

The origin of high-Ca annuli in garnets from the Rand schist of the San Emigdio Mountains, southern California Alan D. Chapman, Peter Luffi, and Jason B. Saleeby



Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA

ABSTRACT

Intergranular element transfer-controlled garnet growth is a recently suggested explanation for high-Ca annuli in chemically zoned garnets from a wide range of bulk compositions. However, little is known regarding the source of requisite elemental fluxes responsible for such Ca disequilibrium during garnet growth. The Rand schist of the San Emigdio Mountains permits testing between two potential sources: (1) fluid enhanced disequilibrium breakdown of metastable plagioclase during metamorphism, and (2) hydrous partial melting. X-ray imagery of garnets from the Rand schist shows distinct zonation patterns in major and trace elements that cannot be reproduced by classical closed system modeling. In several grains displaying typical prograde zonation (core-to-rim Mg# increase and sharp Mn decrease) pronounced high-Ca annuli coincide with markedly decreased concentrations of Ti, Y, and Na. These annuli are also distinguished by abundant zircon inclusions absent from other zones. Calculations based on muscovite - biotite - plagioclase - garnet geobarometry and garnet - biotite geothermometry yield two clusters of P-T conditions at 9.5 kbar and 650°C and at 12 kbar and 740°C, indicating local disequilibrium. Thermodynamic equilibrium considerations corroborated by textural features of the samples favor the higher temperature results as peak conditions. Based on combined evidence from X-ray imagery, thermobarometry, petrography, and inclusion distribution in garnets, a model for garnet growth involving a stage of anatexis is preferred. These observations yield important insight into allochemical processes controlling garnet zonation patterns and into the application of detrital zircon thermochronology to the Rand schist.

BACKGROUND: DISEQUILIBRIUM ELEMENT INCORPORATION MODEL

Thermodynamic models of rocks with MORB composition (Konrad-Schmolke et al., 2005) and garnet zonation patterns from micaceous quartzites (Chernoff and Carlson, 1997) show evidence for disequilibrium incorporation of Ca during garnet growth. These studies show that high-Ca annuli in garnets can be produced during sporadic porphyroblast growth in localized chemical inhomogeneities (figure 1). Zoning profiles from garnets found in the Rand schist of the San Emigdio Mountains, southern California, display similar zonation patterns. However, the observed Ca zonation patterns are ubiquitous at the outcrop scale and coincide with pronounced fluctuations in trace element concentrations. Open system processes such as fluid-fluxed partial melting and/or catastrophic breakdown of Cabearing phases may account for observed variations in garnet composition.

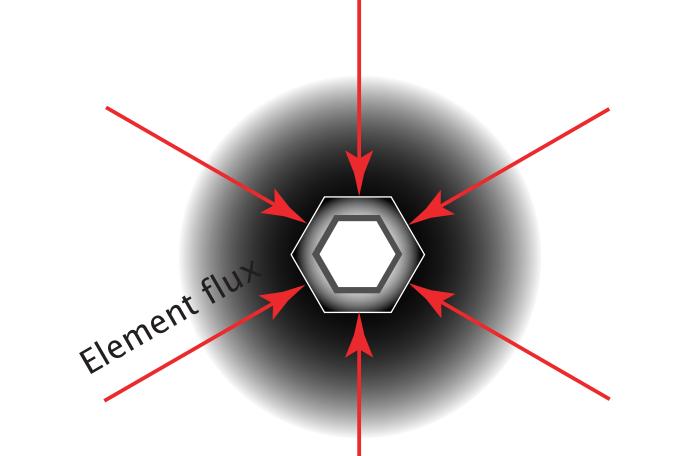
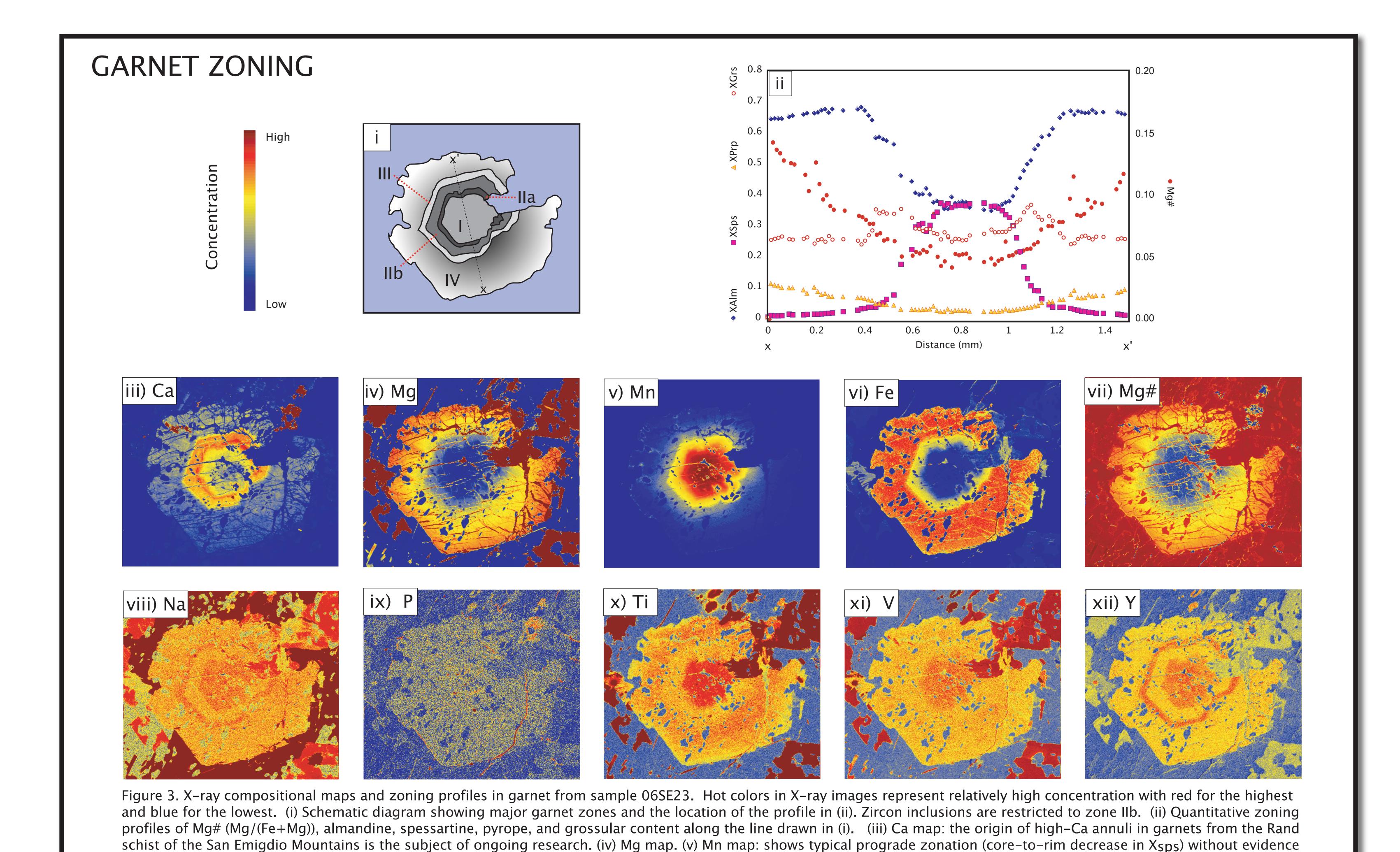


