KINETICS OF CRYSTAL SIZE VARIATION IN REGIONALLY METAMORPOSED ROCKS FROM BROCKWAYS MILLS, VERMONT

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INTRODUCTION

Various workers in the Vermont sequence have commented on the range of garnet crystal sizes observed in both and pelitic and metavolcanic sequences. Increasing crystal size in metamorphic minerals is commonly believed to be associated with increasing metamorphic grade (Spry 1969). But the presence of both large and small garnets at one grade of metamorphism tells us that grade alone is not sufficient to describe why some crystals grow larger than others, especially if the disparate crystal sizes are present in one outcrop.

REGIONAL GEOLOGY

Brockways Mills is located in the Connecticut Valley Synclinorium, to the south and east of the Chester Dome, in southeastern Vermont. The Siluro-Devonian sequence comprised of the Northfield, Waits River and Standing Pond formations are isoclinally folded in this general area, part of a system of large isoclinal folds adjacent to the Chester and Athens Domes. The Devonian Acadian orogeny is believed to be the only major contributor to metamorphism in the units studied, although there is evidence of two events within the Acadian. The first event involved large amounts of deformation, which is recorded in rotated garnet cores in Waits River garnets, and is responsible for the isoclinal folding. The second event was the regional doming which produced the Chester and Athens domes (Rosenfeld 1968).

PURPOSE AND METHODS

Two localities very close to each other were sampled; the first in the Williams riverbed, and the other 1190 meters structurally below the river locality, on a small unnamed hill. Waits River and Standing Pond rocks were obtained from the riverbed, and the Northfield formation was sampled from the hill location. The Waits River and Northfield formations have a gradational boundary at the hill locality, and were largely indistinguishable from each other at this site.

The purpose of this study is to identify some of the factors responsible for the observed grain size variation in garnets along a specific pressure-time-temperature path. The two variables that will be investigated are the composition, and grain size distribution, of the garnet populations in question. The compositional discussion will consist of three parts: 1) determining precise compositions of small garnets relative to large garnets within each lithology, and the compositions of phases relevant to the assemblages being studied, 2) determining the reactions that produce garnet and 3) comparing garnet zoning profiles for information on when each garnet grew. The grain size distribution of the different garnet populations will be compared to other grain size studies in the geologic literature, which postulate various growth and nucleation models based on the observed grain size relationships (Cashman and Ferry 1988; Carlson, in press).

PETROGRAPHIC DESCRIPTION

The Northfield, Waits River and Standing Pond formations have been metamorphosed to the epidote-amphibolite facies (Robinson 1986). The Northfield formation is a dark grey weathering, graphitic garnet mica schist. The Waits River formation is a series of graphitic garnet mica schist, "punky-brown" weathering calc-silicate, and quartzite interbeds. The Standing Pond formation is a metavolcanic unit comprised predominantly of garnet-plagioclase-hornblende amphibolites.

Thin section analysis suggests correlations between composition and garnet size. For instance, garnet N6f'{2}2 from the Northfield formation is a large garnet in a matrix of non-graphitic chlorite and quartz; the other (smaller) garnets in the sample are in the "typical" graphitic pelitic matrix of muscovite, quartz, plagioclase, with small amounts of biotite and chlorite. The Northfield formation is characterized by garnet crystal size variation (CSV) of .25-6.5 mm^2 in the samples analyzed from the locality, and this size range is also captured in one thin section. Waits River garnets are characterized by a size range of .25-9 mm^2 in the samples analyzed, and the greatest size range in any one thin section is 1.75-9mm^2. The Standing Pond formation is compositionally very different from the pelitic Northfield and Waits River formations, and it is also distinct from the two formations in terms of its garnet CSV. The greatest CSV in any one thin section was 2.5-5 mm^2, and in the locality sampled as a whole was .5 mm^2-3.2 cm^2.

RESULTS

Figure 1 presents a summary of the compositional data for 2 thin sections--N6f'{2} and N6c--from the Northfield formation. The most striking difference between small and large garnets for each slide is the signicantly larger MnO content in the cores of large garnets (see figure 1, Tables 1 and 2). MnO content has been related by previous studies to the size of garnets (Chinner 1960, Atherton 1965, Finlay and Kerr 1979). The first two of these studies state that increased MnO content is related to producing small garnets, whereas Finlay and Kerr (1979) suggest that the highest central MnO content is found in the largest garnets. This study's findings support the latter idea.

