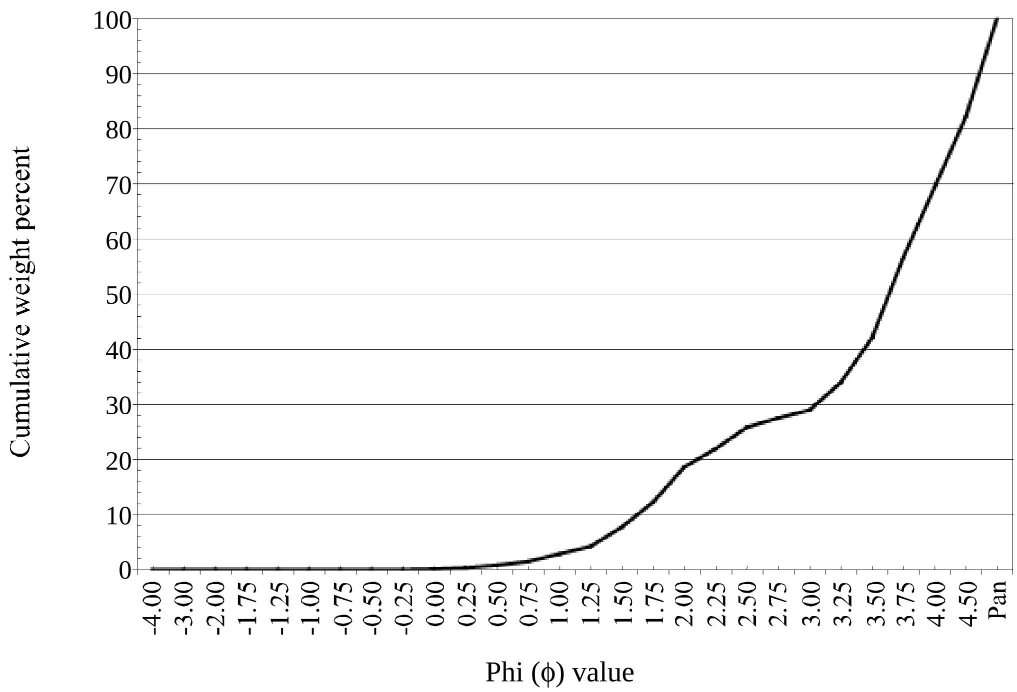
Turkey Ridge R20-01-1, 180-185 feet



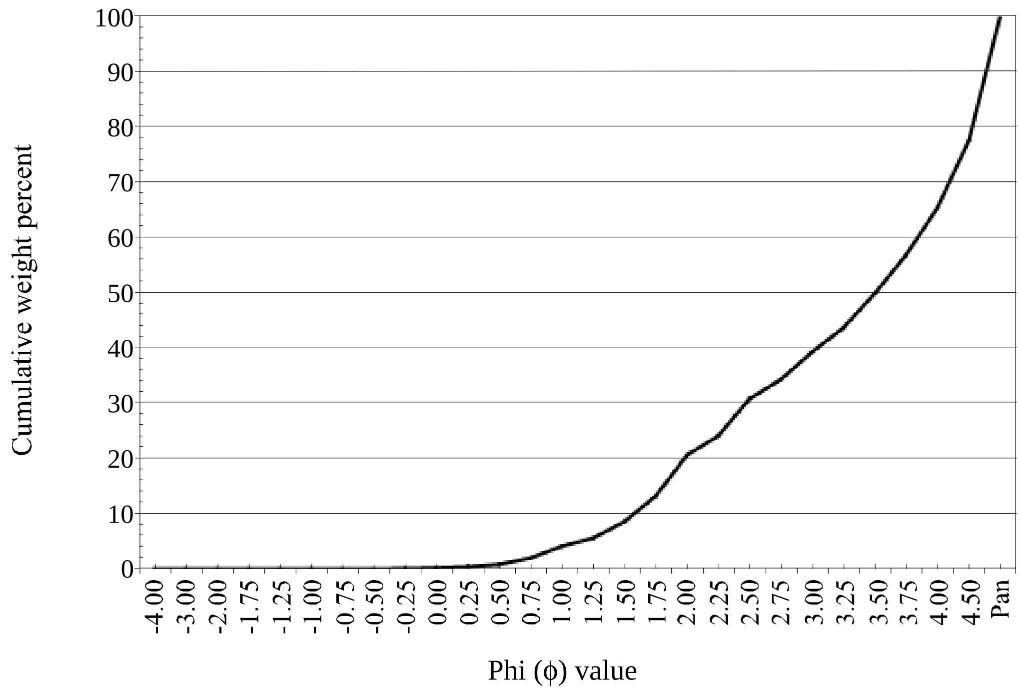
Turkey Ridge R20-01-1, composite



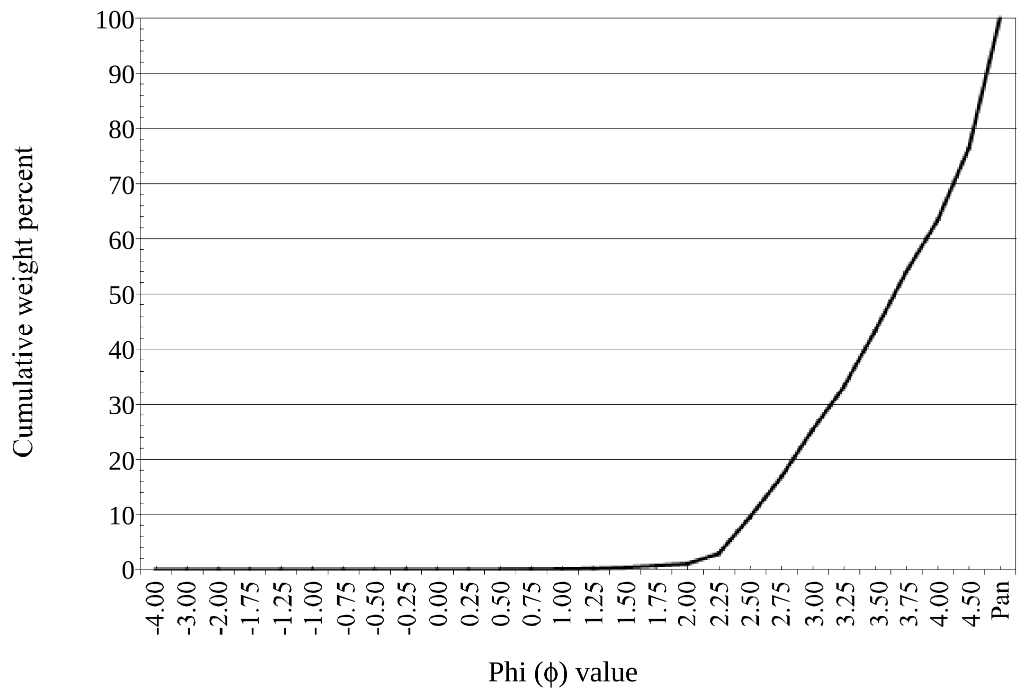
Turkey Ridge R20-87-14, 200-205 feet



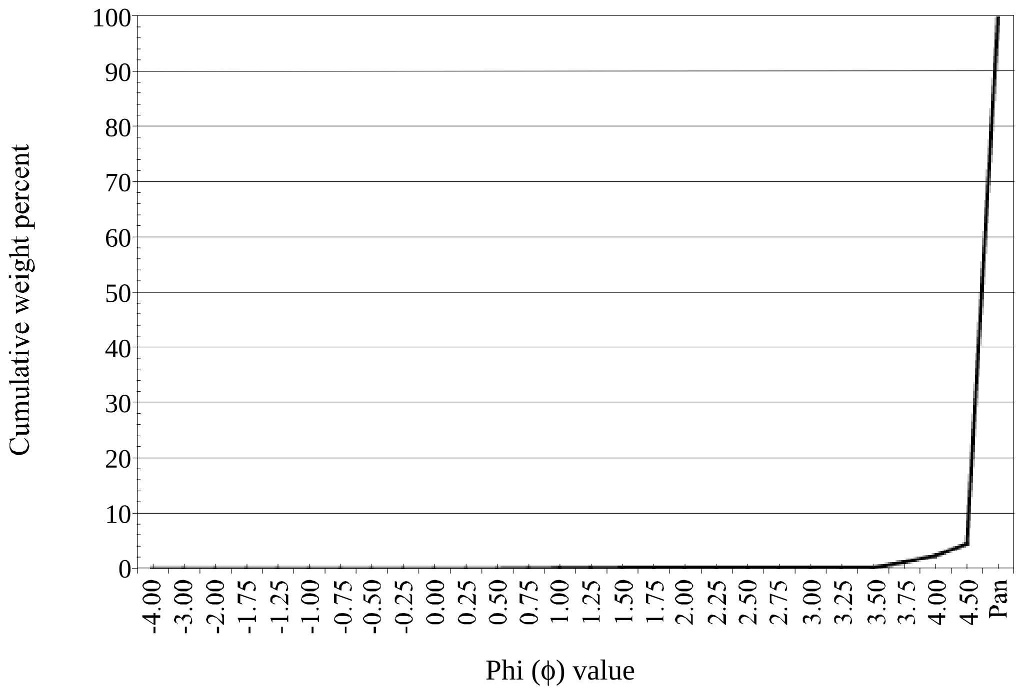
Turkey Ridge R20-87-14, 205-210 feet



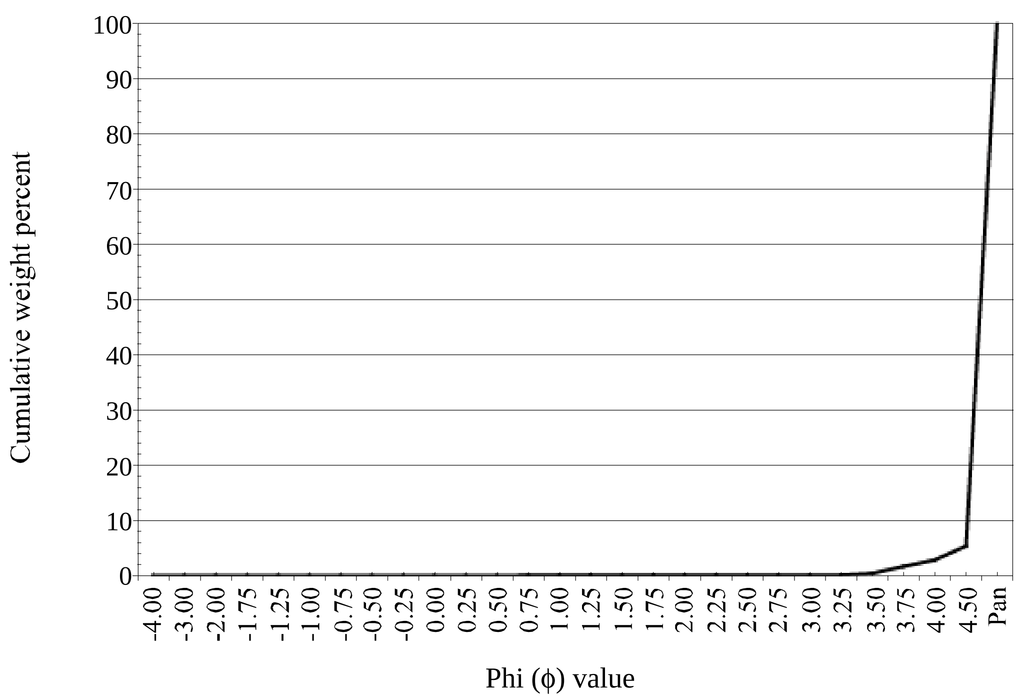
Turkey Ridge R20-87-14, 210-215 feet



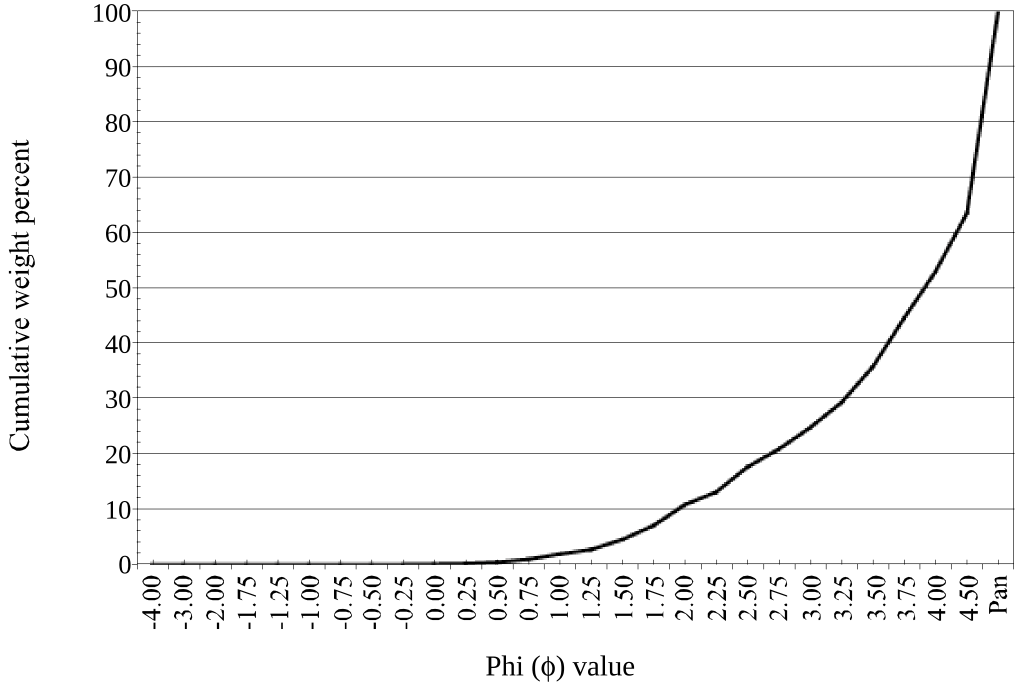
Turkey Ridge R20-87-14, 225-230 feet



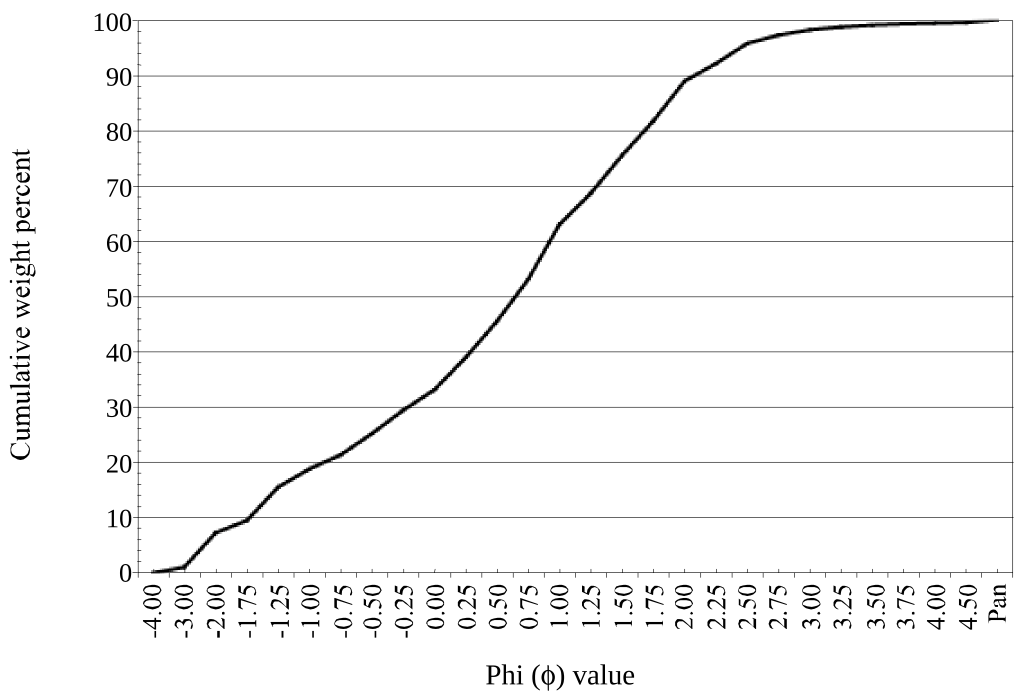
Turkey Ridge R20-87-14, 230-235 feet



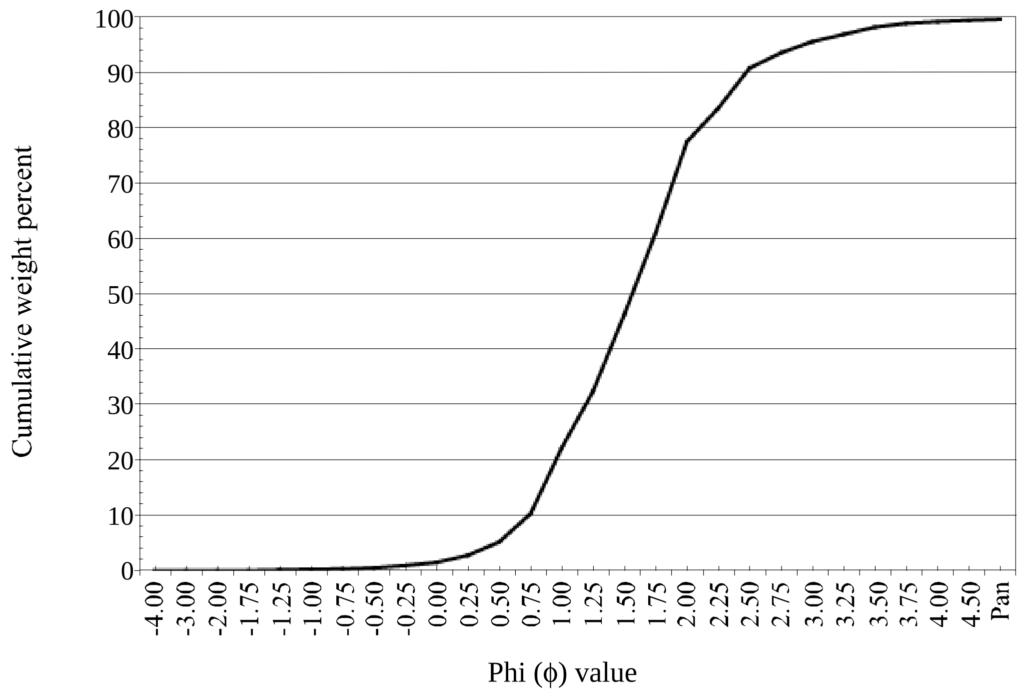
Turkey Ridge R20-87-14, composite



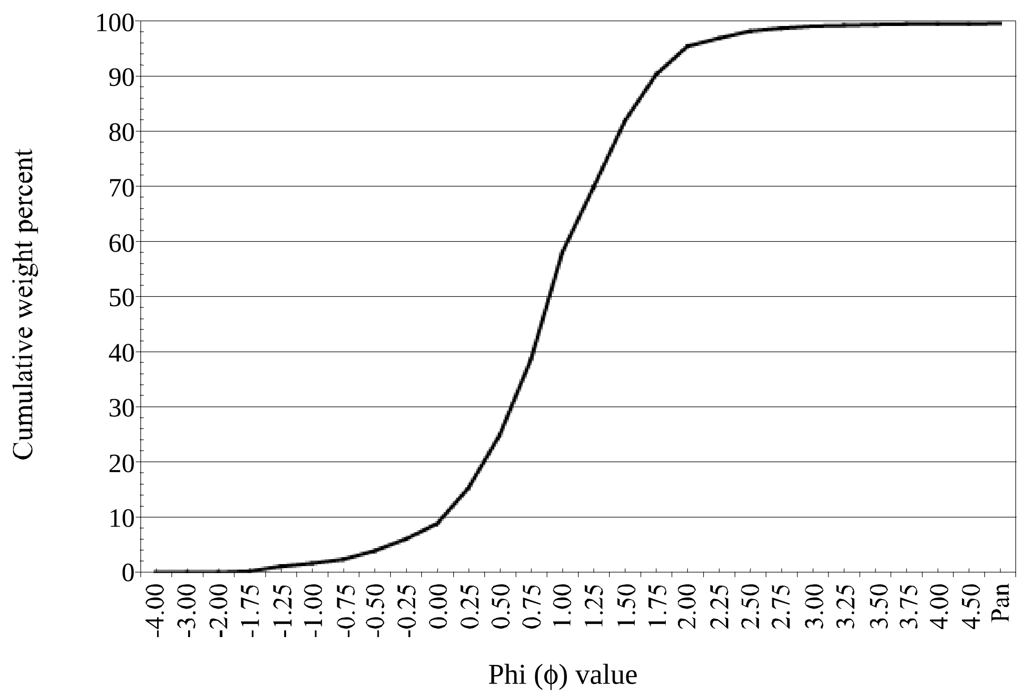
Heeren core, 27.5-28.25 feet



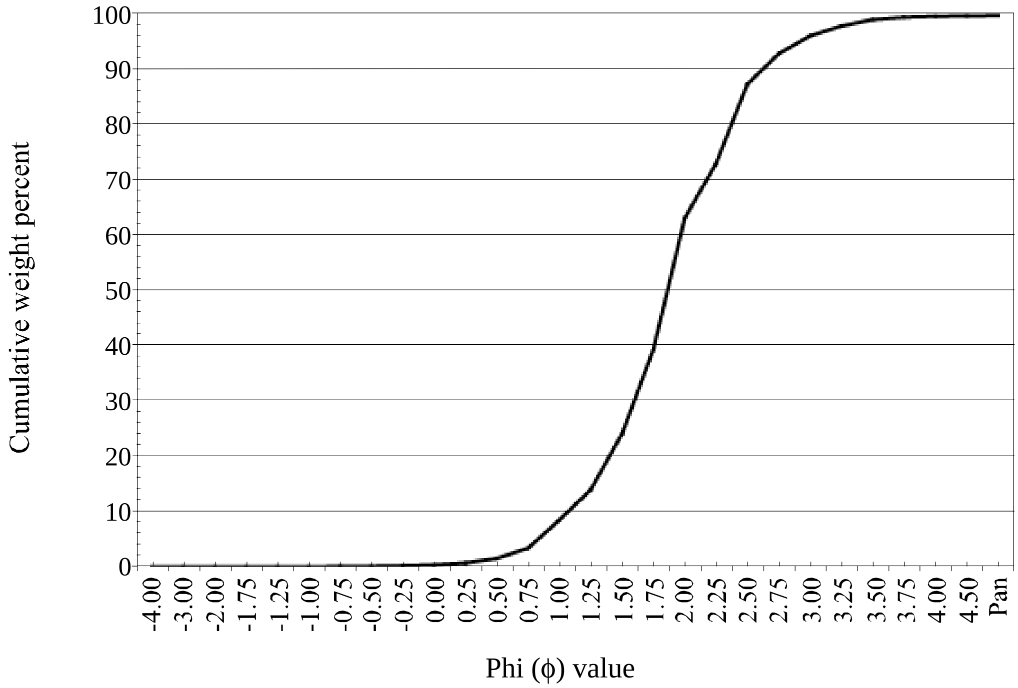
Heeren core, 30-35 feet



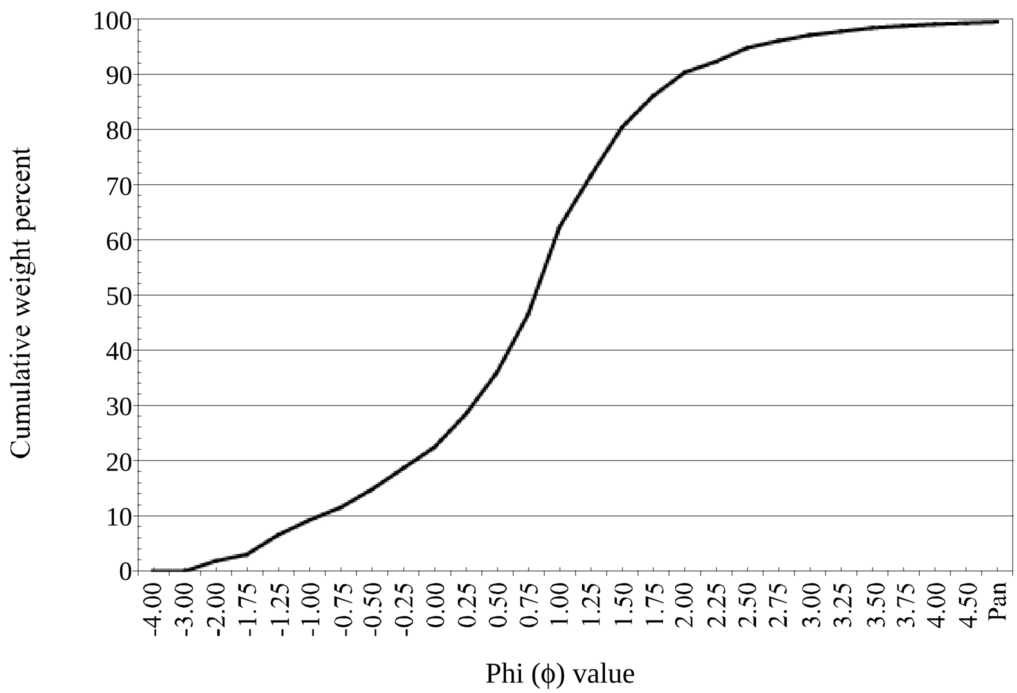
Heeren core, 35-40 feet



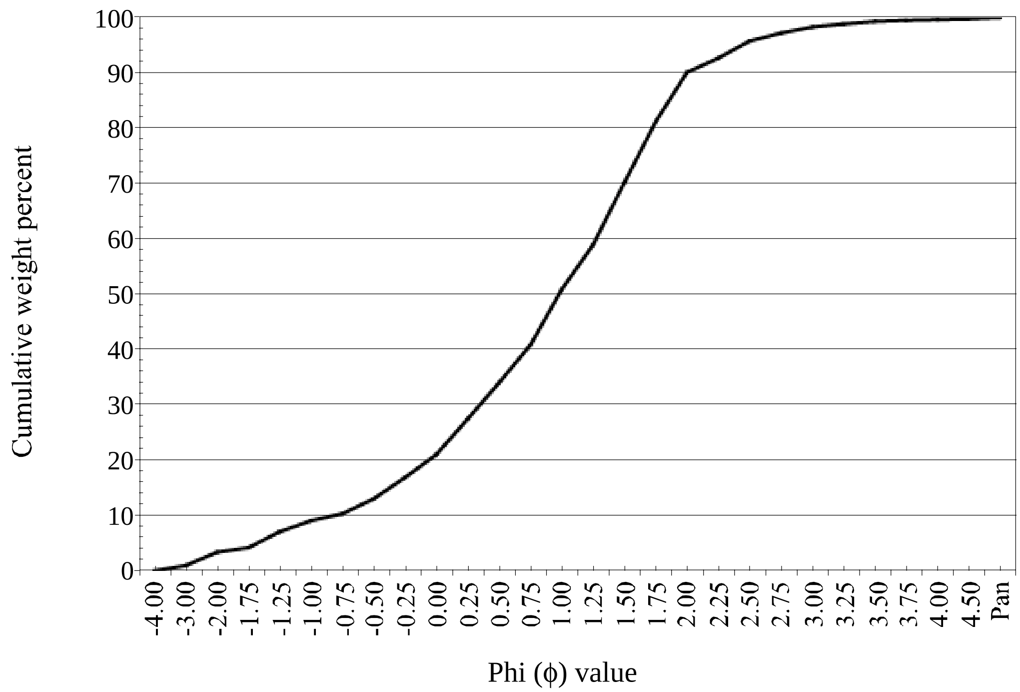
Heeren core, 40-45 feet



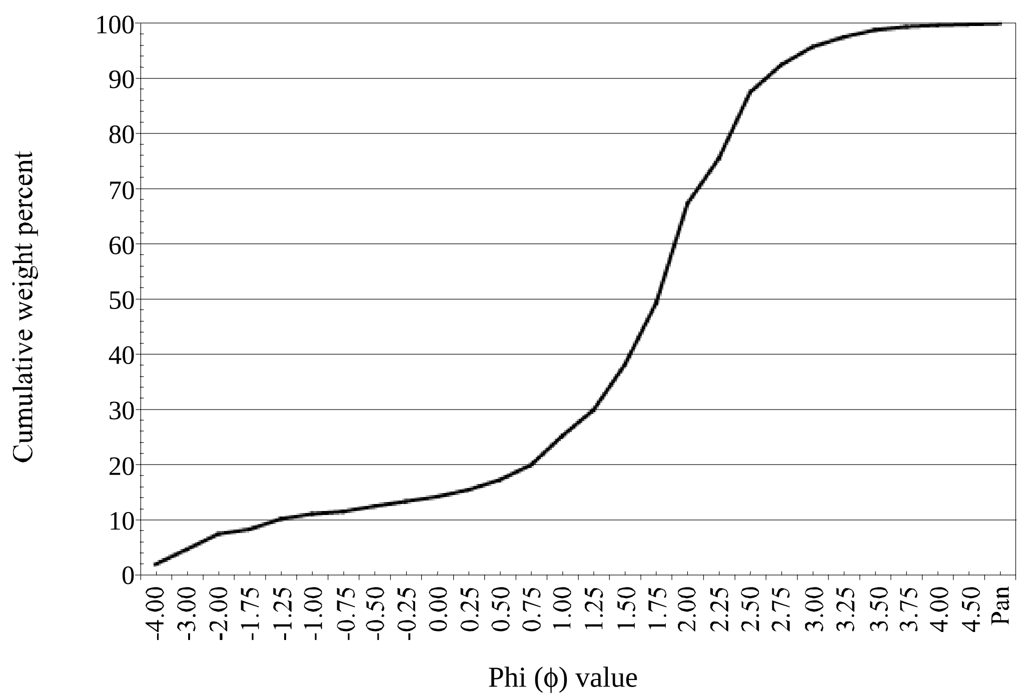
Heeren core, 45-50 feet



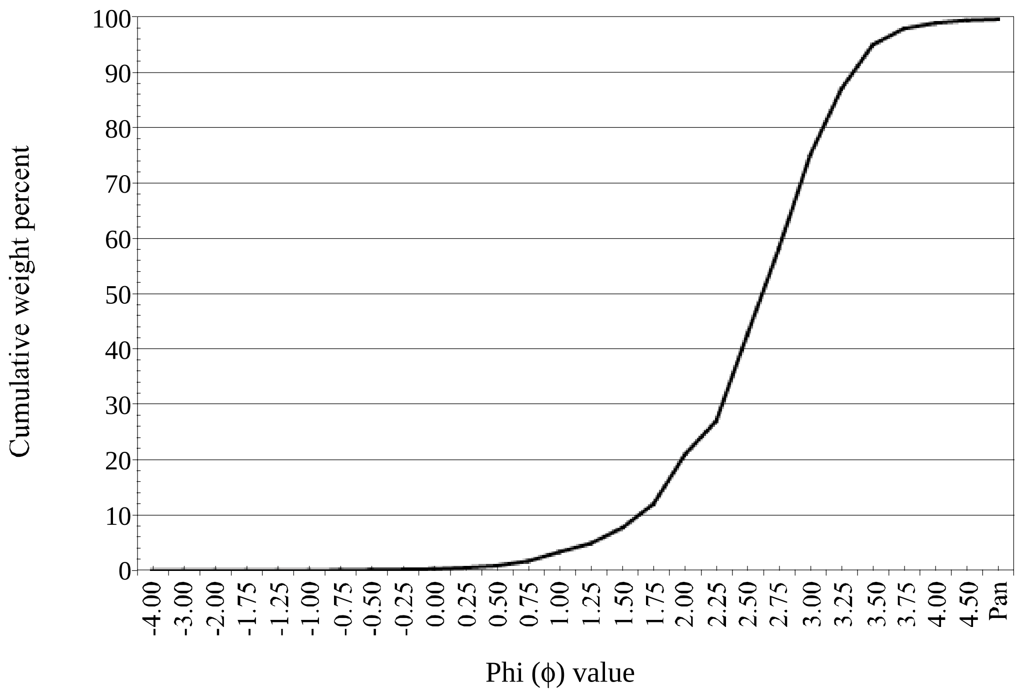
Heeren core, 50-55 feet



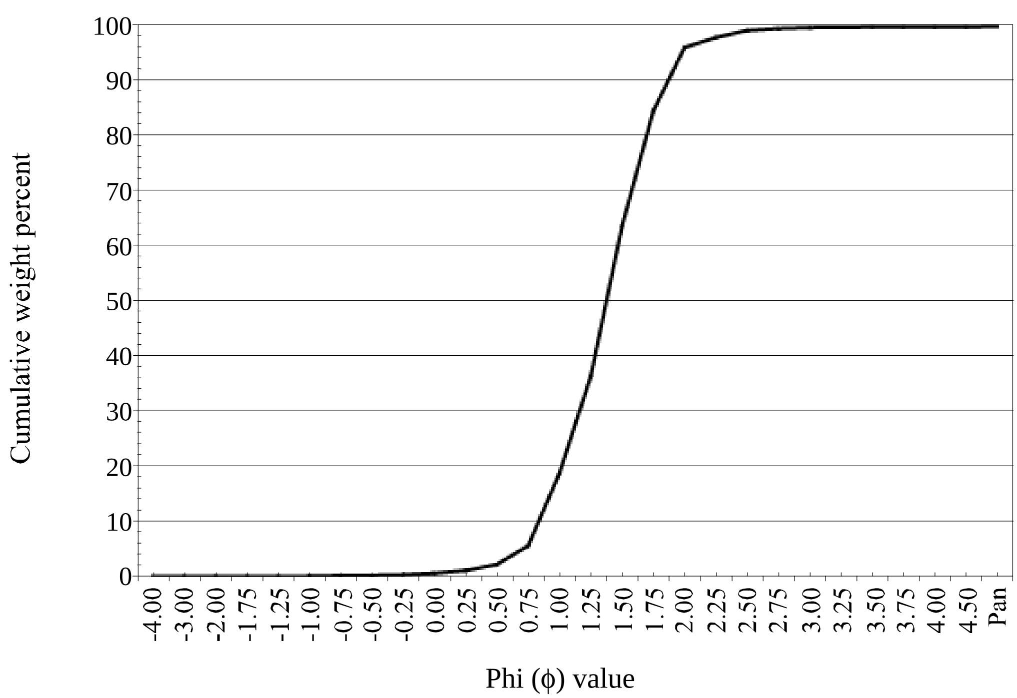
Heeren core, 55-60 feet



