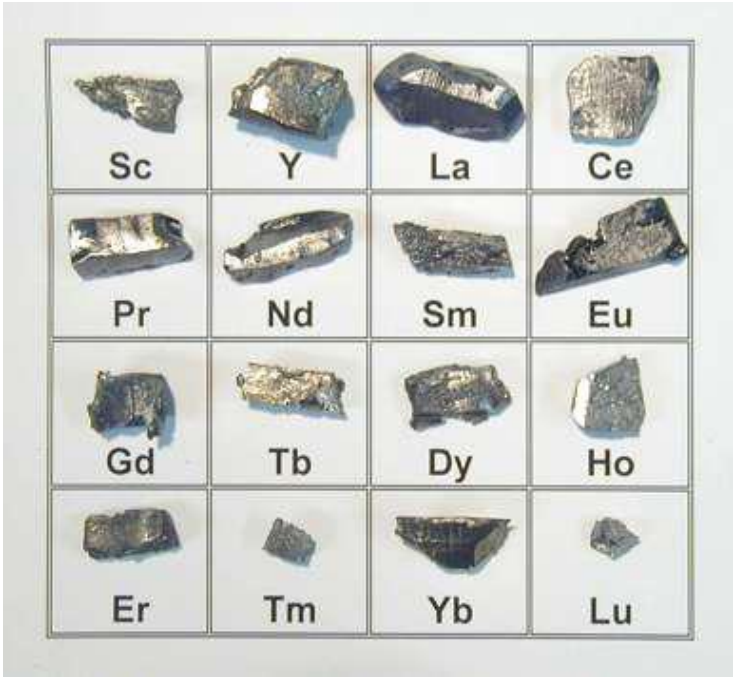
REE in world economy, the relation of REE and bauxite residues (BR's), and a new technical procedure to separate the REE's



DMT

DMT GmbH & Co. KG

EurGeol. Dr. Hartwig Gielisch

Student Workshop Ježevići l 15th October 2019

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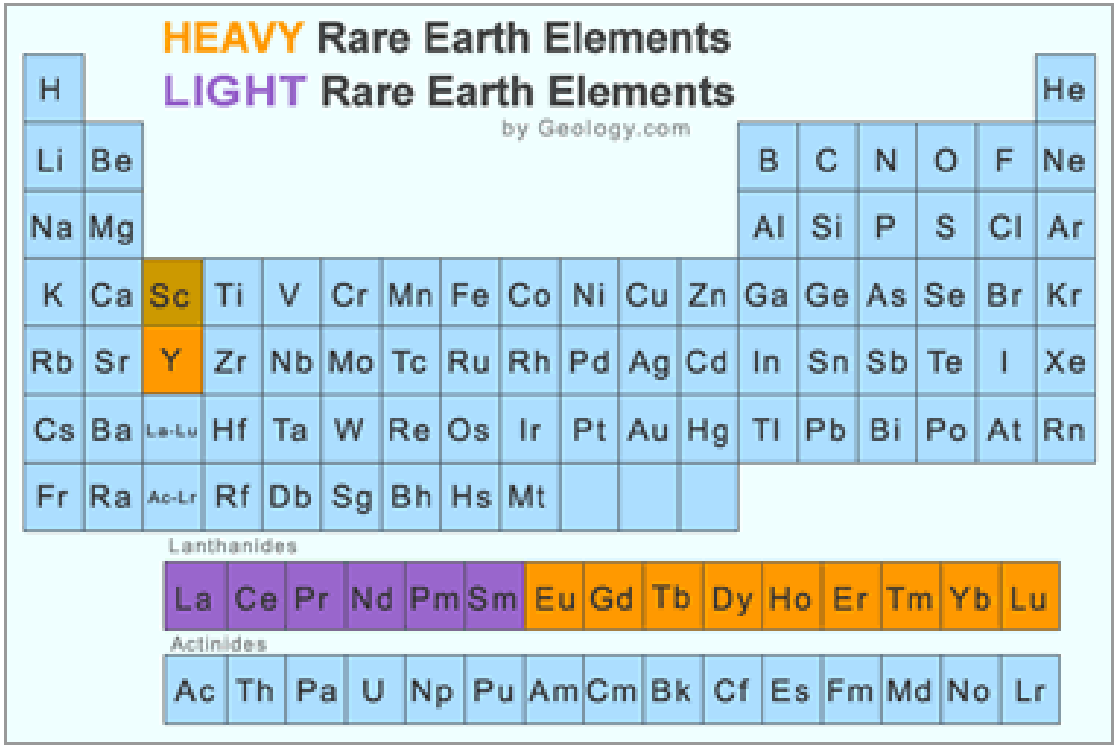
Rare-Earth Elements



- RE = rare earth
- REM = rare-earth metals
- REE = rare-earth elements
- REO = rare-earth oxides
- REY = rare-earth elements and yttrium
- LREE = light rare-earth elements
- HREE = heavy rare-earth elements

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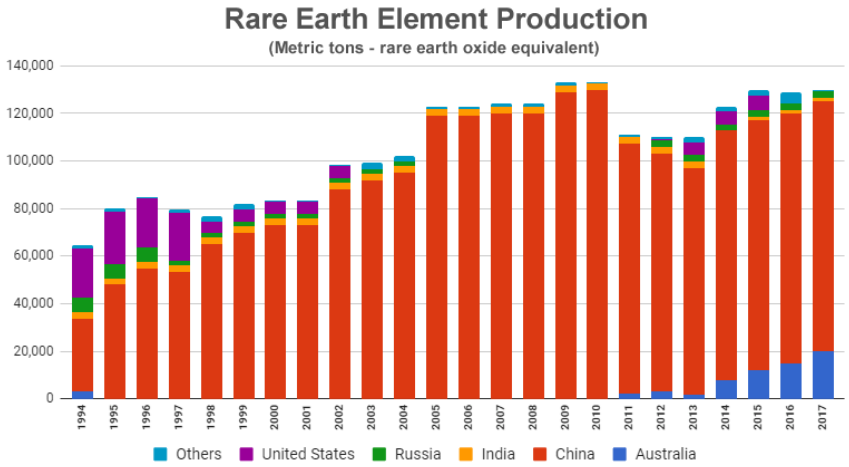
REUTERS

COMMODITIES OCTOBER 24, 2018 / 7:22 PM / 4 MONTHS AGO

China cutting rare earth output, unnerving global manufacturers

Barbara Lewis, Ernest Scheyder 6 MIN READ

LONDON/HOUSTON (Reuters) - The Chinese government is limiting domestic production of rare earth minerals in the second half of the year, a move likely to crimp international exports and send prices for the critical materials higher, according to data from Adamas Intelligence.



