Total Ore Processing Integration and Management

3rd Quarterly Technical Progress Report
01 January - 31 March 2004

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Abstract

This report outlines the technical progress achieved for project DE-FC26-03NT41785 (Total Ore Processing Integration and Management) during the period 01 January through 31 March of 2004.

Table of Contents

List of Graphical Materials

Executive Summary

Work in Progress: Data Mining and Analysis, Minntac Mine

Several approaches are being evaluated for efficient description of the ore grindability at Minntac Mine. Hibtac Mine uses a process that is fundamentally similar, but differs in details of its execution. The grindability data has been fit with a straight line ($Y = mX + b$) which, though simple to calculate, does not completely reflect the curve visible in the data points. Yet it is apparent that the exponential mathematical function does not completely describe the physical processes at work, either. The silica liberation data, however, is fairly well approximated by an exponential curve with asymptote fixed at zero. The goal is to produce a predictive tool that is easy to use and communicate between mine and mill.

Work in Progress: Data Mining, Hibtac Mine

Data mining is at an earlier stage for the Hibtac Mine; consequently, the extent of the pre-study data is still being determined.

Work in Progress: Ore Segregation Tests

Basic hypothesis testing has been partially completed for the second ore segregation test performed at Minntac Mine. The procedure followed is described in Quarterly Technical Progress Report #2.

Work in Progress: Orebody Models

The assay, grindability, and liberation data from the exploration cores at Minntac Mine have been composited into ore blocks that correspond to the average size of the working benches. These composited values were plotted in histograms and cumulative curves to enhance visual evaluation of their distinguishing characteristics. Note that the HIS (high silica) and IBC (interbedded chert) designations together correspond to the Lower Slate layer. These designations reflect qualitative differences in crushing and grinding performance observed by U.S. Steel personnel.

Work in Progress: Correlation between Minntac Mine and Hibtac Mine

The two mines operate in the same geological formations, but over the years they have developed different approaches to characterizing the layers.

Future Work: Data Mining

Previously collected data at both Hibtac and Minntac Mines will continue to be explored and analyzed, supplemented by discussions with mine and laboratory personnel.

Future Work: Orebody Models

The Minntac Mine model will continue to be refined and compared to measured data. A model of the Hibtac Mine will be started sometime during the next two quarters.

Future Work: Ore Segregation Tests

More sophisticated statistical analysis is planned for the data produced during both ore segregation tests at Minntac Mine.

Introduction

This third quarterly report discusses the activities of the project team during the period 1 January through 31 March 2004.

Work in Progress

Data Mining and Analysis, Minntac Mine

The results of previous research conducted by Coleraine Research Laboratories were obtained, courtesy of Coleraine and Pete Niles. This includes data of many different types. In-depth study of this document is underway.

Several approaches are being evaluated for efficient description of the grindability curve as it is currently determined at Minntac Mine. Hibtac Mine uses a process that is fundamentally similar, but differs in details of its execution.

In the Mesabi Range, the magnetic iron is contained within magnetite, which occurs in taconite as granules that average less than 0.1 mm in diameter. Even when they clump to form larger grains, the actual mineral crystals remain much smaller than the clump size. Therefore, the required particle size for effective separation of ore from waste is extremely fine; Minntac Mine uses the coarsest grind (85% passing 270 mesh, or 53 microns max. size), while Hibtac Mine grinds to 80% passing 325 mesh (44 microns). Both mines follow this energy-intensive step with several stages of magnetic separation. Minntac Mine then applies hydrometallurgical (flotation) techniques to remove much of the silica that remains in the concentrate.

The grindability data in this example has been fit with a straight line ($Y = mX + b$) which, though simple to calculate, does not completely reflect the curve visible in the data points. An exponential curve can be used instead ($Y = Y_0 - Ce^{-kX}$), where Y is the silica within the material produced by grinding to time X; Y_0 is the curve's asymptote. Yet the results are not satisfying. As shown in Figure 1, forcing the asymptote to $Y = 100\%$, its correct physical value, results in curves noticeably less well-matched to the data points than letting the asymptote be fitted directly to the data with no constraints on its value. This latter approach yields curves that look more appropriate, but it gives unreasonably high fineness values (above 100% passing 270 mesh) when extrapolated to grinding times longer than actually measured. It is apparent that the exponential mathematical function does not completely describe the physical processes at work.

The silica liberation data, however, is fairly well approximated in this example (Figure 2) by an exponential curve. The asymptote constant Y_0 is fixed at zero in this case.

Figure 3 illustrates one approach to combining grindability and silica liberation data, using a linear predictor for grindability and an exponential predictor for silica liberation. The success of the magnetic separation and flotation stages of processing depends on accurate characterization of the energy required to grind the ore to the necessary fineness, as well as its relationships to liberation of silica and magnetic iron. The goal is to produce a tool that is easy to use and communicate between mine and mill.

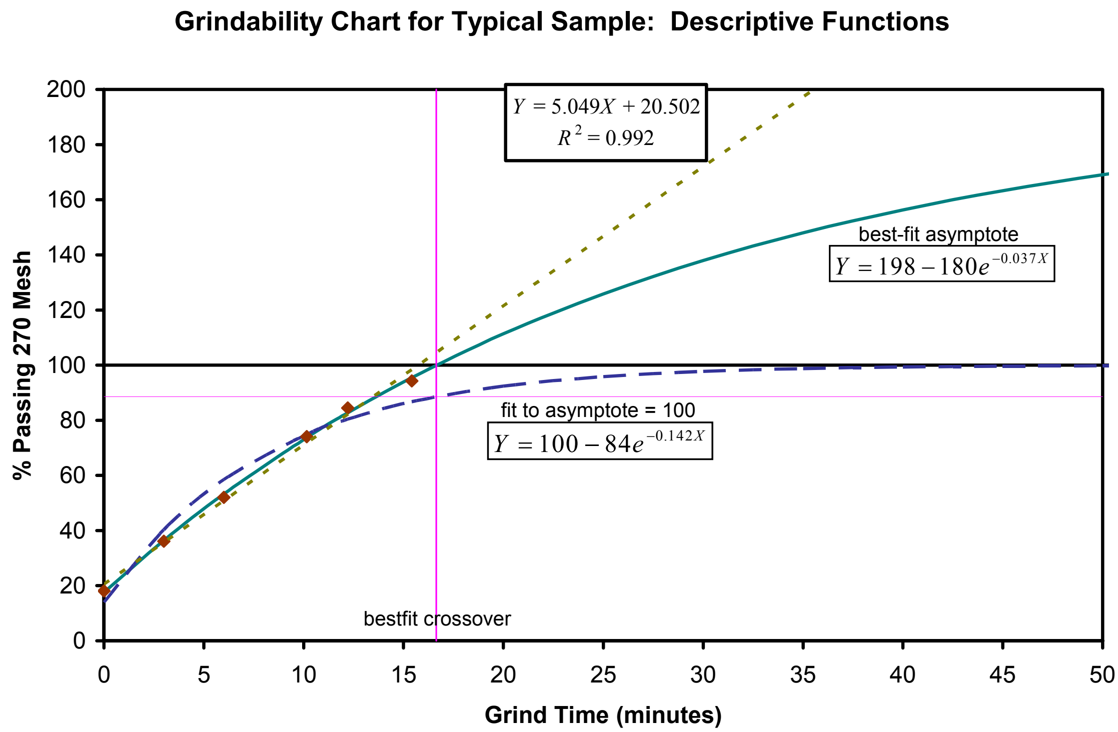


Figure 1. Some approaches to characterizing grindability data.

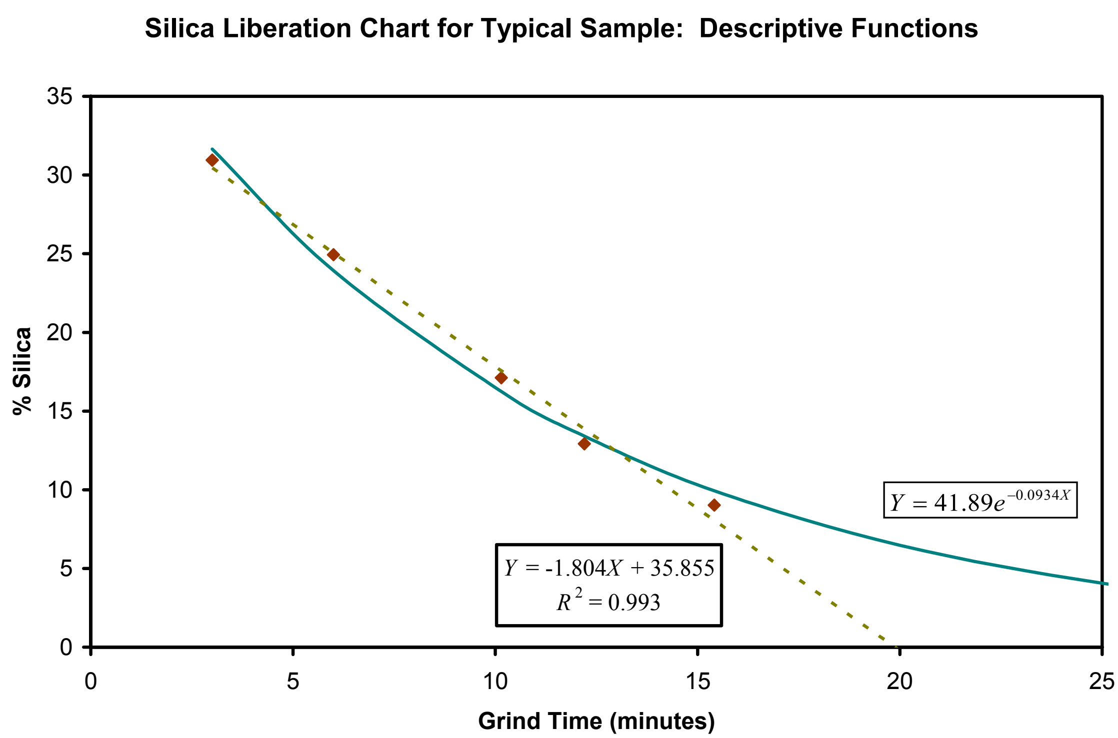


Figure 2. Some approaches to characterizing silica liberation data.

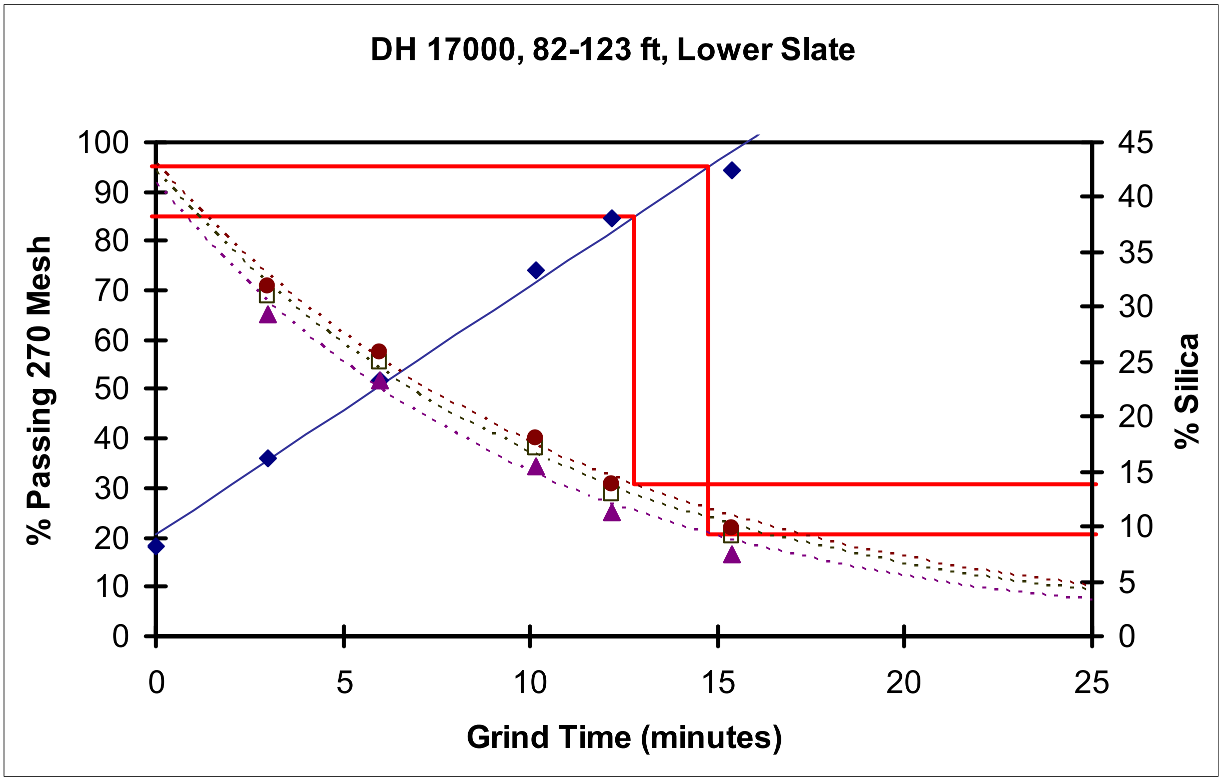


Figure 3. One method of combining grindability and silica liberation. The dashed lines are exponential predictors for silica liberation (measured separately for three sub-intervals). The solid blue line predicts the grindability, measured once for the full interval. The thick red lines indicate the amount of silica available at the standard particle fineness values of 85% and 95%, from which A-factor is calculated.

It should be remembered that not all grindability and liberation data follow these patterns, and so may not be well-fit by these types of curves. Qualitative review of the available data shows several other patterns that will be addressed during the next quarter.

Data Mining, Hibtac Mine

Data mining is at an earlier stage for the Hibtac Mine; consequently, the extent of the pre-study data is still being determined. Figure 4 illustrates a preliminary graphical analysis of six months of muck size distribution data, compared with a liberation index calculated in terms of expected grinding mill power draw. This is the functional equivalent to the A-factor calculated by Minntac Mine.

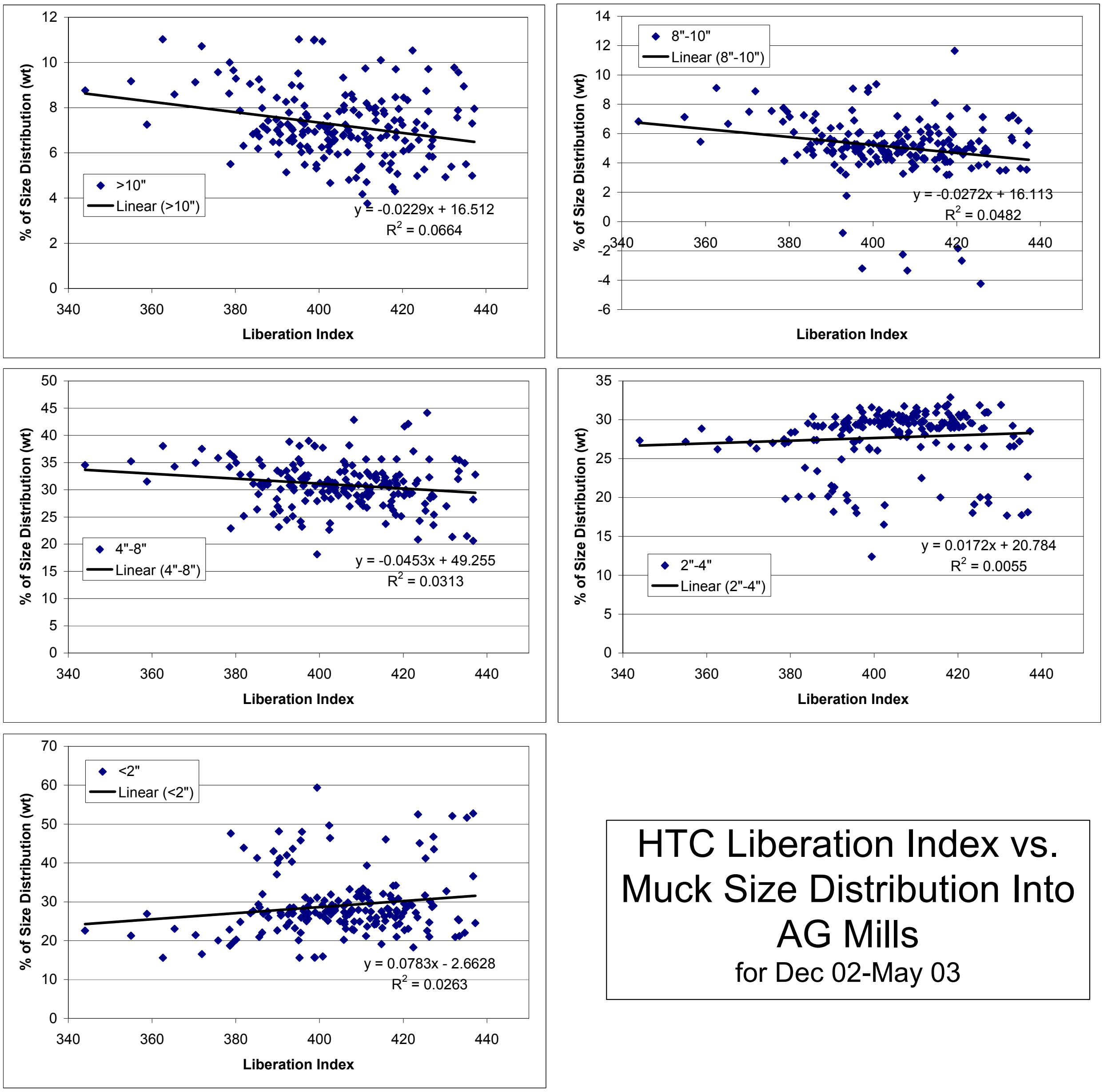


Figure 4.

Ore Segregation Tests

Basic hypothesis testing has been partially completed for the second ore segregation test performed at Minntac Mine. The procedure followed is described in Quarterly Technical Progress Report #2. Partial results from test #2, focused on the front end of the iron milling process, are shown in Table 1.

As was seen during test #1, the high- and low-A factor lines showed different levels of silica, calcium oxide, and alumina. This time there were also differences in levels of magnesium and manganese. Again, it must be noted that the reported instrument errors were and extremely high for alumina readings, due possibly in the latter case to the levels measured being nearly below the detection limit of the inductively coupled plasma (ICP) equipment.

Table 1. Some data comparisons between the low-A factor and the high-A factor ore processing lines before, during, and after the Minntac Mine ore segregation test #2, at 90% confidence level.

STATISTICALLY SIGNIFICANT DIFFERENCES (space)	Crushers 1&2 ≠ Crushers 3&4		Rod Mill 2 ≠ Rod Mill 3					Float Feed FLF ≠ Fload Feed FLD				
	crush - idle	W+E	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before Test								X	X	X	X	X
During Test			X		X	X	X	X	X	X	X	X
After Test								X	X	X	X	X

STATISTICALLY SIGNIF DIFFERENCES (time)	Primary Crushers				Rod Mill #2 Feed (R2S)				
	1&2 crush - idle	1&2 W+E	3&4 crush - idle	3&4 W+E	Al	Ca	Mg	Mn	SiO_2
Before ≠ During	X	X		X	X		X	X	X
Before ≠ After					X	X	X		
During ≠ After	X	X	X		X			X	X

STATISTICALLY SIGNIFICANT DIFFERENCES (time)	Rod Mill #3 Feed (R3S)					Float Feed (FLF)				
	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before ≠ During	X				X		X	X	X	X
Before ≠ After		X	X		X	X	X	X		X
During ≠ After	X		X		X	X		X	X	

STATISTICALLY SIGNIFICANT DIFFERENCES (time)	Float Feed (FFD)					Float Concentrate (FC3)					Float Tails (FLT)				
	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before ≠ During		X	X	X	X		X	X	X		X	X	X	X	
Before ≠ After	X	X	X		X	X	X	X			X	X	X	X	
During ≠ After	X			X		X			X	X	X				X

The power draw to the primary crushers for the two lines was not significantly different before, during, or after this test, even though their performance did change during the test; apparently both crushers reacted similarly (less grinding energy required) even though their feedstock was different. Overall, the results to date for test #2 are less clear-cut than for test #1. More advanced analysis techniques planned for the next quarter may shed some light on this.

Orebody Models

The assay, grindability, and liberation data from the exploration cores at Minntac Mine have been composited into ore blocks that correspond to the average size of the working benches. These composited values were plotted in histograms and cumulative curves to enhance visual evaluation of their distinguishing characteristics (Appendix: Charts). Note that the HIS (high silica) and IBC (interbedded chert) designations together correspond to the Lower Slate layer. These designations reflect qualitative differences in crushing and grinding performance observed by U.S. Steel personnel.

Correlation between Minntac Mine and Hibtac Mine

The two mines operate in the same geological formations, but over the years they have developed different approaches to characterizing the layers. This is due partly to the fact that Minntac mines the Lower Slate as well as the Lower Chert, floating off excess silica after concentration by magnetic separation, while Hibtac works entirely within the Lower Chert, relying entirely on the results of magnetic separation.

Future Work

Data Mining

Previously collected data at both Hibtac and Minntac Mines will continue to be explored and analyzed, supplemented by discussions with mine and laboratory personnel. This includes data collected during operation of blasthole drills at both mines.

Hibtac Mine has collected a significant amount of information regarding the distribution of particle sizes in their autogenous (AG) mill feed, since particle size is an important control on AG mill performance. Their liberation index data will be studied, as Minntac's A-factor has been. Hibtac personnel have identified a number of issues to study that they do not have time to pursue. These will be explored in more detail by the project team.

