

A NEW INVESTIGATION OF VIETNAM'S BERYL

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ABSTRACT

The paper presents briefly new investigation of Vietnam beryl group, especially some characteristics of regional geology of Song Chay granite massif and new find of big crystals of beryl in them. The green beryl is found in quartz - mica - tourmaline, mica - feldspar - quartz pegmatite bodies in the south part of Song Chay granite - gneiss massif near Na Chi and Tan Nam villages, Quang Binh district, Ha Giang province.

Keywords: beryl, gemstones, mineralogical properties

1. INTRODUCTION

The beryl group consists of some members: beryl $\text{Be}_3\text{Al}_2[\text{Si}_6\text{O}_{18}]$ (Emerald, Aquamarine, Morganite, Heliodor, Goshenite, Rosterite *etc.*), Vorobievite $\text{CsBe}_3\text{Al}_2[\text{Si}_6\text{O}_{18}]$, Stoppaniite: $\text{Be}_3(\text{Fe},\text{Al})_2[\text{Si}_6\text{O}_{18}]$, Pezzottaite: $\text{CsBe}_2\text{LiAl}_2[\text{Si}_6\text{O}_{18}]$, Bazzite: $\text{Be}_3(\text{Sc},\text{Al})_2[\text{Si}_6\text{O}_{18}]$ *etc.* of these, only beryl (emerald, aquamarine) and pezzottaite have been found in gem quality.

In recent years, many kinds of gemstones have found in Viet Nam, such as: ruby, sapphir, spinel, tourmaline, garnet, margarite, pargasite, zircon *etc.* Many of them have been exploited. Mineral beryl is found in many places of Viet Nam: Thach Khoan (Phu Tho province in North Viet Nam), Thuong Xuan (Thanh Hoa province in Central Viet Nam) and Bu Khang (Nghe An province in Central Viet Nam). In this paper, the authors present new investigation of Vietnam beryl group, especially some new information on beryl found in Song Chay massif (Ha Giang province, Viet Nam).

2. THE OCCURRENCES OF BERYL IN NORTH VIET NAM

2.1 The Xuan Le deposit (Thuong Xuan district, Thanh Hoa province)

In Xuan Le deposit had found aquamarine in pegmatite vein related with biotite granite and grano - syenite, granophyric granite, quartz syenite. Beryl is formed in pegmatite bodies and distributed inside or at the margin of the intrusive massif. The pegmatite bodies are usually in the form of pocket, lenses, some in the form of veins with varied size. The big bodies are tens meters long and small ones are 10 - 30 cm thick and extend a few meters in length. Beryl crystals are disseminated in the pegmatite. Together with beryl there are topazes, quartz, and opal. The beryl crystals are small in size (1 - 5 mm long) account for 1 - 5% of total minerals, in individual cases up to 30 - 40%. In the primary ore no beryl crystals with jewelry standard have been found. But in the placer have found beryl meeting in the commercial requirement (aquamarine).

2.2 The Deo Sen beryl occurrence (Quy Chau district, Nghe An province)

The Deo Sen beryl occurrence is located in the north of Bu Khang dome. Here, beryl is distributed in the pegmatite bodies 2 - 3 m thick, extending 40 - 50 m long. The grade of beryl in pegmatite bodies has not been evaluated. The prospect of the ore occurrence is not clear yet.

2.3 Thach Khoan deposit (Thanh Son district, Phu Tho province)

The Thach Khoan deposit composed of many occurrences: Di Nau, Doi Dao, Mo Ngot *etc.*. In Thach Khoan deposit beryl (aquamarine *etc.*) are found with white mica, tourmaline, feldspar and crystal quartz.

2.4 The Song Chay occurrence (Quang Binh district, Ha Giang province)

In 2004 year, we found big crystal of beryl in muscovite - feldspar - quartz pegmatite, tourmaline pegmatite bodies in Song Chay granite - gneiss massif. In the same Song Chay massif, the Chinese geologists have found crystal emerald in the Chinese part of Song Chay massif nearby to China - Vietnam boundary.

