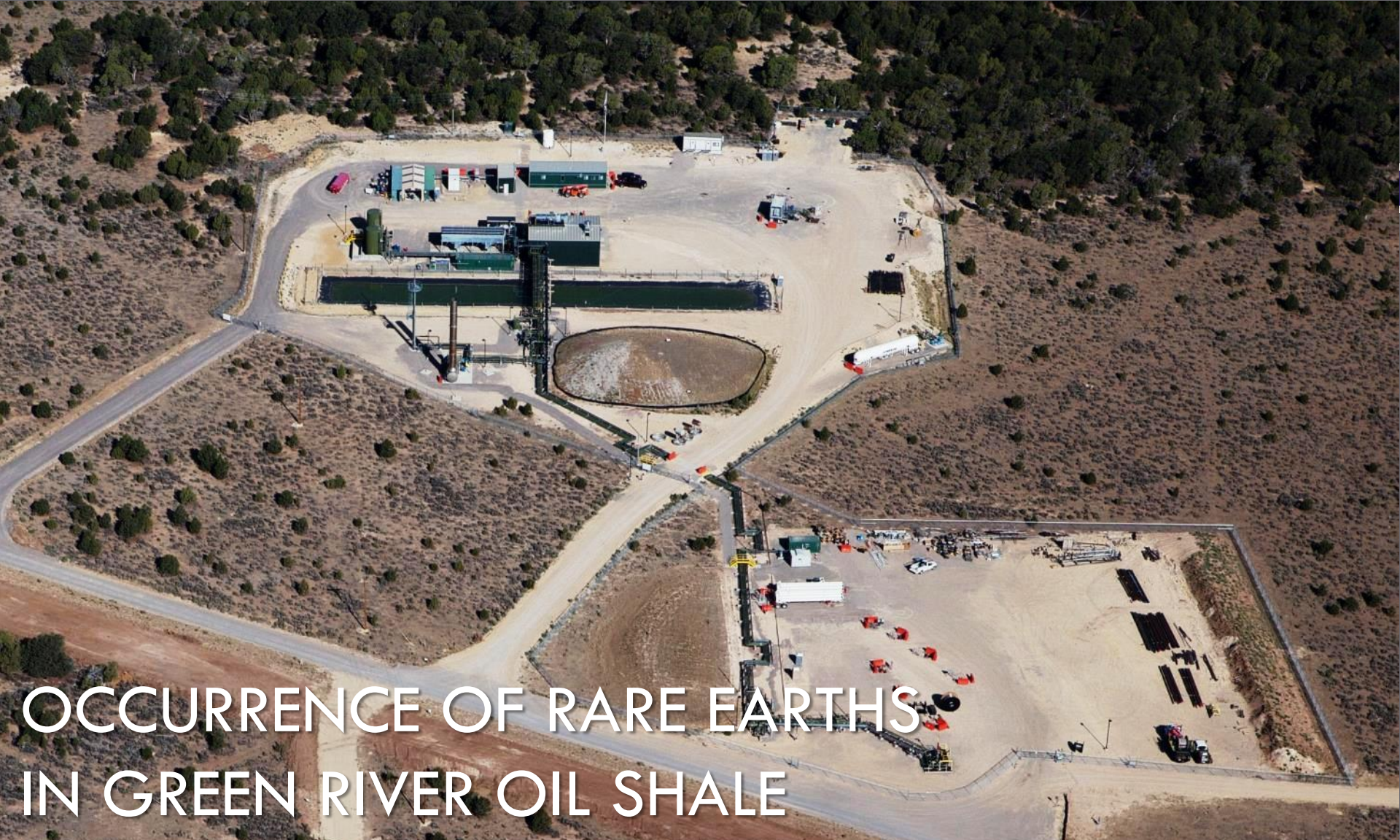




OCCURRENCE OF RARE EARTHS IN GREEN RIVER OIL SHALE

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Is Green River oil shale a potential source of Rare Earths?



