Chemical Fingerprint of Man Sin Spinel, Mogok, Myanmar

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Abstract

Man Sin is located about 5 km from northeast of Mogok where the Jedi spinel (Hot spinel) was initially discovered since 2009. Spinel from the present study area occurs as varieties of colour but most of them are intense red spinel and principally produced Jedi spinel (Hot spinel). Chemical analyses of Man Sin spinel show that Al_2O_3 is ranging from (71.5 – 60.5 wt %) and MgO is from (26.6 – 18.5 wt %). The concentrations of other elements that contained in Man Sin spinel were Cr (3.66 – 0.008 ppm), V (0.633 – 0.005 ppm), Fe (2 – 0.03 ppm), Zn (0.725- 0.038) and Zr (1.103 – 0.219 ppm) respectively. The concentration of Ti (0.113 – 0.008 ppm) and Ga (0.052 – 0.003 ppm) are generally low. Fe+Ti vs V+Cr and Cr+Ti vs V+Fe are negatively associated. Fe- V- Cr Ternary diagram of the red spinel from the Man Sin mine show two population: one is coloured by higher Cr content (> 80 ppm) and V content (> 40 ppm) but Fe content is (12 to < 10 ppm) in red spinel. The other group has average value of Cr and V ranging from (40-60 ppm). The most attractive red colour spinel has higher Cr content. Pink spinel also shows two populated groups such as rich in Cr and rich in V. Fe concentration in these two groups is intermediate (35-55 ppm). A greenish blue sample shows the significantly exceeds Fe concentration (nearly 100 ppm). Cr and other trace elements (V, Ti and Zr) are positively associated but other trace elements such as Fe, Ga and Zn are negatively associated, which indicate increasing of Cr content with decreasing of Fe, Ga and Zn contents. Conversely, red spinel from Htayan Sho mine indicates that Fe content is (> 40 ppm) and the amount of V and Cr contents is (< 60 ppm). So, the chemical fingerprint of the attractive colour of Man Sin Hot spinel is due to the Cr rather than other trace elements such as V and Fe; pink and purple spinel are due to Fe and Cr, V and Ti, and the green spinel is due to the Fe. On the other hand, red spinel from Htanyan Sho is due to the average concentration of Fe and V rather than Cr.

Keywords: Man Sin, Htayan Sho, Jedi Spinel, Hot Spinel, Mogok, Myanmar

Introduction

Spinel is magnesium aluminium oxide mineral. It has been used as a gemstone and tends to be slightly more bright-red color than ruby and is called ***'Ruby Spinel'*** (Balas Ruby). It mostly occurred in metamorphosed impure dolomitic limestone where the protolith was partly incorporated with clayey materials#which were later effected by higher temperature regional metamorphism. Spinel has wide range of elegant colours and the finest red spinel color is similar to ruby. Some spinel colors are more rare and valuable than others. In Myanmar, the finest spinels were producing from Man Sin mine in Mogok which was excavated about 12 years ago, but pocket of ***jedi spinel (hot spinel)*** was first found in 2009 (Pardieu, 2014). Although it was found in 2009 as famous attractive coloured spinel, the composition of such a beautiful gemstones from Man Sin area have not yet been studied in detailed.

Location and Size

Man Sin area is located in Mogok Township, Pyin Oo Lwin District, Mandalay Region. It is situated approximately 205 km from northeast of Mandalay and 5 km from northeast of Mogok. Location map of the study area is shown in (Fig. 1).

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Methods of Study

Field Works

Field works were carried out with conventional methods together with some modern equipment such as GPS which were plotted on Google Earth Map. Samples were collected from the Man Sin primary deposit as well as secondary deposit. Moreover, spinel samples from Htayan Sho mine were collected for comparative study (Fig. 2 A-D).

