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Geological 3D Modelling and Resource Estimation of Budenovskoye Uranium Deposit (Kazakhstan)

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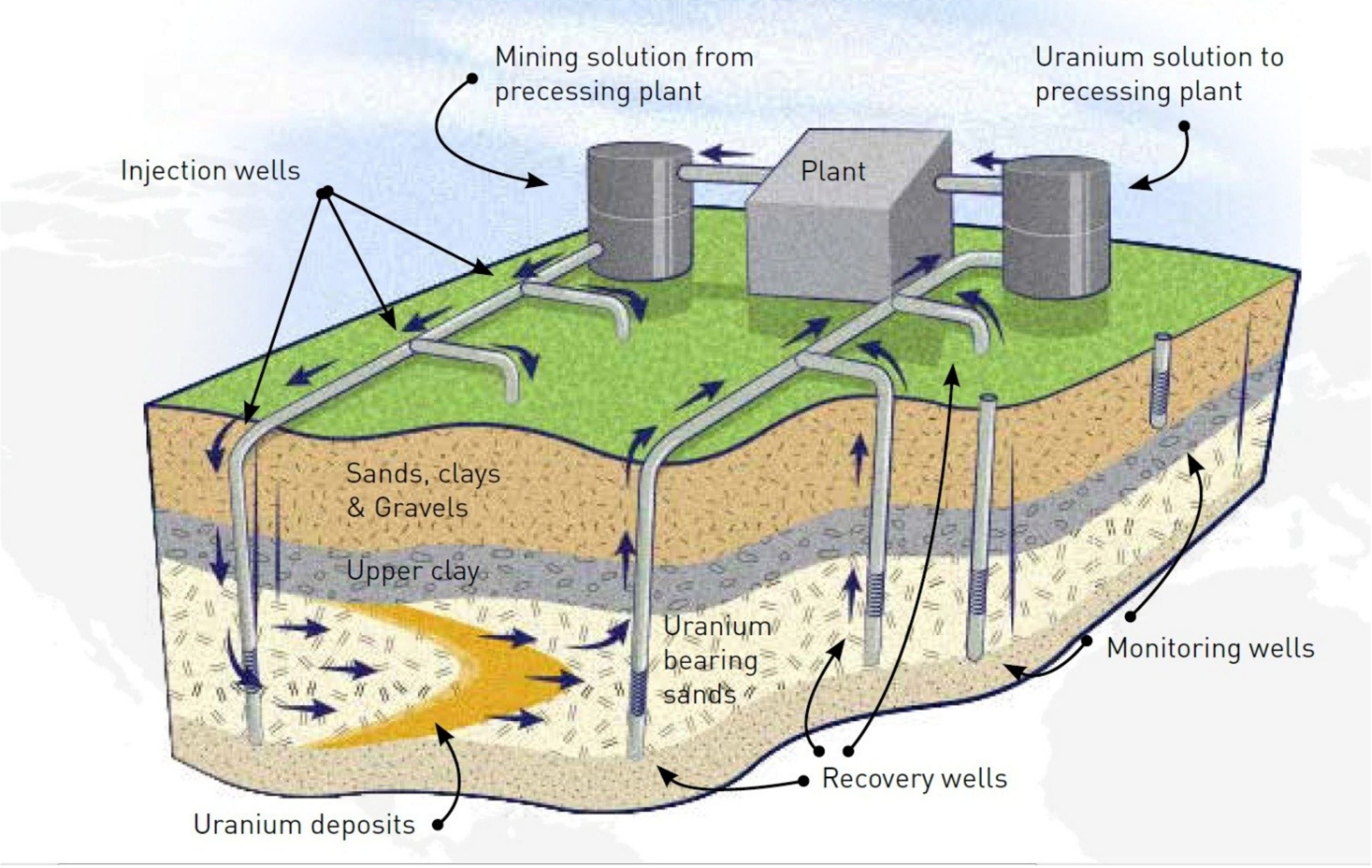
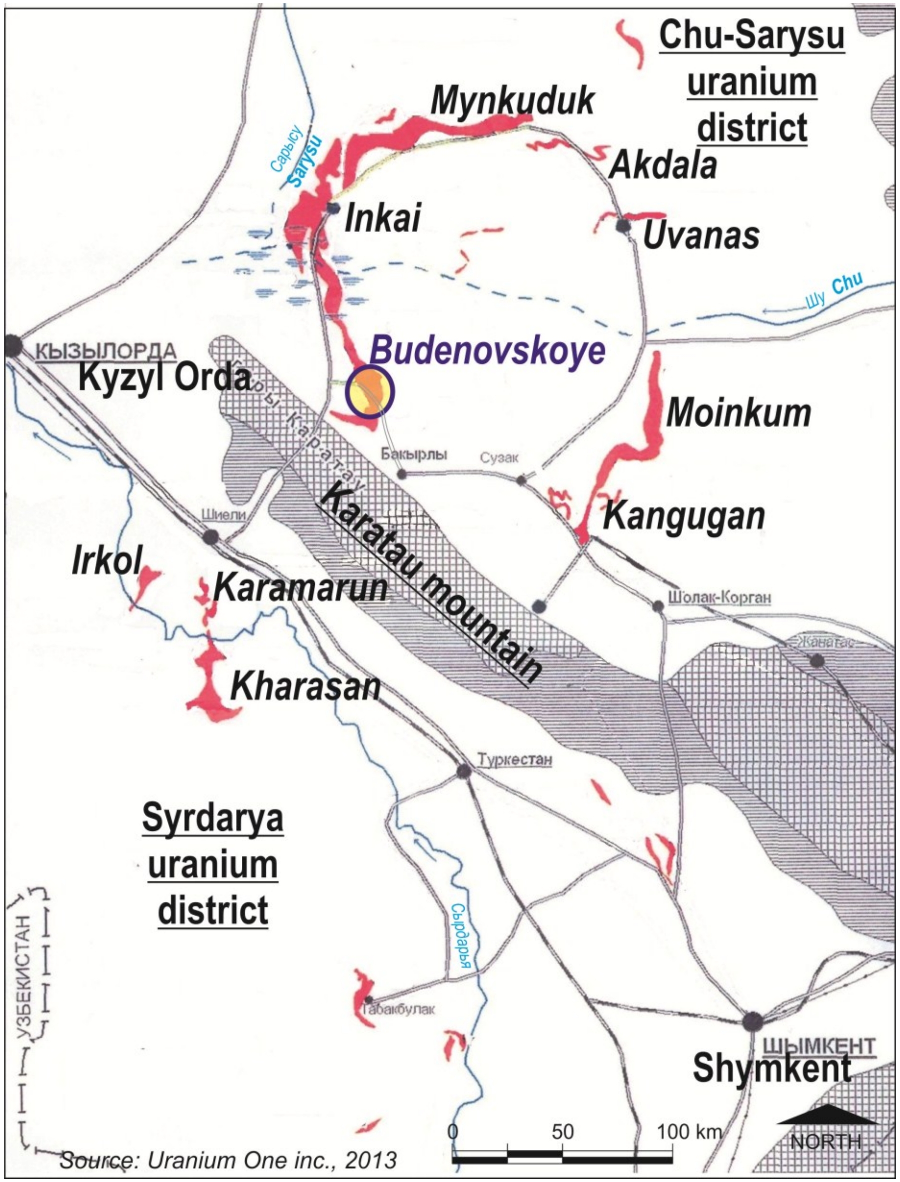
30 YEARS
•1984 - 2014•

Introduction



Roll-front sandstone uranium deposits can be extracted using *in situ recovery* methods with low operational costs

Introduction - South Kazakhstan

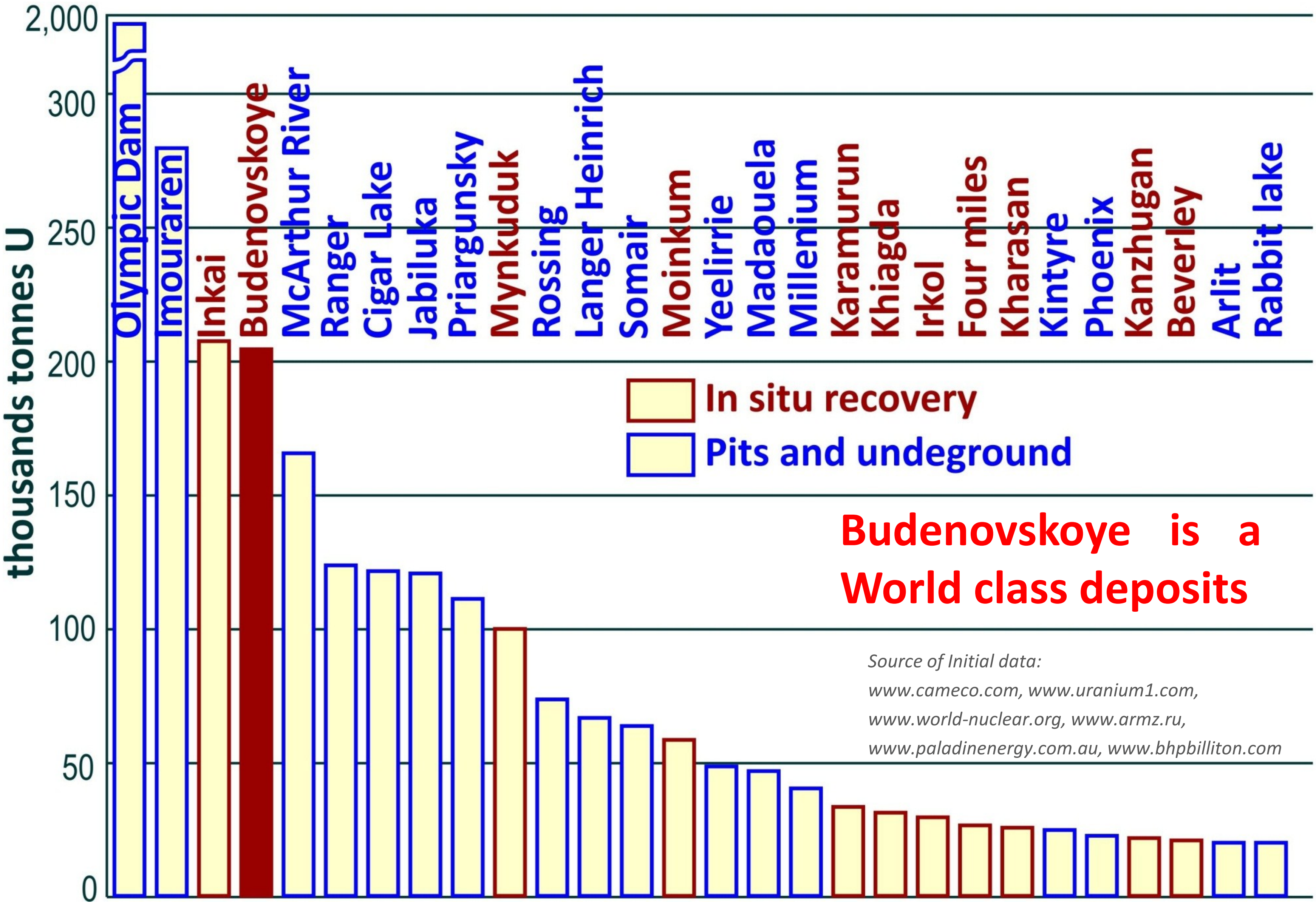


The production share from the Kazakhstan roll-front sandstone-hosted uranium deposits mined using the ISR method comprises 36% of the world total

CSA Global was retained by Uranium One to Resource Estimates for Budenovskoye deposit

