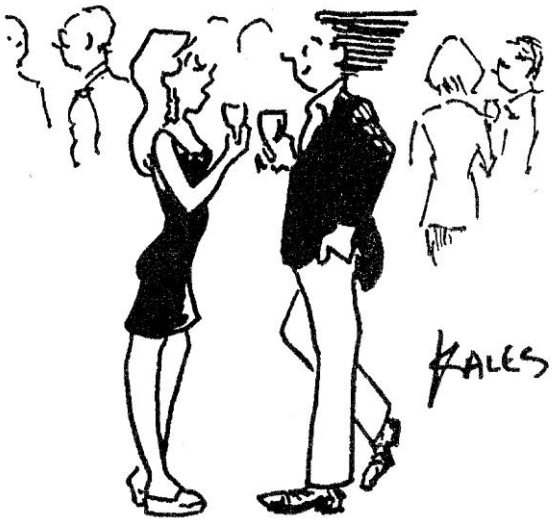
Rare Earth Permanent Magnets: Raw Materials, Magnets and Opportunities

S. R. Trout

Spontaneous Materials

Pepper . . . And Salt

THE WALL STREET JOURNAL



"I understand you work at the wind farm."

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Outline

- Background
- Raw Materials
- Rare Earth Magnets
- Applications
- Final Thoughts

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Background

$SmCo_5$

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Background

Previous Intermag Conferences

- 1976 Pittsburgh
- 1979 New York
- 1980 Boston
- 1981 Grenoble
- 1982 Montréal
- 1983 Philadelphia
- 1985 St. Paul
- 1986 Phoenix
- 1987 Tokyo
- 1989 Washington D.C.
- 1991 Pittsburgh
- 1994 Albuquerque
- 1995 San Antonio
- 2000 Toronto
- 2001 San Antonio

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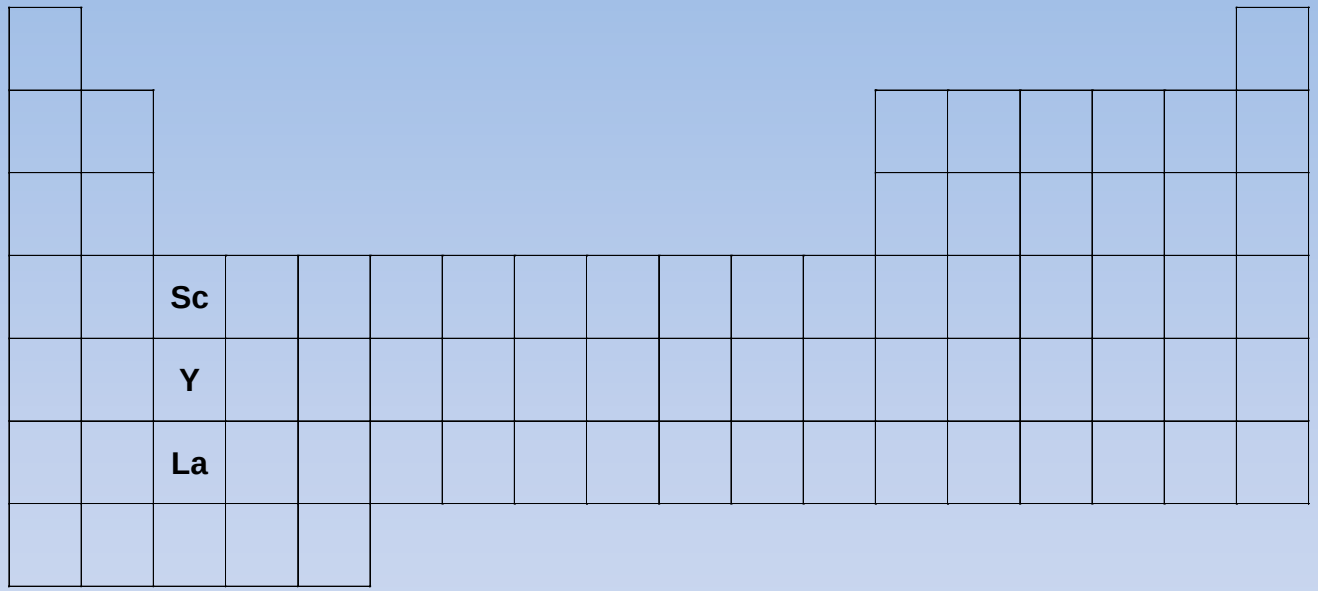
Raw Materials



Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

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Raw Materials

- Ores contain all rare earths except Pm
- There is no shortage of ore
  - *Most rare earths are not rare*
- Most ores are rich in Ce, La, Nd and Pr
- The rare earths are chemically very similar
- Producers try to balance supply and demand

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Raw Materials

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  - *Most rare earths are not rare*
- Most ores are rich in Ce, La, Nd and Pr
- The rare earths are chemically very similar
- Producers try to balance supply and demand
  - And are *rarely* successful!