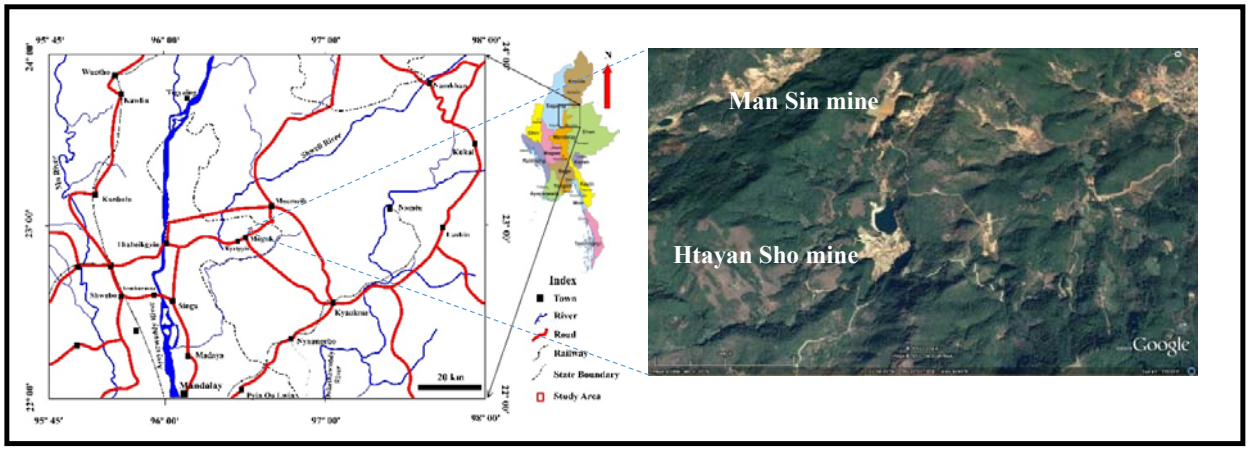


Figure (1). Location map of the Man Sin and its environs.