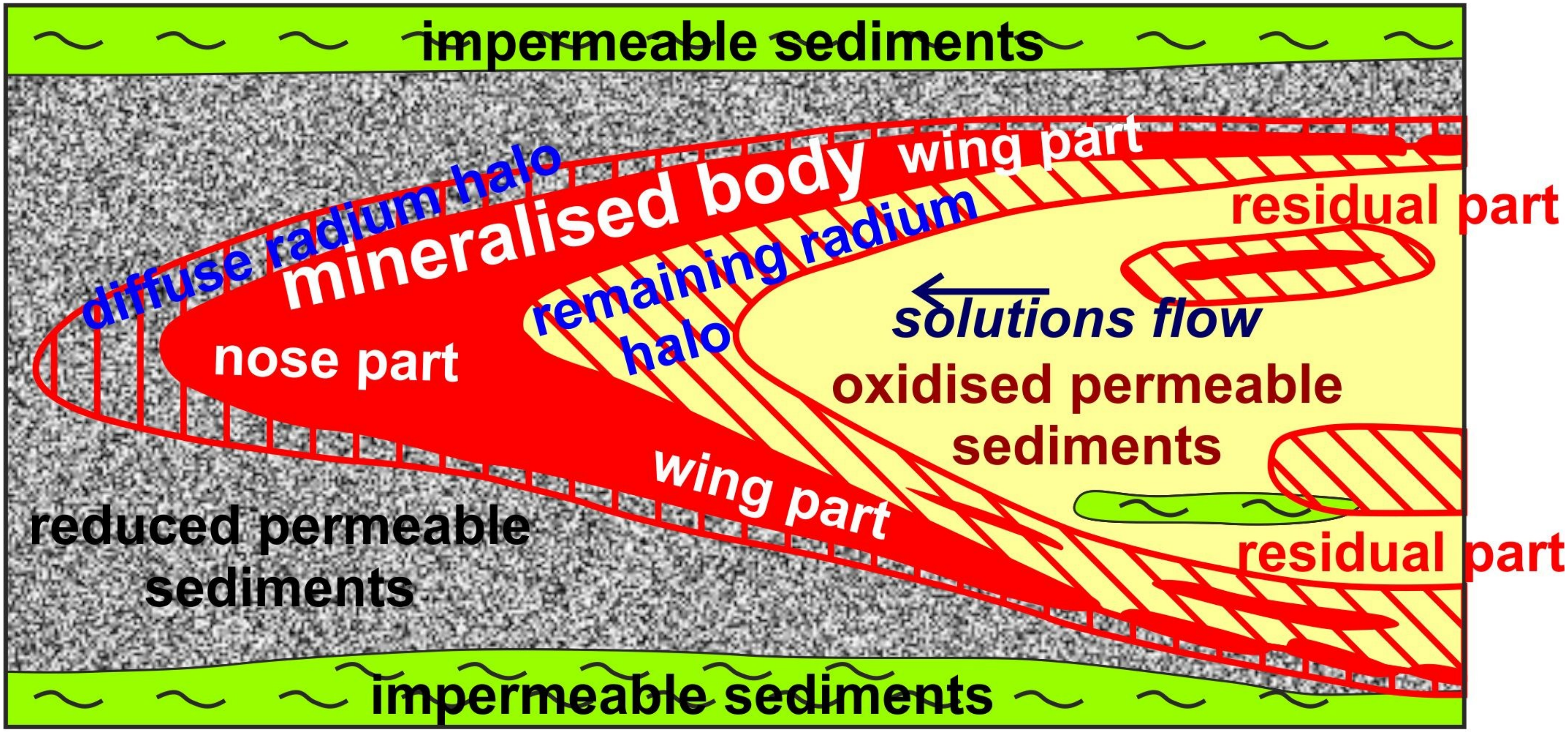
CSA Global has completed modelling and significantly improved the method of modelling roll-front deposits.

Introduction - uranium deposits



Source of Initial data:
www.cameco.com, www.uranium1.com, www.world-nuclear.org, www.armz.ru, www.paladinenergy.com.au, www.bhpbilliton.com

Structure of roll-front deposits



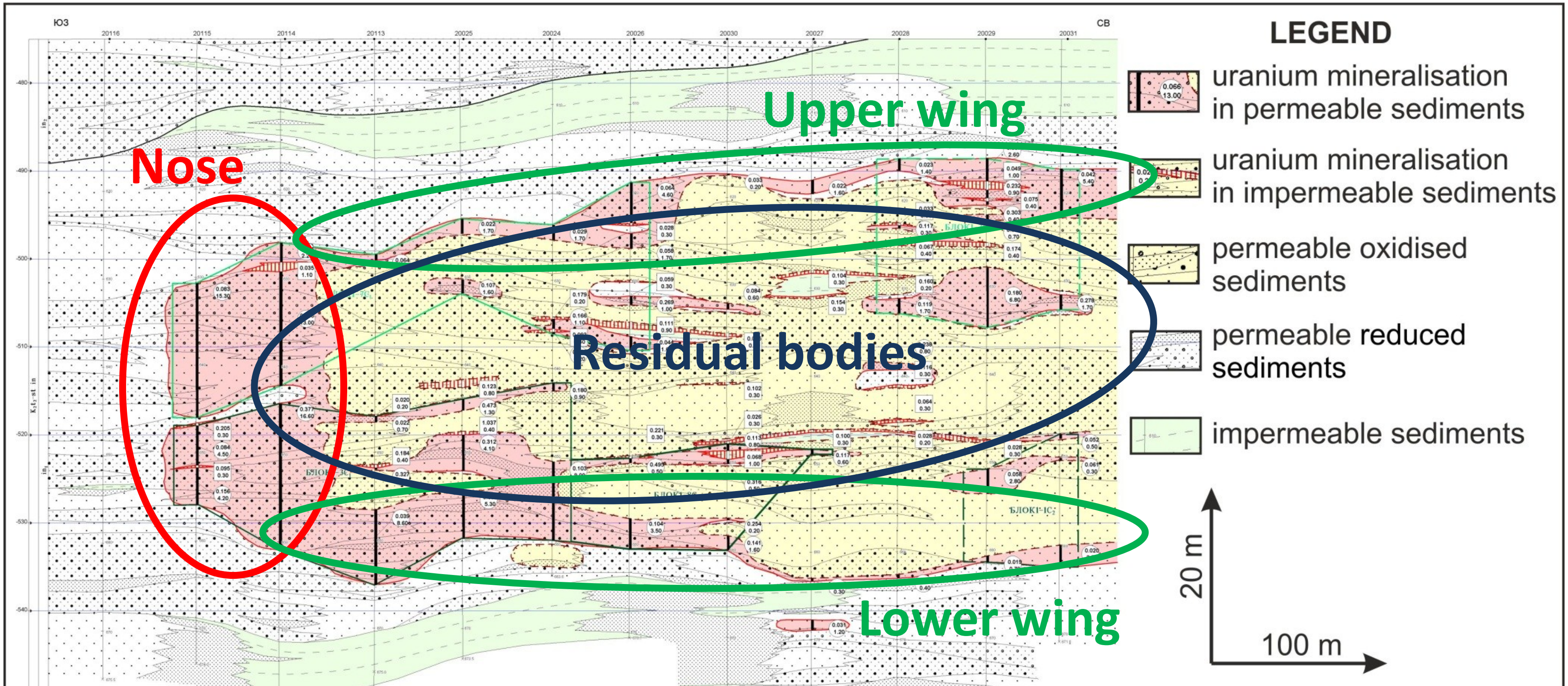
Source: Brovin et al., 1997

Typical cross section of roll-front

The mineralised bodies consist of several morphological elements: noses, wings and residual parts. Mineralised bodies are surrounded by radium halos.

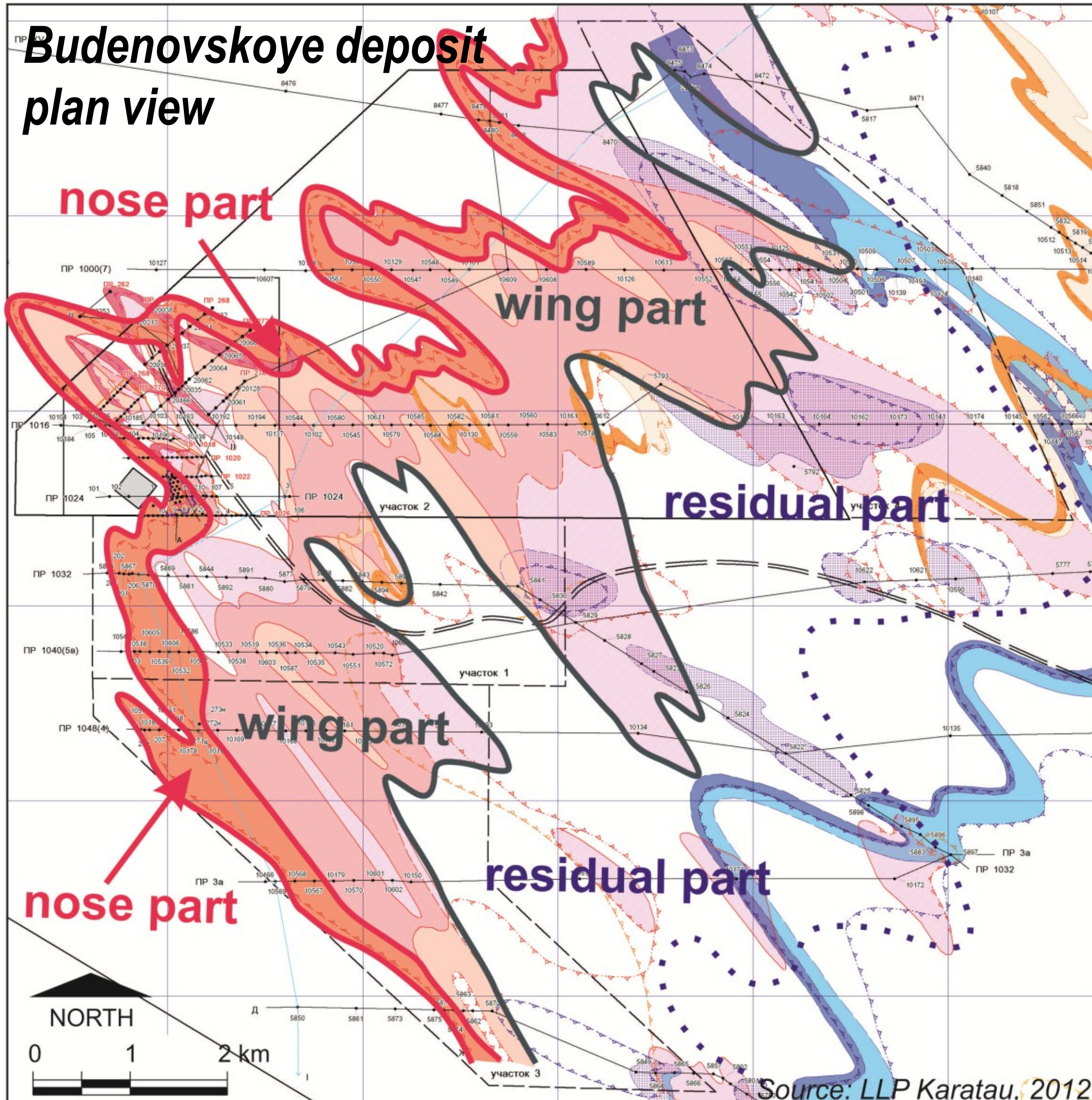
Structure of roll-front deposits

Example mineralised body in cross section at the Budenovskoye



Source: Chernyakov et al, 2010

Structure of roll-front deposits



Roll-front sandstone-hosted uranium mineralisation is spatially and genetically associated with a regional redox front

The distribution of nose parts marks the redox front

The wing and residual parts of rolls are distributed in the rear part of roll-fronts.

Determination of U grades

gamma logging

prompt fission neutron logging

Ra halos definition control method

sampling

assaying

eU modify

U

K, Th

Ra(eU)

REF

U

Ra(eU)

Rn degassing factor

Determination of lithology

electrical logging:

RL - resistivity logging ,

SP - spontaneous polarisation logging

sampling

hydrogeological drilling

definition of permeability

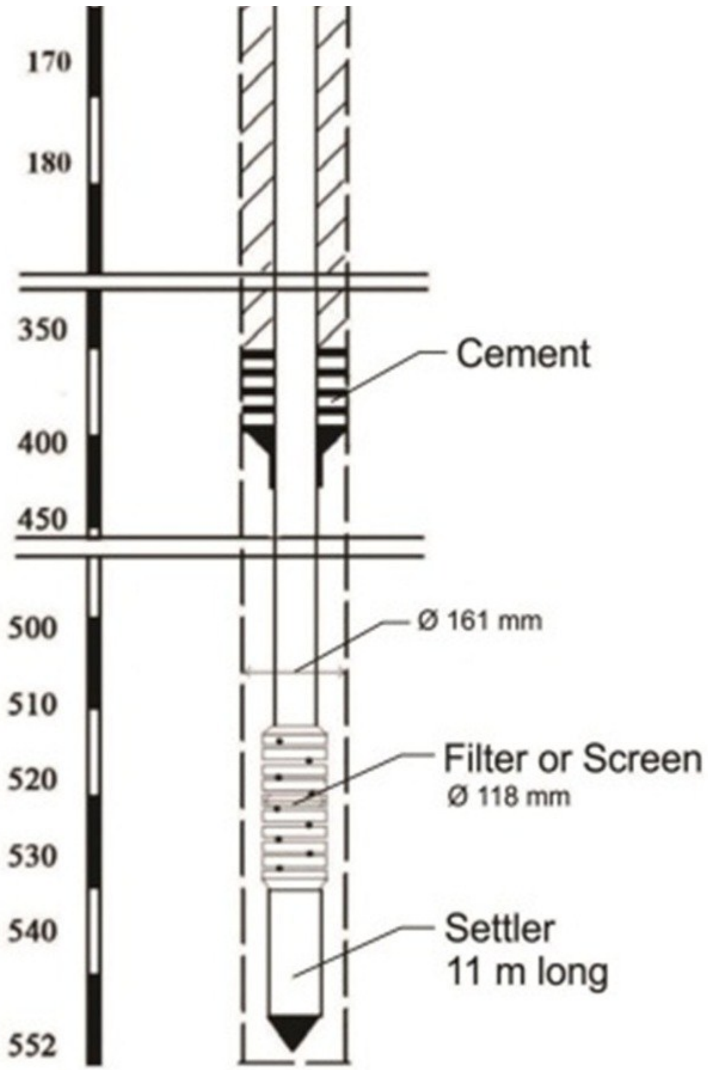
RL (&SP) vs. permeability

permeability vs. grain size

RL (&SP) vs grain size

granulometric analysis

Why use indirect methods?

