Technical Meeting on „Low-grade ore processing"

Alkaline heap leaching of low-grade ore in Hungary (1966-1990)

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The process was elaborated by:
Dr. B. Czegledi, L. Stocker, Dr. J. Egyed, L. Fekete and L. Csikós
IAEA sponsored project (1980-85)

Vienna, 29-31 March 2010

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Outline of the presentation

Part I

1 Practical reasons of using the alkaline heap leaching

2 Laboratory and pilot scale experiments related to the elaboration of HL

3 Heap leaching practice

Part II

Laboratory and Field Investigations for Heap Leach Remediation and Groundwater Restoration

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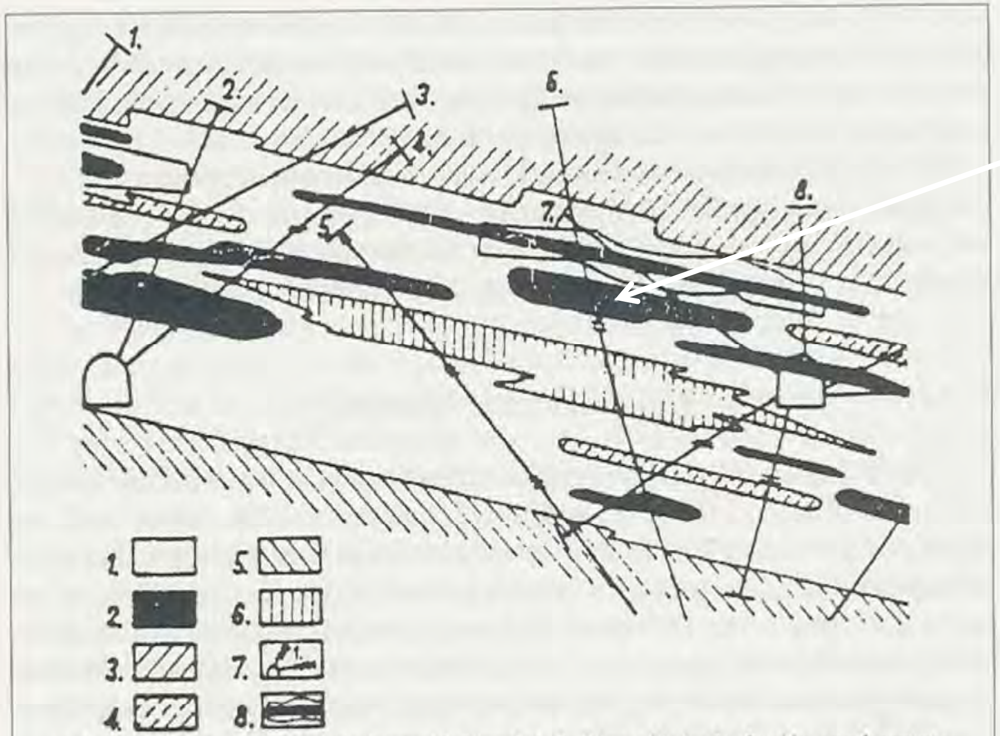
Uranium ore lences in the productive zone



Jelmagyarázat: 1. Produktív homokkőösszlet, 2. Bányafúrások alapján szerkesztett érctestek metszetei, 3. Fedü vörös homokkő, 4. Köztes vörös homokkő 5. Fekü szürke homokkő, 6. Köztes szürke homokkő, 7. Bányavágat fúrásokkal és a nem ipari érchara

Solid ore grade:
U~ 0.12%

After mining (dilution)
U~ 0.06-0.07%

ROM

Smaller lenses were scattered through the sandstone unit (productive zone)

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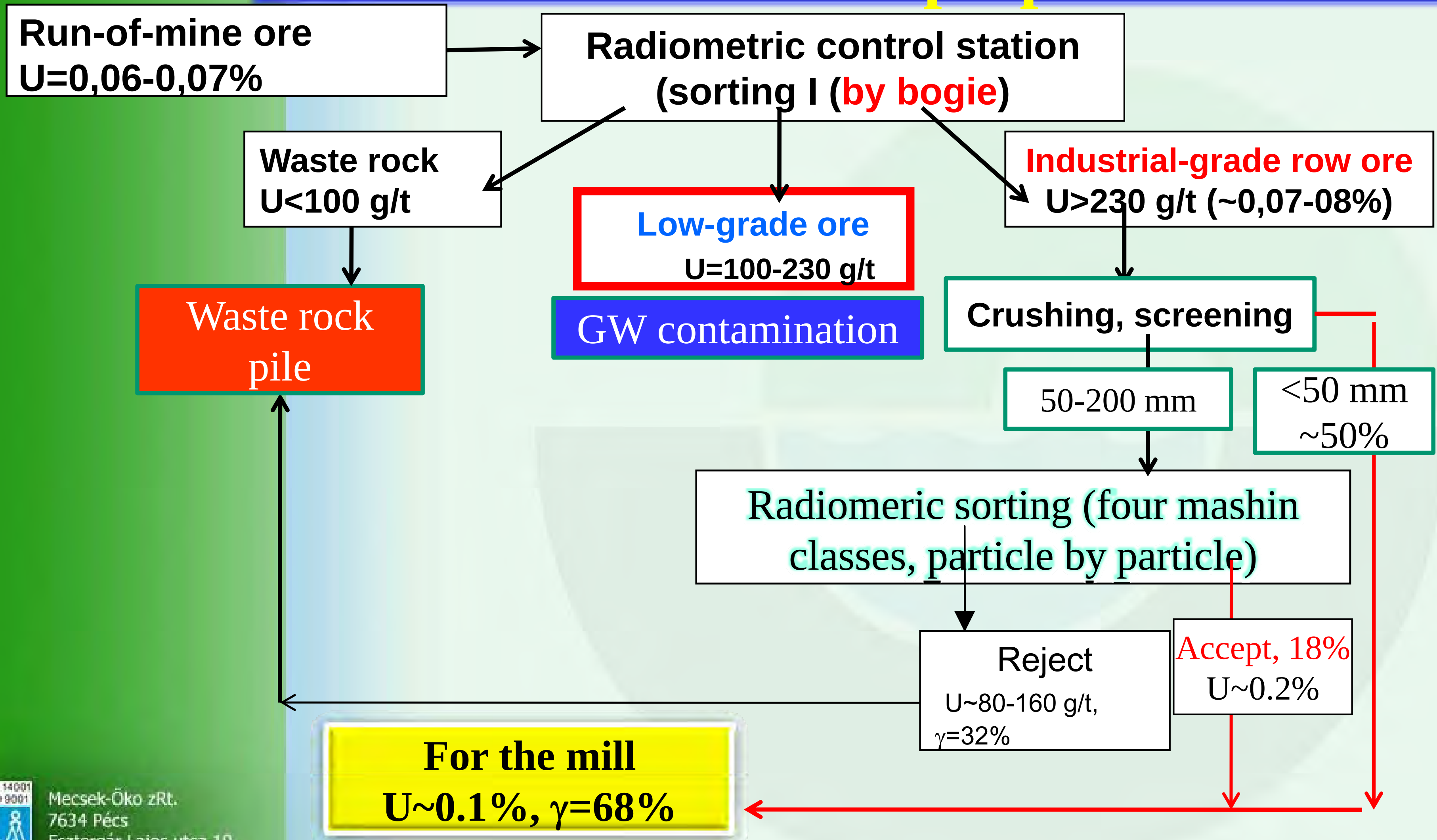
The original general flow sheet of the ore preparation



