Nova-Bollinger Deposit
Mineral Resource Estimation Process

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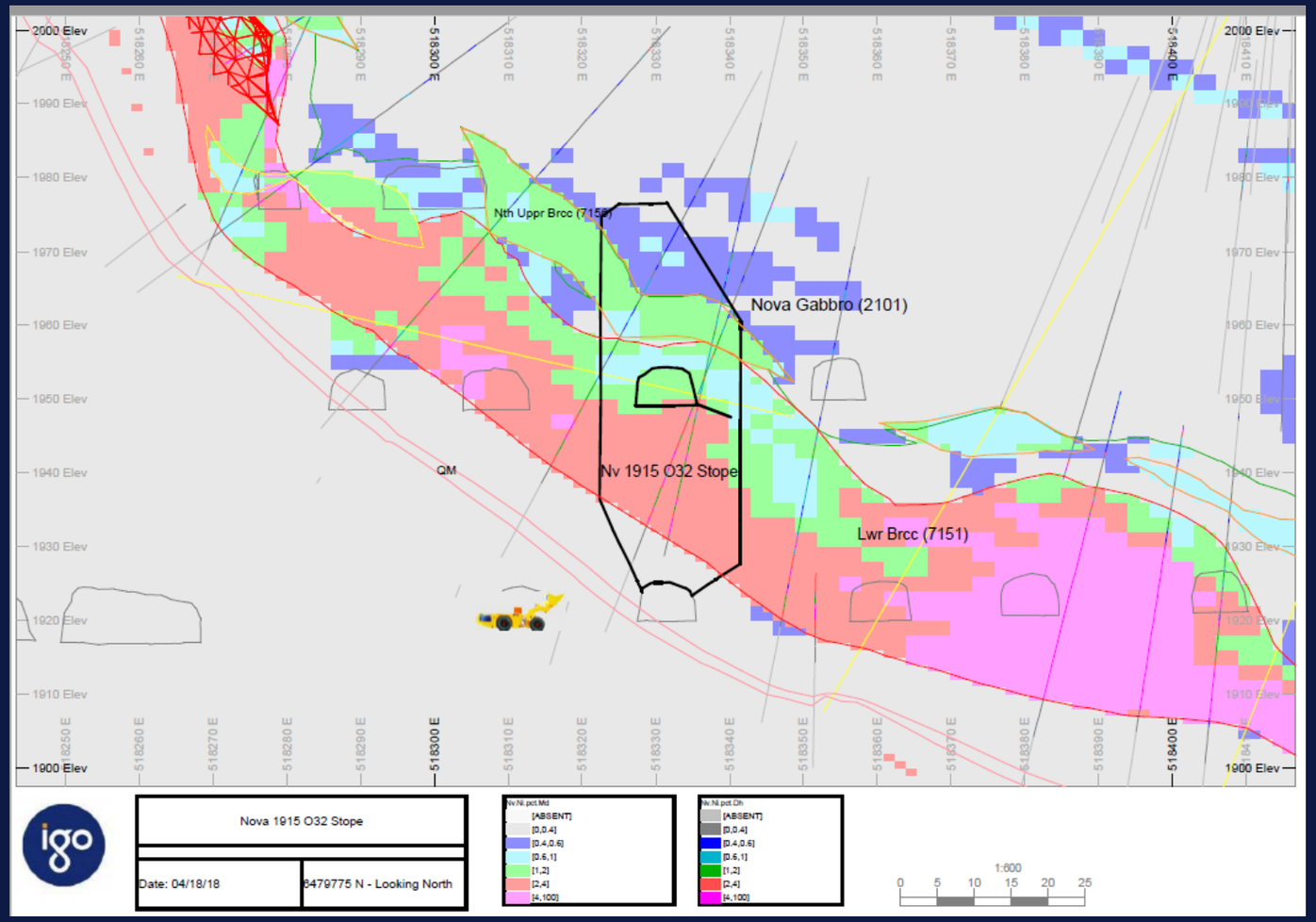

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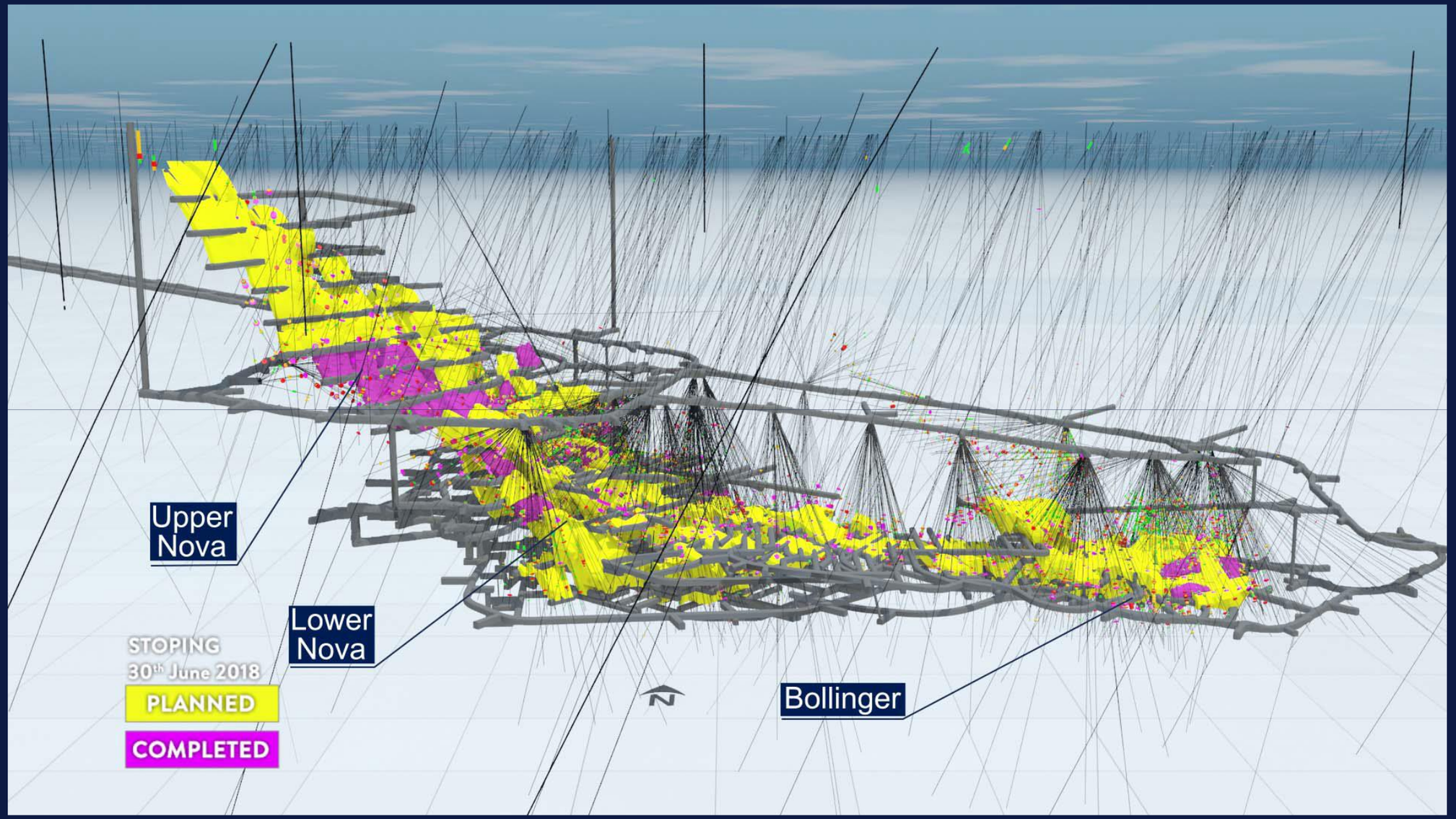
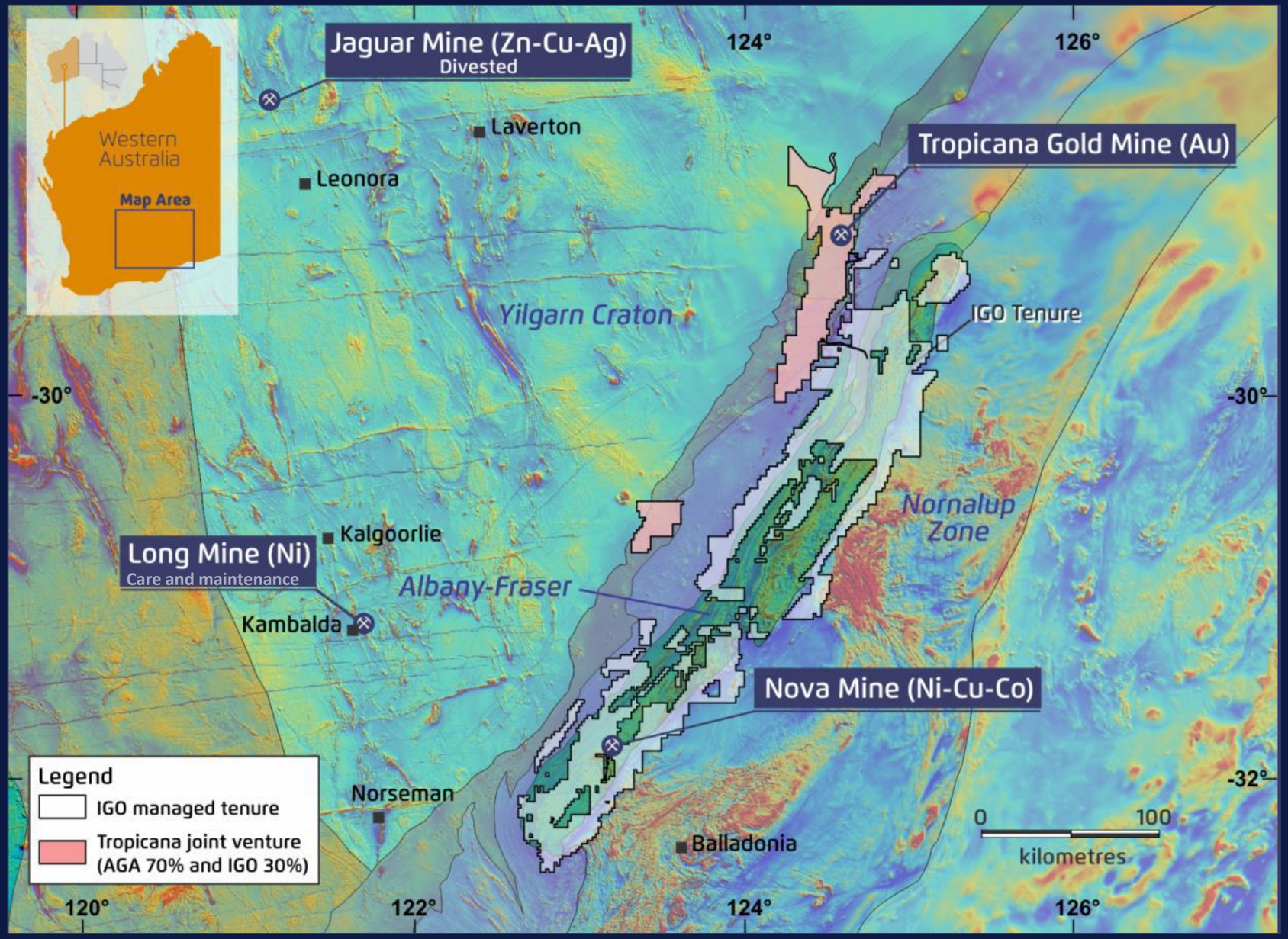
- Introduction
- Geology and Domaining
- Statistics and Simulation
- Validation, Classification and Governance
- Key learnings
- Acknowledgements