Orebody Models

The Minntac Mine model will continue to be refined and compared to measured data. A model of the Hibtac Mine will be started sometime during the next two quarters.

Ore Segregation Tests

More sophisticated statistical analysis is planned for the data produced during both ore segregation tests at Minntac Mine. The Minntac grindability and liberation curve-fit constants m, b, Y_0 , C, and k will be evaluated for their predictive capability for mill performance, by comparing these constants across formation layers, boreholes, and oxidized regions. They also will be compared to drill monitoring data, where available.

Once the muck imaging system comes online at Hibtac Mine, another ore segregation test based on powder factor will be conducted.

Appendix: Data Summary from Minntac Mine Ore Segregation Test #2

	Secondary Crusher Power				Rod Mill #2 Feed (R2S)					Rod Mill #3 Feed (R3S)				
	1&2	1&2	3&4	3&4	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP
AVERAGES	crush - idle	W+E	crush - idle	W+E	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before Test	335	300	334	289	0.0483	0.298	0.227	0.0867	4.99	0.0517	0.273	0.230	0.0800	5.12
During Test	306	261	310	271	0.0425	0.244	0.171	0.1300	4.12	0.0763	0.223	0.266	0.0950	6.18
After Test	333	284	339	279	0.0567	0.218	0.198	0.0950	4.71	0.0550	0.213	0.187	0.0900	4.58
STD DEVIATIONS														
Before Test	31.7	44.7	18.1	16.7	0.00408	0.0637	0.0163	0.0216	0.558	0.00753	0.0615	0.0228	0.0200	0.310
During Test	24.7	21.4	63.0	28.4	0.00463	0.1070	0.0398	0.0200	0.324	0.00744	0.0537	0.0540	0.0169	0.490
After Test	15.1	28.0	31.8	32.8	0.00516	0.0349	0.0172	0.0207	0.175	0.00837	0.0484	0.0339	0.0200	0.621
90% CONFIDENCE LIMITS														
Before Test	13.9	19.6	7.93	7.32	0.00336	0.0524	0.0134	0.0178	0.459	0.00619	0.0506	0.0188	0.0165	0.255
During Test	9.29	8.06	23.7	10.71	0.00310	0.0717	0.0267	0.0134	0.217	0.00498	0.0359	0.0362	0.0113	0.328
After Test	6.00	11.12	12.6	13.07	0.00425	0.0287	0.0142	0.0171	0.144	0.00688	0.0398	0.0279	0.0165	0.511

	Float Feed (FLF)					Float Feed (FFD)				
	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP
AVERAGES	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before Test	0.0000	0.424	0.309	0.0935	5.60	0.0428	0.277	0.188	0.0678	4.11
During Test	0.0700	0.322	0.265	0.1300	5.40	0.0435	0.212	0.156	0.0900	3.87
After Test	0.0771	0.268	0.240	0.1000	5.35	0.0479	0.181	0.144	0.0705	3.88
STD DEVIATIONS										
Before Test	0.00470	0.0892	0.0242	0.0218	0.163	0.00461	0.0633	0.0198	0.0140	0.199
During Test	0.00690	0.1397	0.0580	0.0193	0.302	0.00487	0.0827	0.0314	0.0135	0.229
After Test	0.00845	0.0532	0.0280	0.0152	0.251	0.00535	0.0375	0.0168	0.0113	0.210
90% CONFIDENCE LIMITS										
Before Test	0.00199	0.0378	0.0103	0.00922	0.0689	0.00189	0.0260	0.00811	0.00572	0.0814
During Test	0.00253	0.0513	0.0213	0.00707	0.1108	0.00174	0.0296	0.01126	0.00483	0.0818
After Test	0.00318	0.0200	0.0105	0.00571	0.0946	0.00213	0.0149	0.00667	0.00449	0.0836

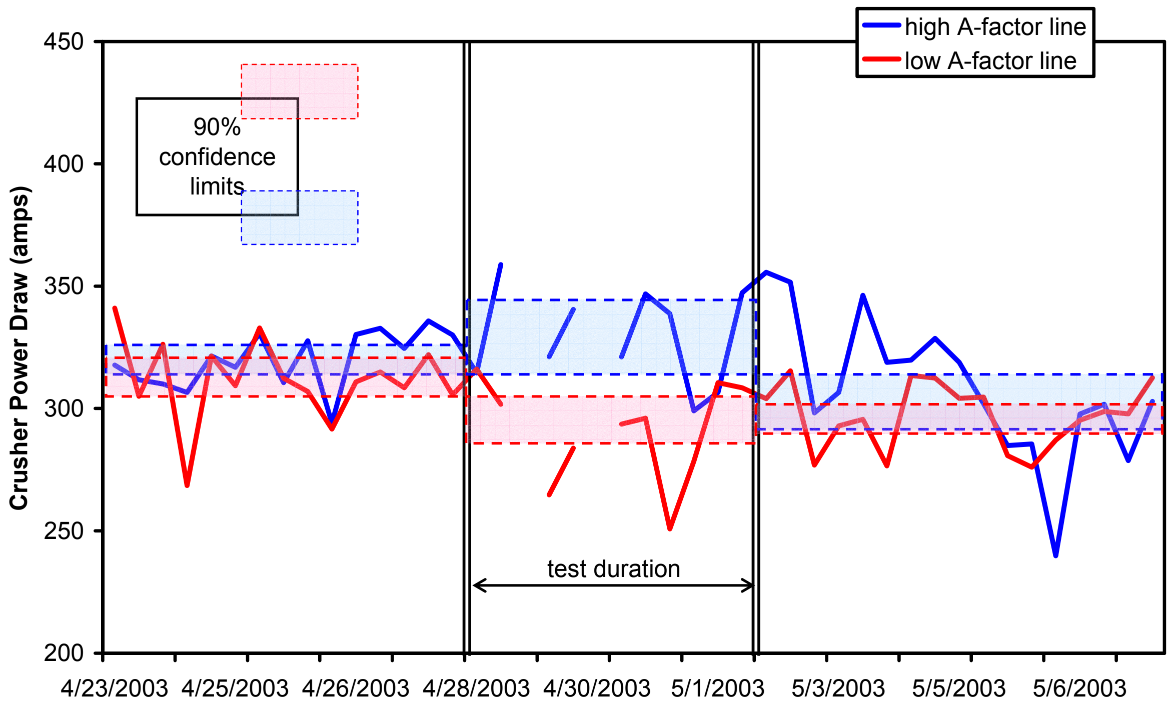
	Float Concentrate (FC3)					Float Tails (FLT)				
	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP	ICP
AVERAGES	Al	Ca	Mg	Mn	SiO_2	Al	Ca	Mg	Mn	SiO_2
Before Test	0.0529	0.376	0.251	0.086	3.94	0.178	1.720	1.068	0.154	22.2
During Test	0.0545	0.276	0.208	0.118	3.83	0.193	0.596	0.744	0.190	20.8
After Test	0.0700	0.239	0.201	0.090	4.00	0.218	0.644	0.743	0.194	24.0
STD DEVIATIONS										
Before Test	0.00588	0.0863	0.0237	0.0180	0.2352	0.0202	1.655	0.449	0.0265	3.58
During Test	0.00596	0.1059	0.0410	0.0180	0.3010	0.0222	0.171	0.151	0.0303	2.45
After Test	0.01049	0.0557	0.0253	0.0143	0.2174	0.0405	0.160	0.153	0.0232	3.60
90% CONFIDENCE LIMITS										
Before Test	0.00249	0.0365	0.0100	0.00764	0.0996	0.00854	0.7008	0.1901	0.0112	1.52
During Test	0.00219	0.0389	0.0150	0.00660	0.1104	0.00836	0.0645	0.0567	0.0114	0.92
After Test	0.00395	0.0210	0.0095	0.00539	0.0818	0.01565	0.0618	0.0590	0.0090	1.39

Terms and abbreviations:

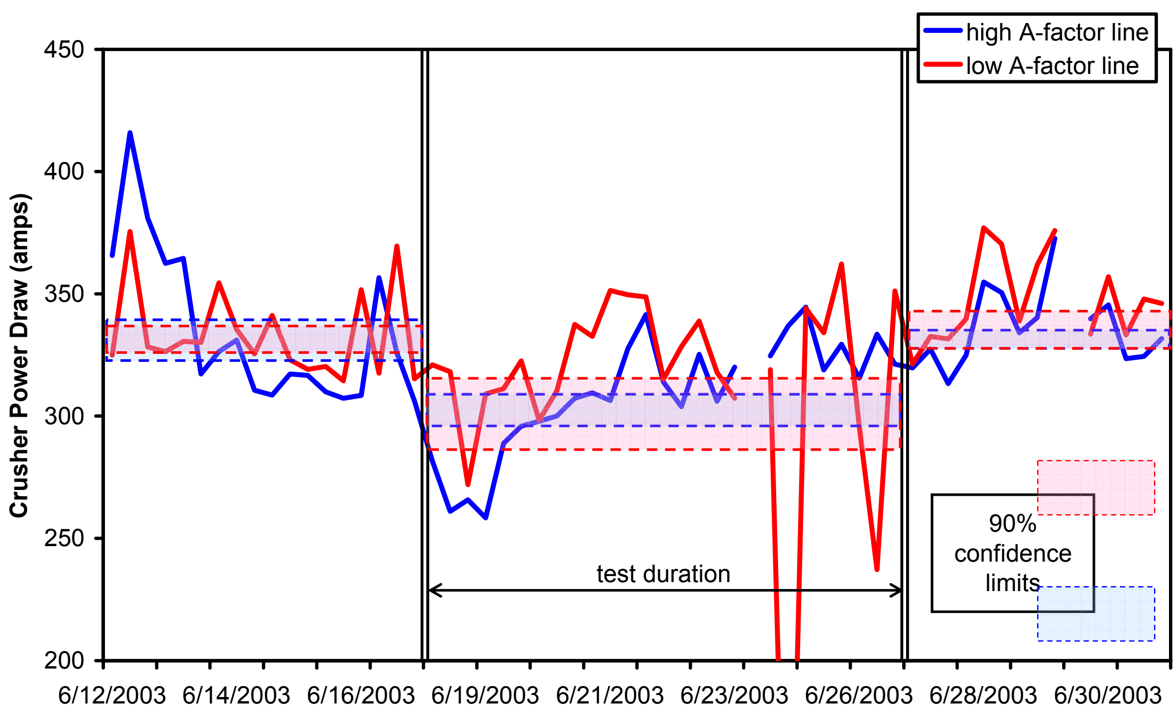
RMF	rod mill feed
Con	concentrate
Crs	coarse
Fne	fine
Mag Fe	magnetic iron
kwh/t	kilowatt-hours/ton
NOLA	nuclear on-line analyzer
FLF & FFD	flotation cell feed
FC3	flotation concentrate (output value)
FLT	flotation tails (output waste)
SiO2	silica
UC	Upper Chert formation
HIS	high-silica portion of UC
IBC	inter-bedded chert portion of UC
L1-2	Lower Slate layers 1 and 2
L3-4	Lower Slate layers 3 and 4
IND TOT	indicated total iron
TLS	tailings
ICP	inductively coupled plasma analysis

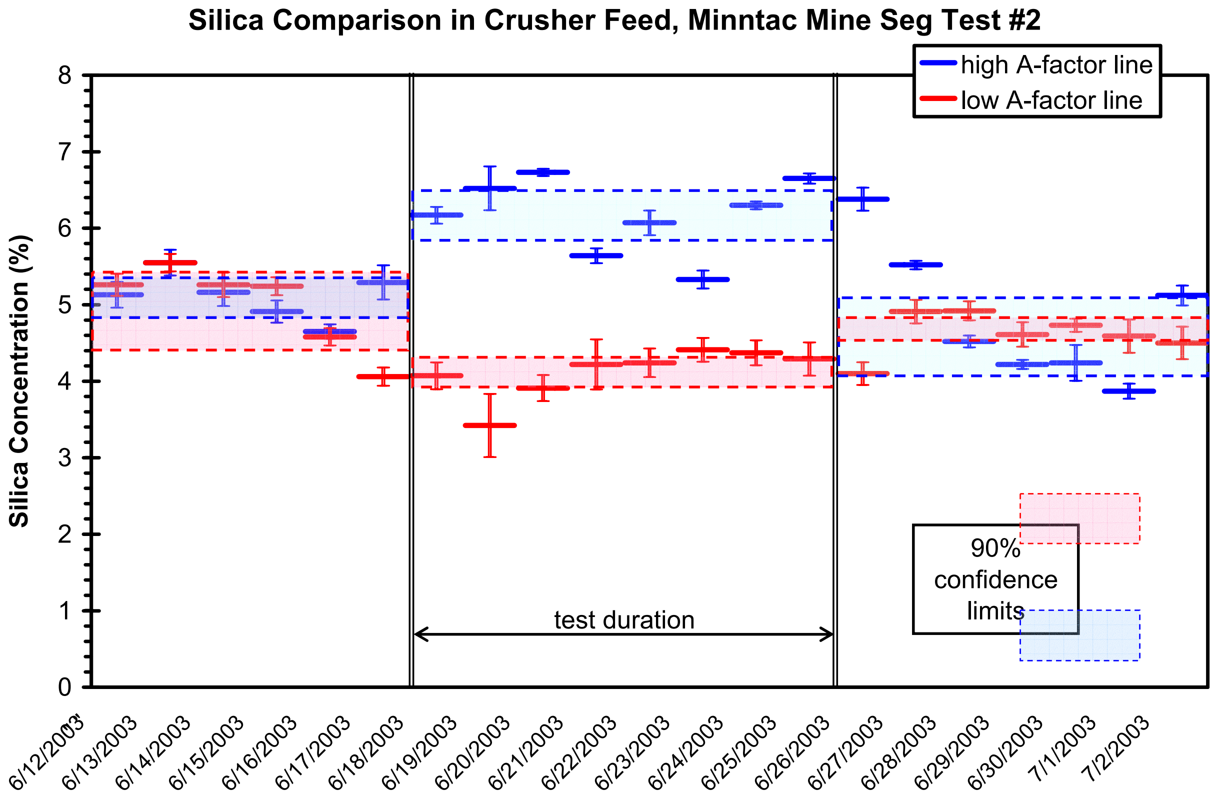
Appendix: Charts from Minntac Mine Ore Segregation Test #2

Crusher Performance During Minntac Mine Segregation Test #1



Crusher Performance During Minntac Mine Segregation Test #2





Silica Comparison in Crusher Feed, Minntac Mine Seg Test #2
high A-factor line
low A-factor line
Silica Concentration (%)
8
7
6
5
4
3
2
1
0
90% confidence limits
test duration
6/12/2003
6/13/2003
6/14/2003
6/15/2003
6/16/2003
6/17/2003
6/18/2003
6/19/2003
6/20/2003
6/21/2003
6/22/2003
6/23/2003
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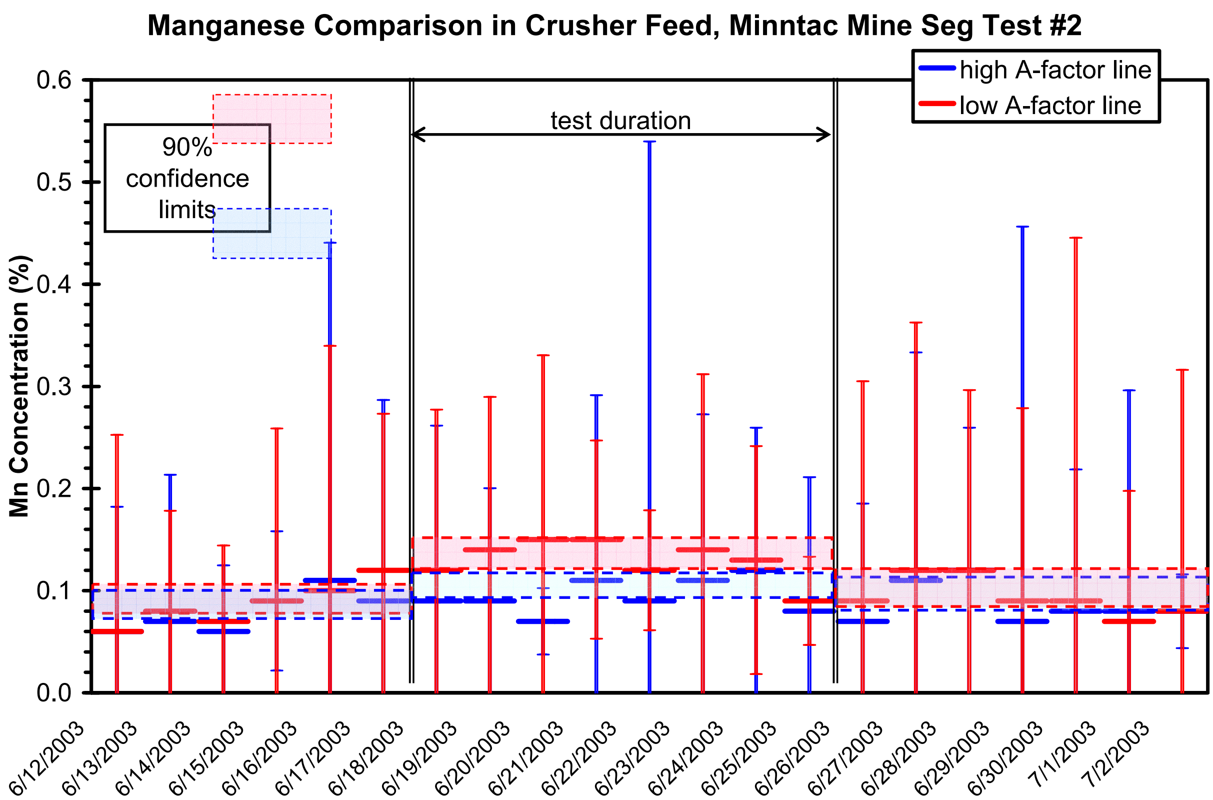
7/1/2003
7/2/2003



Manganese Comparison in Crusher Feed, Minntac Mine Seg Test #2
high A-factor line
low A-factor line
Mn Concentration (%)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
90% confidence limits
test duration
6/12/2003
6/13/2003
6/14/2003
6/15/2003
6/16/2003
6/17/2003
6/18/2003
6/19/2003
6/20/2003
6/21/2003
6/22/2003
6/23/2003
6/24/2003
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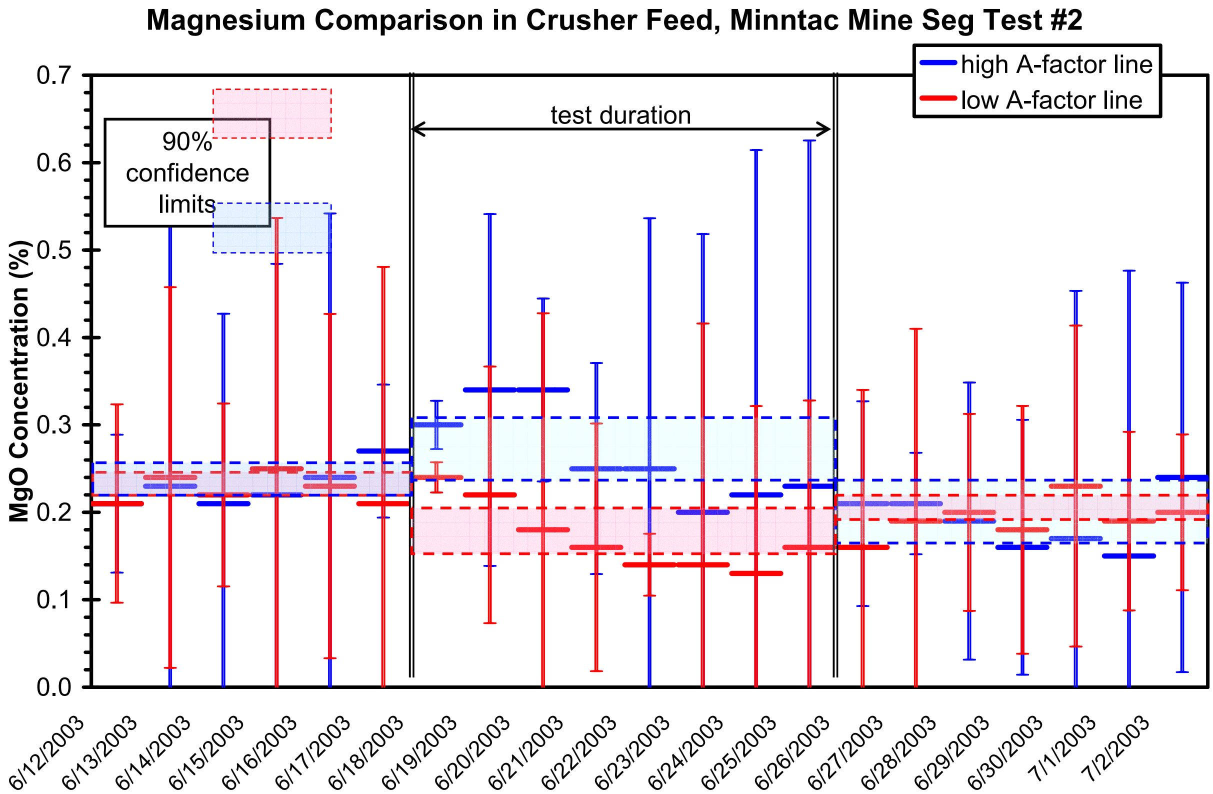
6/30/2003
7/1/2003
7/2/2003