2.4.1 Location

The investigation area is located about 300 Km north of Ha Noi capital in Quang Binh district, Ha Giang province. In Song Chay massif, big crystals of beryl are found nm in south-east of Na Chi and Tan Nam villages, Quang Binh District, Ha Giang Province (North Viet Nam).

2.4.2 Regional geology

The geological map of Song Chay granite - gneiss dome is showed in figure 1. The Song Chay massif is one of the biggest intrusive massifs in Vietnam (2500 km²). The Song Chay massif is located in the North East Vietnam Para - fold Region (Song Lo Zone) belongs to the Sino - Vietnamese Fold system which was consolidated in Late Caledonian. The Song Lo Zone (including Song Chay massif) is bounded by the Ha Giang - Thanh Thuy fault in the northeast and Song Chay fault in the southwest. It is composed of largely distributed Neoproterozoic to Paleozoic sediments forming a large anticlinorium, where a large granite - gneiss batholiths penetrated in the core, forming the Song Chay dome.

In the investigation area, there exist following formations:

- Song Chay Group. The Song Chay Group is composed of terrigeno- carbonate sediments metamorphosed to the epidote - amphibolite and green schist facies, distributed in large bands in the east of the Song Chay massif. It has been subdivided into 2 Formations: An Phu and Thac Ba ones. The Thac Ba Formation (PR₃ - ε_{1tb}) is composed of quartz - feldspar - mica schist bearing garnet with lenses of hornblende plagioclase - epidote schist, quartz - feldspar - two mica schist interbedded with quartzite and calcite - epidote - tremolite schist. The An Phu Formations (PR₃ - ε_{1ap}) is composed of marble bearing graphite, dolomite marble interbedded with two mica schist, feldspar - calcite schist and distributed in some small areas in the forms of xenoliths within this massif.

- Ha Giang Formation (ε_{2hg}). The Ha Giang Formation is largely distributed around the Song Chay massif. The Ha Giang Formation is composed of quartz - biotite schist bearing garnet; sericite - chlorite schist, shungite with some lenses of marbleized limestone bearing oncolite; brecciated limestone phyllite, oolitic limestone marble, clayey limestone.

- Chang Pung Formation (ε_{3cp}). The Chang Pung Formation is distributed in the northeast and

west of the Song Chay massif. This formation is composed of clay - sericite schist grading upward to limestone calcareous clay shale, some beds of oolitic limestone, marlaceous shale, clay shale, limestone, oolitic limestone, clayey limestone and claystone.

- Mia Le Formation (D_{1ml}). The Mia Le (Ma le) Formation is composed of clay - sericite shale, quartzitic sandstone, tuffaceous sandstone interbedded with felsic - alkaline effusives. The Mia Le Formation is rather largely distributed in the east and southeast of the Song Chay massif.

- Khao Loc Formation (D_{1-2kl}). In the investigated area, this Formation is distributed concentratedly in the southeast and east of the Song Chay massif. The Khao Loc Formation is composed of quartzite sandstone, limestone, calcitized limestone, quartz - sericite - chlorite schist, bituminous limestone, marlaceous shale, cherty limestone and calcareous shale.

- Yen Binh Formation (T_{2yb}). The Yen Binh Formation is exposed in some small areas in the north of the Luc Yen district, near the south margin of Song Chay massif. This formation is composed of conglomerate, grey polymictic sandstone, dirty - grey limestone, clay shale, motley colored clayey limestone, sandstone, siltstone.

- Ban Hang Formation ($K? bh$). The Ban Hang Formation is distributed in Yen Binh area, it is composed of polymictic conglomerate, gritstone, siltstone, calcareous sandstone, sandstone.

Magmatic intrusions

- Song Chay complex ($\rho\gamma a D_{1sc}$).