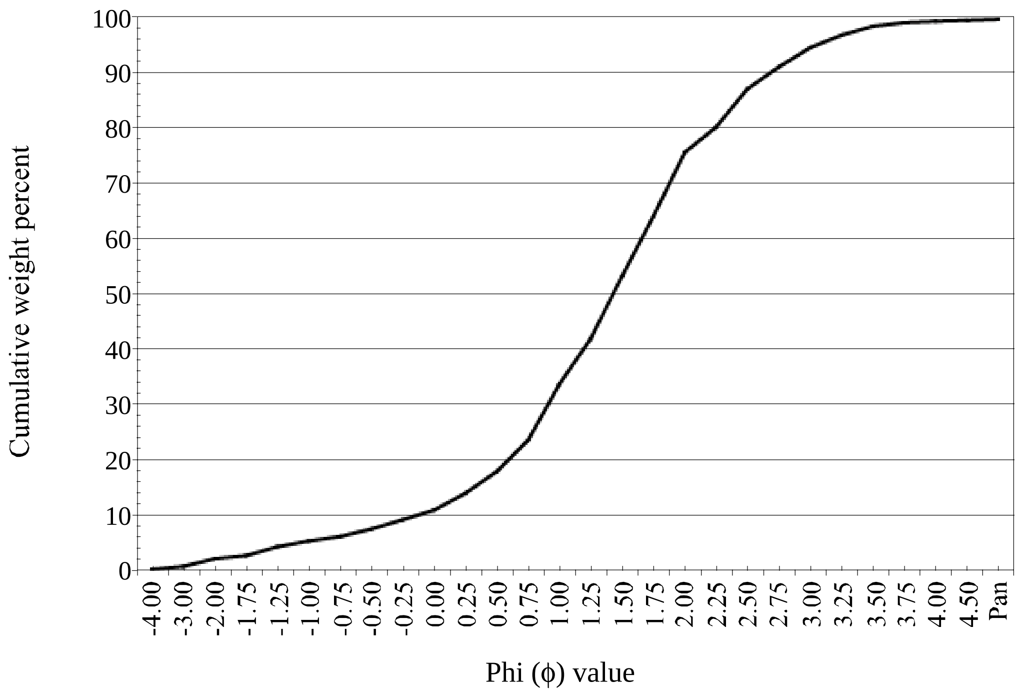
Heeren core, 60-65 feet



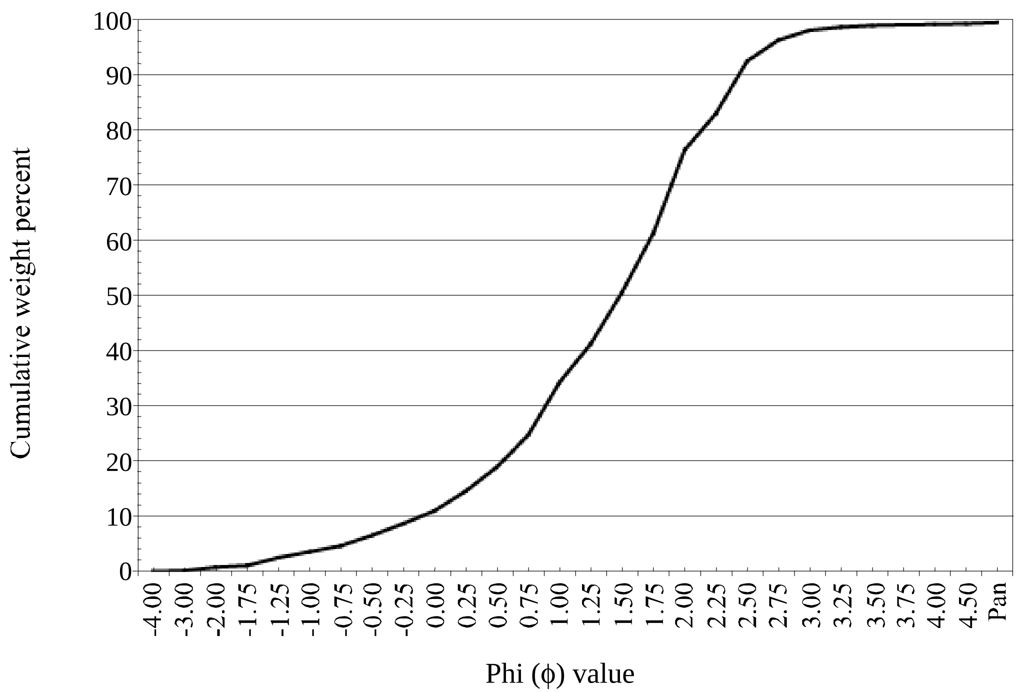
Heeren core, 65-70 feet



Heeren core, composite

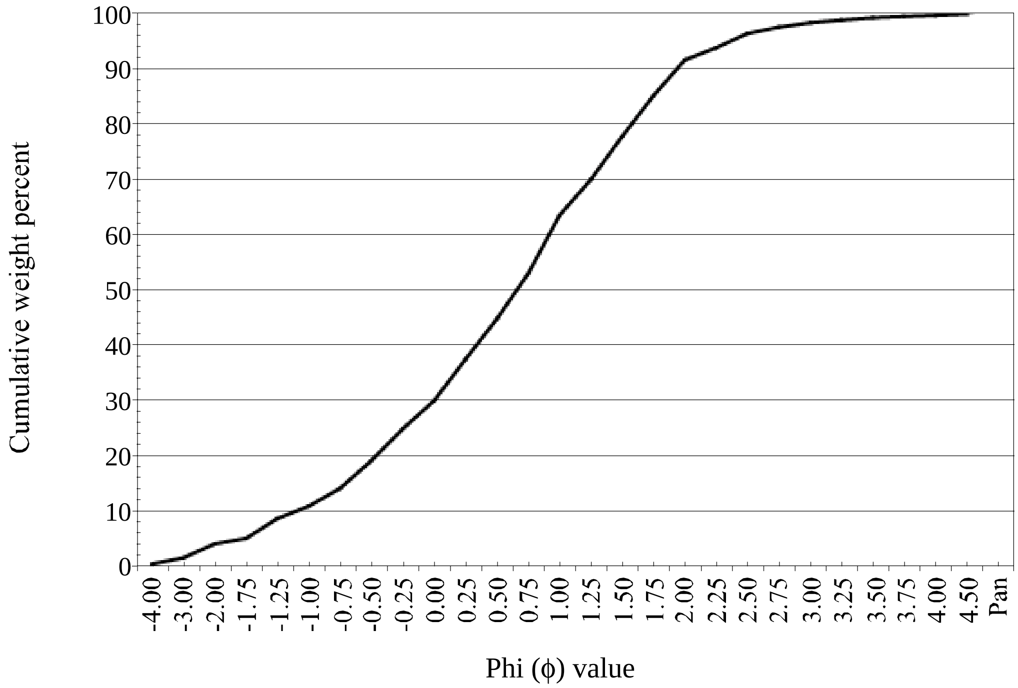


Bon Homme 5-22-2

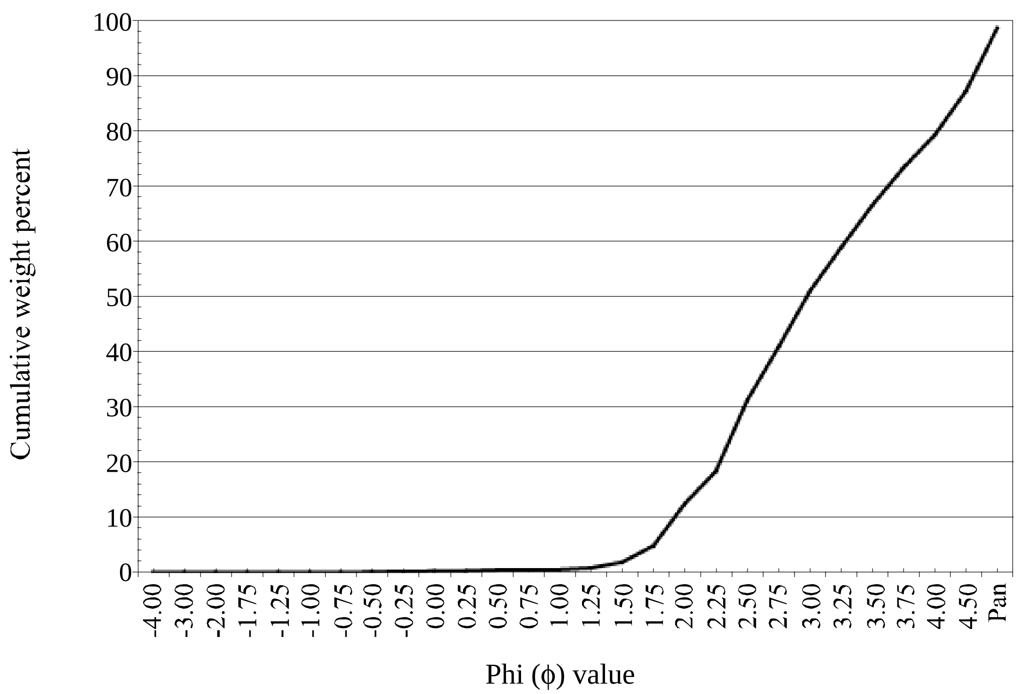


Appendix B – continued

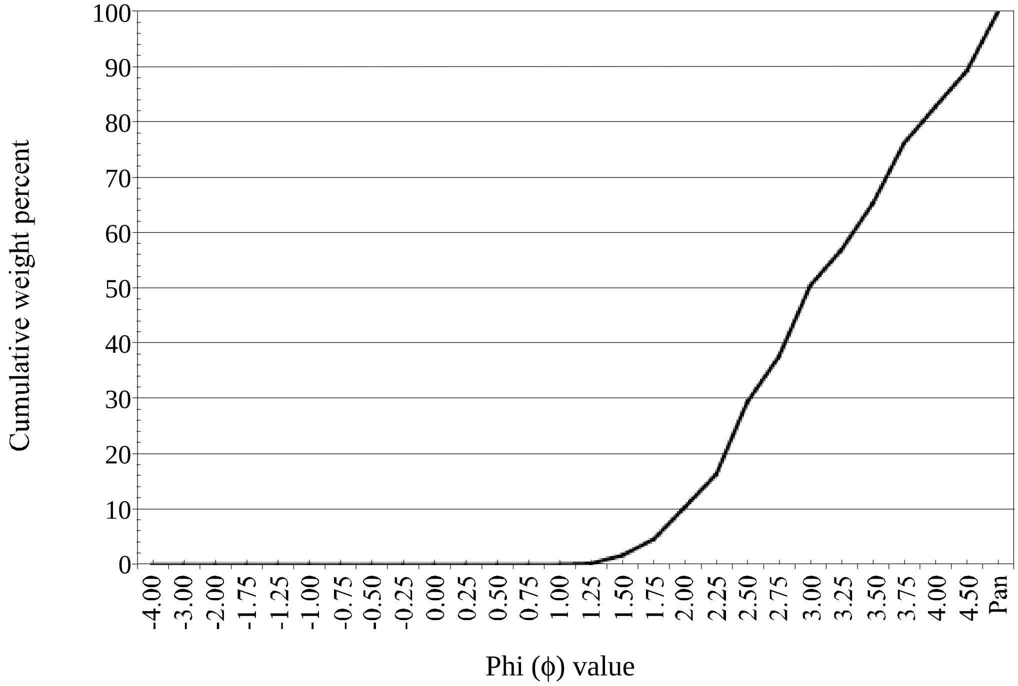
Herrick gravel 5-23-3



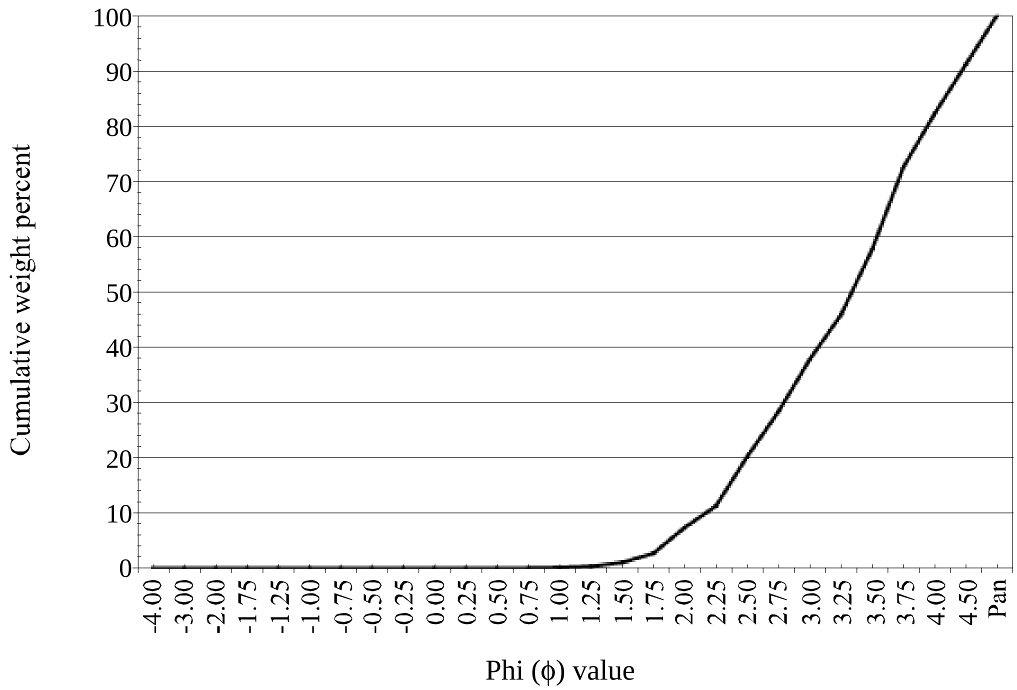
Ash Hollow 5-23-4



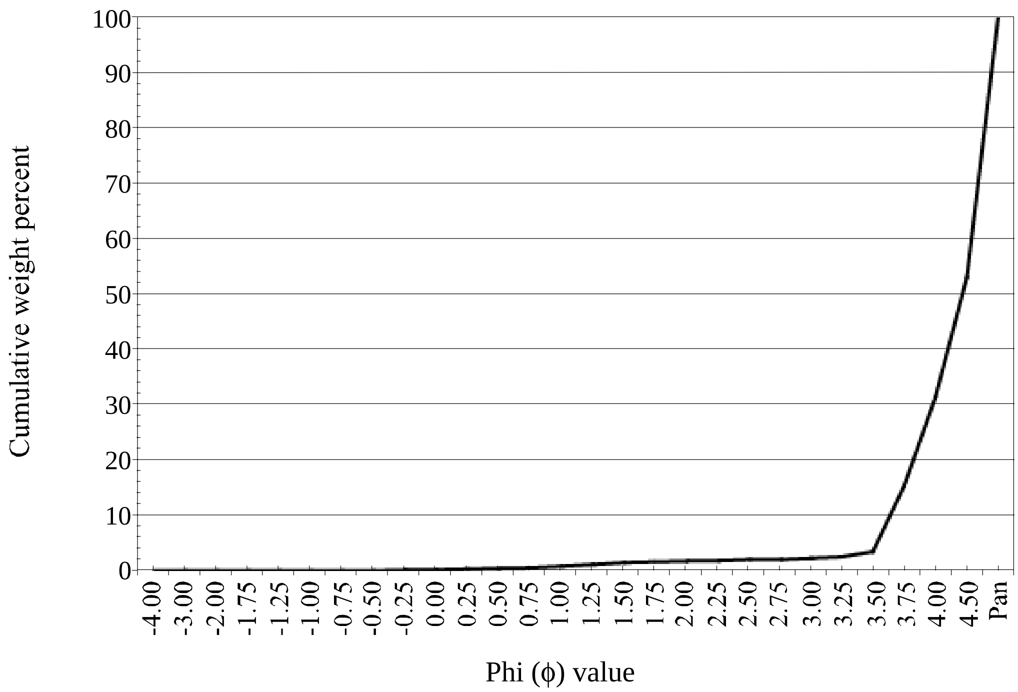
Gregory City 5-23-5



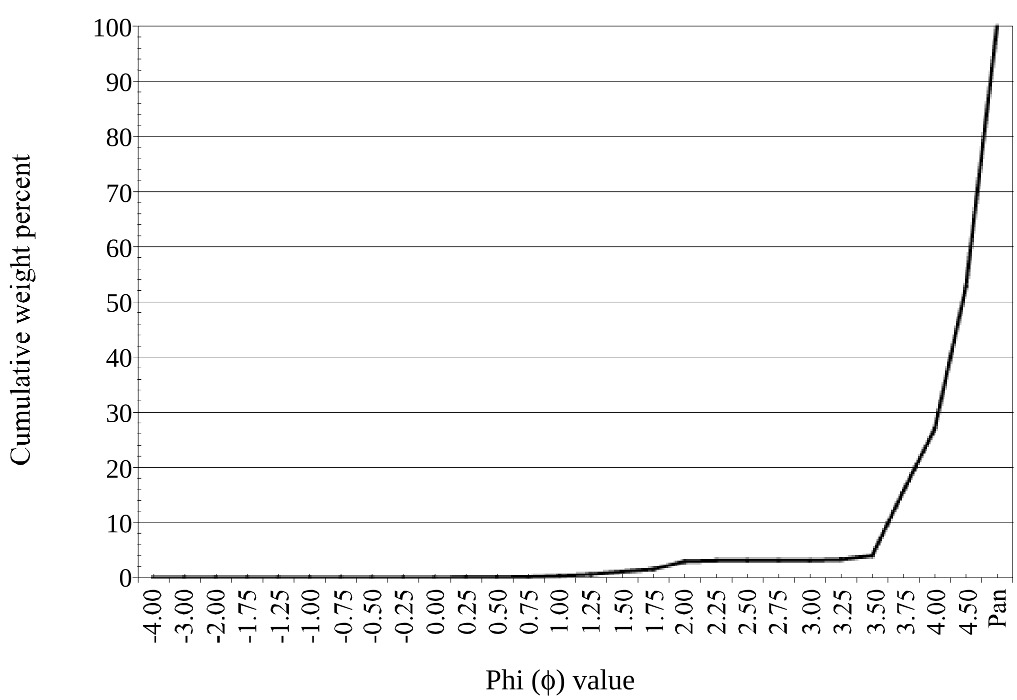
Gregory City 5-23-6



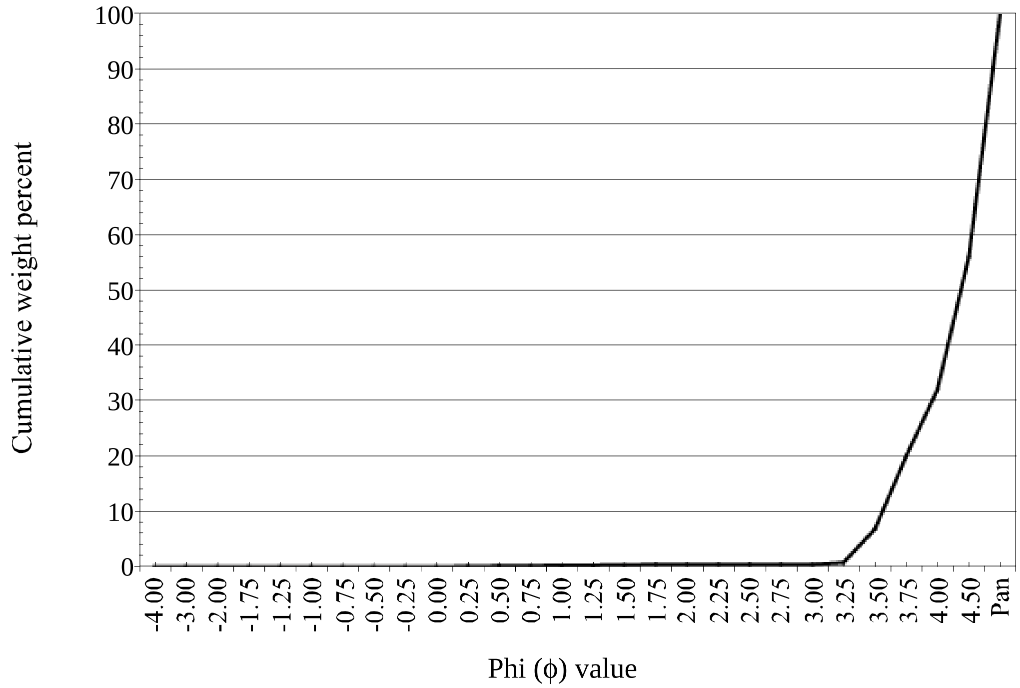
R20-01-5, 27-28 feet



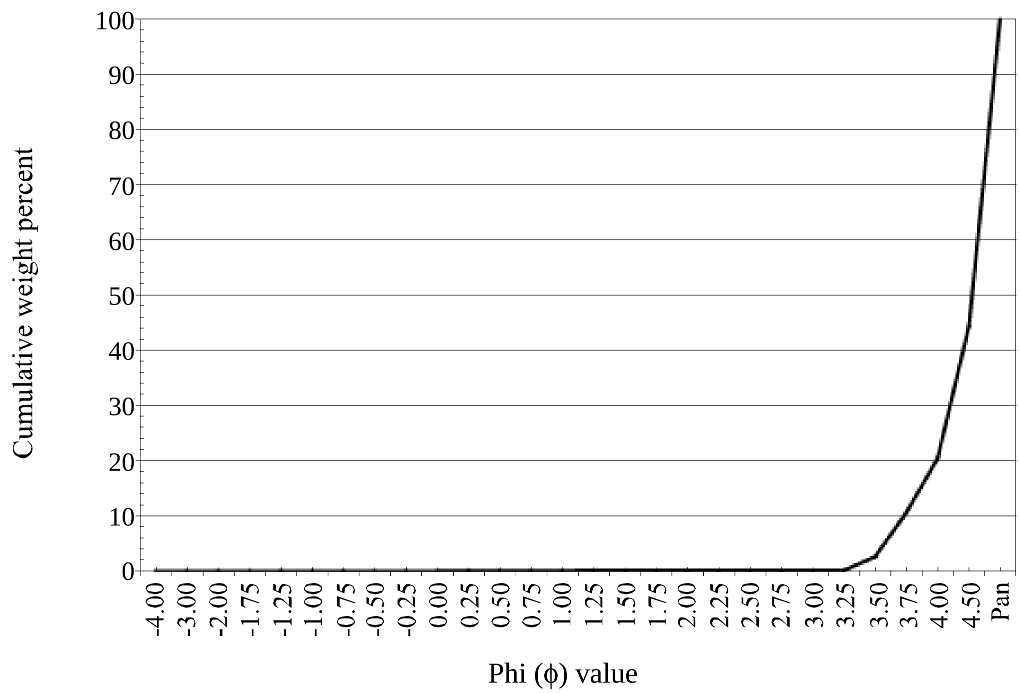
R20-01-5, 40-41 feet



R20-01-5, 58.5-59.5 feet

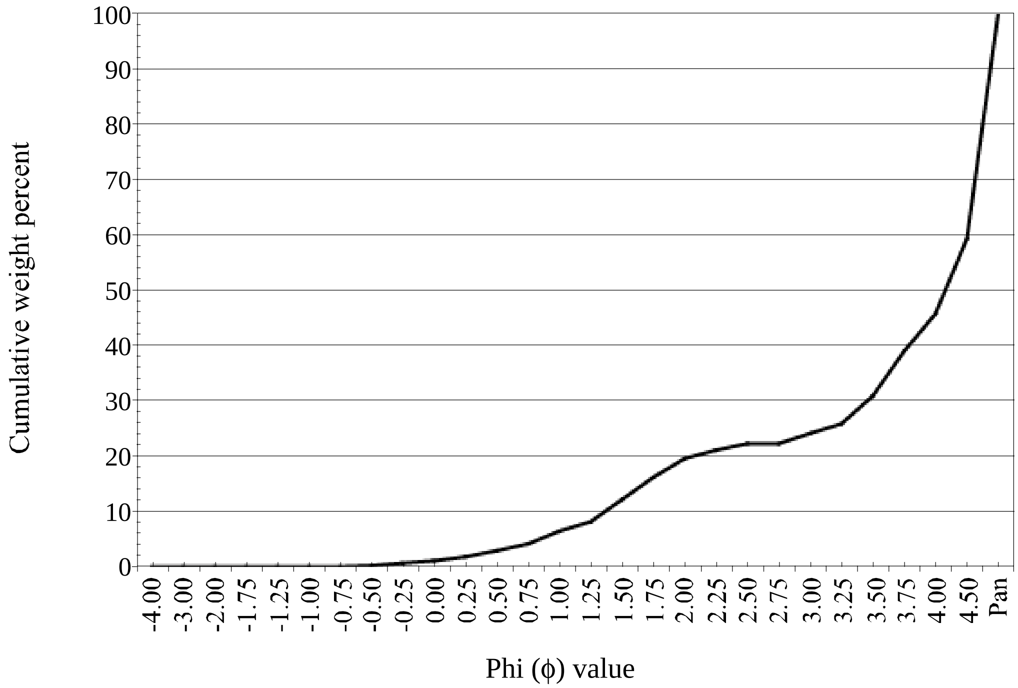


R20-01-5, 67-68 feet

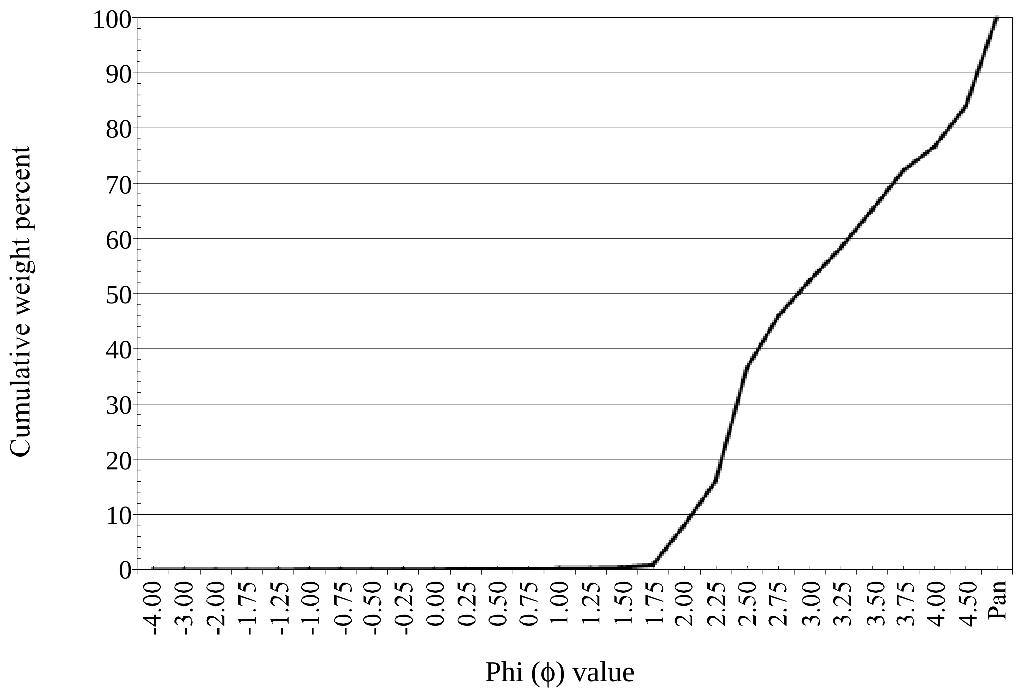


Appendix B – continued

R20-01-5, 75-76 feet

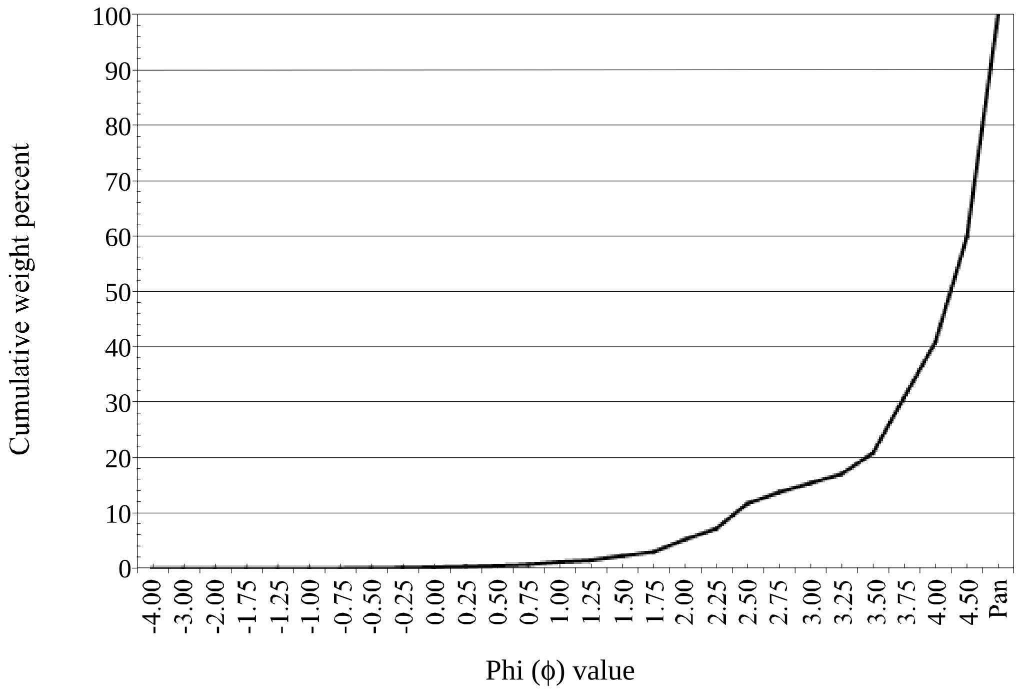


R20-01-5, 88-89 feet

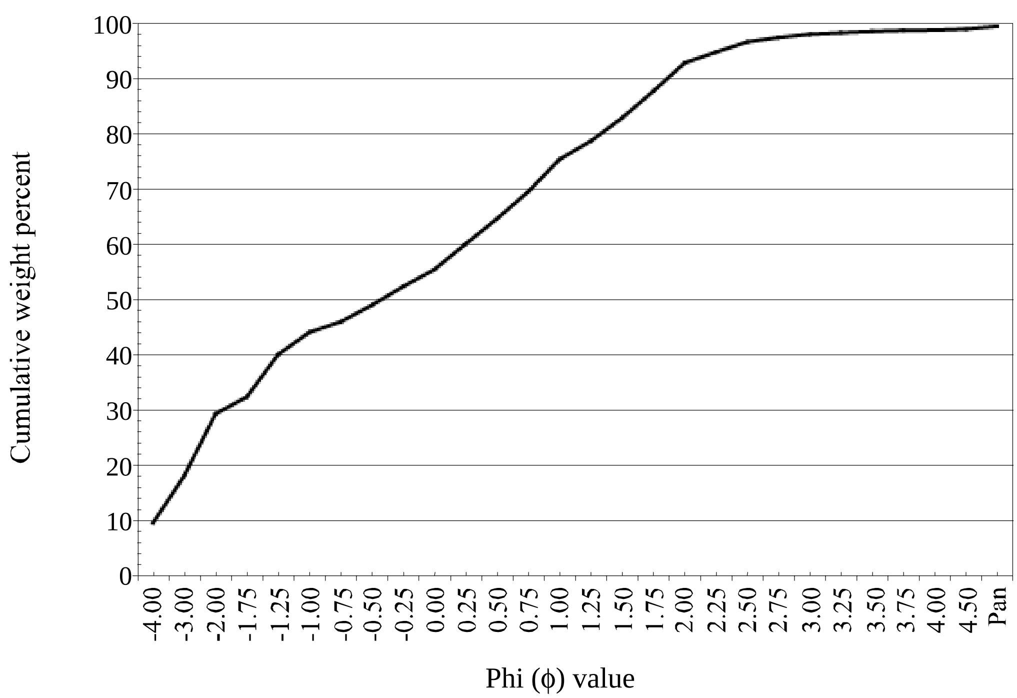


Appendix B – continued

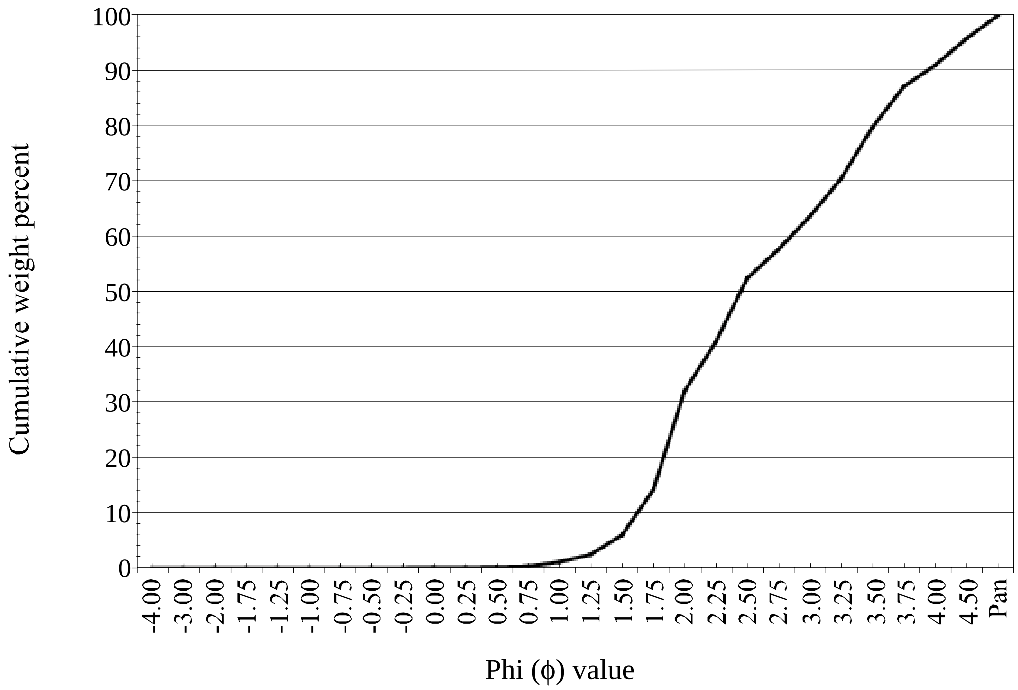
R20-01-5, composite



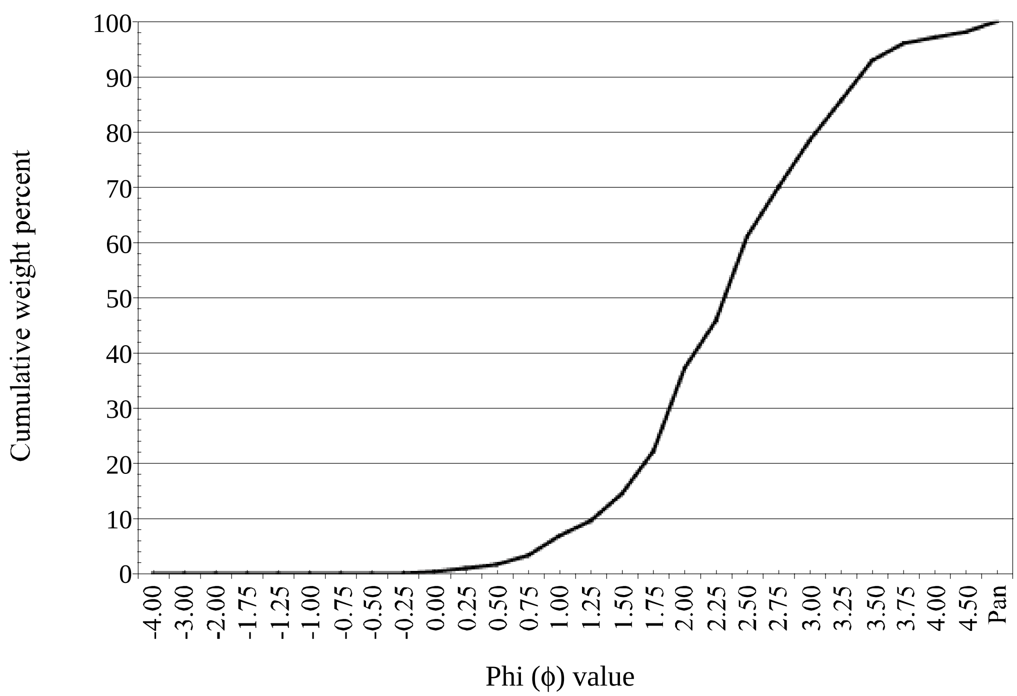
Hurley 5-22-5



Missouri 5-21-1



Spencer quarry 5-10-1



