

Origin of some gem minerals in Sri Lanka: evidence from corundum-spinel-scheelite-taaffeite-bearing rocks

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ABSTRACT: The Ratnapura and Elahera gem fields of Sri Lanka have been renowned for their high quality gemstone for centuries. An improved understanding of the origin of gem minerals does not only have important regional geologic implications, but is also of economic significance. This paper presents the origin of some important gem minerals at Bakamuna (a known gem field in the vicinity of Elahera) and at Rupaha (a particularly unknown area for gems), on the basis of field and petrographical evidence and geochemical characteristics. Silica-undersaturated gem mineral-bearing reaction zones have been formed due to the reaction of chemically dissimilar rocks under high-temperature conditions in both localities. The high-temperature crustal metasomatism was followed by different kind of fluid infiltrations, which carried heavy metals to the higher crustal levels, and formed economically important minerals like scheelite.

1 INTRODUCTION

Sri Lanka has long been renowned for its wide variety of gemstones dominated by varieties of corundum, garnet, spinel, tourmaline, zircon etc. Most of the gem deposits occur in stream valleys as placer deposits. In view of the extremely large potential of gem minerals in Sri Lanka, the location of source rocks for gem minerals should significantly improve the accuracy of locating target areas. A peculiar kind of corundum-spinel-scheelite-taaffeite occurrence has been found in two separate locations, namely Bakamuna and Rupaha, within the central granulite belt of Sri Lanka. Although scheelite and taaffeite are found in Sri Lankan alluvial plains, this is the first report of scheelite and taaffeite found 'in-situ' in Sri Lanka.

2 GEOLOGY

The Proterozoic basement rocks of Sri Lanka occupy more than 90 percent of the country. Four different units were distinguished on the basis of isotopical, geochronological, geochemical and petrological constraints, Highland Complex (HC), Vijayan Complex (VC), Wannai Complex (WC) and Kadugannawa Complex (KC) (Milisenda et al.1988; Kröner et al.1991; Cooray 1994). The timing of peak metamorphism was estimated between 610-550 Ma (Hölzl et al. 1991; Kröner 1991), which coincides with the Pan-African metamorphic orogeny. Both 'in-situ' occurrences of

Bakamuna and Rupaha lie within the granulite-grade HC (Fig.1).



Figure1. Simplified geological map of Sri Lanka (after Milisenda et al. 1988; Kröner et al. 1991; Cooray, 1994) and the locations of the studied areas

3 FIELD RELATIONSHIPS

Reactions between chemically different rock units have resulted in a zonation at their contacts, which ideally is well-defined. The mineralogically zoned 'reaction bands' are collectively forming lens shaped domains from 50cm to 1m in a wide at both localities.

3.1 Rupaha

At Rupaha, three different mineral parageneses have been identified at the contacts between meta-peridotites (ultramafic rocks) and pelitic gneisses in the form of lenses. The sequence is consistent with the minerals of spinel-phlogopite, spinel-corundum-sapphirine, and corundum-biotite-plagioclase from the ultramafic rock towards the pelitic gneisses. The succession is repeated in at least six places at Rupaha. The typical textural evidence suggests that these reaction bands were later overprinted by scheelite, apatite and scapolite in some localities. Very late carbonate veins are quite common throughout the rock unit.

3.2 Bakamuna

The rocks immediately adjacent to the mineralogically zoned body at Bakamuna are marble and high-grade pelitic gneiss, indicating that the metasomatism is responsible for the mineral zonation. The body comprises three mineralogically different zones. The inner zone in contact with marble is spinel and phlogopite rich, in which the X_{phl} content is 0.98 on average. The purple coloured middle zone is confined to the minerals spinel, nepheline and taaffeite, but the latter is confined to inclusions in spinel in the form of needles/blades. The zone adjacent to pelitic rock is a coarse-grained pegmatitic-looking rock with corundum and andesine feldspar (Ab = 70%; An = 30% on average) as main constituents. Both middle zone and pegmatite-looking zone collectively form an area of extensive vein development. Two types of late mineralization have been recognized. One is thought to have formed just after the thermal peak, reflected by minerals such as scheelite and scapolite (Me = 50% on average), while the other is obviously very late consisting mainly of calcite and other carbonate minerals. The textural evidence also suggests that scheelite and scapolite, which are not produced during metasomatism, may have been nucleated at later stages.

4 CHEMISTRY

4.1 Mineral chemistry

The chemical compositions of some important minerals found in the reaction bands are summarized in Table 1. The empirical formula of taaffeite, calculated on the basis of 16 oxygens, is expressed as $\text{Be}_{1.24}\text{Mg}_{2.61}\text{Fe}_{0.11}\text{Al}_{8.02}\text{O}_{16}$ (ideally $\text{BeMg}_3\text{Al}_8\text{O}_{16}$), the Be content calculated by difference. Laser Raman microprobe technique was not successful to identify spinel from taaffeite because absorption peaks from both minerals are almost identical (e.g. Schmetzer 1983). Scheelite was readily identified in the hand specimen due to its fluorescence under short wave ultraviolet light.

