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CORDIERITE – ANTHOPHYLLITE – CUMMINGTONITE ROCKS FROM THE LAR DEPOSIT, LAURIE LAKE, MANITOBA

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Abstract

The assemblage cordierite–anthophyllite characterizes the alteration zone of the Lar Cu–Zn deposit in the Lynn Lake volcanic belt, in Manitoba; in some altered rocks, cummingtonite is present as well. Under appropriate pressure–temperature conditions (approximately 3–4 kbar and 550°–700°C), colinearity in the composition of cordierite, anthophyllite and cummingtonite, in the presence of quartz, results in the degenerate univariant reaction anthophyllite = cordierite + cummingtonite. We suggest that the assemblage cordierite–anthophyllite crystallized below the temperature of this reaction, and the assemblage cordierite – anthophyllite – cummingtonite, slightly above. Mantling of cummingtonite by anthophyllite probably was the result of cooling from peak conditions of metamorphism.

Keywords: cordierite–cummingtonite, metamorphism, Lar deposit, Lynn Lake belt, Manitoba.

Sommaire

L'assemblage cordierite–anthophyllite caractérise la zone d'altération associée au gisement Cu–Zn de Lar, dans la ceinture volcanique du lac Lynn, au Manitoba; la cummingtonite est aussi présente dans certains cas. A des conditions appropriées de pression et de température (environ 3–4 kbar et 550°–700°C), une colinéarité dans la composition des minéraux cordierite, anthophyllite et cummingtonite, en présence de quartz, mène à une réaction univariante dite dégénérée, anthophyllite = cordierite + cummingtonite. À notre avis, l'assemblage cordierite–anthophyllite aurait cristallisé au dessous de la température de cette réaction, et l'assemblage cordierite – anthophyllite – cummingtonite, légèrement au dessus. Une surcroissance d'anthophyllite sur la cummingtonite résulterait d'un refroidissement postérieur à la culmination métamorphique.

(Traduit par la Rédaction)

Mots-clés: cordierite–cummingtonite, métamorphisme, gisement de Lar, ceinture du lac Lynn, Manitoba.

Introduction

In the alteration zone associated with the Lar Cu–Zn deposit at Laurie Lake, Manitoba, cordierite–anthophyllite rocks are accompanied, in some cases, by cummingtonite (Elliott-Meadows & Appleyard 1991). Cummingtonite is typically surrounded by a rim of anthophyllite. The same textural relationship has been recorded by Eskola (1914), Tilley (1937), and Tella & Eade (1978). This feature suggests the stable coexistence of cordierite + cummingtonite at some metamorphic conditions. Earley & Stout (1991) described the occurrence of cordierite + cummingtonite in textural equilibrium in rocks within the stability field of andalusite and, on that basis, defined a low-pressure facies in aluminous ferromagnesian rocks.

Phase relations among cordierite, anthophyllite, and cummingtonite have been discussed by Robinson &

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Jaffe (1969). Based on a study of rocks from the Lar deposit, further considerations of this topic are presented, and phase relations are used as indicators of metamorphic conditions.

Geological Setting

The Lar deposit is located at Laurie Lake (Fig. 1) in the Lynn Lake volcanic belt, a major geological unit in the Precambrian Shield of Manitoba (Gilbert *et al.* 1980, Baldwin *et al.* 1987). Older volcanic rocks and greywacke of the Wasekwan Group (1910 Ma; Baldwin *et al.* 1987) are overlain by greywacke of the Burntwood Group and alluvial sandstone and conglomerate of the Sickle Group. Rocks of all three groups have been metamorphosed in the amphibolite facies. Metamorphosed alteration zones in volcanic rocks of the Wasekwan Group (Fig. 1, location taken from Jackson 1988b) have been studied by Mustard (1974), Lustig (1979), Gale (1983), Barham & Froese (1986), Elliott (1986), Barham (1987), Olson (1987), Jackson (1988a, b), and Elliott-Meadows & Appleyard (1991).