Appendix C. Phi (ϕ) value of percentiles from cumulative frequency curves

Sample name and number	Sample depth (in feet)	Phi (ϕ) value of percentiles from cumulative frequency curve						
		5th	16th	25th	50th	75th	84th	95th
Alcester 6-1-2	surface	-0.30	0.35	0.63	1.18	1.73	2.00	3.68
Alcester 6-1-7	surface	1.56	1.93	2.19	3.07	4.16	4.54	4.70
Newton Hills 5-24-2	surface	0.40	1.06	1.48	1.87	2.25	2.38	2.69
Turkey Ridge R20-01-2	40-50	-1.72	-0.84	-0.46	0.44	1.08	1.62	2.64
Turkey Ridge R20-01-1	105-110	-0.67	0.50	0.82	1.28	1.92	2.44	4.54
	117	2.02	2.45	2.72	2.33	4.00	4.48	4.61
	127	1.81	1.96	2.12	2.47	3.28	3.70	4.53
	141-145	1.51	1.80	1.88	2.12	2.40	2.50	2.98
	151	2.01	2.51	2.87	3.42	4.02	4.50	4.61
	160-161	1.67	1.93	2.09	2.44	2.91	3.17	3.91
	173-174	0.88	1.37	1.61	2.12	2.86	3.65	4.57
	180-185	1.99	2.31	2.41	2.72	3.10	3.28	3.78
	composite	0.78	1.57	1.87	2.43	3.18	3.58	4.53
Turkey Ridge R20-87-14	200-205	1.33	1.91	2.43	3.63	4.20	4.50	4.63
	205-210	1.18	1.83	2.28	3.50	4.38	4.53	4.63
	210-215	2.35	2.72	2.99	3.68	4.44	4.54	4.62
	225-230	4.49	4.55	4.59	4.65	4.69	4.74	4.79
	230-235	4.45	4.55	4.57	4.64	4.70	4.72	4.78
