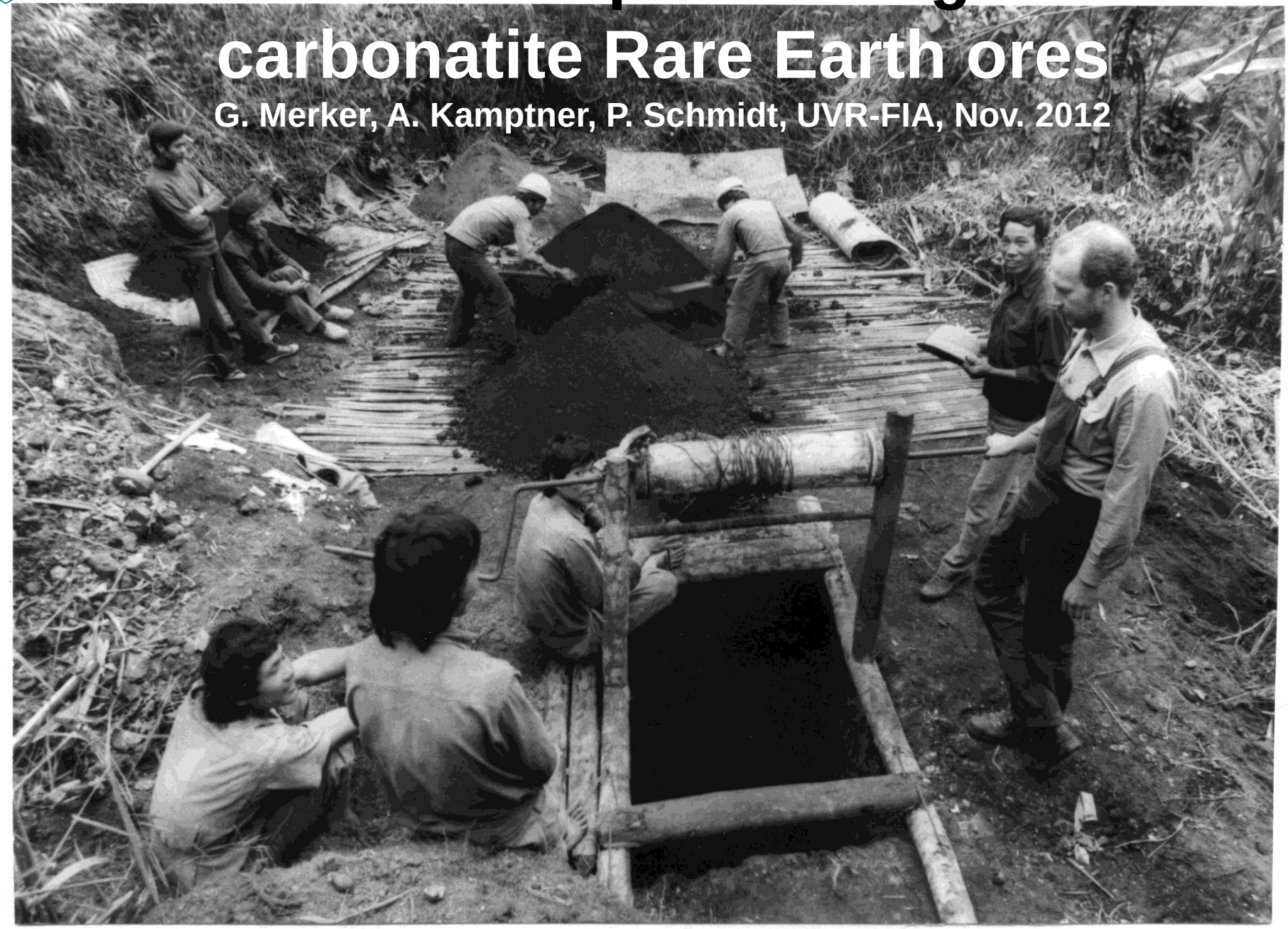
R. Gerhard Merker
- MinERS-pm

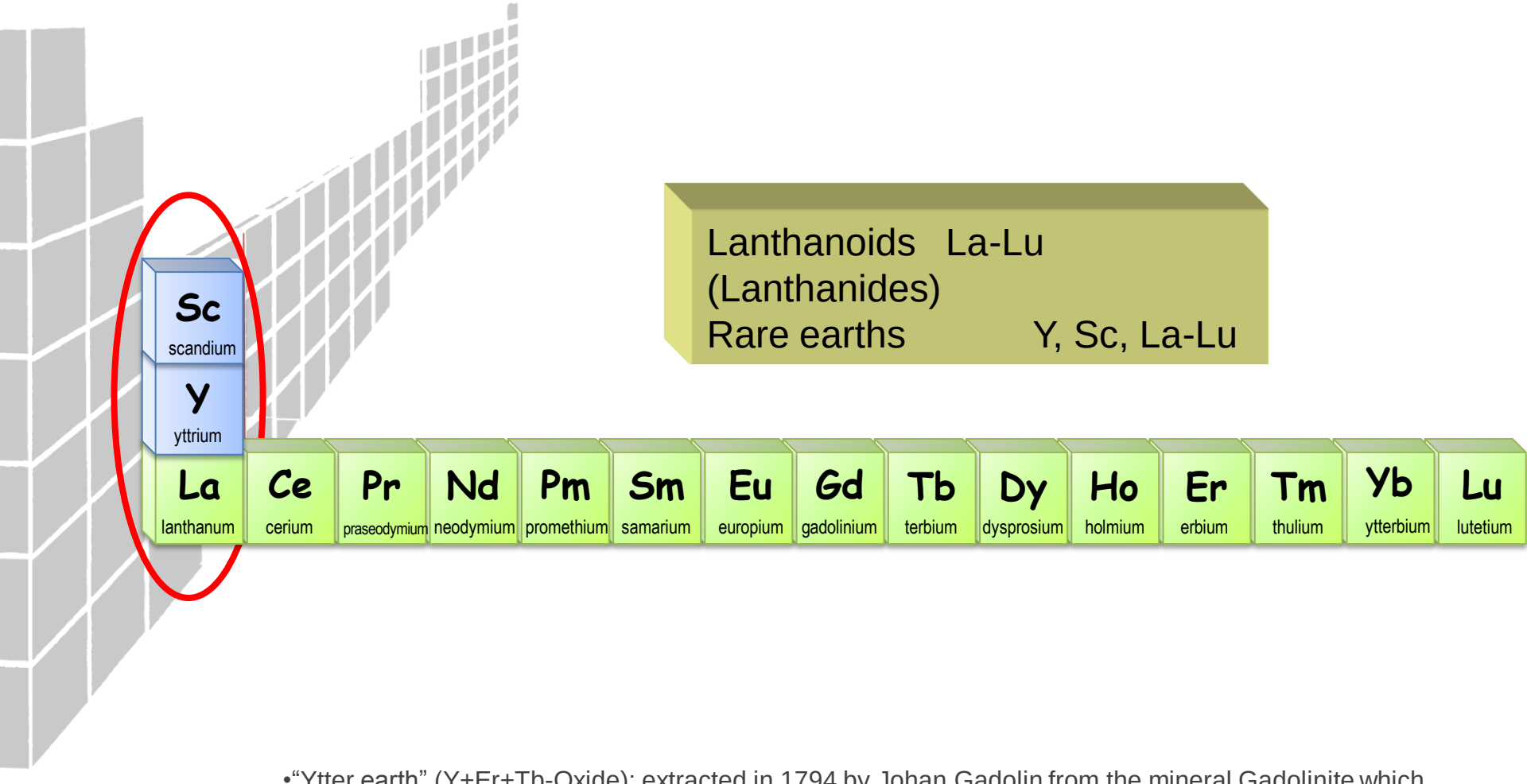
About the processing of carbonatite Rare Earth ores