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Ore characteristics, selection of the process for mill grade ore and for heap leaching

Reagent consuming gang minerals: Calcite, dolomite, siderite (CO_2~2.8-4%);
S (sulphide)~0.1%

Mineralisation: coffinite, **branerite**, uranium-oxides, secondary minerals

For mill grade **ore <u>acid leach</u>** has been choosen.
For low-grade **ore alkaline** process was propoused
(Consumption of H_2SO_4:~90 kg/t
Consumption of Na_2CO_3: ~5kg/t)

Leaching : 20-25 g/l Na_2CO_3+5 g/l $NaHCO_3$

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Column leaching tests with

1 Leaching tests (most often in columns)

Recovery vs crush size and leaching time

-leaching of **uncrushed ore** from the pile

(poor recovery ~15%)

- crush size -5, **-30**, -50, -70 mm

2 Investigations of the catalic oxidation

Cu(II), $KMnO_4$, $\mathbf{Cl_2}$

3 Investigation of the role of **microbiological activity** in the leaching process (PhD work)

4 Investigation of the role of the **oxygen**

(in N_2 atmosphere only10-12% recovery)

5 Leachability of ores from different depth, **exposed** ore and „**fresh**" ore (mineralogical effect)

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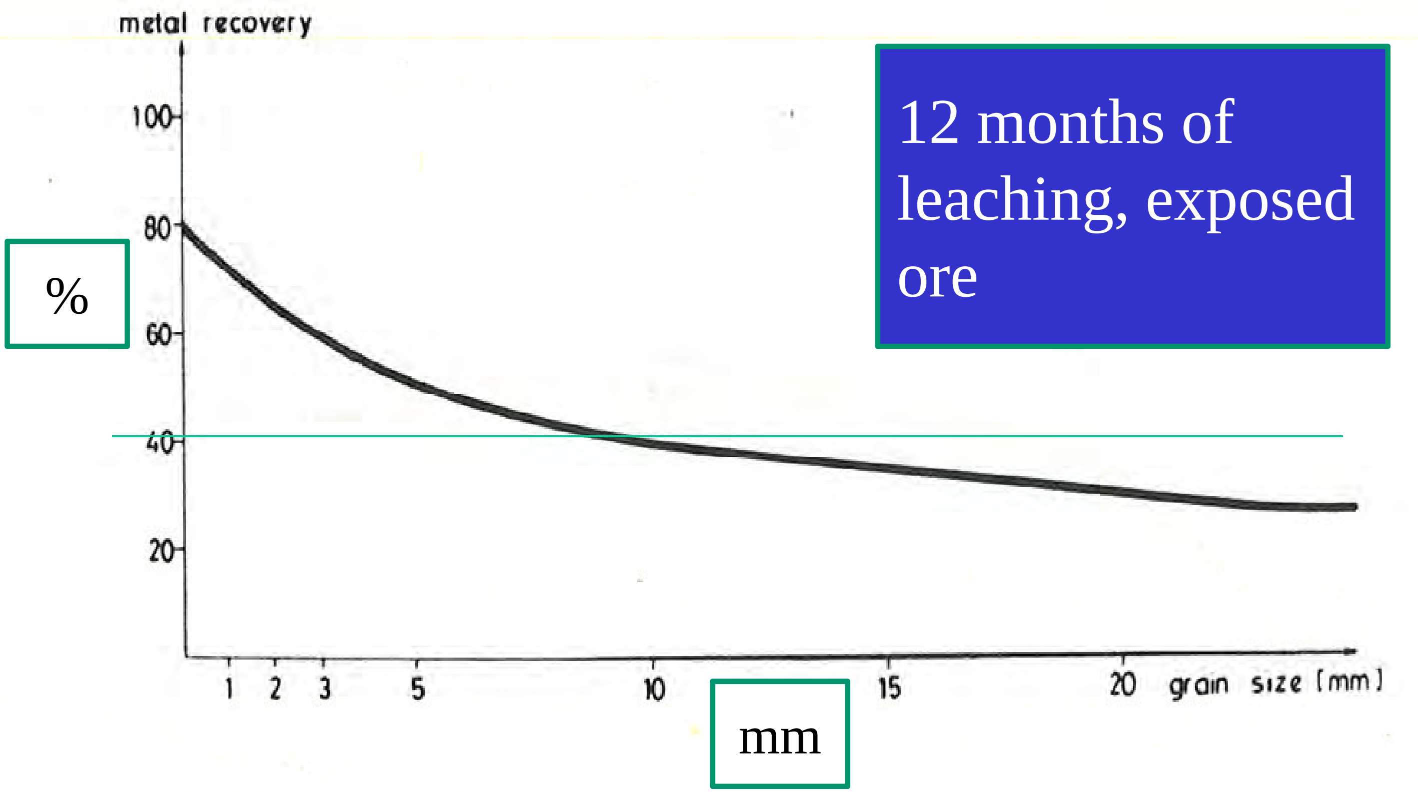
The recovery vs grain size



Penetration rate of leachate in rock: 1 mm/week, finely disseminated mineralization

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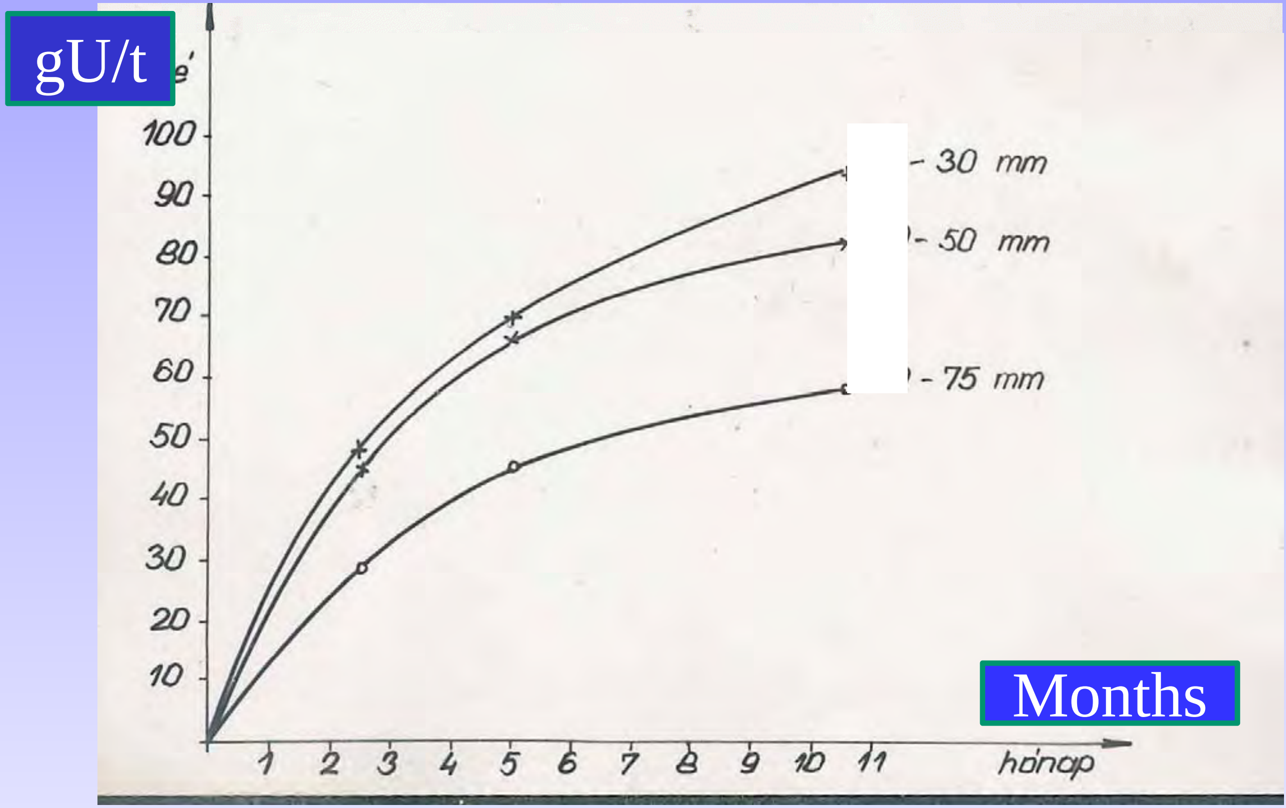
Effect of crush size (for couple of crush size)



