Journal of Mining and Earth Sciences
Website: http://tapchi.humg.edu.vn

Characterization and potential of tin mineralization in Ma Ty - Du Long area Ninh Thuan Province

Tinh Thanh Bui *, Bac Hoang Bui, Dung Tien Nguyen

Faculty of Geology Geosciences and Geoengineering, Hanoi University of Mining and Geology, Vietnam

ARTICLE INFO

Article history:
Received 01 Feb. 2018
Accepted 15 Apr. 2018
Available online 29 Jun. 2018

Keywords:
Tin mineralization
Ma Ty - Du Long
Ninh Thuan
Characterization and Potential

ABSTRACT

The Maty - Du Long area has a high potential of tin ore, which demonstrates quite good quality. Sn content varies from <0.1% to 1.44%, an average of 0.2%, meeting the basic industrial criteria for commericial tin mining. The research results show that tin mineralization mainly occurred along the Northeast - Southwest fracture system in the greisenized biotite granite of the Ca Na complex and the volcanic rocks of the Don Duong Formation. The results have allowed us to identify 5 tin mineralization zones, which are Suoi Giang, Tap La, Dong Thong, Khen Den and Ta Nan and, the total reserve of tin ore in Ma Ty - Du Long area is estimated at ~5,968 tons.

1. Introduction

Tin is one of the widely used metals in industry, daily life and defence security. Tin is characterized by high corrosion resistance, non-toxic, easily melted and it can be used in producing high-grade alloy. In the socio-economic development of the country, the demand of tin ore for the industries is increasing. Therefore, the geological survey and mineral investigating for evaluating tin potentiality of the area is an essential task as it is the basis for subsequent exploration and exploitation of any tin deposit.

The results of geological mapping and mineral prospecting at the scale of 1: 50.000 and 1: 10.000 have recently indicated that the Ma Ty - Du Long area, Ninh Thuan Province has a promising potential of tin ore. The primary tin ore associated with the granite of the Ca Na complex demonstrates good quality and it can be used as raw material sources for industry (Viet Tiep Division, 1986; Tro Huu Do et al, 2005). However, the entire area is characterized by complex geological structure and poor investigation. A better understanding of the characterization of the tin ore will be a valuable database for further studies, plans of industrial production and ore processing. Based on the research results combined with field investigation and sample analysis, the authors have defined the main features and structures related to tin mineralization in the Ma Ty - Du Long area as well as the linkage between the geological structure and primary tin mineralization. The research results confirmed that the area shows a very high potential of tin ore, whose quality and resources

*Corresponding author
E-mail: buitinhhumg@gmail.com

can satisfy the material demand for the development of the domestic industry.

2. Geologyical setting

2.1. Lithology

According to the results of geological mapping at the scale of 1: 50,000 of the Phan Rang - Cam Ranh map sheet in 1986 carried out by the Viet Tiep Geological Division, evaluation report on tin ore in the Ma Ty - Du Long area, Ninh Thuan (2005), stratigraphy of the area varies from the Jurassic to the Quaternary Period (Viet Tiep Division, 1986) Figure 1.

Four formations and three intrusive complexes were recorded within the research area. The main geological formation related to tin mineralization is the Ca Na Complex (G/K2cn), tin ore was observed near the contact between the shallow intrusion of the Ca Na Complex and the Cretaceous volcanic rocks of the Don Duong Formation. The bright granite of the Ca Na Complex is largely exposed in most of the central Ma Ty area and the southeast of the Du Long area with a total area of ~50km^2. The rock has been strongly greisenied. Mineral composition includes quartz 25.41%, plagioclase 30%÷40%, potassium feldspar 20%÷45%, biotite 2%÷9% and less muscovite. The rock owns massive structure and subheral - porphyritic texture (Figure 2, Figure 3).

