CSA Global
Mining Industry Consultants
an ERM Group company

In-Situ Recovery – Progress in the last five years

Presented by:

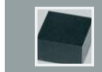
Dr. Maxim Seredkin, Technical Director, Principal Geologist & ISR Lead

ALTA 2023

AGENDA


Introduction

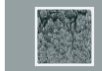

Overview History


Uranium


Copper


Gold and Silver


Nickel, Cobalt, Scandium, Manganese

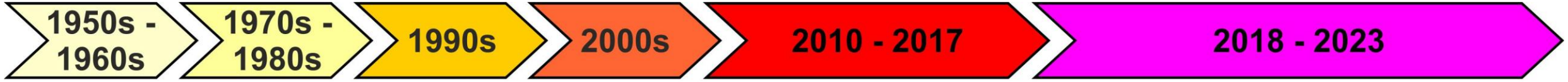

Rare Earth & Yttrium


Tungsten


Boron & Lithium


Conclusions

Introduction – History of ISR



1950s - 1960s

Discovering ISR for U

ISR was developed independently in the former USSR (Ukraine, 1959 and Uzbekistan, 1960s) and the USA (Wyoming, 1958) by acid leaching and alkaline leaching

1970s - 1980s

Initial development ISR for Uranium

Ddiscovering ISR for Cu, Au Pilot test for leaching by-products at the U Mines

ISR mining ramp up the USSR (Uzbekistan, Kazakhstan) and USA (Wyoming, Texas). Period for major sand-stone type uranium deposits discoveries

Test for ISR the following elements as by-products at the uranium Mines: Sc, Re, REE, Y, Mo, V, Se. First ISR tests and mines for Cu in USA (Arizona) and Australia, Au in Canada

1990s

Stagnation in U ISR industry

Developing ISR at the new types of deposits including new commodities (Ni, Co, Mn)

Stagnation period for uranium ISR after Chernobyl disaster and collapsing USSR, development small projects in Russia

Closing the first ISR copper mines in USA, Australia. Developing ISR Mines for Au, Cu in the new regions. Identification of chemical reagents for most effective leaching of Au.

2000s

Wide development ISR for uranium, the displacement of conventional mines

Uranium ISR boom in Kazakhstan (8 new mines). New ISR mines in Uzbekistan, USA, Russia, Australia, including difficult nature conditions

Development ISR technology for new commodities (Ni, Co, Mn) by new lixiviants. Development ISR to new types Cu, Au deposits including tailings

2010 - 2017

Development ISR, discovering of new types non-uranium deposits for ISR (B, W, REE, Sc), development of new methodologies

New ISR uranium mines in Kazakstan, USA, Australia, ISR production share increased to 51% of World uranium production

Non-uranium ISR was spread locally by enthusiasts for Au, Cu, Ni, Co. Development technologies for leaching and extraction metals from pregnant solutions Return to test and pilot operation for ISR of Sc and REE

Definition of general approaches for exploration, modelling and estimation deposits for ISR. Definition criteria and discovering of new types of deposits which can be operated by ISR

2018 - 2023

Discovering new deposits / basins for uranium ISR, development new technologies for uranium ISR

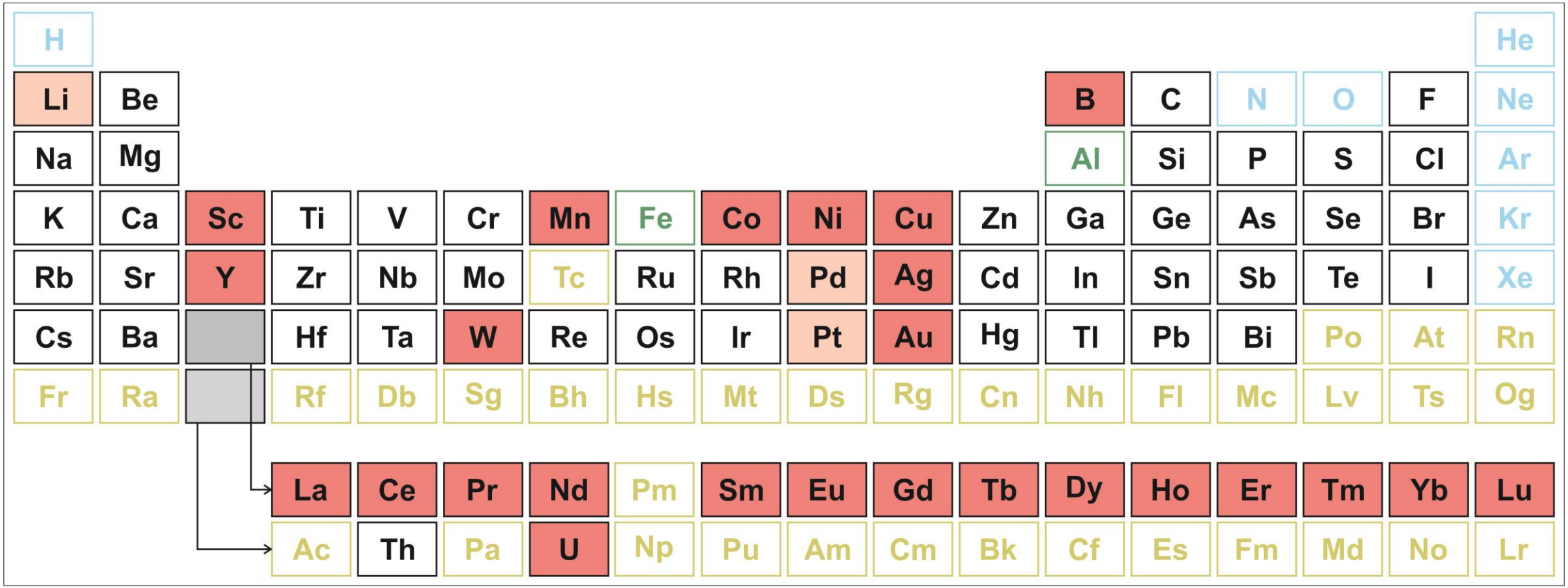
Commercial operations (Cu, Au, Sc, REE) and preparation (Ni, Co, Mn, B, W) to commercial operations for new ISR non-uranium deposits

Development of ISR for new types of uranium deposits (unconformity in Athabasca), discovering new deposits and basins suitable for ISR, development of new technologies of ISR, returning Ukraine for investigation and operation of ISR uranium deposits

Start of commercial operation of new copper ISR projects in USA (Arizona), preparation new ISR copper projects in South Australia, depletion of Gumeshevskoye deposit with start of transformaton to gold ISR project. Commercial operation of gold deposits in Russia, depletion the first gold ISR deposit (Gagarka).
Development of ISR technological scheme for Ni-Co-Sc laterite project with evidences of economic profitability on Scoping Study level and start of pilot operations
(Kazakhstan) Development of tungsten ISR, successful push-pull test with evidences of economic profitability on Scoping Study level Development and pilot test for boron project in USA (California), currency project is on construction stage.
Development if REE&Y ISR for ionic clays