G. Merker, A. Kamptner, P. Schmidt, UVR-FIA, Nov. 2012



1. The Rare Earth Elements (REE)

(courtesy of: Prof. J.-C. G. Bünzli, EPFL Lausanne/CH, /15/)

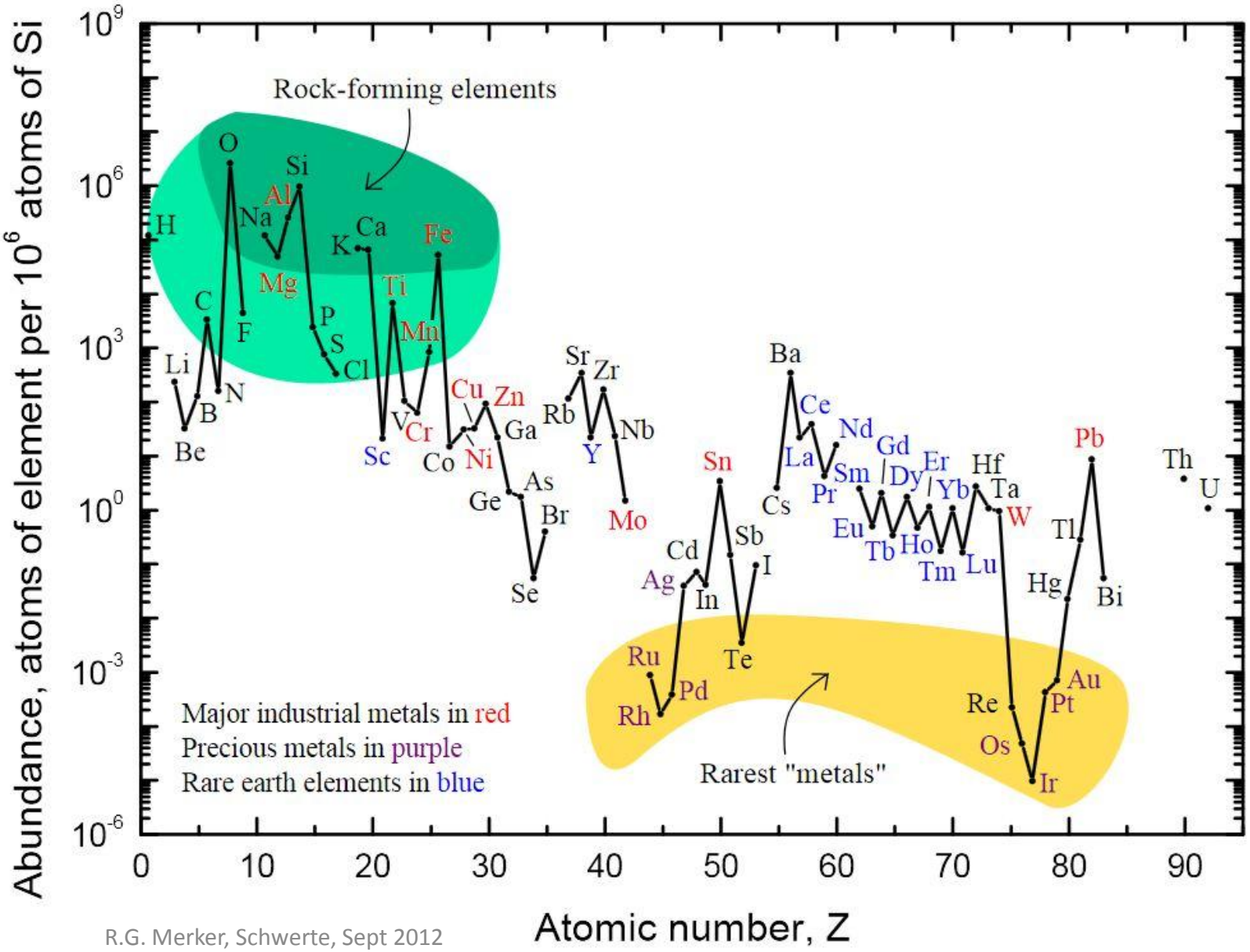


Lanthanoids La-Lu
(Lanthanides)
Rare earths Y, Sc, La-Lu

- "Ytter earth" (Y+Er+Tb-Oxide): extracted in 1794 by Johan Gadolin from the mineral Gadolinite which was discovered 1787
- Berzelius + Klapproth discovered in 1803 the so-called "Cerit earth" (La+Ce+Didym-Oxide) in the mineral Cerite that was found in 1751
- Mosander et al. cracked the "earthes" and separated their components from 1839 on

2. Are the REE really rare?

Sources: /15/: Bünzli REEC Münster,
/20/: wikipedia.org/wiki/File:Elemental_abundances.svg



3.1. Natural occurrence of REE

sources: various web sites /31/, (see sources-slide)

3.2. Natural occurrence of REE

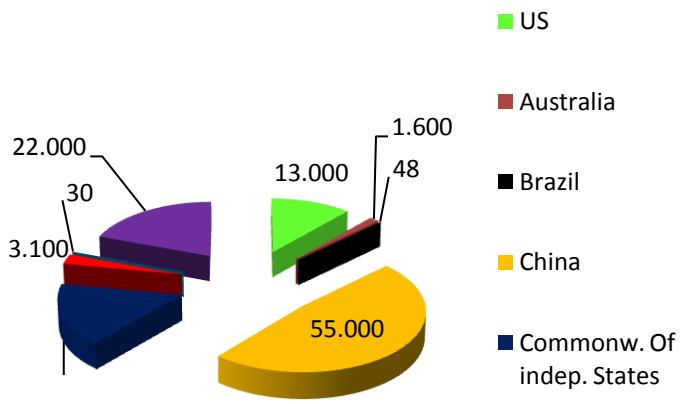
sources: Bulatovic /1/ corrected, Roesler /6/, Öko-Institut /7/, Mineralienatlas /9/, H. Richter /18/

Mineral	Simplified formula	Assay and REO content	true density	Mohs hardness
Monazite	$(Ce,La\ldots\ Th)PO_4$	50-68% RE_2O_3	4.9	5.5
Bastnaesite	$(Ce,La,...)[CO_3/F]$	36-56% Ce_2O_3, ard. 19% La2O3,	4.5-5.2	4-4.5
Synchisite	$Ca\ (Ce,\ La,\ ...)[(CO_3)_2/F]$		3.9-4.15	4.5
Xenotime	YPO_4	52-62% Y_2O_2, +Th, ~5% U,	4.6	4.5
Parisite	$Ca(Ce,\ La\ldots)_2[CO_3]_3F_2$	53- 61% RE_2O_3	4.3	4.5
Loparite	$(Na,Ca,Ce,Sr)_2Ti,Ta,Nb)_2O_6$	42-45 % RE_2O_3, 8-11% $(Ta,Nb)_2O_5$, +Th	4.8	6
Fergusonite	$(Y,Sr,Ce,U)(Nb,Ta,Ti)O_4$	31-42% Y_2O_3, 1-4% ThO_2, 1-6% UO_2	5.6-6.2	5.5-6.5
Eudyalite	$Na_3(Ca,Fe,\ Ce...)_3$ $Zr((OH,Cl)/(Si_3O_9)_2)$	up to 2.9 % REO	2.8-3	5-5.5
Aeschynite	$(Ce,Ca,Th,Y)(Ti,Nb)_2O_6$	20-24% RE_2O_3, 11-17% ThO_2	4.9-5.1	5-6
Lateritic clays	Adsorbed ions	Ce2O3 1-7 %, Nd2O3 5-30, Y2O3 10-63 %	-	-