The Don Duong Formation is only observed in a limited area in the northwest of the Ma Ty area but it is more common in the south and west of the Du Long region. It is mainly rhyolite, which

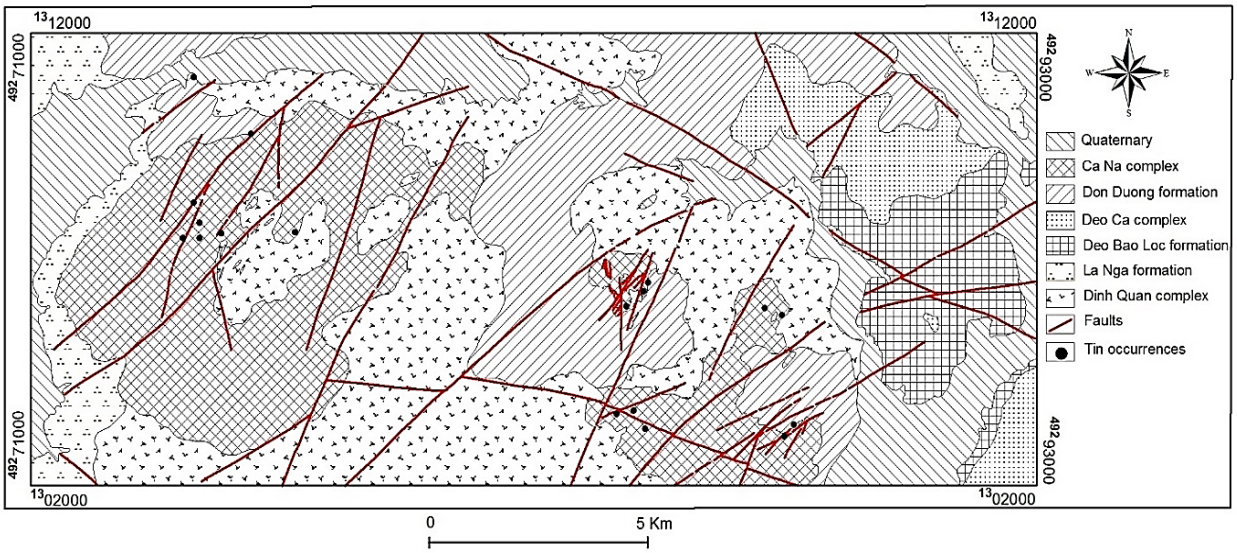

Figure 1. Simplified geology map of the Ma Ty - Du Long area.

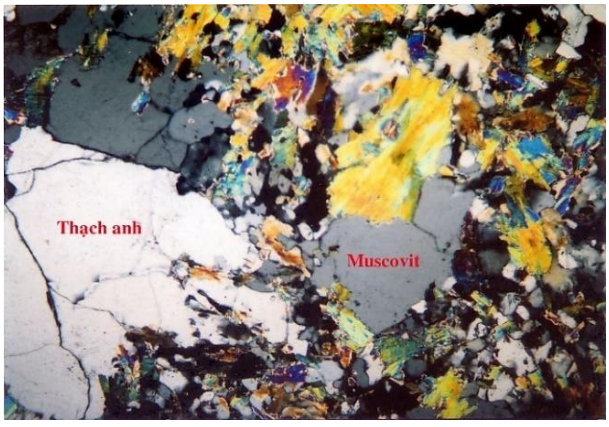

Figure 2. Greisenized granite - The thin section petrology sample M.143, nicol (+) x 35.

Figure 3. Greisenized granite, The thin section petrology sample KTD.288, nicol (+), x 35.

is broken along the faults. the porphyritic sulphide minerals were observed in some places within this rock type.

Composition of minerals include 30-35% glass, 1-13% quartz, less 9% plagioclase, 2-11% potassium feldspars.

2.2. Tectonics

The research area shows a complex tectonic regime, which has been controlled by a large scale syncline oriented in northeast-southwest trend, associated with higher order folds in the same direction. The limbs of syncline are separated by the NW-SW and NW-SE faults, including some master faults such as the Co Lo (F1), Song Vang (F2), Song Sat and the Ta Nang Faults. The NW-SW faults mainly dip to the southeast, with the dip angles of ~70-75^0. They play the controlling role in shaping the structure as well as tin mineralization of this area.

