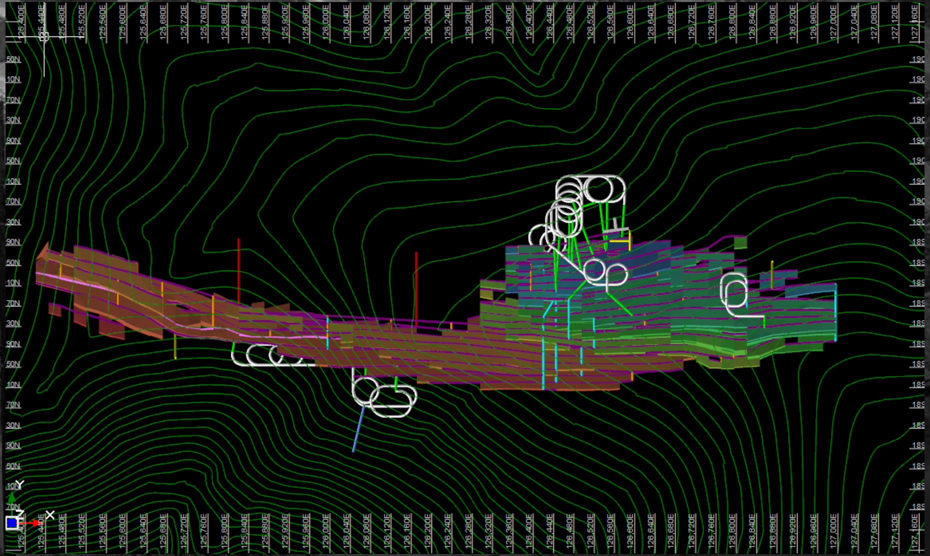
Wolf Mountain Case Study

Strategic Mine Planning for Multiple Narrow Vein Underground Deposits



Presenter: Matt Arnold – Consultant (Mining)

Location: Skellefteå, Sweden

EUROPEAN LITHIUM

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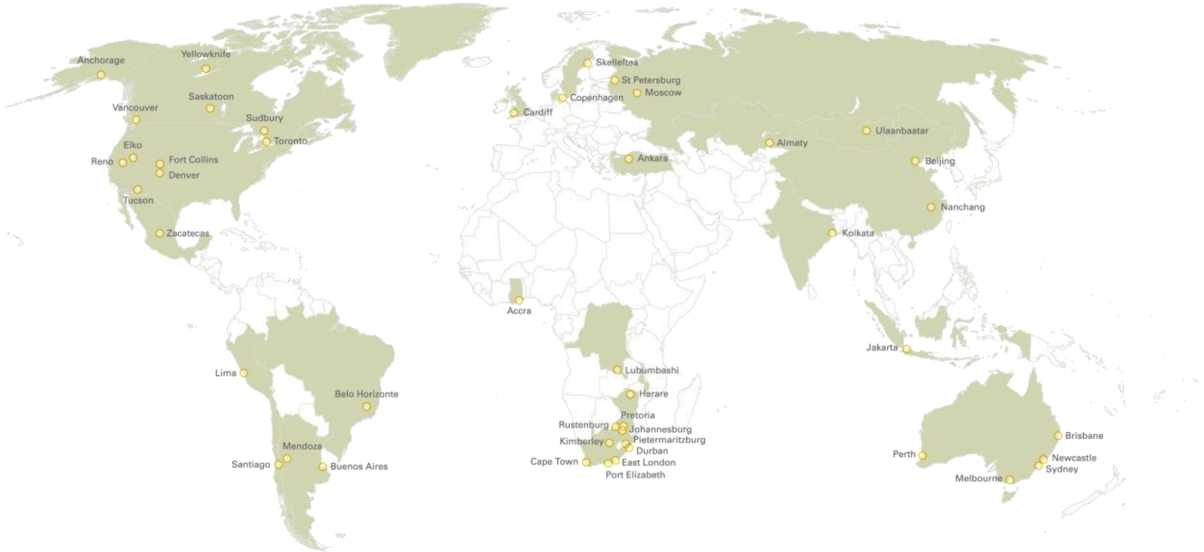
Introduction: Company Profile



- 45 Offices on 6 Continents employing 1,400 Staff (120 in UK Office)
- Geology, Geotechnical, Mining Engineering, Processing, Tailings, Water Management, Geochemistry, Infrastructure, Environmental and Financial Evaluation
- Independent – 100% employee owned
- Technical support from exploration, development, exploitation through to closure
- Internationally Recognised
- Credibility with financiers and regulators
- Strong and lasting relationships with Mining Companies in Nordic regions and other parts of Europe

Introduction: Matt Arnold – Consultant (Mining)

- Graduated in 2013 from Camborne School of Mines, Cornwall, UK. 4 Years industry experience.

