Asian J. Exp. Sci., Vol. 33, No. 2, 2019; 19-25

Online available on : www.ajesjournal.com, ISSSN : 0971-5444

Geochemistry and Petrogenesis of Corundum Pegmatites and Corundum Crystal Geochemistry in Alvand Batholith in the Southwest of Hamadan

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Received: March 5, 2019; Revised: April 10, 2019; Accepted: May 17, 2019

Abstract : Corundum mineralization along with granitoid mass in pegmatitic rocks is located in south of Hamadan (west of Iran) and in the igneous and metamorphic zone of Sanandaj-Sirjan. Corundum crystals within these pegmatites are up to three centimeters long. Most of them are in the form of zinolite, and the margin of these crystals is surrounded by grained mica. These corundums have two types of irregular plates (parting). The results of chemical analysis using Scanning Electron Microscope (SEM) shows that O, C, Fe, Ti, Si, Ca, K, Cl and Alare the main elements forming the studied corundums and their blue color is due to the presence of iron and titanium. The presence of high amounts of silica in these samples could indicate the formation of these corundums from mineralized kyanite due to the increase in pressure and temperature during the Metamorphism.

Keywords: Hamadan, Pegmatites, Corundum, Metamorphism, SEM.

Introduction

Corundum with AL_2O_3 formula has two varieties: ruby and sapphire. The red corundums are called ruby and the non-Red corundums are called sapphire (Yakymchuk and Szila, 2018). Major reserves of this mineral have been discovered and mined in Burma, Kashmir, Australia, Thailand, Sri Lanka, Madagascar, China, East Africa, North America, Greenland, Afghanistan, Tajikistan, and so on (Simon *et al*., 2008; Yakymchuk and Szila 2018).

Blue sapphire is one of the most popular gemstones of corundum species. Its blue color can be due to the presence of iron and titanium. Recently, a new mineralization of corundum with pegmatite dikes has been discovered in the west of Iran. The pegmatite dikes of granitoid mass in Hamadan are located in south of Hamadan and in the metamorphic and igneous zone of Sanandaj-Sirjan (Shahbazi *et al*., 2010). This granitoid mass is formed by the subduction of the Neo-Tethys oceanic crust beneath the margin of the Central Iranian plate, the same as the other granitoid masses of this zone (Mohajjel *et al*., 2003; Shahabpour, 2005; Ahmadi Khalaji *et al*., 2007; Shahbazi *et al*., 2010, Kiani *et al*., 2011). In this paper, we try to investigate the geological and geomorphological features of the corundums in the south of Hamadan.

Methodology

This study is based on electron microscopy (SEM) analysis, petrography, geology and field observations. After studying maps, reports, geological papers and field studies, 20 samples of sapphire-bearing pegmatites were taken, microscopic sections were prepared and analyzed by polarizing microscope accordingly. TESCAN MIRA3 model FESEM (Field Emission Scanning Electron Microscopy) was also used to identify the internal phases and chemical elements of the studied samples in Sharif University of Technology in Tehran.These samples were coated with gold.

Area Geology

The studied area include mesozoic igneous and metamorphic rocks (Baharifar *et al*., 2004). The igneous rocks formed due to melting of Neo-Tethys oceanic crust (Kiani, 2015) include granitoid, pegmatite, diorite and gabbro and hydrothermal quartz veins. These igneous rocks are located within the metamorphic rocks in the area, and have been turned into andalosite hornfels, garnet hornfels and cordierite hornfelsduring the process of contact metamorphism in most regions. (Fig. 1)