The Chinese dominance may have peaked in 2010 when they controlled about 95% of the world's rare earth production, and prices for many rare earth oxides had risen over **500%** in just a few years. The rare earths trade dispute, between China on one side and several countries led by the US on the other, was over China's export restrictions on rare earth elements as well as Tungsten and Molybdenum, which are used to make many electronics.

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RMB/mt 1 Euro = ¥ 7.68 Renminbi

metric ton equal to 1,000 kg

	Products	Prices	Average	Change	Unit	Date	
La	Lanthanum Oxide	14000 - 15000	14500	0	RMB/mt	2018-06-26	2000 € per ton
Ce	Cerium Oxide	14000 - 15000	14500	0	RMB/mt	2018-06-26	2000 € per ton
Nd	Neodymium Oxide	335000 - 340000	337500	0	RMB/mt	2018-06-26	44270 € per ton
Pr	Praseodymium Oxide	420000 - 430000	425000	0	RMB/mt	2018-06-26	55600 € per ton
Tb	Terbium Oxide	3050 - 3100	3075	0	RMB/kg	2018-06-26	400 € per ton
Dy	Dysprosium Oxide	1165 - 1175	1170	0	RMB/kg	2018-06-26	156 € per ton
Eu	Europium Oxide	380 - 400	390	0	RMB/kg	2018-06-26	52 € per ton
Yt	Yttrium Oxide	20000 - 21000	20500	0	RMB/mt	2018-06-26	2750 € per ton
Di	Didymium Oxide	340000 - 345000	342500	0	RMB/mt	2018-06-26	45000 € per ton
Sm	Samarium Oxide	13000 - 14000	13500	0	RMB/mt	2018-06-26	1825 € per ton
Gd	Gadolinium Oxide	135000 - 140000	137500	0	RMB/mt	2018-06-26	18250 € per ton
Er	Erbium Oxide	165000 - 170000	167500	0	RMB/mt	2018-06-26	22200 € per ton

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SMM Shanghai Metals Market

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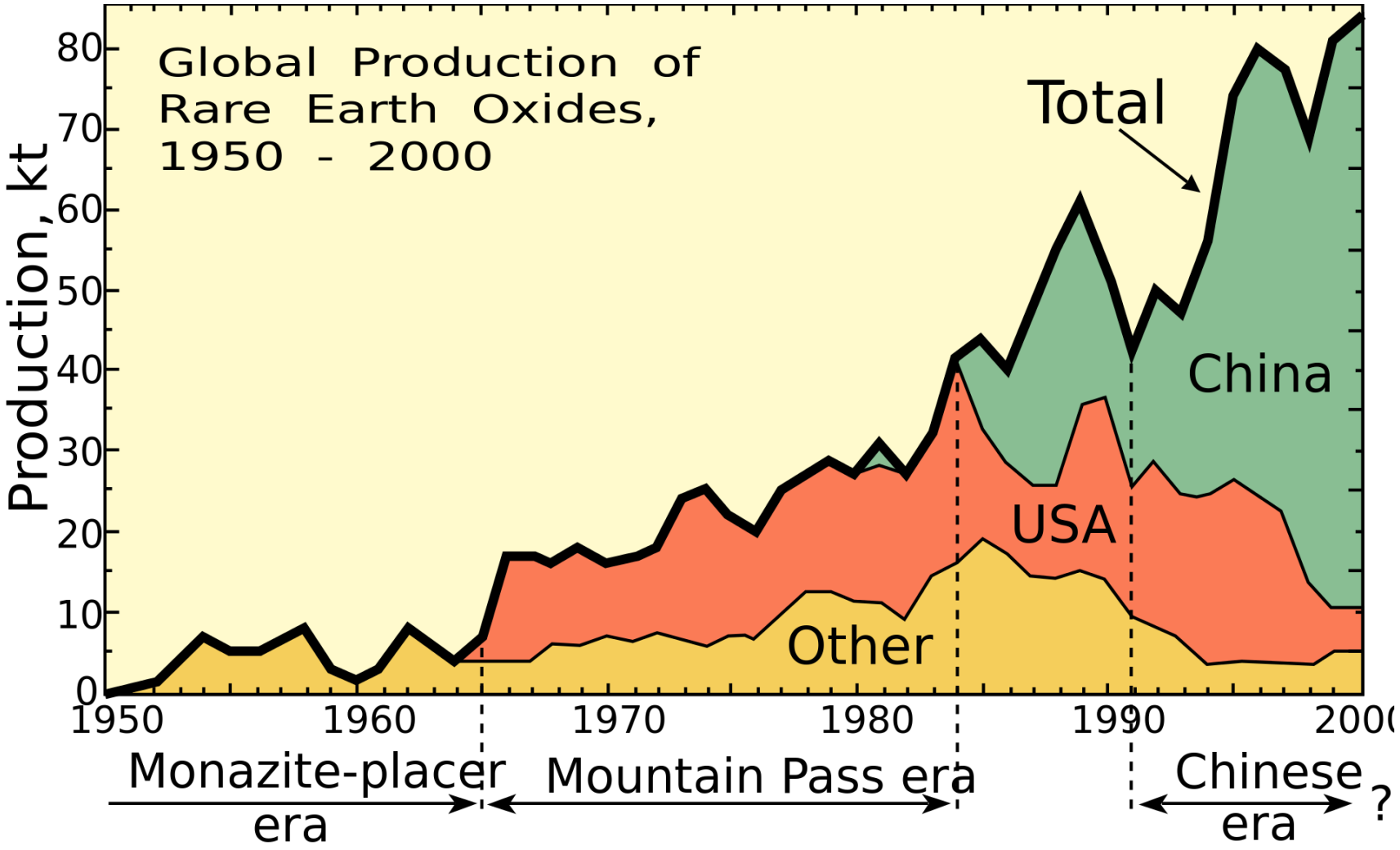