- 4 years mining project experience including:
  - Underground time completed in Australia, Sweden and USA.
  - Mine project experience with Lundin Mining
  - Worked in decline and shaft access mines at varying depths
  - Worked across a number of underground mining disciplines including Long-Hole Open Stoping (LHOS), Cut and Fill, Block Caving and Sub-Level Caving
  - Operational roles in short-, medium- and long-term planning
  - Experience in Nordic regions:
    - Underground exposure programme and engineering project work for Zinkgruvan Mining
    - Involved in multiple projects for LKAB
  - Deswik user since 2016

- 5 Months with SRK
  - Projects with LKAB in both Kiruna and Malmberget
  - Scoping and PFS Study with European Lithium on Wolfsberg

Underground Mining Engineer – Eagle Mine, USA, 2014-2016

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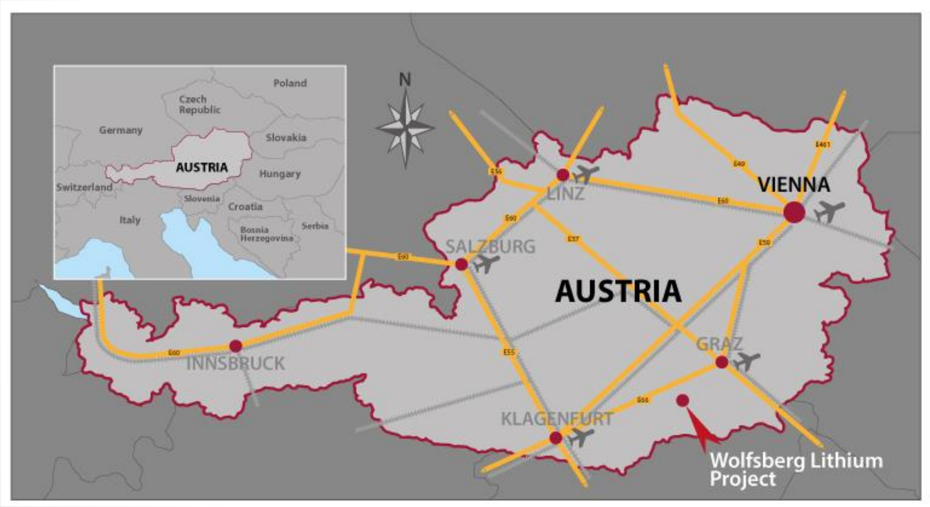
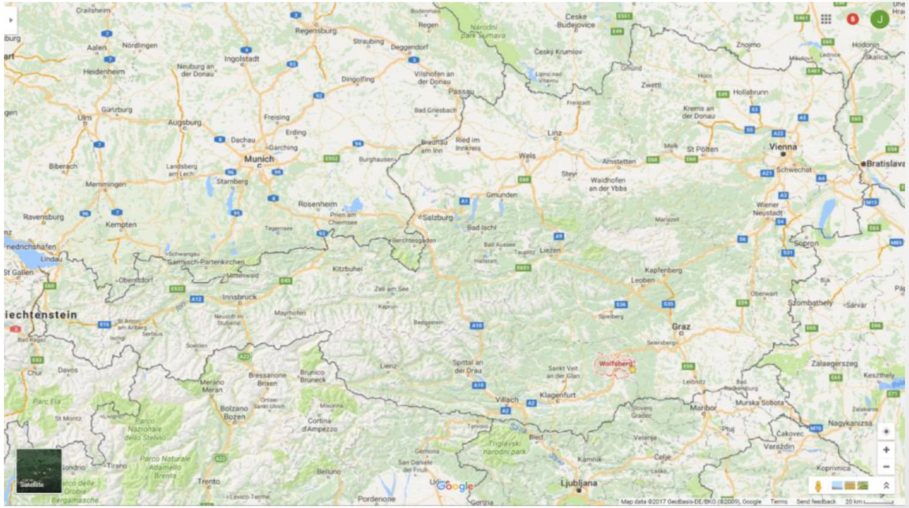
WOLFSBERG LITHIUM DEPOSIT

European Lithium

Wolfsberg: Project Overview

- Located in the Carinthia province of southern Austria
- Wholly owned by ECM Lithium AT GmbH, a subsidiary of European Lithium, a mining exploration and development company listed on the Australian Securities Exchange (ASX code: EUR)

