On garnet in pelitic contact-zones.

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Of the garnet group of minerals, two members only appear to have been synthesized from artificial melts, viz. melanite (L. Michel, 1892) and spessartine (L. Bourgeois, 1883, and A. Gorgeu, 1883); though grossular is once reported by E. S. Shepherd, G. A. Rankin, and F. E. Wright (1909) as being produced by reaction under pressure of calcium orthosilicate and aluminium chloride. In dry melts, pyrope is represented by a cordierite-forsterite-spinel assemblage, but no data are yet available to indicate the dry melt assemblages representing almandine. The home of almandine in sediments is the dynamically metamorphosed pelite, and its widespread regional occurrence in these crystalline schists implies a ready synthesis under the influence of shearing stress.

While stress in this case appears to play the part of a catalyst, a garnet (customarily assumed as almandine) is also found in pelitic contact-rocks, though it is inconstant and sporadic in its occurrence. Examination of the thermal assemblages of a considerable number of contact-zones reveals that almandine is completely absent. Thus in the case of the Kristiania and Comrie contact-zones, though many hundreds of thin sections of the thermal products have been examined, no examples have been found to contain almandine. With one or two isolated exceptions, the same remark would appear to apply to the contact-zones of the Hercynian granites of Cornwall and Devon. In certain aureoles, however, garnet becomes a conspicuous and significant mineral.

To confine attention to the aureoles of the British Isles, we may note its occurrence in the contact-zones of:

(*a*) The Skiddaw granite and Grainsgill greisen; Carrock Fell gabbro.
(*b*) The New Galloway granites (Loch Dee and Cairnsmore of Fleet masses).
(*c*) Leinster granite and Glendalough amphibolites (Co. Wicklow).
(*d*) Insch and Huntly younger intrusives, Banffshire.

(*e*) Carn Chuinneag granite, Ross-shire.

The conditions of genesis in these aureoles have been hitherto unexplained and remain a puzzling petrographic problem.

Destruction of almandine in contact-zones of crystalline schists.—The absence of almandine in the typical contact-zones already mentioned is of such significance that an examination of aureoles of pelitic crystalline schists may throw some light on this question. It is unfortunate that our information in this direction is still limited; nevertheless some pertinent data are already at hand. A number of the Caledonian intrusions of the Scottish Highlands cut well-defined crystalline schists, of which almandine is a prominent constituent. It will suffice to mention the aureoles of the Cruachan, Ross of Mull, and Garabal Hill massifs. In each of these cases hornfelses have been manufactured out of garnet-bearing muscovite-biotite-schists, and in the three aureoles the destruction of almandine can be followed in the regeneration that has resulted. Particularly convincing is an example in the Ben Cruachan aureole where E. B. Bailey (1916) has described the development of hornfelses from garnet-bearing Leven schists, in which the garnet is in process of dissolution, being replaced by and converted into pseudomorphs of cordierite and magnetite, while white mica gives rise to abundant potash-felspar. The same destruction of almandine with the formation of cordierite in its place may be recognized in the other aureoles mentioned, those of the Ross of Mull and Garabal Hill. The mineralogical transformation here revealed is obviously of great importance as attesting the instability of almandine under the conditions which commonly prevail in contact-zones.

The foregoing facts make it obvious that a closer examination of the garnet-bearing aureoles already mentioned is demanded if we are to have insight into the conditions responsible for the production of garnet. It will first be necessary to determine that the garnet in question is essentially almandine; here it is that such information is not forthcoming, as there are no available analyses of the garnets of the Skiddaw, New Galloway, Glendalough, or Carn Chuinneag aureoles. In pelitic stress-zones it is now known that the garnets in some cases contain considerable percentages of the spessartine molecule, and the presence of significant percentages of MnO in the sediment has a profound influence on the order of entry of the index-minerals in progressive metamorphism, the common order chlorite–biotite–garnet being inverted to chlorite–garnet–biotite. With this knowledge before us, it is pertinent to inquire whether the garnets of pelitic contact-zones are characterized by any similar peculiarity.