	composite	1.56	2.41	3.03	3.91	4.55	4.59	4.68
Heeren core	27.5-28.25	-2.22	-1.22	-0.51	0.64	1.47	1.82	2.46
	30-35	0.48	0.89	1.08	1.57	1.98	2.28	2.90
	35-40	-0.38	0.28	0.49	0.89	1.33	1.57	1.98
	40-45	0.83	1.29	1.52	1.87	2.29	2.43	2.92
	45-50	-1.45	-0.43	0.12	0.88	1.35	1.67	2.56
	50-55	-1.57	-0.31	0.17	0.98	1.59	1.83	2.43
	55-60	-2.90	0.32	1.98	1.75	2.23	2.43	2.94
	60-65	1.27	1.88	2.18	2.60	3.00	3.18	3.50
	65-70	0.73	0.97	1.69	1.38	1.63	1.75	1.97
	composite	-1.19	0.38	0.78	1.42	1.98	2.38	3.03
Bon Homme 5-22-2	surface	-0.68	0.36	0.76	1.48	1.99	2.28	2.68
Herrick gravel 5-23-3	surface	-1.78	-0.65	-0.25	0.67	1.41	1.72	2.37
Ash Hollow 5-23-4	surface	1.77	2.17	2.40	2.98	3.82	4.29	4.75
Gregory City 5-23-5	surface	1.76	2.23	2.42	2.98	3.76	4.08	4.58
Gregory City 5-23-6	surface	1.89	2.39	2.66	2.33	3.82	4.18	4.55

Appendix C – continued

Sample name and number	Sample depth (in feet)	Phi (ϕ) value of percentiles from cumulative frequency curve						
		5th	16th	25th	50th	75th	84th	95th
R20-01-5	27-28	3.57	3.78	3.92	4.43	4.58	4.63	4.82
	40-41	3.55	3.75	3.98	4.45	4.58	4.62	4.80
	58.5-59.5	3.47	3.69	3.88	4.38	4.58	4.62	4.71
	67-68	3.61	3.90	4.11	4.52	4.60	4.63	4.71
