Geological Study of Graphite Petrogenesys in Southeast Sulawesi

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Abstract - Kolaka area has quite interesting geological phenomenon by discovered graphite minerals that formed in metamorphic rocks. Graphite is one of the non-metals C carbon allotrope that have conductive properties to electricity and its origin from organic material. Metamorphic rocks of Southeast Sulawesi, precisely in Kolaka has two metamorphic formations with different age in regional geology, they are Mekongga Complex (Carbon) and Pompangeo Complex (Cretaceous-Paleogene). Lithology of the Mekongga Complex consists of dominantly schist (muscovite-quartz-chlorite-graphite), and green schist. Pompangeo Complex composed by phyllite (muscovite-quartz-chlorite-calcite-graphite), green schist, and limestone. Bearer rocks of graphite of research area are graphitic schist in Mekongga Complex and graphitic phyllite in Pompangeo Complex. In this area, magma activity produced intrusion (dyke), that process helped the maturation process of graphite. Petrographic results of these two locations show the presence of graphite with sizes ranging from 0.2-0.8 mm in thin section, graphite was accumulated in foliation of rocks. Graphite characterization was conducted based on characterization of petrographic, LoI, XRD, and EDS-SEM.

Keywords: graphite, carbon, Southeast Sulawesi, Pompangeo Complex

INTRODUCTION

Kolaka area is part of Southeastern arm of Sulawesi and has quite interesting geological phenomenon in terms of tectonics, lithology, and stratigraphy. Metamorphic rock in this research area contain graphitic phyllite, schist, and gneiss. Graphite commonly found in metamorphic rocks that quite wide-spread covering the Mekongga Hills to Kendari area. The Mekongga and Pompangeo Complex are the host rocks of graphite. Graphite belongs to mineral group C (non-metals). The characteristics of graphite are unique, it can be withstand in high temperatures and is able to conduct electricity. Graphite is formed due to changes in organic material during metamorphism and other geological processes.

This research aims to know physical properties of containing graphite in the Pompangeo and Mekongga Complex, its generation and inherited protolith.

DATA AND METHOD

METHOD

Methods that used in this research activity are geological observation (literature review, collecting field data/rock sampling and drilling, geological mapping, and geophysical survey), petrographic analysis, and analysis of LoI, EDS-SEM and XRD (to determine the quantity of rock minerals).

REGIONAL GEOLOGY AND STRATIGRAPHY

"K" shape of Sulawesi Island reflects the complexity of tectonic that occurred in there. Sulawesi Island and its surrounding area have four tectonic activities (Simandjuntak, 1993 in Surono, 2010), are namely: Cordileran Subduction Type (Cretaceous); Mesozoic Tectonic Divergent; Tethyan Subduction Type (Neogene); and Quaternary Subduction.

Hall (1996) reconstructs the evolution history of tectonic plates that begin from the splitting of northern edge of Australian or still known as Gondwana. The reconstruction shows that Southeast Sulawesi is part of East-Sulawesi-Ophiolite Plate, whereas Tukangbesi and Banggai-Sula are part of Bird Head Continent.

The metamorphic rocks that contain graphite occupy Mekongga and Pompangeo Complex (Rusmana et al., 1993 and Simandjuntak et al., 1993). Both complexes have different geological age, Mekongga complex is the oldest complex in Southeast Sulawesi with lithology schist, gneiss, phyllite, quartzite, and slate. Pompangeo Complex formed younger than Mekongga Complex, the lithologies are mica schist, glaucophane schist, amphibolite schist, chlorite schist, layered chert, gneiss schist, marble, and meta-limestone.

