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Exploration strategies - reevaluating Estonian phosphate rock resources

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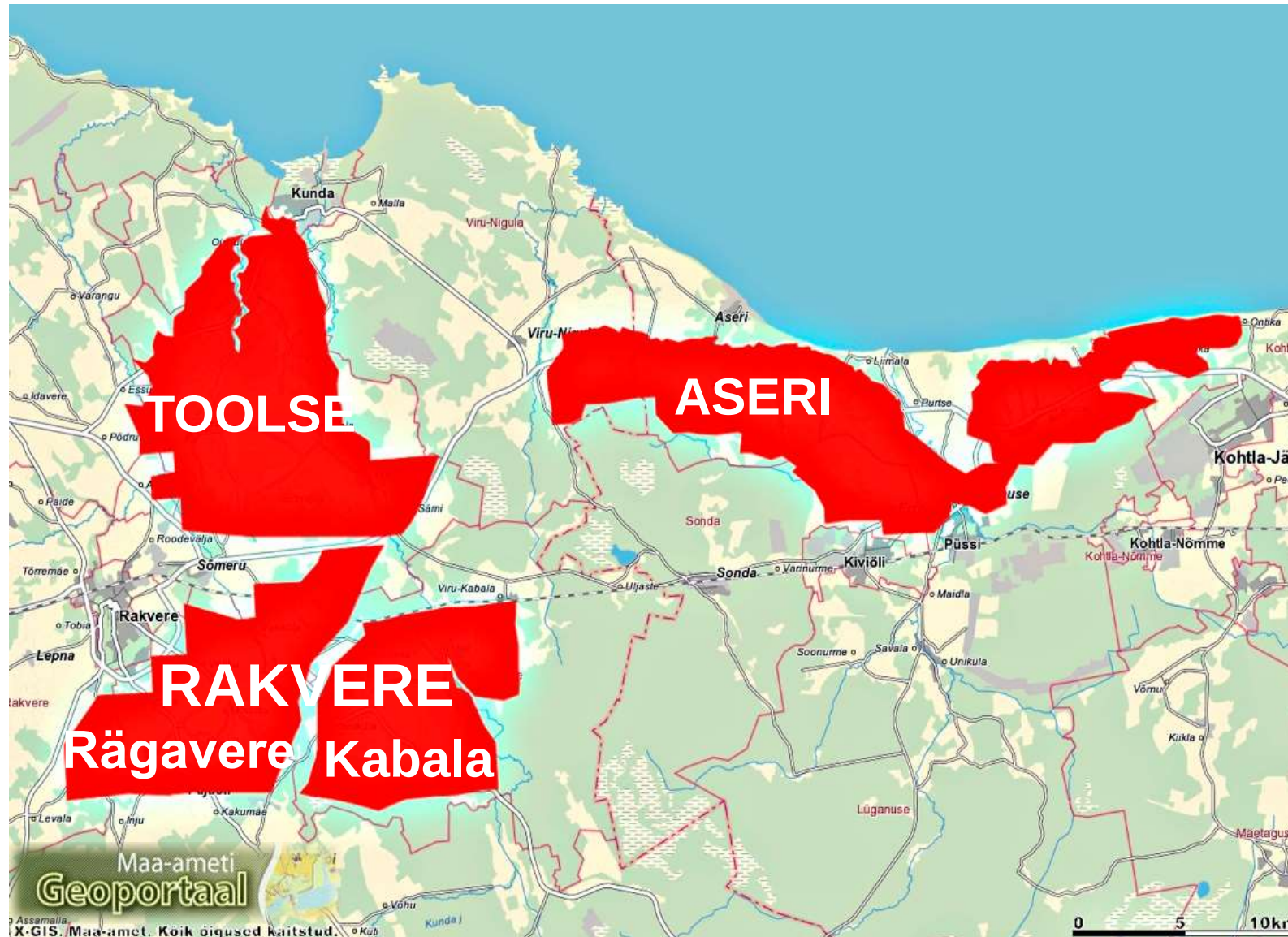
- ▶ • **Overview of Estonian phosphate rock**
- Data and methodology
- Results of resource calculations
- Conclusions and recommendations

Estonian shelly phosphate rock



- Made up of phosphatic linguloid brachiopod shells encased in weakly cemented sandstone matrix
- P_2O_5 concentration in samples ranges between 6-22%
- High concentrations of heavy and light REEs – a multiresource