	75-76	0.86	1.73	3.15	4.15	4.55	4.59	4.68
	88-89	1.93	2.25	2.38	2.92	3.92	4.50	4.60
	composite	1.98	3.10	3.61	4.22	4.55	4.60	4.68
Hurley 5-22-5	surface	-5.65	-3.20	-2.35	-0.40	0.99	1.58	2.30
Missouri 5-21-1	surface	1.46	1.78	1.93	2.48	3.37	3.64	4.39
Spencer quarry 5-10-1	surface	0.89	1.57	1.79	2.30	2.90	3.18	3.67

Appendix D. Statistical parameters based on method of moments and graphical method

Sample name and number	Sample depth (in feet)	Statistical parameters based on method of moments: Mean (ϕ)	Standard deviation (ϕ)	Skewness	Kurtosis	Statistical parameters based on graphical method: Graphical mean (ϕ)	Graphical standard deviation (ϕ)	Skewness	Kurtosis	Median (ϕ)	First mode (ϕ)	Bimodal character (X)
Alcester 6-1-2	surface	1.26	1.13	1.22	6.01	1.18	1.02	0.13	1.48	1.18	1.00	
Alcester 6-1-7	surface	3.22	1.26	0.29	2.02	3.18	1.13	0.08	0.65	3.07	pan fraction	X
Newton Hills 5-24-2	surface	1.78	0.75	-0.69	6.89	1.77	0.68	-0.26	1.22	1.87	2.00	
Turkey Ridge R20-01-2	40-50	0.39	1.35	0.46	4.54	0.41	1.28	-0.02	1.16	0.44	1.00	
Turkey Ridge R20-01-1	105-110	1.54	1.54	0.90	4.27	2.53	1.07	0.13	1.17	4.03	1.00	
