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MAP, Mineral Resource Assessment Platform



This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

NGU, SGU December 15, 2020, Trondheim

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Map WIZARD – Assessment of VMS in the Caledonides

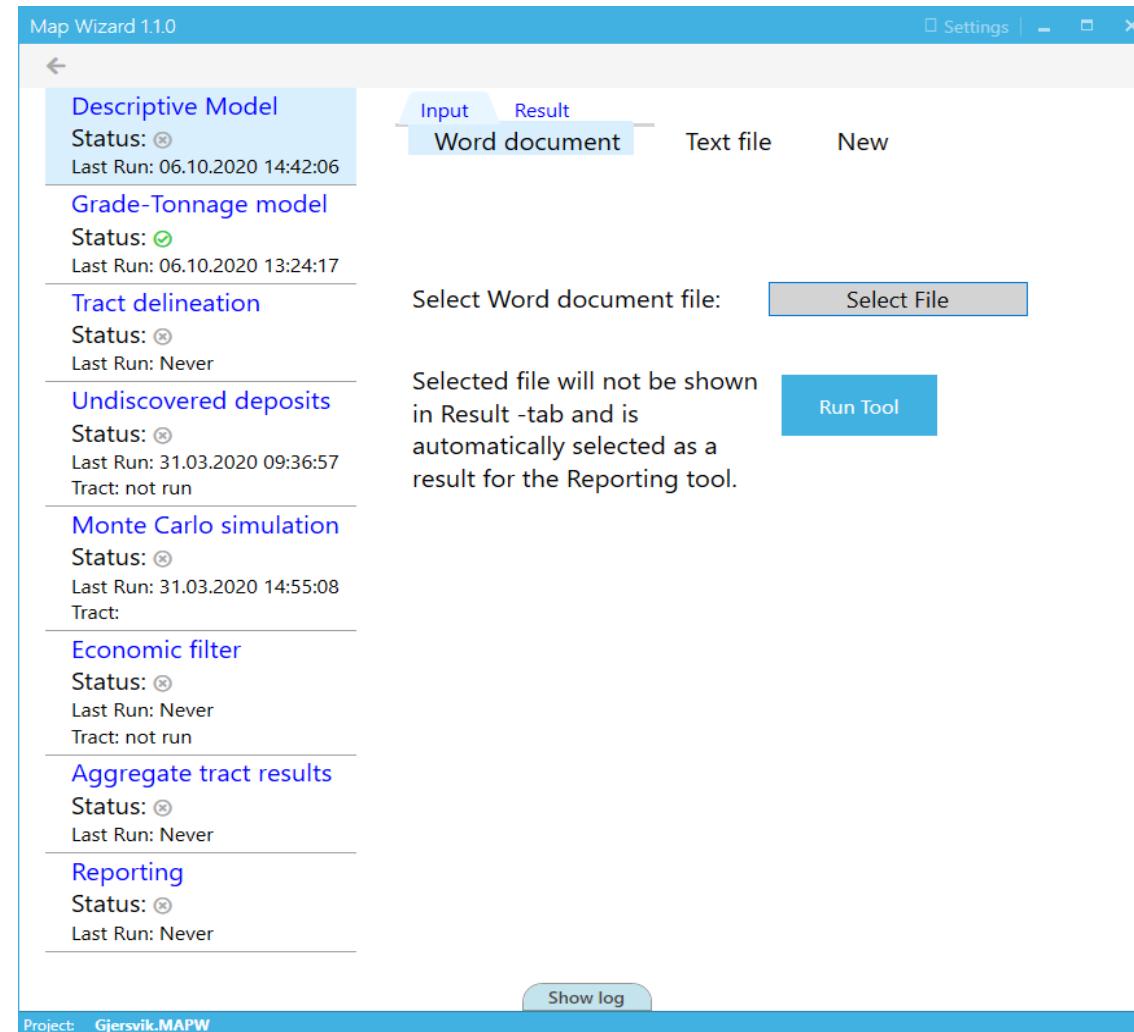


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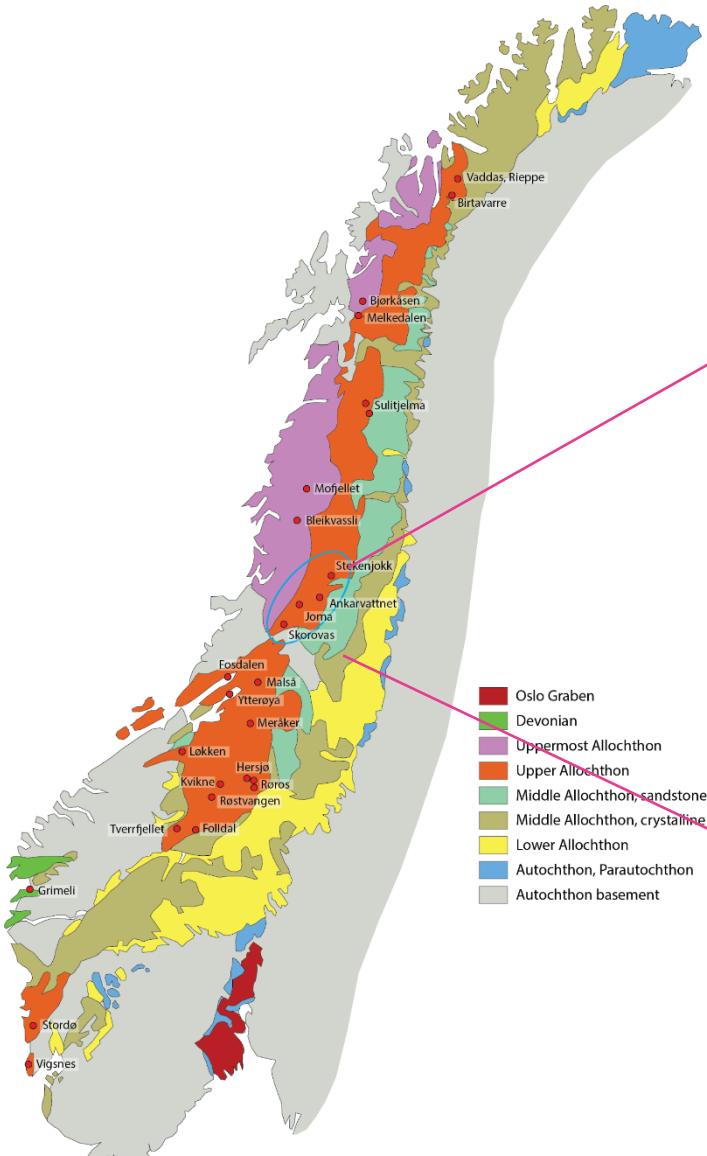
Map WIZARD – Assessment of VMS in the Caledonides