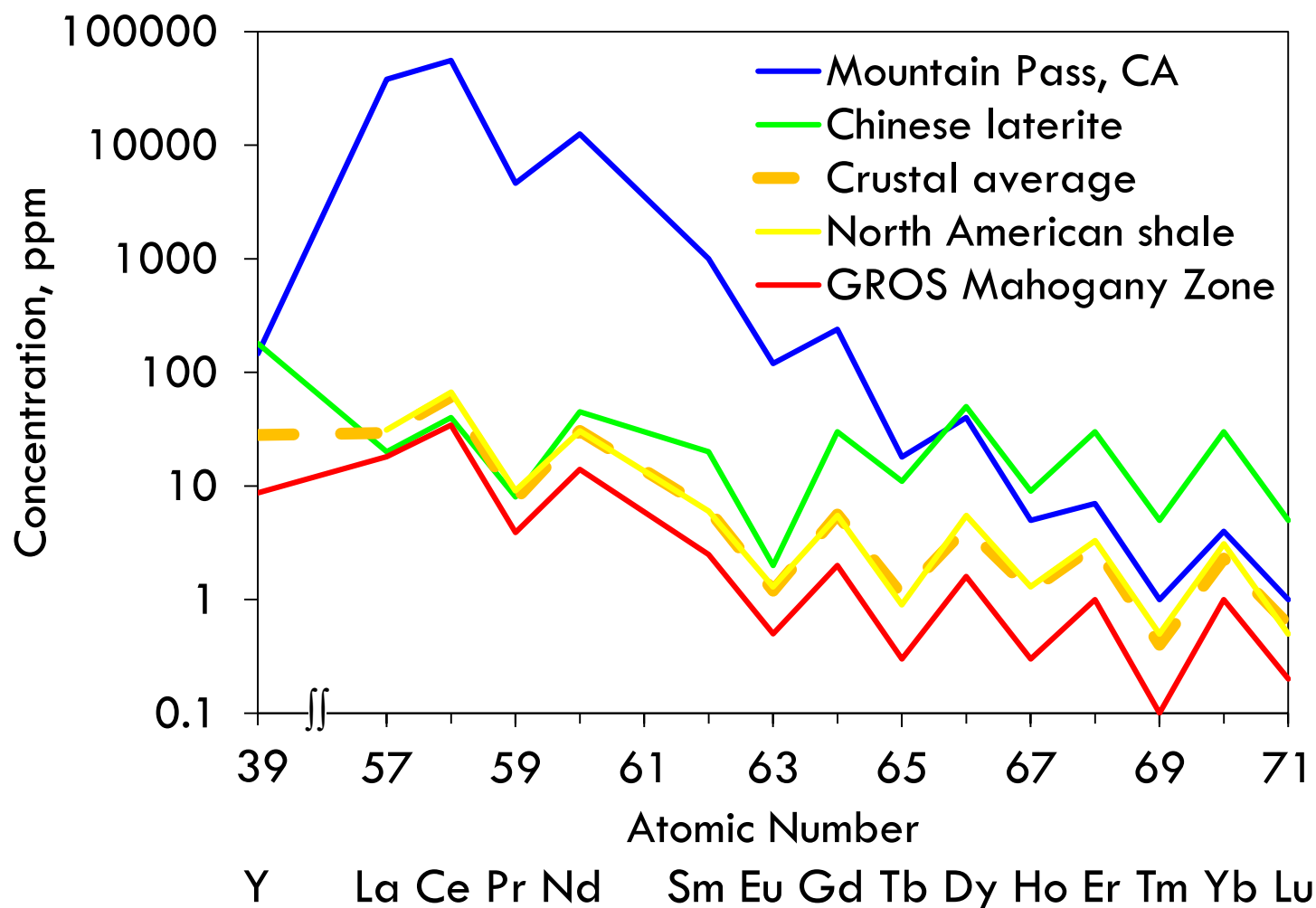
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- » Rare earth elements (REE) are important for many industrial uses
 - Magnets, batteries, lamps, phosphors, lasers, catalysts, medical imaging, high-index glasses, ceramics, etc.
- » China now produces most of the REE
- » Some have proposed Green River oil shale as a source of REE
