ROY, RUSTUM AND C. P. BUSHMER (1965), Influence of neutron irradiation on first order displacive transitions in quartz and cristobalite. *Jour. Appl. Phys.* **36,** 331.

——— and O. F. TUTTLE (1956) Investigations under hydrothermal conditions. *Phys. and Chem. of the Earth,* **1,** ed. L. H. Ahrens, K. Rankama and S. K. Runcorn, Pergamon Press, Inc., 138.

WITTELS, M. C. AND F. A. SHERRILL (1956) Irradiation induced phase transformations in zirconia. *Jour. Appl. Phys.* **27,** 652.

——— AND F. A. SHERRILL (1959) Fission fragment damage in zirconia. *Phys. Rev. Letters,* **3,** 176.

WHITE, W., F. DACHILLE AND R. ROY (1961) High pressure—high temperature polymorphism of the oxides of lead. *Jour. Am. Cer. Soc.* **44,** 170.

THE AMERICAN MINERALOGIST, VOL. 50, SEPTEMBER, 1965

SPESSARTITE-QUARTZ ROCKS (COTICULES) FROM NOVA SCOTIA[1]

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INTRODUCTION

In mainland Nova Scotia, metasedimentary rocks of the Lower Ordovician Halifax Formation contain beds, lenses and nodules composed chiefly of spressartite and quartz. Renard (1878) called similar rocks, from the Ardennes region of Belgium, "coticules." This word is derived from coticula, the feminine diminutive form of the Latin cos, cotis, meaning "any hardstone, flintstone, whetstone, hone or grindstone." Emerson (1898) used the term to describe quartz-garnet rocks in southeastern New England and its use was revived by Clifford (1960) for similar rocks in western New Hampshire. The term gondite (Fermor, 1909) has been applied to similar rocks but appears to embrace a broader group of manganese-bearing rocks than coticule. Take (in Trost, 1958) used the name gondite for spessartite-garnet rocks from Lazy Head, Nova Scotia. These are probably coticules.[2]

Slates and schists of the Halifax Formation are known to contain coticule beds or lenses at several widely separated localities. Good exposures of coticules are present near Port Felix South of Lundy and near Sandford.

LITHOLOGY AND CHEMICAL COMPOSITION

The coticules occur interbedded with and in pelitic rocks that have undergone regional metamorphism of greenschist grade. Locally, near

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[2] The authors acknowledge the assistance rendered by Dr. J. E. Sanders in securing reference material on coticule terminology.

granitic plutons, contact metamorphism, with assemblages characteristic of the hornblende hornfels facies, has been superimposed on the regional metamorphism. These rocks are schistose in many places but are also commonly slaty. Although the Halifax Formation is commonly carbonaceous, coticules are present only in non-carbonaceous strata. Total thickness of coticule beds in coticule-bearing horizons is difficult to estimate because of the lack of continuous outcrop. In some outcrop areas they comprise 5 per cent of the rock and in others less than 1 per cent.

The coticule beds are 2 inches thick or less and average about $\frac{1}{3}$ of an inch thick. These beds are in many places intricately folded. Beds are not traceable for more than a few tens of feet because of small outcrops but they may extend much further. Near Sandford, coticule lenses coalesce to form thin beds, rarely more than $\frac{1}{2}$ inch thick, that pinch and swell. These lenses lie parallel to the bedding in the slate. Nodules on the other hand, that measure up to 2 inches in diameter and $\frac{1}{2}$ inch thick, lie both normal and parallel to the bedding.

In hand specimen coticules are moderate orange pink with a fine-grained sugary texture. Microscopically the rock can be seen to be composed of quartz, spessartite, small amounts of chlorite and locally a trace of carbonate, probably calcite and muscovite. The spessartite is pale yellowish pink to colorless and occurs as individual euhedra and intergrown aggregates of euhedra. The euhedra range from .01 to 0.4 mm in diameter, but in indivudual beds grain size is restricted to close limits such as 0.1 to 0.2 mm. The chlorite occurs chiefly as flakes less than .01 mm but a few grains are as large as 0.25 mm. Most of the chlorite occurs along the border of the coticules but a few grains, especially the larger ones are present interstitial to the quartz and spessartite.

