Rare Earth Elements' Processing;

Current and Emerging Technologies, and evolving needs within the Manufacturing Sector,

Alaska Strategic and Critical Minerals Summit

September 30, 2011

Fairbanks Princess Riverside Lodge

Fairbanks, Alaska

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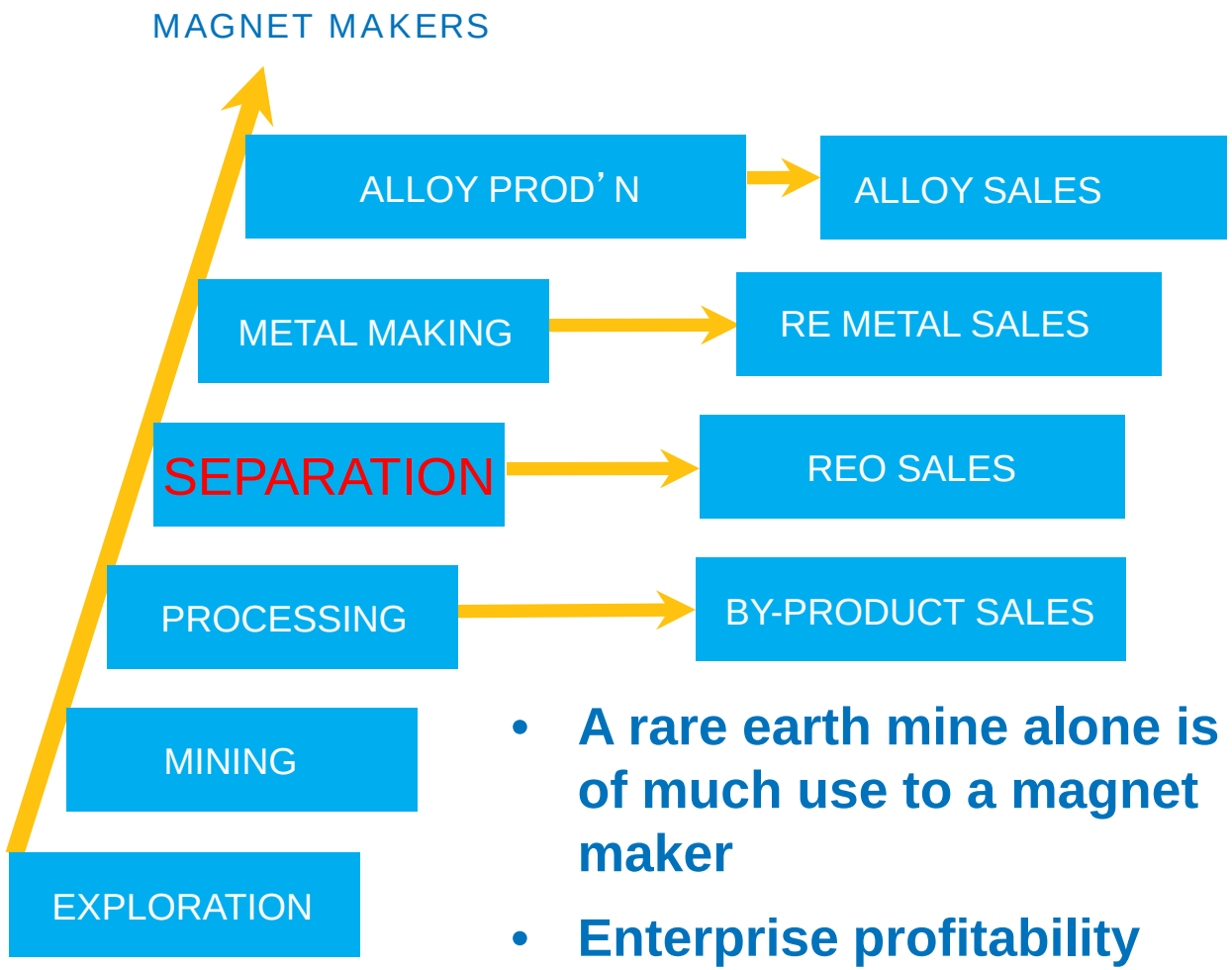
- The SUPPLY CHAIN for any manufactured product made of metal or based on the electronic properties of a metal begins with a MINE not with an ore deposit.
- A MINE is an ORE DEPOSIT from which metal values can be recovered ECONOMICALLY, SAFELY, and LEGALLY.
- For rare metals such as the RARE EARTHS grade is NOT automatically the determining factor for economic recovery.
- *The most important factor for the economic recovery of the rare earths from an ore deposit is the proof that the technologies exist, and are applicable to the particular ore body, that will enable the contained rare earths to be separated from each other as high purity compounds that can be turned into high purity metals at a cost economically competitive with those of existing suppliers.*
- The initial grade of the ore matters, because it may well determine whether or not the ore can be sufficiently concentrated mechanically to allow a known extraction technology to recover sufficient metal values for the above noted separation and purification technologies to be economically competitive.
- The success of an extraction technology in recovering a high percentage of the contained metal values from a mechanically beneficiated "concentrate" is traditionally known as a "metallurgy," but, by itself it is necessary but not sufficent to determine the economic viability of a rare earth mine.

