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Ultrahigh temperature (UHT) mafic granulites from South India: Comparison between temperature derived from REE-based thermometers and major element-based thermometers

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Granulites are relatively rare but provide us a natural window into the composition, structure and P-T conditions of the lower crust and process of continental growth. Therefore, the correct determination of the P-T conditions of exposed granulites is extremely important. UHT metamorphic conditions are best preserved and most commonly reported from the relatively rare Mg-Al rich metapelitic granulites as they preserve characteristic mineral assemblages like sapphirine + quartz, spinel + quartz, orthopyroxene + sillimanite etc., indicating HT-UHT metamorphism. Likewise, in the the Eastern Madurai domain of South India, the rare Mg-Al rich metapelitic granulites preserve characteristic mineral assemblages and record peak metamorphic temperatures of ≈1000ºC at 6 Kbar [1]. However, the co-metamorphosed mafic granulites from the region, comprising garnet + clinopyroxene + orthopyroxene ± quartz, record peak temperatures of ≈800-850ºC at 7-8 Kbar, obtained from Fe-Mg exchange thermometers. The underestimates of temperatures, similar for most other granulite terranes, could be attributed to fast retrograde Fe-Mg re-equilibration that obliterated the initial compositions, and consequently rendering Fe-Mg exchange thermometry less reliable. Therefore, the information obtained from the Mg-Al granulites could not be independently verified from a different rock type.

In order to overcome this problem, we have used a recently developed REE thermometer based on the abundance of REEs in two mineral grains [2]. Since the diffusion rate of the trivalent REEs is much lower than that for the divalent major elements (Fe and Mg), REE abundance should remain relatively unchanged during cooling, thus providing a more reliable peak temperature. In the present study, we have used a garnet-clinopyroxene REE-exchange thermometer [2] on the mafic granulites of the Eastern Madurai domain to obtain the peak metamorphic temperatures and to compare with those obtained using Fe-Mg thermometers. The abundances of the REEs in garnet and clinopyroxene are measured using a LA-ICPMS with a 45um beam diameter. The chondrite-normalized REE patterns show HREE-enriched garnet and LREE-enriched clinopyroxene. No significant compositional difference is observed between the different points of the same grain as well as among different grains of the same mineral in the studied rocks. Temperature estimate obtained using the REE exchange thermometer is 1080±60°C, significantly higher than the temperatures obtained from Fe-Mg exchange thermometers and more similar to those obtained from the surrounding Mg-Al granulites. P-T conditions obtained through pseudosection modelling using Perple_X are 840°-870°C at 6-7 kbar from the X_{Mg} isopleths of garnet, thus agreeing with the results obtained from Fe-Mg exchange thermometers. However, the pseudosection modelling in this case has the same drawback as the Fe-Mg thermometer as garnet is unlikely to preserve the initial Mg/Fe ratio after retrogression. As the Fe-Mg exchange thermometer mostly record the cooling conditions of granulite, the peak metamorphic conditions of mafic granulites require revisiting using alternative approaches. The present study has a strong implication on the study of the granulite terranes where Mg-Al granulites are not present.

References:

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[2] Chenguang Sun et al., (2015) Chemical Geology, **393–394**, 79–92 (2015).