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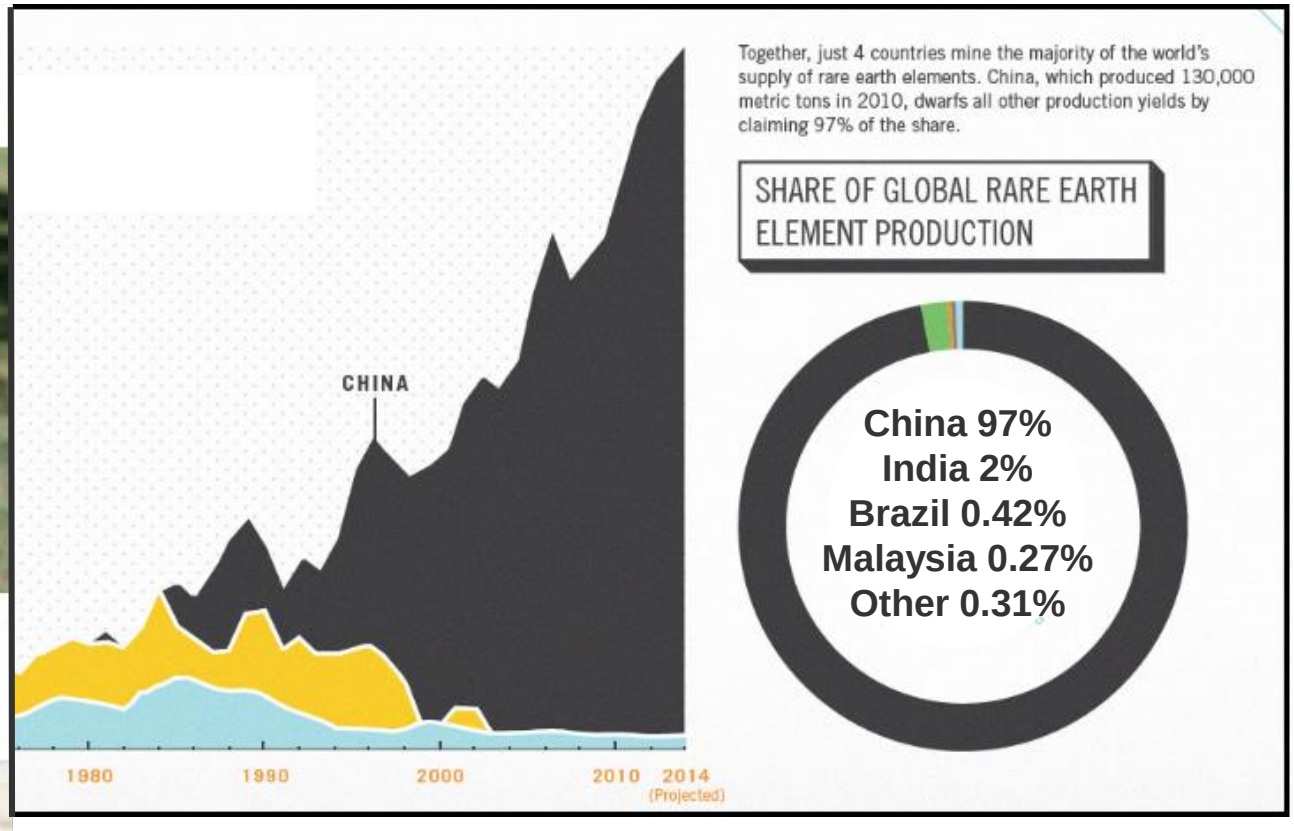

The Chinese monopoly on REE

Today China controls 97% of the production of Rare Earth elements. In 2012, the Obama administration filed a case with the Dispute Settlement Body of the WTO. In 2014, the WTO ruled against China, which led China to drop the export quotas in 2015.