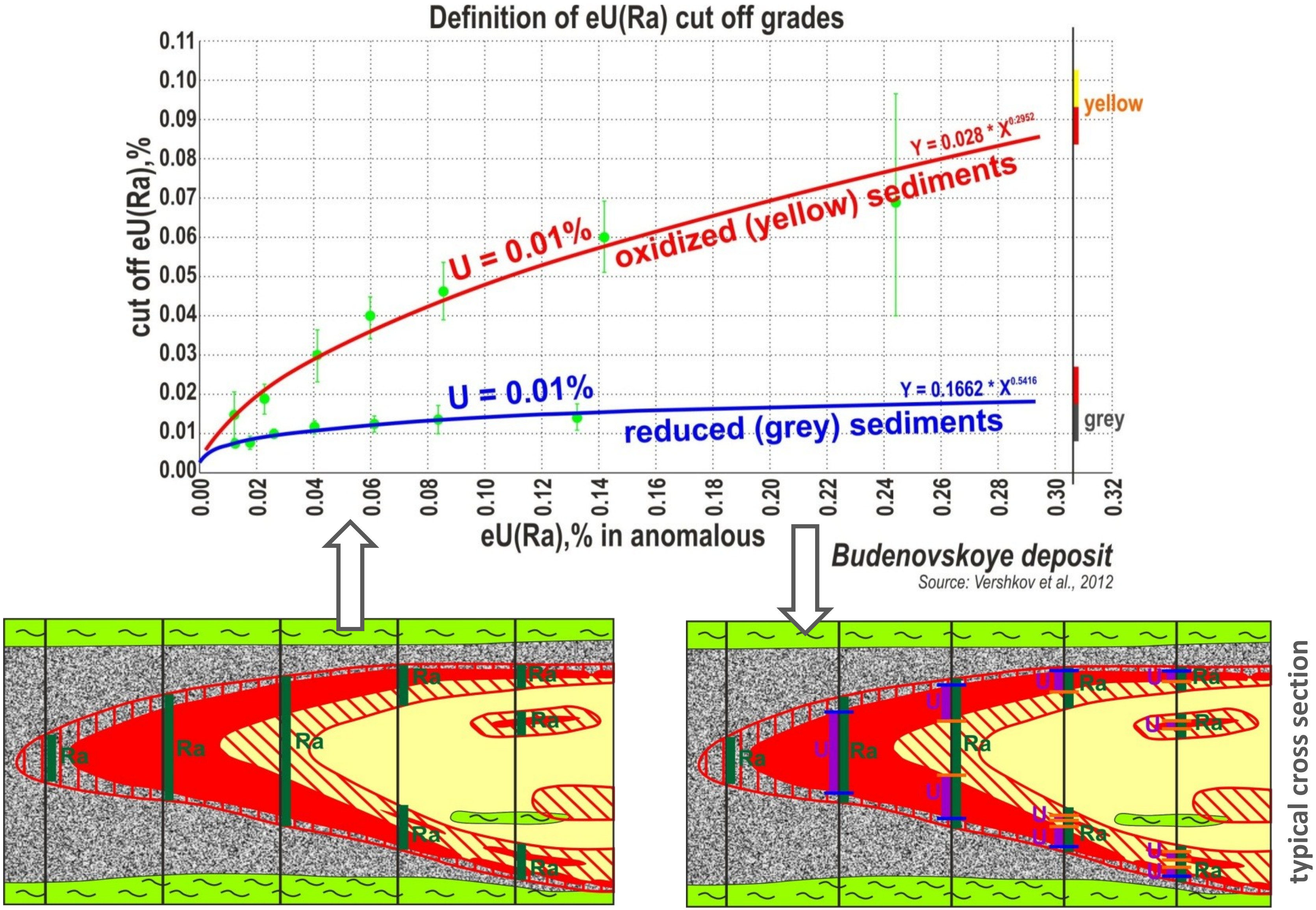


Because screens (filters) need to be set immediately after drilling of operational wells.

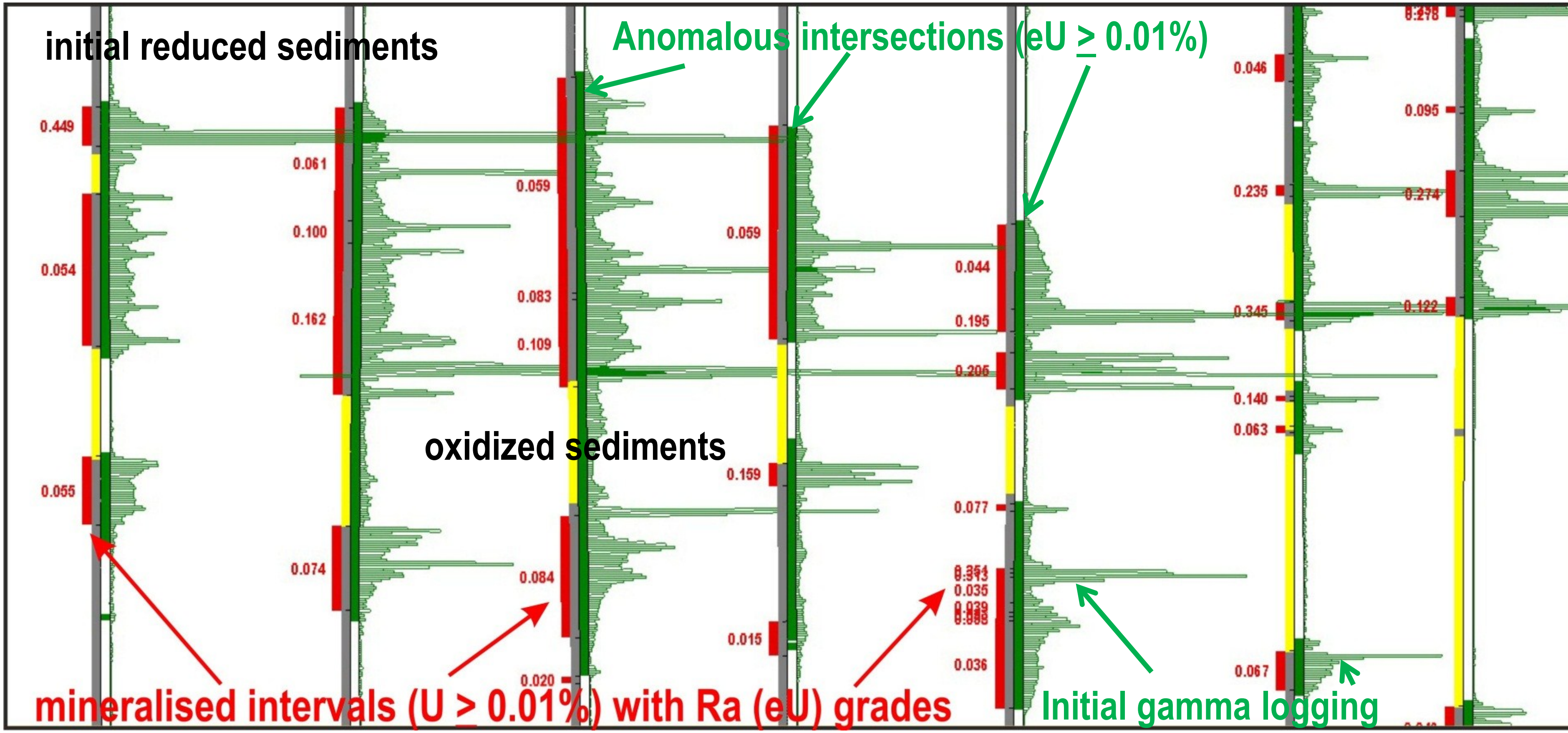
Express wireline methods:

- gamma or prompt fission neutron logging
  - ➔ uranium mineralisation
- electrical logging
  - ➔ permeability of the host sediments.