Introduction

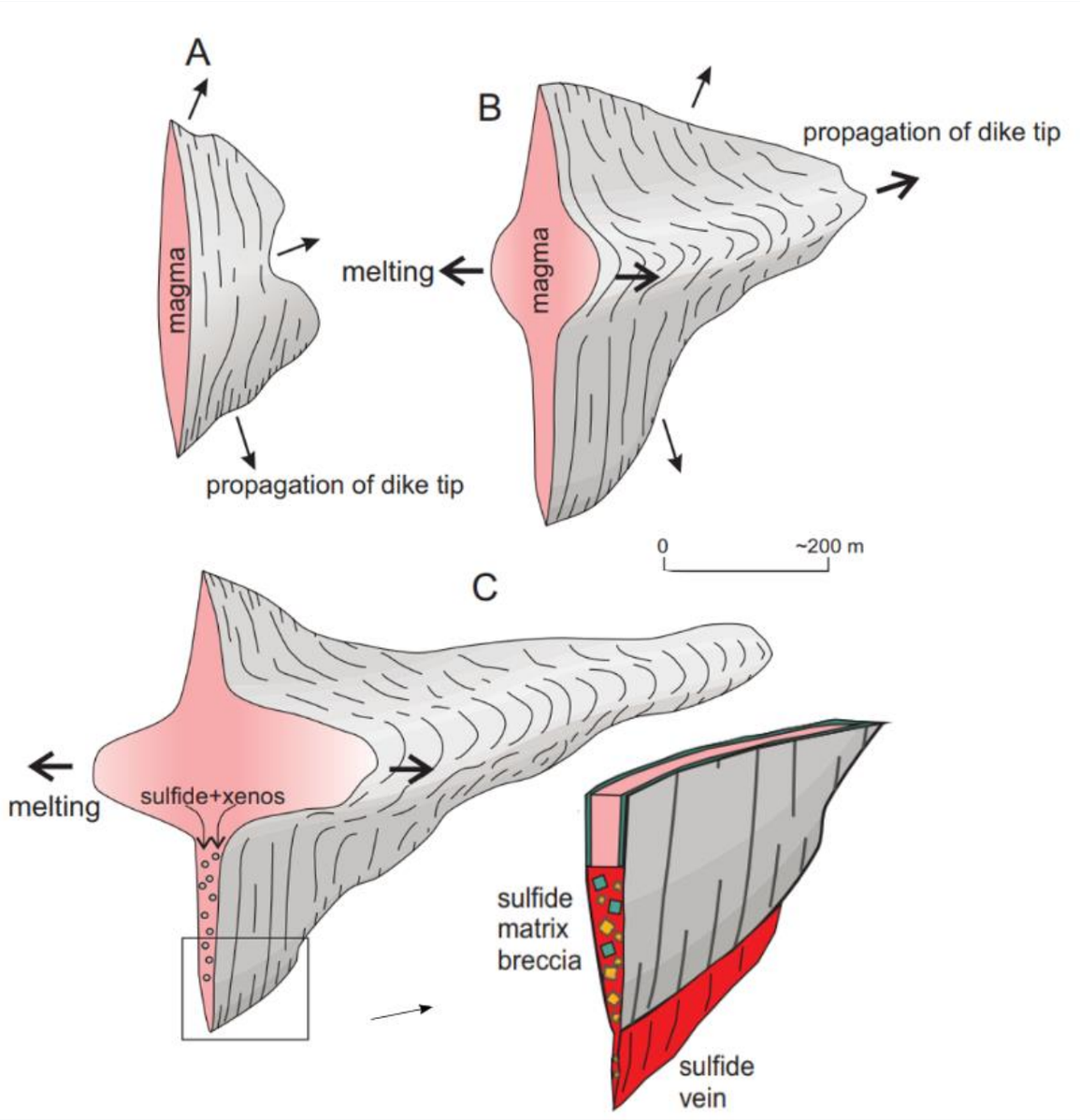


Location and history



- 120 km NNE of Norseman WA
- Within the amphibolite to granulite grade rocks of the Fraser Zone of Albany-Fraser Origin (AFO)
- Discovered by Sirius Resources NL in July 2012 following up targeting a GSWA soil anomaly
- Acquired by IGO September 2015
- First ore processed in July 2016 – ~ 1.9Mt processed to June 2018
- Mineral Resource 13.1Mt grading 2.0% Ni, 0.8% Cu and 0.07% Co
  (ASX release '2018 Mineral Resources and Ore Reserves Update' dated 26 July 2018)

Deposit Type

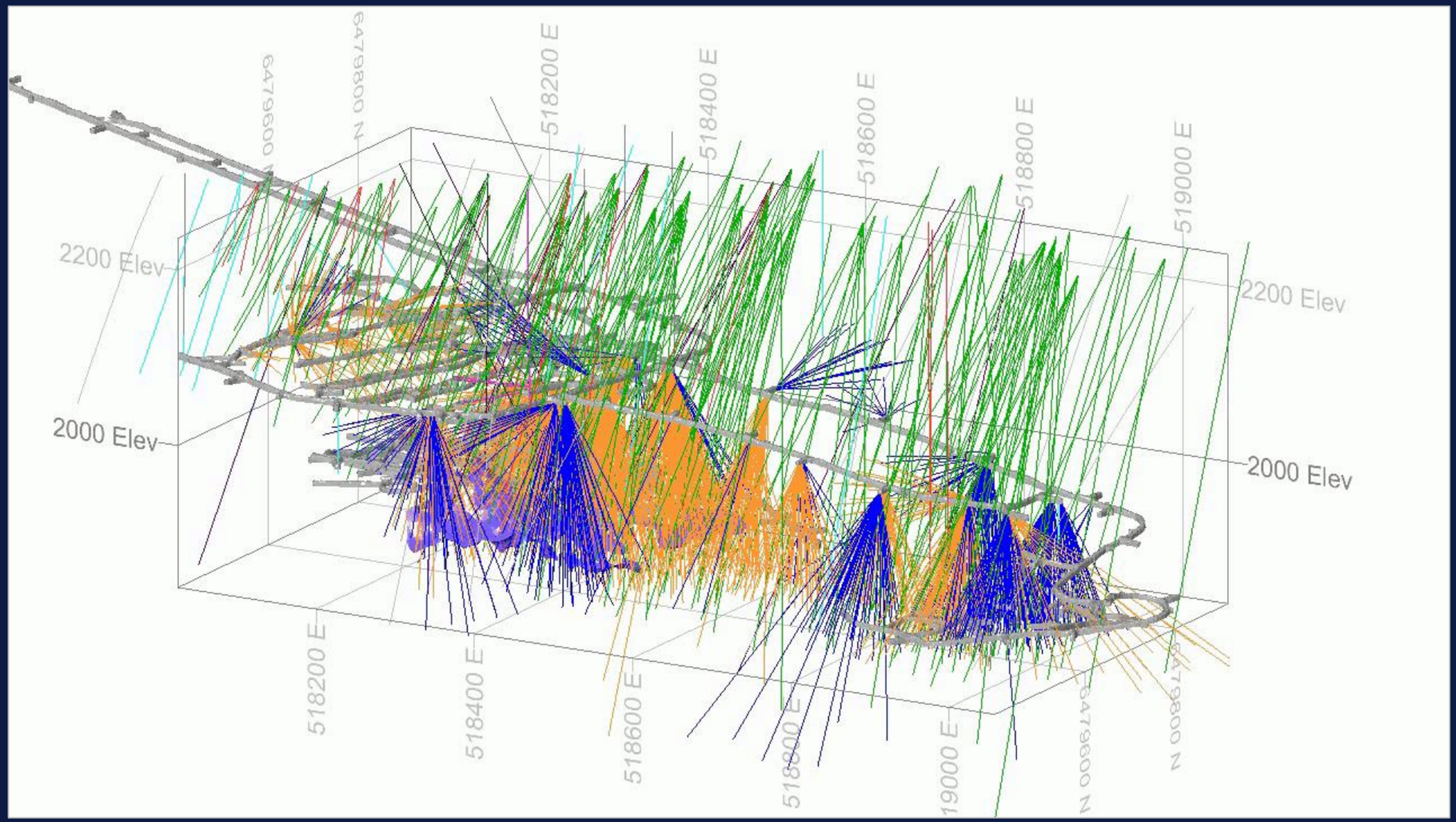


- Magmatic nickel-copper-cobalt deposit
- Pyrrhotite – pentlandite – chalcopyrite ore minerals
- Spatially related to the ‘Nova Gabbro’ chonolith
- Some similarities to the Savannah Deposit with
  - ‘Net textured’ sulfides in a olivine rich unit (picrite) on the south side of the Nova Gabbro
  - Massive sulfide breccia and splay mineralisation adjacent to or injected(?) into major fracture systems away from the gabbro
  - Net mineralisation transitional to gabbro at Bollinger
  - Stringer-style mineralisation clearly remobilised into metasediments

Barnes, S.J. and Mungall, J.E.
Blade-shaped dikes and nickel sulfide deposits: A model for emplacement of ore-bearing small intrusions
Economic Geology (2018) 113 (3): 789-798.

Drilling and sampling

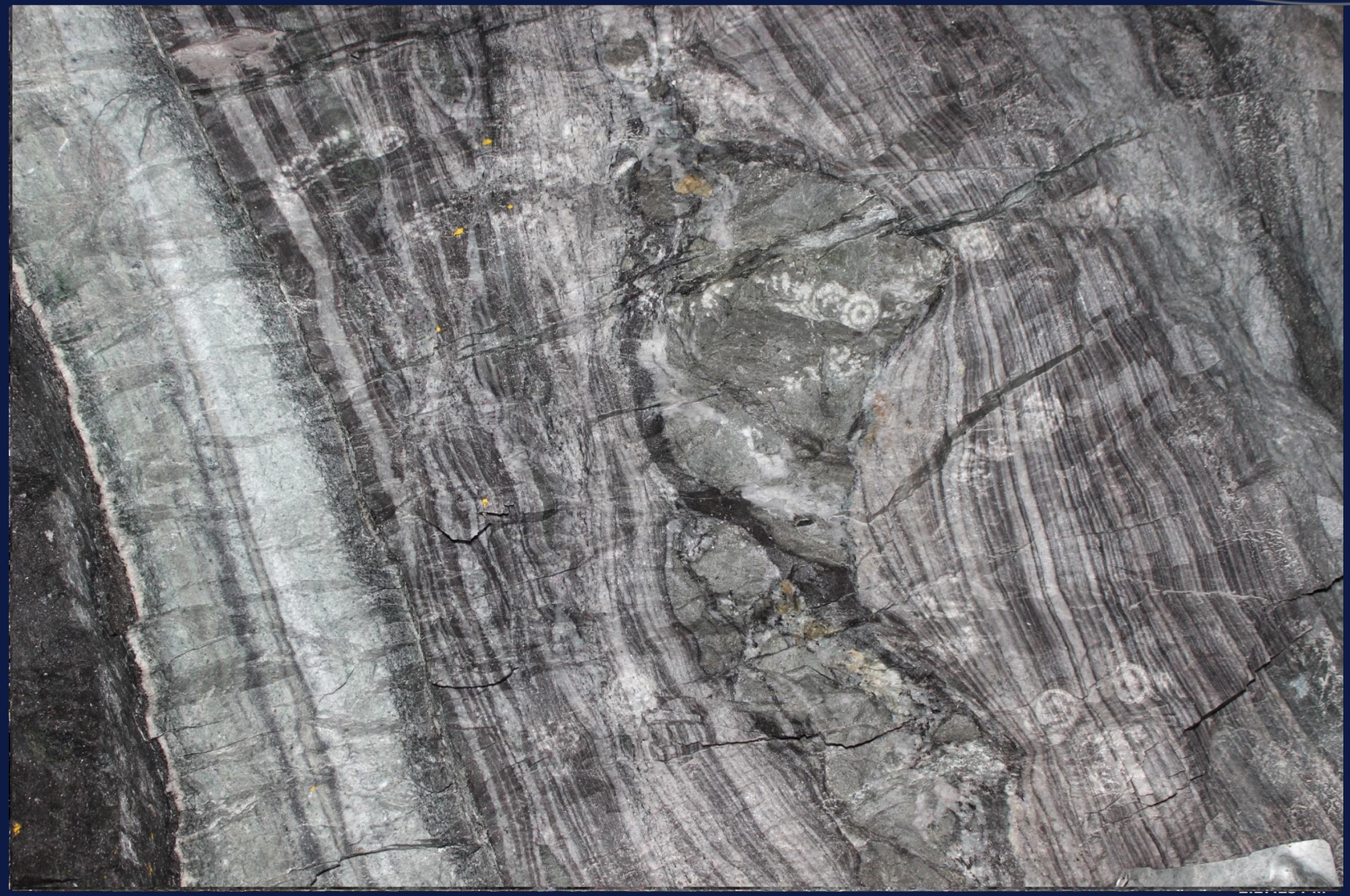
- Underground fan drilling from Nova development and ‘DDR’ (diamond drilling rig drive)
- Target a pierce point spacing of 12.5×12.5m through all estimation zones (+385 km of drilling so far)
- Surface drilling half-core assayed, underground mostly whole core assays