CSA

Introduction – Activity in the last 5 years

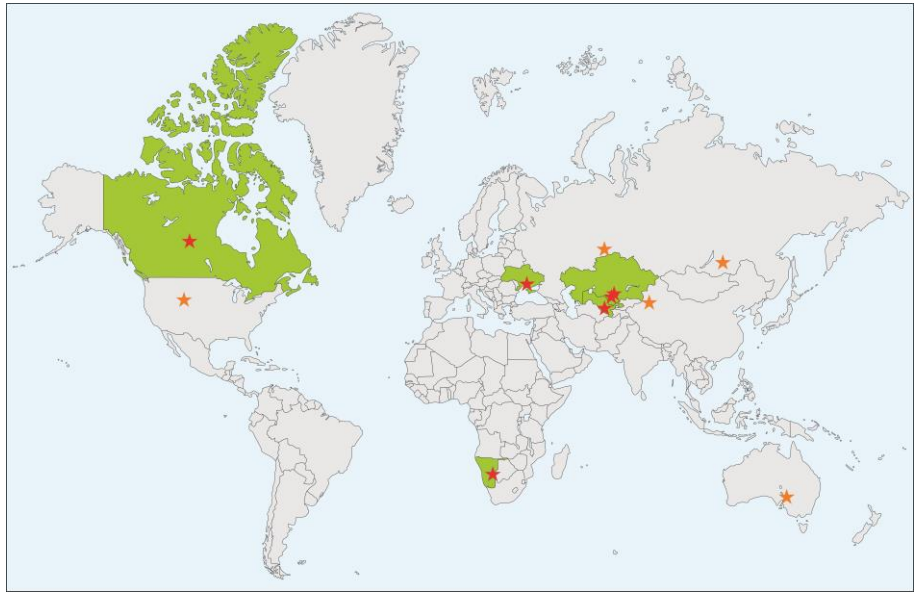


Co ISR was developed in the last five years

Pd ISR tested in the last five years

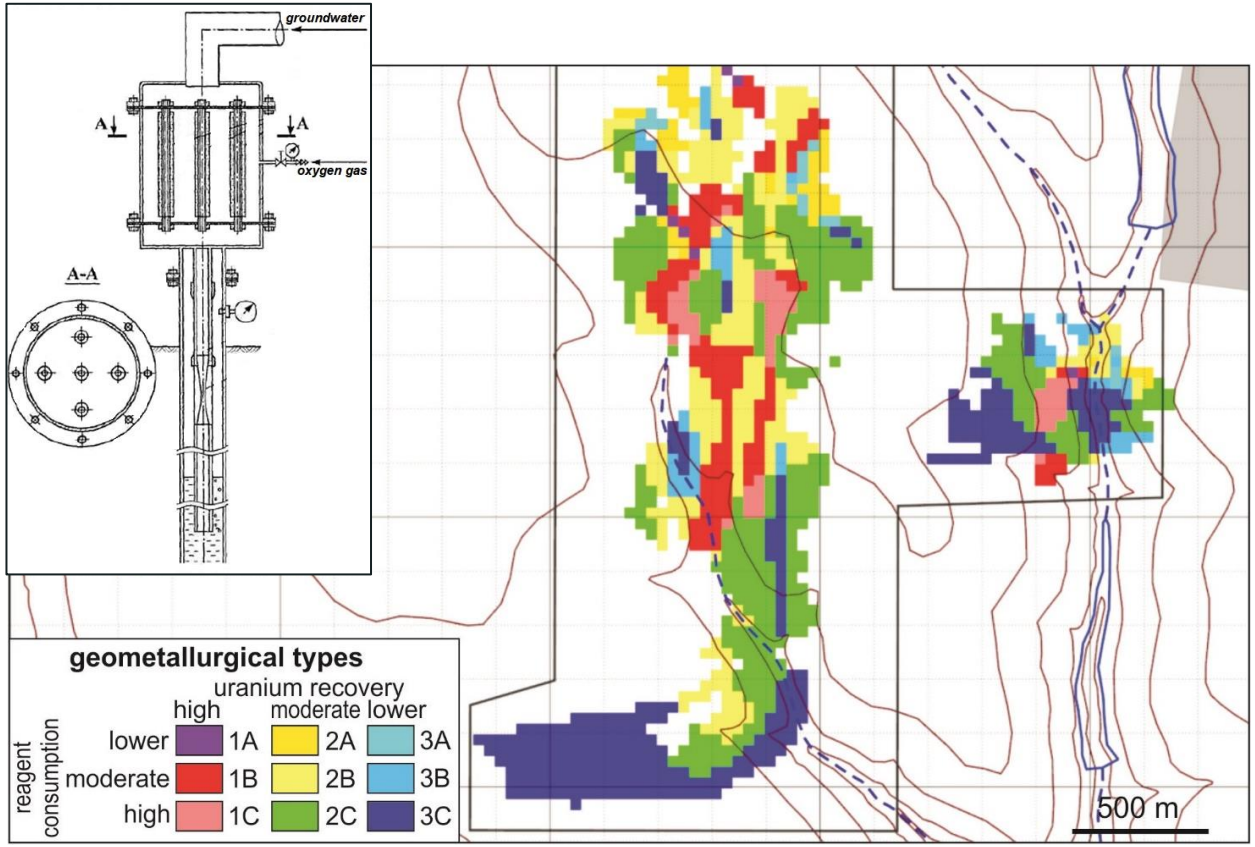
Uranium

- Uranium is the most common commodity extracted by ISR.
- Uranium ISR developed since 1960s and despite this at the last 5 years:
  - Was discovered new major uranium Aranos basin in Namibia.
  - Oxygen gas leaching without or with low grade of sulphuric acid was developed in Uzbekistan and can be used for other projects.
  - ISR technology was developed for unconformity type deposits.
  - Methodology of modelling of roll-front deposits were improved.



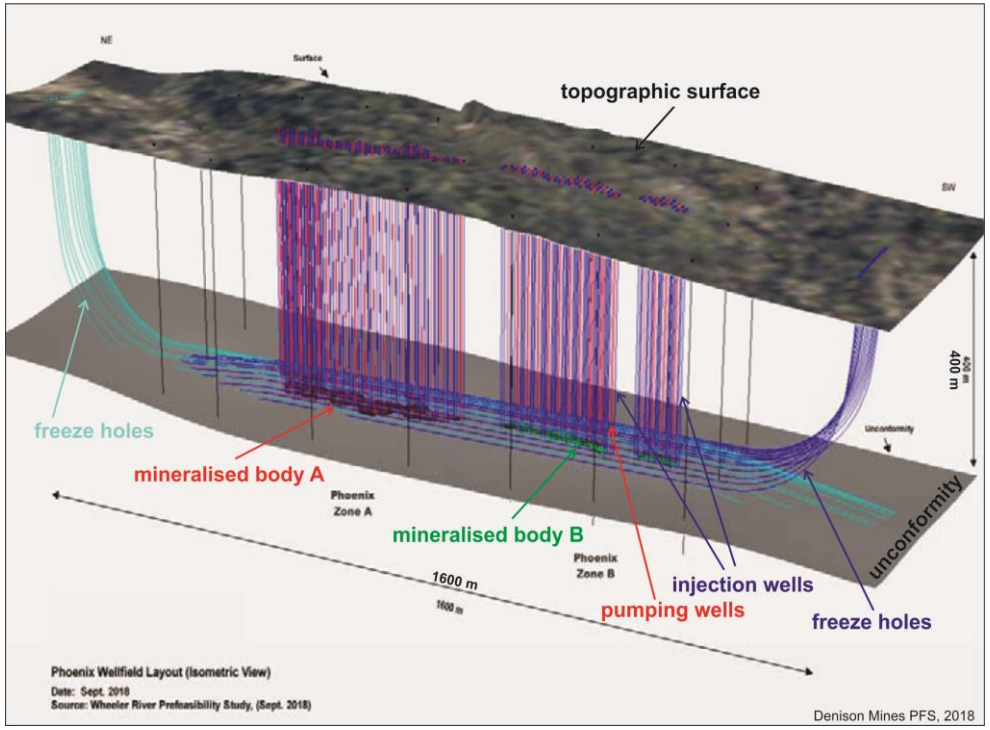
Uranium – Uzbekistan, Sanonovka deposit, Aranos basin

- Tests with oxygen gas, without sulphuric acid, were performed in Uzbekistan (Shiyaev et al., 2020).
- Tests were performed using pressured air with displacement of groundwater from the productive horizon using an ejector and increasing pressure of the ejection of pressured air (Shiyaev et al., 2020).
- Method was proposed for Ukranian Safonofka deposit and Aranos basin in Namibia due to strict environmental limitations.