According to geology and mineral resource of Ma Quan and Bac Quan sheets (F - 48 - IX, F - 48 - XV) the Song Chay complex comprises 3 phases: Phase 1: small to medium grained, porphyritic biotite granite. Mineral composition (%): quartz 20 - 40, microcline 18 - 42, plagioclase 17 - 38, biotite 5 - 18. Accessory minerals: apatite, zircon, tourmaline, garnet, monazite and ilmenite. Phase 2: leucocratic, gneissoid coarse - grained biotite granite. Mineral composition (%): quartz 20 - 38, microcline 30 - 50, plagioclase 10 - 28, biotite 6 - 10, muscovite 1 - 4. Accessory minerals: apatite, zircon, monazite and garnet. Phase 3: vein rocks with aplite, garnet-bearing pegmatite. Petrochemical characteristics: rocks of the complex has the following content (%): SiO_2 63 - 75, CaO 0.1 - 2.4, total alkali 4 - 9; they belong to the potassic or sodic - potassic alkaline type with Na_2O/K_2O 0.4 - 0.8. Geochemical characteristics: the content of Sn, Pb and Zn elements is 2-3 times higher than Clarke value. The studied rocks belong to the S - granite type. A.P. Ponomeva [7] on the basis of geological and mineralogy - geochemical studies divided four series of Song Chay massif granite. These are: sodium, K - sodium, potassium and high potassium series varying from granitoids to leucocratic granites.

Rocks of the Song Chay complex penetrate metamorphic rocks of the Song Chay group, the Ha Giang (ϵ_2hg) Formation and Chang Pung Formation (ϵ_3cp). These have been existed various opinions on the datation of the Song Chay massif.

The isotope ages of the Song Chay granitoids by various methods [1, 5, 6 - 9]:

- 2652, 2452, 2050 (zircon; U - Th - Pb; migmatite, crystalline shale)
- 1007, 1000; 650, 625, 620 (zircon, apatite; U - Pb; gneissoid two mica granite);
- 465, 464, 452, 450, 428 (zircon, biotite; U - Pb, Rb - Sr; gneissoid two mica granite)
- 305, 300, 299, 295 245, 240, 236, 234, 230, 228, 222, 215, 212, 210, 201, 200, 198, 195, 194, 192 (mica, feldspar; Ar - Ar; granitoids);
- 176, 175, 174, 166, 165, 164, 163, 160, 144, 101;
- 40, 28, 24, 23, 20, 19, 16 M.A.

This data shows that granite of Song Chay massif has multistage generation.

