AQUEOUS RARE EARTH ELEMENT PATTERNS AND CONCENTRATION IN CO-PRODUCED BRINES AND INDUSTRIAL PONDS, WYOMING

Charles Nye[1] Ghanashyam Neupane[2] Scott Quillinan[1]
Travis McLing[2] Fred McLaughlin[1] Davin Bagdonas[1]

[1]Carbon Management Institute, University of Wyoming
[2]Idaho National Laboratory

Outline

Serious Title	Cheap Novel Title
The Parent Project	The Big Picture
Isotope Data	Inspiration
General REE Theory	Overlooked?
Measuring ng/L (ppt)	The Challenge
Data by Basin & Field	Found Fingerprints
Conclusions	Explanation

Project Objectives

Element	Type	Applications	Element	Type	Applications
Ce[1]	REE	Oxidizer and catalyst	Mn[1]	Trace	Steel alloys and production
Co[1]	Trace	Batteries and alloys	Nd[1]	REE	Magnets and capacitors
Dy[1]	REE	Magnets and minor alloys additive	Ni[1]	Trace	Multi-purpose metal
Er	REE	Lasers and steel alloys	Pr[1]	REE	Radioactive decay heating
Eu[1]	REE	Lighting and NMR	Sc	REE	Catalyst and lighting
Ga[1]	Trace	Photovoltaics and semiconductors	Sm	REE	Magnets and neutron flux control
Gd	REE	Neutron flux control and many alloys	Tb[1]	REE	Magnets and lasers
Ho	REE	Magnets and lasers	Th	Trace	Fuel and lighting
In[1]	Trace	Photovoltaic film	Tm	REE	Lighting and lasers
La[1]	REE	Catalyst and glass additive	U	Trace	Fuel and ballast
Li[1]	Trace	Flux and batteries	Y[1]	REE	Lasers and steel alloys
Lu	REE	Medical tracer and glass additive	Yb	REE	Reducing agent and steel alloys

[1] DOE identified critical material

National Database - O&G and Geothermal REEs

Refine Measuring Methods

Statistical Screening to predict occurrence

Techno-Economic Assessment

Project Objectives

Element	Type	Applications	Element	Type	Applications
Ce[1]	REE	Oxidizer and catalyst	Mn[1]	Trace	Steel alloys and production
Co[1]	Trace	Batteries and alloys	Nd[1]	REE	Magnets and capacitors
Dy[1]	REE	Magnets and minor alloys additive	Ni[1]	Trace	Multi-purpose metal
Er	REE	Lasers and steel alloys	Pr[1]	REE	Radioactive decay heating
Eu[1]	REE	Lighting and NMR	Sc	REE	Catalyst and lighting
Ga[1]	Trace	Photovoltaics and semiconductors	Sm	REE	Magnets and neutron flux control
Gd	REE	Neutron flux control and many alloys	Tb[1]	REE	Magnets and lasers
Ho	REE	Magnets and lasers	Th	Trace	Fuel and lighting
In[1]	Trace	Photovoltaic film	Tm	REE	Lighting and lasers
La[1]	REE	Catalyst and glass additive	U	Trace	Fuel and ballast
Li[1]	Trace	Flux and batteries	Y[1]	REE	Lasers and steel alloys
Lu	REE	Medical tracer and glass additive	Yb	REE	Reducing agent and steel alloys

