Case Study of pXRF Application in Estimation of Production Ore Grade at Podolsky Mine, Sudbury Basin

Handheld XRF Workshop
Goodman School of Mines
Laurentian University

Case Study of pXRF Application in Estimation of Production Ore Grade at Podolsky Mine, Sudbury Basin

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Outline for the Talk

1. Purpose of the pXRF application at Podolsky Mine
2. Methodology
3. Results:

   A) Proof of Concept

   B) Application in Production

5. Conclusions

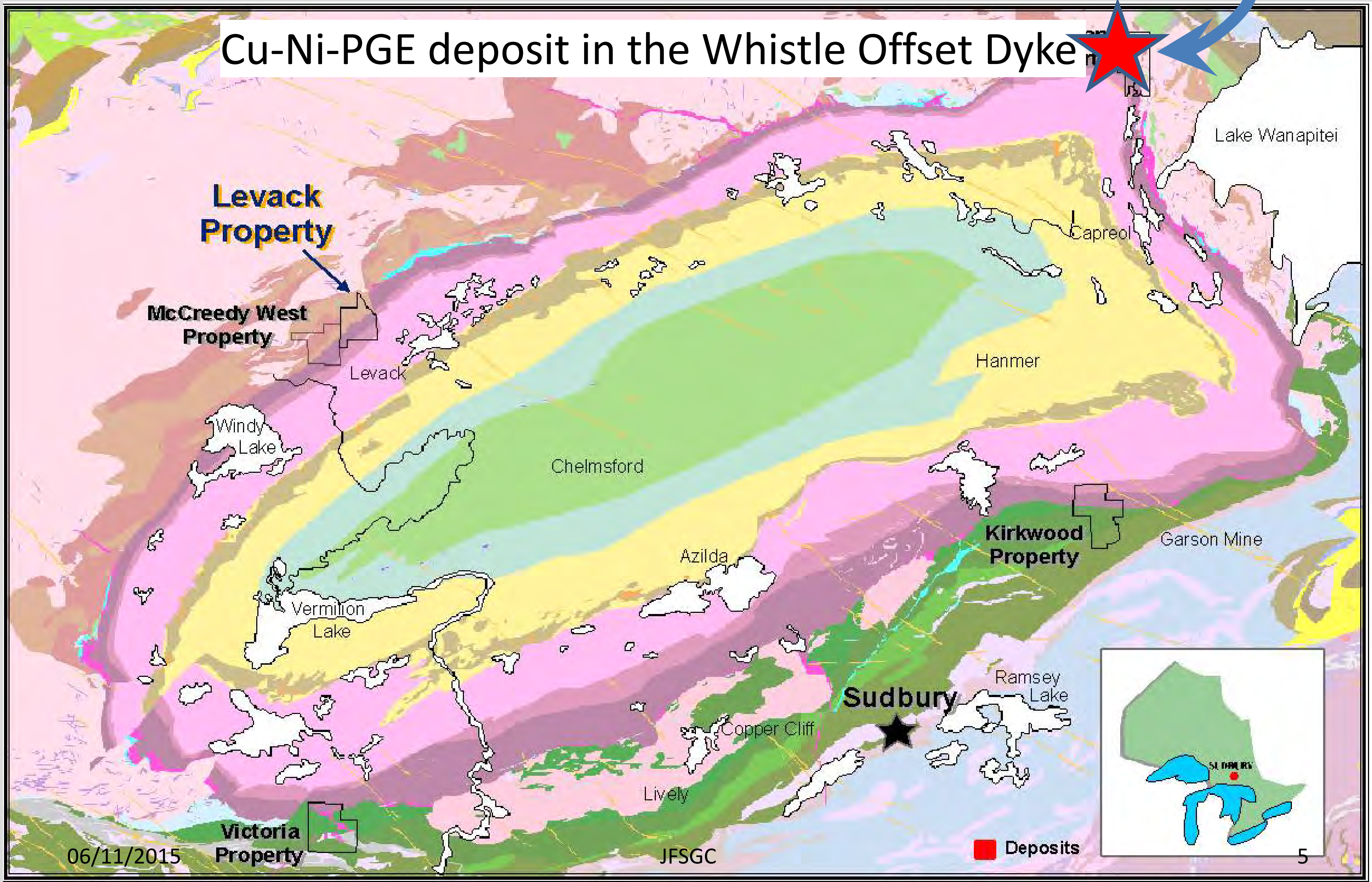
Purpose and Goal of the pXRF Application

Obtain reasonably accurate results for daily production grade using an in-house sampling protocol, and a portable XFR (pXRF) analyzer at Podolsky Mine.

