

Tierras Raras en Residuos Mineros

Preparado por Rolando Jeria, P.Eng – ThreeDify

Abril 11, 2023

Taller Minerales Estratégicos
Comisión Minera Chile

Objetivos

1. ESG y Tierras Raras, Elementos Estratégicos
2. Compromiso de Sustentabilidad
3. Circularidad en Ripios; Relaves
4. Casos
5. Links relacionados
6. Conclusiones

ESG y Tierras Raras, Elementos Estratégicos

ESG; Tabla Periódica; Visión General

ESG

Environmental

Waste & Pollution Resource Depletion
Greenhouse Gas Emission Deforestation
Climate Change

Social

Employee Relations & Diversity
Working Conditions Local Communities
Health & Safety Conflict

Governance

Tax Strategy Executive Remuneration
Donations & Political Lobbying
Corruption & Bribery Board Diversity & Structure

The 32 Responsible Minerals Initiative principles:

1. Legal Compliance
2. Business Integrity
3. Stakeholder Engagement
4. Business Relationships
5. Child Labor
6. Forced Labor
7. Freedom of Association and Collective Bargaining
8. Discrimination and Harassment
9. Gender Equality
10. Working Hours
11. Remuneration
12. Occupational Health and Safety
13. Employee Grievance Mechanism
14. Environmental Risk Management
15. Greenhouse Gas (GHG) Emissions
16. Energy Consumption
17. Freshwater Management and Conservation
18. Waste Management
19. Tailings Management
20. Pollution
21. Biodiversity and Protected Areas
22. Mine Closure and Reclamation
23. Community Health and Safety
24. Community Development
25. Artisanal and Small-Scale Mining
26. Human Rights
27. Security and Human Rights
28. Indigenous Peoples' Rights
29. Land Acquisition and Resettlement
30. Cultural Heritage
31. Due Diligence in Mineral Supply Chains
32. Transparency and Disclosure

Tabla Periodica de los Elementos

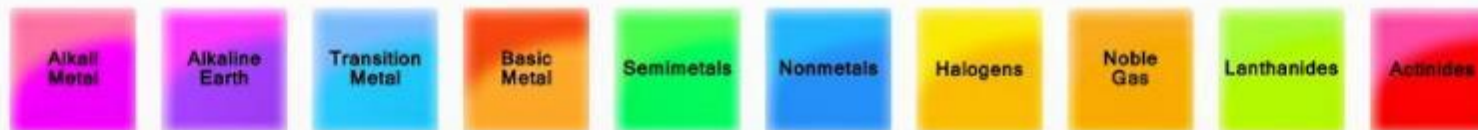
1 IA H Hydrogen 1.0079	2 IIA He Helium 4.00260											13 III A B Boron 10.811	14 IV A C Carbon 12.011	15 V A N Nitrogen 14.00674	16 VI A O Oxygen 15.9994	17 VII A F Fluorine 18.998403	18 VIII A Ne Neon 20.1797
3 Li Lithium 6.941	4 Be Beryllium 9.01218											5 Al Aluminum 26.981539	6 Si Silicon 28.0856	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989768	12 Mg Magnesium 24.305	3 III B	4 IV B	5 V B	6 VI B	7 VII B	VIII B			11 IB	12 IIB	13 Al Aluminum 26.981539	14 Si Silicon 28.0856	15 P Phosphorus 30.973762	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.95591	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938	26 Fe Iron 55.847	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9072	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium [208.9824]	85 At Astatine 209.9871	86 Rn Radon 222.0176
87 Fr Francium 223.0197	88 Ra Radium 226.0254	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Uuq Ununquadium [289]	115 Uup Ununpentium unknown	116 Uuh Ununhexium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Serie de Lantanidos

57 La Lanthanum 138.9055	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.9655	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
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Serie de Actinidos

89 Ac Actinium 227.0278	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium 237.0482	94 Pu Plutonium 244.0842	95 Am Americium 243.0614	96 Cm Curium 247.0703	97 Bk Berkelium 247.0703	98 Cf Californium 251.0796	99 Es Einsteinium [254]	100 Fm Fermium 257.0951	101 Md Mendelevium 258.1	102 No Nobelium 259.1009	103 Lr Lawrencium [262]
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Visión general

- Grandes protagonistas de la transición energética:
 - Litio, grafito, cobalto, tierras raras, cobre, aluminio, níquel...
- Son esenciales para la creación de paneles solares, turbinas eólicas, vehículos eléctricos y el almacenamiento de energía y baterías que implica unas economías bajas en carbono que cumplan con las metas climáticas de los Acuerdos de París.
- Las tierras raras, muy relevantes en el sector de las energías renovables y en la economía digital.
- China — el mayor productor del mundo y con más de un tercio de las reservas conocidas.
- Brasil — segundo lugar.
- Estados Unidos importa el 80% de China.
- La demanda está al alza, en comparación con 2018:
 - Se estima que en el caso del litio, grafito y cobalto, se incrementará cerca de un 500% en 2050.
 - Cobre y aluminio aumentará aproximadamente un tercio y la de níquel, dos tercios, para 2040.
 - Las tierras raras (neodimio, disprosio...) para turbinas eólicas podría incrementarse entre 11 y 14 veces en 2050.

Compromiso de Sustentabilidad

Emision de Carbono; Inteligencia Artificial;
ODD 7 Energía limpia y asequible.



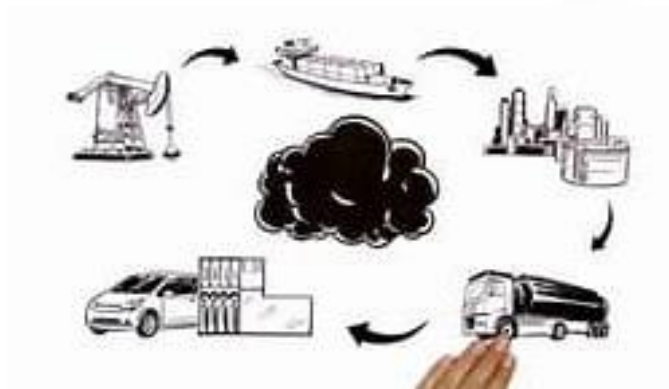
La huella de carbono

Inteligencia Artificial

ODS 7: Energía limpia y asequible

Sitio para calcular tu carbon footprint:

<https://www.carbonfootprint.com/calculator.aspx>



21 juillet 2021

Lever le pied pour sauver la planète

Réduire notre consommation d'énergie grâce aux transports intelligents.



7 septembre 2021

Respirons mieux pour la Journée internationale de l'air pur pour des ciels bleus

Les normes ISC contribuent à la santé de l'air et de la planète.



