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Limestone Diagenetic Records Based on Petrographic Data of Sentolo Formation at Hargorejo Traverse, Kokap, Kulonprogo

Rekaman Proses Diagenesis Berdasarkan Data Petrografi pada Batugamping Formasi Sentolo di Lintasan Hargorejo, Kokap, Kulonprogo

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Abstract

Limestone diagenetic records of Sentolo Formation have been studied in order to trace the history of the geological processes after the deposition of the rocks. A stratigraphic measure traverse was made in Hargorejo Village, Kulonprogo District, to identify the petrological characteristics of the Sentolo Formation. Limestone samples were taken along this traverse, and were used for a petrographic analysis. The analysis of thirty-eight limestone samples shows that the type is dominated by bioclastic grainstones which have been affected by various kinds of diagenetic processes after the deposition. The diagenetic processes recorded under the polarization microscope include cementation, replacement, bioturbation, micritization, recrystallization, dolomitization, compaction, fracturing, and leaching.

Keywords: grainstone, cementation, bioturbation, micritization, compaction

Sari

Rekaman proses diagenesis batugamping pada batugamping dari Formasi Sentolo telah dipelajari guna mengetahui sejarah proses geologi pasca pengendapan batuan. Lintasan pengukuran stratigrafi telah dibuat di Desa Hargorejo, Kabupaten Kulonprogo, untuk menentukan ciri-ciri petrologi batuan penyusun Formasi Sentolo. Sejumlah percontoh batugamping telah diambil di sepanjang lintasan ini, dan dipakai untuk bahan pengujian petrografi di laboratorium. Analisis petrografi yang telah dilakukan terhadap tigapuluh delapan percontoh batugamping yang diambil dari lintasan itu memperlihatkan bahwa jenisnya didominasi oleh batugamping bioklastika grainstone. Batugamping tersebut telah terpengaruh oleh beragam proses diagenesis pasca pengendapan batuan. Rekaman proses diagenesis yang teramati di bawah mikroskop polarisasi meliputi: penyemenan, penggantian, bioturbasi, pemikritan, rekristalisasi, pendolomitan, pemampatan, peretakan, dan pelarutan.

Kata kunci: *grainstone, penyemenan, bioturbasi, pemikritan, pemampatan*

Introduction

A petrographic limestone research generally includes its megascopic and microscopic appearances completed by the description of its type, the amount of components, interpretation of depositional environment, and diagenetic process that have occurred (Bathurst, 1975; Scholle, 1978; Longman, 1980; Flugel, 1982; MacKenzie *et al*., 1984; Read, 1985; Tucker & Wright, 1990; James, 1991; Adams & MacKenzie, 1998; Ulmer-Scholle & Mosley, 2000; Railsback, 2002; and Gregg, 2005). Nevertheles, researches on limestone diagenetic records in Indonesia are still limited. Therefore, aspects of limestone petrography, especially aspects of diagenetic records, are interesting research topics.

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The research of limestone diagenetic records aims at finding out the petrographic characters of limestone forming the Sentolo Formation related to the geological process that occured after the rock deposition. The research object is the Sentolo bioclastic limestone cropping out in Hargorejo Village, Kokap Subregency, Kulonprogo Regency, Special Province of Yogyakarta. The site, located about 4 km western of Wates Municipal, was chosen because in this traverse the limestone which is included to the Sentolo Formation was well cropped out well (Maryanto, 2009).

Method used in this study includes geological data collection at chosen traverse locations, and a limestone petrographic determination completed by an analysis of diagenetic records as well as test interpretation. A field activity was carried out by collecting geological data, especially limestone petrology at a traverse trending north-south in Hargorejo Village, Kulonprogo. The relatively fresh rock samples collected represent their stratigraphic position. The petrographic analysis that is the main laboratory work was carried out using a polarization microscope of Leica-DMRP equipped with a digital camera. The laboratory work includes laboratory tool preparation with its equipments, sample preparation, petrographic test, analysis, and interpretation using selected references. The analysis and petrographic test interpretation were initiated by determining the amount and type of the rock for its grouping followed by the identification of limestone diagenetic records.

STRATIGRAPHY

Systematic geological mapping of the Yogyakarta sheet on scale 1:100.000 was carried out by the Geological Research and Development Centre, Bandung (Rahardjo *et al*., 1995; Figure 1). Stratigraphic sequence of the existing rocks respectively from the older one are fine-grained clastic sediments of the Nanggulan Formation having Eocene-Oligocene age, Oligo-Miocene pyroclastic rock of the Kebobutak Formation, Miocene andesitic and dacitic intrusive rocks, clastic sediments of the Jonggrangan Formation, Mio-Pliocene Sentolo Limestone, and Quaternary Alluvial Deposits.

Regionally, the Sentolo Formation consisting of limestone and marly sandstone is widely spread out in the studied area. This formation comformably overlies and interfingers with the Miocene volcaniclastics and sediments of the Jonggrangan Formation and in turn is unconformably overlain by the alluvial deposits. It is generally known that limestone of the Sentolo Formation at Hargorejo Traverse consists of bedded bioclastic limestone with the total thickness of 180 m (Maryanto *et al.*, 2008). Some marl and tuffaceous marl intercalations can still be found in this formation (Maryanto, 2009; Figure 2).

The stratigraphic sequence of Sentolo Formation in Hargorejo Village is initiated by bioclastic limestone beds existing as grainstone-packstone type with intercalations of marl and tuffaceous marl. This grainstone-packstone bed often dominates the lower part of limestone sequence of Sentolo Formation. The grainstone-packstone bioclastic limestone are well-bedded at the middle part of the formation showing various thickness (Figure 3). Some homogenous layers show sharp contacts. Sedimentary structures are indistict. On the contrary, terrigenous material content dominated by volcanic rock fragments and quartz grains are still widely found in the middle part of this formation, besides in the lower part which consists of terrigenous material. The upper part of the formation is dominated by grainstone-packstone bioclastic limestone with calcareous claystone and marl intercalations. The limestone sequence is directly overlain by alluvial deposites.

PETROGRAPHY

The limestone petrographic analysis using Dunham classification (1962) shows that thirty-eight limestone samples of the Sentolo Formation collected from the studied traverse (Maryanto, 2009; Table 1) have similar textures. The analyzed rocks are dominantly grainstones, which are generally massive with grain orientation, fragmental bioclastic texture with moderately sorted, grain supported, closed fabric, and medium- to very coarse-grained, sub-angular to sub-rounded in shape.