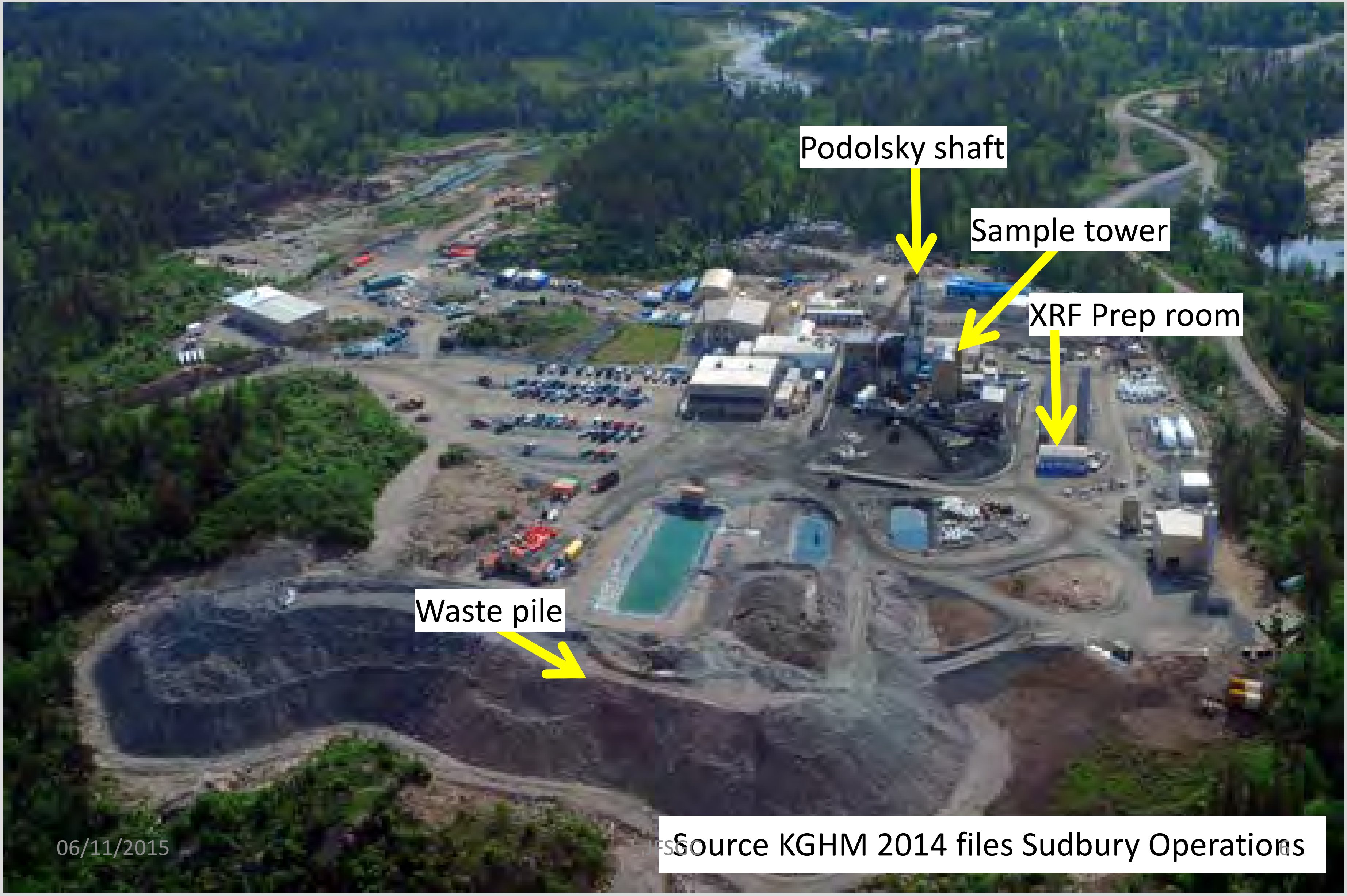
Reasons for the Application

- As Chief Geologist at Podolsky Mine for the period 2005-2008 I was responsible for short term and longer term grade estimates for production.
- Blast hole mining of high grade and lower grade ore meant a mixture of material u/g and on surface. Accurate grade calls can be a challenge in this scenario. The resulting ore pile on surface is a variable mixture of grades.
- There was a definite advantage to having a good estimate of production grade from day to day for inventory tracking. Accountability and payment relied on Barrel Lot assays that had >2 month turnaround. This is too long for short term production accounting of inventory.
- Therefore in order to get quicker results a methodology was set up in-house using a portable XFR for quick and reasonably accurate results of daily production grade.

Location of Podolsky Mine Site



Podolsky Mine Site



Main Components in Strategy

- Obtain meaningful results in Proof of Concept testing
- Apply to mine production estimates of Cu and Ni grade
- Obtain a representative and reproducible sample that meets the Sampling Theory criteria
- Devise a preparation methodology that is simple and brings about reproducible results
- Analysis of sample by XRF
- Processing and compilation of results in PIMS database

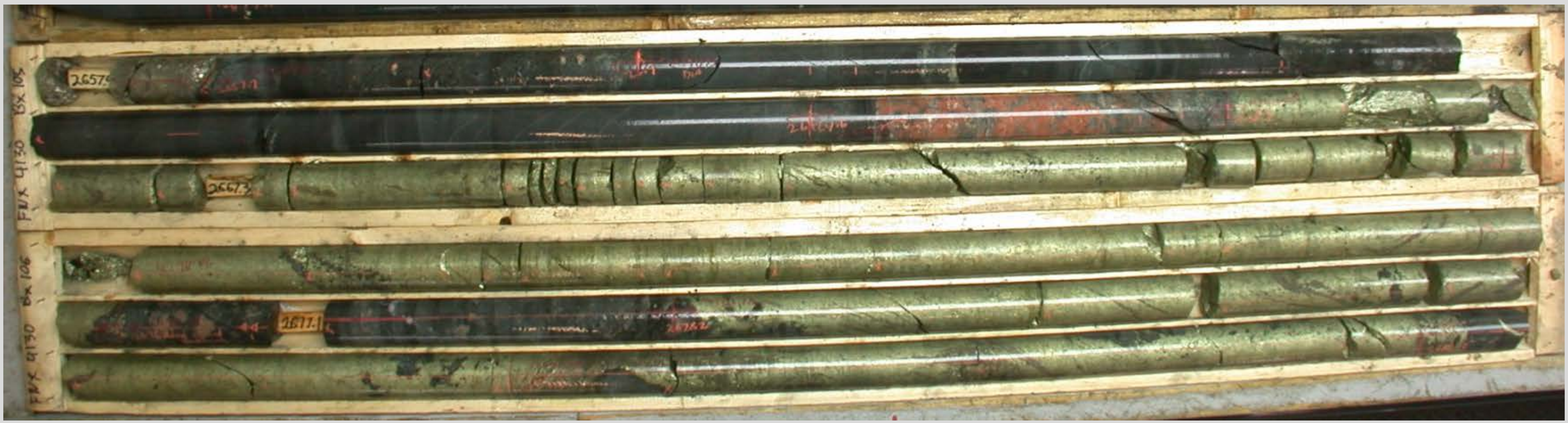
Proof of Concept Testing

Methodology

- In order to reduce matrix effects only homogeneous powders were analyzed in this test
- 20 Sample splits were taken from archived assay pulps of drill core samples from 2000 Zone of Podolsky deposit
- 4 Internal standard reference pulps were included in the set
- Samples pulverized to 100% passing 120 mesh (0.125 mm)
- Analyzed in triplicate with Niton Model XL3 XRF benchtop analyzer in Bulk Mining Mode, and tuned by the instrument supplier for Cu and Ni.
- ICP-AES Assay results represent the actual concentrations, to which the portable XRF data was compared