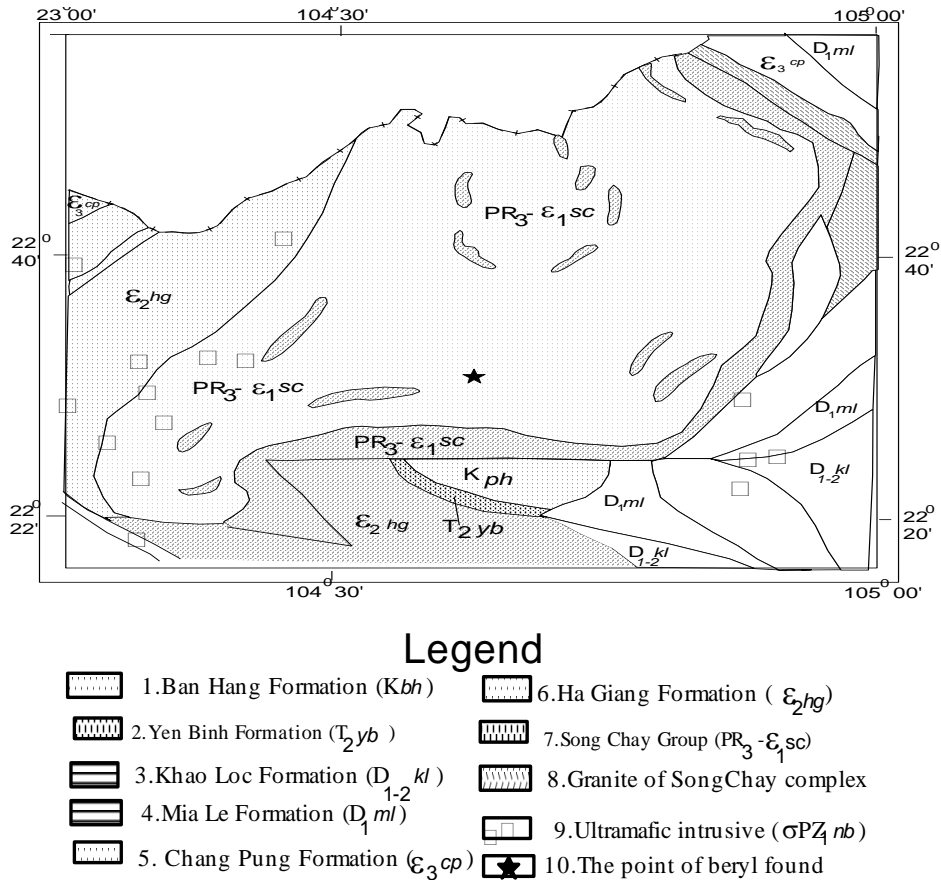


Fig 1: The geological map of investigation area.

3. SOME RESULTS OF STUDY OF VIETNAM BERYL

3.1 Methods of the analyzes

The above sample groups were firstly described visually in detail on their crystalline features, sizes, and angles between the sides... especially, the modern analyzing methods are also applied in studying their mineralogical nature such as: X-Ray diffraction method (New Material Center, Faculty of Physics, HUS and Institute of Materials Science); Microzond (Research Institute of Geology & Mineral Resources (RIGMR)); Raman Spectroscopy (Spectra - gemological Laboratory, Institute of Materials Science); crystallographic optics and gemological method (VIGEMLAB - Institute of Gemology and Jewelry).

3.2 Color characteristics

The mineral color of the beryl group observed under the sun light by naked eyes is different according their origins (Table 1).

Table 1: Typical mineral color of the beryl group.

<i>Mine</i>	<i>Thach Khoan Beryl</i>	<i>Thuong Xuan Aquamarine</i>	<i>Beryl Song Chay</i>
Characteristics			
Color	- Light - yellow green - Light - green - Light - greenish yellow - Light - brownish yellow	- Light sea green - Medium sea green - Dark sea green - Green	- Green - Pale greenish - Blue - Slightly green - Bluish green
Clearness	- Sub clear - Clear (small crystal)	- Clear	- Sub clear

3.3 Morphology

The beryl group have typical prism form and usually found in single crystals, sometimes in crystal mass. Prism face $\{10\bar{1}0\}$ and double face $\{0001\}$ are widely developed. The pyramid face $\{11\bar{2}1\}$, $\{10\bar{1}1\}$ and pyramid double face $\{11\bar{2}0\}$ are rarely found or poorly developed.

The measured angles between faces are as below:

$$\begin{aligned} \{0001\} \wedge \{10\bar{1}1\} &= 29^{\circ} 50' - 29^{\circ} 56' \\ \{10\bar{1}1\} \wedge \{11\bar{2}0\} &= 64^{\circ} 15' - 64^{\circ} 23' \\ \{0001\} \wedge \{11\bar{2}1\} &= 44^{\circ} 51' - 44^{\circ} 56'. \end{aligned}$$

The sizes of mono crystal are various. The Thach Khoan beryl usually has an impressive size with height from several cm to 60 - 70 cm and weight of the crystal may reach nearly 100kg. The aquamarine crystals of Thuong Xuan Pegmatite deposit often have size of 0.1 to 15 cm with the weight reaches 700 - 800 g. The Song Chay massif beryl forms hexagonal crystals (short prisms) hosted by feldspar, quartz, mica and black tourmaline. Individual crystal range to more 2 - 22 cm in diameter and 35 cm long.

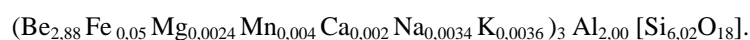
3.4 Chemical composition

The results of chemical analysis are shown in table 2. It is clearly seen that main oxide compositions as SiO_2 , Al_2O_3 , BeO are almost similar in all types of beryl. The differences in weight are in the range of analyzing method.