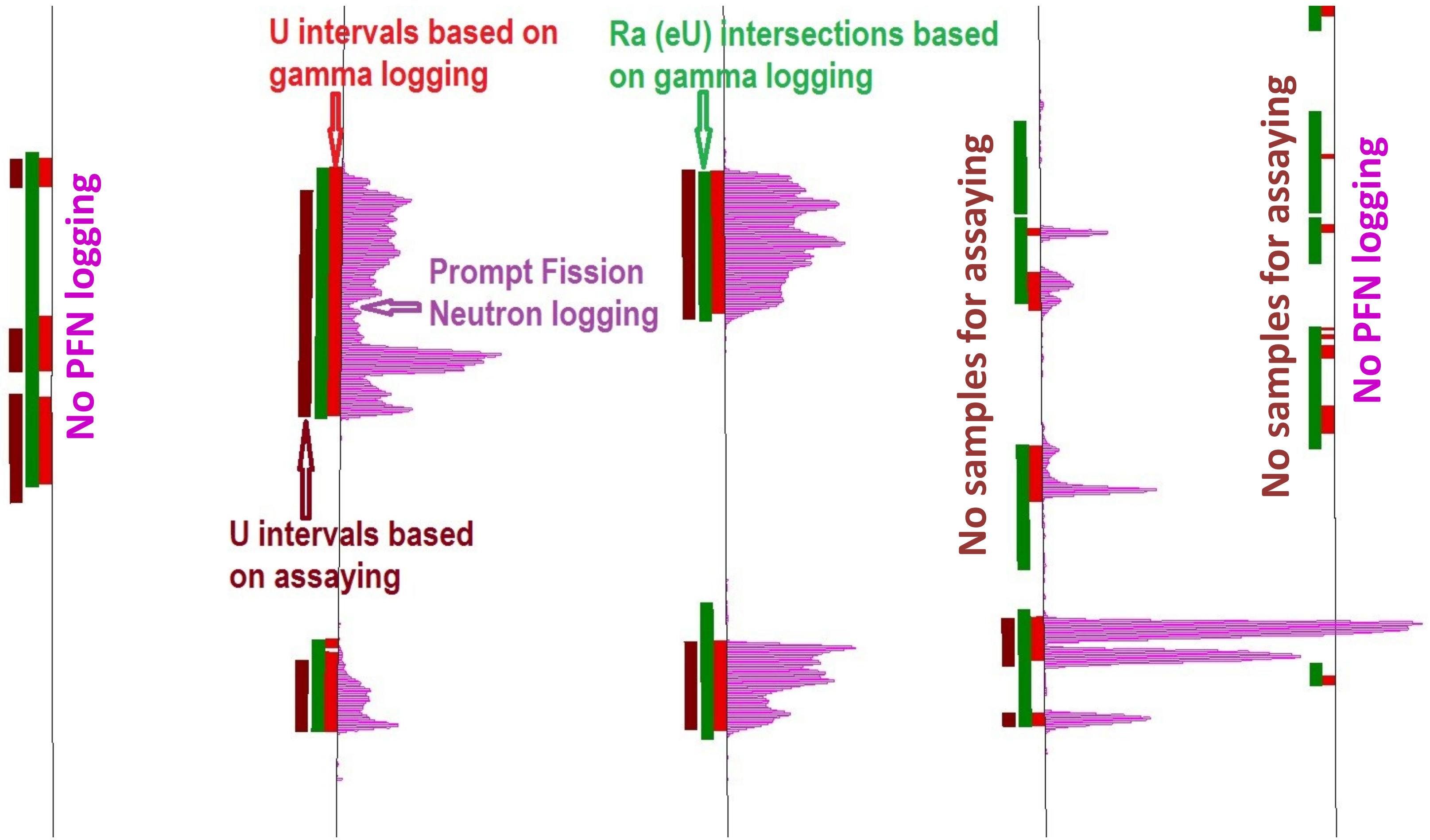
Definition of mineralised intervals



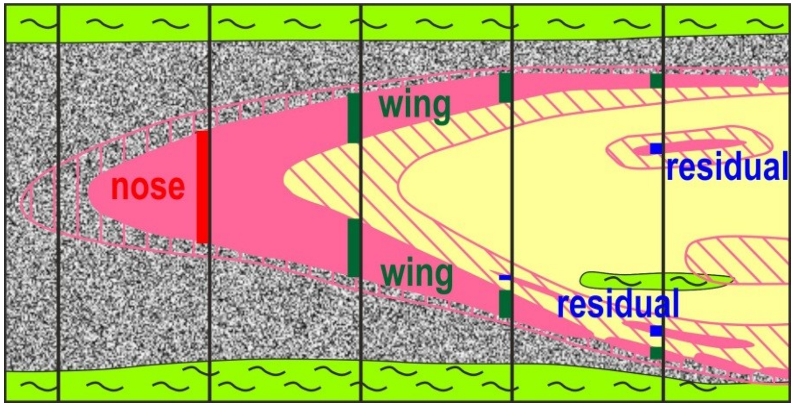
Definition of mineralised intervals



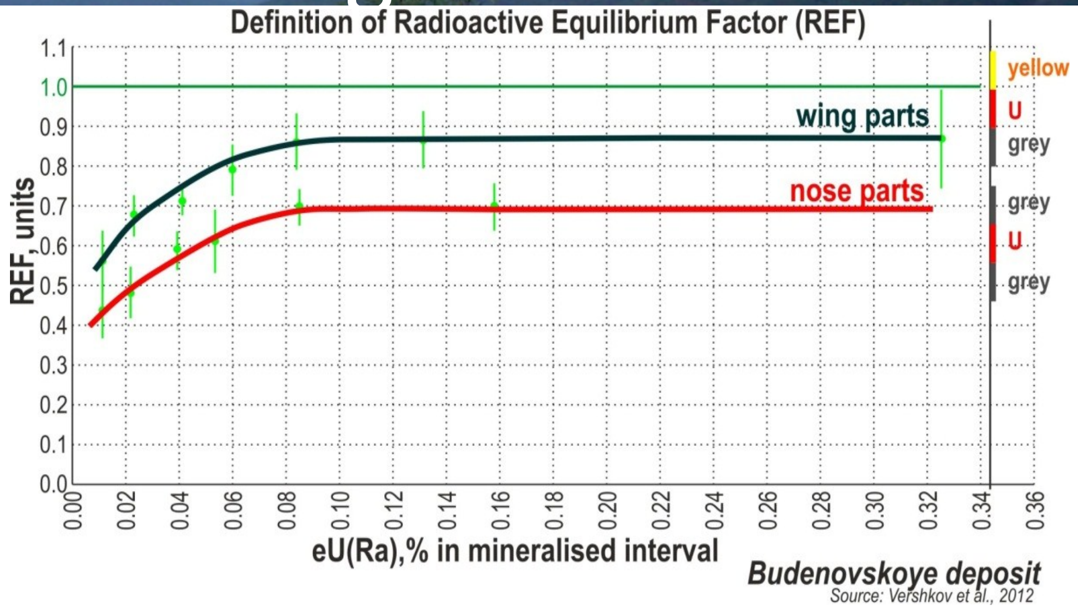
Verification of mineralised intervals

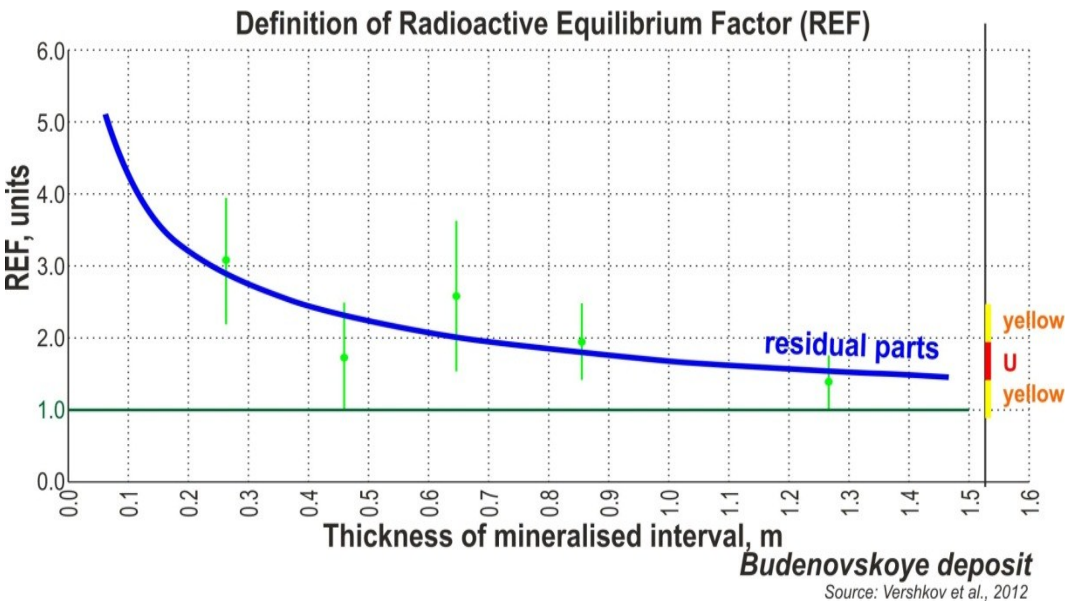


Definition of uranium grades

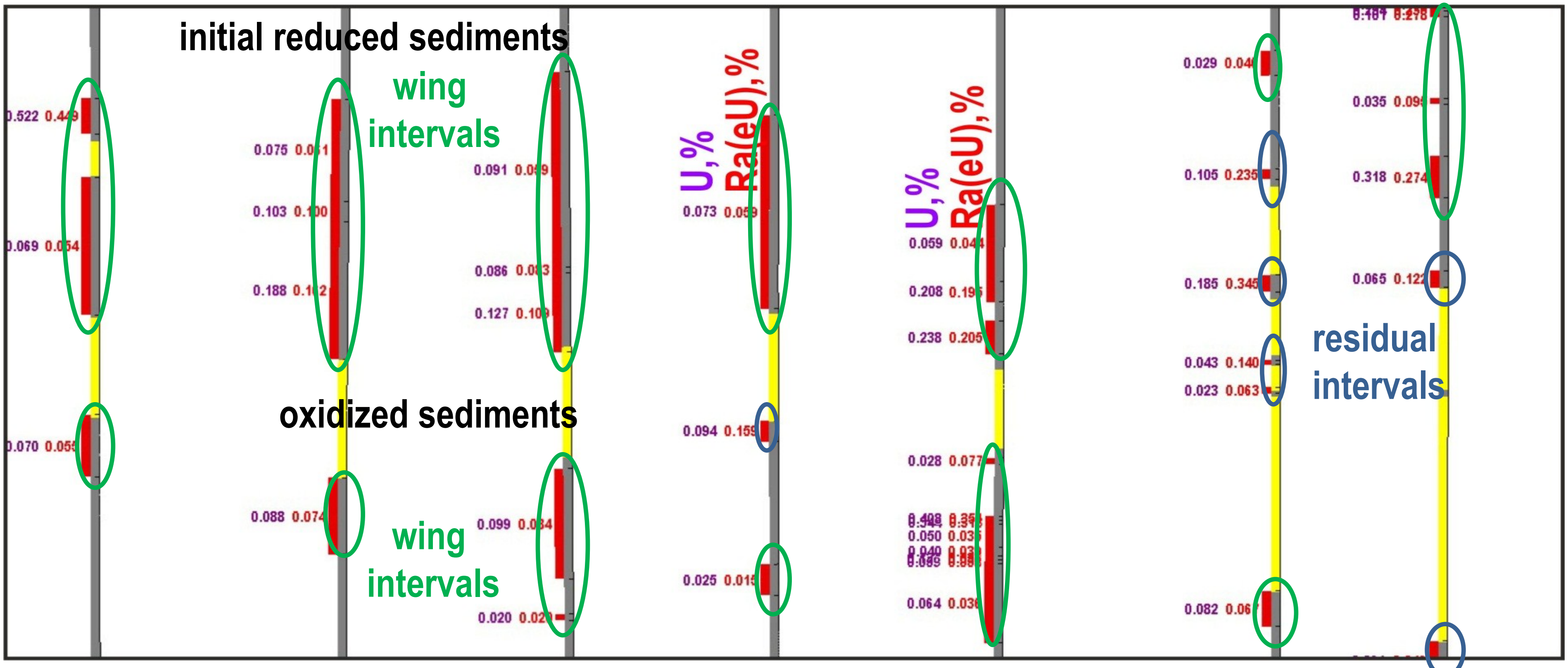


typical cross section

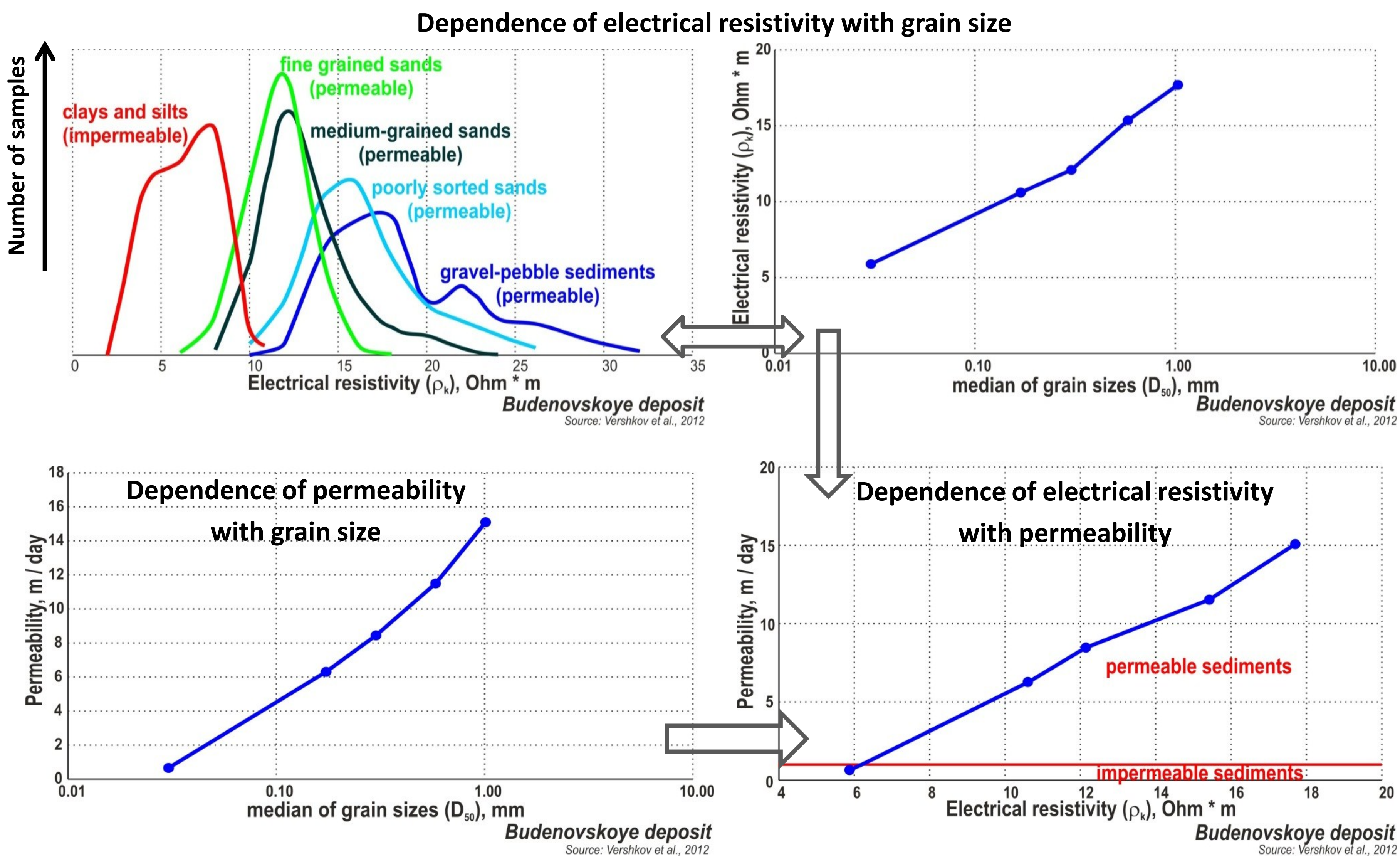