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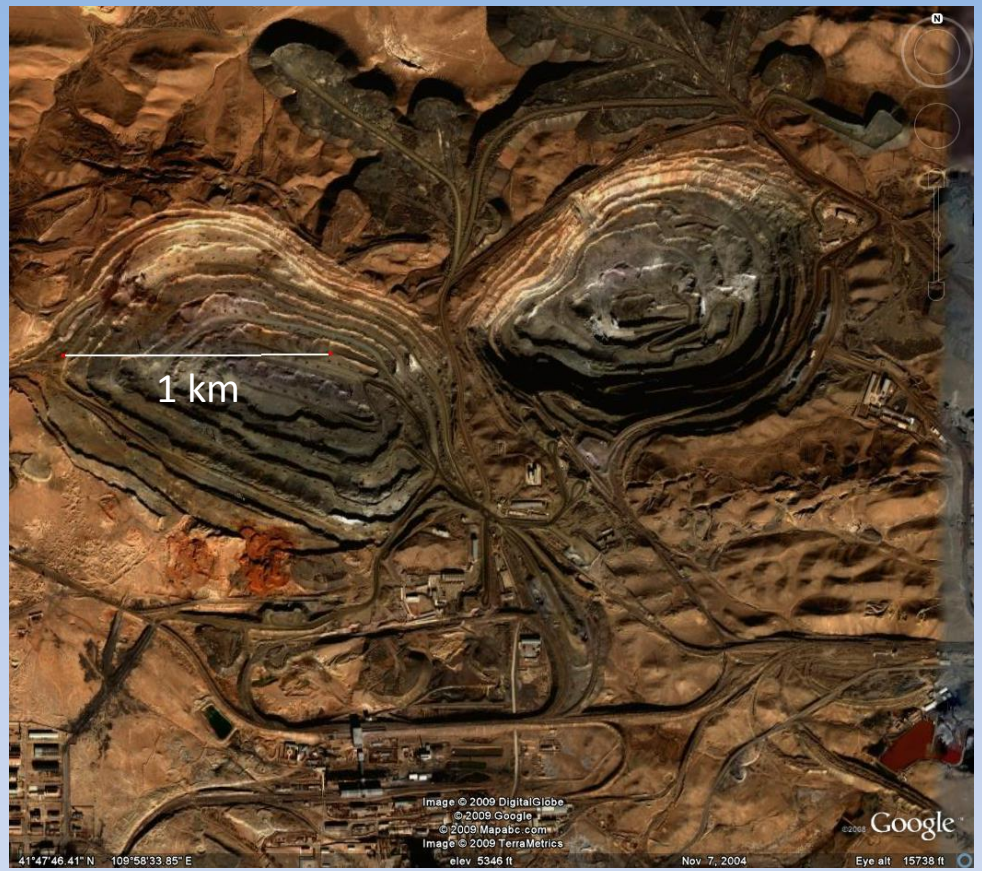

Bayan Obo mine ,
near Baotou, China
Photo from Google Earth

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Mountain Pass, CA
Photo from Molycorp

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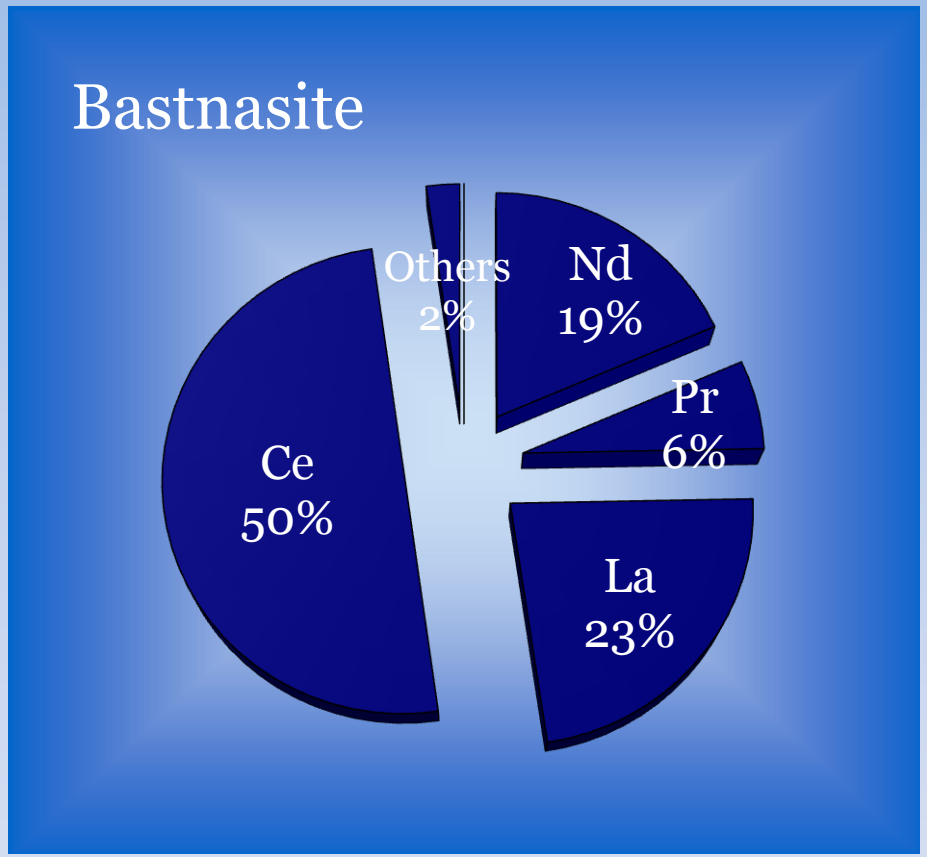
Raw Materials