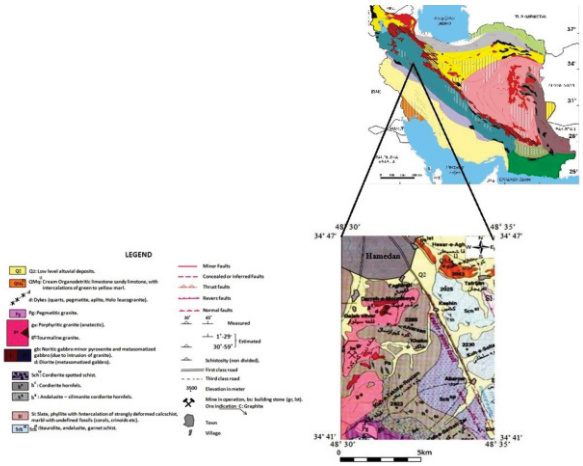


Fig. 1: Geological and geographical location map of the studied area.

In this area, the metamorphic rocks including slate, filth, schist, migmatite and hornfels have been turned into schist and garnet hornfels in the vicinity of the intrusive igneous masses. These rocks have various protoliths. (Baharifar, 1997). Alvand granitoid mass in Hamadan were proposed to be 170 million years old according to the age dating using Zircon U-Pb method on granitoid mass (Shahbazi *et al*., 2010). Sapphire pegmatites are located in the southwest of Khakou village in the south of Hamadan. These pegmatites are streaked inside granitic rocks that are the final phase product of the of Alvand granitoid mass magma (Aliani *et al*., 2012). This pegmatite dike is white to gray with quartz, feldspar, mica, blue corundum (sapphire) and large tourmaline crystals. Corundum crystals within these pegmatites are up to three centimeters long. Most of them are in the form of zinolite, and the margin of these crystals is surrounded by grained mica (Fig. 2).

Fig. 2: A- Metamorphic rocks of the studied area, **B-** Quartz veins within the metamorphic rocks, **C-** corundum pegmatites, **D-** Blue corundum crystals (sapphire) within the pegmatites.

Result & Discussion

Petrography

Perthitic, granular, and graphic textures are observed in the pegmatite microscopic sections in the studied area. (Fig. 3A). The largest volume of these rocks is made up of potassium feldspar. The other minerals include quartz, muscovite, corundum and biotite (Fig. 3B). Partial argillic artifacts are observed in feldspars. Blue corundum (Sapphire) is the most important mineralamong these pegmatites which is semi-shaped and formless and has turned into sericite from the margins. These corundums have two types of irregular plates (parting) and in some cases the large sapphire crystals are crushed due to tectonic activities (Fig. 3C).