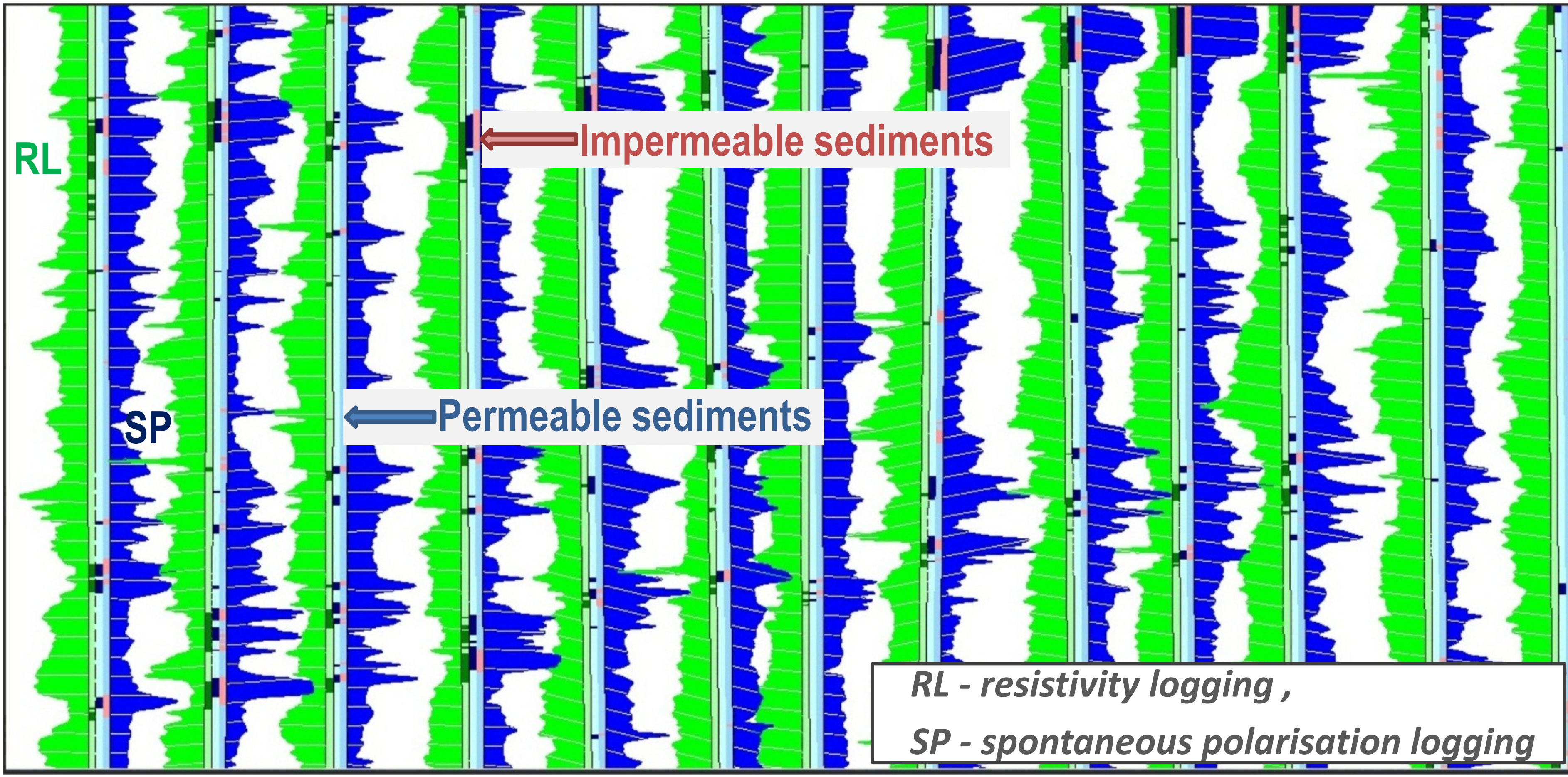
Definition of uranium grades



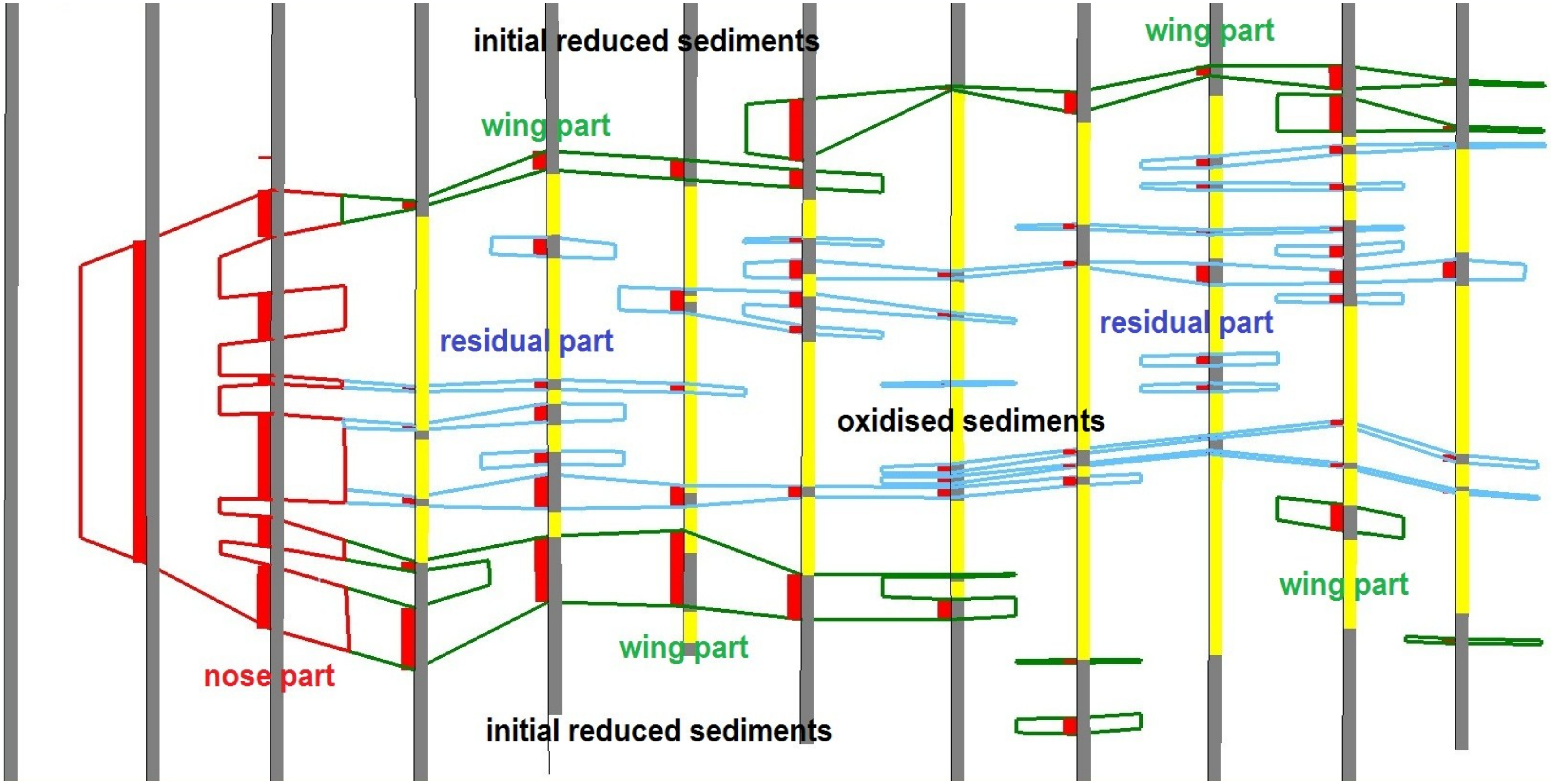
Definition of impermeable rocks



Definition of impermeable rocks

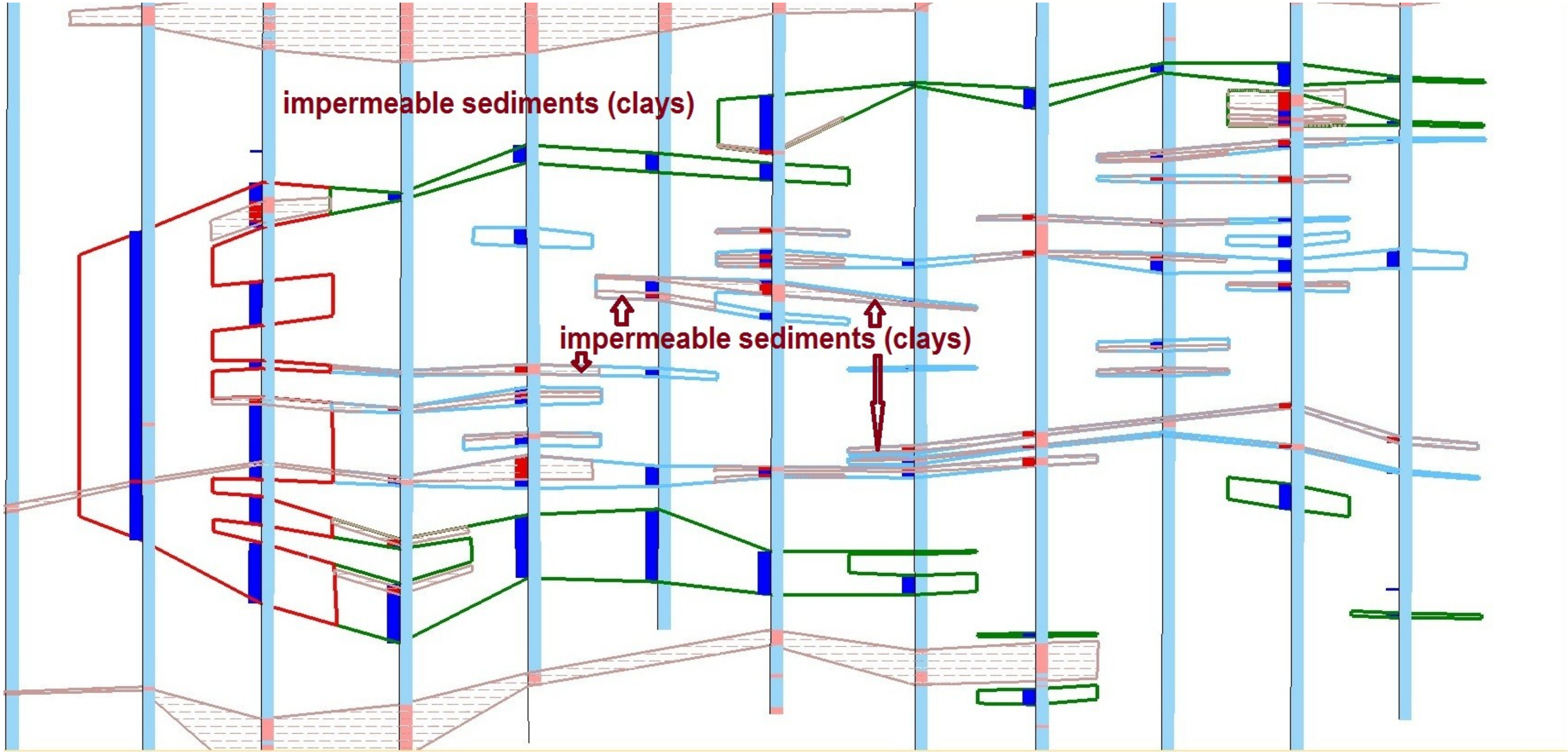


Interpretation of roll-front



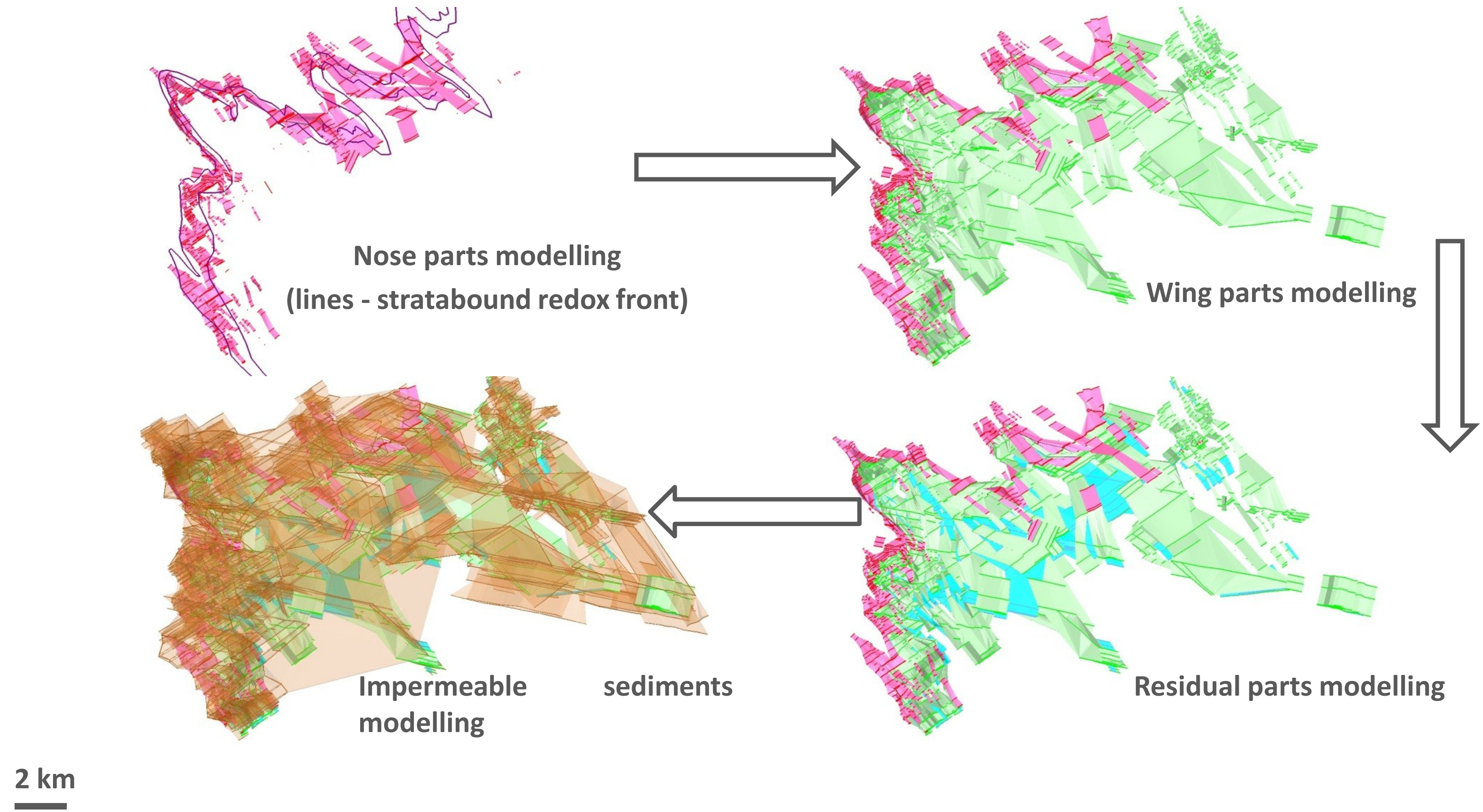
cross section

Interpretation of roll-front

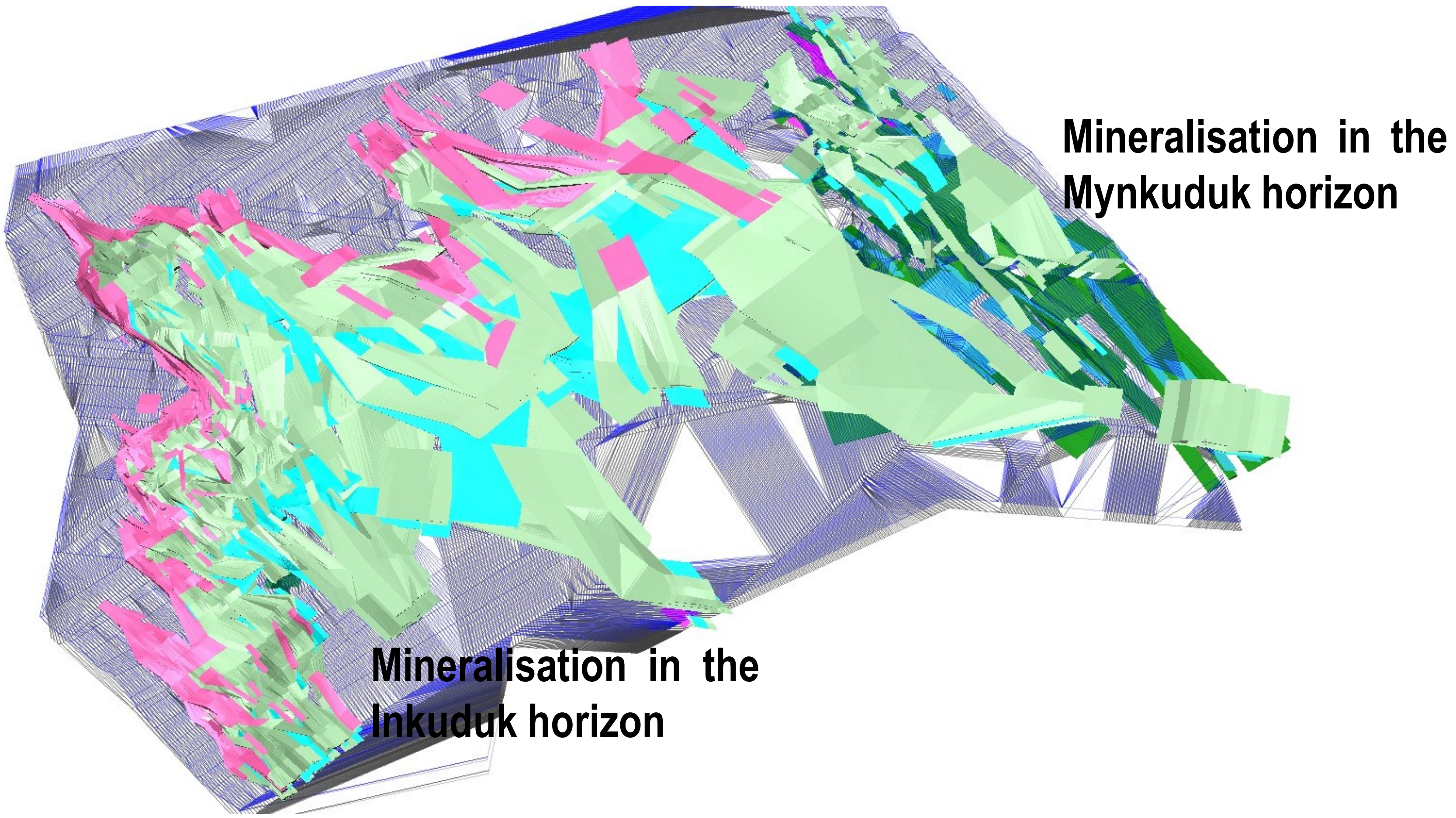


cross section

Wireframe modelling



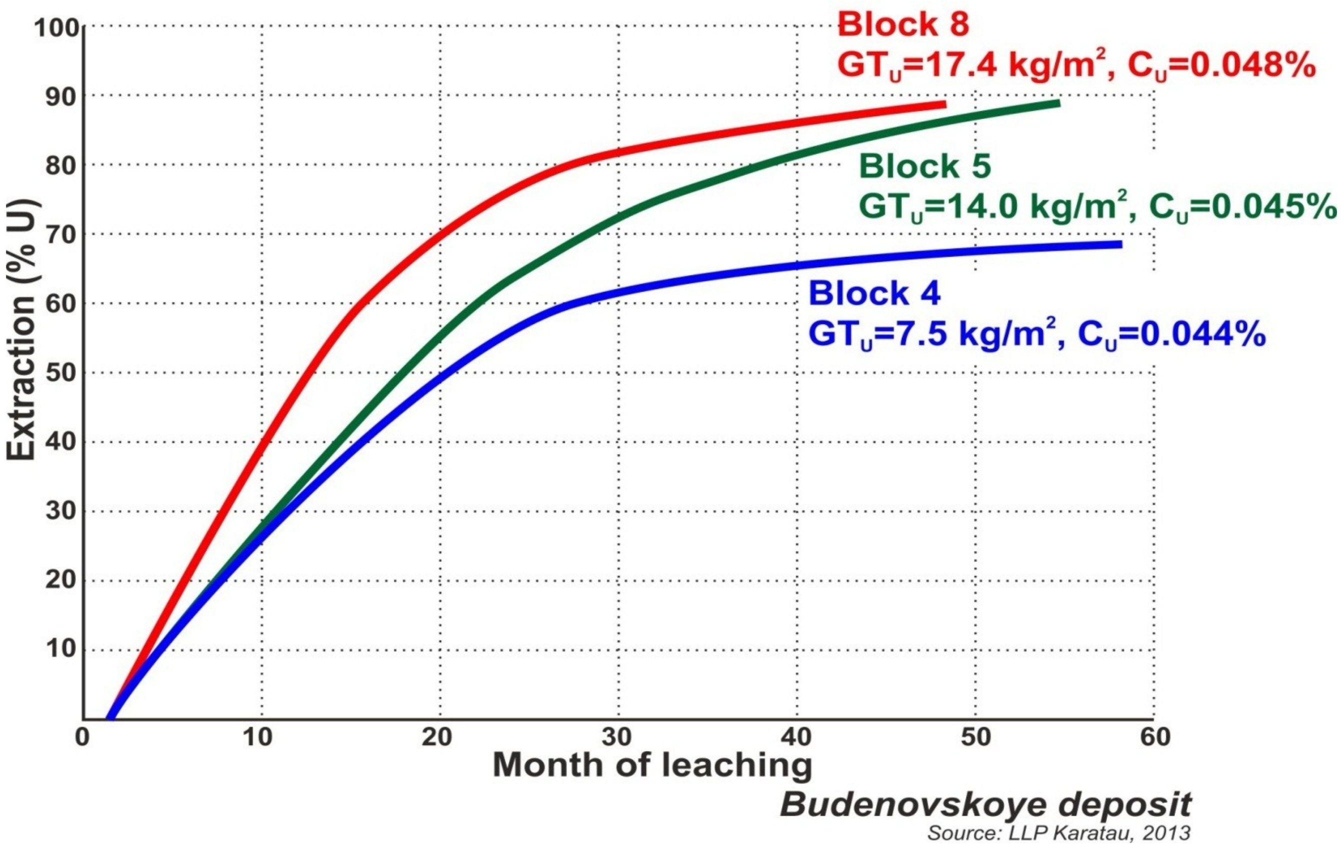