The Lar deposit (Fig. 2) consists of two stacked lenses of massive sulfide, 3 to 9 and 4 m thick, which occur in a sequence of predominantly mafic volcanic rocks, with discontinuous units of felsic volcanic rocks (Elliott-Meadows & Appleyard 1991, Ferreira 1993). Like the surrounding strata, the sulfide lenses dip to the north. The prominence of altered rocks to the north suggests that the sequence is overturned. Rocks assumed to be stratigraphically below the sulfide lenses are extremely altered, notably by Ca depletion and Mg enrichment, probably reflecting common chloritic alteration associated with volcanogenic massive sulfide deposits. At the prevailing grade of metamorphism, this alteration is expressed mainly by the assemblages cordierite–anthophyllite and cordierite – anthophyllite – cummingtonite, accompanied, in some instances, by almandine.

The rocks of the Lar deposit have been metamorphosed in the upper amphibolite facies. Metamorphic

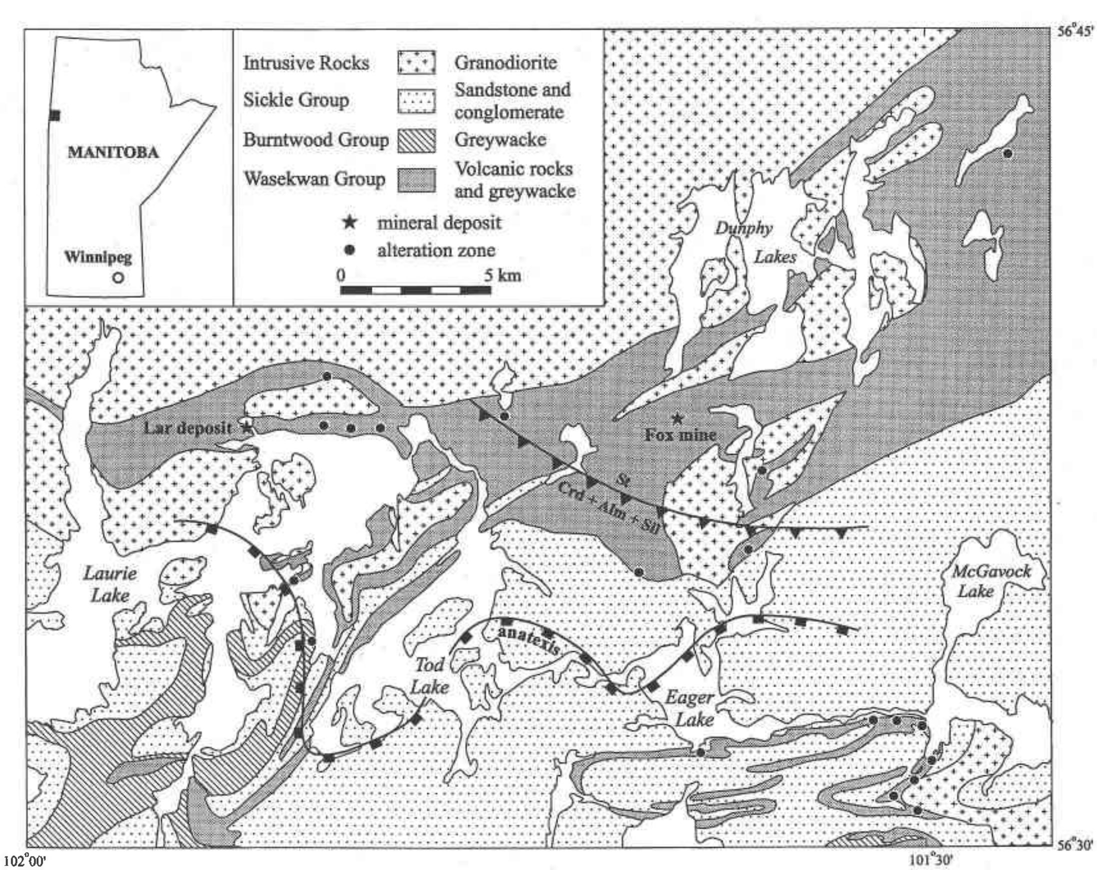

FIG. 1. Geology of the Laurie Lake area (after Gilbert *et al.* 1980). Isograds from Jackson (1988a). Location of alteration zones from Jackson (1988b).