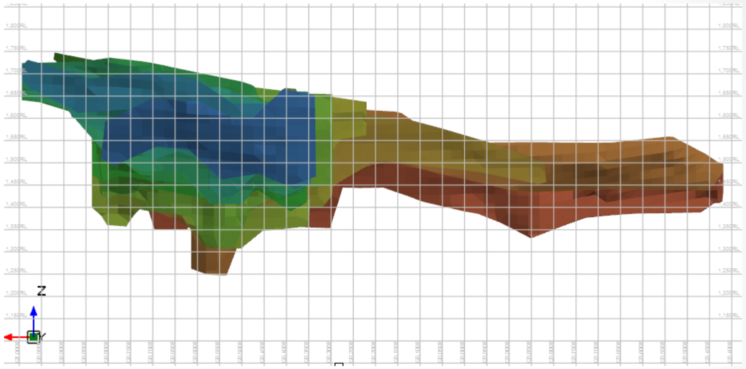


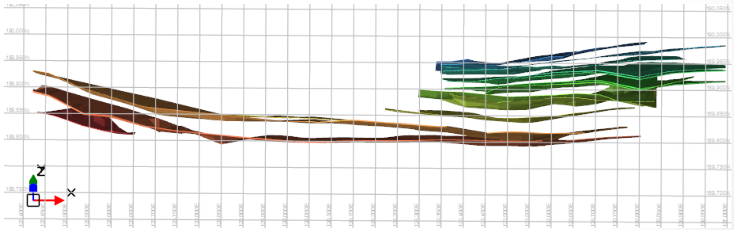


Wolfsberg: Mineral Resources

- The Wolfsberg mineralization consists of a series of spodumene-bearing pegmatites as dyke-like intrusions in the amphibolites and mica-schist horizons.
- These mineralised veins vary in thickness from <1m with some swelling locally to over 5m
- Average vein thickness of 1.41m. Generally ranging from 1.2-2m

Zone	Vein	Measured resources			Indicated resources			Total			
		tonnage	Li_2O	thickness	tonnage	Li_2O	thickness	tonnage	Li2O grade	Li2O content	thickness
1	0	51,800	0.85	0.8	64,200	0.96	0.73	116,000	0.91	1,057	0.76
2	0.1	34,400	1.03	0.96	83,900	1.1	0.9	118,300	1.08	1,277	0.92
3	0.2	27,000	1.57	0.88	29,200	1.49	0.72	56,200	1.53	859	0.80
4	0.3	41,800	1.01	0.68	61,900	0.73	0.65	103,700	0.84	874	0.66
5	1.1	298,900	1.23	1.29	152,400	0.93	1.01	451,300	1.13	5,094	1.20
6	1.2	361,400	0.63	1.79	274,400	0.83	1.86	635,800	0.72	4,554	1.82
7	2.1	442,500	1.61	1.53	177,300	1.25	1.16	619,800	1.51	9,341	1.42
8	2.2	156,100	1.3	0.97	97,400	1.35	1.01	253,500	1.32	3,344	0.99
9	3.1	628,300	1.63	1.53	92,600	1.52	1.21	720,900	1.62	11,649	1.49
10	3.2	118,800	1.31	0.74	155,300	1.29	0.79	274,100	1.30	3,560	0.77
11	4	110,200	1.21	0.83	89,600	1.07	0.74	199,800	1.15	2,292	0.79
12	6.1	6,700	0.9	0.66	81,700	0.67	0.98	88,400	0.69	608	0.96
13	6.2	276,200	1.17	1.22	531,500	1.04	1.5	807,700	1.08	8,759	1.40
14	7	307,800	1.12	1.79	1,469,400	1.13	2.65	1,777,200	1.13	20,052	2.50
15	8	0	0	0	80,800	0.6	1.32	80,800	0.60	485	1.32
	Total	**2,861,800**	**1.28**	**1.31**	**3,441,500**	**1.08**	**1.49**	**6,303,300**	**1.17**	**73,799**	**1.41**





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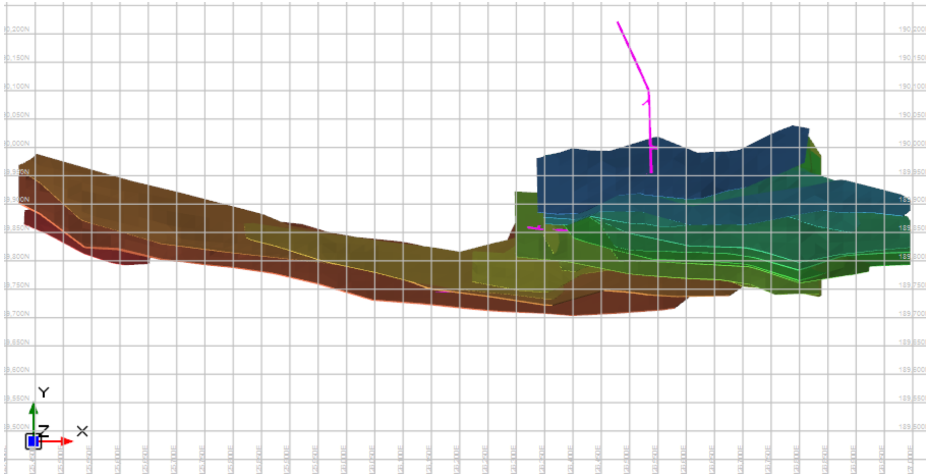
Minegrid: Rotation of Mineralisation Wireframes

- Mineralisation wireframes provided to SRK.
  - Existing wireframes -Topography and existing development as-builts
  - Rotated -20° from North to a new minegrid.
  - Orebody strike parallel to the X axis to facilitate better optimisation and mine design, based on following parameters.

