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Temporal variation in sandstone composition of Miocene Jatiluhur Formation in the Bogor Trough, West Java, Indonesia

Abdurrokhim [1]*, Billy G. Adhiperdana[1], Hendarmawan[1]

[1]*Faculty of Geological Engineering, Padjadjaran University, Jatinangor, 45363, West Java, Indonesia*

* Corresponding author : abdurrokhim@unpad.ac.id
Tel.:+62-822-6103-1000
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Abstract

Bogor Trough in the West Java are typified by turbidity deposits with the source are mostly characterized by volcanoclastic materials from the southern area. The Trough actually receipt the sediment from both volcanoclastic materials from the south and continental source from the north. But, the discussions of sediments in term of composition and temporal variation are rare to be reported, especially the sediments from the north. This manuscript intends to discuss the temporal variation in detrital compositional and depositional facies of the Neogene sediments that delivered from the north (i.e., Sundaland) into the Bogor Trough, which is represented by Miocene Jatiluhur Formation.

A total of 36 selected samples have been taken for identifying the minerals using a polarization microscope. Modal analysis of the Gazzi-Dickinson method was applied for this provenance study of sandstones samples, which are consisting largely of quartz and feldspar, then sedimentary rock and volcanic rock fragments, glaucony, mud chips and skeletal fragments.

Sundaland, a continental block highland area in the north, is interpreted to have been the provenance of sediments of the Jatiluhur Formation, which is also considered to be the source area for the Paleogene sediments. Granitic igneous rocks are interpreted as the source of dominance of monocrystalline quartz grains, or the product of long-distance transport of polycrystalline quartz from metamorphic rocks

But, however late Miocene samples (upper part of formation) represent that the size and amount of glauconite grains are increasing, and texturally mud supported. Volcanic rocks materials are also observed. The upper part of Jatiluhur Formation records the starvation of sediment discharge into the basin, which has been also promoted for development of carbonate reef Klapanunggal Formation in the self-margin setting, and suggesting that the basin have directly received or indirectly some contemporaneous volcanic provenances sediment from the southern area.

Keywords: Provenance sediment, sandstone, facies, Jatiluhur Formation, Bogor Trough

1. Introduction

The Bogor Trough in the center part of West Java was an elongated east–west trending, represented mainly by thick volcanoclastic deep-water deposits with maximum thickness in the center part around 7000 m (Martodjojo, 2003), in association with shallow-marine siliciclastic and carbonate successions along the northern basin margin (Abdurrokhim & Ito, 2013). The trough was considered to have developed as a foreland basin, seated on the southwestern margin of Sundaland in response of interaction between Eurasian Plate and Indian-Australian Plate to the north (Ben-Avraham & Emery, 1973; Clements, Hall, Smyth, & Cottam, 2009; DeCelles & Giles, 1996; Hamilton, 1979) (Fig. 1).

Neogene sediments into the Bogor Trough were delivered from south, typified by volcanoclastic sediments, and from the north which is characterized by continental source sediments. However, discussion of provenance sediments, especially from the north during Neogene time in association with Late Miocene carbonate development in the Bogor Trough is not yet well reported.

In the Jonggol area (Fig. 1 & 2), an area in between Bogor Trough and NW Java Basin, a continued stratification of Miocene Jatiluhur Formation (ca.1000 m in maximum thickness) is well exposed (Sudjatmiko, 1972). The formation was developed as a slope–shelf system and is represented mainly by south- to southwestward-directed paleocurrents (Abdurrokhim & Ito, 2013).

Variation of framework composition of north-delivered siliciclastic sediments in local association with carbonate deposits in the north is very crucial, as represents Miocene deposits in the Bogor Trough, for guiding a better understanding of sediment delivery systems in the southern margin of Sundaland.

In this manuscript, we discuss provenance of Jatiluhur Formation, compositional and temporal variation of Neogene sediments in the northern edge of the Bogor Trough, in association with development of limestone Klapanunggal Formation and volcanic activity.

2. Stratigraphic setting

Bogor Trough was seated on the southern margin of Sundaland (Fig. 1), showing an east-west physiographic elongation in the middle part of West Java and part of modern magmatic arc location. The Jatiluhur Formation is the oldest exposure sedimentary rock unit that discovered in this area that represents the sediment source were delivered mainly from the north (Abdurrokhim & Ito, 2013). The formation are distributed from Purwakarta to the east until Bogor to the west, and were covered locally by Quaternary sediments and volcanoclastic deposits (Effendi, Kusnama, & Hermanto, 1998; Sudjatmiko, 1972) (Fig. 2). The formation is consisting of quartz sandstones and marl, siltstones, claystones, limestone beds, tuffaceous breccias and basalts, and was deposited during the Middle Miocene (Septama et al., 2021).