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Z	Symbol	Name	Etymology	Selected applications	Abundance[5] (ppm[a])
21	Sc	Scandium	from Latin *Scandia* (Scandinavia).	Light aluminium-scandium alloys for aerospace components, additive in metal-halide lamps and mercury-vapor lamps,[6] radioactive tracing agent in oil refineries	22[7]
39	Y	Yttrium	after the village of Ytterby, Sweden, where the first rare earth ore was discovered.	Yttrium aluminium garnet (YAG) laser, yttrium vanadate (YVO_4) as host for europium in television red phosphor, YBCO high-temperature superconductors, yttria-stabilized zirconia (YSZ), yttrium iron garnet (YIG) microwave filters,[6] energy-efficient light bulbs (part of triphosphor white phosphor coating in fluorescent tubes, CFLs and CCFLs, and yellow phosphor coating in white LEDs),[8] spark plugs, gas mantles, additive to steel, cancer treatments	33[7]
57	La	Lanthanum	from the Greek "lanthanein", meaning *to be hidden*.	High refractive index and alkali-resistant glass, flint, hydrogen storage, battery-electrodes, camera lenses, fluid catalytic cracking catalyst for oil refineries	39[7]
58	Ce	Cerium	after the dwarf planet Ceres, named after the Roman goddess of agriculture.	Chemical oxidizing agent, polishing powder, yellow colors in glass and ceramics, catalyst for self-cleaning ovens, fluid catalytic cracking catalyst for oil refineries, ferrocerium flints for lighters	66.5[7]
59	Pr	Praseodymium	from the Greek "prasios", meaning *leek-green*, and "didymos", meaning *twin*.	Rare-earth magnets, lasers, core material for carbon arc lighting, colorant in glasses and enamels, additive in didymium glass used in welding goggles,[6] ferrocerium firesteel (flint) products.	9.2[7]
60	Nd	Neodymium	from the Greek "neos", meaning *new*, and "didymos", meaning *twin*.	Rare-earth magnets, lasers, violet colors in glass and ceramics, didymium glass, ceramic capacitors, electric motors of electric automobiles	41.5[7]
61	Pm	Promethium	after the Titan Prometheus, who brought fire to mortals.	Nuclear batteries, luminous paint	1×10^{-15}[9][b]
62	Sm	Samarium	after mine official, Vasili Samarsky-Bykhovets.	Rare-earth magnets, lasers, neutron capture, masers, control rods of nuclear reactors	7.05[7]
63	Eu	Europium	after the continent of Europe.	Red and blue phosphors, lasers, mercury-vapor lamps, fluorescent lamps, NMR relaxation agent	2[7]
64	Gd	Gadolinium	after Johan Gadolin (1760–1852), to honor his investigation of rare earths.	High refractive index glass or garnets, lasers, X-ray tubes, computer memories, neutron capture, MRI contrast agent, NMR relaxation agent, magnetostrictive alloys such as Galfenol, steel additive	6.2[7]
65	Tb	Terbium	after the village of Ytterby, Sweden.	Additive in Neodymium based magnets, green phosphors, lasers, fluorescent lamps (as part of the white triband phosphor coating), magnetostrictive alloys such as terfenol-D, naval sonar systems, stabilizer of fuel cells	1.2[7]
66	Dy	Dysprosium	from the Greek "dysprositos", meaning *hard to get*.	Additive in Neodymium based magnets, lasers, magnetostrictive alloys such as terfenol-D, hard disk drives	5.2[7]
67	Ho	Holmium	after Stockholm (in Latin, "Holmia"), native city of one of its discoverers.	Lasers, wavelength calibration standards for optical spectrophotometers, magnets	1.3[7]
68	Er	Erbium	after the village of Ytterby, Sweden.	Infrared lasers, vanadium steel, fiber-optic technology	3.5[7]
69	Tm	Thulium	after the mythological northern land of Thule.	Portable X-ray machines, metal-halide lamps, lasers	0.52[7]
70	Yb	Ytterbium	after the village of Ytterby, Sweden.	Infrared lasers, chemical reducing agent, decoy flares, stainless steel, stress gauges, nuclear medicine, monitoring earthquakes	3.2[7]
71	Lu	Lutetium	after Lutetia, the city that later became Paris.	Positron emission tomography – PET scan detectors, high-refractive-index glass, lutetium tantalate hosts for phosphors, catalyst used in refineries, LED light bulb	0.8[7]

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HOW DO WE USE RARE EARTH ELEMENTS?

About 140,000 tons of rare earth elements are processed each year to create a wide variety of technological devices. Below are some examples.

DEFENSE TECHNOLOGIES
Like in the guidance systems of smart bombs

MEDICAL TECHNOLOGIES
Like those used in MRI and X-ray systems

COLOR DISPLAY MONITORS
Like in those used on computers and televisions

ELECTRONIC EQUIPMENT
Like the magnets in your hard drive and speakers

CLEAN ENERGY TECHNOLOGIES
Like in the manufacturing of wind turbines and hybrid cars

OPTICAL LENSES
Like those used in cameras and telescopes

Source: U.S. Geological Survey
Graphic by Alexandra Kanik

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Rare Metals in a smart phone

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Defense One

NEWS THREATS POLITICS BUSINESS TECH IDEAS

China Is Beating the US in the Rare-Earths Game

AA FONT SIZE + PRINT EBENART/SHUTTERSTOCK

BY JAMES KENNEDY
JAMES KENNEDY IS PRESIDENT OF THREE CONSULTING.
READ BIO ›

NOVEMBER 8, 2018

It's time for the administration to use its powers to preserve America's access to vital defense materials.

Defense Uses of Rare Earth Elements	
Lanthanum	night-vision goggles
Neodymium	laser range-finders, guidance systems, communications
Europium	fluorescents and phosphors in lamps and monitors
Erbium	amplifiers in fiber-optic data transmission
Samarium	permanent magnets that are stable at high temperatures
Samarium	precision-guided weapons
Samarium	"white noise" production in stealth technology

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“Bù shì de”

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↓

“Not yes”

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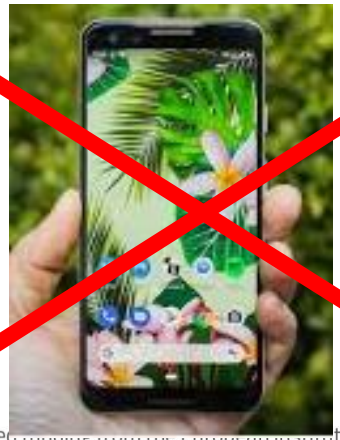
NO



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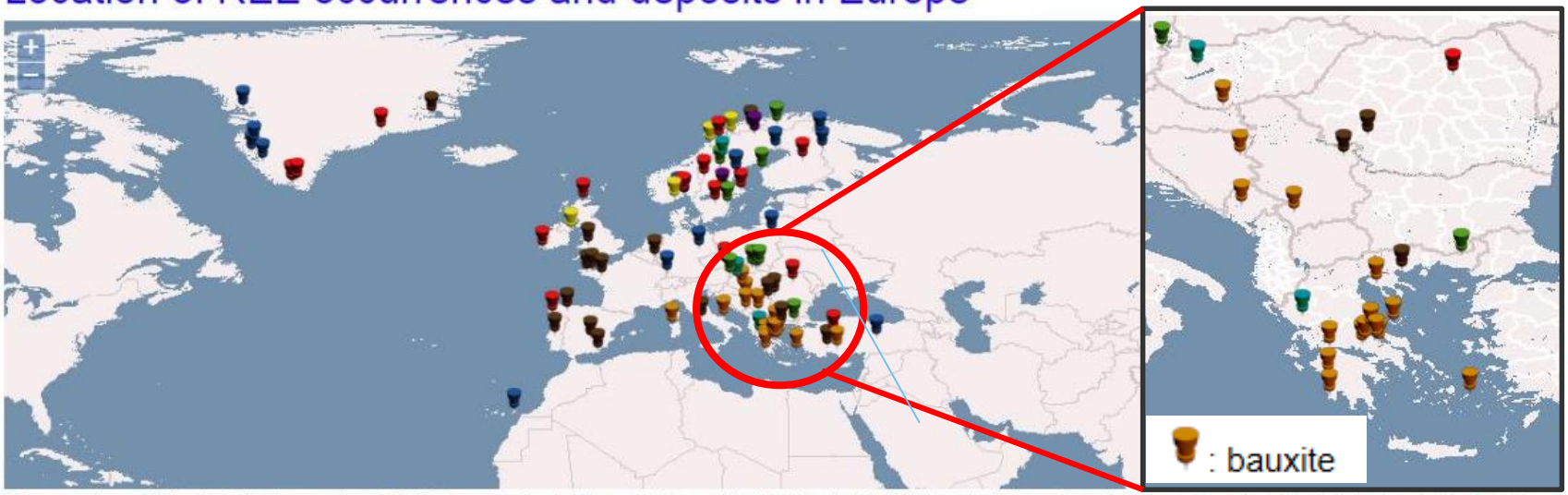
Location of REE occurrences and deposits in Europe