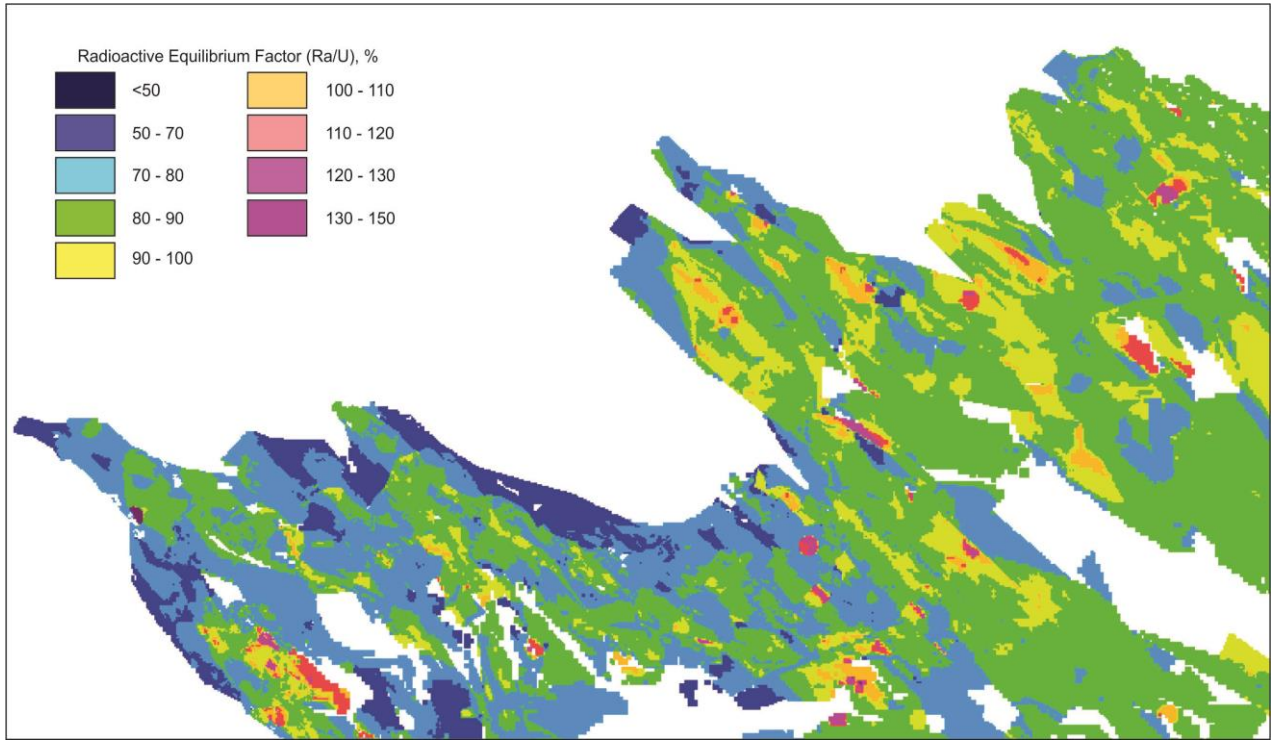
Uranium – Phoenix deposit

- Dennison Mines Corp. successfully investigated ISR for Phoenix uranium deposit of unconformity type in the Athabasca Basin (PFS Report, 2018) and plans to start natural pilot operation.
- Phoenix deposit is located in complicated geological and hydrogeological conditions, uranium grade is high (19% U_3O_8), not favourable for ISR.
- Hydrogeological tests and laboratory leaching tests demonstrated applicability of ISR for this deposit.
- Horizons above and lower uranium mineralisation will be frozen for creating artificial aquicludes for avoiding wide distribution of leaching solutions.
- ISR in cold conditions (< 5°C) was proved earlier at the Khiagda ore field.



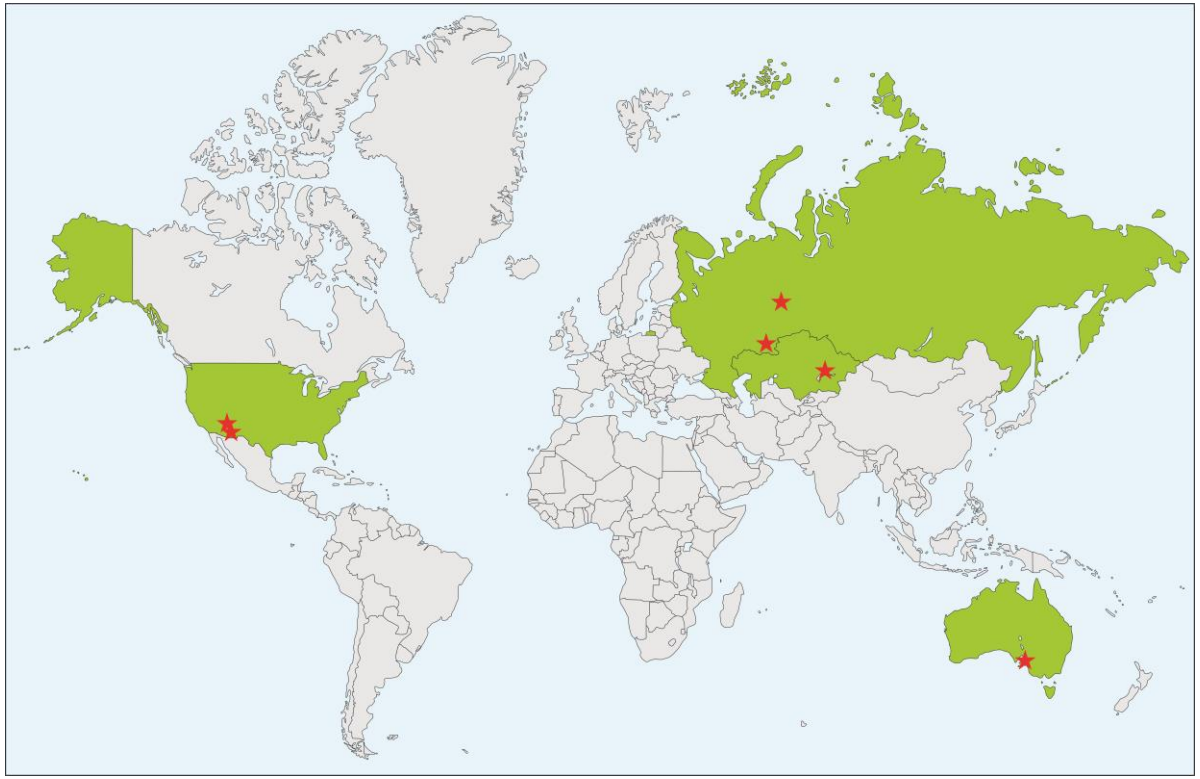
Uranium – Chu-Sarysu and Syrdarya basins

- Subsidiary mines of Kazatomprom improved methodology of modelling and estimation variability of uranium grades.
- The most of roll-front deposits in Kazakhstan has not equilibrium between radium and uranium.
- Estimation of REF variability is required for correct estimation of uranium grades using gamma logging.
- Developed methodology allows to estimate variability of REF using sparce exploration grid with following applying to operation wells.



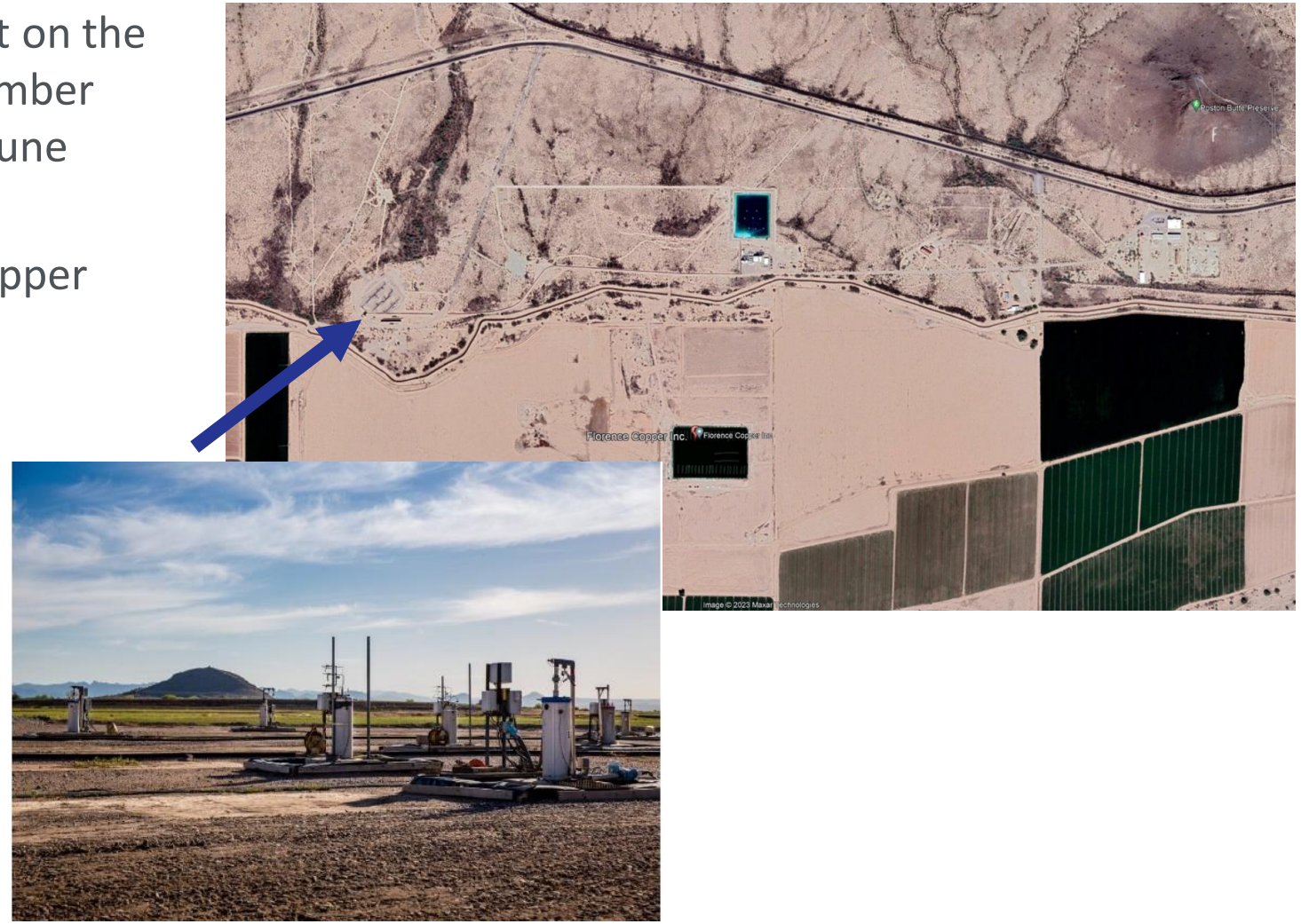
Copper

- Copper ISR initially used on the San-Manuel deposit as additional method to underground operation. Project was closed in the 1990s.
- New ISR copper projects were developed since end 1990s and especially in 2000-2010s.
- Total capacity of Florence and Gunnison projects may reach 100 kt copper per year .