Wireframe modelling



2 km

Why grade x thickness (GT)?

Leaching uranium from blocks with different GT

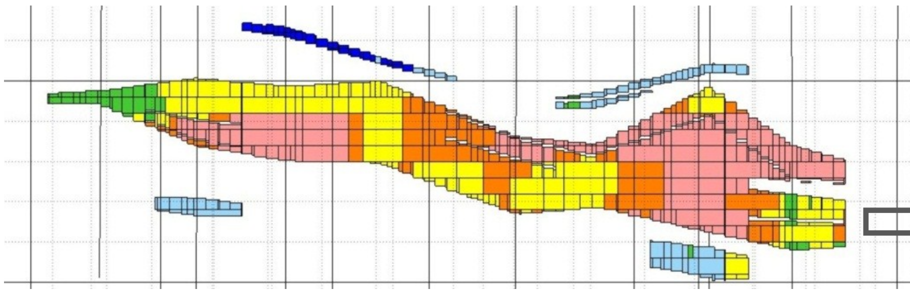


Because for ISR deposits it is important to use a metal accumulation index (grade x thickness or "GT") to define the cut-offs for resource estimation.

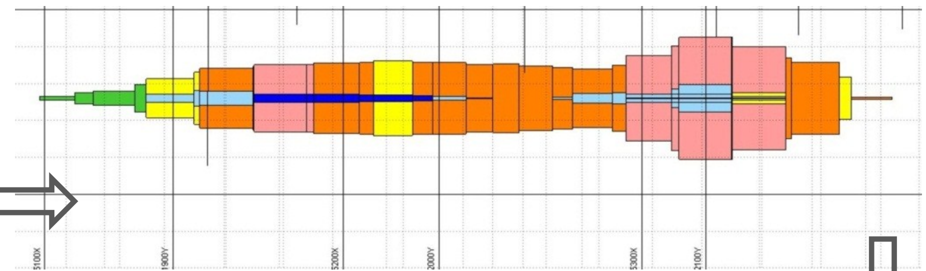
The mineralised interval with 0.04% U x 10 m is better for ISR than 0.10% U x 3 m.