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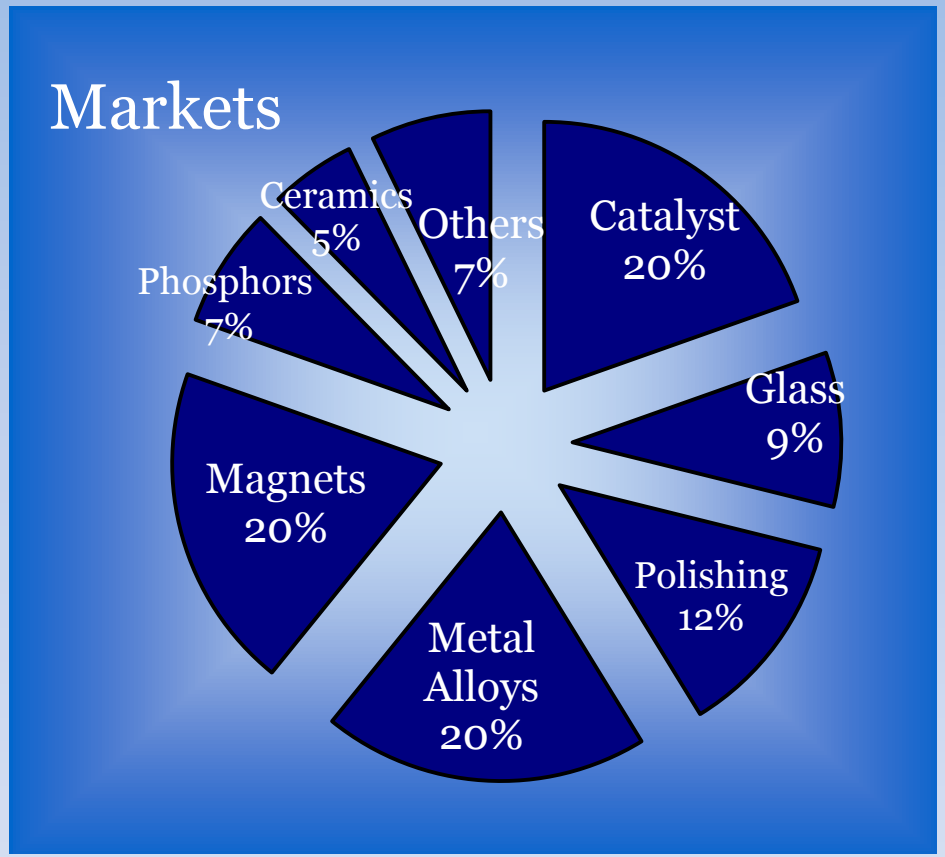
Raw Materials



