35+2 1985 2022 stava
CONVEGNO
SCARTI MINERARI: DA RIFIUTO A RISORSA
6/7 ottobre 2022
Stava di Tesero (TN), Italy

MINERARIA GERREI

Silius fluorspar ore
Sardinia, Italy

The re-use of mining waste in the fluorspar beneficiation process

Umberto Gioia
Mineraria Gerrei Srl

fondazione stava1985 onlus
ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale
GEAM Associazione Georisorse e Ambiente
A.N.I.M. Associazione Nazionale Ingegneri Minerari
AGI Associazione Geotecnica Italiana

COMPANY PROFILE

MINERARIA GERREI SRL

- SPV established in 2018
- Registered seat at Silius Mine, Sardinia, Italy
- Public bid winner for Silius mine takeover and rehab
- Core business fluorspar mining & processing
- Extensive experience in mining and construction

FLUORSPAR DOWNSTREAM PRODUCTS - GENERAL

ALUMINUM	STEEL	AEROSPACE INDUSTRY	BATTERIES AND ENERGY STORAGE
ELECTRONICS AND ELECTRICAL EQUIPMENT	FLUOROCHEMICALS	SPECIAL COATINGS & FIREPROOF MATERIALS	HIGH PERFORMANCE PLASTICS
NUCLEAR POWER	SOLAR POWER	REFRIGERANTS	AIR CONDITIONING
GLASS INDUSTRY	CERAMICS	SUPERCONDUCTORS	HEALTHCARE & PHARMACEUTICALS

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FLUORSPAR DOWNSTREAM PRODUCTS – HI-TECH

SUPERCONDUCTORS

- HFCs used in IC device making for:
  - ✓Reactive Ion Etching process
  - ✓Preparation for metals deposition
  - ✓Plasma chamber cleaning

BATTERIES

- PVDF polymers used as binder in electrodes production
- PVDF used as separator coating
- $LiPF_6$ used as electrolyte in Li-ion batteries
- HF used for purification of natural graphite
- Studies found fluorine as possible substitute for lithium in rechargeable batteries

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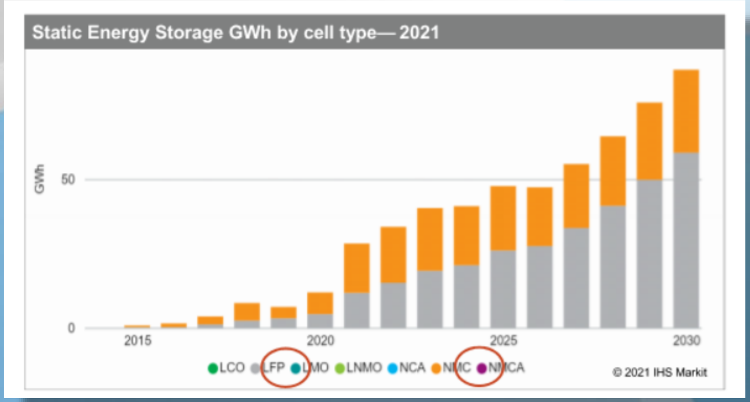
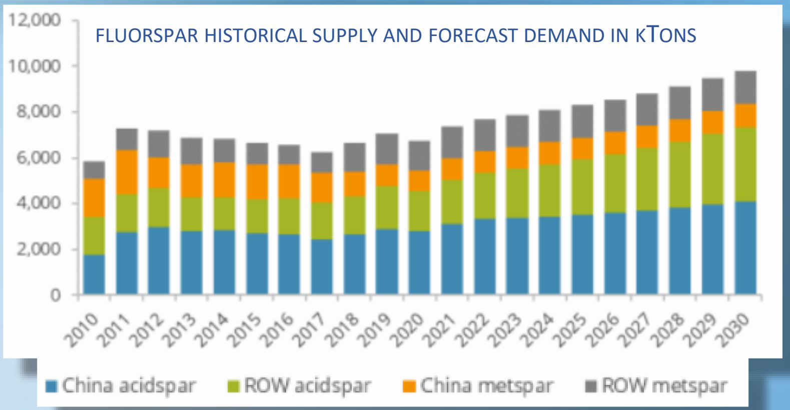
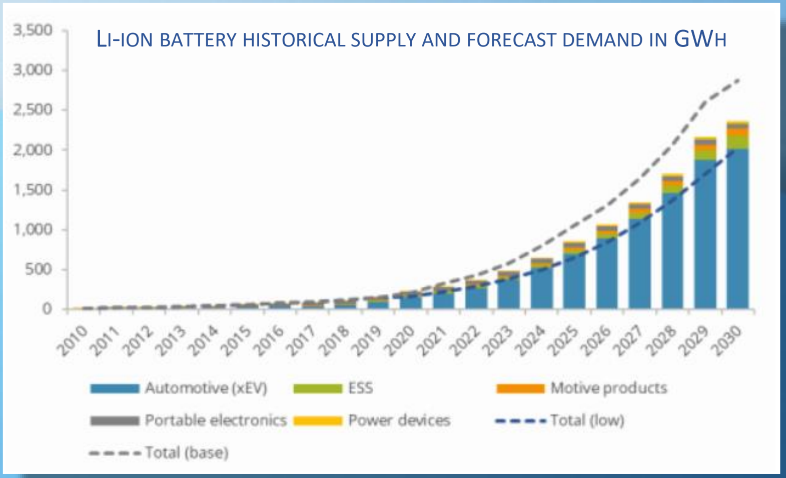
AAGR 2021-2030

- Global fluorspar market +2.9% yearly
- Global acidspar market +4% yearly
- Global metspar market +2% yearly
- Non feedstock fluorocarbons +2% yearly
- Feedstock PVDF +2% yearly
- Feedstock PTFE +4% yearly
- LFP batteries +119% in 2022 and growing



Demand and consumption





MAIN SUPPLIERS

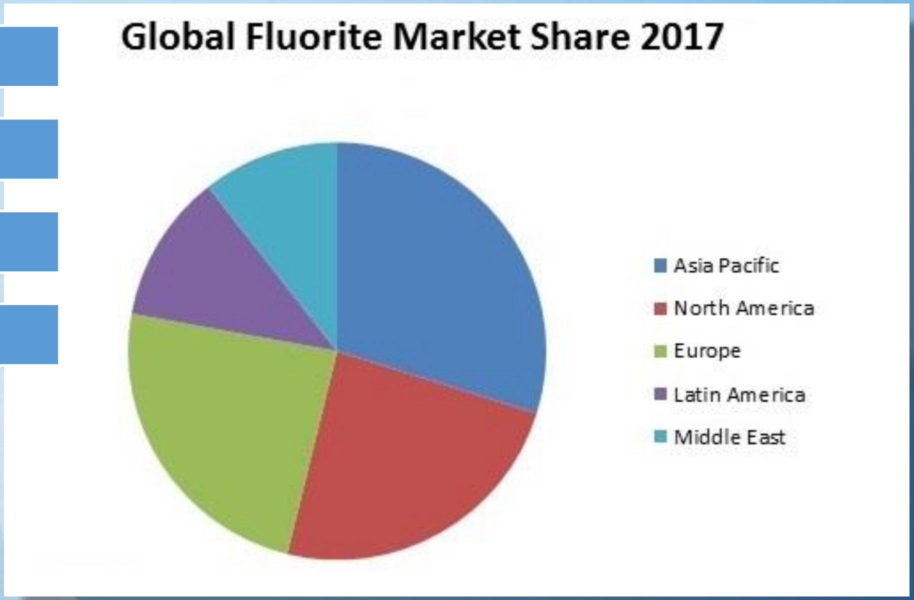
- **MEXICHEM (KOURA)** – Mexico – San Luis P. / Musquiz mines - 1.200.000 t/y acidspar
- **SA FLUORITE PTY** – South Africa – Doornhoek mine – 240.000 t/y acidspar
- **MASAN RESOURCES** – Vietnam – Nui Phao mine – 220.000 t/y acidspar
- **CHINA KING RESOURCES** – China – 6 mines – 200.000 t/y acidspar
- **CANADA FLUORSPAR** – Canada - St. Lawrence mine – 200.000 t/y acidspar
- **CENTRAL FLUOR INDUSTRIES** – China – 4 mines – 200.000 t/y acidspar
- **SEPFLUOR** – South Africa – Nokeng mine – 180.000 t/y acidspar
- **MINERSA** – SAF/Spain – Vergenoeg/Ribadesella mines – 100.000 t/y acidspar