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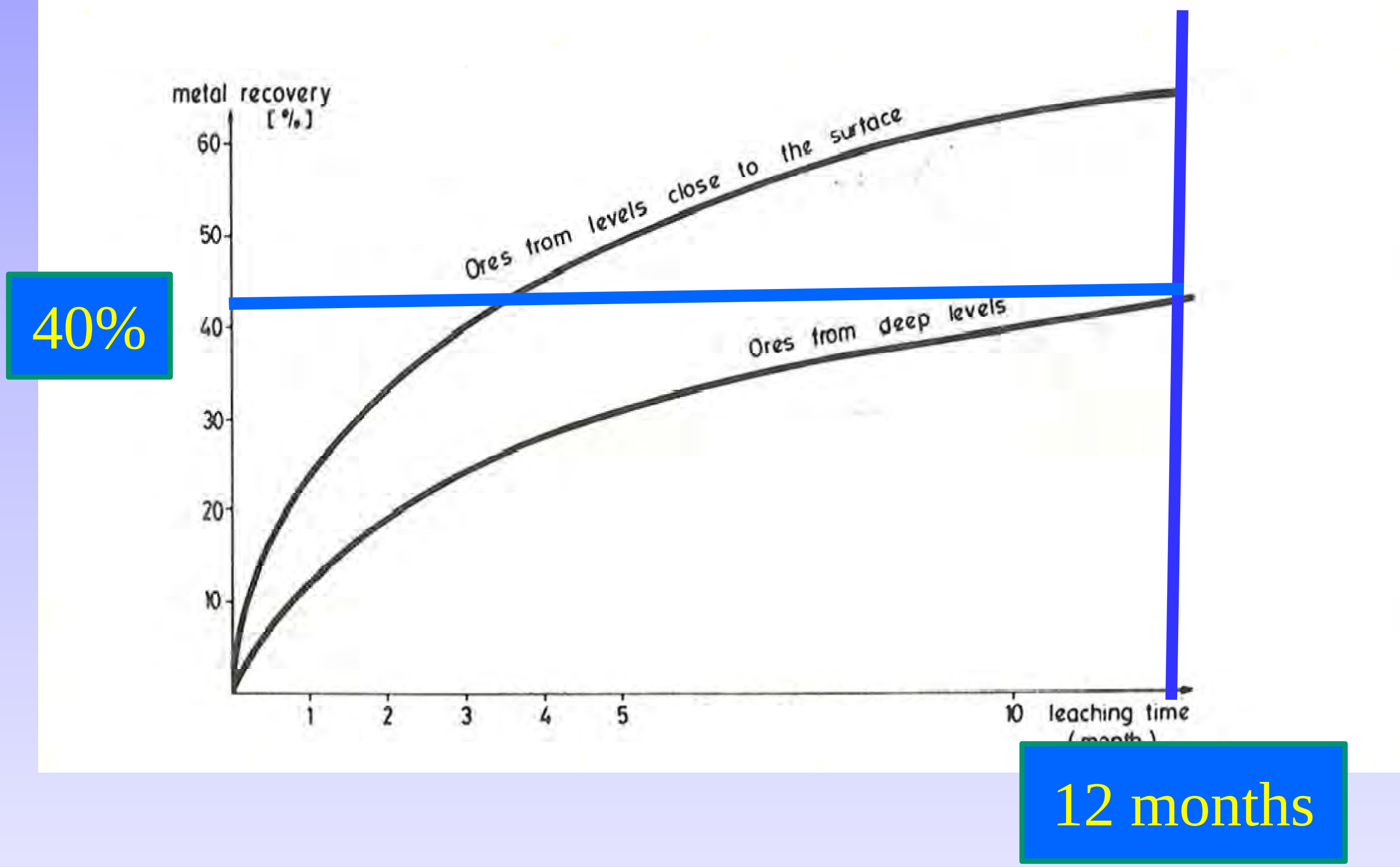
Recovery dependance from ore type



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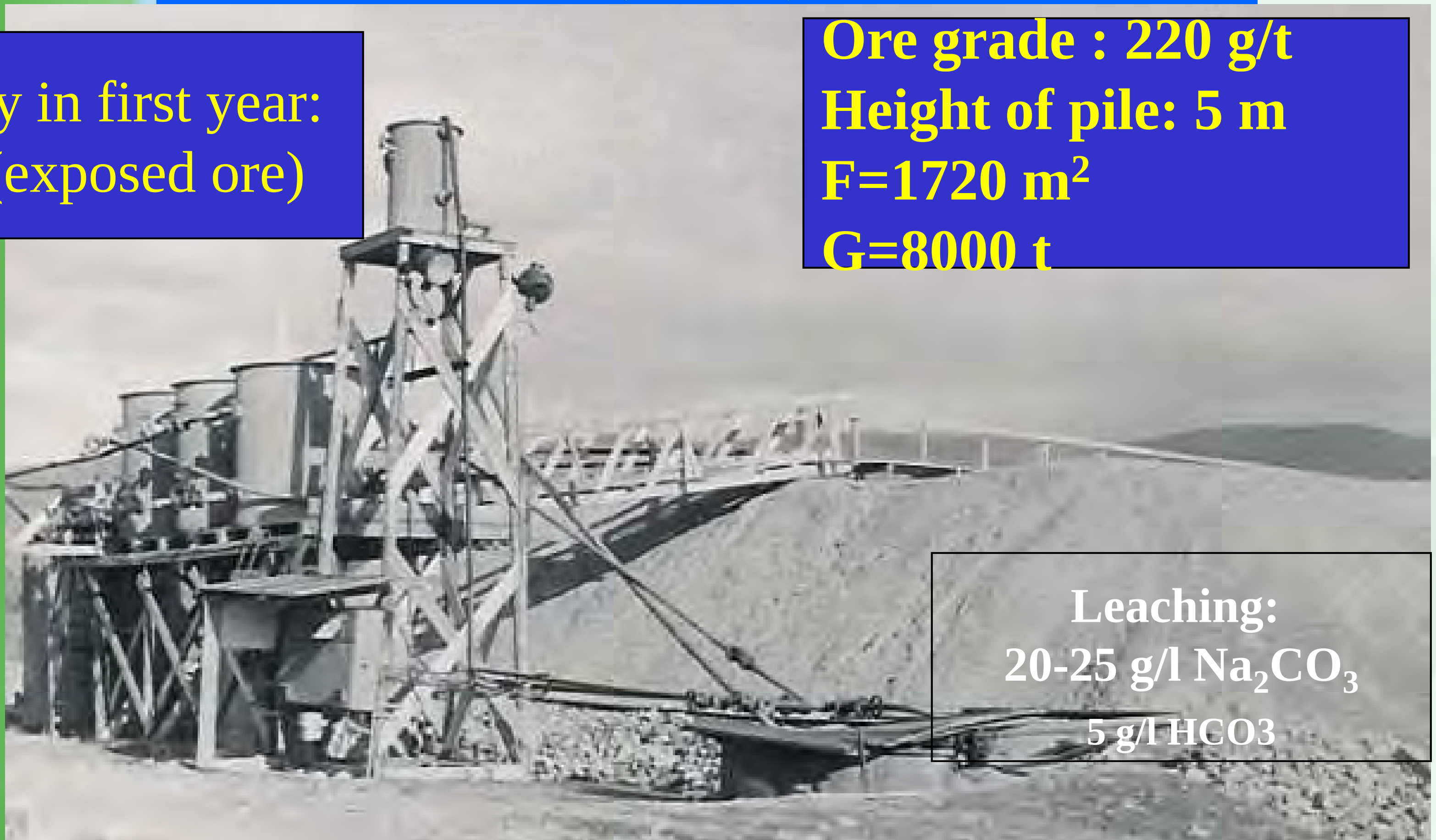
Pilot scale experiments (1965)

