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The provenance of garnet: semi-automatic plotting and classification of garnet compositions

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Garnet is a mineral that is observed in many metamorphic and igneous rocks. It is relatively stable under most weathering conditions and inert to diagenic processes upto a few kilometers overburden. In heavy mineral provenance studies, individual minerals are usually derived from sandstones, or from river or beach sediments. Information on the original composition and metamorphic grade of the garnet-bearing source rock are lost in most cases. Here, we show that garnets can be used to get a crude estimate of the chemistry (felsic, mafic or calc-silicate) and metamorphic facies (amphibolite, granulite or eclogite facies) of the source rock.

The cation composition of garnet varies widely between garnets from felsic, mafic, and calc-silicate rocks (such as siliceous marbles). The garnet composition also depends on the pressure (p) and temperature (T) conditions under which it was formed or recrystallised. This property has been known for a long time and many geothermometers and geobarometers have been developed on this basis. For aluminium-rich garnets especially Mg, Fe and Ca are indicative of host rock composition, and pT conditions of metamorphism. This type of garnets covers the large majority of garnets in igneous and metamorphic rocks.

This study is limited to aluminous garnets. Garnet compositions of metamorphic rocks were taken from 46 publications that cover many different geological settings. Maximum fifteen measurements of each publication were used, to avoid a bias to a certain area or rock type. From each publication the metamorphic facies or pT conditions, which were calculated using pseudo-sections, geothermometers and geobarometers, and the rock type were copied. All garnet compositions were plotted in a triangular diagram, using pyrope (XMg), almandine+spessartine (XFe+Mn), and grossular (XCa) as end-member compositions. The diagrams were divided into seven different groups based on their metamorphic facies and their chemistry.

Garnets in group 1 include kimberlitic garnets and other garnets that underwent ultra-high pressure metamorphism. Garnets in group 2 are mainly felsic granulites. "Felsic" includes all source rock with a politic, semipelitic, metasedimentary, granitic and granodioritic composition. Group 3 comprises mainly felsic amphibolites; these are the lower temperature equivalents of group 2. The transition between these to groups is set at XMg = 25, which corresponds to a temperature of ca. 700-750 ºC. Group 4 consists of a) felsic amphibolites that either have a more Ca-rich or more intermediate composition, like Ca-rich semipelites, b) felsic rocks that underwent eclogite facies metamorphism, or c) charnockites. Group 5 includes intermediate and mafic amphibolites, and eclogites that were formed at relatively low temperature. Group 6 comprises garnet-amphibolites, mafic granulites and higher temperature mafic eclogites. Garnets derived from calc-silicates and anorthositic rocks comprise group 7.

We analysed hundreds of garnet grains with Computer-Controlled Scanning Electron Microscopy (CC-SEM) to test the classification against garnets from a known hinterland. CCSEM is a method for automatised particle analysis (Keulen et al., 2008). These analyses showed a good match with the literature-based classification.

A Python-based freeware program, WxTernary, has been developed that enables plotting of all grain compositions of multiple samples simultaneously in different diagrams. For each sample the density of measured compositions can be calculated and contour plots can be generated. In addition the number of garnet grain compositions that lie in each individual group can be calculated and plotted. The program can easily be adjusted to plot data from other minerals or rocks with three or more variables in a ternary diagram.

Keulen et al. 2008: Geological Survey of Denmark and Greenland Bulletin 15, 93–96. www.geus.dk/publications/bull

WxTernary: http://sourceforge.net/projects/wxternary/