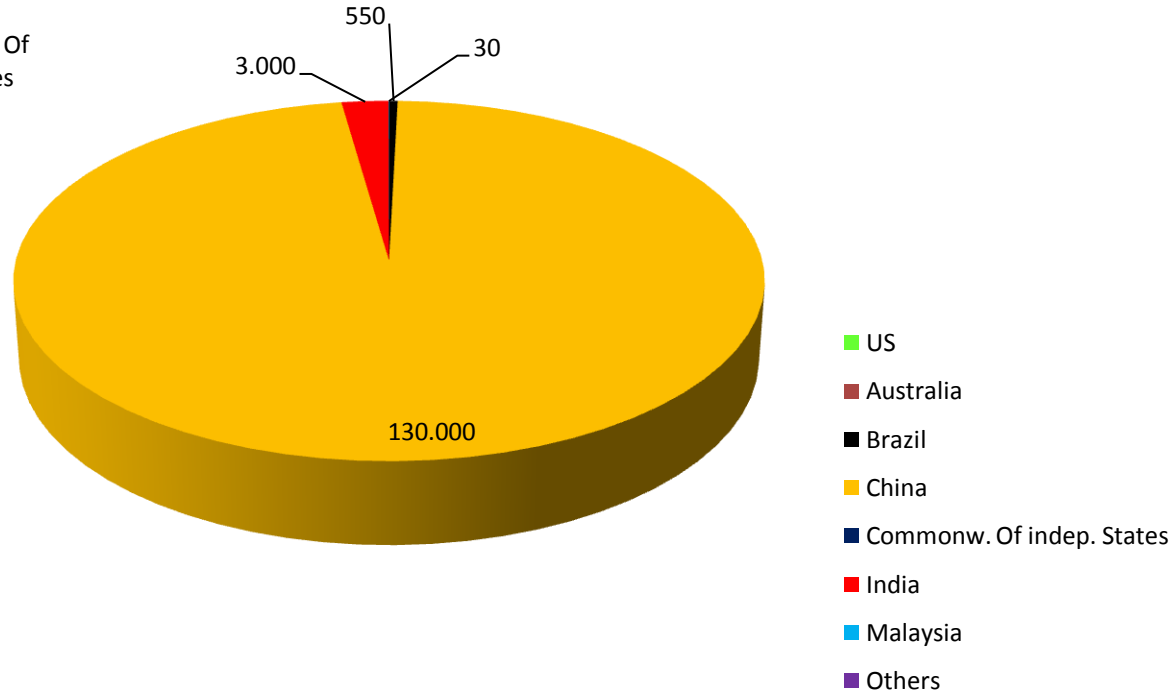
4. Who produces RE?

source /19/: USGS RE fact sheet 2012

RE reserves 2012 (x 1.000t)



RE mine production 2011 mt/a



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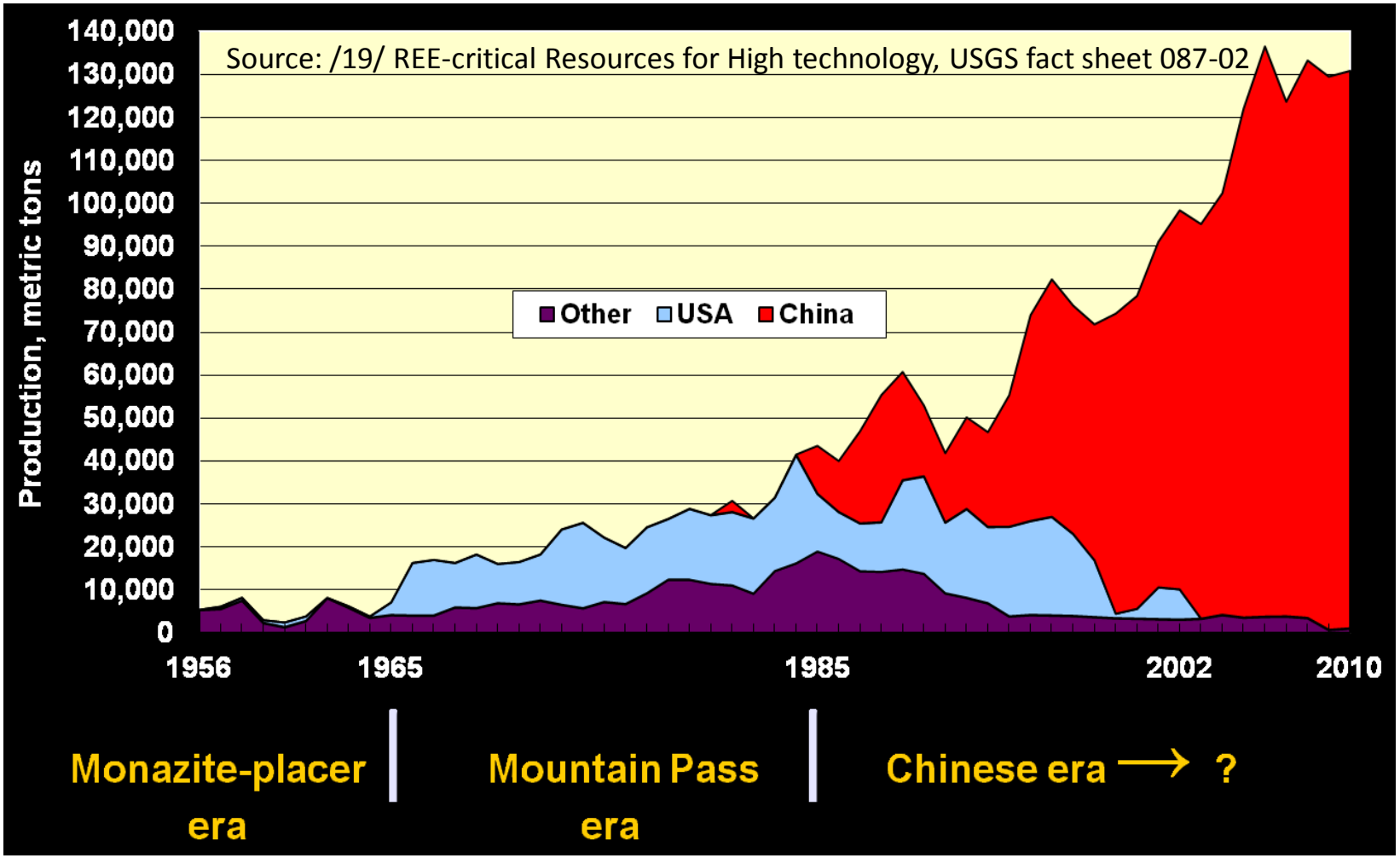
5. Bayan Obo / Baotou: Capital of REE

Source /16/, Bünzli REEC

Baotou iron mining / Inner Mongolia – Source of nearly 60 % of worlds TREO production (estimation based on /7/)

