

FORAMINIFERA ASSEMBLAGES AS A MARKER OF MUD ERUPTION SOURCE IN CIUYAH, CINIRU – KUNINGAN, WEST JAVA

KUMPULAN FORAMINIFERA SEBAGAI PETUNJUK SUMBER ERUPSI LUMPUR DI CIUYAH, CINIRU - KUNINGAN, JAWA BARAT

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ABSTRACT Mud eruptions that rise claystone to sandstone-size fragments, liquid, gas, and heat to the surface have been identified in Ciuyah, Ciniru District, Kuningan. Field observation and sampling were conducted on host rock as well as mud in Ciuyah. Forty-two planktic and forty-two benthic foraminiferal species were identified in rock samples; while 89.28% of them are recorded in mud samples. Foraminifera contained in claystone and sandstone of Pemali and Halang Formations reveals the age of Middle to Late Miocene. Based on their stratigraphic ranges, planktic foraminifera assemblages in mud represent four age-marker groups, there are: older than Zone N.10 / Middle Miocene (indicated by the appearance of *Globorotalia archeomenardii*), ranges of Zone N.11 – N.12 / Middle Miocene (marked by the appearance of *Globorotalia fohsi lobata* and *Globorotalia praemenardii*), ranges of Zone N.13–N.14 / Middle Miocene (*Globorotalia siakensis* and *Globorotalia mayeri*), and ranges of Zone N.15–N.17 / Late Miocene (*Globorotalia acostaensis acostaensis* and *Neogloboquadrina dutertrei dutertrei*). Benthic foraminifera can be grouped into outer neritic and bathyal typical

assemblages. That several age-marker planktic foraminifera groups mixing and deep marine typical benthic occurrence in mud samples is produced by reworking process during turbidity sedimentation, as well as erosion and elution of base- and side-rock composed by Pemali and Halang Formations.

Keywords: foraminifera, mud eruption, source, Ciuyah.

ABSTRAK Semburan lumpur yang membawa fragmen-fragmen berukuran batulempung hingga batupasir, cairan, gas dan panas ke permukaan telah teridentifikasi di Ciuyah, Kecamatan Ciniru, Kuningan. Observasi lapangan dan pengambilan sampel dilakukan terhadap batuan induk serta lumpur di Ciuyah dan sekitarnya. Empat puluh dua spesies foraminifera planktik dan empat puluh dua spesies benthik teridentifikasi dalam sampel batuan; dengan 89,28% di antaranya terekam dalam sampel lumpur. Foraminifera yang terkandung dalam batulempung dan batupasir Formasi Pemali dan Halang menunjukkan umur Miosen Tengah hingga Akhir. Berdasarkan rentang stratigrafinya, kumpulan foraminifera planktik dalam lumpur menunjukkan empat kelompok penanda umur, yaitu: lebih tua dari Zona N.10 / Miosen Tengah (ditunjukkan oleh kehadiran *Globorotalia archeomenardii*), rentang Zona N.11 - N.12 / Miosen Tengah (ditandai oleh kehadiran *Globorotalia fohsi lobata* dan *Globorotalia praemenardii*), rentang Zona N.13 - N.14 / Miosen Tengah (*Globorotalia siakensis* dan *Globorotalia mayeri*), dan rentang Zona N.15 - N.17 / Miosen Akhir (*Globorotalia acostaensis acostaensis* dan *Neogloboquadrina dutertrei dutertrei*). Foraminifera benthik dapat dikelompokkan dalam kumpulan neritik luar dan

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batial. Beberapa kelompok penanda umur foraminifera planktik dan kehadiran bentuk laut dalam pada lumpur dihasilkan oleh pengerjaan ulang selama sedimentasi turbidit, serta erosi dan elusi batuan dasar dan batuan samping yang tersusun oleh Formasi Pemali dan Halang.

Kata Kunci: foraminifera, semburan lumpur, sumber, Ciuyah.