Magnesium Comparison in Crusher Feed, Minntac Mine Seg Test #2
high A-factor line
low A-factor line
test duration
90% confidence limits
MgO Concentration (%)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
6/12/2003
6/13/2003
6/14/2003
6/15/2003
6/16/2003
6/17/2003
6/18/2003
6/19/2003
6/20/2003
6/21/2003
6/22/2003
6/23/2003
6/24/2003
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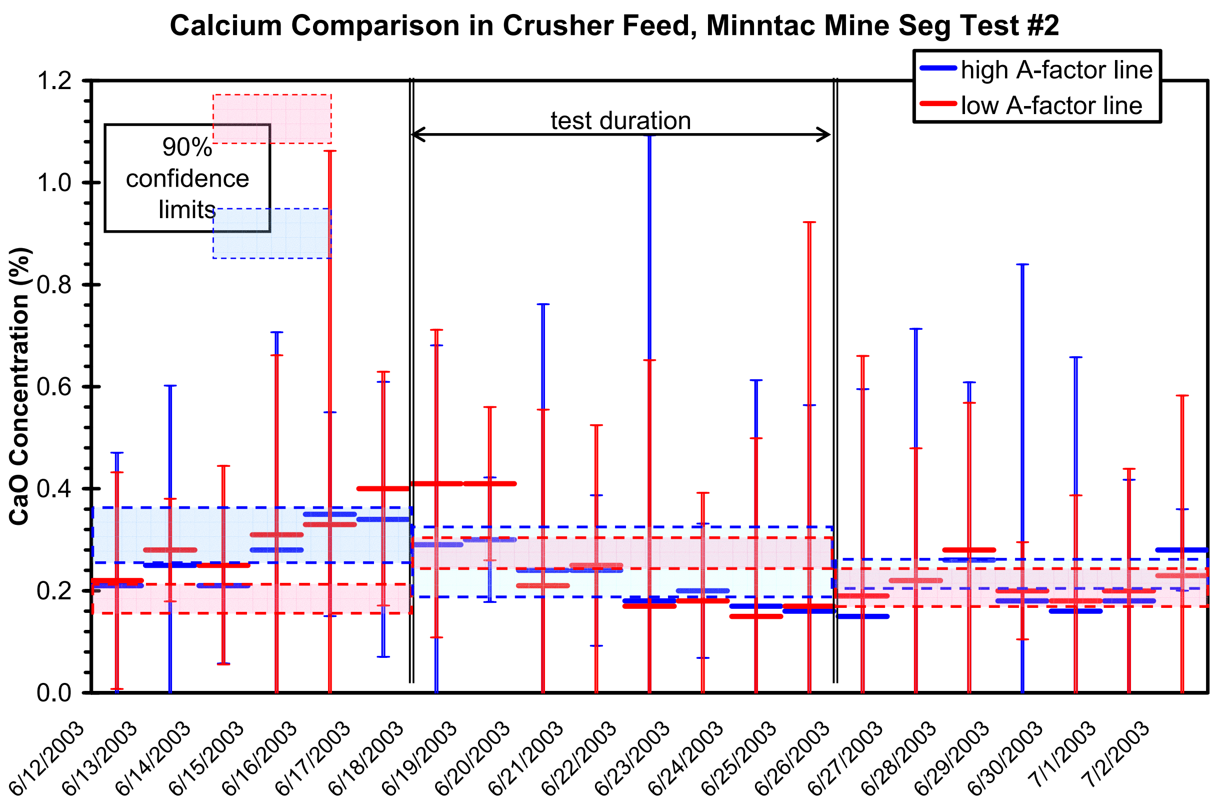
7/1/2003
7/2/2003



Calcium Comparison in Crusher Feed, Minntac Mine Seg Test #2
high A-factor line
low A-factor line
test duration
90% confidence limits
CaO Concentration (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
6/12/2003
6/13/2003
6/14/2003
6/15/2003
6/16/2003
6/17/2003
6/18/2003
6/19/2003
6/20/2003
6/21/2003
6/22/2003
6/23/2003
6/24/2003
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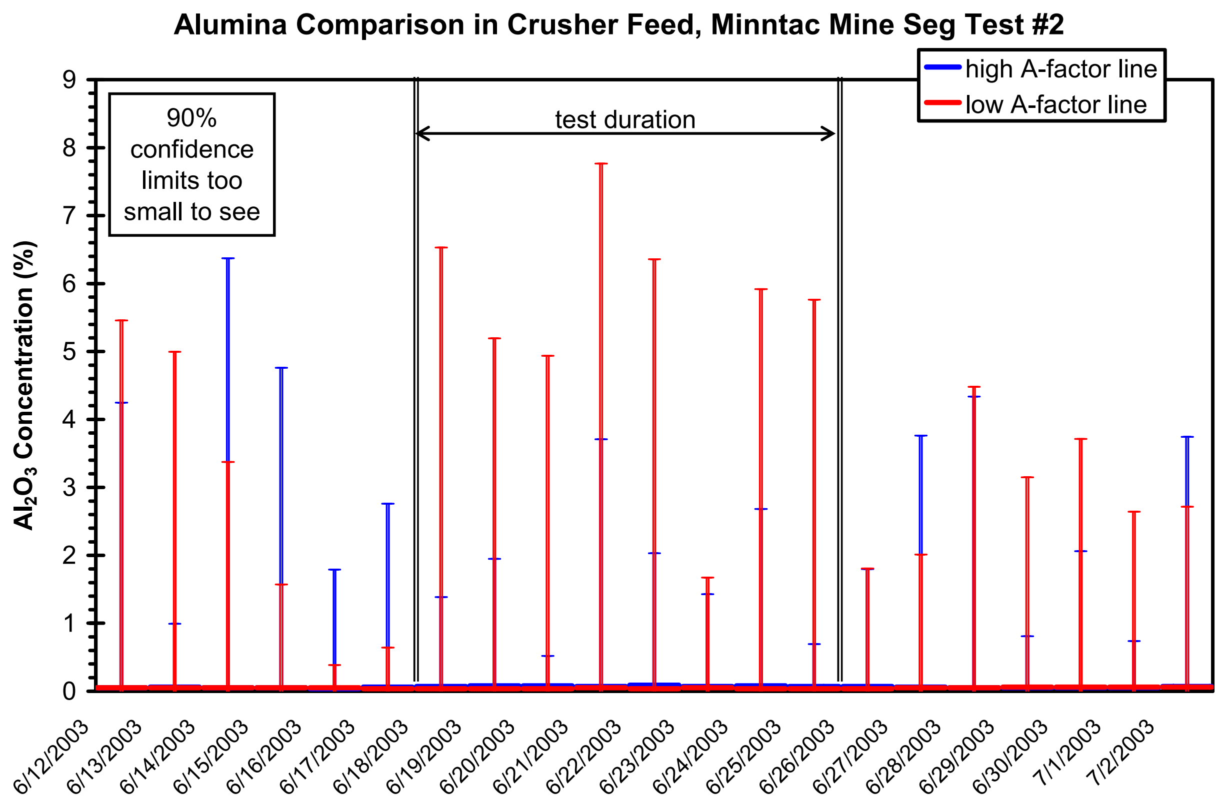
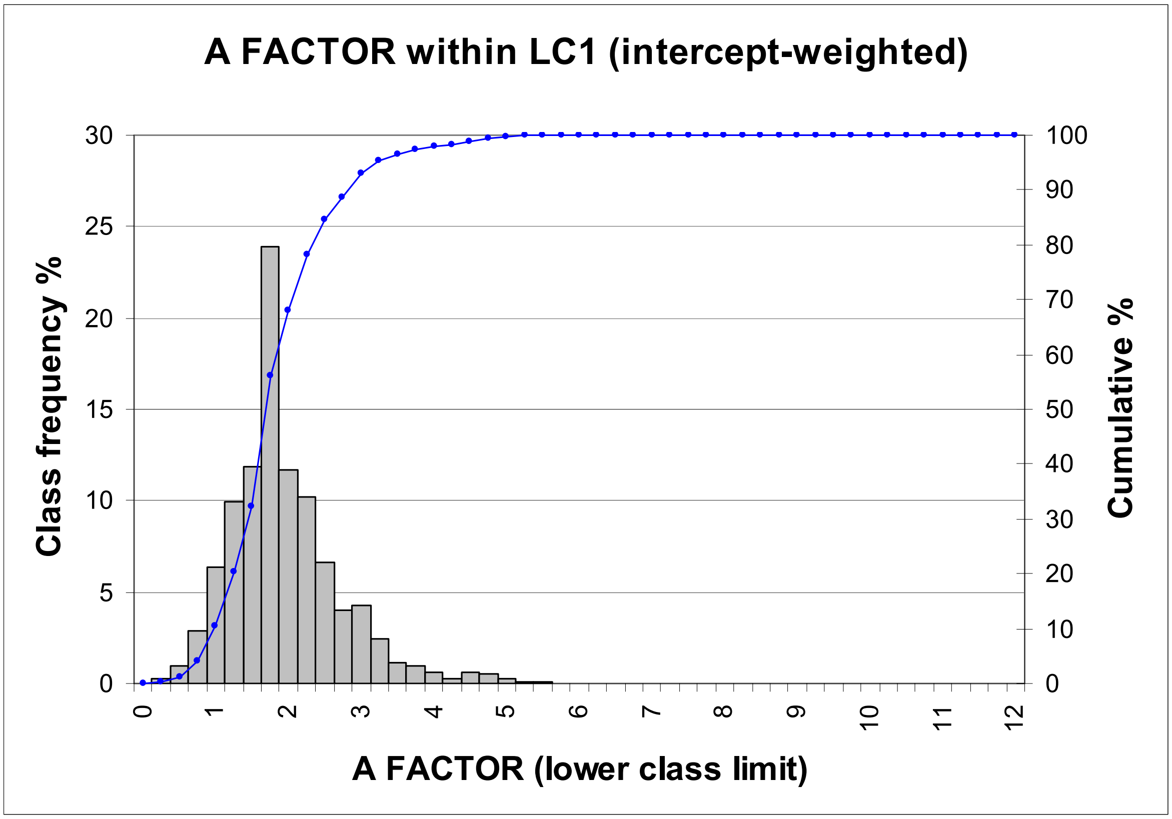
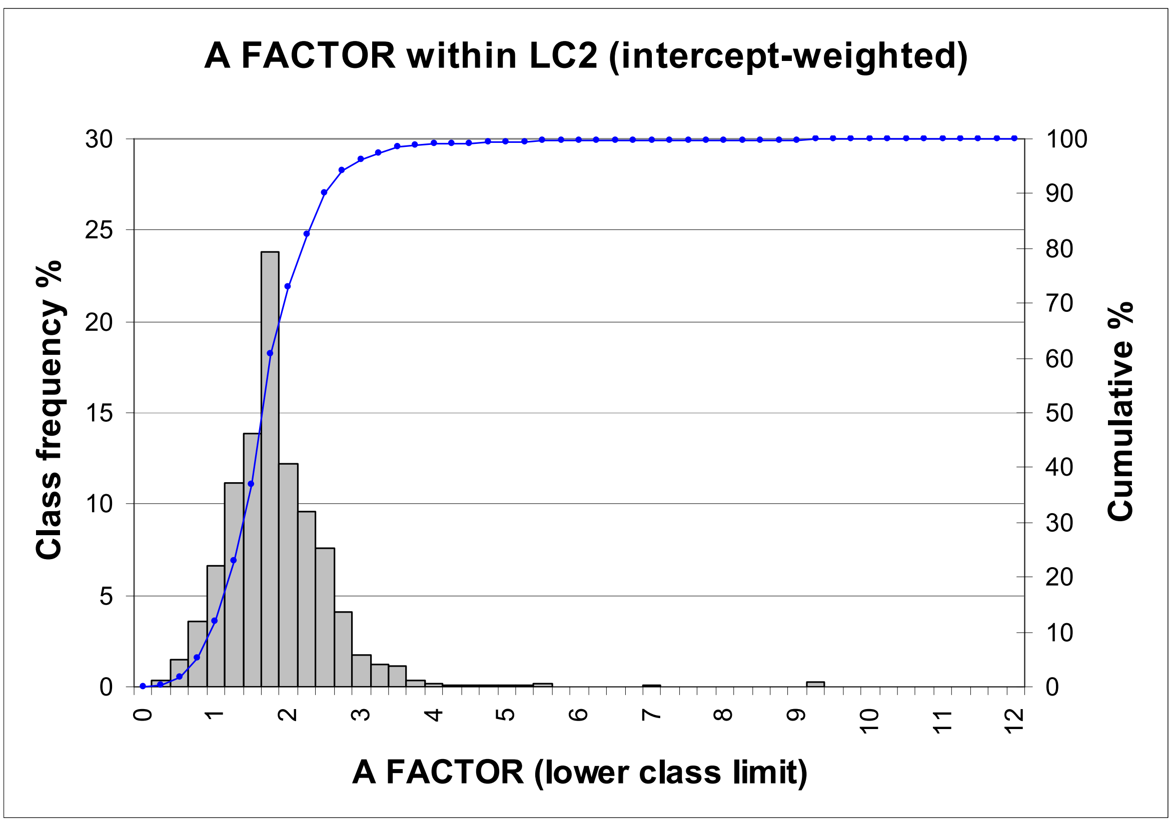
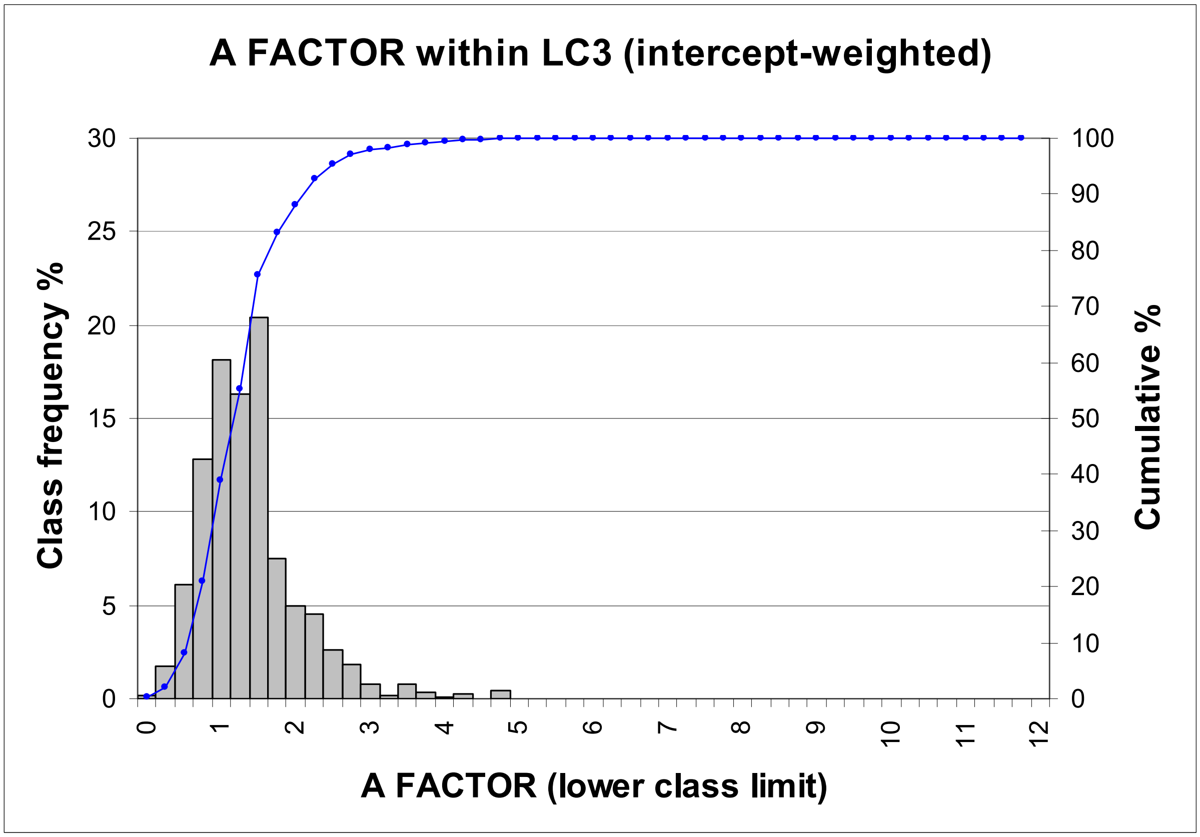
6/30/2003
7/1/2003
7/2/2003

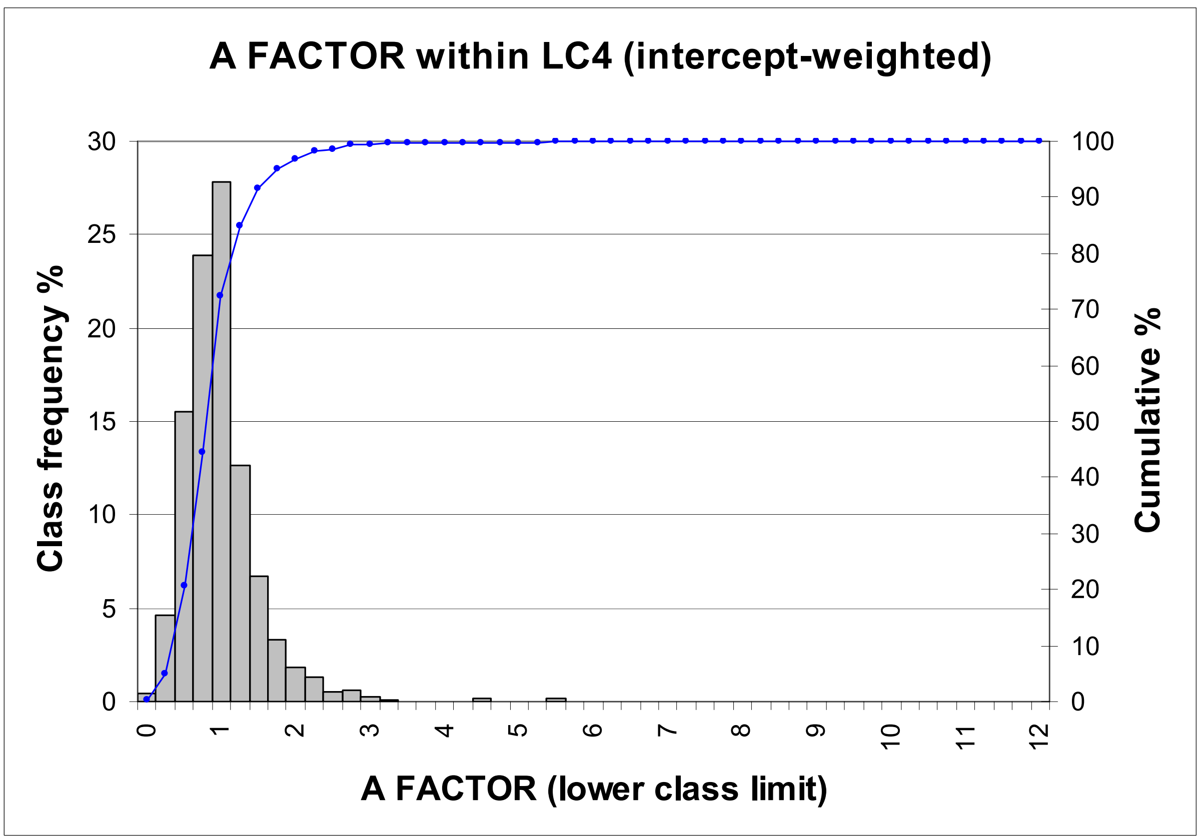

Alumina Comparison in Crusher Feed, Minntac Mine Seg Test #2
high A-factor line
low A-factor line
90% confidence limits too small to see
test duration
Al2O3 Concentration (%)
0
1
2
3
4
5
6
7
8
9
6/12/2003
6/13/2003
6/14/2003
6/15/2003
6/16/2003
6/17/2003
6/18/2003
6/19/2003
6/20/2003
6/21/2003
6/22/2003
6/23/2003
6/24/2003
6/25/2003
6/26/2003
6/27/2003
6/28/2003
6/29/2003
6/30/2003
7/1/2003
7/2/2003