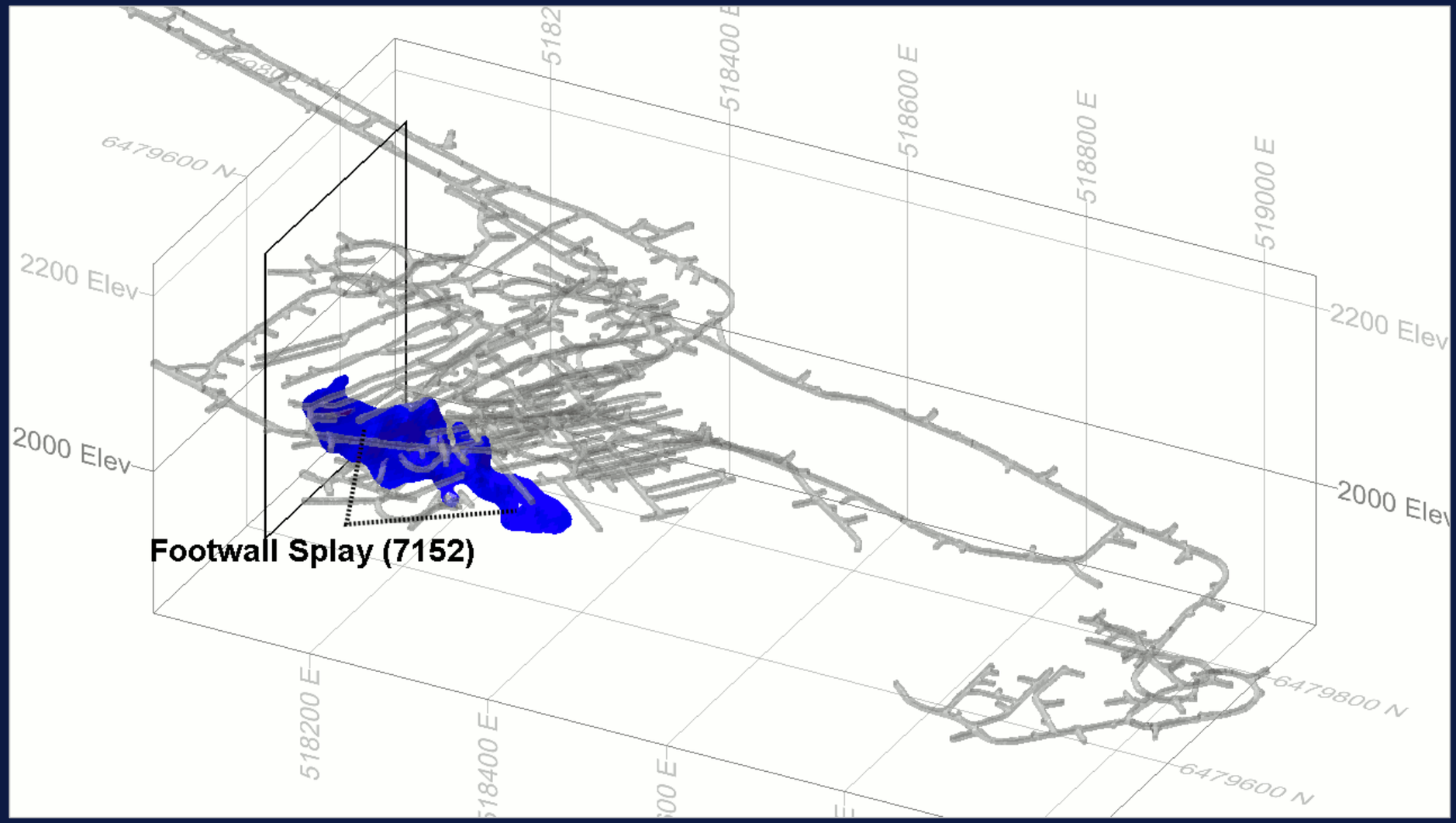
Geology and Domaining

Drill hole logging

- Standard logging legend based around sulfide mineralisation and/or rock type
- Logged styles range through disseminated, blebby, net texture, brecciated and massive
- Key units:
  - Breccias
  - Splays
  - Gabbros
  - Stringer Zones
  - Net (Matrix)
  - Waste halo

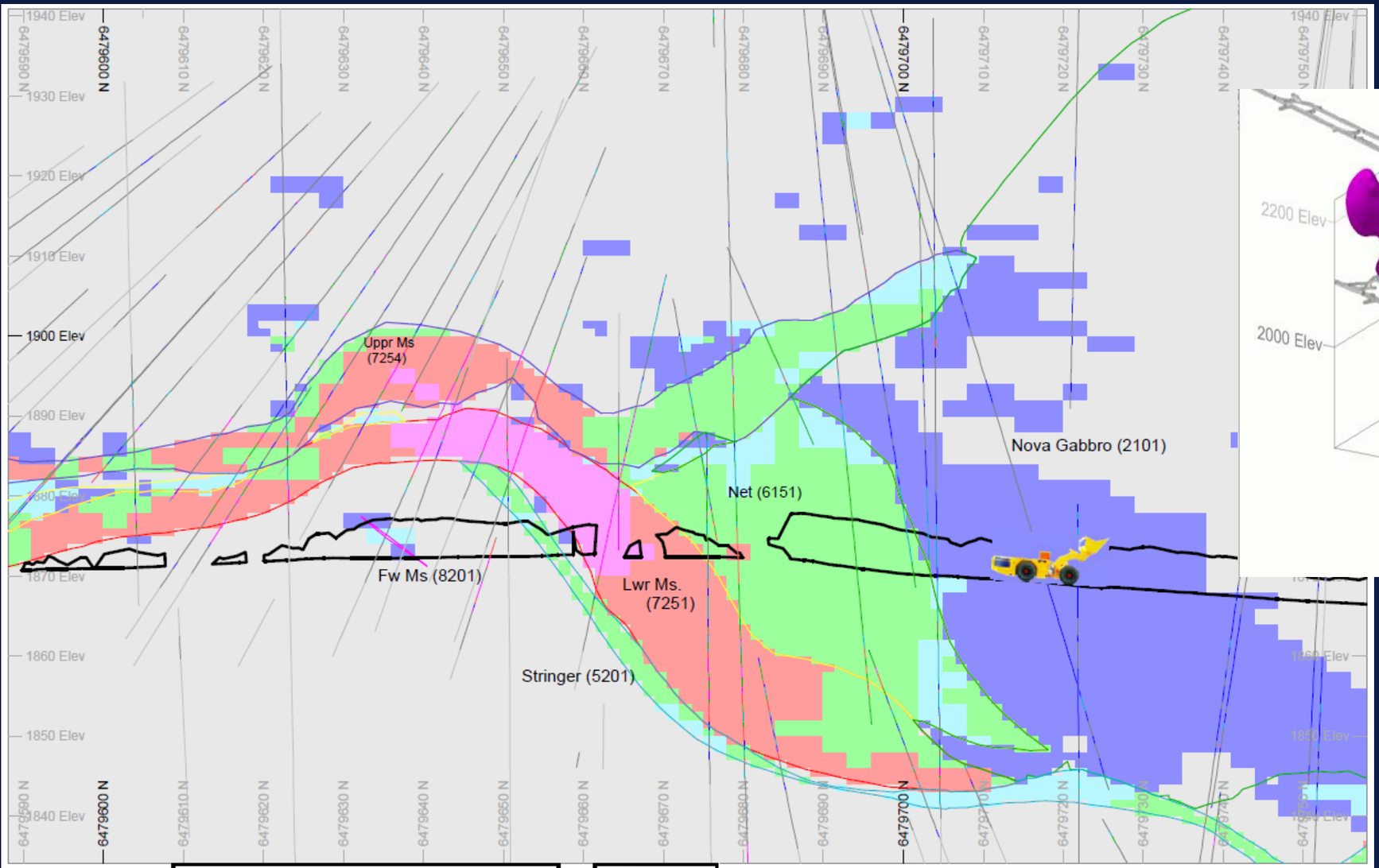


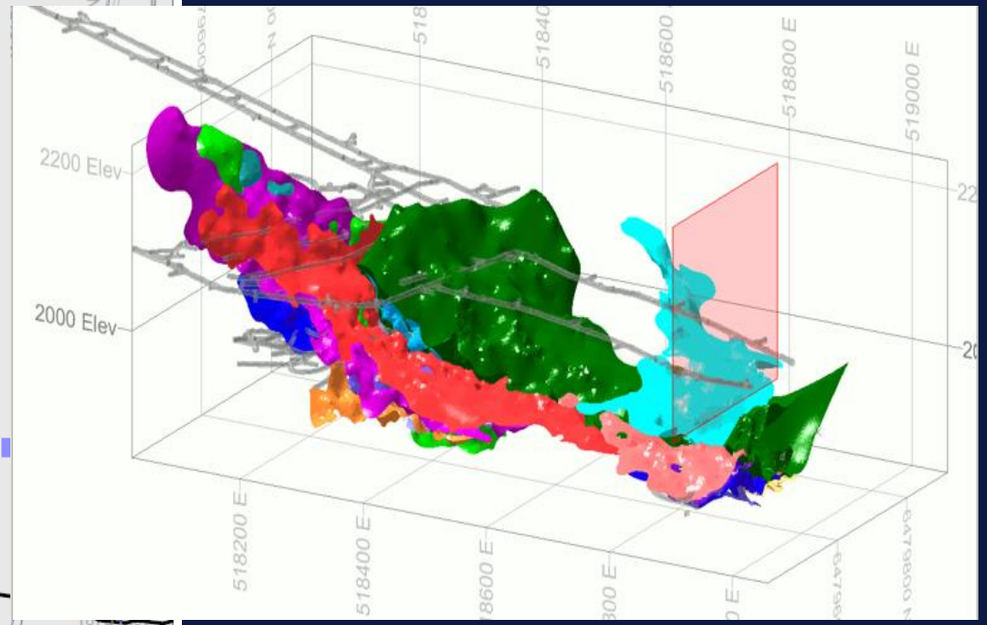
Interpretation – 3D



- 3D interpretation due to fan-style drilling
- LeapFrog with manual control strings as where required
- 20 mineralised domains modelled + waste halo
- Some domains intersect – resolved with Boolean methods