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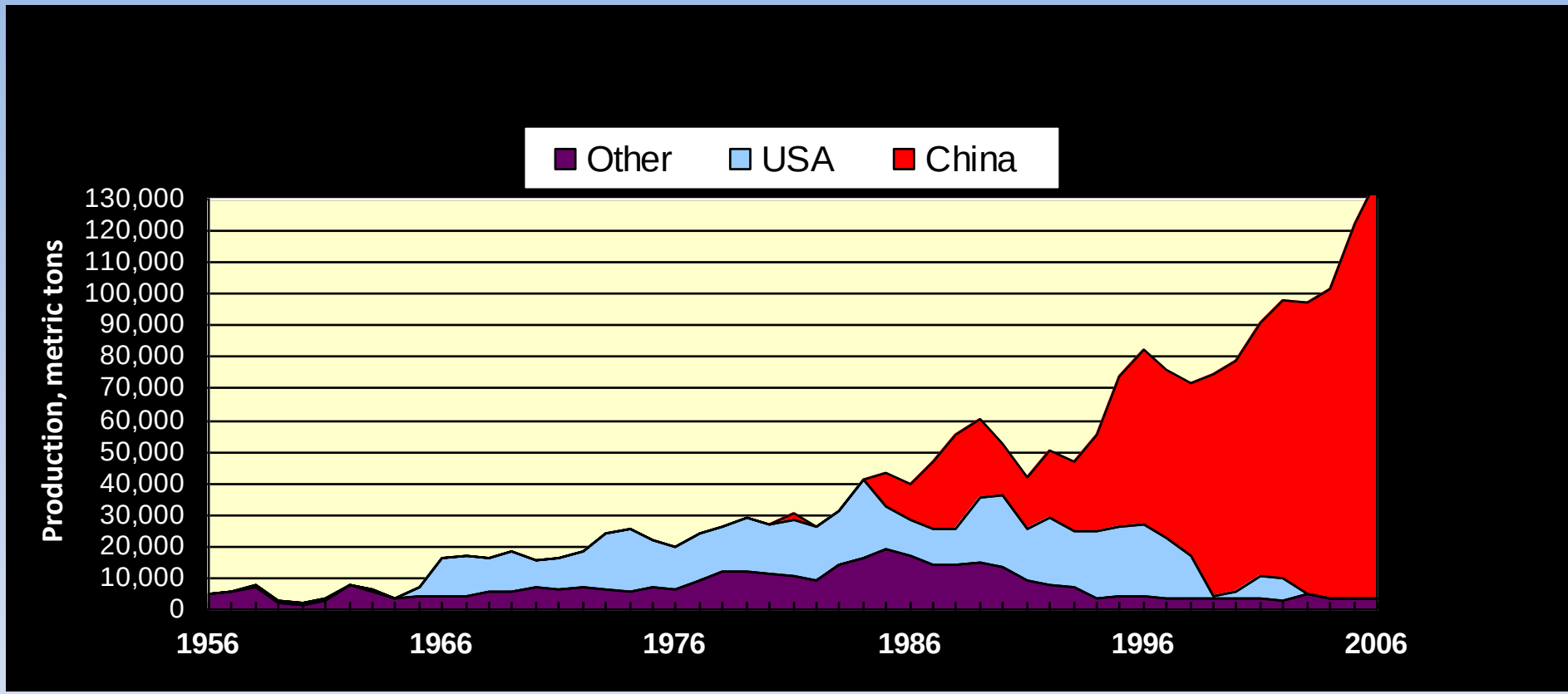
Raw Materials



Source: U.S. Geological Survey

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Raw Materials

- Active mines
  - China
    - Baotou
    - Ionic Ores
- Mines in transition
  - USA
    - Mountain Pass, CA

- Inactive mines or deposits
  - Australia
    - Mt. Weld
    - Nolan's Bore
  - Canada
    - Hoidas Lake
    - Thor Lake
  - India
  - Brazil
  - Vietnam
  - Russia