INTRODUCTION

Geologically erupted liquefied sediments and clay-size fragments, liquids and gasses to surface created mountain-shaped cone known as mud mountain. In Indonesia, this mountain topographical expression is generally produced by shale and clay eruption (Istadi, et al., 2012). Typically, they are most abundant in tectonic subduction zones, accretionary wedges, and passive margins within deltaic settings, collisional tectonic zones, convergent orogenic belts and active fault systems, fault-related folds, as well as anticline axes. The active structure act as a conduit for deep formation fluids to reach the surface. The eruptions usually appear to be in line with the direction of structures (Mazzini, et al., 2009; Sawolo, et al., 2009; Hochstein and Sudarman, 2010). The eruption of mud was believed to be triggered by massive earthquakes (Mellors, et al., 2007; Kumai and Yamamoto, 2007; Manga, 2007; Walters et al., 2007; Davies et al., 2008). Mud eruption is also generally founded in areas with rapid sedimentation rates of thick deposits, active compressional tectonics, hydrothermal formation and the generation of hydrocarbon at depth (Pitt and Hutchinson, 1982; Milkov, 2000; Mazzini, et al., 2009).

Mud eruptions are common in the northern part of Java and Madura (Satyana and Asnidar, 2008). These activities typically are located at the top of an anticline or along the fault in the area. Bledug Kuwu, Api Kayangan, Pengangson, Pulungan, Kalang Anyar, Gunung Anyar, and Bujel Tasek mud eruptions occur at the top of the anticline. Lusi (Sidoarjo) erupted on the extension of the anticlinal structure, while Sangiran mud eruption occurs at the top of the truncated dome on an up-thrown fault block.

Field observation and sampling on erupted materials and host rock are focused in the area between coordinate -6°59'44.4" to -7°4'43.5" and 108°27'34.4" to 108°32'55.7" where mud

eruptions are recorded (Figure 1). The study area is occupied by Tertiary sedimentary rock (Pemali and Halang Formations) as well as Quaternary laharic deposits. Pemali Formation (Tmp) consist of monotoneous beds of greyish blue and green globigerina marls; poorly-well bedded, with sparse intercalation of tuffaceous sandstone and greyish blue sandy limestone. Recognized sedimentary structures are parallel lamination, cross bedding, convolute lamination, and ripple marks. Presumably, the age is Early Miocene. Thickness about 900 m. The Gununghurip member of Halang Formation (Tmhg) is compiled by turbidities, comprising mainly andesitic volcanic breccia; intercalated with sandstone, shale, sandy claystone, and polymict conglomerate; commonly grey, and well-bedded. Common sedimentary structures recognized are parallel and graded beddings. Planktonic fossil assemblage in the sandy claystone tends to indicates a Middle Miocene age. Thickness is up to 2400 m.

Halang Formation (Tmph) consist of tuffaceous sandstone, conglomerate, marl, and claystone; andesitic breccia at the lower part. Sandstone mostly wacke. Deposited as turbidites in an upper bathyal zone. Structures commonly recognized in the unit are graded bedding, parallel lamination, convolute lamination, flute-casts, and load casts, suggesting a deposition in an open marine environment by turbidity currents. Locally, foraminifera and mollusc are found. Presumably, a Middle Miocene-Early Pliocene age. Interfingers with the Gununghurip Member of the Halang Formation. Cipedak lahar deposit (Qc) consist of andesitic rocks fragments, embedded in a coarse sand matrix; well consolidated; probably a product of older Careme volcano, exposed along Cipedak River (Kastowo and Suwarna, 1996; Budhitrisna, 1986) (Figure 2).

The four planktic foraminifera biostratigraphic zones are recognized in stratigraphic succession in the study area (Isnaniawardhani, et al., 2015 a,b), in ascending order:

- Not younger than Zone N.11 – N.12
The appearance of *Globorotalia fohsi lobata* associated with *Globorotalia praemenardii* in succession of Pemali Formation indicated Zone N11 - N.12 (more than 12.5 million years ago) or Middle Miocene.