MARKET OVERVIEW

Major USA/EU fluorspar consumers

- Honeywell Fluorine Products - USA
- Solvay Fluor - Germany
- Chemours (Du Pont) - USA
- Fluorsid - Italy
- Lanxess - Germany
- Derivados del Fluor - Spain
- Fluorchemie - Germany

Main consumers



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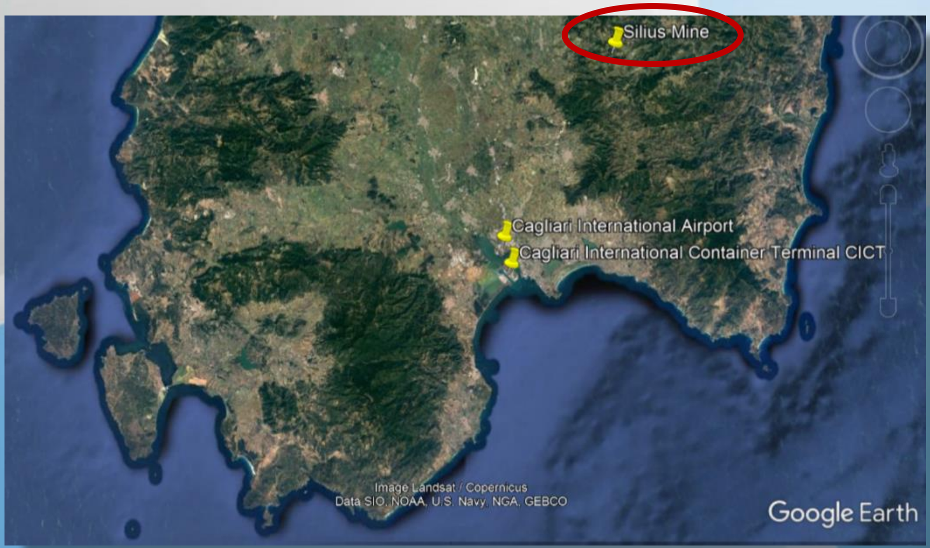
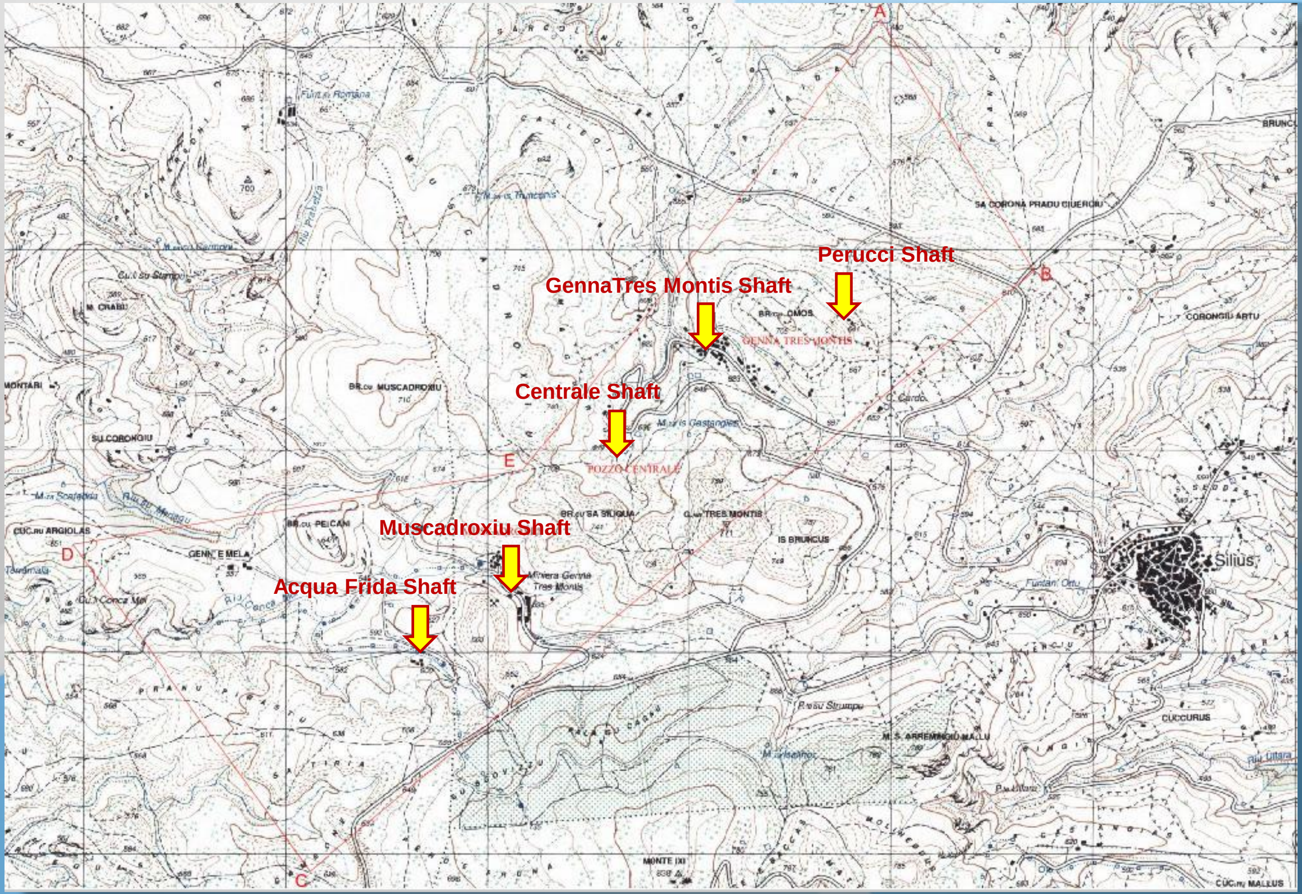
MINE LOCATION



- **South Sardinia, Italy**
- **35 miles NE of Cagliari Intl Airport and Cagliari Intl Container Terminal**
- **In the heart of Mediterranean Sea**

- **Existing mine, open, accessible, held under mantainance, ready for production**
- **Mining claim area 492 ha**
- **2 km East of Silius village, average elevation 600 m a.s.l.**
- **Mining sites easily interconnected with main roads**

MINE SITE



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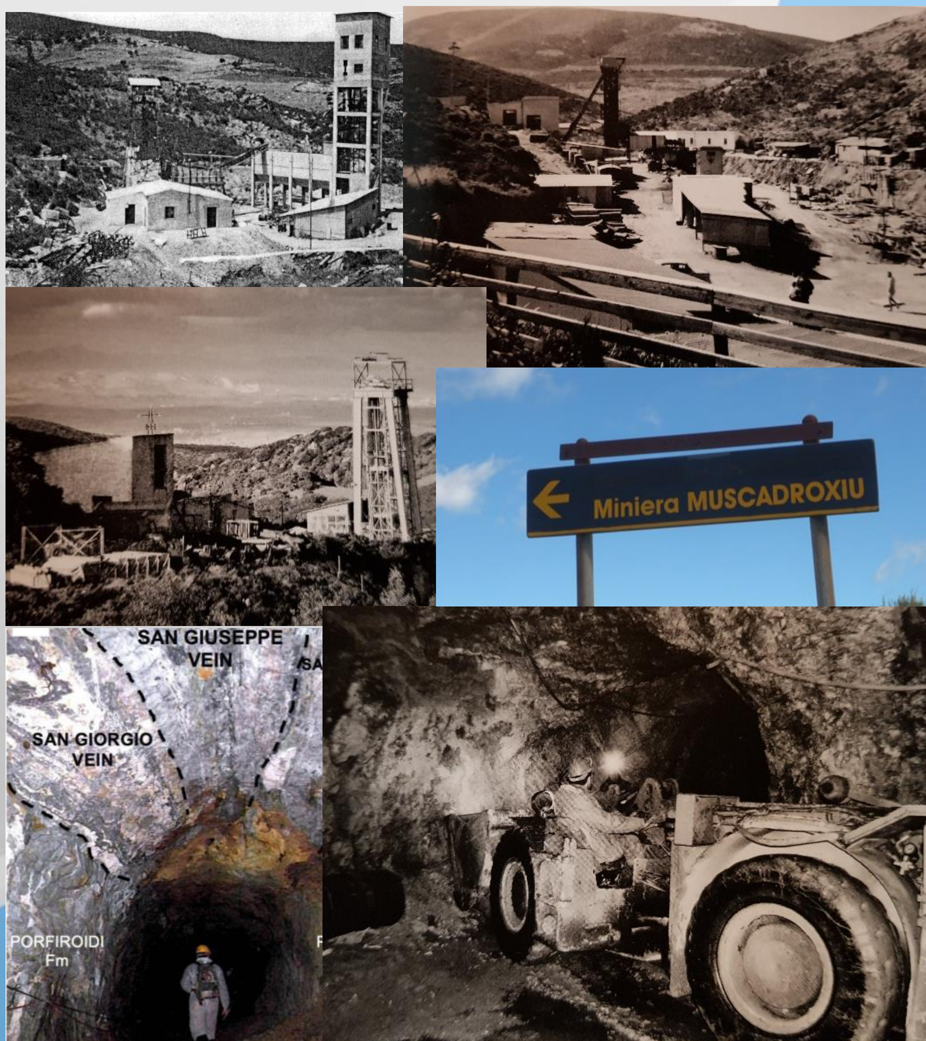
MINE HISTORY

