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Major and trace element characteristics of melts from amphibolites, eclogites and granulites, and an assessment of arc-like scenarios for the Archaean

S.F. Foley and F. Nehring

Institut für Geowissenschaften, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

Most high grade gneisses of Archaean age are tonalitic to trondhjemitic in composition with markedly low concentrations of Nb and Ta relative to other trace elements. Granitoids with these chemical characteristics generally occur in subduction environments on the modern Earth, so that the commonest explanation of the genesis of Archaean gneisses invokes subduction processes and the accretion of island arcs to form the first continents. However, appealing directly to the tectonic environment by analogy with modern tectonic processes overlooks the fact that some unknown proportion of these rocks may have been formed before plate tectonics operated. An independent opinion about their genesis must be obtained by identifying the petrological mechanism, recognising that the major element composition of magmatic rocks depends on the mineralogy of the source rock and the pressure and temperature of melting, and that the trace element patterns are controlled by phases that remain present in the source rock when the melt leaves it. Experiments have shown that melts corresponding to the major element compositions of tonalites and trondhjemites are produced by the melting of basaltic rocks, either as eclogites or amphibolites. Trace element partitioning has been used to argue that eclogite and rutile eclogite could not produce the low Nb/Ta seen in the Archaean gneisses, whereas melting of garnet amphibolite could (Foley et al., 2002). This conclusion can be generalised to group all Ti-oxide minerals with rutile, as the crystal site polyhedron size offered by these oxides is smaller than Ta, which in turn is smaller than Nb. The octahedral sites in common silicate minerals are all larger than the relevant sites in Ti-oxides, and so will favour Nb over Ta in almost all cases. Under higher thermal gradients that were probably more common in the Archaean, melting of basaltic rocks in the form of mafic granulites may have occurred more regularly than today. This requires melting at lower pressures than where garnet amphibolite or eclogite are left in the residue. Natural 3.1-3.2 Ga migmatized granulites of the Iisalmi block in central Finland contain leucosomes which are predominantly tonalitic. The leucosomes usually consist of large subhedral plagioclase crystals in a matrix of quartz indicating growth from a melt. Mafic minerals occur in small amounts but most likely represent entrained restitic material. Granulitic leucosomes are richer in CaO and poorer in Na2O and K2O than leucosomes from amphibolites. Trace elements in leucosomes that are in equilibrium with residual minerals are depleted in strongly incompatible elements and can be distinguished from melts of amphibolites and eclogites. The conclusion is that most Archaean high-grade gneisses are probably produced by partial melting of garnet amphibolites, but this need not imply an island arc-like tectonic scenario.