Another observation, most clearly seen in the N6c garnets, is that small garnets are more homogeneous than large garnets (see Figure 1, Table 3). In fact, the actual percentages of FeO, MgO, MnO, and CaO in small garnets correspond fairly well with the percentages of these components found in the rims of large garnets within the same thin section. A number of past studies have made similar observations (Hollister 1966, Edmunds and Atherton 1971, Kretz 1973, Cygan and Lasaga 1982). Thus, compositional data determined to date strengthen the argument that (bulk) composition influences the size to which a crystal will grow.

Preliminary compositional data from a Waits River sample show a similar increase in central MnO content in a large garnet. No compositional data have yet been gathered for Standing Pond rocks. The determination of garnet-producing reactions will be attempted when more data has been obtained. Grain size distribution analysis is also currently being pursued.

INTERPRETATION

Large garnets in this study are MnO-rich. Presumably the high central MnO content of the larger garnets corresponds to a bulk composition richer in MnO. Then given the fact that increased MnO stabilizes garnet growth, (Chinner 1960) a reasonable conclusion might be that the larger garnets, being stabilized more readily, started growing sooner than the smaller garnets. Furthermore, given that we know that there were two deformational events within the Acadian, the heat necessary to grow the second group of smaller garnets may have been supplied by the later deformational event.

A second interpretation of the data involves the relationship between the rim compositions of large garnets and the overall compositions of small garnets in thin section N6c. This relationship may suggest a model of continous nucleation. (Kretz 1973) Assuming that a reservoir has a homogeneous composition, precipitation of composition X happens at the same time throughout the reservoir. By this argument, the small garnets in N6c started growing at the time that rims were being added to the large garnets in the rock, and therefore must have nucleated later.

However, even knowing that MnO stabilizes garnet growth does not fully explain the problem of crystal size variation existing at one grade. If bulk composition A has a greater MnO content than bulk composition B, then one might expect one of two size:composition relationships. These relationships are distinguished by different nucleation rate to growth rate ratios. One model for nucleation and growth has a high nucleation rate and low growth rate. These conditions would produce a large number of relatively small crystals. For the same MnO content, one might have a low nucleation rate and high growth rate. This modek would produce a small number of relatively large crystals. But growth and nucleation of garnet seem not to be independent of MnO content, and it is not clear if or how MnO differentially affects the two processes. The observation that both size:composition relationships exist in nature is intriguing, and may be a function of a rock's relative MnO content.

References cited:

Atherton, M.P. (1965) The composition of garnet in regionally metamorphosed rocks. In: Pitcher, W.S. and Flinn, G.W. (eds) Controls of Metamorphism: A symposium held under the auspices of The Liverpool Geological Society. Oliver and Boyd, London, 281-290.

Carlson, William D. (in press) The significance of intergranular diffusion to the mechanisms and kinetics of porphyroblast crystallization.

Cashman, K.V. and Ferry, J.M. (1988) Crystal size distribution (CSD) in rocks and the kinetics and dynamics of crystallization III. Metamorphic crystallization. Contrib Mineral Petrol 99:401-415.

Chinner, G.A. (1960) Pelitic gneisses with varying ferrous/ferric ratios from Glen Clora, Angus, Scotland. J Petrol 1:178-217.

Cygan, Randall T. and Lasaga, Antonio C. (1982) Crystal growth and the formation of chemical zoning in garnets. Contrib Mineral Petrol 79:187-200.

Edmunds E.M. and Atherton M.P. (1971) Polymetamorphic evolution of garnet in the Fanad Aureole, Donegal, Eire. Lithos 4:148-161.

Hollister, L.S. (1966) Garnet zoning: An interpretation based on the Rayleigh fractionation model. Science 154:1647-1651.

Kretz, R. (1973 a) Kinetics of the crystallization of garnet at two localities near Yellowknife. Can Mineral 12:1-20.

Robinson, P. (1986) Introduction. In: Robinson, Peter and Elbert, D.C. eds., Field trip guidebook: Regional metamorphism and metamorphic phase relations in northwestern and central New England: Field Trip B-5, International Mineralogical Association, 14th General Meeting at Stanford University, Contribution No. 59, Department of Geology and Geography, University of Massachusetts, Amherst, Massachusetts, 1-10.

Rosenfeld, J.L. (1968) Garnet rotations due to the major Paleozoic deformations in southeast Vermont. In: Zen, E-an, White, W.S., Hadley, J.B., and Thompson, J.B., Jr., eds., Studies of Appalachian geology: northern and maritime. Interscience Publishers, New York, 185-202.

Spry, A. (1969) Metamorphic Textures. Pergamon Press, New York, 114-206.