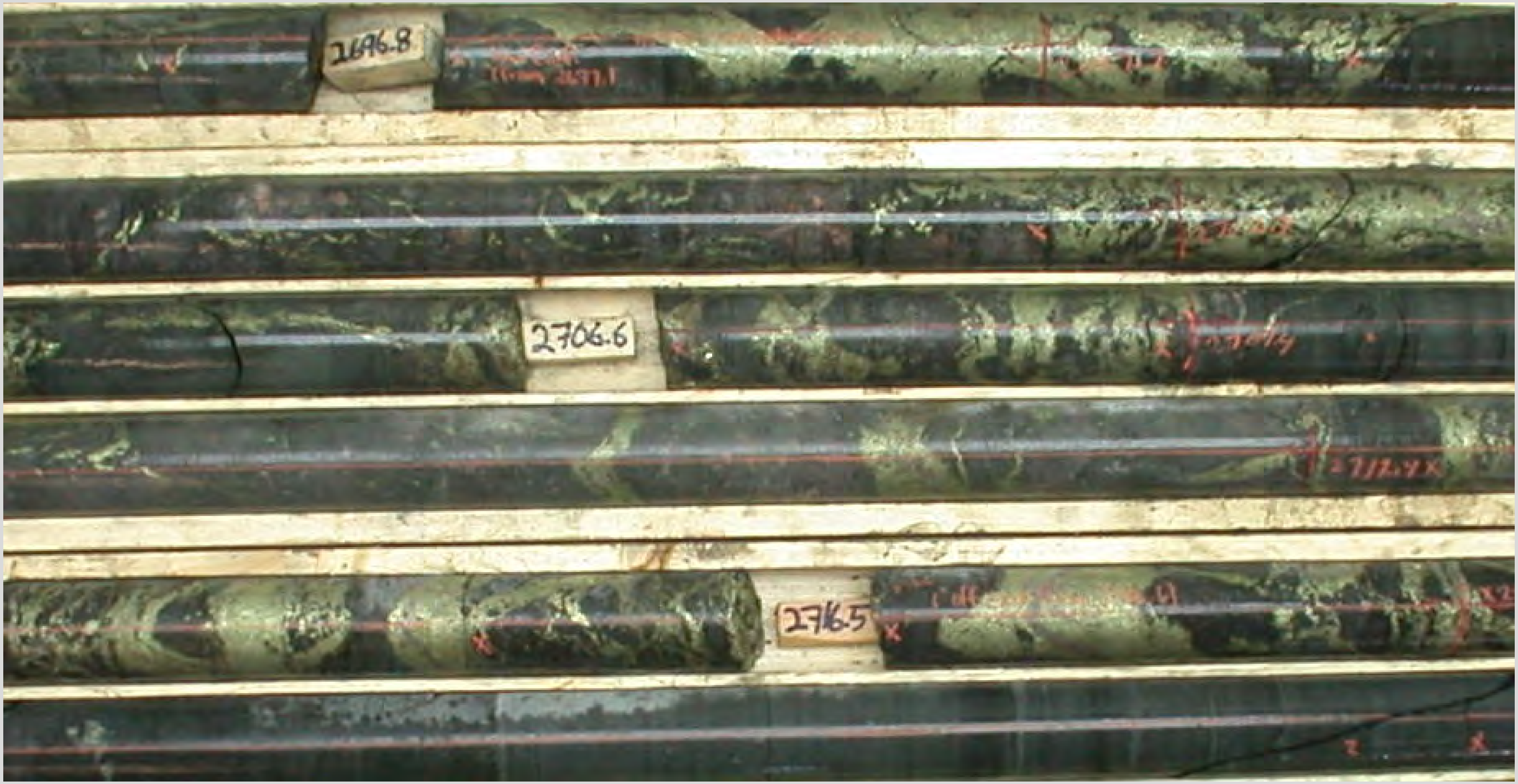
Core Samples

Massive Chalcopyrite Vein in FNX4130 @ 2665ft

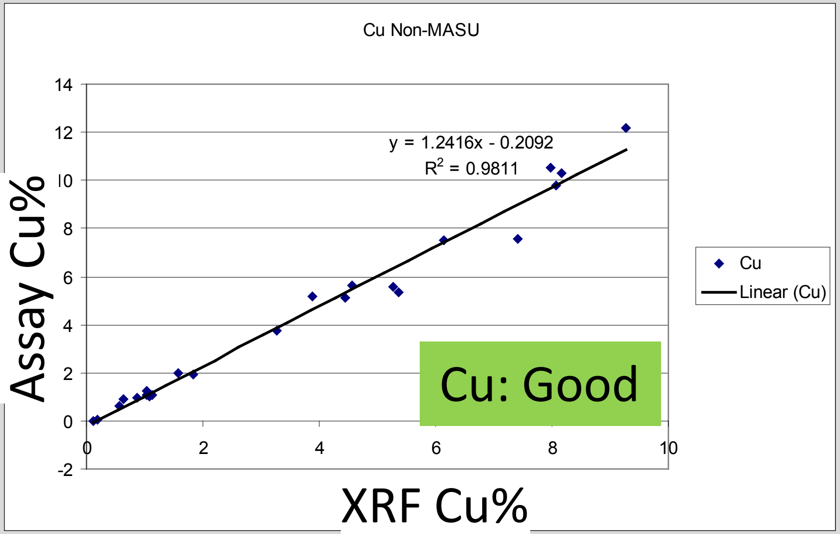


Core Samples

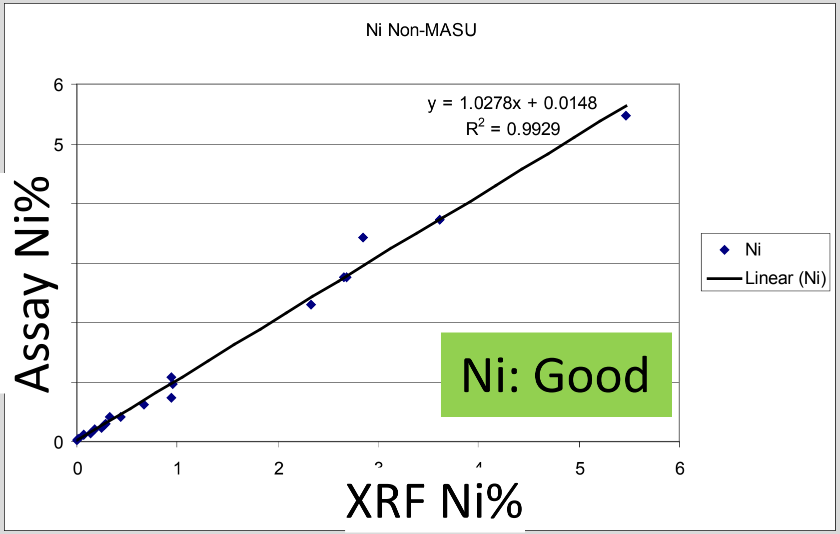
Stockwork Chalcopyrite Veinlets in FNX4130 @ 2697-2717ft



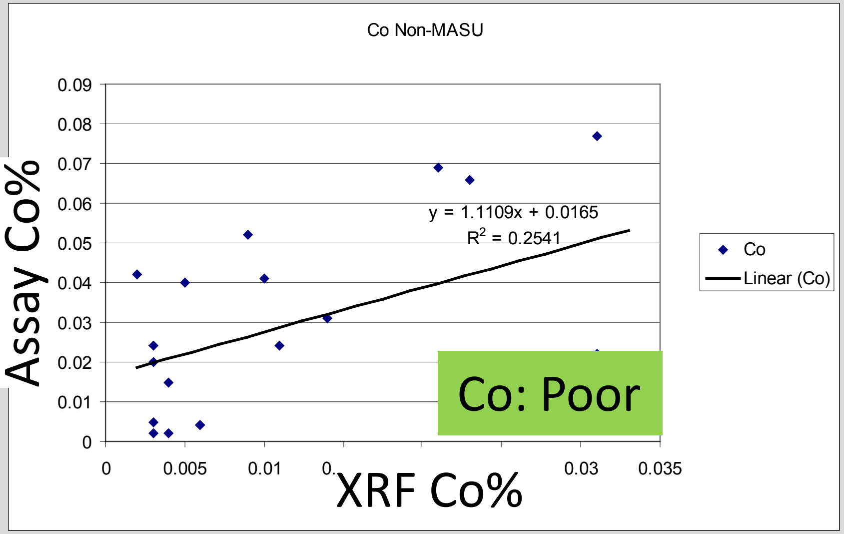
Calibration curves for samples with various levels of Cu and Ni concentration