Interpretation – 2D

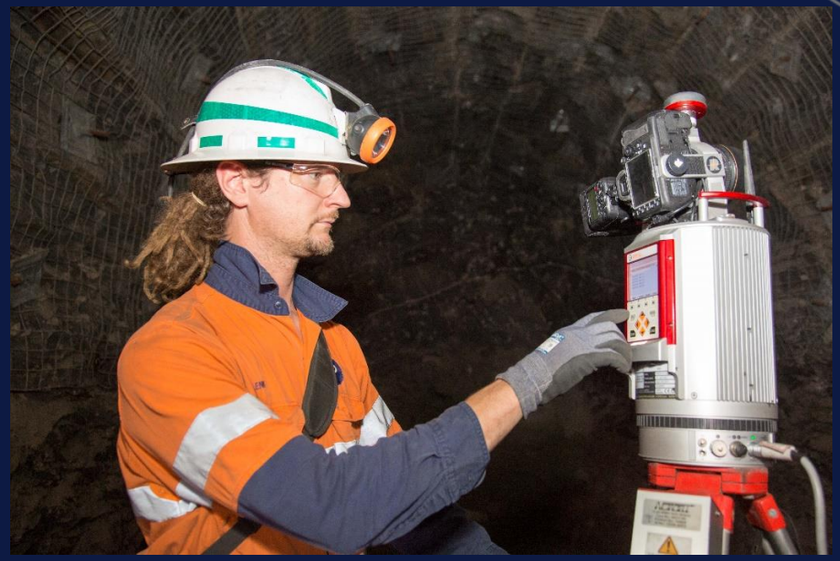


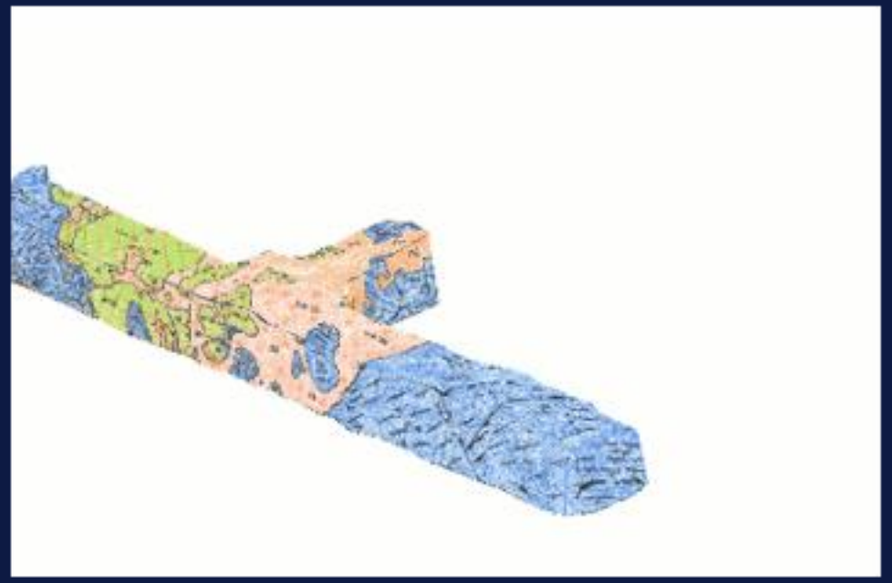


- Bollinger Section looking grid west
- Colour coded by nickel grade

Interpretation – Underground mapping

- Detailed mapping from 3D image scanner (RIEGL)
- Interpretations draped on mine surveys
- Very good correspondence with drill hole interpreted zone boundaries – wireframes updated with scan data

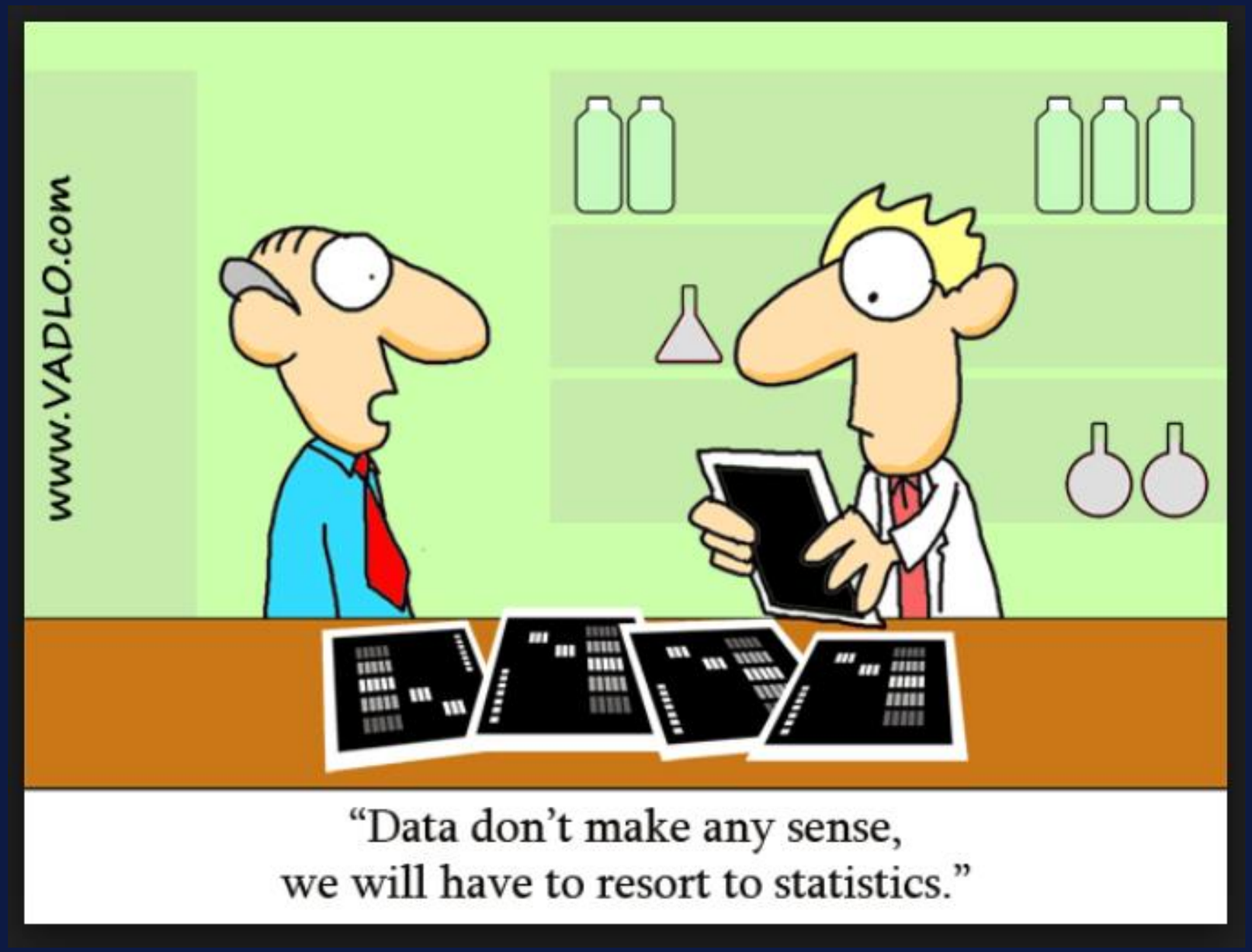




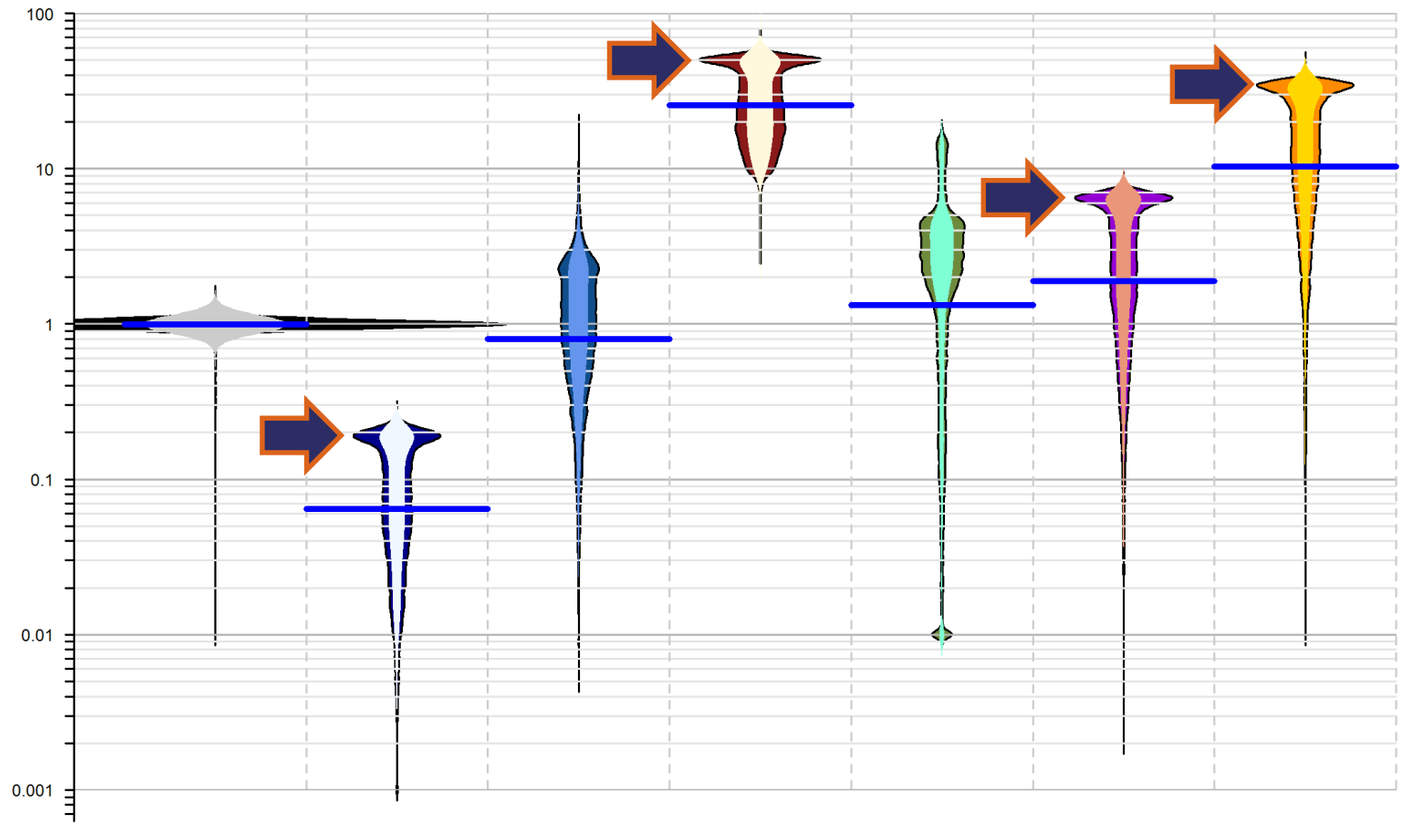
Quiz time

What shape can you see in the sulfides?