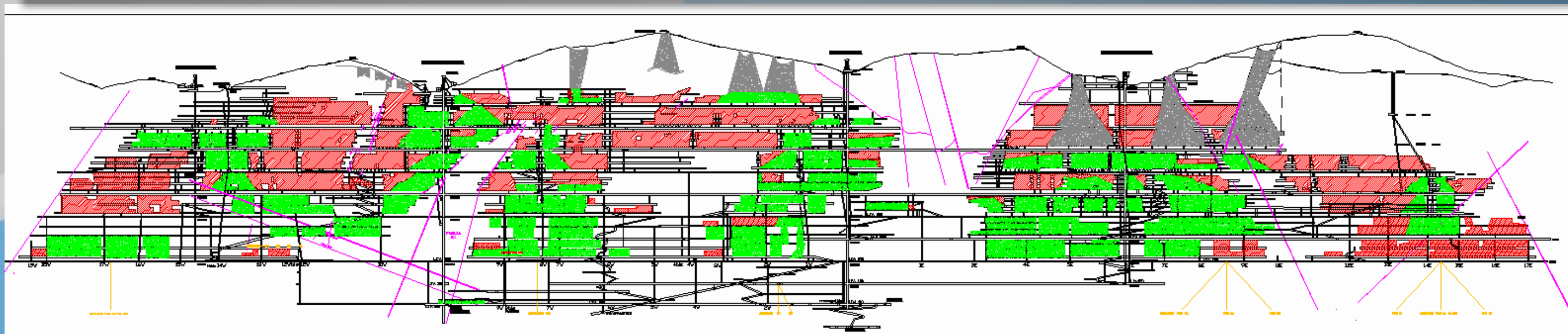


- **Explorations in Silus area started in the 1870's**
- **First mining claim dates back to 1915**
- **Originally licensed for lead and silver surface mining**
- **Underground extensive fluorspar mining started in 1952**
- **From 1954 to 1991 Silius mine was operated by private investor (Mineraria Silius), reaching remarkable levels of CaF_2 production (up to 450.000 t/y TV)**
- **Since 1992, Silius mine has been operated by public companies owned by Sardinia Region**
- **Operation stopped in 2007, after Sardinia decision for mine privatization: such process ended up in 2017, with the mine title awarded to Mineraria Gerrei, subject to mine rehab design and updated exploitation plan**
- **Mineraria Gerrei has just finalized the authorization process for mine reopening**
- **Additional REE (Rare Earths) potential has been discovered in accessory minerals. New mining licence will include rights for REE exploitation**

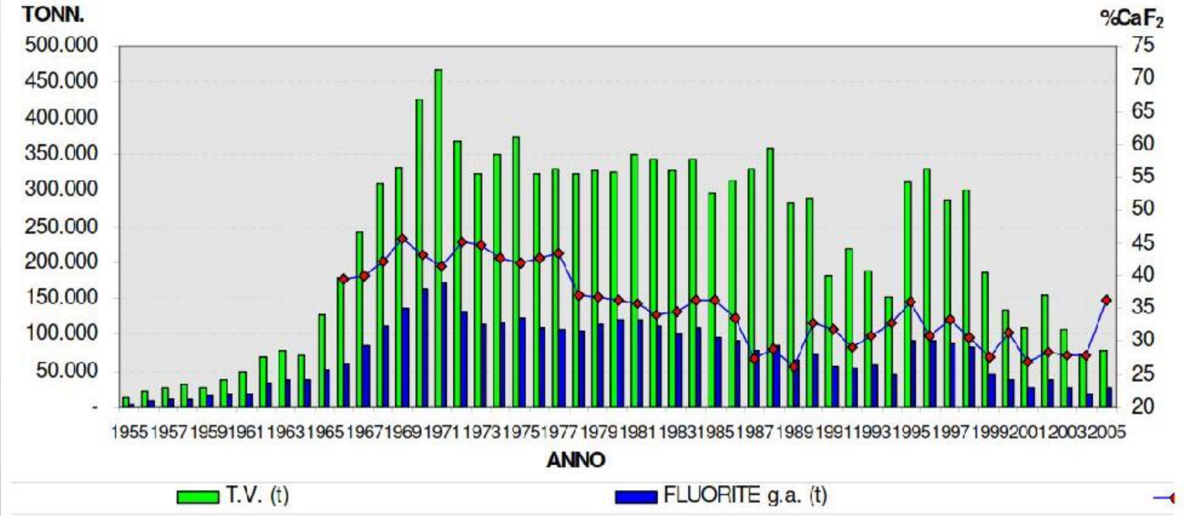
SILIUS MINE

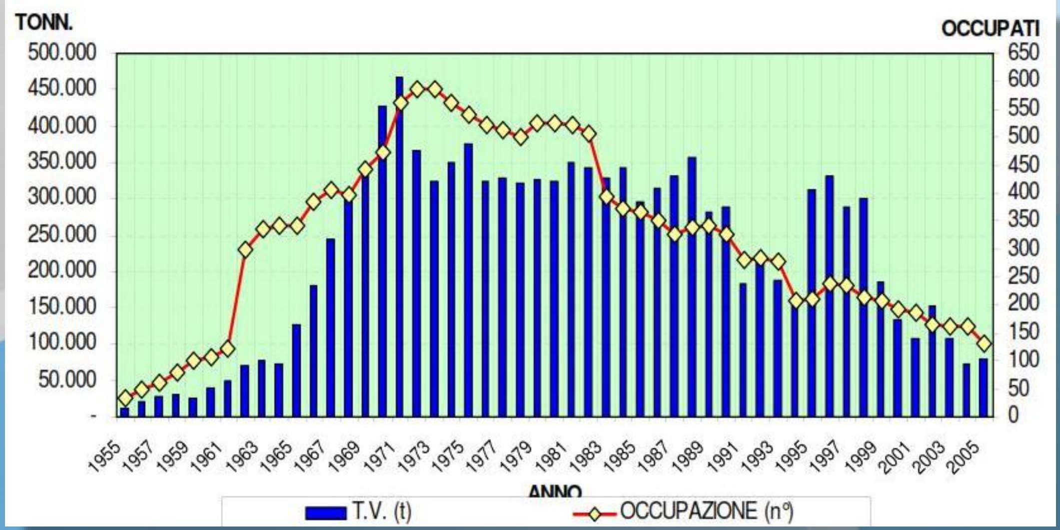
- **Full underground mining, 4.5 km E-W development**
- **> 120 km tunnels, 12 m^2 average section**
- **5 shafts up to 500 mts deep**
- **Main haulage levels each 100 m depth**
- **Sublevels each 20 m depth**
- **Stable rock mass and relatively dry context**
- **Steady natural ventilation with additional forced air circuit**