[1] DOE identified critical material

National Database - O&G and Geothermal REEs

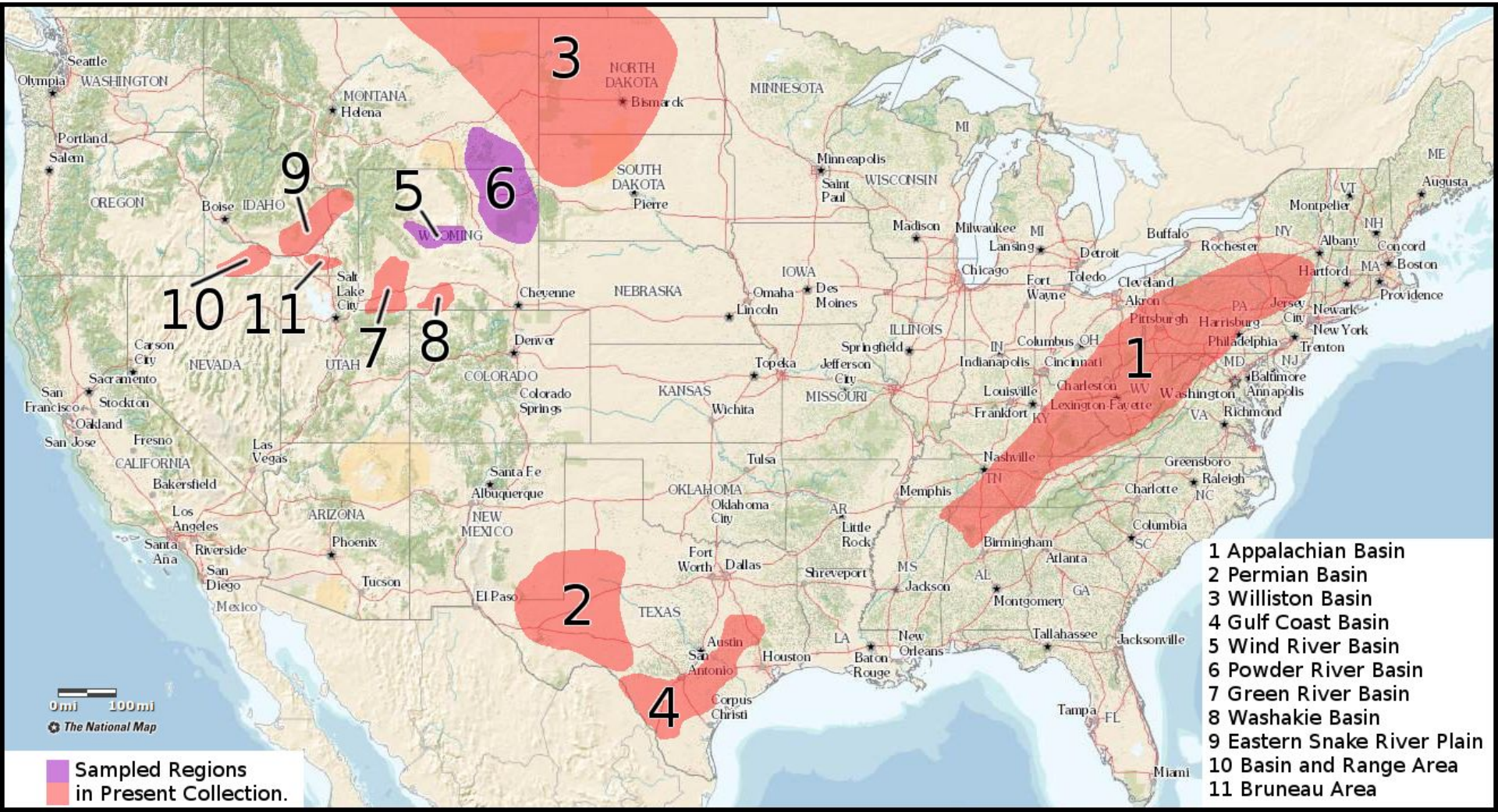
Refine Measuring Methods

Statistical Screening to predict occurrence

Techno-Economic Assessment

Ongoing REE Work

N ≈ 150



Study Area for this talk

N = 28

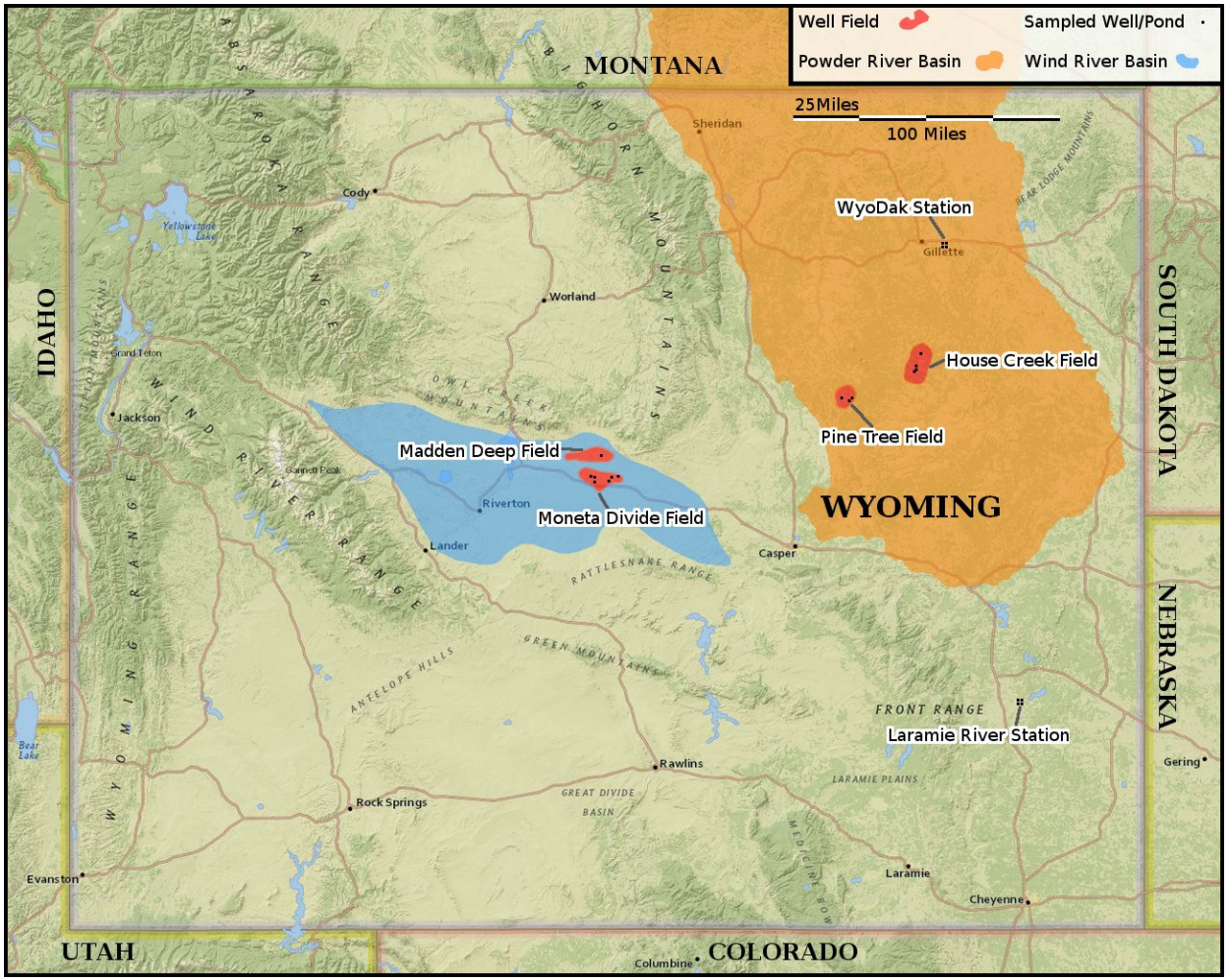
WRB

2 Fields

PRB

2 Fields

2 Power Stations



Strata

WRB:

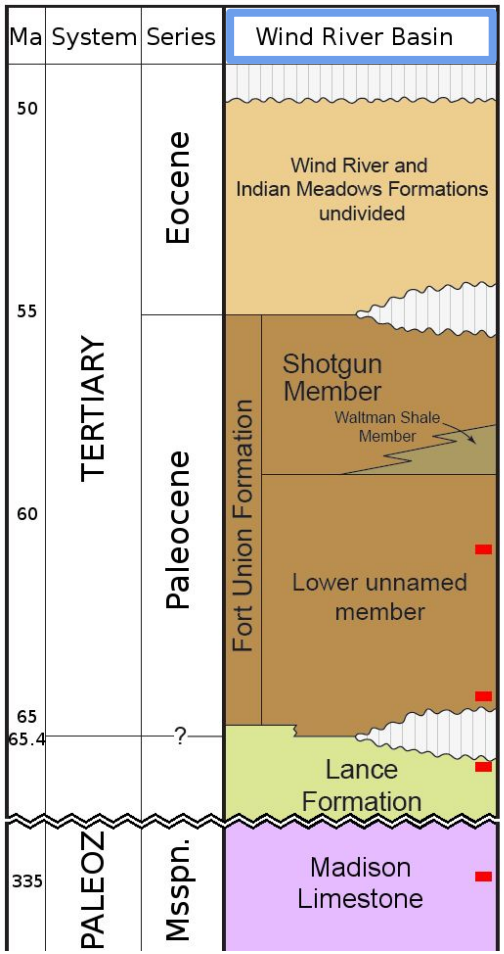
Young-

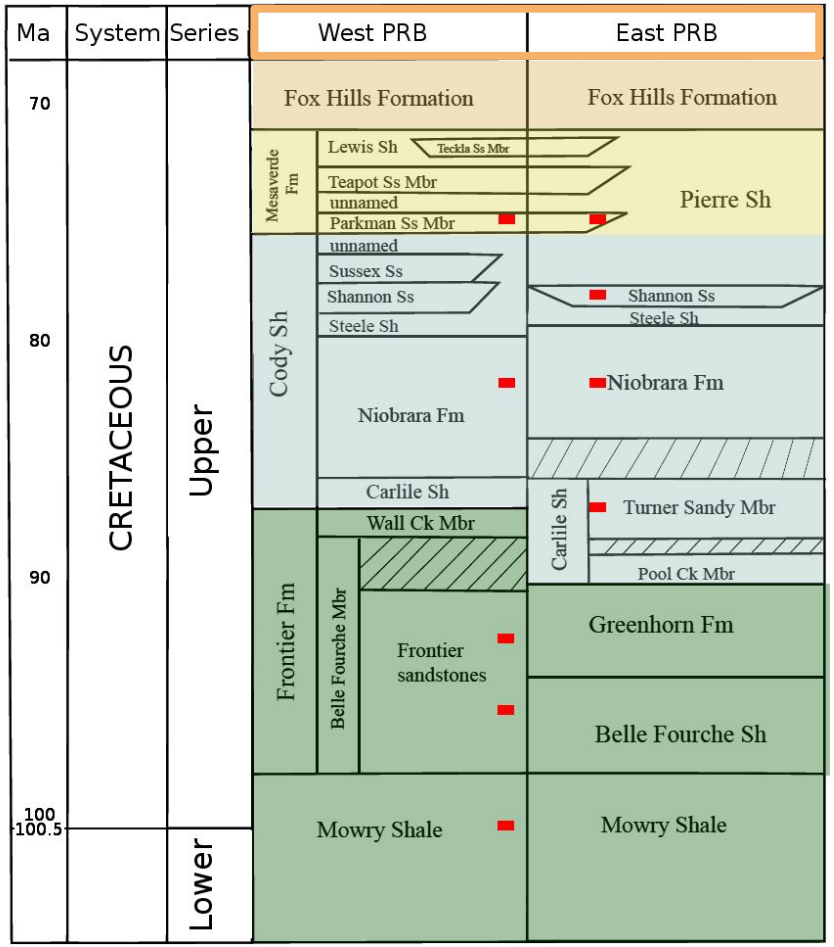
Very Old

PRB:

East-

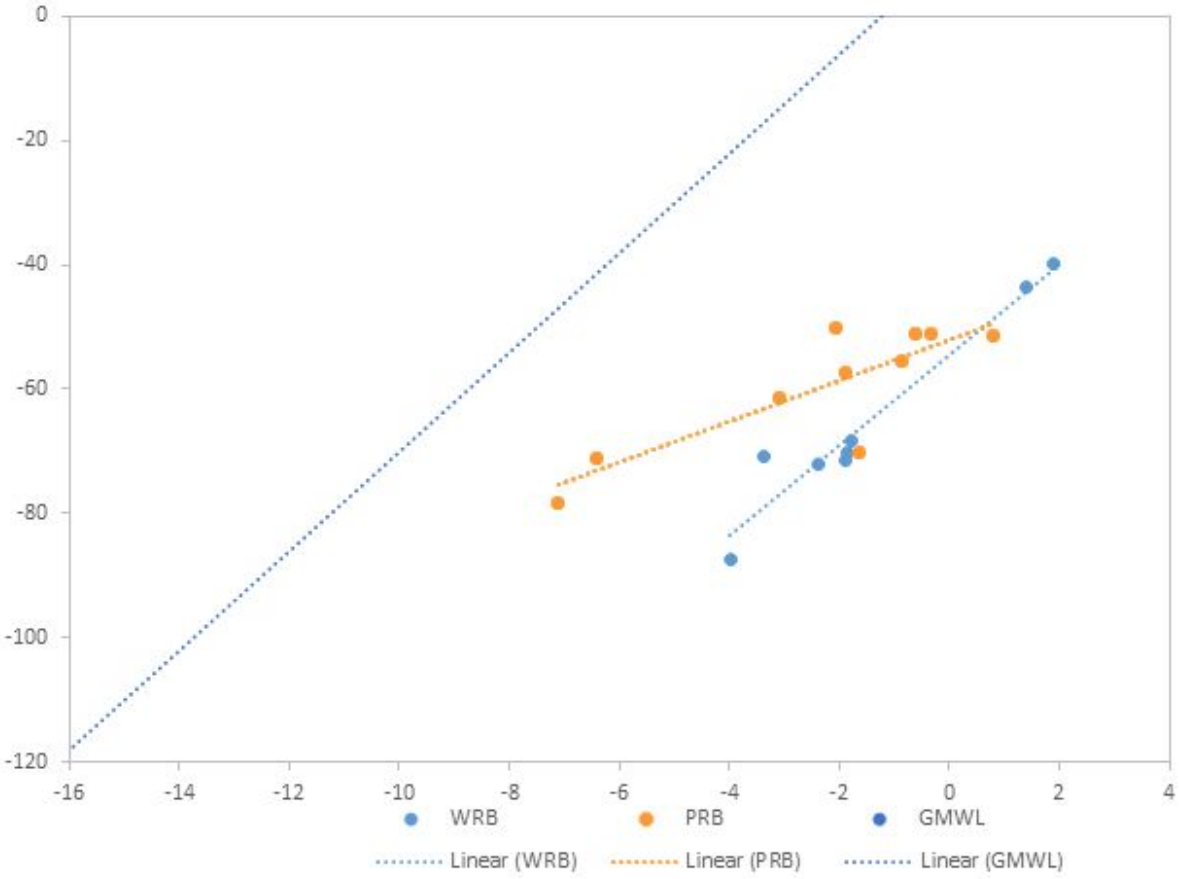
West





Isotopes: δD, δO^{18}

- Right of GMWL
- Prolonged Rxn with Rock
- Good place to see REEs from rock to water



REE Transfer

Mantle

mixing

Emplaced Magma

fract. crystallization

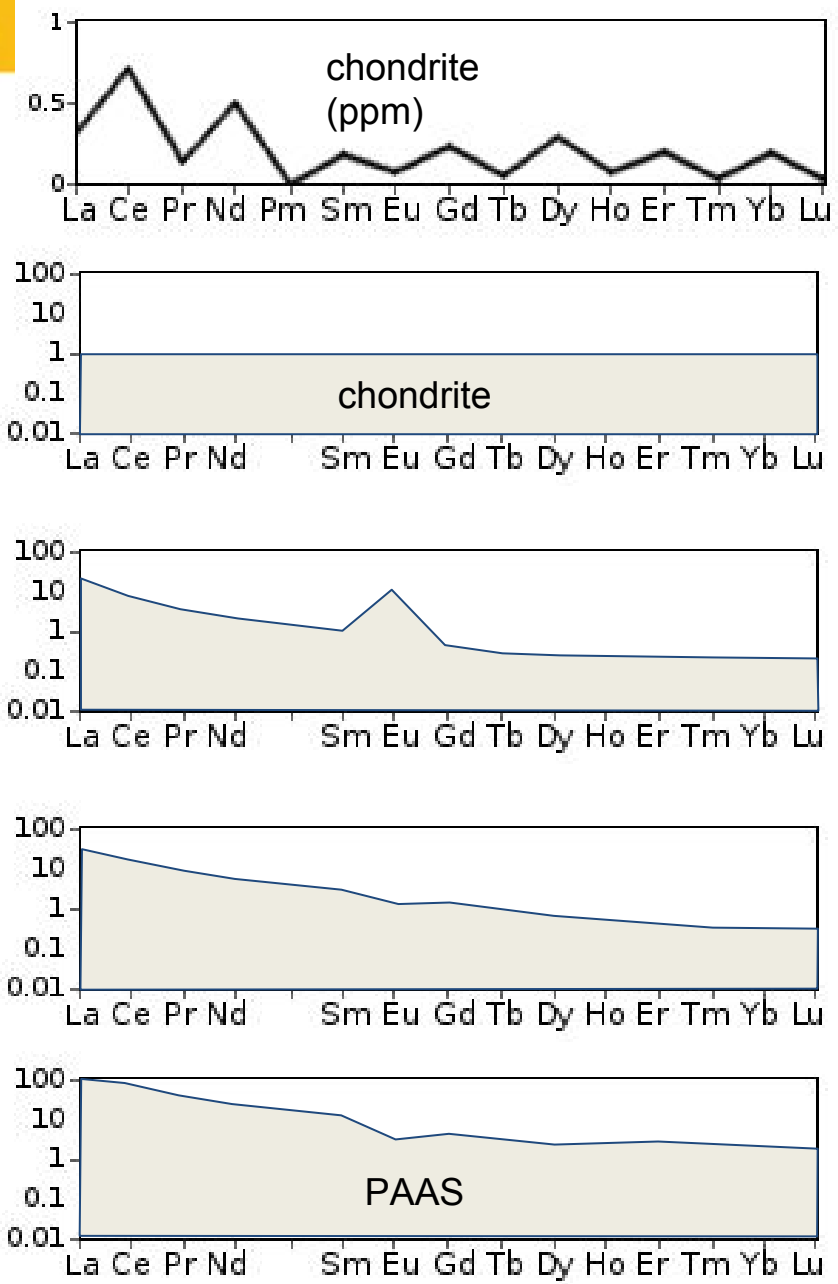
Igneous Metamorphs

weathering

Loose Sediment

diagenesis

Metasediment



Natural Water REE Transfer

Mantle

mixing

Emplaced Magma

fract. crystallization

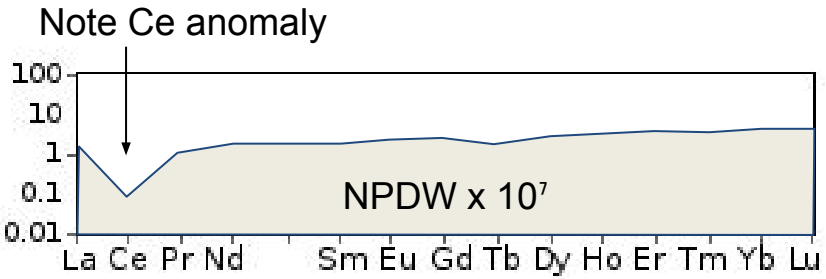
Igneous Metamorphs

weathering

Loose Sediment *dissolution* **Water**

diagenesis *Evaporation*

Metasediment **Evaporites**



Rock normalization inappropriate for Water

Solids - Rock, particulate, sediment:

NASC, PAAS, UCC, RSA, GLOSS, and Chondrite

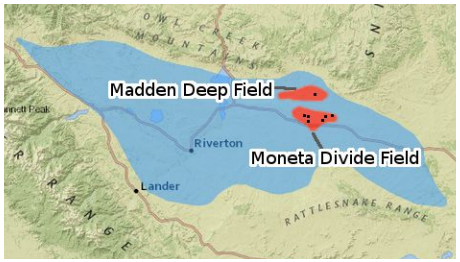
Dissolved - 10^{-7} of solids:

NPDW, NADW, AIW, and various rivers.

Deep Basin Brine normalization remains to be developed.

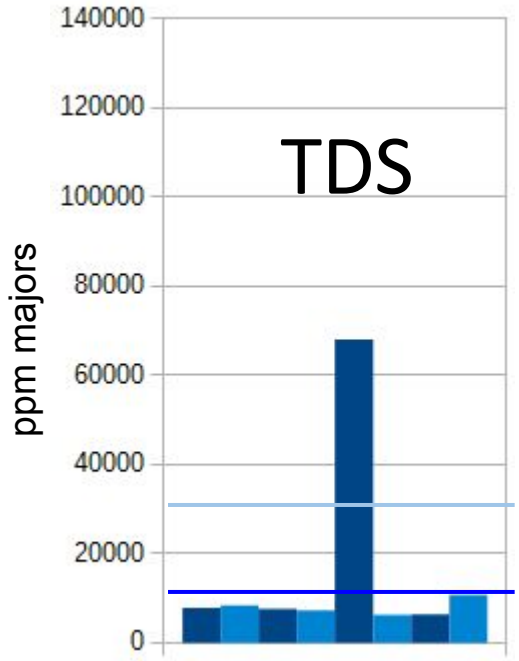
LOW TDS Brine [<4.5 g/L]	High TDS Brine [4.5-300 g/L]
AG 50W-X8 Resin	Chelex-100
Column (Re)generation Water, Concentrated Acid, Water	Column (Re)generation (for 25 mL Chelex) Water, Acid, Water, Ammonia
Sample Chromatography Gravity flow	Sample Chromatography pH adjustment, Gravity flow
Elution of Mono/dia-valent Cations Dilute acid wash, Water rinse	Elution of Mono/dia-valent cations Multi-stage water and ammonia washes
Elution of REEs Concentrated acid wash	Elution of REEs Multi-stage acid wash
Analysis by ICP-MS	Analysis by ICP-MS

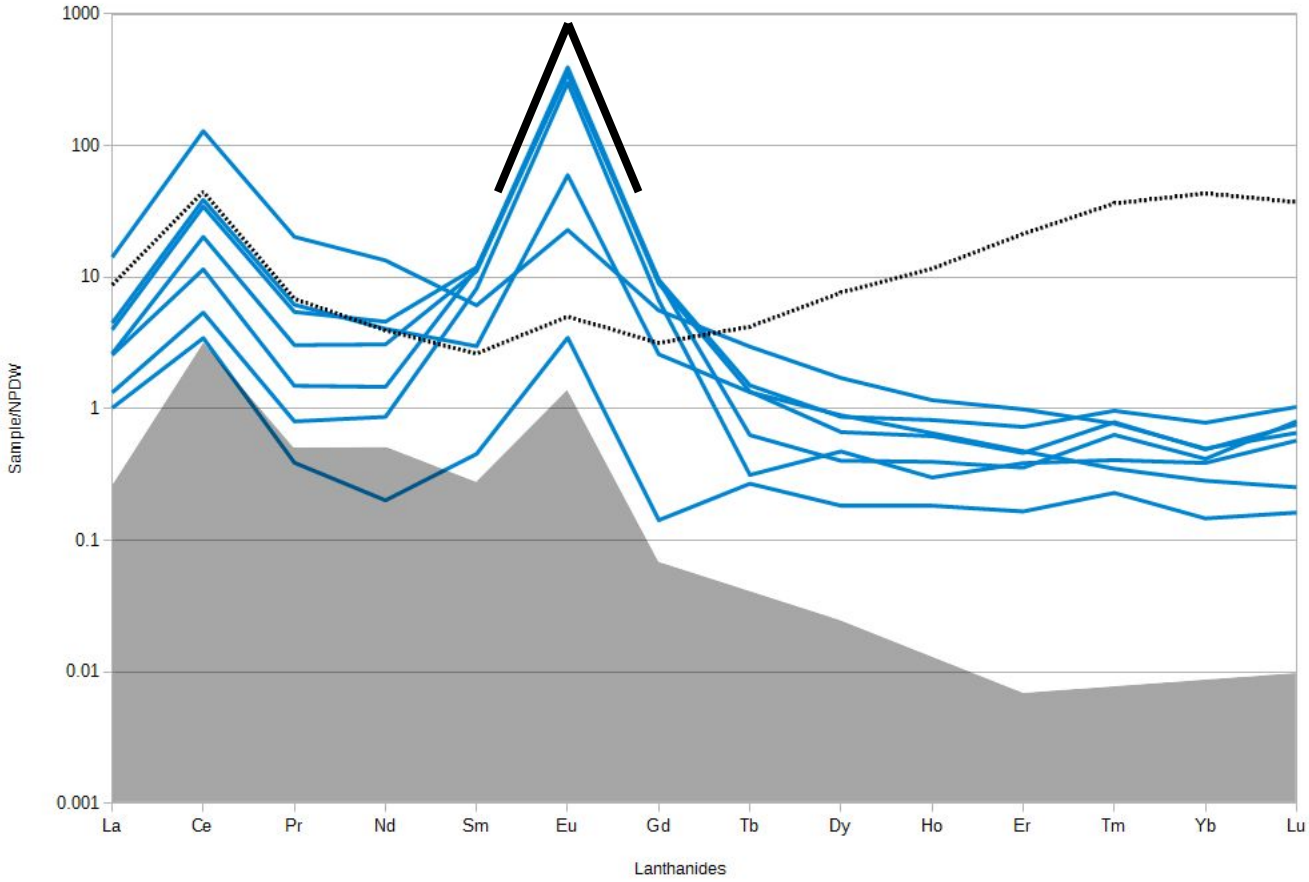
Basin REE



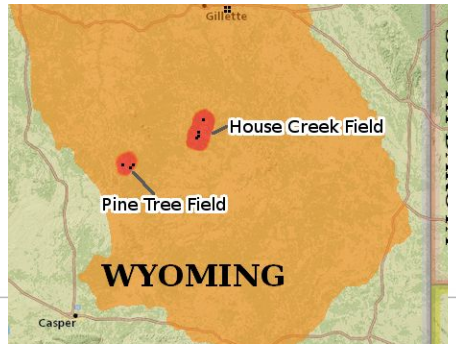
WRB:

Sm≈Gd<<Eu



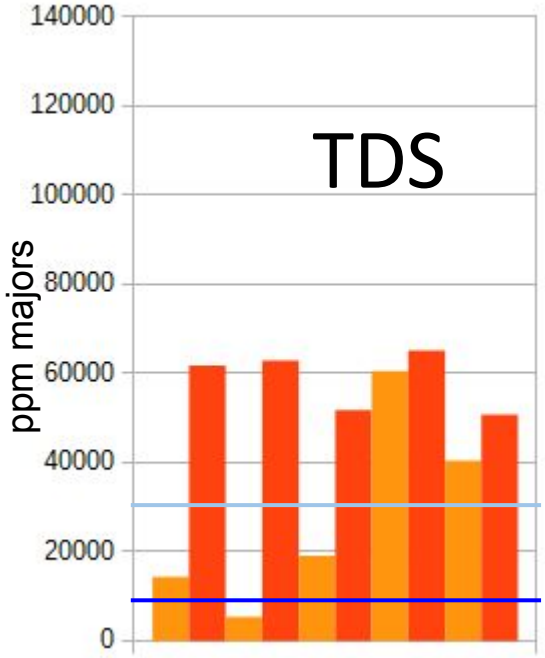


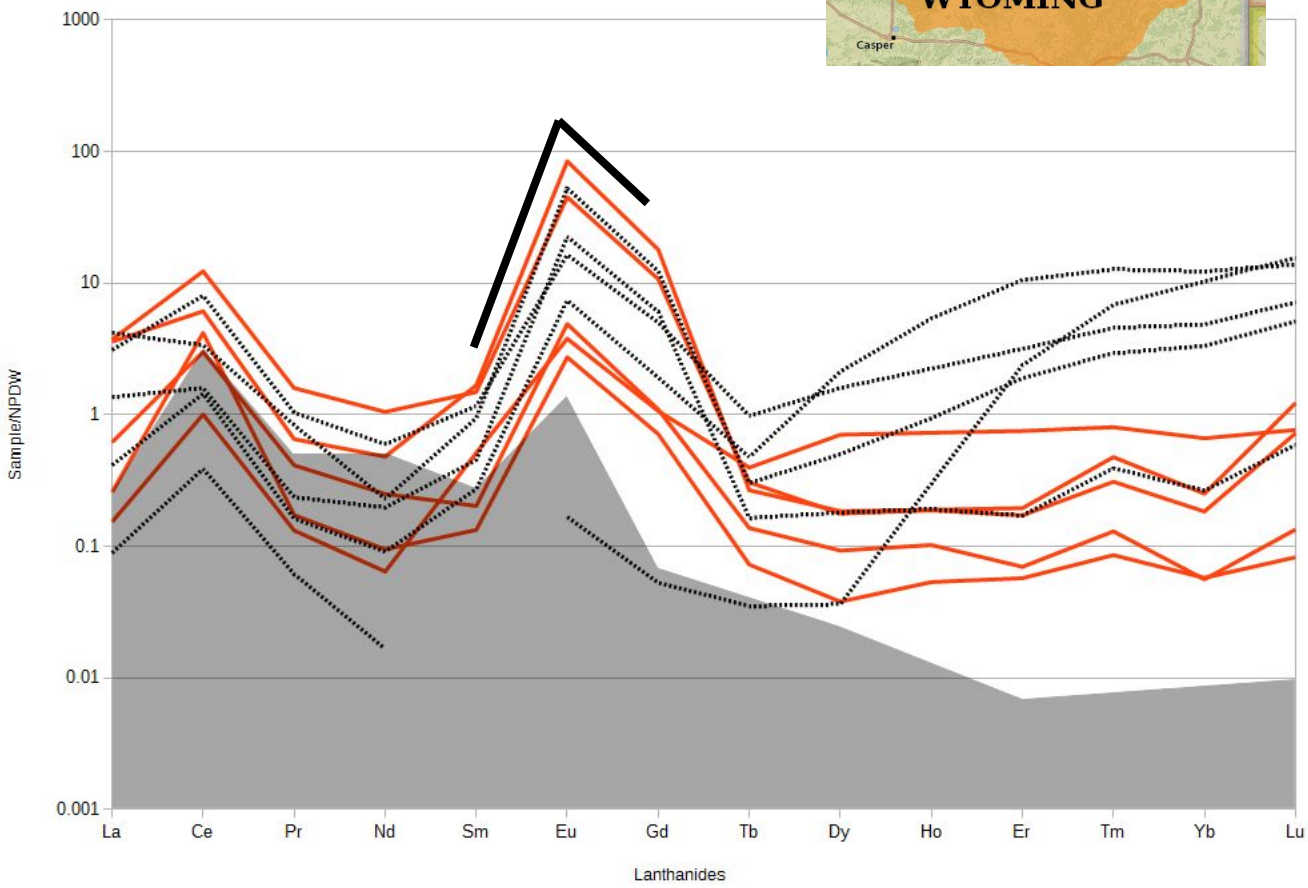
Basin REE



PRB:

Sm<Gd<Eu

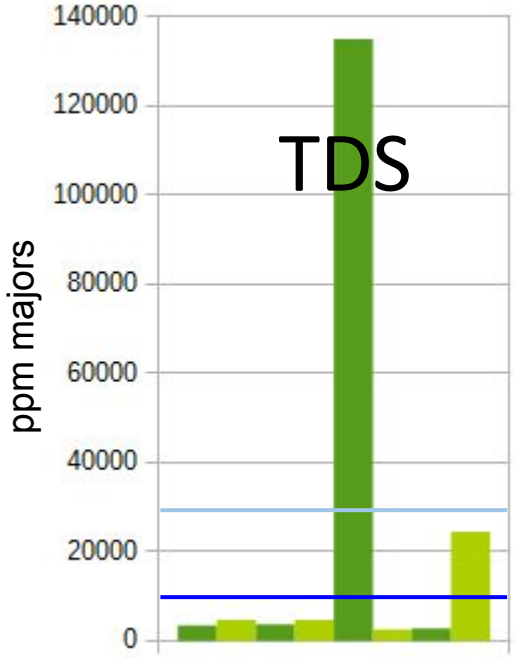


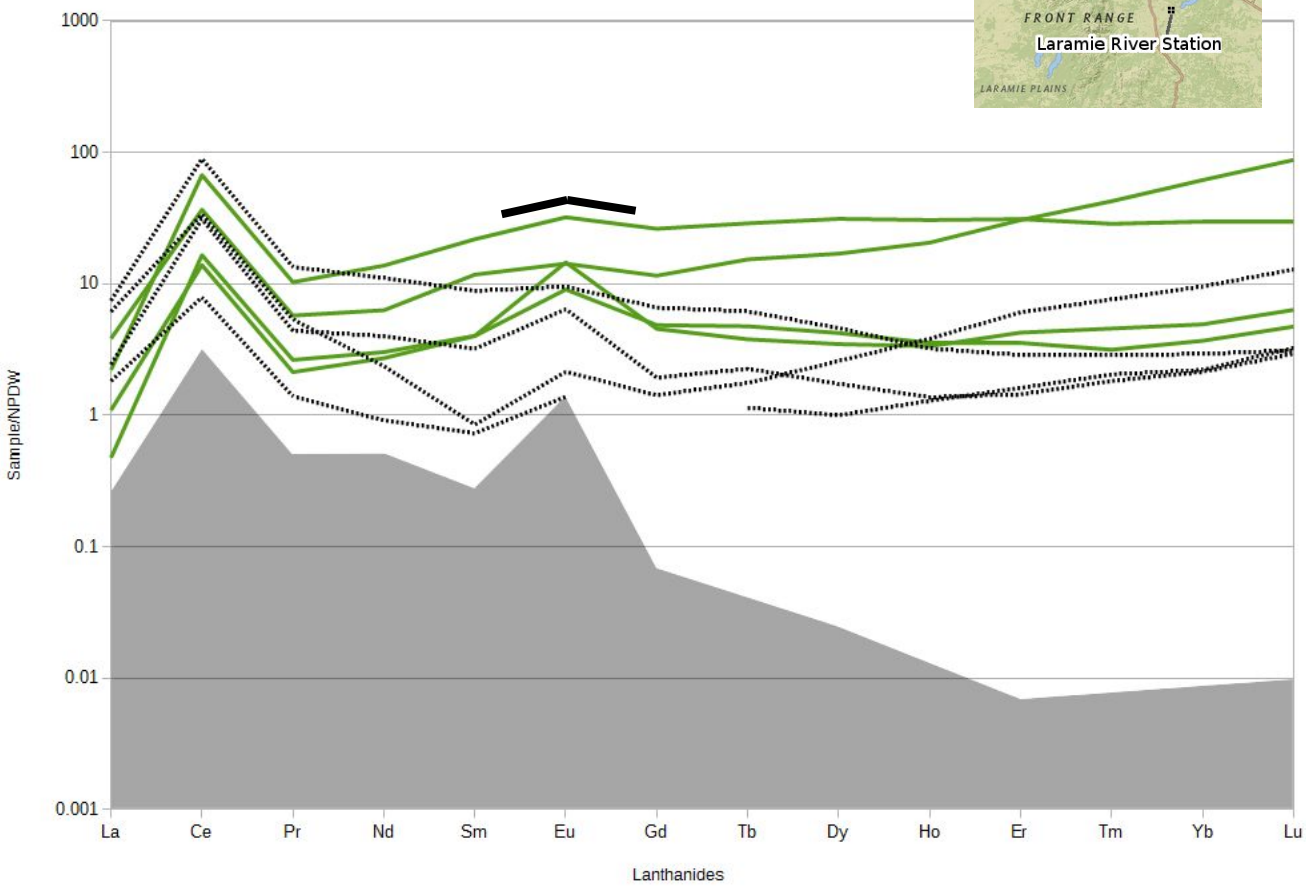


Basin REE

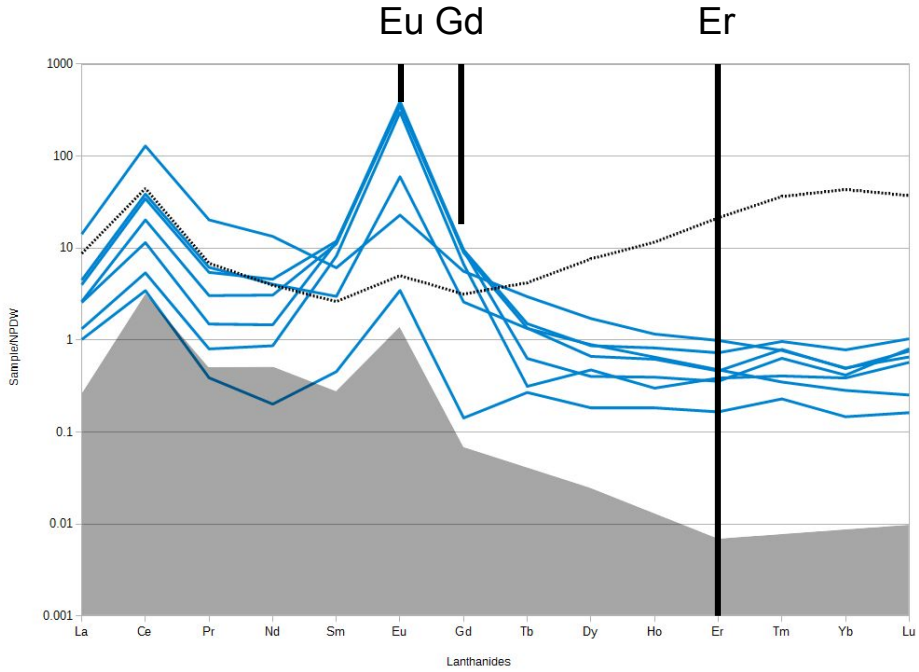
Industrial:

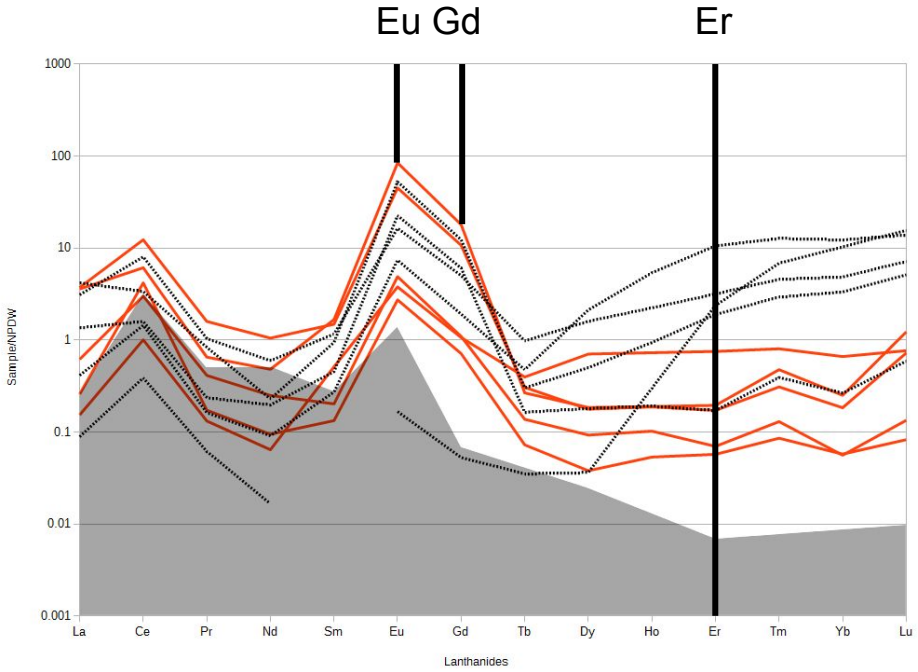
Sm≈Gd≈Eu





Signature for fields





Lost Cabin

Moneta Divide

Pine Tree (PRB-18)

House Creek (PRB-14)

Conclusions

REEs can be measured.

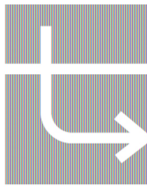
REEs may reflect Geologic Heterogeneity.

Terrestrial/Marine Frac-Sand/Biologics/Age

Many fields have higher concentration than Ocean Water. This does not necessarily imply a better mine. (oil droplets, TDS, disposal)

Future work will improve our ability to read these signatures and identify what they mean.

Acknowledgements



Carbon Management Institute

Funding sources:

DOE: EERE

State of Wyoming

Team Members:

University of Wyoming

USGS

Guidance? Questions? Comments?

This REE project is just beginning.

We need more data. Collection continues.

We welcome any guidance from experts in the audience.