Definition GT in block model

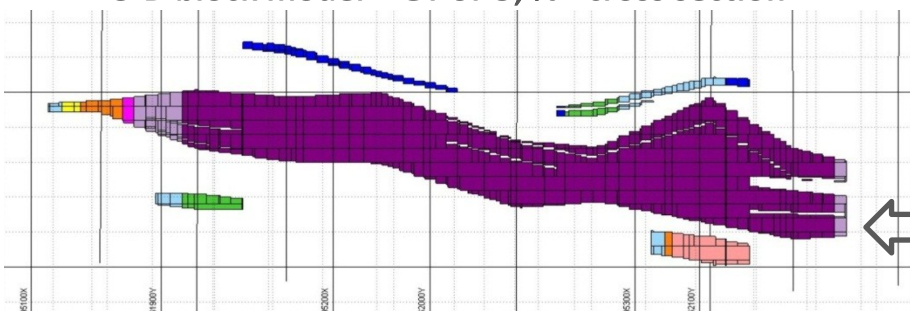
Initial block model – grades of U, % - cross section



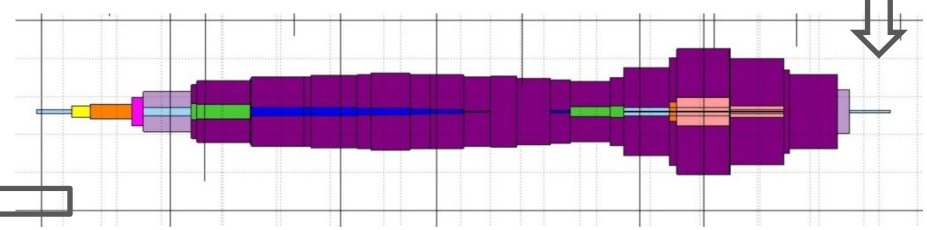
Two-dimensional gridded models – grade of U, % - cross section

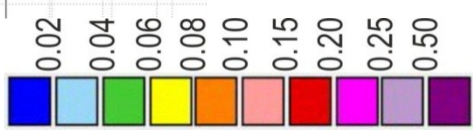


3-D block model – GT of U, % - cross section



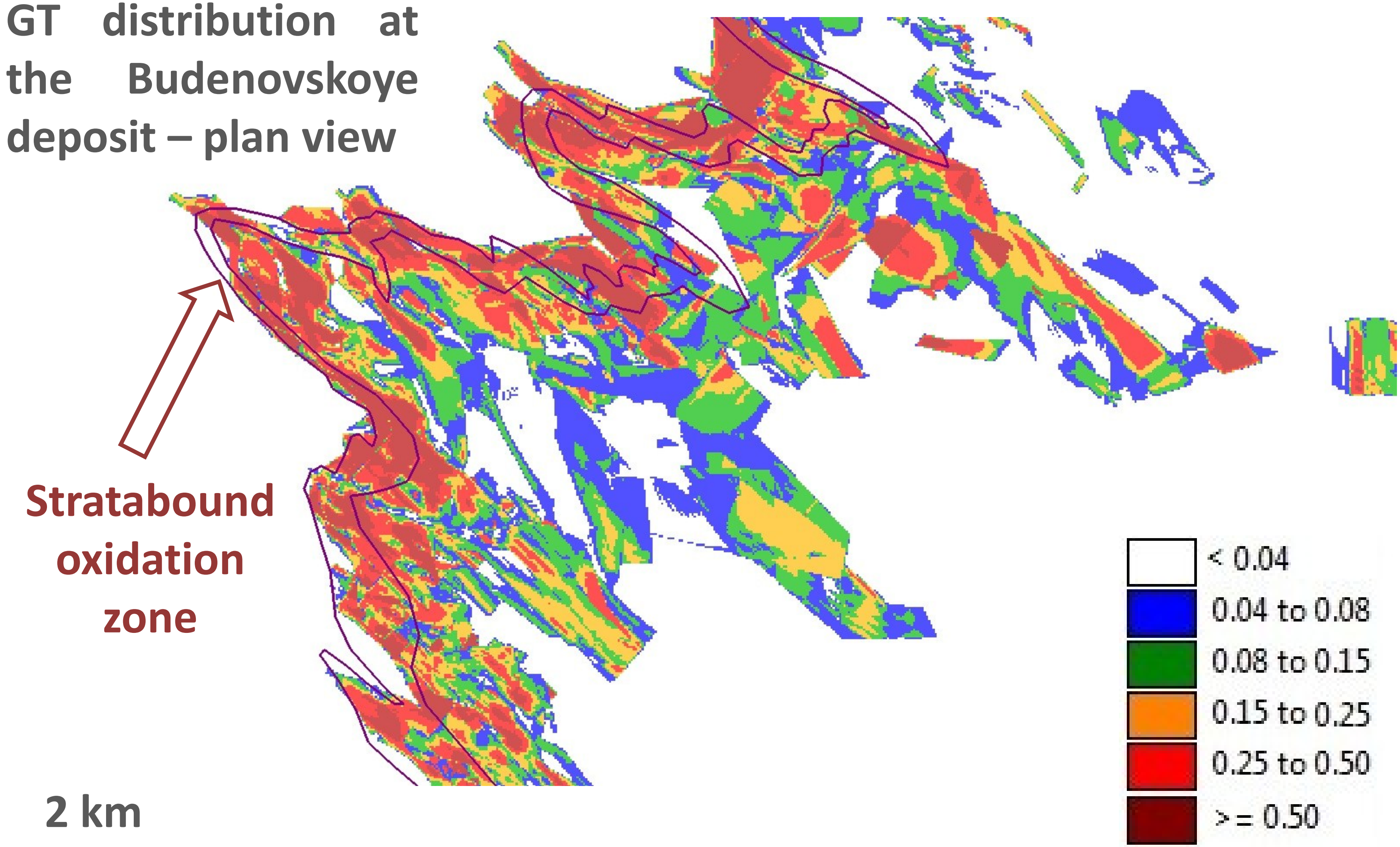
Two-dimensional gridded models – GT of U, % - cross section



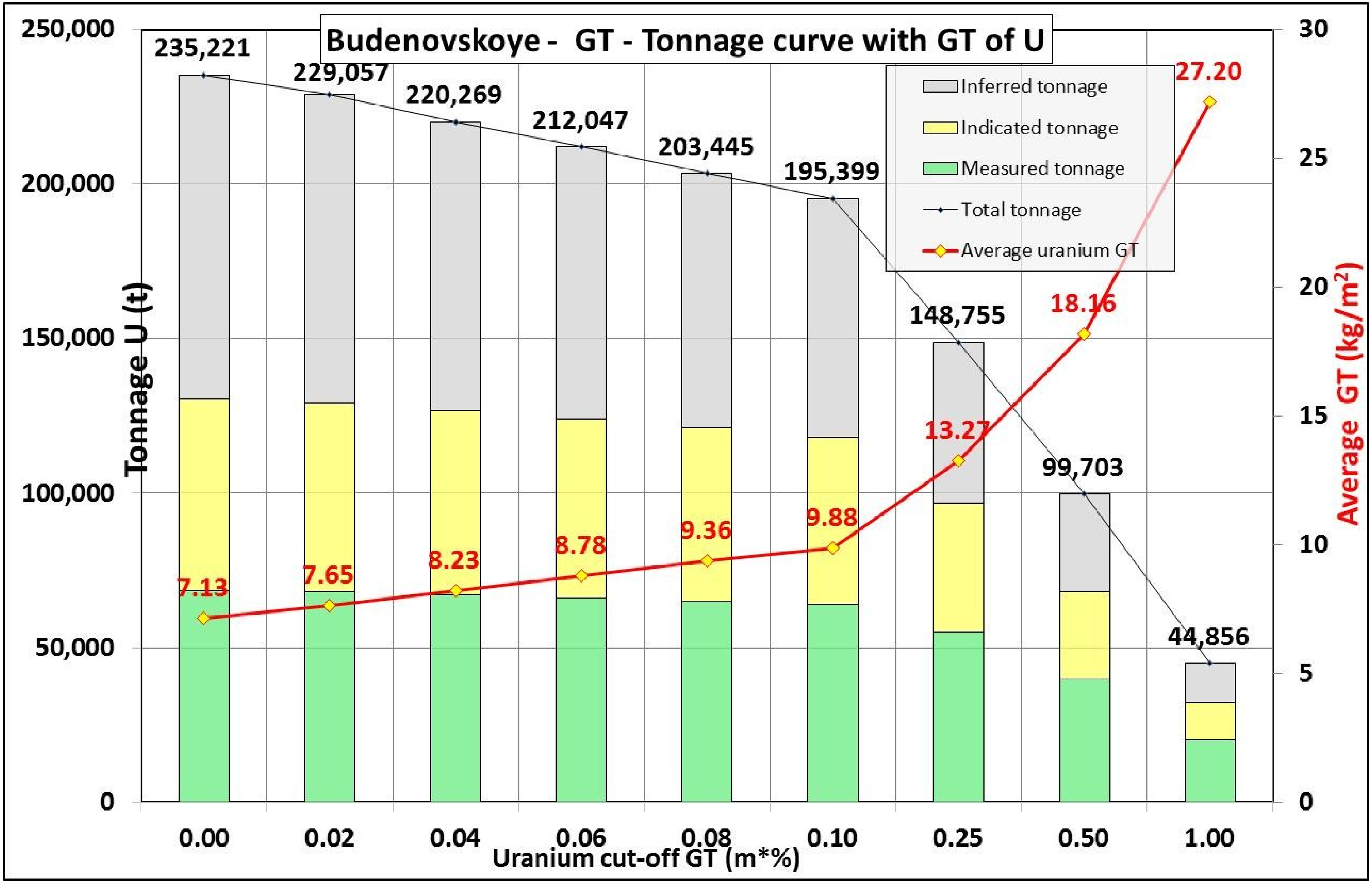


Definition GT in block model

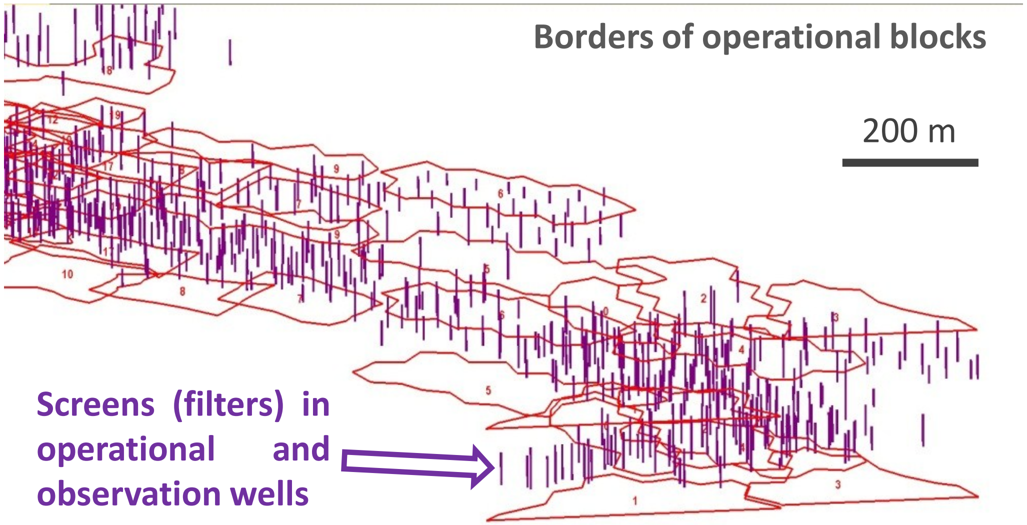
GT distribution at the Budenovskoye deposit – plan view