In addition, granitoid rocks of the Ca Na Complex have been crossed by several fracture systems, especially, the two main fracture systems orienrted in 220÷240^0 direction, 75÷85^0 dip and the 320÷340^0∠10÷15^0 system. In this case, the high angle dip fractures are dominant, which have accommodated tin mineralization. Moreover, the strong tin mineralization was commonly observed at the intersections between the two fracture systems mentioned above.

3. Methodology

3.1. Data collection

Collecting pre-existing geological documents such as topography, geomorphology, geology, geophysics, geochemistry, mineral resources in the research area; The reports on prospecting, in the study area have been collected to study the primary tin minerals. Simultaneously, process and systematize all of them to figure out the main tasks for futher studying tin ore in the area.

3.2. Geological investigation

Implementing field surveys in the Ma Ty - Du Long area to collect field data and samples for subsequent petrological, mineragraphic and SEM-EDS examination in order to define the type, the structure and texture and grade of tine minerals.

3.3. Sample analysis

According to the regulations for the classification of reserves and resources of solid minerals promulgated by Ministry of Natural Resources and Environment of Vietnam (Decision No 06/2006/QD-BTNMT). Samples were collected from drillholes and trenches according to designed grids of 80m ÷ 240 m. The samples have been collected from 8 drillholes and 143 trenches for this study.

Chemical analysis

Samples of tin were analyzed from trenches, core samples, to determine the Sn content (%). Samples are analyzed according to TCN standard 04-I-PTH/94.

Mineragraphic analysis

The ore minerals were examined by using polished section examination under reflected light of the microscope (Carl Zeiss-Axio-Scopea1) to determine the ore material composition, mineral association and ore forming stages.

SEM-EDS analysis

There is another way to examine the minerals through the image of the crystal form, as well as determine the elements and their content. The representative sample was prepared using epoxy resins, polished and made conductive by carbon coating in a Dentom vacuum, DV-502A. The morphology of the cassiterite ore was analyzed in a Quanta 450-FEI scanning electron microscope at accelerating voltage of 20KVA, realtime of 21-36 and livetime of 60 seconds. The chemical elements of the sample were determined by the EDS. The images were shown with point analysis at the positions of the ore particles (Martin Ogwuegbu, 2011; Sri Harjanto, 2014).

3.4. Statistical analysis

One-dimensional statistical method is used to evaluate the statistical distribution characteristics of research parameters, correlation, variance, coefficient of variation (John, 2002). The results show the characteristics of tin ore in the area.

3.5. Resource estimation

To estimate the primary tin resources for the

ore zones in Suoi Giang, Tap La, Dong Thong, Khen Den and Ta Nang. Potential of tin resources in the study area were determined by the arithmetic mean method (Dong Van Nhi et al., 2006).

The amount of ores (Q) are determined as below (1):

$$Q = V.d \quad (1)$$

The number of useful components (P) is determined (2):

$$P = Q.C = V.d.C \quad (2)$$

Where V is the volume of ore (m^3); d is the weight of the ore (kg/m^3); C is the average content of tin.

The volume of a ore zone is calculated according to (3):

$$V = S.m \quad (3)$$

Where m is the average thickness of ore zone (m); S is the area of ore zone (m^2).

The area of the ore zone can be calculated according to (4):

$$S = L.H \quad (4)$$

Where L is the length of tin ore (m); H is the predicted depth (m) (5):

$$H = \frac{1}{4} L \quad (5)$$

4. Results

4.1. Mineralogy

The results of mineragraphic analysis indicated that the common ore minerals include pyrite, specularite, cassiterite, magnetite, chalcopyrite; less common minerals are galenite, sphalerite, molybdenite, wolframite, ilmenite, and hematite; trace minerals composed of galenobismutine, bismuth autogenic minerals and povelite. (Figure 4-8).

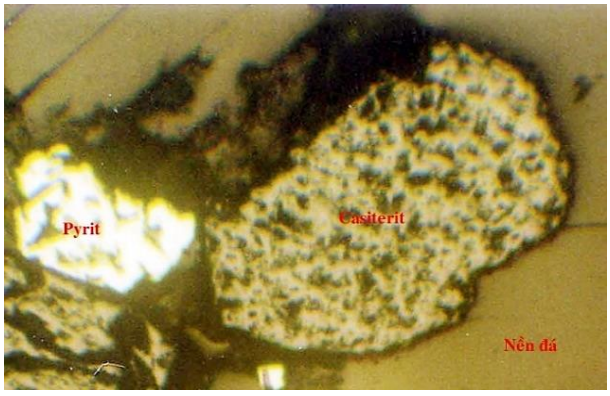

Figure 4. The mineragraphic sample KTD.913 /1x100), cassiterite - pyrite mineral association.