MINE INFRASTRUCTURE



MINE HISTORY



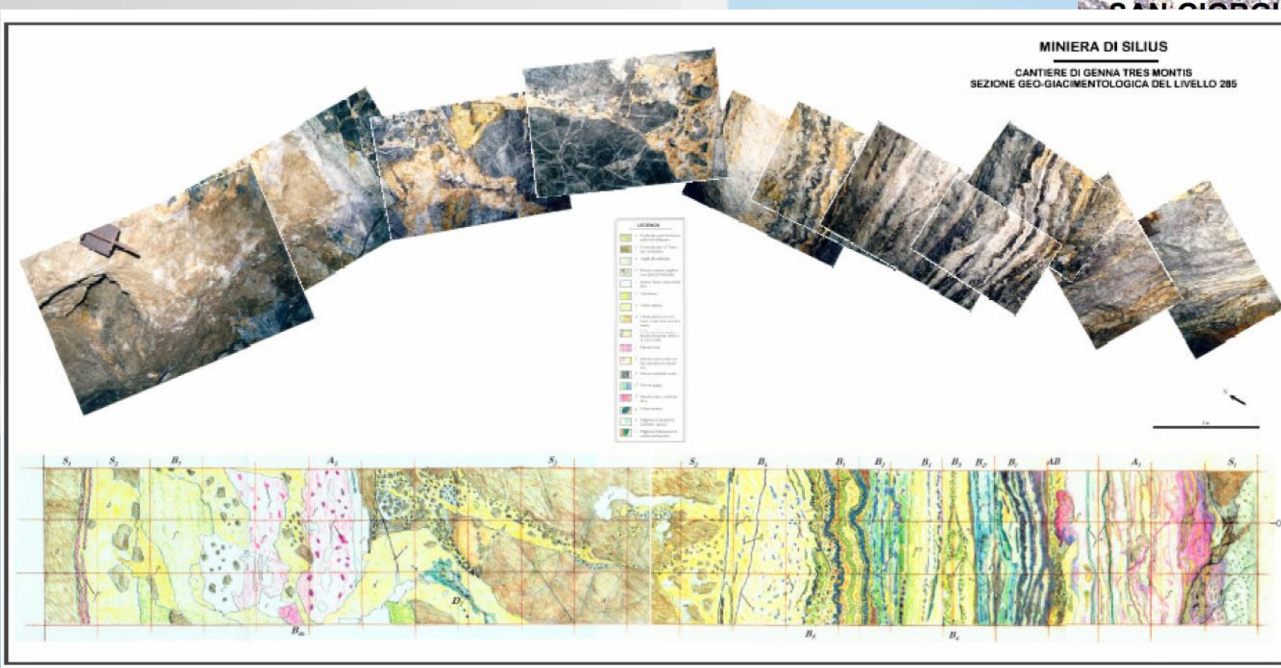


- **Over 11 mln tons of TV extracted and nearly 4 mln tons of acidspar produced in 50 yrs operation**
- **Maximum historical production reached in 1971 (> 450.000 tons TV)**
- **Up to 600 employees in the 1970's**
- **Average historical fluorspar grade 35%**

SILIUS MINE

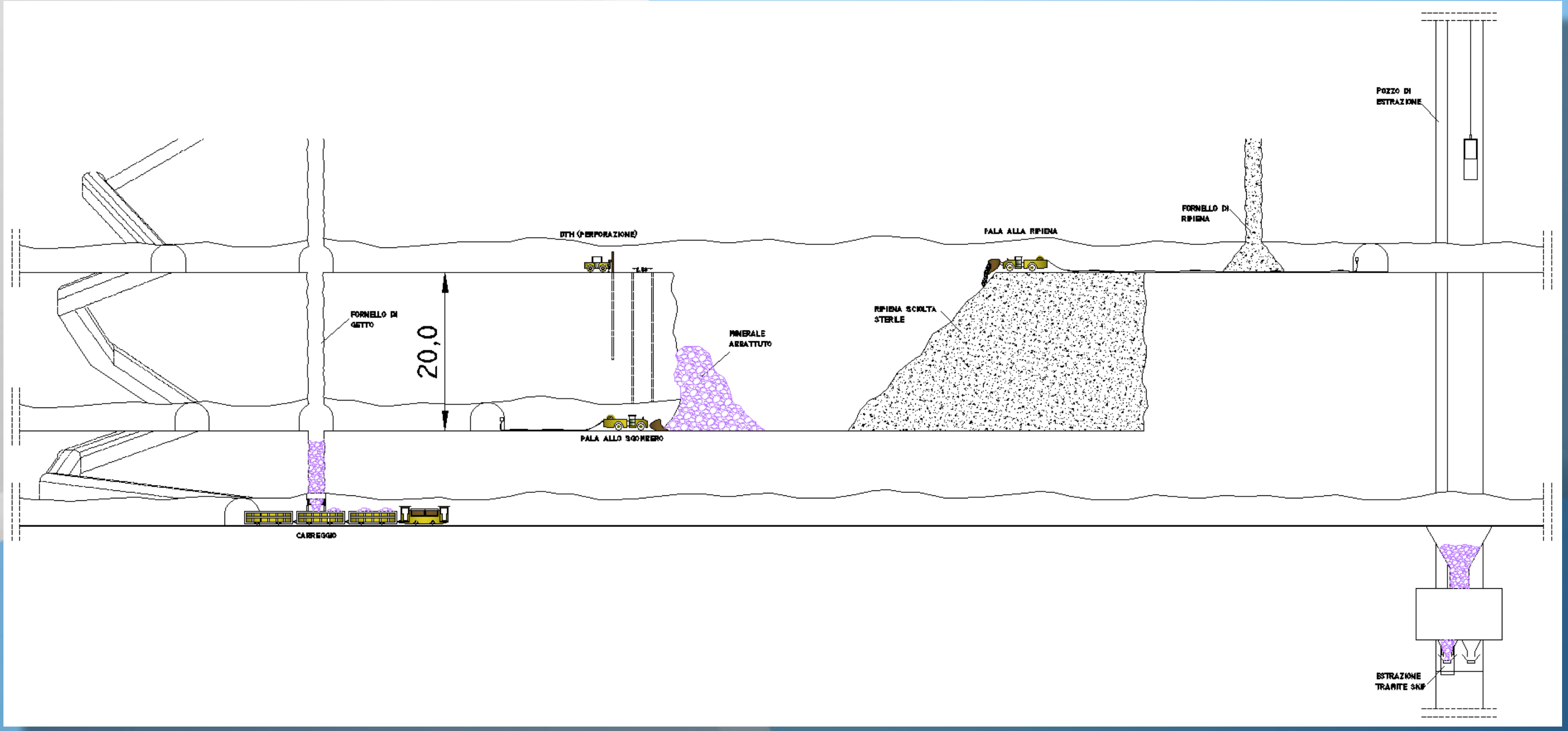
- **Fluorspar veins typically 3-6 mts wide (up to 18 mts)**
- **Extraordinary ore persistence (vein system > 500 m deep, still without relevant CaF_2 % decrease)**
- **Typical paragenesis includes fluorspar, quartz, calcite (source for REE), galena, marcasite, baryte, pyrite and zinc sulfide**

ORE GEOLOGY



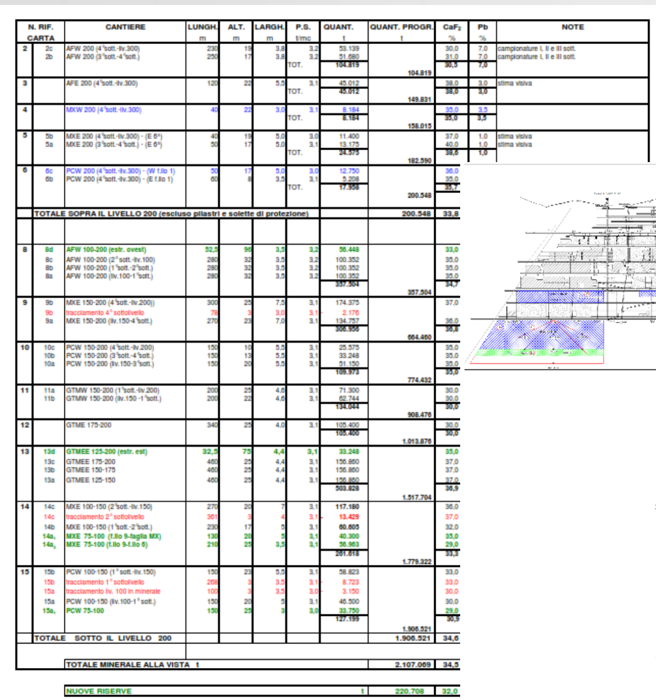
MINING METHOD

- **Effective and extensive use of stoping method with backfilling, proceeding downwards**
- **Locally sub level stoping method without backfilling**
- **Safety ceiling left in place bewteen haulage level and upper first sublevel**