Recovery in first year:
~ 50% (exposed ore)

Ore grade : 220 g/t
Height of pile: 5 m
$F=1720\ m^2$
G=8000 t



Leaching:
20-25 g/l Na_2CO_3
5 g/l HCO3

The assumed recovery over years: ~55-70% (85-110 g/t from grade of 160 gU/t)

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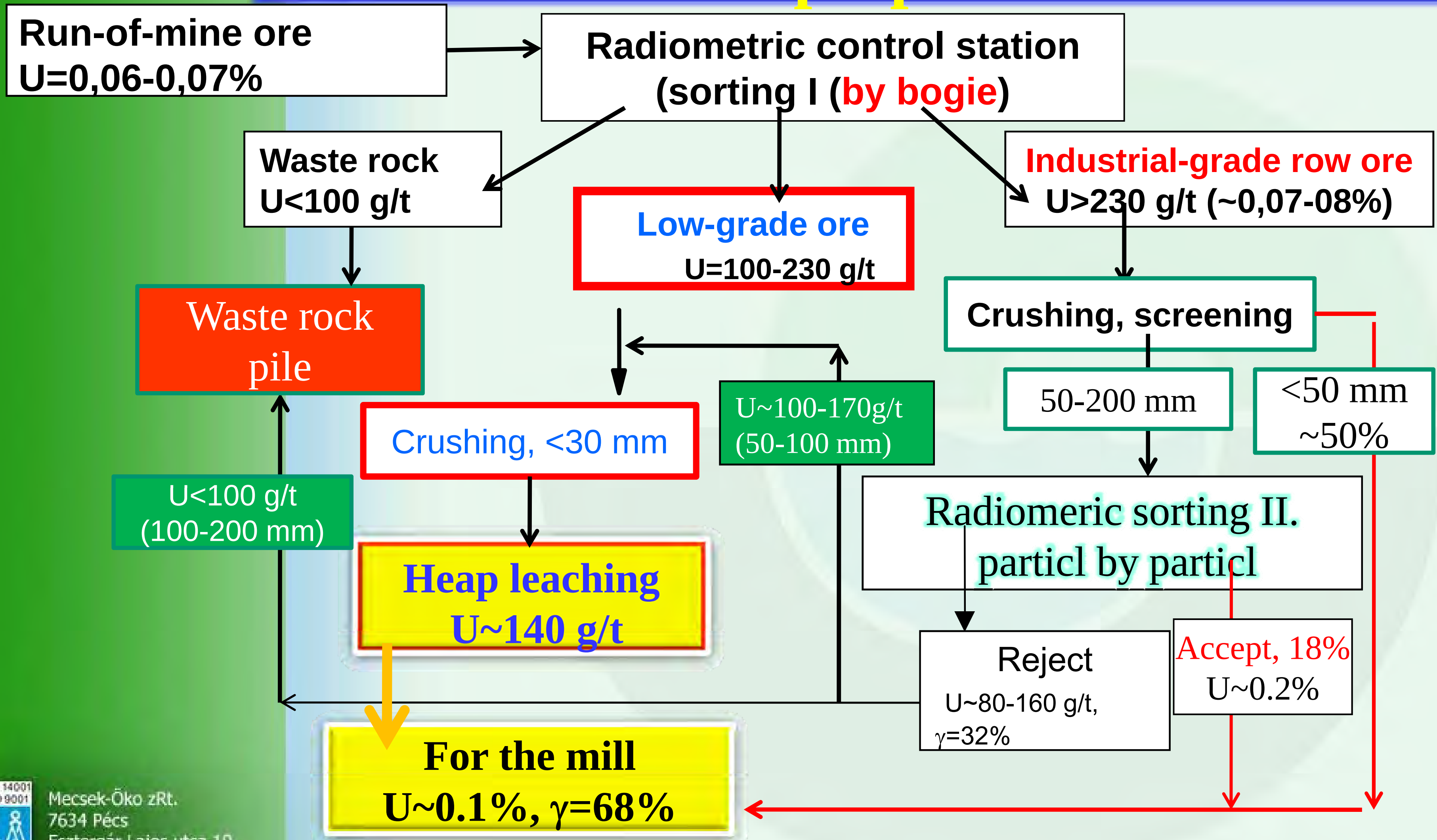
The general flow sheet of the ore preparation with HL



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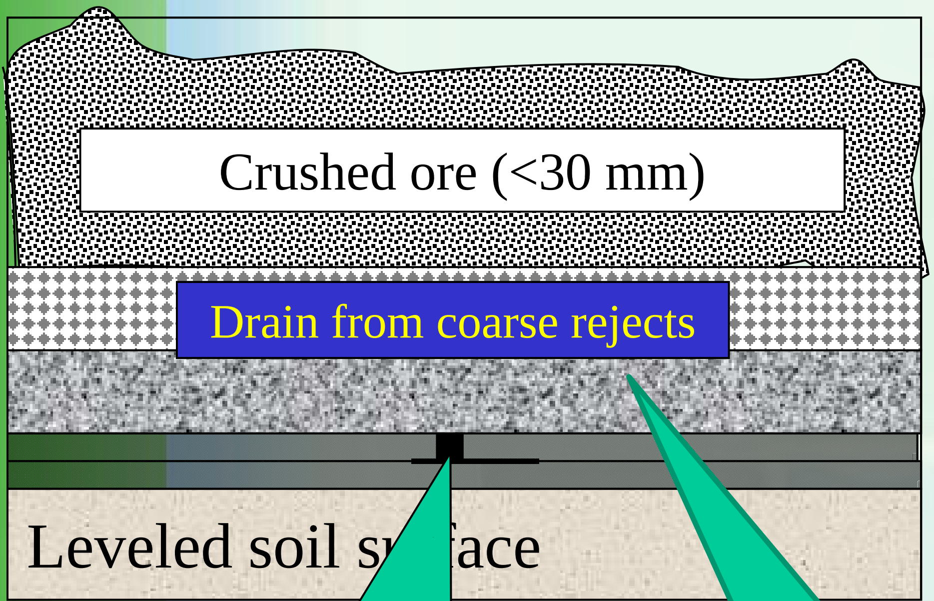
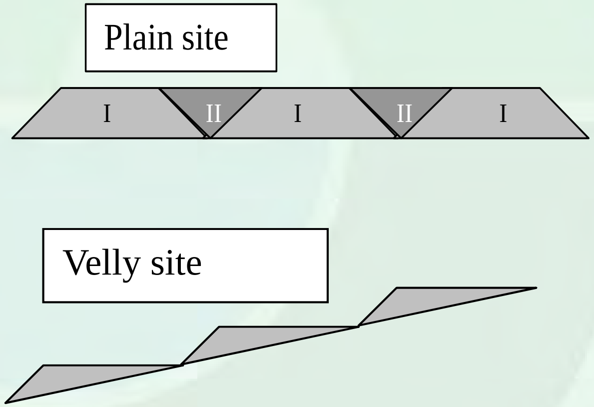
Pad and liner design development (expanding pads)