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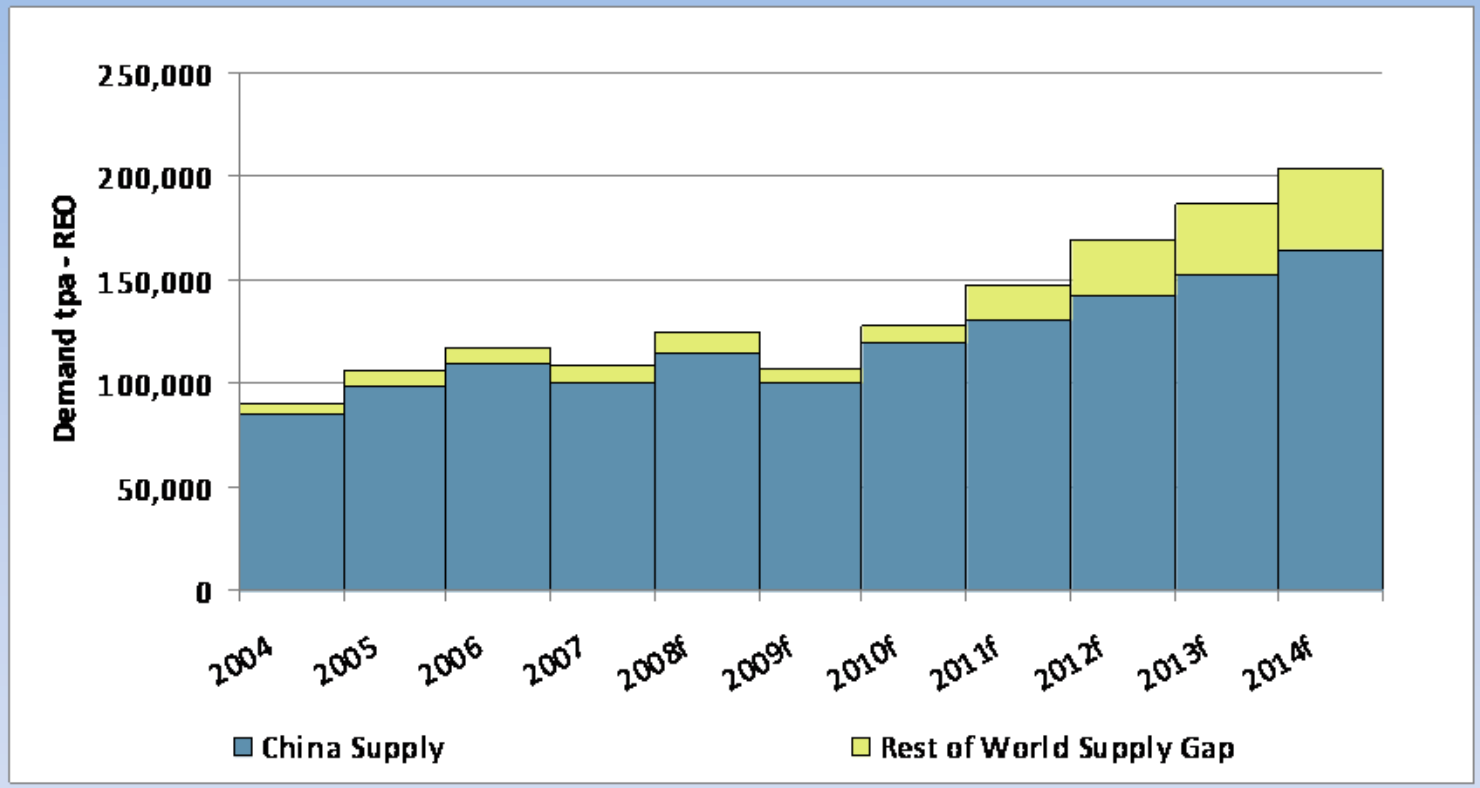
Raw Materials



Source: Dudley Kingsnorth, IMCOA, 2009

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Raw Materials

Issues

- ~~Lack of viable ores~~
  - Most rare earths are not rare
- ~~Shortage of Neodymium~~
  - A self-regulating market
    - Price
    - Design
    - Application
- Dysprosium and Terbium
  - Constrained
- Abrupt changes are extremely disruptive
  - Upsets balance
  - Capital intensive industry
  - Lengthy recovery

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Rare Earth Magnets

Materials

- Sm-Co
  - $SmCo_5$
  - 2-17, $Sm_2(Co,Fe,Cu,Zr/Hf)_{17}$
- Nd-Fe-B
  - $(Nd,Dy)_2(Fe, Co)_{14}B$

Questions

- When?
- Who?
- Where used?
- Speed of implementation?

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Rare Earth Magnets

- Unfinished business
  - The H_{ci} of Nd-Fe-B
    - Why do Dy and Tb Increase H_{ci}?
    - Updating the 1985 explanation

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Rare Earth Magnets

Source: Livingston 1985

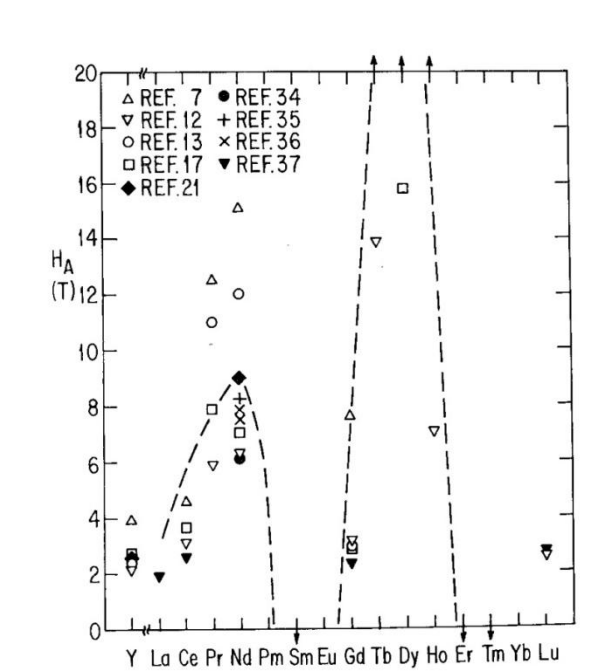

Fig. 4. Reported anisotropy fields of $Fe_{14}R_2B$ compounds. Arrows along top indicates values above 20 T reported for R = Tb, Dy, and Ho in Ref. 7. Arrows along bottom indicate negative (easy-plane) anisotropies reported for R = Sm, Er, and Tm by several investigators.