Minerales Críticos en Canadá

Mapa; Lista



Canada's Critical Minerals Map

Layers



Advanced projects



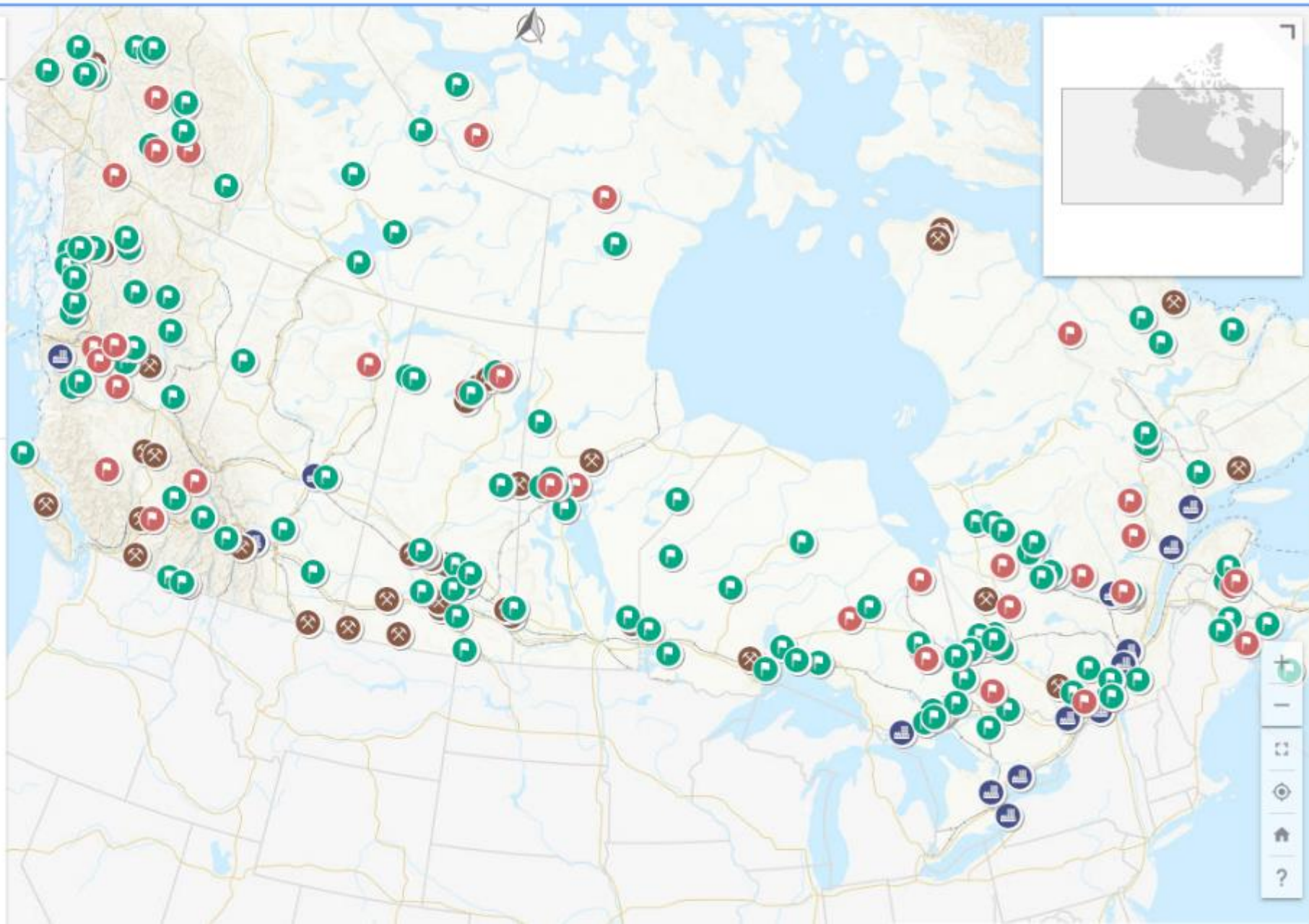
Mines



Processing facilities



Geology - major rock categories








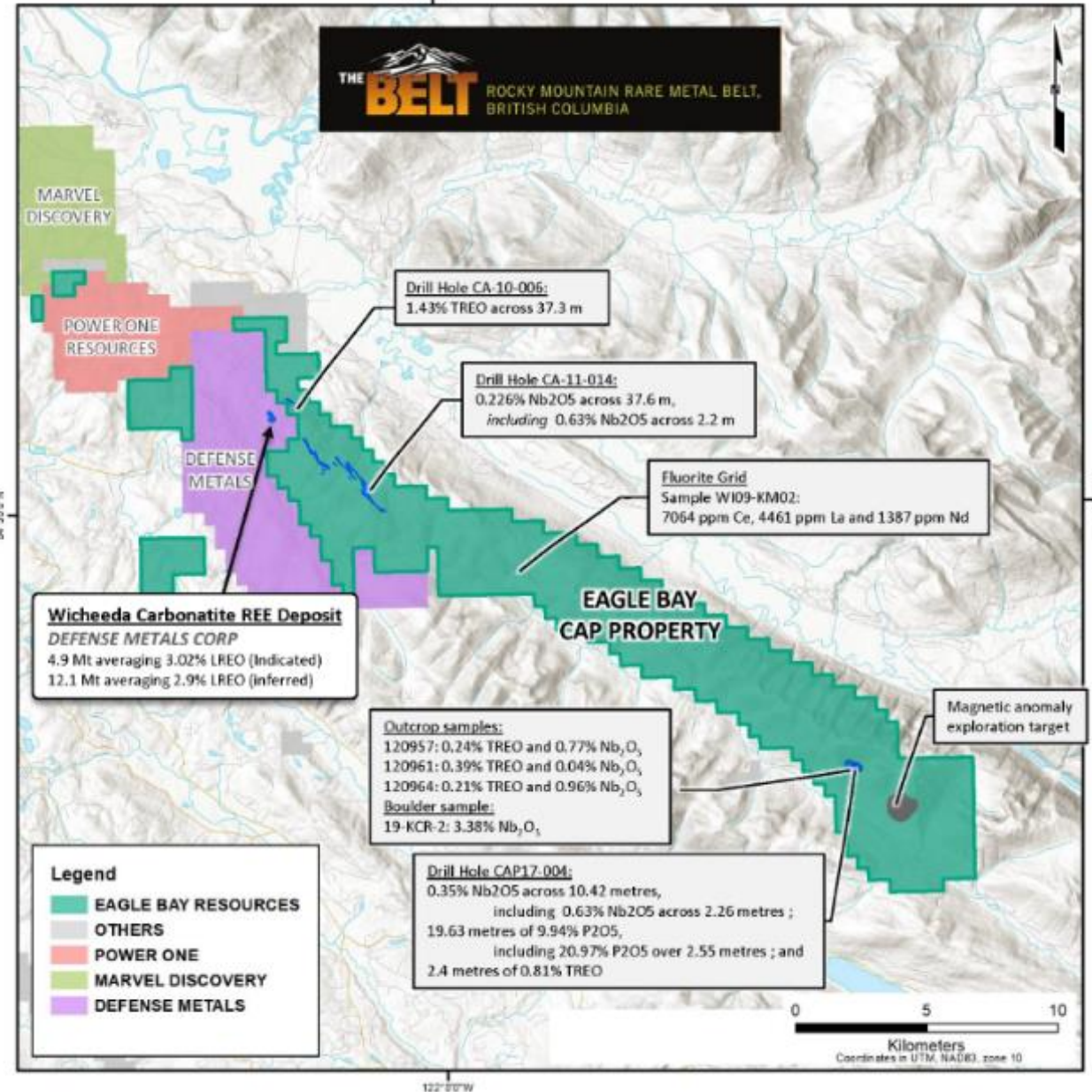
A person wearing a red backpack and a light blue shirt is standing on a rocky path next to a small waterfall. The surrounding area is filled with dense green foliage and trees. The sky is overcast with grey clouds. The overall scene is a natural, outdoor setting.

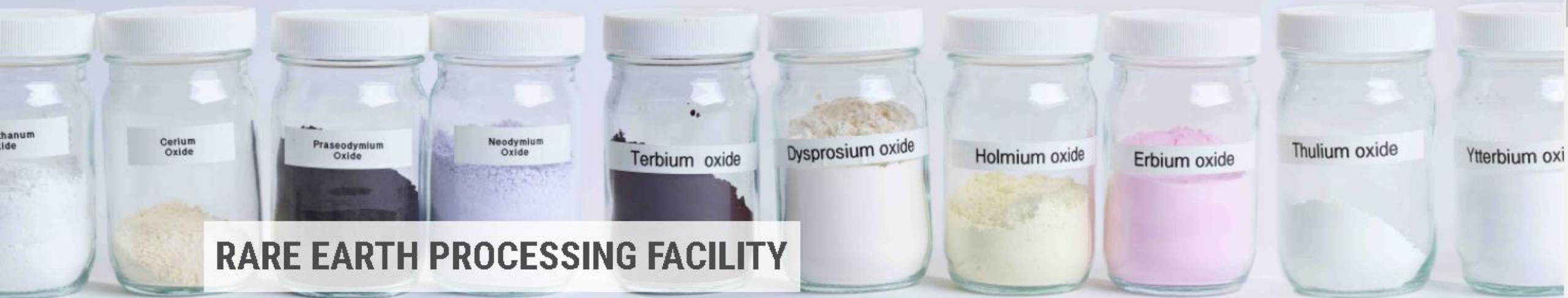
We Explore For Rare Earth Elements & Niobium.

Exploration is underway on its 100% owned Cap Property in Canada, focusing on REE & high-grade Niobium.

Property Location

-  85Km North East of Prince George, BC.
-  Accessible year round.
-  Project shows promise in both Niobium & REE with a focus on Niobium.
-  Wicheeda Carbonatite is REE dominant.
-  Located in proximity to larger resource companies (i.e. Marvel, Gambier, etc.).