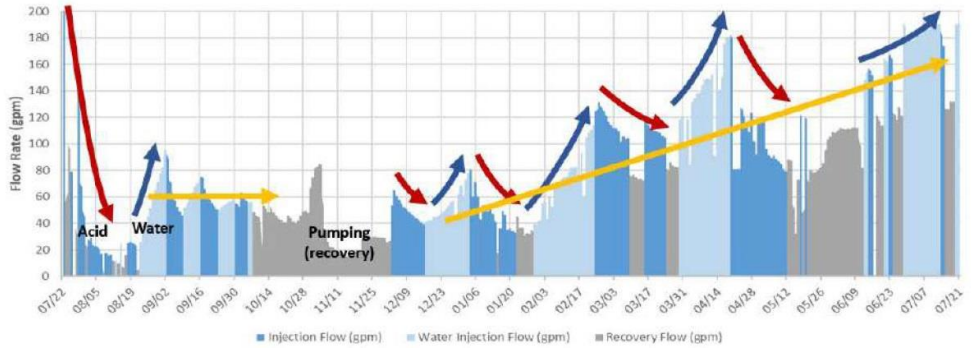
Copper – Florence

- Taseko mining started operation test on the Florence copper ISR project in December 2018 and commercial operation in June 2020 (NI 43-101 report, 2023).
- Proposed full capacity is 38-40 kt copper per year for period at least 22 year.
- Final product is cathode copper.

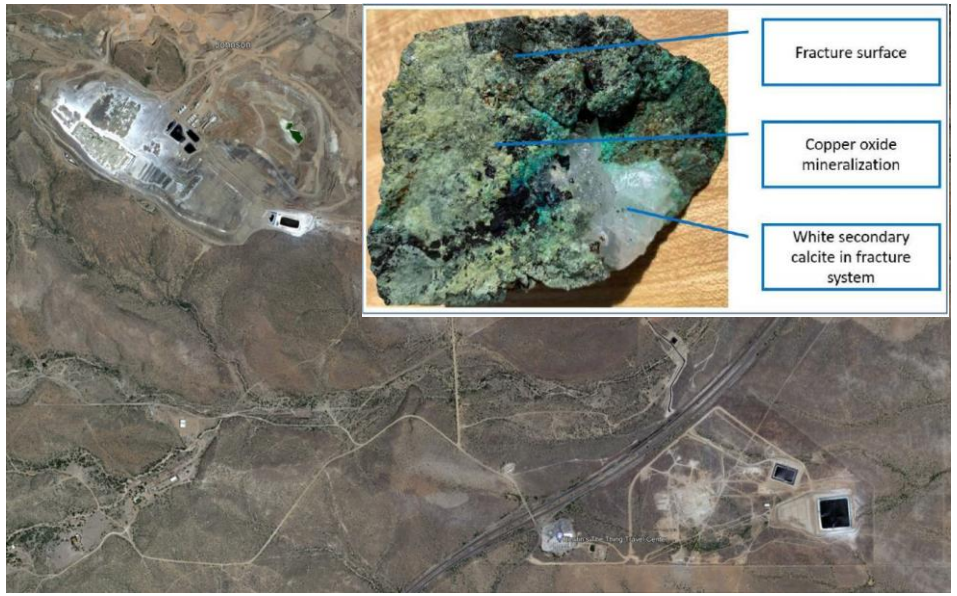


Copper – Gunnison

- Excelsior mining started pilot operation the Gunnison copper ISR project in Q4 2020 (NI 43-101 report, 2023).
- Proposed full capacity is 55-60 kt copper per year for period at least 24 years.
- Company met with blockages by carbon dioxide gas colmatation due to high grade of carbonate material in copper bearing veins and fractures.
- Company plans to resolve this issue by alternating periods of acidification and neutralisation of solutions, this will probably lead to increasing acid consumption.
- Another option was used in the high-carbonate conditions was tested on the Kharasan mine – soft acidification before dissolution of carbonates.



NI 43-101 report, 2023

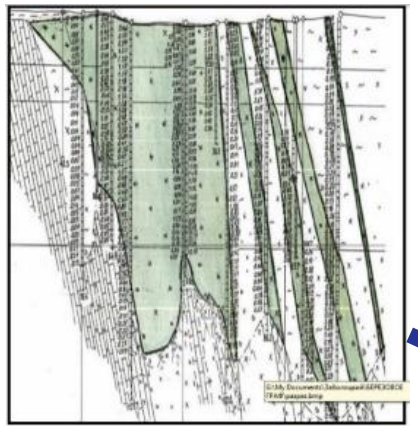


Copper – Kapunda and Moonta

- Enviro Copper extensively tested the Kapunda and Moonta copper ISR projects.
- Completed comprehensive hydrogeological tests, prepared hydrodynamic model, performed leaching tests by different lixiviants.
- Processing of pregnant by ion-exchange (IX) process developed by company is safer and better than common SX process using now for treatment of copper pregnant solutions.
- Company is ready to commence pilot operation.

Copper - Gumeshevskoye

- UralHydroCopper operates the Gumeshevskoye copper ISR project since 1998.
- Capacity of project reached 5-7 kt copper per year however now deposit is almost depleted.
- Copper grades in pregnant solutions is 200 mg/L, this is close to breakeven cut off.
- Company completed extensive program of gold leaching investigations and consider construction of chlorine gas production module as well as processing plant for gold pregnant solutions.

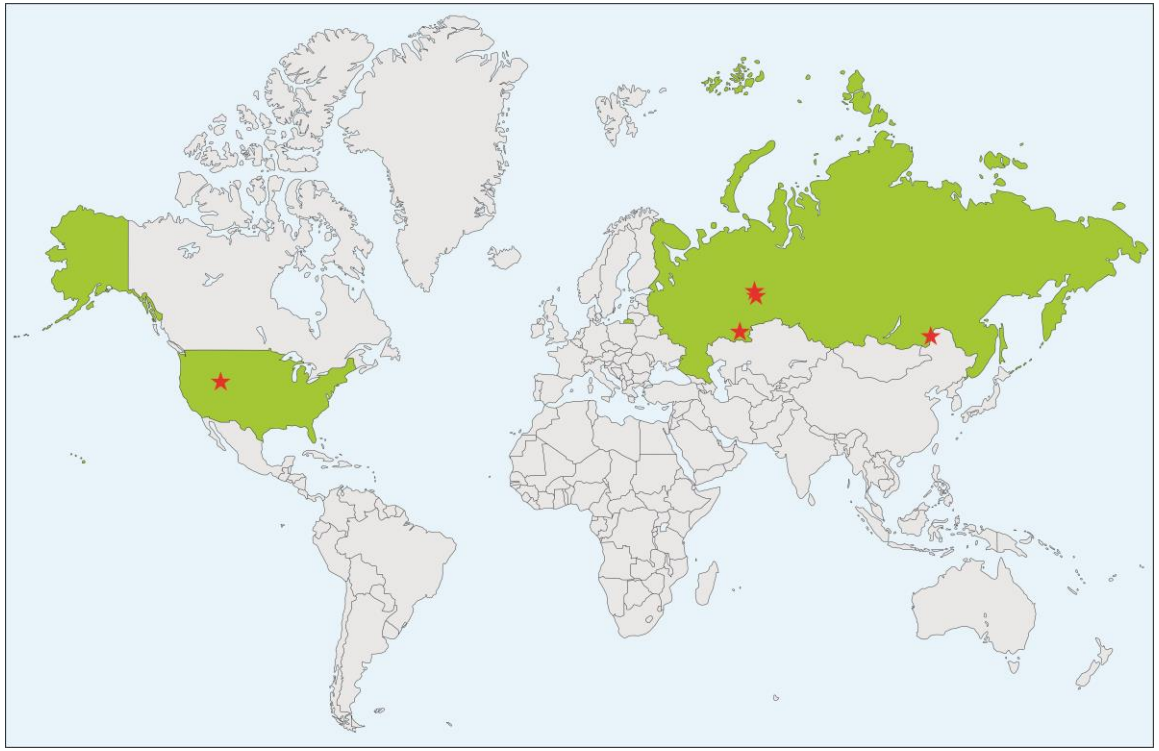


Copper – waste dumps

- ISR technology was successfully applied to copper waste dumps by private companies at the Kounrad deposit in Kazakhstan and Gaysky deposit in Russia.
- This technology addresses to profitable production of cathode copper with resolving of environmental issues by leaching oxide copper which may contaminate superficial water and groundwater.