- » AMSO obtained analyses of many element through the Parachute Creek and Garden Gulch members for a core on its RD&D lease
- » Some samples from other locations were also analyzed

Bottom Line: REE concentrations are near
or below average crustal abundance

Background from USGS reports

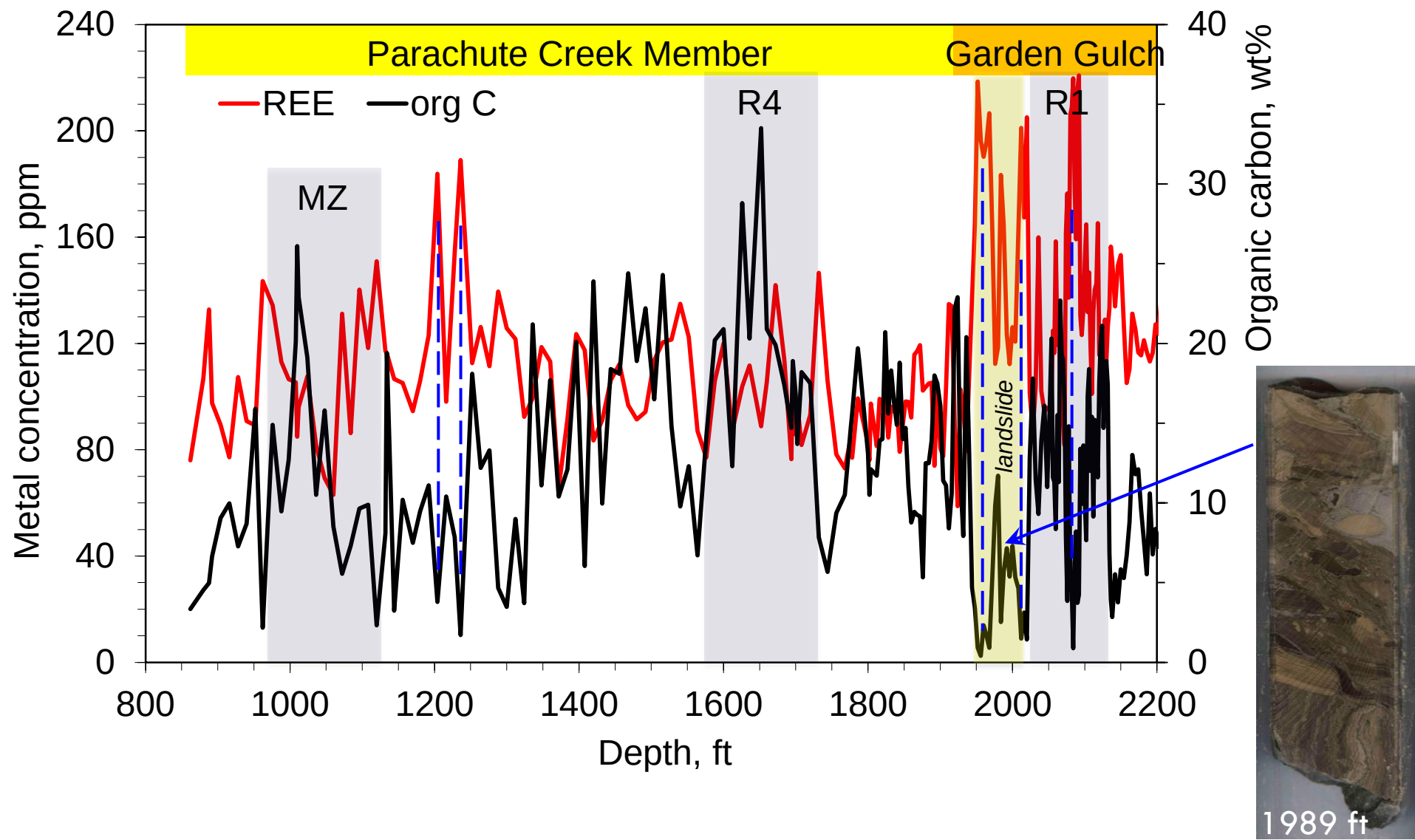
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Long et al., USGS S.I. Rpt. 2010-5220; Birdwell, USGS O.F. Rpt. 2012-1016