To group carbonate grain component, besides using Dunham (1962) classification, Folk (1962) limestone component classification was also used. The carbonate grain component is dominated by fossil fragments and small amounts of intraclast and pellet. The fossil components or bioclastics are generally larger foraminifera fossils (Figure 4),

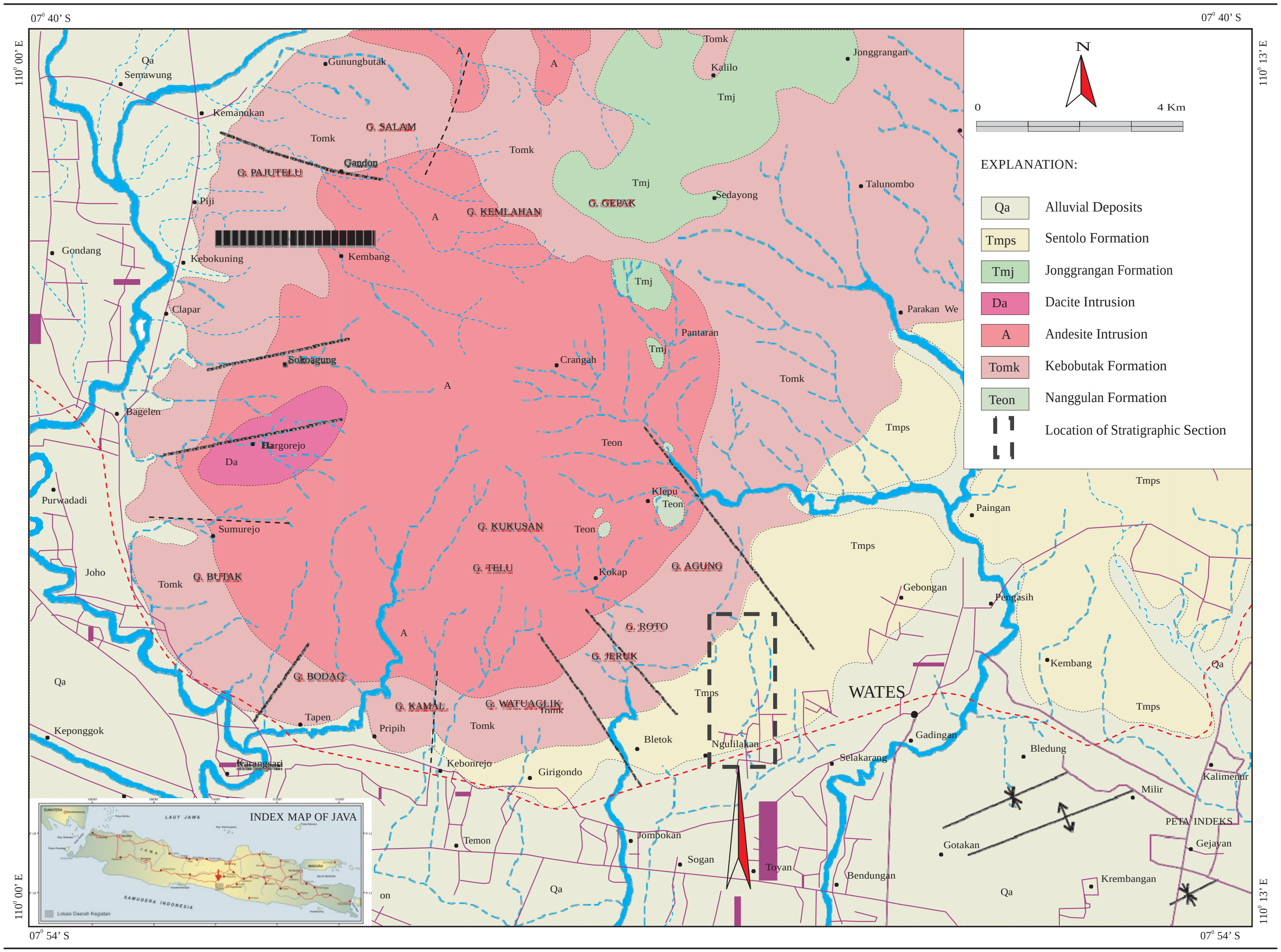
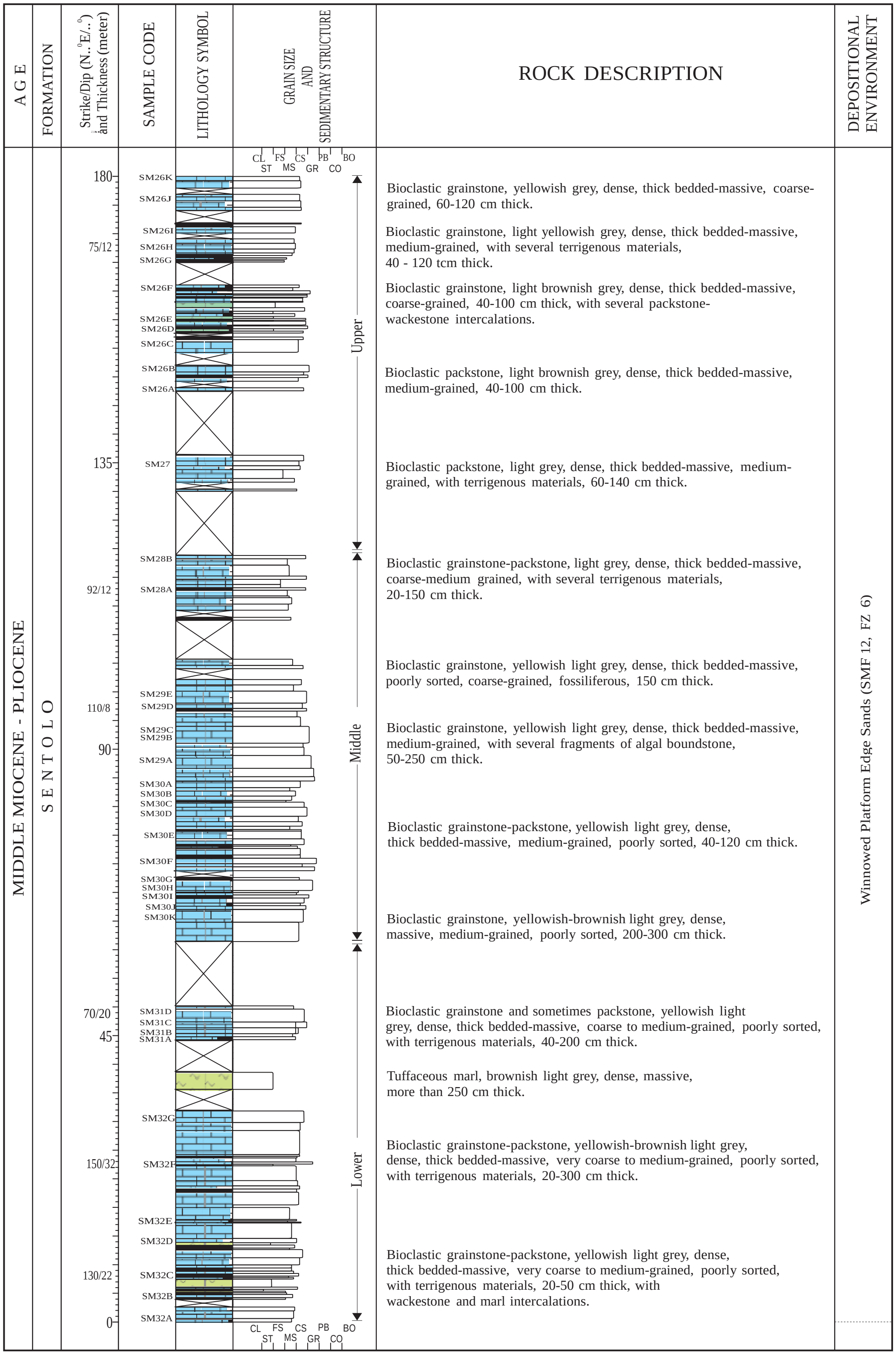


