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Ukraine – the pioneer of in-situ recovery returns to this method of extraction

Dr. Maxim Seredkin (FAusIMM)

Yuri Bakarzhiev

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Introduction

In situ recovery (ISR) is the one of the most effective methods to address the costs of mining. The key feature of ISR is transferring a significant proportion of the hydrometallurgical processing of the mineralised bodies to the subsurface to directly obtain solutions of metals of interest

The first country used ISR for extraction uranium was Ukraine in end 1950s. Ukraine used ISR till end 1980s when suspended all ISR deposits

ISR ramp up in Uzbekistan and USA in 1960-1980s with following period of stagnation in 1990s

Now ISR is the most popular method for uranium extraction. Half of world production of uranium is on ISR projects

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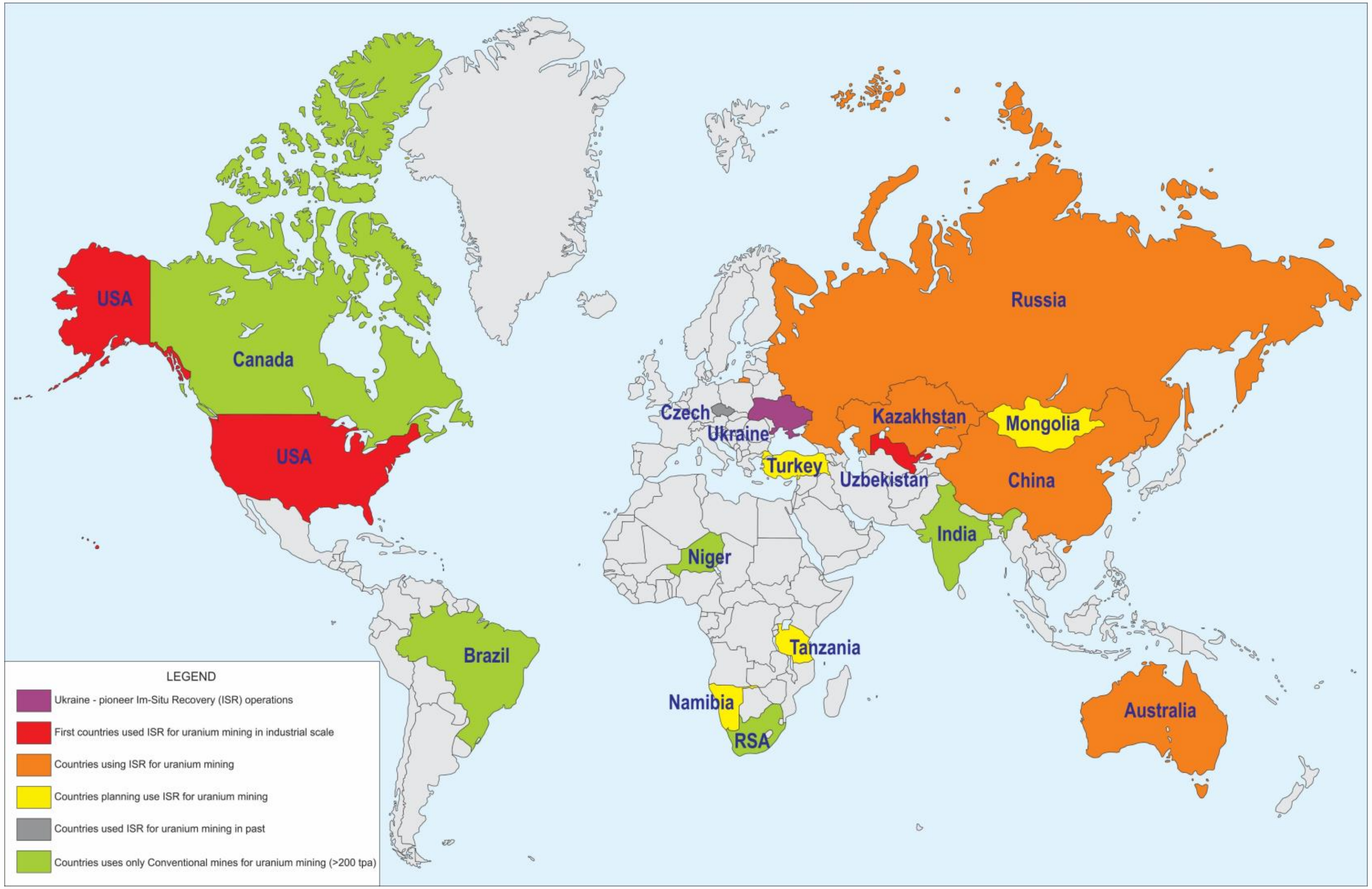
Introduction



ISR mines are located in Kazakhstan, Uzbekistan, USA, Russia, Australia, China

Some other countries planning to use ISR in the nearest future

Ukraine will return to ISR operations after 30-year break

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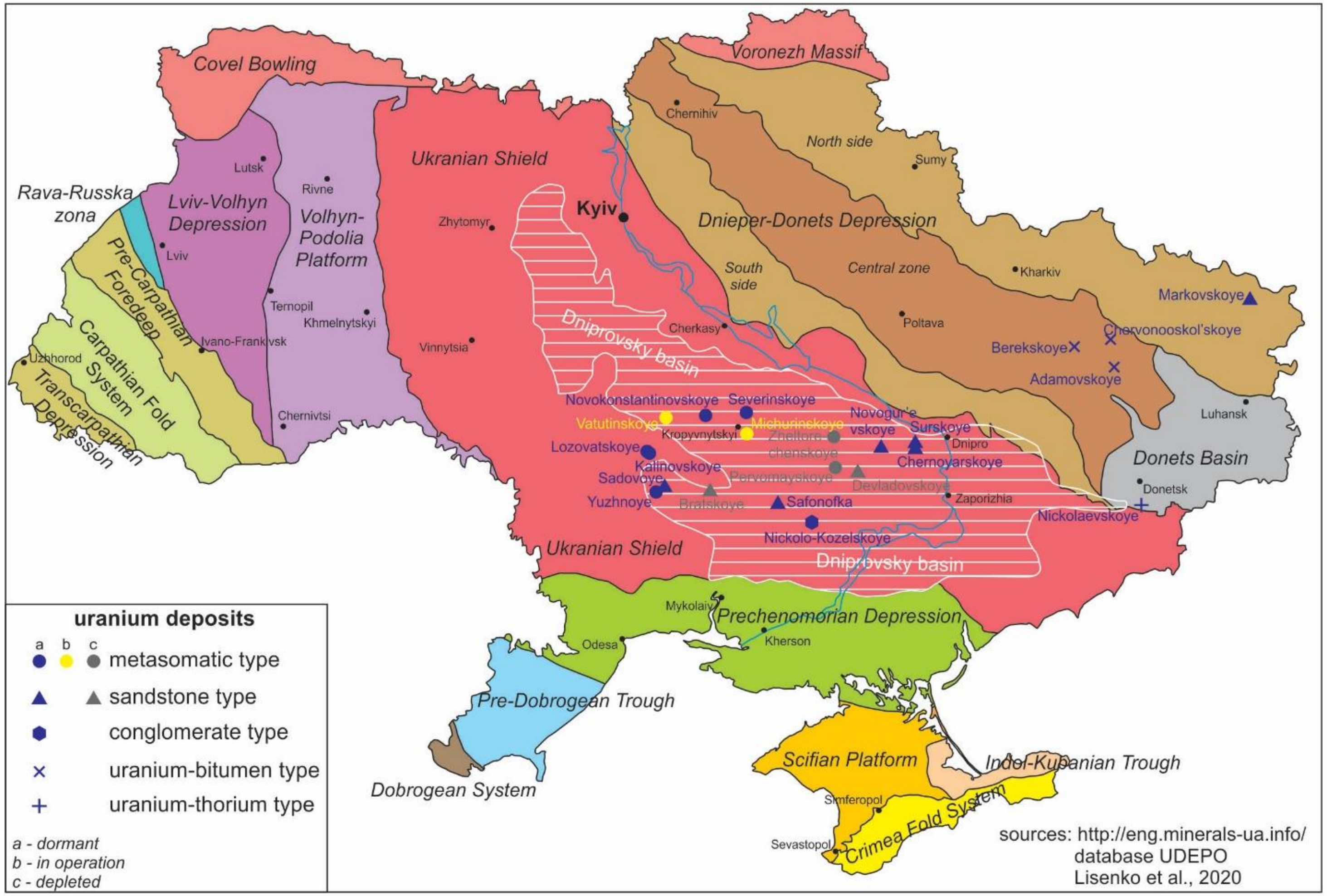
Regional Geology



In Ukraine deposits suitable for ISR are located in the Paleogene Dnipro basin

The most favourable deposits are presented by paleochannel type

Metasomatic deposits mined by conventional method are located in basement of Ukrainian Shield

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Ukrainian Uranium Industry

Share of Power Energy produced on four Nuclear Stations is exceed 50% in Ukraine.