Arrangement of heaps



Two PVC plastic foil layers. The sheets seamed with bitumen

Over-liner material:Wood chips from the mill

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Placement of PVC lining geomembrane

At the very beginning 1.2 m wide foil strips later on wider ones were used

Wood chips

Drain from (100-200 mm) rejects)

Heap pad lined with foil strips (and steamed with bitumen)

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Placement (stacking) of the ore on the pad

Some heterogenity in the density and size distribution of ore most likely took place

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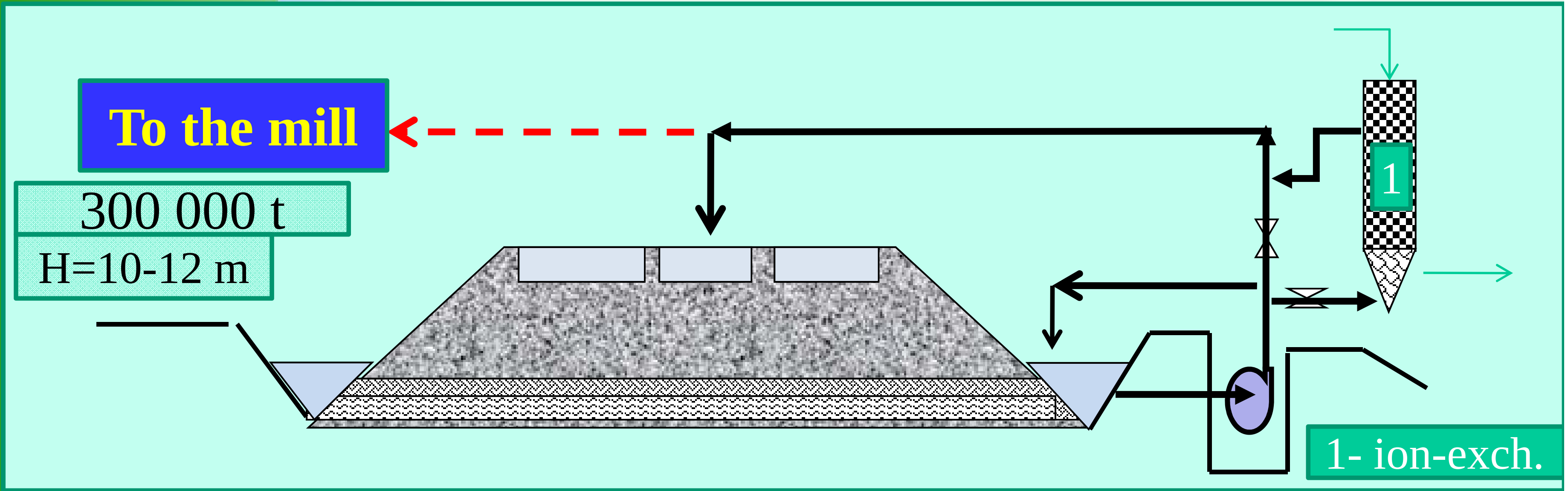
Principal flow sheet of the water management



$4R\text{-}Cl + UO_2(CO_3)^{4-} = R_4[UO_2(CO_3) + 4Cl^-$

Volume of water ~0.25 m^3/t: (20 g/l Na_2CO_3+ 5 g/l $NaHCO_3$)
Overbalance : 37 th m^3/a, to the mill (12% of precipitate)

Water managenet cont.

At the beginning the heaps were very carefully irrigated just as if sprinkling a field

Later on more solution was pumped and storaged on the heaps in small basins

Percolation rate was -5-20 cm/d (swelling)

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Dam failure (HL 1)

Too large basin on the top caused colaption of the dam
App. 3 thousand m^3 of process water
has escaped from the heaps

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Heap Leaching sites

Plain-type site

Hill-type site

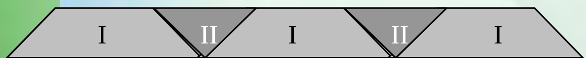
Site N1

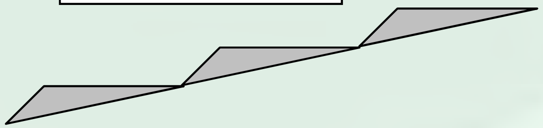
Site N2

~5 Mt

2.2 Mt

Hill-type site





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View on the heaps (Site 2)

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View on the heaps (HL2)