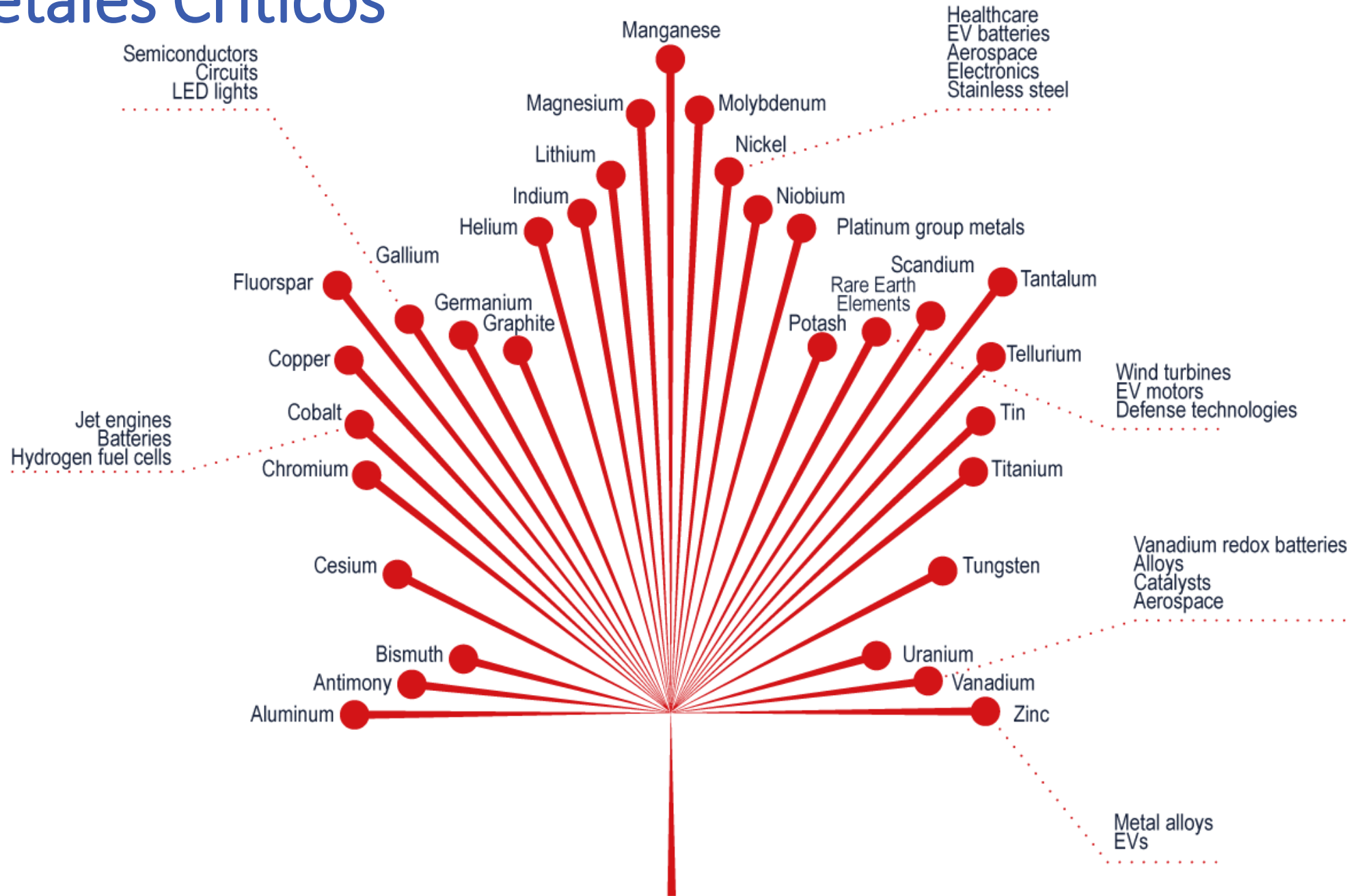


RARE EARTH PROCESSING FACILITY

CANADA'S FIRST RARE EARTH PROCESSING FACILITY

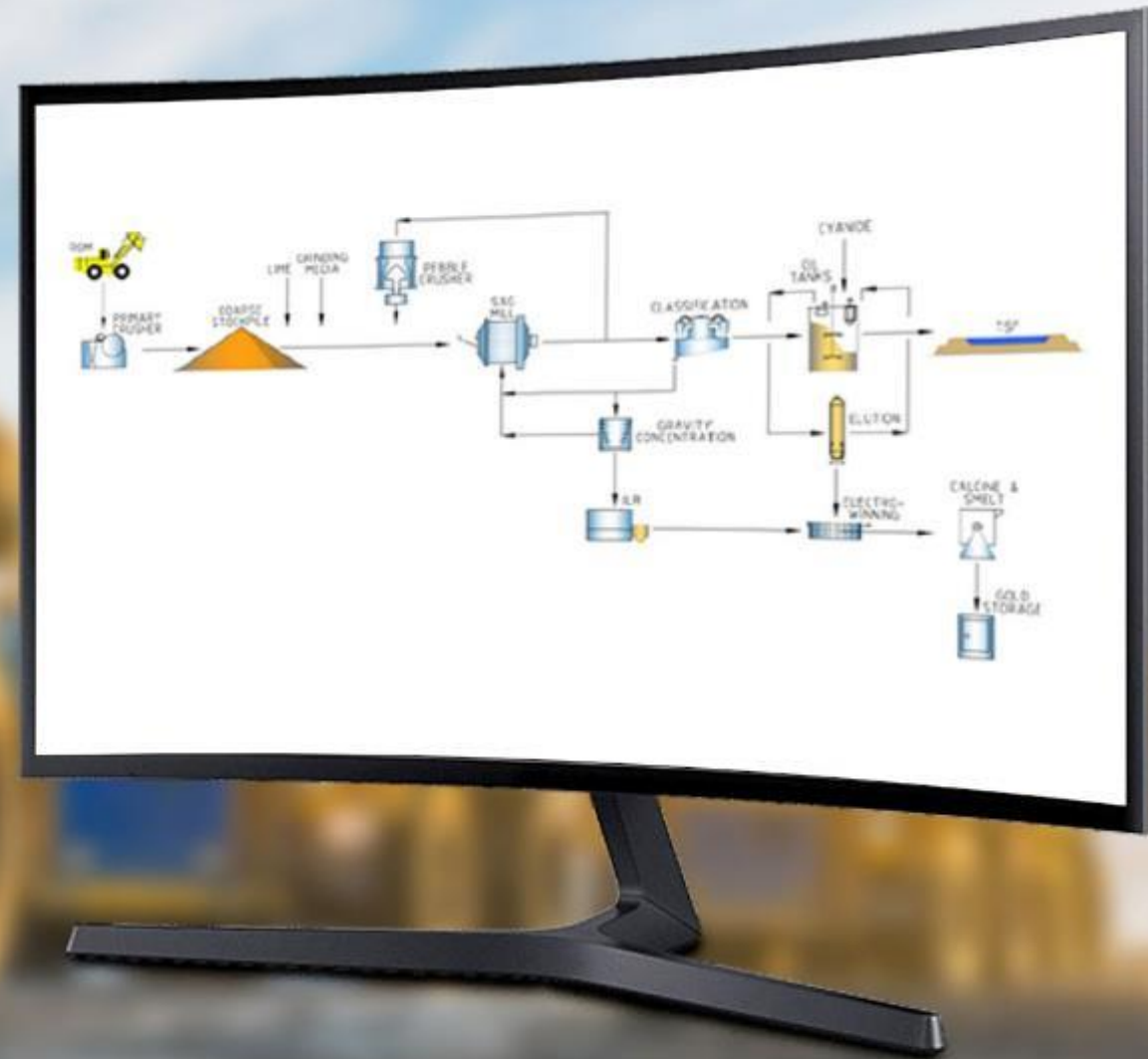
The Government of Saskatchewan and SRC are excited to announce the development of a Rare Earth Processing Facility - the first-of-its-kind in Canada - laying the foundation for a Rare Earth Element (REE) supply chain in Saskatchewan and forming an industry model for future commercial REE resource expansion in the province. [Read the News Release](#).