However, it is noted that there is some difference in the content of the color-bearing elements (FeO , MnO , NiO , and V_2O_5) and alkaline, earth alkaline elements (CaO , MgO , Na_2O and K_2O) between the beryl group.

The empirical mineralogical formulas of two types of beryl modifications have been calculated as follows:

+ *Thach Khoan Beryl (TK-1)*:



+ *Thuong Xuan Aquamarine (TX-1)*:

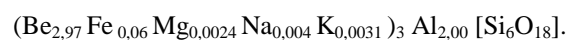


Table 2: Results of chemical analysis.

No.	Oxide	Composition (%) in monocrystals		
		Thach Khoan beryl	Thuong Xuan aquamarine	Beryl Song Chay
1	SiO ₂	63.97	66.25	65,02
2	TiO ₂	0.013	0.002	
3	Al ₂ O ₃	17.62	18.52	17,99
4	Cr ₂ O ₃	0.005	0.004	
5	V ₂ O ₅	-	-	
6	FeO	0.58	0.65	0,33
7	NiO	0.007	0.011	
8	BeO	13.32	13.21	
9	MgO	0.019	0.006	0,58
10	CaO	0.015	0.002	0,57
11	MnO	0.039	0.020	
12	Na ₂ O	0.032	0.023	1,18
13	K ₂ O	0.021	0.012	0,55
14	P ₂ O ₅	0.016	-	
15	H ₂ O			0,99

3.5 Characteristics of absorption and raman spectra

These properties were studied in the Laboratory of Spectroscopy and Gemology, Institute of Materials Science, Academy of Science & Technology. Due to the shortage of the emerald samples, this type of test was only conducted for the Thach Khoan beryl and Thuong Xuan aquamarine. The results of the Raman & absorption spectra analyses are shown in the table 3.

Table 3: Summary of analyzed values of Raman and absorption spectra.

Spectra Types	Thach Khoan Beryl	Thuong Xuan Aquamarine
Absorption	- Wave length 400 - 600 nm - Weak & not clear spectra was presented	- Wave length 410 - 600 nm - Clear spectra was clearly presented at 427 & 456 nm
Raman	- Li-yellow green beryl (milky) 323.9; 397.0; 422.2; 443.2; 530.4; 583.4; <u>685.0</u> ; 771.5; 914.4; 1014.5; 1070.6; 1240.3 - Green beryl (milky) 328.9; 397.0; 421.8; 447.4; 526.5; 623.8; <u>685.0</u> ; 772.5; 915.3; 1010.5; 1067.7; 1240.5	- Sea green aquamarine (clear) 290.0; 325.0; 398.0; 424.0; 443.9; 528.7; 581.3; <u>681.1</u> ; 771.5; 1015.4; 1070.6; 1241.2

As it is clearly seen from table 2, by comparing the determined spectra with the standard spectra, beryl and aquamarine could be easily distinguished. It shows that the absorption and Raman spectra are greatly depended on the content of the isomorphous elements in beryl crystalline structure.

3.6 Crystalline structural characteristics

Beryl of Song Chay massif was measured by X – ray diffractometers (type Siemens D5000 by using Cu-K α , X-ray tube, $\lambda = 1.5406$). X-ray metric: $a = 9.2121$, $b = 9.2121$, $c = 9.1954$, $V = 675.794$. The results are showed in table 5. and Fig. 2. : 3,238 (10) – 2,874 (10) – 2,146 (8) – 1,989 (8) – 1,737 (8) – 1,515 (8) – 1,430 (8) – 1,276 (80) – 0,8066 [d(Cps)] (Fig. 2).

Table 4: Summary of calculated values of crystal lattice parameters of beryl group in Vietnam.