However Resources of raw uranium are presented by metasomatic deposits expensive in operation and small deposits suitable for ISR.

Eastern mining company belonging to Ukranian government mined metasomatic deposits last 30 years after collapsing Soviet Union.

Nuclear Energy Systems of Ukraine LLC (NES) is the first private uranium company in Ukraine which should reduce of raw uranium deficit by extraction uranium using effective ISR method

(Image courtesy of Roy Hill

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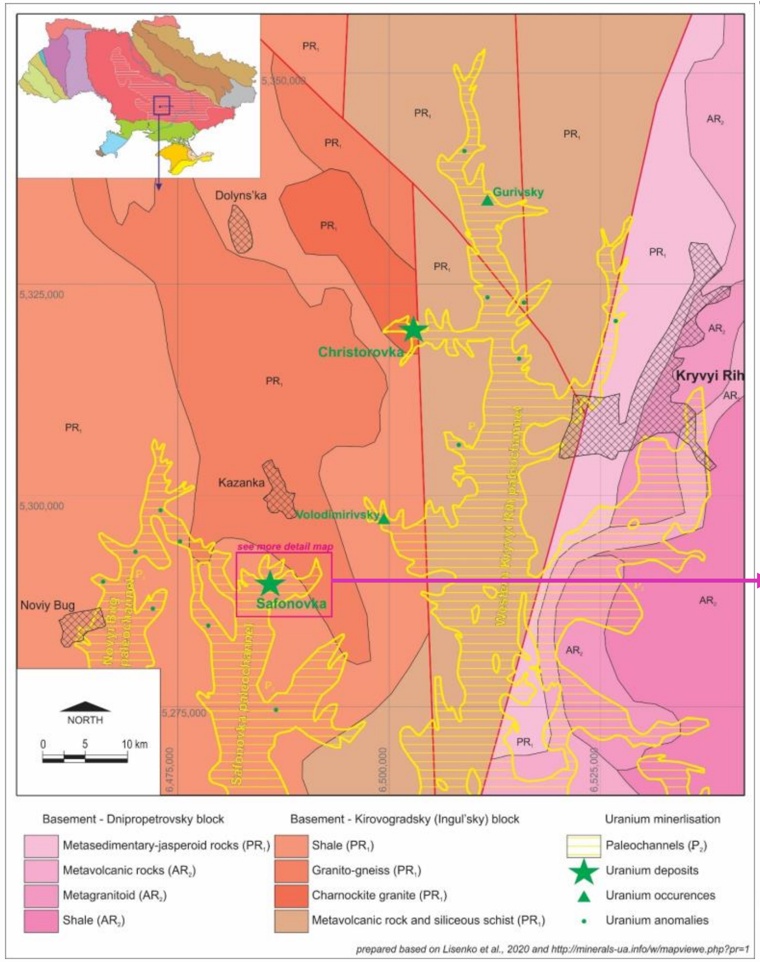
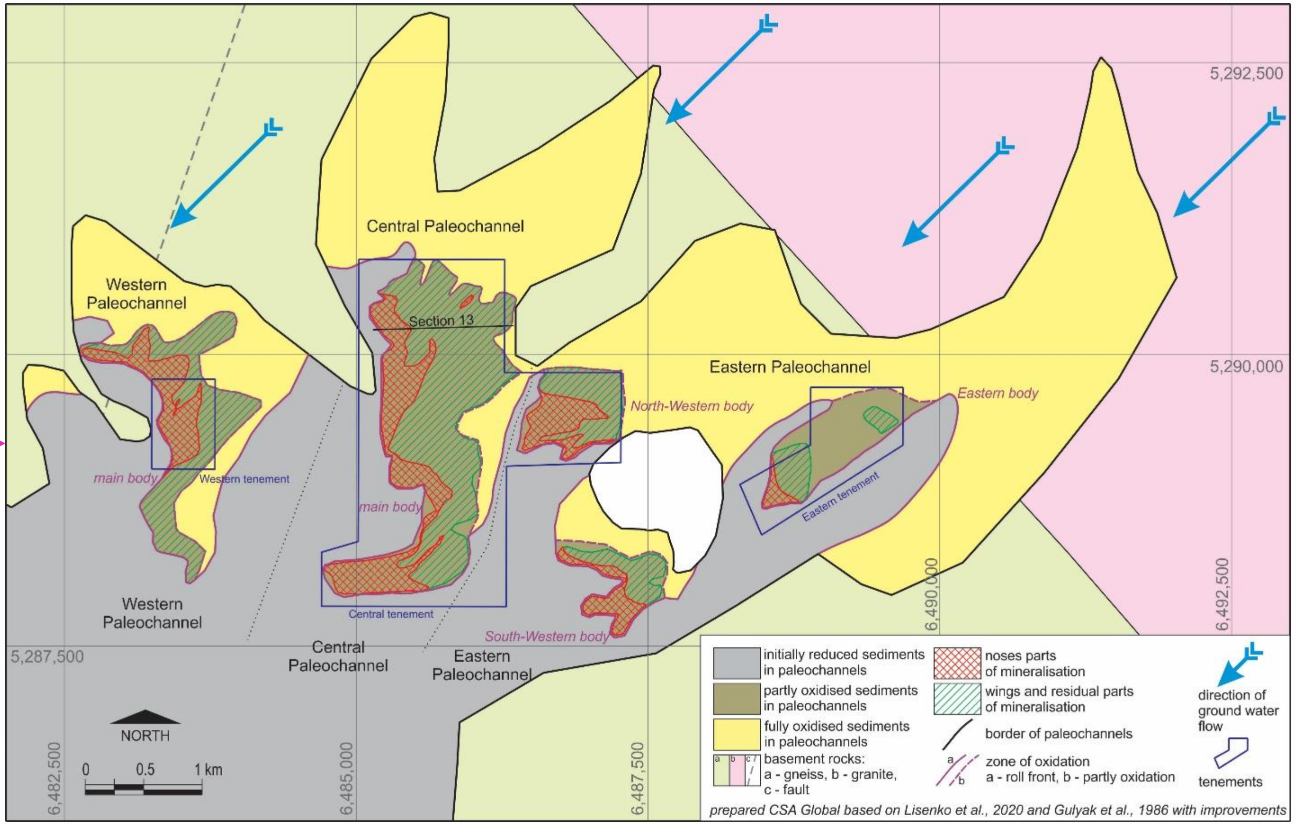
Safonovka deposit

Safonovka deposit is the first uranium project for ISR by NES





Deposit is located in head of paleochanne Is similar to location other deposits of this type in Ukraine