The Garden Gulch Member is richer in REE

4



Rich REE interval near top of the L-1 interval

5

REE ~ 150 ppm

REE 190-220 ppm



Rich REE – lean kerogen interval within R-1

6

REE 160-220 ppm



Good oil shale (avg. 35 gal/ton)

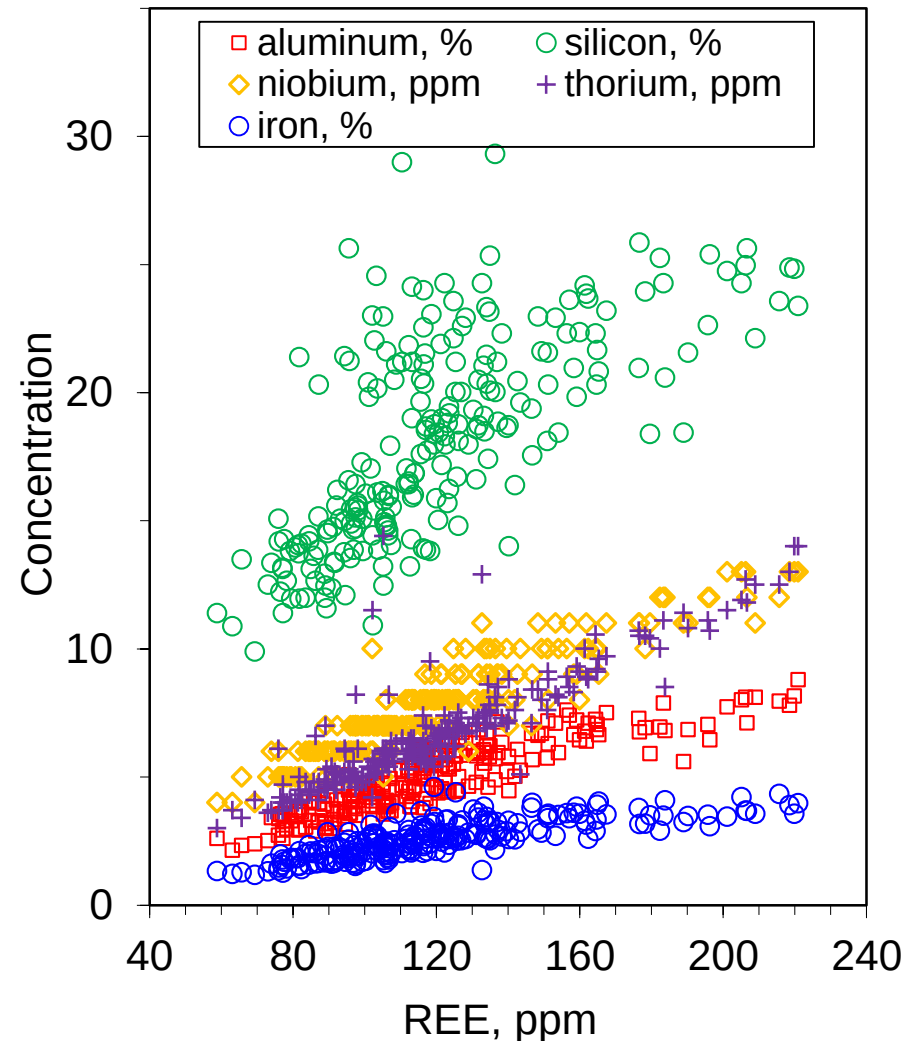
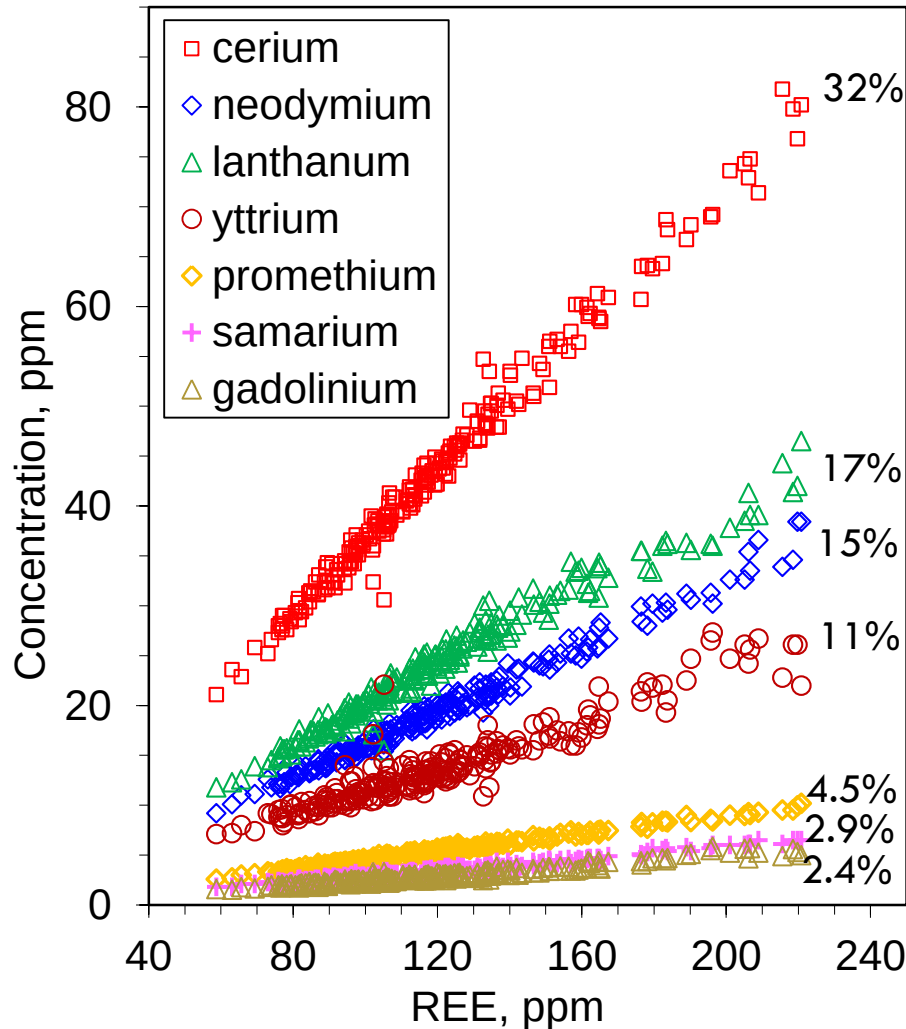