Figure 1. Geological map of Kulonprogo area (Rahardjo *et al*., 1995) and Hargorejo traverse (Maryanto *et al*., 2008).



Bioclastic grainstone, yellowish grey, dense, thick bedded-massive, coarse-grained, 60-120 cm thick.

Bioclastic grainstone, light yellowish grey, dense, thick bedded-massive, medium-grained, with several terrigenous materials, 40 - 120 tcm thick.

Bioclastic grainstone, light brownish grey, dense, thick bedded-massive, coarse-grained, 40-100 cm thick, with several packstone-wackestone intercalations.

Bioclastic packstone, light brownish grey, dense, thick bedded-massive, medium-grained, 40-100 cm thick.

Bioclastic packstone, light grey, dense, thick bedded-massive, medium-grained, with terrigenous materials, 60-140 cm thick.

Bioclastic grainstone-packstone, light grey, dense, thick bedded-massive, coarse-medium grained, with several terrigenous materials, 20-150 cm thick.

Bioclastic grainstone, yellowish light grey, dense, thick bedded-massive, poorly sorted, coarse-grained, fossiliferous, 150 cm thick.

Bioclastic grainstone, yellowish light grey, dense, thick bedded-massive, medium-grained, with several fragments of algal boundstone, 50-250 cm thick.

Bioclastic grainstone-packstone, yellowish light grey, dense, thick bedded-massive, medium-grained, poorly sorted, 40-120 cm thick.

Bioclastic grainstone, yellowish-brownish light grey, dense, massive, medium-grained, poorly sorted, 200-300 cm thick.

Bioclastic grainstone and sometimes packstone, yellowish light grey, dense, thick bedded-massive, coarse to medium-grained, poorly sorted, with terrigenous materials, 40-200 cm thick.

Tuffaceous marl, brownish light grey, dense, massive, more than 250 cm thick.

Bioclastic grainstone-packstone, yellowish-brownish light grey, dense, thick bedded-massive, very coarse to medium-grained, poorly sorted, with terrigenous materials, 20-300 cm thick.

Bioclastic grainstone-packstone, yellowish light grey, dense, thick bedded-massive, very coarse to medium-grained, poorly sorted, with terrigenous materials, 20-50 cm thick, with wackestone and marl intercalations.

Figure 2. Stratigraphic column of the Sentolo Formation at Hargorejo traverse, Kokap, Kulonprogo (Maryanto, 2009).

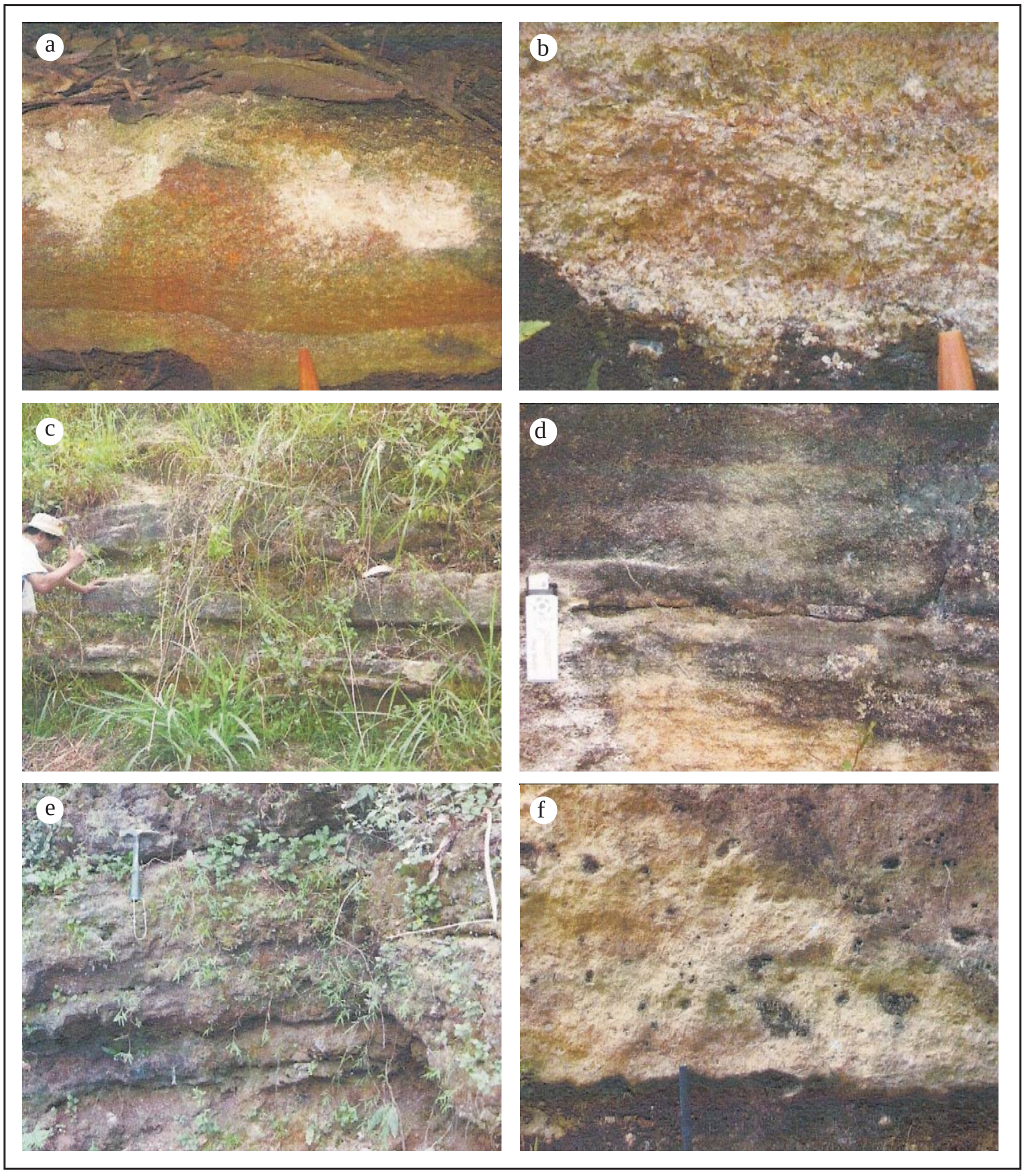


Figure 3. Views of several limestone outcrops of the Sentolo Formation at Hargorejo section, Kokap, Kulonprogo, showing a. erosional base; b. gravely coarse sand size; c. relatively uniform bedded; d. moderately sorted; e. platy bedding; and f. irregularly vuggy pores (Maryanto, 2009).