	117	3.45	0.99	0.48	2.39	3.09	0.90	0.94	0.83	2.39	pan fraction	X
	127	2.79	0.98	1.21	3.75	2.71	0.85	0.46	0.96	3.75	2.50	X
	141-145	2.18	0.55	1.95	12.50	2.14	0.40	0.13	1.16	12.50	2.00	
	151	3.52	0.97	0.35	2.48	3.48	0.89	0.00	0.93	2.48	pan fraction	
	160-161	2.57	0.75	1.44	6.22	2.51	0.65	0.24	1.12	6.22	2.50	
	173-174	2.42	1.24	1.01	3.33	2.38	1.13	0.34	1.21	3.33	2.00	X
	180-185	2.80	0.61	1.43	6.93	2.77	0.51	0.17	1.06	6.93	2.50	
	composite	2.55	1.22	0.17	4.03	2.53	1.07	0.13	1.17	4.03	2.50	X
Turkey Ridge R20-87-14	200-205	3.45	1.26	-0.37	2.43	3.35	1.15	-0.36	0.76	3.63	pan fraction	X
	205-210	3.39	1.37	-0.17	2.02	3.29	1.20	-0.29	0.67	3.50	pan fraction	X
	210-215	3.78	1.00	0.13	2.12	3.65	0.80	-0.11	0.64	3.68	pan fraction	
	225-230	5.19	0.32	-7.31	76.62	4.65	0.09	-0.06	1.23	76.62	pan fraction	

Appendix D – continued

Sample name and number	Sample depth (in feet)	Statistical parameters based on method of moments				Statistical parameters based on graphical method				Median (ϕ)	First mode (ϕ)	Bimodal character (X)
		Mean (ϕ)	Standard deviation (ϕ)	Skewness	Kurtosis	Graphical mean (ϕ)	Graphical standard deviation (ϕ)	Skewness	Kurtosis			
