Textural and mineralogical characteristics of sand grains of Oyo River Deposit at Yogyakarta, Indonesia: implications on sedimentation and origin

I F Lubis¹, A D Titisari¹* and N S Irsani¹

¹Geological Engineering Department, Faculty of Engineering, Universitas Gadjah Mada, Jalan Grafika Bulaksumur 2, Yogyakarta 55284, Indonesia
*E-mail: adewtitisisari@ugm.ac.id

Abstract. Oyo river deposit is one of the potential resources for small scale sand mining in Yogyakarta. The deposit extends along the upstream to downstream area of the river. A detailed study on textural and mineralogical characterization is aimed for better understanding of Oyo River sedimentation and provenance. Ten sediment samples were analyzed by using granulometry method, these include grain size, morphological and mineralogical analysis. The result shows that the average of grain size changes from coarse sand (0.88 mm) in the upstream to medium sand (0.37 mm) in the downstream. Sorting value is dominated by moderately sorted (0.71φ – 0.94φ), skewness is dominated by very fine skewed (0.3φ - 1.10φ), and kurtosis is dominated by extremely leptokurtic (2.8φ – 6.5φ). Meanwhile for the grain shape is dominated by oblate and bladed, sphericity changes from elongate to subequant, roundness is dominated by subangular and subequant. Mineralogical composition consists of magnetite, hematite, pyroxene, amphibole, quartz, feldspar, and lithic fragment. Plotting result on triangular QFL (Quartz Feldspar Lithic-fragment) diagram shows that the provenance of Oyo River sand deposit is coming from dissected arc tectonic setting.

1. Introduction
The Oyo River is one of the rivers where the upstream is located on the Gajah Mungkur Mountains, Wonogiri Regency, while the downstream is located at the Bantul Regency. The length of main river is 106.75 km and watershed area are 639 km². This watershed area is bordered by Baturagung Mountains in the north and the Wonosari Basin in the south. Sedimentation and provenance of Oyo River is interesting to be observed because the position of the upstream river is in the inactive volcanic area while most of the river bodies are in the karst area. It is impacted on the different dynamics compared to other rivers in Yogyakarta. Thus, the objective of this study is to determine the changes in sediment characteristics from upstream to downstream and the origin rocks of the sediments in the Oyo River based on the statistical values.

2. Regional Geology
Physiographically, the Oyo River is in the Southern Mountain Zone where the main physiography through which passed is the Wonosari Basin in the north and the Baturagung Mountains in the west [1]. The south is bordered with karst area and the east is bordered with Pangling and Plopo Mountains. The geomorphic process which controls or works on the Oyo River are dominated by fluvial process.
The regional geological map of Yogyakarta and Surakarta – Giritontro, with a scale of 1:1000,000 by [2] and [3] which passed by Oyo River from the oldest to the youngest formations consists of 5 main formations such as Semilir Formation (Tuff, lapilli tuff, breccia and shale), Nglanggran Formation (Breccia, agglomerate, tuff and lava flow), Sambipitu Formation (sandstone, siltstone, and stone stone), Oyo Formation (tuff, tuff marl and limestone), and Wonosari Formation (limestone and tuff inserts and tuff marl). These formations are passed by the Oyo River as seen in Figure 1. Beside the formation which have mentioned, there are also some types of sediment along the Oyo River such as sediment of mount Merapi which are composed of breccia, lava, and tuff.

The geological structure which develops around the flow of Oyo River includes 3 geological structures [4]. The first is in the Nglipar area of Gunung Kidul Regency—in the form of a descending fault, the second is in the Patuk area of Gunung Kidul Regency which is sinistral shear fault, and the third is in Imogiri Regency—in the form of a dextral shear fault.

Figure 1. Regional geological map of the Surakarta-Giritontro sheet from east to west [3] and the southeastern part of Yogyakarta sheet [2] accompanied by a research path on the Oyo river.

