SEM-EDX study on authigenic clay minerals in sandstone of Jatiluhur formation

T R P Astuti, R Aditiyo, A Oktavioni and Supriyanto
Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia
Corresponding author’s email: supriyanto@sci.ui.ac.id

Abstract. The presence of authigenic clay minerals is usually found in sandstones where these minerals grow in the environment itself. Authigenic clay minerals provide benefits to sandstones, especially to determine the quality of porosity and permeability in sandstones. The samples in this study were collected from an outcrop of measured section at Cipamingkis’ River. The main goal of this study was to understand the presence of authigenic clay minerals in sandstones caused by the diagenetic process using Scanning Electron Microscope and Energy Dispersive X-Ray (SEM – EDX method. The results of this study were kaolinite, smectite, and illite found in very dominant amounts in sandstones as pore linings, pore fillings, replacement, and vug fillings.

Keywords: Authigenic clay minerals, Jatiluhur formation

1. Introduction
The abundance of clay mineral in the sandstone usually is as a matrix. The clay mineral found in sandstones will have thin laminar due to variations in the competence of the depositional environment. The clay mineral found together with the sand can be as detrital clay and biogenic clay. The detrital clay mineral can form clusters of clay minerals that will look like sand-sized material. This occurs because of the erosion of the deposited rock layers immediately after being transported by sandstones.

One of the clay minerals formed in sandstones is authigenic clay minerals. The authigenic clay minerals themselves are clay minerals formed in the environment itself, not from other places. The formation of authigenic clay minerals in sandstones can be formed due to diagenesis process. Diagenesis is a process of overall change both physically, chemically, and biologically after the sediment is deposited [1]. Diagenesis in sandstones includes compaction, dissolution, cementation, and appearance of authigenic clay minerals [1]. In other words, diagenesis has an important role in controlling post-deposition processes.

This research was carried out in the Jatiluhur Formation based on Van Bemmelen’s Physiography where the outcrop was in the Cipamingkis River, Bogor Through (figure 1) [1]. The Jatiluhur Formation was deposited on a slope-shelf system by turbidity current [2]. The sandstone characteristics of the Jatiluhur Formation have an important role because it can be analogous to the Upper Cibulakan Formation which is a good reservoir in one of the oil and gas blocks off the north java basin.
The presence of authigenic clay minerals caused by one of the sandstone diagenesis processes will have implications for the increase and decrease of porosity quality in the sandstones. The aim of this study was to understand the process and the characteristics of authigenic clay mineral formation in sandstone by diagenesis.

2. Data and method

The data in this study was obtained from an outcrop of Jatiluhur Formation at Cipamingkis River, Bogor, West Java Province. This study began with stratigraphic measurements along the Cipamingkis river (A–D). In the outcrop of Jatiluhur Formation is composed mainly of fine to very-fine grained sandstones and intercalated siltstone, parallel and ripple – cross lamination sandstone, normal and inverse grading sandstone, and limestone.

Eight samples of sandstone outcrops with different facies were used for SEM-EDX analysis. Identification of microstructure of clay minerals using SEM is not just taking pictures of the morphology of the mineral, but also looking down into the pores, identify the smallest minerals, and examine the distribution of these minerals within the pores [4]. While Energy Dispersive X-ray spectroscopy (EDX) is an analytical technique used to analyze elements and chemical characterization of a sample. The measurement of chemical elements by EDX is done by analyzing the X-ray beam from the sample produced by moving electrons. SEM-EDX must be operated with electron parameter settings such as high voltage, spot size, bias and beam current as well as optical parameters such as contrast and proper focus to obtain scientifically optimal image results and not provide multiple interpretations.

3. Results and discussion

The results of the SEM-EDX analysis show that there are several authigenic clay minerals in the sandstone including kaolinite, smectite, illite/smectite, and other authigenic minerals such as K-feldspar authigenic overgrowths (albite).

In the SEM (figure 3), the kaolinite \( \text{Al}_4[\text{Si}_4\text{O}_{10}] (\text{OH})_8 \) occurs as face-to-face stacks of pseudohexagonal plates or books. The occurrence of authigenic kaolinite partly fill-pores between detrital quartz. EDX analysis yielding nearly equal peak heights of Si and Al confirms the identification as kaolinite [5].