mollusks (Figure 5), and red algae (Figure 6). Other fossils were indicated in limited amount including bryozoa, coral, echinoderms, and brachiopod. The limestone sometimes still consists of terrigenous material (Figure 7) dominated by andesitic volcanic rock fragments that had altered, less of argillaceous sedimentary rock, quartz, feldspar, glauconite, opaque mineral including ore, and mafic minerals. Petrographically, the limestone is in general carbonate mud matrix and clay mineral free. Rock cements are calcite orthosparite and some other additional cement like iron oxides, quartz silica, and authigenic clay. Secondary minerals consisting of pseudosparite, micritized clay, and dolomite are rarely present. Rock porosity is rarely preserved, in general it has remains of interparticle and vug types. Limestone microfacies interpretation at this traverse (Maryanto, 2009) is winnowed platform edge sands

Table 1. Petrographic Test Result of Limestone Samples from Sentolo Formation at Hargorejo Traverse, Kokap, Kulonprogo (Maryanto, 2009)

No.	**Sample code**	**Carbonate Grains**				**Matrix**	**Cement**				**Re**	**Lm**	**Do**	**Po**
		Bi	**In**	**Pe**	**Te**		**Or**	**Ox**	**Si**	**Ac**				
1.	08SM26K	54.0	4.0	3.0	3.0	0.0	19.0	2.0	0.0	1.0	2.0	6.0	0.0	6.0
2.	08SM26J	49.0	9.0	2.0	12.0	0.0	14.0	3.0	0.0	2.0	0.0	2.0	0.0	7.0
3.	08SM26I	55.0	3.0	1.0	3.0	0.0	18.0	3.0	0.0	1.0	2.0	2.0	0.0	12.0
4.	08SM26H	57.0	5.0	3.0	8.0	0.0	14.0	3.0	0.0	0.0	2.0	2.0	0.0	6.0
5.	08SM26G	55.0	4.0	7.0	5.0	0.0	19.0	2.0	0.0	0.0	1.0	1.0	0.0	6.0
6.	08SM26F	49.0	3.0	0.0	4.0	0.0	26.0	3.0	1.0	1.0	1.0	3.0	0.0	9.0
7.	08SM26E	55.0	3.0	1.0	4.0	0.0	23.0	3.0	0.0	1.0	0.0	1.0	0.0	9.0
8.	08SM26D	38.0	16.0	2.0	10.0	0.0	24.0	2.0	1.0	0.0	3.0	0.0	0.0	4.0
9.	08SM26C	54.0	4.0	3.0	5.0	0.0	15.0	2.0	0.0	2.0	4.0	3.0	0.0	8.0
10.	08SM26B	41.0	10.0	0.0	14.0	0.0	30.0	1.0	0.0	2.0	0.0	0.0	0.0	2.0
11.	08SM27	50.0	4.0	1.0	7.0	0.0	19.0	2.0	0.0	1.0	9.0	2.0	0.0	4.0
12.	08SM28B	46.0	9.0	2.0	9.0	0.0	19.0	3.0	0.0	1.0	3.0	2.0	1.0	5.0
13.	08SM28A	55.0	7.0	0.0	10.0	0.0	17.0	1.0	0.0	1.0	0.0	2.0	0.0	7.0
14.	08SM29E	47.0	7.0	3.0	6.0	0.0	20.0	5.0	0.0	0.0	2.0	4.0	0.0	6.0
15.	08SM29D	44.0	6.0	2.0	13.0	0.0	20.0	3.5	0.0	2.0	4.0	2.0	0.0	3.5
16.	08SM29B	56.0	2.0	0.0	8.0	0.0	22.0	2.0	0.0	0.0	4.0	1.0	0.0	5.0
17.	08SM30A	61.0	4.0	1.0	1.0	0.0	22.0	1.0	0.0	0.0	3.0	1.0	0.0	6.0
18.	08SM30B	49.0	3.0	1.0	3.0	0.0	30.0	2.0	0.0	2.0	4.0	2.0	0.0	4.0
19.	08SM30C	50.0	4.0	3.0	7.0	0.0	18.0	2.0	0.0	3.0	6.0	2.0	0.0	5.0
20.	08SM30D	60.0	6.0	2.0	0.0	0.0	20.0	1.0	0.0	0.0	4.0	1.0	0.0	6.0
21.	08SM30E	59.0	6.0	1.0	3.0	0.0	18.0	1.0	0.0	0.0	4.0	2.0	0.0	6.0
22.	08SM30F	49.0	3.0	2.0	8.0	0.0	18.0	2.0	0.0	0.0	0.0	3.0	2.0	5.0
23.	08SM30G	49.0	6.0	4.0	8.0	0.0	17.0	2.0	0.0	1.0	2.0	2.0	0.0	8.0
24.	08SM30H	51.0	4.0	1.0	5.0	0.0	24.0	3.0	0.0	0.0	2.0	4.0	0.0	6.0
25.	08SM30I	52.0	7.0	1.5	4.5	0.0	24.0	2.0	0.0	0.0	2.0	3.0	0.0	4.0
26.	08SM30J	42.0	8.0	1.0	10.0	0.0	27.0	3.0	0.0	0.0	1.0	5.0	0.0	3.0
27.	08SM30K	50.0	6.0	2.0	8.0	0.0	22.0	2.0	0.0	0.0	2.0	1.0	0.0	7.0
28.	08SM31D	44.0	4.0	1.0	14.0	0.0	28.0	2.0	0.0	0.0	4.0	1.0	0.0	2.0
29.	08SM31C	49.0	3.0	1.0	4.0	0.0	33.0	2.0	0.0	1.0	2.0	1.0	0.0	4.0
30.	08SM31B	40.0	9.0	0.0	9.0	0.0	24.0	4.0	0.0	2.0	0.0	3.0	0.0	9.0
31.	08SM31A	53.0	1.0	1.0	4.0	0.0	27.0	2.0	0.0	1.0	2.0	1.0	0.0	8.0
32.	08SM32G	44.0	3.0	1.0	15.0	0.0	27.0	3.0	0.0	0.0	2.0	2.0	0.0	3.0
33.	08SM32F	48.0	12.0	0.0	5.0	0.0	22.0	3.0	0.0	1.0	2.0	2.0	0.0	5.0
34.	08SM32E	48.0	6.0	0.0	8.0	0.0	24.0	2.0	0.0	1.0	2.0	3.0	0.0	6.0
35.	08SM32D	39.0	12.0	0.0	23.0	0.0	17.0	2.0	0.0	3.0	0.0	1.0	0.0	3.0
36.	08SM32C	32.0	12.0	0.0	27.0	0.0	18.0	3.0	0.0	4.0	0.0	2.0	0.0	2.0
37.	08SM32B	41.0	10.0	0.0	23.0	0.0	16.0	3.0	1.0	2.0	0.0	2.0	0.0	2.0
38.	08SM32A	33.0	6.0	1.0	30.0	0.0	18.0	4.0	0.0	2.0	2.0	2.0	0.0	2.0