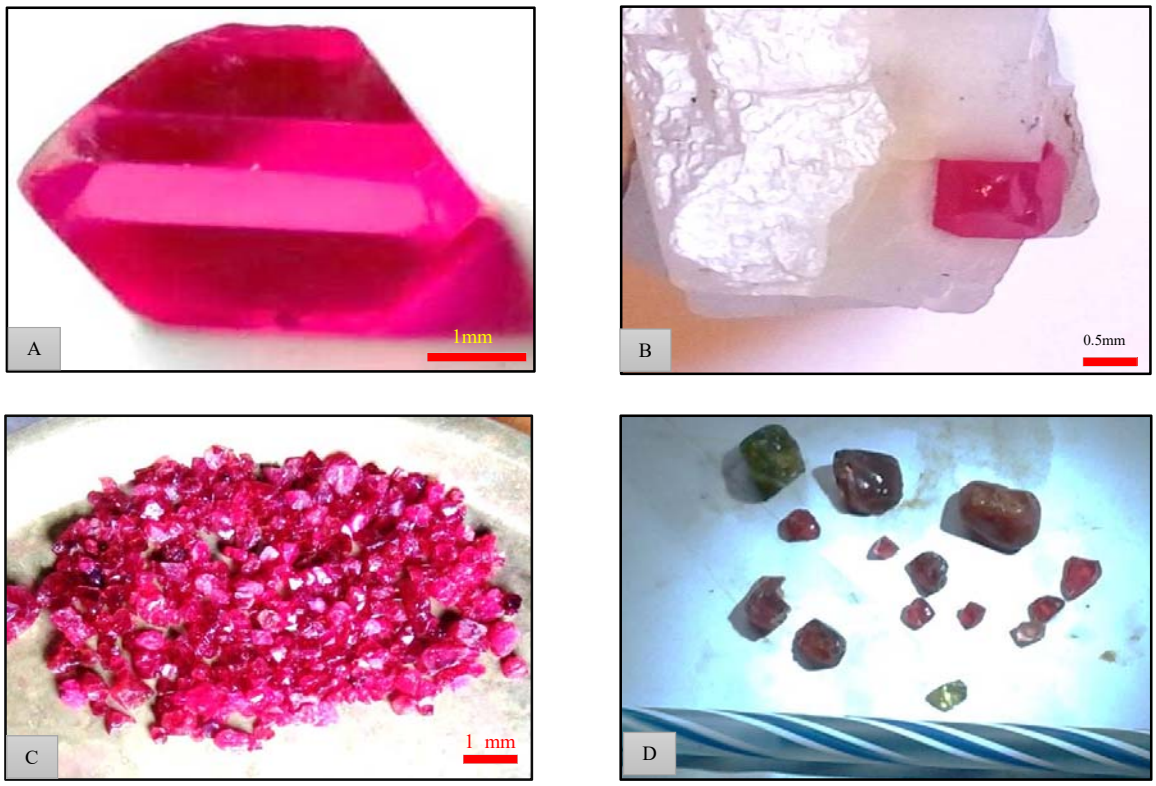


Figure (2). (A-C) Hot spinel crystals from Man Sin mine and (D) Spinel crystals from Htayan Sho mine.

Laboratory Works

Analytical Method

For the present study, sixteen collected spinel were selected for analysis which include thirteen samples from Man Sin mine and three samples from Htayan Sho mine were sent to DGSE and MGJEA Labs. These samples were analysed by using Energy Dispersive X-ray Fluorescence Spectrometry (ED- XRF) method. It can yield major oxide and minor trace element concentrations of spinel samples.

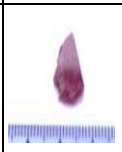
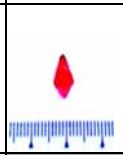
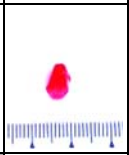
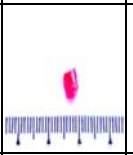
Chemical Parameter of Man Sin Spinel

Analysed EDXRF results for major oxides and trace element concentrations are shown in Table 1. According to chemical analyses of Man Sin spinel express that Al_2O_3 is ranging from (71.5 – 60.5 wt %) and MgO is from (26.6 – 18.5 wt %). The high concentrations of trace elements in Man Sin spinel include Cr (3.66 – 0.008 ppm), V (0.633 – 0.005 ppm), Fe (2 – 0.03 ppm), Zn (0.725- 0.038) and Zr (1.103 – 0.219 ppm) respectively. The concentration of Ti (0.113 – 0.008 ppm) and Ga (0.052 – 0.003 ppm) are generally low. The concentrations of these elements are graphically presented in (Fig. 3). Fe+Ti and V+Cr are used to interpret the colour variation in Man Sin spinel and the plot indicates that they are negatively associated (Fig. 4). Moreover, Cr+Ti and V+Fe are also negatively associated (Fig. 5).

In Fe- V- Cr Ternary diagram of the red spinel from the Man Sin mine shows two populations (Fig. 6). One is coloured by higher Cr content (> 80 ppm) and V content (> 40 ppm) but Fe content is (12 to < 10 ppm) in red spinel. The other group has average value of Cr and V ranging from (40-60 ppm). The most attractive red colour spinel has higher Cr content. Pink spinel also shows two populated groups. One is rich in Cr and other is rich in V. Fe concentration in these two groups is intermediate (35-55 ppm). A greenish blue samples shows the significantly exceeds Fe concentration (nearly 100 ppm).

According to chemical analyses and Ternary diagram, the colour of Man Sin spinel is depend on Cr with minor influence of V and Fe. In this analyses indicate that Cr content is higher than V and Fe contents in red to pink spinel, but more Fe content in greenish blue spinel.

Table (1). Concentration of Major Oxides and Trace Elements of Man Sin Spinel.

Sample. No	MS- 3	MS-4	MS- 5	MS- 6	MS- 7	MS- 8	MS- 9	MS- 10	MS- 11	MS- 12	MS- 13	MS- 14	MS- 15
Colour	Pink	Red	Red	Purple	Red	Pale pink	pink	Deep Red	Deep Red	Deep Red	Deep Red	Red	Greenish Blue
													