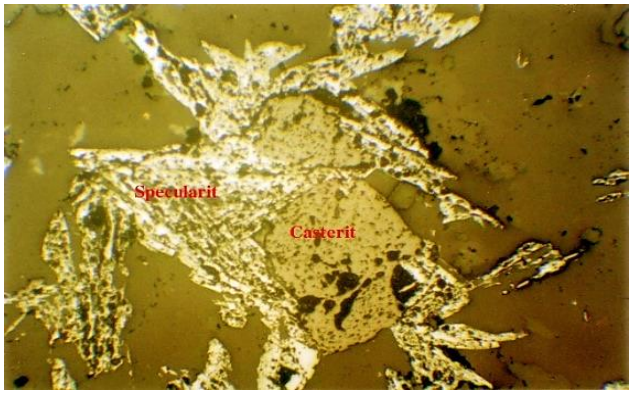

Figure 5. The mineragraphic sample KT.2529 /3x100,Specularite replaces and reattaches cassiterite.

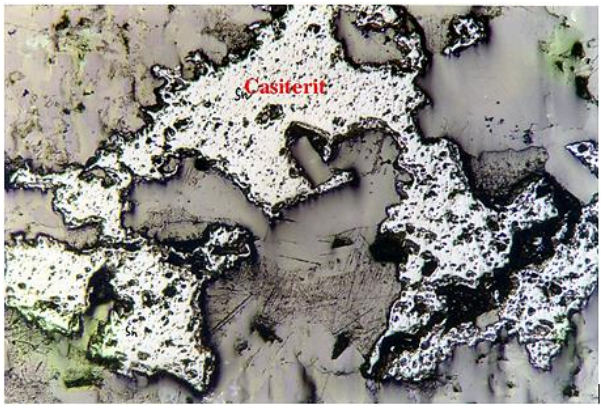

Figure 6. The mineragraphic sample KTD. 1575x50, cassiterite.

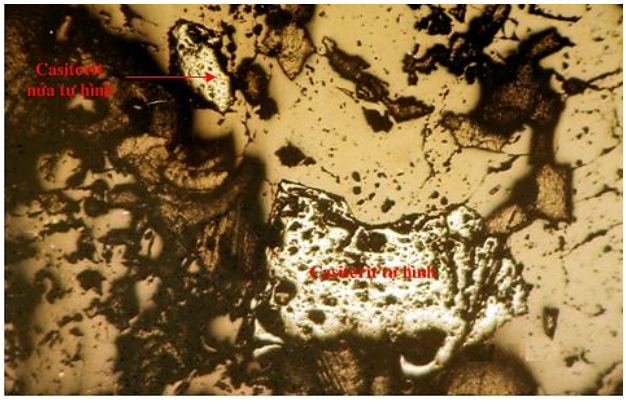

Figure 7. The mineragraphic sample KTH.5DSx40, cassiterite.