Ref

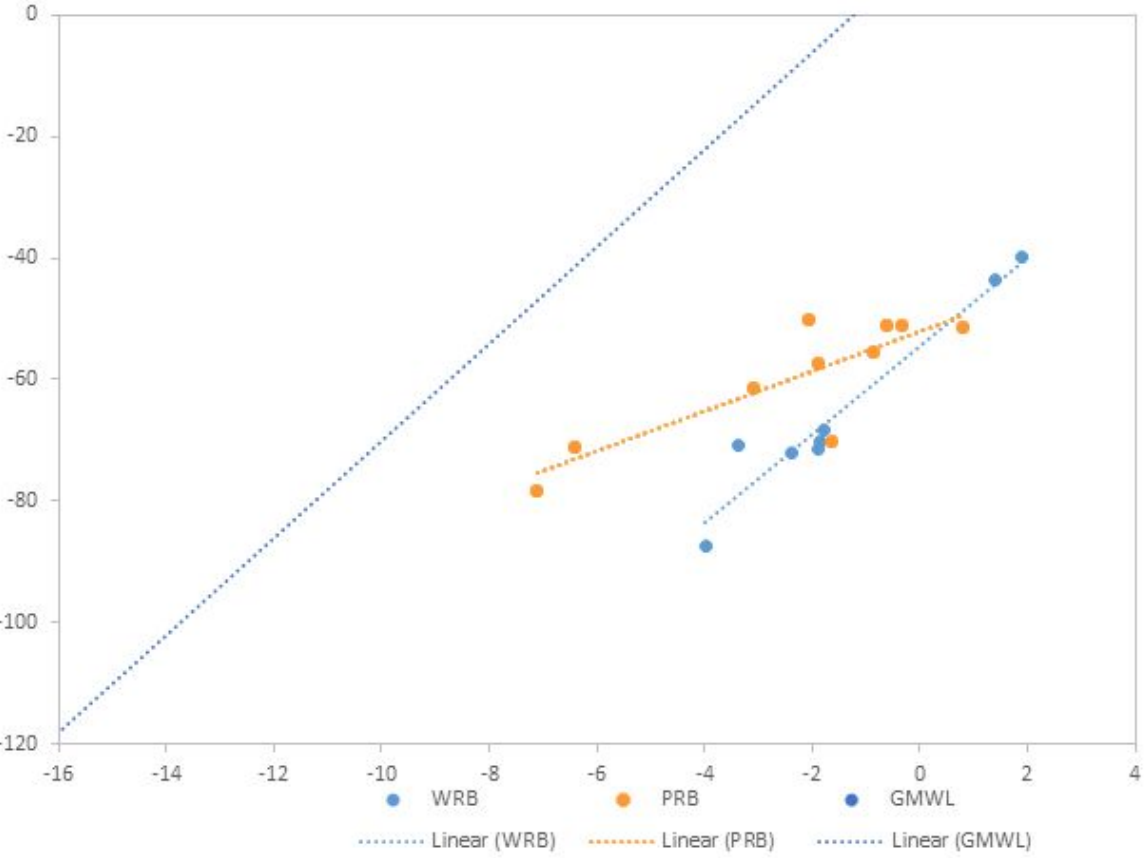
McLennan, S. M. (2001), Relationships between the trace element composition of sedimentary rocks and upper continental crust, Geochem. Geophys. Geosyst., 2, 1021, doi:10.1029/2000GC000109.

Clark, Ian, and Peter Fritz, 1997, Environmental isotopes in hydrogeology: Boca Raton, Fla., Lewis Publishers.

Hatje, Vanessa, Bruland K., and Flegal A. R."Increases in Anthropogenic Gadolinium Anomalies and Rare Earth Element Concentrations in San Francisco Bay over a 20 Year Record" Environmental Science & Technology 2016 50 (8), 4159-4168 DOI: 10.1021/acs.est.5b04322

http://www.sciencedirect.com/science/article/pii/0016703785900900

Isotopes from Water-Rock



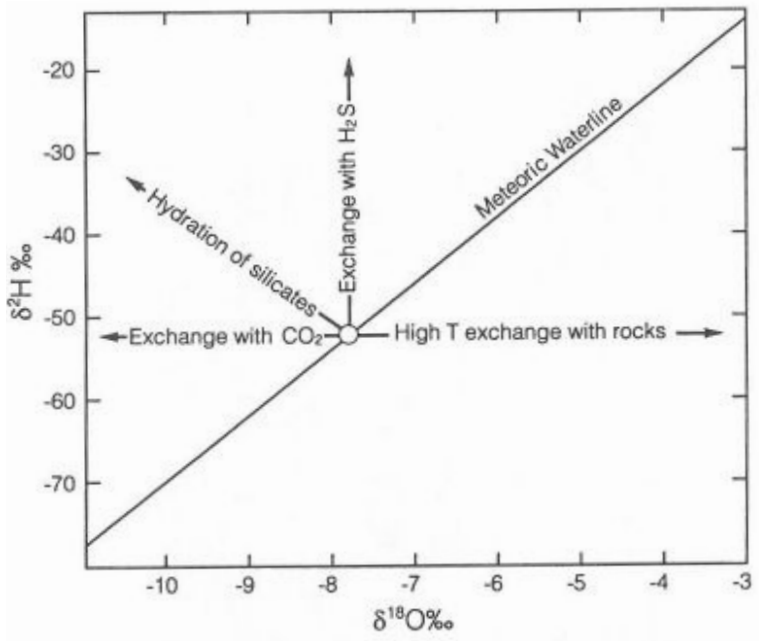


Fig. 9-1 Isotope exchange processes that can modify the isotopic composition of meteoric waters.