Largest phosphate rock deposits in Estonia

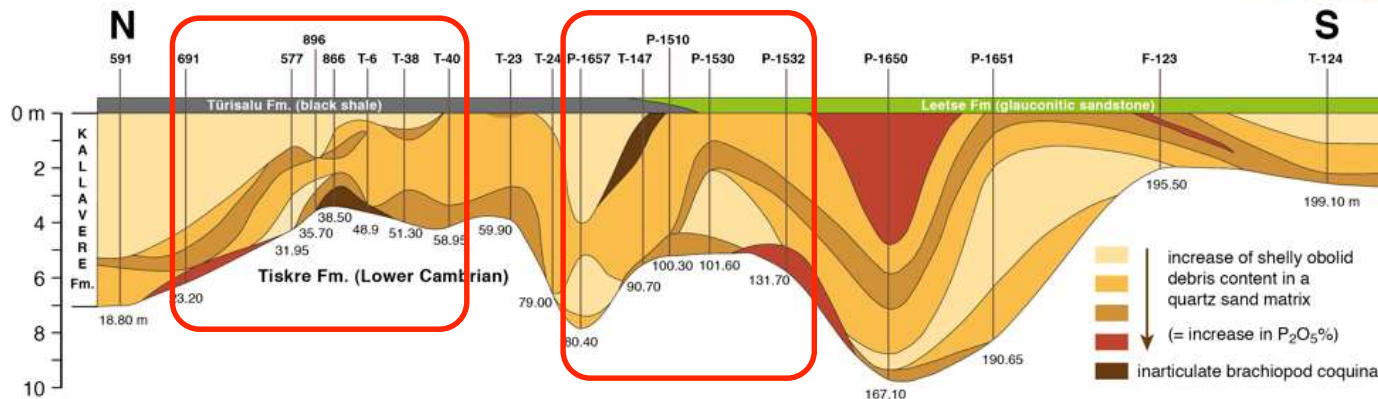
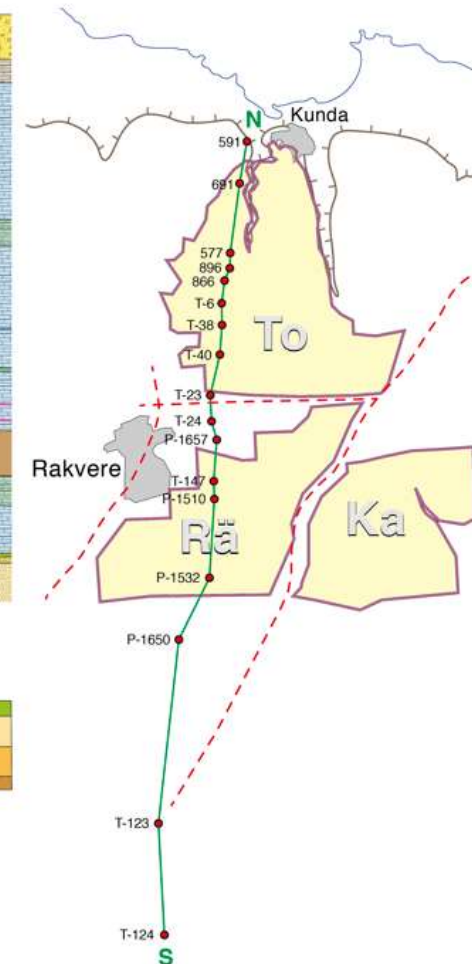
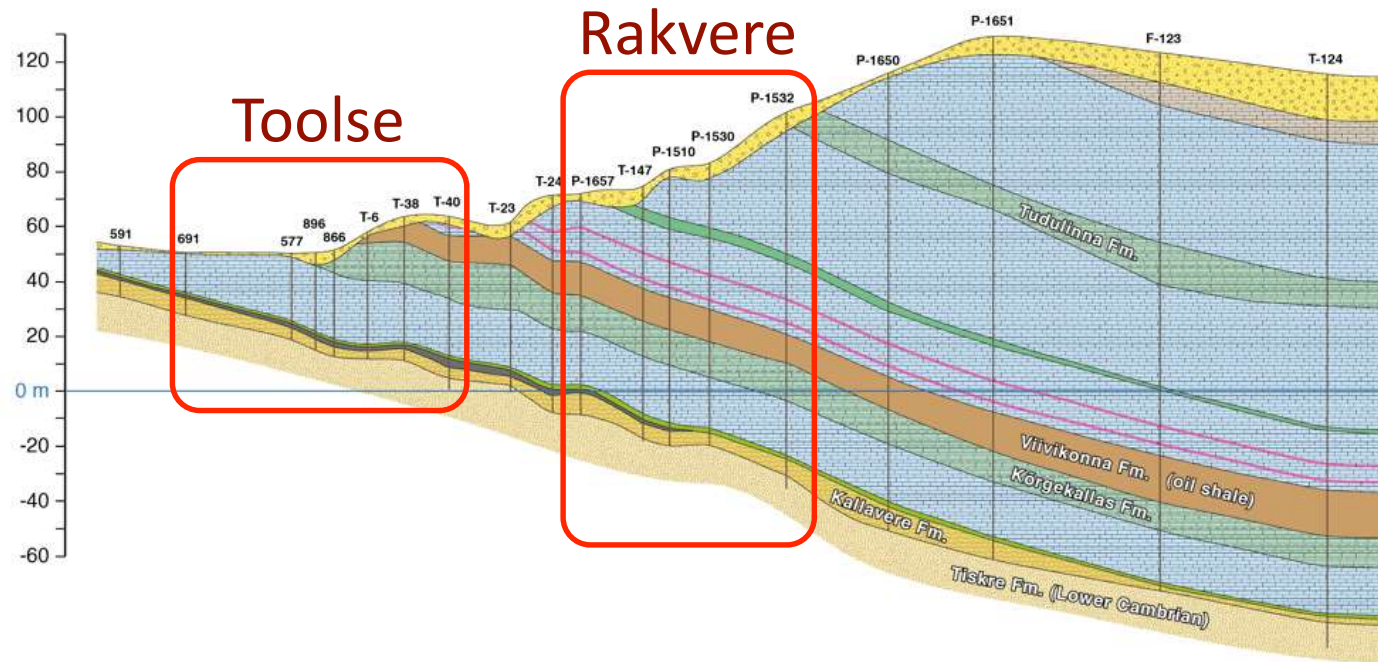


- Majority of resources are located in Rakvere deposit

N – S cross section of the Cambrian–Ordovician succession through the Toolse & Rakvere deposits



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- Majority of research conducted during the Soviet era (mainly between 1950s-80s)
- Over 5000 wells targeting the phosphorite-bearing formation have been drilled
- Deposits were defined as locations, where the P_2O_5 concentration exceeds 6 wt% and 3% in individual samples
- The Rakvere deposit was divided up into blocks, each block was considered homogenous in terms of the spread of P_2O_5 concentration

→ **Basis for resource calculations in the Soviet era – still represented in the Mineral Resources Registry**

To perform a preliminary recalculation of the estimated passive proven resources for the Rakvere phosphate rock deposit.

The following pre-established conditions were followed for the purpose of this exercise:

1. Minimum P_2O_5 concentration cut-off at 8%
2. The minimum thickness of the ore body is 1.8 m
3. Further calculations were conducted with an ore body thickness between 1.8 and 3.5m and that the ore body is made up of a single mineable layer
4. No further geological constraints were applied to the generated 3D ore body