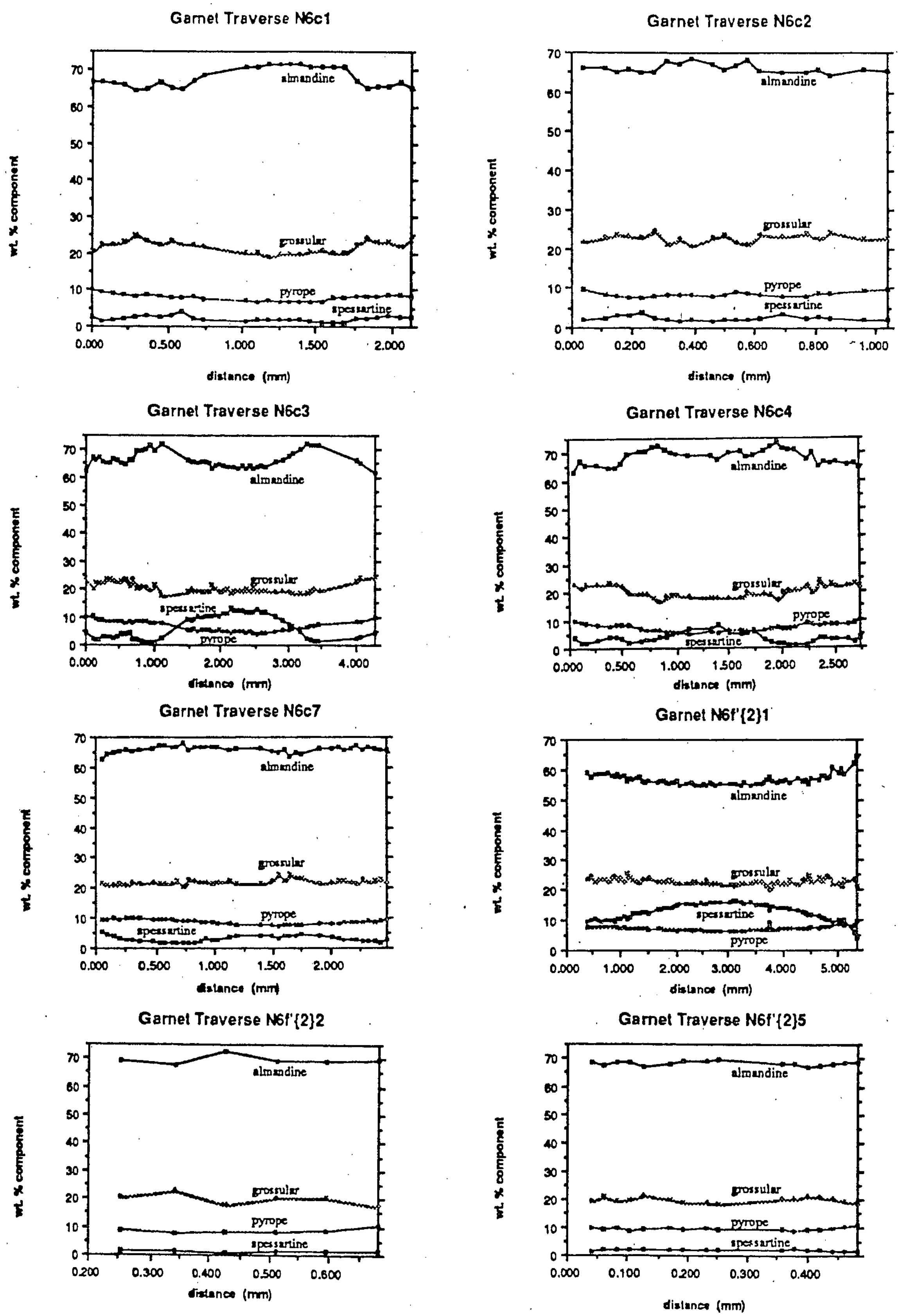

Figure 1. Garnet traverses from thin sections N6c and N6f'{2}

Wt. % components		Large garnets	Small garnets
	FeO	60-72	67-72
	MgO	5-10	8-10
	MnO	0-14	1-5
	CaO	16-24	20-25

Table 1. Comparison of N6c large and small garnets

Wt. % components		Large garnets	Small garnets
	FeO	57-65	68-72
	MgO	8-9	8-10
	MnO	10-15	1-2
	CaO	20-25	17-23

Table 2. Comparison of N6f{2} large and small garnets

Wt. % components		Large cores	Small garnets
	FeO	62-72	67-72
	MgO	9-10	8-10
	MnO	0-5	1-5
	CaO	20-24	20-25

Table 3. Comparison of N6c large garnet cores and small garnets