The different tools in the MAP Wizard

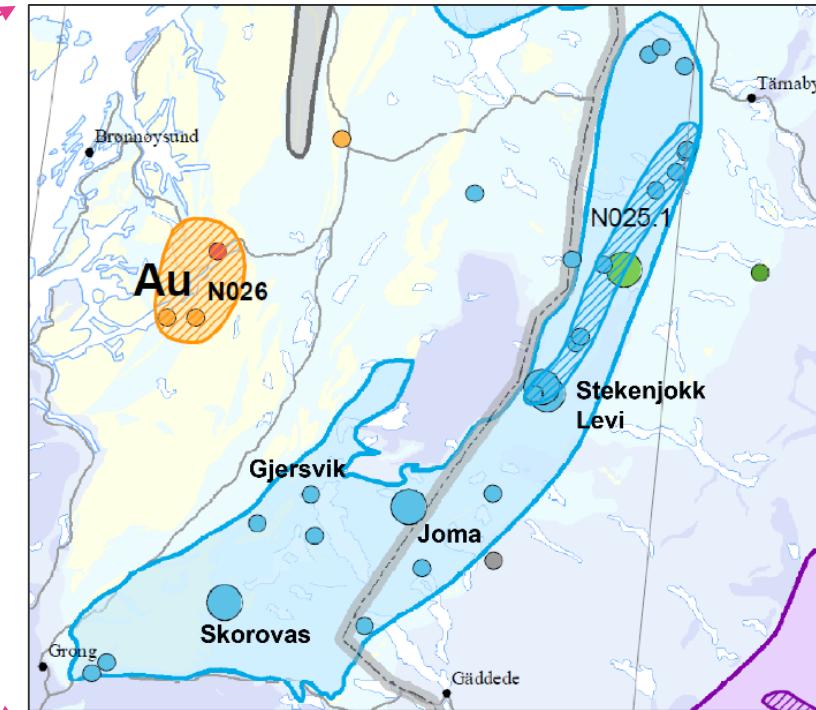
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Map WIZARD – Assessment of VMS in the Caledonides



Simplified tectonostratigraphy of the Scandinavian Caledonides

The Grong-Stekenjokk metallogenic area

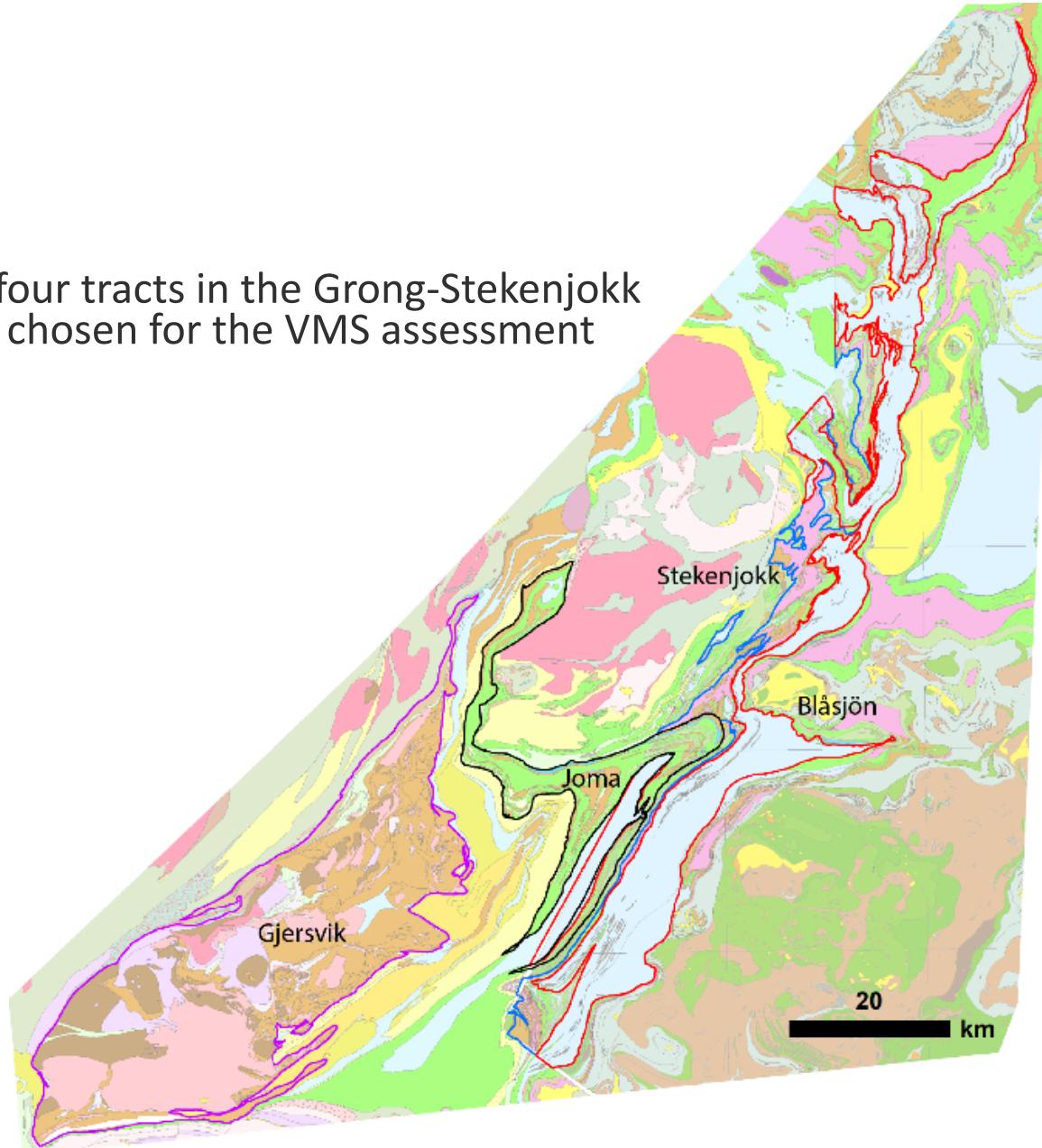


Section of the FODD map (Eilu et al., 2009)