- Overview of Estonian phosphate rock



- **Data and methodology**

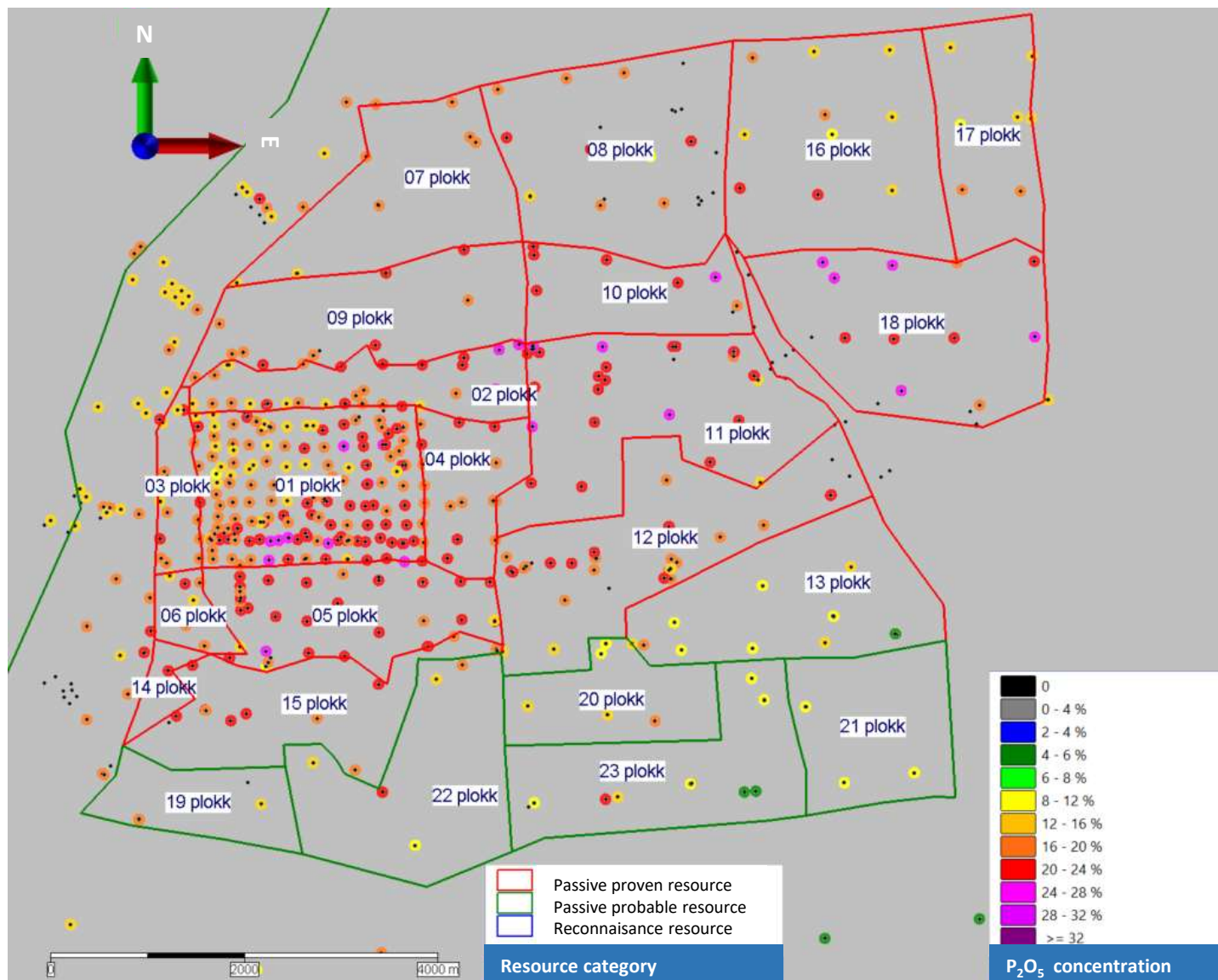
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DATASET OVERVIEW



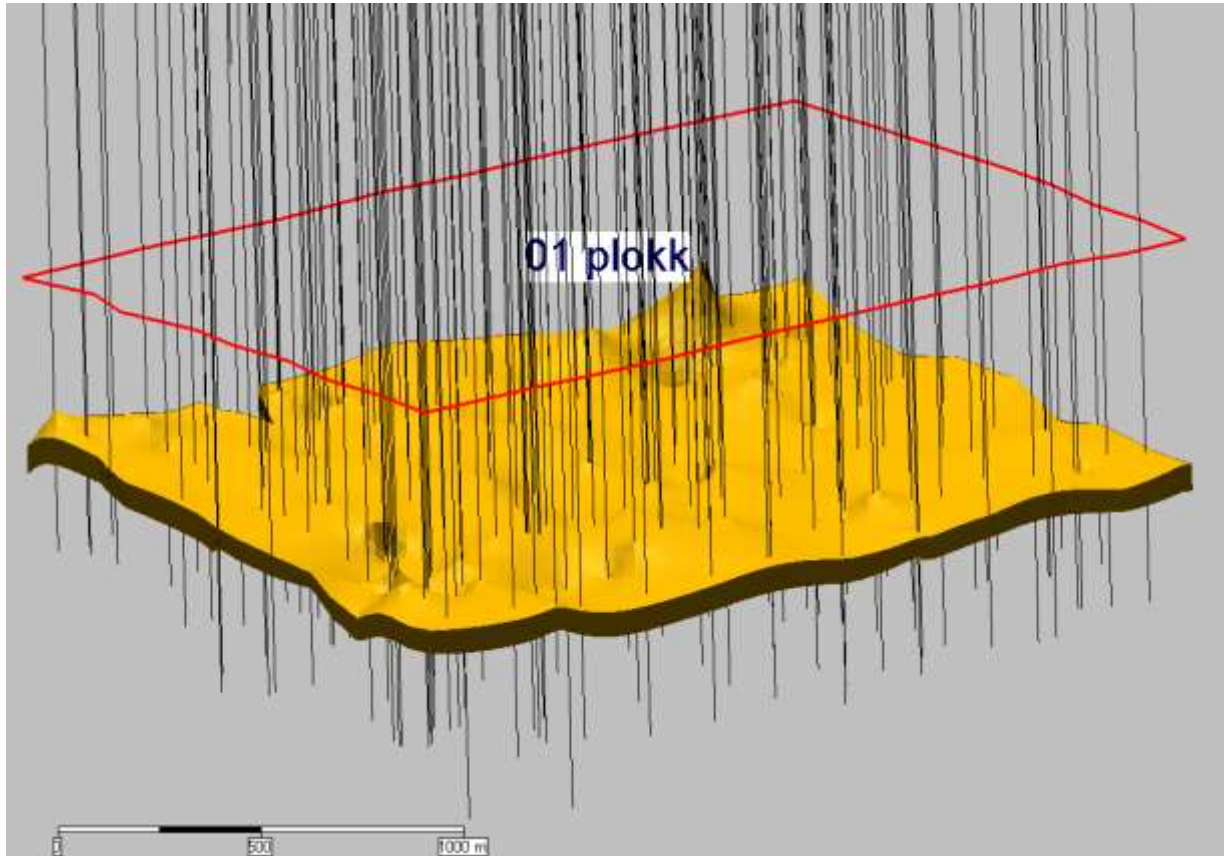
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- Passive resource blocks downloaded from the Mineral Resources Registry, incl GIS polygons
- Data from 509 wells, digitalised by GSE
 - Location coordinates
 - Geochemical data from individual sample intervals
- **At this stage, only Block 01 has sufficient well data density for reliable resource calculations**