Site N2

~5.2 Mt

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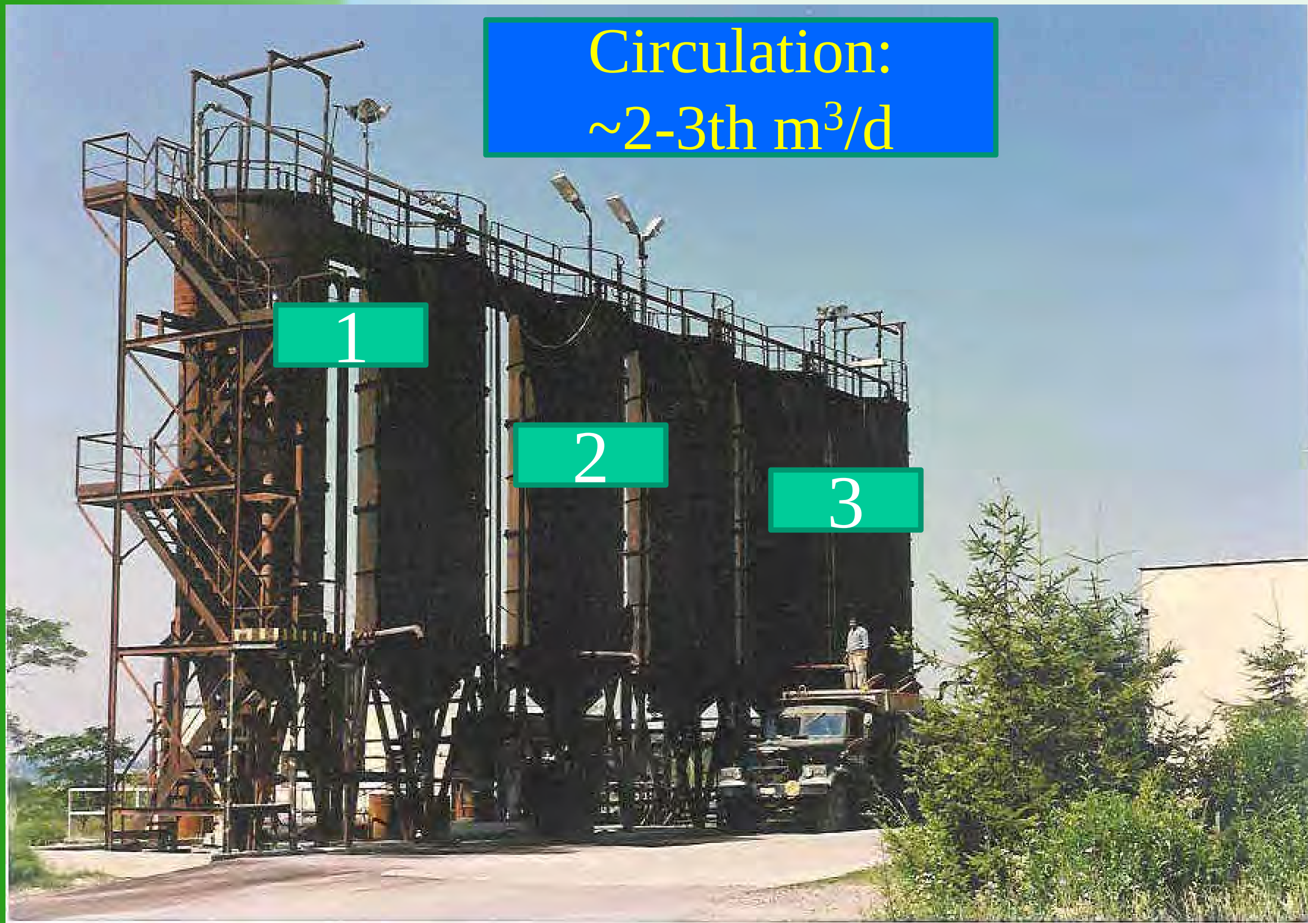
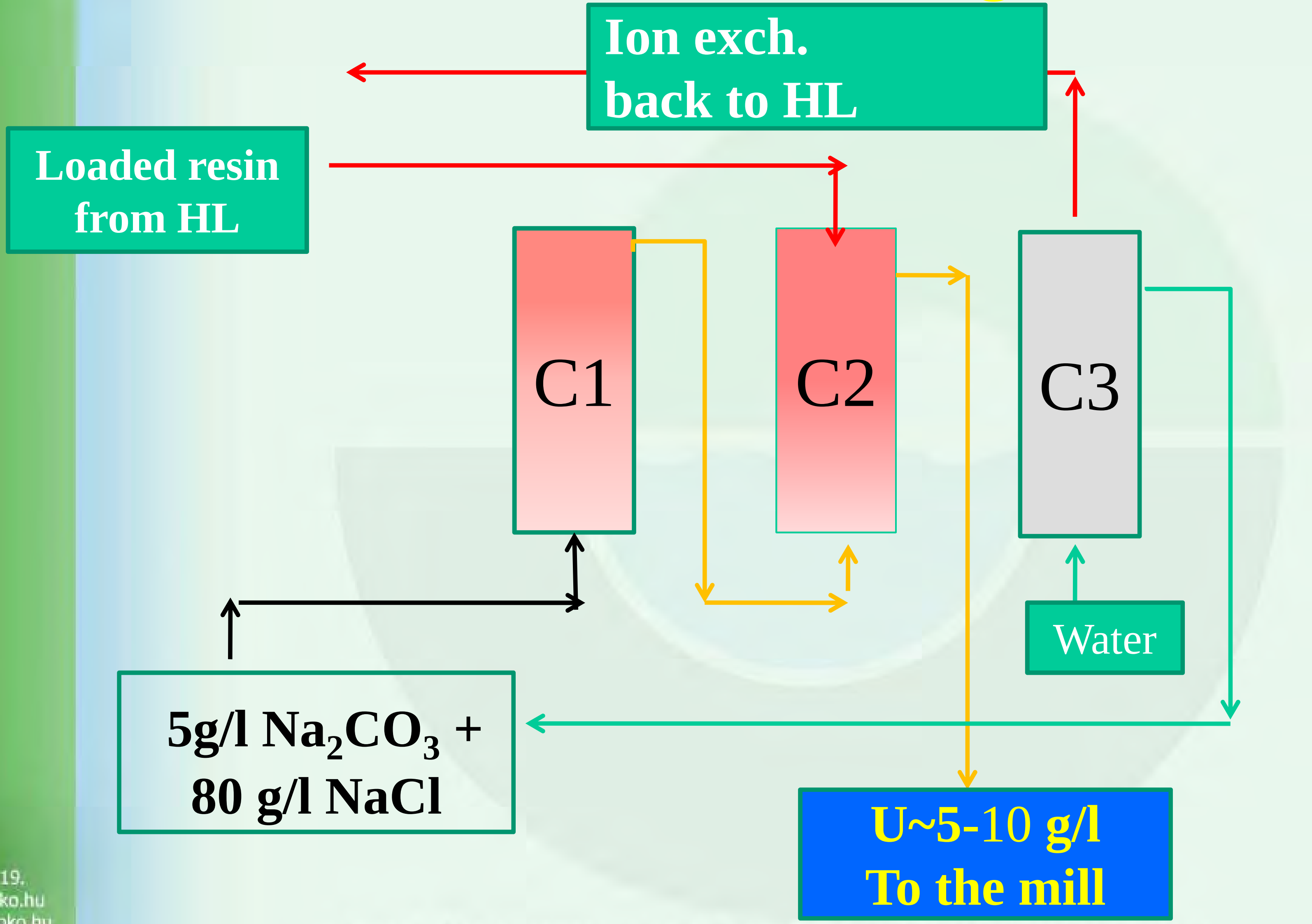
Ion exchange columns



Na	K	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	TDS	U
g/l								mg/l
5-10	0.5-1	3-5	3-5	1-2	4-8	0.05-0.2	15-25	30-200

Three separate underflow pipe lines operated for segregation of the solutions from heaps of different age (for better sorption efficiency)