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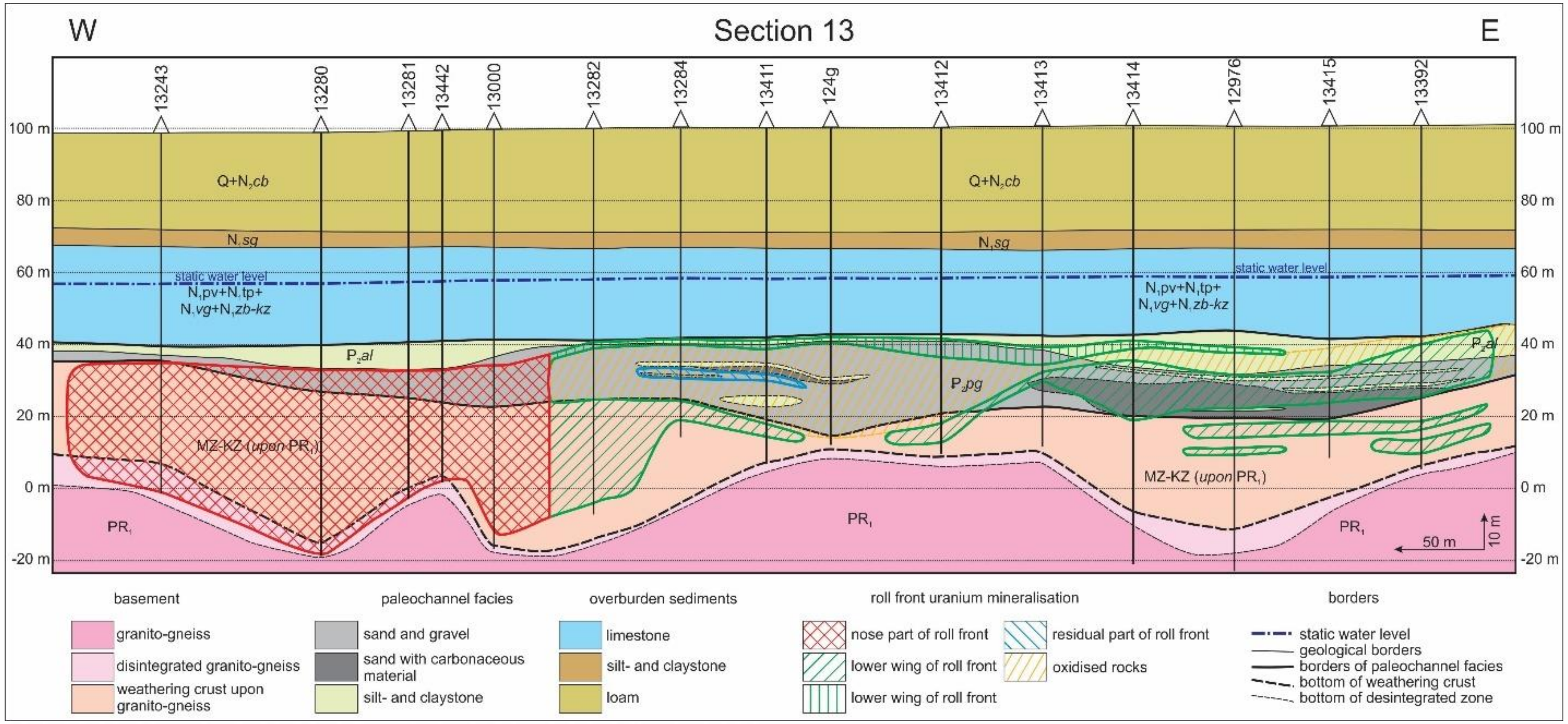
Geology of the Safonovka deposit



Mineralisation forms classical roll-front bodies in paleochannel facies.

Mineralisation is located is in weathering crust (typical for lower wing) and undelay claystone (typical for upper wing

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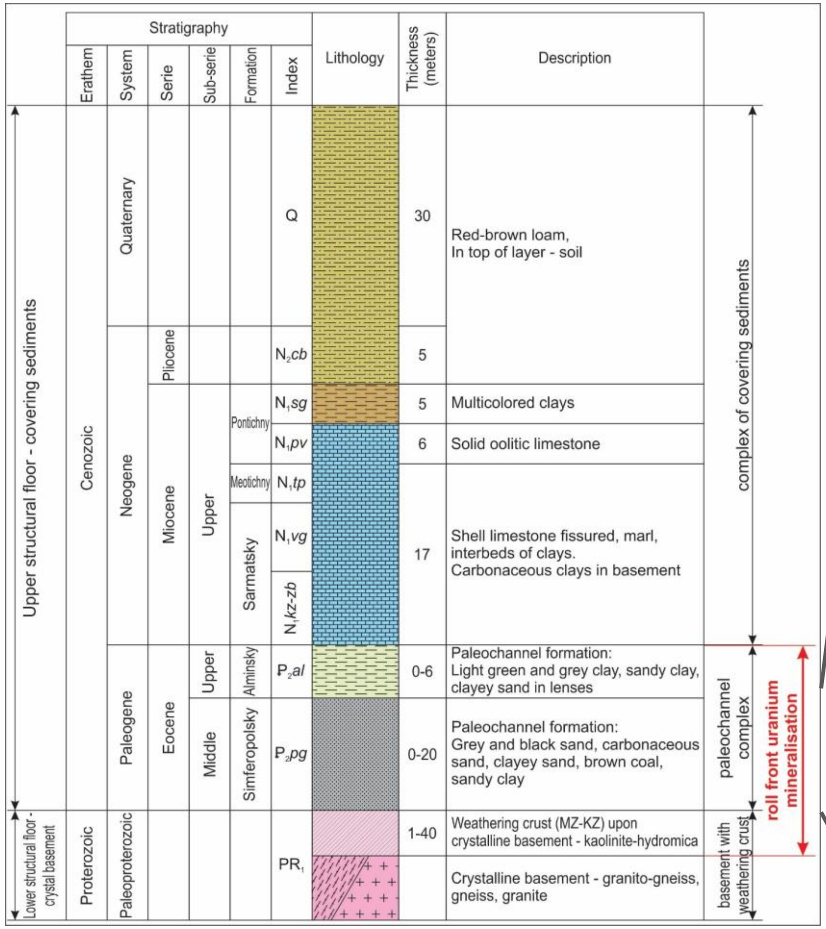
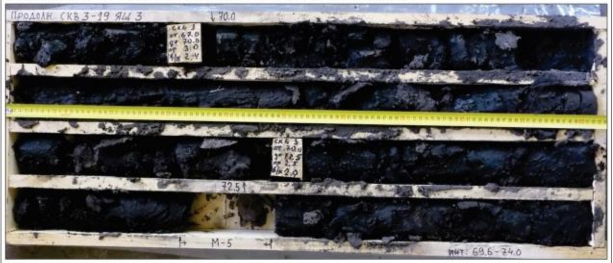
Geology of the Safonovka deposit

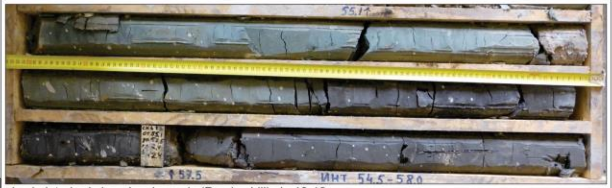


initially reduced (grey) sand (P_2pg) - drillhole 4-19

initially reduced sand with carbonaceous material (P_2pg) - drillhole 3-19



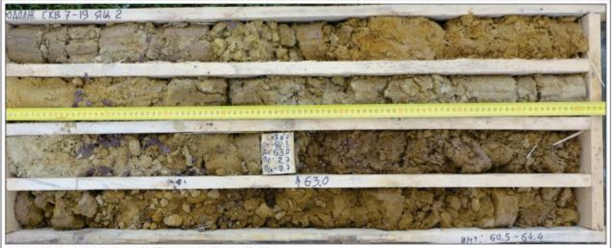
sandy-carbonaceous sediments (P_2pg) - drillhole 3-19



clay in interbeds in paleochannels (P_2pg) - drillhole 13-19

Initially reduced sands with different grade of carbona-ceous material

Clay interbeds



secondary oxidised sand (P_2pg) - drillhole 7-19

Secondary oxidised sands

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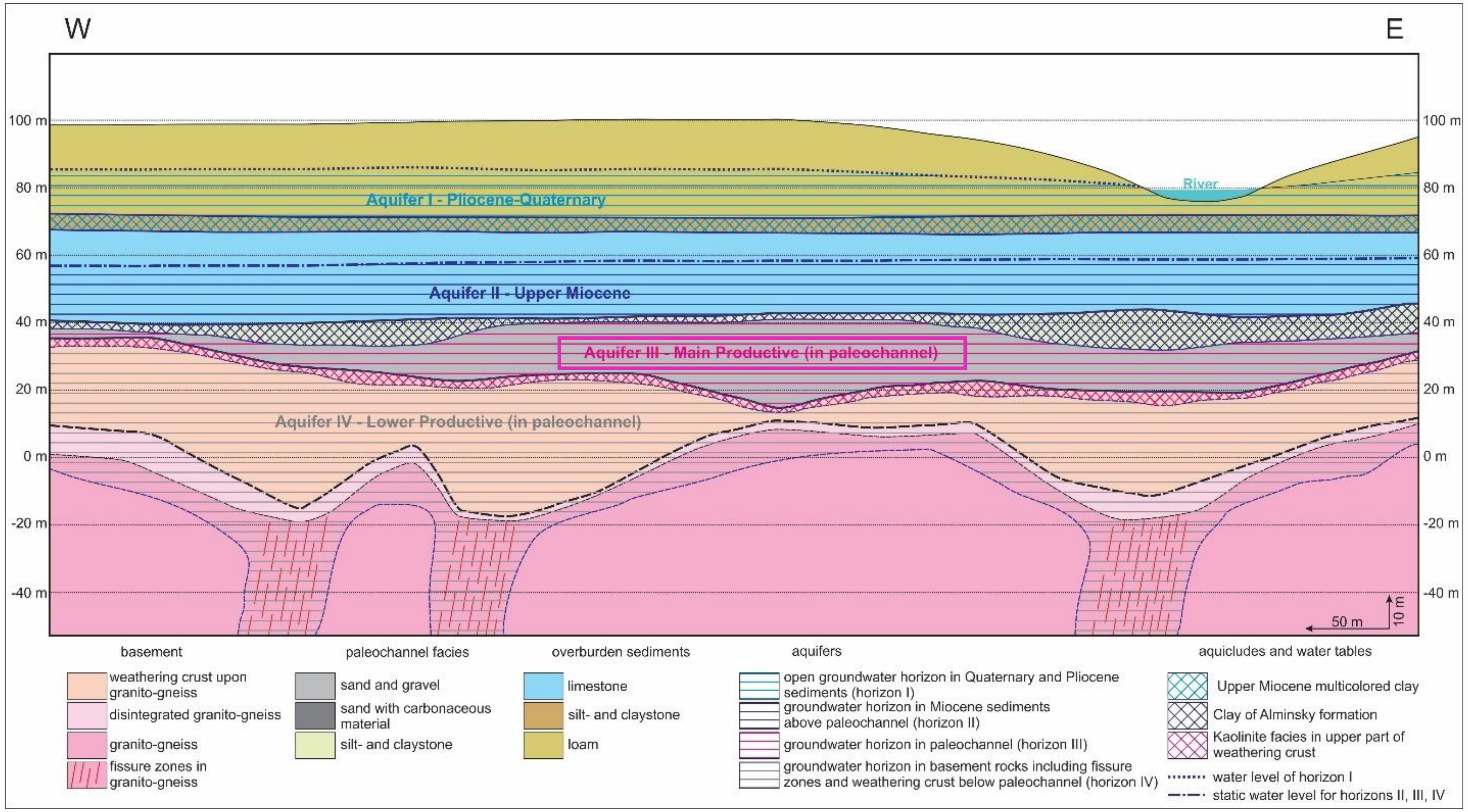
Hydrogeology