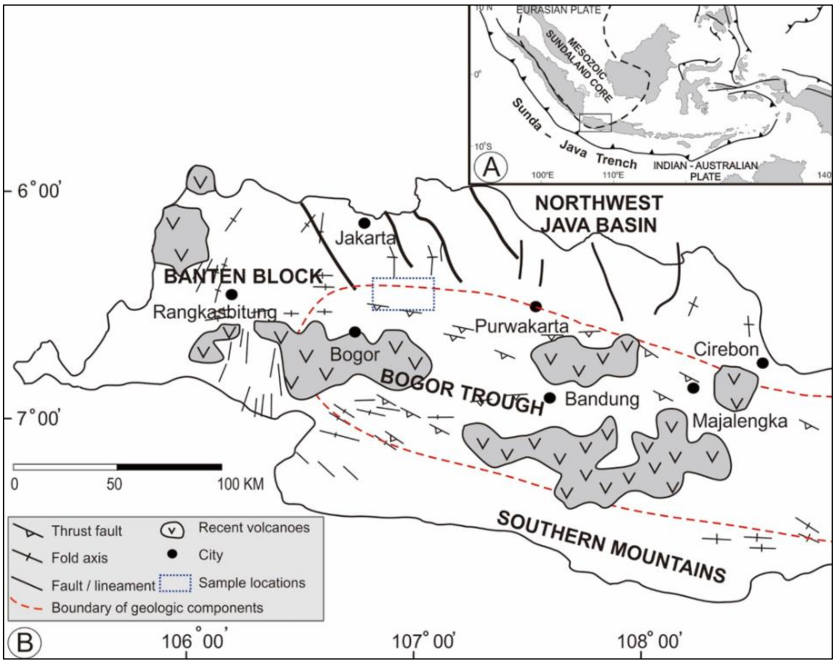


Fig 1. (A) Indonesian region tectonic setting, represents Indian-Australian plate subducts below the Eurasian plate, research area is located on the southern edge of Mesozoic Sundaland core (Hall, 2002). (B) The outline of Bogor Trough and surrounding in the West Java. Modified mainly after Martodjojo (2003).

But in the research area, where the samples taken from from the Cipamingkis and Cileungsi River sections, the Jatiluhur Formation was deposited in the middle–late Miocene (N12–N16) (Nurani, 2010; Zahara, 2012) (Fig. 3).

Jatiluhur Formation is unconformably overlaid by a volcanoclastic deposits of the Cantayan Formation to the south (N17–N18), and conformably overlaid by Carbonate reef Klapanunggal Formation to the north (N14–N16). Those formations are conformably overlain by marine mudstone dominated facies of Subang Formation (N17) ((Septama et al., 2021) (Fig. 2 & 4). An emergence of volcanic materials in the Early Neogene was interpreted as the establishment of the Bogor Trough, which later was extensively prograding to the north (Martodjojo, 2003), and Cantayan Formation is the youngest deep-water volcanoclastic deposit in the research area (Fig. 4).

3. Samples and method

In the research area, Jatiluhur Formation consists of siltstones and sandy siltstones, very thin- to thick-bedded sandstone, thick-bedded carbonate in the upper part, channel-fill deposits, slump and slump-scar-fill deposits in the lower part (Abdurrokhim & Ito, 2013).