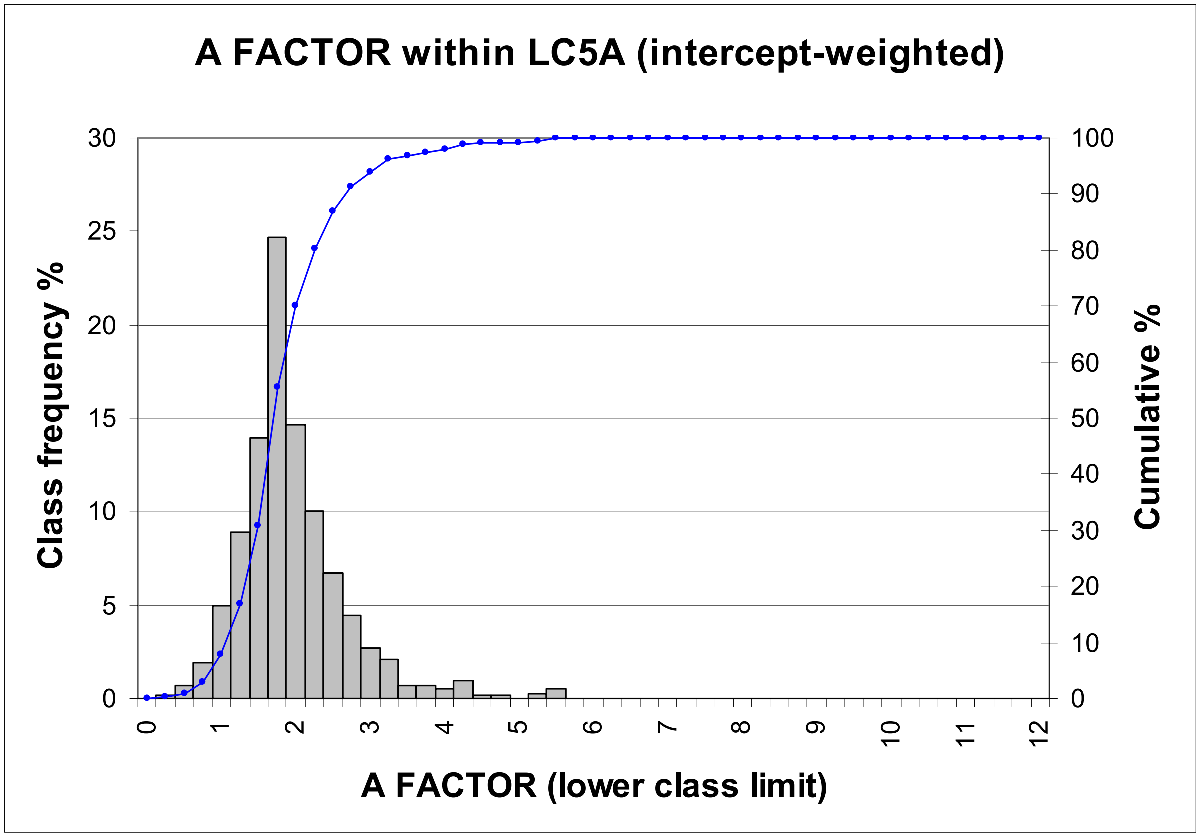
Charts of Ore Grindability, by Layer, from Orebody Model for Minntac Mine

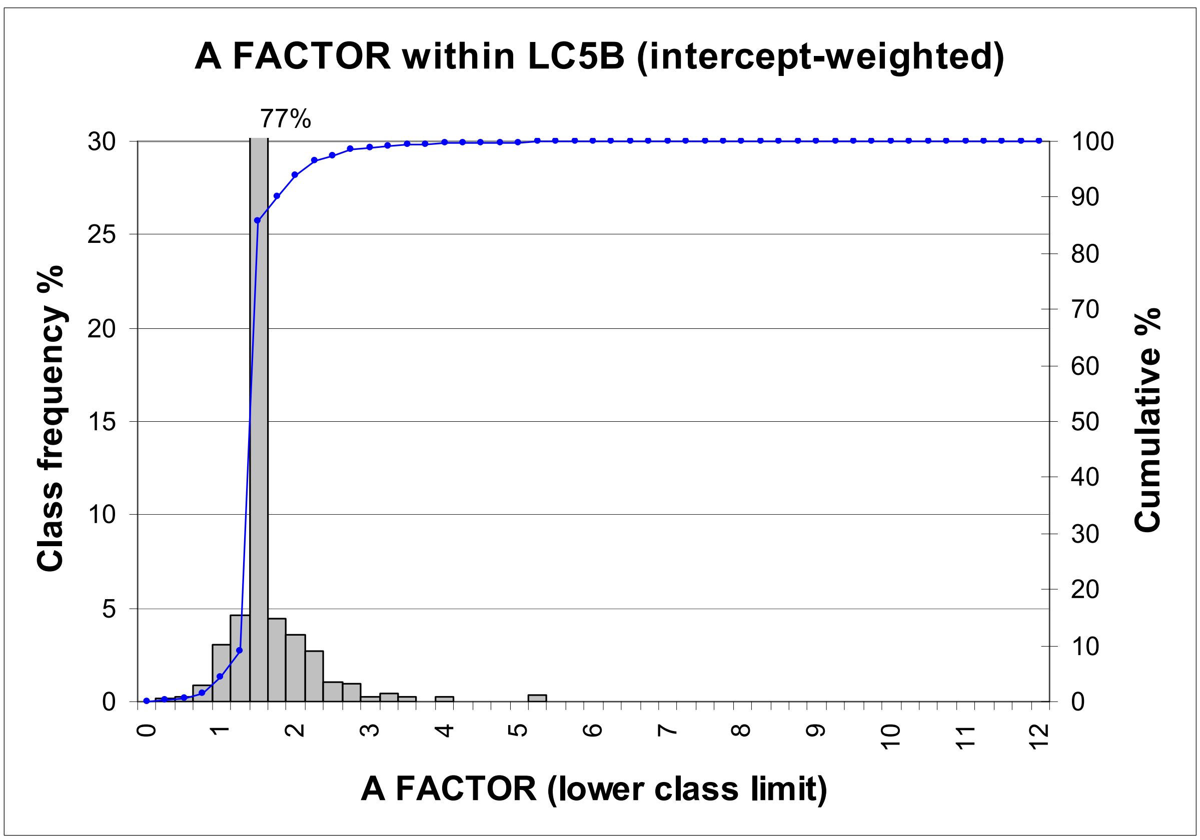


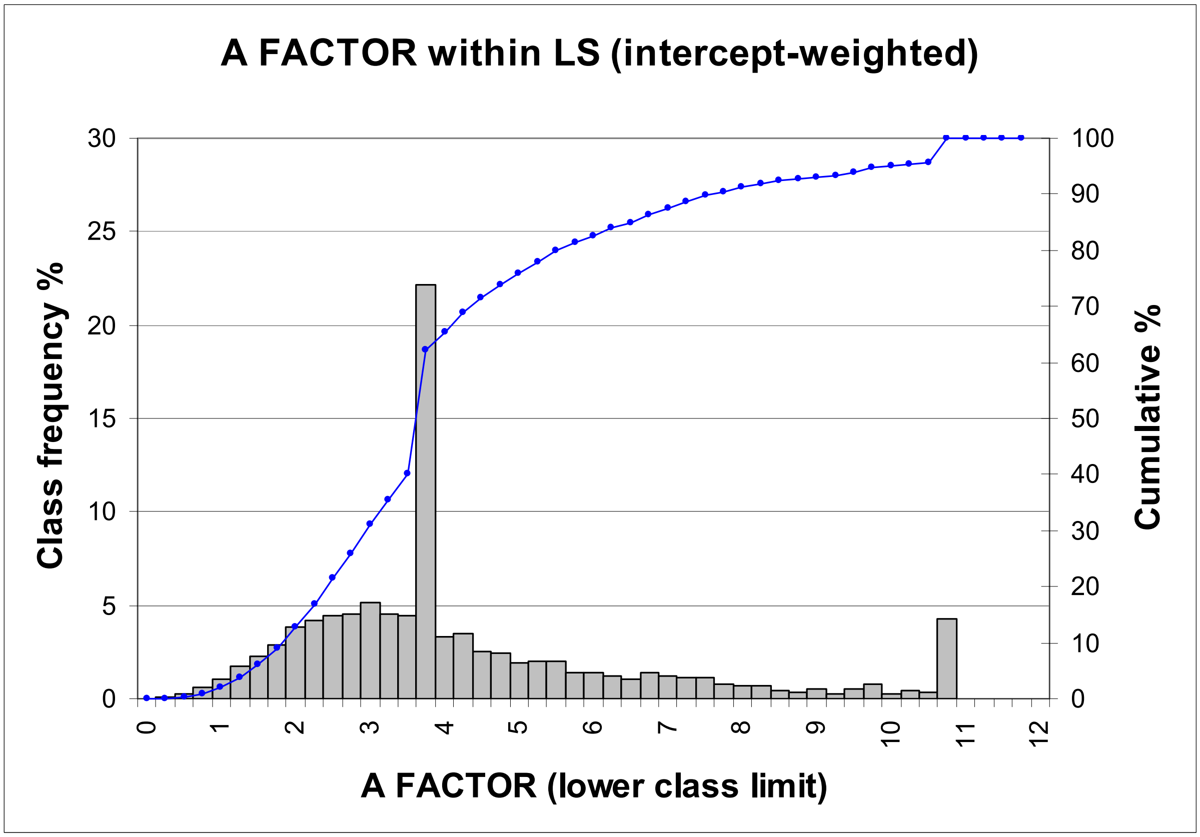


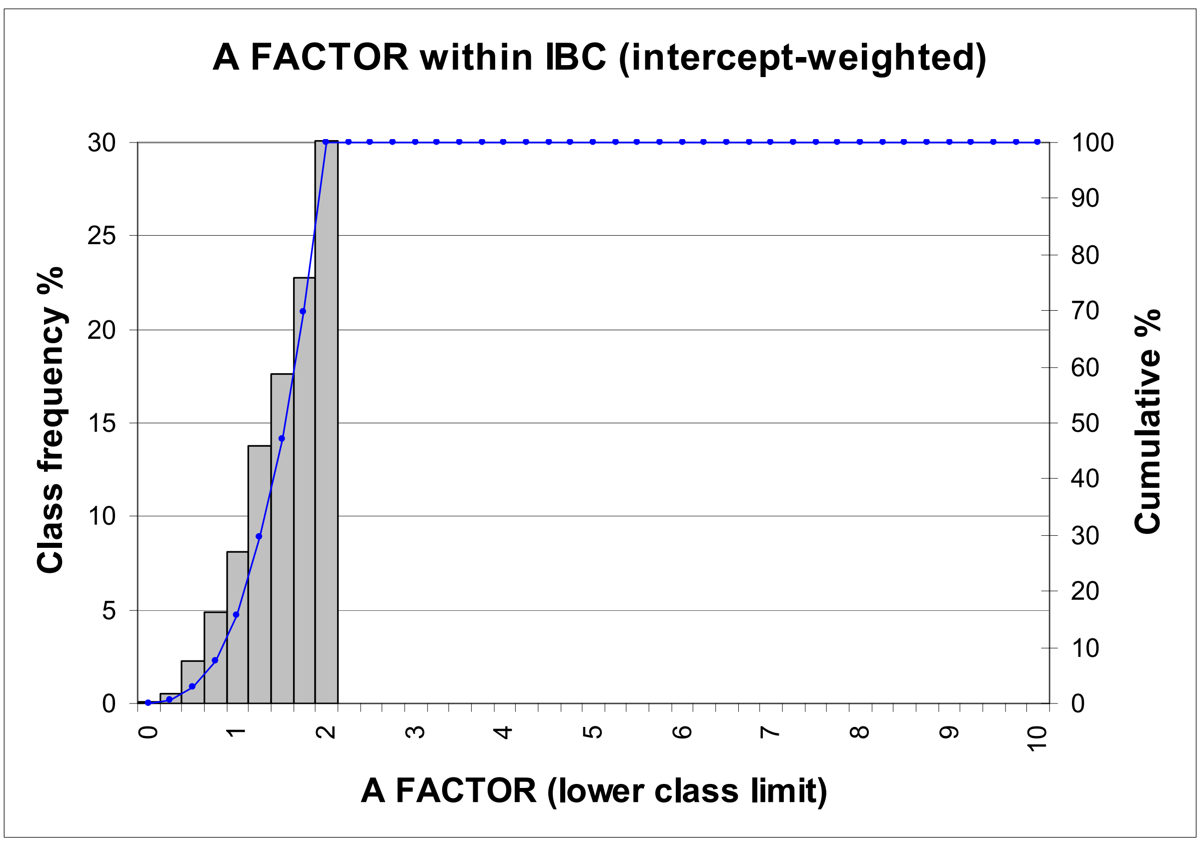

A FACTOR within LC3 (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12

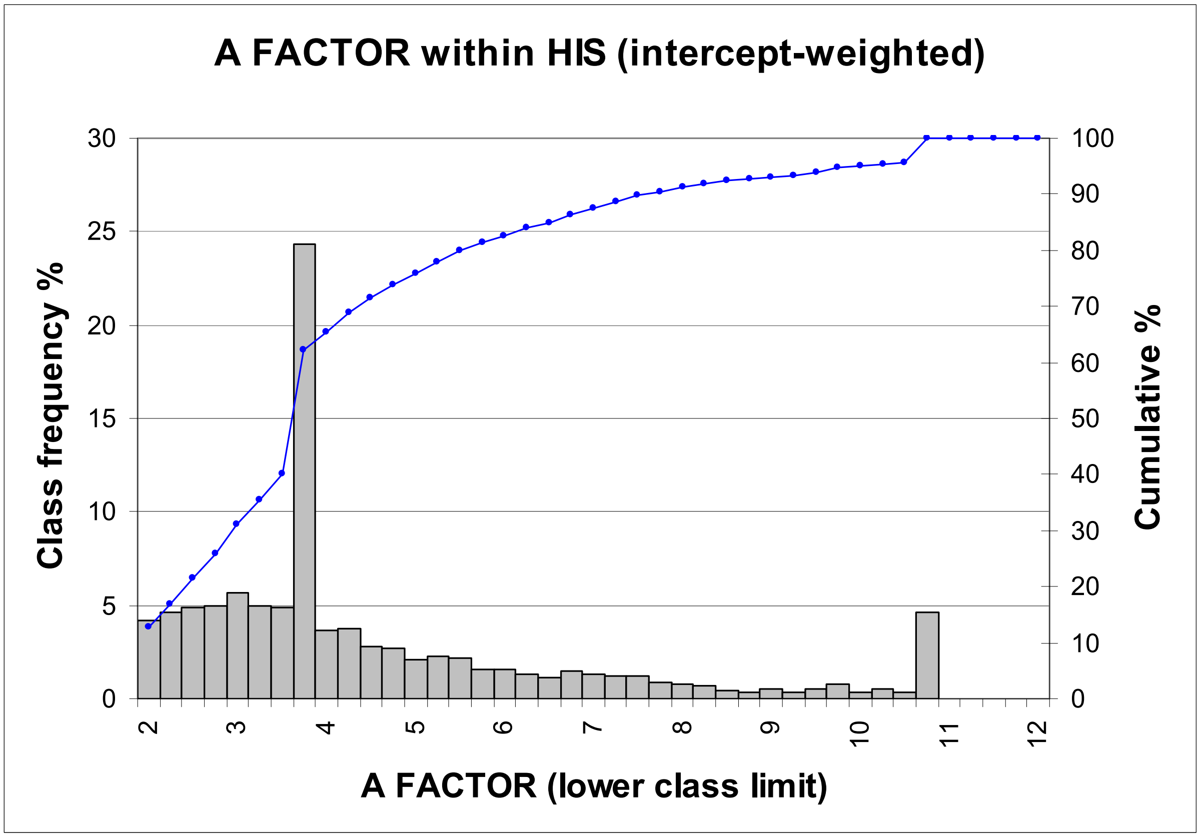

A FACTOR within LC4 (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12

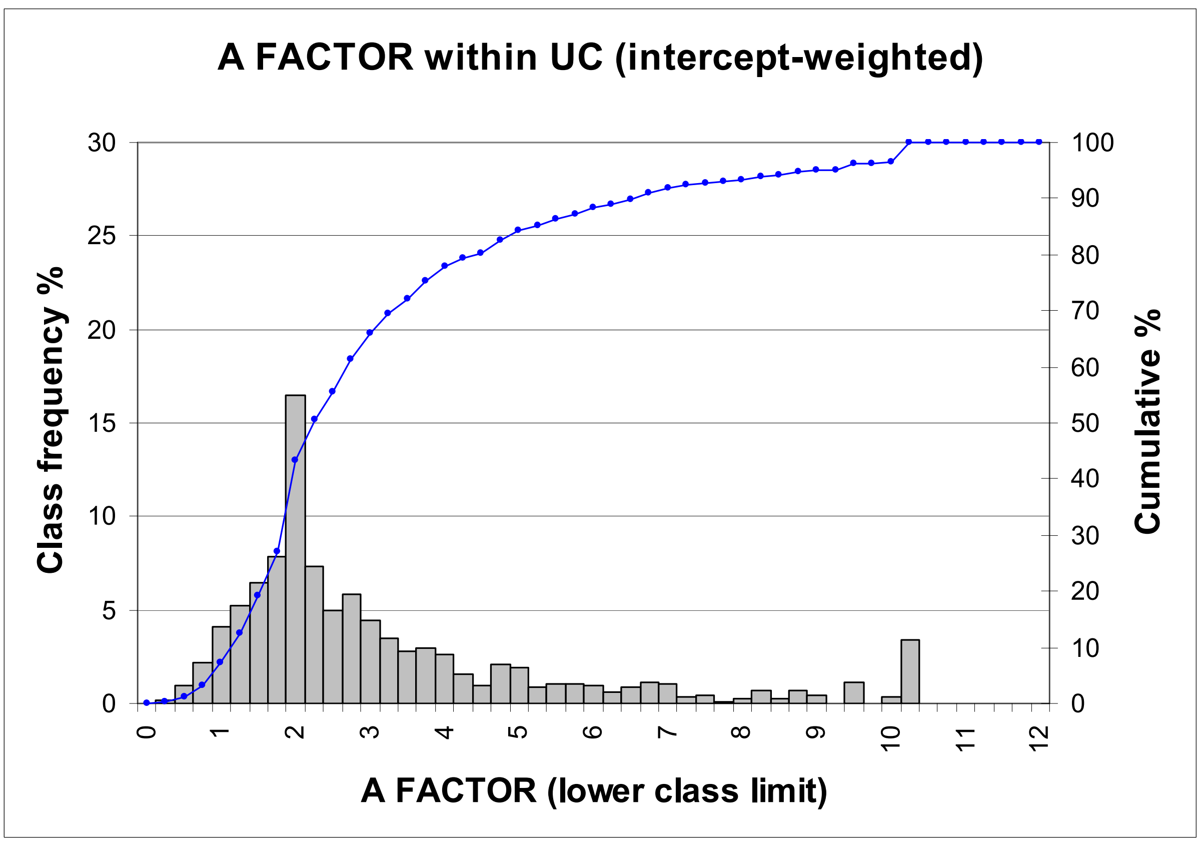

A FACTOR within LC5A (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0 5 10 15 20 25 30
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12


A FACTOR within LC5B (intercept-weighted)
77%
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0 5 10 15 20 25 30
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12