Uranium mineralisation is located in aquifer divided from upper aquifers by two aquicludes. This feature allows to protect agriculture industry development in area of the Safonovka deposit location

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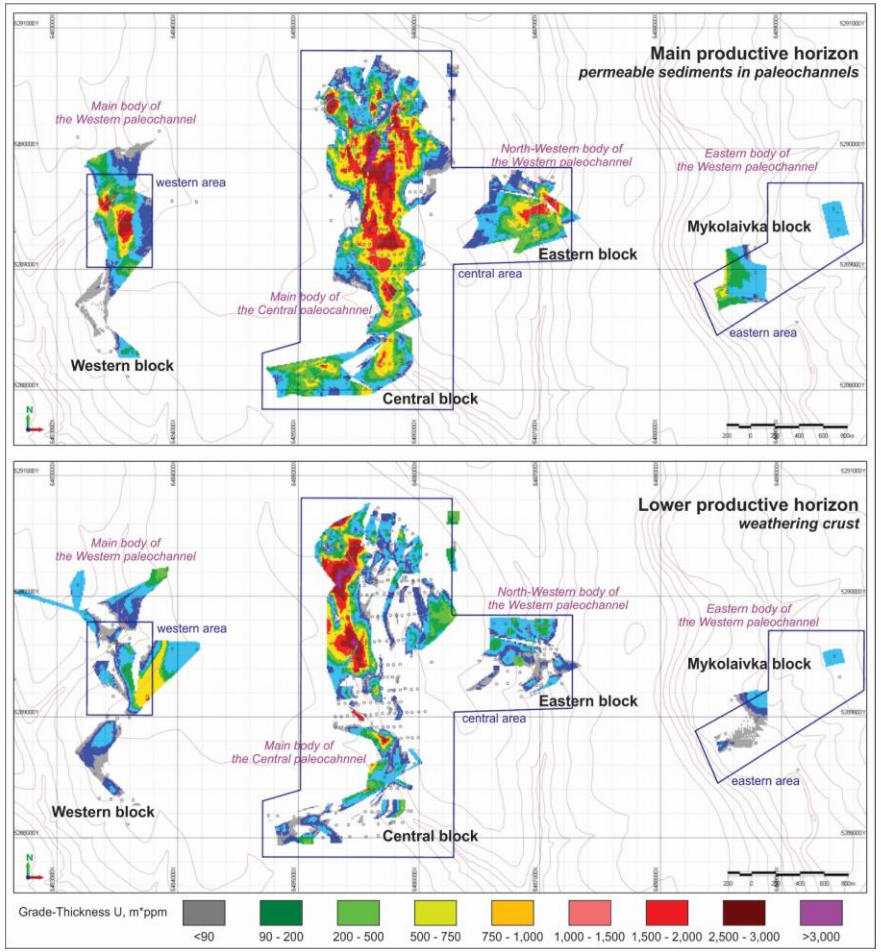
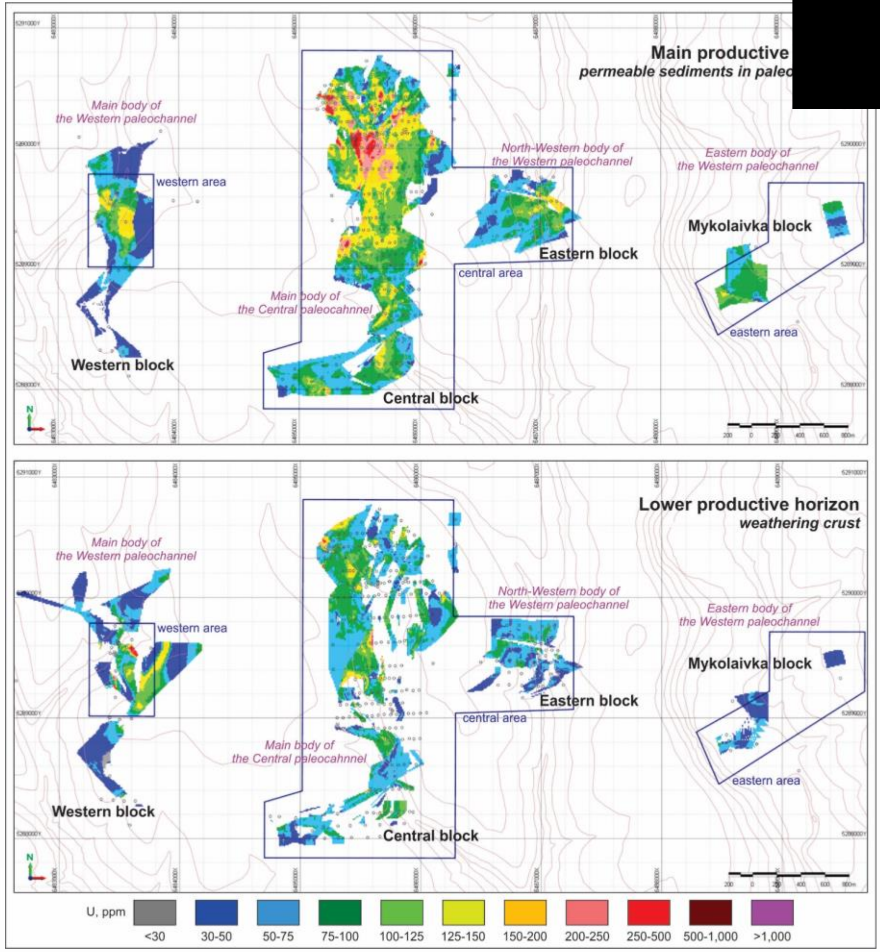
Mineralisation

Grade-thicknesses



Grades



Uranium mineralisation of the Safonovka deposit is quite low grade and productive however located close to surface (depth ~100 m) and with favourable geometallurgical parameters