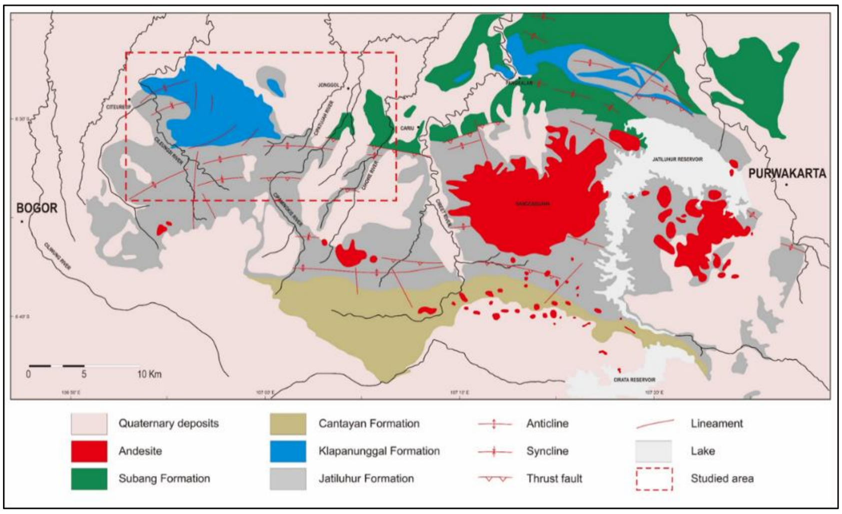


Fig 2. Geological sketch map of Bogor-Purwakarta area, where research area located in the north-western part (Sudjatmiko, 1972). Jatiluhur Formation is overlaid conformable by carbonate Klapanunggal Formation to the north, and to the south by volcanoclastic Cantayan Formation. Both Klapanunggal and Cantayan formations developed mainly during late Miocene.

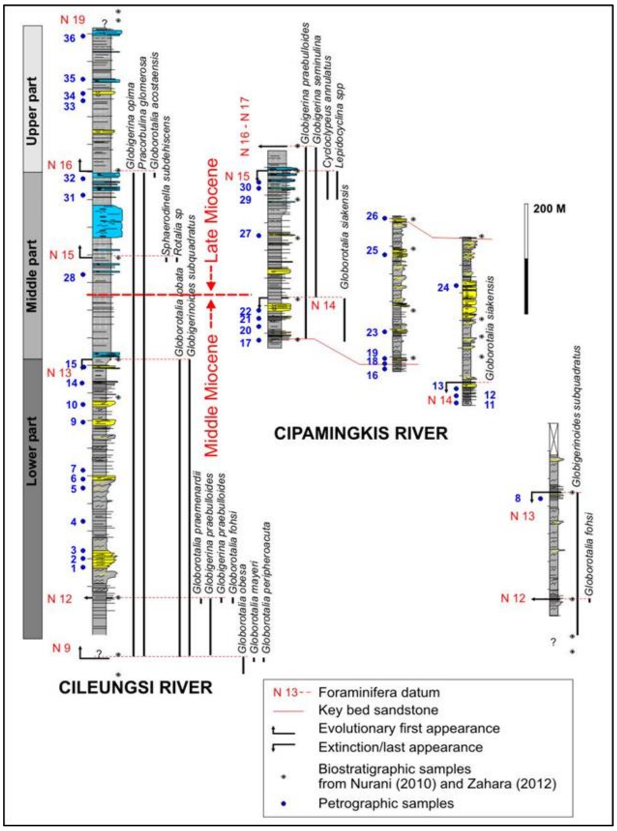


Fig 3. Selected measured sections from Cileungsi and Cipamingkis rivers indicating major biostratigraphic age datums and stratigraphic positions of sandstone samples for petrographic analyses.

Fig 4. Thick-bedded sandstone overlaid slump deposits of the Jatiluhur Formation observed in the Cileungsi River. Figure circled for scale.

There are 36 selected sandstone samples from sandstone outcrops (Fig. 5 & 6), and prepared for thin section analysis using a polarizing microscope. Among these samples, there are 25 samples were taken from lower part of Jatiluhur Formation (i.e., middle Miocene deposits) and the other 11 samples were taken from the upper part of Jatiluhur Formation (i.e., late Miocene deposits). Sandstone samples were collected from various lithofacies associations, which are taken along the Cileungsi and Cipamingkis rivers (Fig. 3).

Modal analysis is conducted, by using point-counting of 450 or more framework grains per thin section. For minimalizing compositional effect of grain size, the Gazzi-Dickinson method was adopted (Garzanti, 2019), although framework grains larger than 0.0625 mm in size were mainly examined by the present study. Each grain was assigned to one of two components, framework and interstitial components, and framework composition was recalculated on the three categories of non-carbonate extrabasinal grains (Table 1).

4. Petrographic analysis

4.1. Texture and composition

Sediments of Jatiluhur Formation consists of siliciclastic and carbonate. Feldspar and quartz are the most prominent framework grains found in sandstone beds in the lower interval. In addition to quartz and feldspar grains, skeletal carbonate fragments and glaucony are also commonly found in the upper interval (Fig. 8C & D).

Sandstones commonly show arenite textural framework (Fig. 7A). However, small numbers of matrix- rich, wacke to subwacke sandstones were also found (Fig. 7B.). The size and shape of sand framework grains are diverse, and are composed angular to rounded of fine- to medium-grained, poorly sorted to moderately sorted sand grains.