Research area composed by grouping the dominant lithology that can be observed in the field. Mekongga Complex can be grouped into five rock units, from older to younger as follows:

- Quart-muscovite-chlorite-graphite-siliceous schist unit;
- Green schist unit (Quartz-chlorite-siliceous schist);
- Quartz-muscovite-chlorite-graphite-carbonate schist unit;
- Intercalation of muscovite-quartz-graphite-siliceous schist with calcareous schist unit; and

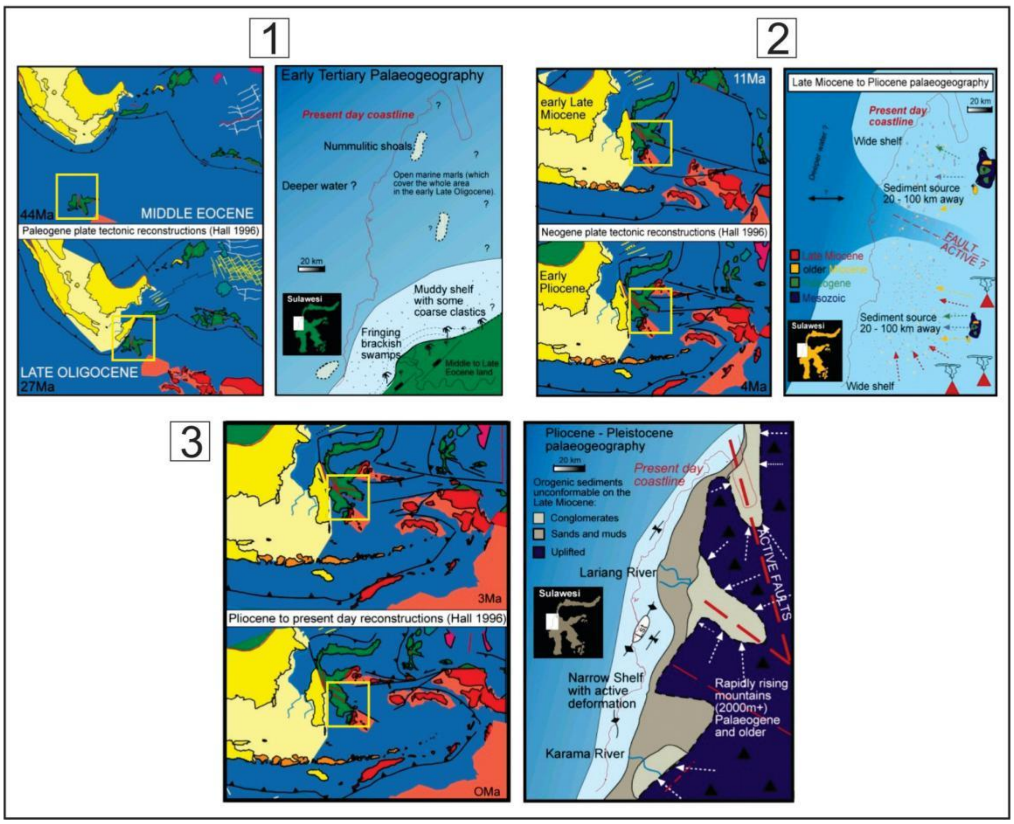


Figure 1. Reconstruction of tectonic plates of Sulawesi (Middle Eocene – Present) (Hall, 1996).

GEOLOGY OF THE MEKONGGA AND POMPANGEO COMPLEX

Mekongga Complex (PT. Mekongga Sejahtera) and Pompangeo Complex (PT. Trans Jawa Sulawesi) are in different basin, yet both basins have economic value to produce graphite.

- Travertin unit

Meanwhile, Pompangeo Complex composed by 3 rock units, from older to younger as follows:

- Intercalation of slate-phyllite-graphitic unit;
- Intercalation of green schist with meta-sandstone unit; and

- Crystalline limestone unit.

Based on data results, graphite from Mekongga Complex is quantitively contained in quartz-muscovite-chlorite-graphite-siliceous schist unit and quartz-muscovite-chlorite-graphite-carbonate schist unit, whilst in Pompangeo Complex it is contained in intercalation of slate-phyllite-graphitic unit.