This map shows all the individual examples of REE mineralisation in Europe that were identified by the EURARE project. Zoom in on the map and click on the individual points to identify them. An indication of the scale of the deposit is given on the basis of the following definitions:

1. **Resource:** REE mineralisation that has a formal resource estimate which is compliant with JORC or a similar code
2. **Deposit:** REE mineralisation for which the available evidence suggests that an economic resource could be identified with further exploration
3. **Occurrence:** REE mineralisation that appears to be localised and is not considered to be of economic interest on the basis of current evidence
4. **By-product:** REE mineralisation that may be economic as a by-product of extraction of other minerals.

These classifications may be subject to change as new evidence is gathered.

Key

- : alkaline igneous rocks
- : carbonatite
- : vein and skarn (hydrothermal)
- : iron oxide-apatite
- : granite and pegmatite
- : bauxite
- : placer
- : other

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Table 3. Trace element composition of the samples. Error is given as one standard deviation of a duplicate measurement.

Element	Karst Bauxite Greece	Lateritic BauxiteGhana	Bauxite ResidueGreece, AoG
	ICP-MS	INAA	ICP-MS
	(mg/kg)	(mg/kg)	(mg/kg)
La	57 ± 7	19.1 ± 1.3	130 ± 1
Ce	206 ± 8	34 ± 1	480 ± 26
Pr	15 ± 1	n/a	29 ± 2
Nd	53 ± 6	13 ± 1	107 ± 0
Sm	9.8 ± 1.0	2.0 ± 0.2	19.4 ± 0.2
Eu	2.4 ± 0.9	0.8 ± 0.2	4.6 ± 1.1
Gd	10.6 ± 0.6	n/a	22.0 ± 0.3
Tb	2.3 ± 0.5	<0.5	3.3 ± 0.0
Dy	9.8 ± 0.3	n/a	20.1 ± 0.1
Ho	2.1 ± 0.1	n/a	4.1 ± 0.1
Er	7.2 ± 0.8	n/a	13.3 ± 0.3
Tm	<2	n/a	<2
Yb	7.0 ± 0.4	2.5 ± 0.3	13.8 ± 0.3
Lu	<2	0.4 ± 0.0	2.2 ± 0.0
Y	48 ± 2	n/a	108 ± 2
Nb	55 ± 9	n/a	100 ± 1
Th	51 ± 2	22.7 ± 2.3	105 ± 2
ΣLn [1]	382.3		854.4
ΣREE [2]	430.6		962.5

[1] Sum of lanthanides; [2] Sum of lanthanides and yttrium.

Rare Earth Element Phases in Bauxite Residue
Johannes Vind et al. 2018

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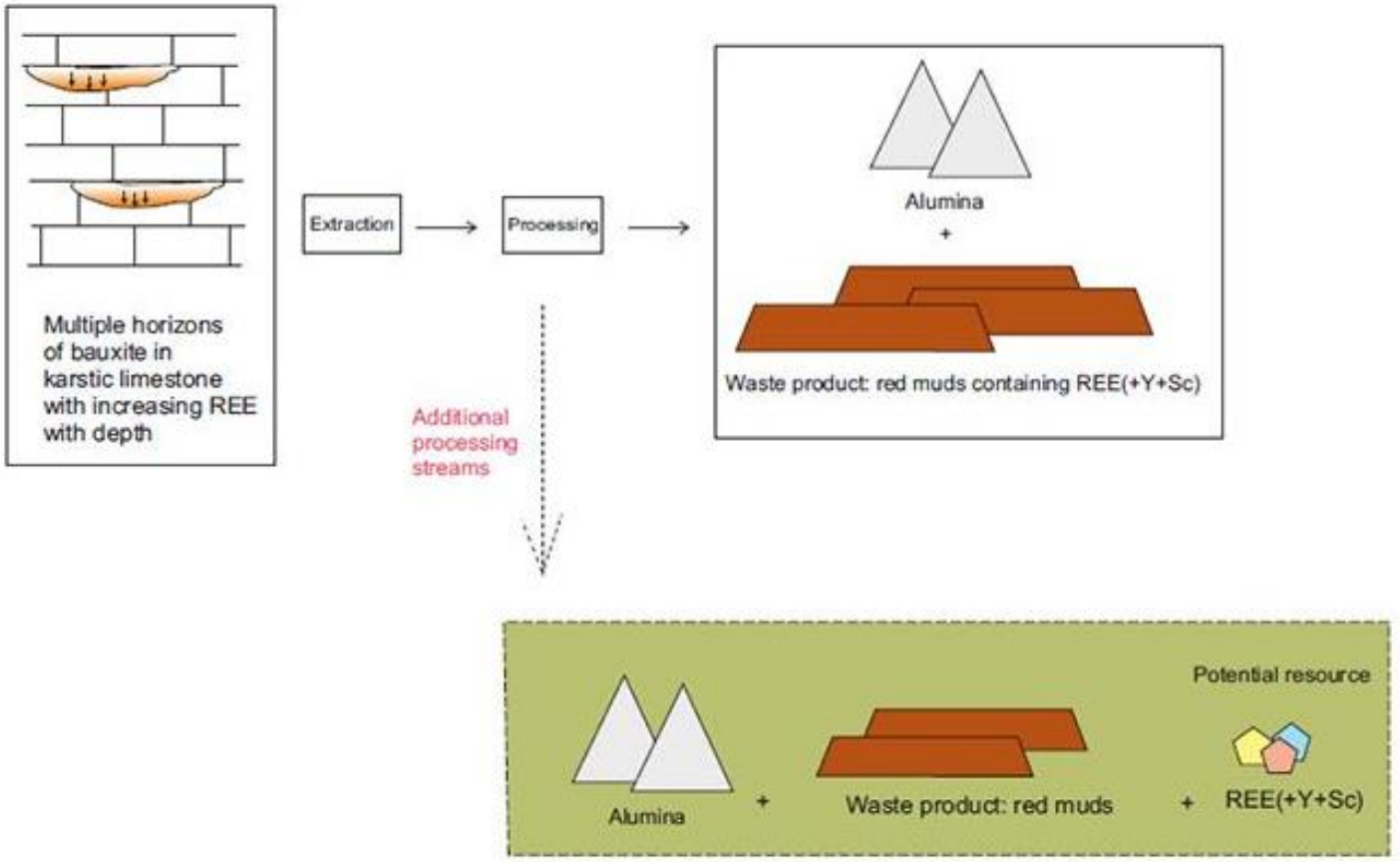