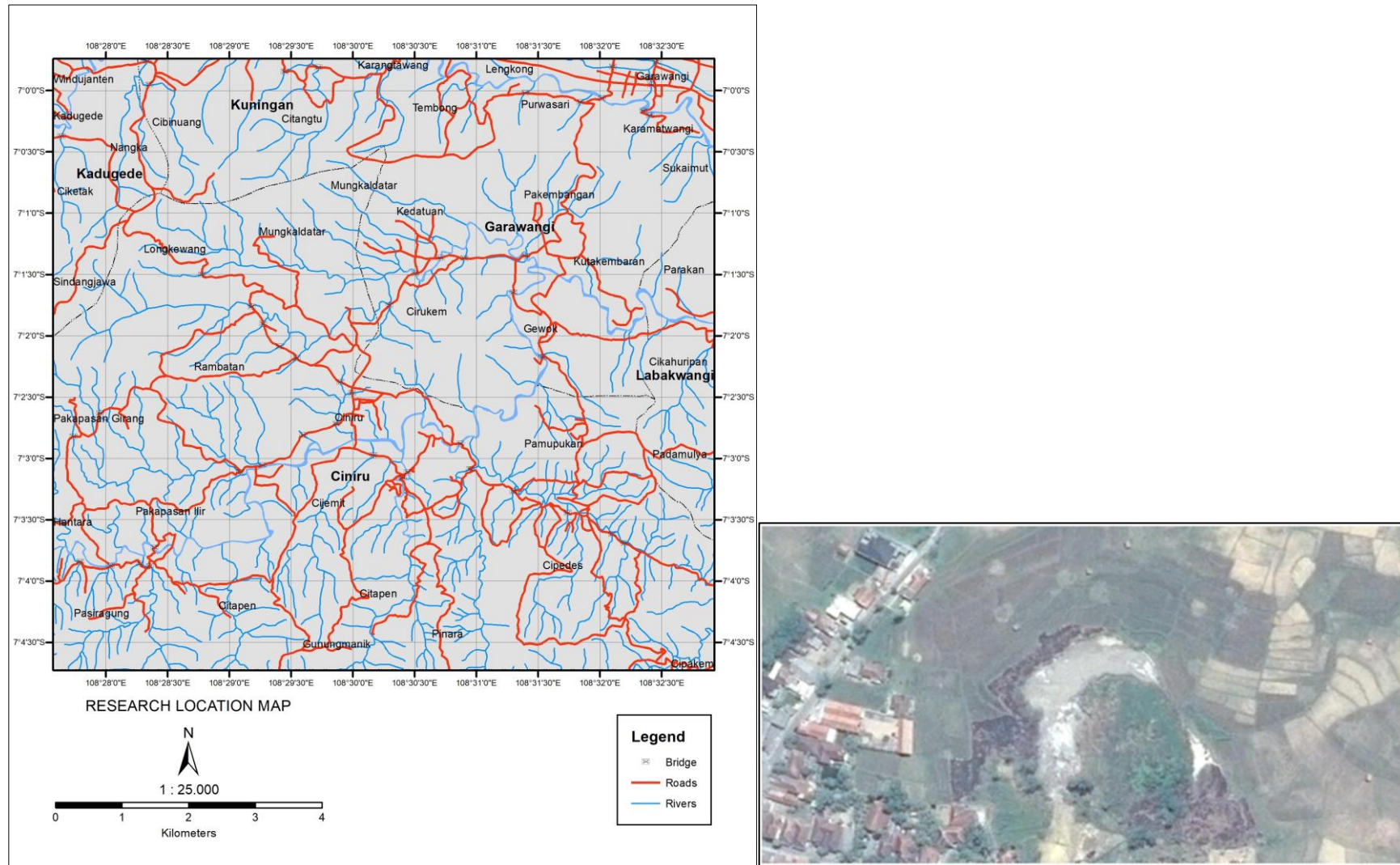


Figure 1. Mud eruption location near Ciremai volcano in the northern part of West Java.