An Integrated Production Model with Value Added Product Sales Points shown on the right



- **A rare earth mine alone is not of much use to a magnet maker**
- **Enterprise profitability increases with each stage of processing**
- **Graphic Courtesy of Great Western Minerals Group, Ltd**

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- A workshop in Washington, DC, next week entitled: EU-Japan-US Workshop on Critical Materials R&D (on October 4,5)will address what I call the separation issue in the following agenda:

Workshop B: Resource efficiency: production, reuse, recovery, recycling > Session B1: Materials and processes for environmentally sound, economical separation of rare earths in diverse ore bodies and recycling streams (Tuesday, October 4, 15:00-18:00) >

- Organic solvents >
- Supercritical solvents >
- Membranes >
- Biological processes >
- Ion exchange

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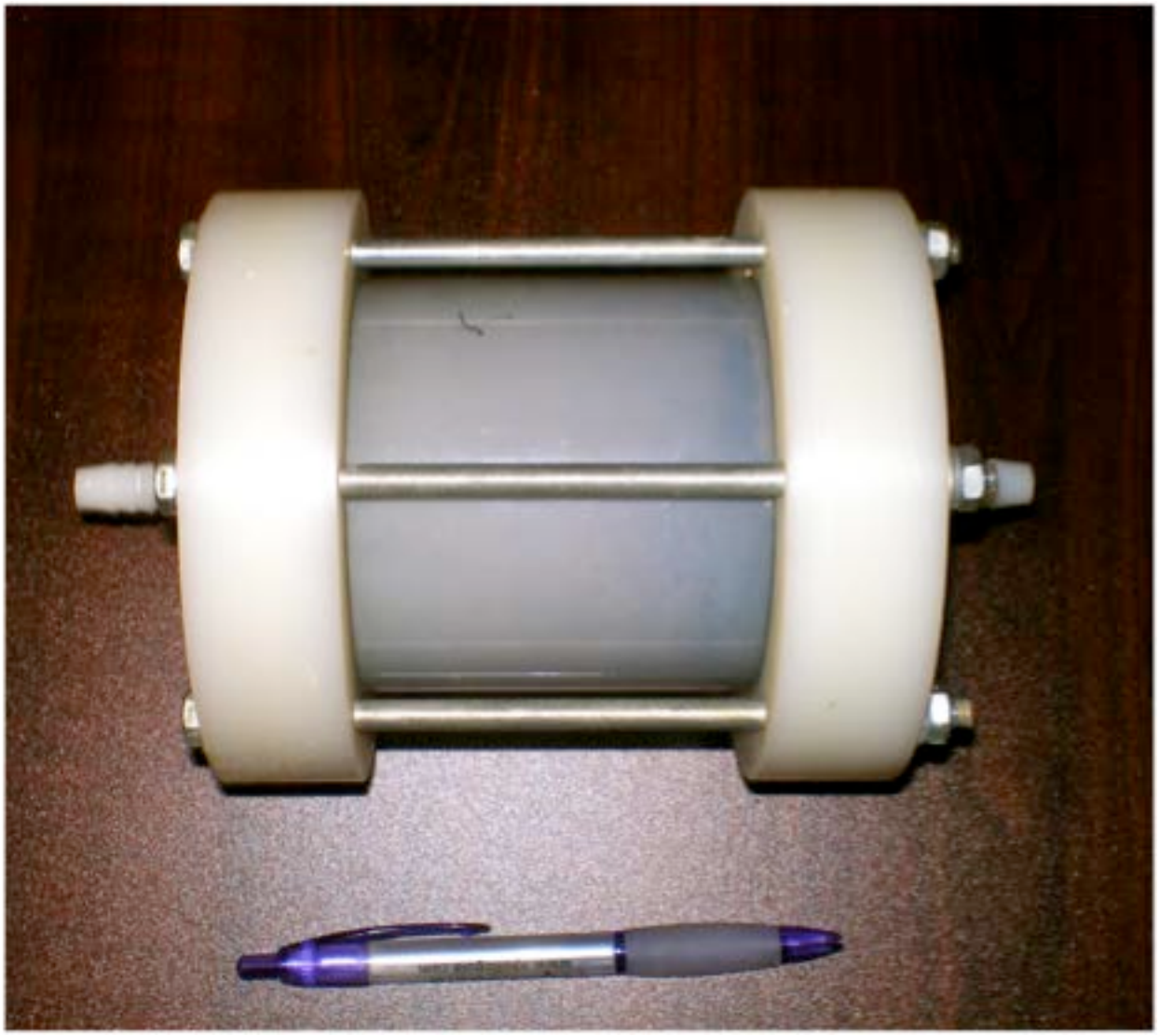
- The next two slides are:
- 1. A view of a solvent exchange facility in Baotou, China, and
- 2. An Ion-exchange (Solid Phase Exchange) column used to separate and purify REEs.
- A bench-top SPE separation system