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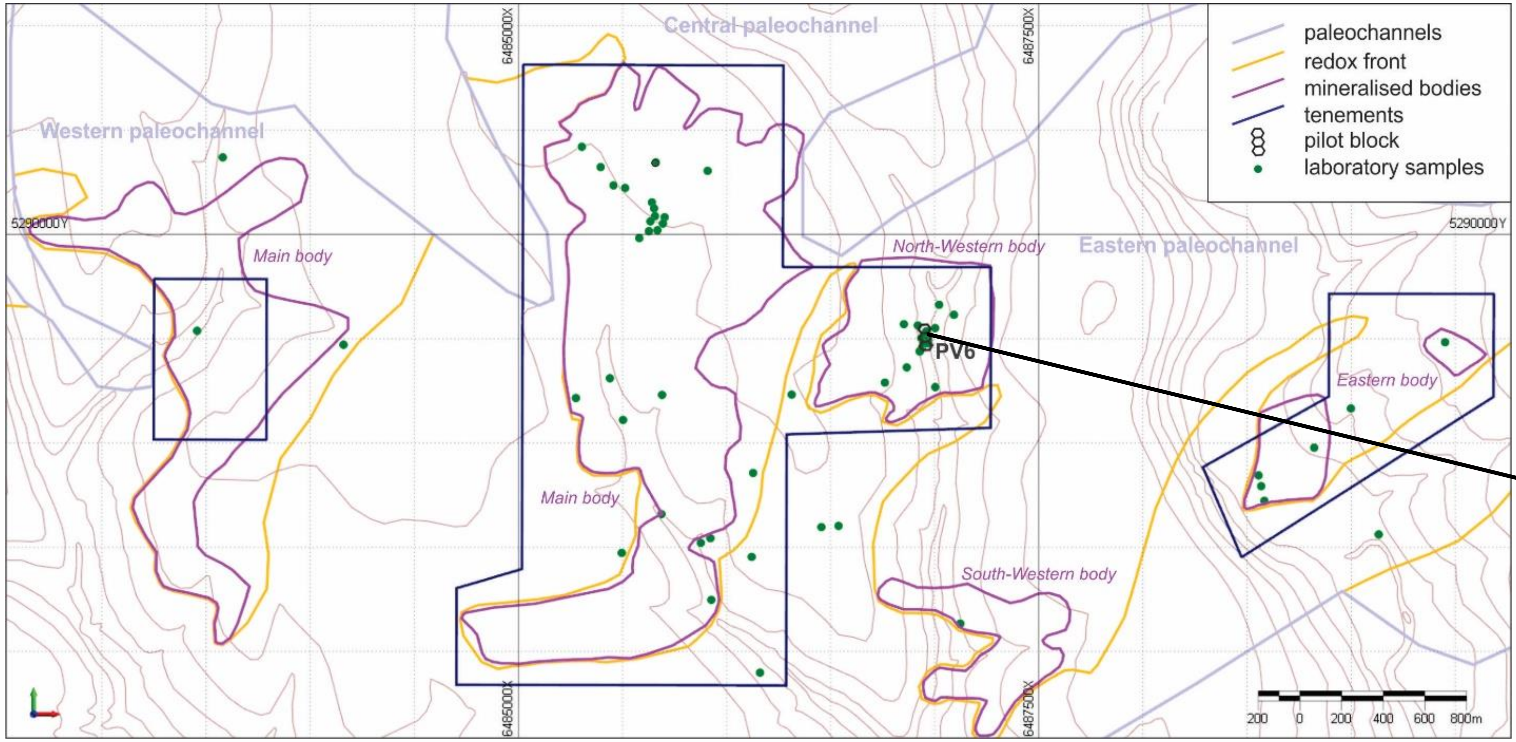
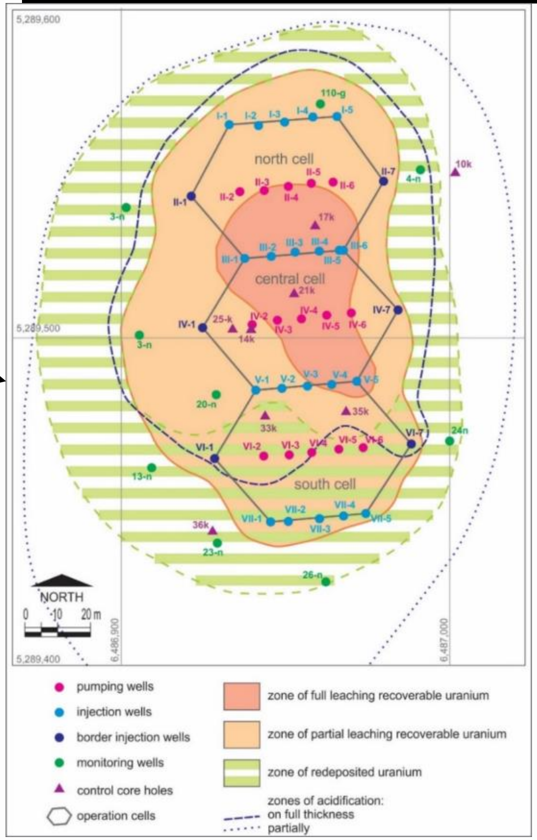
Geometallurgy





Safonovka deposit is well-investigated for standard sulphuric acid ISR

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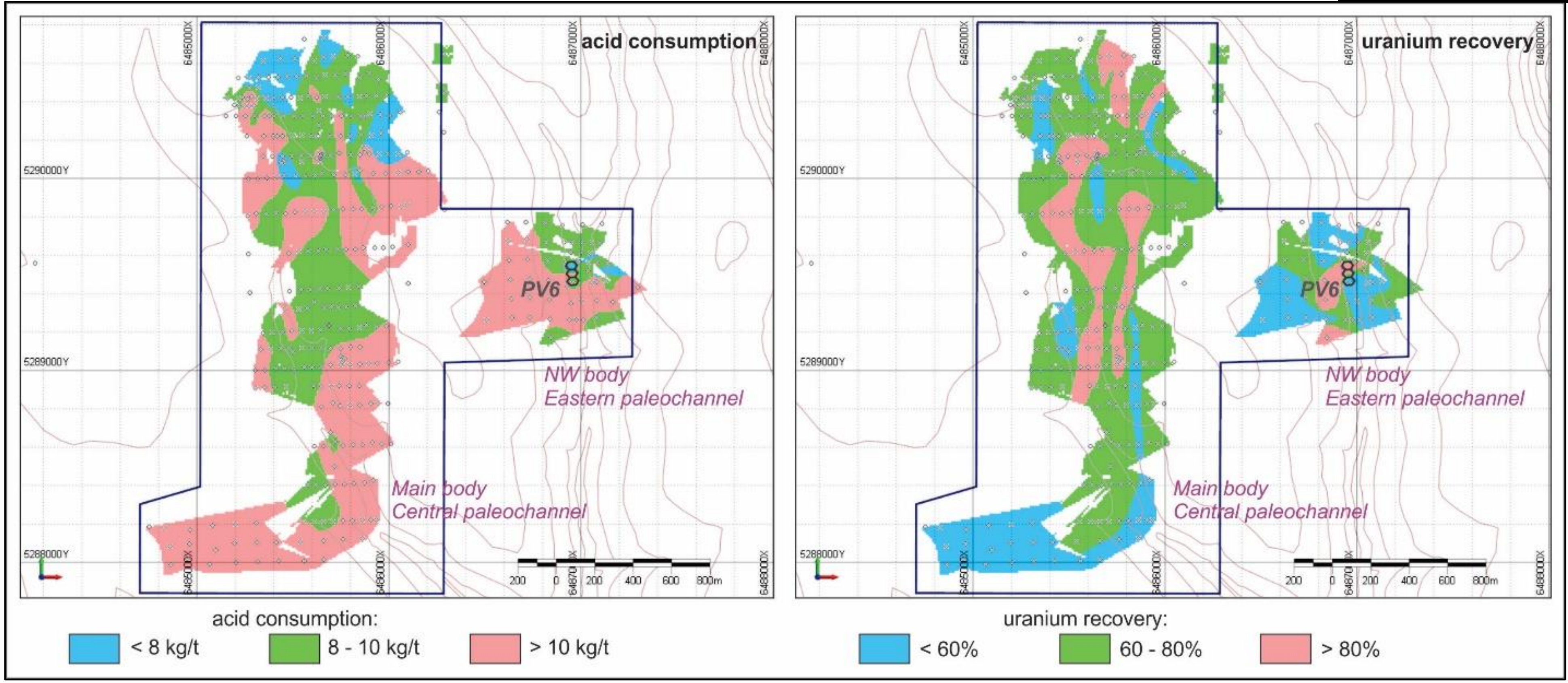
Geometallurgy



Geometallurgical parameters are favourable:

- Low acid consumption
- Quite good uranium recovery for low grade material

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General methods of uranium ISR

Three basic technologies are used for uranium ISR:

- Acid leaching by sulphuric acid with or without oxidants is the most popular. This type of leaching is feasible for low carbonate mineralisation with CO_2 <3%
- Alkaline leaching by using mixture of Na_2CO_3, CO_2 (or $NaHCO_3$) and O_2 is alternate method feasible for high-carbonate mineralisation
- Leaching by oxygen gas without acid or alkaline by oxidation uranium to a UO_2^{2+} form which dissolves in water. This method has some

(Image courtesy of Roy Hill)

Safonovka: Geometallurgical types

Totally nine geometallurgical type of mineralisation were selected on the Safonovka deposit based on:

- Acid consumption
  - Type A – High Acid Consumption
  - Type B – Medium Acid Consumption
  - Type C – Low Acid Consumption
- Uranium Recovery
  - Type 1 – High Uranium Recovery
  - Type 2 – Medium Uranium Recovery
  - Type 3 – Low Uranium Recovery

