Worldwide ISL Uranium Mining Outlook

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- ISL uranium production historical review and current status
- ISL versus conventional mining
- Acid versus alkaline ISL
- ISL cost considerations
- Principal criteria and parameters for ISL mining
- ISL production forecast and resources availability

Acknowledgements and references:
1. *Manual of acid in situ leach uranium mining technology, IAEA-TECDOC-1239, Vienna, 2001.*
2. *Uranium Production Cost Study. UxC Consulting Report, August 2013.*

ISL Historical Overview

Early 1960s

- ISL was developed independently in the former Soviet Union (Ukraine 1959, Uzbekistan) and the U.S.A using similar engineering and technological approaches

1970s-1980s

- ISL mining ramp up in the USSR (Kazakhstan, and Uzbekistan) and USA
- New ISL mines in Bulgaria, Czechoslovakia and China
- Period of major sandstone type deposits discoveries worldwide

1990s

- Stagnation period.
- New small ISL projects in Russia, Australia
- ISL production at existing mines in Kazakhstan, Uzbekistan
- ISL mines closure in the USA, Europe.

2000s

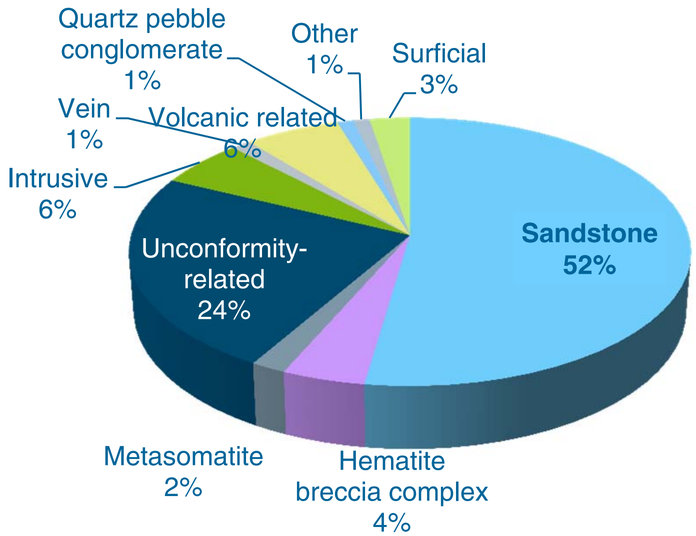
- ISL mining boom in Kazakhstan (8 new mines)
- New ISL mines in Uzbekistan, USA, Russia, Australia,

2010s

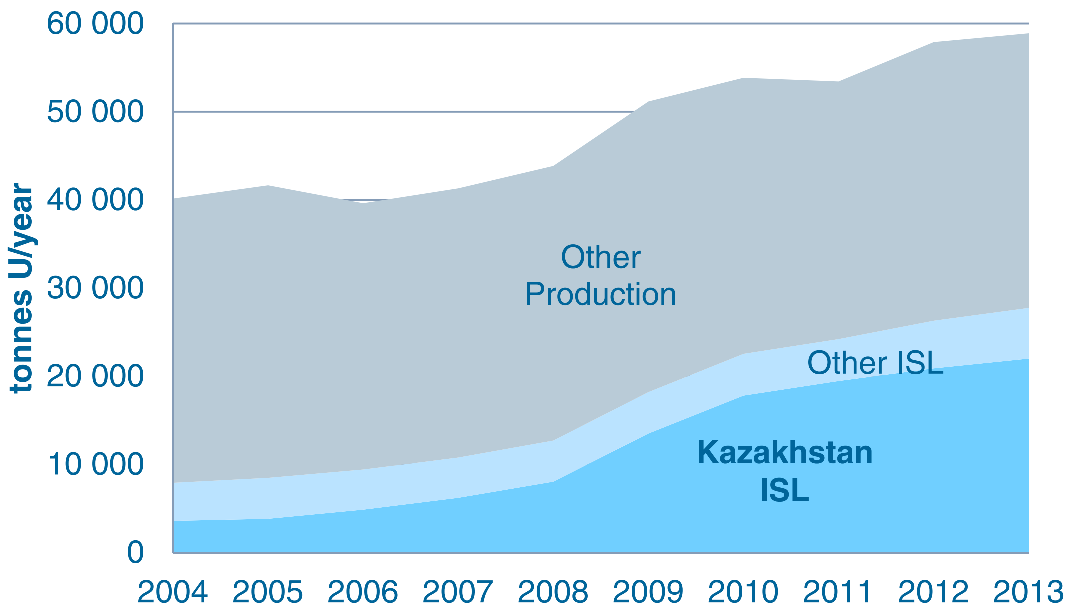
- New ISL mines in:
- Kazakhstan (Kharasan, Akbastau, Semizbai),
- USA (Lost Creek, Nichols Ranch, Willow Creek),
- Australia (Four Mile),
- Russia (Khiagda),
- Uzbekistan (Sugraly, N. Kenimekh, Alendy).