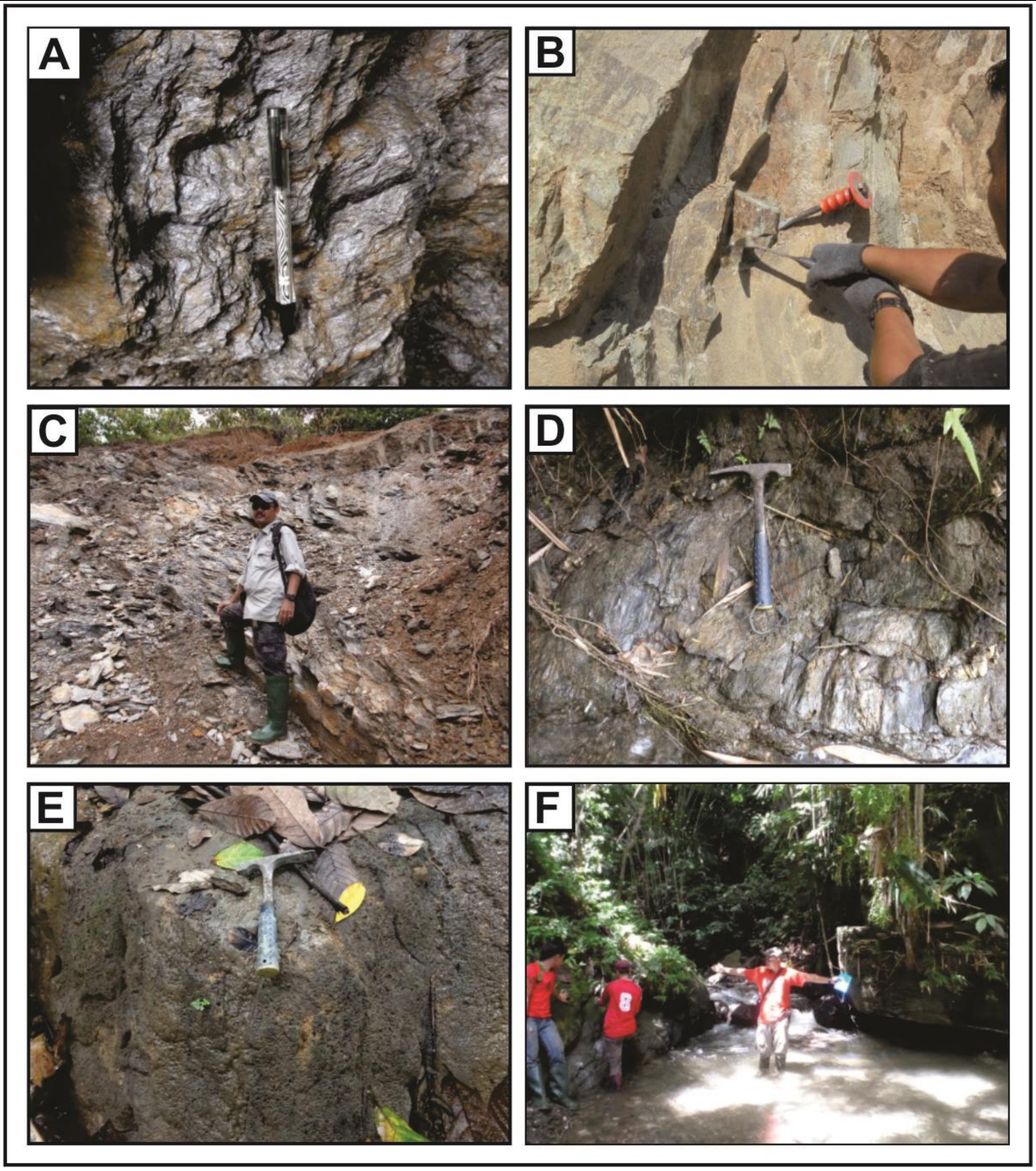


Figure 2. Figure of outcrop in Mekongga Complex A) Quartz-Muscovite-Chlorite-Graphite-Siliceous Schist Unit, B) Green Schist outcrop, C) Quartz-Muscovite-Chlorite-Graphite-Carbonate Schist Unit, D) Intercalation of Muscovite-Quartz-Graphite-Siliceous Schist with Calcareous Schist Unit, E) Travertin Unit, F) Fault plane in Quartz-Muscovite-Chlorite-Graphite-Siliceous Schist Unit.

Figure 3. Figure of outcrop in Pompangeo Complex A) Intercalation of slate-phyllite-graphite unit, B) Intercalation of green schist-meta-sandstone and phyllite, C) Crystalline limestone.

Figure 4. Intrusion outcrop in research area.