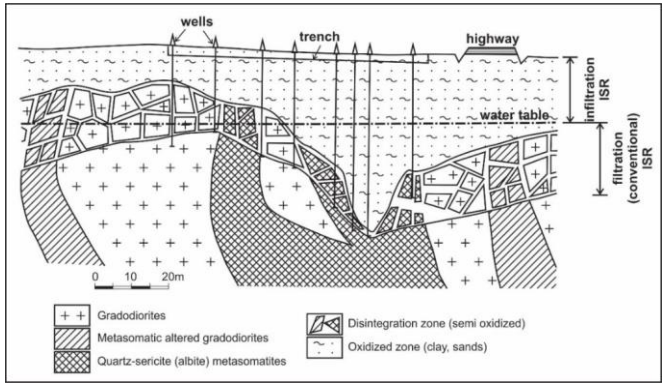
Gold

- Gold ISR was developed last 30 years but still used for small deposits with small capacity by private companies.
- Annual capacity of new Tuba-Kain ISR project may reach 15kOz.
- Carlin type of gold deposits considered for ISR in 2018 and this idea is productive and may be realised in the nearest future.
- Deep gold placers are suitable for ISR too!



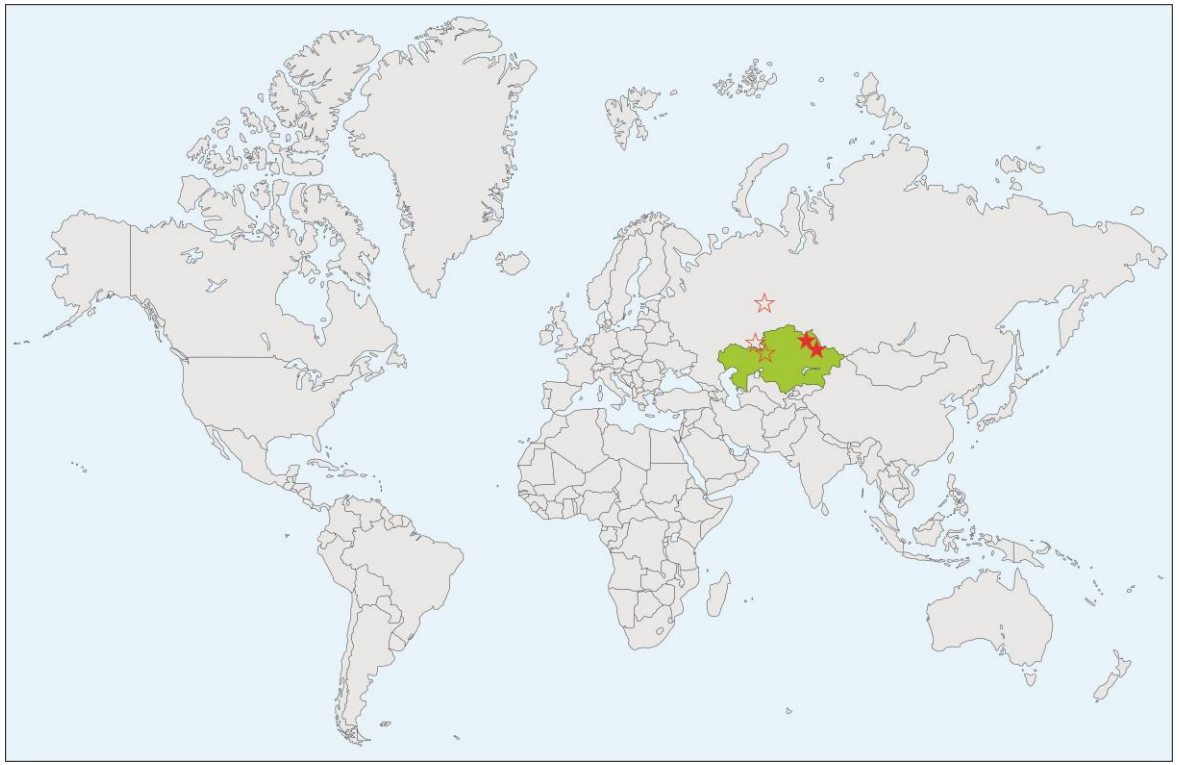
Gold (continued)

- Gold ISR was realised by small private companies on the Urals. Lixiviants are chlorine gas or sodium hypochlorite.
- Annual capacity of gold ISR miners is 2-6 kOz however on the Tuba-Kain will be increased up to 15 kOz per year. This capacity is not intersecting for bigger mining companies.
- The first gold ISR Gagarka mine is depleted and in remediation process now.
- Gold ISR was considered by Nornickel on the Bystrinsko-Shirinskoye deposit but this project was suspended in 2019 due to low dynamics of leaching.
- The project demonstrated that production of fresh lixiviants on mining sites are the best option for ISR.



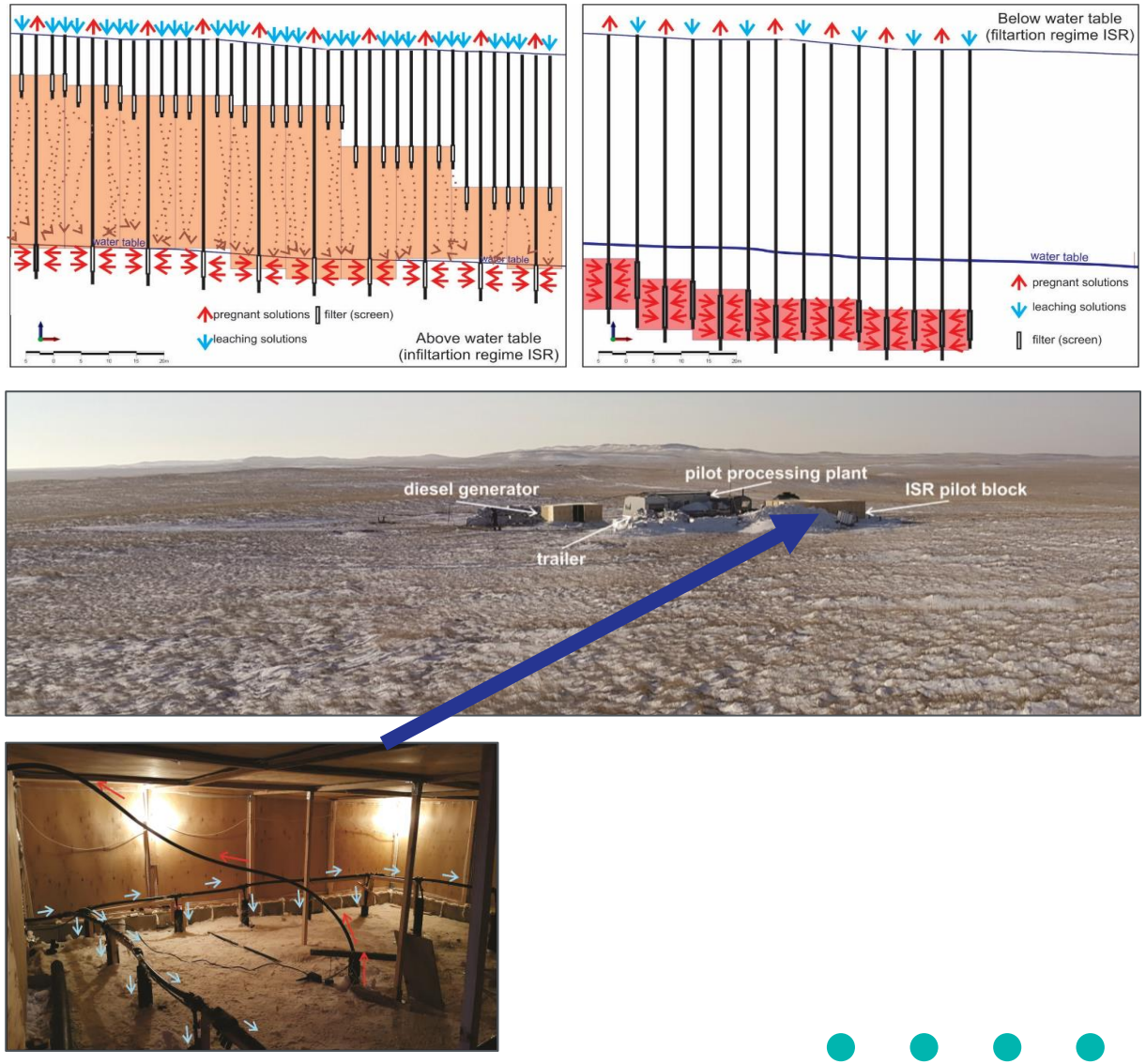
Nickel-Cobalt-Manganese-Scandium

- Nickel-Cobalt-Manganese-Scandium ISR from laterite deposits was extensively developed last 5 years.
- This technology is close to realisation at Pre-Feasibility Study.
- This technology is widely applicable to laterite Ni-Co-Mn-Sc deposits due to quite similar geological conditions.