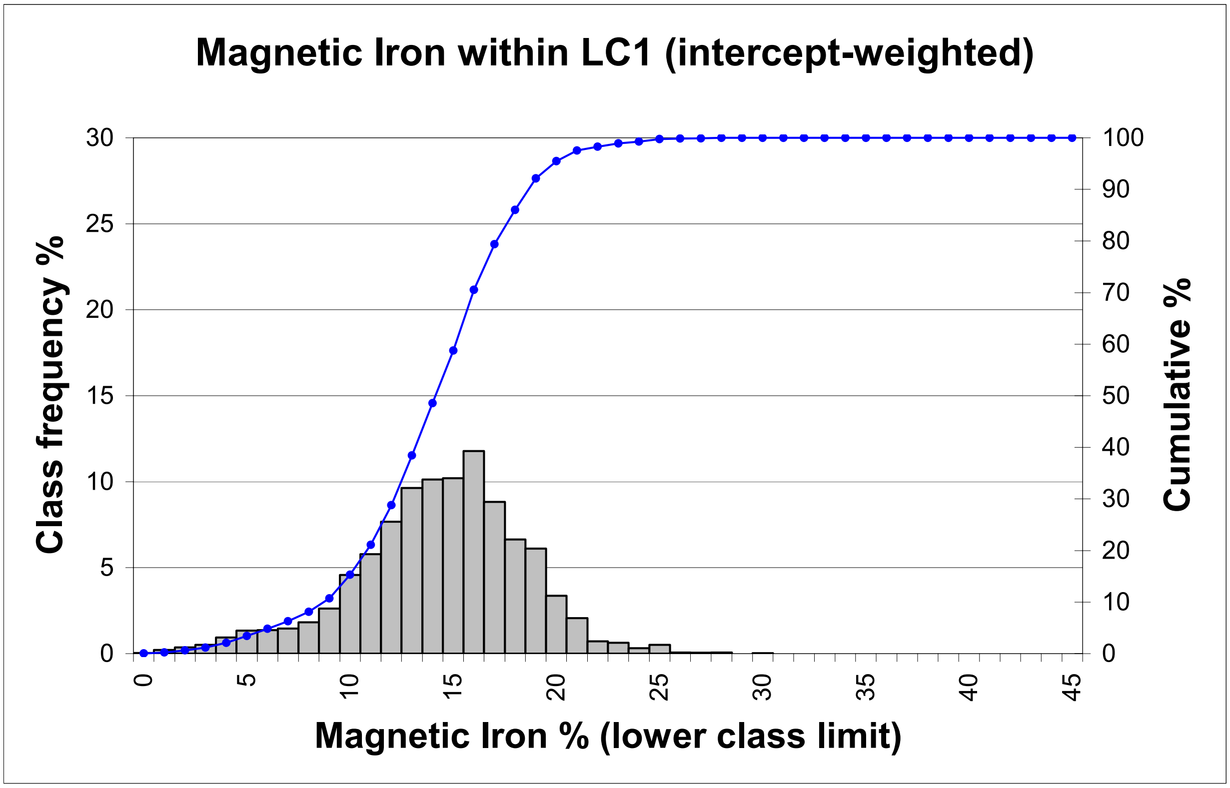

A FACTOR within LS (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12

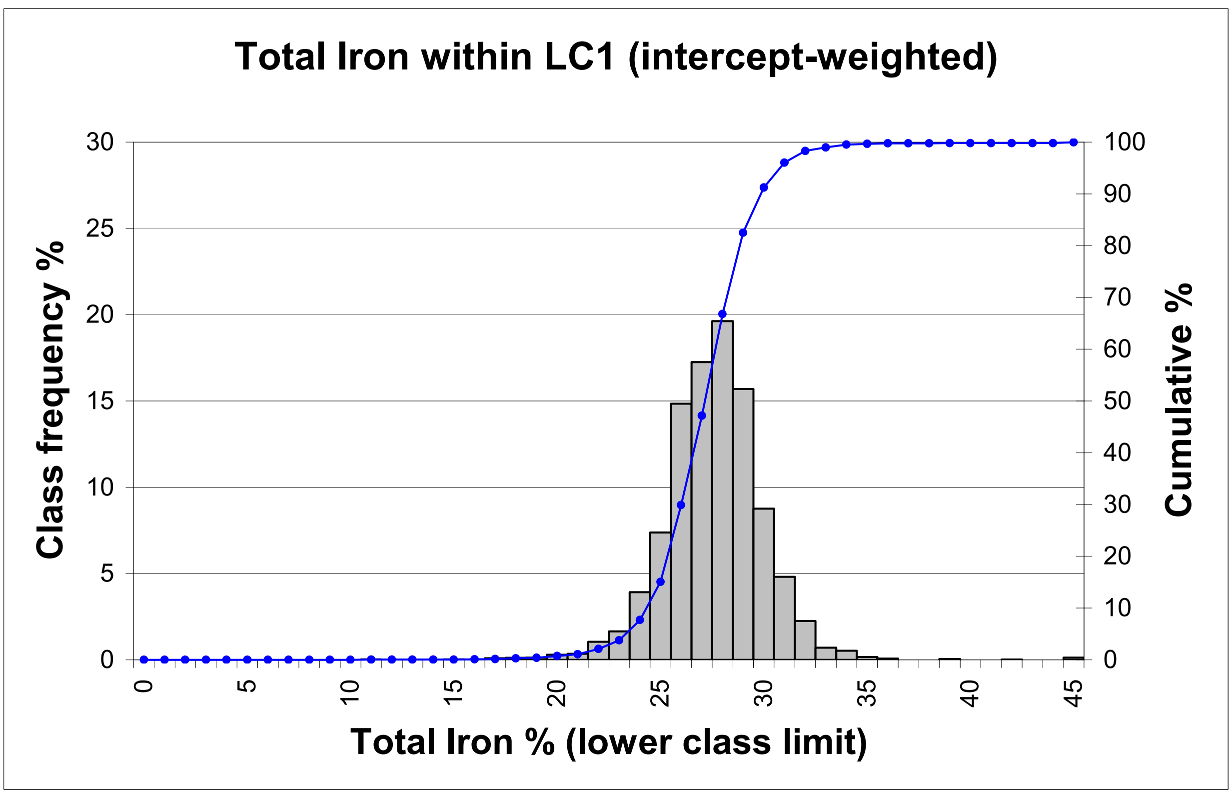

A FACTOR within IBC (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10

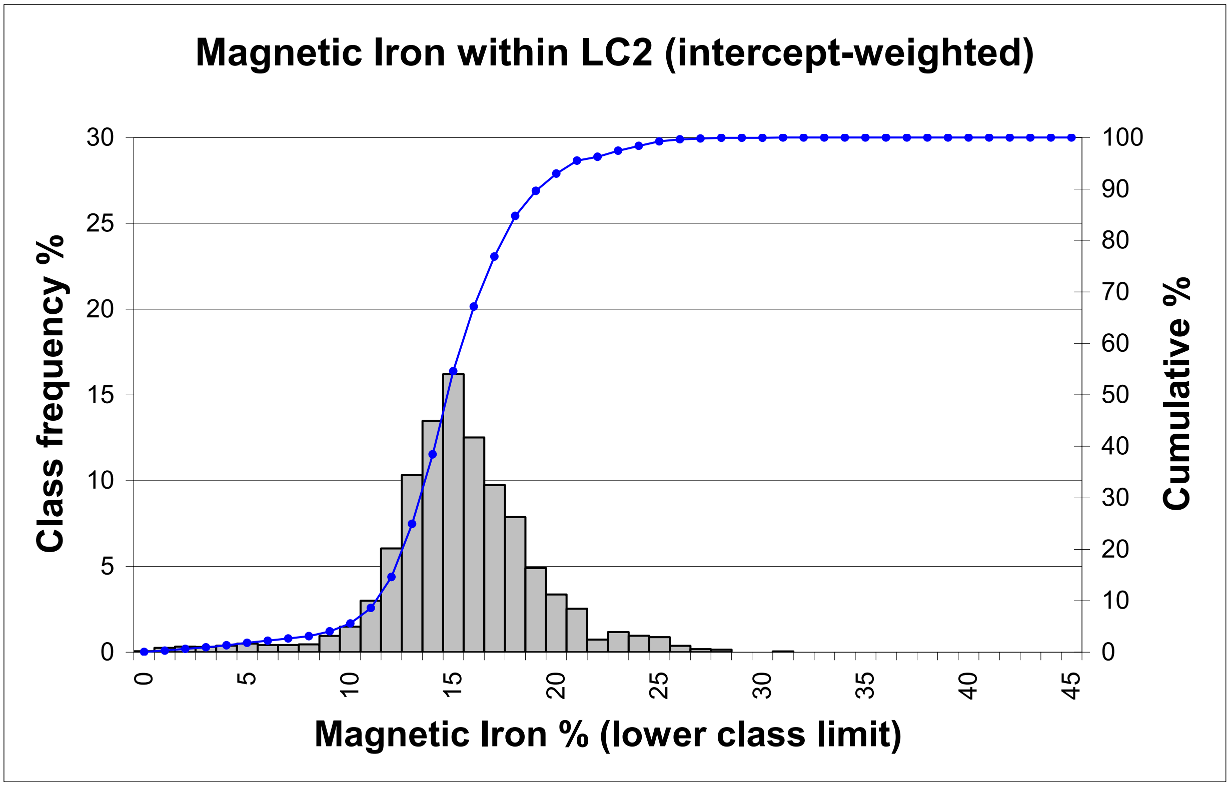

A FACTOR within HIS (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
2
3
4
5
6
7
8
9
10
11
12

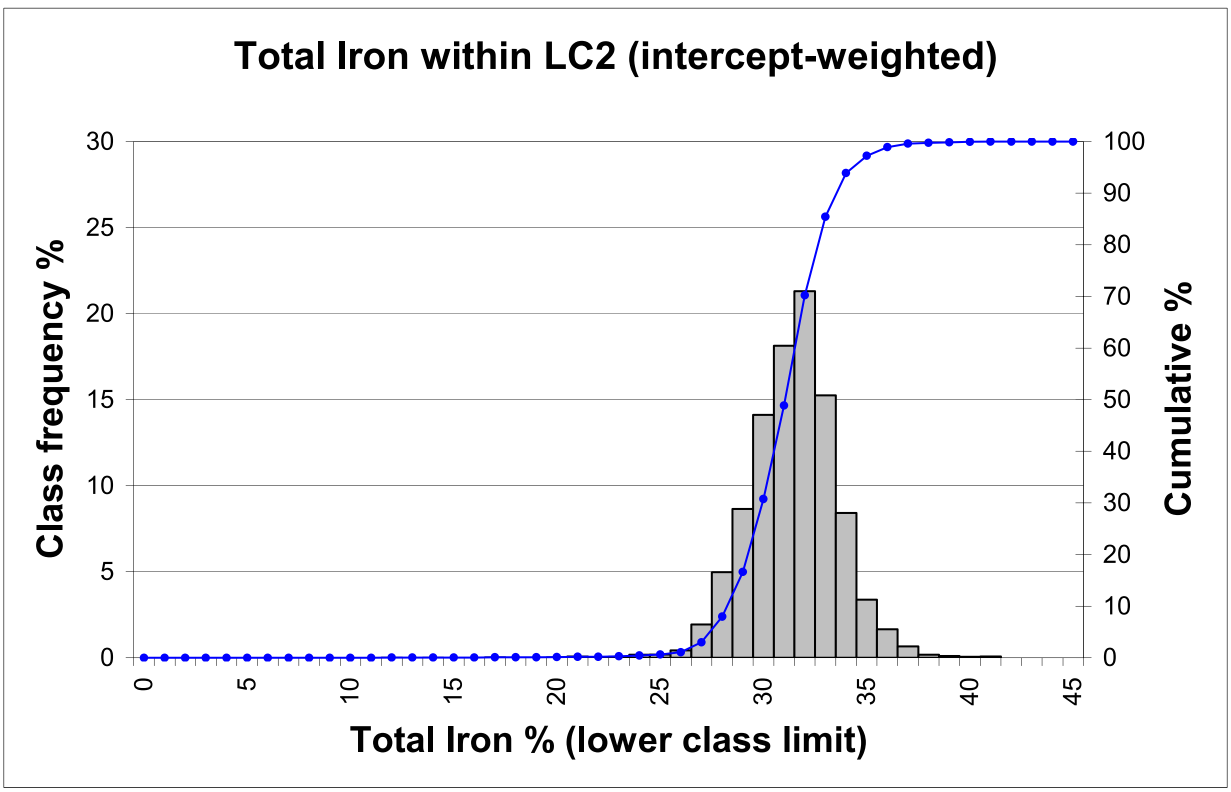

A FACTOR within UC (intercept-weighted)
Class frequency %
Cumulative %
A FACTOR (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12

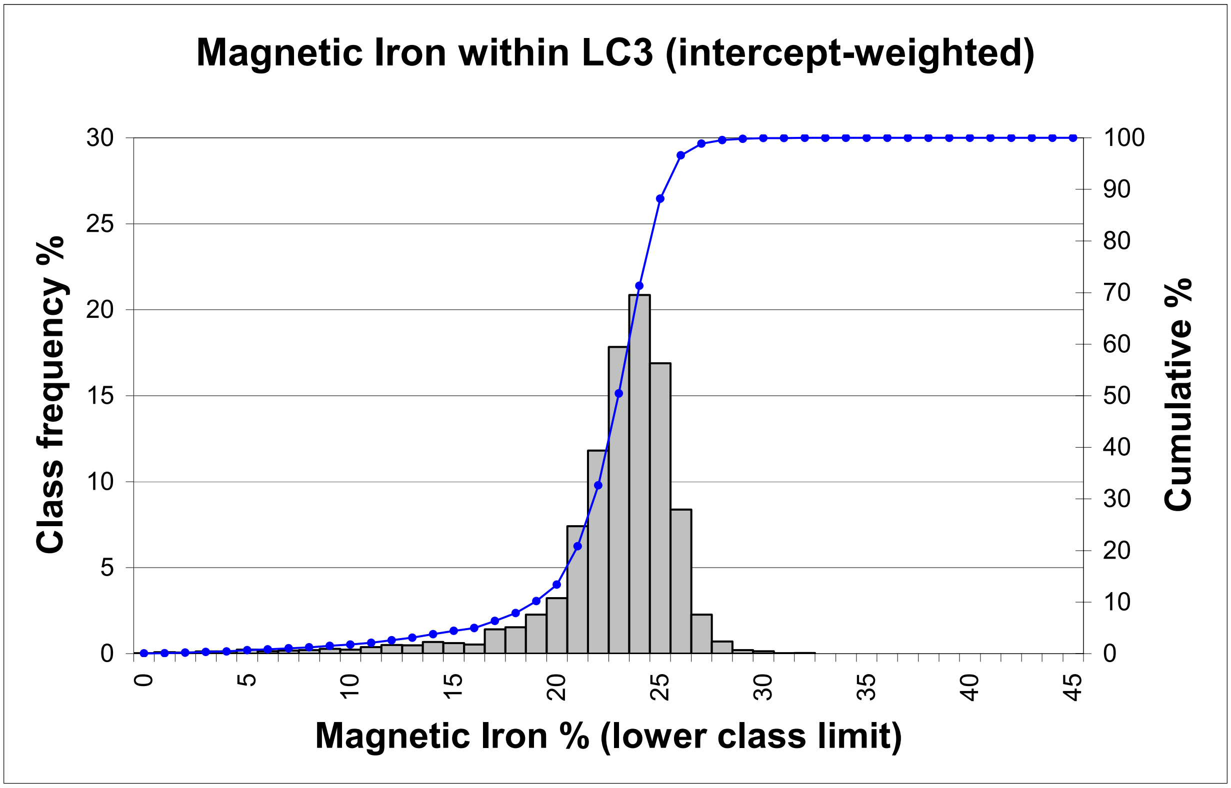
Charts of Iron Content, by Layer, from Orebody Model for Minntac Mine

