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A case for Archaean S-type granite genesis from metapelites of the Ancient Gneiss Complex; Swaziland

J. Taylor and G. Stevens
Department of Geosciences, Stellenbosch University, Private bag X1, 7602, South Africa

This study has focused on Archaean metasedimentary units within the Ancient Gneiss Complex (AGC) of Swaziland, with the long-term aim of understanding the relationship of this large block of medium to high-grade geology (the AGC) to the various discrete, generally lower grade, tectono-metamorphic blocks of the Barberton granite greenstone terrain to the north and north-west. To date the work has focused on the small inliers of supracrustal rocks constituting the Mkhondo Metamorphic Suite in south-central Swaziland and has produced results that appear to make a very strong case for the production of Meso-Archaean S-type magmas with an age much older than any recorded granites of this type.

The rocks consist of interlayered metapelites and metapsammites that have experienced high grades of metamorphism well into the granulite facies, and contain abundant evidence of partial melting. The metapelitic layers, in particular, contain several different varieties of in-situ anatectic leucosomes that are all associated with garnet: small nebulitic leucosomes, with no foliation in the leucosome, contain foliated remnants of the host gneiss as well as abundant, coarsely crystalline poikiloblastic garnet; thin (mm) scale anastomizing leucosomes, developed parallel to the foliation but oblique to bedding, are present in association with the garnet generation described above - these thin veins form a network, encapsulating domains in the rock where the proportion of garnet is significantly higher (and crystals are larger) than in the matrix of the gneiss; the third type are leucosomes developed parallel to the foliation, that are internally un-foliated and that thicken into small discordant magma bodies that cross-cut the foliation - these leucosomes are also characterized by an abundance of garnet.

This study was restricted to those units with peak metamorphic mineral assemblages which appear to be the most suitable and potentially useful in recording metamorphic change $i.e.$ garnet + cordierite + biotite + plagioclase + perthitic K-feldspar + quartz. Importantly, the K-feldspar in the rocks chosen for study is clearly metamorphic in texture and has not crystallized solely from the melt. Whole-rock XRF major element data was used for the construction of pseudosections using Thermocalc 3.30 software. As water controls melting, the water content choices are crucial in modeling rocks of this type. A rock water content was chosen that was sufficient to saturate the pre-anatectic amphibolite facies rock in hydrous minerals, but produce as little excess water as possible. In essence, this limits the wet granite melting reaction to produce an insignificant amount of melt, with major melting being realized through the fluid-absent incongruent melting of the hydrous minerals. As a result, the peak metamorphic assemblage was predicted to be stable within the PT window 825-900 ºC and 6-8 kbars.

Isopleths of mineral composition were plotted for garnet in an attempt to further constrain the PT conditions. The measured garnet compositions plotted far from the field of mineral stability. This is surprising for several reasons: garnet is clearly produced during the peak metamorphic anatectic event; garnet in the rocks has a flat zonation pattern; garnet is not obviously consumed by retrograde reactions; and lastly garnet is the least likely mineral to have changed composition during retrogression. Cordierite and biotite isopleths also plotted outside of this field.

The above assemblage stability field – mineral isopleth mismatch cannot be ascribed purely to resetting of mineral compositions during retrogression for the reasons mentioned above. However, a substantial shift in bulk rock Mg# (lowering Mg# by $\pm$ 10%), results in a shift of the appropriate mineral stability field to lower pressures and temperatures (800 to 875 ºC and 4 to 7 kbars) and a shift in the positions of the calculated mineral isopleths to overlap this field. The migmatitic character of the rocks and the degree of garnet incorporated into the leucosomes give important clues as to the mechanism of the required Mg# shift. Backwards modeling of the rocks as residua after the loss of 50% melt and 10% entrained peritectic garnet produces the compositions described above where the stability field of the granulite facies assemblage and the isopleths of diagnostic mineral compositions are perfectly concordant. Collectively this new information restricts the peak PT conditions of metamorphism to 800 to 850 ºC and 3.8 and 4.5 kbars. The refractory nature of the metasedimentary package combined with the requirement of melt loss described above indicates the production of a significant volume of strongly peraluminous magma from this portion of the AGC. Thus, these rocks preserve evidence for the oldest know production of S-type granitic magma, despite the fact that the resultant intrusions are not preserved.