Example – 3D ore body model in Block 1

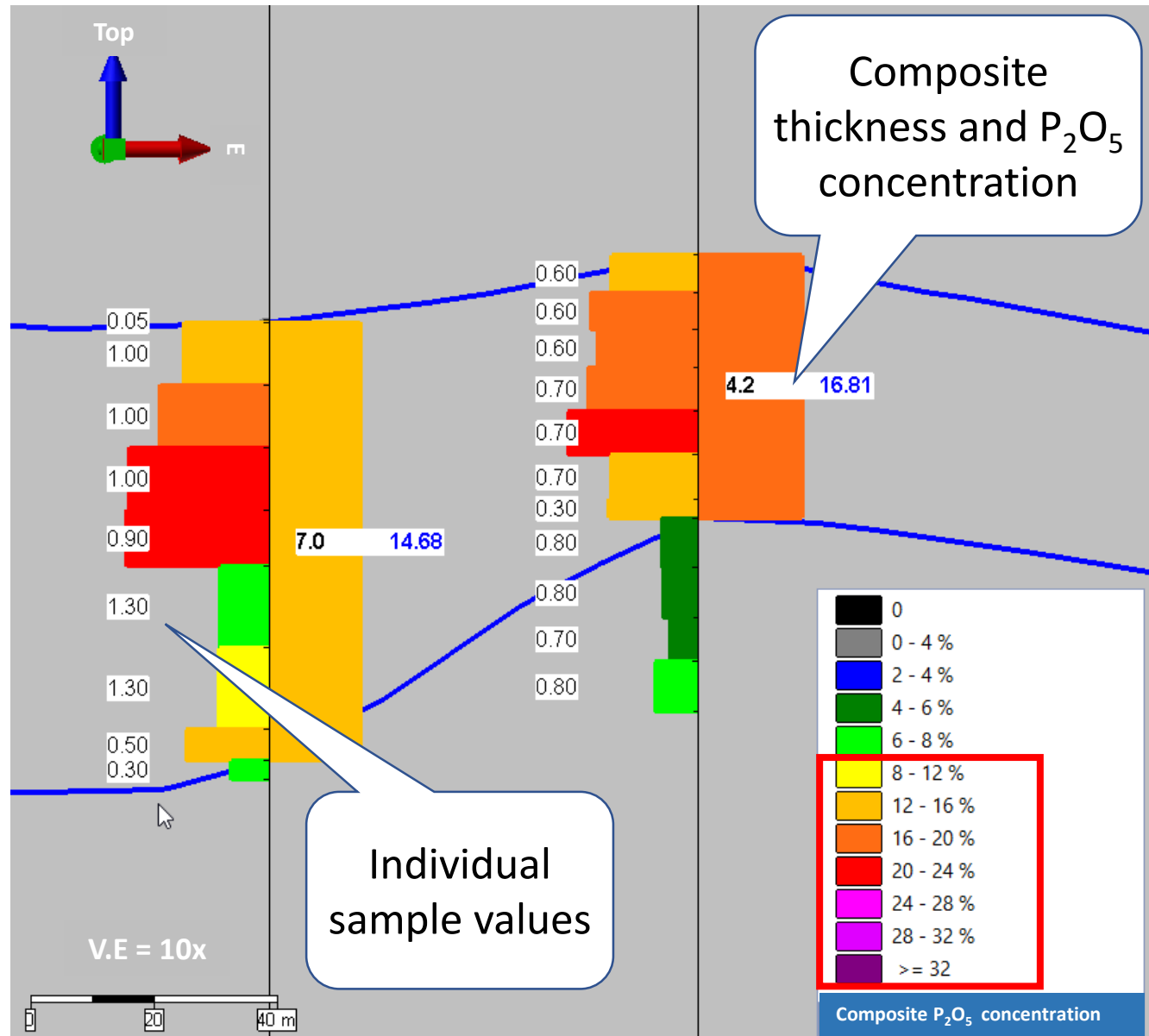
- Min P_2O_5 concentration of 8%
- Min thickness 1,8m
- Max thickness 3,5 m



Two-step process:

1. Create a 3D ore body model with pre-established parameters
2. Calculate the average P_2O_5 content in the ore body → Total P_2O_5 resources in tons