3. Research Method
The research method used is laboratory analysis on the sand-sized sediment samples [5]. Sediment sample is taken from ten observation locations along the Oyo River, Central Java Province and D.I. Yogyakarta Province.

The laboratory analysis is carried out in the form of granulometric analysis and the composition of the sand sediment with each sample represent an observation location [6]. Granulometric analysis is carried out by visual comparison method [7]. The sieving process in this granulometric analysis uses mesh sizes 18 (very coarse sand), 35 (coarse sand), 60 (medium sand), 120 (fine sand), 270 (very fine sand) and> 270 (silt) [8].

The parameters used to interpret sedimentation mechanism are average grain size (mean), grain size distribution value (sorting), the symmetrical value of the frequency curve (skewness), the curve puncturing value (kurtosis) [9]. Meanwhile, determination of the provenance is carried out by separating heavy and light mineral content continued with petrographic observations using binocular microscope [10].
4. Results

4.1. Granulometric Data

4.1.1. Mean. Mean is the average value of grain size. Based on the mathematical calculation, the results are obtained from 5 samples of coarse sand and 5 samples of medium size sand as seen in Figure 2a. Based on the mean graph, it is obtained that the fluctuation of the change in the average grain size value from upstream to downstream. Generally, the curve shows smooth trend from stop site 1 to stop site 8 then it is continued to rough trend at stop site 9 and stop site 10.

4.1.2. Sorting. Sorting is the standard deviation value of grain sizes which shows the level of uniformity. Based on mathematical calculation, it is obtained the value that 9 samples have moderately sorted values, and 1 sample has moderately well sorted value as seen in Table 1 and Figure 2b. Based on the graph, it is found that the sorting value shows the relatively stable values in the moderately sorted range.

4.1.3. Skewness. Skewness shows the symmetric value of the frequency curve. Based on mathematical calculation, it is found that 9 samples have very fine skewed value, and 1 sample has near-symmetrical value. Based on the graph, it is known that the skewness value decreases which means that the further downstream is dominated by smoother grain size. However, at stop site 9 and stop site 10 increase to be the dominant of coarser grain.

4.1.4. Kurtosis. Kurtosis is the key value of the curve. Based on mathematical calculation, it is found the result that all samples have very leptokurtic value and extremely leptokurtic value. Based on the graph, the kurtosis value shows the increasing trend as it approaches the downstream. However, but the trend changes downward at stop site 9 and stop site 10 showing poor sorting dominance.

| Stopsite (STA) | Mean | Sorting Classification | Skewness Classification | Kurtosis Classification |
|---------------|------|------------------------|-------------------------|------------------------|
| 1             | 0.18 | Moderately Sorted      | Very Fine Skewed        | Extremely Leptokurtic  |
| 2             | 0.61 | Moderately Sorted      | Fine Skewed             | Very Leptokurtic       |
| 3             | 0.89 | Moderately Sorted      | Fine Skewed             | Extremely Leptokurtic  |
| 4             | 1.11 | Moderately Sorted      | Fine Skewed             | Extremely Leptokurtic  |
| 5             | 1.27 | Moderately Sorted      | Fine Skewed             | Very Leptokurtic       |
| 6             | 1.30 | Moderately Sorted      | Near Symmetrical        | Very Leptokurtic       |
| 7             | 1.32 | Moderately Sorted      | Fine Skewed             | Extremely Leptokurtic  |
| 8             | 1.43 | Moderately Sorted      | Fine Skewed             | Extremely Leptokurtic  |
| 9             | 0.63 | Moderately Sorted      | Fine Skewed             | Extremely Leptokurtic  |
| 10            | 0.36 | Moderately well Sorted | Very Fine Skewed        | Extremely Leptokurtic  |
4.2 Sand Grain Morphology

4.2.1 Grain Shape. Based on the results of visual observations using binocular microscope, it is found that the oblate and equant grains dominate good on the grain size of the sand as seen in Figure 3a. The shape of the oblate grain is characterized by the ratio of the longest and middle axes which are relatively similar. However, the ratio of them with the shortest axis is relatively different. While the equant grain shape is characterized by the ratio of the longest to the shortest axes which are relatively similar. The shape of the available oblate grain and equant grain can be formed by transport mechanism which tends to suspend or bedload. Besides, it can be caused by the initial shape of the grain before transporting has been oblate or equant.

