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# Methodological Improvement for Reconstructing the Paleo-topography of Lombok Island before the Samalas AD 1257 Eruption

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*Abstract*—**Paleo-topographic reconstruction due to volcanic eruptions is a fascinating study, especially if the erupting volcano has a large magnitude of the eruption. Recently, at least three previous studies present well-organized methods and computational analysis for paleo-topography reconstruction. By reviewing those research and did a simple test, we found that there are small gaps that need to be improved. This paper is proposed an improvement method for paleo-topography reconstruction. It is important to notice that this improved methodology is not technically based, but only focused on a conceptual framework. The improvement review involves five variables, i.e., 1) the present-day topography, 2) stratigraphic composite, 3) data correlation, 4) paleo-channel validation, and 5) final paleo-topography validation. This improvement will be applied in future research in a complete reconstruction of Lombok island paleo-topography before the Samalas AD 1257 eruption.**

## I. Introduction

Samalas volcano is located in Lombok Island, Indonesia. This volcano experienced a significant eruption in AD 1257 which is known as one of the most significant volcanic eruptions in recent human history [1], [2]. This eruption is speculated to have caused the climatic change at both the local and global scales [2]–[4]. As a local impact, Lombok paleo-topography has been mostly buried by the volcanic deposits in the western, northern, and eastern regions (Fig. 1). The dynamic impact at the local scale has been reconstructed along the eastern part of Lombok Island, adjacent to Alas Strait [5]. The eastern part reconstruction showed that the morphology dramatically changed due to pumice-rich PDC deposit, which thickness ranged up to 30 m. The burial deposit significantly changed the pattern of the valleys from 1257 to the present day.

The landscape prior to the 1257 eruption has not been fully reconstructed yet especially in the northern and western parts. A study from Ref. [5] is useful as baseline because it emphasized that burial deposit consists of pumice-rich PDC deposits; sand with pumice fragments (laharic); flood derived deposits (sand material domination), and reworked materials with limited or no pumice deposits. A similar study of paleo-topography reconstruction was also previously performed in the Sarno River plain (Italy) due to Somma-Vesuvius eruption in AD 79 [6],[7]. The method from Ref. [6], [7] has been then improved by Ref. [5] for reconstructing eastern part of Lombok. However, those methodologies especially from Ref. [5] is still possible to be improved in order to reconstructing the northern and eastern part $13^{th}$ century topography of Lombok Island. This paper provides proposed methods for reconstructing paleo-topography.

## II. Methods

This paper presents a methodological review especially from Ref. [5] and Ref. [7], to enhance a better methodological framework. Five fundamental proposed variables for nearly future improvement were applied in Mataram city, western part Lombok Island (Fig. 1). The first variable is present-day topography. The paleo-topography modeling is depending on the present topography input, which can be represented using DEM (digital elevation model). A study from Ref. [7] has mentioned that present topography is the most importance as a variable predictor. The second variable is composite stratigraphy. The third one is a correlation between various data input, e.g. cores data, wells data, outcrops, etc. The fourth variable is paleo-channel validation. The last one is the paleo-topography validation method.

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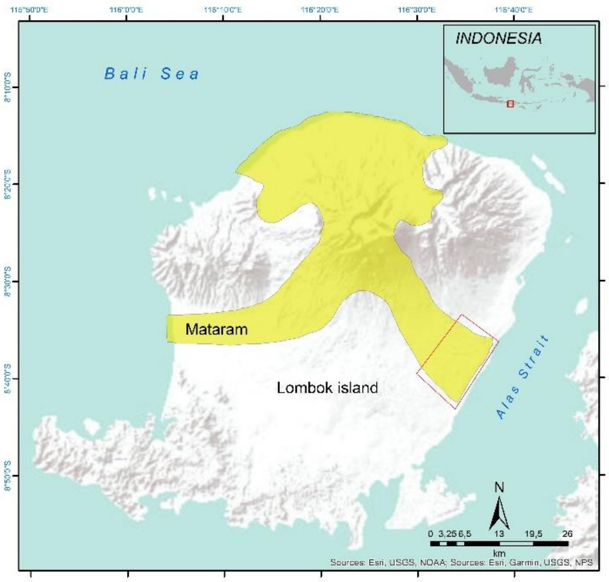


**Figure 1.** Mataram city, located in the western part of Lombok Island. Yellow color represents areas that have been buried by PDC deposits from the 1257 eruption of Samalas volcano [1], [4]. Red box adjacent to Alas Strait is the previous paleo-topography reconstruction performed by Ref. [5].