Turkey Ridge R20-87-14 (continued)	230-235	5.18	0.34	-5.98	52.77	4.64	0.09	-0.11	1.04	52.77	pan fraction	
	composite	3.88	1.29	-0.55	2.35	3.64	1.02	-0.44	0.84	3.91	pan fraction	X
Heeren core	27.5-28.25	0.42	1.48	-0.33	3.04	0.41	1.47	-0.22	0.97	0.64	1.00	X
	30-35	1.57	0.75	0.41	4.90	1.58	0.71	0.06	1.10	1.57	2.00	
	35-40	0.89	0.73	-0.20	5.07	0.91	0.68	-0.01	1.15	0.89	1.00	
	40-45	1.87	0.62	0.07	4.43	1.86	0.60	-0.01	1.11	1.87	2.00	
	45-50	0.68	1.16	-0.20	3.97	0.71	1.13	-0.20	1.34	0.88	1.00	X
	50-55	0.79	1.24	-0.75	4.40	0.83	1.14	-0.24	1.15	0.98	1.50	X
	55-60	1.26	1.67	-1.77	5.99	1.50	1.41	-0.47	9.57	1.75	2.00	X
	60-65	2.53	0.70	-0.67	4.50	2.55	0.66	-0.15	1.11	2.60	3.00	
	65-70	1.36	0.44	0.16	9.31	1.37	0.38	-0.05	0.94	1.38	1.50	
	composite	1.29	1.23	-1.06	5.70	1.39	1.14	-0.14	1.44	1.42	2.00	X
Bon Homme 5-22-2	surface	1.29	1.05	-0.83	4.61	1.37	0.99	-0.23	1.12	1.48	2.00	
Herrick gravel 5-23-3	surface	0.54	1.35	-0.41	4.62	0.58	1.22	-0.15	1.02	0.67	1.00	
Ash Hollow 5-23-4	surface	3.15	1.06	0.46	2.85	3.15	0.98	0.21	0.86	2.98	2.50	
Gregory City 5-23-5	surface	3.17	1.00	0.58	2.73	3.10	0.89	0.16	0.86	2.98	2.50	