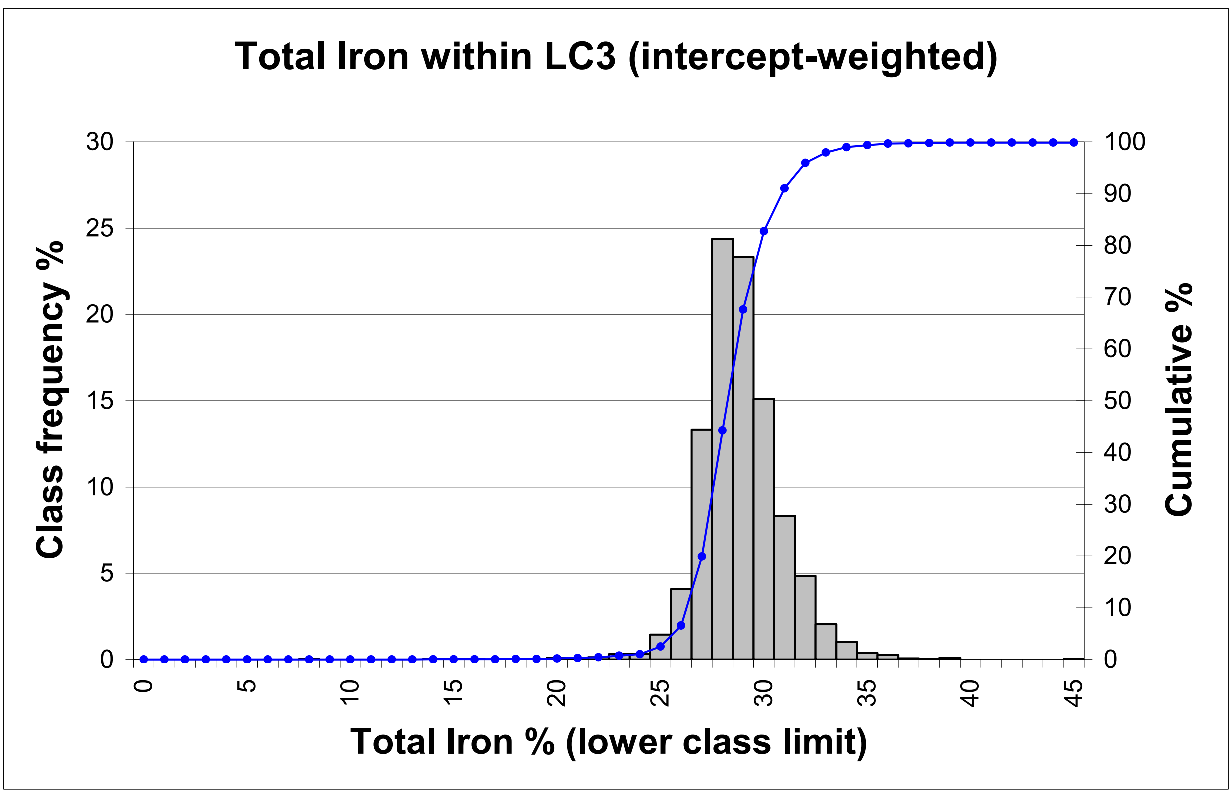


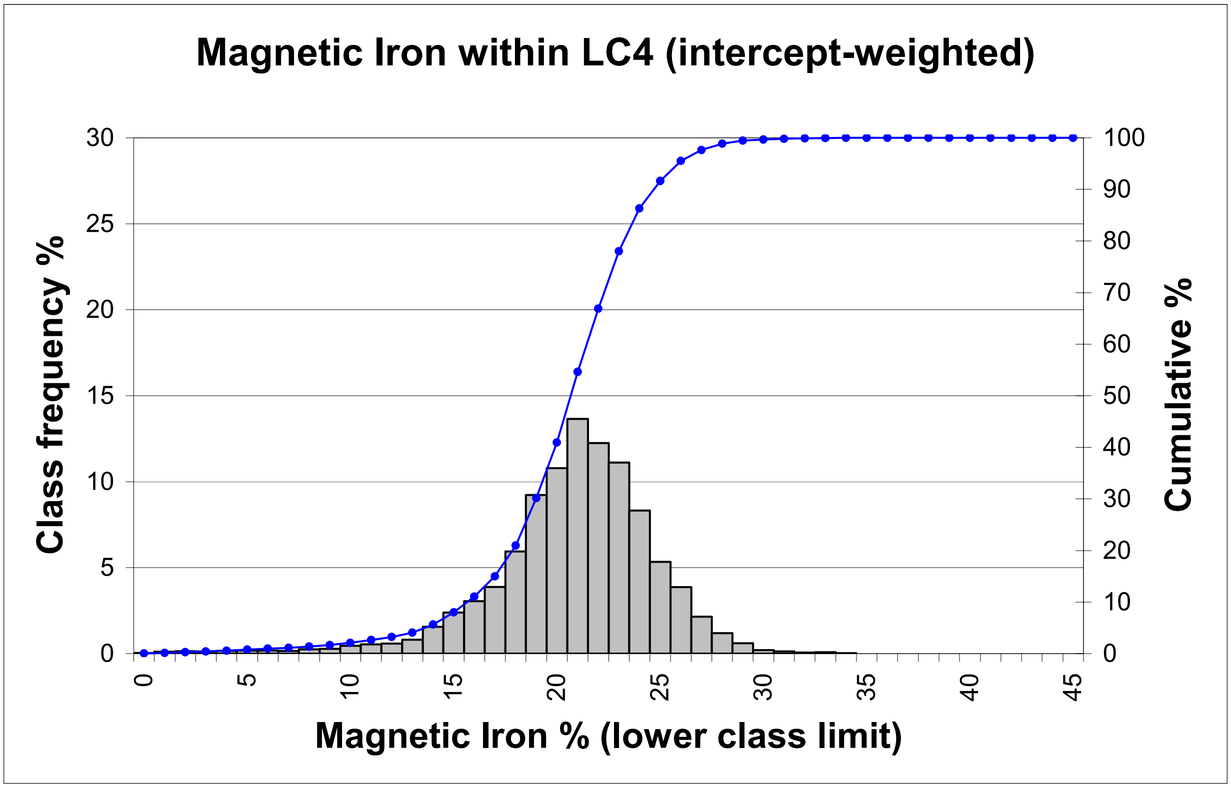


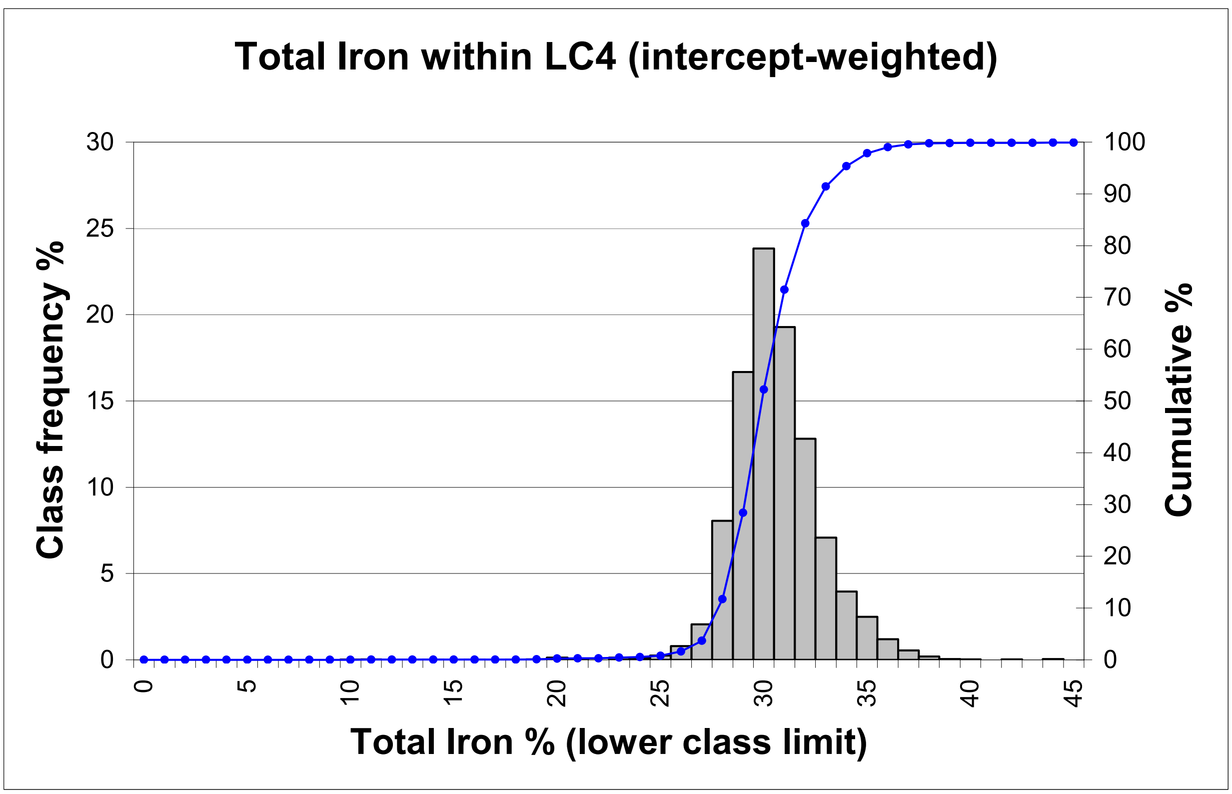

Magnetic Iron within LC2 (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

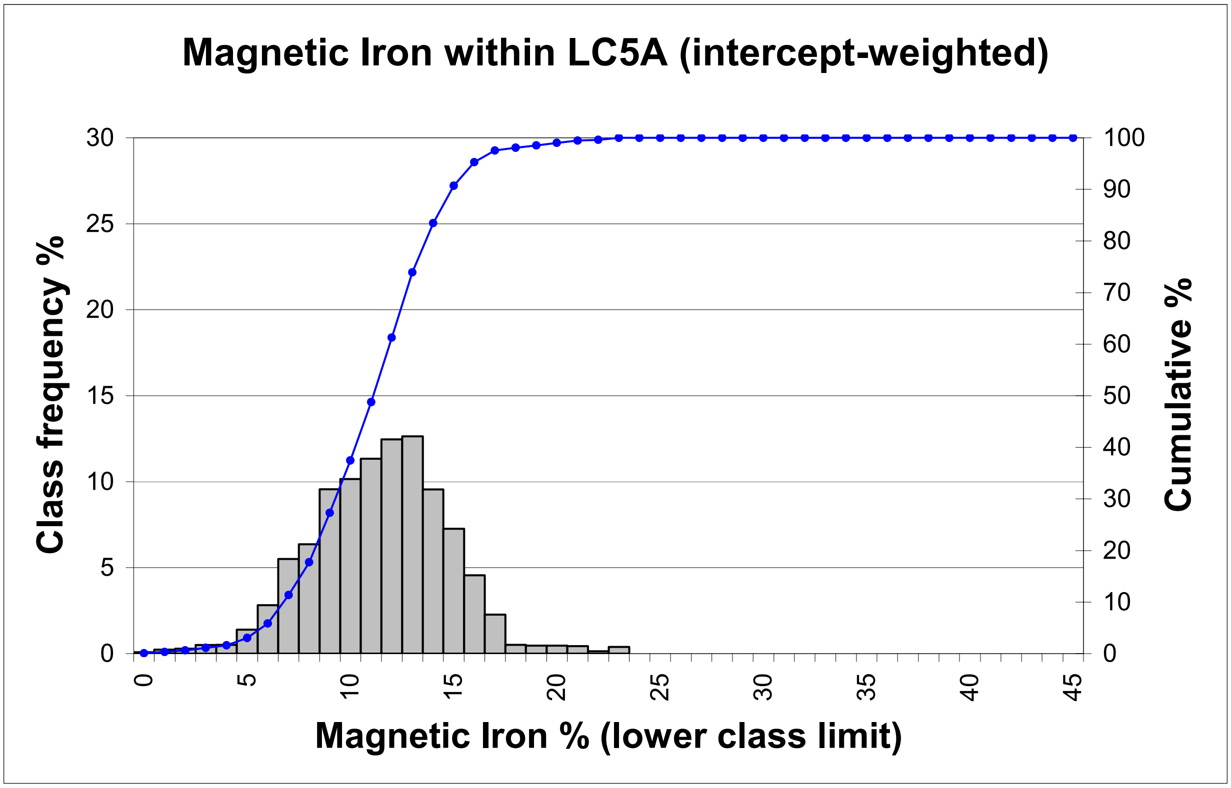

Total Iron within LC2 (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45


Magnetic Iron within LC3 (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
35
40
45

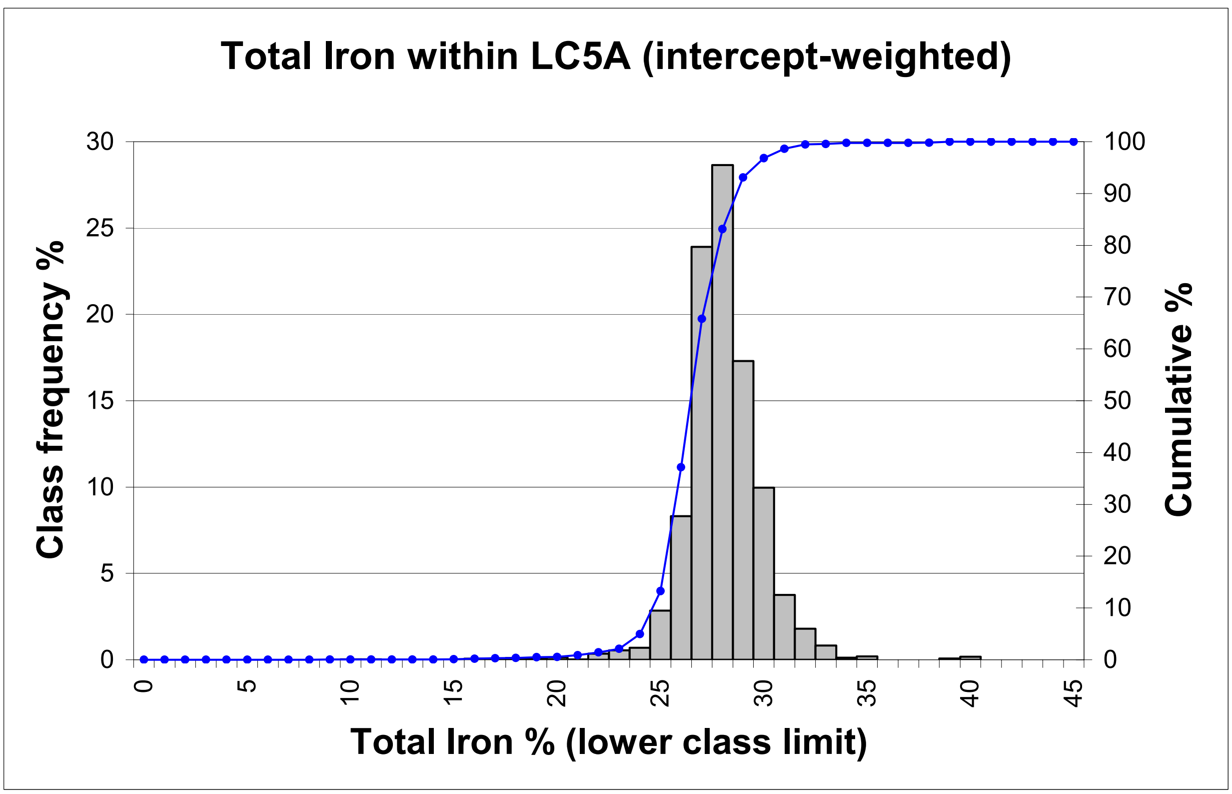

Total Iron within LC3 (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
35
40
45


Magnetic Iron within LC4 (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

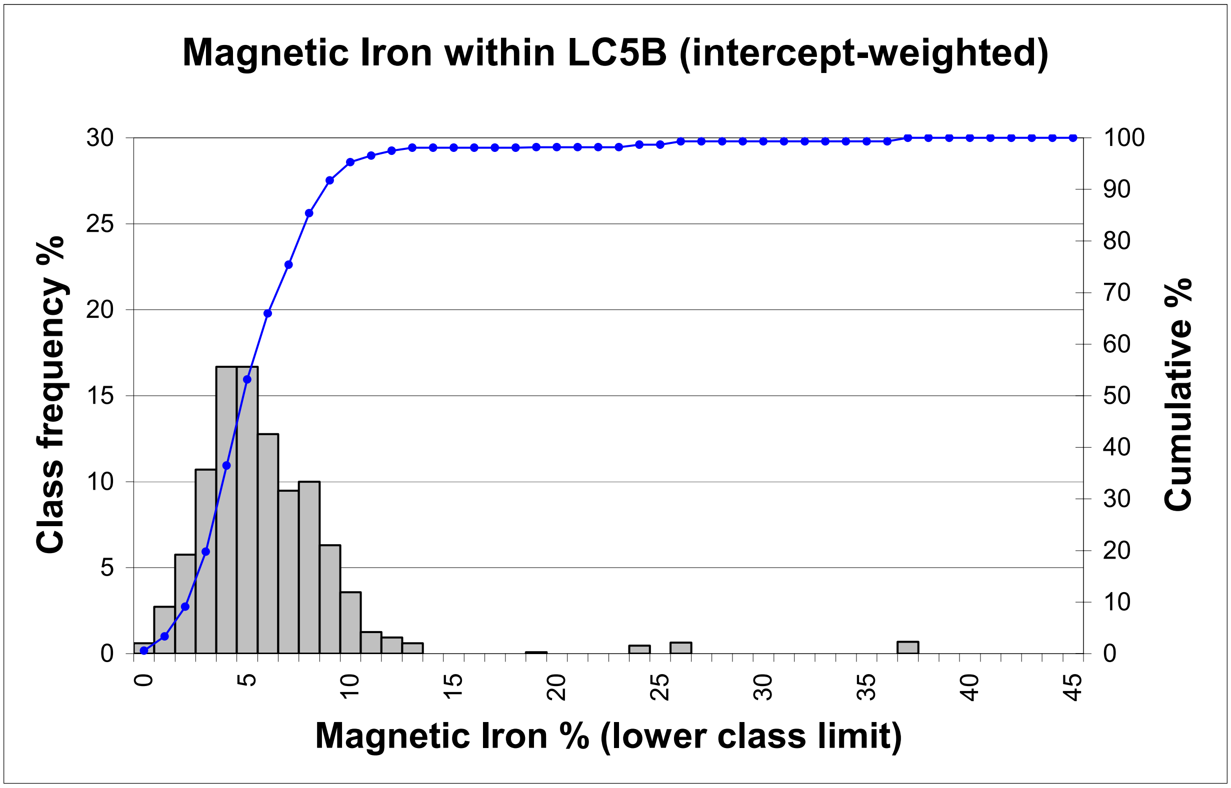

Total Iron within LC4 (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

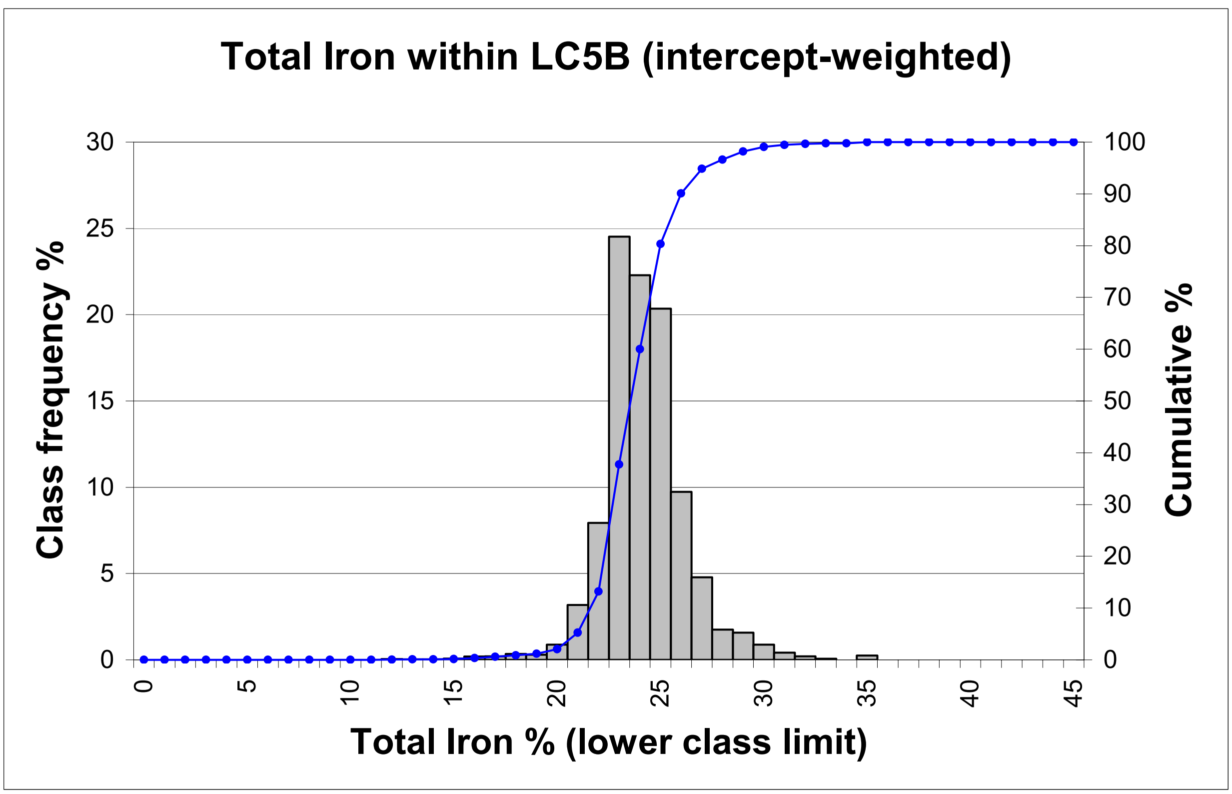


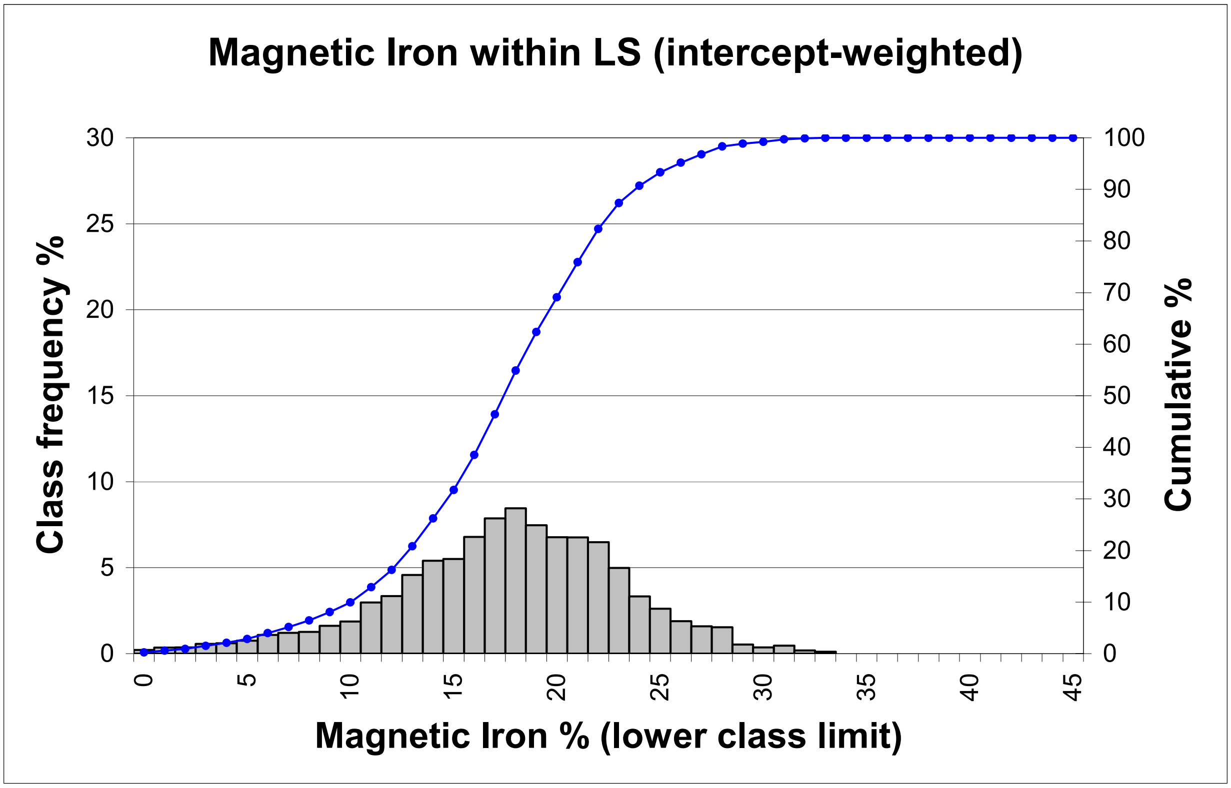
Magnetic Iron within LC5A (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50
40
30
20
10

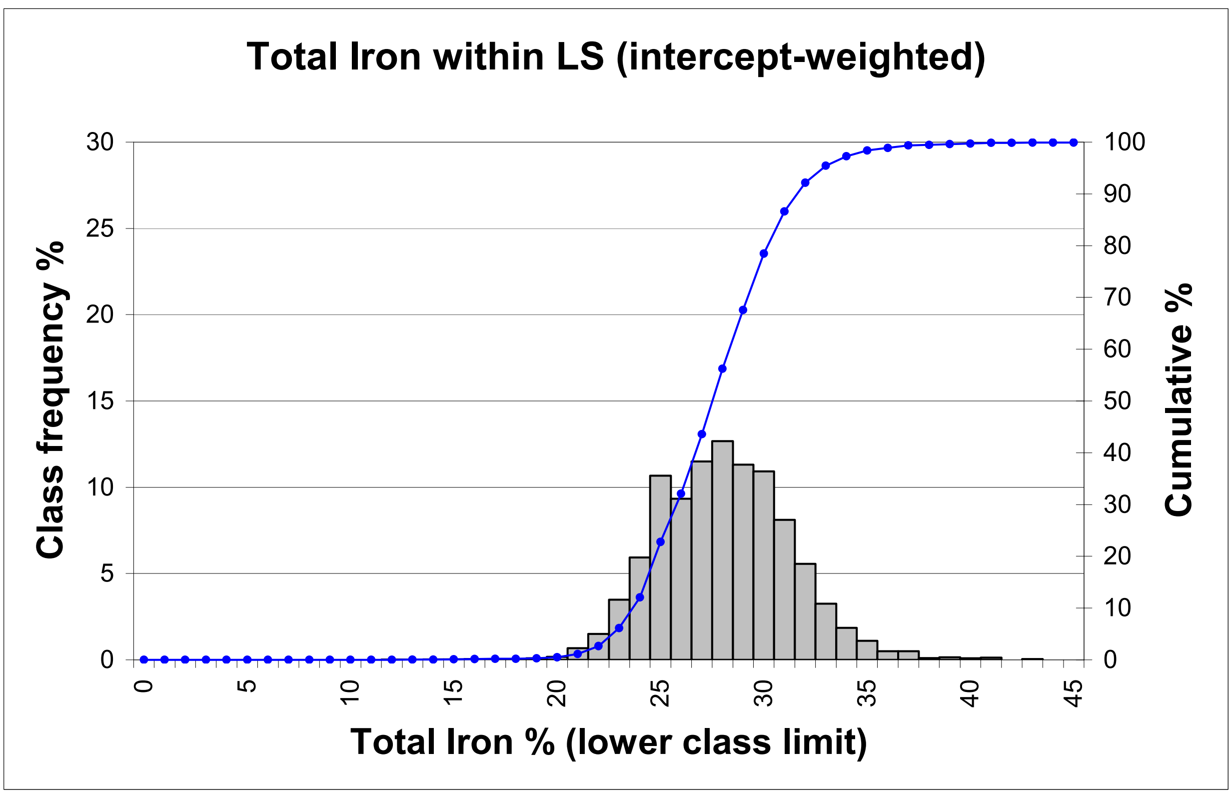


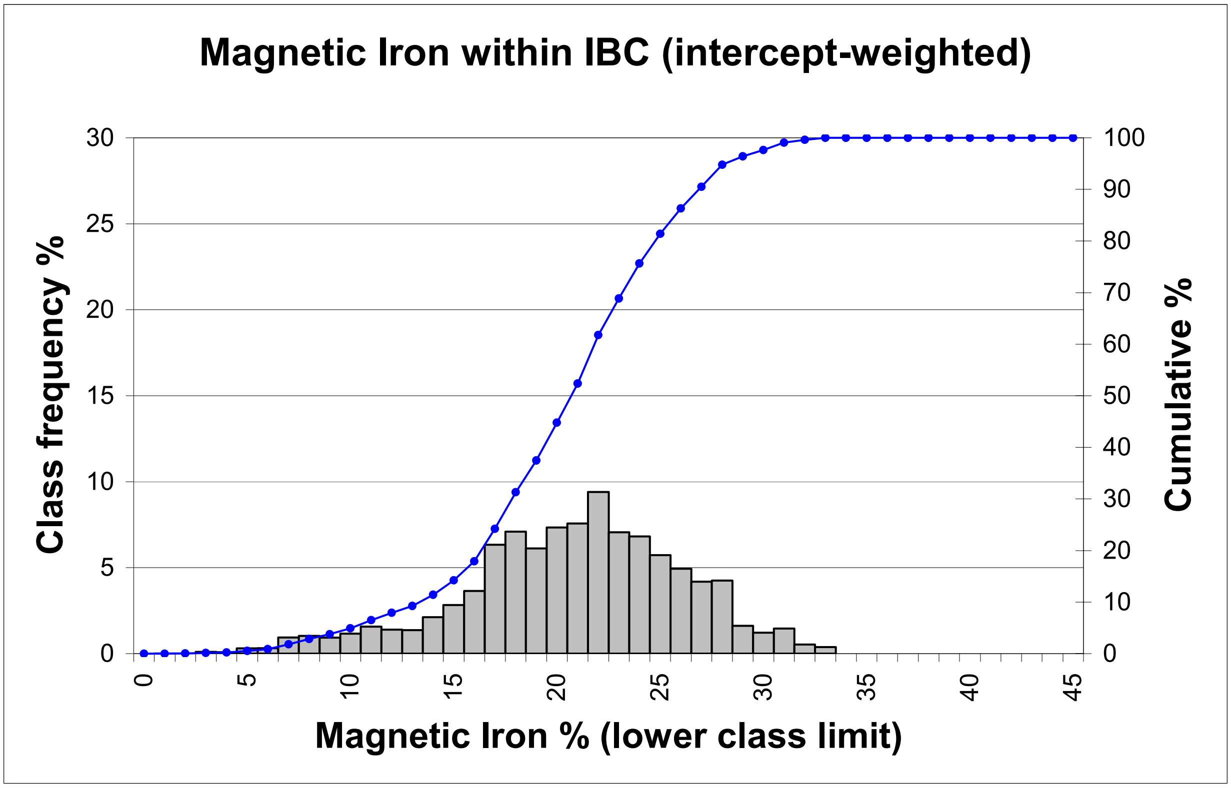
Total Iron within LC5A (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50
40
30
20
10