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Map WIZARD – Assessment of VMS in the Caledonides

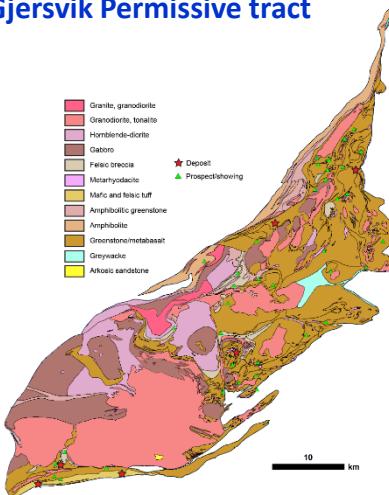
The four tracts in the Grong-Stekenjokk area chosen for the VMS assessment



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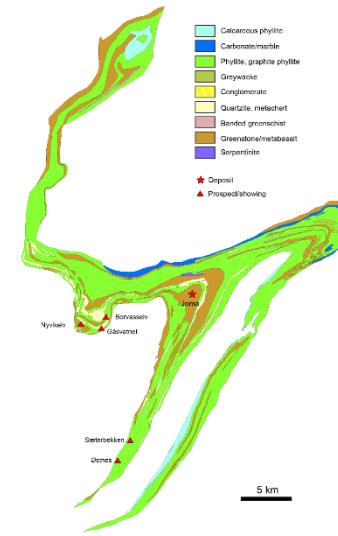
Map WIZARD – Assessment of VMS in the Caledonides

Gjersvik Permissive tract



- + Area is 564 km²
- + VMS Bimodal Mafic subtype
- + Arc volcanics – mafic with subordinate felsic metavolcanics
- + 2 deposits mined (Skorovas: 6.9 Mt, Gjersvik 1.62 Mt total ore)
- + 4 other deposits, ≈ 40 occurrences, incl. distal exhalites
- + Exploration data includes detailed geophysics, geochemistry, geology, covering the tract

Joma Permissive tract

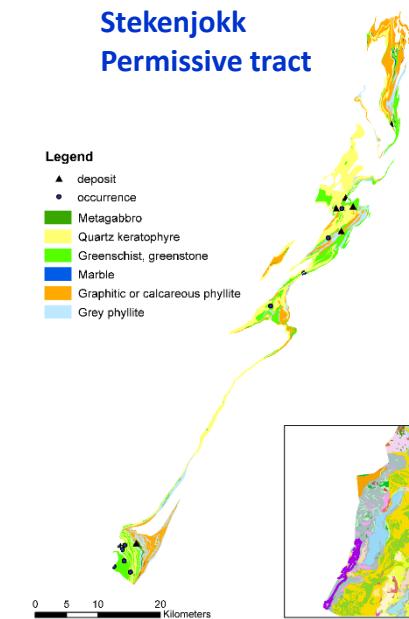


- + Area is 290 km²
- + VMS Mafic subtype
- + MORB volcanics – abundant graphitic to calc. phyllites, ribbon chert
- + 1 deposit mined (Joma: 22.5 Mt total ore)
- + 5 occurrences
- + Exploration data includes detailed geophysics, geochemistry, geology, covering parts of the tract

Stekenjokk Permissive tract

Legend

- ▲ deposit
- occurrence
- Metagabbro
- Quartz keratophyre
- Greenschist, greenstone
- Marble
- Graphitic or calcareous phyllite
- Grey phyllite

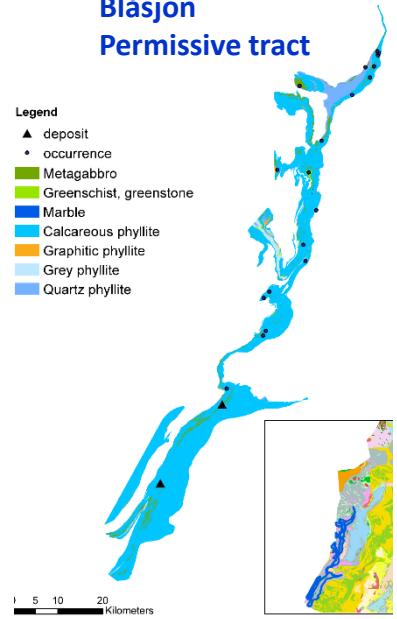


- + Area is 242 km²
- + VMS Bimodal Felsic subtype
- + Arc volcanics – felsic with subordinate mafic metavolcanics
- + 1 deposit mined (Stekenjokk: 11.9 Mt total ore)
- + 2 other deposits, 12 occurrences
- + Exploration data includes some detailed geophysics, geochemistry, geology, covering parts of the tract

Blåsjön Permissive tract

Legend

- ▲ deposit
- occurrence
- Metagabbro
- Greenschist, greenstone
- Marble
- Calcareous phyllite
- Graphitic phyllite
- Grey phyllite
- Quartz phyllite



- + Area is 801 km²
- + VMS Siliciclastic-Mafic subtype
- + Calcareous turbiditic phyllite, subordinate graphite, gabbro sills
- + no deposits mined
- + 2 deposits and 19 occurrences
- + Exploration data includes some detailed geophysics, geochemistry, geology, covering parts of the tract

Map WIZARD – Assessment of VMS in the Caledonides

Grade & Tonnage data summary statistics for the VMS classes – 208 Caledonian and Appalachian VMS deposits