As regards analytical data for British aureoles, we are practically limited to an analysis by W. J. Sollas[1] of a garnet-hornfels and its constituent minerals, from the Leinster granite contact, near Carrickmines, Co. Dublin. The analysis of the garnet shows it to be a spessartine-rich type, as follows: SiO_2 37·63, Al_2O_3 16·43, Fe_2O_3 7·85, FeO 14·59, MnO 18·55, CaO 3·49, MgO 2·10. This analysis may be expressed in atomic percentages as $Fe_{40}Mn_{40}Mg_{10}Ca_{10}$.

In order to obtain further information as to the composition of the contact garnets, two partial analyses have been carried out of (*a*) garnet from a garnet-sillimanite-contact-rock from Knocknairling Hill, New Galloway, and (*b*) garnet from a metamorphosed grit at Grainsgill (Cumberland). The New Galloway garnet yielded on analysis SiO_2 37·80, Al_2O_3 20·79, Fe_2O_3 0·43, FeO 21·87, MnO 14·88, CaO 1·60, MgO 1·75, which can be expressed as $Fe_{52}Mn_{36}Mg_7Ca_5$; while for the Grainsgill garnet analysis gave FeO 30·16, MnO 6·02, expressed as $Fe_{70}Mn_{14}$.

The most striking feature of the garnet-rocks of the aureole of the New Galloway granites is the abundance of white potash-mica, in which indeed the garnets are not infrequently enclosed. The other common associates in addition to quartz are sillimanite and biotite. Cordierite is much less common, while potash-felspar, sometimes wholly absent, appears to be never more than an accessory constituent. Quite similar features characterize the contact-metamorphosed Ordovician slates of Co. Wicklow (J. A. Thomson, 1908).

The sharpest contrast is found in the assemblages of the aureoles of Kristiania or Comrie. In these, garnet is absent, cordierite is dominant, potash-felspar is present to the exclusion of white mica, which here is never a primary mineral. When we turn to the garnet-bearing rocks of the Skiddaw area, the contrast is not so sharp, but is nevertheless marked. Throughout the Skiddaw aureole generally, potash-felspar is a subordinate constituent, while white mica as a primary mineral is common, as of course is also biotite. These conditions hold for the garnet-bearing types. Comparing the two types of assemblages, it may be considered that in their abundance of cordierite, potash-felspar, and magnetite to the exclusion of white mica, the Kristiania-Comrie aureoles were relatively dry, and that the garnet-bearing aureoles in their paucity of potash-felspar and abundant micas were relatively wet.

Turning to igneous rocks (Archaean tracts apart) we find that spessartine or spessartine-almandine is a characteristic mineral of certain granite-pegmatites, and even of druses and miaroles of hypabyssal and

[1] W. J. Sollas, Sci. Proc. R. Dublin Soc., 1891, n. ser., vol. 7, p. 49.

volcanic rocks, where its association with pneumatolytic minerals, as topaz, tourmaline, and beryl, betrays the presence of residual solutions rich in mineralizers. The absence of almandine in the normal contact-aureole, the visible evidence of its replacement when introduced into the sphere of influence of igneous intrusions, conspire to demonstrate that the iron-garnet is unstable under the conditions prevailing in normal contact-metamorphism. When the garnet of garnet-bearing aureoles is shown to contain notable quantities of MnO, and when further such garnets are inconstant and sporadic in their occurrence (suggesting local concentration of manganese), it would appear legitimate to conclude that the formation of garnet in pelite aureoles is conditioned by the presence of MnO in the sediment, leading to the formation of a spessartine-bearing type. This is the more acceptable when it is realized that spessartine is readily synthesized in artificial melts. It is as yet impossible to estimate what contributory part, if any, the presence of abundant water during metamorphism—as the principal garnet-bearing aureoles reveal—plays in producing a concentration of an orthosilicate molecule as garnet. The essence of these remarks is the stress laid upon the presence of MnO as promoting the formation of garnet in contact-zones of pelites.