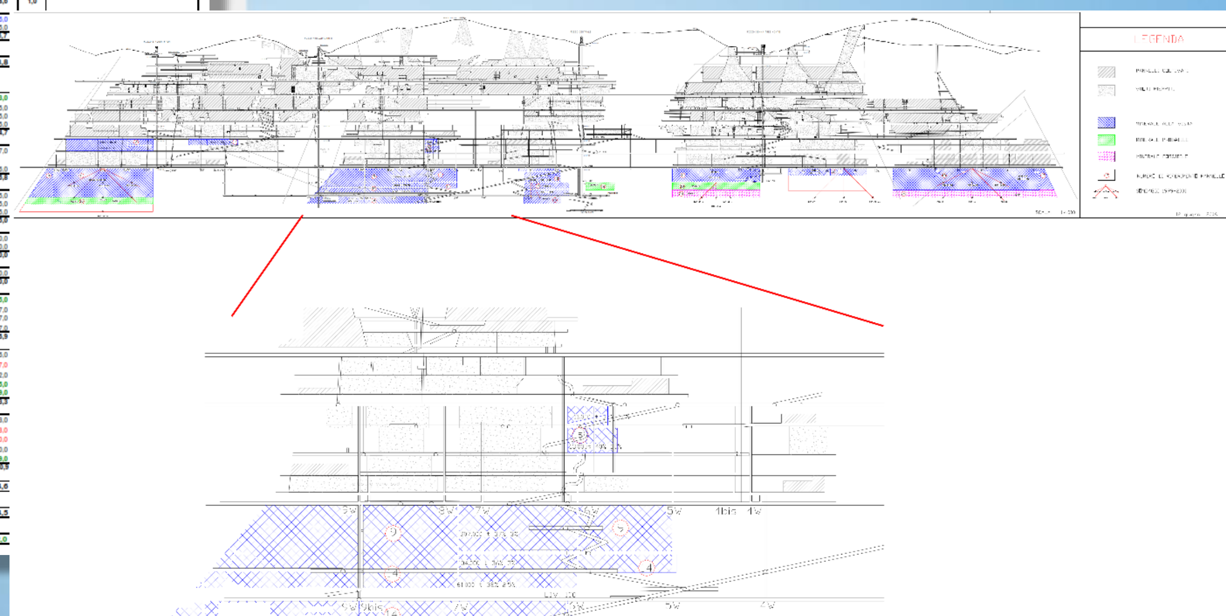


Reserves – Fluorspar

- **Certified resources (BRGM independent audit)**
- **2.100.000 tons measured resources (average grade 32% CaF_2, 3% Pb)**
- **1.200.000 tons of indicated resources (upper levels unexploited panels with CaF_2 cutoff grade <30%)**
- **Huge potential for additional resources (unexplored veins system prosecution over Eastern ore boundary fault)**



N. RIF.	CARTA	CANTIERE	LUNGH. m	ALT. m	LARGH. m	P.S. t/mc	QUANT. t	QUANT. PROGR. t	CaF_2 %	Pb %	NOTE
2	2c	AFW 200 (4°sott.-liv.300)	230	19	3,8	3,2	53.139		30,0	7,0	campionature I, II e III sott.
	2b	AFW 200 (3°sott.-4°sott.)	250	17	3,8	3,2	51.680		31,0	7,0	campionature I, II e III sott.
						TOT.	104.819	104.819	30,5	7,0	
3		AFE 200 (4°sott.-liv.300)	120	22	5,5	3,1	45.012		38,0	3,0	stima visiva
						TOT.	45.012	149.831	38,0	3,0	
4		MXW 200 (4°sott.-liv.300)	40	22	3,0	3,1	8.184		35,0	3,5	
						TOT.	8.184	158.015	35,0	3,5	
5	5b	MXE 200 (4°sott.-liv.300) - (E 6°)	40	19	5,0	3,0	11.400		37,0	1,0	stima visiva
	5a	MXE 200 (3°sott.-4°sott.) - (E 6°)	50	17	5,0	3,1	13.175		40,0	1,0	stima visiva
						TOT.	24.575	182.590	38,6	1,0	
6	6c	PCW 200 (4°sott.-liv.300) - (W f.lo 1)	50	17	5,0	3,0	12.750		36,0		
	6b	PCW 200 (4°sott.-liv.300) - (E f.lo 1)	60	8	3,5	3,1	5.208		35,0		
						TOT.	17.958	200.548	35,7		
	TOTALE SOPRA IL LIVELLO 200 (escluso pilastri e solette di protezione)							200.548	33,8		
8	8d	AFW 100-200 (estr. ovest)	52,5	96	3,5	3,2	56.448		33,0		
	8c	AFW 100-200 (2°sott.-liv.100)	280	32	3,5	3,2	100.352		35,0		
	8b	AFW 100-200 (1°sott.-2°sott.)	280	32	3,5	3,2	100.352		35,0		
	8a	AFW 100-200 (liv.100-1°sott.)	280	32	3,5	3,2	100.352		35,0		
							357.504	357.504	34,7		
9	9b	MXE 150-200 (4°sott.-liv.200))	300	25	7,5	3,1	174.375		37,0		
	9b	tracciamento 4° sottolivello	78	3	3,0	3,1	2.176				
	9a	MXE 150-200 (liv.150-4°sott.)	270	23	7,0	3,1	134.757		36,0		
							306.956	664.460	36,8		
10	10c	PCW 150-200 (4°sott.-liv.200)	150	10	5,5	3,1	25.575		35,0		
	10b	PCW 150-200 (3°sott.-4°sott.)	150	13	5,5	3,1	33.248		35,0		
	10a	PCW 150-200 (liv.150-3°sott.)	150	20	5,5	3,1	51.150		35,0		
							109.973	774.432	35,0		
11	11a	GTMW 150-200 (1°sott.-liv.200)	200	25	4,6	3,1	71.300		30,0		
	11b	GTMW 150-200 (liv.150 -1°sott.)	200	22	4,6	3,1	62.744		30,0		
							134.044	908.476	30,0		
12		GTME 175-200	340	25	4,0	3,1	105.400		30,0		
							105.400	1.013.876	30,0		
13	13d	GTMEE 125-200 (estr. est)	32,5	75	4,4	3,1	33.248		35,0		
	13c	GTMEE 175-200	460	25	4,4	3,1	156.860		37,0		
	13b	GTMEE 150-175	460	25	4,4	3,1	156.860		37,0		
	13a	GTMEE 125-150	460	25	4,4	3,1	156.860		37,0		
							503.828	1.517.704	36,9		
14	14c	MXE 100-150 (2°sott.-liv.150)	270	20	7	3,1	117.180		36,0		
	14c	tracciamento 2° sottolivello	361	3	4	3,1	13.429		37,0		
	14b	MXE 100-150 (1°sott.-2°sott.)	230	17	5	3,1	60.605		32,0		
	14a₁	MXE 75-100 (f.lo 9-faglia MX)	130	20	5	3,1	40.300		35,0		
	14a₂	MXE 75-100 (f.lo 9-f.lo 6)	210	25	3,5	3,1	56.963		29,0		
							261.618	1.779.322	33,3		
15	15b	PCW 100-150 (1°sott.-liv.150)	150	23	5,5	3,1	58.823		33,0		
	15b	tracciamento 1° sottolivello	268	3	3,5	3,1	8.723		33,0		
	15a	tracciamento liv. 100 in minerale	100	3	3,5	3,0	3.150		30,0		
	15a	PCW 100-150 (liv.100-1°sott.)	150	20	5	3,1	46.500		30,0		
	15a₁	PCW 75-100	150	25	3	3,0	33.750		29,0		
							127.199	1.906.521	30,9		
	TOTALE SOTTO IL LIVELLO 200							1.906.521	34,6		
		TOTALE MINERALE ALLA VISTA t						2.107.069	34,5		
		NUOVE RISERVE					t	220.708	32,0		



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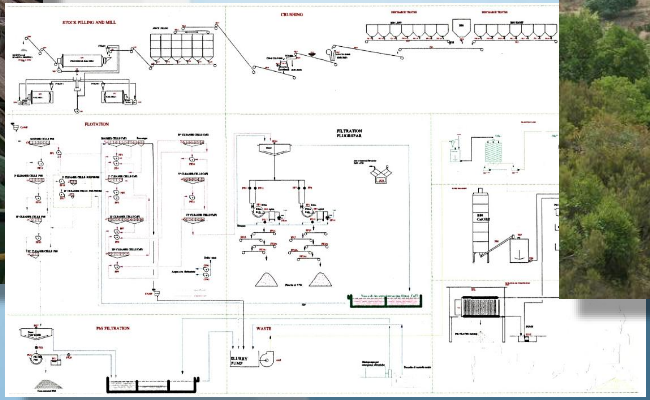
SILIUS MINE

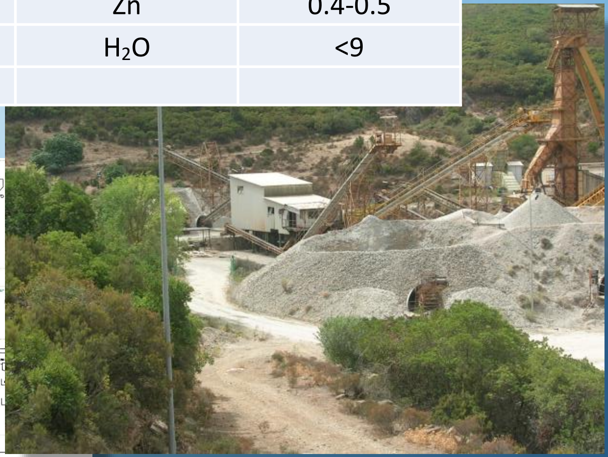
CONCENTRATION PROCESS

- **Extensive ore concentration track record (50 years of flotation tests and plants upgrade)**
- **Pre concentration through sink float treatment plant**
- **Concentration through flotation plant, with separated circuits for fluorspar and galena**
- **Calcite (source for REE) is fluorspar flotation waste product**