METHODOLOGY – GENERATING COMPOSITES



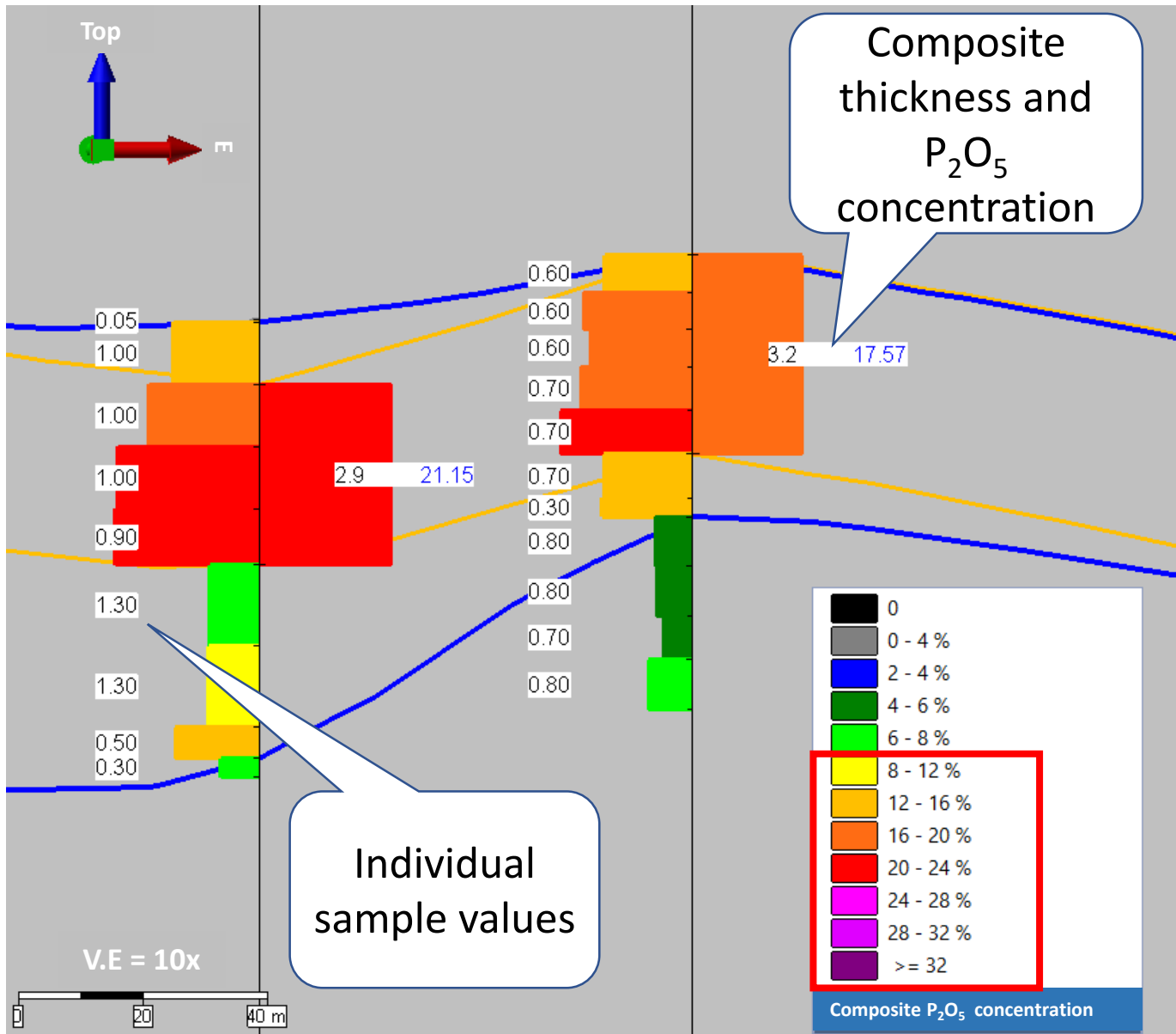
Example: $P_2O_5 > 8\%$ composites with no maximum thickness limitations

- Composites – weighted average of individual samples in a well
- Thickness of the sample was the basis for weighted average
- Two alternative composites were generated in all wells:
 - No maximum thickness
 - Maximum thickness of 3.5m

METHODOLOGY – GENERATING COMPOSITES



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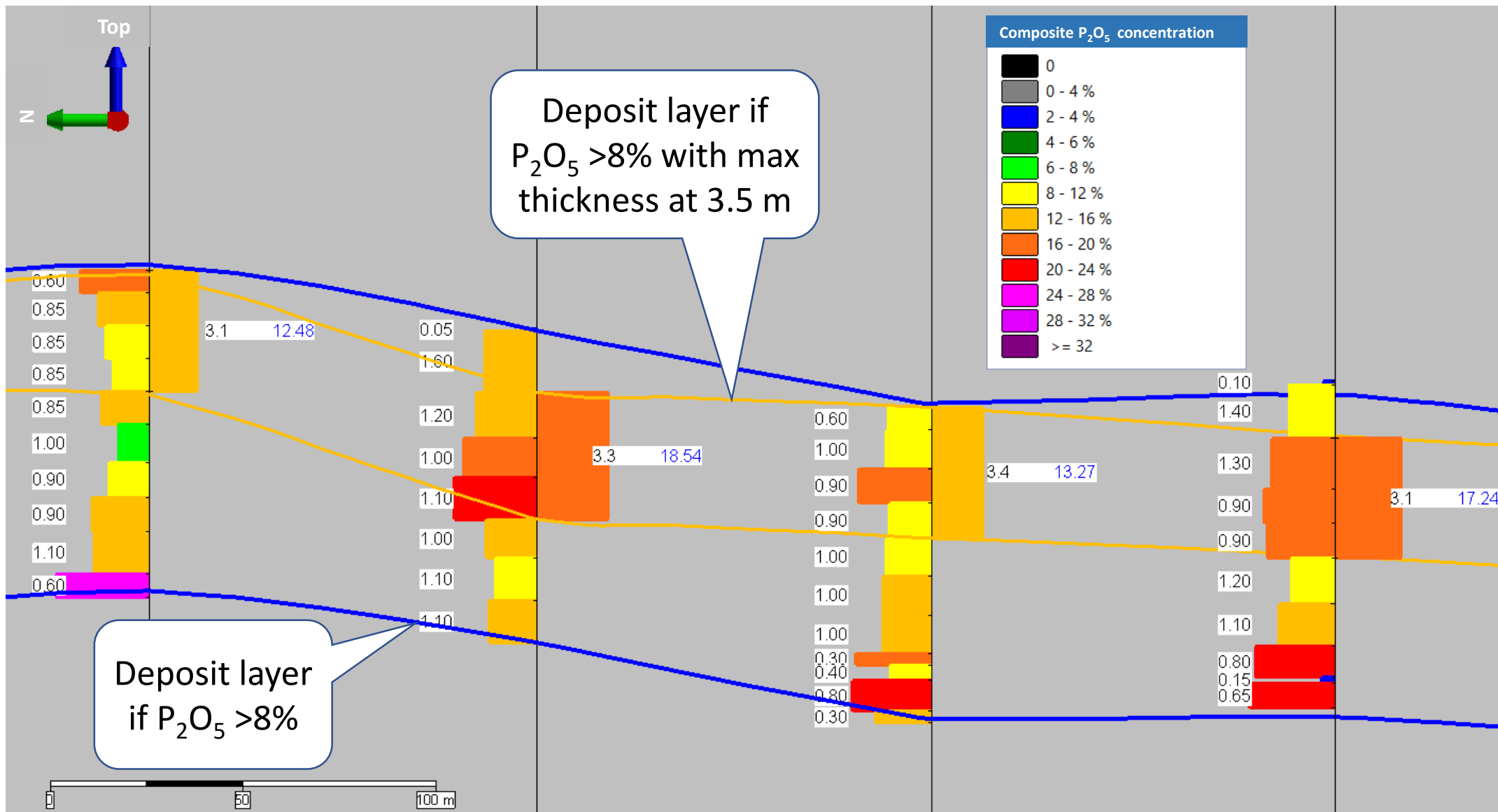
Example: $P_2O_5 > 8\%$ composites with a maximum thickness of 3.5m