Historical uranium production by deposits types and mining methods

2011 world U production by deposit types



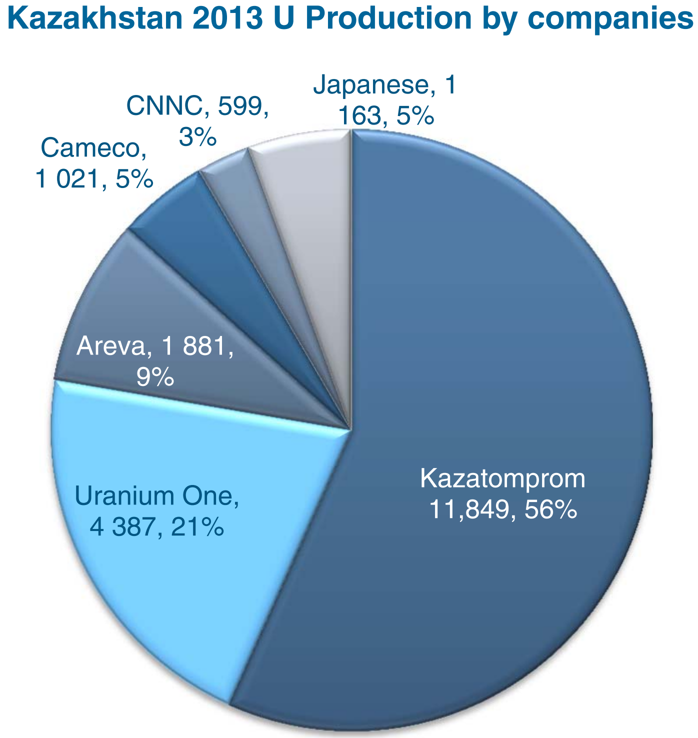
World U production by methods

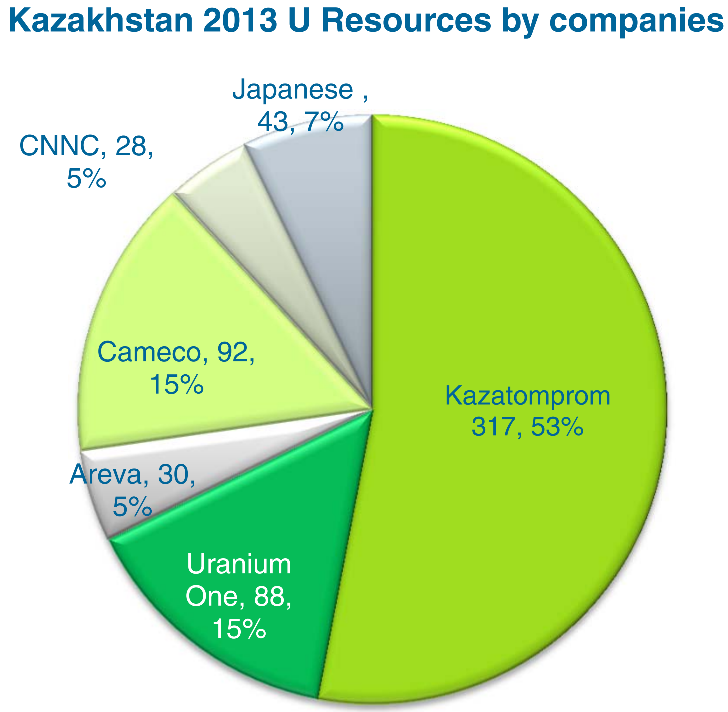


IAEA/OECD. Uranium 2011: Resources, Production, Demand.

- **U mining from sandstone type deposits - 52% of the 2011 world total**
- **ISL U production share increased from 20% in 2005 to 47% in 2013:**
  - **Kazakhstan is the world top uranium producer since 2009**
  - **Kazakhstan 2013 ISL production 22,000tU - a 37% of world total**
  - **Other 2013 ISL production in Uzbekistan, Russia, USA, China, Australia - 5,750tU (10% of total)**

Kazakhstan 2013
Uranium ISL production and resources by companies

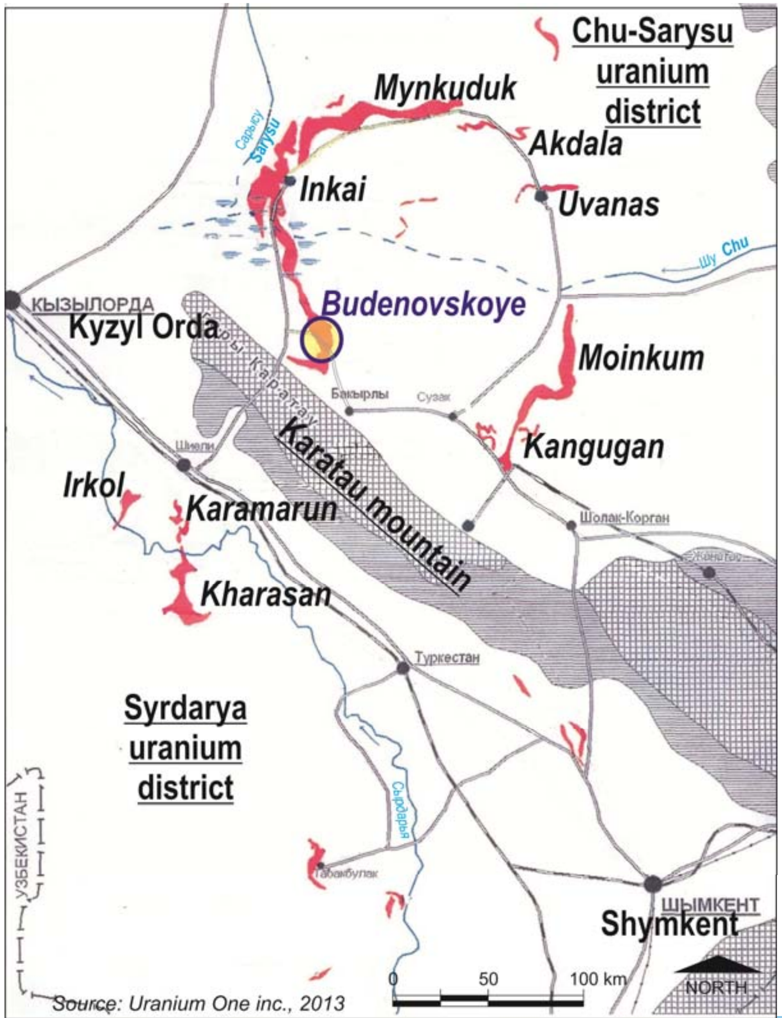




- **Kazatomprom attributable production* in Kazakhstan - 56%, Uranium One - 21%, followed by Areva and Cameco**
- **Kazatomprom attributable resources* in Kazakhstan - 53%, Uranium One and Cameco - 15% each, followed by Areva, Japanese and Chinese companies**

*- attributable by JV share (not marketing)

Location of major ISL mines and deposits - Kazakhstan, Chu-Sarysu Uranium province



Unique Chu-Sarysu Uranium province:

- ✓Area 40,000 sq.km
- ✓Eight deposits with 900,000tU initial resources hosted in Upper Cretaceous and Palaeogene sediments
- ✓ Main deposits – Budennovskoe, Inkai, Mynkuduk, Moinkum
- ✓13 operating mines with 20,000tU aggregated annual production capacity