Molecular per cent of end members:

Almandine	21.4
Andradite	6.1
Pyrope	4.7
Spessartite	65.6
Grossularite	2.2.

The garnet has an index of refraction of $1.805 \pm .005$ and the cell edge is 11.613 Å. A spectrographic analysis of the same sample showed the following trace elements present in approximate order of decreasing abundance: V, Co, Cr, Cu and Sr.

Other garnets from biotite-muscovite-quartz schist that contains a coticule bed have a cell edge of 11.588 Å and showed refractive indices between 1.81 and 1.82 for some and 1.80 and 1.81 for others. Although these garnets were not analyzed their similar cell edge and refractive indices

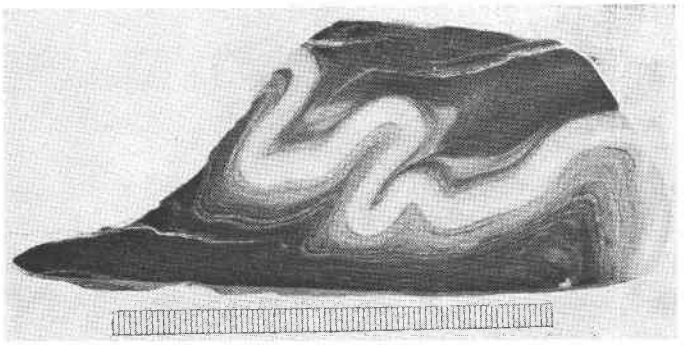

FIG. 1. Photograph of polished slab showing intricately folded coticule bed in chlorite schist. ×1.

shows that the garnets in the schist differ only slightly from those in the coticule bed.

ORIGIN

The occurrence of coticules interbedded with metasedimentary rocks and the conformity of coticule beds with the enclosing strata, even where highly contorted, indicates that the coticules are derived from a sediment.

The nature of the sediment involved however has not been defined. Clifford (1960) concluded that coticules were originally manganese-rich sandy beds whereas Thompson (in Clifford, 1960) suggested they were probably metamorphosed cherts. Woodland (1939) considered similar

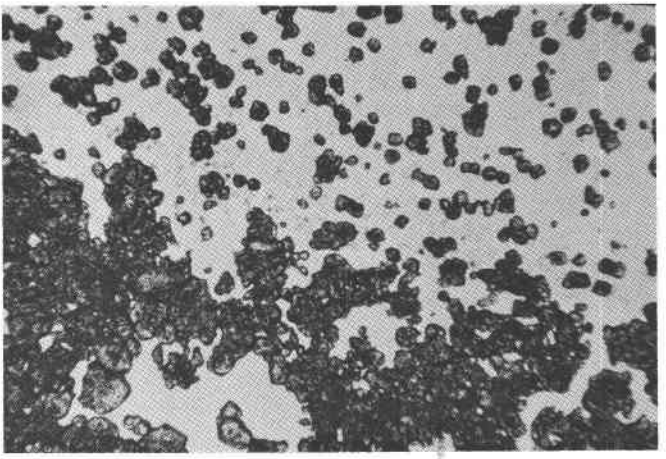

FIG. 2. Photomicrograph of coticule showing intergrown garnet grains in quartz matrix. Plane-polarized light ×60.