Statistics and Simulation



Composite statistics and outlier grade caps

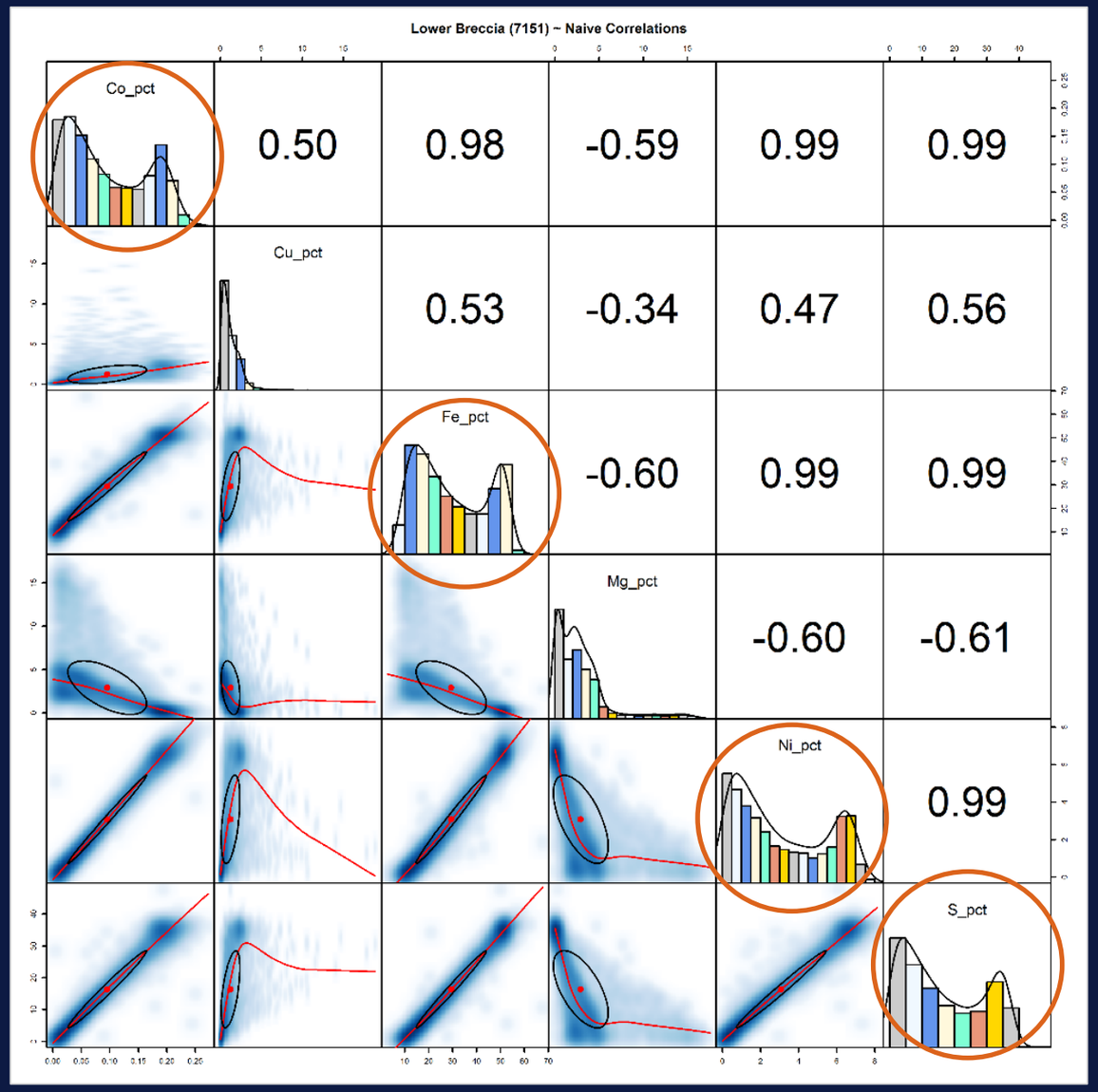


	LENGTH		CO_PCT		CU_PCT		FE_PCT		MG_PCT		NI_PCT		S_PCT	
	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt	Eq.Wt.	Dcl.Wt
Data |>	8390	8390	8390	8390	8390	8390	8390	8390	8390	8390	8390	8390	8390	8390
Min. |>	0.010	0.010	0.000	0.000	0.005	0.005	2.880	2.880	0.010	0.010	0.002	0.002	0.010	0.010
Max. |>	1.500	1.500	0.272	0.272	18.920	18.920	67.638	67.638	17.565	17.565	8.124	8.124	47.813	47.813
Mean |>	**0.993**	**0.994**	**0.095**	**0.095**	**1.238**	**1.242**	**29.415**	**29.301**	**2.908**	**2.900**	**3.085**	**3.066**	**16.389**	**16.253**
SD |>	0.062	0.080	0.069	0.068	1.142	1.145	14.708	14.413	3.103	3.003	2.338	2.316	12.126	11.930
CV |>	**0.062**	**0.080**	**0.723**	**0.715**	**0.922**	**0.922**	**0.500**	**0.492**	**1.067**	**1.035**	**0.764**	**0.756**	**0.741**	**0.732**
P05 |>	0.943	0.933	0.010	0.011	0.105	0.109	10.182	10.340	0.035	0.046	0.188	0.216	1.023	1.277
P50 |>	0.997	0.997	0.077	0.076	0.930	0.929	26.141	25.895	2.225	2.269	2.421	2.365	13.349	13.094
P95 |>	1.044	1.060	0.207	0.207	3.097	3.135	51.943	51.779	10.478	9.656	6.831	6.794	35.849	35.534
P97.5 |>	1.070	1.110	0.216	0.215	3.811	3.983	52.634	52.476	13.346	13.031	7.040	7.004	36.566	36.309

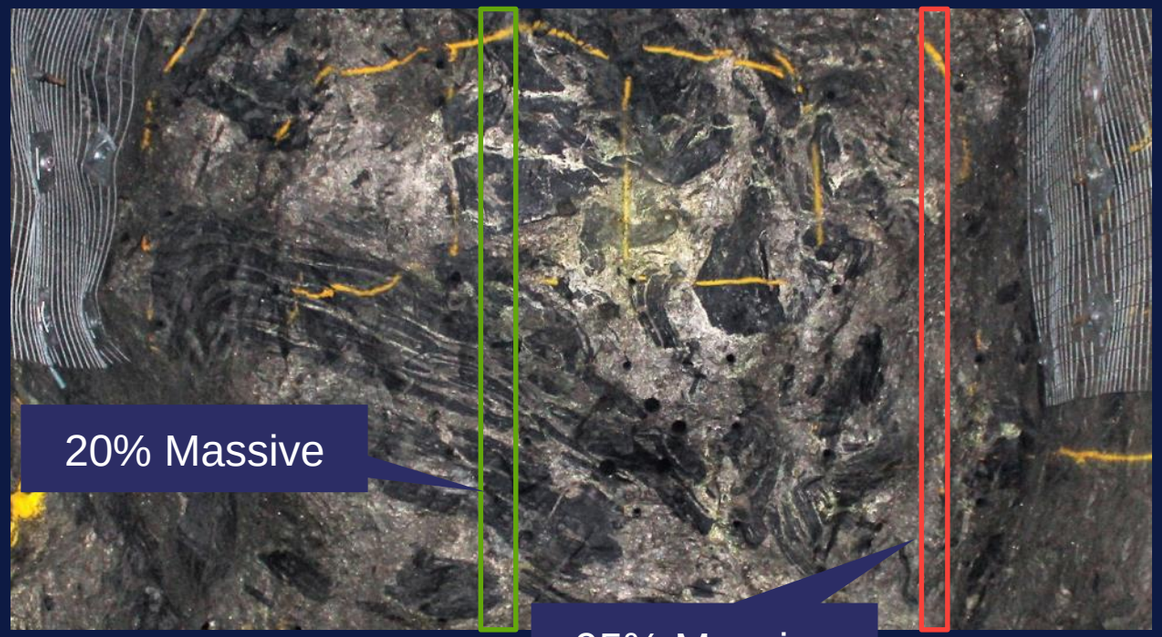
(Bean plots are not declustered but cell declustering weights are applied to results in blue)

- Bean-plots (reflected histograms) prepared for ‘1m’ composites for each estimation zone
- Equal-weighted and NN spatially -weighted statics compared
- Usually only minor differences between equal weighed and spatially weighed results
- All CVs are low (below 1.5) and no material outliers - no grade capping required
- Note high-grade (sulfide) sub populations in all Co-Fe-Ni-S distributions