Metales Críticos



Circularidad en Ripios; Relaves

Cobre; Oro



OBTENCIÓN DEL COBRE

Óxidos

Minas

Sulfuros

Proceso Hidrometalúrgico

Chancado

Lixiviación

Ripios

Extracción por solventes

Electroobtención



Proceso Pirometalúrgico

Chancado

Molienda

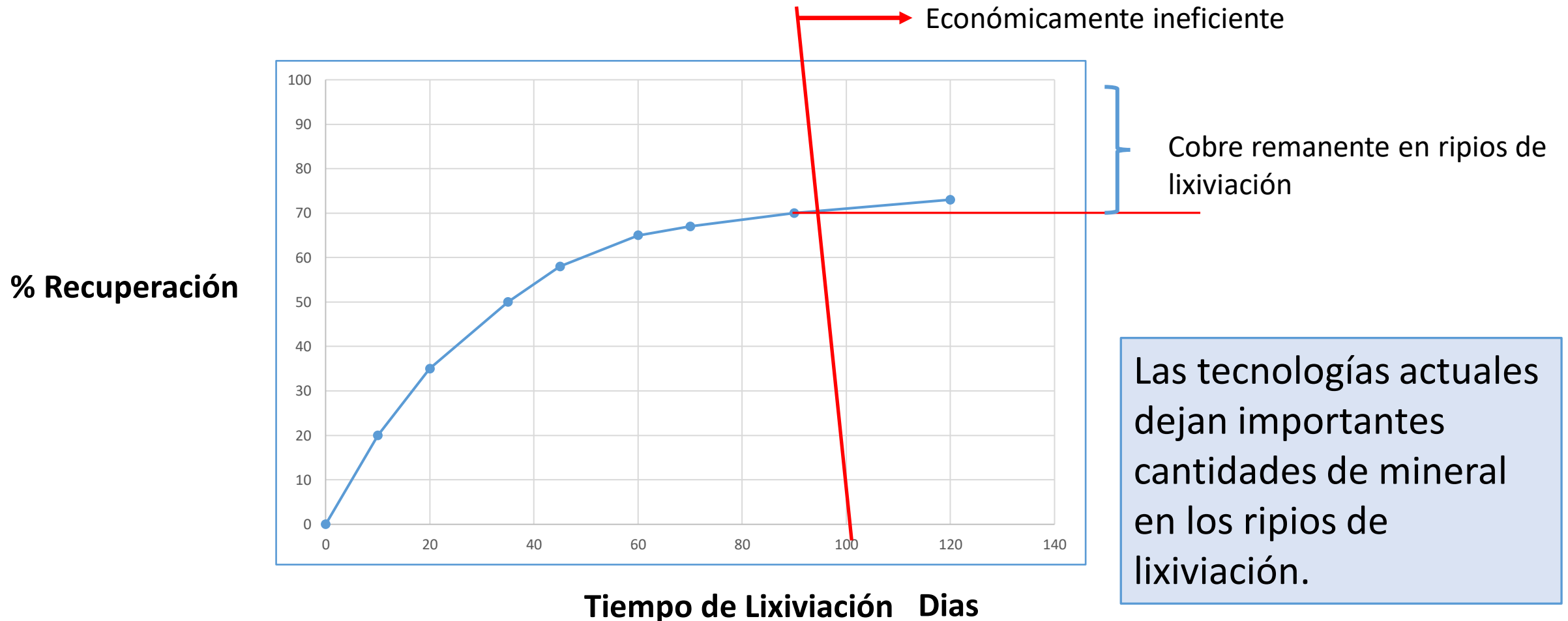
Flotación

Relaves

Fundición

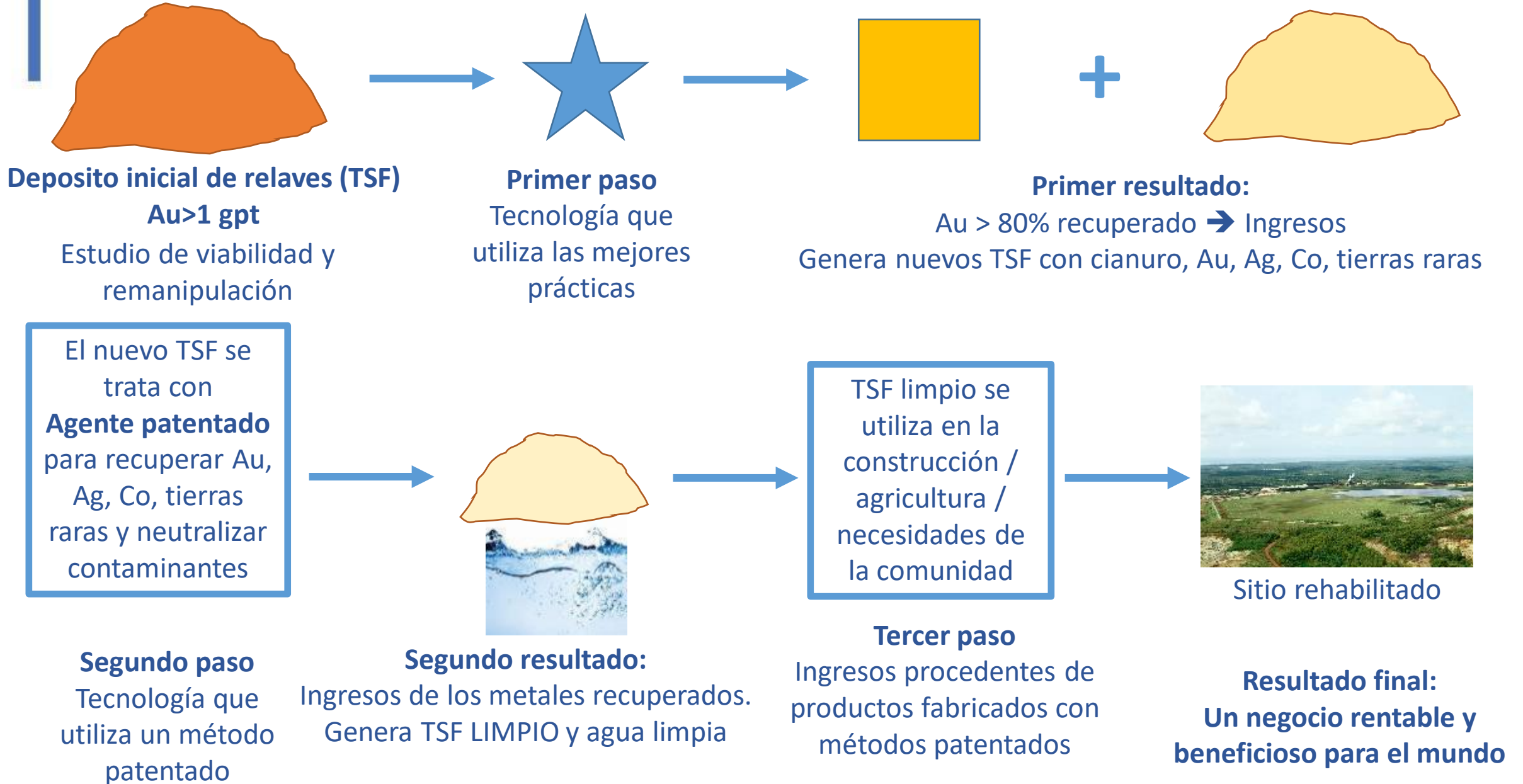
Refinación
Electrolítica

Los actuales procesos de Lixiviación para obtener Cobre, no son suficientemente eficientes