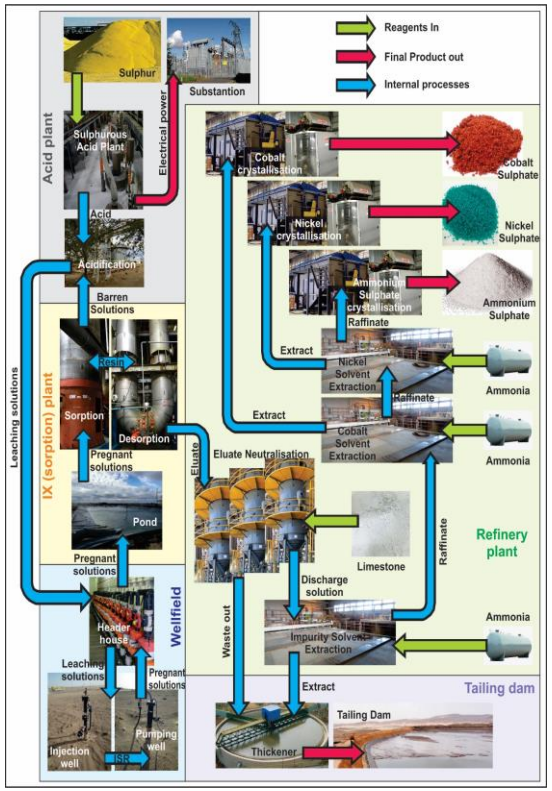
Nickel-Cobalt-Manganese-Scandium

- ISR of Nickel and Cobalt from laterite mineralisation was developed by private companies in Russia since 2000s due to uneconomic of pyrometallurgy method.
- Sulphurous acid as the best lixiviant was discovered in 2011-2013 and field tested at the Ekibastuz-Shiderty deposit in 2018.
- Sulphurous acid was used for leaching of cobalt-manganese ore on the open pit Mt Thirsty project in Western Australia.
- Manganese and Scandium can be leached from laterite deposits too.



Nickel-Cobalt-Manganese-Scandium

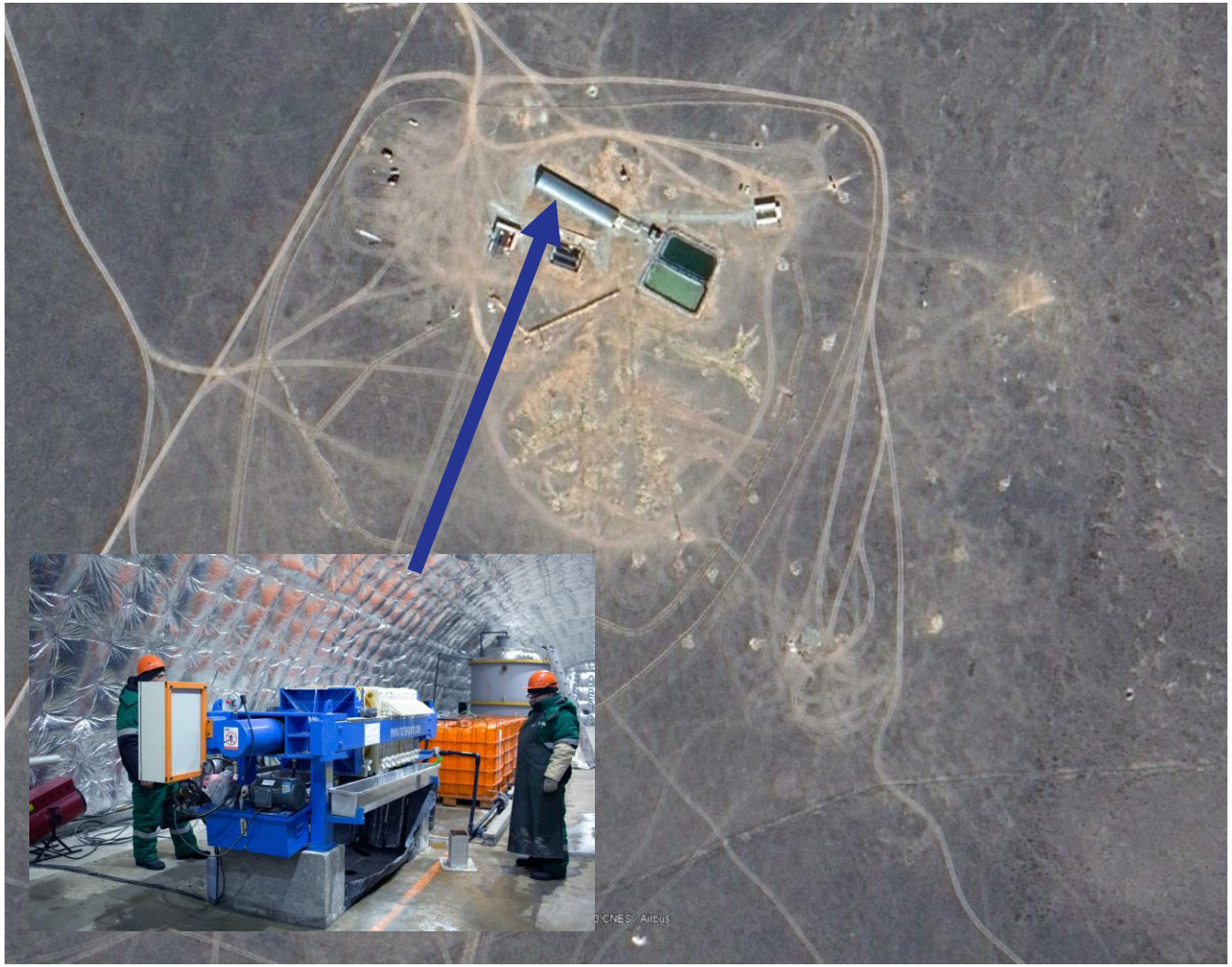
- Processing of pregnant solutions in pilot ISR test allowed to produce from poor pregnant solutions (100-120 mg/l) Ni-Co eluate with composition comparable with eluate in SunRise project (CleanTeQ) produced from pregnant solutions after HPAL process.
- Comparable composition of eluate allows to use processing flowsheet detailly designed by CleanTeQ use for processing pregnant solutions after ISR.
- CSA Global integrated technologies for ISR projects in 2019.



Component	SunRise (Fairfield, 2018)	Ekibastuz-Shiderty
Ni, g/l	31	22
Co, g/l	3	10
Mn. g/l	0.7	4
Sc, mg/l		50
Fe, g/l	4	5
Al, g/l	2.9	1.5
Mg, g/l	0.4	3

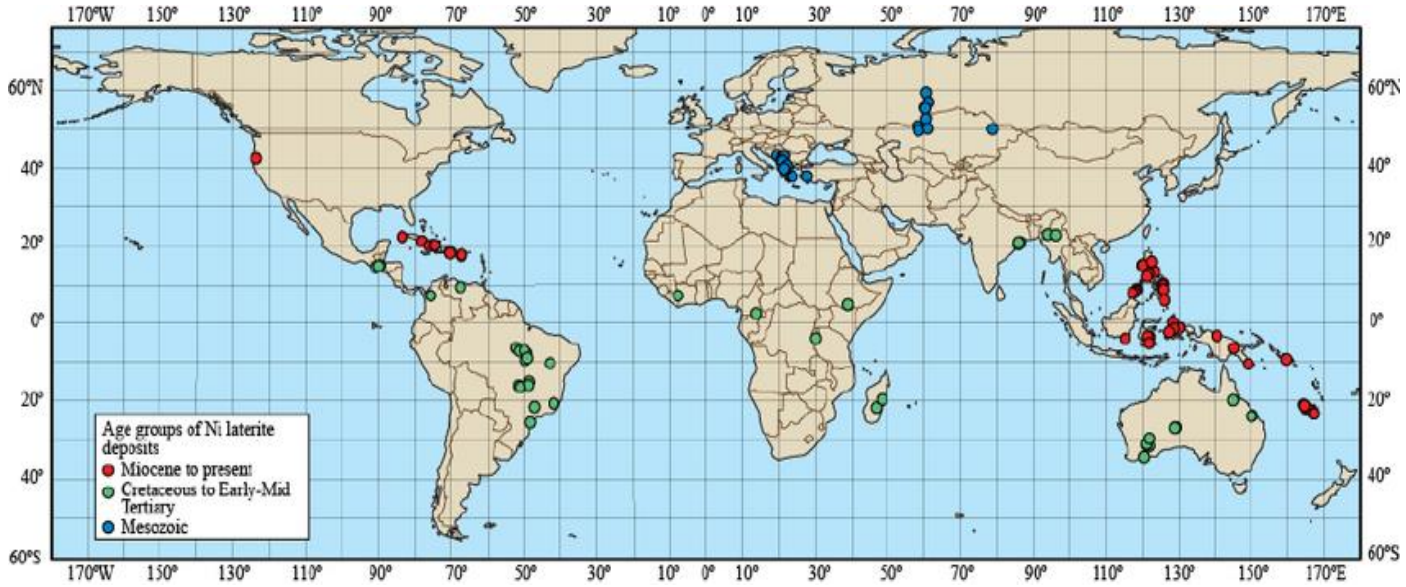
Nickel-Cobalt-Manganese-Scandium

- Kaznickel constructed the first Ni-Co pilot ISR plant in 2019 and performed operations in 2019-2021.
- Tested different lixiviants and ion-change processes for selection the most suitable technology.
- Demonstrated successful operation above the water table.