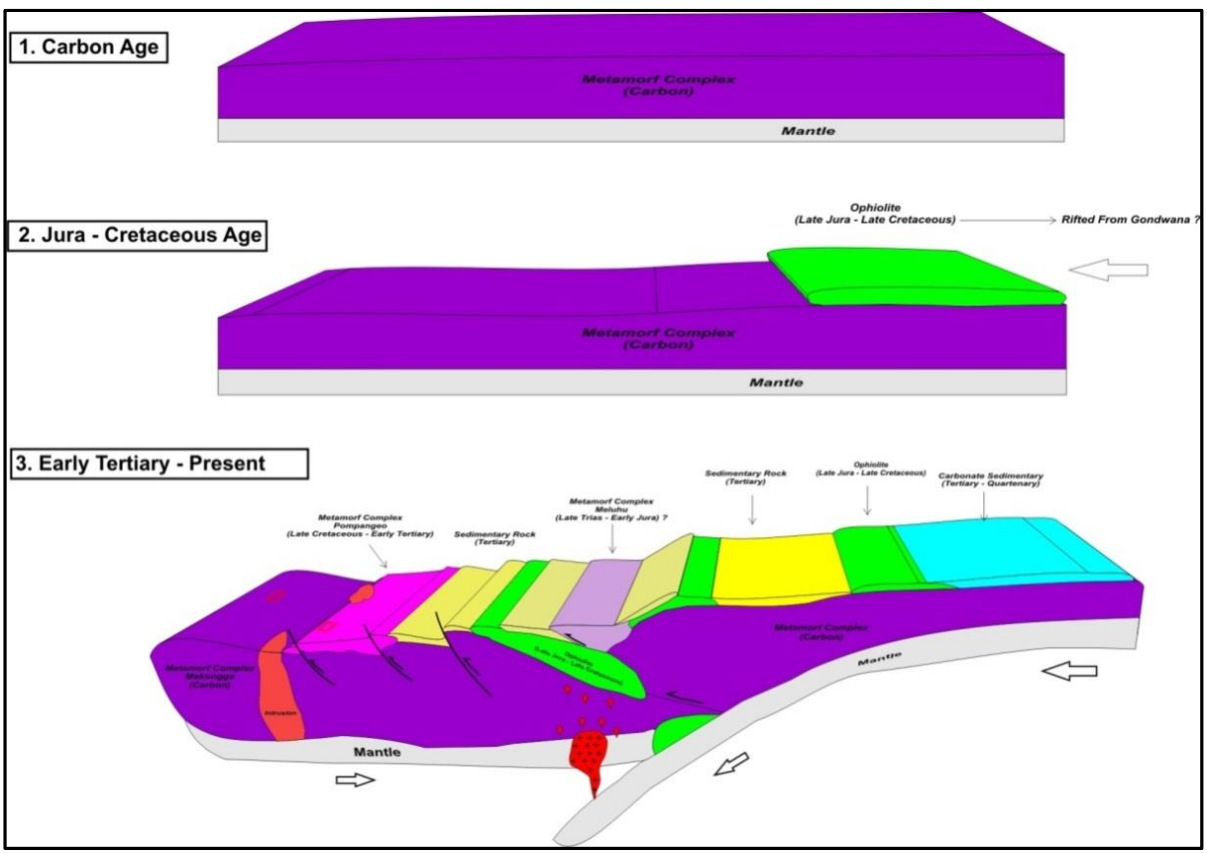


Figure 5. Reconstruction of geological history of research area.

GEOLOGY AND BEARER ROCK CHARACTERISTIC OF GRAPHITE IN KOLAKA AREA

Graphite of two complexes are derived from organic material deposition inside its protolith, then metamorphism processes occured caused by heat/temperature (T) and pressure (P). Bearer rocks of graphite in both complexes are graphitic schist (Mekongga Complex – PT. Mekongga Sejahtera) and graphitic phyllite (Pompangeo Complex – PT. Trans Jawa Sulawesi).

Bearer rocks of graphite have unique characteristic in its forming processes. Field data and laboratory analysis show that there is a lot of carbonate minerals (calcite). Calcite presents as catalyst during formation of graphite (metamorphism processes), also acts as cement of bearer rock of graphite. Therefore formed-graphite is covered up by calcite. In this case, calcite as polluter during purifying process.