6. Why about Carbonatites?

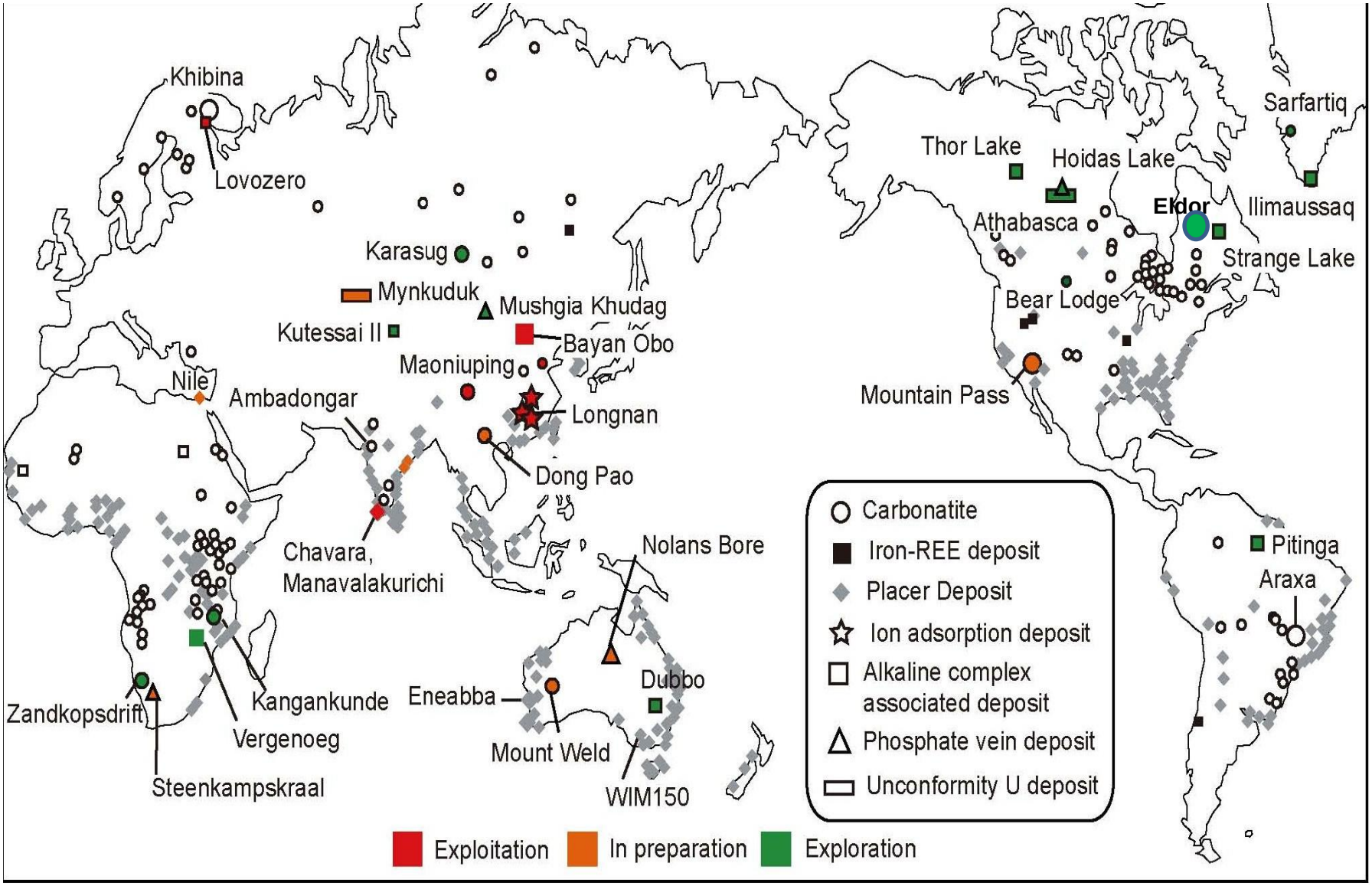
from placer to carbonatite deposits



Global rare earth element production (1 kt=10^6 kg) from 1950 through 2000, in four categories: United States, almost entirely from Mountain Pass, California; China, from several deposits; all other countries combined, largely from monazite-bearing placers; and global total. Four periods of production are evident: the monazite-placer era, starting in the late 1800s and ending abruptly in 1964; the Mountain Pass era = start of **the carbonatite era,**

7. Selected RE-Projects, (out of some 400-550)

(source /16/: www.matamec);



8. Selected natural factors of the processing of k-RE-ores

Factor	RE-ores
Paragenesis (Association)	Chemically similar associated minerals, same Cat- and Anions (Ca, F, CO3), … tricky separation by flotation
Weathering	Slime formation trend can occur, even enrichment of RE within the slime fraction
Grain size / Locking	Often finely intergrown, partly multi-stage milling down below 20 microns needed
Milling properties / hardness	Enrichment in the fines can occur
Geochemical spread of the RE	Usually bound by various RE-Minerals, even partly dissemination into the lattice of gangue minerals possible (limited recovery!)
Magnetic properties	fluctuating, partly weak-magnetic properties, partly not
Density	Usually pretty high, but often too fine grain size for a gravity separation
Flotability / surface properties	Often similar by chemical alikeness of the associated minerals, causes usually more or less complicated multi-stage techniques (several collectors and depressants, pH-control, water-exchange, desorption, hot processing, a. o. gadgets.)

Each and every ore / RE-project shows different features and edge conditions.
Jedes Erz / jedes Projekt hat eine andere Charakteristik und zeigt unterschiedliche Randbedingungen!!!

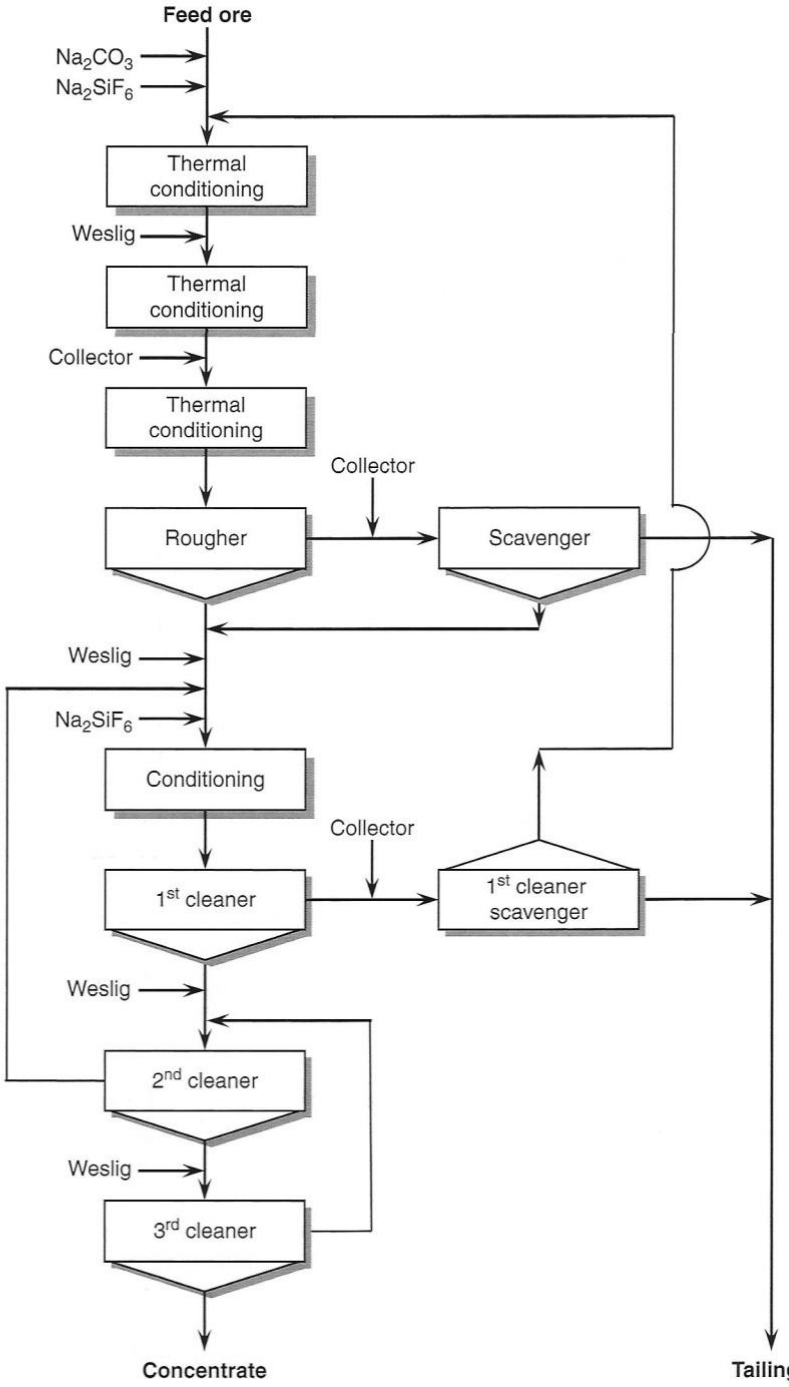
9. The classic carbonatite project: Mountain Pass/US

source /11/, Molycorp website 2012

Mountain Pass overview and processing facility,

10. Processing of carbonatite RE-ores, Flow sheet Mountain Pass,

Source: /1/ Bulatovic



Molycorp plant metallurgical results

Product	Weight (%)	Assays (%)					% Distribution	
		REO	Ce_2O_3	La_2O_3	$BaSO_4$	CaO	REO	Ce_2O_3
Final bastnaesite concentrate	9.38	64.1	31.4	22.2	2.7	3.1	75.6	75.5
Final bastnaesite tailing	90.62	2.28	1.06	0.74	26.3	16.9	24.4	24.5
Feed	100.00	8.09	3.9	2.76	26.3	15.6	100.0	100.0