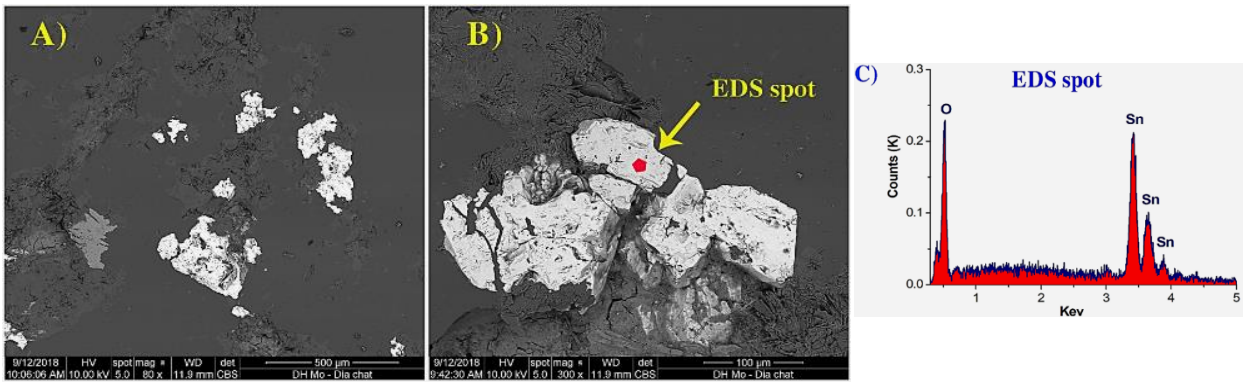

Figure 8. SEM-EDS analysis shows that the presence of minerals of Sn in the sample. A-B) SEM images of tin mineral; C) EDS spot of tin mineral.

Pyrite (FeS_2): It is the most common mineral associated with tin ore but it does not show significant amount in quantity. The pyrite shows low content (few percent), with some samples demonstrates are 6-15%. The textures involve panautomorphic, leptomorphic, subhedral. Pyrite irregularly disseminates as small pockets in the matrix of the bedrock (Figure 4).

Specularite (Fe_2O_3): relatively common in tin ore bodies but it is not much in quantity. Specularite content varies from 0,1% to 0,5% or less and chrystallized in tabular, shingle, packet, acicubar forms (Figure 5).

Cassiterite (SnO_2): It is a common mineral unevenly disseminated in in tin ore bodies. Casiterite content spans from <0.1 to 2-3%, some samples are 5-7% or higher; the ore was observed in various host rocks with high content up to 10-40%. In addition, cassiterite also exists in the form of independent crystals or in the fracture surfaces (Figure 4-8).

The typical mineral association is cassiterite-pyrit-specularit.

Chalcopyrite ($CuFeS_2$): Minerals are less common than pyrite in tin mineralization zone, usually in the form of extra minerals, the content is 0.1%, rarely 0.5-1%. They are usually small and panautomorphic to subhedral and leptomorphic texture. Chalcopyrite is scattered and unevenly disseminated in rock, which is syngenetic with sphalerite, galenite, cozalite.

Magnetite (Fe_3O_4): rarely seen and accounts small amounts; content is from few grains to 1%, dispersed unevenly in the rock, sometimes in pocket, develops along discontinuous microveins.

4.2. Mineral chemistry

Results from electron microprobe analysis indicated that the average chemical composition of cassiterite include: SnO_2 = 99.42%, TiO_2 = 0.05%, Fe_2O_3 = 0.27%. Nb = 0.46%, W = 0.737%, Mg = 0.20% (Table 1).

SEM-EDS was used to determine the chemical elements in the ore-bearing cassiterite in the study area (Figure 8). The sizes of the particles varied from 0.1mm to 2mm. The SEM image shows the intercalation of some minerals within some crystal aggregates. The EDS chemical analysis showed that the elements intercalate in the ore-bearing cassiterite were Sn, Fe, W (Figure 8).

Analytical results of the inductively coupled plasma samples and the atomic absorption samples show that in addition to Sn in the ore, there are also intercalative elements such as W, Mo, Cu, Pb, Zn.

4.3. Characterization of tin-ore zones

There are four tin ore zones in Suoi Giang, Tap La, Dong Thong, Khe Den of Du Long area and one tin ore zone in Ma Ty area. Suoi Giang and Tap La are the two most potential.

Tin mineralization has taken place along the fracture systems oriented in NE-SW direction with dip angle of ~70-85^o. The morphology of ore zones is complicated. Ores that develop along fracture systems are usually in form of vein or vein nets type. At the intersection of the fracture systems, the mineralization became richer and more diversified. In some places, the casiterite ore

is dispersed in the original rock in the form of subhedral texture, or large casiterite crystals (up to 1mm to 2mm in size).

Based on research results, we have identified two main types of tin ore as follows:

- The quartz - cassiterite mineralization type: This ore type is mainly located in Ta Nang, Ma Ty. Cassiterite is usually concentrated in small quarzt bunch, whose size varies from a few centimeters to 20 centimeters.