Bi : bioturbation
Do : dolomitization
Ox : iron oxides
Pe : pollet
Re : recrystalization
Ac : authigenic clay
Or : orthosparite
In : intraclast
Lm : micritized mud
Si : quartz silica
Te : terigeneous mat.
Po : porosity

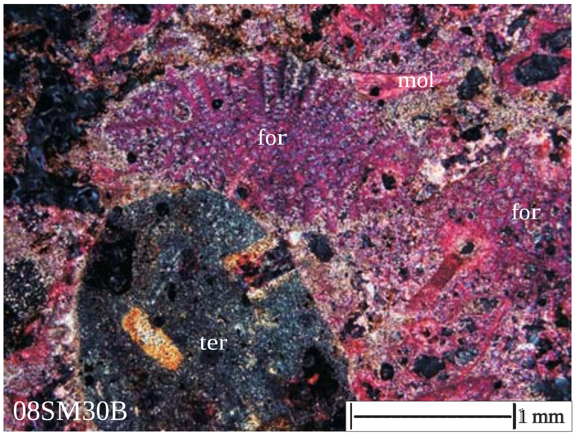


Figure 4. Photomicrograph of bioclastic grainstone with several bioclastics of foraminifera (for), as well as terrigenous materials (ter) and mollusks (mol). Sample SM30B, with cross-nicol and carbonate staining.

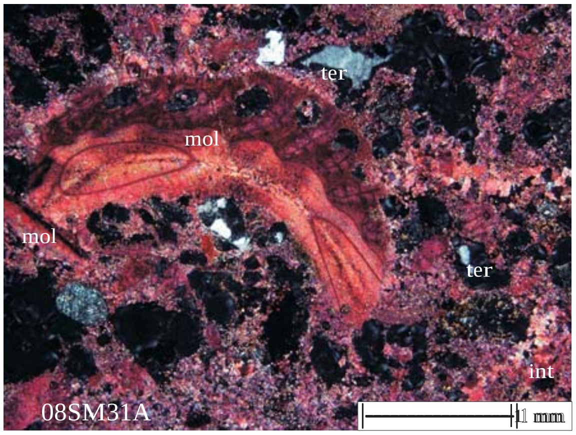


Figure 5. Photomicrograph ofioclastic grainstone showing several grain components of mollusks (mol) and terigenous materials (ter). Sample SM31A, with cross-nicol and carbonate staining.

which was notified by Smf-11 Fz-6 (Flugel, 1982; Wilson, 1975).

DIAGENETIC PROCESS RECORDS

Petrographic test result shows some preserved diagenetic process records on the limestone of Sentolo Formation at Hargorejo Traverse which include cementation, replacement, bioturbation, micritization, recrystallization, dolomitization, compaction, fracturing, and dissolution.

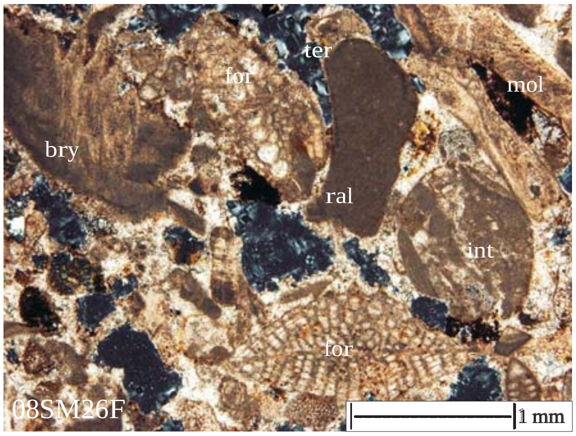


Figure 6. Photomicrograph ofioclastic grainstone showing several bioclastic components as red algae (ral), foraminifera (for), bryozoans (bry), mollusks (mol), and intraclasts (int). Sample SM26F, with parallel-nicol and without carbonate staining.

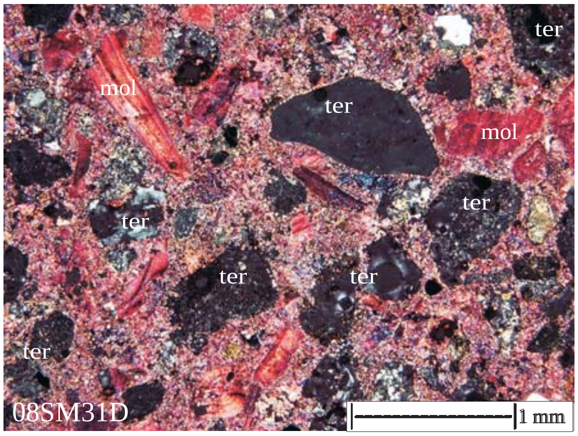


Figure 7. Photomicrograph ofioclastic grainstone appearing a lot of terrigenous materials (ter) and mollusks (mol). Sample SM31D, with cross-nicol and carbonate staining.

Cementation

The main and greater part of limestone diagenetic records of the Sentolo Formation at Hargorejo Traverse is cementation. Cementing material is always present in the rock in a large amount and various types. The main cement is carbonate cement originated from marine environment, followed by carbonate cement from meteoric phreatic environment, and very rare non-carbonate cement from meteoric vadose environment.

Carbonate cement from marine environment is concentrated around pore margins, both inside and among grains, with radial isopachous crystal structure (Figure 8). This kind of cement is preserved limitedly in some samples because it mainly is presumed to have been damaged or replaced by the next phase carbonate cement originated from meteoric phreatic environment.