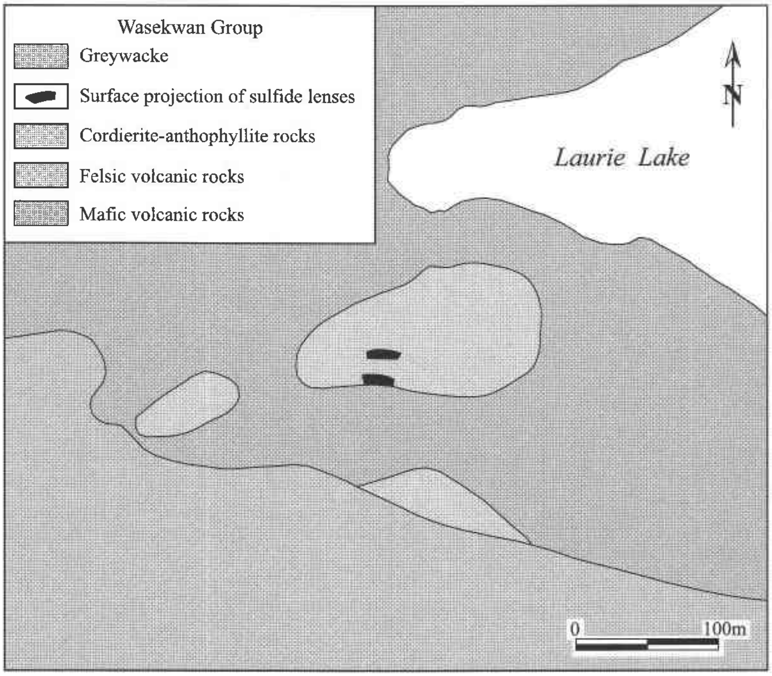

FIG. 2. Geological setting of the Lar deposit (from Elliott-Meadows & Appleyard 1991).

conditions are bracketed by the reaction (in the presence of quartz)

staurolite = cordierite + almandine + sillimanite (1)

and the beginning of anatexis (Jackson 1988a).

The mafic volcanic rocks surrounding the cordierite–anthophyllite rocks are fine to medium grained and typically consist of plagioclase and hornblende, with minor amounts of quartz and epidote. Clinopyroxene is present in some rocks and cummingtonite in slightly Ca-depleted rocks. The cordierite–anthophyllite rocks are medium to coarse grained. Plagioclase is rare. Cummingtonite is present in some rocks and, in some instances, is in contact with cordierite. However, more commonly, it constitutes the core of composite grains with anthophyllite forming an outer shell (Fig. 3). In some samples, grains of optically homogeneous orthoamphibole with a highly variable Al content in different analyzed sites, ranging from 4 to 15 weight % Al_2O_3, have been observed. These were not considered in the study of phase relations. Mineral assemblages from altered and unaltered volcanic rocks are given in Table 1.

PHASE RELATIONS IN CORDIERITE – ANTHOPHYLLITE – CUMMINGTONITE ROCKS

Minerals from three rocks (Table 2) were analyzed using a Cameca SX–50 electron microprobe at the Geological Survey of Canada. Operating conditions were 15 kV, with a beam current of 10 or 30 nA. The raw

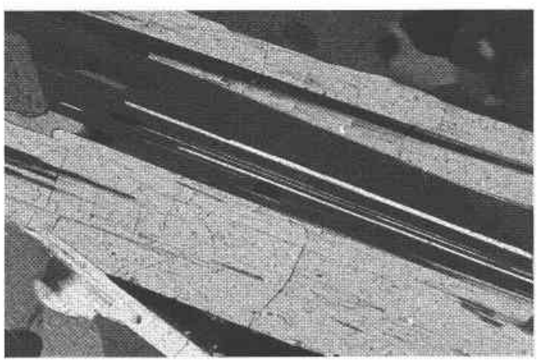

FIG. 3. Anthophyllite grain with a core of cummingtonite (Lar–042). Field of view is 0.67 mm in width.