Nickel-Cobalt-Manganese-Scandium

- Nickel-Cobalt-Manganese-Scandium ISR from laterite deposits may be developed to widely distribute technology similar to uranium
- ISR due to similar geological conditions on laterite deposits across the world.

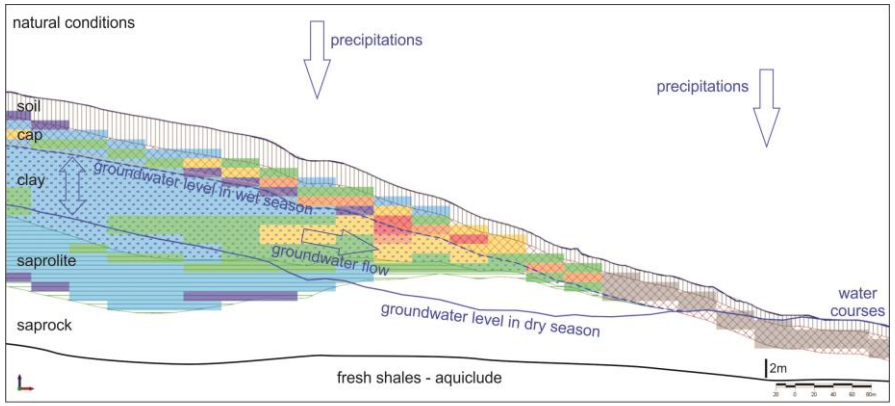


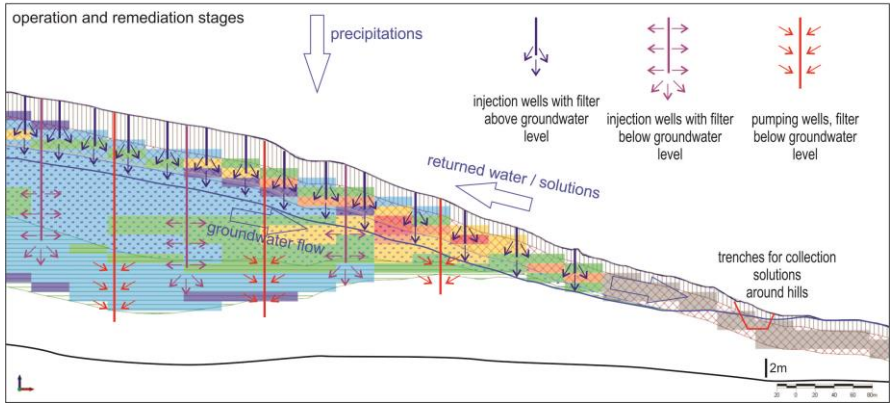
Rare Earth Elements & Yttrium

- ISR technology is very prospective for ionic rare earth clays and applied in China - ready for reducing impact of REE mining.
- Australian companies has interest to development of REE ISR for ionic rare earth clays due to identifying many this type projects in Australia and Africa.

Rare Earth Elements & Yttrium

- Rare Earth and Yttrium ISR technology was developed in China due to conventional mining impacted to environmental very strongly up to disaster situation.
- Leaching of rare earth can be described as desorption from clays by sodium carbonate or sulphate solutions and quite effective.
- Potential re-soluble issue is high fluctuation of groundwater level during year cycle.



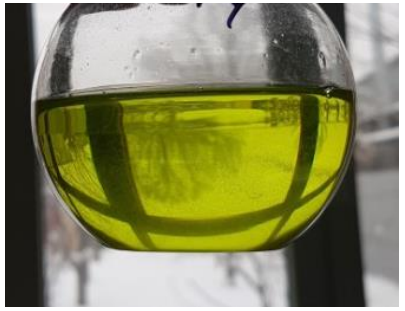


Tungsten

- New ISR technology was developed for tungsten mineralisation in weathering crusts and skarns.

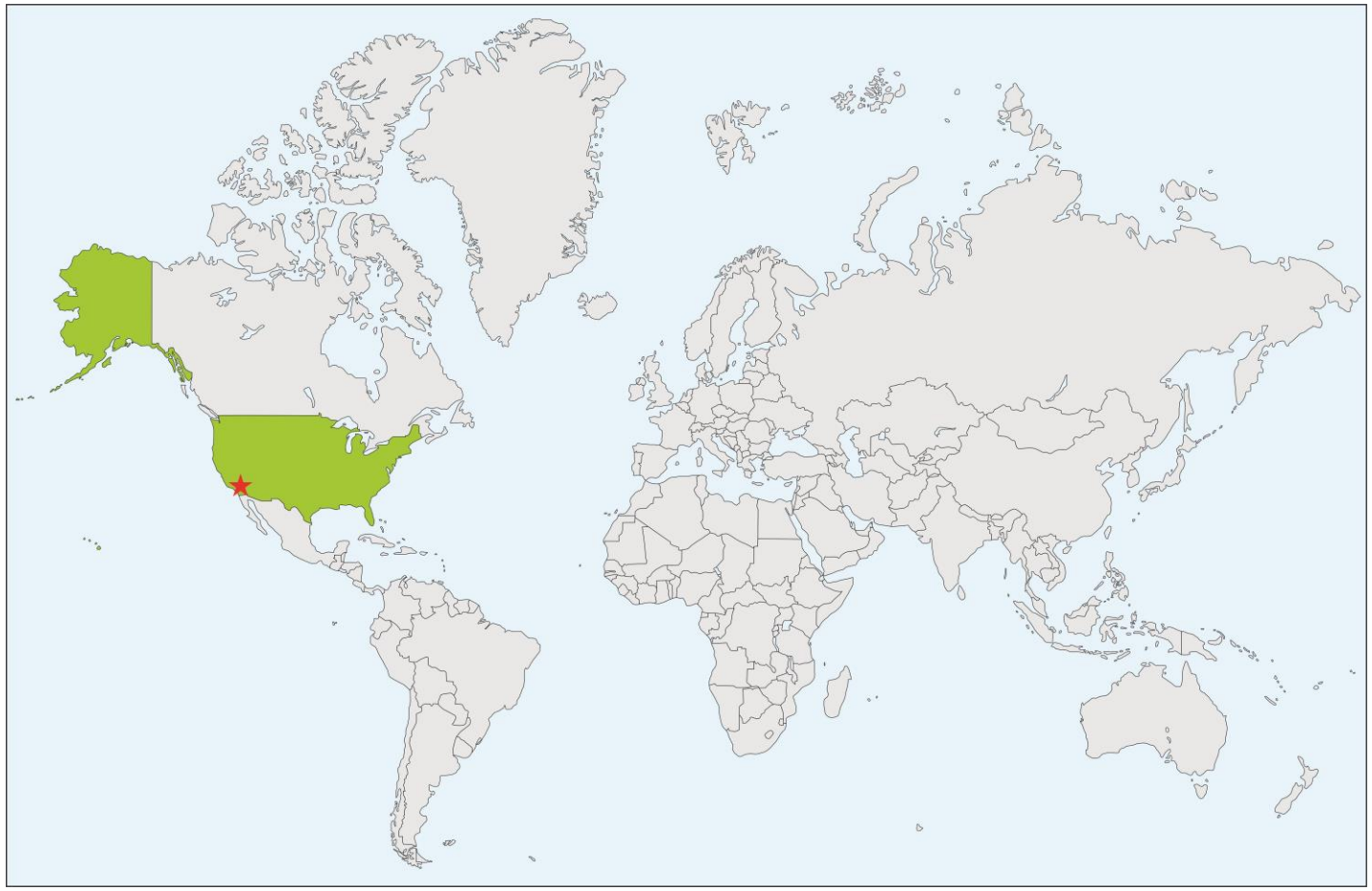
Tungsten - Koktenkol

- ISR was developed by Dala Mining in 2019.
- Lixiviant with based on Oxalic acid and hydrochloric (or sulphurous) acid allows to extraction of tungsten to solutions in oxalate complexes.
- Technology was tested by push-pull test, tungsten grade in pregnant solutions reached to 250-300 mg/L.