Parameters of crystal lattice	Thach Khoan Beryl	Thuong Xuan Aquamarine	Beryl Song Chay	Remark
a_0	9.2130 ± 0.002 9.2091 ± 0.003	9.2073 ± 0.007	$a_0 = 9.2121$ $b_0 = 9.2121$	Value a_0 of beryl aquamarine & emerald is stable
c_0	9.2126 ± 0.008 9.1934 ± 0.001	9.1973 ± 0.003	9.1954	Value c_0 change a little
$a_0 : c_0$	1: 0.9999 1: 0.9982	1: 0.9989	1,0018	Value $a_0 : c_0$ of is stable

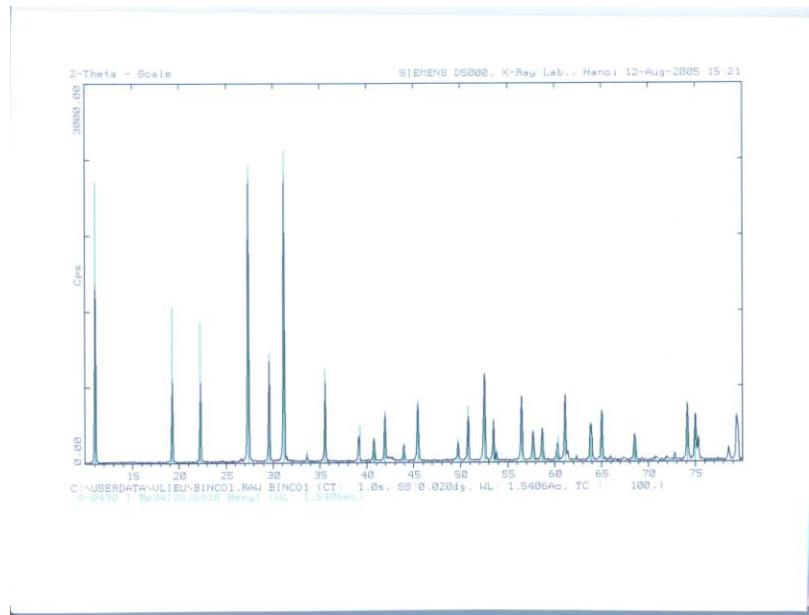


Fig. 2: Typical XRD pattern of the Song Chay green beryl.

Table 5: Result of X-ray diagram calculation of Song Chay massif.

dA	Int	H k l	dA	Int	H k l
7.98	90	1 0 0			
4.60	50	0 0 2	1.7110	14	4 1 1
3.99	45	2 0 0	1.7007	4	3 2 2
3.254	95	1 1 2			
3.015	35	2 1 0	1.6265	18	2 2 4
			1.5953	8	5 0 0
2.867	100	2 1 1	1.5710	10	3 2 3
2.660	4	3 0 0	1.5690	8	2 1 5
2.523	30	2 1 2	1.5349	6	3 3 0
2.293	12	0 0 4			
2.213	8	3 1 0	1.5320	8	0 0 6
			1.5138	16	4 1 3
2.208	4	1 0 4	1.4882	2	4 2 1
2.152	16	3 1 1	1.4566	10	3 3 2
2.060	4	2 2 2	1.4535	12	1 1 6
2.056	6	1 1 4			
1.9926	20	2 0 4	1.4324	14	3 2 4
			1.4148	2	3 1 5
1.8308	8	3 2 0	1.3682	8	5 1 2
1.7954	18	3 2 1	1.3556	6	2 1 6
1.7397	20	3 0 4	1.3306	<1	6 0 0

4. THE POSSIBILITY TO FIND AQUAMARINE AND EMERALD IN SONG CHAY MASSIF

In the Song Chay massif, the big green beryl is found in quartz – mica – tourmaline, mica – feldspar - quartz pegmatite bodies. In the same Song Chay massif, the Chinese geologists have found crystal emerald in the Chinese part of Song Chay massif nearby to Chine – Viet Nam boundary. We thing that emerald and aquamarine are mostly found in Vietnamese part of Song Chay massif because in Song Chay massif there are many bodies of mafic and ultramafic rocks penetrate granitoide rocks (see Fig. 1).

