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Re-Evaluation of Uranium Resources in Batubulan Sector, Melawi, West Kalimantan

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ABSTRACT

Batubulan Sector, Melawi, has a relatively high occurrence of uranium. Several exploration activities have been conducted since 1973 in this region. The study is conducted by surface geological mapping, radiometric mapping, borehole logging, and resources estimation to determine the subsurface properties, geometry, mineralization direction, and speculative uranium resources in the Batubulan Sector. Based on these researches, the geology of the Batubulan Sector is composed of metamorphic rocks, metasedimentary rocks, and intrusive rocks with coarse and fine grain sizes. Uranium mineralization has been found in a spotted form in the veins with a maximum thickness of 10 cm and has a high radioactivity concentration of about 15,000 c/s. The lithologies of the study area consist of metapelites, quartzite, micro biotite, and meta-tuff. Drilling and borehole logging activities are conducted at four boreholes with a total depth of about 400 m and 75 – 120 m each. Based on resources estimation, the speculative resources of uranium (U_3O_8) in the Batubulan Sector are about 540 tonnes. It is necessary to conduct more advanced and more systematic exploration methods to estimate uranium resources in this area.

Keywords: Batubulan, logging, uranium, radioactive mineral, resources

INTRODUCTION

Nuclear energy has become one of the alternative energy sources which is much more effective than other conventional energy sources, like coal, oil, or natural gas. Radioactive mineral, like uranium, is one of the critical minerals used as a core element of nuclear fuel. For that reason, uranium resources estimation in all potential sectors is necessary to support the sustainable establishment of the development of nuclear power plants in Indonesia.

Batubulan Sector, Melawi, has a relatively high occurrence of uranium. Batubulan Sector is located on the banks of Ella River in Ella Ilir District, Melawi Regency, West Kalimantan. The radioactive mineral exploration activities were conducted in this region from 1973 to 1992 [1–4]. Those studies concluded significant radiometric anomalies in the veins of magnetite, pyrite, apatite, tourmaline, quartz, and feldspar intruded metamorphic rocks and magnetite lenses in granite. Those veins have 1.5 – 6 m length and NW – SE direction.

Generally, The uranium mineralization characteristic is vein–shaped, which can be found in fractures. Those veins have 1–30 cm width, NW–SE strike direction with northwest to vertical dip direction, and 250 – 15.000 count per second (c/s) radioactivity. The mineralogy and positive autoradiography analyses determine that the minerals in these veins are uraninite [3]. The lithology and uranium mineralization characteristics have also been identified on the microscopic scale.

Therefore, it is necessary to conduct an advanced comprehensive study to define and determine the potential for uranium in those areas. The study aims to determine the subsurface properties, geometry, mineralization direction, and speculative resources of uranium in the Batubulan Sector.

METHODOLOGY

The study uses various literature studies, surface geological mapping, radiometric mapping, borehole logging, and resources estimation. The literature study is based on the previous research and exploration report of the study area and surroundings. Surface geological mapping is observing the variety and mineralogy property of the outcrops while emphasizing the occurrences of uranium mineralization. Radiometric mapping measured the radioactivity of the study area by using an RS-125 spectrometer. Core analysis and borehole logging determine the lithology and in-situ radioactivity in four boreholes: BB-01, BB-02, BB-03, BB-04. Furthermore, geological surface interpretation, radiometric measurement, and borehole logging data are used as a reference for resources estimation of uranium ore (U_3O_8).