11. The presumably next big project, Mount weld / Au, pit and concentration plant

Source: /12/ web site of Lynas corp. 2012

12. Processing of RE-Carbonatite ores, proposed flow sheet Mount Weld

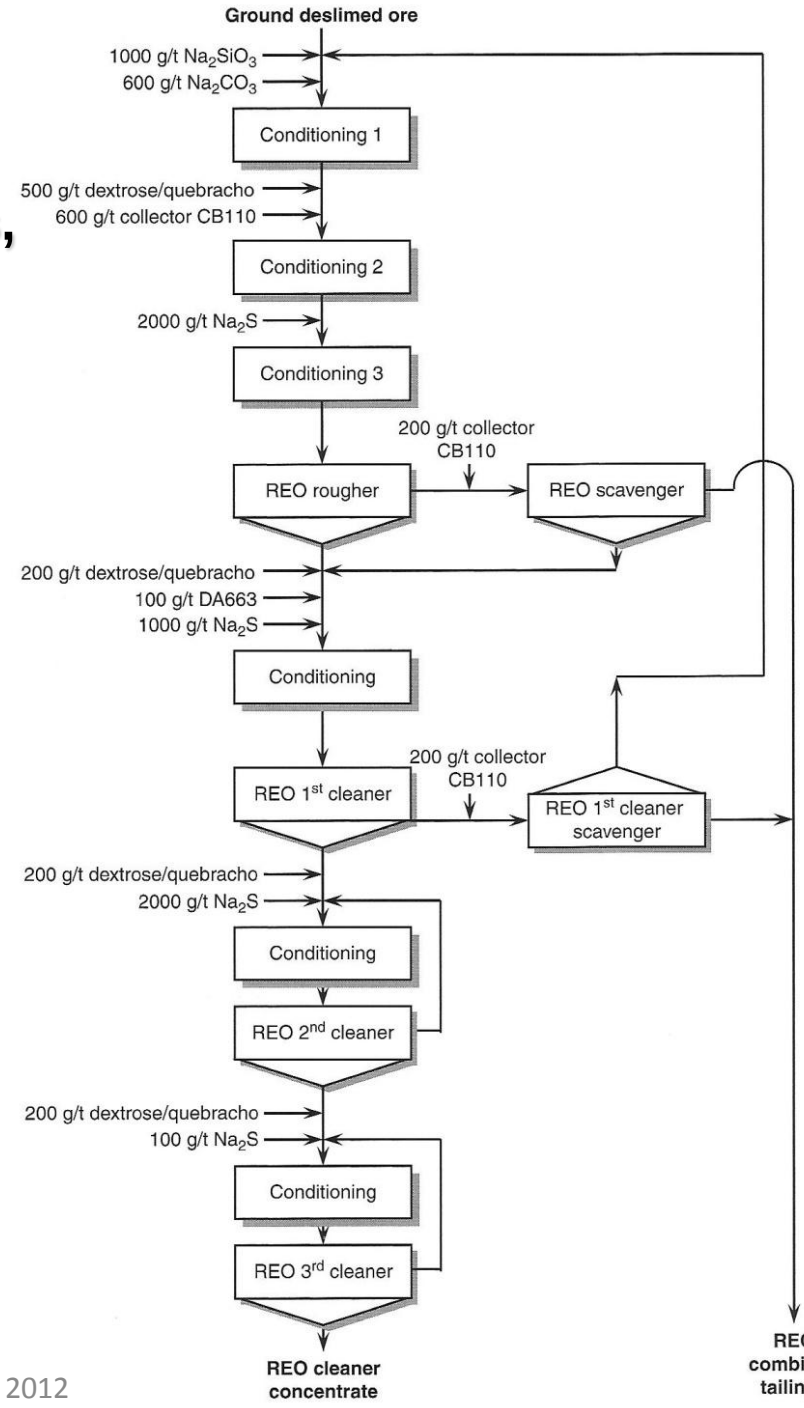
Source /1/ Bulatovic 2010

Head analyses of the Mount Weld ore

Element	Assays (%)
Total REO	15.50
Cerium (Ce_2O_3)	9.54
Lanthanum (La_2O_3)	4.21
Samarium (Sm_2O_3)	0.39
Yttrium (Y_2O_3)	0.30
Iron (Fe_2O_3)	60.5
Alumina (Al_2O_3)	15.5
Magnesia (MgO)	4.60
Calcium (CaO)	10.8
Phosphorus (P_2O_5)	2.66

Overall metallurgical results obtained on the Mount Weld ore

Product	Weight (%)	% Monazite assay	% Monazite recovery
Cleaner concentrate	20.89	58.5	77.5
Combined tail	54.51	2.55	8.8
Slimes	24.6	8.8	13.7
Feed	100.00	15.8	100.0



13. RE-carbonatite investigations in Germany?

- **1970ies and 80ies: Storkwitz carbonatite, ZGI Berlin, IfR Dresden, FIA Freiberg, exploration core drillings and processing tests; (currently DRAG)**

- **Beginning of the 1980ies: Bayan Obo ore, KHD Humboldt Wedag Cologne, development of a processing technique for the Fe-RE-ores**

- **1980ies: geological exploration and process development, Feasibility Study Dong Pao/Vietnam, IfR Dresden + FIA Freiberg**

- **2012: Participation in processing tests of a Feasibility Study of an international RE-project (Eldor), UVR-FIA + consultant**

- **more projects in the pipeline?**

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14. Project Dong Pao, pictures of the RE-Deposit of Dong Pao

Source /22/: R.G.Merker

R.G. Merker, Schwerte, Sept 2012

15. Aufbereitung von RE-Karbonatiterzen, weathered ore of Dong Pao

Source /2/: Merker et al.: Erzmetall 1991 etc.

Table 2 – *Structure of grain sizes, together with distribution of RE depending upon grain size, as demonstrated by a mixed sample of ore type I*

Grain size in mm	Distribution in %				Assay in %		
	Mass	SE_2O_3	Barytes	Fluorite	SE_2O_3	Barytes	Fluorite
< 0.015	16.8	43.9	7.5	4.1	35.7	22.3	3.9
0.015 – 0.032	7.4	8.0	7.3	5.1	14.7	48.8	11.2
0.032 – 0.063	5.7	5.4	5.3	4.3	12.5	48.6	12.7
0.063 – 0.1	9.1	9.7	10.2	7.3	13.9	58.3	13.4
0.1 – 0.315	11.1	10.9	11.4	10.9	12.9	53.4	16.5
0.315 – 0.5	6.5	6.0	6.5	8.4	12.1	51.7	21.6
0.5 – 1.0	12.2	7.7	12.2	17.4	8.3	51.9	23.9
1.0 – 2.0	12.4	4.8	14.8	18.0	5.1	62.0	24.4
> 2.0	18.8	3.6	24.8	24.5	2.6	68.1	21.8
	100.0	100.0	100.0	100.0	13.1	51.9	16.8

16. Processing of RE-Carbonatite ores, one of the proposed flow sheets Dong Pao (IfR+FIA 1990)

Source /2/: Merker et al.: Erzmetall 1991

r processing Dong Pao Rare Earth ores. Commentary in text.