PRECONCENTRATED SINK FLOAT (%)	
CaF_2	42-55
SiO_2	25-35
$CaCO_3$	8-10
$MgCa(CO_3)_2$	8-10
PbS	2-5
$BaSO_4$	1-4
ZnS	0.5-1

CONCENTRATED FLOTATION (%)			
Fluorspar circuit		Galena circuit	
CaF_2	97.0-97.5	Pb	65-70
SiO_2	<1.3	Ag	120-160 ppm
$CaCO_3$	<1.5	Cu	0.1-0.3
Ba	<0.3	F	0.3-0.4
SO_3	<0.3	Zn	0.4-0.5
P_2O_5	<200 ppm	H_2O	<9
H_2O	<9		





HISTORICAL TREATMENT PROCESS

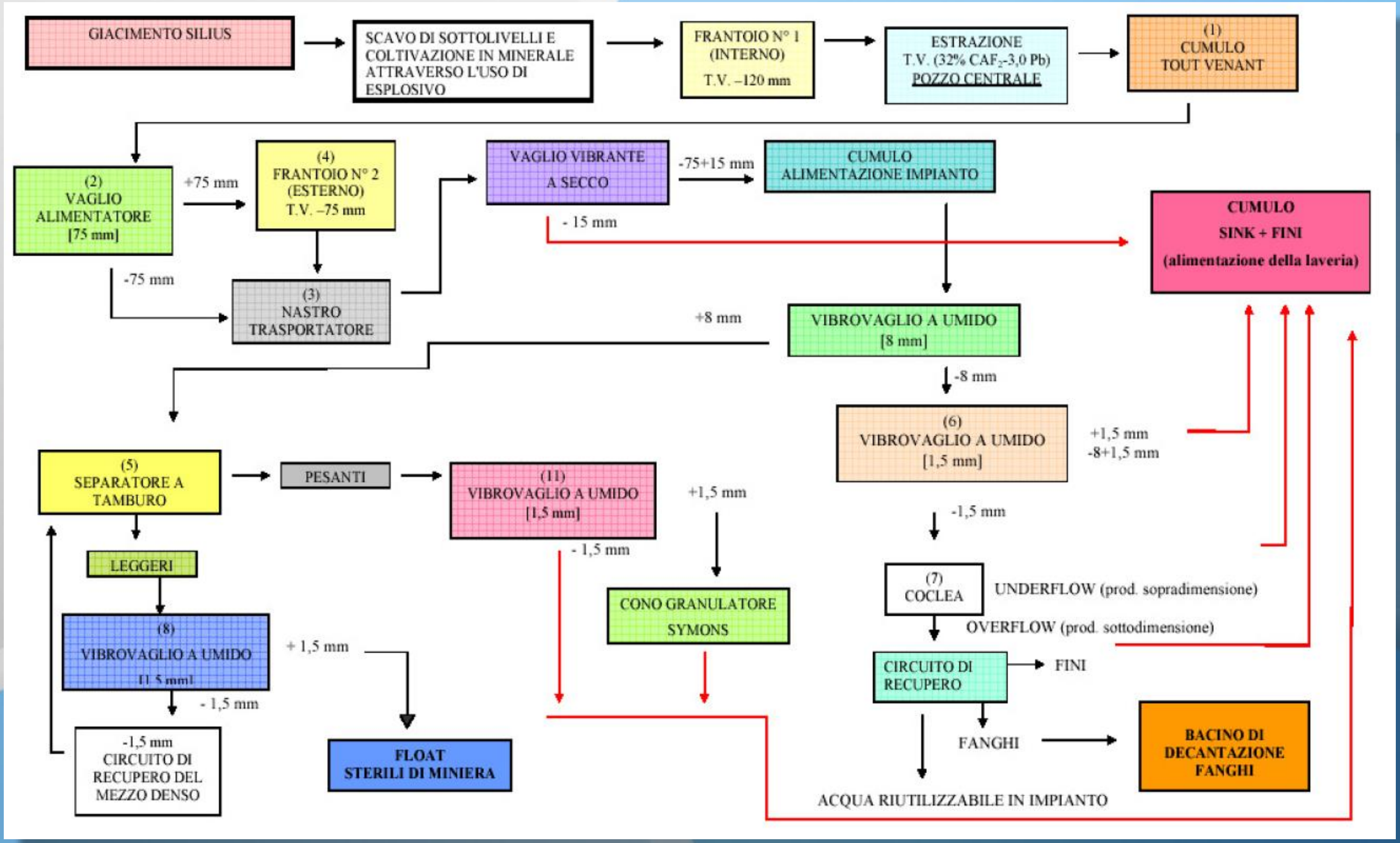
BASICS

- Tout venant from Silius mine with average 34% CaF_2 + 3.5% PbS
- Pre-concentration with sink-float plant at mine site, resulting in 31% wastes avg (used for underground landfills, up to 75 mm size) and 69% preconcentrated ore (average 46% CaF_2 + 4% PbS)
- Flotation plant in Assemini (50 km far from mine site), reaching 97% CaF_2 + 70% PbS, with tailings (basically – Mg/$CaCO_3$ and SiO_2 sands and silts) reaching 47% in weight w/respect to preconcentrated stock
- Each 100.000 tons TV generates 31.000 tons sink-float wastes (underground disposal at Silius mine) and 32.000 tons flotation wastes (surface landfills at Assemini site)

LIMITS

- Preconcentration process efficiency: uneffective separation (reduced waste volumes with high CaF_2 grades, bigger amounts of preconcentrated material sent to flotation with lower CaF_2 grade) and no tailings filtration
- Flotation process efficiency: CaF_2 Dorr overflow not thickened (still rich in fluorspar), waste of first PbS cycle still rich in PbS. i.e. lost value and environmental problems), reagents addition in flotation cells
- Higher flotation cost (higher treatment volumes) and transportation costs (high waste/payload ratio)
- Need for additional material (from quarries), and related costs, to fill underground voids
- Need for huge tailings enbankment areas (with related problem of eluate management and dust dispersion)
- Process waters (mostly from wells) treated and released to the environment (no or partially closed circuit), with relevant pumping and treatment costs (both in preconcentration and flotation plants)