## III. Results and Conclusions

### *A. Present-day topography/elevation data*

Indonesia has been published a free DEM data source in national coverage, namely DEMNAS data with the best resolution in 8 meter. The DEMNAS data can be accessed in: http://tides.big.go.id/DEMNAS/login.php. Compared to topography data (contour) from RBI (Rupa Bumi Indonesia/ Indonesia Topographic Map), DEMNAS data provides better data as shown in Fig. 2. The SRTM and ASTER GDEM resolution data are even lower (30m respectively). The DEMNAS is preferable to use for a basic data of present-day topography. However, for paleo-topographic reconstruction, present-day topography is not sufficient only using DEM data. Geodetic measurement of x,y,z data is essential by putting some ground control point (GCP) data as a reference detailed coordinate. The number of GCP points is custom, depending on the area and topographic form [8]. As comparison, digital elevation model (DEM) used in the Sarno River plain stated as high resolution DEM, but the detailed resolution has not mentioned neither its type nor source-generated. It is only mentioned that the expected result in scale 1:5,000 [7]. For the eastern part of Lombok, present day DEM was generated from Indonesia Topographic Map (RBI) in scale 1:25,000 [5]. Basically, aerial photography is the fastest way for obtaining present day DEM, but for a densely vegetated area this method is slightly difficult to apply [9], also an aerial photograph is costly. Therefore, the combination between DEMNAS data and GCP measurement will produce better present-day elevation model with better resolution.

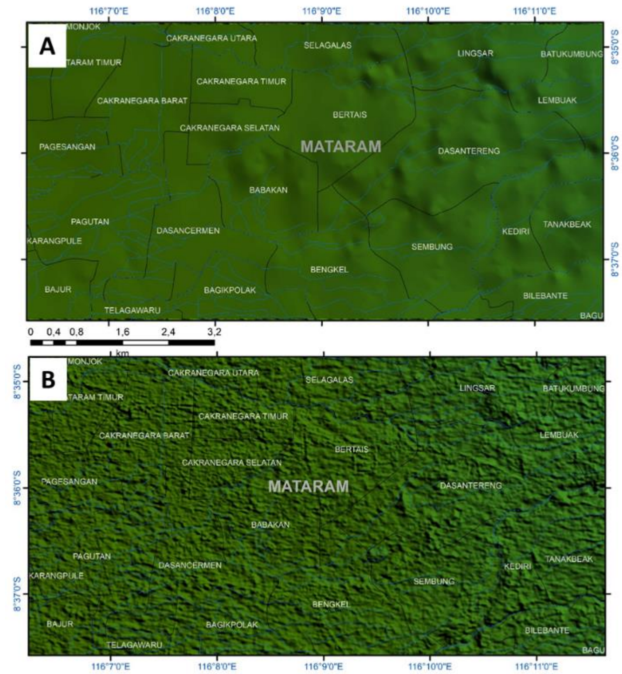


**Figure 2.** Comparison of DEM data derived from RBI contour map (A) and DEMNAS (B). As shows in the figure, DEMNAS data has more detailed morphology expression.

### *B. Stratigraphic Composite*

Composite stratigraphy was reconstructed in the western part of Lombok using deep core data from the Government of Nusa Tenggara Barat Province (Fig. 3). In this composite stratigraphy, information of paleosol and and physical characteristics of rock, especially pumice, is essential to better understand the arrangement of buried materials since the 13th century eruption. Stratigraphic reference from Ref. [4] also useful for the contruction of stratigraphic composite. This stratigraphic composite method has been applied in Merapi volcano for reconstructing the dynamic buried materials since 4,800 years BP to present [10]. Previous modeling in the eastern part of Lombok does not display any stratigraphic composite information because in this area PDC rich deposits from Samalas AD 1257 is dominant, so the rock layers condition is mostly similar.