Samples contents are mostly quartz, alkali feldspar, plagioclase, and rock fragments (extra basinal), glaucony, mudstone chip and skeletal fragments represent intrabasinal components (Fig. 8B). The dominance quartz grains are monocrystalline quartz, typified by sub-rounded to sub-angular shapes with locally represent strained features, overgrowth, and undulatory extinction. Some polycrystalline quartz grains are locally also observed. Quartz volume is ranging 3 to 72% of the total samples, with a mean of 34.6%. In the upper interval, relative grain abundance of quartz abruptly decreases, while abundance of plagioclase grains is increasing (Fig. 8A).

The second most common mineral frameworks are feldspar grains, and then become the most dominance mineral framework grains in the upper part (i.e. the late Miocene samples). Both alkali feldspars and plagioclase are observed in whole samples. The numerous of alkali feldspars are more dominance compare to plagioclase feldspars, except in few sample from the upper part intervals. Although a staining method is not used in this study, feldspar grains can be distinguished from quartz, and the presence of clouded appearance and twin structures are the indicator for separating alkali feldspar and plagioclase in thin sections. Plagioclase is characterized by distinctive albite twinning, (Fig. 8B & D), and are common to be partly replaced by clay minerals and carbonate. Total feldspar grains are ranging 31 to 91%, with a mean of 56.2%.

The minor components of mineral frameworks are rock fragments, characterized by sub-rounded to rounded grains of mostly metamorphic rock fragments. In the upper part intervals, some samples represent volcanic rock materials, characterized by very coarse-grained, angular to sub-angular, and represents porphyritic texture (plagioclase phenocrysts in microlite groundmass) (Fig. 8C). The groundmass comprises mostly volcanic glass and has been replaced partly by carbonate. This volcanic glass also has been altered locally become clay minerals and carbonates. The rock fragments volume is ranging of 25%, with a mean of 9.2%. Glauconite minerals are observed at almost all interval, but in the upper part of Jatiluhur Formation samples (late Miocene), size and volume of glauconite grains is increasing (Fig. 8B).

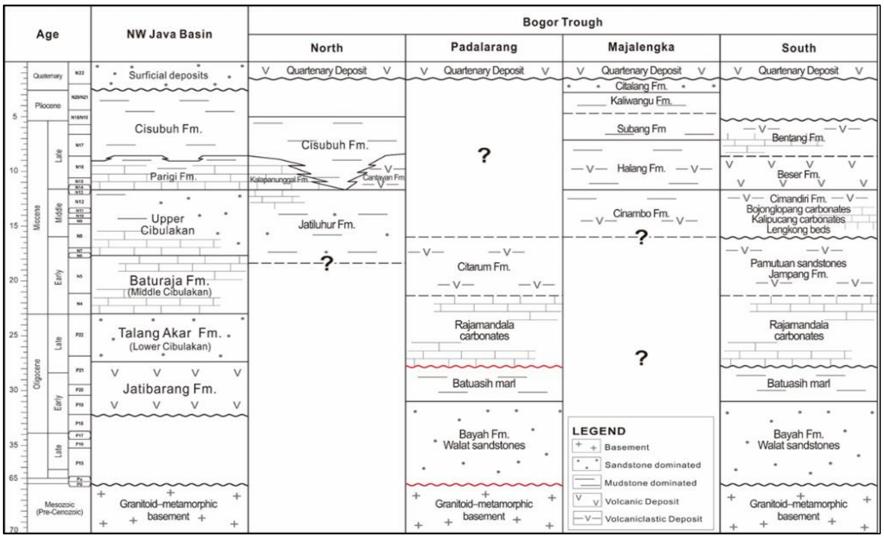
4.2. Classification

Based on percentage matrix and relative abundance of total quartz and feldspar grains and rock fragments, petrographic facies of Miocene Jatiluhur Formation can be classified into 2 groups: (F1) feldspathic arenite, and (F2) feldspathic greywacke (Fig. 7A & B).

Feldspathic arenites (F1) (Boggs, 2009; Garzanti, 2019) composed of quartz grains (monocrystalline + polycrystalline) < 90%, feldspar <40% of feldspar and the rock fragments <10%. Sandstones are commonly medium-grained size, moderately sorted, consisting of fine- to coarse-grained, grain-supported, carbonate cement in the matrix. Coarse-grain fragments are usually skeletal fragments or foraminiferal tests.

