Dimensionality and regional strike analyses of the Cibeber segment, Cimandiri fault zone, West Jawa, Indonesia

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Abstract. The dimensionality and regional strike analyses of the Cimandiri Fault, West Java, Indonesia have been investigated. The Cimandiri Fault consists of six segments. They are Loji, Cidadap, Nyalindung, Cibeber, Saguling and Padalarang segments. The magnetotelluric (MT) investigation was done in the Cibeber segment. There were 42 observation points of the magnetotelluric data, which were distributed along 2 lines. The magnetotelluric phase tensor has been applied to determine the dimensionality and regional strike of the Cibeber segment, Cimandiri Fault, West Java. The result of the dimensionality analysis shows that the range values of the skew angle value which indicate the dimensionality of the study area are -5 ≤ β ≥ 5. These values indicate if we would like to generate the subsurface model of the Cibeber segment by using the magnetotelluric data, it is safe to assume that the Cibeber segment has the 2-D. While the regional strike analysis presents that the regional strike of the Cibeber segment is about N70-80°E.

1. Introduction

The magnetotellurics (MT) is a passive-surface electromagnetic technique to investigate the electrical resistivity structure from the near surface to the upper mantle [1]. The MT method is useful in fault zone investigations because resistivity in the fault zone is significantly low due to the existence of fluids [2, 3].

There are four distinct morphological and structural units in West Java: (1) the northern coastal plain of West Java, (2) the folded mountains of Bogor, (3) the Bandung zone, which mostly covered by recent volcanic products, and (4) the southern mountain of West Java [4]. The boundary between the Bandung zone and the southern mountain is called the Cimandiri fault zone (from now on, CFZ) the zone is located along the Cimandiri River and is mostly covered by recent volcanic products [4-7]. This area is located eastward of the transitional zone between the frontal subduction of Java and the oblique subduction of Sumatra [7]. The horizontal displacement of the CFZ is about 0.5-1.7 cm/yr on the surface [8].
The Cimandiri fault runs SW-NE, from Pelabuhan Ratu to Padalarang near Bandung and through populated cities such as Pelabuhan Ratu, Sukabumi, and Bandung. The length of the CFZ is about 100 km. The geologic map also shows that the fault zone appears to form a broad deformation zone instead of a narrow zone of fault or faults [9]. The previous study suggested that there are 6 segments of the CFZ [9]. They are Loji, Cidadap, Nyalindung, Cibeber, Saguling, Padalarang segments.

The investigation of the dimensionality and regional strike of the Loji segment has been done [10]. The results presented that the dimensionality of the Loji segment has is 2-D and its regional strike is about N70-80° E. Since the segments of the CFZ is not continued each other and consist of the numerous micro faults which have the length ranging from a few centimeters to a few meters, therefore it is needed to know the dimensionality and regional strike of the other segments. In this study, we focused to investigate the regional strike and dimensionality of the Cibeber segment based on the magnetotelluric data. This study is the preliminary analysis before we will apply the modeling of the subsurface of the CFZ by using the magnetotelluric data.

2. Data and method

Figure 1b shows the topography map and the location of the 6 segments of the CFZ. The estimated location of the segments based on the recent study [9] is also shown in figure 1b. In this study, the MT investigation was conducted in the Cibeber segment. The MT observation was held in 2015. There were 42 MT observation points which were deployed in the two lines, as presented in figure 1c. The line 1 consisted of the observation points from CM 01- CM 21, whereas, the CM 22 until CM 42 were located along the line 2. The frequency range of all MT data is 0.1 Hz - 10.000 Hz. For further analysis, we used the data which have the coherency ≥ 0.5 as the good data indicator.

To investigate the dimensionality and regional strike of the study area, we applied the phase tensor analysis [11]. According to [11], the magnetotelluric phase tensor, $\Phi$, can be represented as an ellipse which has the principal axes represented by the major and minor axes of the ellipse. The major ($\Phi_{\text{max}}$) and minor axes ($\Phi_{\text{min}}$) of the ellipse illustrate the principal axes, whereas values of the tensor with the orientation of the major axes are defined by angle $\alpha-\beta$. The $\alpha$ and $\beta$ values can be formulated as follows:

$$\beta = \frac{1}{2} \arctan \left( \frac{\Phi_{22} - \Phi_{21}}{\Phi_{11} + \Phi_{22}} \right) \quad \alpha = \frac{1}{2} \arctan \left( \frac{\Phi_{12} + \Phi_{21}}{\Phi_{11} + \Phi_{22}} \right)$$

where $\Phi_{11}$, $\Phi_{12}$, $\Phi_{21}$, and $\Phi_{22}$ are the components of the phase tensor if it is written as the matrix. To calculate the phase tensor, the analyses does not need an assumption about the dimensionality of the underlying conductivity distribution. Furthermore, it is also applicable if the heterogeneity and the regional conductivity structures of the study area are 3-D [11].