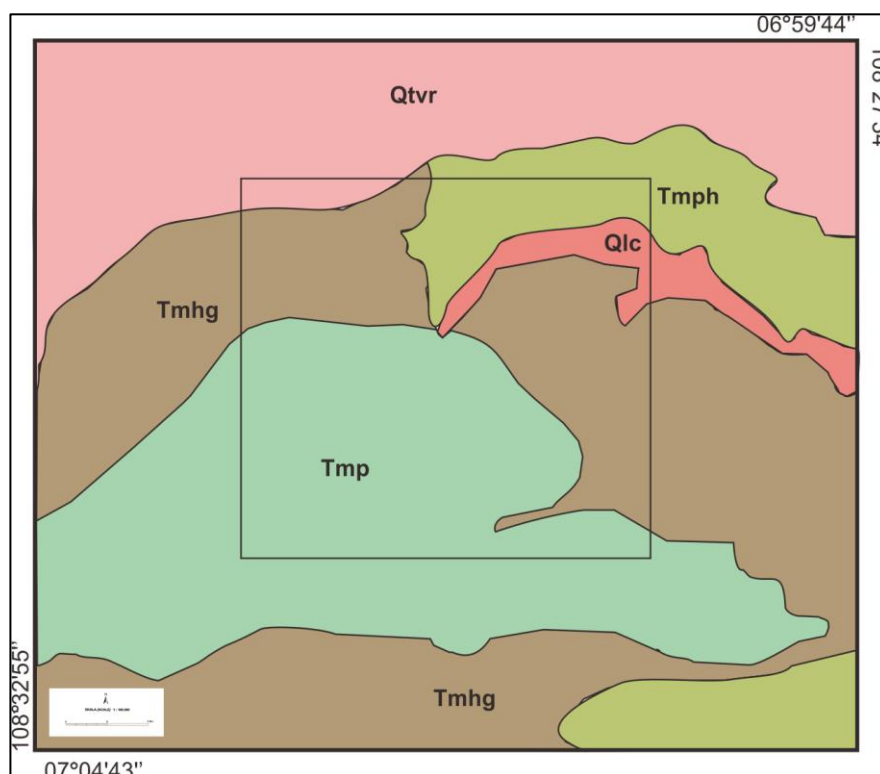


Figure 2. The Miocene strata of Pemali (Tmph) and Halang Formations (Tmhg & Tmp) overlain unconformably by Quaternary deposits (Qc) in the study area (rectangle).

– Zone N.13 - N.14

The appearance of *Sphaerodinellopsis subdehiscens*, *Globorotalia siakensis*, and *Globorotalia mayeri* associated with *Globigerinoides subquadratus*, *Hastigerina siphonifera* and *Globorotalia menardii menardii* in the lower part of Halang Formation indicated Zone N.13 - N.14 (about more than 11.3 my before present) or Middle Miocene.

– Zone N.15

The appearance of *Globigerina nepenthes*, *Globigerina praebulloides praebulloides*, *Globorotalia continua*, *Globorotalia menardii menardii*, *Globorotalia pesudomiocena*, *Globigerinoides subquadratus*, and *Hastigerina aequilateralis* in the middle part of Halang Formation indicated Zone N.15 (about 11.3 to 7.1 my BP) or Late Miocene.

– Zone N.16-N.17

The appearance of *Globorotalia acostaensis acostaensis*, *Globorotalia merotumida*, *Neogloboquadrina dutertrei dutertrei*,

Globorotalia humerosa humerosa, *Globigerinoides ruber*, *Candeina nitida*, *Globigerinoides obliquus extremus* and *Hastigerina aequilateralis* in the upper part of Halang Formation indicated Zone N.16 – N.17 (about 7.1 to 5.3 my BP) or Late Miocene.

Mud eruption in Ciuyah has been ejected claystone to sandstone-size fragments, liquid, gas, and heat. The sedimentary fragments contain microfossils (foraminifera) which their hard shells are incorporated and preserved in the surrounding sediment. Therefore, the research on foraminifera contents in the ejected material will confirm the source of mud which breaches the earth surface.

Based on the chemical and isotope analysis, it is concluded that fluid drains out from Ciuyah is a formation water originated from the clastic sediments consisting of clay and sandstone. It is also concluded that most likely that Ciuyah water is the result of mixing between formation water and meteoric water flowing from Ciremai hydrologic system. The temperature of water remains stable at 37°C both in rainy and dry seasons (Isnaniawardhani, et al., 2018).

METHODS

The actual research was done in several stages; was started by the study and collection of secondary data. The geological mapping was taken mainly to identify rock in Ciuyah and its surrounding, as well as mud around eruption area. Fourteen host rocks and nine mud samples are collected to laboratory analysis. In paleontology laboratory, each sample was prepared using hydrogen peroxide to release foraminifera. The residual samples are observed using slab microscope of 40 magnifications. The research adopted some basic methods for identification of foraminifera by Loeblich and Tappan (1988), Bolli and Saunders (1986) and van Marle (1991). Determine stratigraphic age range, as well as biostratigraphic zones, refers to standard zonation of Blow (1969) in Blow (1979), Bolli and Saunders (1986) and Nathan and Leckie (2003).

