Evaluating mechanisms for rare-earth phosphate mineralization in Proterozoic gneiss, Music Valley, California

S. Tyson McKinney and John M. Cottle

Department of Earth Science - The University of California Santa Barbara

Introduction

Phosphate minerals such as monazite and xenotime are the primary source of rare earth elements (REE). With the rapid rise of industry and technology that depend on REE, monazite and xenotime have become increasingly significant economically.

This research will decipher the mechanisms of REE mineral formation in the Music Valley region (MVR) of southern California. It will provide a genetic model for ore formation to aid in future REE exploration and enhance the understanding of the chemical behavior of REE in the crust.

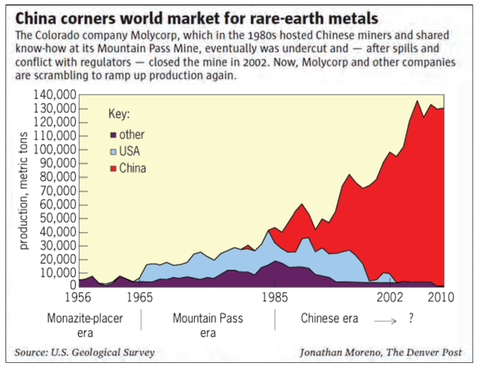
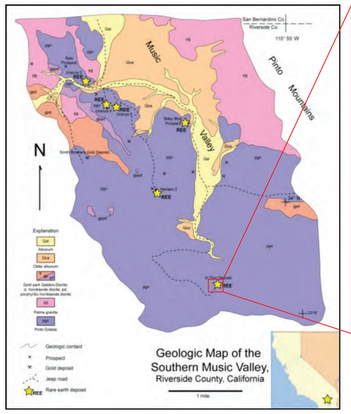


Figure 1: Graphical representation of worldwide REE production since the mid-1950's (courtesy of the USGS).



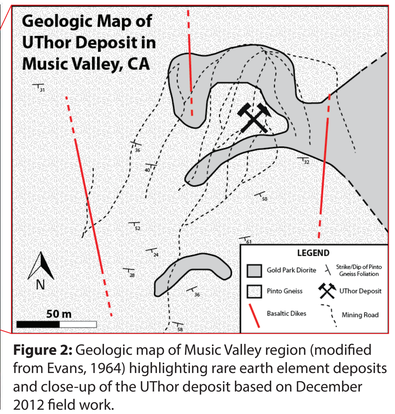


Figure 2: Geologic map of Music Valley region (modified from Evans, 1964) highlighting rare earth element deposits and close-up of the UThor deposit based on December 2012 field work.

Field Observations

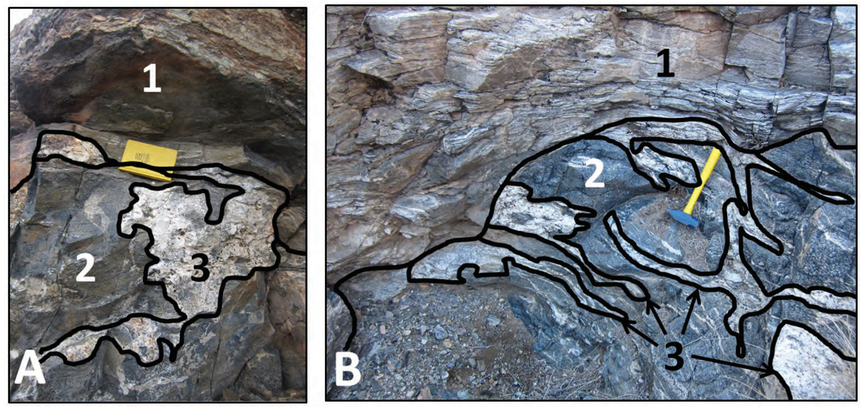


Figure 3: *(above)* Field relationships of 1) Pinto Gneiss, 2) Gold Park Diorite and 3) pegmatite veins at A) main U-Thor deposit and B) a prospect pit located ~300m east of main U-Thor deposit. *(below)* Use of radiation detector in field to locate ore rock

Radiation 101:
1554 micro-Roentgens/hr = 1.554 mrem/hr
U.S. NRC Recommended annual dose = 5,000 mrem

Radiation Exposure from Every-day Sources:
External background radiation = 50 mrem/yr
Natural K-40 radiation in body = 40 mrem/yr
Air travel round trip (LA-NY) = 5 mrem
Radon in the home = 200 mrem/yr (variable)
Medical (X-ray, MRI, etc.) = 60 mrem/yr (average)