Al_2O_3	60.5	63.4	62.1	70.3	68.6	70.1	69.7	71.5	71	70.2	71.1	66.2	66.5
MgO	19.7	18.5	22.7	24.9	25.5	26.6	26	24.2	25	26.2	26.1	23.4	24.8
SiO_2	12.9	12.2	6.97	1.09	1.79	1.13	2.68	0.681	0.978	1.49	0.603	5.76	3.05
SO_3	0.195	0.188	0.119	0.0876	0.23	0.258	0.134	0.0718	0.069	0.0651	0.0533	0.25	0.278
K_2O	0.931	0.0753	0.0759	0.0176	0.0739	0.0481	0.0552	0.0156	0.0223	0.0255	0.0153	0.122	0.123
CaO	0.132	0.149	0.131	0.0213	0.0444	0.306	0.0655	ND	0.0305	0.0222	0.0268	0.108	0.11
MnO	ND	ND	0.0234	ND	ND	0.0036	0.0019	0.0176	ND	ND	ND	0.0106	0.0275
Cr	1.019	1.82	3.66	0.493	0.985	0.058	0.138	0.666	0.395	0.4	0.442	1.341	0.008
V	0.113	0.633	0.398	0.171	0.248	0.127	0.033	0.543	0.292	0.333	0.315	0.132	0.005
Fe	1.406	0.239	0.317	0.45	0.174	0.233	0.083	0.044	0.234	0.093	0.03	0.124	2
Ti	0.065	0.113	0.058	0.098	0.03	0.014	0.008	0.062	0.016	0.089	0.088	0.105	0.04
Zr	0.444	0.566	0.65	0.547	0.707	0.219	0.399	0.911	0.452	0.37	0.466	1.103	0.473
Ga	0.027	0.012	0.014	0.052	0.031	0.02	0.018	0.004	0.028	0.004	0.003	0.01	0.042
Zn	0.68	0.228	0.204	0.693	0.428	0.092	0.332	0.049	0.619	0.038	0.065	0.056	0.725
Sum	98.112	98.1233	97.4203	98.9205	98.8413	99.2087	99.6476	98.765	99.1358	99.3298	99.3074	98.7216	98.1815

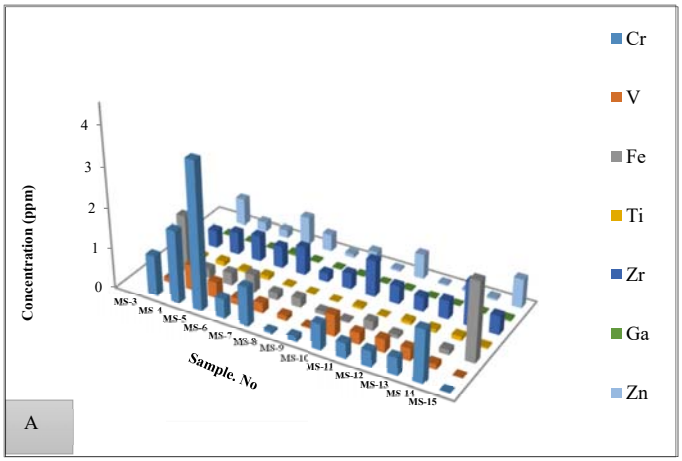


Figure (3). Trace elements variation diagram of spinel from Man Sin mine.

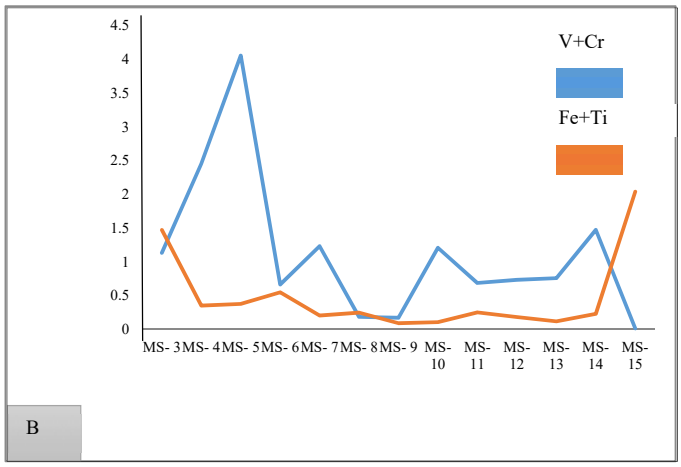


Figure (4). V+Cr and Fe+Ti plot indicate that they are negatively associated for the colour variation in Man Sin spinel.