Simplified overview of the alumina processing stream. The development of an additional processing stream for the extraction of REE from red muds could lead to European production of REE.

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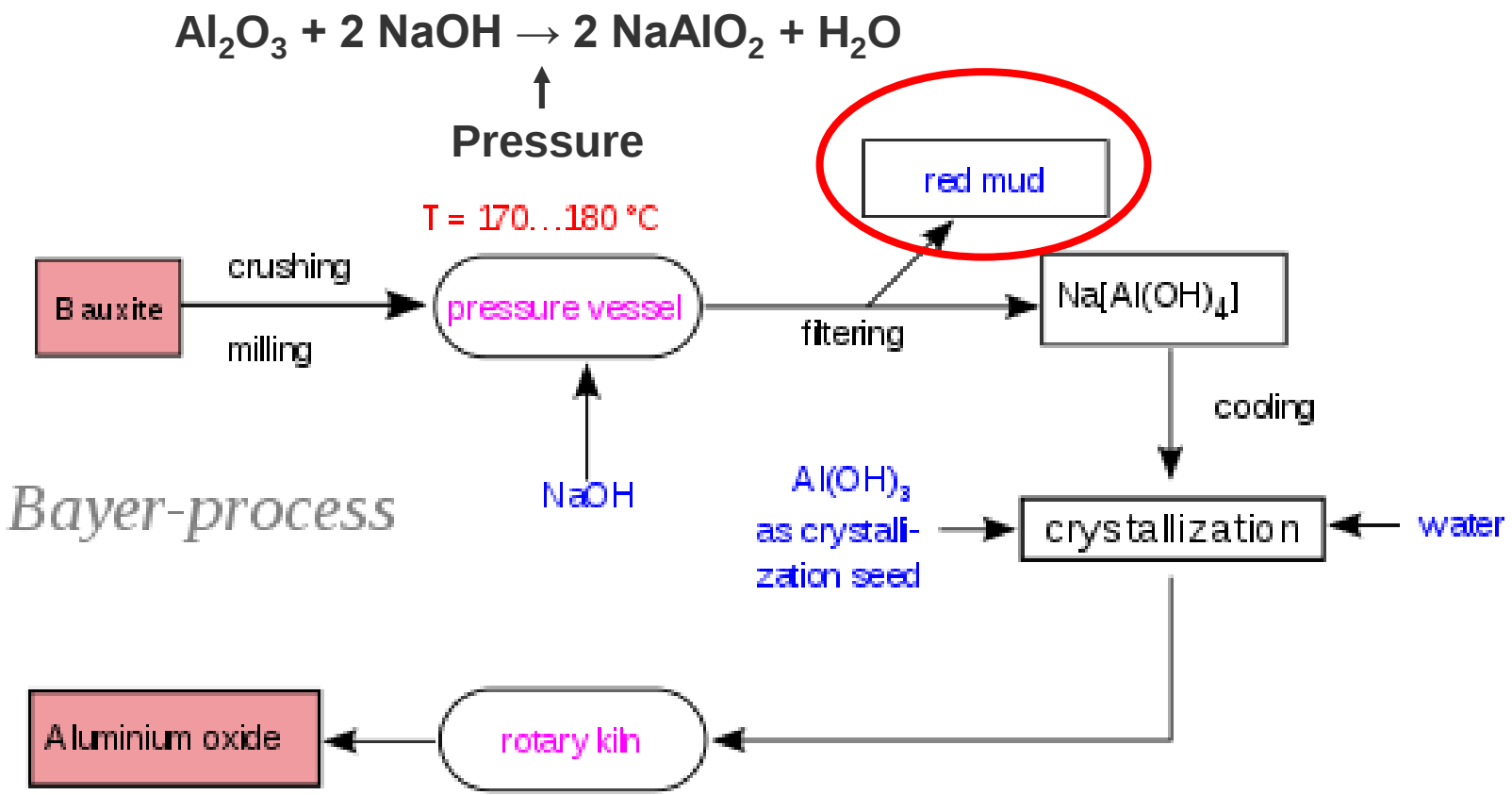
$Al_2O_3 + 2\ NaOH \rightarrow 2\ NaAlO_2 + H_2O$