Monazite

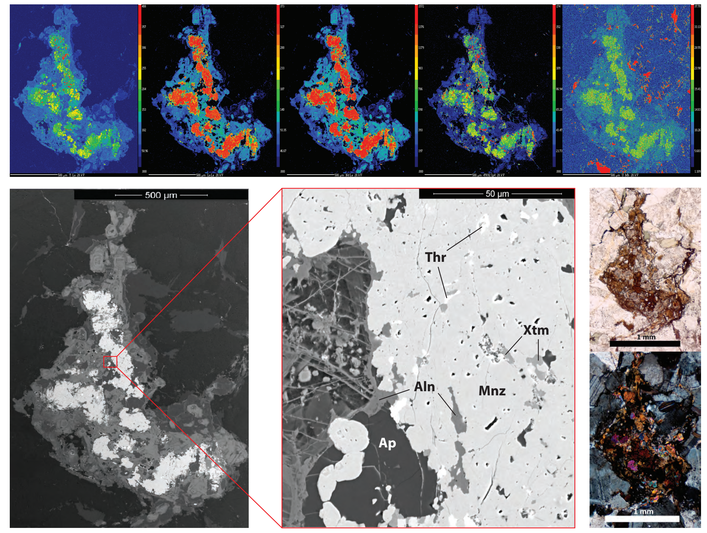


Figure 4: Various images of a monazite (Mnz) breakdown reaction to form allanite (Aln) and apatite (Ap); *(top)* Electron microprobe x-ray maps (elements from left to right: Y, La, Nd, Th, U); *(bottom left)* scanning electron microscope (SEM) image with close-up of reaction front and poikiloblastic texture of monazite with xenotime (Xtm), allanite (Aln) and thorite (Thr) inclusions; *(bottom right)* photo-micrographs taken using an optical microscope (top image taken using plane polarized light; bottom image taken using cross-polarized light).

Xenotime

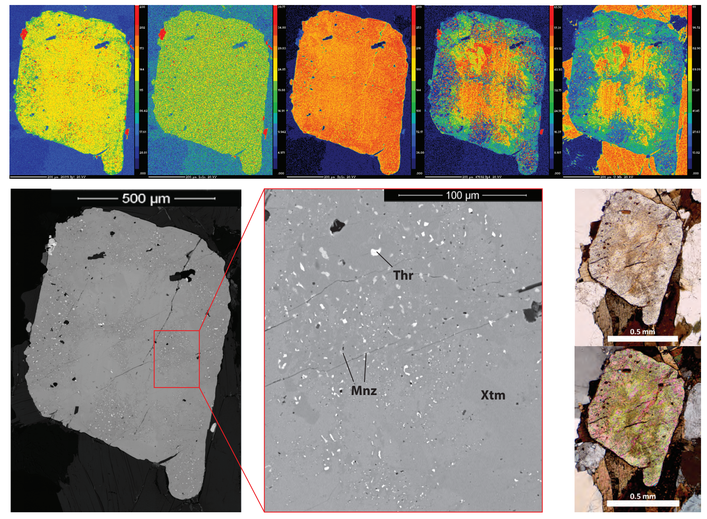


Figure 5: Various images of a subhedral xenotime grain with poikiloblastic texture; *(top)* Electron microprobe x-ray maps (elements from left to right: Nd, La, Dy, Th, U); *(bottom left)* scanning electron microscope (SEM) image with close-up of poikiloblastic texture with monazite (mnz) and thorite (thr) inclusions; *(bottom right)* photo-micrographs taken using an optical microscope (top image taken using plane polarized light; bottom image taken using cross-polarized light).

Geochemistry

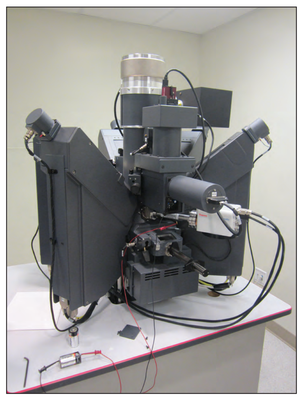


Figure 6: Cameca SX-100 electron microprobe located at UCSB used to collect compositional analyses and create elemental x-ray maps.

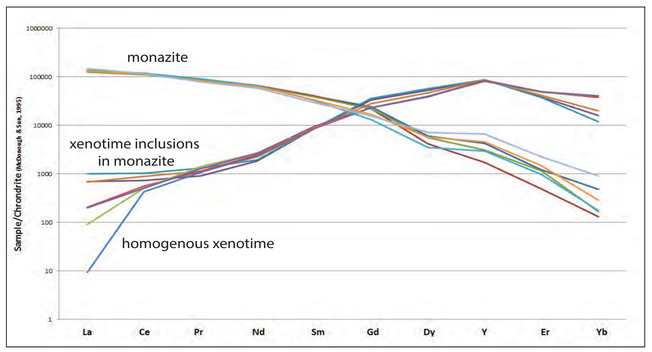


Figure 7: Concentrations (ppm) of REE and yttrium (Y) in monazite and xenotime normalized to chondritic values (from McDonough & Sun, 1995). Xenotime inclusions in monazite are slightly enriched in La and Ce and slightly depleted in Er and Yb with respect to more homogenous xenotime grains.