Geology of Batubulan Sector

Regionally, the geology setting of Ella Ilir consists of Pinoh Metamorphics (PzRP) and Sepauk Tonalite (Kls) [5,6] (Figure 1). Pinoh Metamorphics consist of muscovite-quartz schist, phyllite, slate, hornfels, some metatuff, quartzite, andalusite, cordierite, and biotite in places; sillimanite and garnet are rare. Sepauk Tonalite consists of light grey biotite-hornblende tonalite and granodiorite; some diorite, granite, monzodiorite, and quartz diorite. Pinoh Metamorphics was formed in the Paleozoic – Triassic, and Sepauk Tonalite are formed in Lower Cretaceous [7,8]. However, U-Pb zircon dating on metapelites of Pinoh Metamorphics shows that the volcanogenic protolith was created in the Early Cretaceous, 130 million years ago [9,10], while Sepauk Tonalite was formed in Jurassic–Triassic (157 – 177 million years ago) based on K-Ar dating [11].

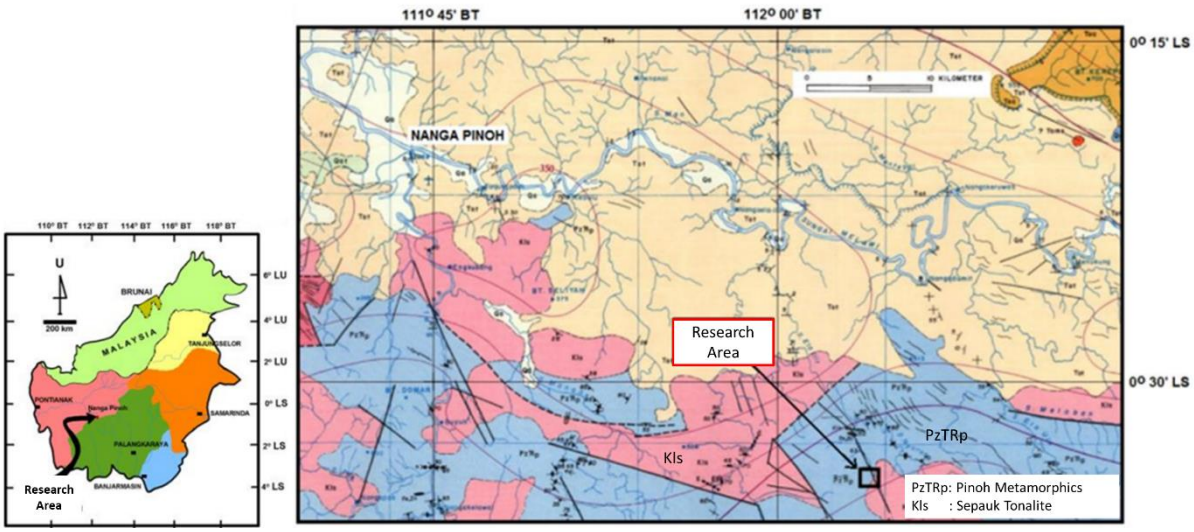

Figure 1. The Regional Geology Map of The Study Area and Its Surroundings [4,5]

RESULTS AND DISCUSSION

The lithology of the Batubulan Sector is mainly composed of metamorphic rocks, metasedimentary rocks, and igneous rocks. Metamorphic rocks consist of micro-biotite quartzite, and hornfels. Metasedimentary rocks consist of metapelites and metatuff, while igneous rocks consist of dolerite. The geological map of the study area is shown in Figure 2.

Metapelite is greyish white, clay – silt grain size, blastopelitic texture, mineralogy consisting of quartz, mica, and feldspar, massive structure, parallel dike in place. Metatuff is grey to dark grey, fine to coarse ash grain size, blastosapmitic texture, mineralogy consisting of quartz, feldspar, biotite, rounded blue cordierite in place, poor sorting, quartz-feldspar lenses or veins in place with 20 cm length and 0.5 to 1 cm width. Micro–biotite quartz is grey, fine to medium sand grain size, blastopsamitic texture, mineralogy consists of quartz, biotite, feldspar, and muscovite. Hornfels is dark grey, silt to fine sand grain size, massive structure, granoblastic texture, mineralogy consisting of quartz and biotite. Hornfels appears as lenses in metatuff. Dolerite is black, has a fine crystal size, inequigranular texture, and mineralogy consisting of olivine.