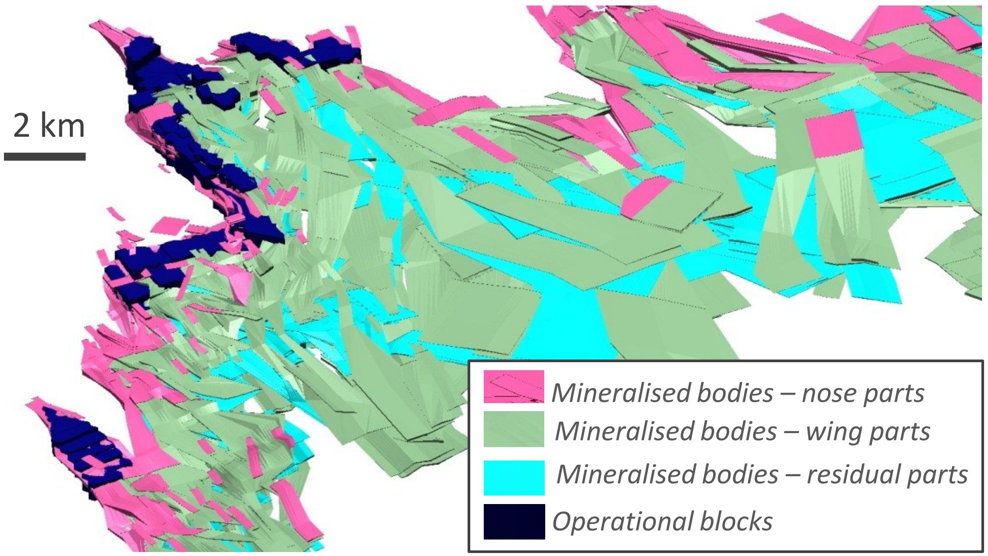


Mineral Resources CIM compliant



Depletion of uranium





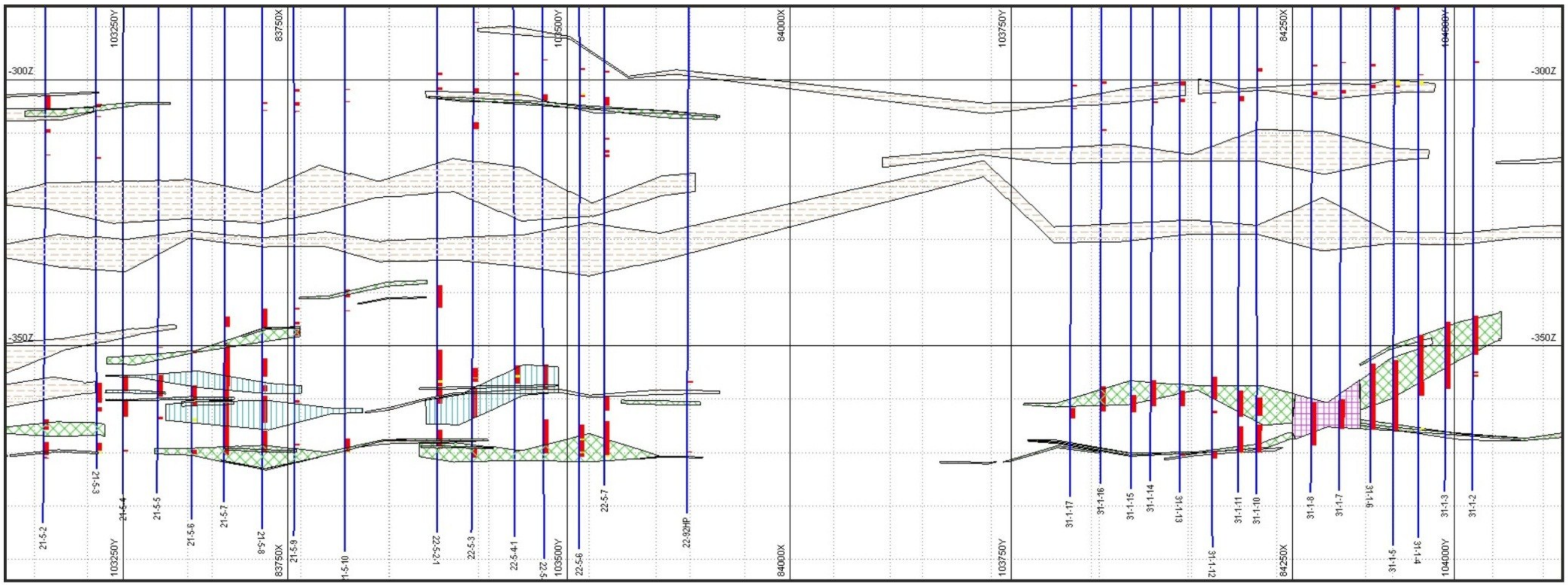
Operational blocks and mineralised bodies

In ISR operations, the host rock remains undisturbed while the valuable component is dissolved by the leaching solution

For a mine it is considered sufficient to volumetrically delineate contours of production blocks and to deduct the depleted metal (recovery and *in situ* loss) from the Mineral Resources. Grades and GT will decrease proportionally because the volume of rock mass remains.

Block model vs. production blocks

Comparison of mineralised intervals in operational wells with mineralised bodies based on exploration drill holes



wireframes of nose parts

wireframes of wing parts

wireframes of residual parts

wireframes of impermeable sediments

mineralised intervals in operational wells (a - in permeable sediments, b - in impermeable sediments)

5 m | 100 m

Mineral Resources as of 30/06/13

Category	Volume	Tonne	Productivity (GT)		Grade		Mineral Resources	
	‘000 m^3	‘000 m^3	m x %	kg / m^2	U, %	U_3O_8, %	Tonnes	M lb
Measured	43,227	73,487	0.46	7.8	0.072	0.085	52,646	136.88
Indicated	38,692	65,777	0.46	7.8	0.088	0.104	58,484	152.06
Measured & Indicated	81,921	139,265	0.46	7.8	0.080	0.094	111,131	288.94
Inferred	58,177	98,901	0.37	6.2	0.095	0.111	93,623	243.42

Mineral Resources based on 0.04 m% (grade x thickness) cut-off per hole

Mineral Resources based on CIM definition

Depletion estimated using losses 10%

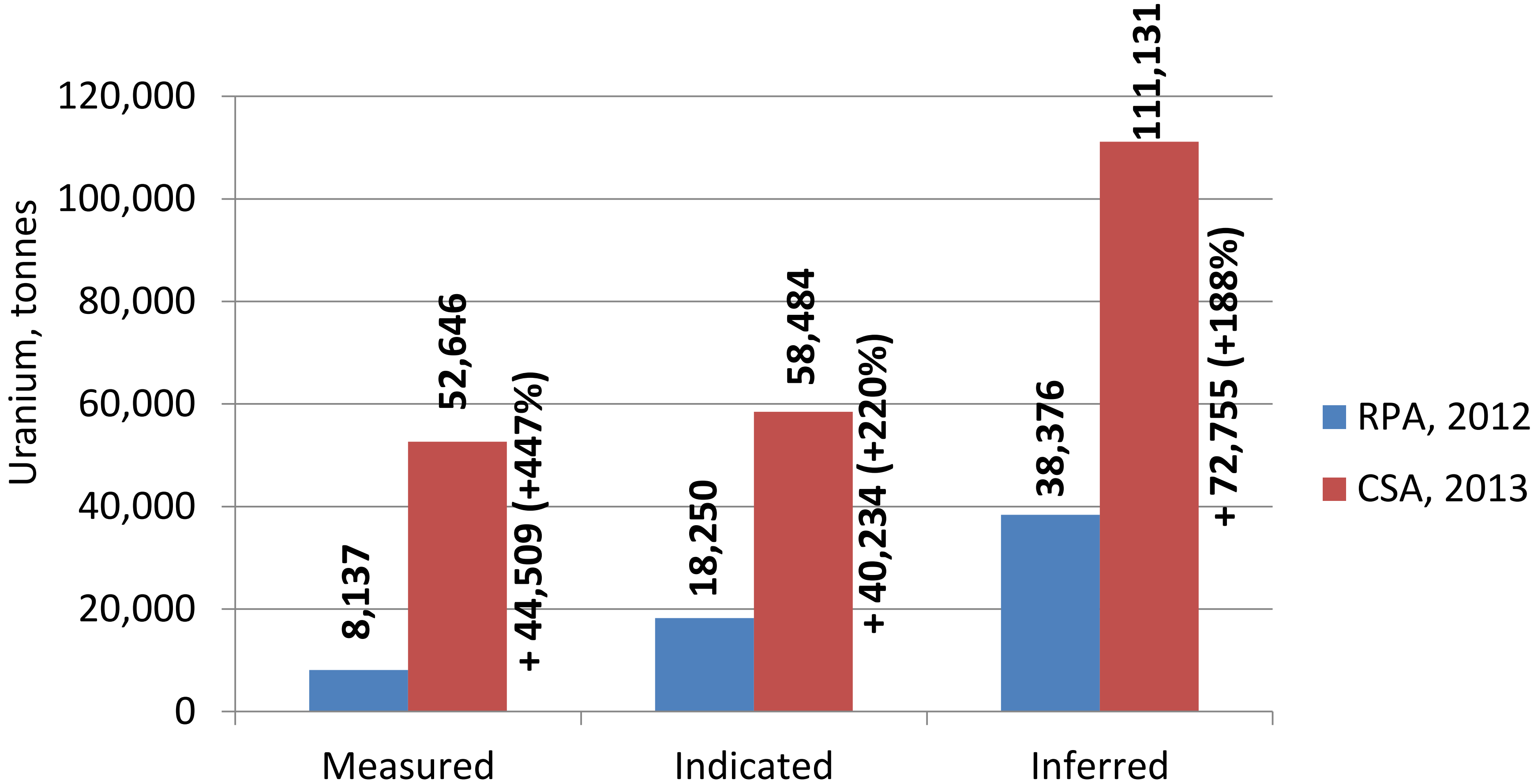
Measured Mineral Resources based on exploration drilling density of 50 m x 200 m (excluding residual mineralised bodies)

Indicated Mineral Resources based on exploration drilling density of 50-100 m x 400 m (excluding residual mineralised bodies) and 50 m x 200 m for residual mineralised bodies

Inferred Mineral Resources are based on exploration drilling density of 100-800 m x 400-1600 m

Mineral Resources include Mineral Reserves

Mineral Resources 2013 vs. 2012



RPA's resource estimation was based on conservative transformation of GKZ resources to CIM Mineral Resources: Operational blocks -> Measured, C_1 -> Indicated, C_2 -> Inferred.

CSA's resource estimation is based on geological modelling including latest exploration data

Conclusion

Using the improved methodology of geological modelling and resource estimation discussed in this presentation,

the average differences between resource estimates based only on exploration drill holes and estimates using all production wells **are less than 5 %,**

whereas the classical approach of resource estimation based on cut off grade commonly gave differences in the order of 20 —90%.

Summary

Work by CSA and Uranium One has:

- developed an advanced and unique modelling methodology for *in situ* recovery deposits,
- modelled one of the largest and most complex sandstone-hosted uranium deposits in the world,
- successfully reconciled our resource modelling against production results,
- Seen the adoption by the mine of our modelling in order to optimise production, where,
- It is expected there will be a significant positive economic impact from using our improved resource estimation approach,
- Geological model can be used for operational modelling with good economical effect,
- Measured and Indicated Resources were increased by 84,743 tU (321%)

Authors

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Over 17 years' geological experience in exploration, deposit modelling and resource estimation for a range of commodities, but particularly uranium.

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37 years of broad and advanced practical national Russian and international experience in uranium deposits exploration, resource estimation, mining, and processing.

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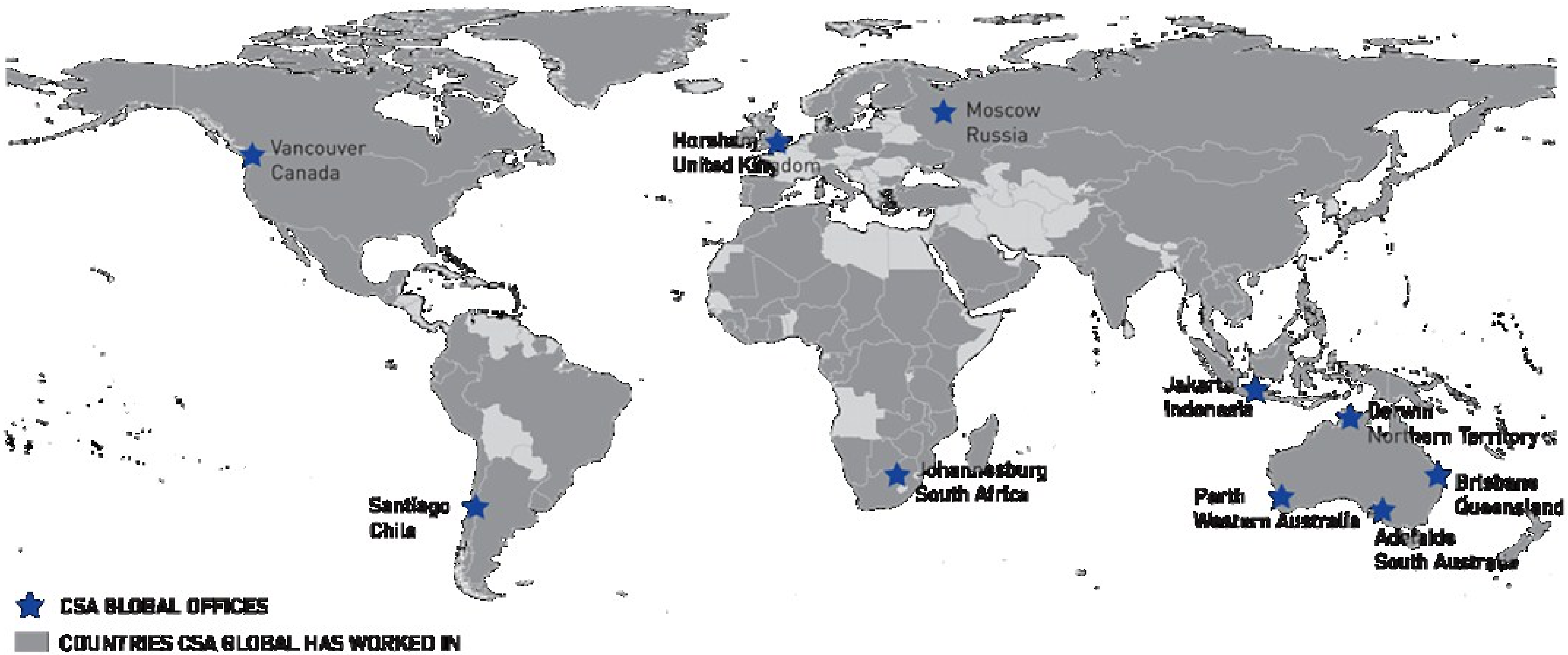
30 years of broad and advanced practical international experience in gold, uranium and other deposits, exploration, resource estimation, and mining.

Contact CSA Global



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