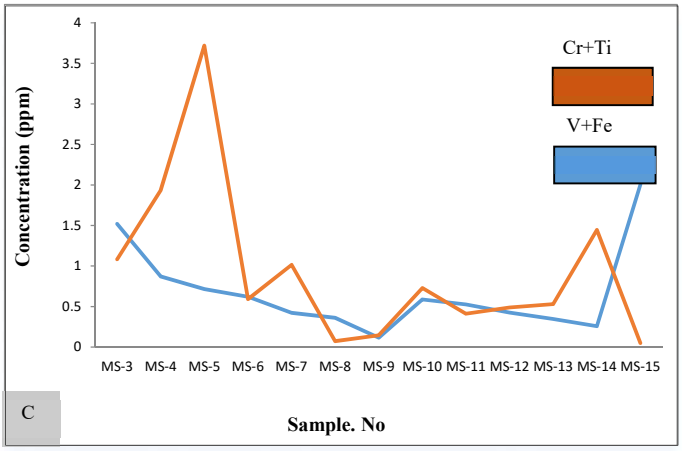


Figure (5). Cr+Ti and V+Fe plot indicate that they are negatively associated for the colour variation in Man Sin spinel.

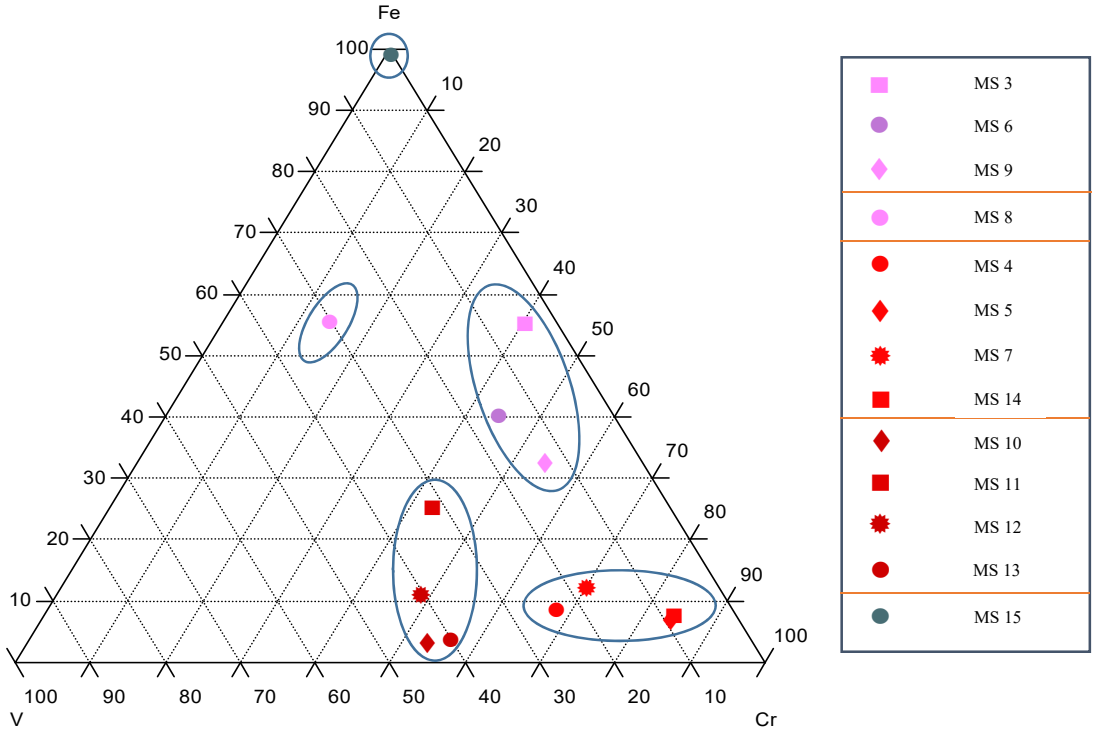


Figure (6). Fe- V- Cr Ternary diagram showing increasing Cr contents in red spinel with two groups, and increasing Fe content in pink spinel with Cr rich and V rich groups and higher Fe concentration in greenish blue spinel from Man Sin mine. See also Table 1.