Boron

- ISR technology was applied to boric-lithium mineralisation in the last five years.



Boron – Fort Cady

- American Pacific Borates company developed ISR technology for leaching of boron from colemanite mineralisation on the Fort Cady project in California (Corporate Presentation, 2019).
- Lixiviant is heated hydrochloric acid, process is push pull due to colemanite mineralisation is impermeable.
- Final product is boric acid, lithium is in pregnant solutions as by product, leached from clay interbeds.
- Mine and processing plant is in construction stage now and company is almost ready for start of commercial operations.

Conclusion

Commodity		Price	OPEX	Wellfield construction	Unit of capacity	Plant and infrastructure construction	Level of technology development
Uranium	Acid ISR, roll-front	122 US$/kg U	12 – 35 US$/kg U	5 – 10 US$/kg U	1000 tpa U	30 – 150 MUS$	Commercial operation
	Acid ISR, paleochannel	122 US$/kg U	35 – 65 US$/kg U	15 – 25 US$/kg U	1000 tpa U	50 – 130 MUS$	Commercial operation
	Alkaline ISR	122 US$/kg U	25 – 55 US$/kg U	10 – 30 US$/kg U	1000 tpa U	25 – 110 MUS$	Commercial operation
Copper. Sulphuric acid ISR		9.6 US$/kg Cu	1.8 – 2.5 US$/kg Cu	0.4 – 0.7 US$/kg Cu	1000 tpa Cu	4 – 7 MUS$	Commercial operation
Gold and Silver. Sodium hypochlorite ISR		1,850 USD$/oz Au	250 – 300 USD$/oz Au	100 – 300 USD$/oz Au	1 tpa Au	1 – 4 MUS$	Operation
Nickel & Cobalt. Sulphurous acid ISR		28 USD$/kg Ni	5 – 8 USD$/kg Ni	2 – 5 USD$/kg Ni	1000 tpa Ni	25 – 40 MUS$	Scoping level, pilot tests
Tungsten. Oxalic acid ISR		42 USD$/kg W	16 – 27 USD$/kg W	0.8 – 2 USD$/kg W	1000 tpa W	20 – 50 MUS$	Scoping level, push-pull test

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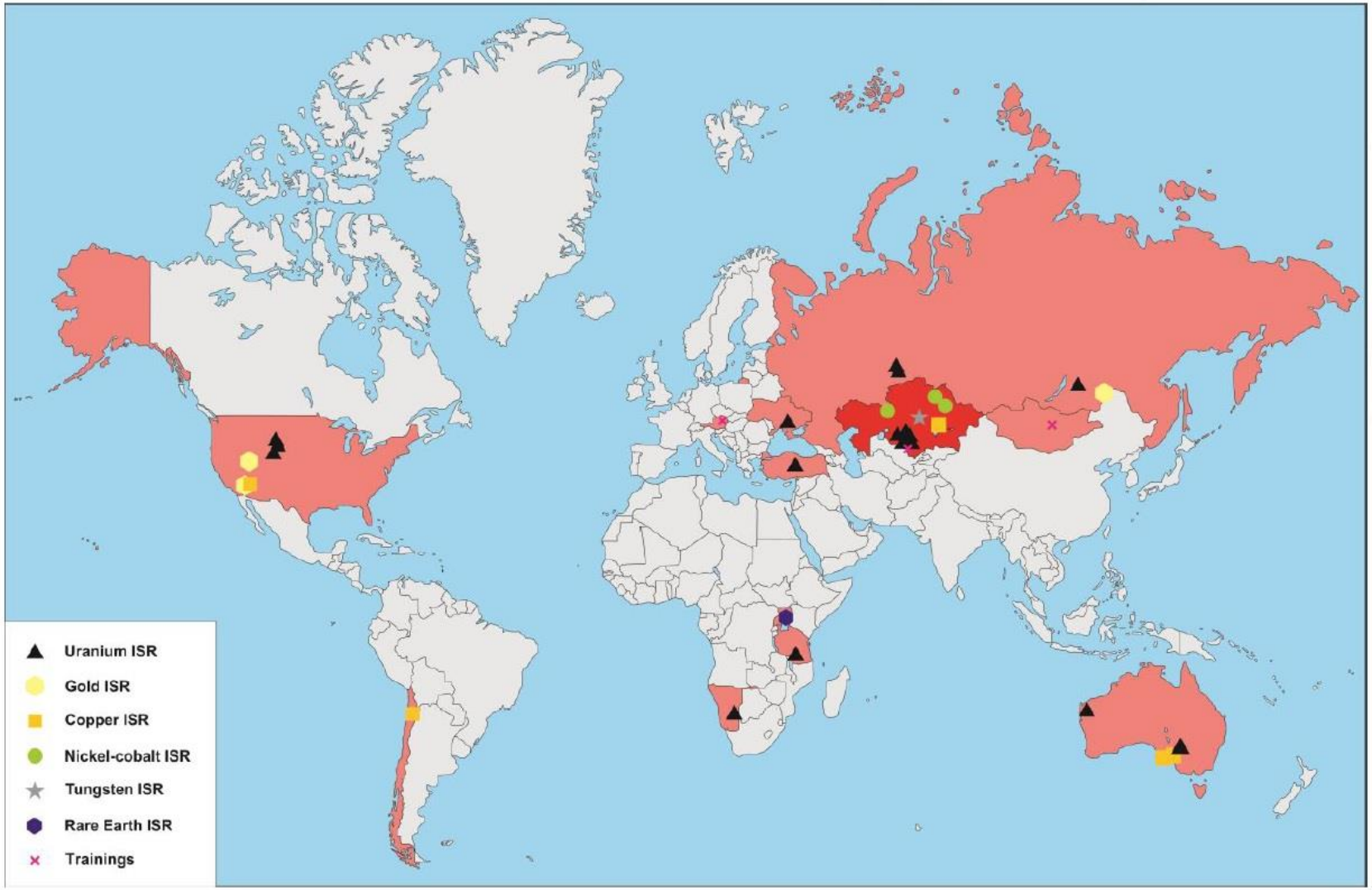
CSA Global Experience in ISR

- Employees and consultants of CSA Global have been involved to ISR projects from conceptual stage to operational and remediation stages.
- ISR projects completed by our team are located in all continents excluding Antarctica.
- CSA Global has completed U, Cu, Au-Ag, Ni-Co, REE, W ISR projects.



Meet our specialists

Graham Jeffress | Partner, APAC, Principal Resource Geologist

- A geologist with more than 30 years' experience in exploration and management in Australia, PNG and Indonesia.
- Serves on Joint Ore Reserves Committee (JORC) ensures he is very well informed in key regulatory matters.
- Manages small and large projects throughout Africa, the Middle East, Asia, Europe, the Americas, and Australasia.

Paul Heaney | Partner, Principal Hydrogeologist

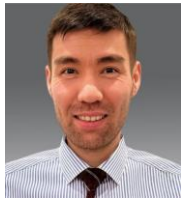
- More than 27 years' consulting experience in water resources assessment, development and management.
- Experience includes hydrogeological and hydrological studies associated with mine water supply, mine dewatering, groundwater/surface water modelling.
- Has worked on projects in Africa, Australia, Asia, CIS, Europe and the Middle East.

Richard Wagner | Principal Metallurgist/Process Engineer

- More than 40 years of experience working in Canada in the mining industry
- Experience in operations, auditing, lab testing services and consulting.
- Background includes 9 years in operations at processing plant, as well as refinery and assay lab knowledge.

Dr Maxim Seredkin | Technical Director – Principal Geologist & ISR Lead

- More than 20 years' experience in academic researching, exploration, geometallurgy, mining and management in Russia, Kazakhstan, Guinea and Australia.
- Experience includes all aspects of In-Situ Recovery (ISR).
- Manages small and large projects with our clients throughout Australia, CIS, Africa, Asia, Europe, the Americas across multiple commodities.



Dr Khairulla Aben | Principal Mining Engineer

- An experienced mining professional who has undertaken the delivery of mining engineering, mine planning, and economic evaluation for projects, technical studies, and operations.
- Has delivered open pit, underground and ISR related projects and studies.
- Experience across multiple commodities, with responsibilities for design, planning, scheduling of mine operations, and economic evaluation.

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For more information:

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