4.2.2 Sphericity. Sphericity is a measure of how a grain size approaches spherical shape. Based on the determination of the sphericity of sand grains by comparing it with the visual image, it is conducted the result that sphericity result at the quartz mineral is dominated by sub-elongate, the sphericity result of the feldspar mineral is dominated by sub-equant, the sphericity result of the mineral lytic is dominated by sub-equant, the result of sphericity is obtained that in pyroxene mineral is dominated by very elongate as seen in Figure 3b. The value on the Oyo River indicates that the downstream tends to be more rounded from stop site 1 to stop site 8 then this value decreases when it is at stop site 9 and stop site 10. This can occur due to the erosion process and sedimentation that is taking place on the Oyo River. This process is also influenced by the level of resistance at the mineral which observed different. This can be seen on the difference in the dominance of different forms of sphericity.

4.2.3 Roundness. Roundness relates to the sharpness of the edges or corners of the sediment grains. Based on the determination of the roundness by comparing it with the visual, the roundness results of the quartz mineral are dominated by subangular, the roundness results of the mineral feldspar are dominated by rounded, the roundness results are obtained in the mineral lithic dominated by subrounded, the roundness results in pyroxene minerals are dominated by angular as seen in Figure 3c. The value that is on the Oyo River indicates that the downstream tends to be more rounded from stop site 1 to stop site 8 then this value decreases when it is at stop site 9 and stop site 10. This can occur due to the process of erosion and sedimentation that is taking place on the Oyo River. This process is also influenced by the level of resistance in minerals which is observed different, this can be seen the difference in the dominance of different degree of roundness.

Figure 2 (a) The graphic of mean (b) The graphic of sorting from Oyo River granulometric data.
Figure 3. (a) The graphic of grain shape (b) The graphic of roundness (c) The Graphic of sphericity from Oyo River data.

4.3 Sand Grain Composition Data
The sand grain samples which are analyzed for the observation is 10 samples from all the observation locations. From the 10 samples, each sample are taken about 100 grams sample on a mesh size of 60. Based on the composition analysis of the grain sand, the results of light minerals are quartz, feldspar, and mineral lytic. The composition of light minerals changes with the addition of new sedimentary materials and the distance of the stop sites to light mineral resistance. At stop site 1 as seen in Figure 4, it is observed that the presence of feldspar minerals is quite a lot, then decreases as the addition of distance and time of the sedimentation to stop site 8, then at stop site 9 and stop site 10 the number increase again as seen in Table 2 and Table 3. Heavy mineral obtained are hematite, magnetite, amphibole, pyroxene, pyrite, rutile, ilmenite, and olivine. Heavy mineral is dominated by opaque mineral in the form of magnetite, hematite, stable meta minerals, amphibole, and pyroxene as seen in Figure 5.
Figure 4. The mineralogy data which was observed under binocular microscope, both for heavy (left) and light (right) minerals.