Semi-counter current eluation (stripping) of the loaded anion exchanger



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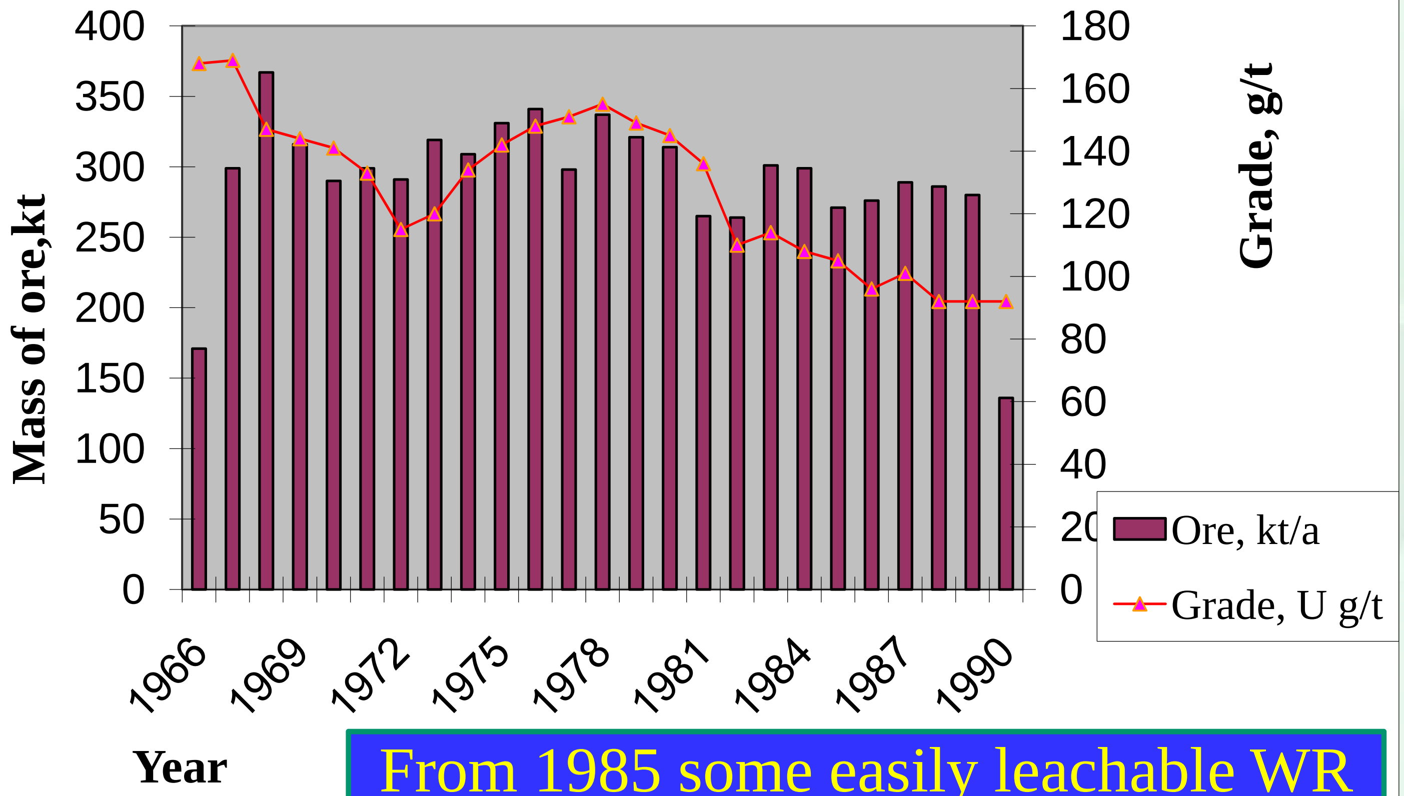
Yearly processed low grade ore



From 1985 some easily leachable WR has been processed too.

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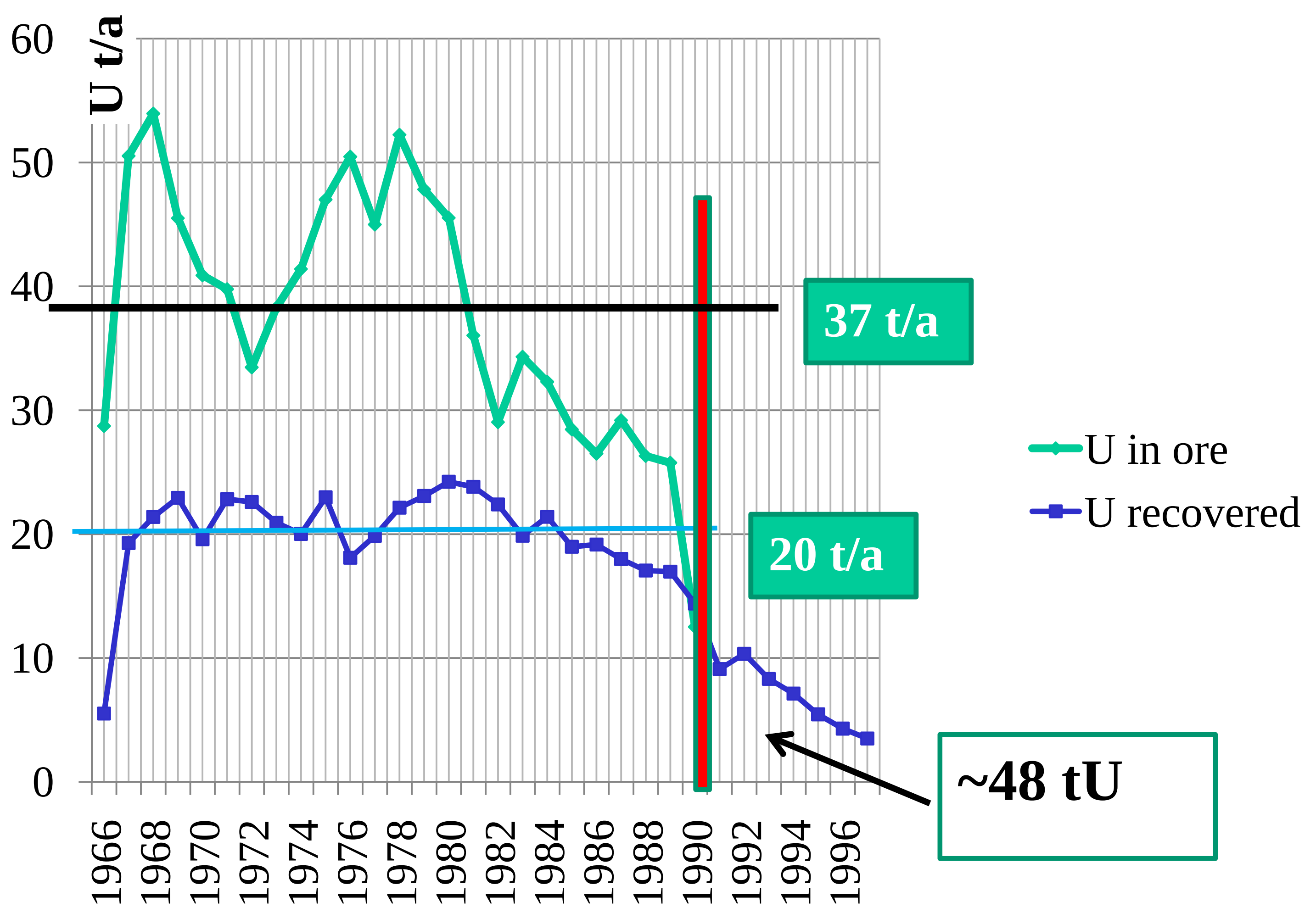
Uranium recovery (%)