RESULTS AND DISCUSSION

The appearance of foraminifera, biostratigraphy and depositional environment of the host rock

A total of 84 foraminiferal species was identified in outcropped samples in Ciuyah and its surrounding area. Forty-two of them are planktic and forty-two are benthic. Planktic foraminiferal assemblages were identified in host rock samples, consist of:

- fourteen species of genus Globorotalia: *G. acostaensis acostaensis* Blow, *G. archeomenardii* Bolli, *G. continua* Blow, *G. fohsi lobata* Bermudez, *G. humerosa humerosa* Takayanagi & Saito, *G. mayeri* Cushman & Ellisor, *G. menardii menardii* (Parker, Jones & Brady), *G. merotumida* Banner & Blow, *G. obesa* Bolli, *G. opima nana* Bolli, *G. praemenardii* Cushman & Stainforth, *G. pseudomiocenica* Bolli & Bermudez, *G. pseudopima* Blow and *G. siakensis* (Leroy).
- ten species of genus Globigerinoides: *G. conglobatus* (Brady), *G. obliquus extremus* Bolli & Bermudez, *G. obliquus obliquus* Bolli, *G. quadrilobatus* (d'Orbigny), *G. ruber* (d'Orbigny), *G. sicanus* de Stefani, *G. subquadratus* Brommimann, *G. trilobus trilobus* (Reuss), *G. trilobus immaturus* LeRoy, and *G. trilobus sacculifer* (Brady).

- three species of both genera Globigerina, Hastigerina, Orbulina, and Sphaerodinellopsis. Globigerina: *G. nepenthes* Todd, *G. praebulloides praebulloides* Blow, *G. venezuelana* Hedberg. Hastigerina: *H. aequilateralis* (Brady), *H. praesiphonifera* Blow, *H. siphonifera* (d'Orbigny). Orbulina: *O. bilobata* (d'Orbigny), *O. suturalis* Bronnimann, *O. universa* d'Orbigny. Sphaerodinellopsis: *S. disjuncta* (Finlay), *S. seminulina* (Schwager), *S. subdehiscens* Blow.
- two species of genera Globoquadrina and Neogloboquadrina. Globoquadrina: *G. altispira altispira* (Cushman & Jarvis), *G. dehiscens* (Chapman, Parr & Collins). Neogloboquadrina: *N. dutertrei blowi* Rogl & Bolli, *N. dutertrei dutertrei* (d'Orbigny).
- each consisting of a species of both genera Candeina and Catapsydrax. Candeina: *C. nitida* d'Orbigny; and Catapsydrax: *C. dissimilis* (Cushman & Bermudez).

Based on shells composition, benthic foraminifera in rock samples can be grouped to:

- Calcareous shells or Subordo Rotaliina, consist of genera Amphistegina d'Orbigny (*A. papilosa*, *A. radiata*), Anomalinaella Cushman (*A. rostrata*), Anomalinoidea Brotzen (*A. globulus*), Bolivina d'Orbigny, Brizalina Costa, Bulimina d'Orbigny, Cassidulina d'Orbigny, Cibicides De Montfort, Duplella Patterson & Richardson (*D. trinalimarginata*), Eggrella Cushman, Elphidium De Montfort (*E. neosimplex*), Eponides De Montfort (*E. pusillus*), Fiscerinella McCulloch (*F. diversa*), Fijionion Hornibrook (*F. fijianse*), Glandulina d'Orbigny (*G. symmetrical*), Globocassidulina Voloshinova, Gyroidina d'Orbigny, Hanzawaia Asano (*H. grossepunctata*), Heterolepa Franzenau (*H. subhaidingeri*), Hyalina Hofker, Hyperammina Brady (*H. noavaealandia*), Melonis De Montfort, Missipina Felker (*M. pacifica*), Nodogenerina Cushman (*N. lepidula*), Nonion De Montfort (*N. pauperatum*), Nummulites Lamarck, Planulina d'Orbigny, Pseudononion Asano (*P. granuloumbilicatum*), Robulus Montfort,

Rotalia Lamarck, Stilostomella Guppy and Uvigerina d’Orbigny.