TABLE 1. TYPICAL MINERAL ASSEMBLAGES, LAR DEPOSIT

	Qtz	Pl	Bt	Sil	Crd	Ath	Alm	Cum	Hbl	Ep	Cpx
Lar–089	x		x	x	x	x					
Lar–179	x				x	x	x				
Lar–088	x	x	x		x	x					
Lar–042	x		x		x	x		x			
Lar–060	x				x	x	x	x			
Lar–140	x	x					x	x	x		
Lar–513		x	x				x		x		
Lar–167	x	x						x	x		
Lar–447	x	x							x	x	
Lar–492	x	x							x	x	x

Note: In Lar–089, Sil is enclosed in Crd.
Mineral abbbreviations: Qtz quartz, Crd cordierite, Hbl hornblende, Pl plagioclase, Ath anthophyllite, Ep epidote, Bt biotite, Alm almandine, Cpx clinopyroxene, Sil sillimanite, Cum cummingtonite.

TABLE 2. MINERAL COMPOSITIONS, LAR DEPOSIT

	Lar–179			Lar–042			Lar–060			
	Ath	Crd	Alm	Ath	Cum	Crd	Ath	Cum	Crd	Alm
n	8	3	6	7	6	4	7	6	5	6
SiO_2	50.59	48.69	37.29	51.18	53.98	48.72	50.40	51.34	48.91	37.68
TiO_2	0.07	–	0.04	0.15	0.08	0.02	0.07	0.05	–	0.03
Al_2O_3	4.21	34.03	21.29	5.20	1.63	32.22	3.98	1.67	32.88	21.15
FeO	23.87	6.25	33.65	19.23	19.84	4.23	24.08	24.44	6.54	34.26
MnO	0.28	0.14	1.17	0.42	0.42	0.07	0.05	0.06	0.04	0.29
MgO	16.72	9.85	5.50	18.46	19.42	10.74	16.17	16.75	9.60	4.93
CaO	0.28	–	1.33	0.42	0.58	–	0.31	0.40	–	1.44
Na_2O	0.21	0.03	–	0.50	0.09	0.21	0.18	–	0.02	–
Total	96.23	98.99	100.27	95.56	96.04	96.21	95.24	94.71	97.99	99.78
ma	Qtz, Crd, Ath, Alm, Mgt			Qtz, Bt, Crd, Ath, Cum, Ilm, gahnite			Qtz, Crd, Ath, Cum, Alm, Ilm			

Electron-microprobe analyses by J.A.R. Stirling, Geological Survey of Canada.
n: number of sites analyzed, ma: mineral assemblage. Results expressed in wt.%.

counts were corrected to elemental concentrations using the Cameca PAP program (Pouchou & Pichoir 1985).

In Figure 4, the stability fields of the aluminum silicates and the location of reaction (1) have been taken from the grid of D.M. Carmichael in Davidson *et al.* (1990). Also shown are reactions radiating from the invariant point involving chlorite – almandine – cordierite – anthophyllite – cummingtonite, obtained by intersecting the following two reactions, in the presence of quartz, taken from the grid of Spear (1993):

chlorite + almandine = cordierite + cummingtonite (2)

chlorite + anthophyllite = cordierite + cummingtonite (3)