Isotopes from Water-Rock

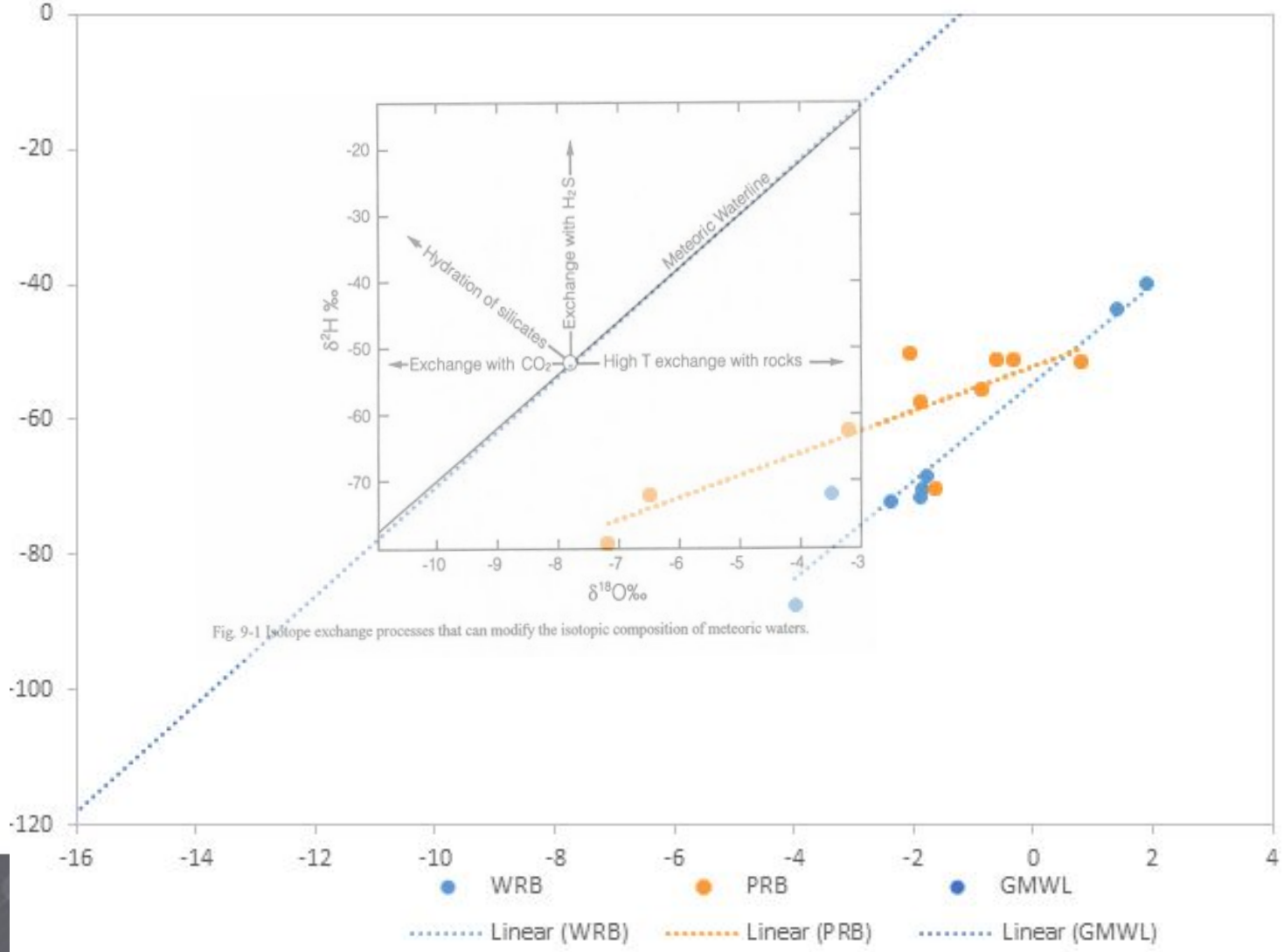
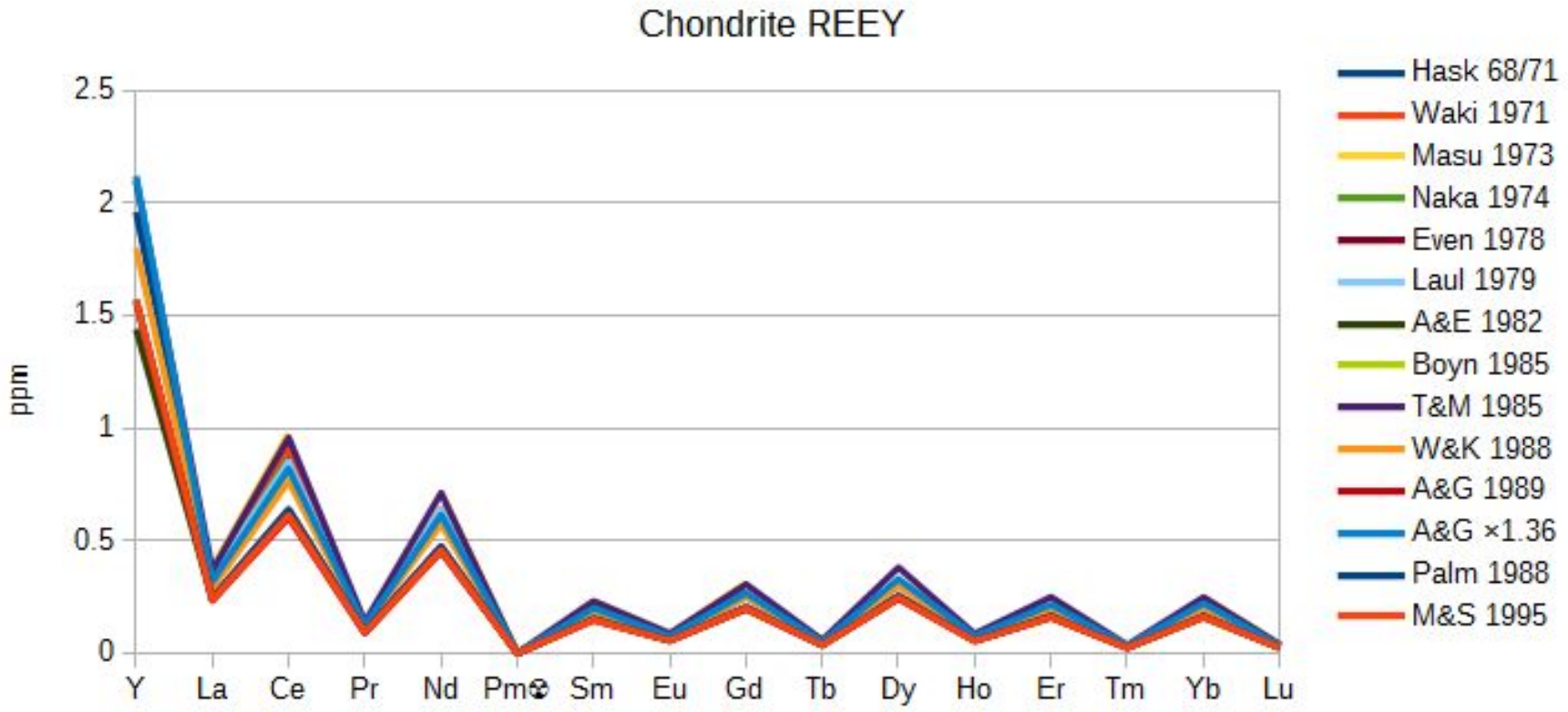


Fig. 9-1 Isotope exchange processes that can modify the isotopic composition of meteoric waters.

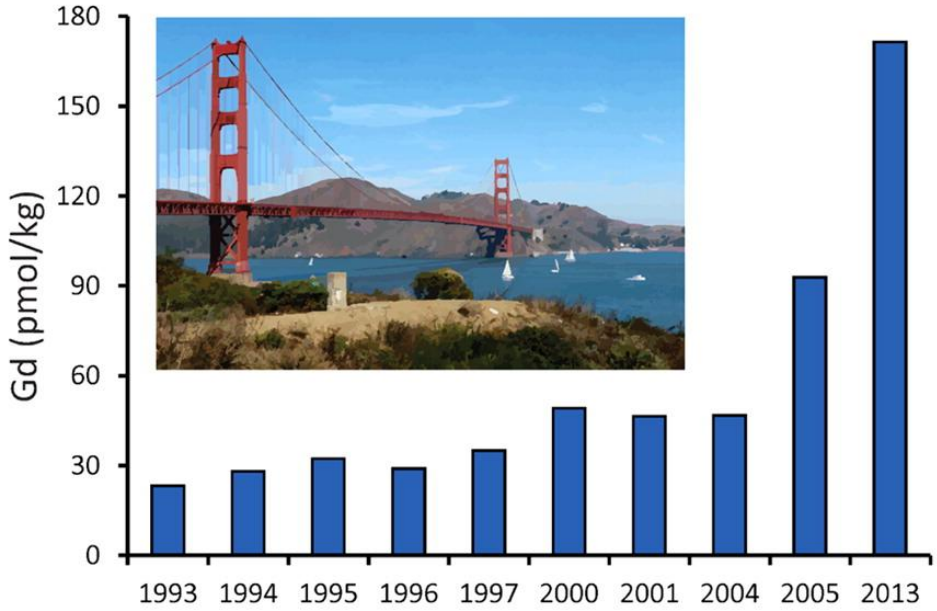
Chondrite ppm and Oddo–Harkins

Fig from data collected by Korotev 2009



Gd and MRI

Gd in near-city waters can indicate Hospitals with MRIs …. but….



No hospitals 75ma (rock) nor even ~2ka (water)

Recycled frac/mud?