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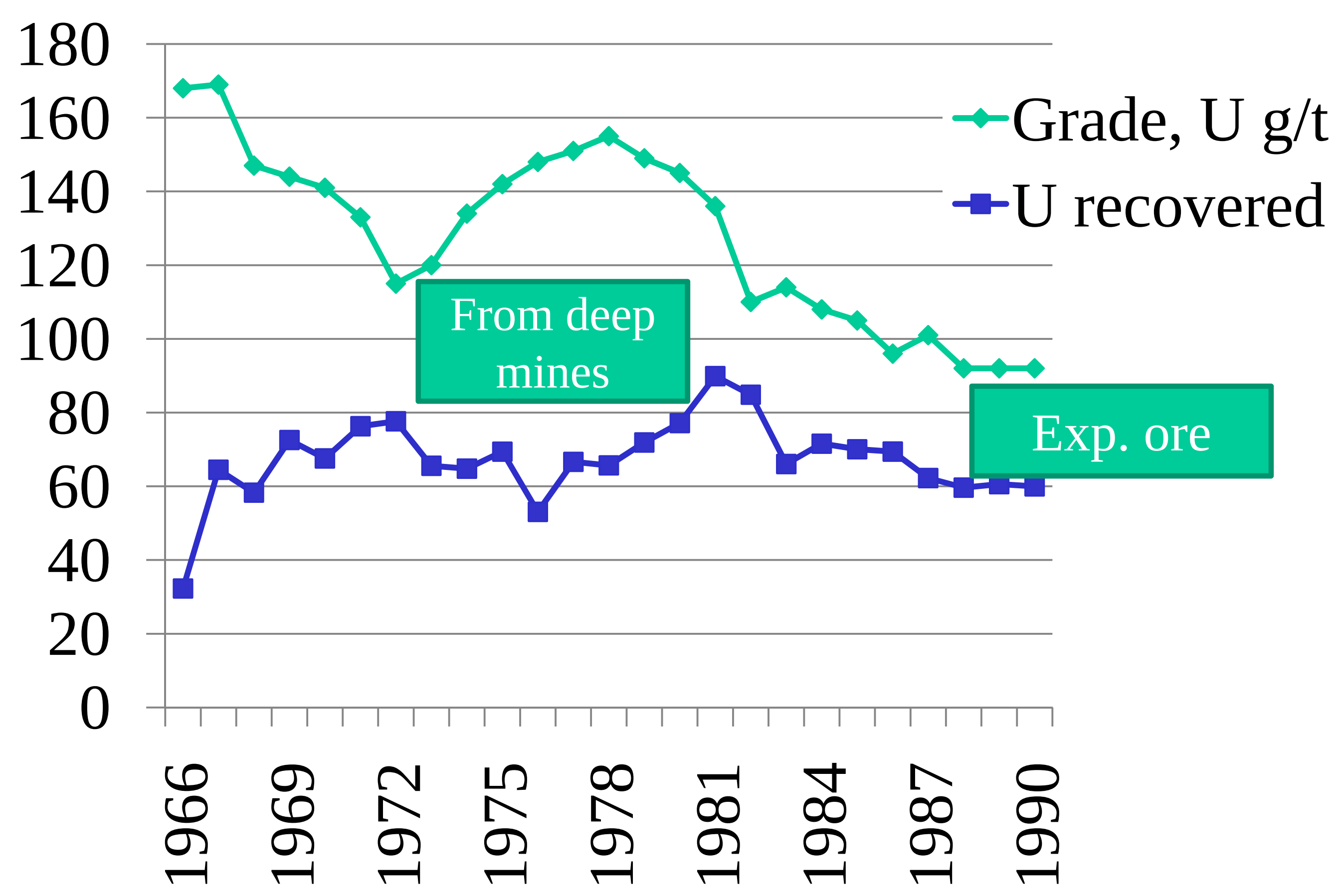
Uranium recovery, g/t



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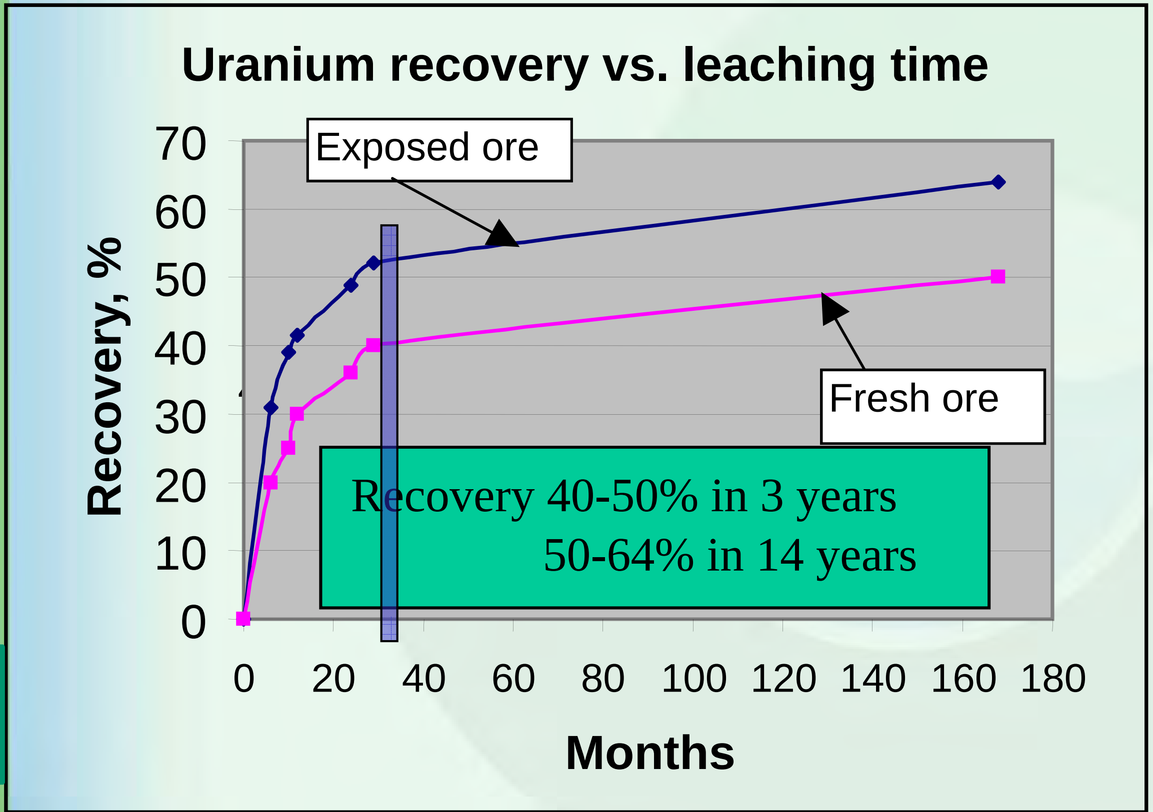
Dependence of the uranium recovery from leaching time and ore type

U~136 g/t

U~64 g/t



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Data for the economic evaluation of the process

Mining: no cost

Crushing: 2 kWh/t

Chemicals: NaCl-0.8 kg/t

Na_2CO_3-5 kg/ t

Ion exch. resin: 0.07 dm^3/t

Haulage: 2 km distance

Pumping: ~12 kwh/t (circulation of the solution)

Payroll: ~1 $/t

Pad, Sealing: ~0.07 m^2/t

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Ruff cost distribution

Items	$/kgU
Chemicals (NaCl, Na_2CO_3, Ion exch.etc.), supplementary materials	16
Electricity (mainly for pumping)	20
Payroll	17
Others (service from other comp.)	9
Total	62

Data for 1992 $=75 HUF

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Working experience and lessons

1 To avoid unequal compaction of the heaps (dam failure)

- Sprinkling for some months before filling the basins on the top of heaps was needed

2 **Decreasing** of the percolation rate (to 2-3 cm/d)

- Increased clay content and its swelling
- **Algae population** (in summer time) was observed ($CuSO_4$ addition)

3 **Decreasing** of the uranium loading of the ion exchanger,

- High TDS (Cl, SO4 in lechates),
- Remove of some process water for water balance (~12% of yearly precipitate)
- Separation of water collection systems of the younger and older heaps

Conclusions

- Using alkiline haeap leaching app. 50-65% of uranium has been removed from the **very low-grade and rather refractory ore** (50% from unexposed ore, 64% from exposed ore).
- Technological process became more **flexible** in respect ore grade, cutt-off grade, mill operation, mining technology, etc.
- **Less quantity** of uranium was placed into the WRP, therefore the loading of the environment with uranium decreased by one thierd.
- The used liner system proved to be acceptable but **very sensitive** for ultraviolet light (damages on the dams).

Conclusions cont.

- It seems that using **reusable pad** for leaching is more acceptable from environmental point of view (less soil contamination is expected). The expanding pads needed ~7 ha/Mt

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