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Formation of Archaean TTGs during lower crustal melting of mafic rocks: Constraints from P-T pseudosection analyses

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TTG magmatism on a massive scale marked the crust forming processes in the Archaean. Highly fractionated HREE-depleted rare earth element patterns of these TTGs suggest their origin by partial melting of a mafic source with garnet, amphibole and clinopyroxene as residues. Such processes of TTG formation are also consistent with the results obtained from experimental works and petrogenetic models. Garnet-clinopyroxene bearing assemblages have so far being recorded from the supracrustal rocks of the Barberton, De Kraalen, Witrivier gneiss-greenstone terrains of the SE Kaapvaal and the Singhbhum Cratons. Such assemblages were formed during the high-grade metamorphic events occurring at ∼3.2 Ga. Though, the peak pressure conditions recorded from such assemblages in all these terrains are similar (14-15 kbar), the temperature recorded at Witrivier greenstone belt (750-800˚C) is much higher than in other terrains (600-650˚C). It needs to be established whether the metamorphic events recorded from these terrains represent some partial melting processes leading to formation of TTG-like melts. In this study we have conducted P-T pseudosection analyses to model formation of garnet-clinopyroxene-bearing assemblages and TTG-like melts from two mafic source rocks: (1) amphibolites, (2) calc-silicate (considered to be formed by sea-floor alteration of basalts). These two rock types form part of the supracrustal sequence in the Witrivier greenstone belt of SE Kaapvaal Craton. The pseudosections have been constructed in the NCFMASH system with PERPLE_X.

P-T pseudosection analyses reveal formation of TTG-like melts under water-saturated conditions at $\geq$ 10-16 kbar, >750˚C by breakdown of (1) zoisite/epidote and plagioclase in case of the calc-silicate and (2) amphibole in case of the amphibolite. At 15 kbar, 750˚C garnet-clinopyroxene-quartz bearing assemblages co-exist with ∼40 vol% melt in case of both calc-silicate and amphibolite. Under such P-T conditions, X_{Mg} and grossular contents of the garnets are respectively (1) ∼ 0.1 and ∼ 40 % in calc-silicate and (2) ∼ 0.26 and ∼23 % in case of amphibolite. These garnet compositions are similar to that recorded from the high pressure assemblages in the supracrustal rocks of the terrains. P-T pseudosection analyses further reveal that water-undersaturated melting at similar P-T conditions lead to formation of 10-12 vol% of TTG-like melts.

Hence the analyses indicate that high-pressure melting of mafic supracrustal rocks under water-saturated conditions can produce ∼40 vol% of TTG-like melts, which is twice the melt escape threshold (∼20-25 vol%). It is possible that such processes may have led to (1) formation of the garnet-clinopyroxene- bearing assemblages in the supracrustal rocks of the terrains and (2) segregation and transport of TTG-like melts in the Archaean.

Pseudosection analyses have also been conducted in order to further constrain the metamorphic processes operating during exhumation of the garnet-clinopyroxene- bearing rocks, post to melt segregation. TTG-like melts are formed at pressure ranges of 3-7 kbar, >830˚C, by breakdown of amphibole. Solid phases co-existing with these melts are clinopyroxene-plagioclase-quartz. Similar assemblages are noted in some of the amphibolites from the Witrivier greenstone belts. These amphibolites also preserve some quartzo-feldspathic bands, possibly indicating such medium-pressure melting processes.