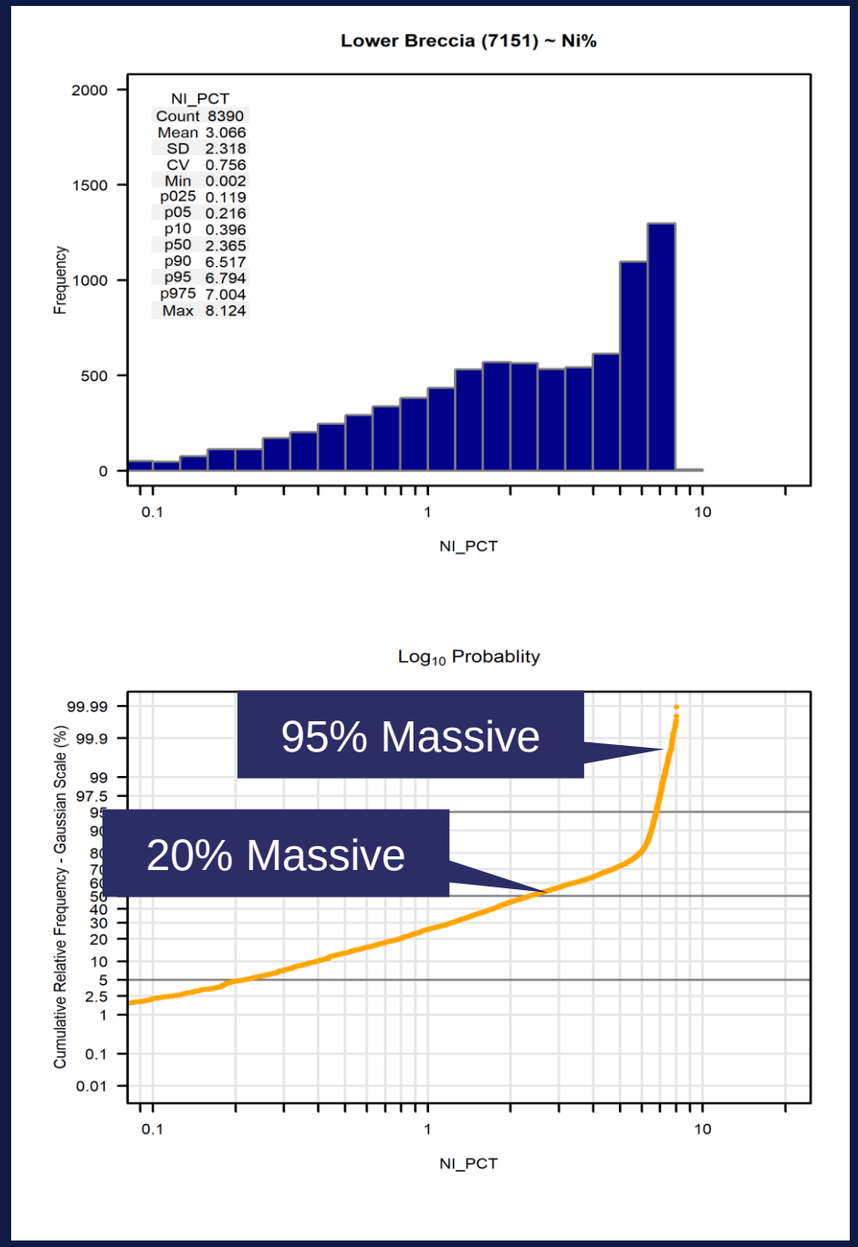
Mixed Population Problems

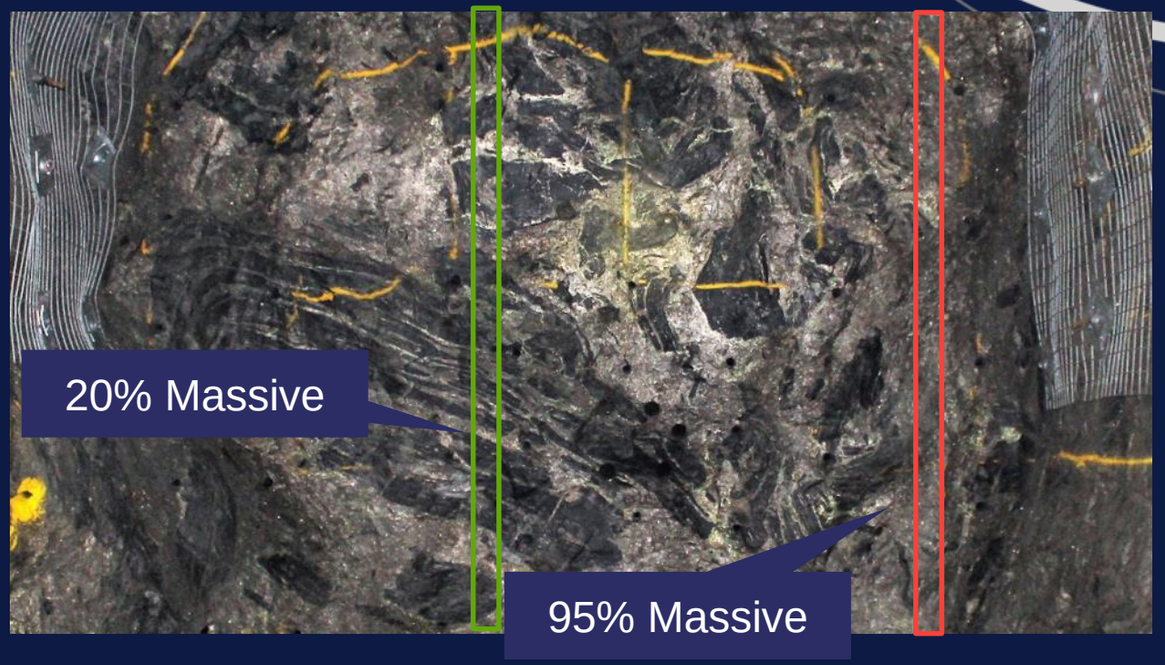


- Estimation zones interpreted based on similar geological (sulfide) character
- But zone drill hole composite histograms have mixed populations
- Bimodal shapes often a function of pure sulfides mixed with breccia blocks of with lower grades



Estimation – Mixed populations – What to do?



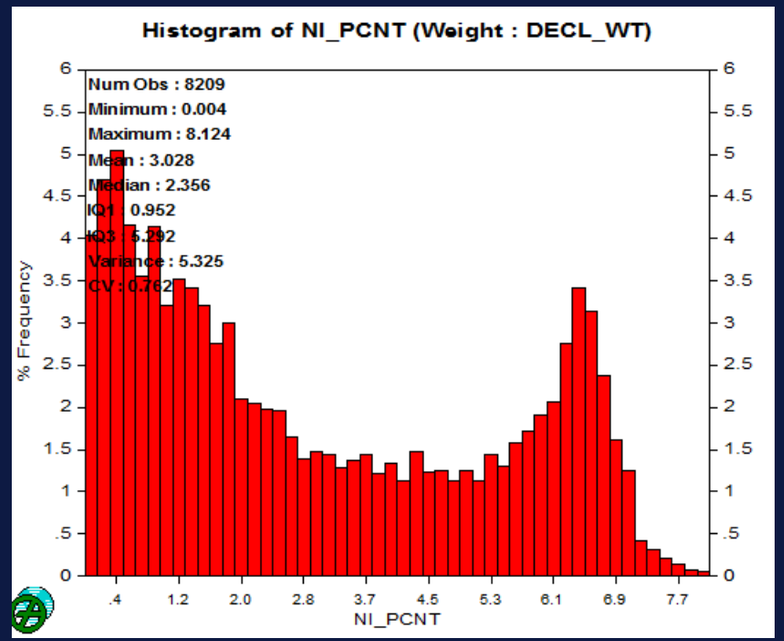


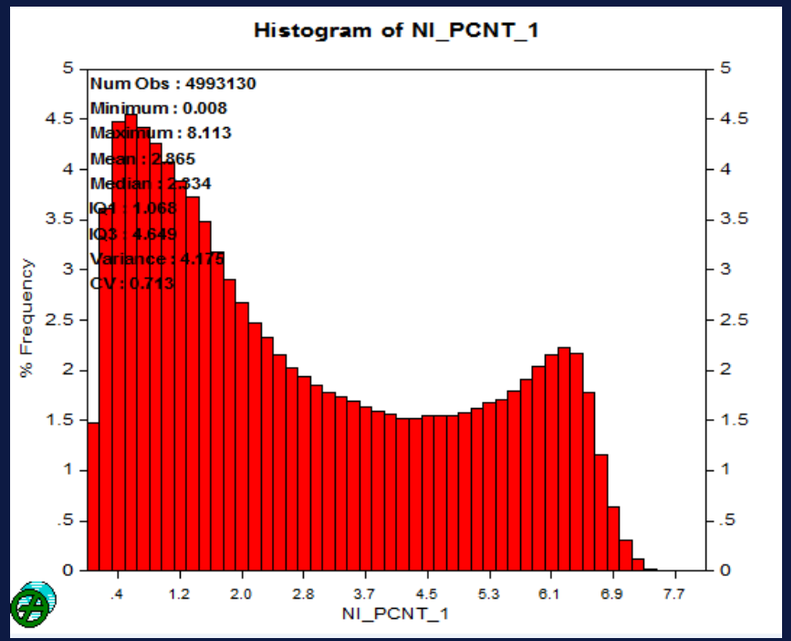
- Manual interpretation of ‘higher’ grades zones – subjective ?
- Indicator (categorical) code higher grade zones – has some statistical basis but can suffer the ‘spotted dog’ effect ? (applied on prior estimate)
- Indicator estimation of high and low grade zones and ‘tuning’ of proportions – has some statistical basis but the ‘tuning’ is subjective ?
- Use ordinary block kriging (OBK) as there is sufficient data to control local trends ?

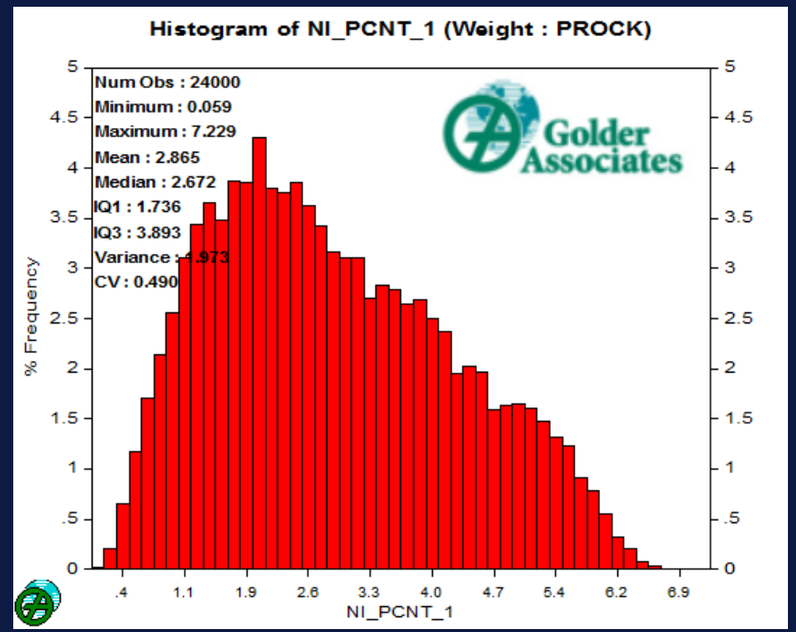
Conditional Simulation Study for Answers

- Conditionally simulate zones on a close grid (0.5 mE × 0.5 mN × 1.0 mElv) ~ 5 million nodes
- Some smoothing but histogram reproduction deemed reasonable ~ two histogram peaks reproduced
- Average simulation nodes into blocks (4 mE × 6 mN × 2 mElv)

Estimation 1 m composites	Realisation of 1 m composites	Block-averaged realisation





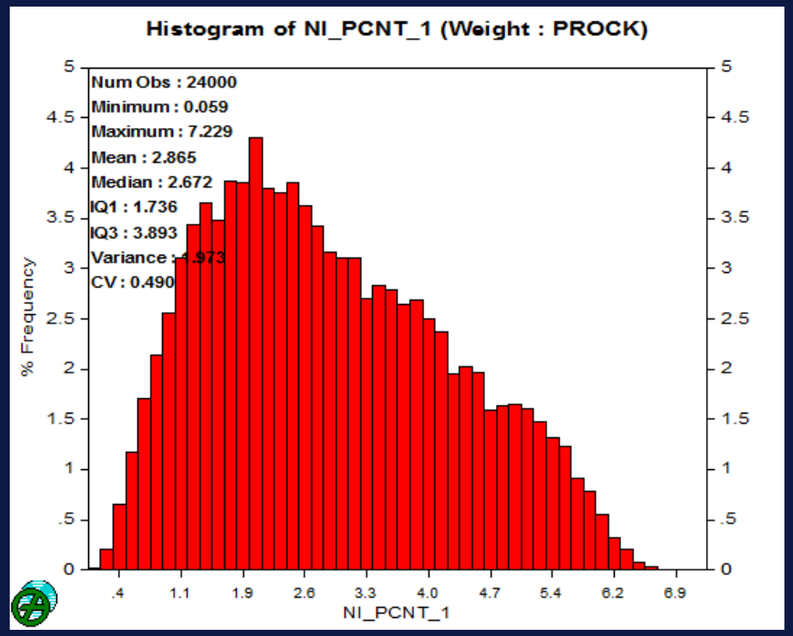


- Histogram shape normalises for blocks ~ this is the shape that should expected for block estimate