- Single continuous layer throughout the ore body
- Composite boundaries set at sample boundaries
- Required manual adjustment of composite boundaries in order to include samples with highest P_2O_5 concentrations
- No geologic interpretation was applied between wells when picking composite locations

METHODOLOGY – GENERATING COMPOSITES



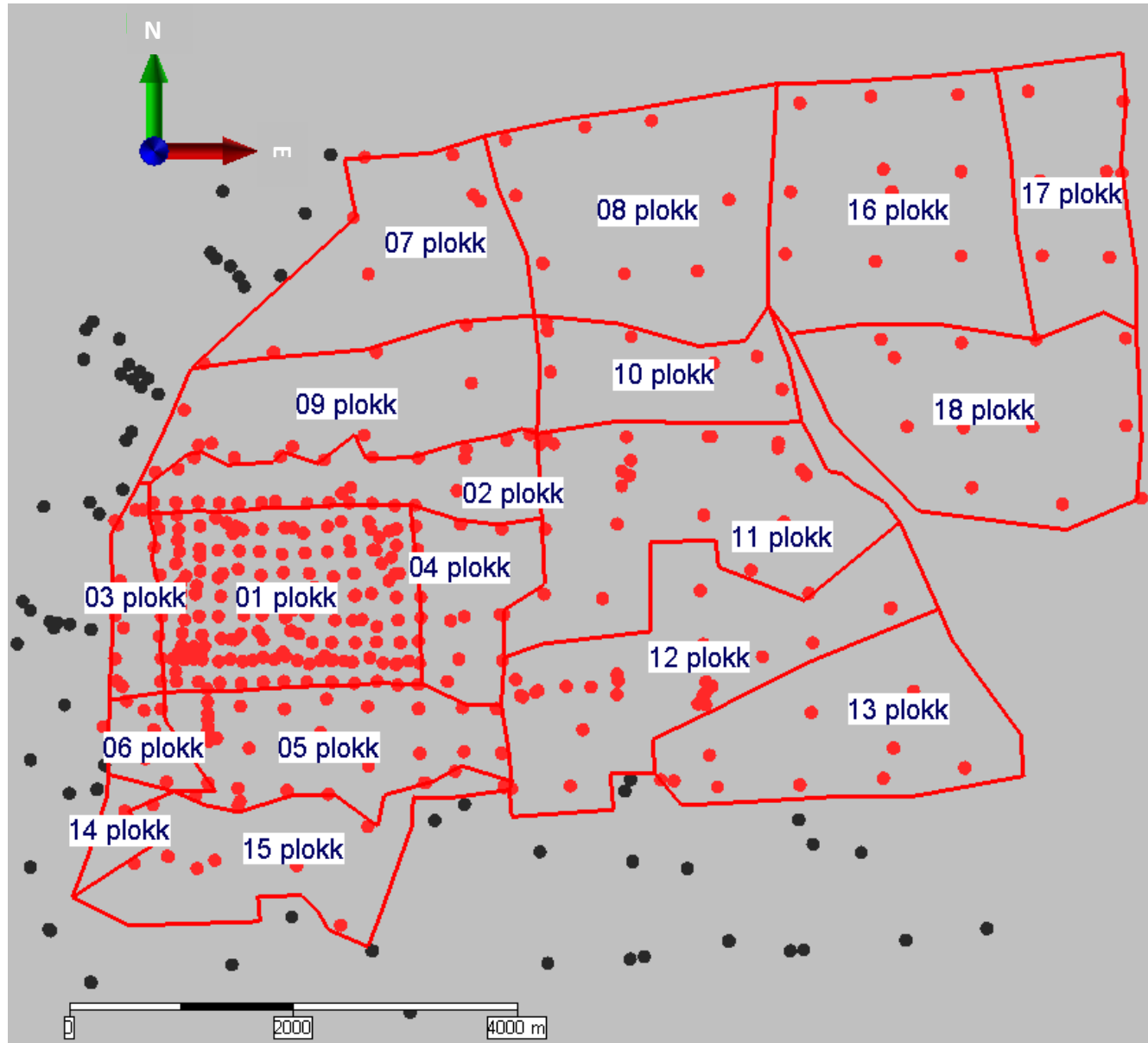
Example: cross-section from western part of Block 01