Siliciclastic-Mafic

	Tonnage (Mt)	Cu %	Zn %	Pb %	Au g/t	Ag g/t
N	38	47	39	17	14	17
Minimum	0.01	0.02	0.03	0.002	0.1	3
Maximum	19.09	9.85	9.40	2.98	3.0	69
Mean	1.98	1.55	2.33	0.58	0.5	22
St.dev	4.31	1.68	2.27	0.92	0.7	21
10%	6.30	3.26	5.48	2.52	1.8	56
50% (median)	0.78	1.20	2.00	0.40	0.4	17
90%	0.06	0.17	0.10	0.004	0.1	3

Bimodal-Mafic

	Tonnage (Mt)	Cu %	Zn %	Pb %	Au g/t	Ag g/t
N	39	39	35	13	17	16
Minimum	0.03	0.15	0.10	0.05	0.1	3
Maximum	30.00	2.25	21.00	11.40	6.3	274
Mean	2.82	1.00	4.25	2.31	1.2	64
St.dev	5.39	0.53	4.63	2.95	1.5	74
10%	6.90	1.80	9.18	8.60	3.4	220
50% (median)	0.78	0.95	3.00	1.57	0.7	35
90%	0.09	0.30	0.56	0.05	0.1	4

Mafic

	Tonnage (Mt)	Cu %	Zn %	Pb %	Au g/t	Ag g/t
N	37	37	26	5	7	6
Minimum	0.10	0.50	0.01	0.02	0.1	7
Maximum	30.00	10.00	7.00	0.30	0.9	27
Mean	3.54	1.82	1.57	0.13	0.3	15
St.dev	6.49	1.53	1.49	0.10	0.3	6
10%	12.20	2.84	3.42	n.d.	n.d.	n.d.
50% (median)	1.06	1.50	1.10	0.10	0.2	14
90%	0.19	0.83	0.29	n.d.	n.d.	n.d.

Bimodal-Felsic

	Tonnage (Mt)	Cu %	Zn %	Pb %	Au g/t	Ag g/t
N	68	78	78	66	35	66
Minimum	0.05	0.01	0.01	0.01	0.03	0.1
Maximum	137.3	2.48	17.00	9.30	15.0	253
Mean	6.62	0.75	4.11	1.56	1.3	45
St.dev	19.09	0.59	3.84	1.93	3.0	44
10%	12.87	1.47	9.06	3.34	2.0	106
50% (median)	1.17	0.60	3.07	0.72	0.5	31
90%	0.15	0.12	0.07	0.04	0.1	5

Main differences between the classes:

Tonnage (Mean): Felsic (6.6 Mt) > Mafic (3.5 Mt) > Bimodal-Mafic (2.8 Mt) > Siliciclastic-Mafic (2.0 Mt)

Cu (Mean): Mafic (1.8%) > Siliciclastic-Mafic (1.6 %) > Bimodal-Mafic (1.0 %) > Bimodal-Felsic (0.8 %)

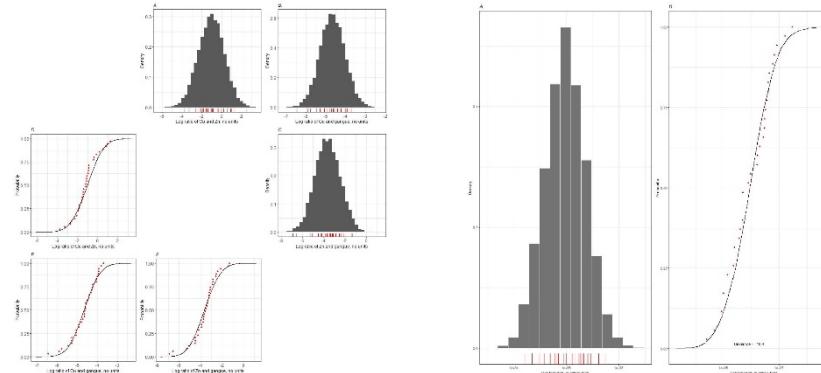
Zn (Mean): Bimodal-Mafic (4.3 %) > Bimodal-Felsic (4.1 %) > Siliciclastic-Mafic (2.3 %) > Mafic (1.6 %)

Bimodal classes richest in Au, Ag and Pb.

Map WIZARD – Assessment of VMS in the Caledonides

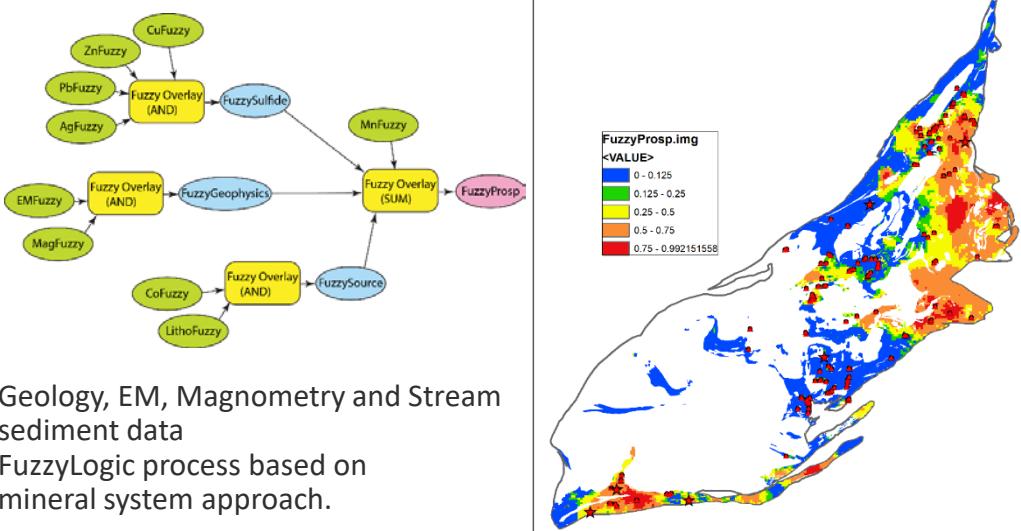
MAP Wizard example for the Gjersvik tract:

Grade-Tonnage model tool: probability density function



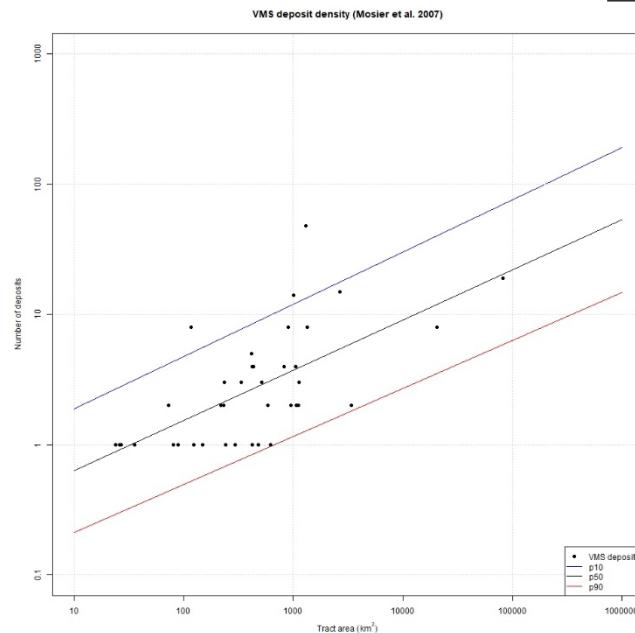
median 0.88% Cu, 2.61 % Zn, 0.85 Mt; mean 0.90% Cu, 2.62% Zn, 4.08 Mt
Bimodal-Mafic model – 35 discovered deposits (pdf – probability density function)

Tract delineation tool

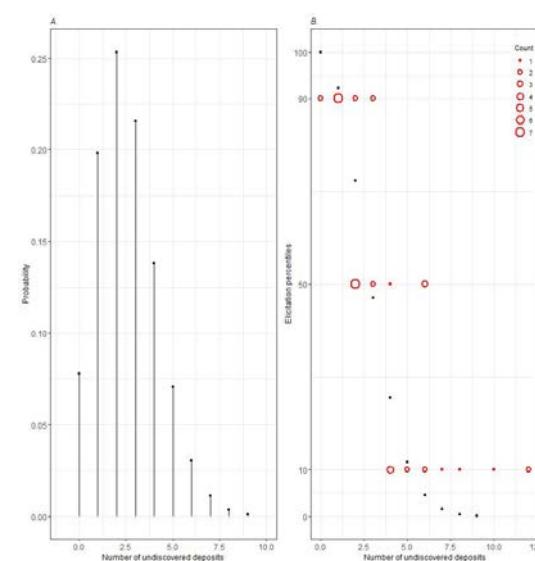


Geology, EM, Magnometry and Stream sediment data
FuzzyLogic process based on mineral system approach.

Undiscovered deposits tool



VMS deposit density model (Mosier et al. 2007)
gives probability
N90: 0 deposits
N50: 1 deposit
N10: 3 deposits



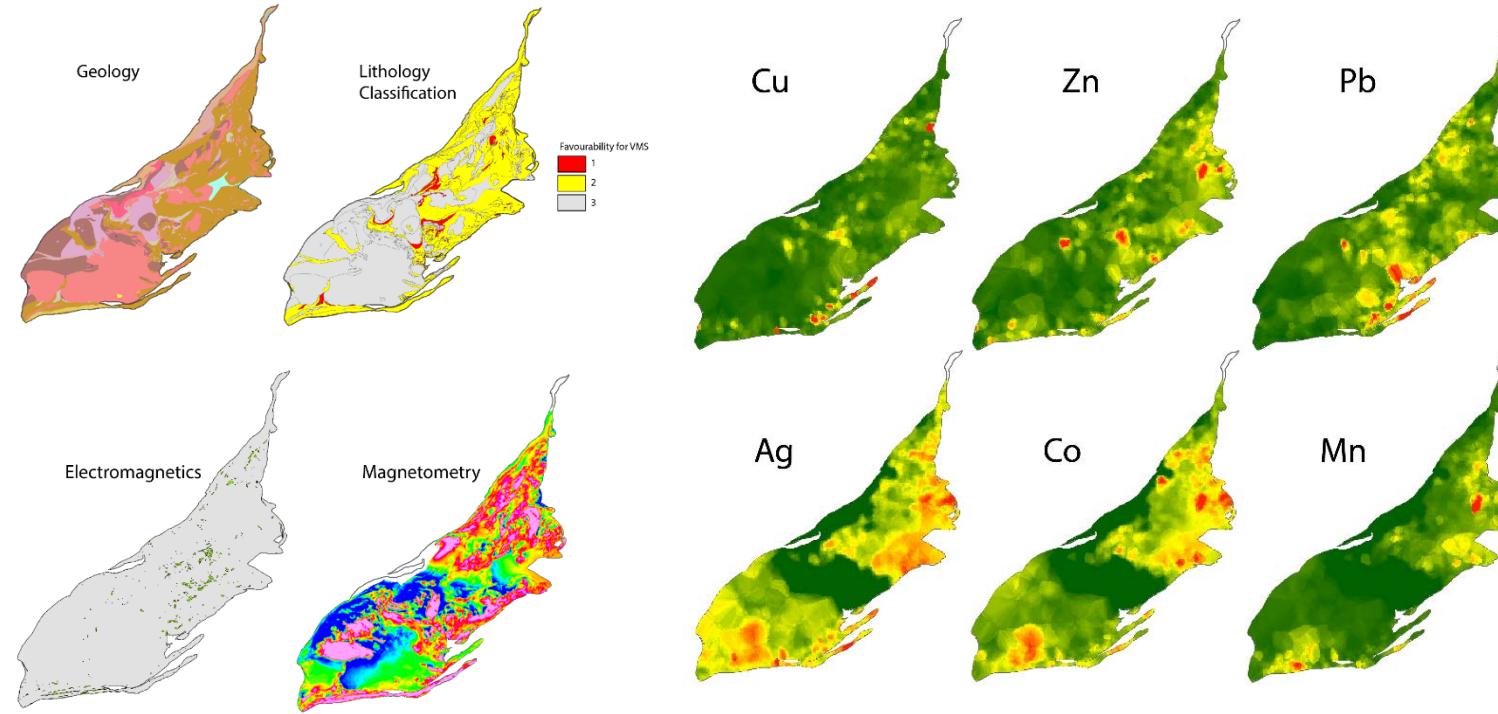
Expert	N90	N50	N10	Summary of pmf, number of undisc. deposits	
				Type	NegBinomial
MST	1	2	4	Mean	2.55533
JSS	2	3	6	Variance	2.54817
KR	1	2	5	St. Dev.	1.5963
STB	1	2	4	Mode	2
OO	1	6	10	Smallest N deposits in pmf	0
MS	0	2	5	Largest N deposits in pmf	9
TB	1	2	8	Inform. entropy	1.84229
KSU	3	6	12		
KSA	1	2	4		
AH	2	4	7		
TG	3	6	12		
BK	1	3	6		
HS	0	2	4		