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World top seven ISL uranium mines with annual capacity above 1,500tU

Mine	Karatau	Akbastau	South Inkai	Inkai	South Moinkum	Tortkuduk	Central Mynkuduk
Deposit	Budenovskoe site 2	Budenovskoe sites 1,3,4	Inkai , site 4	Inkai 1,2,3	Muyunkum	Muyunkum North	Mynkuduk
Owners	50 % Kazatom-prom, 50% Uranium One	50% Kazatom-prom, 50% Uranium One	70% Uranium One, 30% Kazatomprom	60% Cameco, 40% Kazatom-prom	51% Areva, 49% Kazatom-prom	51% Areva, 49% Kazatom-0prom	100% Kazatomprom
Resources, KtU	56	41	48	153	35	24	52
Production capacity, tU/year	2,000 (to 3,000)	2,000	2,000	2,000 (to 4,000)	1,500	2,500	2,000
2013 production, tU	2,114	1,495	2,030	2,030	1,437	2,563	1,800
Full production cost, $/lbU3O8*	21	29	31	31	25		36
2013 cash cost $/lbU3O8**	11	13	18	NA	NA		NA

** Uranium Production Cost Study. UxC Consulting Report, August 2013.*
*** Uranium One 2013 Annual Report*

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ISL advantages versus conventional mining

Lower capital and operational costs:
- low power consumption,
- less equipment required,
- reduced labor costs per unit produced
- low restoration cost

Economic uranium recovery from low grade ores (200 to 800ppm);

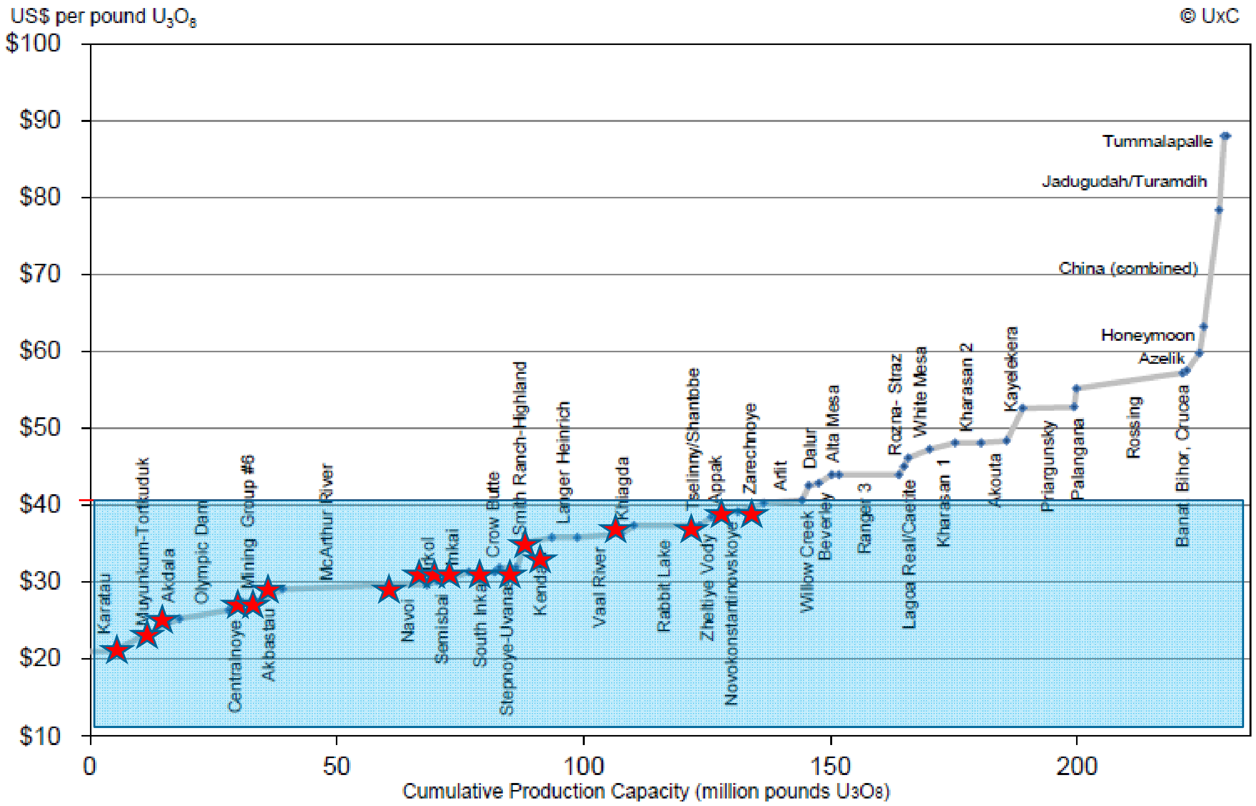
Reduced period of project development and start-up;

Reduced radiation exposure and lower environmental impacts

Greatly reduced solid wastes (no rock damps, tailings)