- The quartz - sulphide - cassiterite mineralization type: In this type, ore minerals were observed in the greisenization rock along fracture systems. Especially, the Northeast-Shouthwest fractures with the dip angle of ~75-85^0 is the most common and most promising structure for tin mineralization in Du Long.

The result from 500 chemical samples indicated that tin content in 5 ore zones in Ma Ty -Du Long area is variable (Do Huu Tro et al, 2005; Dong Van Nhi et al, 2006; Luong Quang Khang et al, 2012; Nguyen Tien Dung, 2015).

The result also shows that the tin ore content in Suoi Giang changes from 0.1% to 0.81%, with an average of 0.35%, It varies irregularly with coefficient of variation is 92.5%. The thickness of ore bodies is from 1.0m to 3.6m, with an average of 2m. The length is from 80m to 340m, with average of 241m. The ore bodies are in vein form and steep dipping, and the common bedding direction is 140-150^0∠75-85^0. They are situated along the fractured zones oriented in the Northeast - Southwest direction, parallel to the boundary between the biotite granite of the Ca Na Complex and the effusive rock of the Don Duong Formation (Figure 9) (Table 2).

- In Tap La, the lowest tin ore content is 0.10% while the highest is 0.88%, average 0.31% and coefficient of variation is 131%, Sn content is very irregularly distributed. the minimum thickness is 0.8m, the largest 3.57m, with average of 1.86m. The ore bodies are complicated in shape, which is dominated by veins and pocket structure. The host rocks are mainly greisenized biotite granite situated at 290-300^0∠70÷80^0 and 220-240^0∠5÷10^0 in the contact between the biotite granite of the Ca Na Complex and the rhyolite of the Don Duong Formation (Figure 10) (Table 2).

- In Khe Den, Sn content unevenly varies from 0.1% to 0.43%, with an average of 0.28%. The thickness is increased from 0.6m to 1.1m and average of 0.73 m. The coefficient of variation changes special irregularly (280%), and the ore bodies are situated in the greisenization zone along the fracture systems at a bedding attitude of 100÷120^0∠70÷80^0 (Figure 12) (Table 2).

- In Dong Thong, mainly is the vein-structure ore bodies, Sn content is from 0.1% to 0.22%, with average of 0.16%, and the coefficient of variation is 59.3% which means that tin ore content changes irregularly. The thickness is from 0.65 to 2.0 meters, average of 1.15 m (Figure 11, Table 2).

Table 1. The table of general analytical results of the inductively coupled plasma samples at the tin ore zones (Do Huu Tro et al., 2005).

Content	Analytical Results (g/t)									
	Mo	As	Zn	Bi	Pb	Cu	W	Sn	Ta	Nb
Min	11		35	10	10	23	11	218	3	16
Max	610		774	761	1399	260	560	53346	18	115
Average	89.88		131.64	134.56	99.82	64.09	97.86	6452.64	7.77	43.03

Table 2. Statistical analysis of Sn content of 5 zones in Ma Ty - Du Long area.

Ore Zones	Min (%)	Max (%)	Average (%)	Sample Variance	Coefficient of variation (V%)
Suoi Giang	0.03	0.51	0.11	0.01	92.5
Tap La	0.03	1.44	0.2	0.069	131
Dong Thong	0.04	0.25	0.11	0.004	59.3
Khe Den	0.04	0.7	0.2	1.8	280
Ta Nang	0.04	0.79	0.11	0.01	85.9

- Tin ore in Ta Nang area have Sn content from 0.10% to 0.79%; average of 0.345, the coefficient of variation is 85.9%, Sn content is irregularly distributed. The thickness is from 0.6 to 1.2 meters; with average of 1m, bedding $100 \div 150^0 \angle 75 \div 80^0$. They have complicated shape: bunch and vein ore (Figure 13, Table 2).