The Bayer-Process in the prossesing of Aluminium ore



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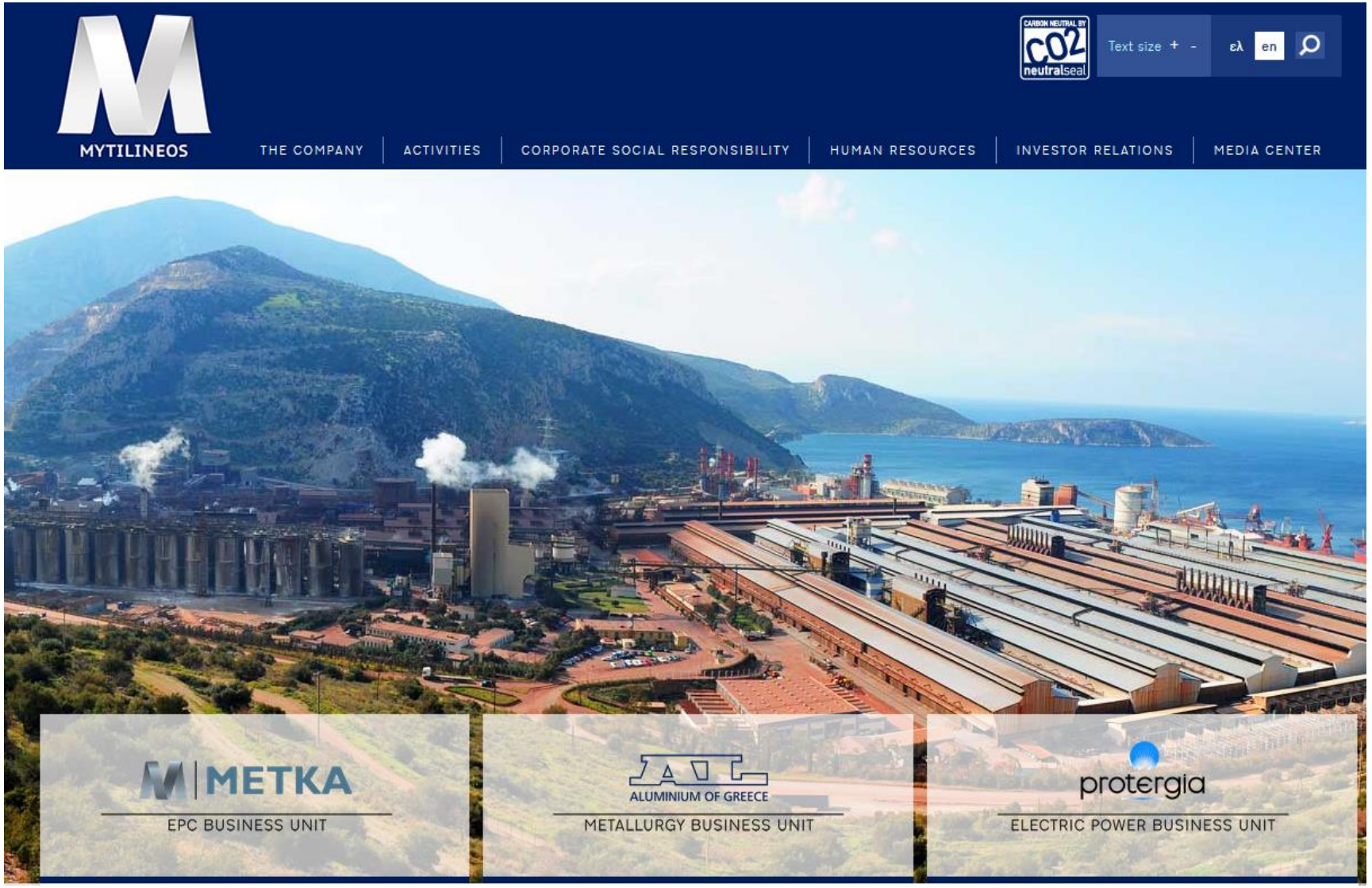

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ALUMINIUM OF GREECE

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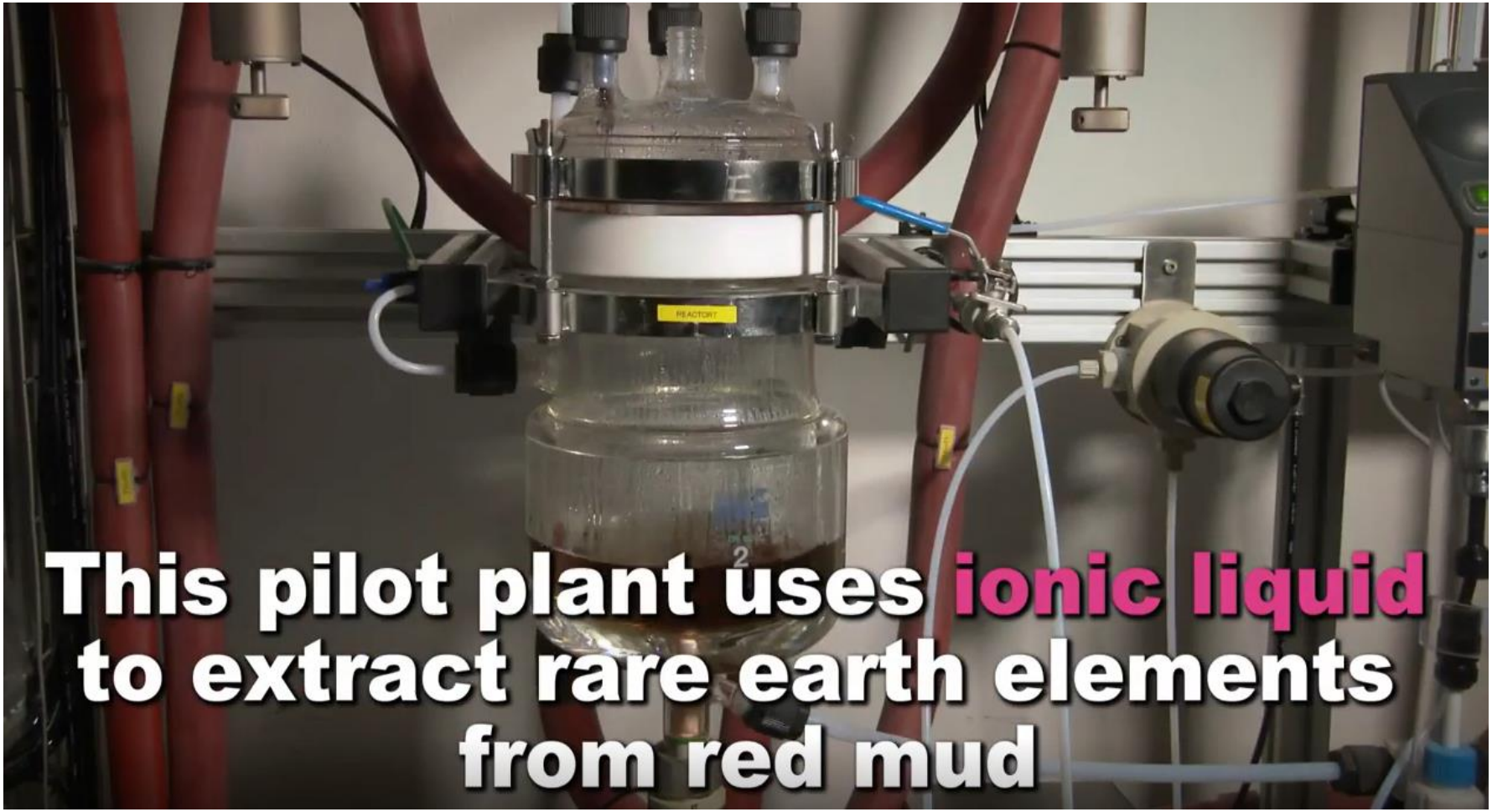