Lean oil shale (avg. <10 gal/ton)

REE correlate strongly with each other and to varying degrees with Th, Al, Nb, Fe, and Si



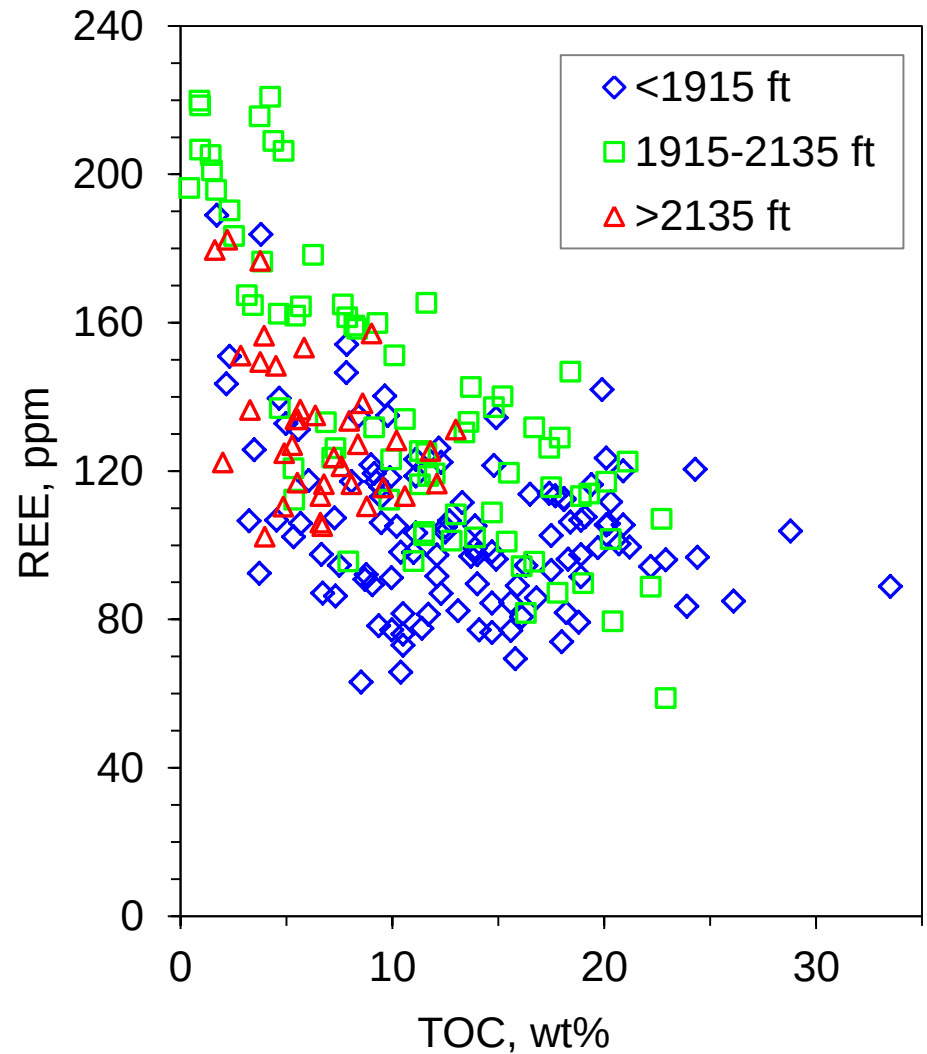
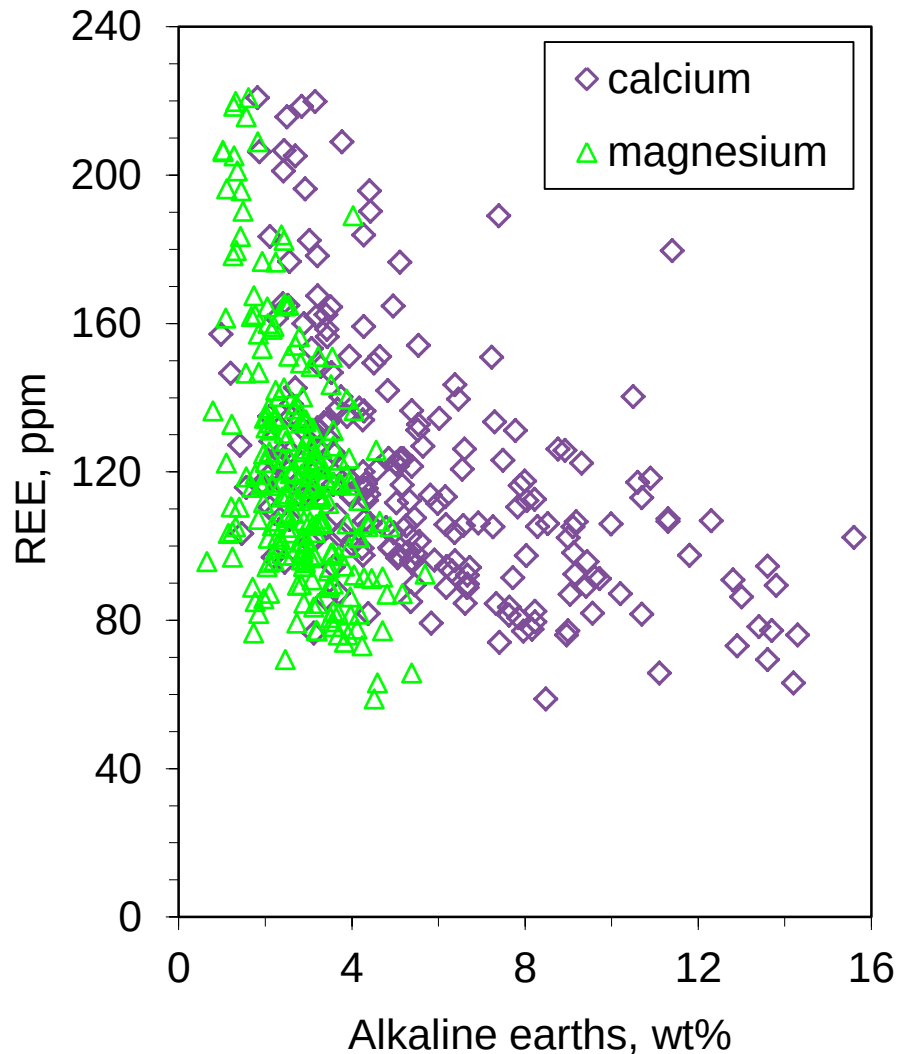