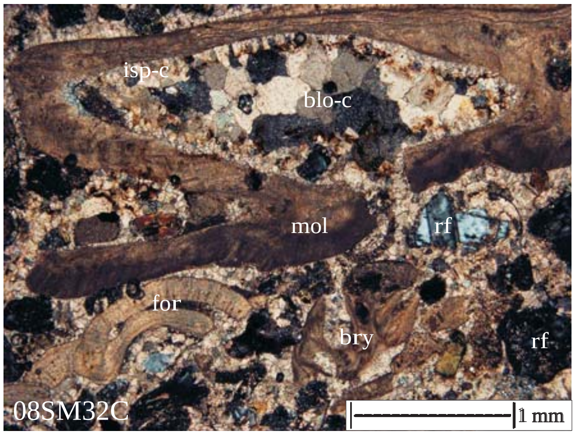


Figure 8. Photomicrograph of bioclastic grainstone showing infilled interparticle porosities, formerly by very fine isopacous cement (isp-c) from marine environment, followed by blocky drussy mosaic anhedral cement (blo-c) from meteoric phreatic environment. Several grains of mollusks (mol), foraminifera (for), bryozoans (bry), and volcanic rock fragment (rf) appear in this sample. Sample SM32C, with cross nicol and without carbonate staining.

Carbonate cement from meteoric phreatic is the main cement in limestone at the studied traverse. This cement has in general of blocky drussy mosaic anhedral structure with very fine to medium crystal size (Figures 8 & 9). Almost the whole pores of interparticle and intraparticle had been filled with the cement from this meteoric phreatic environment.

The existing non-carbonate cement from meteoric phreatic environment of post-carbonate cementing is anhedral granular mosaic of very fine quartz crystal found in very limited amount. Non-carbonate cement originated from meteoric vadose environment is present as authigenic clay minerals and iron oxides. Clay minerals are concentrated as fractures and joints filler in the rocks. The limited iron oxide cement with irregular form and scatterring also fill the pores and fractures of the rocks forming iron oxides veinlets.

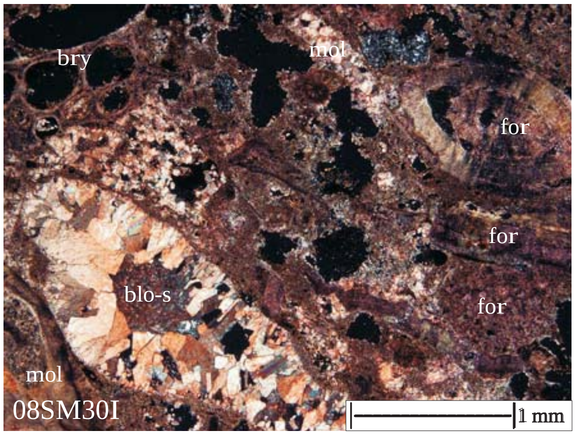


Figure 9. Photomicrograph of bioclastic grainstone indicating several dissolute fossils infilled by blocky drussy mosaic anhedral (blo-s) from meteoric phreatic environment. This sample also shows several fossils of foraminifera (for), mollusks (mol), and bryozoa (bry). Sample SM30I, with cross nicol and without carbonate staining.

Replacement

Replacement process records also took place in some fossils, especially mollusks, which were replaced by meteoric phreatic calcite crystals (Figure 9). The grain replacement produced pseudosparite having mosaic anhedral crystals which in general having medium crystal size reaching 0.8 mm (Figure 10). The replacement process records, especially fossil

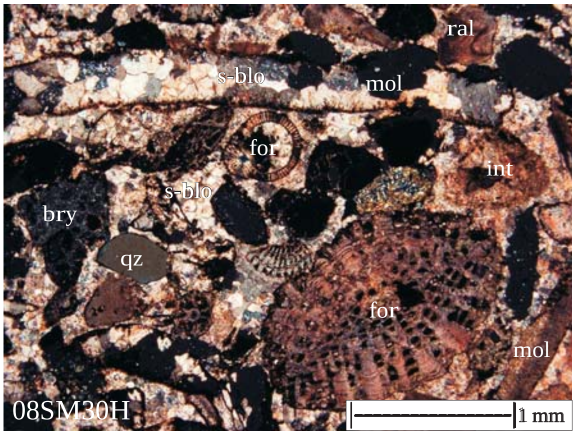


Figure 10. Photomicrograph of well cemented bioclastic grainstone points out several grains of foraminifera (for), bryozoa (bry), red algae (ral), intraclast (int), qurtz (qz), and ghost structure of mollusks (mol upper part) due to replacement. Sample SM30H, with cross nicol and without carbonate staining.

replacement, always take place in all rocks although the material is in limited amount. Some fossils can no longer be identified due to this replacement, although some fossil individuals can be observed from the grain margins, which are presumed to be mollusks.

Bioturbation

The bioturbation appearance, especially the trace of organism burrowing (Choquette & Pray, 1970) is observed only at some rock samples in very limited amount. Pores of these bioturbation traces generally have size less than 1 mm and irregularly spread on the rocks. The pores of bioturbation traces had in general been infilled by fine to medium size orthosparite carbonate cement having blocky drussy mosaic anhedral structure from meteoric phreatic environment (Figure 11). In this case, bioturbation processes forming the pores were immediately followed by the process of pore filling or cementation.

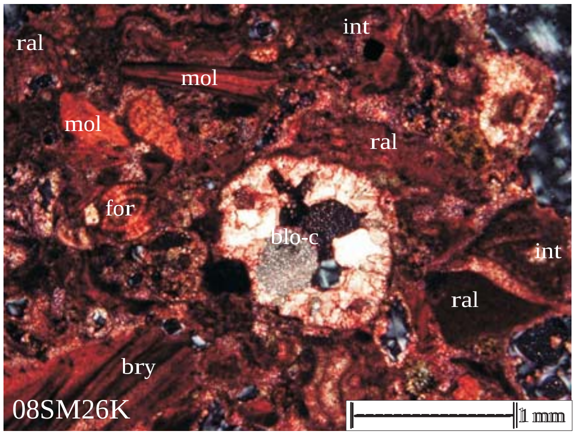


Figure 11. Photomicrograph of bioclastic packstone displaying several mollusks (mol), foraminifera (for), bryozoans (bry), intraclasts (int), and bioturbation pores infilled by blocky drussy mosaic anhedral cement (blo-c) from meteoric phreatic environment. Sample SM26K, with cross nicol and without carbonate staining.

Micritization

Records of micritization processes were only observed on some rock samples in a small amount. Carbonate mud as the result of the micritization usually is concentrated at the edge of carbonate grains which by some researcher were called as micrite envelops (Figure 12) like at the bryozoa fossil margin of (Figure 6), red algae, mollusks, and larger foraminifera.