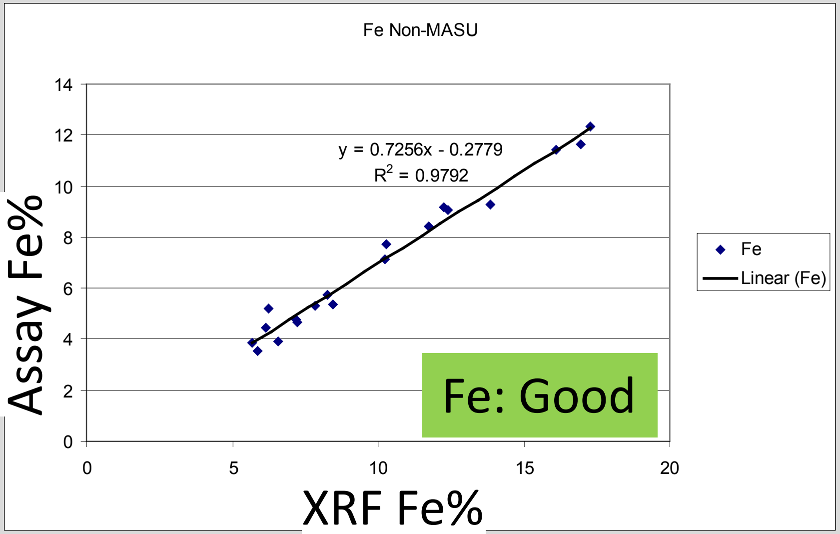
Cu : R^2 = 0.9811



Ni : R^2 = 0.9929



Co : R^2 = 0.2541



Fe : R^2 = 0.9792

Proof of Concept Results

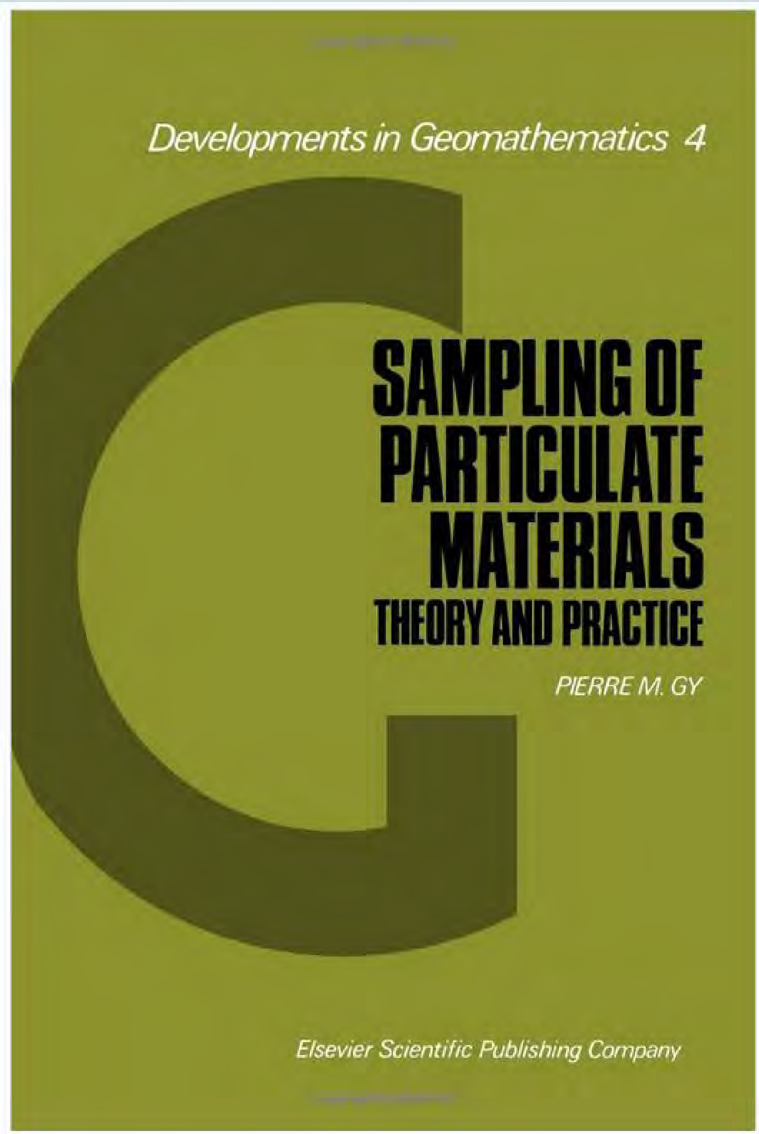
- 24 core and standard reference samples were run for Cu, Ni, Co, Fe, and other elements
- Reproducible results that correlated well with Assays were obtained for Cu and Ni in the concentration range of 0.6%-10% Cu, and 0.15-5.5% Ni
- Correlation coefficients of 0.98 for Cu, and 0.99 for Ni were obtained for this range of concentrations
- Correlation dropped off for Massive Chalcopyrite (e.g. samples with 25-33% Cu)
- Co did not give good results for most samples
- No meaningful PGE concentrations (2-15ppm) were obtained

Obtaining a Representative Sample of Production Grade

Obtaining a Representative Sample of Production Grade

- Since Podolsky Mine was shipping raw ore it was important that the estimate of production grade be obtained from a representative sample
- In order to obtain a representative sample correct sampling procedures must be carried out
- All sampling variances must be estimated for the sampling procedure in order to have a good level of confidence that the sample is representative of the shipped ore.

Pierre Gy, 1979, Sampling of Particulate Material: Theory and Practice. 488pp.



In the theory of Gy (1979), **correct sampling** is defined as a sampling scenario in which all particles have the same probability of being included in the sample.

$$V = \frac{1-q}{qM_{\text{batch}}^2} \sum_{i=1}^{N} m_i^2 \left(a_i - a_{\text{batch}}\right)^2$$

V = variance of the sampling error,
q = the probability of including the particle of the population in the sample
m i = the mass of the particle of the population
a i = the mass concentration of the property of interest
a_{batch} = the concentration of the property of interest in the population from which the sample is to be drawn
M_{batch} = the mass of the population from which the sample is to be drawn.

https://pediaview.com/openpedia/Gy's_sampling_theory

Lot Sampling Application at Podolsky Mine
Calculation of Fundamental Sampling Error (FSE)

In order to have correct sampling, all variances must be estimated throughout the sampling procedure. This estimate is called the Fundamental Sampling Error (FSE).