- Porcelaneous shells that typified by subordo Miliolina and Lagenina, consist of genera Amphycorina Schlumberger (*A. sublineata*), Dentalina Risso, Laevidentalina d’Orbigny. (*L. bradyensis*), Lenticulina Lamarck (*L. calcar*, *L. domantayi*), Nodosaria Lamarck, Pyrgo DeFrance, Quinqueloculina d’Orbigny (*Q. limbata*), and Sigmoidina Finlay.
- Arenaceous shells or subordo Textulariina is represented by genera Martinotiella Cushman and Textularia DeFrance.

Erupted Materials

The materials ejected from subsurface are fragments, liquid, gas, and heat (Figure 3). Mud contains claystone, fine to coarse grain sandstone of sedimentary, sub-rounded fine grain calcareous sandstone, sub-rounded fine to coarse grain tuffaceous sandstone, igneous rock and limestone sandstone-size fragments (Isnaniawardhani, et al., 2015b).

The fragments of mud generally contain foraminifera in variety type and amounts of species. Thirty-seven planktic foraminiferal species are recorded from mud samples (Figure 4).



Figure 3. Eruption activity in Ciuyah ejected clay to sandstone-size fragments, fluids, and gasses.

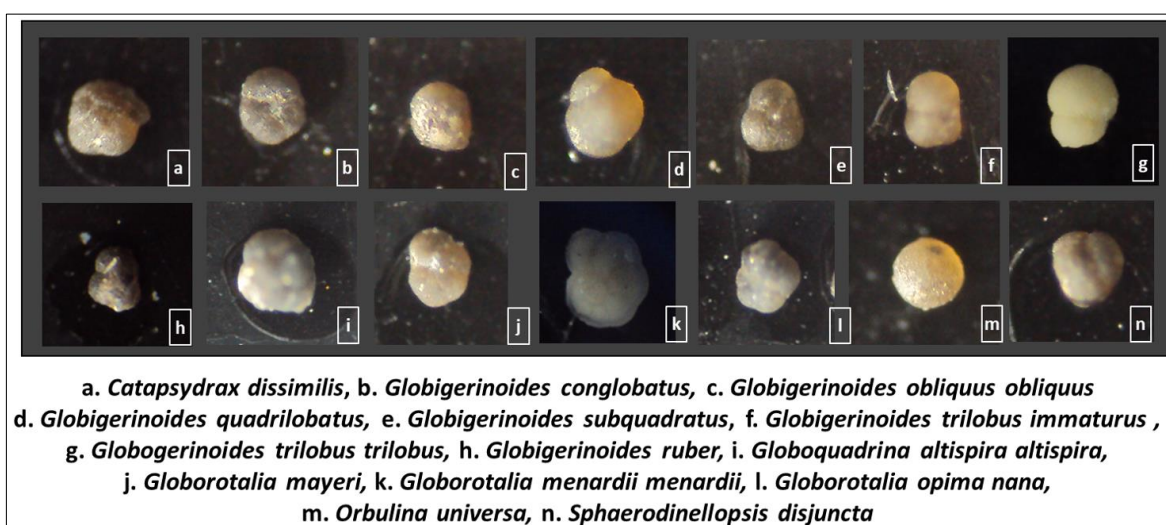


Figure 4. Planktic foraminifera assemblages in erupted mud originated from host rock (Pemali and Halang Formations).



Figure 5. Benthic foraminifera assemblages in erupted mud.

Only four species (4.76%) are not founded in mud, there are *Globorotalia continuosa*, *G. pseudopima*, *Globigerinoides sicanus*, and *Hastigerina praesiphonifera*. Thirty-eight benthic species can be identified in mud (Figure 3). *Amphycorina sublineata*, *Anomalinaella rostrata*, *Fiscerinaella diversa*, *Glandulina symmetrical*, *Laevidentalina bradyensis*, and *Missipina pasifica* – benthic foram are not recorded in mud (7.14%).