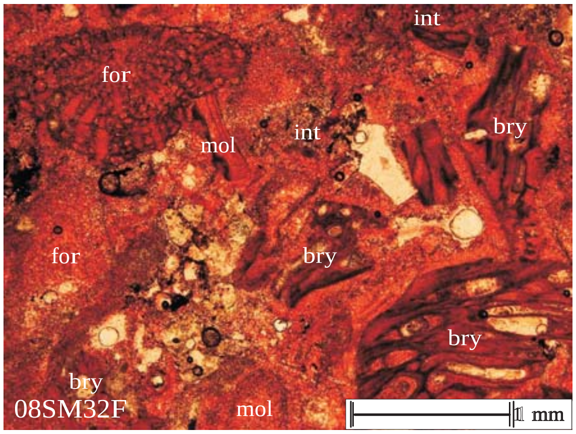


Figure 12. Photomicrograph of several micritized bryozoa fragments (bry) at grainstone and the other grains of foraminifera (for), mollusks (mol), and intraclast (int). Sample SM32F, with parallel nicol and without carbonate staining.

Recrystallization

Recrystallization processes are recorded on some carbonate grains although the number is limited. Pseudosparite observed as the result of the recrystallization of carbonate grain component, especially fossil grains (Figure 13), so that the type of the fossils can

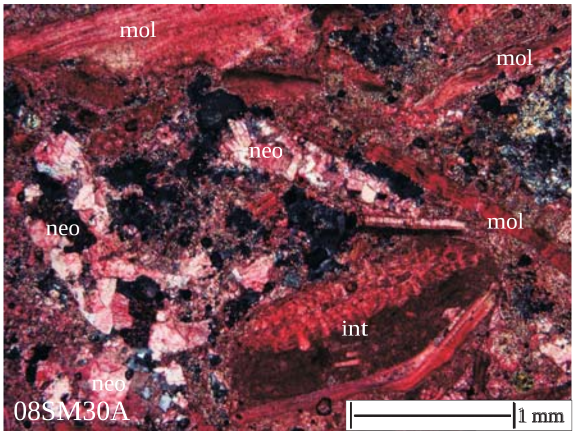


Figure 13. Photomicrograph of grainstone pointing out several grains of intraclast (int), mollusks (mol), and unidentified fossil fragments at grainstone due to replacement (neo). Sample SM30A, with cross nicol and with carbonate staining.

no longer be identified. The existing fossil appearance can only be identified from the initial grains as a ghost structure. Sometimes, the boundary between the initial grains and the carbonate cement is no longer clear or diffused due to this recrystallization process.

Dolomitization

Dolomitization randomly took place on some rock samples of the Sentolo Formation, both on grains and carbonate cement. Dolomite is present in a limited amount, nonferrous with fine crystal size conforms to the initial material, and having mosaic granular structure.

Compaction

Rock compaction processes were clearly observed on some rocks marked by the grain shapes which are long, concave-convex, and sutured (Figure 14). The compaction process directly drew clay mineral which was concentrated to form very low amplitude stylolite features. On some rocks, the compaction processes were not clearly observed because they were preceeded by somewhat intensive cementation processes.

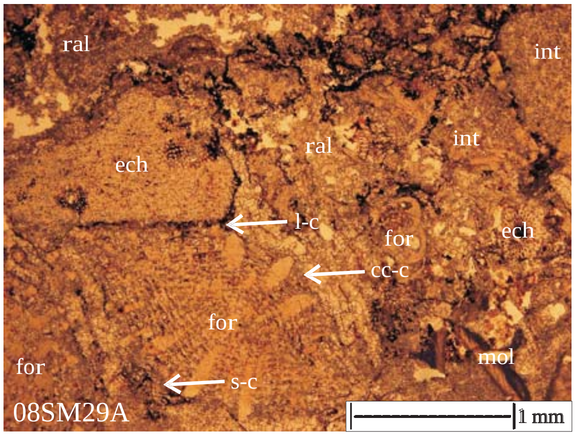


Figure 14. Photomicrograph of long (l-c), concave-convex (cc-c), and sutured (s-c) grain contacts at grainstone due to compaction and pressure-solution. It also shows intraclast (int), foraminifera (for), mollusks (mol), red algae (ral), and echinoderms (ech). Sample SM29A, with parallel nicol and without carbonate staining.

Fracturing

Joints and fractures are present in some limestone samples. Shear joint is present as hairy joints cutting grains and other materials. Rock fracturing nowadays often takes place as plant activities on the surface. Some of the fractures remain empty leaving the type of fracture porosity. Some of the fractures had been infilled by carbonate cement from meteoric environment with blocky mosaic granular having medium crystal size (Figure 15).

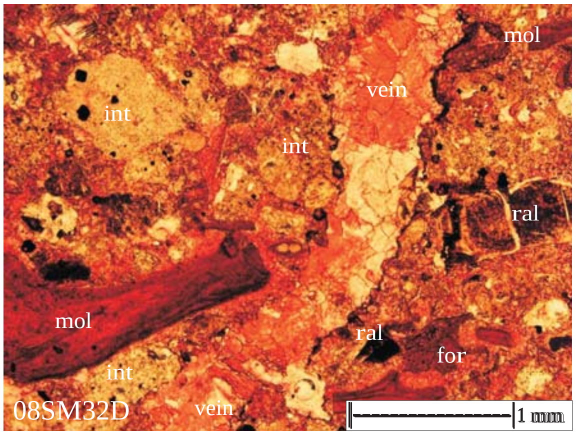


Figure 15. Photomicrograph of rock fracture finally infilled by blocky mosaic anhedral calcite from meteoric phreatic environment (vein). It also points out intraclast (int), foraminifera (for), mollusks (mol), and red algae (ral). Sample SM32D, with parallel nicol and without carbonate staining.

Dissolution

Limestone dissolution processes can take place on various diagenetic environments, although in general they take place on meteoric vadose environment. Dissolution process records can be found in some rock samples, although they have low intensity. Dissolution processes was not fabric selective, they randomly took place on limestone components, both of grains and cement materials. The results of the dissolution process are vuggy type secondary porosity which is the development of interparticle primary porosity type (Figure 9). The porosity size found is in general fine and it has not connected to each other to form channel porosity type.