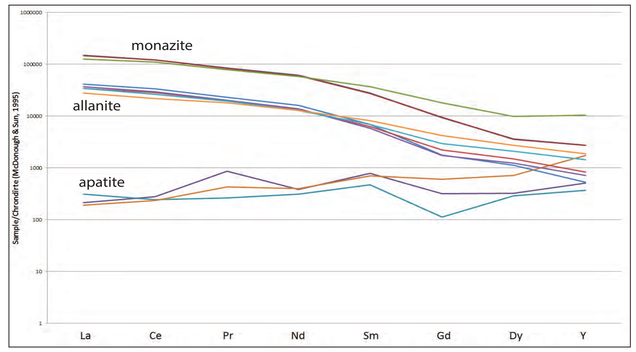


Figure 8: Concentrations (ppm) of REE and yttrium (Y) in monazite, allanite and apatite in reaction grains (as seen in Figure 4) normalized to chondritic values (from McDonough & Sun, 1995).

Geochronology

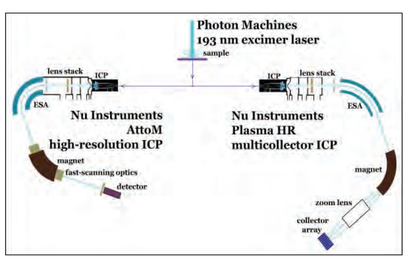
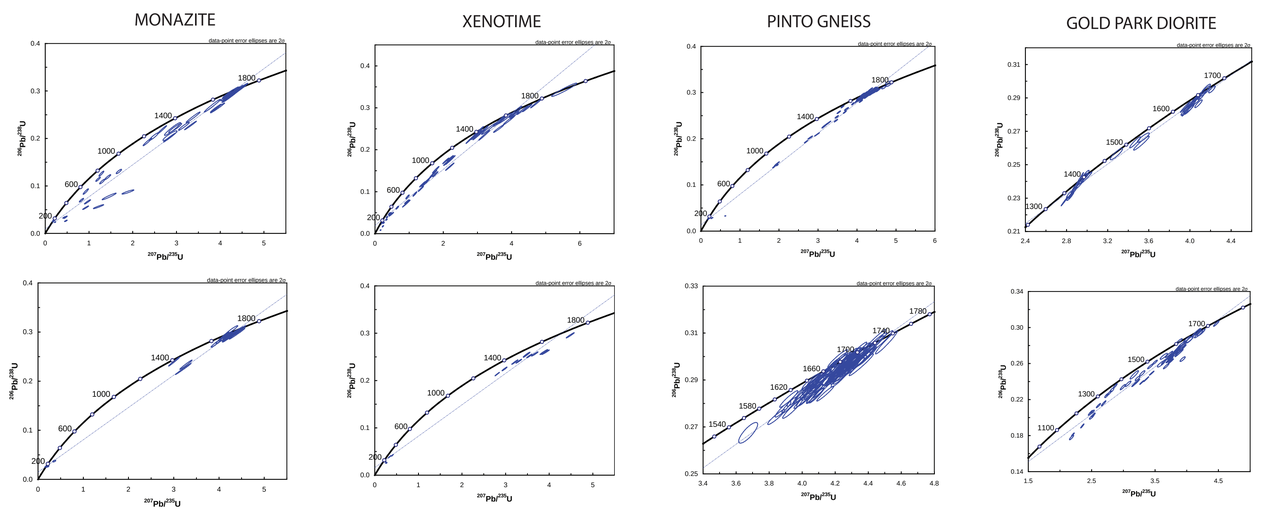


Figure 9: Uranium (U) and lead (Pb) isotopic compositions were used to determine the absolute ages of the rock units of the MVR and the ore minerals monazite and xenotime found in the Pinto Gneiss. The isotopic concentrations were collected using the state of the art laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS) system located here at The University of California Santa Barbara. U and Pb isotopes were measured using the Nu Plasma HR multicollector ICP.



Future Work

- Determine cause of poikiloblastic texture observed in both monazite and xenotime grains through chemical means (i.e. stoichiometric calculations).

- Understand and date monazite breakdown reaction by obtaining ages of euhedral allanite grains.

- Obtain age data for pegmatite veins associated with ore deposits and relate their generation to the overall tectonic history of the region.

- Interpret preliminary age data obtained for monazite, xenotime, Pinto Gneiss and Gold Park Diorite.

References

Evans, J.R.,1964. Xenotime mineralization in the southern Music Valley area, Riverside County, California. *California Division of Mines and Geology Special Report,* **79**, 24 p.

McDonough, W.F. & Sun, S., 1995. The composition of the Earth. *Chemical Geology*, **120:3-4**, p. 223-253.