![Figure 1](image_url)

**Figure 1.** (a) West Java physiography, and (b) The stratigraphic measurement path on the RBI Map of Dayeuhkaum Sheet (Scale 1:25,000).
In the SEM (figure 4), the present smectite clay mineral is very abundant in sample 9 B. Smectite 
\((\frac{1}{2}\text{Ca, Na})_0.7 (\text{Al, Mg, Fe})_4 [(\text{Si, Al})_8\text{O}_{20}] \cdot n\text{H}_2\text{O}\) has a structure of 2:1 with one octahedral layer in the 
middle of the two tetrahedral layers [6]. Among these layers, present cations that cause the swelling 
properties of the smectite. The morphology of authigenic smectite appears as a thin, webby crust. The 
abundance of authigenic smectite in sandstone is usually as partly coating (pore-lining) a detrital 
quartz grain. EDX spectrum showing the major elements of smectite (Si, Al, Mg, Fe, and K).

Figure 2. (a) Sandstone with inverse grading structure; (b) sandstone with parallel lamination 
structure; (c) limestone; (d) fine to very–fine grained sandstone; (e) very–fine grained 
sandstone with intercalated siltstone; (f) sandstone with slump structure.

Figure 3. (a) Authigenic kaolinite partly filling pores (magnification 1500x); (b) EDX of kaolinite.
In figure 5, Illite $K_{1.1-1.5}Al_{4}[Si_{7-6.5}Al_{1-1.5}O_{20}](OH)_4$ has a morphology that traces and is present as a pore-lining. Illite also usually acts as a pore-bridging which has major elements: Si, Al, and K, with a minor amount of Mg, Ca, and Fe. Note: in the illite EDX spectrum, the relative peak height of K is usually less than that of Al. This is in contrast to K-feldspars where the K and Al peaks are of equal height [5].

Albite in SEM (figure 6), seen overgrowths as small rhombic crystals, partly covering a detrital K-Feldspar surface. Identification of both the detrital and authigenic minerals is based on EDX analysis yielding the major elements Si, Al, and K (see EDX on facing page). This is a typical EDX spectrum for K-feldspar [5]. Authigenic K-feldspar overgrowths on a detrital K-feldspar grain [7].

Authigenic clay minerals formed in the sandstone of the Jatiluhur Formation are caused by diagenesis process. Diagenesis process are strongly influenced by depositional environment and mineralogy in rocks. The formation of authigenic clay minerals in sandstones can be formed due to precipitation of formation water [7]. Autigenesis that occurs, among others, is indicated by changes in feldspar and volcanic glass into clay minerals, or from one type of clay mineral to another type of clay mineral.

The authigenic minerals found in the study area were kaolinite, smectite, illite. Kaolinite is present due to changes in K-feldspar minerals. Kaolinite occurs as face-to-face stacks of pseudohexagonal...
plates or books. Smectites are produced by differences in the interstratification of mineral layers in a single structure [1]. Smectite has a flat and permeating morphology, while illite has a morphology that is thick and tapering. With further burial and temperature increase, the dioctahedral smectite can be transformed into illite, which passes through the interlayer form. Smectite dioctahedral can have a range of compositions but characteristically has a low Al/Si ratio and contains Ca, Fe, and Mg [1]. Kaolinite, smectite, and illite in siliciclastic rocks can be in eodiagenesis and mesogenesis stage [8]. In the study area, there was an increasing presence of smectite-illite autogenesis into older aged rocks. This is interpreted as a result of further burial and the addition of temperature that produces the authigenic mineral. When viewed from SEM analysis, it can be observed that the presence of smectite and illite minerals simultaneously has more abundance of smectite than illite.

Based on results of SEM analysis, it can be seen that the behavior and morphology of secondary minerals, especially clay minerals, greatly influence the porosity values in the sandstone of the Jatiluhur Formation. The abundance of secondary minerals as pore-lining, pore-filling, and dissolution in each sandstone’s facies makes the porosity values of each facies also vary. Samples with the presence of albite dissolution, tend to increase porosity values because dissolving albites will make secondary porosity (intragranular porosity). Samples with illite abundance also tend to increase or at least maintain porosity due to illite morphology which is tapered and thickened so that it still allows cavities between them and illite also tends to prevent overgrowth of quartz minerals. Meanwhile, samples with the presence of kaolinite and smectite tend to reduce porosity due to their nature as pore fillers.

4. Conclusion

The results of the SEM-EDX analysis show that there are several authigenic clay minerals in the sandstone including kaolinite, smectite, illite/smectite, and other authigenic minerals such as K-feldspar authigenic overgrowths (albite). The abundance of authigenic minerals as pore-lining, pore-filling, and dissolution will affect the increase and decrease in sandstone porosity value.

Acknowledgments

The major contribution came from Quantitative Sedimentology Research Group, Universitas Indonesia, financially supported by Universitas Indonesia through the Hibah PIT-9 with grant number NKB-0033/UN2.R3.1/HKP.05.00/2019.
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