Feldspathic greywacke (F2) is matrix supported, compositionally similar to F1, with the matrix abundant ranging more than 15%. This facies is commonly taken from muddy sandstones.

Fig 5. Lenticular geometry of fine-grained sandstone bed of the Jatiluhur Formation observed in the Cipamingkis River. Figure circled for scale.



Figu 6. N-S stratigraphic column of the Cenozoic stratigraphic units in West Java (Djuhaeni & Martodjojo, 1989; Martodjojo, 2003; Septama et al., 2021)

Table 1. Modal composition of the middle – late Miocene Jatiluhur Formation

Sample	Quartz (%)	Feldspar (%)	Rock fragment (%)	Mono quartz (%)	Feldspar (%)	Lithic (%)
1	71.59	25.17	3.23	69.28	25.17	5.54
2	32.46	64.06	3.48	30.72	64.06	5.22
3	22.02	69.72	8.26	21.41	69.72	8.87
4	38.93	54.13	6.93	38.40	54.13	7.47
5	22.95	67.71	9.35	21.25	67.71	11.05
6	27.48	64.75	7.77	25.76	64.75	9.50
7	50.47	40.65	8.88	48.36	40.65	10.98
8	35.96	50.00	14.04	32.46	50.00	17.54
9	35.69	54.88	9.43	32.66	54.88	12.46
10	37.00	60.79	2.20	35.68	60.79	3.52
11	22.28	74.75	2.97	22.28	74.75	2.97
12	42.91	54.76	2.33	41.36	54.76	3.88
13	34.12	64.12	1.76	32.94	64.12	2.94
14	24.51	70.75	4.74	24.51	70.75	4.74
15	39.05	56.43	4.52	38.57	56.43	5.00
16	36.49	50.18	13.33	36.14	50.18	13.68
17	31.98	52.79	15.23	31.98	52.79	15.23
18	55.78	36.39	7.82	55.10	36.39	8.50
19	47.27	45.45	7.27	46.36	45.45	8.18
20	52.15	31.58	16.27	48.33	31.58	20.10
21	47.67	36.63	15.70	44.77	36.63	18.60
22	46.89	40.67	12.44	44.02	40.67	15.31
23	55.42	39.76	4.82	55.42	39.76	4.82
24	40.78	42.20	17.02	37.23	42.20	20.57
26	38.41	51.22	10.37	36.59	51.22	12.20
27	31.48	61.11	7.41	29.63	61.11	9.26
28	50.00	39.22	10.78	47.06	39.22	13.73
29	2.78	81.48	15.74	2.78	81.48	15.74
30	11.19	74.13	14.69	11.19	74.13	14.69
31	15.45	70.73	13.82	15.45	70.73	13.82
32	22.58	66.94	10.48	22.58	66.94	10.48
33	16.67	68.94	14.39	13.64	68.94	17.42
34	4.35	91.30	4.35	4.35	91.30	4.35
35	32.00	65.33	2.67	32.00	65.33	2.67
36	28.81	69.49	1.69	28.81	69.49	1.69