HISTORICAL TREATMENT PROCESS - PRECONCENTRATION



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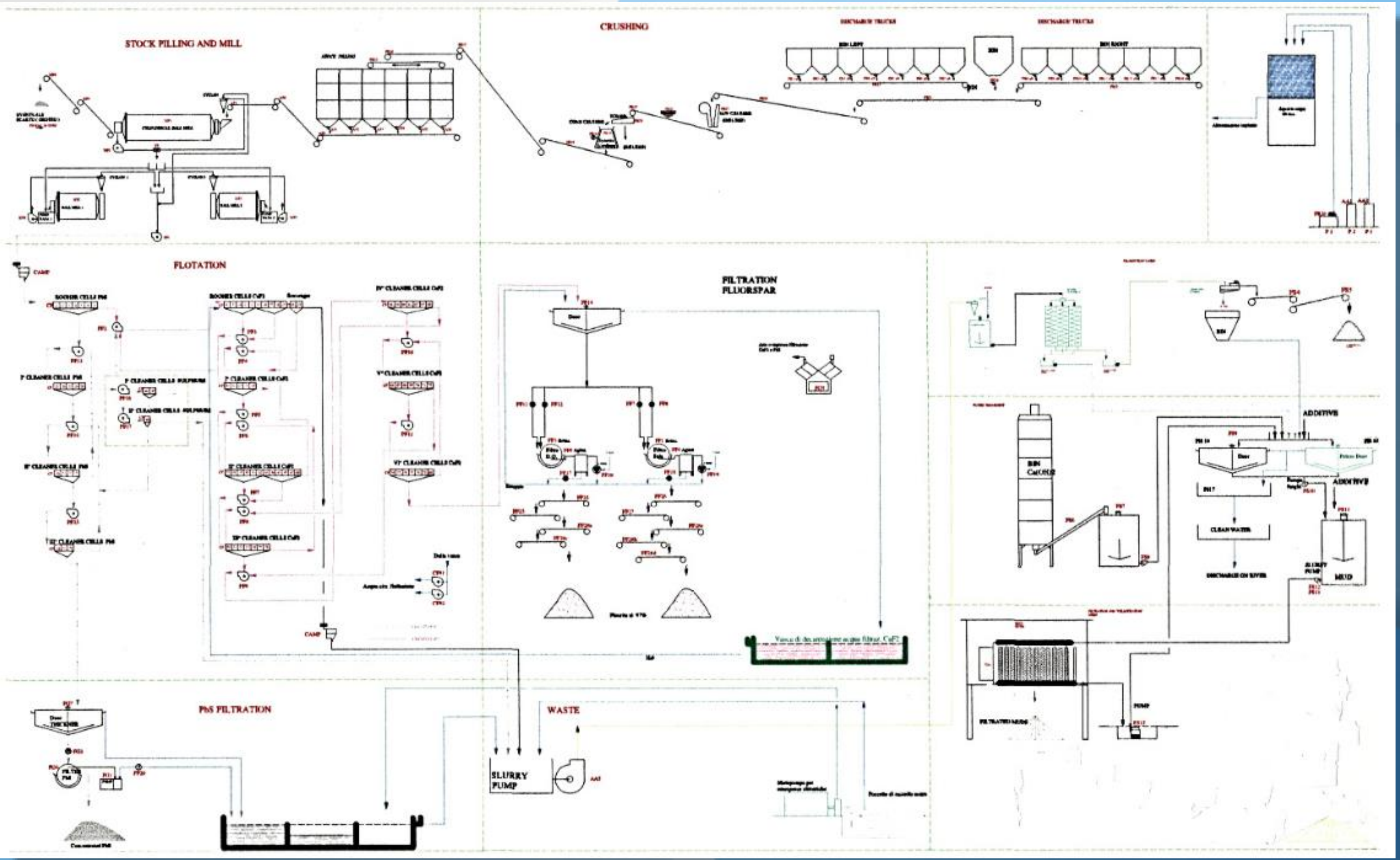
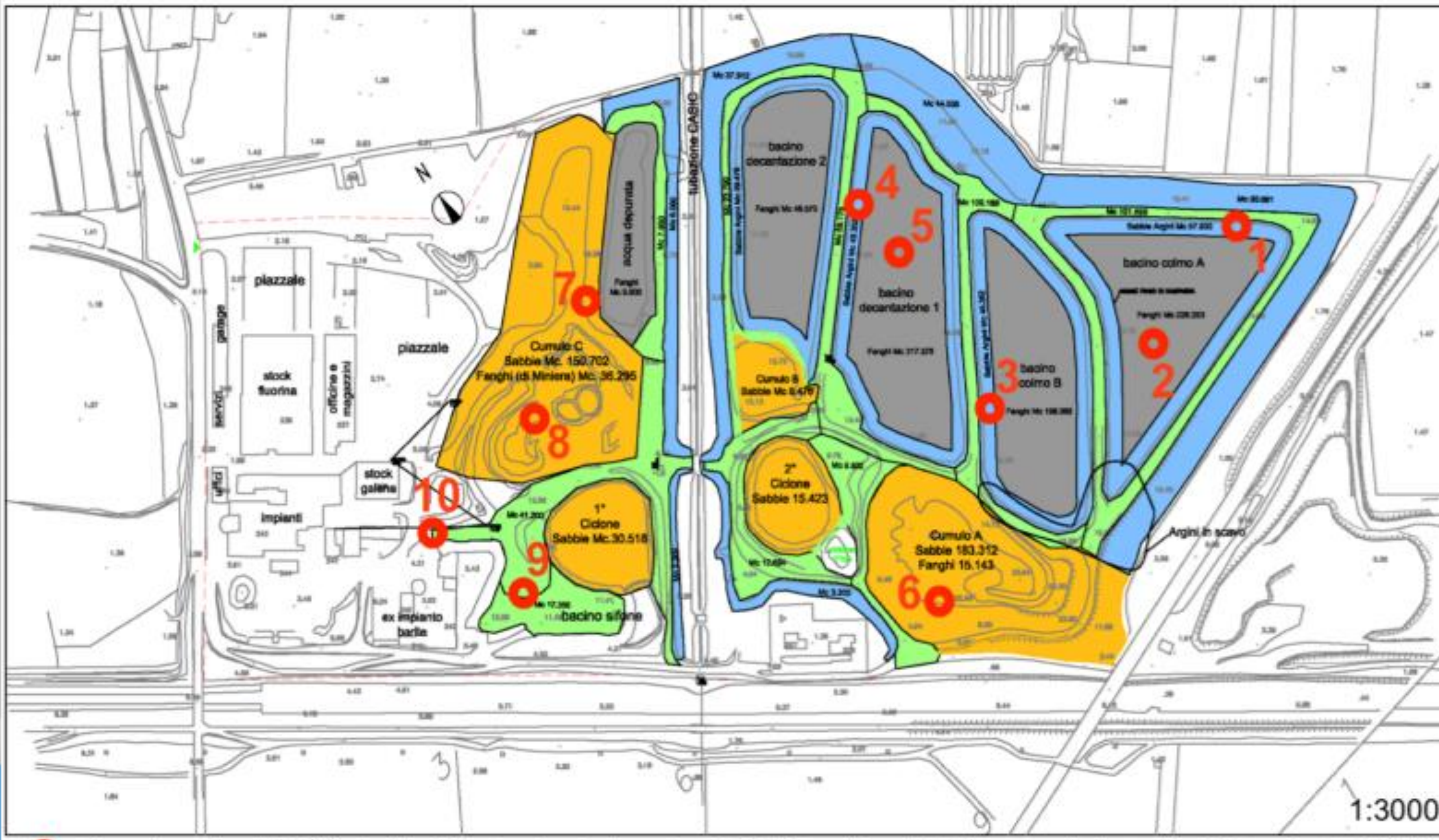
HISTORICAL TREATMENT PROCESS - PRECONCENTRATION

HISTORICAL TREATMENT PROCESS - FLOTATION



SILIUS MINE

Historical treatment process - flotation



Sampling sites (#1 -10)	#1 - old basin no.1, embankment area (ref. B1A)
Sands	#2 - old basin no.1, central area (ref. B1C)
Muds	#3 - old basin no.2, embankment area (ref. B2A)
Embankments	#4 - old basin no.3, embankment area (ref. B3A)
Lanes	#5 - old basin no.3, central area (ref. B3C)

#6 - material storage sampled beyond the "Pedemontana" (ref. D1P)
#7 - new sand bank, perimetrical area (ref. SN1)
#8 - new sand bank, central area (ref. SN2)
#9 - muds from the Silius sink float (ref. SF1)
#10 - milling gravel (ref. Br1)

SILIUS MINE

HISTORICAL TREATMENT PROCESS - FLOTATION

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SILIUS MINE

Historical treatment process - flotation

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NEW TREATMENT PROCESS - PRECONCENTRATION

UPGRADES

- **Wet screening at plant feeding, incl. new screen (8 mm mesh), water sprayers, thickening cochlea after sieve**
- **Dynamic separator (suitable for highly implicated ores)**
- **Filterpress for muds dewatering (better management of silts rich in fluorspar, lower losses due to liquid muds)**
- **Mixing plant at mine site to reach optimal blend of coarse and fine wastes (and eventual additives) for landfills**
- **Recycling of process waters (closed circuit) and fully new water treatment plant**
- **Missing underground landfill volumes from quarries' wastes, uploaded along the trucks path back to mine**

RESULTS

- **Recovering additional fluorspar (improved separation due to effective screening, higher CaF_2 recovery from filterpressed muds)**
- **Obtaining cleaner product (less quartz and carbonates in preconcentrated stocks, bound to flotation. i.e. up to 50-52% CaF_2 grade in preconcentrated product)**
- **Obtaining cleaner waste (lower CaF_2 and PbS grade in float wastes)**
- **Reducing flotation volumes (up to 40% sink float wastes out of TV, i.e. + 9% material for underground landfills and - 9% payload to flotation)**
- **No need for desilting basins at mine site (i.e. no need for land occupation and reclamation)**
- **Saving use of freshwater (just integration of water losses due to humidity of preconcentrated ore)**
- **No need for new quarries to match the landfill volume balance**