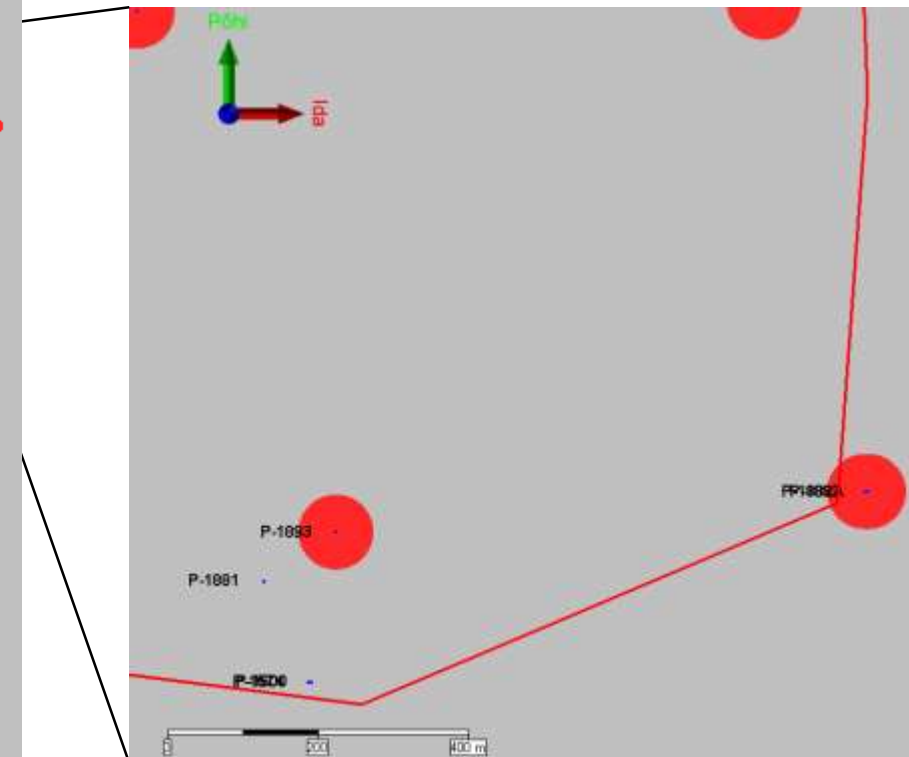
METHODOLOGY – USE OF COMPOSITES



Red circles mark the composites used in resource calculation



- Composite values were allocated to the block where it was located
 - Exceptions were cases where the well was located <50 m outside the block





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RESULTS OF RESOURCE CALCULATIONS



Block	Mineral Resources Registry			Min P ₂ O ₅ cut-off at 8%			Min P ₂ O ₅ cut-off at 8% + min layer thickness at 1,8 m			Min P ₂ O ₅ cut-off at 8% + layer thickness between 1,8 - 3,5 m																						
	Thickness (m)	P ₂ O ₅ %	Resources (P ₂ O ₅ t)	Thickness (m)	P ₂ O ₅ %	Resources (P ₂ O ₅ t)	Thickness (m)	P ₂ O ₅ %	Resources (P ₂ O ₅ t)	Thickness (m)	P ₂ O ₅ %	Resources (P ₂ O ₅ t)																				
01 block	7.7	13.97	9234000	6.0	16.00	8121408	6.0	16.01	8093512	3.0	18.99	4833169																				
02 block	7.8	15.35	5052000	7.0	16.16	4698752	7.0	16.16	4696390	3.0	18.40	2297885																				
03 block	7.9	14.42	1883000	6.8	15.53	1720131	6.8	15.53	1720115	3.0	17.69	854111																				
04 block	7.4	13.89	3487000	5.3	16.88	3008957	5.3	16.88	3008956	3.2	19.26	2026748																				
05 block	7.8	13.14	6379000	4.8	17.68	5186658	4.8	17.68	5186658	3.1	20.51	3830802																				
06 block	7.6	13.75	1263000	5.7	15.79	1063744	5.7	15.79	1063744	3.0	17.93	630087																				
07 block	5.9	16.27	7007000	5.8	15.87	6565774	5.8	15.87	6565774	2.9	17.23	3629903																				
08 block	5.7	16.35	13831000	5.1	16.32	8562188	5.1	16.32	8562188	3.2	18.15	5965973																				
09 block	7.4	16.26	8812000	6.8	16.46	8005248	6.8	16.46	8005248	3.1	19.29	4331605																				
10 block	7.1	17.66	5513000	6.5	18.36	5120243	6.5	18.36	5120243	3.2	20.83	2837466																				
11 block	7.6	15.59	11946000	6.2	17.63	10765386	6.2	17.63	10765386	3.1	21.73	6704610																				
12 block	7.2	11.1	8022000	3.5	17.67	6131273	3.6	17.65	6027621	2.8	18.86	5031370																				
13 block	6.4	7.98	4221000	2.6	11.89	2519066	2.7	11.81	2375403	2.4	11.17	1981572																				
14 block	8.7	12.86	954000	6.2	15.52	801389	6.2	15.52	801389	3.2	22.44	609514																				
15 block	8.6	12.19	6742000	4.7	17.48	5153822	4.7	17.48	5153792	3.0	19.93	3318067																				
16 block	5.9	14.12	9229000	5.6	13.69	8407347	5.6	13.69	8407347	3.1	15.76	5389744																				
17 block	5.7	12.82	3989000	4.8	13.15	3421500	4.8	13.15	3421500	3.1	14.66	2462588																				
18 block	7	16.71	11909000	5.5	19.48	10833325	5.5	19.48	10833325	3.1	21.48	6725152																				
Avg P ₂ O ₅ Total Resources %			Avg P ₂ O ₅ Total Resources (P ₂ O ₅ t)			Avg P ₂ O ₅ Total Resources %			Avg P ₂ O ₅ Total Resources (P ₂ O ₅ t)			Avg P ₂ O ₅ Total Resources %			Avg P ₂ O ₅ Total Resources (P ₂ O ₅ t)																	
14.86%			119 473 000			5.5			16.41%			100 086 210			5.5			16.42%			99 808 590			3.0			18.53%			63 460 366		

Total P₂O₅ resources compared to the Mineral Resources Registry :