MINERÍA CIRCULAR SOSTENIBLE: Sí, podemos hacerlo

SECUENCIA



Casos

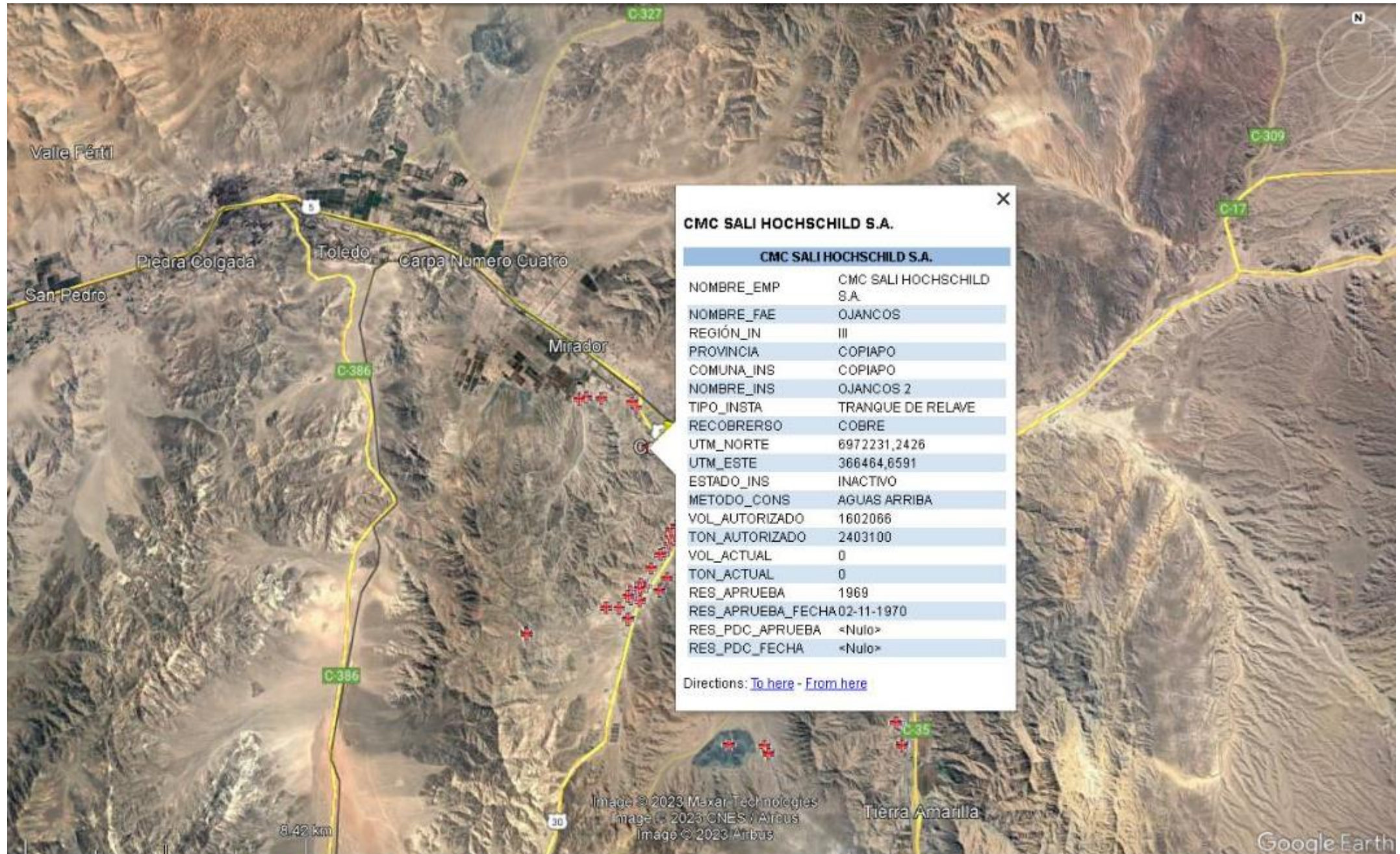
Chile

Manitoba, Canadá

Perú



Catastro Sernageomin de relaves Google Earth



Impacto del valor del contenido

<https://www.sernageomin.cl/datos-publicos-deposito-de-relaves/>

Usos de tierras raras en automóviles híbridos



Tierras Raras Livianas

	Y(g/t)	La(g/t)	Ce(g/t)	Pr(g/t)	Nd(g/t)	Sm(g/t)
	1	4.27	8.5	1.02	4.57	0.91
	1	2.49	6.44	0.83	3.56	0.78
	1	3.19	9.54	1.27	4.73	0.86
	25	5.85	15.05	2.06	8.14	2.08
Kg contenido	1001	860	2048	263	1098	237
USD/kg	7.39	2.86	2.01	106.19	97.34	2.45

Tierras Raras Pesadas

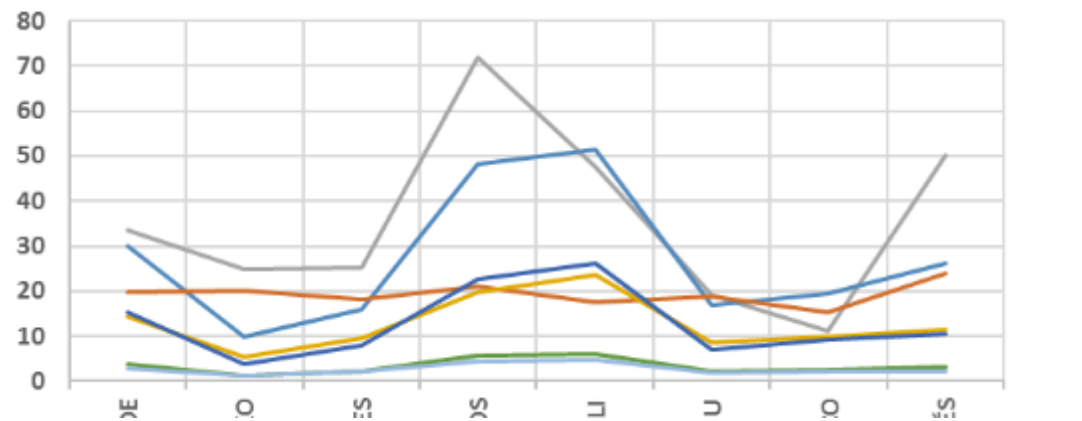
Eu(g/t)	Gd(g/t)	Tb(g/t)	Dy(g/t)	Ho(g/t)	Er(g/t)	Tm(g/t)	Yb(g/t)	Lu(g/t)
0.23	0.81	0.11	0.67	0.12	0.41	0.06	0.29	0.05
0.22	0.76	0.09	0.55	0.11	0.3	0.04	0.34	0.05
0.27	0.47	0.07	0.29	0.05	0.13	0.02	0.07	0.02
0.5	1.65	0.25	1.42	0.28	0.89	0.13	0.8	0.13
63	200	27	158	30	93	13	81	13
49.35	37.16	1,415.92	566.37	111.5	34.64	0	17.66	707.96

6,185 kg @ 49.31US/kg = 304,945 US\$

LEYES LEVANTAMIENTO GEOQUÍMICO RELAVES XXX

Fuente: Sernageomin, "Datos de Geoquímica de Depósitos de Relaves de Chile", enero 2020

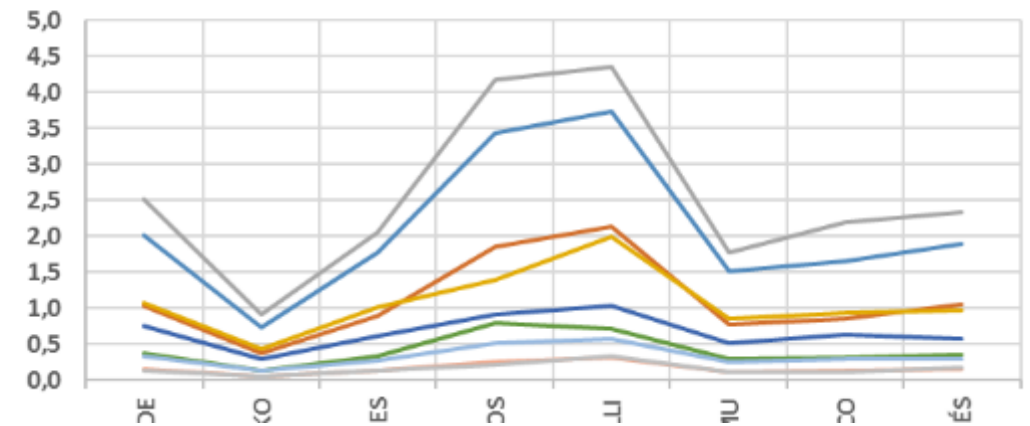
Tierras raras - livianas



RELAVE

— Y(g/t) — Ce(g/t) — Sc(g/t) — Nd(g/t) — La(g/t) — Pr(g/t) — Sm(g/t)

Tierras raras - pesadas



RELAVE

— Gd(g/t) — Dy(g/t) — Yb(g/t) — Er(g/t) — Eu(g/t)
 — Ho(g/t) — Tb(g/t) — Tm(g/t) — Lu(g/t)

Datos de documentos

Tierras Raras Livianas (Y, La, Ce, Pr, Nd, Sm)