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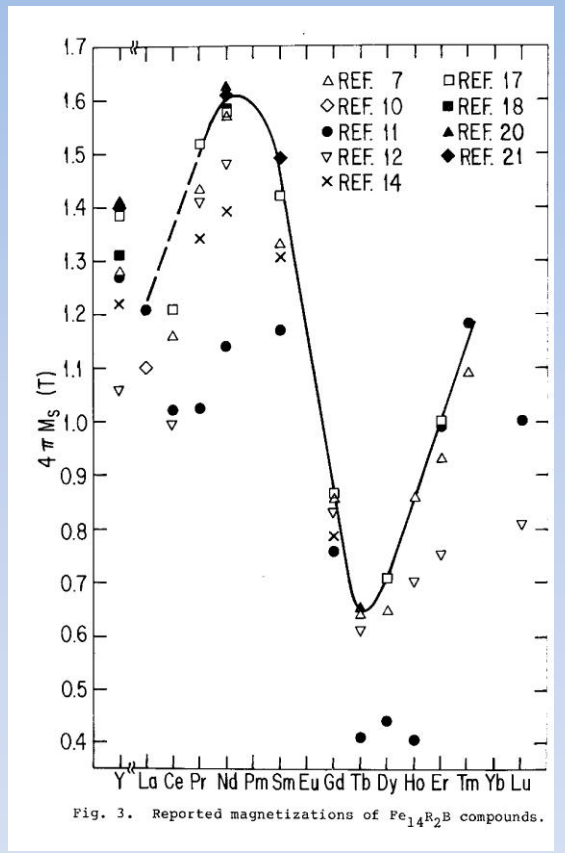

Fig. 3. Reported magnetizations of $Fe_{14}R_2B$ compounds.

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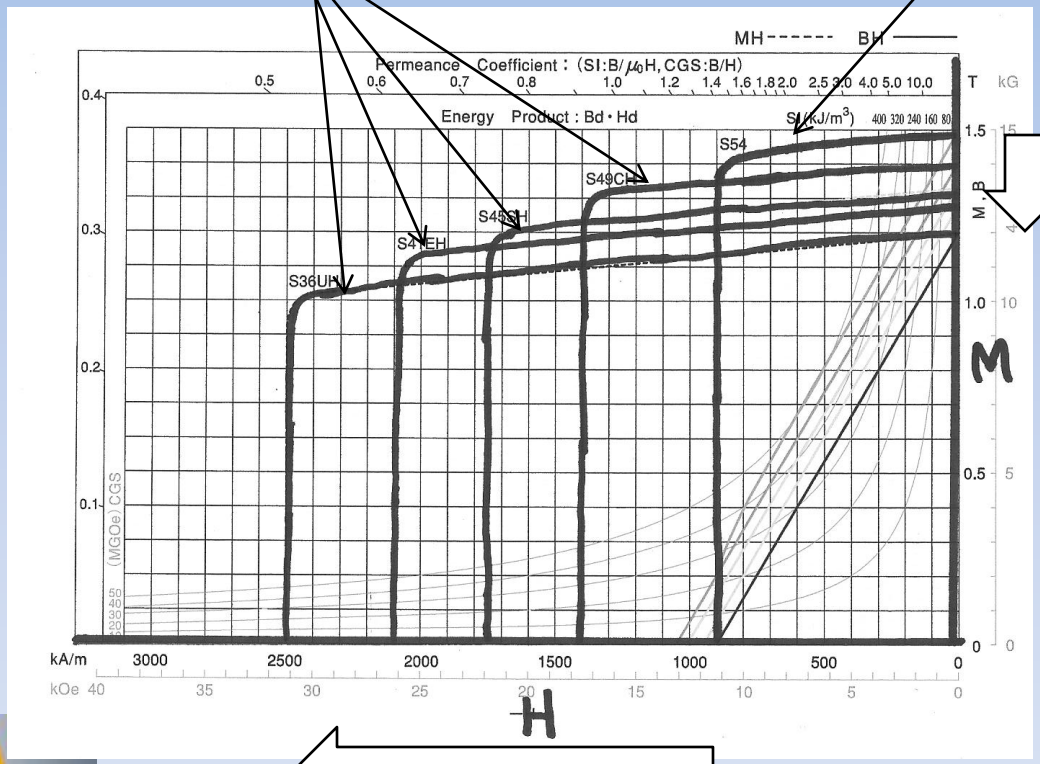
Rare Earth Magnets