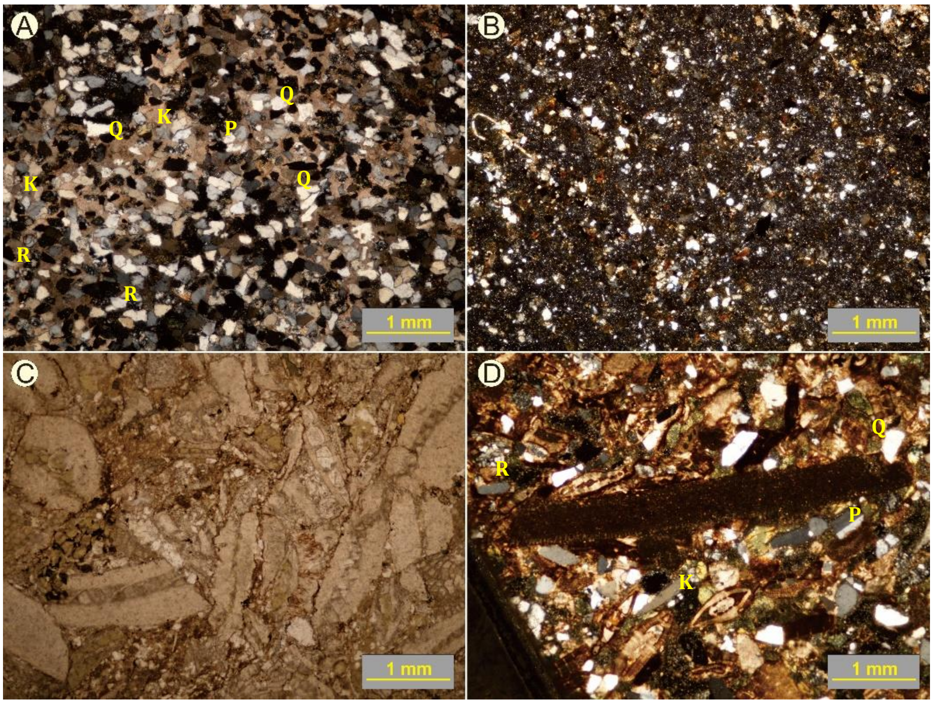


Fig 7. Mix of siliciclastic and carbonate composition of Jatiluhur Formation. (A) Grain-supported extra basinal frame work (lower part interval of formation), largely consists of quartz and feldspar grains with minor rock fragments. (B) Muddy-matrix-supported texture in upper part interval of formation. (C) Grainstone (Dunham, 1962) carbonate bed in the upper part of formation. (D) Mix siliciclastic and carbonate fragments. Note: Q = Quartz, P = Plagioclase, K = K-Feldspar, R = Rock Fragment

4.3. Provenance

The framework composition of Jatiluhur Formation sandstones represents that the provenance can be classified into the basement-uplifted continent blocks in association with a minor dissected arc (Garzanti, 2019) (Fig. 10). The paleocurrent data also indicates that sediments delivered from the north (Abdurrokhim & Ito, 2013). Siliciclastic sediments were delivered from the Sundaland in the north and/or some other northern mountains in the farther northern area, which were delivered through the shelf margin of the NW Java Basin trough the Bogor Trough that have also occurred since the Paleogene time (cf. Clements & Hall, 2011).

Monocrystalline quartz domination refers a granitic igneous rocks source (Garzanti, 2019; Garzanti et al., 2013), or disaggregation of original polycrystalline quartz from long-distant transport from metamorphic and/or sedimentary sources. In addition, some undulatory quartz extinction and aggregation of polycrystalline quartz grain indicate that those quartz grains were product of a metamorphic rocks (i.e. first-cycle sands of low-rank metamorphic quartz (eg. Garzanti & Vezzoli, 2003; Najafzadeh, Jafarzadeh, & Moussavi-Harami, 2010).

The feldspar grains can also interpreted to have been product from crystalline rock sources. Although some plagioclase grains may have been derived originally from volcanic arc provenances to the south, since K-feldspar grains are important constituent of felsic igneous rocks, intermediate gneisses, pegmatites, and/or felsic (eg. Garzanti, 2019; Garzanti & Vezzoli, 2003).