83.8%

83.5%

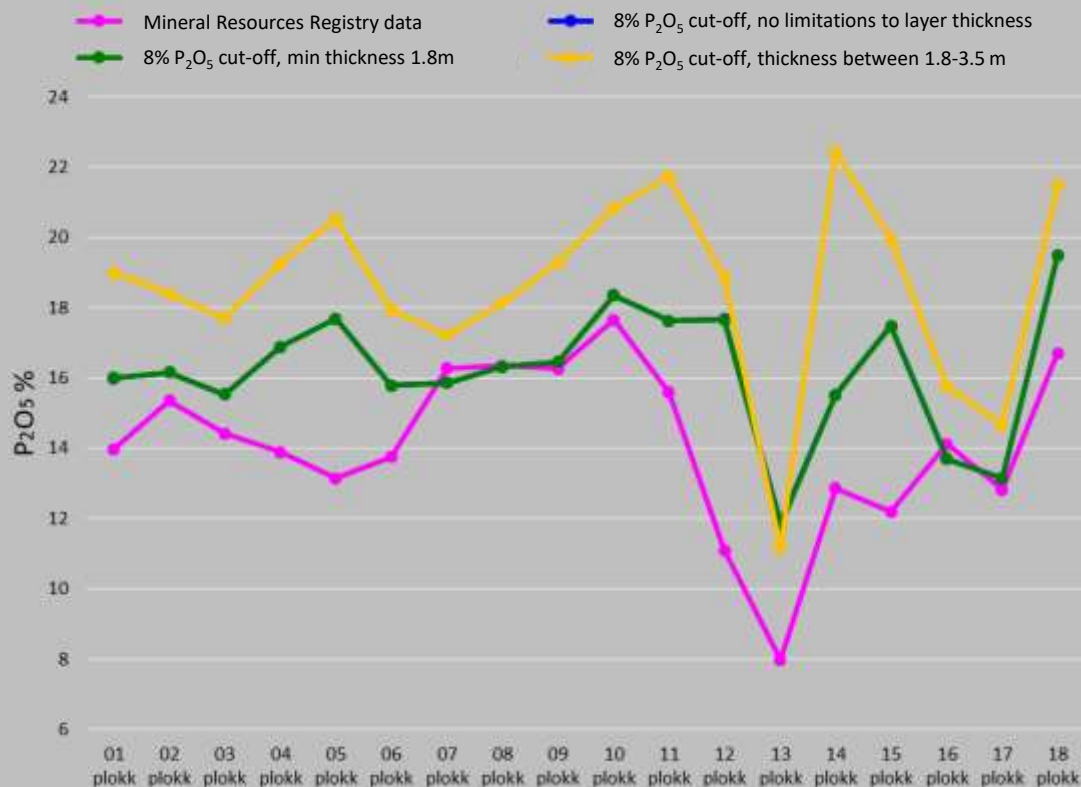
53.1%

RESULTS OF RESOURCE CALCULATIONS

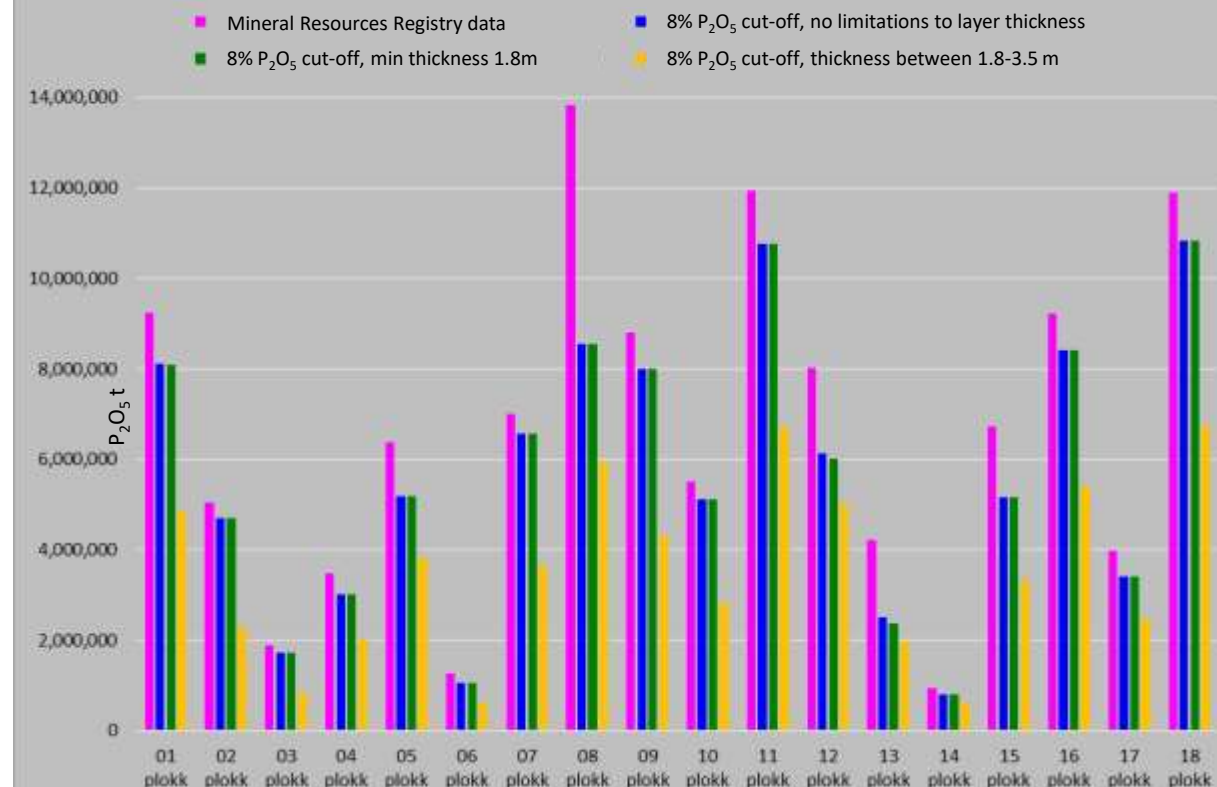


- The deposit exhibits a great deal of lateral heterogeneity
- By increasing the P_2O_5 cut-off from 6% to 8%:
 - Total P_2O_5 resource tons decreased for the whole Rakvere deposit
 - Average P_2O_5 concentration increased in terms of the defined ore body

Average P_2O_5 concentration by block (%)



Average P_2O_5 content by block (t)





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- Previous resource estimates were calculated with a homogenised view of the deposit, using average concentration and thicknesses
- The preliminary resource recalculation was performed in order to generate a 3D ore body and get a better estimate with current industrial use in mind
 - Gives an overview on how the amount of resources change when certain parameters are scaled to current economic standards
 - By digitalising the individual samples, the P_2O_5 cut-offs can be fine-tuned for more precise resource calculations in the future
- **Current work is still way too broad for any potential mine developments!**

- **Compiling all previously gathered data into a single digital database**
- **New wells have to be drilled in order to:**
 - **a) validate pre-existing data**
 - **b) obtain additional data for modifying factors and pre-feasibility study**
 - Location and required density of new wells to be determined by geostatistics
- **Modelling the spread of other chemical components, e.g rock strength vs MgO content**



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Thank you!