4.4. Resource of tin ore in Ma Ty - Du Long area

The potential of tin ore in the research area was evaluated base on morphological characteristics, size and the bedding of ore zones determined during prospecting and field investigation. Taking tin ore density of 2.7 t/m^3,

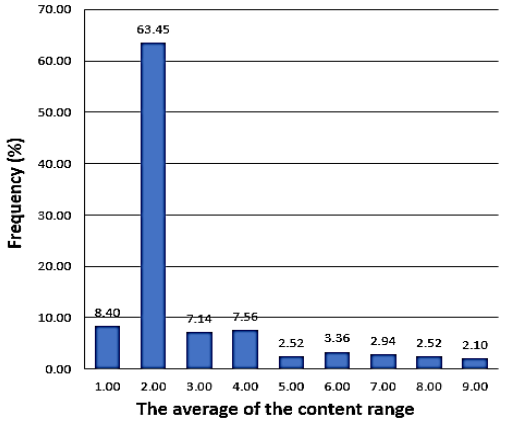

Figure 9. The Frequency graph of tin content in Suoi Giang.

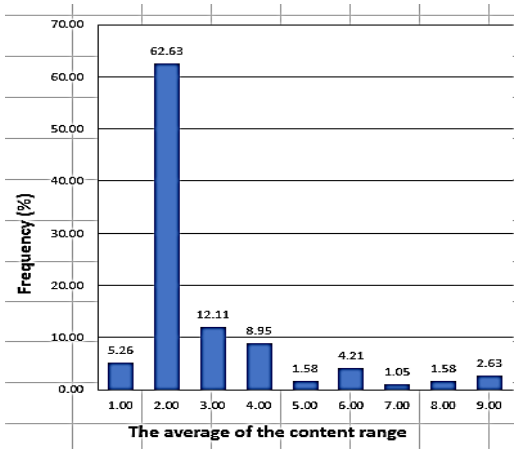

Figure 10. The Frequency graph of tin content in Tap La.

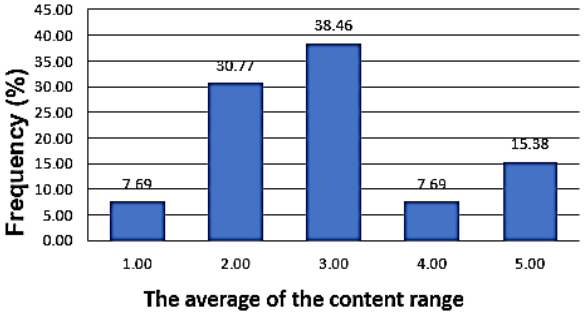

Figure 11. The Frequency graph of tin content in Dong Thong.

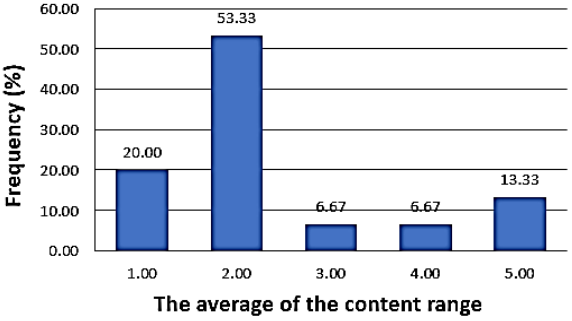

Figure 12. The Frequency graph of tin content in Khe Den.

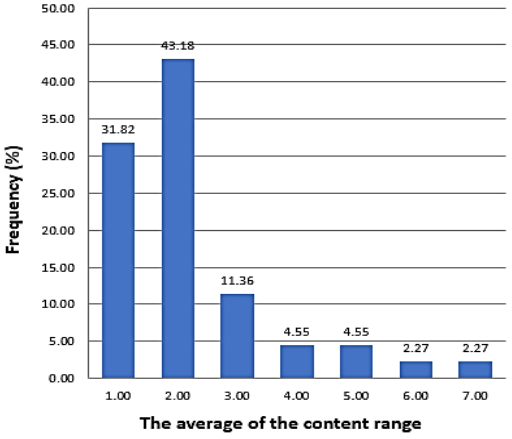

Figure 13. The Frequency graph of tin content in Ta Nang.

the thickness is a summation of ore-bearing sample lengths with Sn content ≥ 0.1%; the length was determined and predicted on the basis of detail prospecting results. The depth is predicted to be one-fourth the length of the ore body according to Guver's rule, total tin resources was estimated at 334a category and presented in the Table 3 below:

Table 3. Resource of tin ore in the Ma Ty-Du Long area.