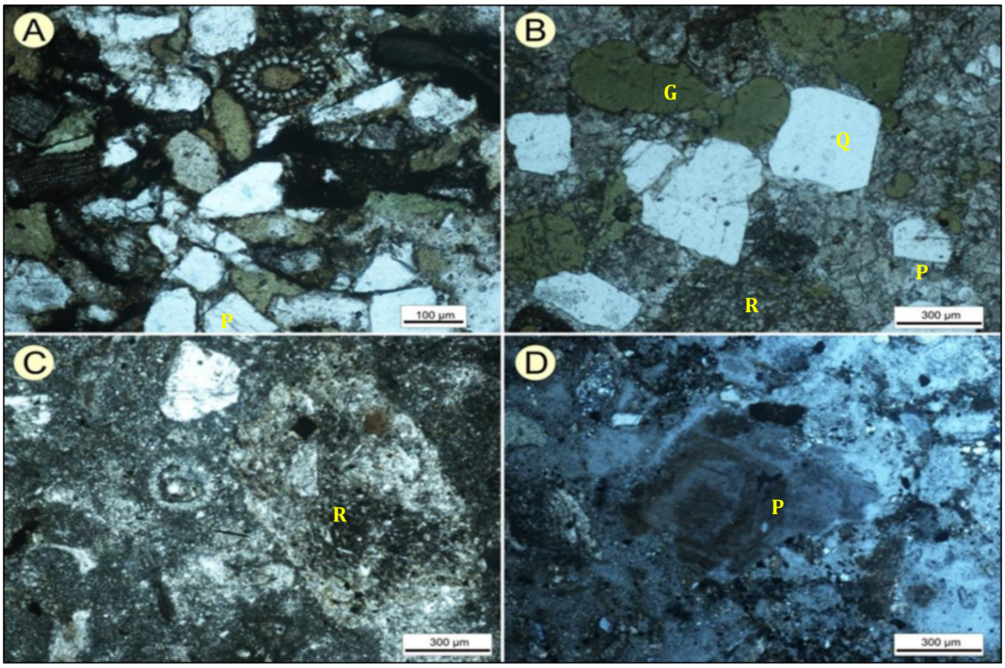


Fig 8. Representative thin section photograph of upper interval Jatiluhur Formation sandstones (i.e. late Miocene deposits). (A) Coarse-grained siliciclastic and intraclasts fragments. (B) Coarse-grained plagioclase and glaucony minerals. (C) Coarse-grained fragment of volcanic rock. (D) Plagioclase zoning. Note: Q = Quartz, P = Plagioclase, G = Glauconite, R = Rock Fragment.

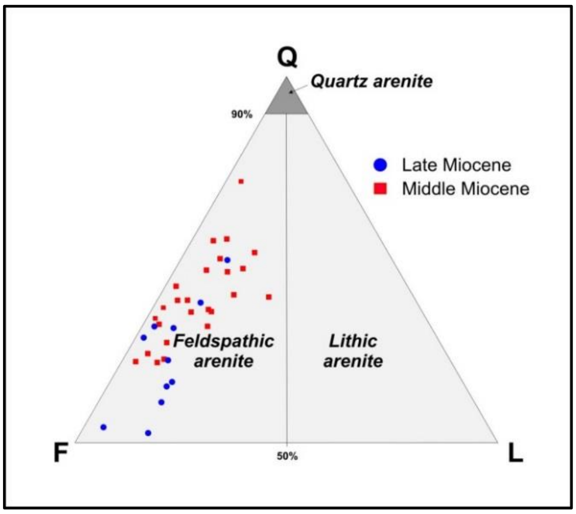


Fig 9. Sandstone classification of the Jatiluhur Formation on the Q (Quartz)-F (K-feldspar + Plagioclase)-L (Rock fragment).

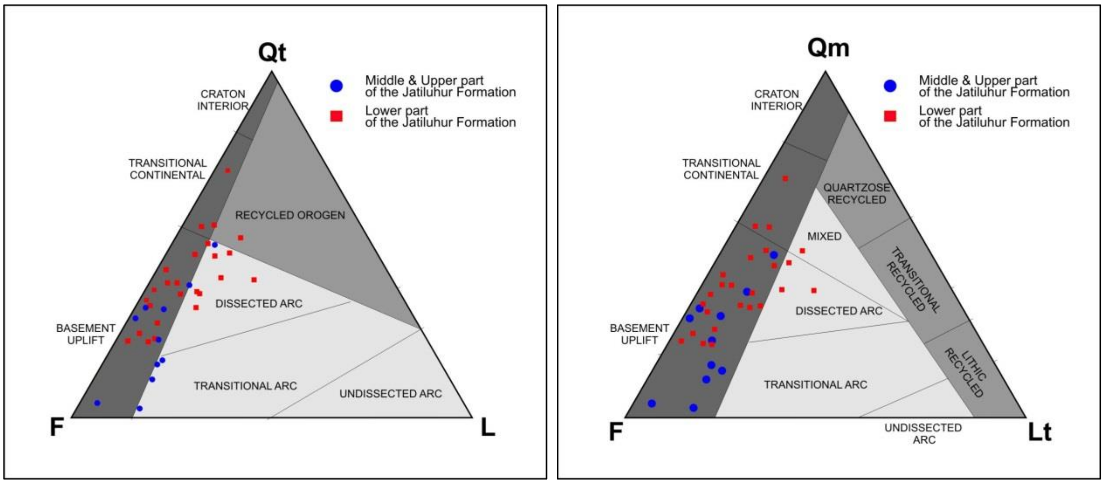


Fig 10. Framework composition of the Jatiluhur Formation sandstones. Provenance fields are from (Dickinson, 1983; Weltje, 2006). Qt = Quartz); F = K-Feldspar + Plagioclase ; L = Rock fragment; Qm = Monocrystalline quartz; Lt = Rock fragment + Polycrystalline quartz.