The mud eruption composes mostly of water, particularly in the wet season. In contrary, in the dry season, very little water drains out from the volcano, resulting in the intensive evaporation of salt travertine. This phenomenon might indicate that water of Ciuyah is also influenced by the meteoric water. It was also reported that the unconfined water at about one kilometer radius in Ciuyah area was saline.

Stratigraphic ranges and depositional environment of foraminifera contained in mud samples

Based on their stratigraphic ranges (Table 1), planktic foraminifera assemblages represent four age ranges, there are:

- Older than Zone N.10 (more than 16.4 my BP) or lowest of Middle Miocene, indicated by the appearance of *Globorotalia archeomenardii*. The last appearance of this species is taking place at top of Zone N.10 (Bolli and Saunders, 1984).
- Ranges of Zone N.13 – N.14 (12.5 – 11.3 my BP) or Middle Miocene, indicated by the appearance of *Globorotalia siakensis* and *Globorotalia mayeri*. The last appearance of *Globorotalia siakensis* is used to mark the top of Zone N.14 (Blow, 1969 in Blow, 1979). Bronnimann (1951) in Bolli and Saunders (1986), Nathan and Leckie (2003) mentoined

the last appearance of *Globorotalia mayeri* is taken place at top N.14 or 10.49 my BP.

- Ranges of Zone N.15 – N.17 (11.3 – 5.3 my BP) or Late Miocene. The appearance of *Globorotalia acostaensis acostaensis*, *Neogloboquadrina dutertrei dutertrei* associated with *Candeina nitida*, *Globigerinoides obliquus extremus*, *Globigerinoides ruber*, and *Globorotalia humerosa humerosa* reflected a younger group.

Based on the typical environment, benthic foraminifera in mud samples can be grouped to:

- Outer neritic zone, represented by genera *Amphistegina*, *Anomalinoidea*, *Bolivina*, *Cibicides*, *Duplella*, *Elphidium*, *Eponides*, *Fijinionion*, *Heterolepa*, *Hyalinea*, *Hyperammina*, *Nonion*, *Planulina*, *Pseudononion*, *Pyrgo*, and *Quinqueloculina*.
- Bathyal zone, represented by genera *Brizalina*, *Lenticulina*, *Melonis* and *Textularia*.

Several age-marker foraminifera groups mixing in mud samples is caused by:

- The host rock is deposited by turbidity currents. The appearance of *Globorotalia archeomenardii* reflected a reworking process during sedimentation caused gravity-flow mechanism. As a reworked fossil, this specimen is characterized by damaged or broken shape, scratches on the shells, differences on type and color of closed sediment.
- The ejected material is derived through Pemali and Halang Formations (Figure 6). Lower Middle Miocene aged fossil assemblages are originated from Pemali

Formation, while Mid-Middle Miocene to Late Miocene aged fossil assemblages from Halang Formation. It is supported by the similarity of species found in both host rock and mud.

The foraminifera assemblages in mud samples are most similar to it assemblages in Middle to Late Miocene sediment (Isnaniawardhani, et al., 2005

a, b) that contained in Pemali and Halang Formations (Kastowo & Suwarna, 1996 and Budhitrisna, 1996). The thick turbidity sediments succession of these formations are formed in rapid sedimentation rate in the active tectonic area, whereas mud eruption phenomenon usually occurred (Pitt & Hutchinson, 1982; Milkov, 2000; Mazzini, et al., 2009).

Table 1. Stratigraphic ranges of each planktic foraminifera contained in mud samples.

STRATIGRAPHIC RANGES	<i>Globorotalia archeomenardii</i>	<i>Globorotalia fohsi lobata</i>	<i>Globorotalia praemenardii</i>	<i>Globorotalia siakensis</i>	<i>Globorotalia mayeri</i>	<i>Globigerinoides subquadratus</i>	<i>Globigerina praebulloides</i>	<i>Hastigerina siphonifera</i>	<i>Globorotalia menardii</i>	<i>Sphaeroidinellopsis subdehiscens</i>	<i>Globigerina nepenthes</i>	<i>Globorotalia pseudomiocenica</i>	<i>Hastigerina aequilateralis</i>	<i>Candeina nitida</i>	<i>Globorotalia acostaensis acostaensis</i>	<i>Globigerinoides obliquus extremus</i>	<i>Globigerinoides ruber</i>	<i>Neogloboquadrina dutertrei dutertrei</i>	<i>Globorotalia humerosa humerosa</i>	Others
N. 17																				
N. 16																				
N. 15																				
N. 14																				
N. 13																				
N. 12																				
N. 11																				
N. 10																				
N. 9																				

