Petrology of Cr-rich calc-silicate rocks from the Archean Dharwar craton, southern India

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In the present study, we report the petrologic significance of Cr-rich calc-silicate rocks in the Archean Dharwar craton of peninsular India. Discontinuous exposures of calc-silicate rocks are associated with pelites, quartzites, amphibolites and banded iron formations are confined to the southwestern margin of the Closepet granite, a N-S trending belt of granitoids emplaced at 2.52 Ga. Calc-silicate rocks contain characteristic porphyroblasts of green garnet, in a typical mineral assemblage of clinopyroxene + garnet (uvarovite and spessartine) + epidote + amphibole + pumpellyite + titanite + calcite + plagioclase + quartz + opaque minerals, with minor amounts of pentlandite.

Earlier study has reported green garnets in the Archean low-pressure metamorphic calc-silicate rocks from Dharwar craton (Parthasarathy *et al.,* 1999). Cr-rich garnet lattice imparts a green color making it a sought after semiprecious gem stone. Chromian garnets form a part of the ugrandite series. In this study we have identified two types of green garnets in the calc-silicate rocks, euhedral type and resorbed type. A maximum value of 19.6 wt.% Cr_2O_3 was observed in a resorbed garnet grain that contain numerous chromite inclusions (Pyr 1 mol%, Alm 10 mol%, And 16 mol%, Sps 7 mol%, Uv 67 mol%). Furthermore the same garnet grain has high spessartine content at specific locales (Pyr 3 mol%, Alm 23 mol%, and 36 mol%, Sps 24 mol%, Uv 14 mol%). The uvarovite content of garnet shows wide range from 14 to 67 mol%. Other Cr-bearing minerals are epidote, pumpellyite, diopside, and titanite. Epidote is clinozoisite in composition containing up to 4.0 wt.% of Cr_2O_3. Tremolitic calcic-amphibole is commonly found in the matrix, whereas blades of secondary amphiboles with edenitic to actinolitic composition were also observed. Clinopyroxene is diopside with minor amounts of hedenbergite component.

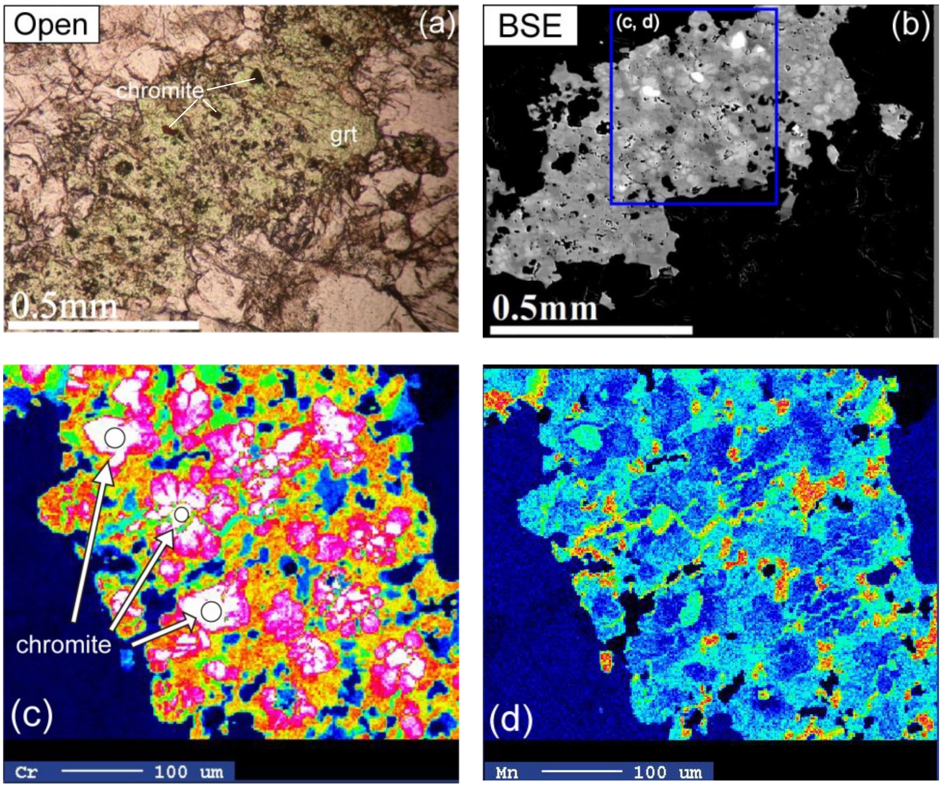

Figure 1. (a) Resorbed green garnet (plane - polarized light) contain numerous chromite grains as inclusions. A maximum value of 19.6 wt. % Cr_2O_3 was observed in this resorbed garnet grain. (b) BSE image of resorbed garnet. (c) Cr element map of the resorbed garnet showing chromium enriched portions surrounding chromite inclusions. (d) Mn element distribution map showing sporadically high Mn content of garnet.