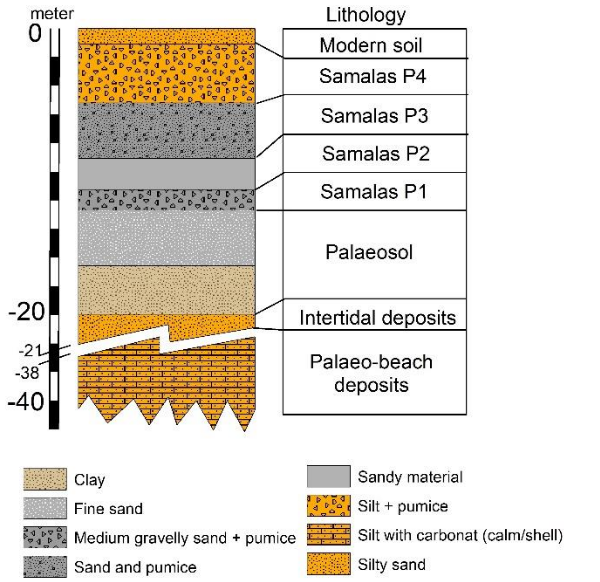


**Figure 3.** Stratigraphic composite from several deep core data in Islamic Centre of Lombok island. The term of Samalas P1-P4 (ejected material during eruption phase 1-4) and paleo-beach deposits lithology is refers to Ref.[1], [4]. Paleosol is selected as former surface topography, while modern soil and Samalas P1-P4 are buried material after 13th century.

### *C. Data correlation*

The composite stratigraphy is the main reference of bedding classification. Other lithology data such as outcrops, wells data, boreholes must be correlated to the main stratigraphic reference. Borehole data can be obtained using percussion drill or soil auger. For the western and northern part of Lombok, we proposed a correlation order as shows in Fig. 4. We suggest that the main stratigraphic reference for correlation purpose is deep core data, while the numerous data is wells data because it is easy to obtain from wellsman. Usually when they made a wells, they were recorded the material found at every depth. In addition, the distribution of data is considerable by using grid method. Each grid should be represented by minimum of a wells data.

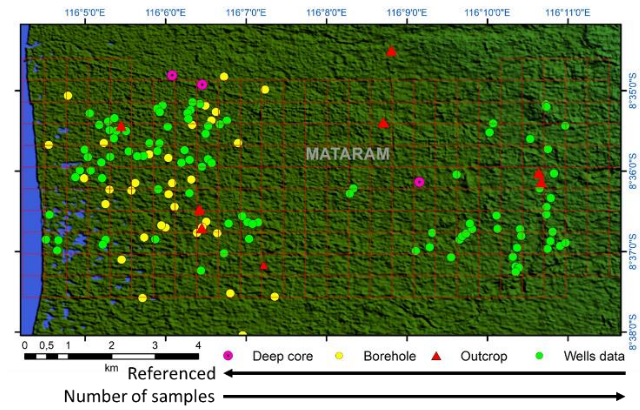


**Figure 4.** The data availability and its correlation order in Mataram city, which consist of cores, boreholes, outcrops, and wells data.

### *D. Paleo-channel validation*

Interpreted resistivity data can be used as paleo-channel validation. Fig. 5 shows the suspected paleo-channel in Mataram city. Cross-section was performed in north-south direction. Resistivity data can well detect the paleo-channel especially if there was a wide river valley. Buried material form volcanic deposits follows the past topographic form as shown in Fig. 5. Both of Sarno River plain and eastern part of Lombok are performing paleo-channel reconstruction. The method is slightly similar by using "watershed" modeling in GIS software and geological data inventory. This method is robust and rapid but need more validation strategies by using resistivity data.