Old		New	
Y1	189806.863	Y1	189943.009
X1	126828.351	X1	126844.264
Y2	190302.792	Y2	189943.009
X2	125465.797	X2	125394.264



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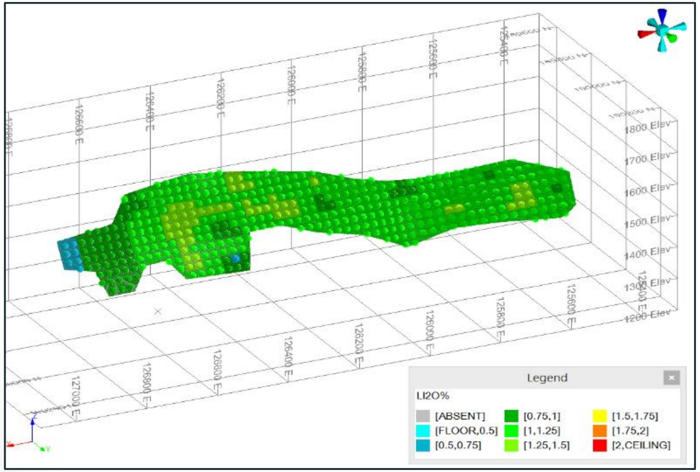
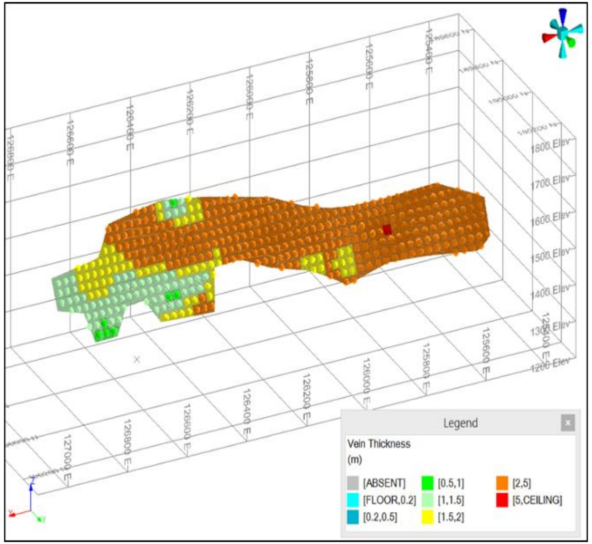
Wolfsberg: 3D Block Model Generation

- Block model generated with block sizes of 1.5m x 1.5m x 0.5m within the rotated mineralisation wireframes
  - 2D composite drillholes provided were projected onto the rotated 3D vein wireframes.
  - Lithium grade and thickness variables were then estimated into the model for each individual vein.

- For consistency with the 2D estimate in terms of tonnage and grade, estimate undertaken with square search volume (25m x 25m, to reflect drillhole spacing) assigning lithium and thickness to each block.
  - Li2O and thickness assigned using nearest neighbour interpolant method
  - Only one sample to inform each block (closest sample).



Zone 14 - block model and 25m grid points coloured by Li2O% grade

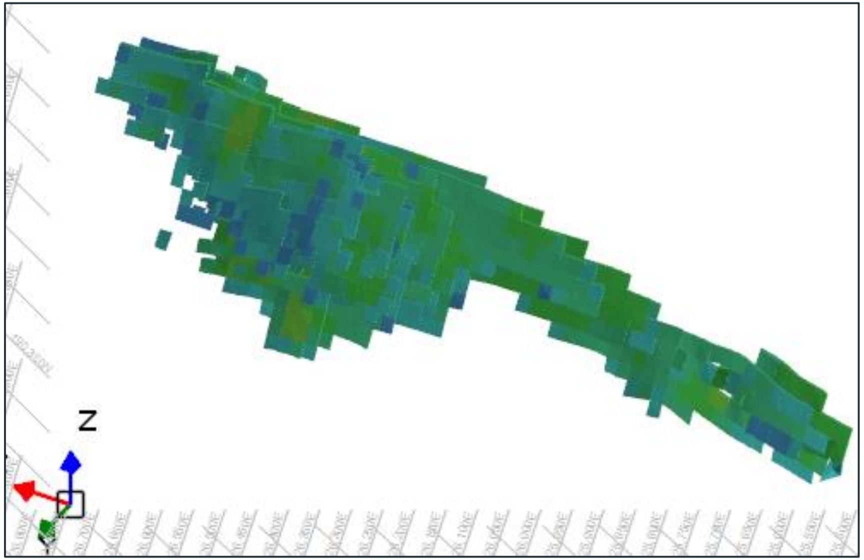


Zone 14 - block model and 25m grid points coloured by thickness (m)

Wolfsberg: Deswik Stope Optimiser

- Resultant block model used to generate shapes using Deswik Stope Optimiser
  - Optimisation field Li2O
  - COG 0.3% Li2O
  - Following parameters used to generate stope shapes:

Parameter	Value	Unit
Default dip	55	degrees
Default strike	0	degrees
Section spacing	25	m
Level spacing	25	m
Footwall dilution	0.3	M
Hanging wall dilution	0.5	M
Cut-off grade	0.3	% Li_2O
Max Waste Content	60	%
Min Waste Pillar	7	m
Minimum Stope Width	1.2	m
Maximum Stope Width	12	m