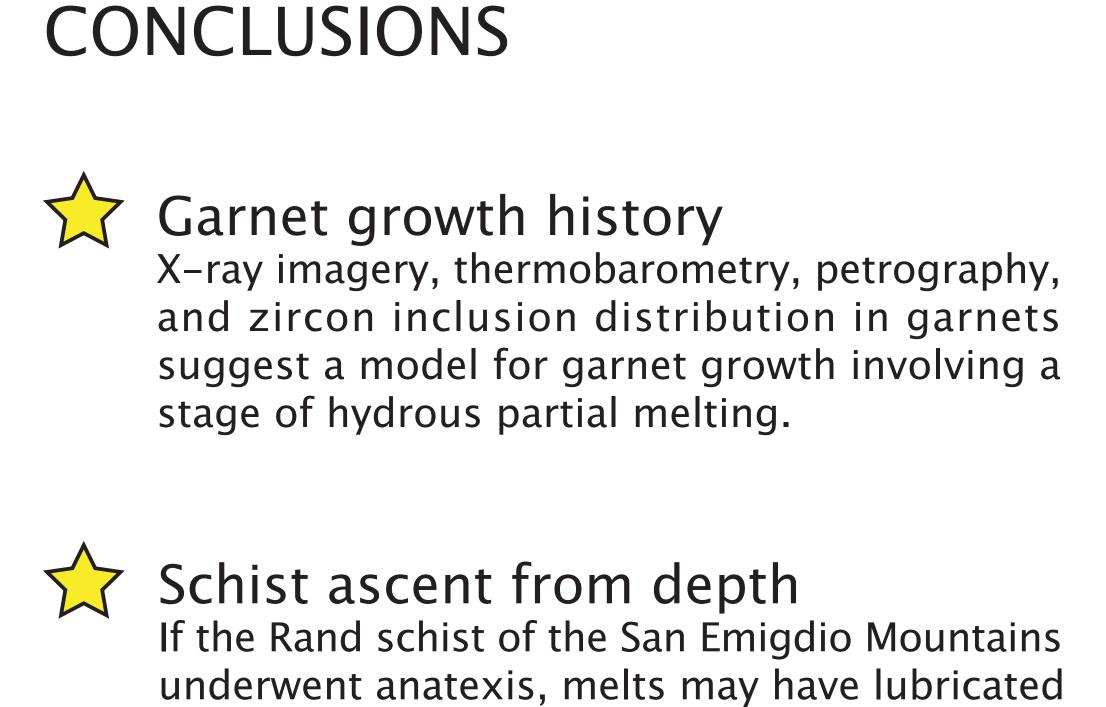
Figure 1. Schematic showing porphyroblast growth within a concentration gradient. Garnet zonation patterns are the result of disequilibrium element flux toward the surface of the porphyroblast. Redrawn after Konrad-Schmolke, 2005