Contenido 27.9 t

Valor contenido 124 MUS

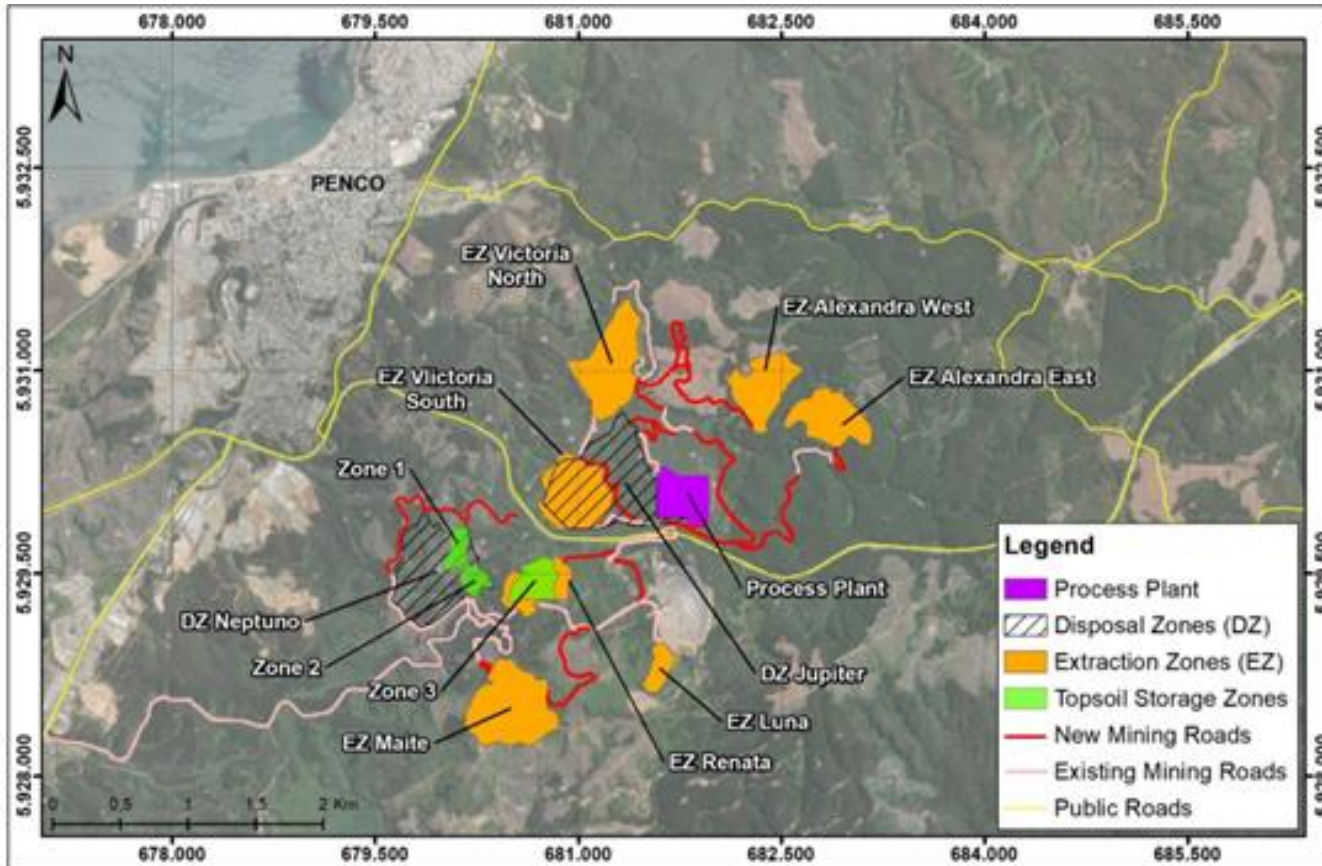
Tierras Raras Pesadas (Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)

Contenido 3.4 t

Valor contenido 188 MUS\$

Sample ID	Assay (ppm)						Method-Solid	Method-Liquid
	OR-0D	OR-0W	OR-1	OR-2	OR-3	OR-4		
RML Protoc	Dry	Slurry, no Poly	.005% Poly	.05% Poly	.5% Poly	1% Poly		SI
Sample Mass	15.0	75.0	75.0	75.0	75.0	75.0		
Au	1.96	NA	NA	NA	NA	NA	Fire Assay	NA
Ag	60	0.0001	0.0001	0.00006	0.0006	0.002	R1 (REE MS)	ICP-MS
Al	19112	0.630	1.414	2.112	3.372	2.515	ICP1 TD	ICP-MS
As	1390	0.249	0.376	0.357	0.460	0.587	R1 (REE MS)	ICP-MS
Ce	111	0.001	0.009	0.0008	0.001	0.013	R1 (REE MS)	ICP-MS
Co	29	0.001	0.002	0.003	0.004	0.005	R1 (REE MS)	ICP-MS
Cr	58	0.035	0.052	0.025	0.082	0.086	ICP1 TD	ICP-MS
Cu	1300	0.090	0.151	0.158	0.196	0.225	R1 (REE MS)	ICP-MS
Dy	7.2	0.00009	0.0001	0.00009	0.0001	0.0002	R1 (REE MS)	ICP-MS
Er	2.7	0.00004	0.00007	0.00007	0.00008	0.00008	R1 (REE MS)	ICP-MS
Eu	1.1	0.00004	0.00005	0.00005	0.00008	0.00006	R1 (REE MS)	ICP-MS
Fe	73500	4.263	4.459	5.257	10.031	10.381	ICP1 TD	ICP-MS
Gd	6.1	0.00008	0.00005	0.0001	0.0007	0.0002	R1 (REE MS)	ICP-MS
Ho	1.5	0.00002	0.00003	0.00003	0.00005	0.00005	R1 (REE MS)	ICP-MS
La	13	0.0003	0.0006	0.0002	0.0006	0.0004	R1 (REE MS)	ICP-MS
Lu	0.5	<0.001	<0.001	0.000006	0.00002	0.000008	R1 (REE MS)	ICP-MS
Mg	2533	4.914	5.801	8.930	9.485	9.672	ICP1 TD	ICP-MS
Mo	0.3	0.003	0.003	0.002	0.003	0.003	R1 (REE MS)	ICP-MS
Nd	33	0.0004	0.0007	0.0003	0.0006	0.0005	R1 (REE MS)	ICP-MS
Pb	44	0.006	0.005	0.006	0.007	0.008	ICP1 TD	ICP-MS
Pr	7.3	0.0002	0.0002	0.0002	0.0002	0.0002	R1 (REE MS)	ICP-MS
Sb	6.0	0.0003	0.0007	0.0006	0.0007	0.001	R1 (REE MS)	ICP-MS
Sc	6.0	0.0001	0.0005	0.0010	0.002	0.002	ICP1 TD	ICP-MS
Si	364933	4.93	4.77	6.00	10.79	7.59	ICP WR	Si on Liquid
Sm	7.1	0.0001	0.0001	0.00007	0.0006	0.0001	R1 (REE MS)	ICP-MS
Tb	1.2	0.00001	0.000009	0.000009	0.00002	0.00002	R1 (REE MS)	ICP-MS
Th	44	0.001	0.00004	0.00100	0.00001	0.0001	R1 (REE MS)	ICP-MS
Tm	0.5	0.00001	0.00001	0.00003	0.00002	0.00002	R1 (REE MS)	ICP-MS
Y	30	0.0005	0.0006	0.0007	0.0008	0.0009	R1 (REE MS)	ICP-MS
Yb	3.5	0.00003	0.00007	0.00007	0.0002	0.00008	R1 (REE MS)	ICP-MS
Zn	302	0.002	0.003	0.006	0.008	0.002	R1 (REE MS)	ICP-MS
Zr	21	0.0003	0.002	0.004	0.002	0.0004	R1 (REE MS)	ICP-MS