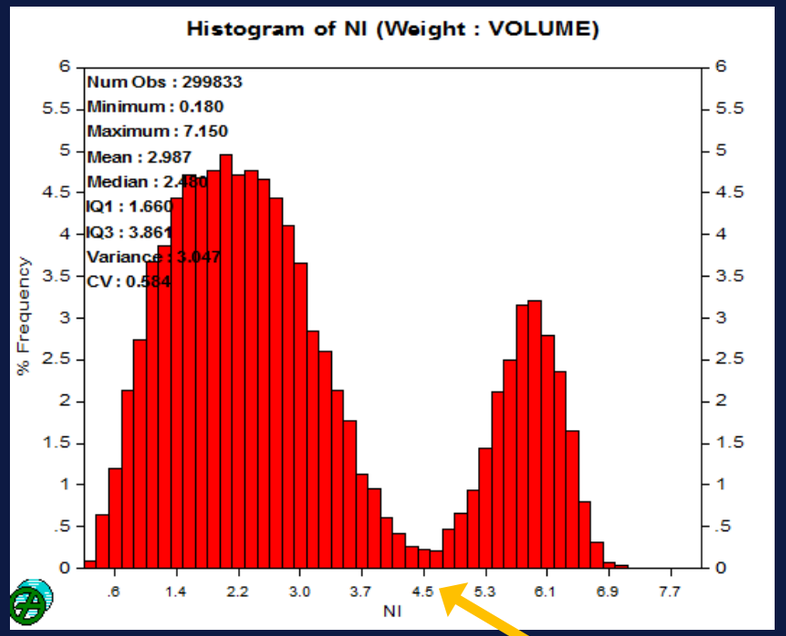
Compare Simulation to Categorical Estimate

- Compare block-average simulation histogram to the histogram of the categorical-indicator domained OBK estimate

Block-averaged realisation



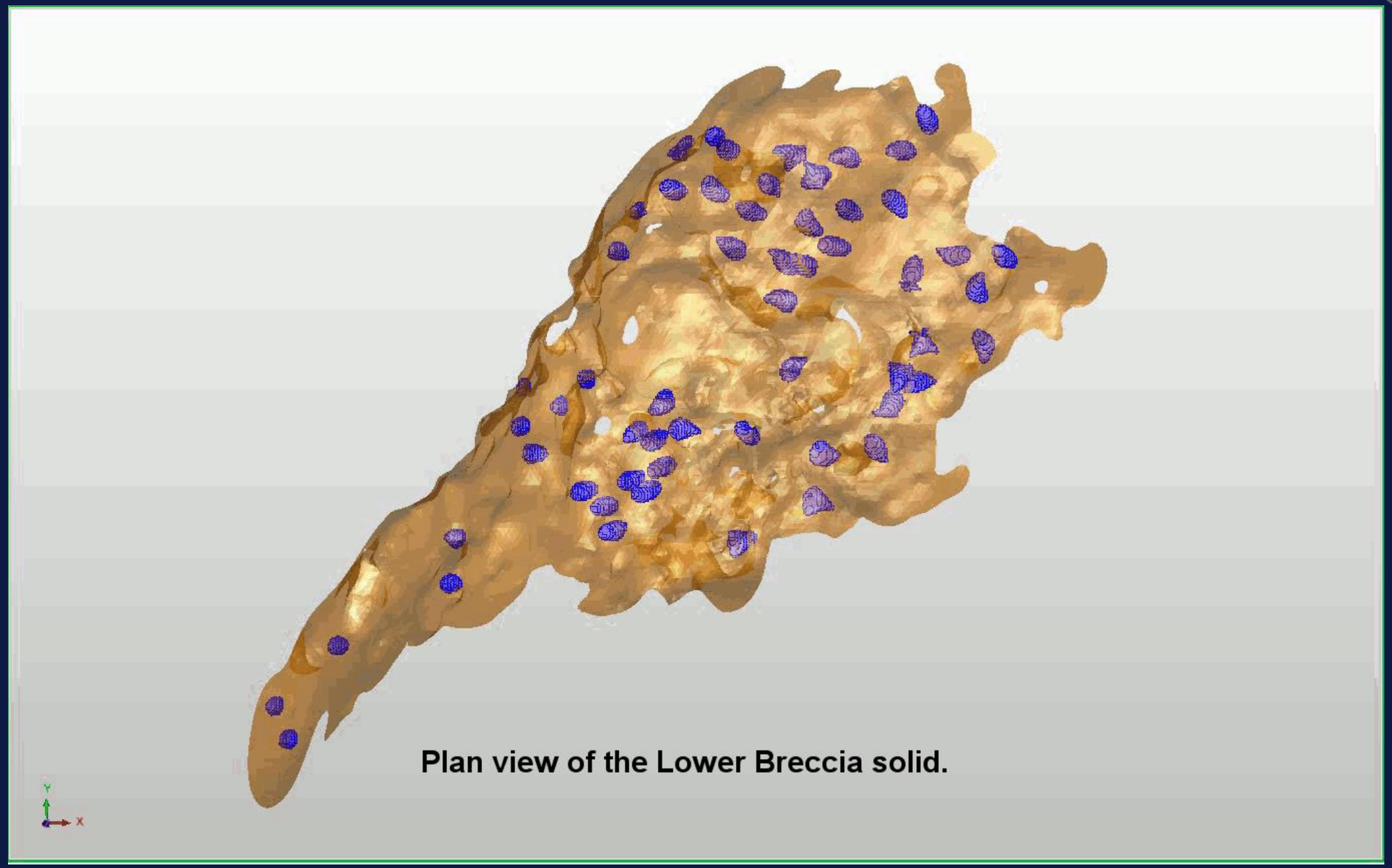
Categorical OBK estimate



- Conclusions:
  - The grade hard boundary at ~ 4.5% Ni creates and unrealistic block distribution
  - Categorical approach likely overstates the proportion of very high grade (>4.5% Ni)
  - Understates the tonnage of high grades (3% to 4.5%Ni)
  - Ordinary (whole domain) block kriging should give a reasonable representation

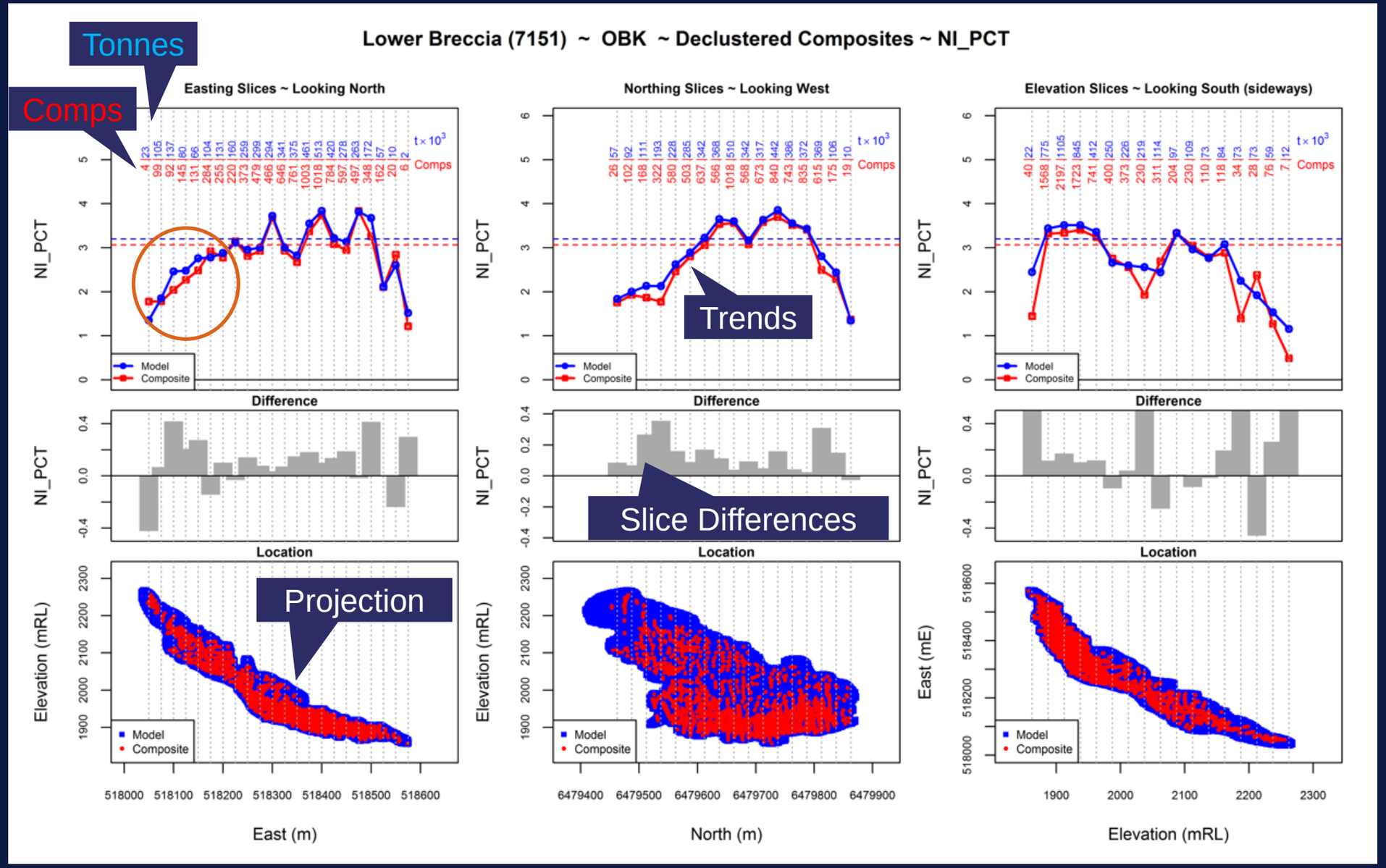
Validation, Classification and Governance

Dynamic Anisotropy Validation



- Dynamic search implemented using Interpolator add-on to Surpac

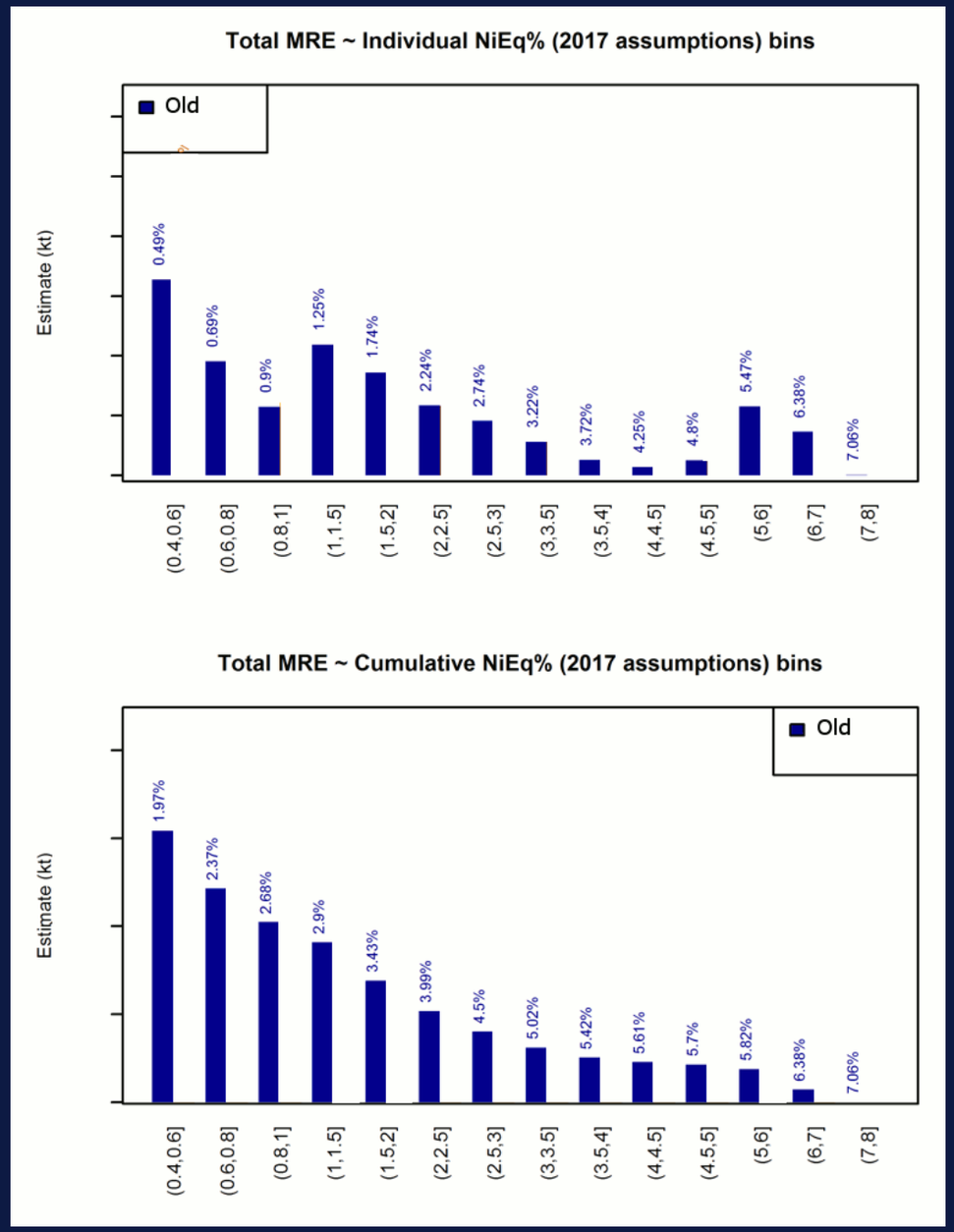
Validation of Global and Moving-window Means