Production cost curve – operating mines

UxC, 2013 Report

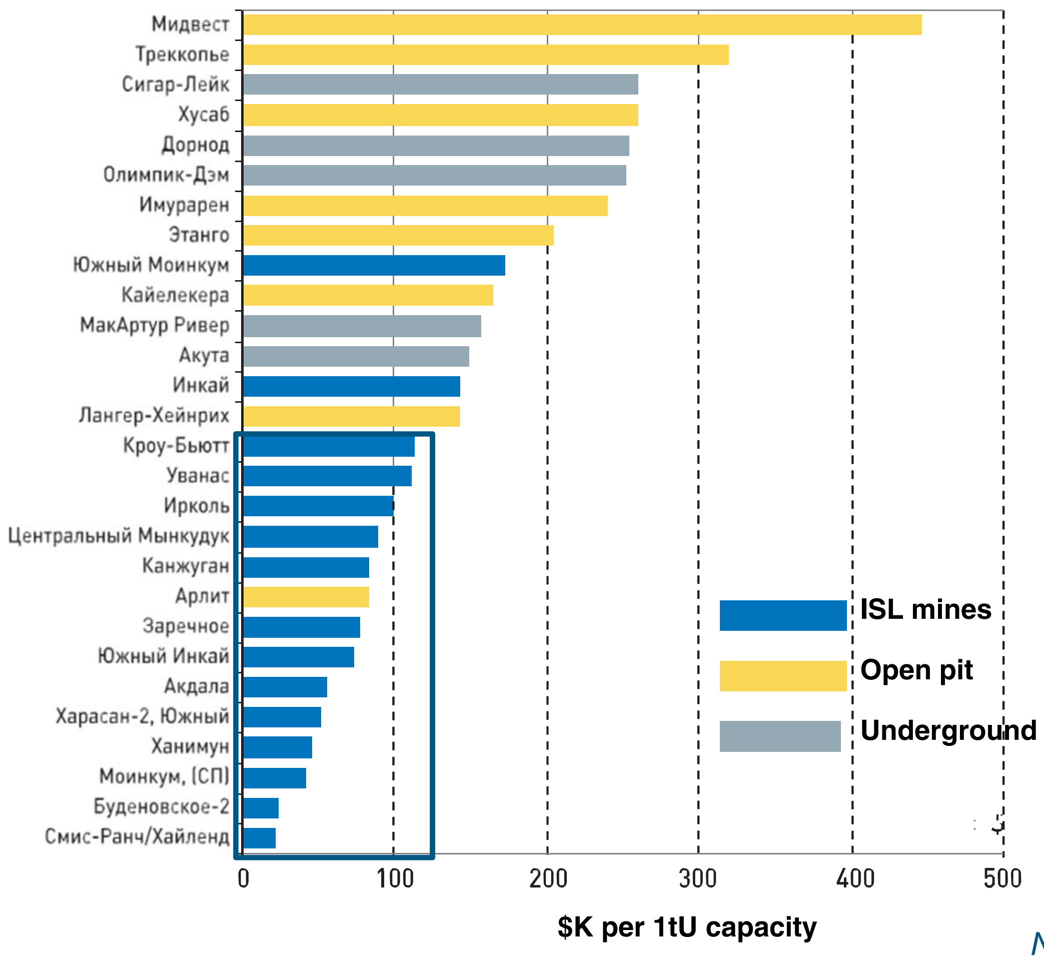


ISL uranium mines:

- 30 of 52currently operating U mines (58%)
- 20 of 28 in the category below $40/lb (72%)
- Total ISL mines production capacity is 42kt U (110 Mlbs U_3O_8)
- 29kt U (75 Mlbs U_3O_8) is the capacity of ISL mines in below $40/lb cost

Uranium Production Cost Study. UxC Consulting Report, August 2013.

Uranium Mines Specific CAPEX



- 13 of 14 mines with the lowest specific CAPEX are ISL mines
- 10 of such mines are in Kazakhstan
- $80M is an average CAPEX estimation for 1,000tU capacity ISL mine (including $48M for processing plant)

NAC international, 2010

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Sulphuric Acid Versus Alkaline ISL Mining

Acid Leach Advantages

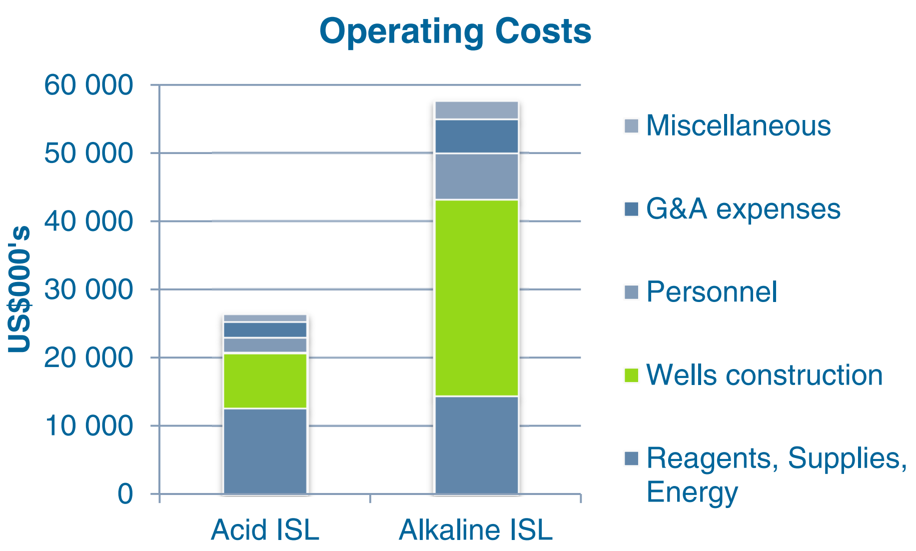
- Higher degree of uranium recovery (70-90% versus 60-70%);
- Favorable leaching kinetics (at 80% recovery, the number of pore volumes of leach solution circulated is 3-4, compared to 10-12 for alkaline solutions);
- A comparatively short leaching period of 3-5 years for acid (depending on the wellfield size, ore permeability, well pattern, etc.);
- Possibility of natural attenuation of the remaining leach solution;
- Radium is not recovered and requires no special restoration;
- **Lower capital and operational project costs (next slide)**