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17. Current RE-projects of UVR-FIA, column flotation, source /15/ UVR

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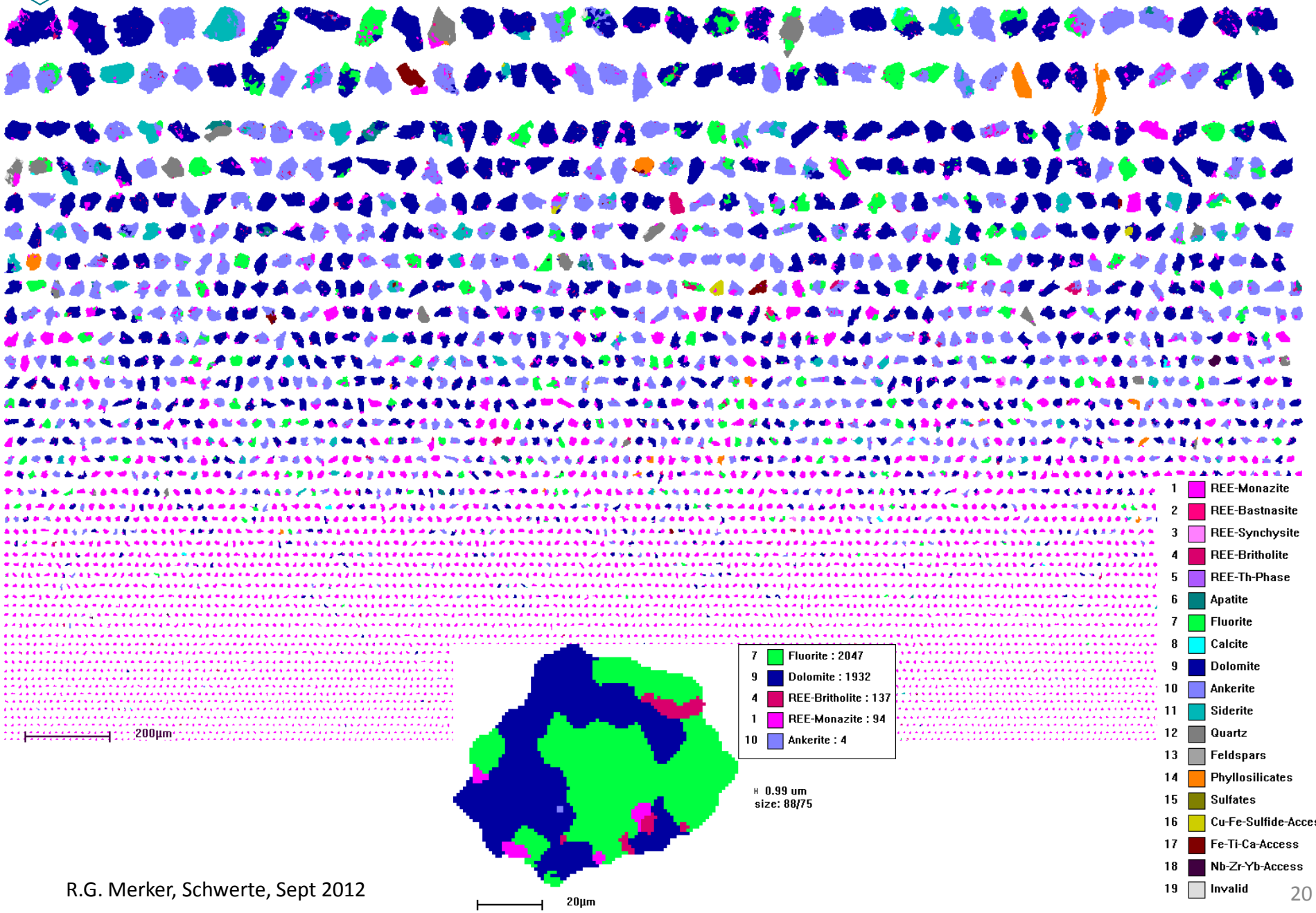
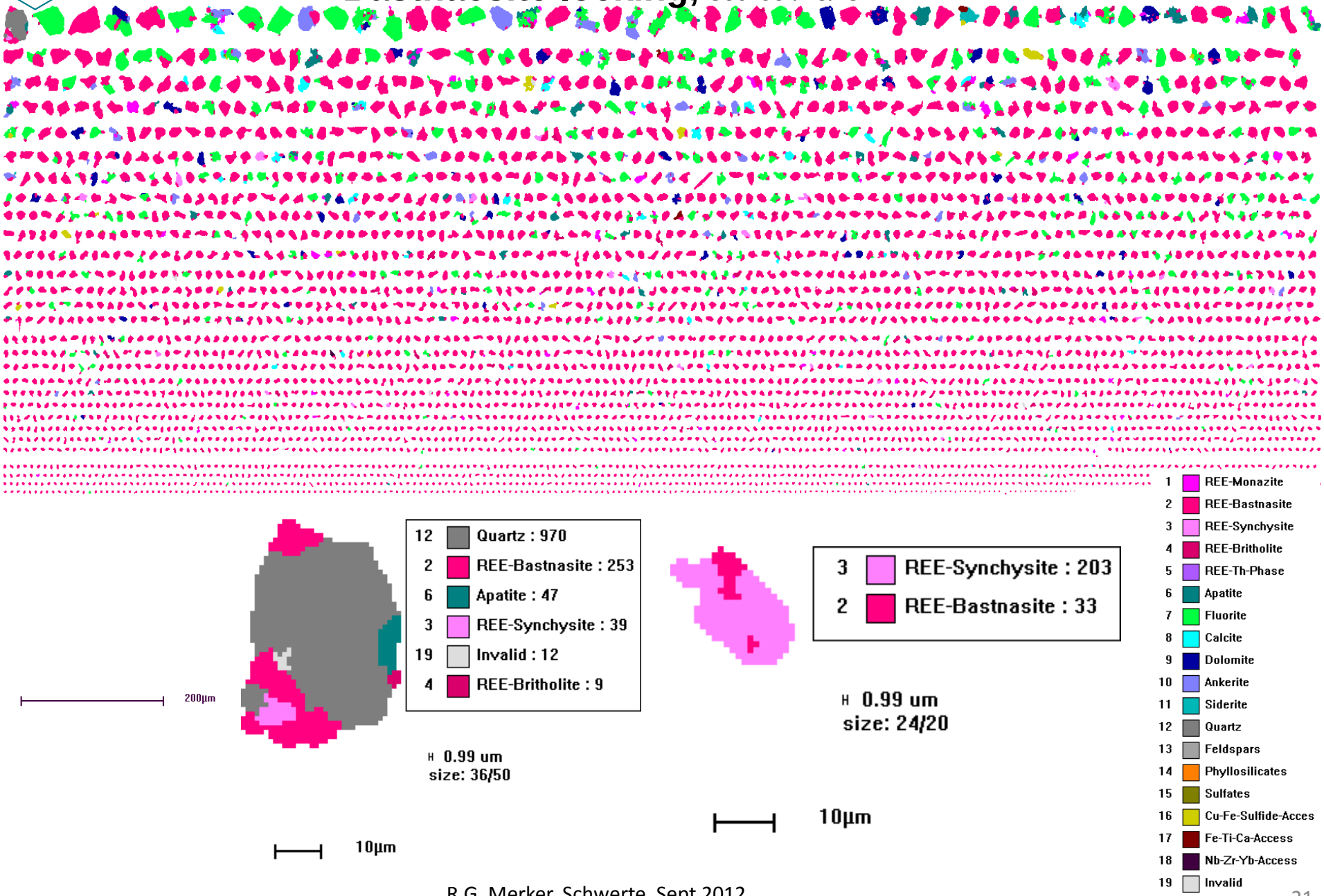
18.1. UVR project E/A, Ore III 45, minus 70 µ
Monazite locking, source /15/ UVR-FIA