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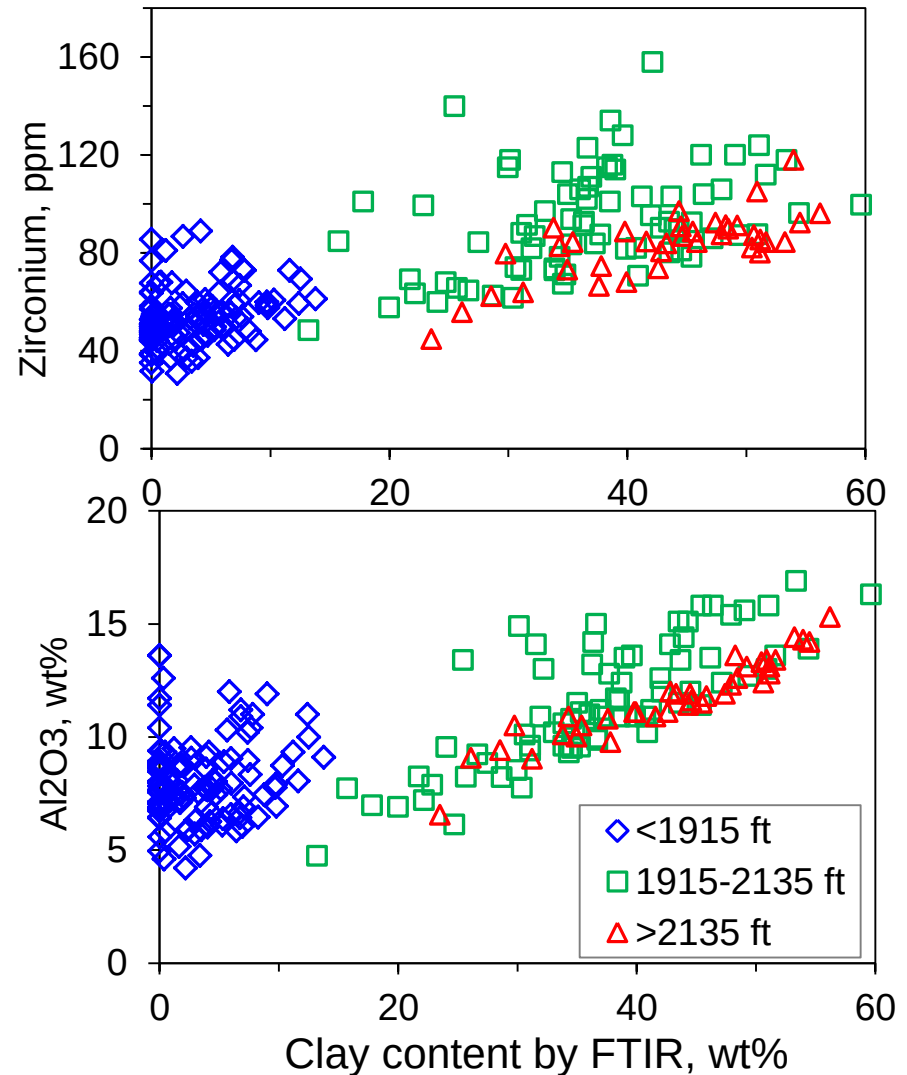
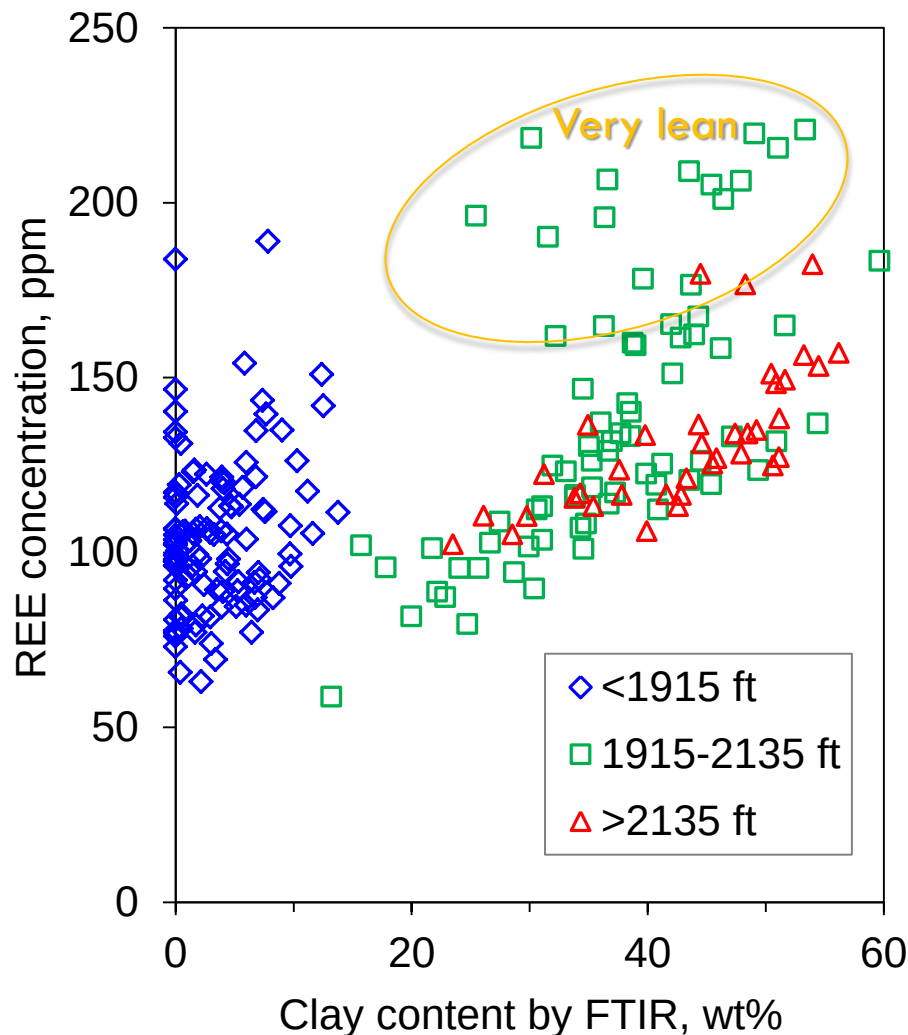
Distribution and maximum values are at crustal average!