SO Shapes coloured by Li2O grade

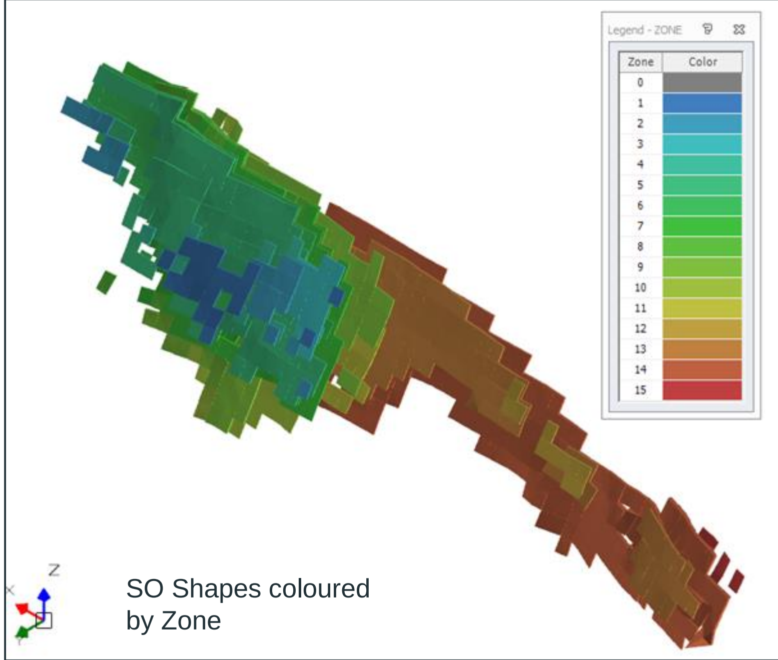
Legend - STO...

Li2O	Color
0 to 0.2	
0.2 to 0.4	
0.4 to 0.6	
0.6 to 0.8	
0.8 to 1	
1 to 1.2	
1.2 to 1.4	
1.4 to 1.6	
1.6 to 1.8	
1.8 to 2	

Wolfsberg: Stope Optimiser Results

- Stope optimiser gave shapes as shown below
- WF ratio = waste fraction of stope (weighted by tonnes)
- Dilution = ratio of additional waste to the mineralized material.
- These numbers do not include mining losses due to crown, rib and sill pillars left in-situ (20% losses)

	Stopes		Contained mineralized material				
Zone	MSO Tonnes	MSO Li %	Min Tonnes	Min Li2O %	Waste Tonnes	WF	Dilution
1	68,588	0.40	35,834	0.86	32,754	0.48	91%
2	93,567	0.52	47,767	1.06	45,800	0.49	96%
3	66,979	0.70	29,863	1.61	37,116	0.55	124%
4	70,098	0.46	28,457	1.20	41,641	0.59	146%
5	632,164	0.63	346,711	1.19	285,453	0.45	82%
6	662,635	0.50	491,020	0.72	171,615	0.26	35%
7	1,012,764	0.79	496,093	1.58	516,671	0.51	104%
8	332,819	0.65	133,409	1.39	199,410	0.60	149%
9	1,081,554	0.90	596,933	1.63	484,620	0.45	81%
10	229,493	0.59	76,434	1.72	153,059	0.67	200%
11	196,677	0.57	95,114	1.21	101,563	0.52	107%
12	37,968	0.39	23,216	0.69	14,752	0.39	64%
13	845,919	0.70	540,904	1.13	305,015	0.36	56%
14	2,169,934	0.76	1,506,607	1.13	663,327	0.31	44%
15	22,999	0.35	20,644	0.61	2,355	0.10	11%
Total	**7,524,158**	**0.72**	**4,469,006**	**1.22**	**3,055,152**	**0.41**	**68%**



SO Shapes coloured by Zone

STOPE REPORTING IN NARROW VEIN DEPOSITS

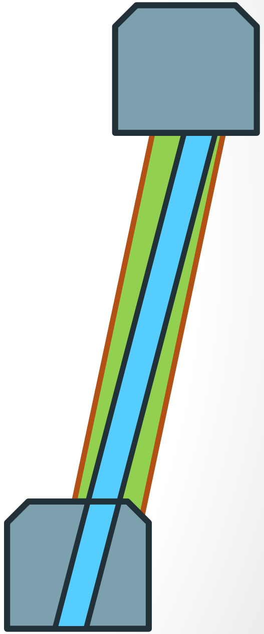
Difficulties in narrow vein scheduling and reporting and potential solutions

Narrow Vein Stope Shapes: The Issues

- Difficult to generate stope shapes in Stope Optimiser Packages
  - Swelling of veins – practical inter-stope dimensions & ratios: F-B and T-B
  - Long processing times – small resolution BMs
- High waste dilution when applying practical dilution offsets
  - Waste modelled at zero grade – overall headgrade reduction
- Changes in dip & strike angles within mineralisation
  - Maximum permissible strike and dip change between stopes?
- Tonnage reporting within wireframes (stopes, development, etc.)
  - Volume error depends on the block size (blame the geologists) and the reporting method (blame the engineers).
  - Specific gravity (SG) error depends on the SG sampling density and accuracy (blame the geologists).
- Block size
  - Geologists prefer larger blocks based on the 0.3 to 0.5 times the drill spacing. Creating smaller blocks implies a higher level of accuracy, which is not supported by the drill spacing (information density) in their opinion.
  - Mining engineers prefer the smallest block size possible to reduce the difference between the tonnages based on the wireframe volumes (taken as the most exact estimation) and the tonnages reported from the blockmodel.
  - Intermediate solution is to estimate grades in parent blocks and create a sub-blocked model (with all sub-blocks having the same grade as the parent block).
  - However, large parent blocks cannot be used when estimating the grades within multiple narrow vein deposits when each vein is estimated separately (such as at Wolfsberg) as the blocks would overlap several veins.