5. Tectonic activity

Although the sediments of Jatiluhur Formation are generally having similar composition of extrabasinal grain, there are some notes of late Miocene samples (upper part of formation): (1) Late Miocene samples content of volcanic materials and intrabasinal materials (skeletal fragments), and (2) Volumetric proportion of feldspar, especially plagioclase, is much higher than quartz and rock fragments for some samples, and also the glaucony minerals content.

The late Miocene succession was considered as a response to a diminishing supply of siliciclastic sediment from the hinterland, which was indicated by the presence of glauconite that is commonly formed in the starvation state of a marine-shelf environment. This condition may also fulfill the requirement for the carbonate reef of Klapanunggal Formation to develop.

Developing of shelf and shelf margin systems allow glauconite formation within the marine sediments of late Miocene. This condition has been interpreted as a period of low siliciclastic discharge from the northern hinterland (Clift & Plum, 2008).

In comparison with the middle Miocene Jatiluhur deposit, the late Miocene Jatiluhur deposit has volcanic rock fragment within its composition. These volcanic rock fragment are porphyritic in texture, contains phenocrysts of plagioclase within carbonate and microlite groundmass (Fig. 8C). Plagioclase and volcanic glasses may locally be exchanged by clay minerals and carbonate. Relative increasing of volcanic material abundance within upper interval of the Jatiluhur formation (i.e. late Miocene deposits) also documents the activity of the southern volcanoes as provenance for the pyroclastic and volcaniclastic material.

Moreover, the presence of plagioclase grains is exceedingly abundant compared to K-feldspar and quartz grains of late Miocene deposit. The plagioclase grains are coarse to very coarse, subhedral shaped with albite and carlsbad twins along with a locally developed also zoning (Fig. 8D), is the common feature of feldspars formed in igneous rocks (eg. Garzanti et al., 2013; Najafzadeh et al., 2010). Even so, an increasing of plagioclase grains abundance in the upper part of Jatiluhur Formation was considered as a response to an active shedding of materials from the southern mountain provenance, rather than being a plutonic igneous rocks or metamorphic in origin (Garzanti & Vezzoli, 2003).

Due to the general paleocurrents directions of the Jatiluhur Formation were to the south and southwest, volcanoclastic sediments may not have directly been supplied to the Bogor Trough and seem to have been reworked once they were deposited in the shallow-marine shelf and coastal environments in eastern and/or northern margins of the basin, except for some grains supplied as pyroclastic deposits.

Magmatic activities during the Neogene period are represented by three phases as follows: (1) tholeiitic magmatism of the Oligocene-Miocene Island Arc, (2) tholeiitic pillow basalt during Late Miocene, and (3) calc-alkaline magmatism of Pliocene and Quaternary (Soeria-Atmadja & Noeradi, 2005). Magmatic belt in Java Island was shifted to north since late Miocene may also contribute of volcanic source materials to the Bogor Trough.

Limestone beds at the upper Jatiluhur Formation are interpreted to represent facies changing of the Late Miocene carbonate reef Klapanunggal Formation (Abdurrokhim & Ito, 2013), and this reef was drowned in association with tectonic subsidence, parallel evidence of tectonic subsidence, magmatism and increasing volcanic materials during late Miocene as interpreted due to tectonic loading in the south.

6. Conclusion

The frame work sediments of Jatiluhur Formation are feldspathic arenite and feldspathic greywacke. Texture is representing mainly consist of grain-supported, with several limited samples showing a mud-matrix-supported, consist of quartz (monocrystalline and polycrystalline), K-feldspar, plagioclase, rock fragment (extrabasinal arenaceous component), and glaucony, foraminiferal test and mud chips (intrabasinal component)

The sediment composition was shown to have a continental origin which most likely came from the northward Sundaland, just as how it has been considered for the Paleogene deposit. This interpretation was also supported by the Paleocurrent data. Composition of the sediment was also dominated by the dominance of monocrystalline quartz grain as an indicator of a granitic igneous rocks provenance, or as the product of polycrystalline quartz disaggregation from a metamorphic source due to a long-distance transport process.

The late Miocene samples indicates the increase in glauconite relative abundance, which may document the starvation period and diminishing supply. These conditions may also support the carbonate reefs development. An increasing of relative volcanic fragments abundance of the late Miocene samples also indicates the magmatism activity of the southern contemporaneous southern volcanoes which that act as a sediment discharge source for the Jatiluhur Formation either as a direct supply such as deposit of fall-related volcanic eruptions in the south, or indirectly such as recycling from a northwestern shallow-marine shelf and coastal area.

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