Geological structures which developed are rock strata, foliation, and fault. The rock layers have NW – SE strike direction and 65º–83º dipping to SW, while foliations are NW – SE strike direction and 80º – 85º dipping to SW. Lineaments and mylonitic outcrops indicate the faults.

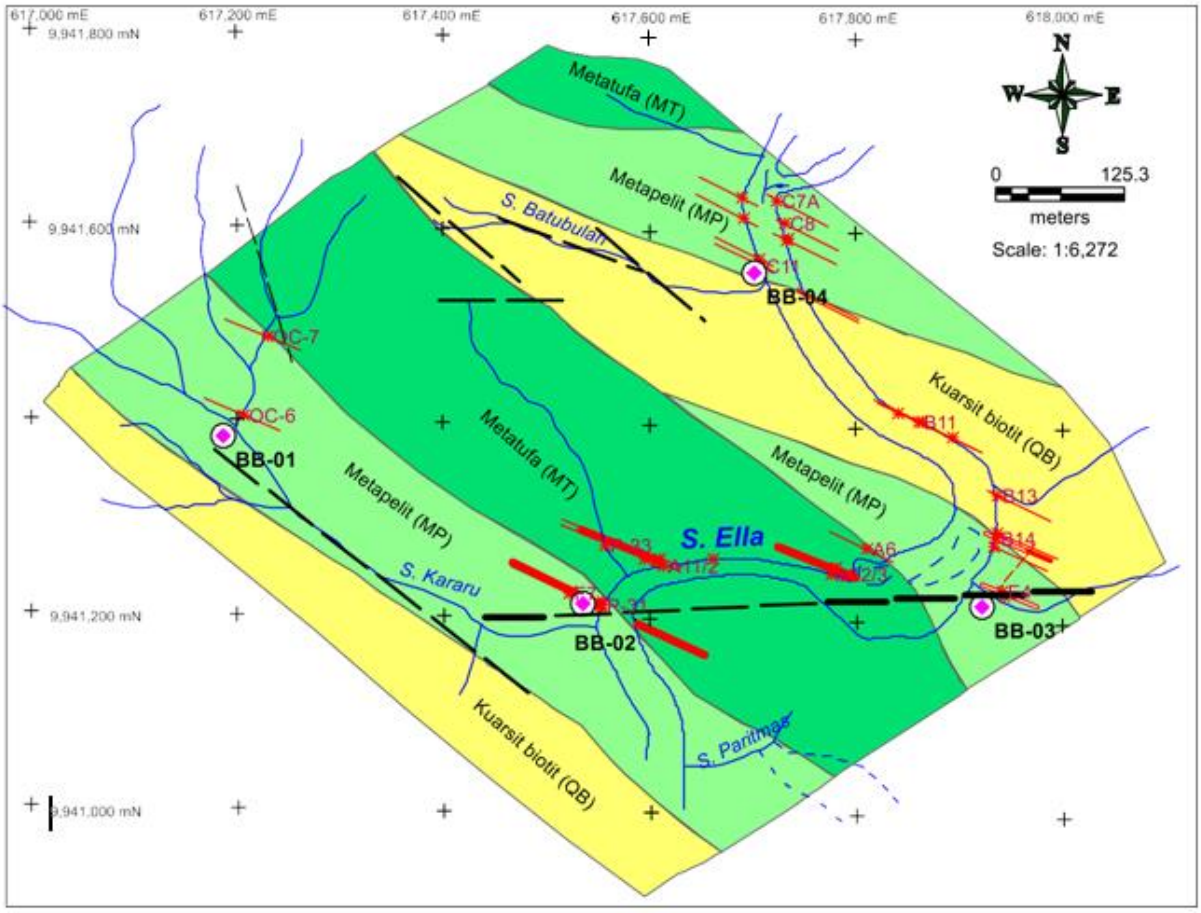

Figure 2. The Geological Map of the Batubulan Sector

Radioactive Mineralization

The radioactivity of the outcrops from radiometric mapping in the study area indicated that there are occurrences of radioactive mineralization. Generally, radioactive mineralization occurrences in Melawi, especially in Kalan, are associated with tourmalines and sulfide minerals [11–15]. Mineralization outcrops most likely related to radioactive minerals in Batubulan Sector are divided into two mineralization types: magnetite brecciation and vein-type (Figure 3).