Generally, if the regional conductivity distribution is 3-D, the skew angle ($\beta$) value is non-zero and represents the rotation of the major axes of the phase tensor ellipse. Moreover, the phase tensor is symmetric ($\beta = 0$), the principal values of the tensor are equal to its eigenvalues. It occurs if the distribution of the regional conductivity is 1-D or 2-D. In this situation, the orientation of the major axes is defined by $\alpha$. The 2-D case occurs when $\Phi_{\text{max}} = \Phi_{\text{min}}$ and it will be two directions for which a linearly polarized magnetic field will give rise to a linearly polarized electric field. However, when $\Phi$ is symmetric and has equal principal values, it will be 1-D. In this case, the electric field will be linearly polarized if the magnetic field is linearly polarized [11].
Figure 1. (a) The map of Indonesia. The red color area is the Cimandiri Fault Zone location. (b) The topography map of the Cimandiri Fault Zone; A. Loji segment, B. Cidadap segment, C. Nyalindung segment, D. Cibeber segment, E. Saguling segment, F. Padalarang segment. (c) The MT observation points which were investigated in the Cibeber segment.
3. Results and discussion

Figure 2 presents the rose diagram of the major axes orientation which was defined by angle $\alpha - \beta$. Theoretically, the estimated values of the calculated major axes orientation have $90^\circ$ ambiguity. Figure 2 shows that the dominated general regional strike is generally in the NE-NW direction.

![Rose diagrams](image)

**Figure 2.** The rose diagrams which represent the orientation of the major axes of the tensor and defined by angle $\alpha - \beta$. (a) for the frequency range 0.1-1 Hz. (b) for the frequency range 1-10 Hz. (c) for the frequency range 10-100 Hz. (d) for the frequency range 100-1000 Hz. (e) for all frequency range.

For the frequency range of 1-10 Hz, 10-100 Hz, 100-1000 Hz and whole frequency, the results show consistently that the calculated regional strike is about N60-80$^\circ$E. The results of the regional strike
estimation in the Cibeber segment for the lower frequency are different to that of in the Loji segment [10]. However, for the higher frequency, the results are consistent with the previous results [7, 10]. It also supports the previous study that along the CFZ length is expressed in the bedrock by numerous NE, west, and NW trending thrust- and strike-slip faults and folds [9].

Figure 3 presents the skew angle ($\beta$) results for all the observation points in this study. The skew angle ($\beta$) values can indicate the dimensionality of the study area. Generally, the skew angle values for all observation points are $-5 \leq \beta \geq 5$, as indicated by the color scale in figure 3. These results are also consistent to the dimensionality analysis results in the Loji segment [10].

Figure 3 also shows that the skew angle ($\beta$) for the frequency below 1 Hz more complex than that of the frequency more than 1 Hz. For the higher frequency, the phase tensor analysis results reveal the homogeneous skew angle values. The values are about 0. Figure 3 also shows that the observation points of 10, 31, and 32 are the most complex observation points from the lower frequency to higher frequency range based on the magnetotelluric phase tensor analysis. It is possibly associated with the geological feature near the observation points of 10, 31, and 32. The geological map of the study area presents that these observation points are near the transition of the surface geological product in the study area [12].

According to this result, it is safe to assume that the dimensionality of the regional conductivity structures in the study area is 2-D. Therefore, it can be used as the criterion to image the subsurface of the Cibeber segment by using the magnetotelluric data in the next analysis.

The regional strike and dimensionality analyses have been done for the Loji and Cibeber segments. To know more detail about the regional strike and dimensionality of the CFZ, it is important to also investigate other segments.

![Figure 3](image-url)

**Figure 3.** The skew angle ($\beta$) of all MT observation points. The number from 01 to 42 related to the CM 01 until CM 42 in the figure 1. The vertical axes indicate the frequency (in log scale). The horizontal axes indicate the observation points distance. The color scale indicates the skew angle $\beta$. (a) The skew angle ($\beta$) of the CM 01 - CM 21. (b) The skew angle ($\beta$) of the CM 22 - CM 42.
4. Conclusion
The investigation of the regional strike and dimensionality in the Cibeber segment, Cimandiri Fault Zone, West Java, by using the magnetotelluric data has been done. All 42 MT observation data which have coherency ≥ 0.5 were analyzed by using the magnetotelluric phase tensor. The results show that the regional strike in the Cibeber segments is NW-NE direction, about N60-80°E. The skew angle values which represent the dimensionality of the study area are -5 ≤ β ≥ 5. These results are consistent with the previous results. Based on the results, for the further analysis, it is safe to assume that the dimensionality of the Cibeber segment is 2-D.

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