Metamorphic temperature condition and fluid composition during the formation of the Dharwar calc-silicate rocks were calculated in the system of SiO_2-Al_2O_3-MgO-CaO-CO_2-H_2O at 3 kbar using the THERMOCALC 3.21. The metamorphic conditions were constrained based on the mineral assemblage of clinopyroxene, garnet, epidote, amphibole, chromite, plagioclase and calcite. Measured compositions of these minerals were used for calculating the activity following the procedure described in Skippen and Carmichael (1977). However, Cr_2O_3 is not included in the database, and the behavior of chromite in low-temperature metamorphism is not well studied. Therefore, as a first approximation spinel is included in the *P-T-X* calculations, with activities calculated from the analytical data of chromite following the scheme $a_{sp} = [Mg]\cdot[Al/2]^2$ (cf. Stroh, 1976). The metamorphic condition was evaluated using T-$X_{(CO2)}$ phase diagrams separately for garnet core and rim compositions. The assemblages in equilibrium with garnet core correspond to intersection of reactions (1), (3), (4), (6), (8), and (9) the invariant point [zo], at 471 ˚C, whereas for those assemblages corresponding to the invariant point [di] is defined by the reactions (2), (5), (6), and (7) at 437 ˚C (Fig. 2a). The invariant points in the T-X_{CO2} grid will become metastable for the garnet rim composition and new intersection of equilibria (1), (5), (6), and (7) the invariant point [tr] at 465 ºC and intersection [gr] of equilibria (3), (4), (5), and (7) at 446 ˚C become stable (Fig. 2b). Calc-silicate rocks of the study area suggest that the fluid composition varied during peak (X_{CO2} ~ 0.3) and retrograde metamorphism (X_{CO2} < 0.1). Preliminary SHRIMP analysis of titanite yielded a $^{206}Pb/^{238}U$ mean age of 2480 ± 14 Ma (95% conf., MSWD = 1.19), which is interpreted as the timing of metamorphism of calc-silicate and adjacent rocks. The age is consistent with other estimates of high-T metamorphism in the eastern Dharwar craton.

The mineralogical features of the Cr-rich calc silicate rocks are similar to those reported from the White river gold prospect in the Hemlo area of Ontario (Pan *et al.*, 1989). The Archean sedimentary rocks are enriched in Cr and Ni. Naqvi et al. (1981) in a study of chemical composition of Archean sedimentary rocks of the Dharwar Craton has shown evidence for their enrichment in Cr and Ni. High contents of Cr, Mn, Ni and V in calc-silicate minerals indicate that the rocks were internally buffered and evolved through low oxygen fugacity conditions.

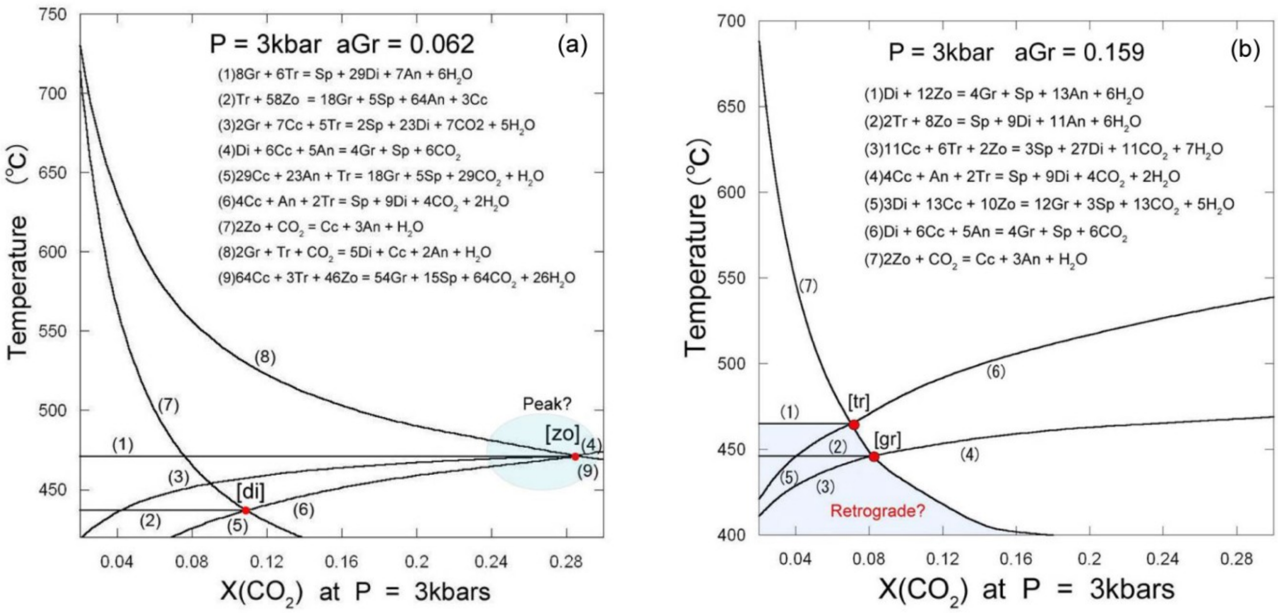

Figure 2. Activity corrected T-$X_{(CO2)}$ phase diagram in the system of SiO_2-Al_2O_3-MgO-CaO-CO_2-H_2O at 3 kbars, with mineral activities for the Cr-rich calc-silicate rocks, computed with the THERMOCALC program using analyzed mineral compositions of the calc-silicate rocks: An = anorthite, Cc = calcite, Zo = zoisite, Di = diopside, Gr = grossular, Tr = tremolite, and Sp = spinel. (a) T-$X_{(CO2)}$ phase diagram corresponding to the activity of garnet core. (b) T-$X_{(CO2)}$ phase diagram corresponding to the activity of garnet rim.

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