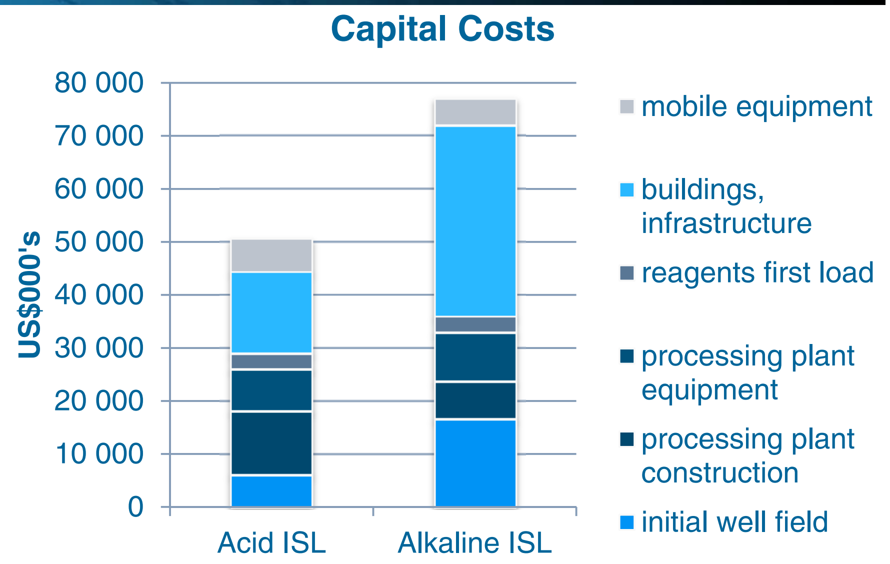
Alkaline Leach Advantages

- Uranium leaching from carbonate-bearing ores (i.e. CO_2 content over 1.5-2.0%) (acid increases chemical costs and make the process non-economic);
- Lower risk of pore plugging by newly formed gypsum and gas bubbles;
- Lower concentration of dissolved solids in leaching solutions;
- No corrosion in materials and equipment (pumps).

Acid Versus Alkaline ISL Costs

for a 1000t U annual capacity mine





	Acid	Alkaline
Operating cost, $/lb U3O8	12	26
Operating costs total, $M	27	58
Capital costs, $M	56	85

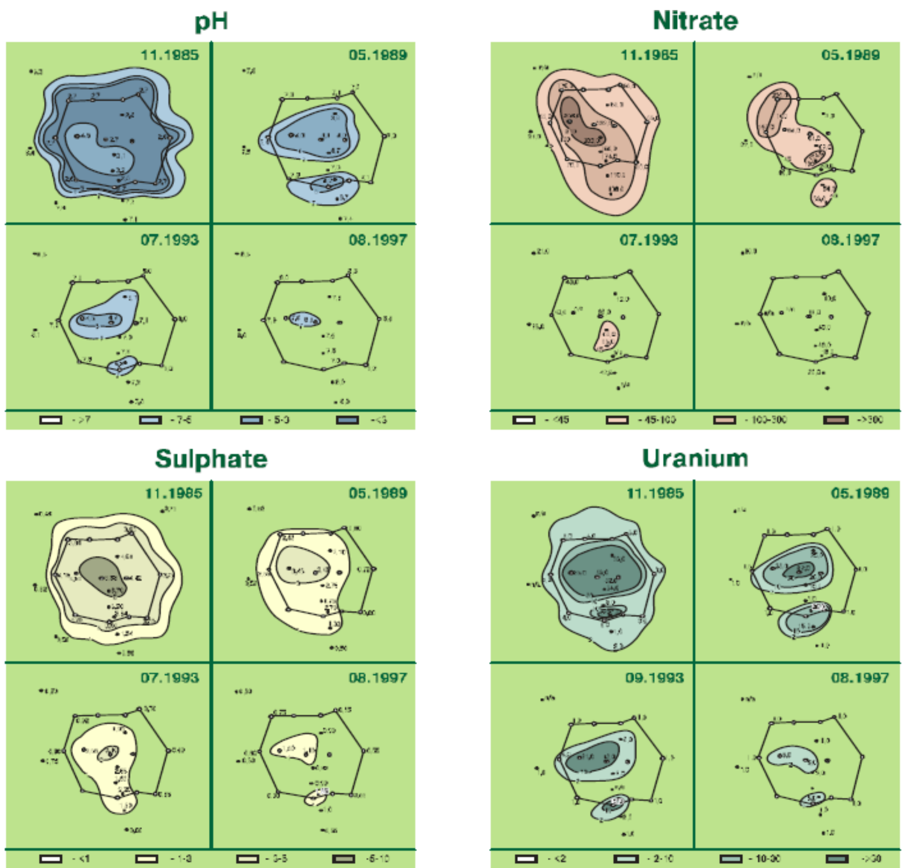
Alkaline ISL – main reasons for higher costs:

- ✓ Lower flow rate per recovery well
- ✓ Lower U concentration in pregnant solutions
- ✓ Smaller distance between recovery in injection wells (higher drill costs)
- ✓ Higher costs for aquifer restoration

Uranium Production Cost Study. UxC Consulting Report, August 2013.

Aquifer Natural Attenuation after ISL

Kazakhstan Irkol case study (after Gorbatenko, NAC Kazatomprom)



Aquifer natural restoration after acid ISL due to residual solution dilution and reaction with the hosting environment

Case of environmental monitoring after pilot test at Irkol deposit (Kazakhstan)

- **Four main parameters monitored (pH, sulphate ion, nitrate ion, Uranium)**
- **ISL exposed area decreased in 50% during four years**
- **Complete restoration occurred within 12 years**

Principal parameters for sulphuric acid ISL mining*

Parameter	Limits
Lithology	Sands, and gravels (clay fraction below 30%)
Ore productivity	Above 1 kgU/m^2
Depth of ore body	Below 900m
Aquifer thickness	1 to 30m
Carbonate content (CO2)	Not exceed 2 %
Hydrogeology	Water confining beds above and below aquifer, no hydraulic connection
TDS	Below 10 g/dm^3
Water table level	Above the mineralization
Hydraulic conductivity (permeability)	Above 1 m/day
Transmissivity	Above 10 m^2/day
Environmental issues	No potable water supply

**- IAEA-TECDOC-1239, Manual of acid in situ leach uranium mining technology.*

How to improve major ISL technical parameters?