Magnetite brecciations in Batubulan Sector are mainly located at the banks of the Ella River. Three (3) distinctive magnetite brecciation outcrops were identified in the study area (B1, B2, and B3). Magnetite brecciation-01 (B1) is located at the west bank Ella River. This outcrop height is >25 m and >90 m wide. By megascopic observation, B1 is brownish-black, massive structure, uranium mineralization is indicated by high radioactivity (300 – 2,000 c/s), uranium (U) grade is 392.6 ppm, and thorium (Th) grade is 0 ppm, found spotted or parallel orientation in place in breccia.

Magnetite brecciation-02 (B2) is located at the west bank of Ella River, 66 meters northward of B1. This outcrop spread continuously to the southeastern and northwestern sides of the river. The megascopic appearance of B2 is brownish-black, massive structure, very resistant, uranium mineralization is indicated by high radioactivity (2,700 c/s), U grade is 380 ppm, and Th grade is 0 ppm, formed as mineralization breccia associated with pyrite and tourmaline, 70 cm width, N 125^o E /50^o - 70^o E orientation. This bedding spread continuously to the northwest with a radioactivity value of 3,000 – 5,000 c/s, U grade is 315 – 699.7 ppm. Borehole BB-02 is located there.

Magnetite brecciation-03 (B3) is located at the west bank of Ella River, 195 m eastward of B2. B3 is lenses shaped, has a 50 m length, and is more than 5 m wide. Uranium mineralization is identified as spotted parallel with magnetite brecciation orientation. The highest radioactivity measured is 2,000 c/s, U grade is 172 ppm, Th grade is 18.7 ppm.

Other uranium mineralizations appeared as boudinage veins found at A6, B14A, B14, B13A, B13, B12, B11, B10, and OC-08. Those veins are collectively grouped into a 150 m width mineralization zone (middle zone). Those veins individually have 10 – 50 cm width, NW – SE direction, dipping 75^o to vertical to SW. Association minerals between each of the veins are not similar. Vein A6 has N 130^o E/74^o E orientation associated with quartz tourmaline, feldspar, and hematite with a 5 – 10 cm width. Radioactivity in this vein is 4,500 c/s, and U grade is 662 ppm. Vein B14 has lithology of schistose metapelites, reddish-brown color, strong silicification, U mineralization has 0.5 m width, mineralogy consists of feldspathic quartz vein, tourmaline, iron oxide, and pyrite. U mineralization orientation is N 130^o E /65^o E, radioactivity is 12,000 c/s, U grade is 2,965 ppm, and Th grade is 0 ppm. The mineralization beds of the middle zone became the main target of borehole BB-03, especially at B14 and OC-08.

Another group of mineralization veins is located in the north of Batubulan Sector, near the estuary of Batubulan River (north zone). Those outcrops are located at C7, C8, C9, and OC-9 in the eastern of Ella River. C7 consists of metapelites, and mineralization is formed as a vein of 0.1 m width. The north zone collectively has 80 m width, consist of centimetric – decimetric sized veins,

radioactivity values ranging from 1,000–10,000 c/s, U grade is between 318.7 – 1,026 ppm, Th grade is between 0 – 6.6 ppm.

Mineralogy consists of feldspathic quartz and a little tourmaline, and radioactivity is 4,000 c/s, U grade is 519.6 ppm, Th grade is 6.1 ppm, located in place along the vein. C9 appeared as schistose metapelites light brown; U mineralization is found in tourmaline vein, molybdenite, pyrite, pyrite vein, and biotite. Its radioactivity is 4,000 – 10,000 c/s, U grade is 609.5 – 1,026 ppm. The north zone became the main target of borehole BB-04. Other outcrops, such as OC-07 and OC-06 near Kararu River, also have high radioactivity (750 c/s). Therefore, this location has become a drilling point of BB-01. The mineralization outcrops and borehole points are shown in Figure 2.