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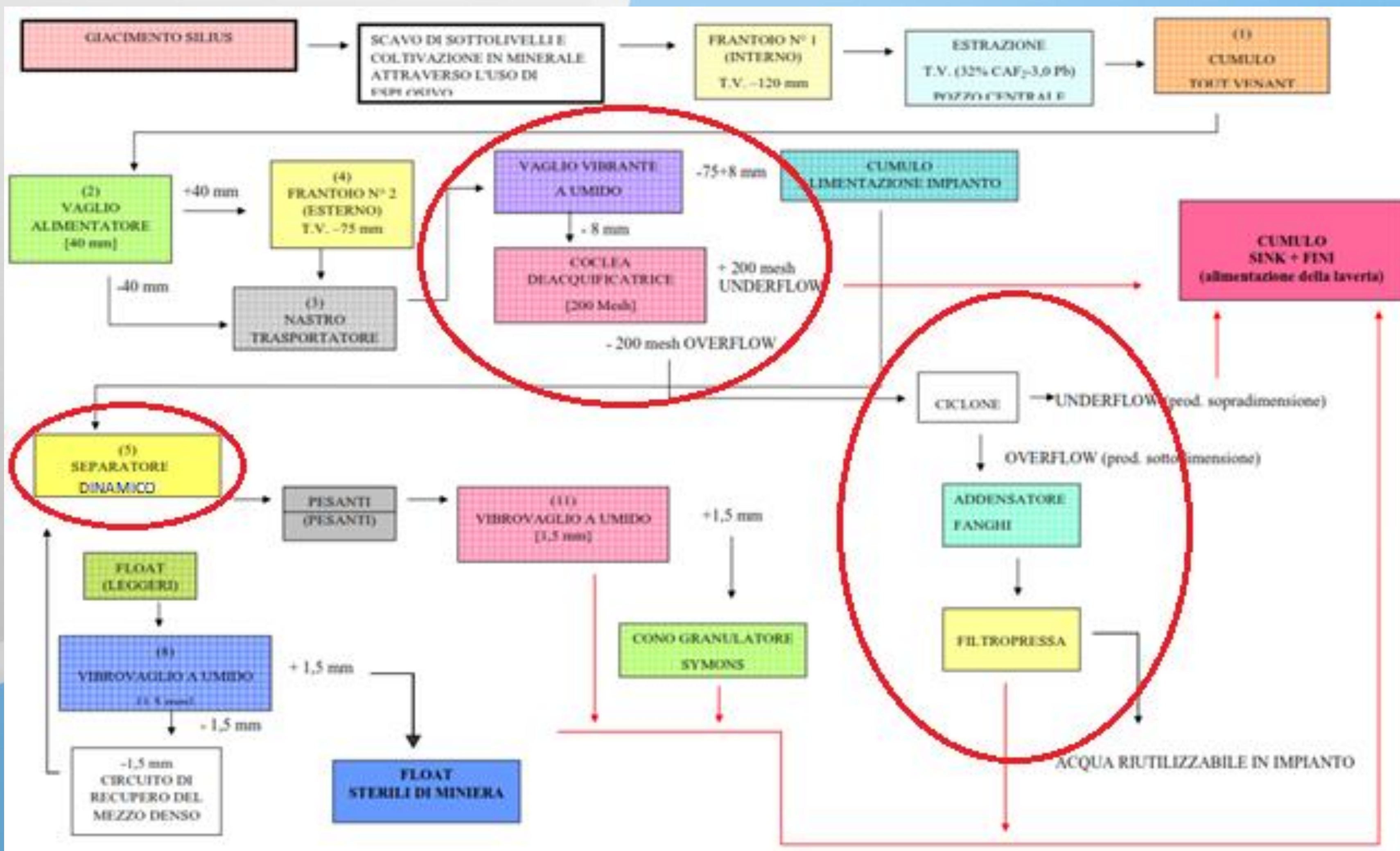
NEW TREATMENT PROCESS - PRECONCENTRATION



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NEW TREATMENT PROCESS - FLOTATION

UPGRADES

- **Flotation plant at mine site, integrated with preconcentration plant**
- **Fully automated 4.0 plant, powered by newly installed wind and solar plants with storage facilities**
- **Additional treatment downstream of first PbS circuit**
- **Additional thickening and dewatering circuit for Dorr overflows**
- **Slurry conditioning plant moved on top of the process**
- **Substitution of usual chemical reagents with new biodegradable additives**
- **Installation of pilot plant for REE recovery from mining waste**

RESULTS

- **Recovering additional PbS (from rejection of first galena circuit)**
- **Recovering additional CaF_2 (from Dorr overflow thickening process)**
- **Recovering process waters (from Dorr overflow dewatering process)**
- **Saving reagents (due to more efficient slurry conditioning and to Dorr overflow thickening process)**
- **Saving energy (due to digital controlling of the process and to higher plant efficiency)**
- **No need for waste disposal at mine site (full re-use of mining wastes for underground landfills)**
- **Integrated multilevel modular design of preconcentration/flotation plant at mine site, with no land consumption and neglectible environmental impact**
- **Huge potential for REE recovery**

MINERARIA GERREI

SILIUS MINE

NEW TREATMENT PROCESS - FLOTATION

NEW TREATMENT PROCESS - INNOVATION

FOCUS

- Silius mine restart project answers to growing issues for lower environmental impact of mining activities
- Licensed project provides:
  - Improvement of ore exploitment (maximization of fluorspar recovery, according to EU CRM directives)
  - Reduced use of natural resources (water, land, etc.)
  - Full electrification of mine operation (no air pollution, no emission of climate-harming gases, limited needs for underground forced ventilation, energy saving)
  - Mine powering through installation of dedicated RES power plants, with proper energy storage facilities in order to reach full self consumption layout
  - Full automation and digitalization of mining process
  - Full re-use of mining process byproducts (cancelling the word ‘waste’ from the mining cycle)

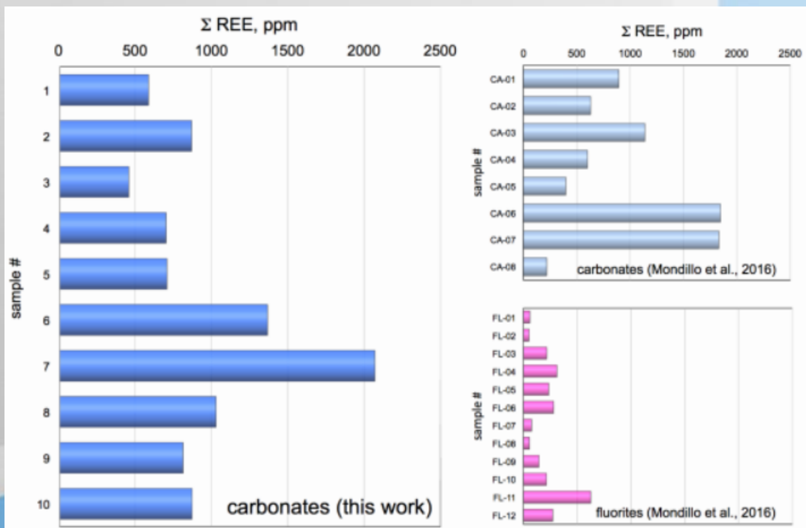
AWARDS

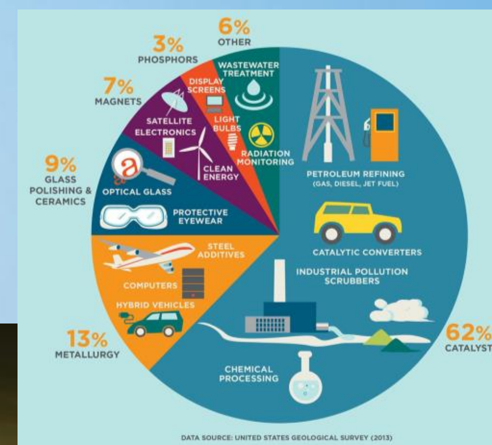
- Due to its highly innovative approach, Silius project has been acknowledged as suitable for PNRR funding
- Funding on both industrial and environmental lines is under evaluation (the former related to CRM exploitation and to automated mining process, the latter related to environmental footprint and circular economy)

MINERARIA GERREI

Reserves – REE Rare Earth Elements

- **Extensive studies and analysis performed by University of Naples over the last 10 years**
- **Veins gangue carbonates (calcite and ferroan dolomite) contain REE-minerals synchysite-(Ce) and xenotime**
- **The fluorocarbonate synchysite-(Ce) [formula $Ca_{1.07}(La_{0.19},Ce_{0.36},Pr_{0.04},Nd_{0.15},Sm_{0.03},Gd_{0.03},Y_{0.13})(CO_3)_2F$] is the most common REE mineral**
- **Concentrations range between 462 and 2,071 ppm (951 ppm on average), mainly consisting of LREE**
- **1220 tons of pure REE can be obtained through primary or secondary mining processes**
- **Re-treatment of old dumps for REE exploitation may lead to recovery of residual fluorspar amounts and additional material for underground landfill**





MINERARIA GERREI

Thank you
and
KEEP MINING !