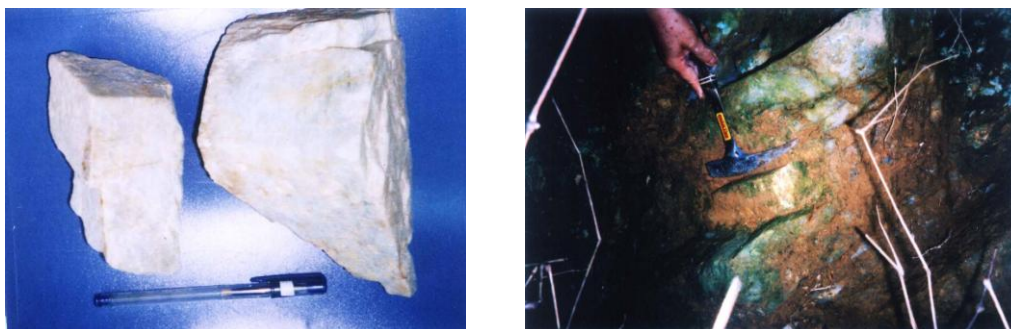


Fig. 3a: Beryl in Song Chay massif and The point detect on Song Chay's beryl.



Fig. 3b: Beryl's crystal in Song Chay massif.

5. CONCLUSION

The Song Chay granite - gneiss massif is situated in Song Chay Precambrian folded zone which reformed in Paleozoic time and is belonging to the Precambrian oceanic types. The green beryl is found in quartz - mica - tourmaline, mica - feldspar - quartz pegmatite bodies in the south part of Song Chay granite - gneiss massif near Na Chi and Tan Nam villages, Quang Binh district, Ha Giang province.

The mineral beryl group of North Viet Nam is distributed mainly in the pegmatite related to acid magmatic. New discoveries of gemstones occurrences allow us to suggest that in the future exploration will reveal additional deposit of economical significance

REFERENCES

1. Dovzhikov, A.E., *et al.* (1965), Geology of North Viet Nam, Ha Noi, p. 668 (in Russian).
2. Geology and mineral resources of Bac Quang sheet (F – 48 – XV), scale 1: 200 000 (Editor: Tran Xuyen), Ha Noi, 2001. (in Vietnamese).
3. Geology and mineral resources of Ma Quang sheet (F – 48 – XV), scale 1: 200 000 (Editor: Tran Xuyen), Ha Noi, 2001. (in Vietnamese).
4. Geological map of Viet Nam scale 1: 500 000 (Editor: Tran Duc Luong, Nguyen Xuan Bao), Ha Noi, 1981 - 1988. (in Vietnamese).
5. Geology of Viet Nam, Magmatic formations (Editor: Dao Dinh Thuc, Huynh Trung). Geol. Suvr. of Viet Nam. Vol. 2, p. 359 (in Vietnamese).
6. Izokh, E.P., Phan Viet Ky, Nguyen Van Quyen, Tran Quoc Hai, and Nguyen Thac Nhan (1981), Geological position and possible mechanism of Song Chay granite formation. "Geological Mapping", No. 48, pp. 20 - 26. (in Vietnamese).
7. Ponomareva, A.P., Vladimirov, A.G., Phan Luu Anh, Krut, N.N., Rudnev, S.N., Ponomarchuk, V.A., Bibikova, E.V., and D.Z. Zhuravlov (1997), The Song Chay high - alumina granite massif in Northern Viet Nam: substantiation of The Ordovician age, petrogenesis and tectonic position. J. "Russian Geology and Geophysics", pp. 1792 - 1806. (in Russian).
8. Ta Trong Thang, Vu Van Tich, and Le Thi Thu Huong (2002), Mesozoic - Cenozoic geodynamic evolution of the deformation area from Bu Khang to Song Chay dome. "J. of Sciences of the Earth. pp. 129 - 137. (in Vietnamese).

9. Tugarinov, A.I., Nguyen Khac Vinh, Zykov, S.I., and Stubnikova, N.I. (1979), Pb – U geochronology of Song Chay granite Complex North Viet Nam). J. "Moscow University Geology Bulletin", pp. 94 - 97. (in Russian).