Figure 3: Outcrops of a. B1, b. B2, c. C7, and d. C9

Borehole Logging of BB-01

Borehole BB-01 is referred to the orientation of OC-06 mineralization, which has a direction of N 120º E/80º SW. This borehole has N 45° E azimuth, 65° NE inclination, and 75.11 m depth. The subsurface lithology of BB-01 is metapelites, fine-grained size, grey to light grey color due to silicification, intercalation of quartz and micro muscovite in place, moderately fractured. Mineralization is identified as bedded and pinched vein associated with feldspathic quartz, pyrite, biotite, and tourmaline.

Radioactive anomaly measured by RS 125 can be found in several intervals, as seen in Table 1. Based on geophysical well logging, there are radioactive anomalies in several intervals, as seen in Table 2. The borehole profile is shown in Figure 4.

Table 1. Radiometric measurement and anomalies on BB-01rock cores

Depth (m)	Width (m)	Radioactivity (c/s)	Mineral Association
43,65	0.055	200	pyrite and less tourmaline
45,20	0.02	300 – 350	pyrite and less tourmaline
45,60	0.02	200	pyrite and less tourmaline, 24.4 ppm eU, and 9.9 ppm eTh
45,75	0.005 – 0.015	250	pyrite and less tourmaline, 31.3 ppm eU, and 9.3 ppm eTh.
61,60	0.01 – 0.02	750	pyrite and less tourmaline, 31.3 ppm eU, and 9.3 ppm eTh.

Table 2. Radioactivity anomalies from geophysical logging on BB-01 borehole

Depth (m)	Width (m)	Radioativity (c/s)
44,60 – 45,80	1.2	<100 – 647.5
60.95 – 61.20	0.25	<100 – 381.9
68.60 – 69,25	0.65	<100 – 12,071.8

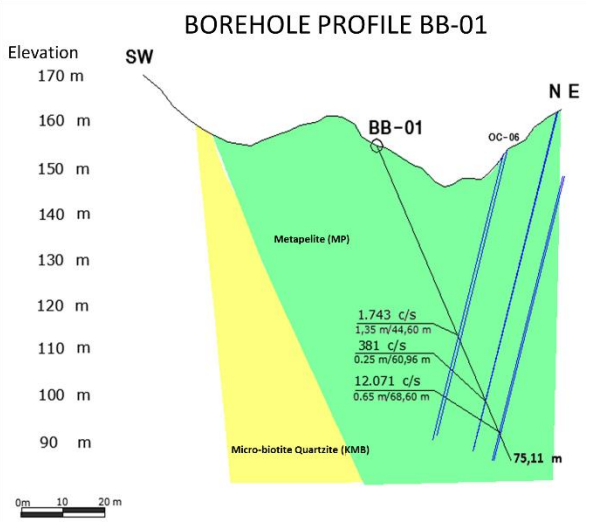

Figure 4. Borehole profile of BB-01

Borehole Logging of BB-02

Borehole BB-02 has N 20° E azimuth, 60° NE inclination, and 85.45 m depth. The subsurface lithology of BB-02 is metapelites and metatuff, fine-grained size, grey to light grey color due to silicification, intercalation of micro quartzite in place, moderately fractured, and intensively fractured in a particular interval. Mineralization is identified as magnetite brecciation from 1.19 – 7.50 m interval with radioactivity is 90 c/s. In 7.50 m– 17.48 m interval is specified as sulfide veins (pyrite mostly), centimetric width, interbedded with feldspathic quartz, but low radioactivity.