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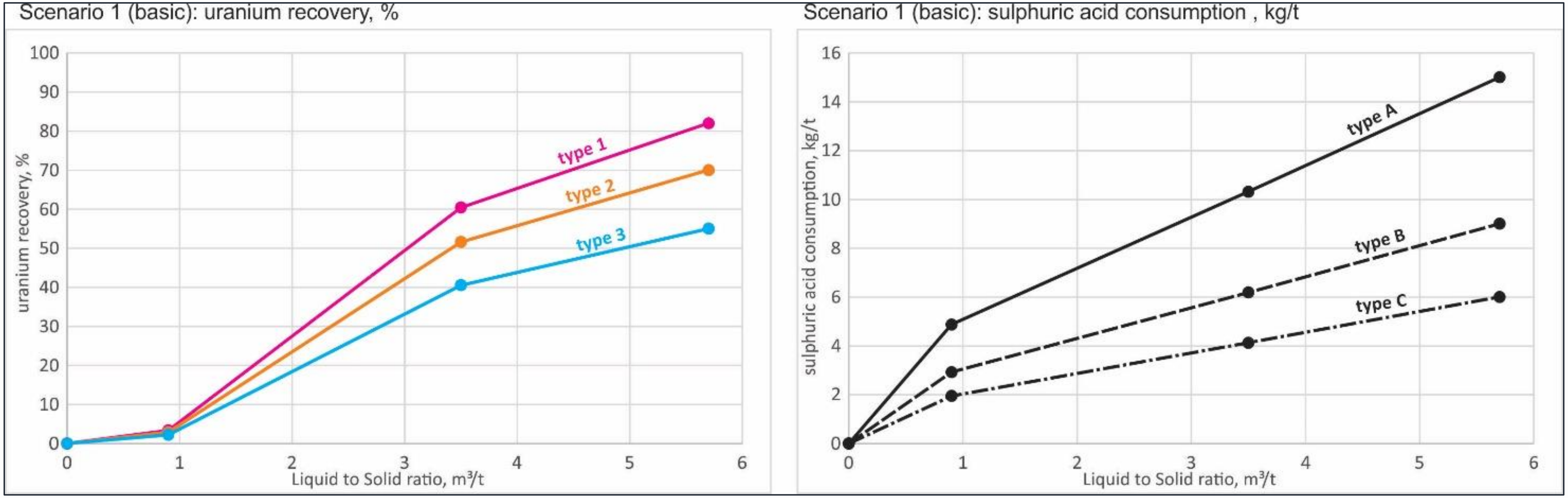
Sulphuric Acid without oxidants



This scenario was investigated in natural test but economic parameters are not the best due to high grade of carbonaceous material

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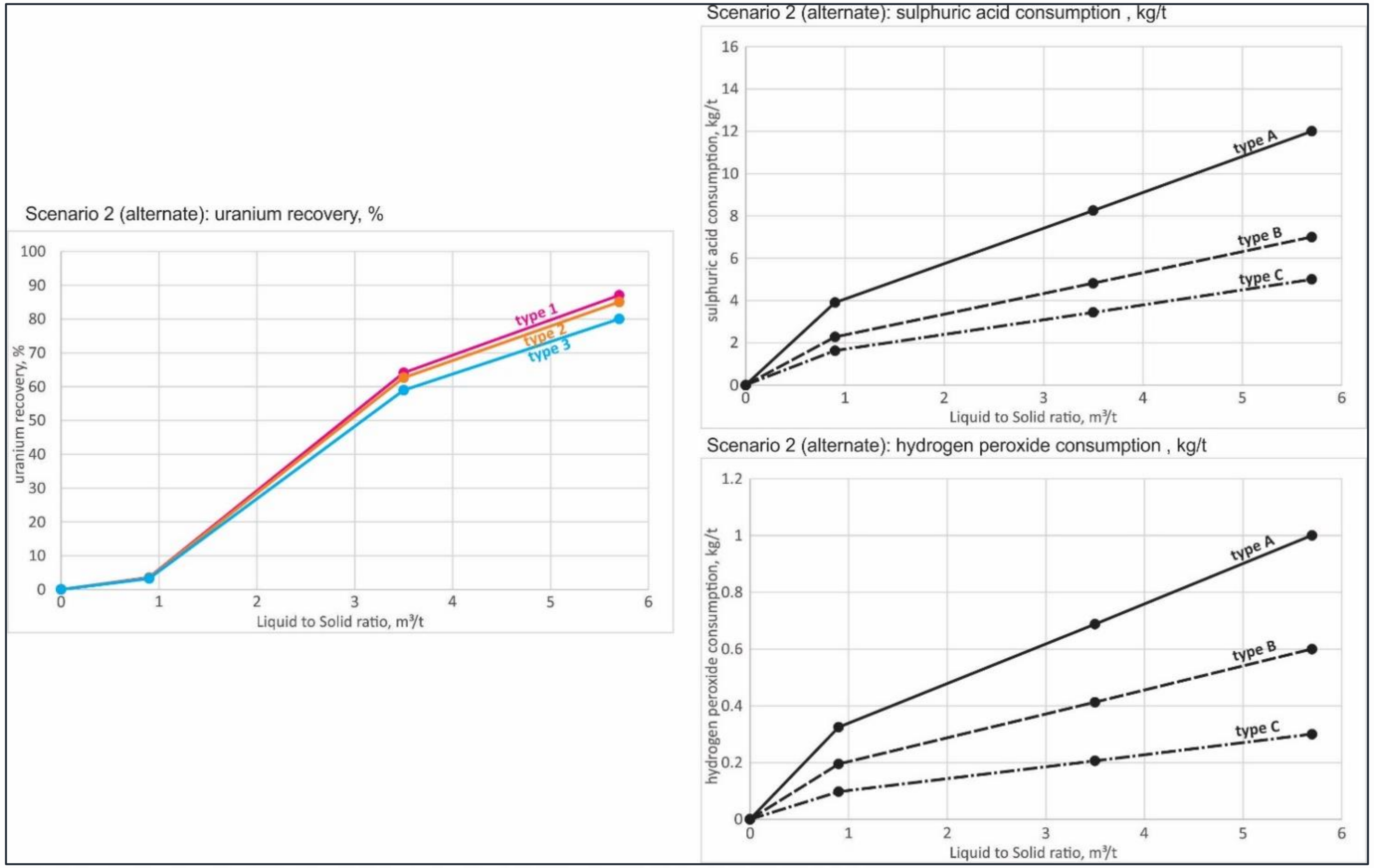
Sulphuric acid with H2O2



Usage of oxidant such as H2O2 allows to increase uranium recovery and decrease acid consumption.