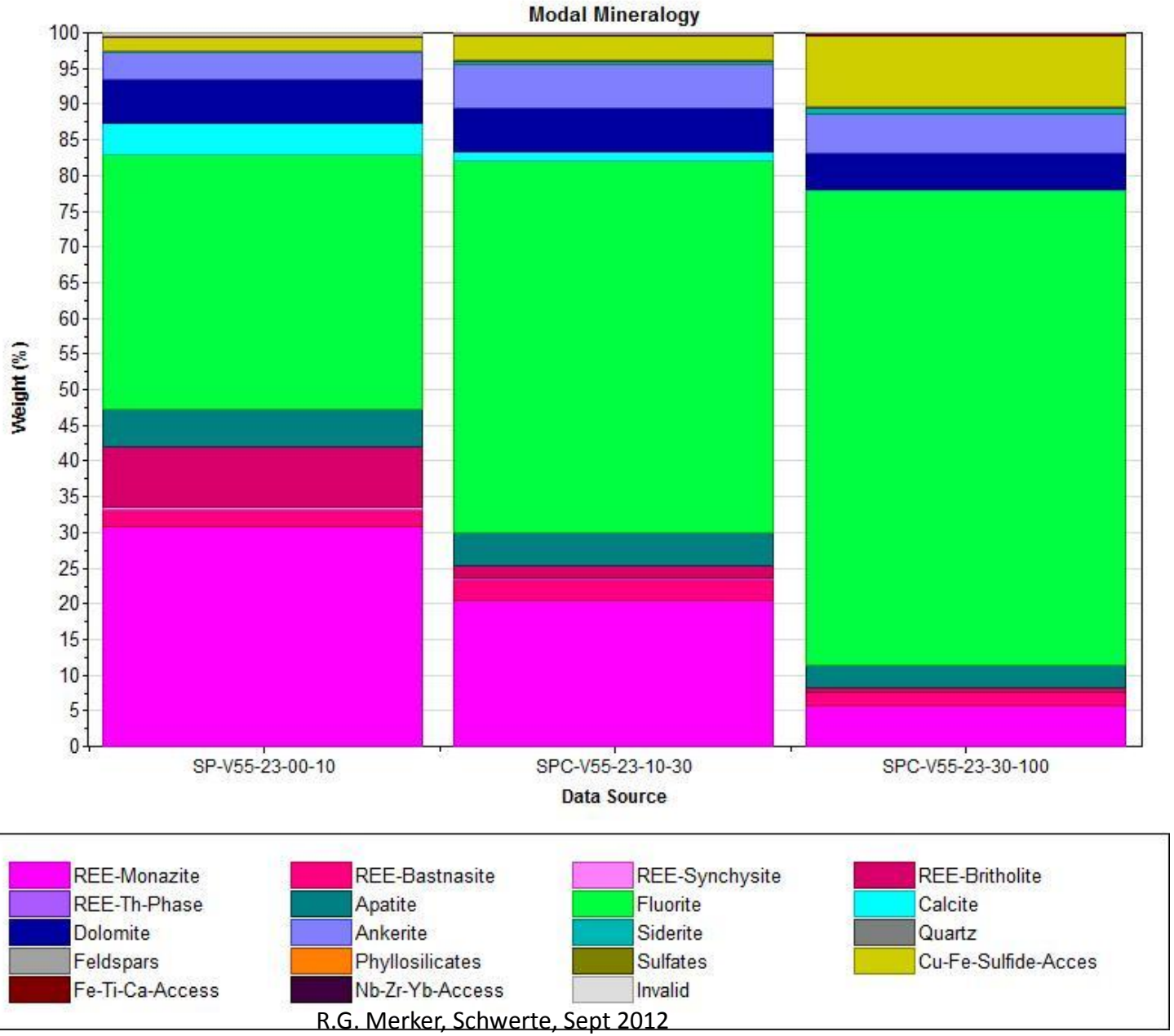
18.2. UVR project E/A, flot. Con 55-23, Bastnaesite locking, source /15/ UVR-FIA



R.G. Merker, Schwerte, Sept 2012

19. Mineralogy of bulk flotation, con UVR-E/A

MLA TU BAF Freiberg, source /15/ UVR-FIA



R.G. Merker, Schwerte, Sept 2012

20. Selected technical factors of the Flotation of RE-minerals

Faktor	Faktor
Natürlicher pH	Gelöste Ionen / Wasserqualität
pH Regler (NaOH, HCl, H2SO4 etc.)	Temperatur (Bsp. MP, Storkwitz und XA)
Drücker (Bsp XA Lignex / Ultrazine)	Flotationszeit
Sammlertyp / chem. Modifikationen / Kombinationen	Konditionierung / Konditionierungszeit
Aktivatoren	Schaumstabilität / Schäumer
Selektivität der Reagenz-Kombination	Persönliche Einflussfaktoren
Reagenzmengen	Dispergierung / Turbulenz
Desorbierbarkeit	Feststoffgehalte Trübe
Mahlung / Mahlfeinheit	Geometrische Faktoren (Größe, Form der Zellen etc.)
Schlammbildung / Entschlämmung	Luftmenge / Blasengröße

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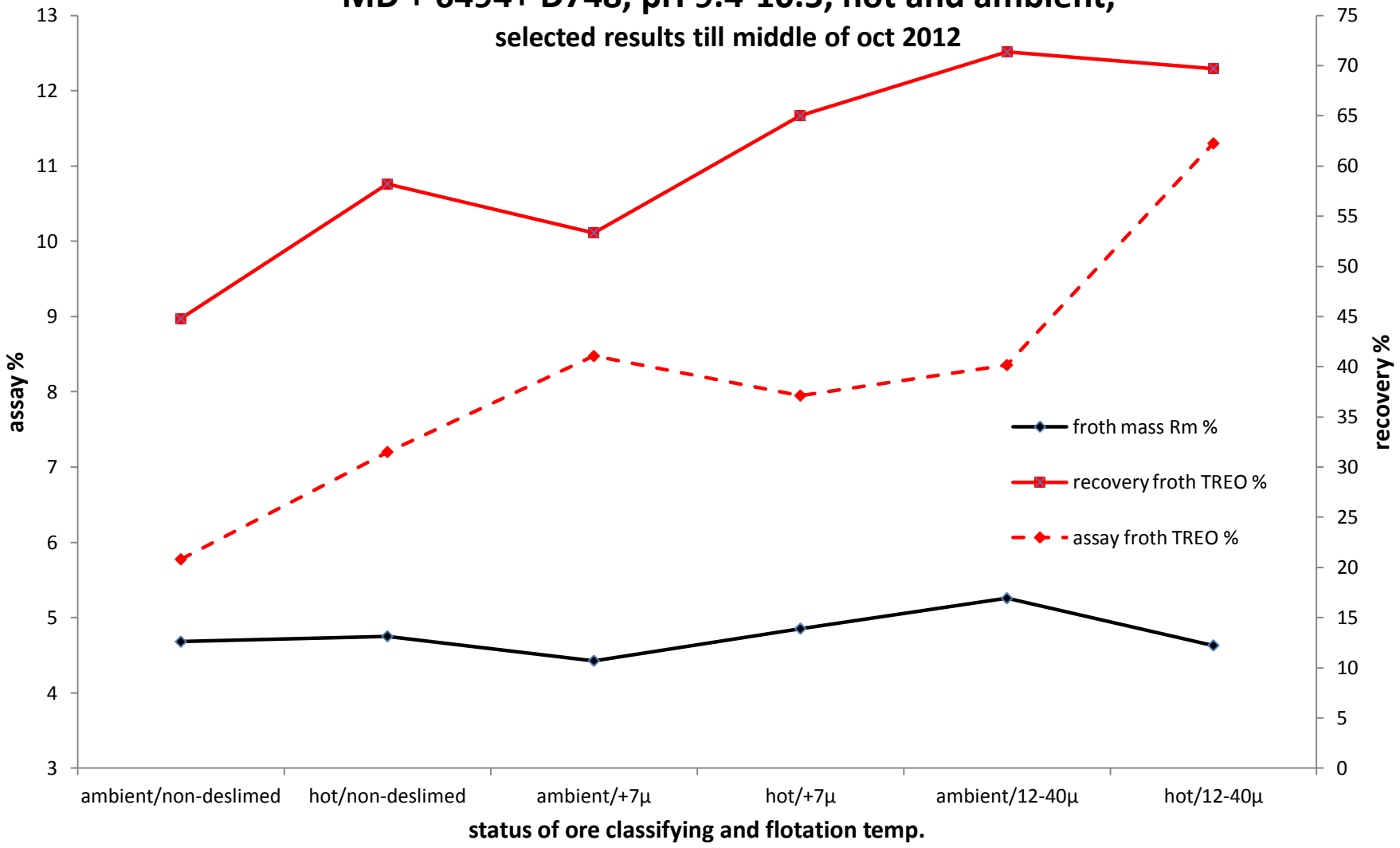
21.1. Selected details about own results, influence of grain size and T on flotation, E/A