$Nd_{2-x}Dy_xFe_{14}B$

$Nd_2Fe_{14}B$



Increasing x

Increasing x

Source: Neomax

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Rare Earth Magnets

- Unfinished business
  - The H_{ci} of Nd-Fe-B
    - Why do Dy and Tb Increase H_{ci}?
    - Updating the 1985 explanation
    - Controlling β, the temp. coefficient of H_{ci}
    - Wiser use of Dy and Tb
  - Anisotropic bonded Nd-Fe-B
  - Recycling, reuse
  - Lower cost

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Rare Earth Magnets
Applications

- Hard drive
  - Voice Coil Motor (VCM)
  - Spindle motors

Source: Western Digital

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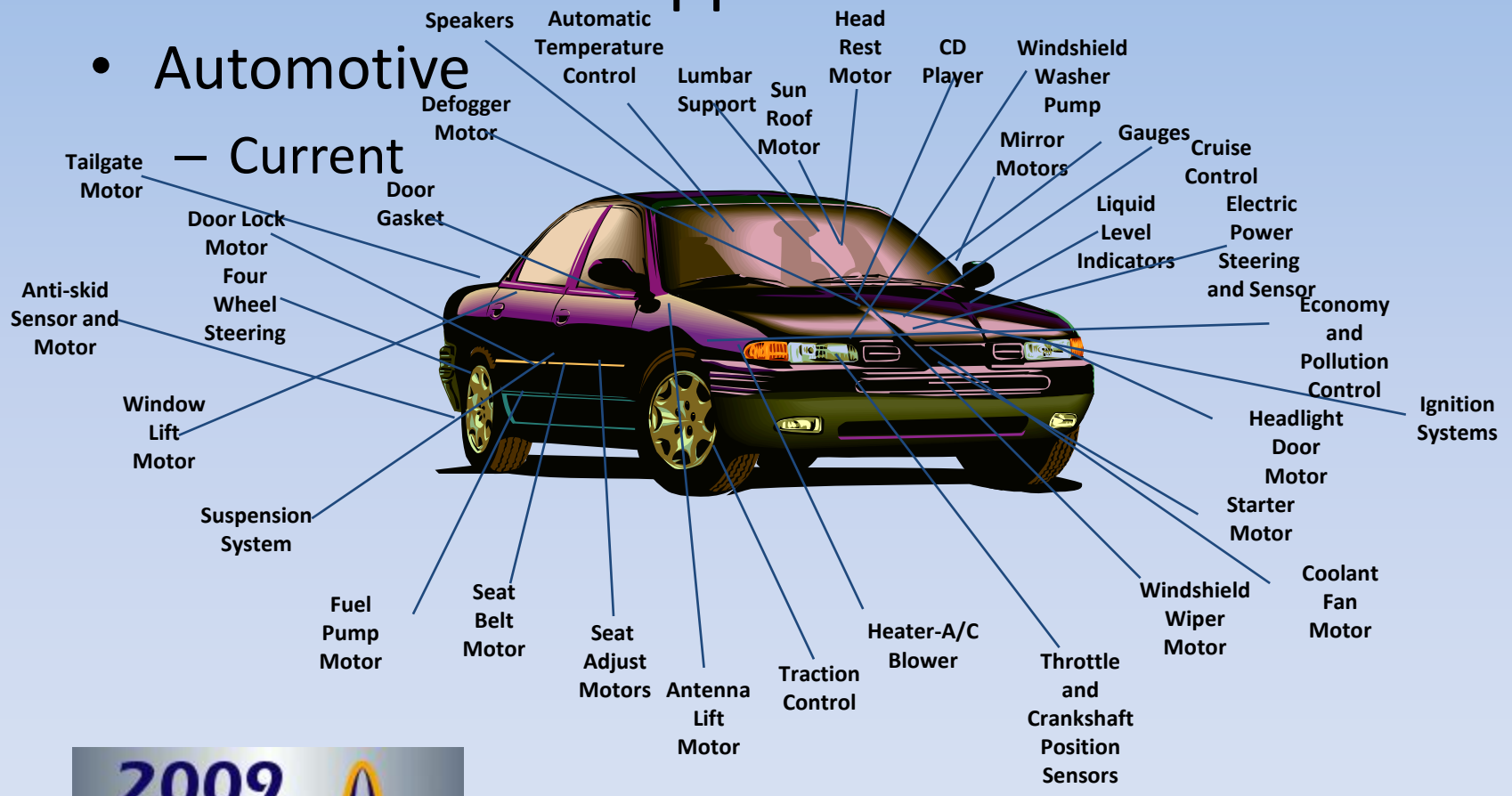
Rare Earth Magnets