This method is used for ISR on some paleochannel deposits

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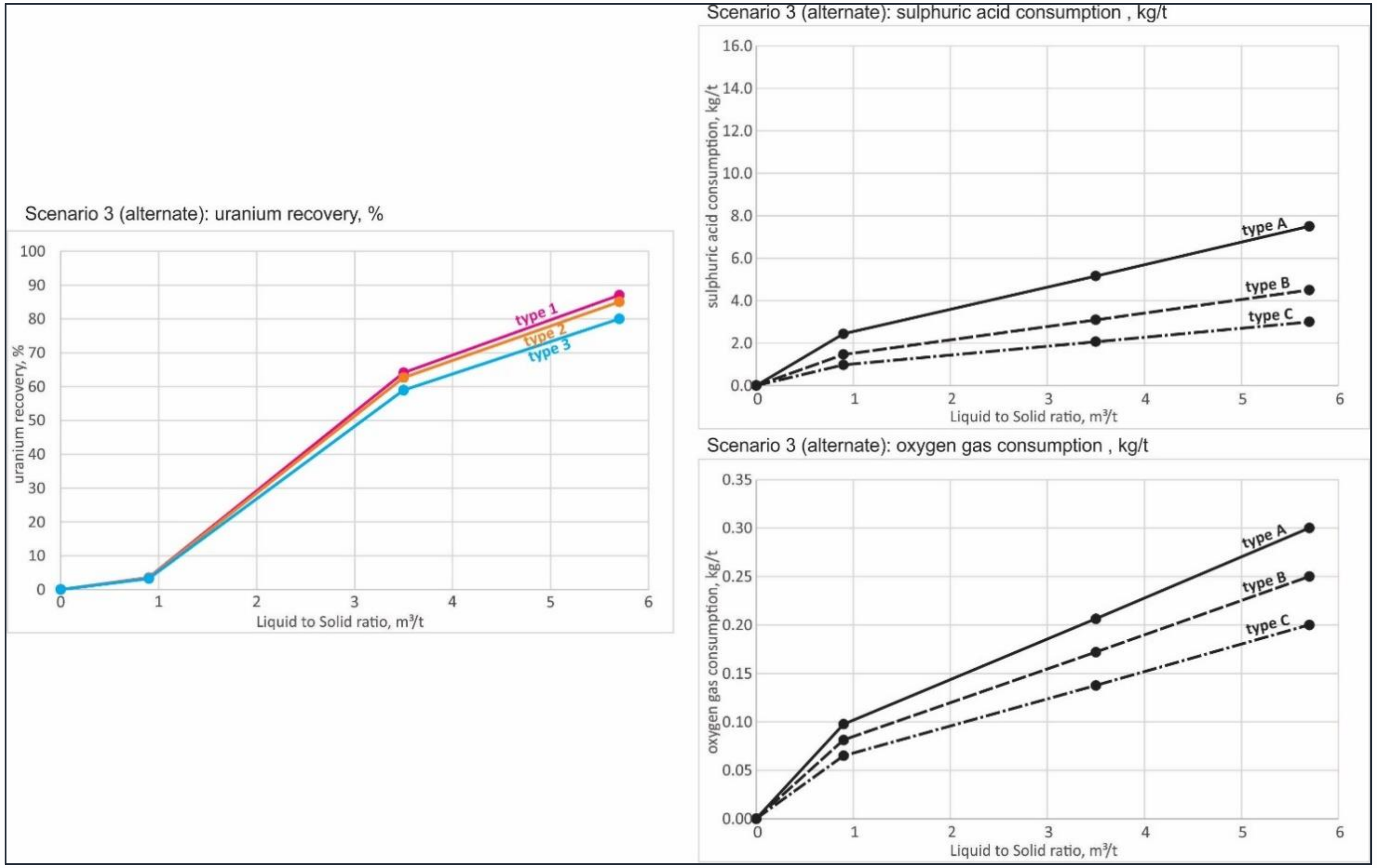
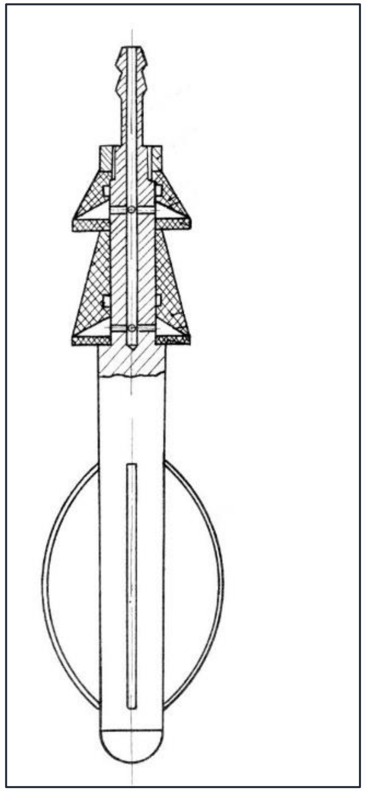
Sulphuric acid with oxygen gas





Oxygen gas is the best alternate option of oxidant, but required usage of gas handler for saturation groundwater by oxygen.

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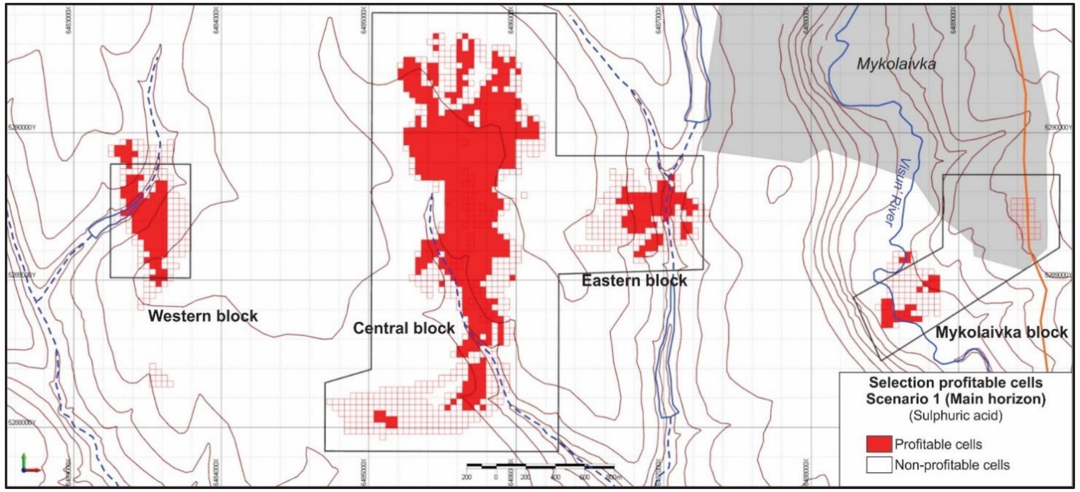
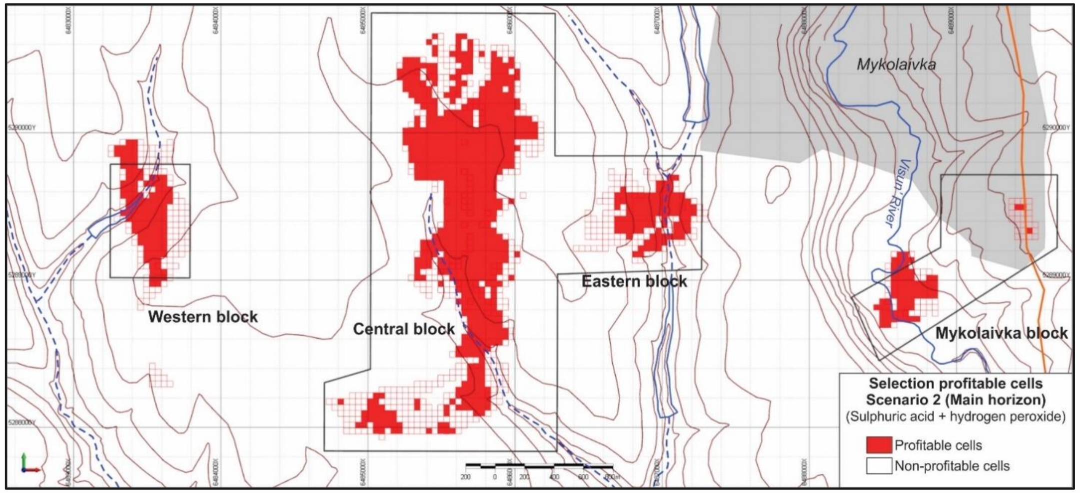
Comparison scenarios





Scenarios with oxidants are close to each other and may be regarded together

Oxidant usage allows to increase quantity of profitable cells for operation due to decreasing operation costs