Figure 5. Petrography analysis PPL and XPL of the mineral to validate mineral composition (a-b) Stopsite 1 (c-d) Stopsite 8 (e-f) Stopsite 10.
Table 2. Heavy minerals counting from each stop site. Ilm = Ilmenite, Mt = Magnetite, Ol = Olivine, Px = Pyroxene, Hm = Hematite, Py = Pyrite, Amph = Amphibole.

| Stop Site | Ilm | Mt | Ol | Px | Hm | Amph |
|-----------|-----|----|----|----|----|------|
| 1         | 16  | 147| 7  | 55 | 118| 135  |
| 2         | 15  | 166| 5  | 46 | 105| 137  |
| 3         | 13  | 149| 3  | 33 | 127| 125  |
| 4         | 14  | 155| 3  | 23 | 121| 117  |
| 5         | 14  | 145| 3  | 24 | 133| 118  |
| 6         | 14  | 161| 3  | 30 | 132| 116  |
| 7         | 18  | 148| 3  | 26 | 138| 116  |
| 8         | 15  | 158| 2  | 32 | 134| 122  |
| 9         | 19  | 149| 6  | 42 | 142| 136  |
| 10        | 25  | 112| 8  | 44 | 122| 135  |

Table 3. Light minerals counting from each stop site. Qz = Quarts, Fs = Feldspar, Chl = Chlorite.

| Stop Site | Qz | Fs | Lithic Fragment | Fossil |
|-----------|----|----|----------------|--------|
| 1         | 110| 123| 119            | 36     |
| 2         | 151| 123| 114            | 33     |
| 3         | 182| 106| 109            | 33     |
| 4         | 173| 100| 110            | 41     |
| 5         | 158| 102| 96             | 76     |
| 6         | 157| 101| 104            | 73     |
| 7         | 163| 103| 111            | 94     |
| 8         | 150| 110| 117            | 94     |
| 9         | 183| 114| 119            | 36     |
| 10        | 158| 112| 109            | 26     |

4.4 Origin of Rock
In the original rock type determination, it is used the QtFL triangle (Qt = total quartz, F = feldspar, L = lithic) according to [11]. The result of plotting was obtained that the original rock originated from a dissected arc can be interpreted as the result of volcanic material which lined up on the island arc which is still active and also from volcano which eroded at the continental boundary. Meanwhile, the paleoclimate determination is based on the QFL triangle diagram (Q = quartz, F = feldspar, L = lithic). The result of plotting was obtained that the original rock was formed on the humid climate and dry climate in plutonic rocks.

5. Discussion
5.1 Sedimentation
The interpretation of the sedimentation mechanism which occurs in the sand deposits along the Oyo River is based on the results of the analysis of grain size and grain morphology. The results of the analysis show that the deposited material through the transport mechanism by bedload is a combination of rolling, sliding, and saltation. However, there is also a transport mechanism in the form of suspension on a small portion of the sediment particles which are very smooth in size.

If it is seen from the grain morphology (grain shape) in the four types of minerals such as quartz, feldspar, lytic and pyroxene are gotten the dominant form of equant and oblate. This grain shape indicates that the transportation process which occur is more dominated by rolling and saltation,
especially near the downstream part of the stop site 8, the value of minerals that have this shape increases well.

If it is seen from grain morphology (degree of sphericity) on the three types of minerals such as quartz, feldspar, pyroxene, and lithic. Their shape is dominated by very elongated to equant depends on the resistance value of the observed minerals. The tendency of sand grain is more swollen or the value of spericity is getting bigger suitable with the distance from the sediment source, stop site 8 as the downstream area has a greater value than the upstream area at stop site 1.

If it is seen from the sand morphology (degree of roundness) in the three types of minerals and lithic, it is found that the dominance of smooth forms starts from very angular to rounded depend on the resistance value of the observed minerals. The tendency of sand grains is observed to have smoother degree of roundness or more roundness, suitable with the distance to the sediment source, stop site 8 as the downstream area has bigger value or smoother value than upstream area at stop site 1.