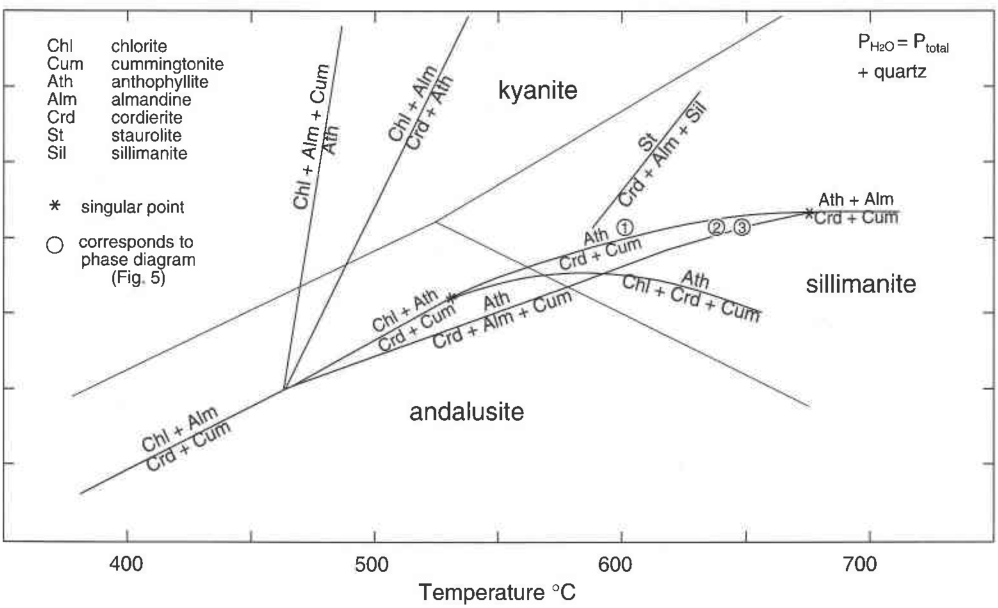

FIG. 4. Reaction grid for minerals in the system $SiO_2 – Al_2O_3 – FeO – MgO$.

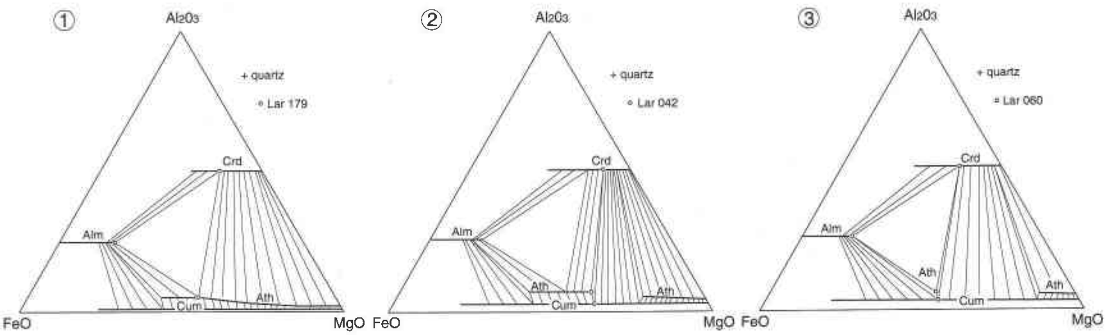

FIG. 5. Phase relations at three temperatures shown in Figure 4 in the system $SiO_2 – Al_2O_3 – FeO – MgO$.

Reaction (3) is shown with a somewhat steeper slope in order to accommodate cordierite–cummingtonite rocks described by Earley & Stout (1991), presumably metamorphosed at 550°C and 3 kbar.

According to Stout (1972), anthophyllite is more magnesian than coexisting cummingtonite if X_{Mg} of cummingtonite is greater than 0.605, but the partitioning is reversed for less magnesian cummingtonite. Thus it is expected that for cummingtonite with X_{Mg} slightly greater than 0.605, the compositions of cordierite, anthophyllite, and cummingtonite should become colinear in the system $Al_2O_3 – FeO – MgO$. In such a case, a reaction involving the three minerals changes stoichiometry. For instance, in reaction (3), chlorite changes from a reactant to a product. This change along a univariant reaction is known as a singular point (Abart *et al.* 1992, Will 1998). Two singular points are shown in Figure 4, joined by the degenerate univariant reaction

anthophyllite = cordierite + cummingtonite (4)

Interpreted phase relations at 4 kbar and three slightly different temperatures are shown in Figure 5. Neglecting the content of minor components, the minerals have been approximately represented in the system $SiO_2–Al_2O_3–FeO–MgO$. At lower temperatures, the assemblage cordierite + anthophyllite is stable over a wide range of composition (Elliott-Meadows & Appleyard 1991). Crossing reaction (4) produces the tie line cordierite–cummingtonite, which, with further rise in temperature, expands into a bank of tie lines, flanked by two three-phase fields cordierite – cummingtonite – anthophyllite. Some rocks at the Lar deposit reached metamorphic conditions of the reaction

anthophyllite = cordierite + almandine + cummingtonite (5)

Decreasing temperature would shift the three-phase assemblage cordierite – anthophyllite – cummingtonite to the right, consuming cummingtonite and producing anthophyllite. Rims of anthophyllite on cummingtonite probably are due to such a retrograde reaction. Most rocks completely re-equilibrated at a temperature below that of reaction (4), producing the more common assemblage cordierite–anthophyllite.

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