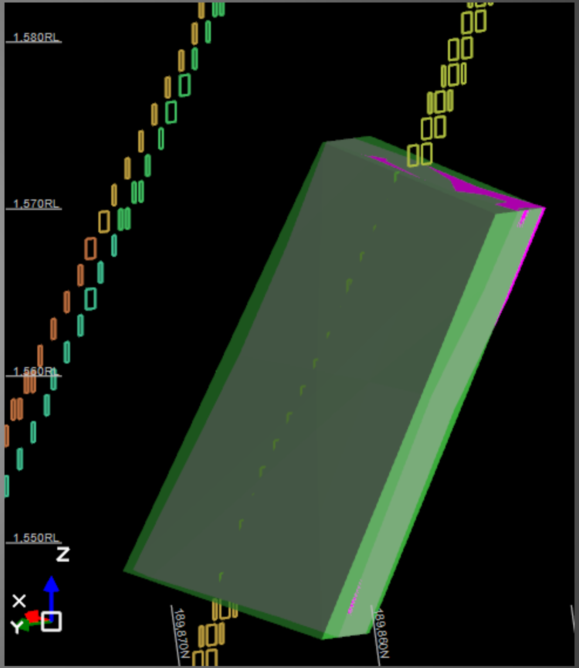
Narrow Vein reporting – Working Solution

- **Solution – Wireframes attributing**
  - Use wireframes to interrogate the blockmodel information Do not re-query the BM once the information has been assigned unless stope shapes change.
- **Advantages**
  - Exact volumes as based on wireframes which can be any size, thickness, and shape.
    - Stope tonnages and grades determined from: contained mineralisation WF (blue) + waste within the MSO shape (green) This data is contained within the MSO shape (orange outline).
    - Wireframes can be coloured based on legends and filtered out as per usual.
  - Wireframes within one deposit can query different blockmodels.
    - Each vein can have its own blockmodel with large block sizes, reducing file sizes and increasing transparency.
    - There are no constraints on the block sizes for each blockmodel.
  - Tonnes and grades of the wireframes can be manipulated, e.g. add additional dilution and recovery factors or calculate exact % waste (by volume) within the stope.
  - Wireframes can be cut exactly to fit each other (development, stope outline, contained mineralization) or to use the structural controls such as faults.
- **Disadvantages**
  - Reporting issues – inaccuracy of nearest wireframe 25m slices to stope shape – overhangs etc.
  - Attributes other than volume rely on BM interrogation



WOLFSBERG EXAMPLE: ISSUES AND SOLUTIONS

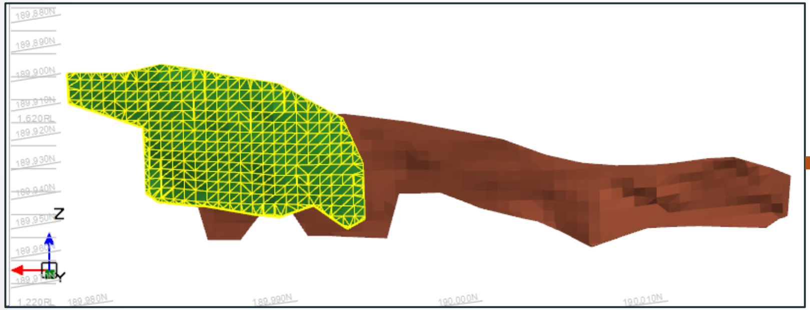
Difficulties in narrow vein scheduling and reporting and potential solutions



Wolfsberg Stope Optimiser Shapes: The Problem - Small Blocking Bias

- SRK reported the 'ORE' and 'WASTE' content in each stope shape, based on BM interrogation.
  - ORE: $Li_2O > 0.00$
  - WASTE $Li_2O = 0.00$
- Unfortunately a bias observed in the BM reporting, due to small block sizes. (INCLUSIVE, EXCLUSIVE BLOCKING)
- Because of the narrow nature of the deposit, sub-blocking around the wireframe boundaries is **difficult whilst maintaining a usable resolution** on BM.
- SRK split the mineralised wireframes into 25m x 25m sections on the same grid which stopes were generated.