5.2 Provenance (Origin)
The presence of several minerals which are less stable (meta-stable) such as olivine and pyroxene are found on the enough far distance from the source indicate that the origin area on the area where has high relief. These minerals can be found, it is possible because the supply of minerals from the surrounding rocks are still quite a lot although the level of weathering is high too [5]. Based on the heavy mineral association it can be estimated that the sand samples along Oyo River come from the Provenance type of intermediate igneous rock. If it is seen in Figure 6 from the result of triangular diagram [11], shows the provenance type originates from the dissected arc area which represents the magmatic arc zone. In the plotting results of diagram from [12] it was known that the climate of deposition is available on the humid to arid climates. The presence of opaque minerals such as magnetite, hematite and ilmenite in the Oyo River area are interpreted from the rocks in the Semilir Formation and Nglanggran Formation which contains altered volcanic rocks.

![Dickinson Triangular Diagram](image)

**Figure 6.** Dickinson Triangular Diagram shows the provenance of sand [11] (top). QFL Diagram of Igneous and Metamorphic Rock Paleoclimate [12] (Bottom).
6. Conclusion
1. Sand deposits along Oyo River have an average grain size value dominated by coarse sand to medium sand, with dominant sorting of moderately sorted, skewness dominated by very fine skewed, and extremely leptokurtic kurtosis.
2. The shape of the grains of sand is dominated by oblate and equant, the value of sphericity is dominated by very elongated to equant, and the rounded value is dominated by very angular up to rounded.
3. The rock type from sand deposit is interpreted to be intermediate igneous rock originating from the erosion of the Semilir or Nglanggran Formations.
4. The sedimentation process of sand deposits along the Oyo River is dominated by a bedload mechanism with a combination of rolling, sliding, saltation along with a slight suspension process.
5. The provenance of Oyo River sand deposit is coming from dissected arc tectonic setting.

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References
[1] Husein, S. dan Srijono. 2010. Peta Geomorfologi Daerah Istimewa Yogyakarta. Symposium Geologi Yogyakarta: 1-6. (in Bahasa Indonesia)
[2] Raharjo, W., Sukandarrumidi, dan H. M. S. Rosidi. 1995. Peta Geologi Lembar Yogyakarta, skala 1:100.000. Pusat Penelitian dan Pengembangan Geologi, Bandung (in Bahasa Indonesia)
[3] Surono, dan Permana. A. 1992. Peta Geologi Lembar Surakarta-Giritontro, skala 1:100.000. Pusat Penelitian dan Pengembangan Geologi, Bandung. (in Bahasa Indonesia)
[4] Prasetyadi, S. Sudarno, I. Indranadi, V. B. dan Surono. 2011. Pola dan Genesa Struktur Geologi Pegunungan Selatan, Provinsi Daerah Istimewa Yogyakarta dan Provinsi Jawa Tengah. Jurnal Sumber Daya Geologi Vol 21 No. 2 (in Bahasa Indonesia)
[5] Surjono, S. S. dan D. H. Amijaya. 2017. Sedimentologi. Gadjah Mada University Press. Yogyakarta. (in Bahasa Indonesia)
[6] Pettijohn, F. J. 1975, Sedimentary Rocks. 3rd ed. Harper & Row Publishing Co. New York.
[7] Wadell, H. 1932. Volume, Shape and Roundness of Rocks Particles. The Journal of Geology 40(5), 443-51
[8] Boggs, S. Jr. 1987. Principles of Sedimentology and Stratigraphy. Merril Publishing Co. Columbus
[9] Wentworth, C. K. 1922. A Scale of Grade and Class Terms for Clastic Sediments. The Journal of Geology, 30(5), 37
[10] Tucker, M. E. 1991. Sedimentary Petrology: An Introduction to The Origin of Sedimentary Rocks, 2nd ed. Blackwell Scientific Publications. London
[11] Dickinson, W. R. and Suczek, C.A.,1979. Plate Tectonics and Sandstone Compositions. The American of Petroleum Geologist Bulletin. V.63. No 12
[12] Suttner, L.J., Basu, A.S. and Mack, G.H. 1981. Climate and Origin of Quartz Arenites. Journal of Sedimentary Petrology 51(4), 1235 – 1246