Aclara - Penco



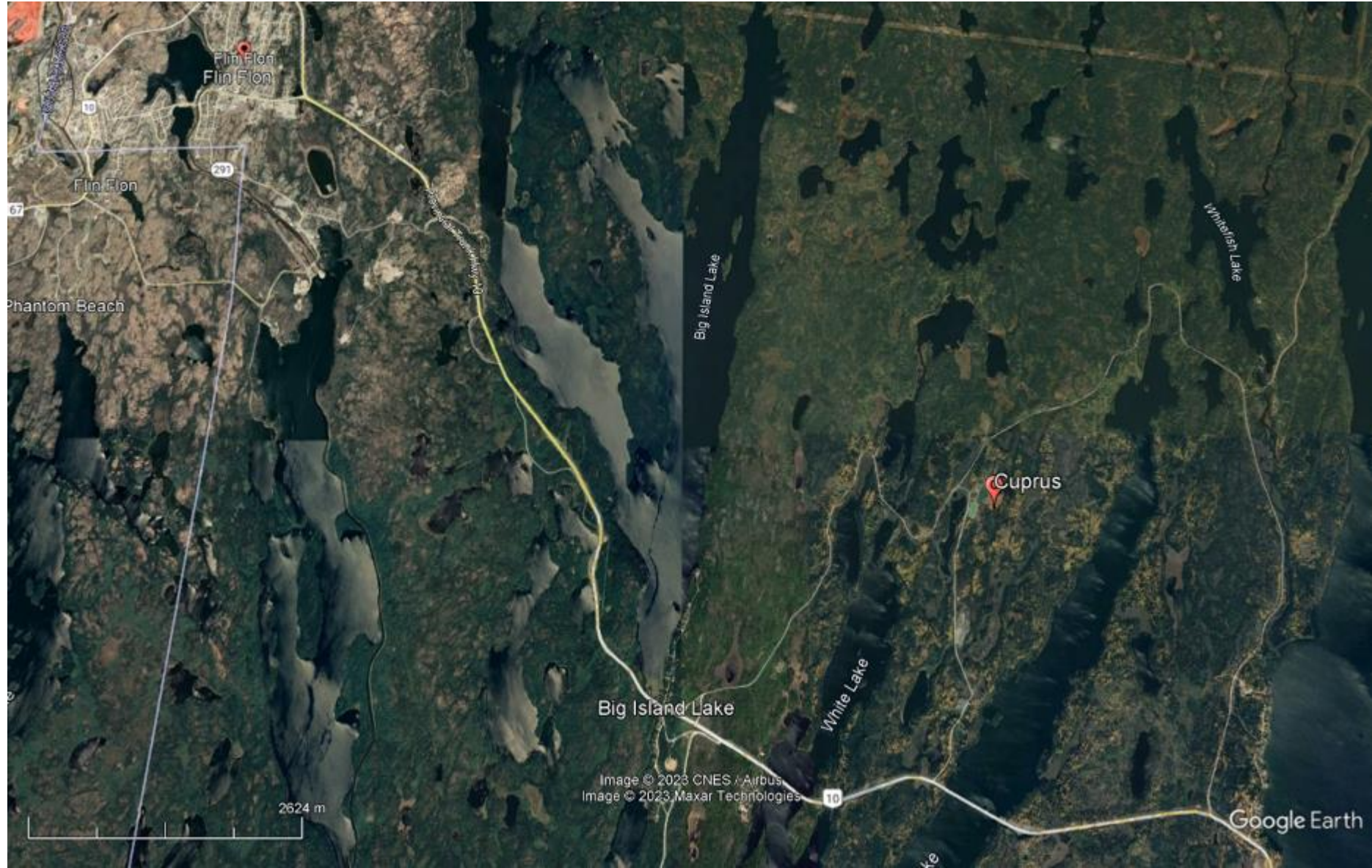
- Group 1: Heavy Rare Earth Elements (HREE)
 - o Dysprosium
 - o Terbium
 - o Lutetium
 - o Yttrium
 - o Gadolinium
 - o Erbium
 - o Holmium
 - o Ytterbium
 - o Thulium

- Group 2: Light Rare Earth Elements (LREE)
 - o Neodymium
 - o Praseodymium
 - o Lanthanum
 - o Samarium
 - o Cerium

Element	Leaching %	Plant Recovery %	Total Recovery %
REE Total	18.49	98.1	18.13

Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
356	338	682	74	319	53	3	52	9	62	13	39	6	35	5

Cerca de la ciudad de Flin Flon, Canadá



ICP mass

	ICP results	Ag	As	Ce	Co	Cu	Dy	Er	Eu	Gd	Hf	Ho
Date	Sample Typ											
10-14-2022	Standard	3.1	11.7	2220	7	17	123	68	17	107	9.6	29
10-14-2022	Solid	0.9	4160	8	31	532	1.4	1.1	0.3	0.8	2.6	0.2

La	Lu	Mo	Nd	Ni	Pr	Rb	Sb	Sm	Sn	Tb	Te	Th	Tm	Y	Yb
1320	7.9	0.7	670	12	223	205	<1	110	5.6	18	0.1	1030	12	708	62
4	0.1	16	5.2	113	1.1	8.7	96	1	204	0.1	3.4	0.79	0	11	0.8

Y(g/t)	La(g/t)	Ce(g/t)	Pr(g/t)	Nd(g/t)	Sm(g/t)	Eu(g/t)	Gd(g/t)	Tb(g/t)	Dy(g/t)	Ho(g/t)	Er(g/t)	Tm(g/t)	Yb(g/t)	Lu(g/t)
7.39	2.86	2.01	106.19	97.34	2.45	49.35	37.16	1,415.92	566.37	111.5	34.64	0.00	17.66	707.96

Datos de documentos

Tiene más de 450 kt para ser reprocesado. Las siguientes cifras son del informe de alimentación del molino.

Tonnes	% Cu	% Zn	g. Au/ton	g. Ag/ton
462,002	3.24	6.42	1.365	28.688

Period	0	1	2	3	4	5	Total
Production		9,000	90,000	180,000	142,835		421,835
Income	-	211,531	2,115,311	4,230,622	3,357,122	-	9,914,586
CAPEX	566,950						566,950
OPEX	-	130,820	1,308,196	2,616,392	2,076,183	-	6,131,591
Profit Other 1USD/t		9,000	90,000	180,000	142,835	-	421,835
Cash Flow BT	(566,950)	89,711	897,115	1,794,230	1,423,774	-	3,637,880
Taxes (27%)		24,222	242,221	484,442	384,419	-	1,135,304
Cash Flow AT	(566,950)	65,489	654,894	1,309,788	1,039,355	-	2,502,576
NPV @	12%	\$1,434,295		IRR	102%		

Tests de efluentes, Mina en Perú



PRODUCTOS	CONCENTRACIÓN POR FLOTACIÓN				SUELO PARA SUELO EXTRACTIVO				PESADOS			
	Ba (ppm)	Cd (ppm)	Hg (ppm)	Pb (ppm)	Ba (ppm)	Cd (ppm)	Hg (ppm)	Pb (ppm)	Ba (%)	Cd (%)	Hg (%)	Pb (%)
CABEZA 1	16	1	3	110	2000	22	24	1200	100.00	100.00	100.00	100.00
CONCENTRADO	23	1	8	189					28.72	21.02	50.96	40.87
MEDIOS	19	1	3	224					6.11	4.89	7.16	15.04
RELAVE	15	1	2	65					65.17	74.09	41.88	44.09
CABEZA	16.000	1.000	3.000	110.000					100.00	100.00	100.00	100.00
CONCENTRADO	16.393	1.000	4.849	229.302					13.37	17.69	19.7	12.62
MEDIOS	12.271	1.000	2.091	122.417					7.87	14.65	7.21	5.26
RELAVE	24.641	1.000	4.618	378.651					78.76	67.66	73.09	82.12
CABEZA	16.000	1.000	3.000	110.000					100.00	100.00	100.00	100.00
CONCENTRADO	34.000	1.000	3.000	380.000					7.44	4.54	6.51	6.75
MEDIOS	27.000	1.000	5.000	416.000					2.2	1.64	4	2.73
RELAVE	20.000	1.000	2.000	247.000					90.36	93.82	89.49	90.52
CABEZA	16.000	1.000	3.000	110.000	100.00	100.00	100.00	100.00				
CONCENTRADO	35.000	1.000	4.000	445.000	6.93	4.09	7.66	8.00				
MEDIOS	22.000	1.000	3.000	267.000	6.10	5.56	8.12	6.80				
CONCENTRADO	18.000	1.000	2.000	204.000	2.53	2.80	2.80	2.64				