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Main ISL capital intensive cost parameters	• Drilling and wellfield construction (65 - 85% of CAPEX) costs • Reagents (acid) consumption (30% of OPEX)
Main ISL operating parameters	• Uranium concentration in pregnant solutions • Recovery wells flow rates • Acid consumption
Innovations to increase wells productivity	• Effective drilling technique and wells construction (casing, material, pump, screen, packing) • Optimal wellfield pattern configuration and spacing between recovery and injection wells • Wells damage control and work over
Innovations in leaching effectiveness and modelling	• Geological, hydrological and ISL process 3D modelling • New generation of PFN logging tool • Using effective reagents and oxidants to reduce acid consumption and increase productivity

Uranium resources as a key factor for sustainable uranium production

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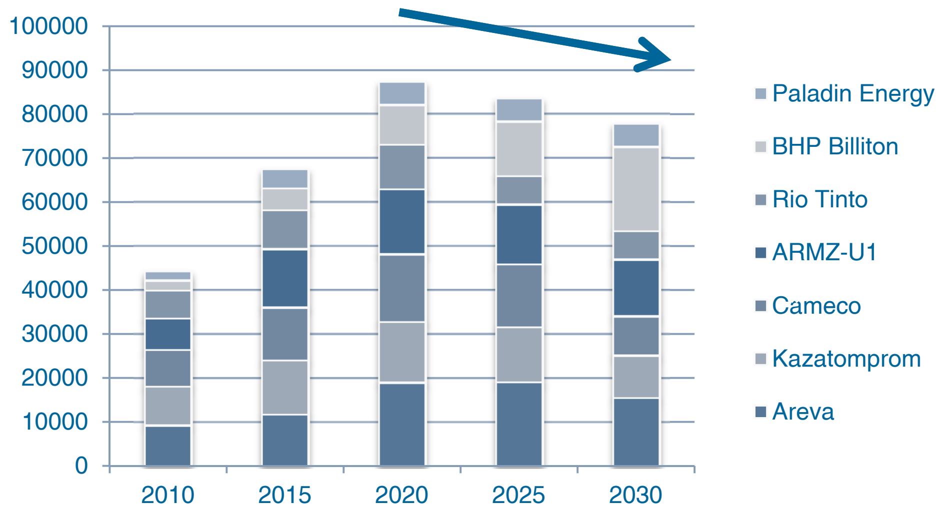
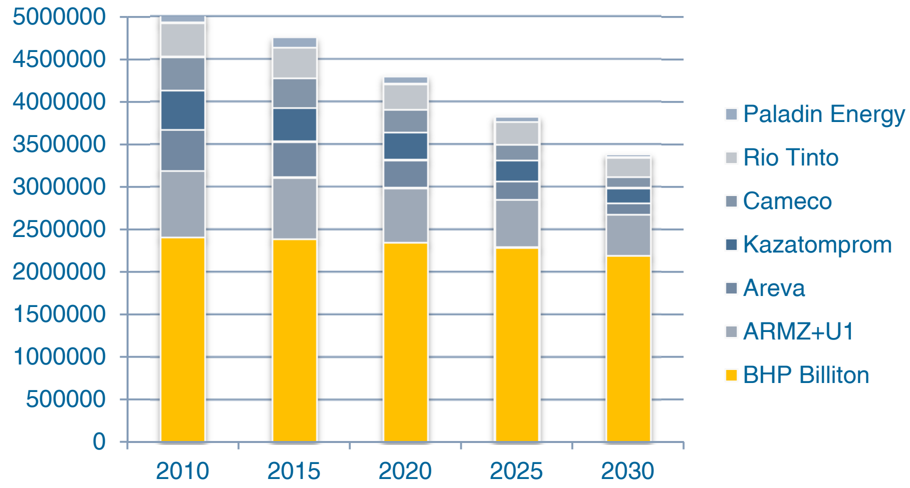
Uranium production forecast by the leading companies, tU



U resources mining depletion by the leading companies, tU



- **Aggregated U production in 2012 – 2030 estimated at 1,5 MtU, which is 24% of total known resources and 40% of resources below US$80/kgU category**
- **U resources of primary uranium mines will be decreased more than two fold by 2030, more than a half of remaining U resources are in the Olympic Dam (copper is main product)**
- **After 2020, uranium market may face shortage of low cost U resources.**

Uranium ISL Uranium Production Forecast to 2030

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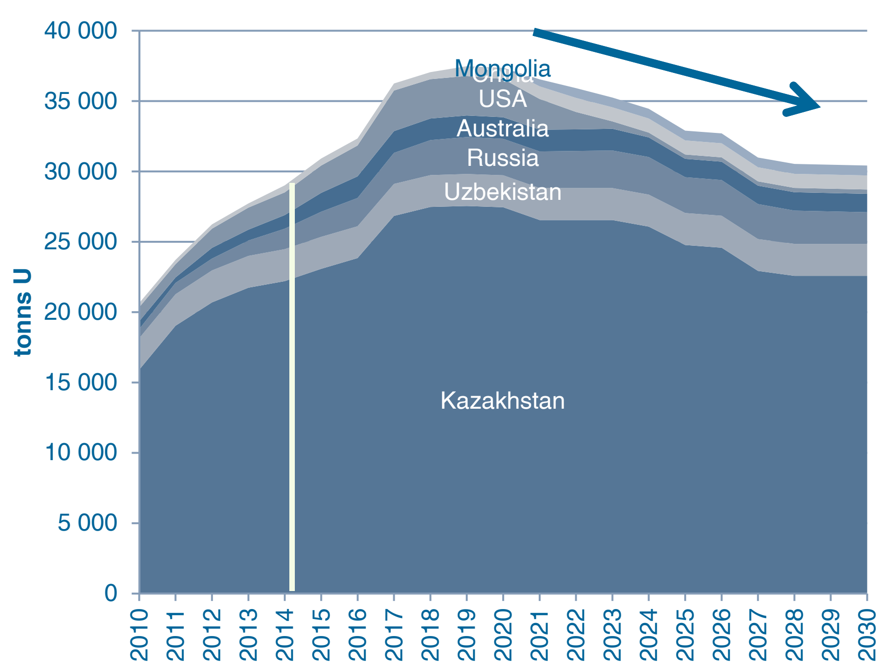
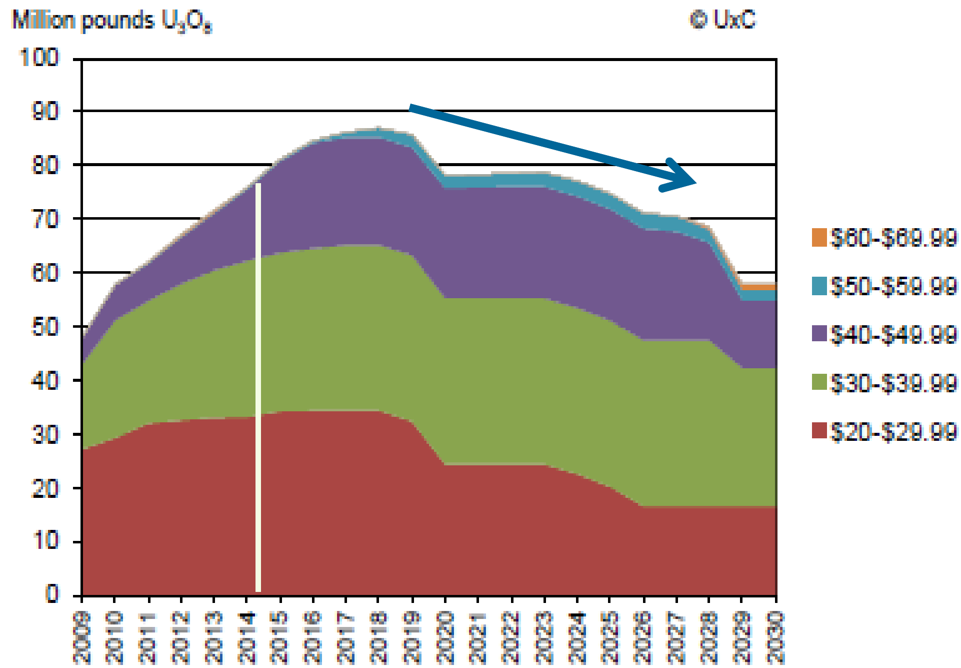
ISL Uranium Production Forecast by Countries