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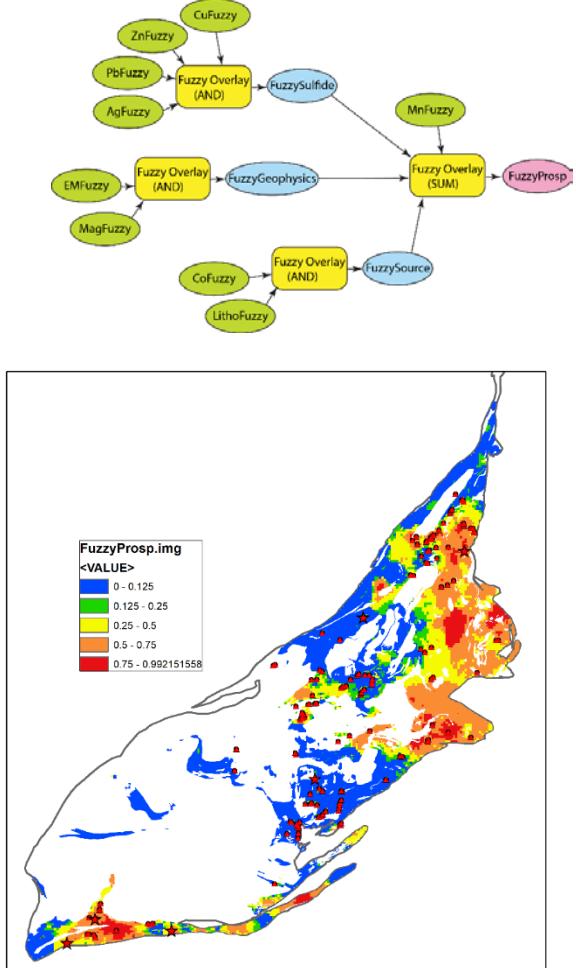
Map WIZARD – Assessment of VMS in the Caledonides

MAP Wizard example for the Gjersvik tract:

Mineral Potential Mapping/Tract Delineation



Geology, EM, Magnometry and Stream sediment data
FuzzyLogic process based on mineral system approach.

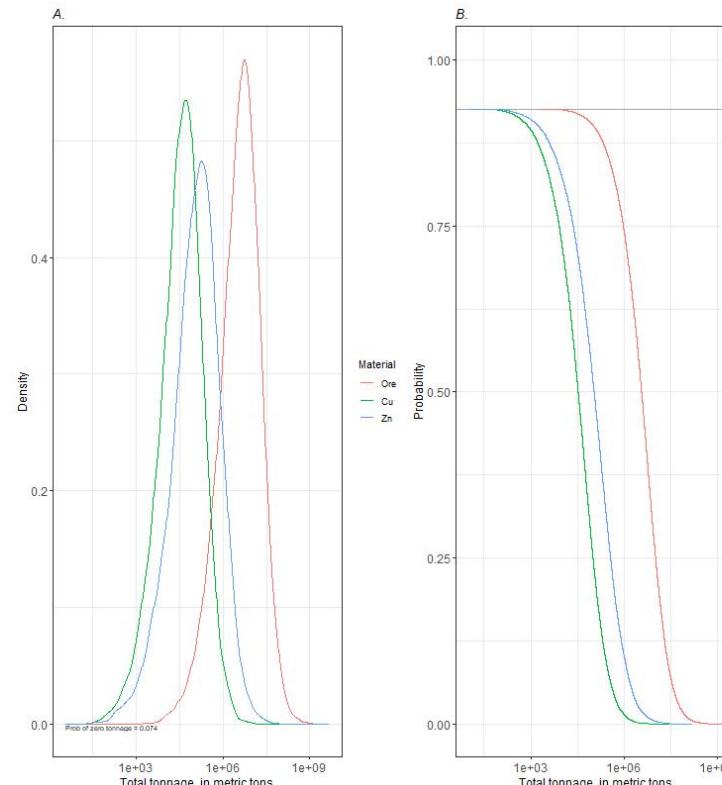


MAP Wizard example for the Gjersvik tract:

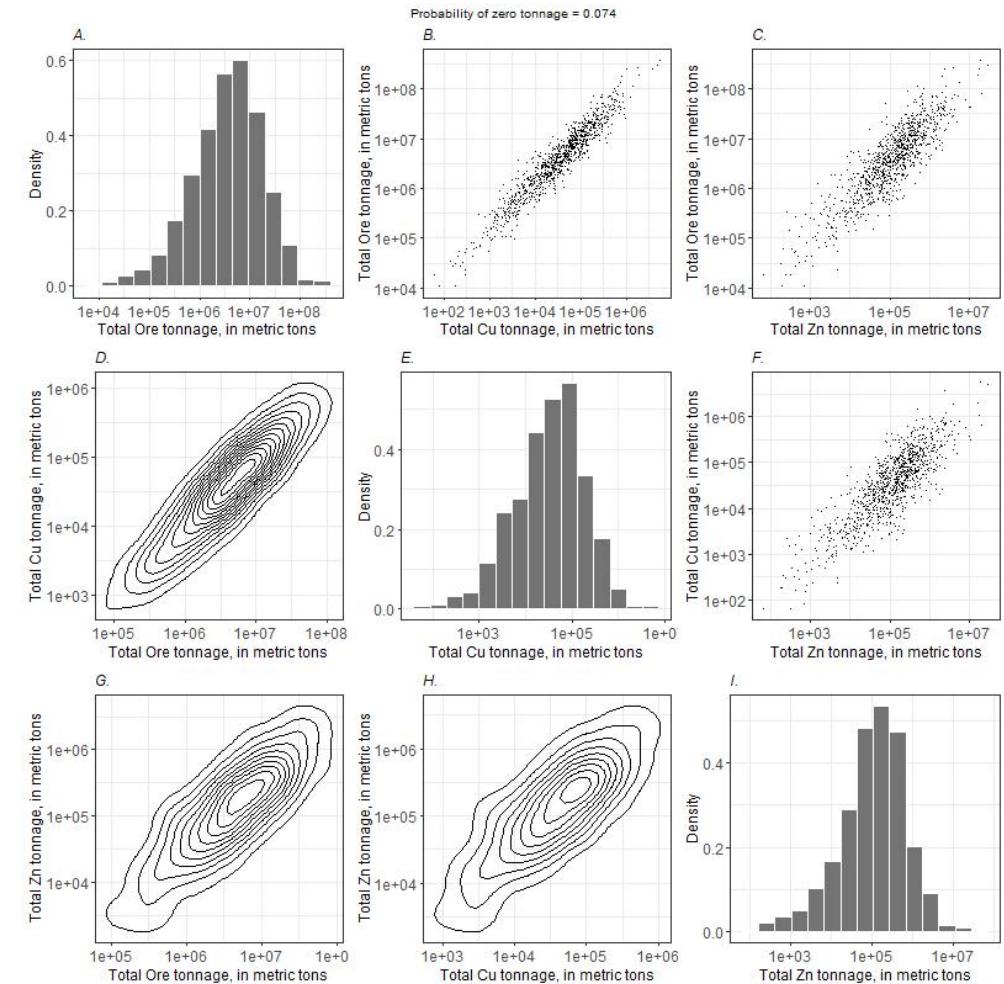
Monte Carlo Simulation (N = 20 000 deposits)

Summary of the pdf for the total ore and resource tonnages in all undiscovered deposits within the permissive tract.

	0.05q	0.1q	0.25q	0.5q	0.75q	0.9q	0.95q	Mean	P(0)	P(>mean)
Ore	0	0.106	0.938	3.61	10.2	23.7	39.3	10.5	0.0738	0.243
Cu	0	0.0008	0.008	0.033	0.099	0.249	0.432	0.112	0.0738	0.226
Zn	0	0.0018	0.023	0.108	0.365	1.020	1.810	0.476	0.0738	0.201



Plots of A: univariate marginal probability density functions and B: cumulative distribution functions for total ore Cu and Zn tonnages in the undiscovered deposits



Plots of univariate and bivariate marginal distributions for total ore and metal tonnages in the undiscovered deposits.

MAP Wizard example for the Gjersvik tract:

Economic Filter toolInput data for the filtering using interactive run:**Tract area:** Gjersvik Tract 564 km²**Simulated Deposits file:** Monte Carlo Simulation Gjersvik**Depth Intervals:** 1; 0 - 1000 m and fraction 1**Deposit Type:** Flat-bedded/stratiform**Mine method:** based on depth to the top of the deposit, if depth >= 61m:

Room and Pillar, if depth < 61m: Open Pit

Mill type: 1 – Product flotation**Days of operation:** 350 days**Marshall-Swift Cost updating index (MSC):** 1.26**Investment rate of return:** 0.15 (15 %)**Cap cost inflation factor:** 1**Operating cost inflation factor:** 1**CV_Cu, MRR_Cu:** 3813.958, 0.91 (Commodity Value in 2008\$/t,

Metallurgical Recovery rate 91%)

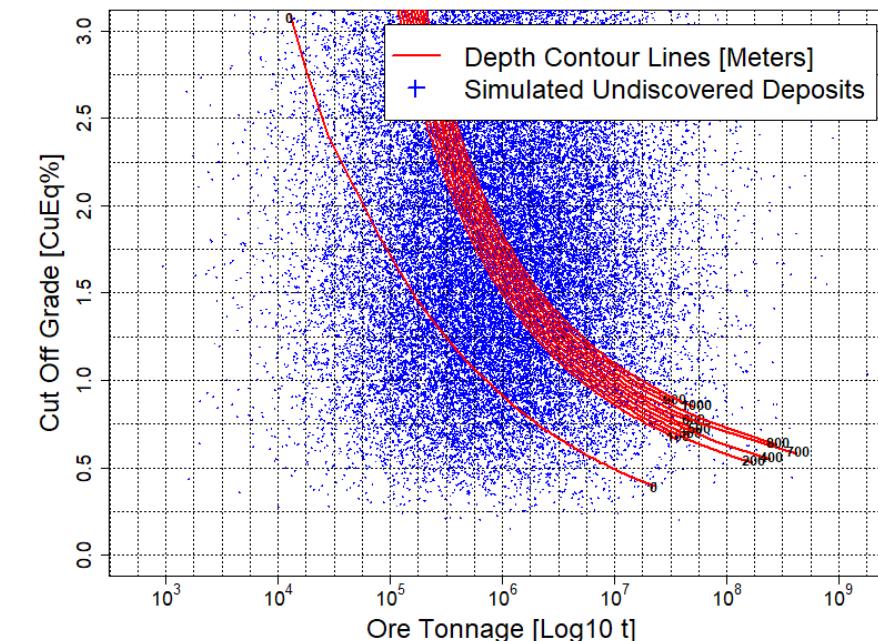
CV_Zn, MRR_Zn: 1851.864, 0.9 (Commodity Value in 2008\$/t,

Metallurgical Recovery rate 90 %)

Waste management options not chosen

Summary statistics for in-ground contained resources and recovered resources (in Mt):