Magma activity that continues over time help the maturation process of graphite. Migmatite process occurred and produced intrusive body (dyke) in this research area, thus affecting the maturation process of graphite.

RESULT AND DISCUSSION

Graphite quality is determined by its purity, crystallinity, shape and size of particle, surface, and porosity (Figure 6.). These factors would be important evaluation of graphite, especially mineralization confirmation, it may affect application areas and consideration of economic value. Information of carbon content or purity of graphite can be determined by various methods, i.e. LoI (ASTM C709) and LECO. Crystallinity of the samples tested by using XRD spectrometer. Distribution information and size of the graphite at the host rock can be obtained using petrographic analysis. Porosity information and graphite surface can be confirmed by using SEM and TEM techniques.

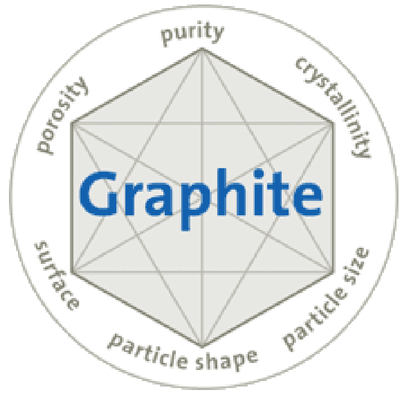


Figure. 6. Characterization of graphite quality.

Characterization of Graphite
By using LoI technique

LoI presents simple and effective techniques to examine graphite content. This technique is very useful to test large number of samples and products resulting from beneficiation. Table 1. shows list of graphite content that produced by LoI technique (ASTM C709).

Table 1. Result of LoI test (Duplo) for determination of graphite.

No.	Sample Code	Ash Content (%)	LoI (%)	Average LoI (%)
1	Graphite ore	93.55	6.45	6.42
		93.61	6.39	

Titration

Generally, graphite ore appear together with carbonate minerals. Titration is done to determine carbonate content inside the ore. The characteristic of carbon between graphite and carbonate is almost similiar, so it can not be identified by LoI.

Petrographic Analysis

Analysis of petrography that have been done before show the percentage of presences of graphite and other minerals in thin section. Information of graphite