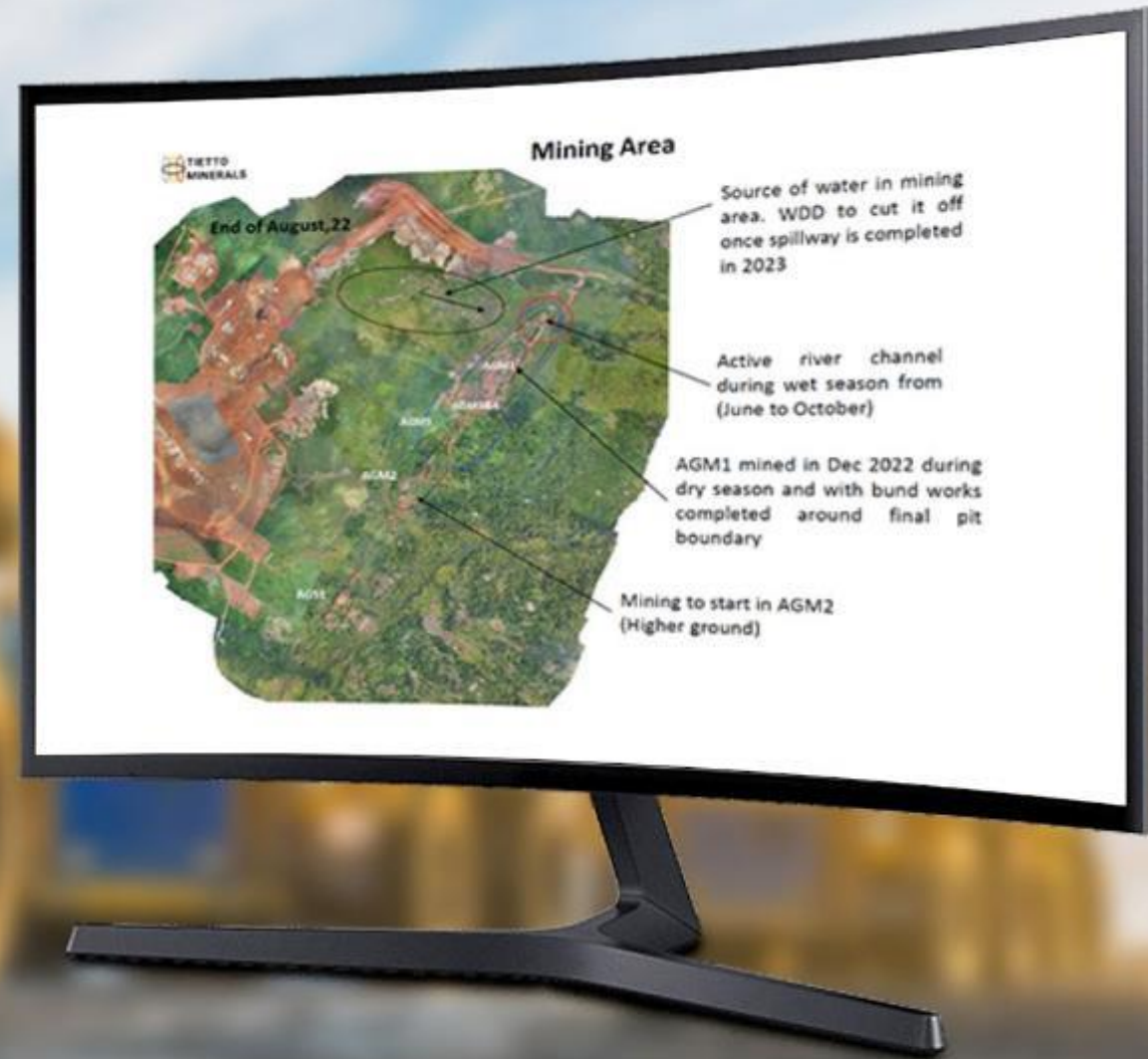
Fabricación ladrillos Eco-Tecnológicos



PROBETA DE LADRILLO	TIPO DE CEMENTO PORTLAND	NÚMERO DE DÍAS DE CURACIÓN	RESISTENCIA A LA COMPRESIÓN (Kg/cm ²)	RESISTENCIA A LA COMPRESIÓN SEGÚN NTP (Kg/cm ²)
CI-07	I	7	148.97	145.00
CI-14	I	14	270.00	
CI-28	I	28	399.00	

Links relacionados

Compañías involucradas en tierras raras



Sitio web de Compañías RE

Canada

[Insight R&D \(insight-rnd.com\)](http://insight-rnd.com)

www.cannorth.com

www.processortech.com

www.continental-carbon.com

www.xps.ca

<https://eaglebayresources.com/>

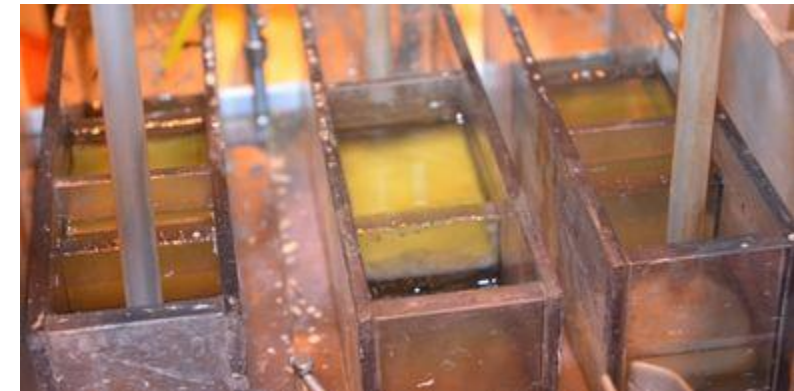
Chile

<https://www.aclara-re.com/>

Otros

www.mplaninternational.com

www.ionicre.com.au



Conclusiones

RE Sí se puede

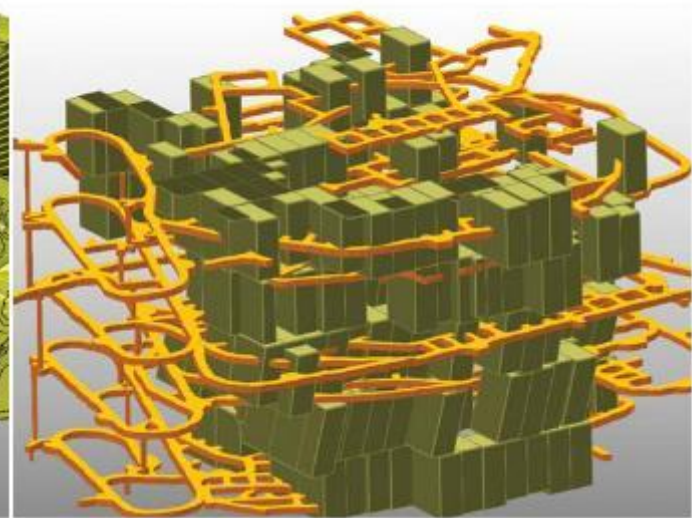
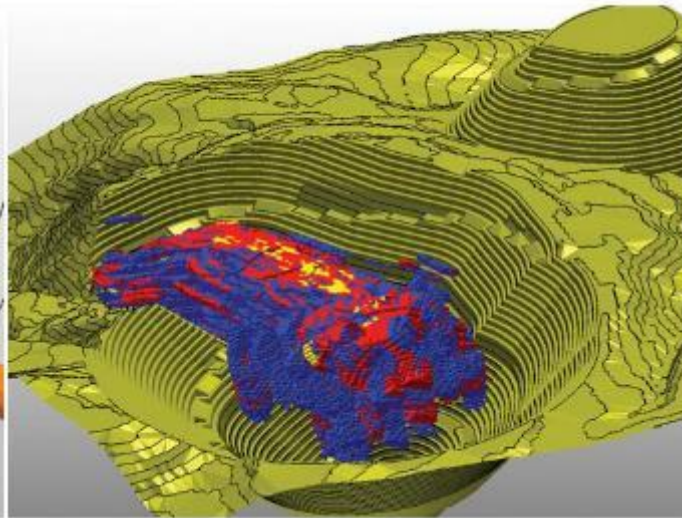
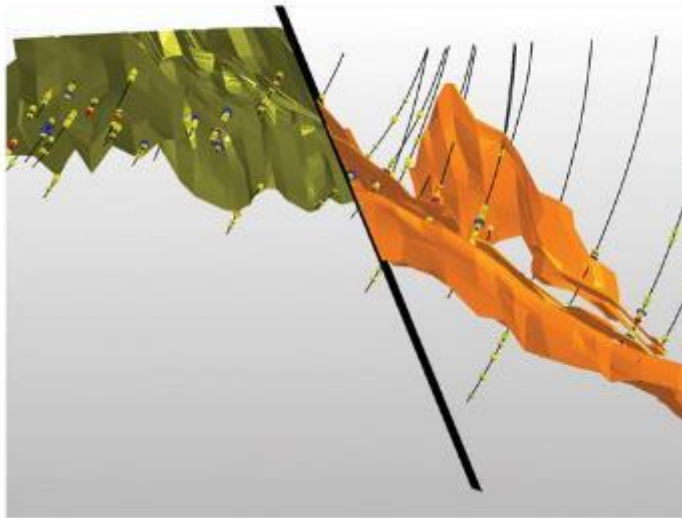


RE Sí se puede

- Todos los relaves tienen tierras raras (en ppm = gpt).
- Existen metodologías para recuperación selectiva de metales/minerales.
- El valor de venta es Elevado. Ejemplo el Cesio (Cs) en 2020 estaba a 9,670 Eur/gramo!!! (<https://www.scrapmonster.com/metal-prices/high-purity-metals/cesium/1033>)
- Rodhium 93,600 Eur/gramo.
- Hafnium 1,000 Eur/gramo.
- Oro a 1,800 USD/oz ==> 55 Eur/gramo

Las pruebas piloto de Manitoba, Chile ayudarán a despegar este negocio minero ignorado por la industria minera hasta ahora!!! **Y ESTAMOS LISTOS.....**

PARA AYUDAR A LIMPIAR EL PLANETA



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Muchas Gracias



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