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MINERAL CHEMISTRY AND CRYSTAL STRUCTURE OF TWO AMPHIBOLES FROM RUBY AND SPINEL BEARING MARBLES, LUC YEN, PROVINCE YEN BAI, VIETNAM

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Introduction

Northern Vietnam is an important gem stone producing area in Southeast Asia. Especially the areas around Luc Yen, Province Yen Bai, have reported important gem stone deposits. Two different types of gem bearing rocks occur: (1) Corundum (ruby), brown amphibol, and phlogopite bearing calcite marbles, and (2) spinel, green amphibole ± forsterite ± clinohumite ± chlorite calcite - dolomite marbles.

The focus of this abstract will not be on the gem stones but we will report mineral chemistry and crystal structure data of two unusual amphiboles, which are found in these gem bearing marbles.

Geological Setting

The northern part of Vietnam consists of Precambrian (?) metamorphic rocks, Proterozoic to late Cenozoic magmatic rocks, and Paleozoic to Quarternary sedimentary and vulcano-sedimentary rocks (Tran Duc Luong and Nguyen Xuan Bao 1986). The intrusive magamtism has widely and multiformly developed in Vietnam and its age range from Pre-Late Proterozoic to Late Cenozoic. The metamorphic rocks are thought to be mainly Precambrian in age and the grade in metamorphic rocks ranges from weakly metamorphosed rocks such as quartz-sericite schists, quartzites, and marbles to medium grade like kyanite-sillimanite bearing micaschists and gneisses and garnet amphibolites. The highest metamorhic grade (granulite facies) is found in the Kontum geoblock (Tran Duc Luong and Nguyen Xuan Bao 1986).

A narrow band (10-15 km width, 300 km length) of high grade metamorphic rocks is stretching NW of Hanoi to Yen Bai and further to the Chinese border. According to Leloup et al 1995, this metamorphic terrain (Day Nui Con Voi), which is bordered by the Song Chay and Song Hong fault (part of the red river shear zone), exhibits granulite facies metamorphism. (Figure 1). The Day Nui Con Voi is part of the Ailao Shan - Red River metamorphic belt and consists mainly of mylonitic gneisses. K/Ar, Ar/Ar, and U/Pb ages indicate much younger ages (80 - 29 Ma) as described in the geological map of Vietnam (Leloup et al. 1995).

Occurrence and chemical composition

The chemical composition of the amphibols was determined by electron microprobe (Jeol 6310 EDX and WDX) for major elements and LA-ICP-MS for trace elements.

Brown amphibole is found only in corundum bearing marble. Within a matrix of coarse grained calcite 5 -20 mm large prismatic amphibole crystals occur. In addition, centimeter large corundum crystals, some graphite and sulfides are found. The chemical composition of the brownish amphibole is aluminum and fluorine rich and can be classified as fluorian Aluminopargasite to fluorian Magnesiosadanagaite (Table 1).

The second type of amphibole is associated with red spinel and is found in coarse grained calcite-dolomite marbles. The crystals can measure up to 5 cm, are idiomorphic with an

intensive green colour and good luster. These amphibole crystals contain less aluminum compared to the first type, are also rich in fluorine and can be classified as fluorian Pargasite (Table 2).

Sample	Parg	Sad		Parg	Sad		Parg	Sad		Parg	Sad
			O = 23, Cat = 15+Na+K				[ppm]	[ppm]		[ppm]	[ppm]
SiO_2	45,78	38,48				Li	64,3	39			
TiO_2	0,27	1,59	Si	6,335	5,493	Be	19,7	18	La	0,4	0,5
Al_2O_3	14,59	22,29	Ti	0,028	0,171	V	421,1	312	Ce	0,8	3,8
Cr_2O_3	0,34	0,09	Al	2,379	3,750	Cr	1737,5	337	Nd	1,5	5,3
Fe_2O_3	0,01	0,00	Cr	0,037	0,010	Mn	45,1	69	Sm	0,6	3,5
FeO	0,00	1,66	Fe^{3+}	0,001	0,000	Co	0,2	1	Eu	0,3	0,1
MnO	0,01	0,00	Fe^{2+}	0,000	0,198	Ni	1,7	3,63	Gd	0,9	2,9
MgO	20,59	16,04	Mn	0,001	0,000	Zn	24,0	237,3	Dy	1,1	5,2
CaO	13,30	12,85	Mg	4,247	3,412	Ga	15,3	40,8	Er	0,6	2,3
Na_2O	2,47	2,99	Ca	1,972	1,965	Rb	2,2	21,0	Yb	0,4	1,8
K_2O	0,32	1,04	Na	0,662	0,828	Sr	102,4	38,3	Lu	0,0	0,2
F	1,24	1,06	K	0,056	0,189	Y	9,6	33,4	Hf	2,1	5,1
Cl	0,00	0,03	F	0,543	0,479	Zr	97,7	122,3	Ta	0,8	2,3
H2O	1,58	1,59	Cl	0,000	0,008	Nb	12,5	20,3	Pb	1,7	2,2
Total	100,50	99,71	H	1,457	1,514	Cs	0,0	0,1	Th	1,0	2,1
F,Cl=O	0,52	0,45	Sum	15,719	16,017	Ba	34,9	28,2	U	1,2	0,5
Total	**99,97**	**99,26**									