Original mineralisation wireframes

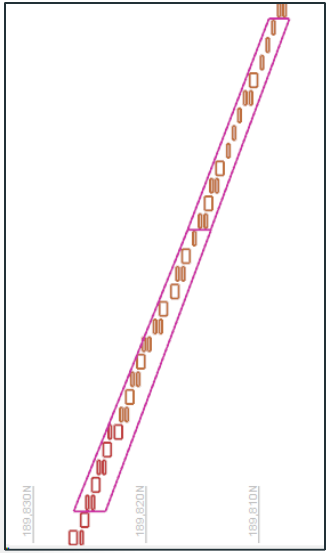


Wireframes split on 25m x 25m grid

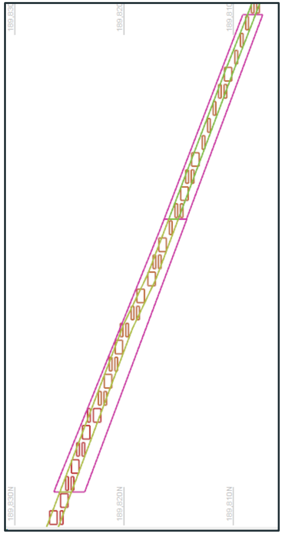
Wolfsberg Stope Optimiser Shapes: Solution - Mineralisation Attributing

- Attributes of these mineralised wireframes attributed to same quadrant stope shapes:
  - Assigned 'MINVOL' attribute to every 25m wireframe – exact volume of the 25m wireframe
  - Interrogated for Density and Li_2O Grade of each 25m wireframe.
- These attributes then assigned to nearest quadrant stope shape.
  - MODIFY > ATTRIBUTES > SET FROM NEAREST
- Can then report the exact mineralised volume, tonnes and grade as per the original wireframes in each stope

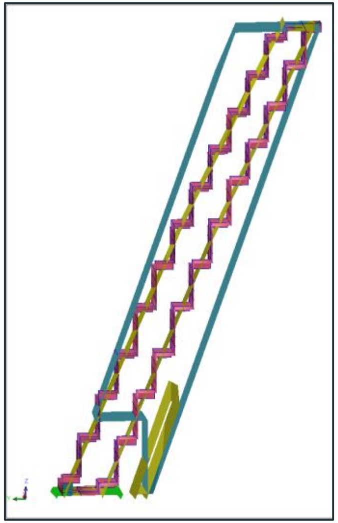
Stope outline against BM



Stope and Min. Wireframe against BM



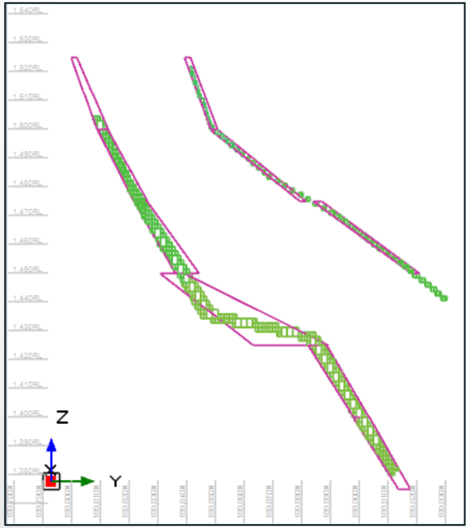
Visualisation of BM fitting to narrow vein wireframes



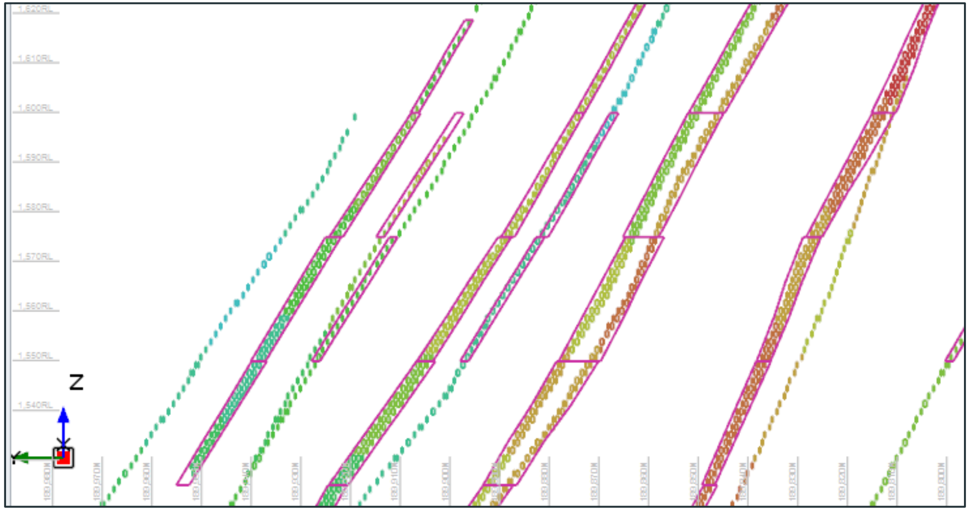
Wolfsberg Stope Optimiser Shapes: Solution - Issues

- As always this is not a perfect solution
  - For example, instances where one stope shape was encompassing two veins – which vein mineralisation volume was it taking
  - Overcome manually, although lengthy and difficult to replicate in following SO runs
    - Manually Attributing and filtering in Deswik Sched – replicable?