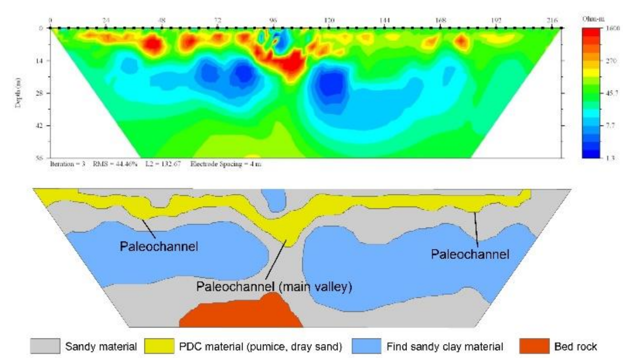


**Figure 5**. Suspected paleo-channel generated from resistivity data interpretation.

*E. Paleotopography validation*

A simple test of RMSE (rot-mean square error) was calculated in some area of Mataram 13th century topography using wells data inventory. The modeling of paleo-topography (Fig. 6) is shows a good validation with the value of RMSE 0.447. The interpolation methods are using IDW. Comparing to Ref. [5], [7] modeling, the data used in this test is limited, but shows proper validation. In this case, we noted that RMSE is a basic for validation, but we proposed additional validation methods. The first is calculating RMSE in three different locations, such as in the ridge (hilly), plain, and valley. We believe that they will have a different estimated error. Comparison of topographic section between paleo and present-topography is also useful for selecting the location for error calculation (Fig. 7). The second is performing random outcrops observation or borehole test in those three different locations to searching the real base of paleo-topography. When the random point is used for validation, we believe it will be resulting in more satisfied validation than using data input for modeling.

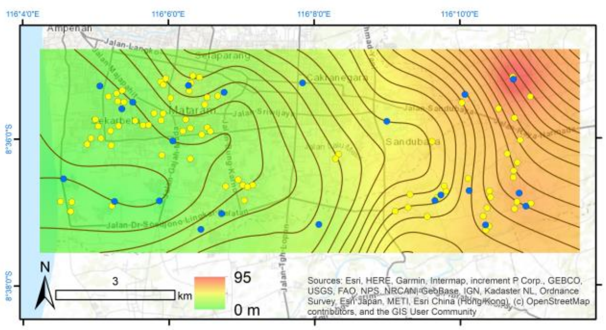


**Figure 6**. The preliminary paleo-topography of the 13th century in Mataram, modeled using wells data inventory (yellow dot) and additional reference points (blue dot).

In conclusion, we assumed that better paleo-topography reconstruction should build from a better conceptual methodological framework. Even if results from Ref. [7] and Ref. [5] are convinced, we have shown that they can be improved using additional strategies. The proposed method described in this paper starts from data input, then stratigraphically analysis, and validation strategy. The data processing technic is not explained in detail because we focused on the conceptual framework. This improvement review will be applied in near future research for a complete work.

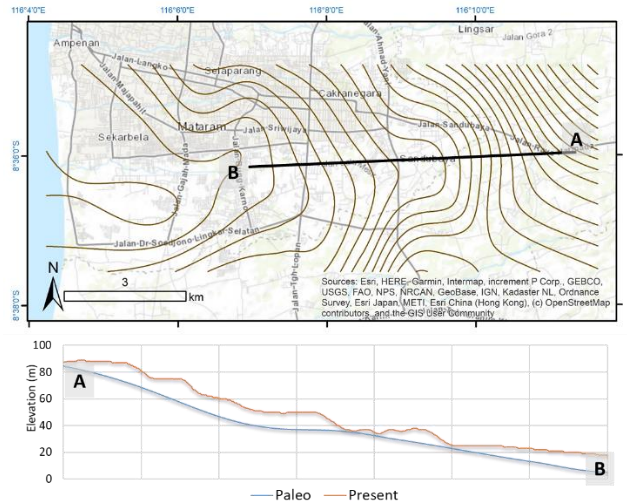


**Figure 7**. Comparison between paleo and present-day topographic profile of Mataram. Profile line A-B shows that paleo-topography is rather smooth with minor topographic expression.

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