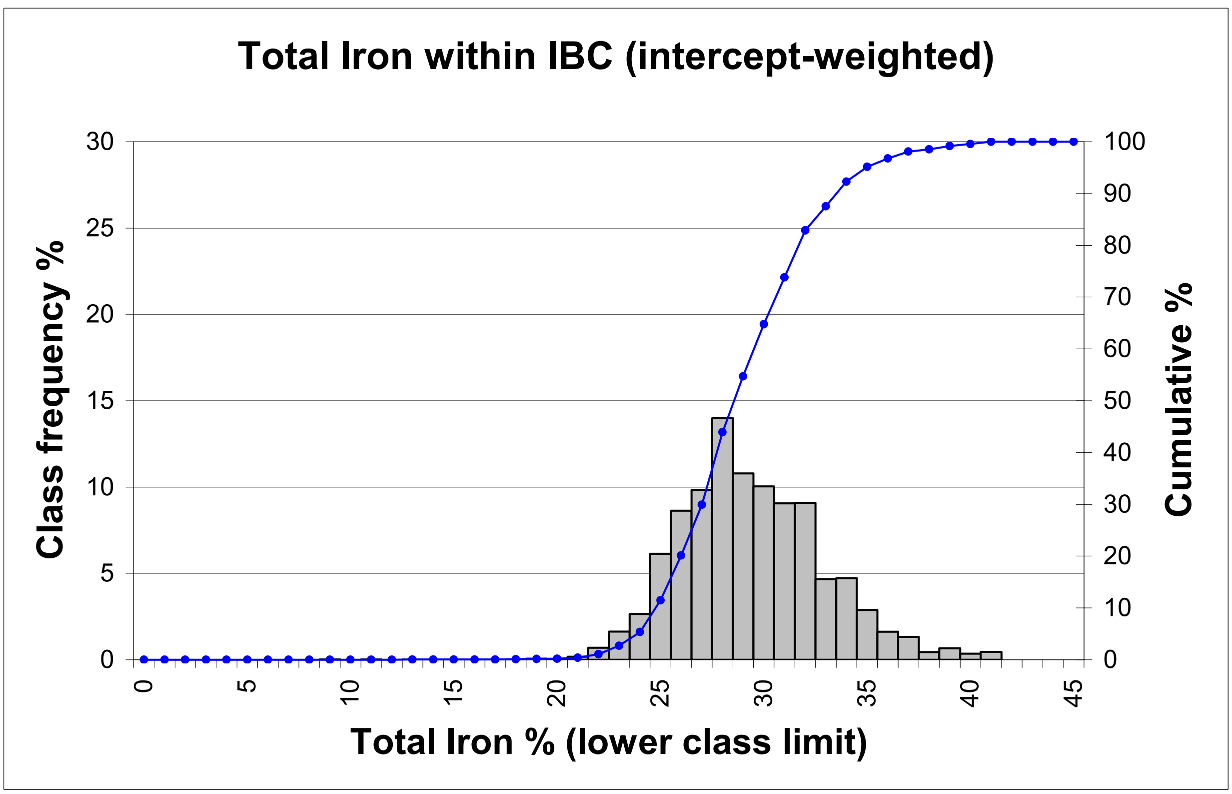

Magnetic Iron within LC5B (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

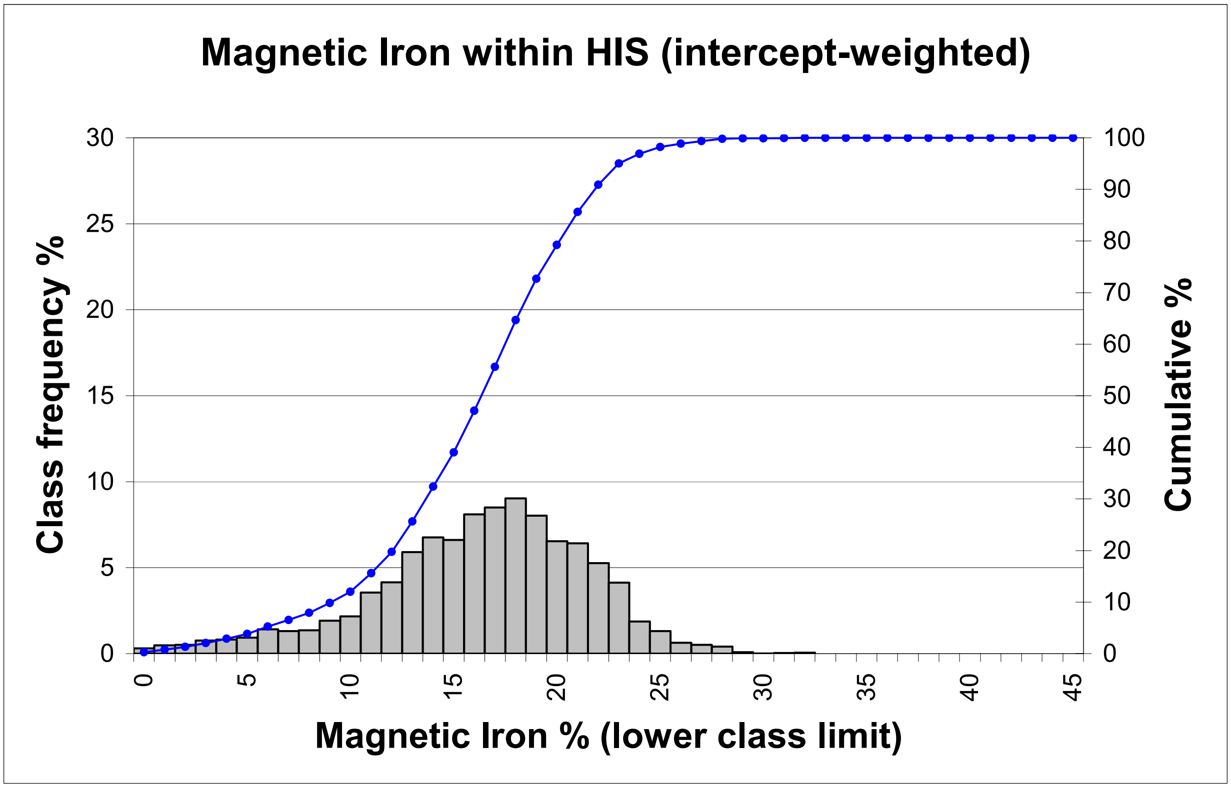

Total Iron within LC5B (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45


Magnetic Iron within LS (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
90
100

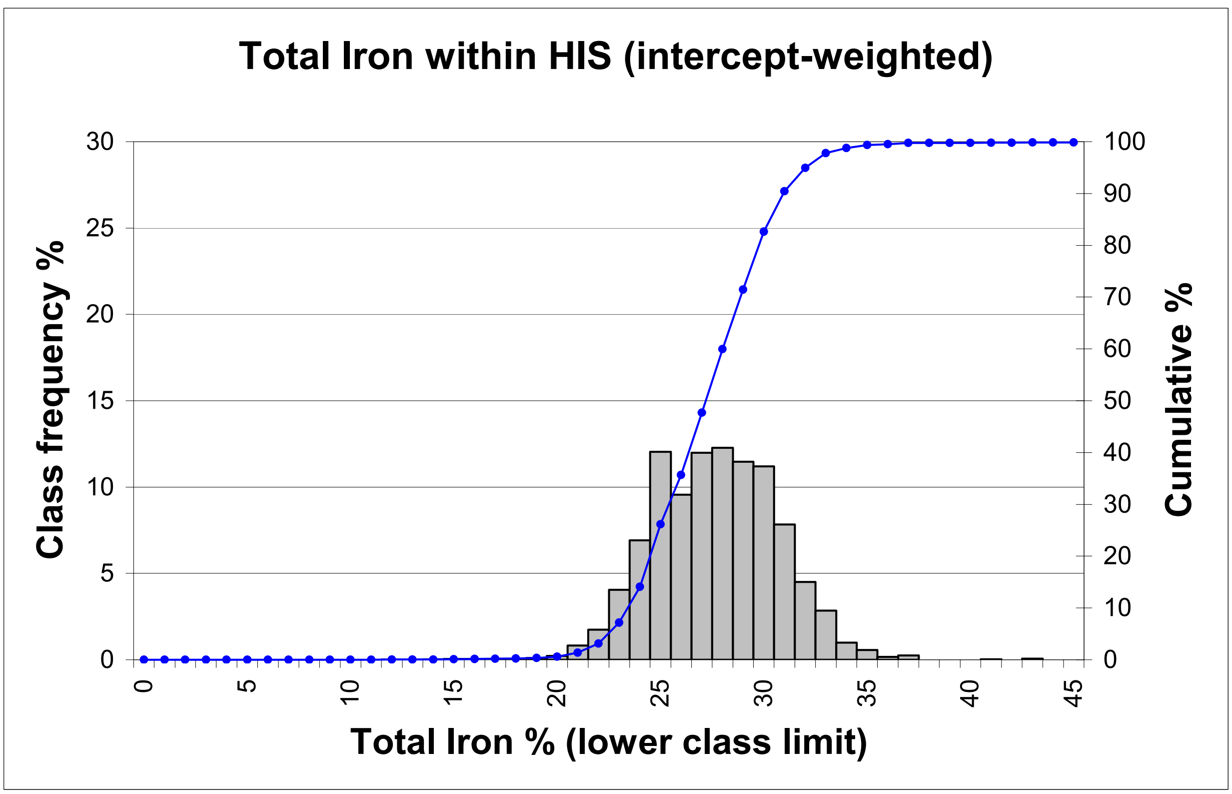

Total Iron within LS (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
90
100


Magnetic Iron within IBC (intercept-weighted)
Class frequency %
Cumulative %
30
25
20
15
10
5
0
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
Magnetic Iron % (lower class limit)

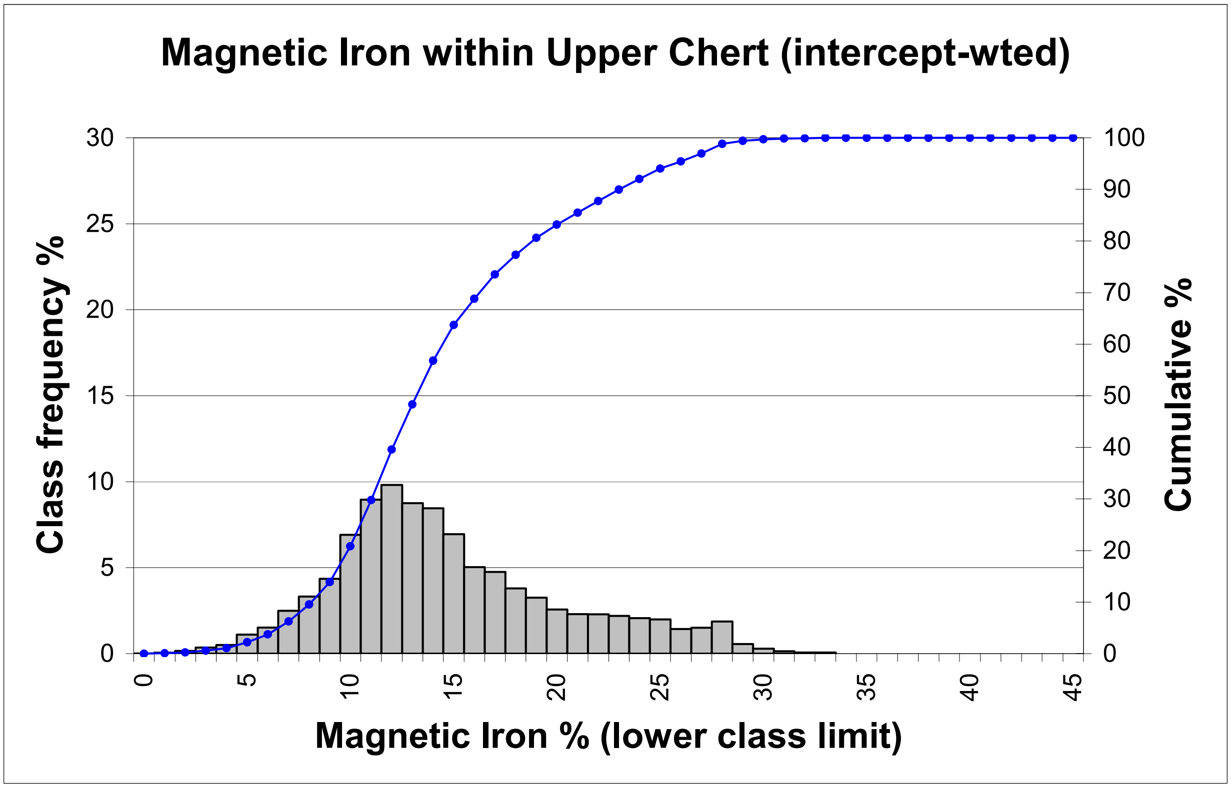

Total Iron within IBC (intercept-weighted)
Class frequency %
Cumulative %
30
25
20
15
10
5
0
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
Total Iron % (lower class limit)

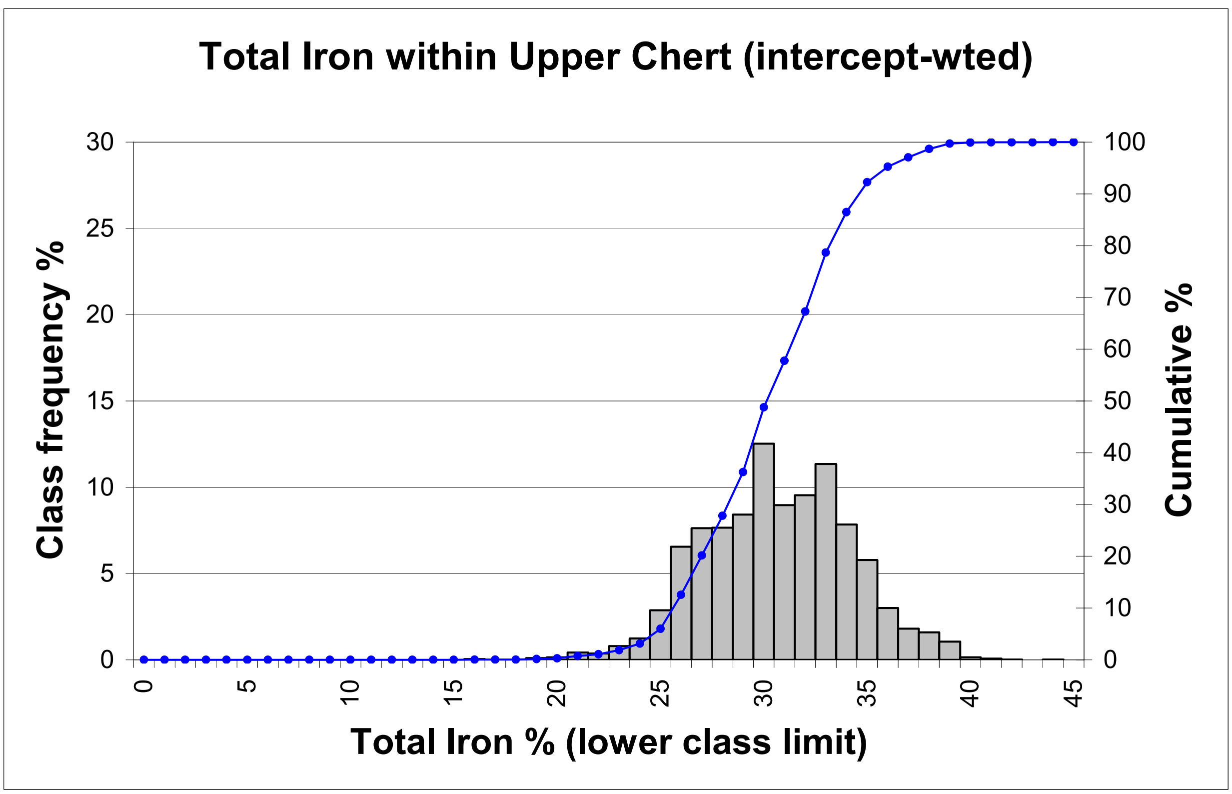


Magnetic Iron within HIS (intercept-weighted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90
100

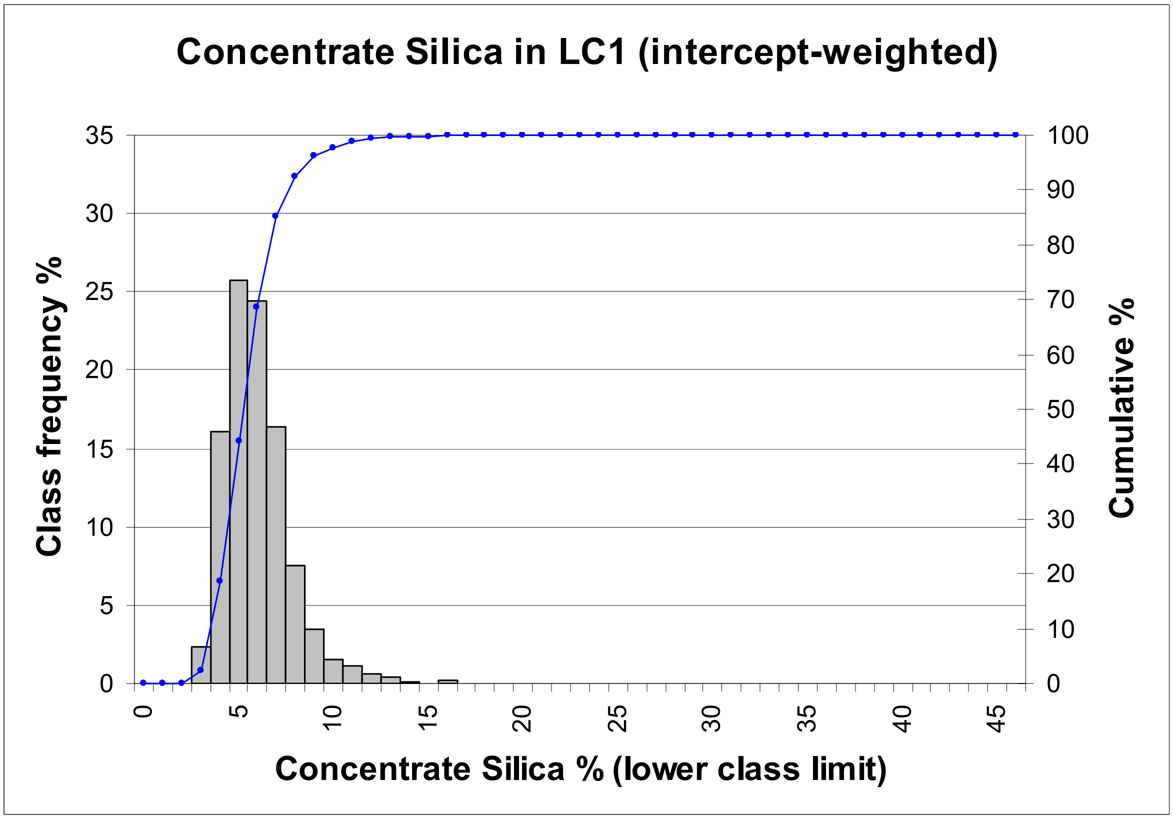


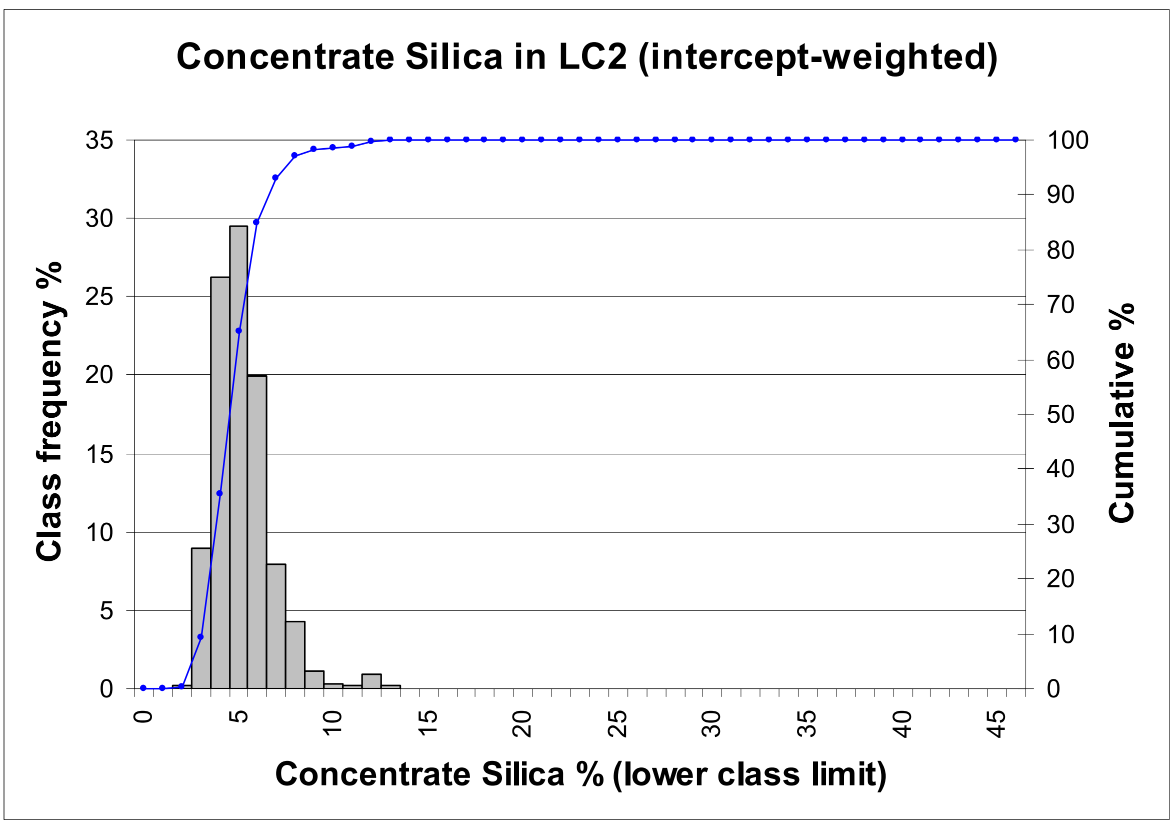
Total Iron within HIS (intercept-weighted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
35
40
45
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90
100