ISL Uranium Production forecast by cost categories



Uranium Production Cost Study. UxC Consulting Report, August 2013.

- **Ramp up ISL U production to 2018**
- **Decline of ISL U production after 2020 due to resources depletion and mine closure**
- **Higher cost resources will be developed in future**
- **It is expected that new deposits will be discovered in the coming years which will lead to additional low cost resources for ISL mining**

Historical exploration expenditures versus uranium prices

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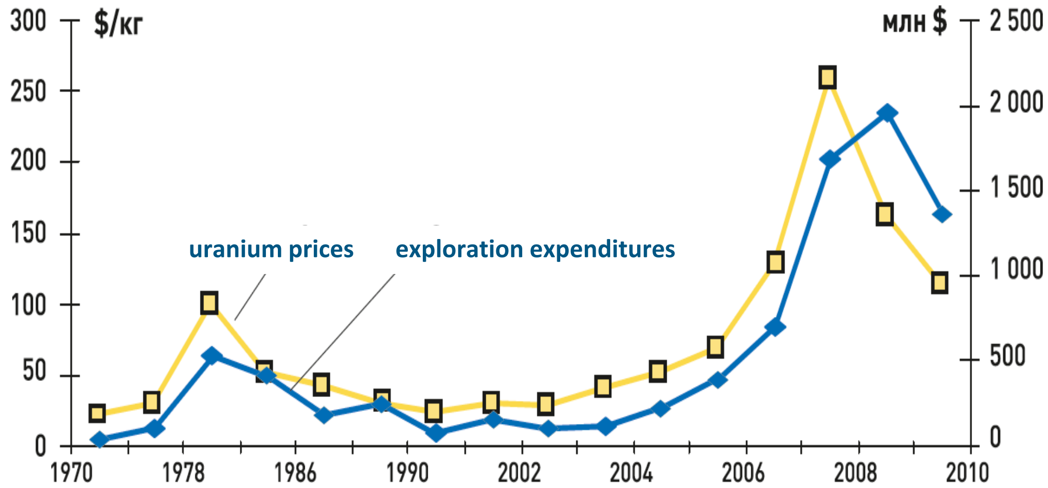
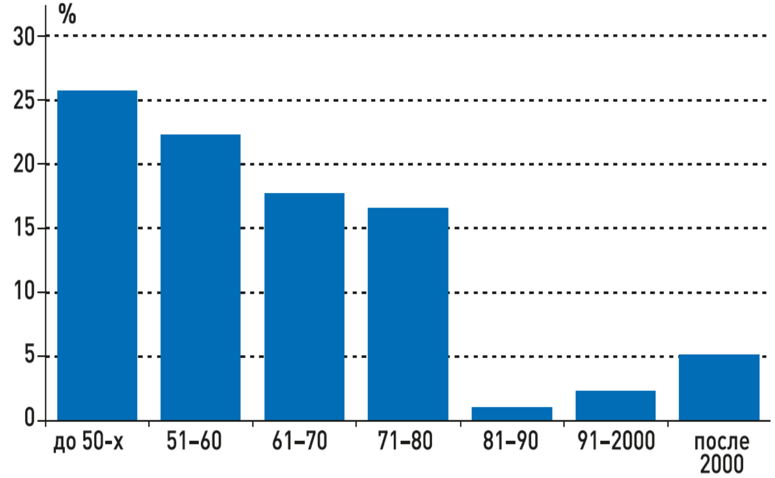
Historical exploration expenditures (Red Book data) and uranium prices



Historical uranium deposits discovery (200 deposits)



- ✓ Historical correlation between exploration expenditures and uranium prices
- ✓ Current low uranium prices don't promote investments in U exploration
- ✓ 90% of U deposits were discovered more than 35 years.
- ✓ The era of easy discoveries is over
- ✓ Recent discoveries were promoted by U market activation in mid 2000s (before Fukusima)

- ✓ Current depressed U market is not favorable for uranium exploration and new developments