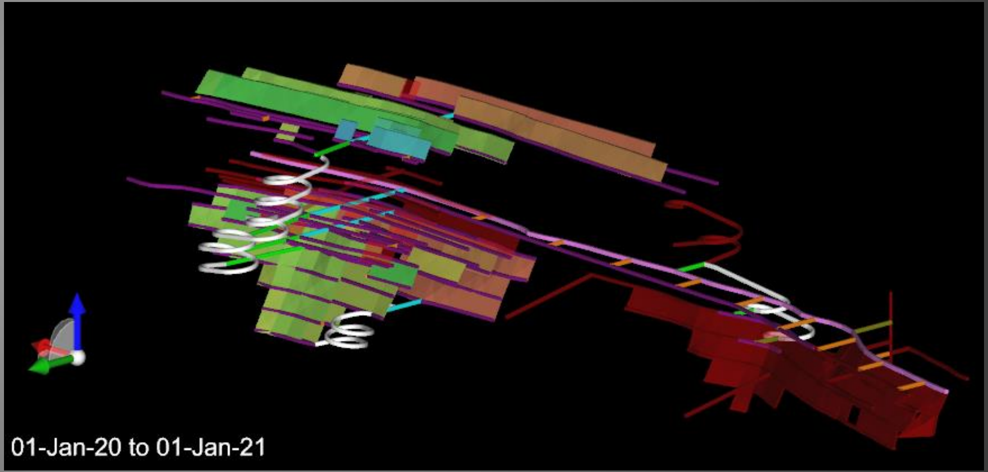
Geologists…



Multi Vein Stopes – Volume Assignment



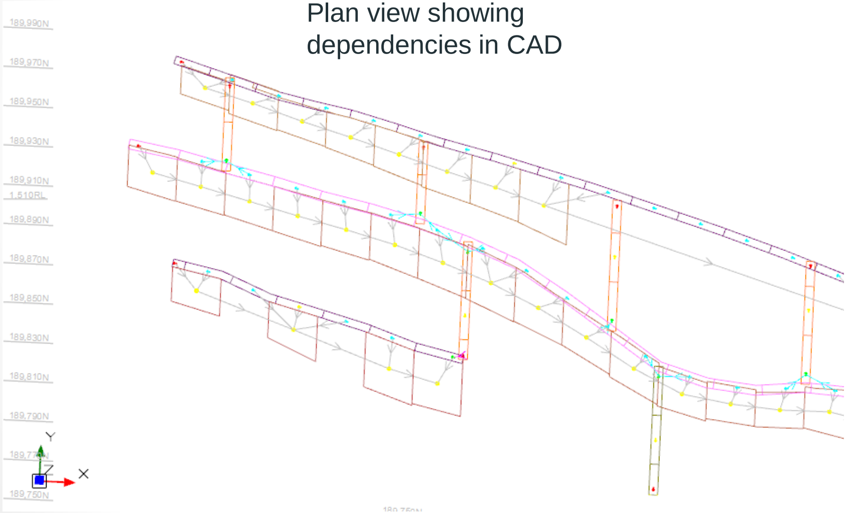
RESULTANT STRATEGIC SCHEDULE FOR WOLFSBERG

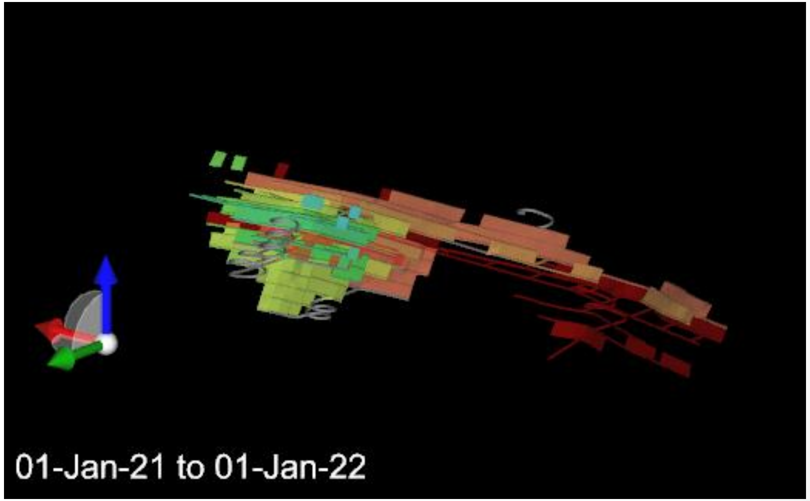


Wolfsberg Strategic Schedule

- After overcoming the issues mentioned, the schedule was produced as normal in Deswik CAD, IS and Sched.
  - Reporting of 'ORE' in sched was designated as the tonnage of the mineralised content contained within each stope shape.
  - Schedule driven based on this attribute as opposed to interrogated ore tonnage for stope shapes.
- Dependencies created in CAD, using both spatial and grouping attributes
- Underground split into 4 main mining 'blocks' – flexibility in scheduling, natural blocks due to lithology.

Plan view showing dependencies in CAD





Top Tip: When changing colour when alternating between Shaded/Animation visualisation modes, animation period text colour does not change – noted 09.05/2017 22:45 (Deswik CAD 2016.1.1580)

THANKS FOR YOUR ATTENTION

QUESTIONS?

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