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LILE-depletion in the Archaean lower continental crust: the Lewisian granulites revisited

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The Lewisian granulites of northwest Scotland have long been regarded as a type-example of Archaean, felsic, lower, continental crust, although their extreme depletion in the large ion lithophile elements (LILE) places them as an end-member of a spectrum of lower crustal compositions. Recently two new observations have revived interest in the processes leading to these extreme compositions. Firstly, new SIMS geochemistry of clinopyroxenes from granulite facies pyroxenites suggests that there was extensive light rare earth element mobility during the granulite facies metamorphism, implying the migration of a fluid or melt phase during granulite metamorphism. Secondly, a revaluation of their metamorphic conditions (Johnson and White, J. Geol. Soc. Lond. 2011) shows that the metamorphic peak was between 875-975 oC and 8.5-11.5 kb, less extreme than previously proposed, but sufficient to permit dehydration melting in a hydrated protolith.

Here, new trace element data for felsic Lewisian granulites at Scourie confirm for the first time a hornblende signature in these granulites. Primary granulite facies hornblende is absent in these rocks indicating that the igneous protolith to the granulites was a hornblende tonalite. Thus their prior hydrous state permits their dehydration melting during granulite facies metamorphism. Previous field and geochemical studies have been equivocal on this matter, some authors claiming that LILE depletion was the result of partial melting, others arguing from the absence of partial melts that the depletion was inherited from the pre-metamorphic magma generation process.

The trace element composition of granulites at Scourie and Assynt is compared with that of gneisses of similar age, but of lower metamorphic grade at Torridon, assumed to be unmodified by partial melting. There are significant geochemical differences between the two, confirming the well-known granulite LILE depletion, but also extending it to include the elements Cs, Pb, Nb and Ta. Geochemical modelling based on partition coefficient data from the GERM database and phase relations from experimental studies on Lewisian rocks allows the composition of the granulite protolith to be calculated prior to melt extraction. The results shows that it is substantially different from the composition of the unmodified Torridon gneisses, its supposed unmetamorphosed counterpart. It is proposed that the Lewisian felsic granulites experienced element depletion twice. Once during melt removal during granulite facies dehydration melting, but also during melt generation implying a depleted source. Thus the creation of new felsic Archaean crust at Scourie in the central region of the Lewisian and at Torridon in the south were via different processes.

The very high Nb/Ta ratio of the Lewisian felsic granulites (Nb/Ta=54) has not been previously noted and is much higher than that of the Torridon gneisses (Nb/Ta=16), which are more typical of Archaean felsic gneisses. These differences originated in the contrasting source regions of the felsic magmas.