Applications

- Automotive
  - Current



Source: Magnequench

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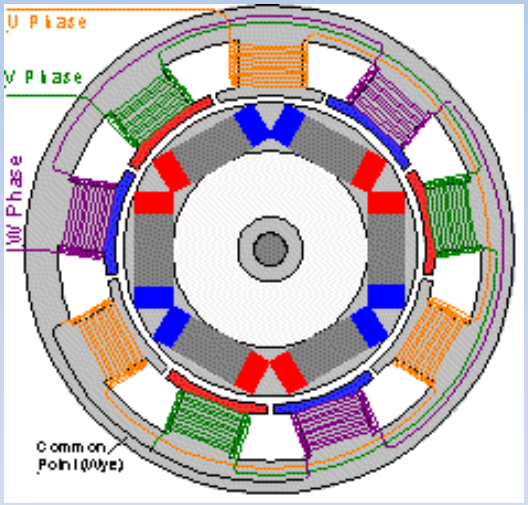
Rare Earth Magnets
Applications

- Automotive
  - Hybrids



Source: Toyota

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Rare Earth Magnets
Applications

- Wind Turbine
  - Magnet vs. asynchronous
  - One tonne of magnet per turbine
  - The future?

Source: Vestas AS

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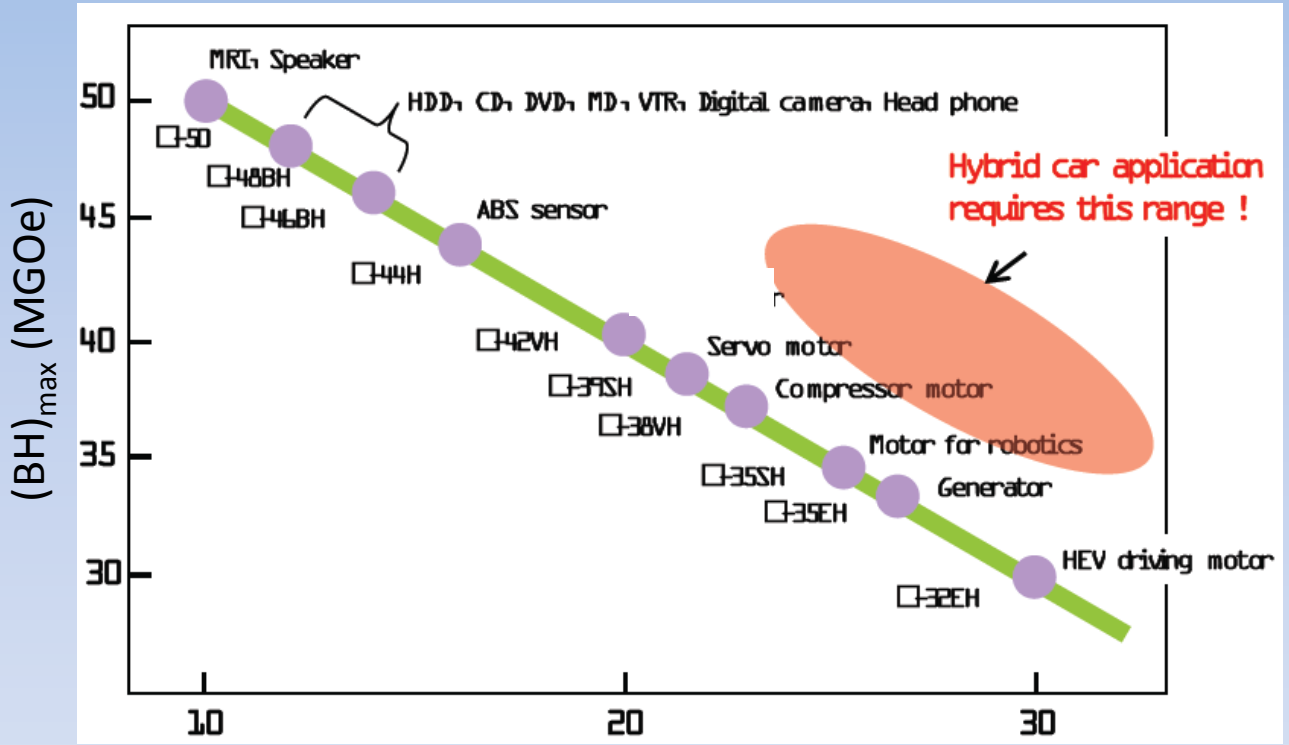
Rare Earth Magnets
The Dy Issue



Source: Magnequench

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Final Thoughts

Raw Materials

- Issues
  - Dysprosium
  - Sudden changes
- Opportunities
  - Green technologies
    - Magnets
    - Ni-metal hydride batteries
    - Lighting phosphors

Rare Earth Magnets

- Issues
  - Dysprosium
    - What does it really do?
    - How can we use less of it?
  - Limited production outside China
- Opportunities
  - Hybrid vehicles
  - Wind turbines
  - Recycling

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Final Thoughts

Presentation will be available on

www.spontaneousmaterials.com

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