EDAX

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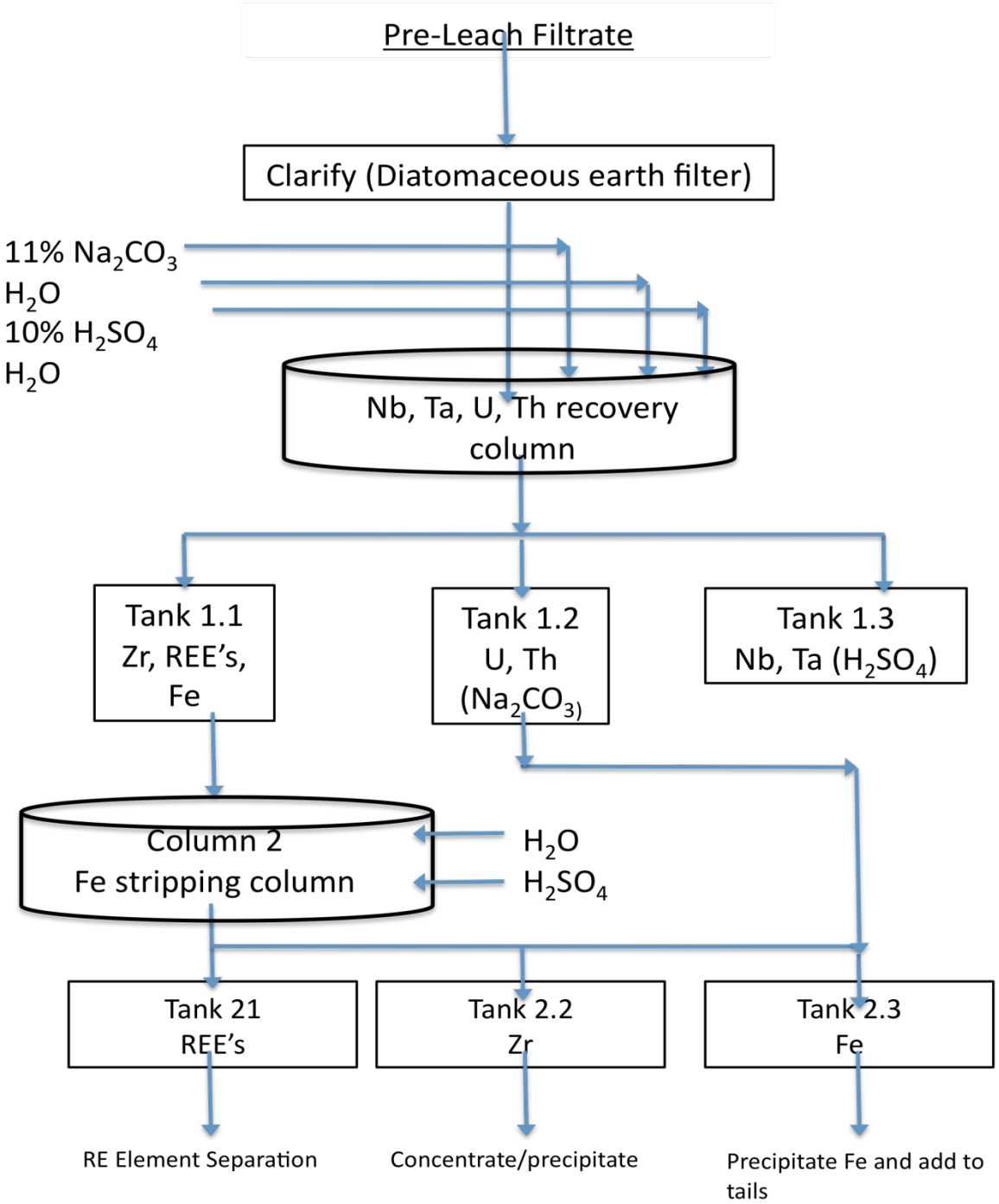
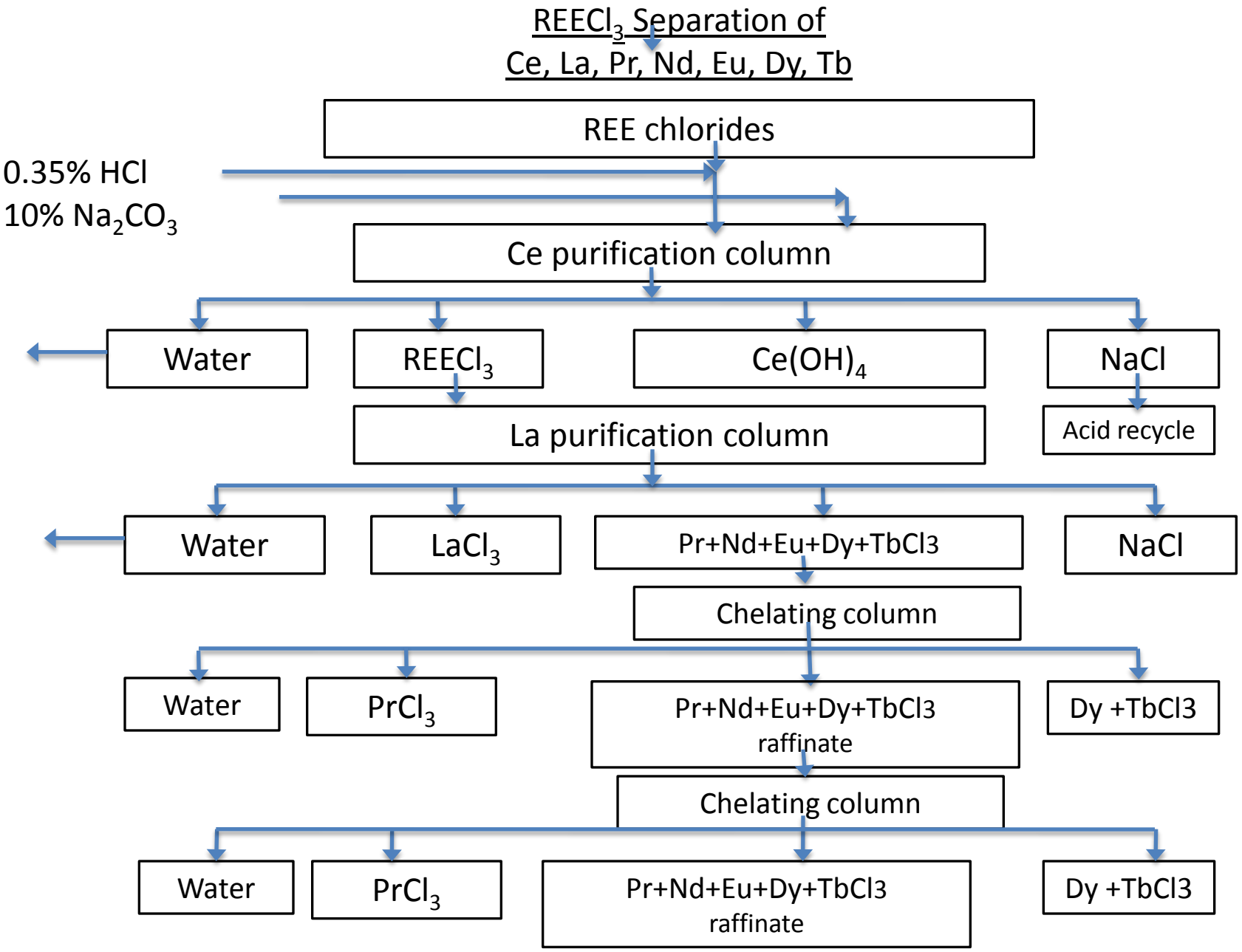
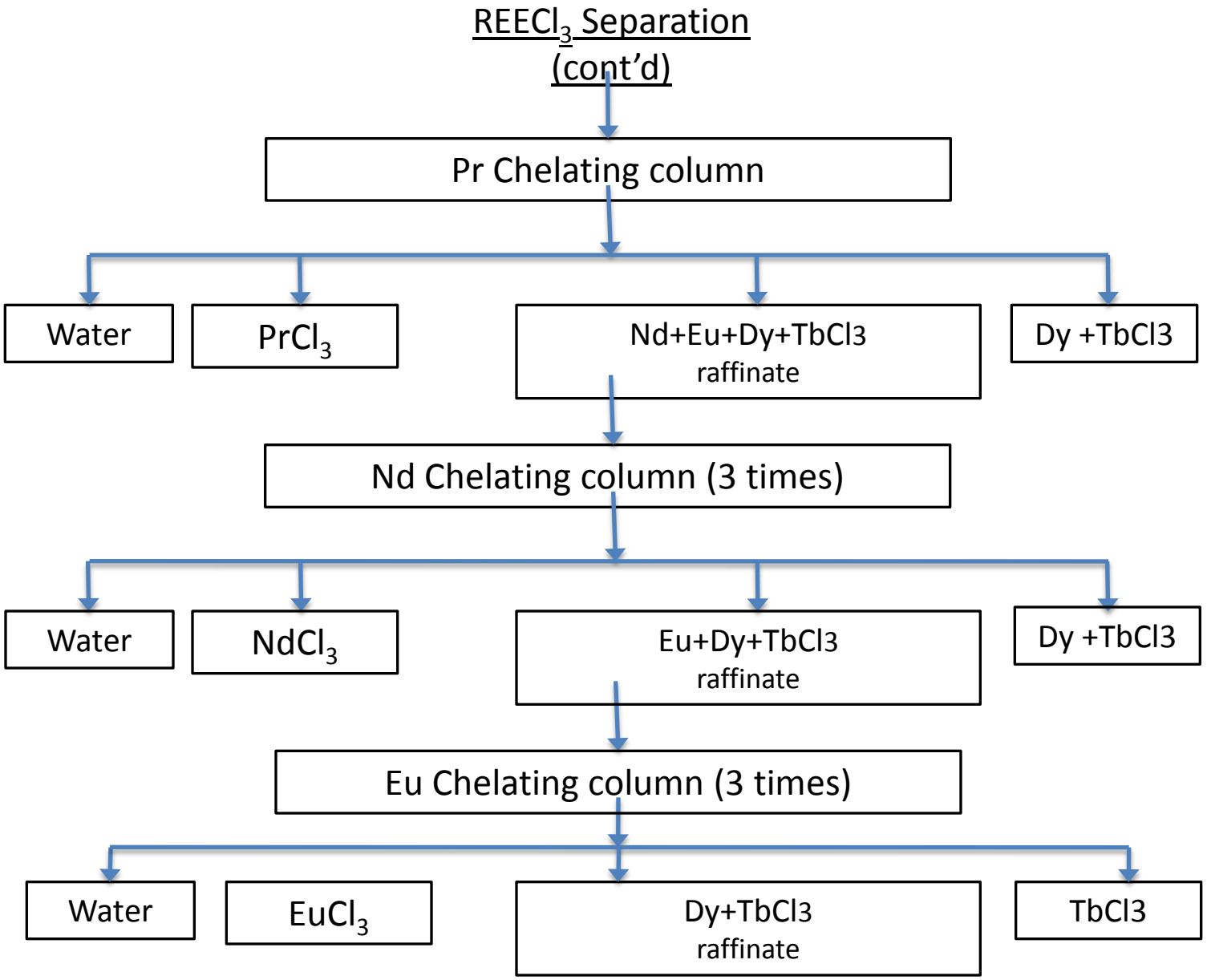
- In Every Known Case of North American REE deposits they are associated with radioactive nuisance elements and/or other metallic elements such as Nb, Ta, Zr, Hf, and Fe, which may add value to the mine's output.