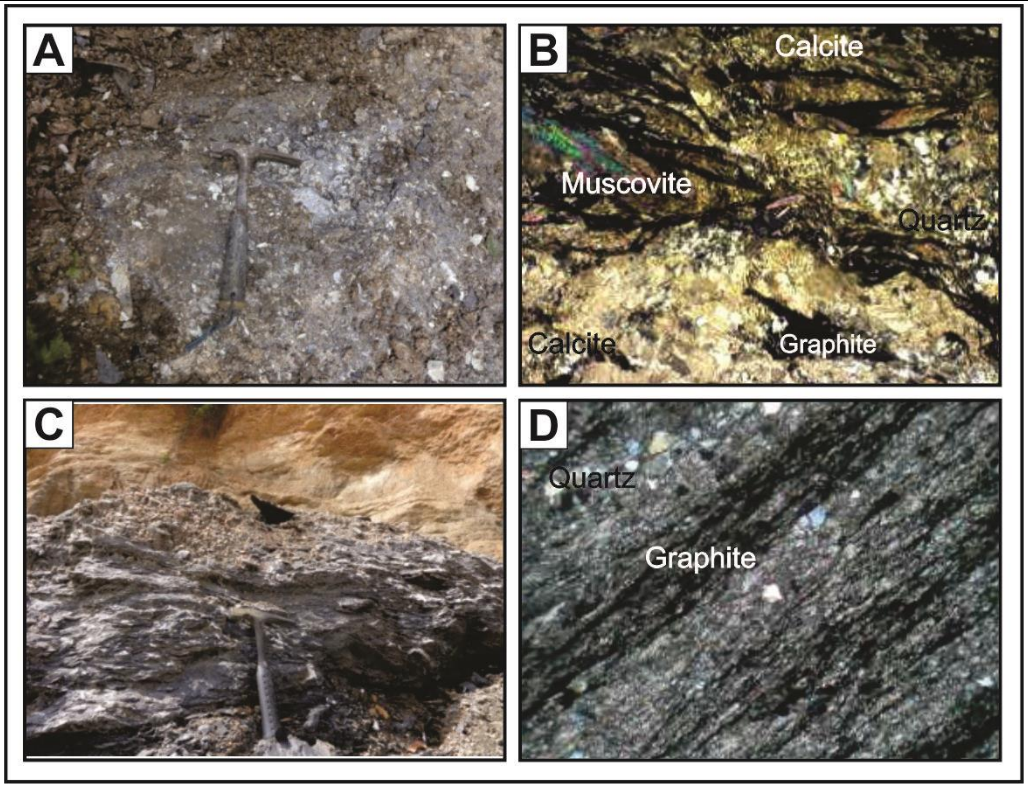


Figure 7. Outcrop of A) graphitic schist in Mekongga Complex and C) graphitic phyllite in Pompangeo Complex; Thin section of rock B) Graphitic schist and D) graphitic phyllite (cross nicol).

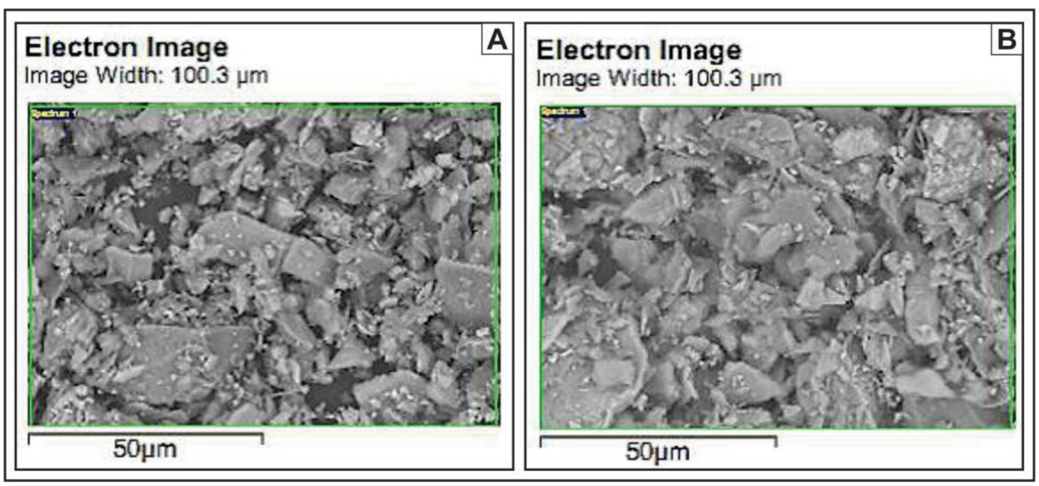
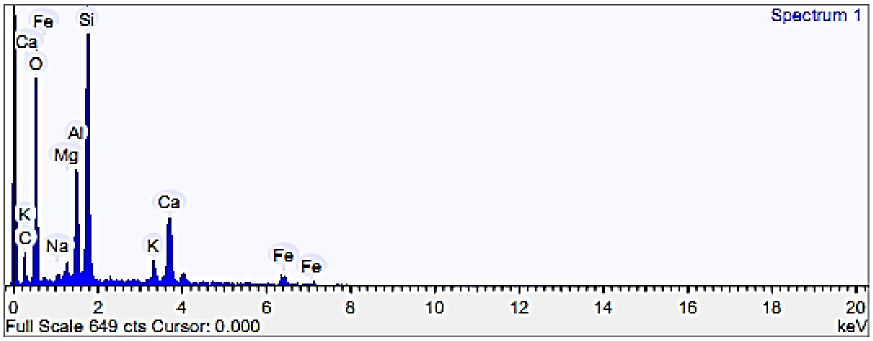


Figure 8. Outcrop of A) graphitic schist in Mekongga Complex and C) graphitic phyllite in Pompangeo Complex; Thin section of rock B) Graphitic schist and D) graphitic phyllite (cross nicol).