Moreover, trace elements (V, Fe, Ga, Zr, Zn and Ti) versus Cr variation diagrams also explain the correlation of these elements in the Man Sin spinel (Fig. 7 A-F). In these diagram, Cr and other trace elements (V, Ti and Zr) are positively associated but other trace elements such as Fe, Ga and Zn are negatively associated, which display increasing of Cr content with decreasing of Fe, Ga and Zn contents.

Comparison of Man Sin and Htanyan Sho Spinels

The comparison of trace elements (Cr, V, Fe and Ti) of spinel from Man Sin with Htayan Sho are shown in Table 2.

In variation diagram, the concentration of trace elements Fe+Ti and V+Cr are used to interpret the colour variation of spinel from two mine sites (Fig. 8 A, B). This diagram shows that colour variation in Man Sin mine has higher concentration of Cr with V content than Htayan Sho mine but the amount Fe with Ti concentrations are decreases.

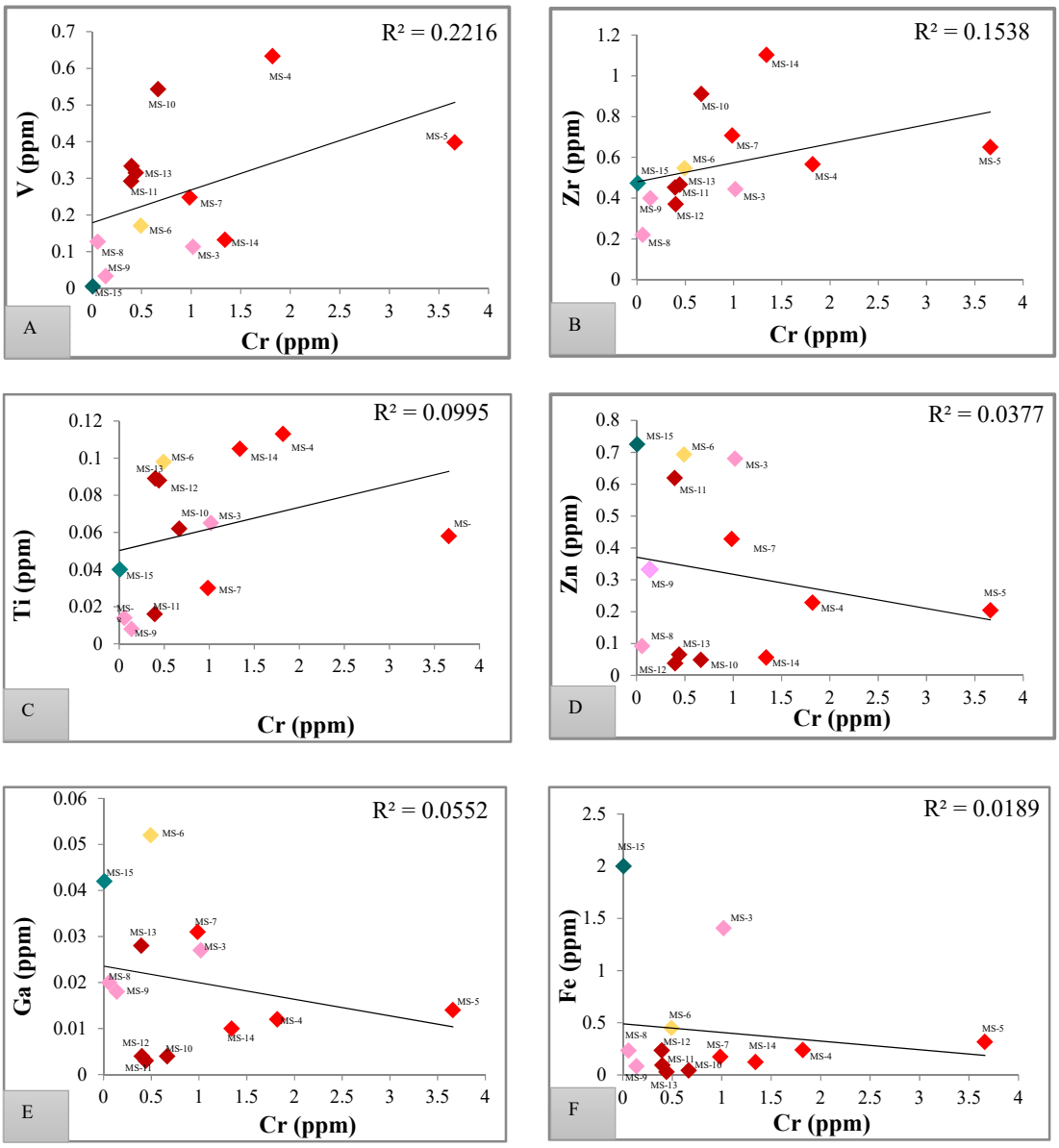


Figure (7). (A-F) Variation diagrams of Cr vs trace elements in Man Sin spinel.