Uranium mineralizations are indicated at intervals 49.10 – 49.80 m (radioactivity is 750 c/s, spotted, associated with pyrite), 52,00 m, 67.95 m, 73.80 m, and 80.40 m (radioactivity is 240 c/s, formed as nodules, millimetric to 3 cm sized). Based on geophysical well logging, there are radioactive anomalies in several intervals, as seen in Table 3. The borehole profile is shown in Figure 5.

Table 3. Radioactivity anomalies from geophysical logging on BB-02 borehole

Depth (m)	Width (m)	Radioativity (c/s)
3.30 – 3.55	0.25	<100 – 175.92
27.90 – 28.10	0.20	<100 – 12.071,8
48.80 – 50.15	1.35	<100 – 1.743,16

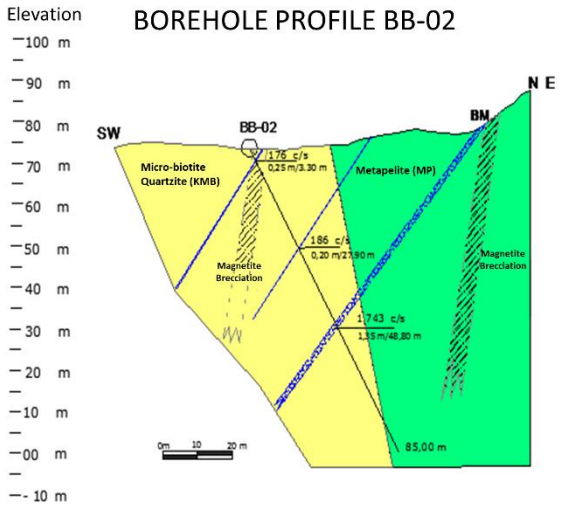

Figure 5. Borehole Profile of BB-02

Borehole Logging of BB-03

Borehole BB-03 is referred to the orientation of OC-06 mineralization, which has a direction of N 120^o E/80^o SW. This borehole has N 40° E azimuth, 60° NE inclination, and 121.79 m depth. The subsurface lithology of BB-03 is interbedding of metapelites and hornfels, also dolerite from 103 – 121.79 m depth. This borehole is intensively fractured. Mineralization is identified as magnetite brecciation with 1.40 m width, consisting primarily of magnetite with less sulfide. At interval 28.35 – 32 m, there is a magnetite breccia zone, feldspathic quartz, and pyrite. The radioactive anomaly was barely found at intervals 70.05 – 70.65 m, where maximum radioactivity was 298.13 c/s. The borehole profile is shown in Figure 6.

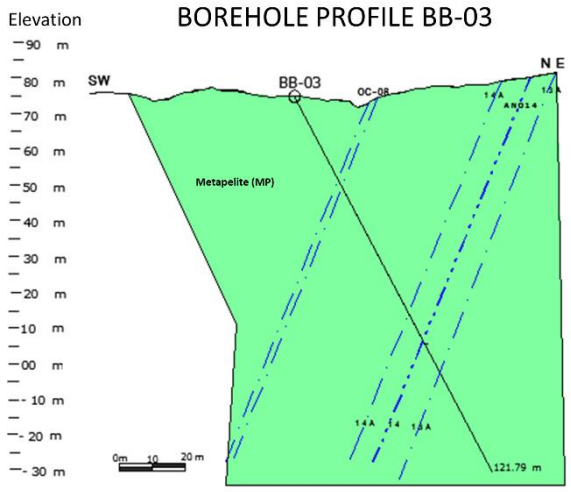

Figure 6. Borehole Profile of BB-03

Borehole Logging of BB-04

Borehole BB-04 is referred to the orientation of U mineralization that occurs intensively at both banks of northern Ella River near Batubulan River estuary. This borehole has N 42° E azimuth, 60° NE inclination, and 121.49 m depth. The subsurface lithology of BB-04 is biotite quartzite, hornfels, and metapelites (0 – 21.26 m), massive andesite (21.26 – 63.0 m), and Schistose metapelites with feldspathic quartz vein in its fracture (63 – 121.49 m). Schistosities along boreholes are very intensive, and some of them are filled by uranium–associated mineralization.