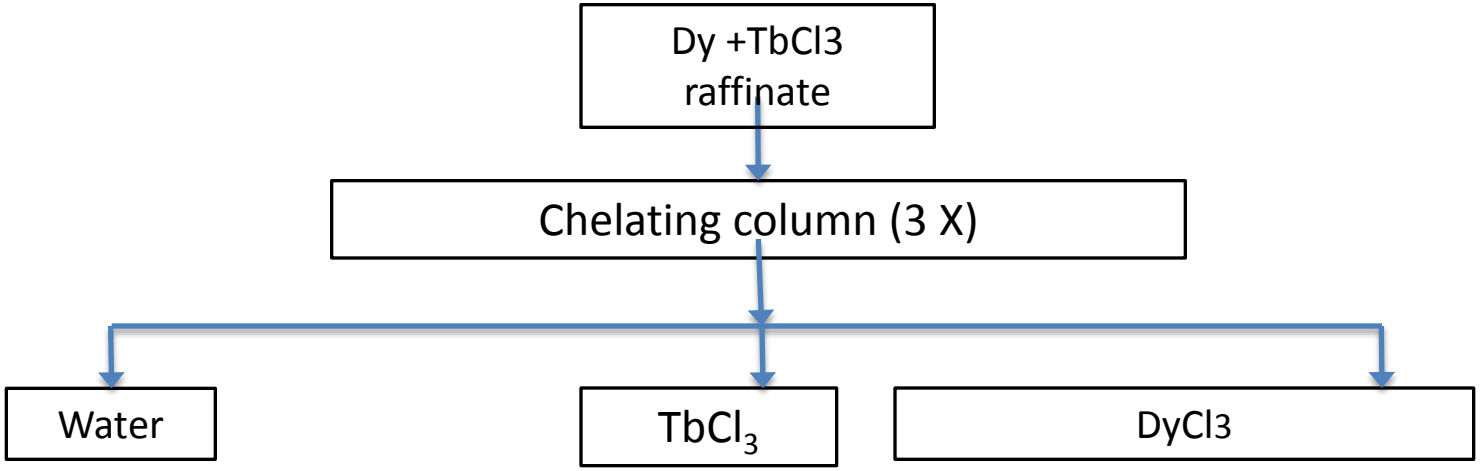
- In order to ultimately produce the desired rare earth metal products, all of the elements first need to be separated from the "nuisance" metals Fe, Th, and U. Second, the elements need to be separated into classes of elements. Third, separation into purified individual element products will give maximum value for the mine.