Gregory City 5-23-6	surface	3.32	0.92	0.30	2.92	2.97	0.85	0.87	0.94	2.33	3.75	

Appendix D – continued

Sample name and number	Sample depth (in feet)		Statistical parameters based on method of moments: Mean (ϕ)	Standard deviation (ϕ)	Skewness	Kurtosis		Statistical parameters based on graphical method: Graphical mean (ϕ)	Graphical standard deviation (ϕ)	Skewness	Kurtosis		Median (ϕ)	First mode (ϕ)	Bimodal character (X)
R20-01-5	27-28		4.51	0.84	-1.51	7.84		4.28	0.40	-0.45	0.78		4.43	pan fraction	
	40-41		4.51	0.84	-1.41	6.49		4.27	0.41	-0.52	0.85		4.45	pan fraction	
	58.5-59.5		4.49	0.74	-0.56	3.87		4.23	0.42	-0.48	0.73		4.38	pan fraction	
	67-68		4.69	0.67	-0.94	4.81		4.35	0.35	-0.68	0.92		4.52	pan fraction	
	75-76		3.84	1.55	-0.88	2.63		3.49	1.29	-0.71	1.12		4.15	pan fraction	X
	88-89		3.23	1.11	0.59	2.51		3.22	0.97	0.33	0.71		2.92	2.50	X
	composite		4.17	1.13	-0.96	3.58		3.97	0.78	-0.58	1.18		4.22	pan fraction	X
Hurley 5-22-5	surface		-0.73	2.15	-0.17	2.18		-0.67	2.40	-0.25	0.98		-0.40	-2.00	X
Missouri 5-21-1	surface		2.68	0.98	0.68	3.10		2.63	0.91	0.28	0.83		2.48	2.00	X
Spencer quarry 5-10-1	surface		2.34	0.89	0.38	4.13		2.35	0.82	0.04	1.03		2.30	2.50	