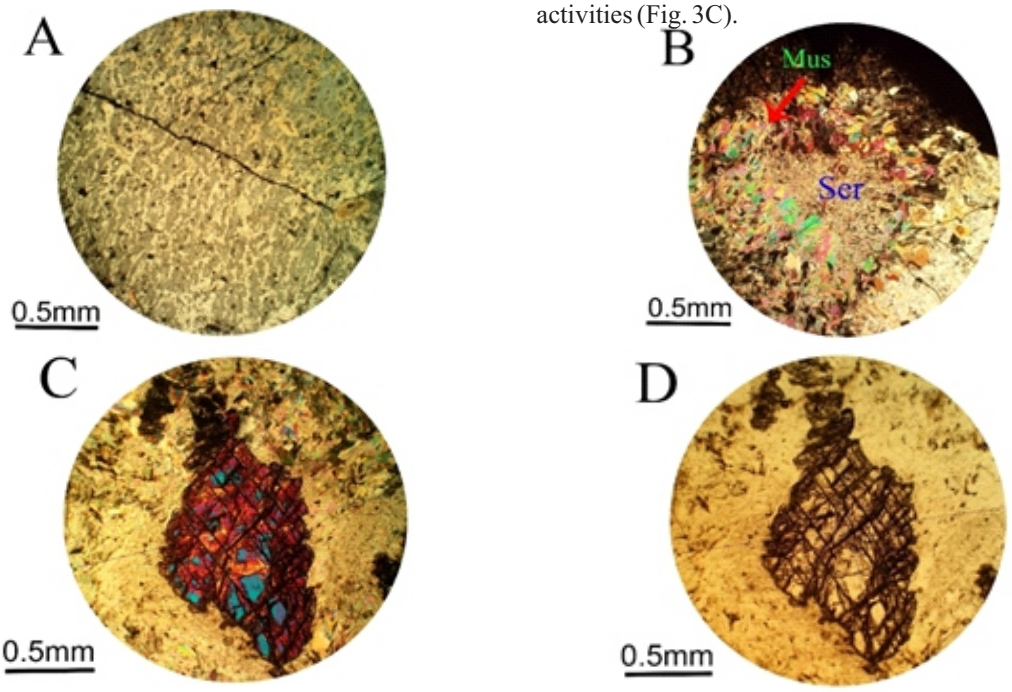


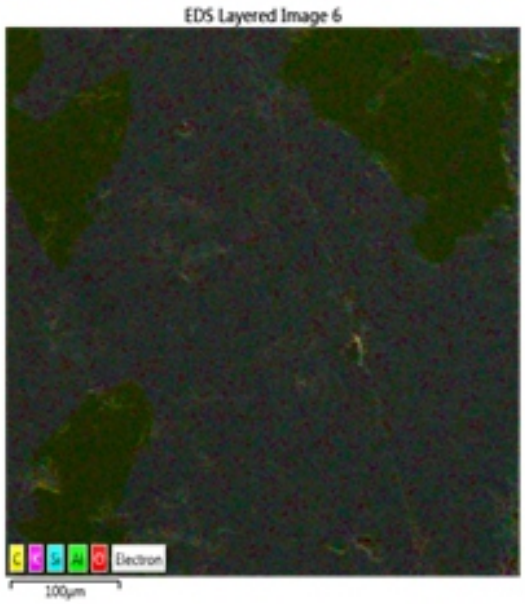
Fig. 3: ***A-*** *graphic texture in the pegmatites found in thestudied area,* ***B-*** *Muscovite and sericitecrystals in the margins of corundum crystals,* ***C and D-*** *Corundum crystals with transparent parting, A, B, C) xpl and D ppl.*