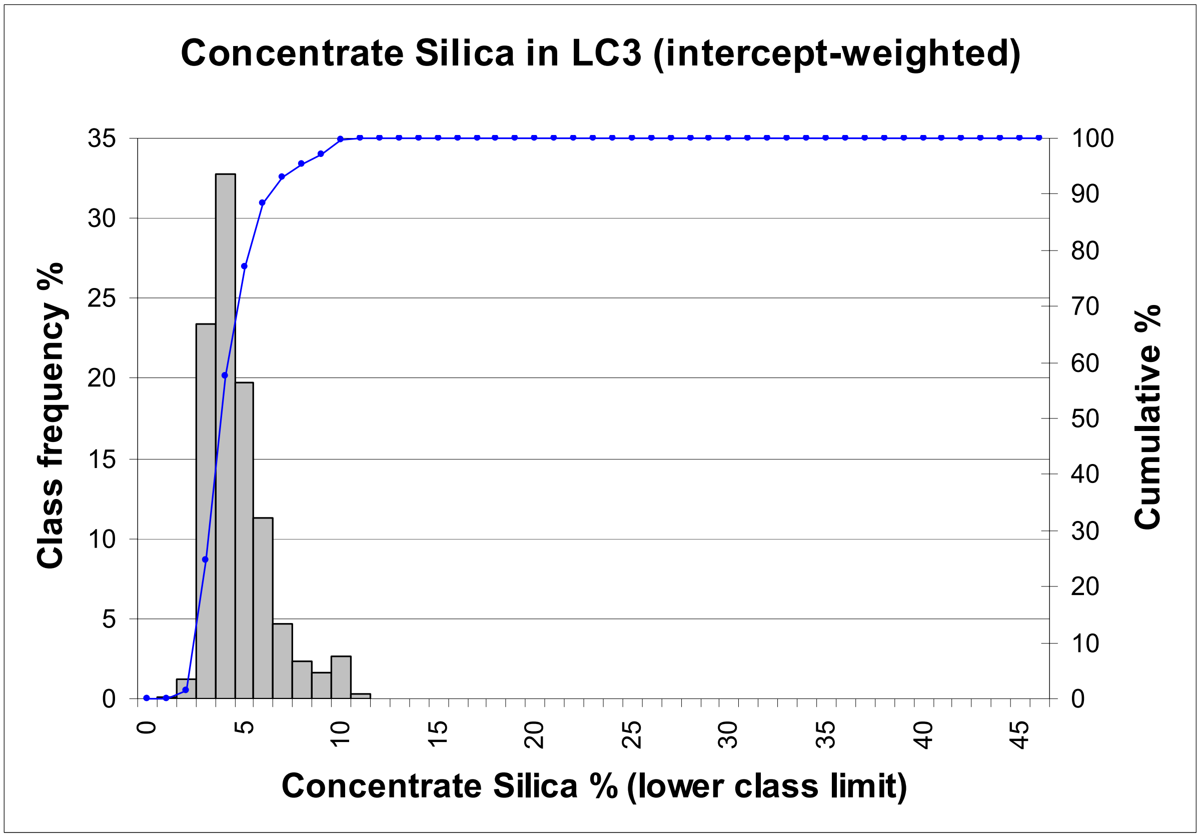

Magnetic Iron within Upper Chert (intercept-wted)
Class frequency %
Cumulative %
Magnetic Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

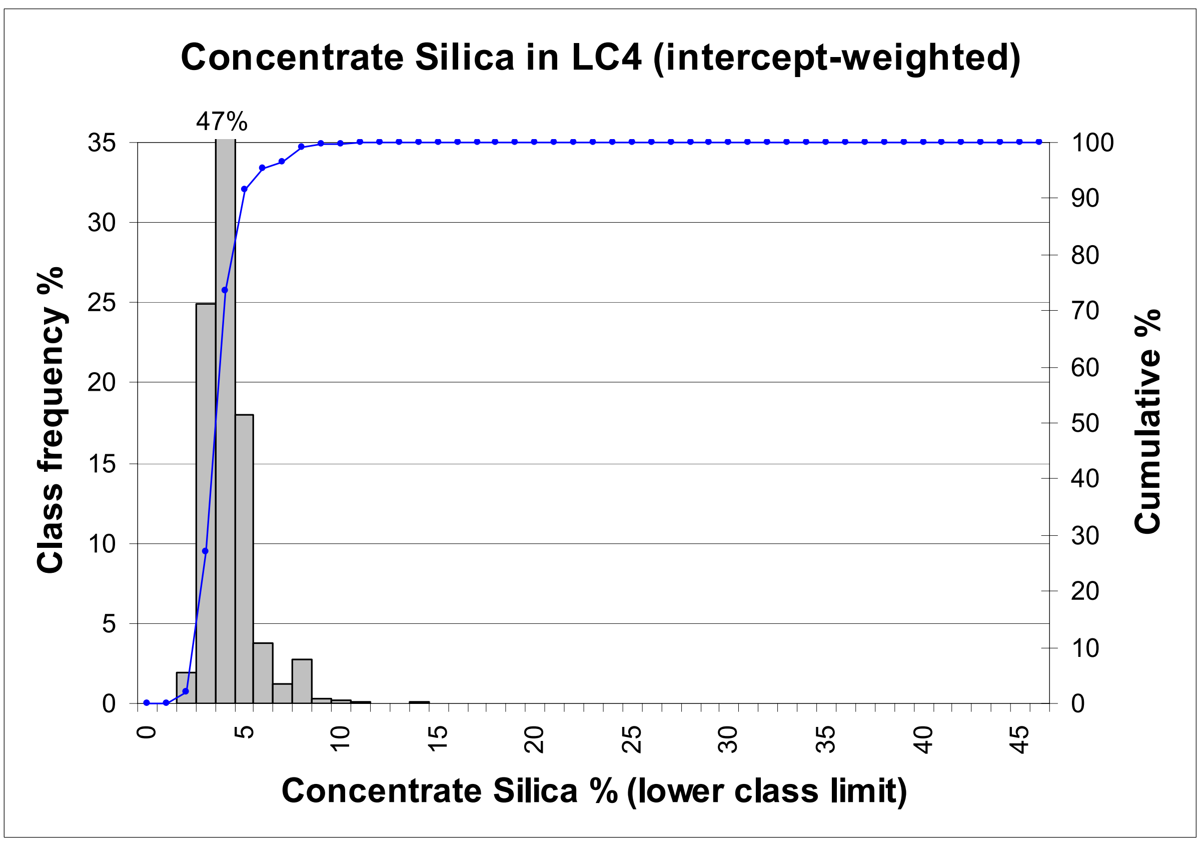

Total Iron within Upper Chert (intercept-wted)
Class frequency %
Cumulative %
Total Iron % (lower class limit)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
30
35
40
45

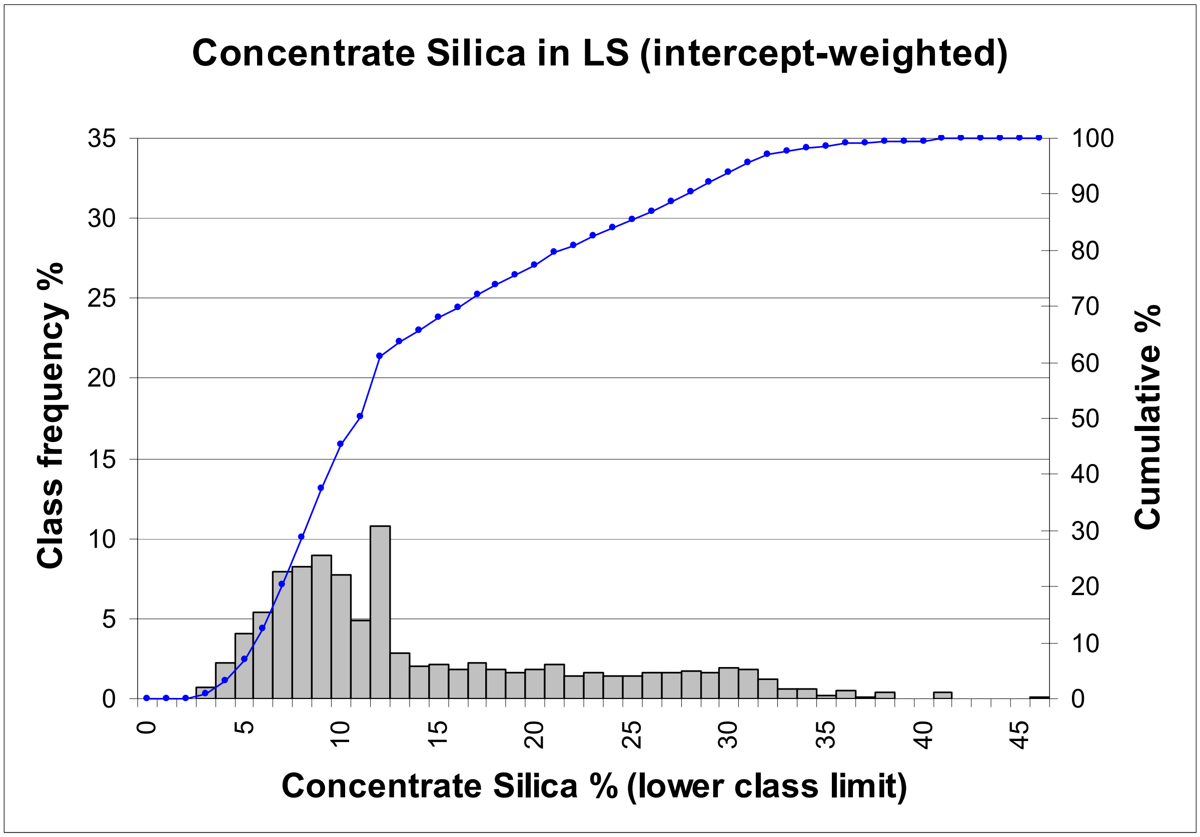
Charts of Concentrate Silica, by Layer, from Orebody Model for Minntac Mine

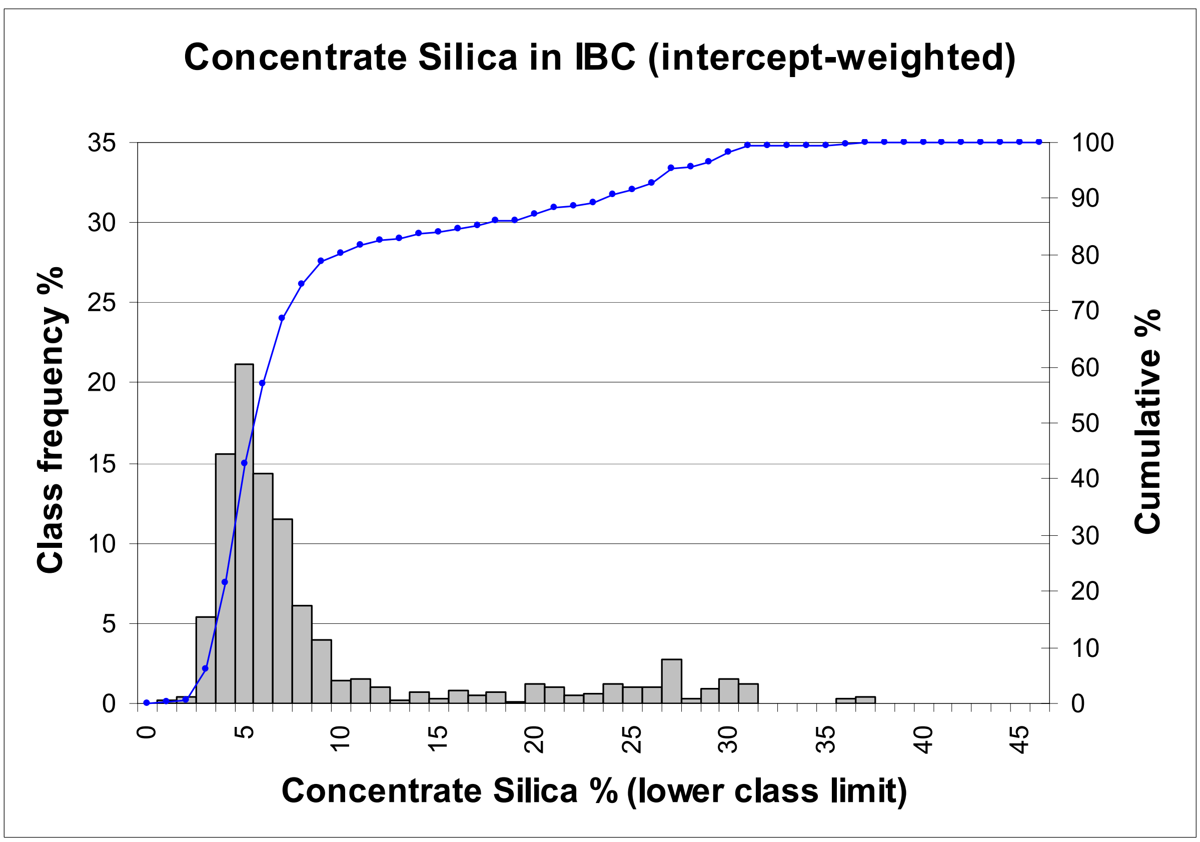


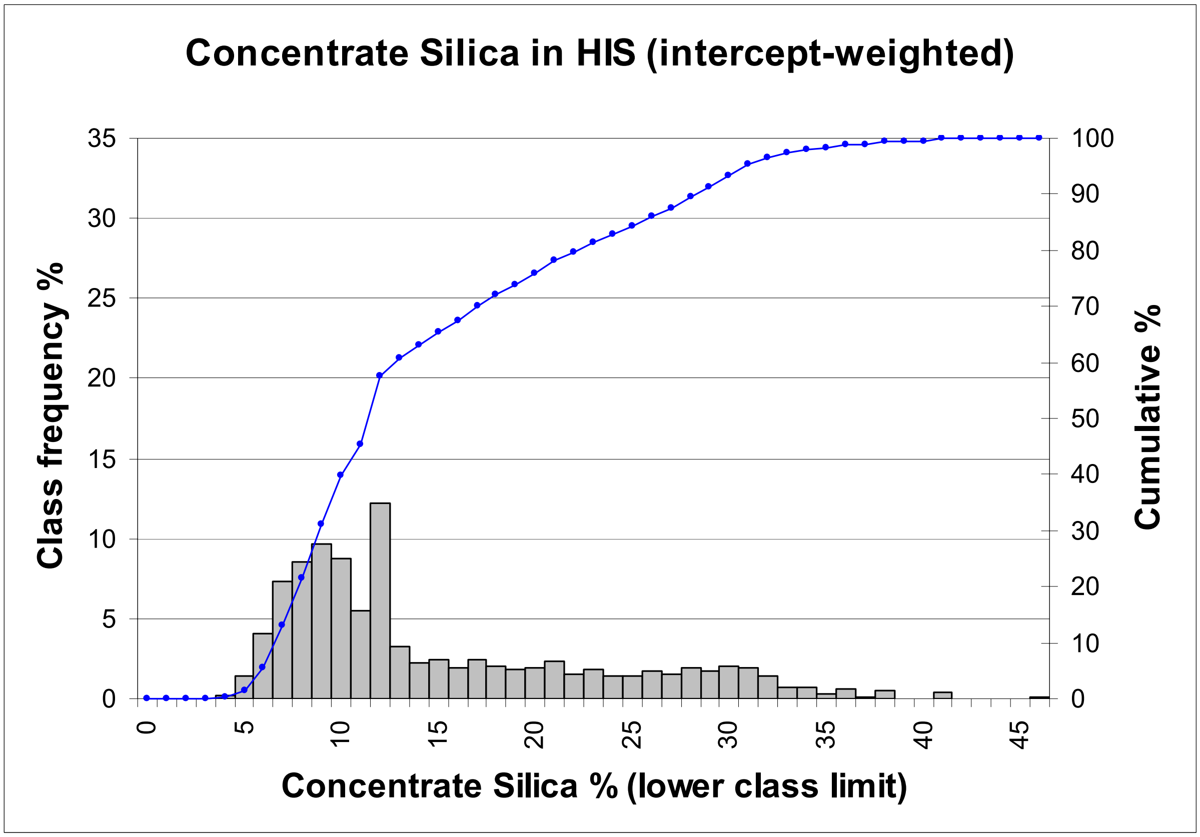


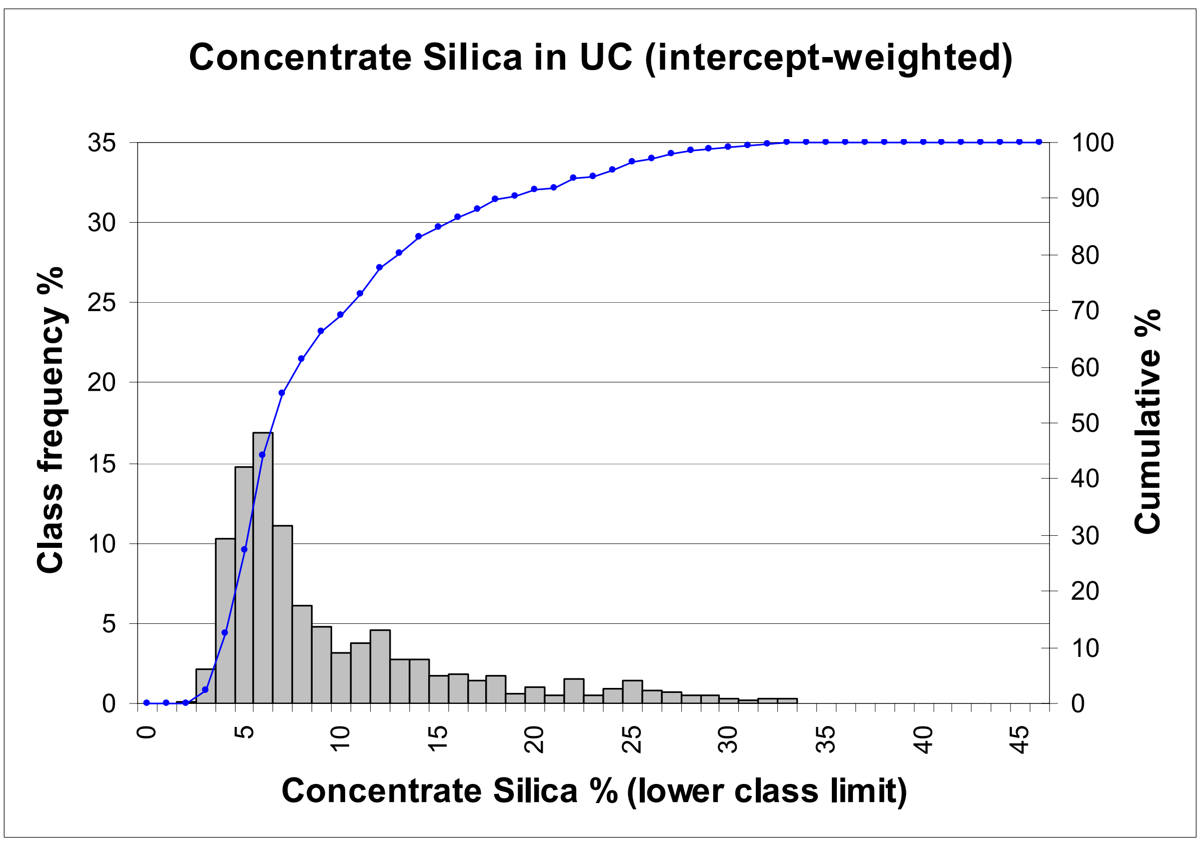

Concentrate Silica in LC3 (intercept-weighted)
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)


Concentrate Silica in LC4 (intercept-weighted)
47%
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)


Concentrate Silica in LS (intercept-weighted)
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50


Concentrate Silica in IBC (intercept-weighted)
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50


Concentrate Silica in HIS (intercept-weighted)
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50


Concentrate Silica in UC (intercept-weighted)
Class frequency %
Cumulative %
Concentrate Silica % (lower class limit)
0
5
10
15
20
25
30
35
40
45
100
90
80
70
60
50