TABLE 1. CHEMICAL ANALYSIS OF GARNET FROM COTICULE

	%	Mol. prop. after recal. to 100%	
SiO_2	39.74	0.6660	
TiO_2	0.34	0.00426	
Al_2O_3	18.79	0.1855	
Fe_2O_3	1.52	0.0096	
FeO	8.79	0.1229	
MnO	26.60	0.3767	
MgO	1.09	0.0270	
CaO	2.66	0.0476	
Na_2O	0.02		
P_2O_5	0.07		
H_2O	0.26	J. A. Maxwell, Geological	
H_2O	0.08	Survey of Canada, Analyst.	
	99.96		
Number of ions on the basis of 24 (0)			
Si	6.395	6.507	
Al*	0.112		
Al	3.449		
Fe^3	0.1840	3.674	R^3
Ti	0.0409		
Fe^2	1.180		
Mg^2	0.257	5.509	R^2
Ca^2	0.457		
Mn^2	3.615		

* Quartz and unidentifiable semi-opaque impurities occur in the analyzed garnet. The sum of R^2 was kept constant and the ratio $R^3/R^2 = 2/3$ was achieved by assigning 0.112 Al to Si.

spessartite garnet rocks to have had a non-detrital sedimentary origin.

The Nova Scotia coticules, from near Sandford, are associated with low grade greenschist metamorphism (quartz-albite-chlorite subfacies). In nearby argillite and graywacke original detrital grain boundaries of quartz and feldspar are preserved. Nowhere are detrital grain boundaries present in coticules. It is assumed therefore that the quartz of the coticules is of non-detrital origin, possibly a chert. The presence of a high manganese content also indicates a non-detrital deposition of the sediment from which the coticules were derived. Of significance is the fact that coticules are present only in the non-carbonaceous parts of the predominantly carbonaceous Halifax Formation. This probably is a reflec-

tion of an oxidizing environment necessary for manganese precipitation. The carbonaceous parts of the Halifax Formation are most probably products of a reducing environment. The alumina content is probably derived from clay detritus simultaneously deposited with the silica and manganese.

Clifford (1960), in a study of some New Hampshire coticules, suggested that the presence of the trace element assemblage K, Ba, Co, Ni, Cu and perhaps Zr, may be regarded as a characteristic trace-element assemblage for spessartite garnet of metasedimentary origin. Spectrographic analysis of the Nova Scotian spessartite failed to confirm Clifford's thesis as the two assemblages have only Co and Cu in common. A manganese garnet in metasedimentary rocks in Wales (Mohr, 1956) contains 16 trace elements that includes both the Nova Scotia trace element assemblage and Clifford's assemblage. This agreement is possibly due to the large number of trace elements present in the Welsh garnet. On the basis of present findings a trace element assemblage characteristic of spessartite garnet of metasedimentary origin may exist for some rocks but it is not an infallible petrological tool.

Conclusions

Nova Scotia coticules, consisting chiefly of quartz and spessartite garnet, are of sedimentary origin and are probably derived from chemically precipitated silica and manganese and small amounts of detrital clay particles. They are the product of greenschist regional metamorphism but are stable also into the hornblende hornfels facies range of contact metamorphism. The existence of a trace element assemblage characteristic of metasedimentary spessartite was not confirmed.

References

Clifford, T. N. (1960) Spessartite and magnesian biotite in coticule-bearing rocks from Mill Hollow. Alstead Township, New Hampshire, U.S.A.: *Neues Jahrb. Mineral. Abh.*, **94,** 1369–1400.

Emerson, B. K. (1898) Geology of Old Hampshire County, Mass. *U. S. Geol. Surv. Mono.* **29.**

Fermor, L. L. (1909) The manganese-ore deposits of India. *Geol. Surv. India Mem.* **37.**

Mohr, P. A. (1956) Trace element distribution in a garnet-chlorite rock from Foel Ddu, near Harlech, Merionethshire. *Mineral. Mag.* **31,** 319–327.

Renard, A. (1878) Sur la structure et la composition mineralogique du coticule. *Mem. Cour. Mem. Sav. Etr. Acad. Roy. Belg. XLI.*

Trost, W. R. (1958) The chemistry of manganese deposits. *Dept. Mines Tech. Surv., Canada, Mines Branch Research Report R.* **8.**

Woodland, A. W. (1939) The petrography and petrology of the Lower Cambrian manganese ore of West Merionethshire. *Quart. Jour. Geol. Soc. London,* **95,** 1–35.