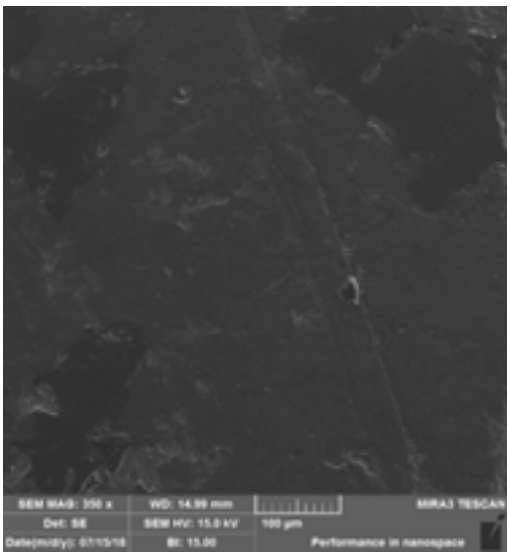
Electron Microscopy Studies

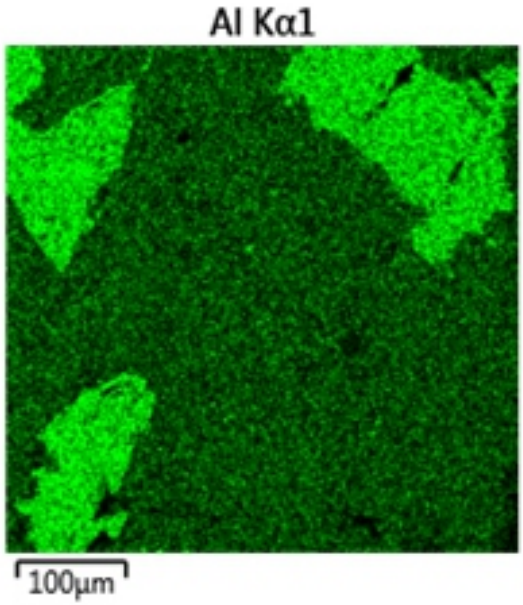
The images of the electron microscope analysis and the result of the elemental analysis using this device are shown in Figs. 4, 5 and Table 1. The electron microscope image of the studied samples shows the dark and gray areas in the studied corundum samples. The results of chemical analysis by SEM show that O, C, Fe, Ti, Si, Ca, K, Cl and Alare the main elements of the studied corundums. The distribution of the main elementsin these corundums show that the oxygen element has a uniform distribution but Al and Si have cumulative distribution. Noteworthy in these samples is the high content of Si at 18.2 wt% considered as the main component of this mineral, yet it doesn't exist in the chemical formula of the corundum and it can indicate the formation of these corundums from kyanite during the increase in pressure and temperature in the process of Metamorphism.

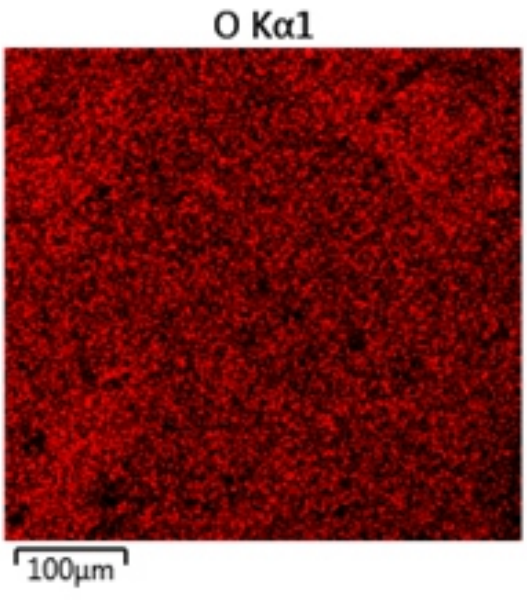
corundum (Al_2O_3) + stishovite (SiO_2) kyanite (Al_2SiO_5)

The corundumsub-elements are usually coloring agents such as Cr (causing red to pink color inrubies), Fe and Ti (creating color in the sapphires). The presence of coloring agent in these samples could be due to the high iron content.