Table 1. Chemical analysis and formula of brown fluorian Magnesio- sadanagaite and green fluorian Pargasite

X-ray experiments and structure refinement

The crystal structure of the brown amphibole (Magnesiosadanagaite) gives a = 9.858(1), b = 17.892(2), c = 5.3146(3) Å, ß = 105.39(1)º, V = 903.8 $Å^3$, C2/m, Z = 2, and has been refined to an R index of 3.3% using 922 observed intensities measured with MoKα X-radiation (Bruker AXS SMART APEX). From refinement site occupancies and taking into account the calculated interatomic distances following site populations resulted (apfu): T1: 2.05 Si + 1.95 Al, (T1-O = 1.681 Å), T2: 3.45 Si + 0.55 Al, (T2-O = 1.648 Å), M1: 1.88 Mg + 0.12 Fe^{2+} (M1-O = 2.088 Å), M2: 1.23 Al + 0.60 Mg + 0.17 Ti (M2-O = 1.995 Å), M3: 0.91 Mg + 0.09 Fe^{3+} (M3-O = 2.076 Å), M4: 1.95 Ca + 0.05 Na (M4-O = 2.470 Å). Na and K are disordered around the A(2/m)-site and obtained by electron density at A(2): 0.50 Na and A(m): 0.19 K + 0.25 Na. There is a significant order of Al at T1 and M2, the refined site occupancies of Al at T1, T2 and M2 are in good agreement with data of magnesiosadanagaite. The formula from structure refinement is:

$(K_{0.19}\ Na_{0.75})_{0.94}\ (Ca_{1.95}\ Na_{0.05})_{2.00}\ (Mg_{3.39}\ Al_{1.23}\ Fe^{2+}_{0.12}\ Fe^{3+}_{0.09}\ Ti_{0.17})_{5.00}\ (Si_{5.50}\ Al_{2.50})_{8.00}\ O_{22}\ ((OH)_{1.35}\ F_{0.65})_{2.00}$

The crystal structure of the green chromian pargasite results in a = 9.845(2), b = 17.928(4), c = 5.285(1) Å, ß = 105.36(3)º, V = 899.4 $Å^3$, C2/m, Z = 2, and has been refined to an R index of 3.6% using 937 observed intensities measured with MoKα X-radiation (Bruker AXS SMART APEX). From refinement site occupancies and taking into account the calculated interatomic distances following site populations resulted (apfu): T1: 2.39 Si + 1.61 Al, (T1-O = 1.670 Å), T2: 3.90 Si + 0.10 Al, (T2-O = 1.635 Å), M1: 2.00 Mg (M1-O = 2.075 Å), M2: 1.43 Mg + 0.54 Al + 0.03 Cr (M2-O = 2.038 Å), M3: 0.97 Mg + 0.03 Ti (M3-O = 2.048 Å), M4: 1.93 Ca + 0.07 Na (M4-O = 2.477 Å). Na and K are disordered around the A(2/m)-site

and obtained by electron density at A(2): 0.53 Na and A(m): 0.13 K + 0.08 Na. There is a significant order of Al at T1 and M2, the formula from structure refinement is:

$(K_{0.13}\ Na_{0.61})_{0.74}\ (Ca_{1.93}\ Na_{0.07})_{2.00}\ (Mg_{4.4}\ Al_{0.54}\ Cr_{0.03}\ Ti_{0.03})_{5.00}\ (Si_{6.29}\ Al_{1.71})_{8.00}\ O_{22}\ ((OH)_{1.47}\ F_{0.53})_{2.00}$