GEOLOGY OF THE SAN EMIGDIO MOUNTAINS Thrust fault - teeth on upper plate Rand schist Table 1: Thermobarometric results from five samples of garnet-bearing upper and lower plate rocks Figure 2. Geologic context of the San Emigdio Mountains. (a) Map of arkosic schist distribution throughout southern California and adjacent areas. Major Late Cretaceous to Early Tertiary schist bodies are colored black. Cretaceous and 7.1 (Kohn and Spear, 1990) 660 (Holland and Blundy, 1994) older batholithic and associated metamorphic rocks are shown in light blue. Rocks of the Franciscan Complex (FC) are 642 (Ganguly et al., 1996) colored green. GF=Garlock fault, GVF=Great Valley forearc basin, PRB=Peninsular Ranges batholith, SAF=San Andreas 11.9 (Hoisch, 1991) 696 (Ganguly et al., 1996) fault, SNB=Sierra Nevada batholith, redrawn after Kidder and Ducea, 2006. (b) Geologic map after Ross, 1989 of the Rand schist 595 (Ganguly et al., 1996) 9.1 (Hoisch, 1991) crystalline basement of the San Emigdio Mountains, which are overlain to the north by younger sedimentary and Rand schist 737 (Ganguly et al., 1996) 11.4 (Hoisch, 1991) volcanic rocks. (c) Geologic map of a ridge studied in detail. Yellow arrows show the observed shear sense between batholithic rocks which constitute a regional upper plate and the lower plate Rand schist. Garnet abundance and size * Temperature calculated assuming P = 7.1 kbar increases north of the +grt isograd.

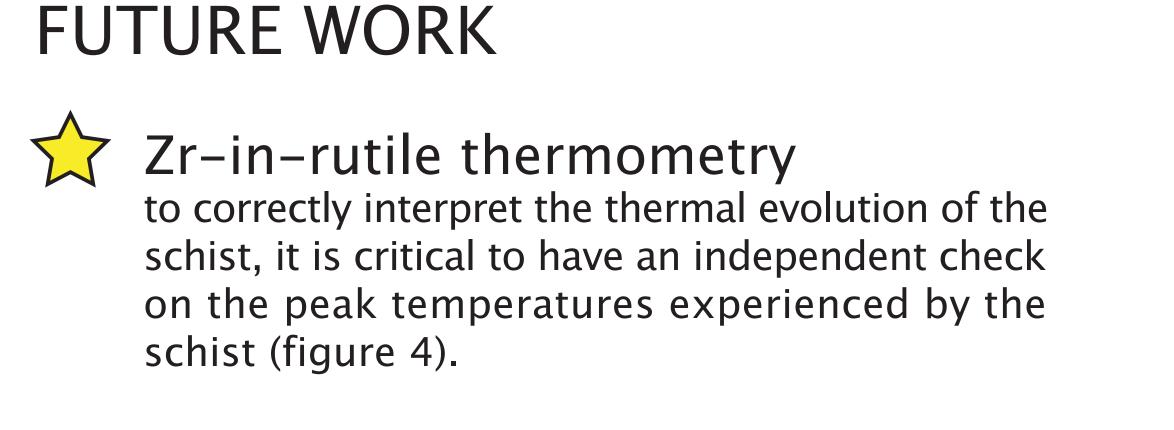


of a Mn "kick-up" (Kohn & Spear, 2000) at rims. (vi) Fe map (vii) Mg# map: note continuously increasing Mg# from core to rim. This suggests continually increasing temperature

during garnet growth without evidence for cooling during exhumation. (viii-xii) Trace element maps. In general, measured trace elements show the same, but inverted, zonation pattern as Ca.



the margins of the schist and facilitated its exhumation from depth.





Equilibrium thermodynamic modelling of mineral assemblages and compositions using THERIAK-DOMINO.



Garnet [18] profiles to assess the nature of fluid-rock interaction in the Rand schist of the San Emigdio Mountains.

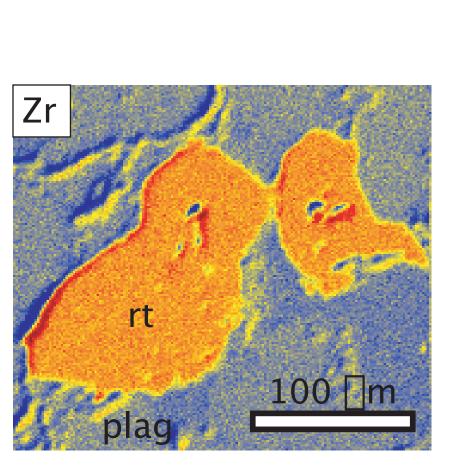


Figure 4. X-ray compositional map of Zr content in rutile from sample 06SE23. Qualitative scale is the same as in figure 3. Temperature has a strong positive correlation with the Zr content in rutile. Note a narrow zone of high Zr near the rim of each rutile grain. This zone may have been the result of a late stage of heating.