REE concentrations are diluted by carbonates and kerogen

8

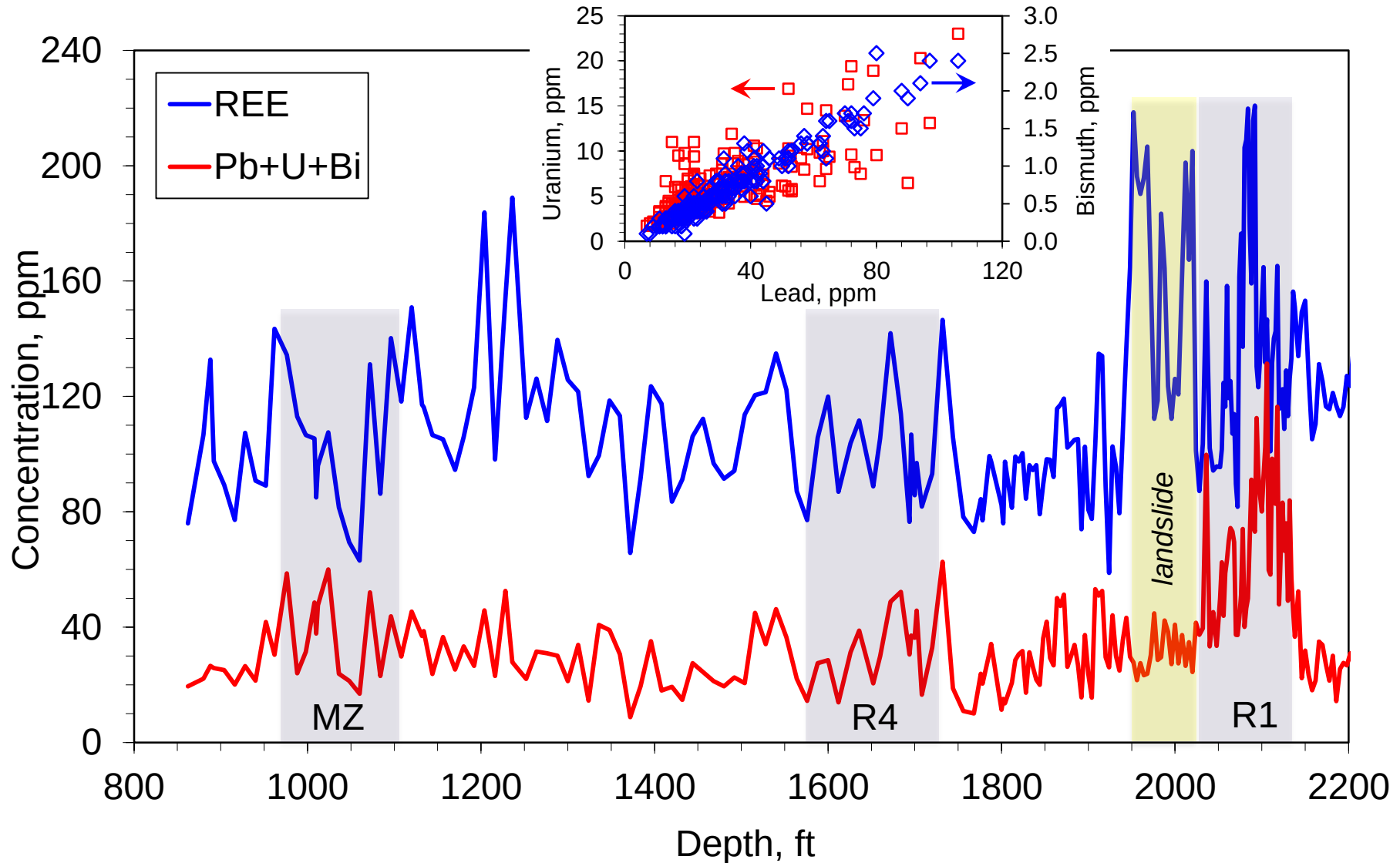


REE, Al_2O_3 and Zr correlate roughly with clay content in the Garden Gulch member



REE are elevated in the landslide and R1 intervals but U, Bi, and Pb only in the R1

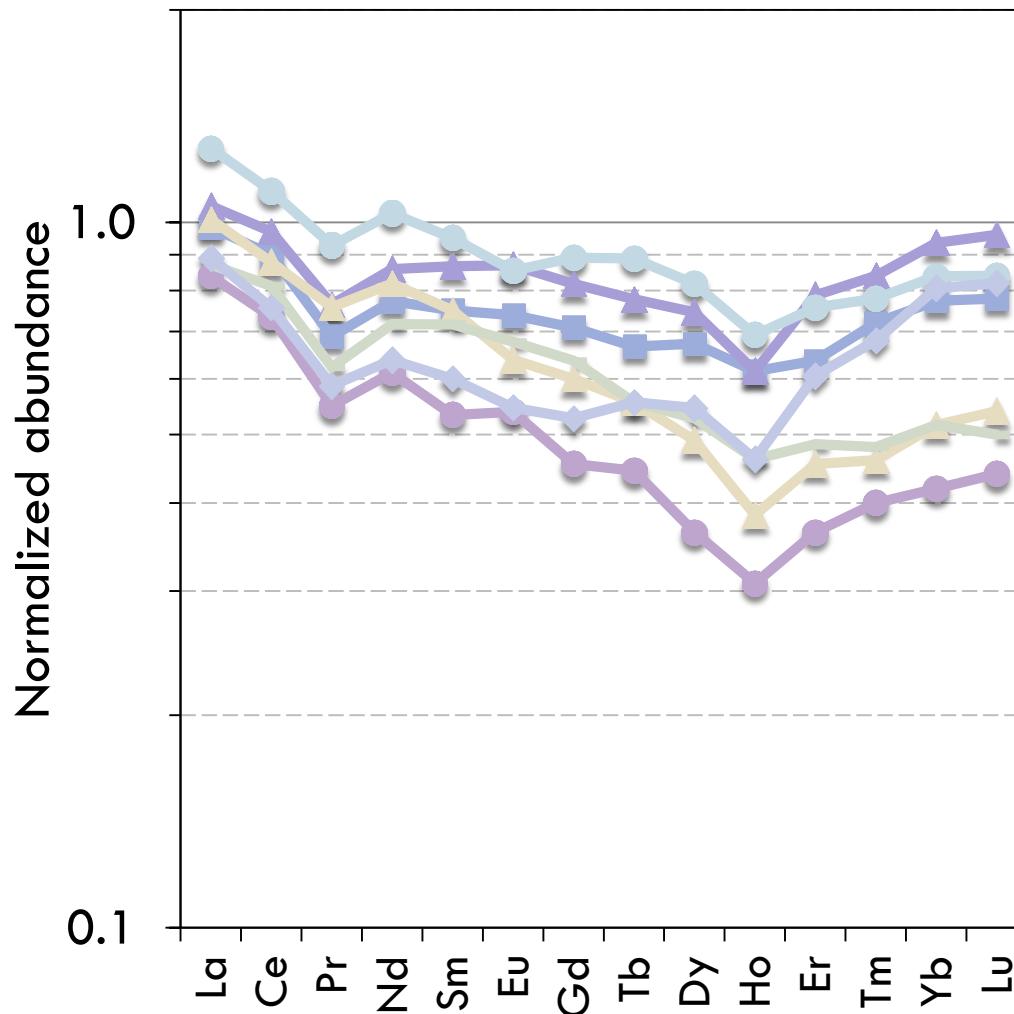
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Similar results are obtained from the western portion of the Piceance Basin