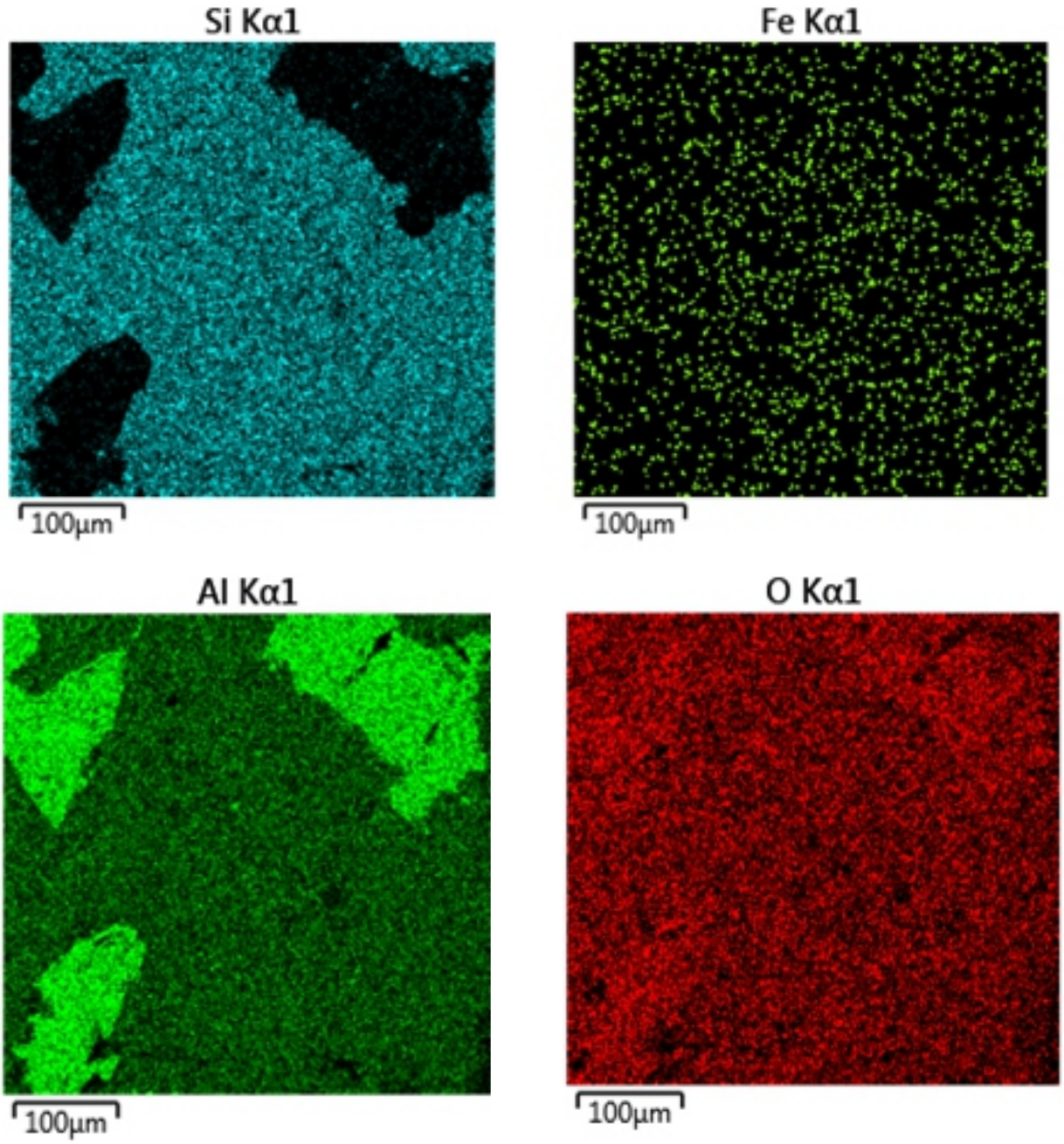


Fig. 4. The image of electron microscope and elemental maps prepared from the studied samples.