Source /15/, UVR-FIA

rougher flotation of ore III and IV, dependancy on classifying, standard MD + 6494+ D748, pH 9.4-10.5, hot and ambient,

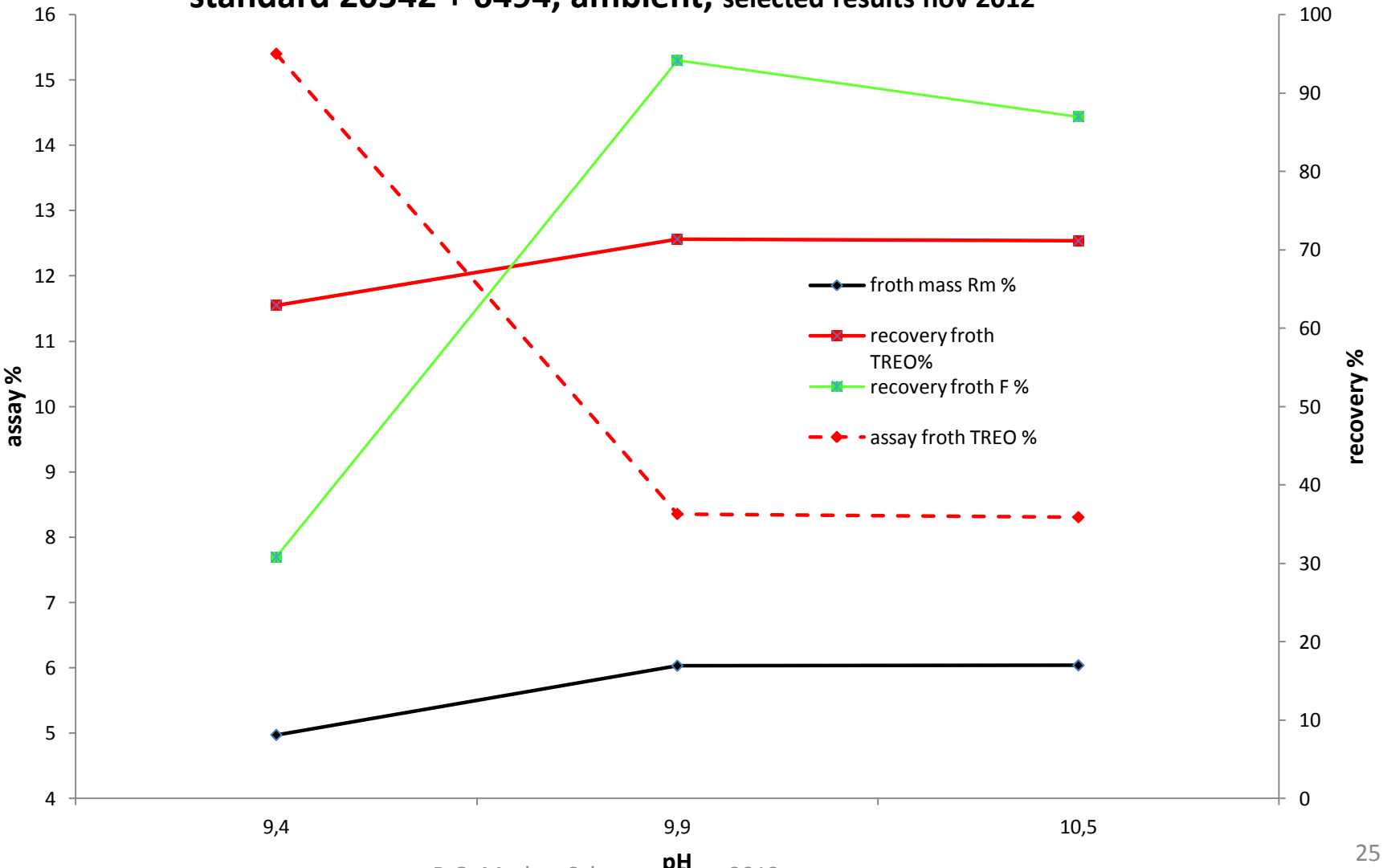
selected results till middle of oct 2012



21.2. Selected details about own results, pH influence, UVR-E/A

Source /15/, UVR-FIA

rougher flotation ore IV, 12-40 microns, pH dependency, standard 20542 + 6494, ambient, selected results nov 2012



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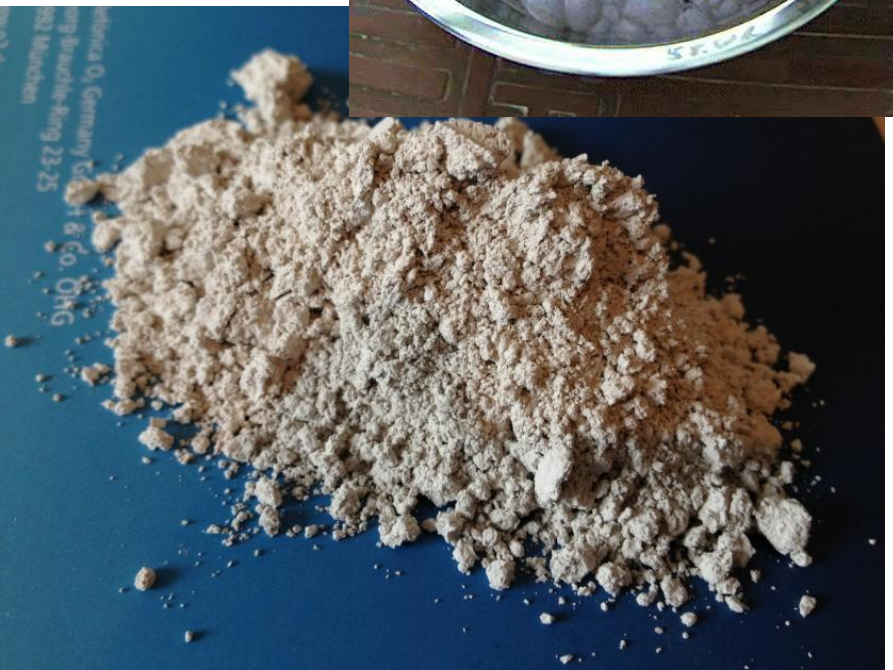
22. Current RE-projects of UVR, fancy colors by flotation, source /15/ UVR



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23. Thank you for you kind attention!

UVR-FIA can help pushing your RE-Project too!
Don‘t be shy – contact us!

Ihr Anlaufpunkt in Fragen der RE-Erzaufbereitung: UVR-FIA + G.Merker

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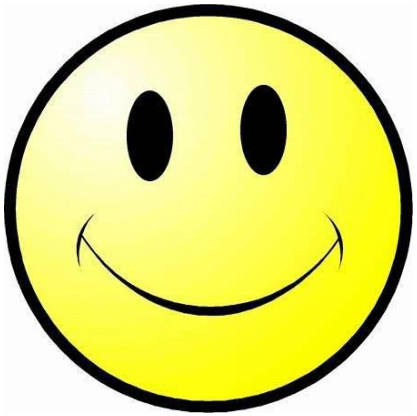

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