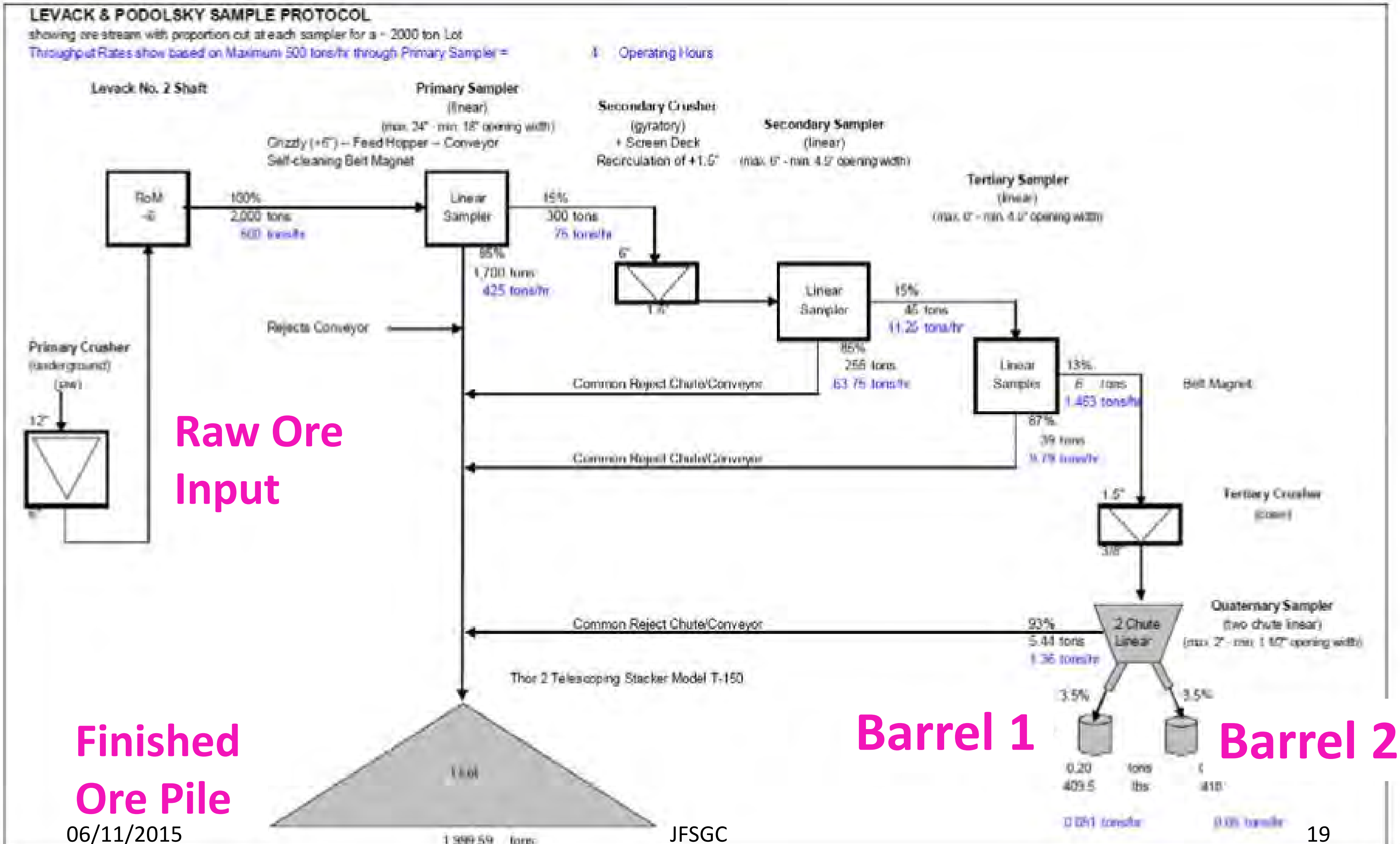
FSE^2 =	**$C \times dn^3(1/Ms - 1/Ml)$**	**where**	**$C = c \times f \times g \times l$**	
Formula	density of chalcopyrite		ρM	
Items	mineralogical factor		c	≡ ρM t
	shape factor		f	
	granulometric factor		g	
	particle size (95% passing 6")		dn	
	final particle size (95% passing 1.25")		dn	
	Sampling Constant		C	
	sample mass		Ms	
	lot mass		Ml	

Developed by Jim Muir, FNX Director of Mine Technical Services

Obtaining a Representative Sample

- Sample Tower constructed to produce a homogeneous representative sample for each 2000 ton Ore Lot
- Sequential crushing, splits, and belt cuts result in 2 identical barrel samples per 2000 ton Lot. These are 520lb each. Approximately 0.25 lb sample per each ton of ore.
- 1 Barrel sent for Assay to determine payable grade
- 1 Barrel stored on site for Reference