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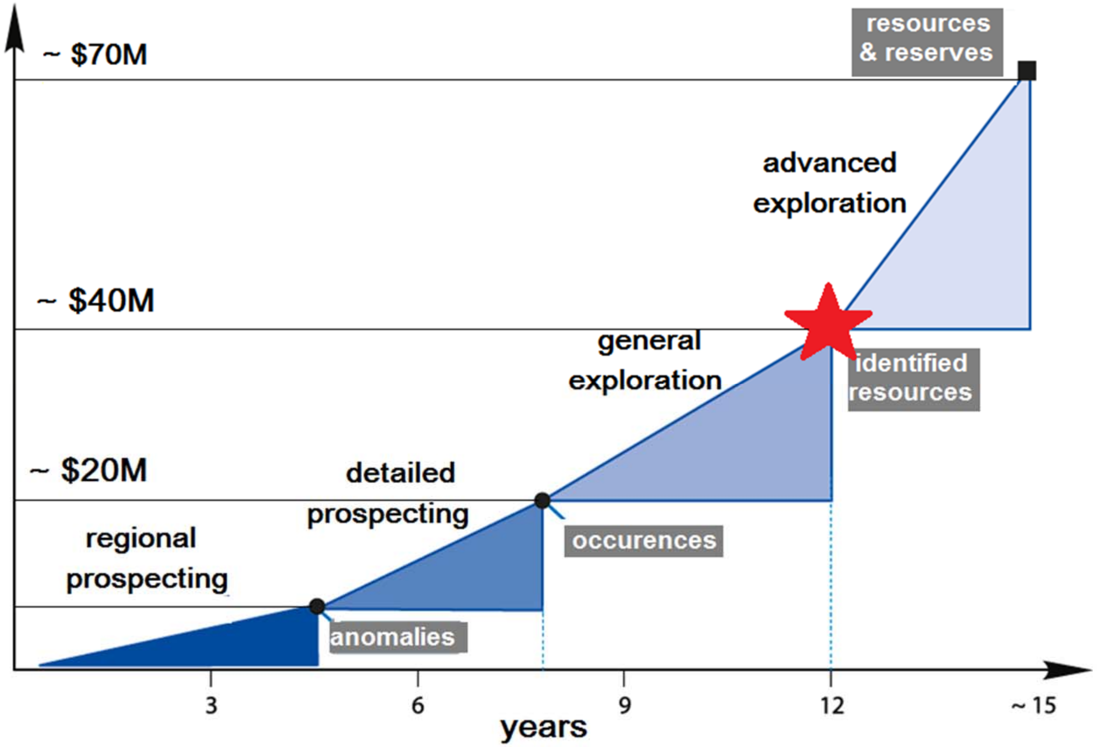
How to discover uranium deposit for ISL mining? Major exploration stages and costs



- Average historical discovery cost (in 1945-2003) for 9 major countries $1.82kgU (The Red Book retrospective, OECD 2006)
- The current inflated discovery cost is ~ $20kgU
- The medium size U deposit (20ktU) discovery cost is $40M
- Another $ 30M for resources and reserves delineation and estimation
- S80M - CAPEX for a 1,000tU capacity ISL mine
- Total costs $150M

Exploration requires special knowledge and expertise

- ✓ Specific complex of exploration criteria must be identified during each stage: paleoclimate reconstruction, tectonics, lithology, hydrogeology, radiology, geochemistry, alteration.
- ✓ Advanced geophysical surveying focused on stratigraphic, hydrogeological and tectonic modelling

Regions favorable for new sandstone type deposits for ISL mining

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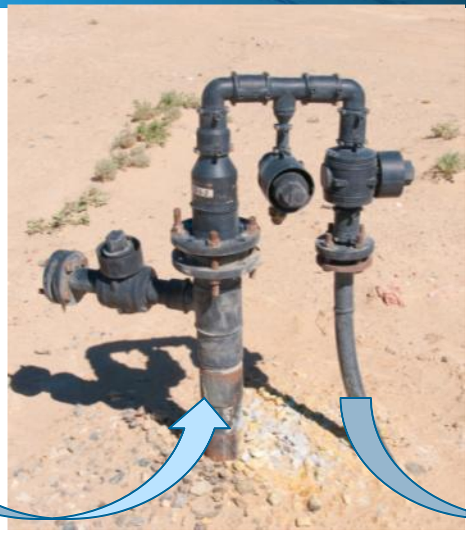
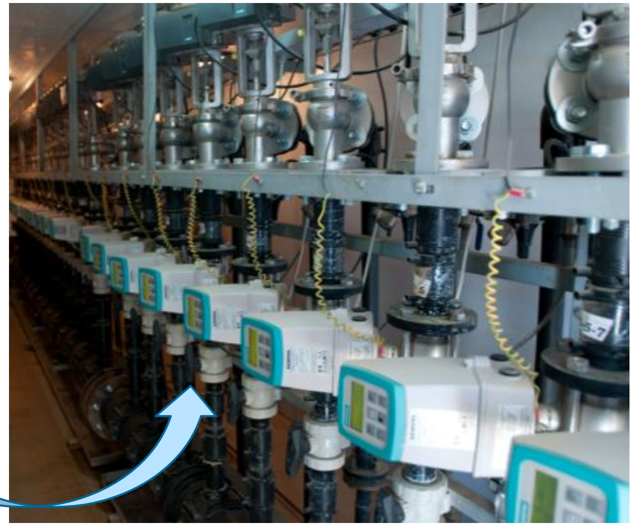
Good Luck in uranium exploration and in ISL mining!





Major exploration stages for the sandstone types uranium deposits (after I.Pechenkin)

Stages	Regional metallogeny study	Regional Prospecting	Detailed prospecting	General exploration	Advanced exploration
Main target	To identify areas favorable for redox front zones	To identify redox front zones and areas favorable for uranium deposits	Redox front zone delineation, Speculative resources evaluation	Deposit discovery, Inferred resources estimation	Mineralization delineation, resources estimation
Scale	1:2,500,000 to 1:1,000,000	1:500,000 to 1:200,000	1: 100 000	1: 50 000	1: 25 000
Drill spacing	No	12.8 x 6.4-3.2km	6.4-3.2x km	3.2-1.6x0.2-0.1km	1.6 -0.8x0.2-0.05km

Specific factors and criteria for each stage:
paleoclimate, tectonic, lithology, hydrogeology, radiology, hydrodynamics, geochemistry, microbiology, alteration.

Historical exploration expenditures versus resource discovery