Acquisition conditions

Acquisition time (s) : 10.0 Process time : 5

Accelerating voltage (kV) : 15.0



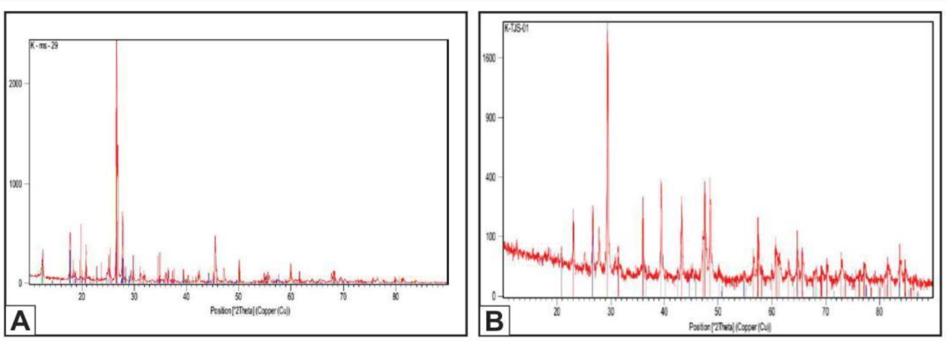
Quantification Settings

Quantification method : All elements (normalised) Coating element : None

Summary results

Element	Weight %	Weight % σ	Atomic %
Carbon	11.123	2.651	17.198
Oxygen	53.309	1.764	61.879
Sodium	0.632	0.160	0.511
Magnesium	0.791	0.151	0.604
Aluminum	5.655	0.292	3.892
Silicon	15.742	0.609	10.409
Potassium	2.000	0.193	0.950
Calcium	7.519	0.378	3.484
Iron	3.230	0.427	1.074

Figure 9. Results of EDS quantitative analysis of DDH MS 03 – 17,00 – 18,00 m.



C

No.	Ref. Code	Compound Name	Chemical Formula	SemiQuant [%]
1	01-070-7345	Quartz	Si O2	18
2	01-073-3765	Lipscombite	Fe1.375 (P O4) (O H)	8
3	01-073-7867	Birnessite	K0.27 (Mn0.96 O2) (H2 O)0.69	1
4	01-071-3809	Fersilicite	Fe Si	2
5	01-072-1214	Calcite	Ca C O3	1
6	01-072-1234	Chlorite	Mg2.5 Fe1.65 Al1.5 Si2.2 Al1.8 O10 (O H)8	8
7	01-071-3739	Graphite-2H	C	16
8	01-070-3754	Muscovite-2M1	K (Al4 Si2 O9 (O H)3)	42
9	01-071-2397	Butlerite	Fe (S O4) (O H) (H2 O)2	4

D

No.	Ref. Code	Compound Name	Chemical Formula	SemiQuant [%]
1	01-071-3699	Calcite	Ca (C O3)	84
2	01-071-3739	Graphite-2H	C	6
3	01-070-3755	Quartz	Si O2	10

Figure 10. The XRD pattern of A) Graphitic schist rock, and B) Graphitic phyllite rock; Quantitative XRD analysis of C) Graphitic schist rock, and D) Graphitic phyllite rock.

size can be used as a benchmark of size, which graphite is detached from the host rock, so that graphite beneficiation process through froth flotation method is able to achieve optimal results.

By Using SEM and EDS Photos

SEM photos can show the porosity of graphite in the host rock (Figure 9.). By using EDS technique which is integrated to the SEM engine, the information of contained-elements of the ore can be known (Figure 10.).

By Using XRD Analysis

Results of XRD (X-ray Diffraction) analysis shows the quantity of graphite in two complexes. Besides purity and shape and size of graphite, crystallinity is greatly affect graphite quality. The analysis results obtained from graphite, generally appropriate to both complexes (graphitic schist and graphitic phyllite).

CONCLUSIONS

Based on field data and analysis results, this research can be concluded that graphite contained schist and phyllite are found in greenschist facies of Mekongga and Pompangeo Schist Complex. Petrographic analysis show its flake up to 0,8 mm long within rock foliation. They are derived from organic material in calcareous sandy -clay protolith rock. Existence of the calcareous material may decrease its graphite separation ratio. Graphite content in graphitic schist and phyllite may vary from 5 up to 15% of fixed carbon, with the majority of impurity minerals i.e. muscovite, silica, and carbonate.

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