Table 1. Chemical compositions of some minerals from Bakamuna and Rupaha

Mineral	Bakamuna				Rupaha		
	spl	taaf	scap	phl	neph	crn	spr
Na ₂ O	0.00	0.00	6.79	1.15	17.76	0.00	0.04
K ₂ O	0.02	0.01	0.14	7.62	2.37	0.00	0.02
FeO	3.08	1.37	0.00	0.94	0.00	0.18	0.89
SiO ₂	0.01	0.04	52.86	35.61	43.11	0.03	11.92
MgO	26.07	18.96	0.00	21.62	0.00	0.02	19.97
CaO	0.01	0.05	12.93	0.03	2.17	0.00	0.05
TiO ₂	0.00	0.00	0.02	4.09	0.01	0.13	0.04
MnO	0.00	0.06	0.00	0.04	0.00	0.00	0.03
Al ₂ O ₃	70.36	73.81	24.43	17.29	34.29	99.71	66.99
Cr ₂ O ₃	0.00	0.06	0.03	0.02	0.01	0.00	0.00
BaO	0.00	0.00	0.00	1.48	0.00	0.00	0.00
*BeO	-	5.61	-	-	-	-	-
NiO	0.00	0.03	0.00	0.00	0.00	0.00	0.00
F	0.00	0.00	0.00	0.45	0.00	0.00	0.00
Cl	0.00	0.00	1.36	0.18	0.00	0.00	0.00
Total	99.55	100.00	98.56	90.52	99.72	100.07	99.95
Na	0.00	0.00	1.93	0.33	6.56	0.000	0.01
K	0.00	0.00	0.03	1.44	0.58	0.000	0.00
Fe	0.06	0.11	0.00	0.12	0.00	0.003	0.09
Si	0.00	0.01	7.77	5.28	8.22	0.001	1.38
Al	2.00	8.02	4.23	3.02	7.70	1.990	9.12
Mg	0.94	2.61	0.00	4.78	0.00	0.001	3.44
Ca	0.00	0.01	2.04	0.01	0.44	0.000	0.01
Ti	0.00	0.00	0.00	0.46	0.00	0.002	0.00
Mn	0.00	0.01	0.00	0.01	0.00	0.000	0.00
Cr	0.00	0.01	0.00	0.00	0.00	0.000	0.00
Ba	0.00	0.00	0.00	0.09	0.00	0.000	0.00
Be	-	1.24	-	-	-	-	-
F	-	-	0.00	0.21	-	-	-
Cl	-	-	0.34	0.04	-	-	-
T cat	3.00	12.02	16.00	15.54	23.50	1.997	-
# of Oxy	4	6	(Si+Al=12)	22	32	3	20
X _{Phl}	-	-	-	0.98	-	-	-
Me	-	-	51.30	-	-	-	-
An Eq	-	-	0.41	-	-	-	-
X _{CO2}	-	-	0.66	-	-	-	-

* Be content in taaffeite by difference

Mineral abbreviations: phl-phlogopite
crn-corundum; spl-spinel; scap-scapolite;

neph-nepheline; taaf-taaffeite; spr-sapphirine;

4.2 Whole rock chemistry

Comparisons of the bulk compositions of all the sequences demonstrate that significant quantities of components have been added to the mineralized zones, especially for tungsten. In particular, Bakamuna rocks give values for tungsten ranging from 0.37% to 1.63% in the spinel-nepheline-taaffeite-bearing zone while values of 700 ppm were reported from the spinel-corundum zone at Rupaha.

Table 2. Whole rock chemistry of some important profiles at Bakamuna and Rupaha

	Bakamuna		Rupaha	
	corundum rich part	spl-neph taaf zone	spl-phl zone	crn-spr-spl zone
SiO ₂	6.30	18.80	35.13	16.98
TiO ₂	0.13	0.17	0.24	0.23
Al ₂ O ₃	86.59	47.66	42.44	52.19
FeO	0.85	1.45	0.59	4.06
MnO	0.03	0.04	0.01	0.05
MgO	0.04	4.26	3.68	17.90
CaO	1.66	2.93	7.04	0.91
Na ₂ O	0.11	4.35	3.07	0.16
K ₂ O	0.11	1.10	2.22	3.29
P ₂ O ₅	0.03	0.05	0.03	0.18
LOI	2.30	3.52	4.75	2.99
Total	98.15	84.33	99.20	98.94
(ppm)				
Ba	30	300	1108	1365
Nb	34	590	17	15
Rb	04	76	149	212
Sr	248	18	1573	172
U	25	111	41	26
W	16339	3697	650	697
Zn	63	331	12	2074
Zr	327	242	168	58

* Total Fe as FeO

5 CONCLUSIONS

On the basis of geochemical, textural, and field criteria, the origin of mineralized zones at both localities seems to be identical to each other. The significant mineralogical zoning marks the first stage of metasomatism at granulite facies conditions in the lower crust, followed by late-stage fluid-rock interaction processes. The infiltration of saline fluids along with H₂O-CO₂ may have transported metals like sodium, beryllium and especially tungsten to mid crustal levels to produce scheelite-nepheline-taaffeite at Elahera and scheelite + apatite at Rupaha.

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