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The concentration of REE during the Bayer-Process

Element	Karst Bauxite Greece	Lateritic BauxiteGhana	Bauxite ResidueGreece, AoG
	ICP-MS	INAA	ICP-MS
	(mg/kg)	(mg/kg)	(mg/kg)
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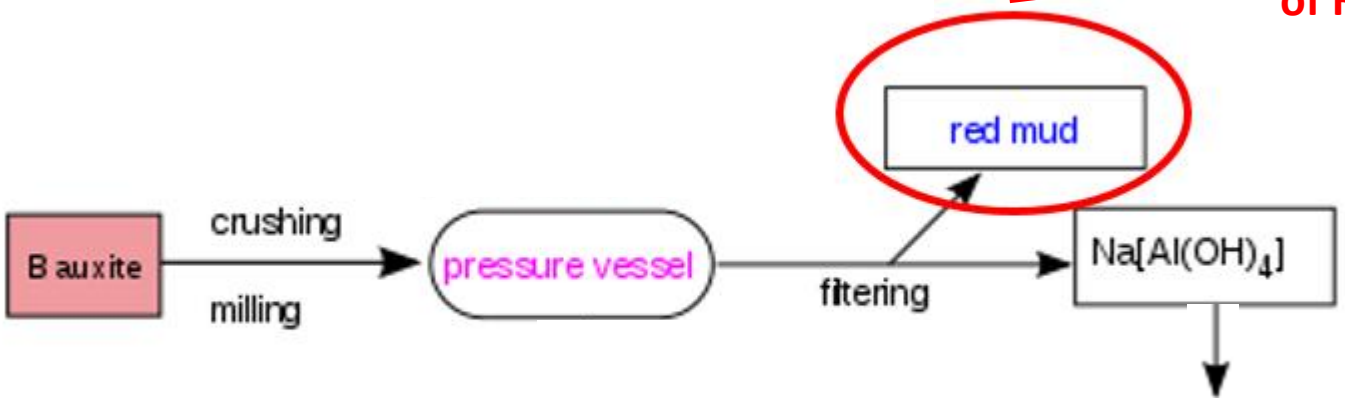
Extraction of REE



Bayer-process

Aluminium Production

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REE Extraction using Ionic Liquids (IL)

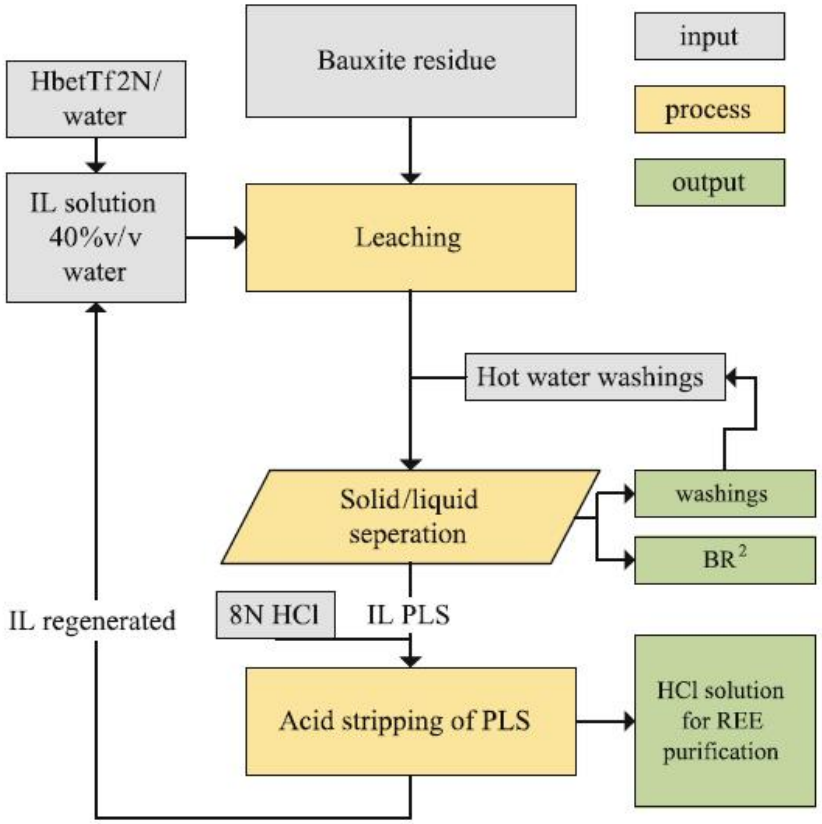

Fig. 7 BR flowsheet treatment with HbetTf2N to produce a final REE solution and regenerate the IL for reuse (left). Demonstration of the proposed flowsheet to a mini pilot plant built in Athens (right)

Developing New Process for Selective Extraction of Rare Earth Elements from Bauxite Residue Based on Functionalized Ionic Liquids - Panagiotis Davris, Efthymios Balomenos, Dimitrios Panias, and Ioannis Paspaliarls (0. Martin (ed.), Light Metals 2018, The Minerals, Metals & Materials Series, https://doi.org/10.10071978-3-319-72284-9_20

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