Fe- V- Cr Ternary diagram shows that the increasing amount of Cr content with decreasing amount of Fe and V contents in red to pink spinel from Man Sin mine than Htanyan Sho mine (Fig. 9). Spinel from Htayan Sho mine indicates that Fe content is (> 40 ppm) and the amount of V and Cr contents is (< 60 ppm).

Table (2). Comparison of Trace elements (Cr, V, Fe and Ti) concentration in Man Sin and Htayan Sho Spinels.

Mine Site		Man Sin												Htayan Sho		
Sample. No	MS-4	MS-5	MS-7	MS-14	MS-10	MS-11	MS-12	MS-13	MS-3	MS-8	MS-9	MS-6	MS-15	HYS-N1	HYS-N2	HYS-N3
Location (UTM 47Q KF)	481425													478414		
Colour / Elements (ppm)	Red	Red	Red	Red	Deep Red	Deep Red	Deep Red	Deep Red	Pink	Pale Pink	Pink	Purple	Green-ish Blue	Red	Orange Red	Purple
Cr	1.82	3.66	0.985	1.341	0.666	0.395	0.4	0.442	1.019	0.058	0.138	0.493	0.008	0.413	0.116	0.142
V	0.633	0.398	0.248	0.132	0.543	0.292	0.333	0.315	0.113	0.127	0.033	0.171	0.005	0.449	0.180	0.156
Fe	0.239	0.317	0.174	0.124	0.044	0.234	0.093	0.03	1.406	0.233	0.083	0.45	2	0.625	0.497	0.484
Ti	0.113	0.058	0.03	0.105	0.062	0.016	0.089	0.088	0.065	0.014	0.008	0.098	0.04	0.04	0.034	0.031

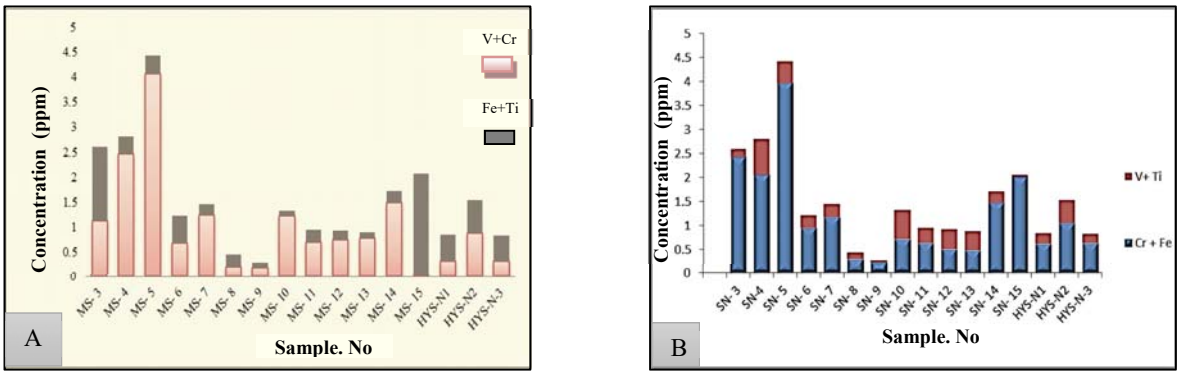


Figure (8). (A) Fe+Ti and V+Cr concentration and (B) V+Ti and Cr+Fe concentration in Man Sin and Htayan Sho spinel.