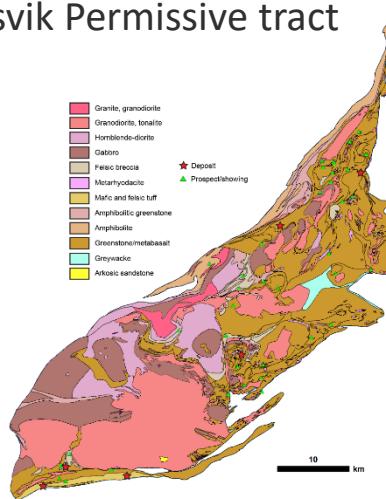
	means	min-max	median	std	P90	P70	P30	P10	Prob>=mean
Ore	10.505	0-1802	3.613	30.110	0.106	1.318	8.188	23.710	0.24325
Cu_con	0.112	0-29	0.033	0.387	0.001	0.012	0.079	0.249	0.22645
Zn con	0.476	0-158	0.108	2.007	0.002	0.034	0.284	1.020	0.2009
Cu rec	0.074	0-22	0.010	0.301	0	0	0.043	0.175	0.214
Zn rec	0.343	0-121	0.054	1.538	0	0	0.189	0.751	0.19855
NPV_tr	2.1e08	0-4.6e10	2.4e07	7.6e08	0	0	1.1e08	5.2e08	0.2122



Copper equivalent (CuEq%) grade/tonnage plot with cutoff grade versus deposit tonnage as a function of depth to top of the deposit in meters.

Map WIZARD – Assessment of VMS in the Caledonides

Gjersvik Permissive tract



G&T model (mean): 0.9% Cu, 2.6% Zn, 4.1 Mt

Tract delineation: 564 Km²

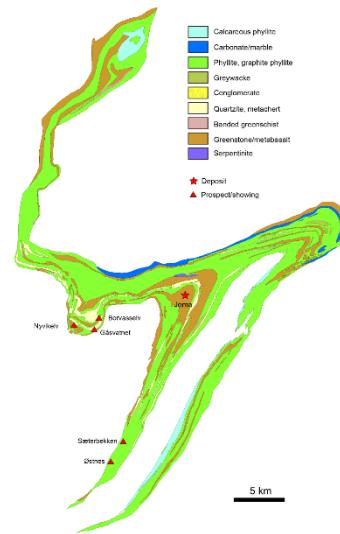
Deposit density model: N90=0, N50=1, N10=3

Undiscovered expert data: 2 deposits

MC simulation (mean): 1.1 % Cu, 4.5 % Zn, 10.5 Mt/median 0.9% Cu, 3.0% Zn, 3.6 Mt

Economic Filter: cont. 0.112 Mt Cu, 0.476 Mt Zn, recover. 0.074 Mt Cu, 0.343 Mt Zn

Joma Permissive tract



G&T model (mean): 1.5% Cu, 1.0% Zn, 4.6 Mt

Tract delineation: 290 Km²

Deposit density model: N90=1, N50=1, N10=4

Undiscovered expert data: 2 deposits

MC simulation (mean): 1.7 % Cu, 2.0 % Zn, 10.6 Mt/median 1.5% Cu, 1.2% Zn, 5.0 Mt

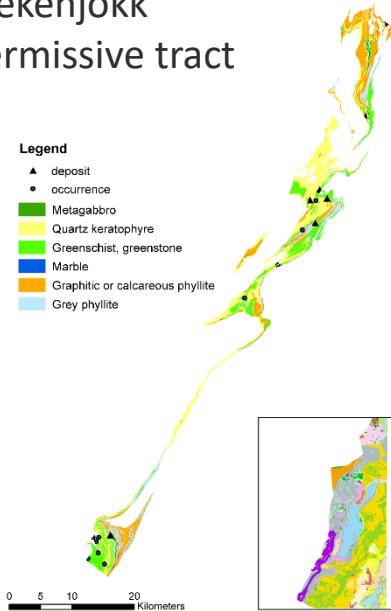
Economic Filter: cont. 0.180 Mt Cu, 0.209 Mt Zn, recover. 0.131 Mt Cu, 0.163 Mt Zn

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Map WIZARD – Assessment of VMS in the Caledonides

Stekenjokk

Permissive tract



G&T model (mean): 0.7% Cu, 3.0% Zn, 7.2 Mt

Tract delineation: 242 Km²

Deposit density model: N90=0, N50=1, N10=4

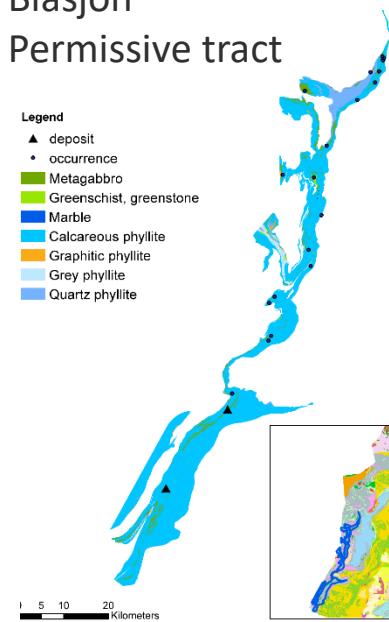
Undiscovered expert data: 3 deposits

MC simulation (mean): 0.9 % Cu, 5.4 % Zn, 17.7 Mt/median 0.7% Cu, 3.4% Zn, 5.7 Mt

Economic Filter: cont. 0.158 Mt Cu, 0.949 Mt Zn, recover. 0.118 Mt Cu, 0.769 Mt Zn

Blåsjön

Permissive tract



G&T model (mean): 0.9% Cu, 1.2% Zn, 2.7 Mt

Tract delineation: 801 Km²

Deposit density model: N90=1, N50=2, N10=5

Undiscovered expert data: 2 deposits

MC simulation (mean): 1.3 % Cu, 3.0 % Zn, 6.5 Mt/median 1.0% Cu, 1.5% Zn, 2.0 Mt

Economic Filter: cont. 0.090 Mt Cu, 0.197 Mt Zn, recover. 0.063 Mt Cu, 0.148 Mt Zn

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