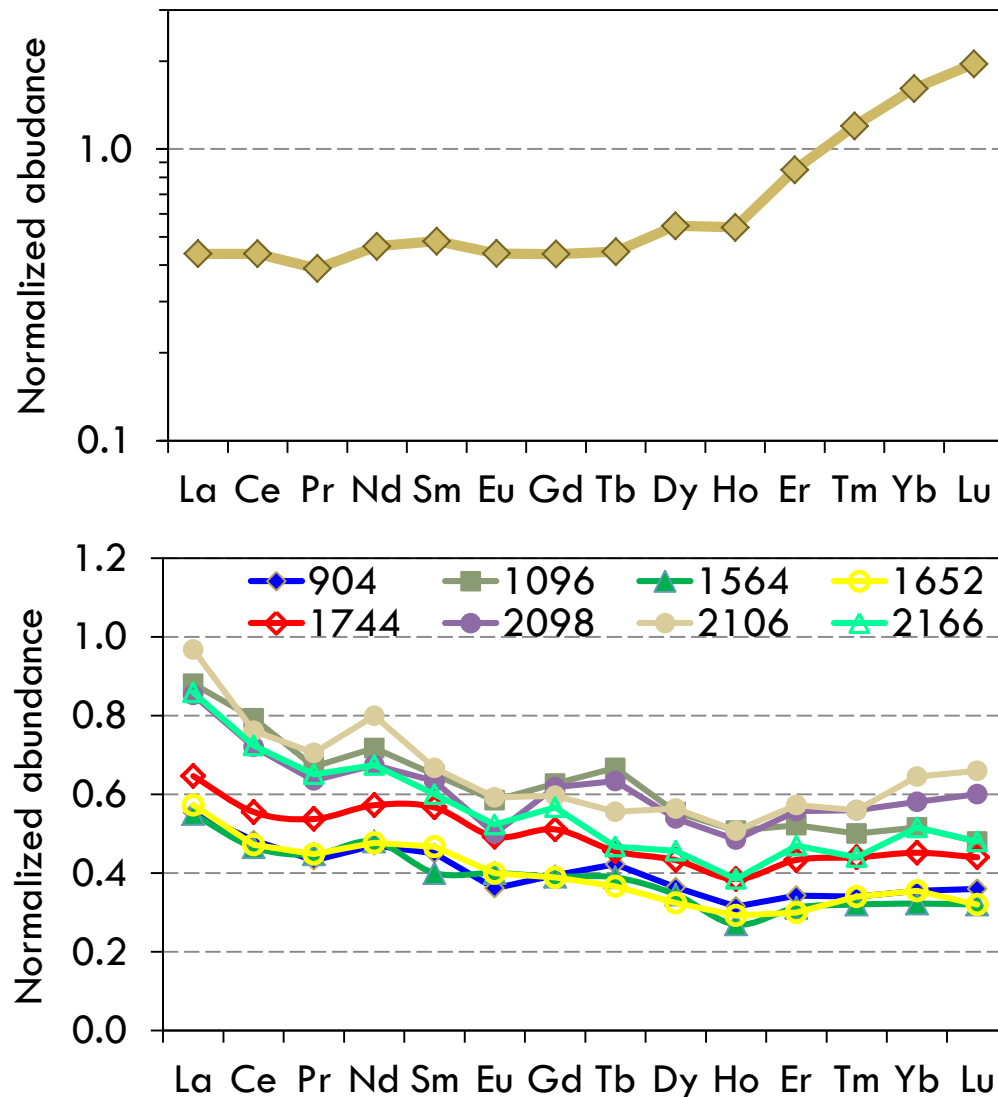
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- » Various samples from the lower Green River Form. (Douglas Creek)
- » Normalized to North American shale composite
- » No enrichment!
- » Dilution by carbonates and kerogen means lower concentrations than crustal abundance

Samples richest in phosphate are not particularly enriched, either

12



- » REE often substitute for Ca in apatite
- » Mahogany Zone sample near Cathedral Bluffs
 - 3.4% P_2O_5
 - Slightly enriched in the heaviest REE
 - 23% CaO explains depletion of light REE
- » Eight samples from the AMSO core had 1-2% P_2O_5
 - None were enriched in REE

Green River oil shale is not a viable source for Rare Earth Elements



13

- » The maximum concentrations of REE in the Green River Formation are approximately crustal abundance
 - The distribution among the elements reflects very large scale averaging through sediment recycling
- » The highest REE concentrations are associated with very lean strata
- » REE concentrations correlate strongly with other elements associated with clay minerals
- » REE concentrations are diluted by carbonates and kerogen
- » REE concentrations do not correlate with U, Pb and Bi concentrations, which correlate with each other