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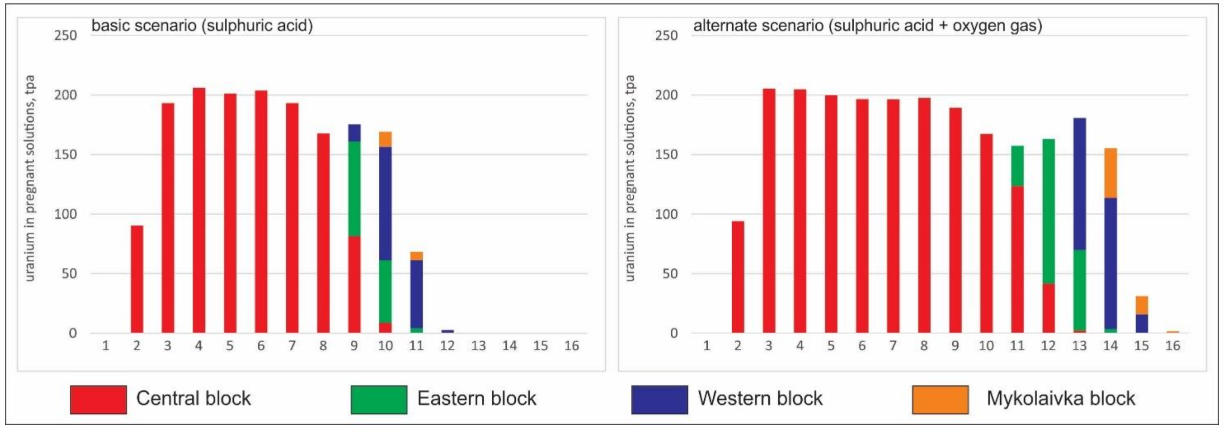
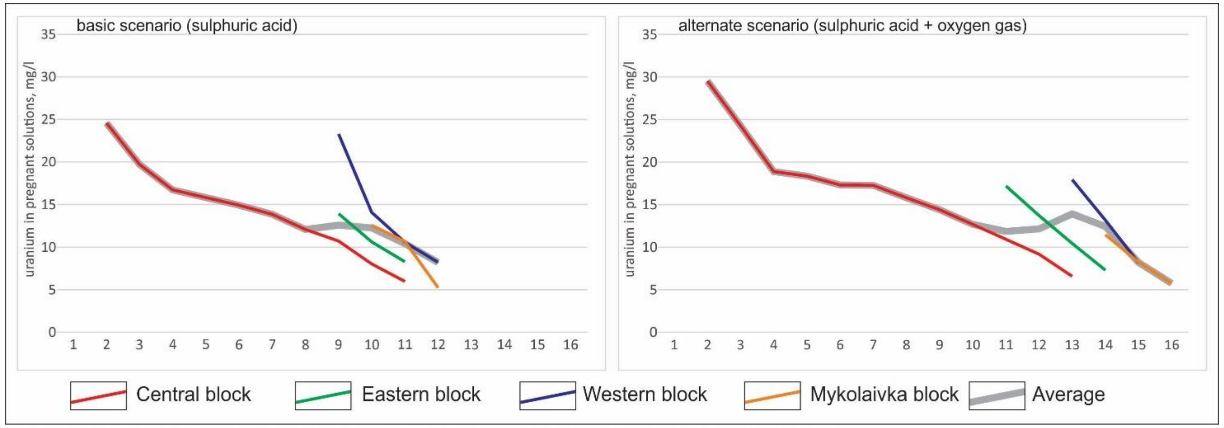
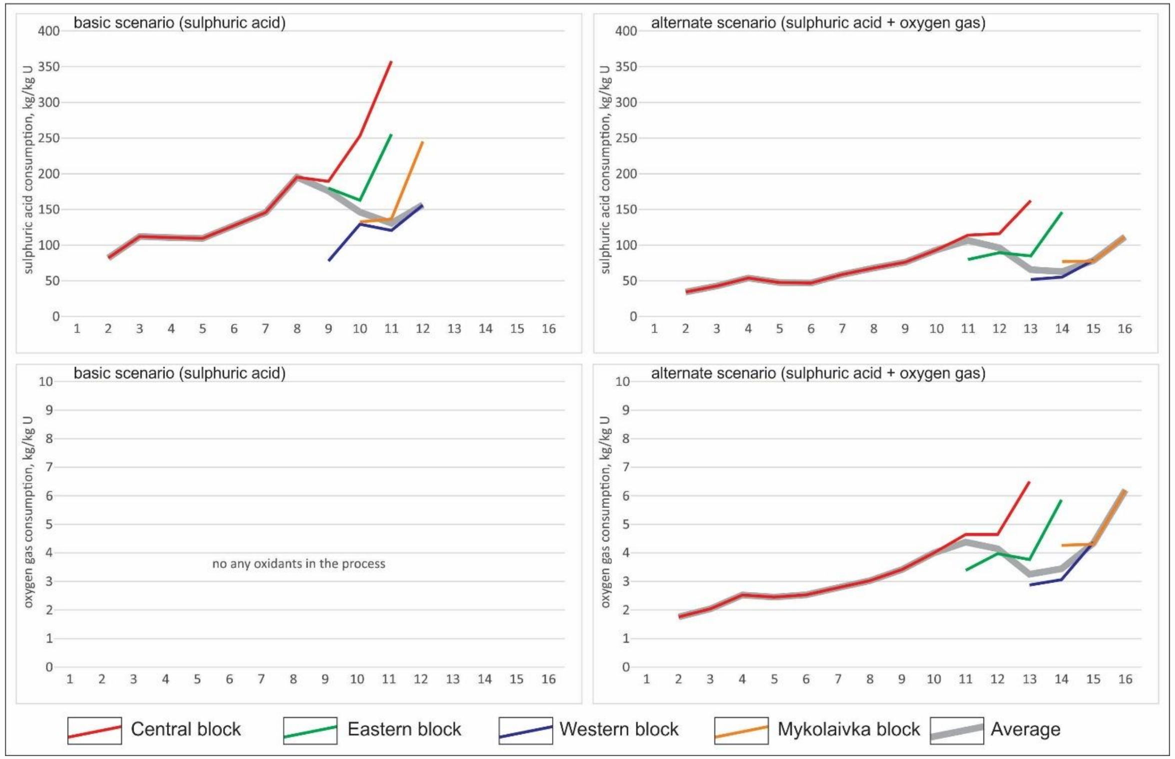
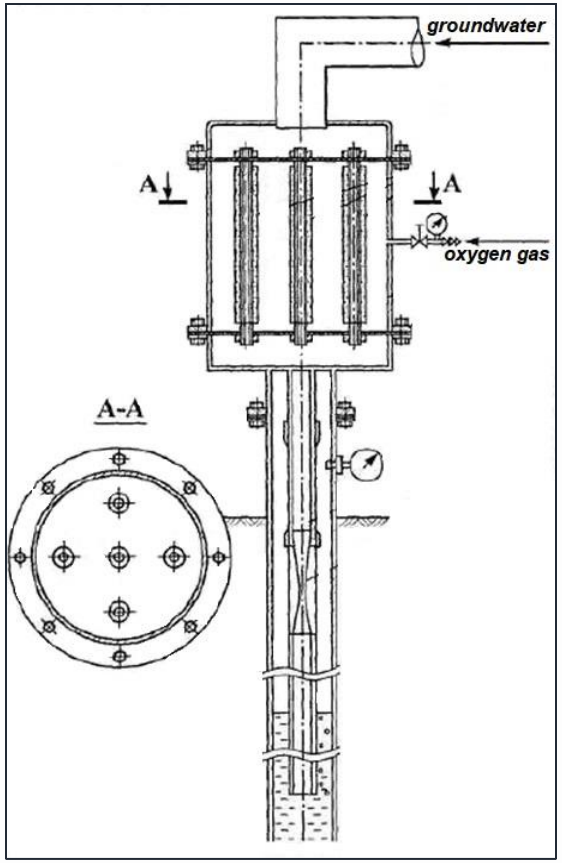
Comparison scenarios







ISR by oxygen gas without acid



Ejector used in tests

Tests run with oxygen gas, without sulphuric acid solutions, were performed in Uzbekistan, particularly on the Uchkuduk and Maylisay deposits (information provided by ElitStroyProekt, Kazakhstan based consulting company).

Tests were performed by several methods:

- Using pressured air with displacement of groundwater from the productive horizon using an ejector
- By increasing pressure of the ejection of pressured air
- By pressured air using gas handlers.

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ISR by oxygen gas without acid

Tests demonstrated uranium recovery 25-32% for Liquid to Solid ratio (L/S) 0.3 – 0.6 and oxygen gas consumption 0.04 – 0.14 kg/t for reached extraction level. Higher levels of uranium extraction are potentially feasible and estimated as 85% for L/S = 2.5

The method for uranium leaching by oxygen gas without sulphuric acid by displacement of groundwater, is cyclic. The productive horizon should be saturated by oxygen gas with a displacement of groundwater, and retained for one month approximately, followed by the rapid pumping of a water-air mixture.

This method has some limitations, but the Safonovka deposit meets all the requirements (see next slide)

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ISR by oxygen gas without acid

List of limitations for extraction uranium by oxygen gas without sulphuric acid	Required parameters	Safonovka deposit	Compliance of Safonovka deposit with the required parameters
Depth of mineralisation	Up to 100–200 m	33–100 m	Yes
Continuity of aquiclude	Continuous upper and lower aquicludes	Continuous both aquicludes excluding two areas on the north and south of Central block	Yes, for the most blocks excluding areas with eroded upper aquiclude on the north and south part of Central block of deposit
Permeability	10 m/day and more	Average permeability is 7.9 m/day, 74% <10 m/day (average 4 m/day), 26% >10 m/day (average 19 m/day)	Yes for 26% of mineralisation where permeability >10 m/day, probably for other parts of deposit
Composition of mineralisation	Presenting pyrite or marcasite	Pyrite and marcasite are presented	Yes

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Conclusion

- Ukraine develops private business for operation of small uranium deposits in Dnipro basin by effective ISR method for reducing deficit of raw uranium material for nuclear stations
- Safonovka deposit is the first deposit for operation by ISR. CSA Global prepared Scoping Study based on several geometallurgical scenarios. The most effective scenario is sulphuric acid leaching with oxidant (H_2O_2 or Oxygen Gas)
- Innovative method for extraction of uranium without acid is potentially feasible on the Safonovka deposit and should be tested as the most efficient and environmental-friendly

(Image courtesy of Roy Hill)

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*Image courtesy of Roy Hill