No	Ore zone	Ore resource (ton)	Metal resource (ton)
1	Suoi Giang	35,907	3,950
2	Tap La	4,821	964
3	Dong Thong	4,358	479
4	Khe Den	399	80
5	Ta Nang	4,496	495
	Total	49,980	5,968

5. Conclusions and recommendation

Tin mineralization in the study area show complicated forms developing in the contact between granitoid rocks of the Ca Na Complex and the volcanic rock of the Don Duong Fornation. The industrial ores bodies are situated in greisenization zones along the Northeast - Southwest fracture systems, the dip is 75-85^{o}, a few ore bodies are in the intersection of two fracture systems. The mineral composition of primary ore is mainly pyrite, specularite, cassiterite, magnetite, chalcopyrite, less galenite, sphalerite, molidenite, wolframite.

Total tin resource of the Ma Ty - Du Long area estimated at 334a category is 49.980 tons of tin ores and 5.968 tons of Sn. Based on the results of the study, the Maty - Du Long is a very promissing area in terms of tin mineralization. Therefore, a comprehensive assessment is vital to clarify the characteristics and potential of the primary tin ores for the whole studied area. On that basis, selected the potential areas for investment plans with different levels of research in each area accordingly. The priority should be put on Suoi Giang area, which has the largest Sn-ore volumes in the Maty - Du Long area with the Sn content changes irregularly.

References

Decision No 06/2006/QD-BTNMT: Regulations on classification of solid mineral resourcesand reserves. *Minister of Natural Resources and Environment of Vietnam* (2006).

Do Huu Tro, Nguyen Manh Hai, Nguyen Duc Hiep, Dao Huu Lien, Hoang Dinh Luat, Nguyen Duc Quan, Duong Ngoc Tinh, Nguyen Thanh Vien, 2005. Report on evaluation of original tin ore in Ma Ty - Du Long, Ninh Thuan. North central Geological Division. *General Department of Geology and Minerals of Viet Nam*.

Dong Van Nhi, Luong Quang Khang, Nguyen Phuong, Van Nguyen Lam, 2006. *Lecture of geological information processing Methods for geological investigation survey*. Ha Noi university of mining and geology.

John, C. D, 2002. Statistics and Data Analysis in Geology. New York J. Wiley.

Luong Quang Khang, Bui Hoang Bac, Tran Le Chau, 2012. Research on characterization and potential of tin ore at Chau Tien area, Nghe An province, Viet Nam. *Proceedings of the 2nd international conference on Advances in Mining and Tunneling*, August 23-25, Ha Noi, Viet Nam. 27-30.

Martin, O., Gerald, O., 2011. Mineralogical Characterization of Kuru Cassiterite Ore by SEM-EDS, XRD and ICP Techniques. *Journal of Minerals & Materials Characterization & Engineering 10(9)*. 855 - 863.

Nguyen Tien Dung, 2015. Characteristics of quality and potential of pegmatite feldspar in Dai Loc, Quang Nam. *Journal of mining and earth sciences 51*. 31-38.

Nguyen Tien Dung, Bui Hoang Bac, Do Manh An, Tran Thi Van Anh, 2017. Distribution and Reserve Potential of Titanium-Zirconium Heavy Minerals in Quang an Area, Thua Thien Hue Province, Vietnam. Advances and Applications in Geospatial Technology and Earth Resources. 326-339.

Nicholas, J. G., John, P. S., Allan, T., Laurence, J. R., 2015. Tin mining in Myanmar: Production and potential. *Resources Policy 46*. 219-223.

Sri, H., Shinta, V., Eva, A., 2014. Characterization of indonesia rare earth minerals and their

potential processing techniques. *Conference: Rare Earth Elements.*

Viet Tiep Division, 1986. Mapping geology and minerals in Phan Rang (Ninh Thuan province) - Cam Ranh (Khanh Hoa province) scale 1: 50.000. Center for information and archives geology. *General Department of Geology and Minerals of Viet Nam*.