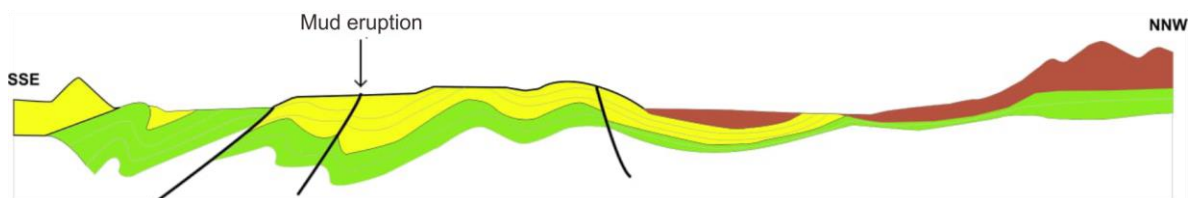


Figure 6. Profile of eruption system in escaping ejected mud to the surface (modification after Isnaniawardhani, et al., 2015b) Pemali Formation = green, Halang Formation = yellow, Quaternary Lahar Deposits = brown.

CONCLUSIONS

- A total of 84 foraminiferal species was identified in host rock. Forty-two species of them are planktic (genera *Candeina*, *Catapsydrax*, *Globigerina*, *Globigerinoides*, *Globoquadrina*, *Globorotalia*, *Hastigerina*, *Neogloboquadrina*, *Orbulina* and *Sphaerodinellopsis*) and forty-two species (genera *Amphistegina*, *Amphycorina*, *Anomalina*, *Anomalinoides*, *Bolivina*, *Brizalina*, *Bulimina*, *Cassidulina*, *Cibicides*, *Dentalina*, *Duplella*, *Eggrella*, *Elphidium*, *Eponides*, *Fiscerina*, *Fijini*, *Glandulina*, *Globocassidulina*, *Gyrogonia*, *Hanzawaia*, *Heterolepa*, *Hyalinea*, *Hyperammina*, *Laevidentalina*, *Lenticulina*, *Martinotiella*, *Melonis*, *Missipina*, *Nodogenerina*, *Nodosaria*, *Nonion*, *Nummulites*, *Planulina*, *Pseudononion*, *Pyrgo*, *Quinqueloculina*, *Robulus*, *Rotalia*, *Sigmoilina*, *Stilostomella*, *Textularia* and *Uvigerina*) are benthic.
- Planktic foraminifera assemblages contained in host rock reveals the age of Middle to Late Miocene (Zone N.11 to N.17). Based on benthic foraminifera, the rocks were deposited in outer neritic to bathyal influenced by turbidite mechanism.
- Materials ejected from subsurface are claystone to sandstone-size fragments, liquid, gas, and heat. The sedimentary rock fragments generally contain foraminifera. About 89.28% of foraminiferal species is recorded in the mud.
- Based on their stratigraphic ranges, planktic foraminifera represent four age-marker groups, there are: older than Zone N.10/Middle Miocene (indicated by the appearance of *Globorotalia archeomenardii*), ranges of Zone N.11 – N.12/Middle Miocene (marked by the appearance of *Globorotalia fohsi lobata* and *Globorotalia praemenardii*), ranges of Zone N.13 – N.14/Middle Miocene (*Globorotalia siakensis* and *Globorotalia mayeri*), and ranges of Zone N.15 – N.17/Late Miocene (*Globorotalia acostaensis acostaensis* and *Neogloboquadrina dutertrei dutertrei*).

- Benthic foraminifera assemblages in mud samples can be grouped to outer neritic and bathyal typical groups.
- The similarity and mixing of foraminifera assemblages in mud samples indicate material erupted have originated from erosion and elution of base- and side-rocks of Pemali and Halang Formations deposited during Middle to Late Late Miocene. Fluid and gas outputs under excess pressure condition will move to the surface by carrying the material.

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