Tower Sampling Flowchart

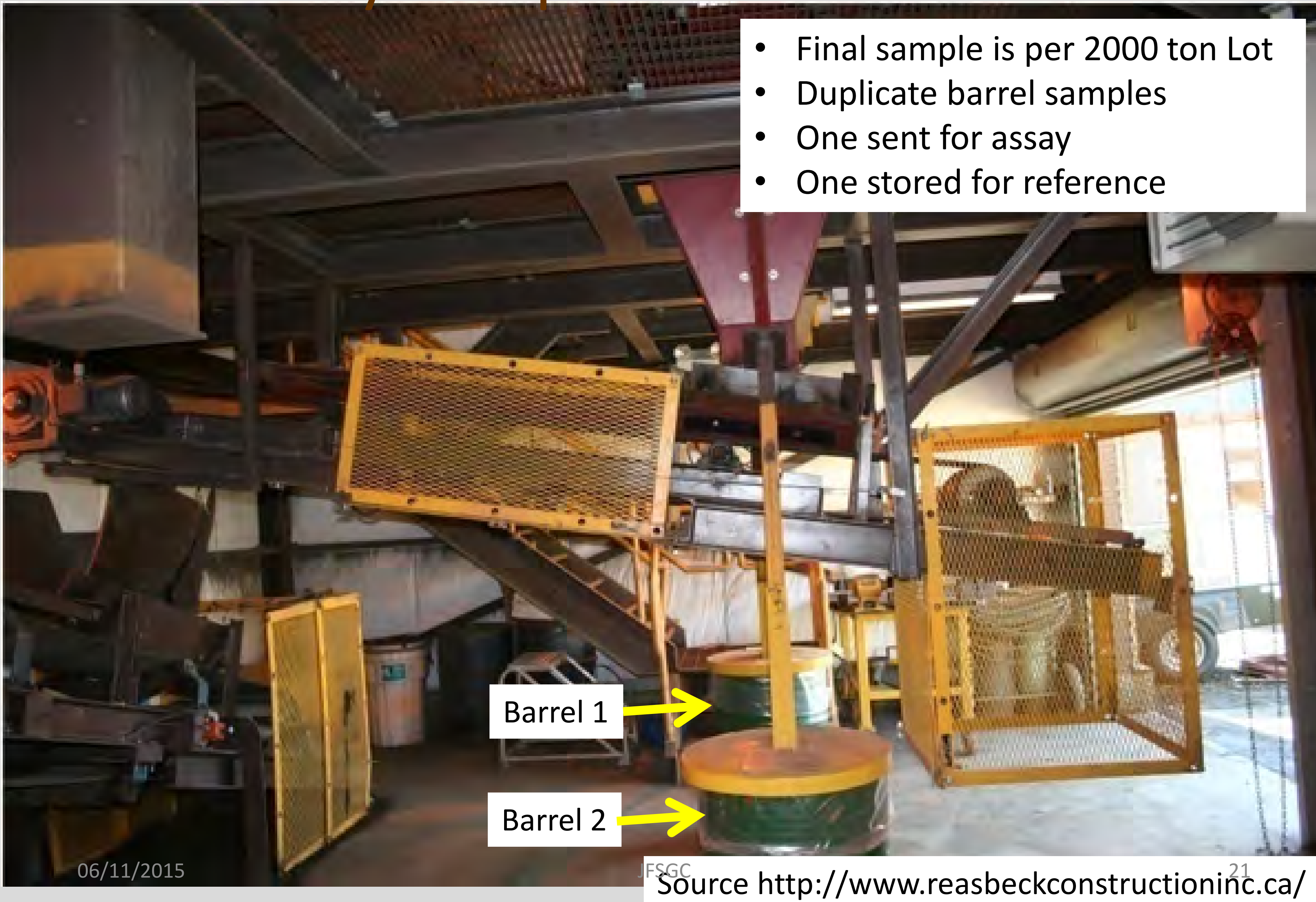


Podolsky Sample Tower March 2008

- 5 Level Sample Tower
- Belt cuts taken sequentially
- Output is representative barrel samples for each 2000 ton lot

http://www.reasbeckconstructioninc.ca/

Podolsky Sample Tower March 2008



XRF Sample Preparation

- Stored Reference Barrel was sampled in triplicate with an in-house developed sampling spoon
- Triplicate aliquots of 1kg prepped and analyzed
- Drying oven was used to remove all moisture first
- Samples pulverized to between 0.1mm to 2.0mm.
- Sieving done with shaker assembly
- 100% passing 120 mesh was used for analysis. The fine grain size helped minimize the matrix effects that are otherwise inescapable for pXRF analysis
- 2.5cm x 2.5cm homogeneous dry puck of fine size fraction was used for XRF analysis
- This procedure provided a **correct sample** with an acceptable FSE, and a fine grain size for pXRF analysis.
- QA/QC standards and various size fractions were included intermittently

Oven for sample drying

Rocklabs Crusher: 2.0 to 0.1mm prep size

Sieve set and shaker apparatus

Niton XRF Analyzer

- Model XL3
- Contained sample chamber to maintain sample distance and angle
- Prep "pucks" analyzed for Cu, Ni, Co, Fe...
- Standards for calibration

Estimates of Production Grade for Cu and Ni at Podolsky

Example of Production Grade Dataset

Estimate Cu Assay Cu Est. Ni Assay Ni

Sample_number	ContractualDate	estCu_pct	fnxCu_pct	estNi_pct	fnxNi_pct	estCo_pct	fnxCo_pct
PD30-00054	30-May-08	9.9181	9.24	0.7031	0.73	0.0082	0.01
PD30-00055	02-Jun-08	3.971	4.31	0.2939	0.48	0.0028	0.01
PD30-00056	06-Jun-08	7.6958	3.86	0.5449	0.42	0.0071	0.01
PD30-00057	10-Jun-08	12.8298	6.66	0.816	0.69	0.011	0.01
PD30-00058	12-Jun-08	10.2214	5.14	0.6523	0.48	0.0088	0.01
PD30-00059	15-Jun-08	6.5135	3.3	0.4764	0.47	0.0077	0.02
PD30-00060	17-Jun-08	5.2036	2.99	0.3672	0.35	0.0049	0.01
PD30-00061	19-Jun-08	5.1809	3.49	0.3735	0.4	0.0048	0.01
PD30-00062	21-Jun-08	6.2538	4.01	0.4904	0.39	0.0062	0.01
PD30-00063	24-Jun-08	3.9659	3.92	0.3139	0.37	0.0042	0.01
PD30-00064	25-Jun-08	3.3404	3.58	0.251	0.4	0.0033	0.01
PD30-00065	27-Jun-08	3.7816	4.34	0.293	0.4	0.0032	0.01
PD30-00066	30-Jun-08	4.59	4.92	0.3658	0.33	0.0029	0.01
PD30-00067	06-Jul-08	3.3596	3.42	0.2707	0.24	0.0031	0.01
PD30-00068	09-Jul-08	1.7663	1.32	0.1482	0.17	0.0025	0.01
PD30-00069	10-Jul-08	2.2748	0.89	0.189	0.12	0.0026	0.01
PD30-00070	12-Jul-08	1.8602	1.09	0.1559	0.09	0.0021	0.01
PD30-00071	15-Jul-08	1.79	1.7	0.1501	0.11	0.0023	0.01
PD30-00072	19-Jul-08	1.89	1.39	0.1583	0.11	0.0026	0.01
PD30-00073	22-Jul-08	4.14	4.41	0.4241	0.45	0.0056	0.01
PD30-00074	25-Jul-08	5.7269	4.92	0.5712	0.63	0.0076	0.01
PD30-00075	29-Jul-08	7.0322	5.2	0.5345	0.66	0.0058	0.01
PD30-00076	31-Jul-08	6.102	5.12	0.6682	0.57	0.0088	0.01
PD30-00077	31-Jul-08	6.2704	4.69	0.5798	0.54	0.0071	0.01
PD30-00078	02-Aug-08	7.2325	6.53	0.5477	0.56	0.0055	0.01