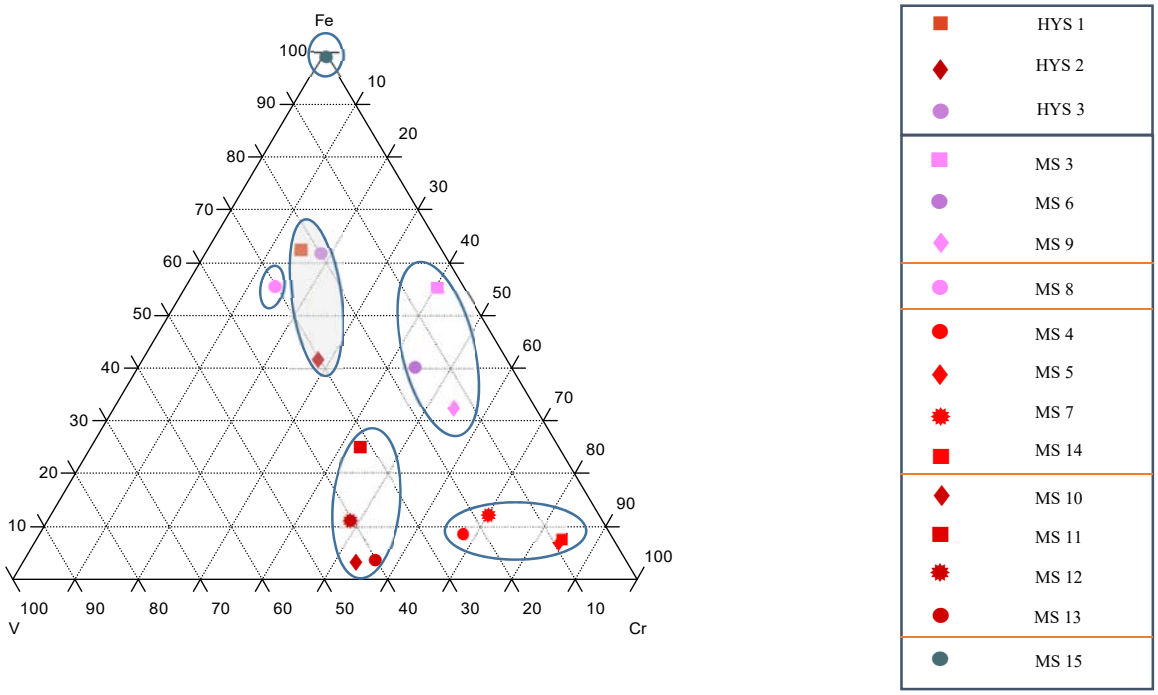


Figure (9). Fe- V- Cr Ternary diagram of Man Sin and Htayan Sho spinel. See also Table 2.

Conclusions

Spinel deposits are located from central to south east Asia which is associated within the Himalayan mountain belt. This belt was formed by continental collision between the India and Eurasia during the Tertiary. Spinel was formed in both mafic igneous rock and metamorphic rock which found in carbonate series underwent high temperature amphibolite to lower granulite grade regional metamorphism (Malsy & Klemm; 2010). The formation of spinel is formed at temperatures 600˚- 700˚C and depending on the amount of magnesium

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which played an important factor during the genesis of spinel. Spinel would have formed when magnesium exceed aluminium (Themelis, 2009).

Spinel was formed as a result of contact metamorphism or skarn metasomatism within regionally metamorphosed basement rocks in Mogok where the presence of fluids played an important role (Iyer, 1953; Themelis, 2009). Spinel occurs within a relatively narrow aluminium rich layer in the marble.

The formation of Man Sin spinel in the marble would be the certain amount of magnesium in the spinel- graphite marble. Graphite and spinel association in the marble express that this marble (Limestone for the Protolith) was deposited in the carbon and magnesium rich environment.

The chemical fingerprint of the attractive colour of Man Sin Hot spinel is due to the Cr rather than other trace elements such as V and Fe; pink and purple spinel are due to Fe and Cr, V and Ti, and the green spinel is due to the Fe. On the other hand, red spinel from Htanyan Sho is due to the average concentration of Fe and V rather than Cr.

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