- These objectives can be accomplished with circuits of chelating ion exchange columns that effect the separation of metals into classes with similar chemical properties.


Pre-Leach Filtrate
Clarify (Diatomaceous earth filter)
11% Na_2CO_3
H_2O
10% H_2SO_4
H_2O
Nb, Ta, U, Th recovery column
Tank 1.1
Zr, REE's, Fe
Tank 1.2
U, Th (Na_2CO_3)
Tank 1.3
Nb, Ta (H_2SO_4)
Column 2
Fe stripping column
H_2O
H_2SO_4
Tank 21
REE's
Tank 2.2
Zr
Tank 2.3
Fe
RE Element Separation
Concentrate/precipitate
Precipitate Fe and add to tails


REECl3 Separation of
Ce, La, Pr, Nd, Eu, Dy, Tb
REE chlorides
0.35% HCl
10% Na2CO3
Ce purification column
Water
REECl3
Ce(OH)4
NaCl
Acid recycle
La purification column
Water
LaCl3
Pr+Nd+Eu+Dy+TbCl3
NaCl
Chelating column
Water
PrCl3
Pr+Nd+Eu+Dy+TbCl3
raffinate
Dy +TbCl3
Chelating column
Water
PrCl3
Pr+Nd+Eu+Dy+TbCl3
raffinate
Dy +TbCl3


REECl3 Separation
(cont'd)
Pr Chelating column
Water
PrCl3
Nd+Eu+Dy+TbCl3
raffinate
Dy +TbCl3
Nd Chelating column (3 times)
Water
NdCl3
Eu+Dy+TbCl3
raffinate
Dy +TbCl3
Eu Chelating column (3 times)
Water
EuCl3
Dy+TbCl3
raffinate
TbCl3


Dy +TbCl3
raffinate
Chelating column (3 X)
Water
TbCl3
DyCl3