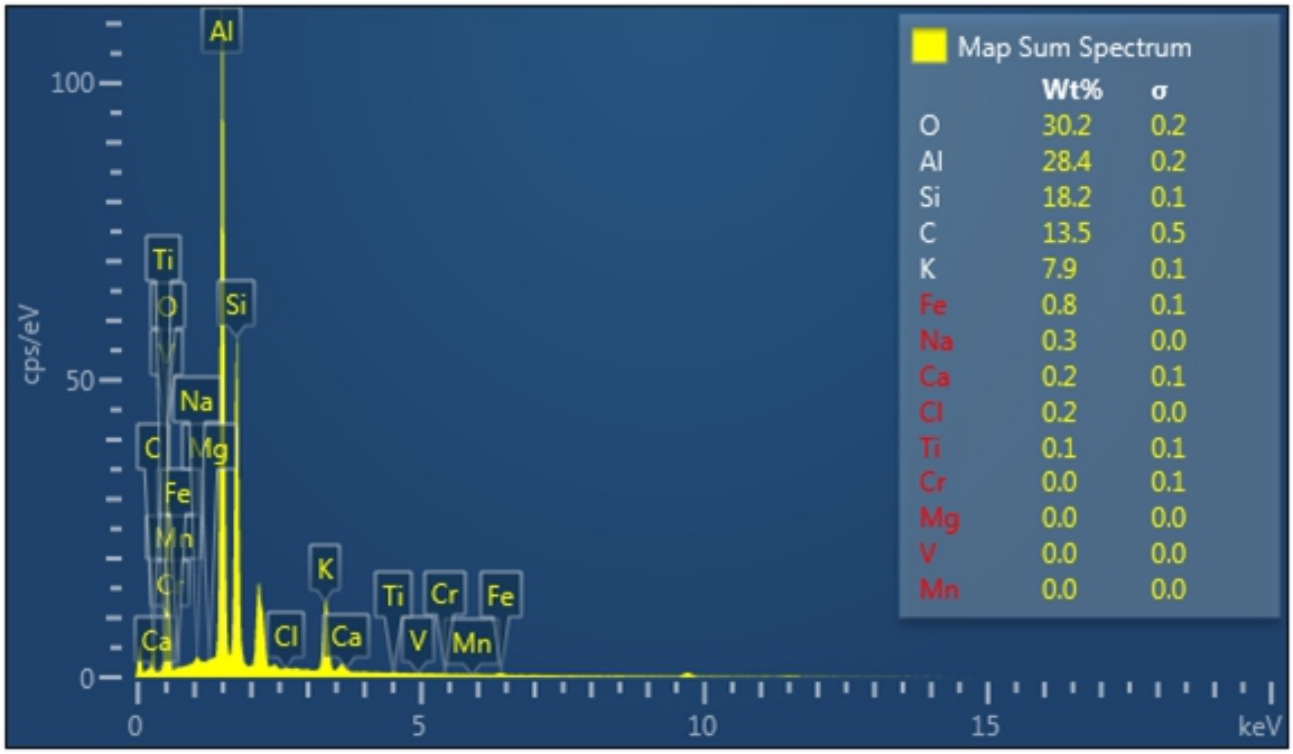


Fig. 5. The results of elemental analysis in the studied corundums using EDS method.

Table 1. The results of elemental analysis in the studied corundumsusing EDS method.

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Atomic %	Standard Label	Factory Standard
O	K series	16.65	0.05603	30.23	0.25	38.09	SiO_2	Yes
Al	K series	17.33	0.12449	28.45	0.2	21.25	Al_2O_3	Yes
Si	K series	8.88	0.07035	18.21	0.15	13.07	SiO_2	Yes
C	K series	1.22	0.01223	13.53	0.48	22.7	C Vit	Yes
K	K series	4.2	0.03557	7.87	0.1	4.06	KBr	Yes
Fe	K series	0.36	0.00364	0.84	0.11	0.3	Fe	Yes
Na	K series	0.2	0.00085	0.26	0.04	0.23	Albite	Yes

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Atomic %	Standard Label	Factory Standard
Ca	K series	0.12	0.00111	0.24	0.05	0.12	Wollastonite	Yes
Cl	K series	0.08	0.00072	0.17	0.04	0.1	NaCl	Yes
Ti	K series	0.05	0.00054	0.12	0.06	0.05	Ti	Yes
Cr	K series	0.02	0.00021	0.05	0.08	0.02	Cr	Yes
Mg	K series	0.01	0.0001	0.02	0.03	0.02	MgO	Yes
V	K series	0	0	0	0	0	V	Yes
Mn	K series	0	0	0	0	0	Mn	Yes
Total:				100		100		

Conclusion

Corundum crystals within the pegmatites in Khakou zone, in the south of Hamadan, are up to three centimeters long. Most of them are in the form of zinolite, and the margin of these crystals is surrounded by grained mica due to Metamorphism. These corundums have two types of irregular plates (parting) and in some cases the large sapphire crystals are crushed due to tectonic activities. The results of chemical analysis by SEM show that the main elements of the corundums include O, C, Fe, Ti, Si, Ca, K, Cl and Al, and their blue color is due to the presence of iron and titanium. The presence of high amounts of silica in these samples indicates the formation of these corundums from kyanite during the increase in pressure and temperature in the process of Metamorphism.

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