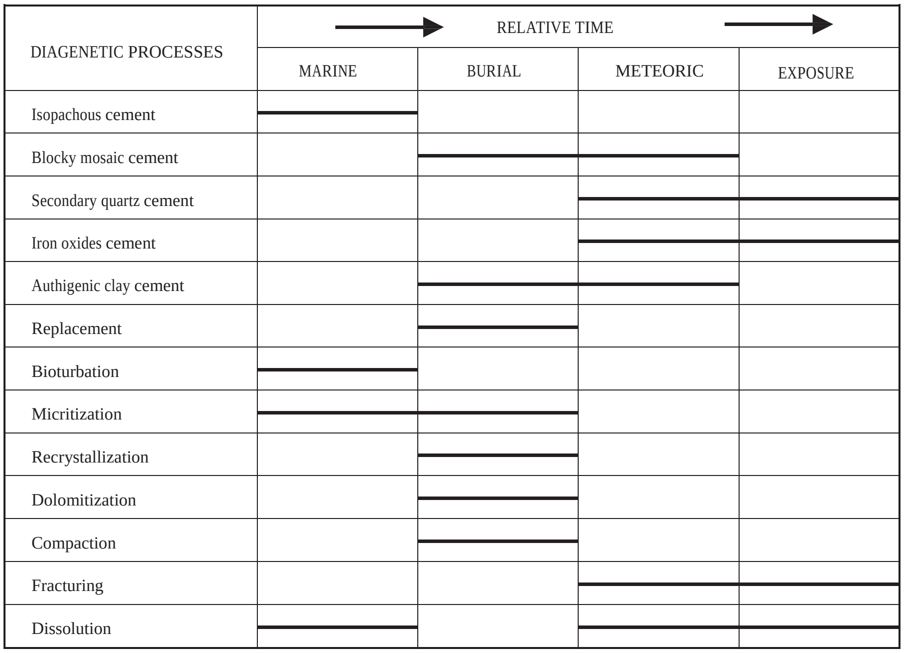
Some pores as dissolution results have been infilled by orthosparite in meteoric environment, mixed with iron oxides, authigenic clay minerals, and secondary quartz. Vadose environment and the process has been happening up to now.

Discussion

Diagenetic processes affecting limestone of the Sentolo Formation took place immediately after its initial deposition and during and after its appearance at the surface now. One diagenetic process took places coincidently to another one or it followed the other one (Figure 16). In that case, of course there are correlations among those processes. Petrographic test result shows there is a similarity in limestone texture deposited in winnowed platform edge sands facies (Smf-11 Fz-6; Maryanto, 2009). The rise and fall of the tides after the deposition of the rocks made the cementation process take place well (Braithwaite *et al.,* 2000). This marine cementation process was followed by cementation process in marine burial environment (marine burial diagenesis; Melim *et al*., 2001; Ramadan *et al*., 2004). Nevertheless, both carbonate cements from these diagenetic environments had been damaged and replaced by neomorphism and cementation processes in meteoric phreatic environment where the rock was cropped out.

Replacing processes took place on some fossils, especially mollusks after the rock deposition and the rock was overlain by another layer at the next deposition. This process is without a dissolution phase in terms of aragonite crystal forming mollusk shell was suddenly replaced by calcite crystal. This process still leaves a structure on the mollusk fossils. Fossil replacement continued to recrystallization process in some fossils. The identification of this process is the damage of fossil internal structure and fossil boundary had unseparated unified with blocky mosaic cement. Limestone recrystallization in the Sentolo Formation affects the whole components or known as non selected fabric recrystallization (Moore, 1997). The replacement process was also followed by a little dolomitization process. The irregular characteristic of fine non-ferrous non-planar dolomite crystal is indicative of the moderately burial diagenesis phase (Yoo *et al.,* 2000) until shallow burial diagenesis (Smith & Simo, 1997).

Organism burrowing process is apparently preserved only on some samples in a small amount. The process took place immediately after the rocks were overlain by another layer in the next deposition as the result of marine organism activities. Bioturbation is tightly related to micritization process of some fossils. In this case, the fossil micritization can also happen at the end of the diagenetic process at the time of the rock crops out, or it can be called as dissolution or near-surface weathering (Smith &



DIAGENETIC PROCESSES	RELATIVE TIME →			
	MARINE	BURIAL	METEORIC	EXPOSURE
Isopachous cement	—			
Blocky mosaic cement		—	—	
Secondary quartz cement			—	—
Iron oxides cement			—	—
Authigenic clay cement		—	—	
Replacement		—		
Bioturbation	—			
Micritization	—	—		
Recrystallization		—		
Dolomitization		—		
Compaction		—		
Fracturing			—	—
Dissolution	—		—	—

Figure 16. Diagenetic processes history in relation with relatively time of the limestone samples from Sentolo Formation.

Simo, 1997). Micritization in some fossil fragments is preserved more intensively, and it was initiated by a rock dissolution process.

The abovementioned burial diagenetic phase also caused rock compaction. Although regionally no rock formation was found overlying the Sentolo Formation, post deposition burial by the formation would cause the compaction process to happen well. The compaction process would soon end at the time of the rock crops out. Although the record is vague, jointing process as the result of tectonic followed by the formation uplifting, was still observed on some samples. Authigenic clay minerals were present in some rock samples infilling fractures caused by overburden (Tucker & Wright, 1990). Sometimes clay minerals are present as cementing material concentrated in dissolution pores immediately followed by secondary quartz and iron oxides in meteoric vadose environment at the diagenetic phase of rock cropping out.

The end result of the dissolution process after uplifting at meteoric vadose zone at the diagenetic phase of rock cropping out is the forming the vuggy type porosity (Moore, 1997). Diagenetic processes undergone within the Sentolo Formation caused the rock pores to develop in concommittance with the sequence of the diagenetic processes. The rock pores were initiated by the number of interparticle pore type. This is identified by the small amount of carbonate cement from marine environment as well as from burial environment. The interparticle pore type is very dominant along with some pore types of intraparticle, fenestral, and shelter. The type of mouldic and vuggy types took place afterwards along with fracture pore type from shear joint due to tectonics. The last porosity type had been recovered by meteoric phreatic and meteoric vadose cements which also took place at the diagenetic phase of rock cropping out.

Conclusions

Petrographic analysis carried out towards thirty-eight limestone samples at Hargorejo Traverse, Kokap, Kulonprogo, shows a similar texture, namely grainstone. The prominent similarity is that the existing carbonate grains have well been sorted, abraded, and leached showing similar microfacies, that is winnowed platform edge sands facies (Smf-11 Fz-6). The diagenetic process records preserved on that rock include cementation, replacement, bioturbation, micritization, recrystallization, dolomitization, compaction, fracturing, and dissolution.

Cement from marine and burial environments generally had damaged and replaced by the cement from meteoric phreatic environment. Replacement of some fossils by meteoric phreatic calcite crystals causes the fossils no longer could be identified. Trace of organism burrowing formed pores which was immediately followed by pores filling process or cementation. Carbonate mud as the result of micritization is in general concentrated at the carbonate grain margins forming micrite envelops. The presence of dolomite is limited and non-ferrous with fine crystal size conformed to the original material. Compaction on some rocks is marked by long, concave-convex, and sutured grain contacts. Some joints and fractures are infilled by carbonate cement having blocky mosaic granular in medium size. Dissolution took place in various diagenetic environments, although generally in meteoric vadose environment at the rock cropping out diagenesis phase.

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