Variable	Global Means		Comparisons	
	Comps (a)	Blocks (b)	(a)-(b)	(a)/(b)
Co%	0.095	0.099	0.004	104%
Cu%	1.242	1.282	0.039	103%
Fe%	29.301	30.113	0.813	103%
Mg%	2.900	2.804	-0.097	97%
Ni%	3.066	3.200	0.134	104%
S%	16.253	16.965	0.712	104%
Dn t/m³	3.743	3.770	0.027	101%

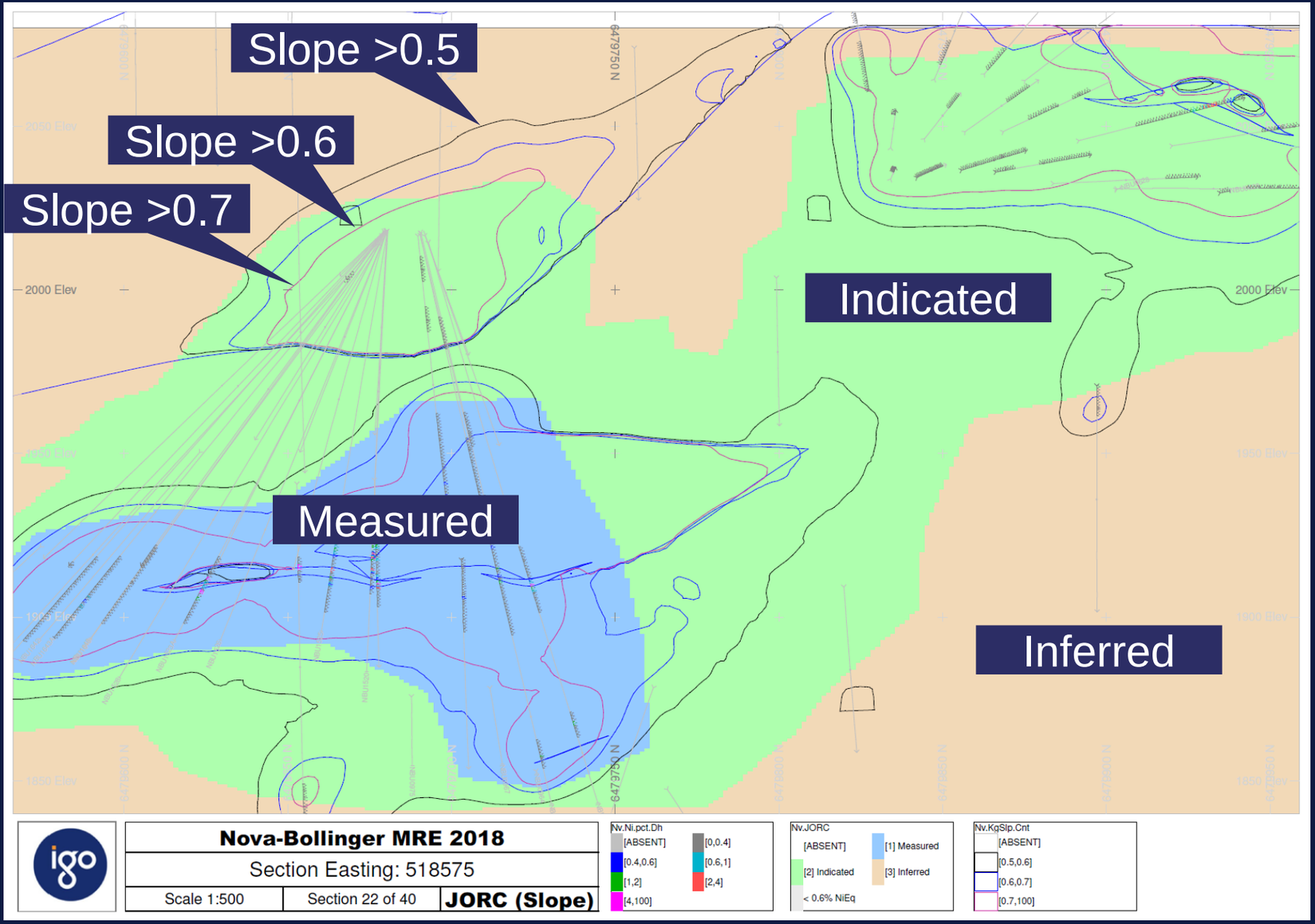
- Global means from NN declustered composites and tonnage-weighted block grades
- Swath plots prepared to confirm local response of grades and block in moving windows
- Results generally acceptable

New versus Old Estimates



- Prepare comparative grade-tonnage histogram between updated and prior estimates
- Assess changes in histogram bins and cumulative trends
- Removal of categorical hard boundary changes histogram for high grade bins
- Result consistent with simulation study predictions

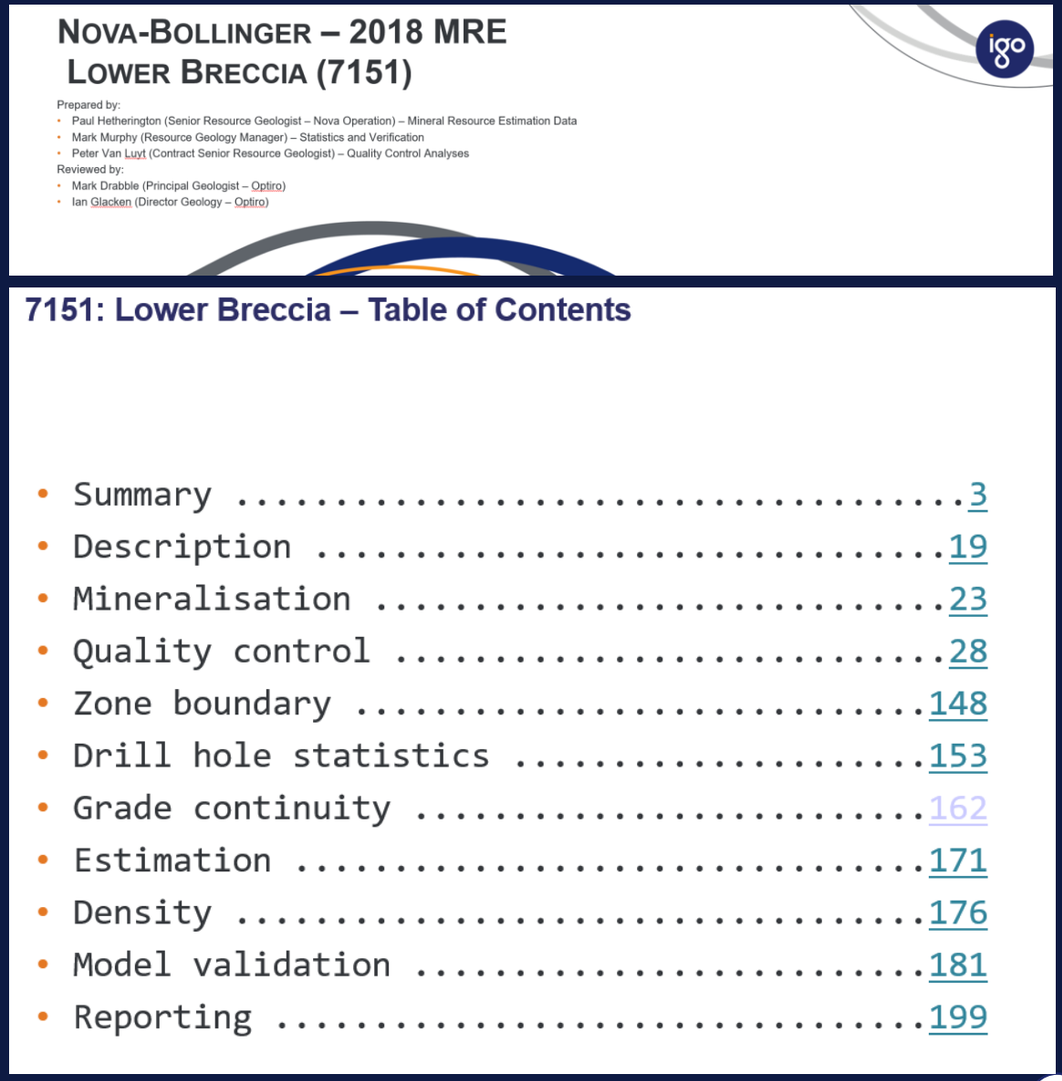
Resource JORC Code Classification



- Classification primarily spaced on data spacing given good data quality and generally well structured experimental continuity models
- Bulk mining method requires waste to be classified
- Kriging regression slope used as a spacing index guide for cross sectional assignment of JORC Code classes
- Lower confidence assigned where perceived higher geological uncertainty or where variography confidence less robust (such as used of omnidirectional semivariograms)

Governance and Review

- Modellers prepare PowerPoint presentations of input and outputs for each estimate, updating items during the modelling process
- Data and estimates are prepared used industry recognised software systems (Surpac for estimation, Supervisor for variography, AcQuire for data management, Datamine internal review)
- Many accessory calculations are prepared in R-software so the calculation trail can be traced from data source to tabulations and other graphic output
- Parallel external review completed a reputable consultant firm (Optiro).



Key Learnings

- Nova is a complex heterogeneous deposit from an estimation point of view
- Always challenge the previous estimate methodology - never fall in love with a model
- What was correct for previous datasets may not be applicable with new information

The credits..

- Mine Geology Team – IGO Nova
  - Drill management , data collection, face images, core photography and mapping
- Mine Engineering Team – IGO Nova
  - Inputs on model limits and development of NSR equations
- Bronwyn Barkla – Database administrator – IGO Perth
  - Drill data preparation and data management
- Peter van Luyt – Casual Resource Geologist – Perth
  - Data quality reviews
- Optiro
  - External reviews
- Golder Associates
  - Multivariate unfolded simulation study
- Professor Clayton Deutsch – University of Alberta
  - advice and vein uncertainty modelling prototype
- IGO for providing permission to present this story