There are mineralization zones at several intervals, such as 76.10 – 76.50 m (750 c/s), 77.10 – 77.40 m (750 c/s), and 109.20 – 110.10 m (300 c/s). The mineralization zones in this borehole are associated with pyrite, tourmaline, and quartz. Radioactivity anomalies from geophysical logging are shown in Table 4. The borehole profile is shown in Figure 7.

Table 4. Radioactivity anomalies from geophysical logging on BB-02 borehole

Depth (m)	Width (m)	Radioativity (c/s)
75.60 – 76.95	1.35	<100 – 3.012,29
108.70 – 109.65	0.95	<100 – 1361,14

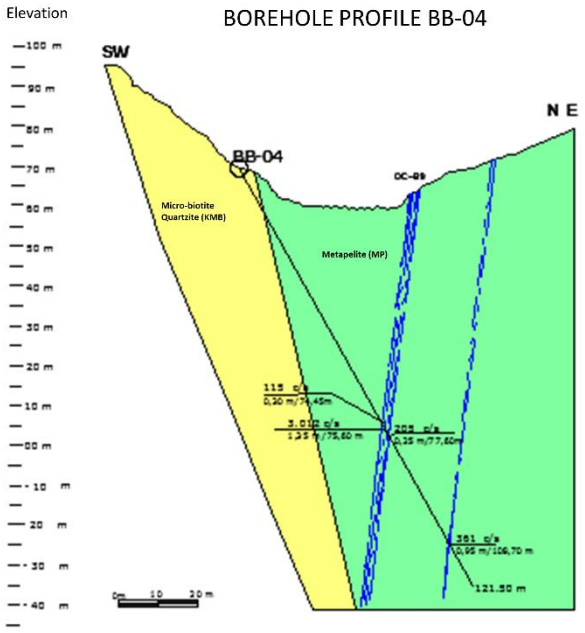

Figure 7. Borehole Profile of BB-04

Resources Estimation

The resources estimation of uranium ore (U3O8) is shown in Table 5. Resources

estimation is conducted by using borehole log data, especially collar (borehole coordinate), survey (borehole azimuth and inclination), and quality (geological data at respective depth intervals) which be processed by resources modeling software. The uranium resources in Batubulan Sector are estimated at 540 tonnes U_3O_8.

Table 5. Resources Estimation of Batubulan Sector

Borehole	Ore Name	Volume (m^3)	U_3O_8 (ppm U)	Density (g/cm^3)	Tonnage	Total
BB-01	ore1	21,590	314	3.2	21.6936	**319.3623**
	ore2	4,787	278	3.2	4.2585	
	ore3	11,942	7,678	3.2	293.4102	
BB-02	ore1	10,201	105	3.2	3.4275	**107.2755**
	ore2	54,345	585	3.2	101.7338	
	ore3	7,682	86	3.2	2.1141	
BB-03	ore1	14,124	153	3.2	6.9151	**6.9151**
BB-04	ore1	18,553	1,544	3.2	91.6667	**106.4891**
	ore2	23,160	200	3.2	14.8224	
Resources Estimation (tonnes)						**540.04**

CONCLUSION

Uranium mineralization zones in the study area are mainly formed as magnetite brecciation or veins, which became the reference point for four borehole drilling (BB-01, BB-02, BB-03, and BB-04). The boreholes have convincingly projected the spreading of the uranium mineralization zone in the subsurface. The resources estimation of U_3O_8 from the boreholes in the Batubulan Sector is 540 tonnes. However, due to the width interval of the ore being extensive (more than 400 m) and lateral spreading of the ore is still based on mineralization orientation, the resources category is speculative. It is necessary to conduct a more advanced and more systematic exploration method to enhance the resources estimation in Batubulan Sector.

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