Comparison of Lot Assay vs Grade Estimates

Visual Grade Calls only

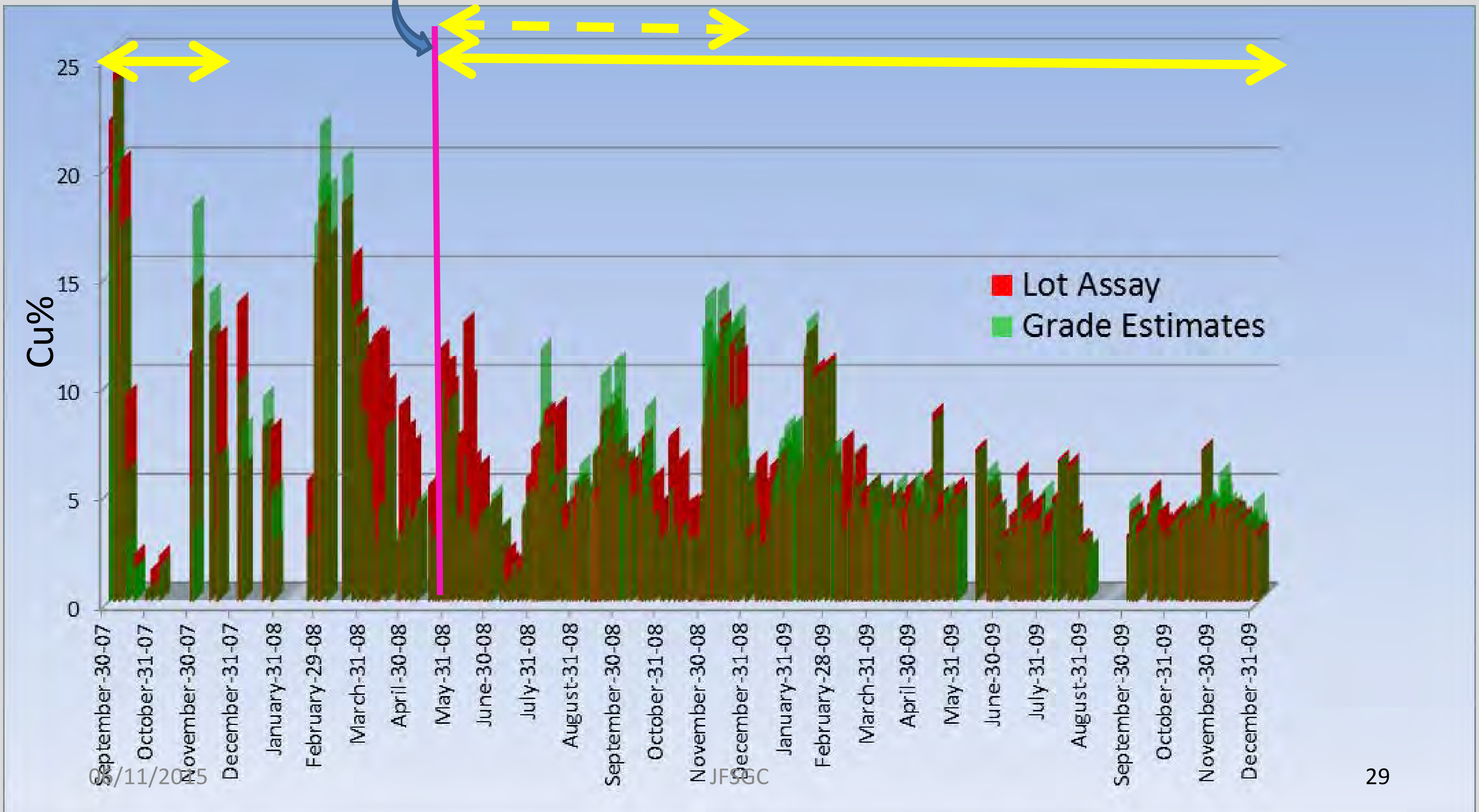
Pre-production

Commercial Production

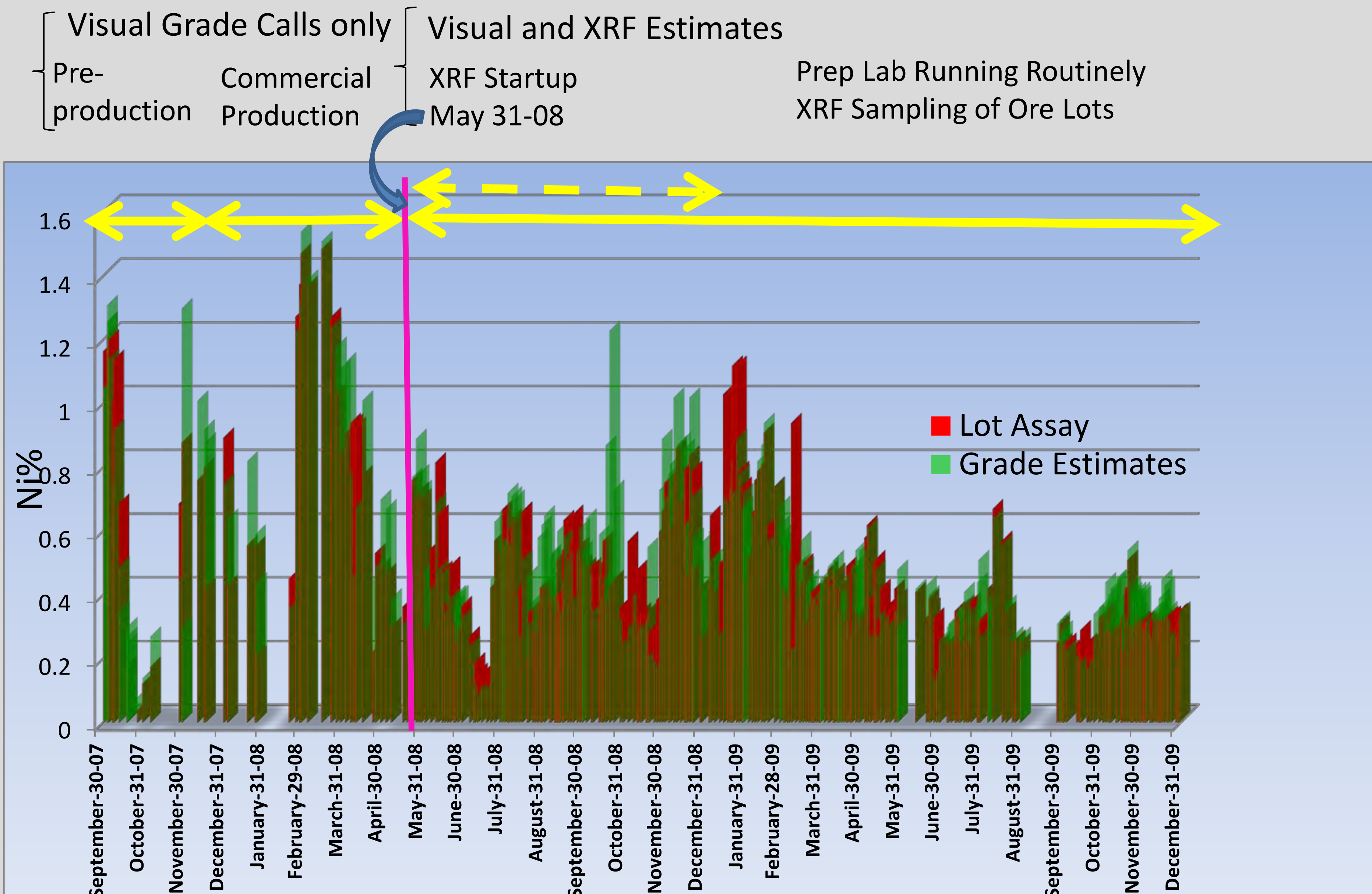
Visual and XRF Estimates

XRF Startup May 31-08

Prep Lab Running Routinely XRF Sampling of Ore Lots



Comparison of Ni% Lot Assay vs Grade Estimates

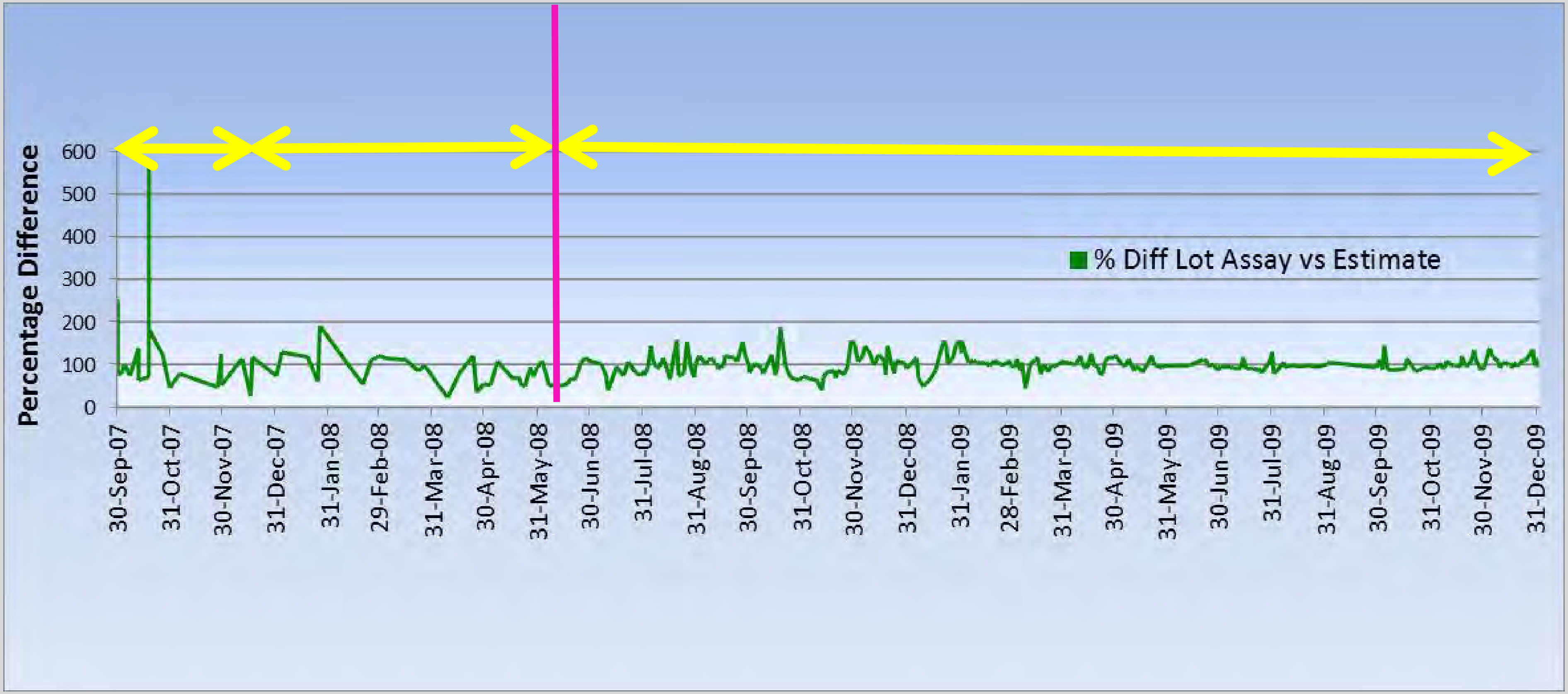


Comparison of Lot Assay vs Estimate % Difference for Cu%

Production
Visual Grade Calls
U/G and surface piles

XRF
Implementation

XRF Steady State use

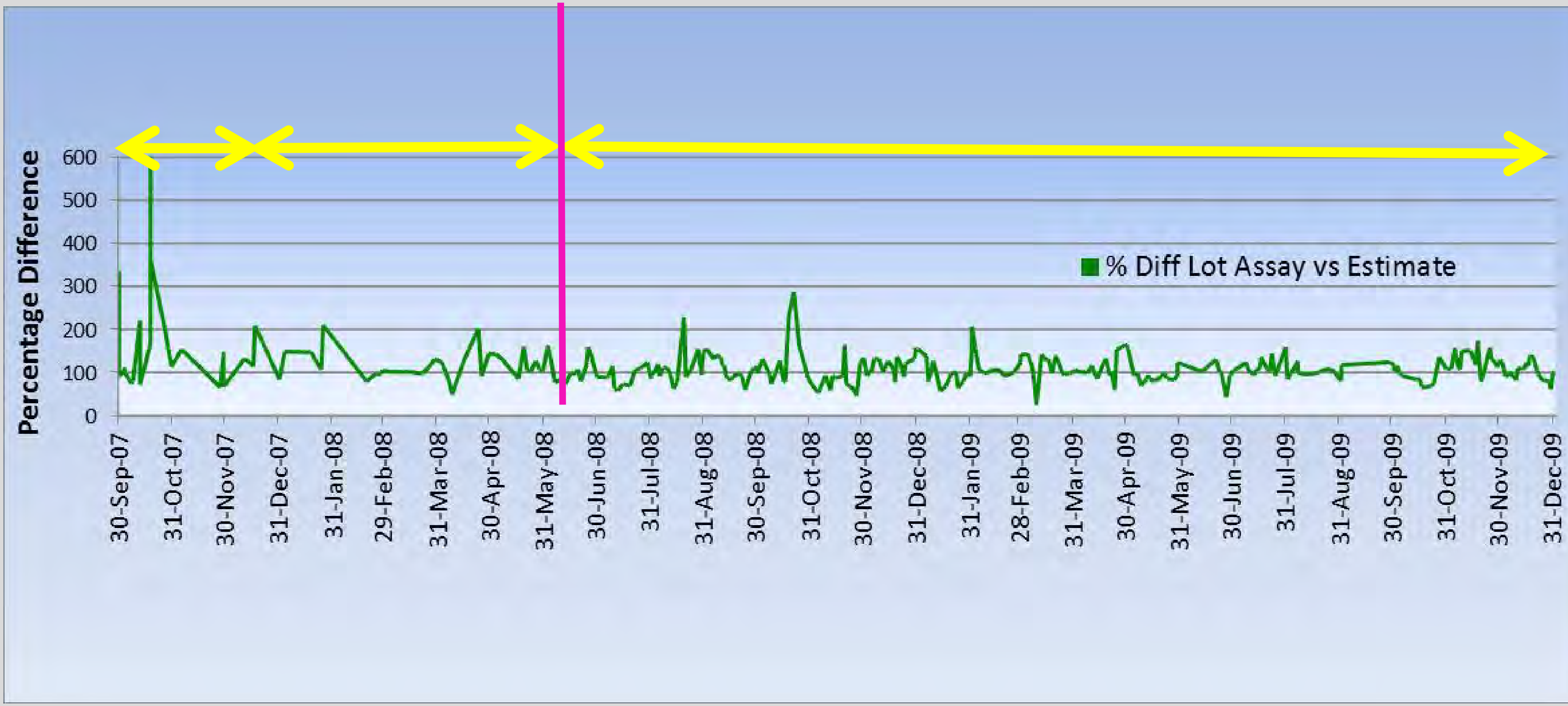


Comparison of Lot Assay vs Estimate % Difference for Ni%

Production
Visual Grade Calls
U/G and surface piles

XRF
Implementation

XRF Steady State use



Conclusions

- The applied methodology and the use of the portable XRF improved the estimates for the grade of shipped ore.
- With incremental implementation of the technique the estimates were on average around 80% of the actual assay grade, for 246 Lots in the 2 year period.
- The technique helped provide meaningful estimates of Cu and Ni grade for inventory database, especially with mixed ore grades from various stopes
- Gave a credible reason for requesting umpire assays if Lot Assay results seemed low
- Gave a credibility advantage to the Geology Department, since it was seen that our production grade estimates were reliable.

Acknowledgements

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