MOUNTAIN-FRONT SINUOSITY AND ASYMMETRICAL FACTOR OF LELES-GARUT INTRA-ARC BASIN, WEST JAVA

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ABSTRACT

The Leles-Garut Basin, with an elevation ranges between 650 and 725 above mean sea level, is a Quaternary topographic basin area situated in the east-trending volcanic arc of West Java. In contrast to the adjacent Bandung Basin, the nature of the basin bounding area of the Leles-Garut Basin is not clearly defined. The presence of volcanic chain and structural lineament exhibits the difference in morphological features. A quantification of morphological indices was chosen to redefine an active tectonic involvement in surrounding basin border. Mountain-front sinuosity indices range from 1.1 to 3.9 and basin asymmetrical factor suggests a wide range of the effects of active tectonic even a little tilting. The study unveil that the basin bounding is not only volcano-bounded but also fault-bounded.

Keyword: mountain-front sinuosity, asymmetrical factor, intra-arc basin.

INTRODUCTION

Intra-arc basin that form within a volcanic island arc system typically covering less area and having shallower depths than their fore-arc and back-arc counterpart basins. Their origin is complex and diverse (Ingersoll, 1988; Ingersoll and Busby, 1995) and they generally developed, filled, and were inverted rapidly with sedimentation lasting less than four million years (Draut and Clift, 2012). According to Smith and Landis., (1995), the intra-arc basins may be classified into two-end members, *i.e.*, the volcano-bounded and the fault-bounded intra-arc basins.

The Leles-Garut plateau is a Quaternary topographic basinal area situated in the east-trending volcanic arc of West Java. It lies to the southeast of the Quaternary Bandung Basin (or Bandung Plateau) and, morphologically, they are similarly surrounded by volcanic areas. The Bandung Basin, however, is clearly bounded by fault to its northern and southern margins (Dam, 1997), whereas the Leles-Garut Basin is surrounded almost exclusively by volcanic centers. Depositional history of the basin, moreover, is somewhat different. The Bandung Basin is characterized by its large-scale lacustrine depositional stage, while the Leles-Garut has never had such a depositional stage. Such similarities and contrasts between two closely contiguous intra-arc basins warrant a close examination to unveil their nature, origin, and development.

This paper describes a quantitative approach on geomorphologic features. Such a method is well known to indicate neotectonic activity (Doornkamp, 1986; Elias, 2015), morphotectonic (Toudeshki and Mehran, 2011), and regional tectonic implications (Özkaymak, 2015). It aims to provide an alternative interpretation of the Leles-Garut Basin boundaries. It is hoped that the results will aid in producing a more refined understanding on the nature of the basin and, in a wider geological context, the role of structural geology and volcanic processes in the development of an intra-arc basin.

GEOLOGIC SETTINGS

The Leles-Garut Basin is located in West Java, Indonesia, with an elevation ranges between 650 and 725 above mean sea level, and divided into the Leles and Garut sub-basins (Figure 1).

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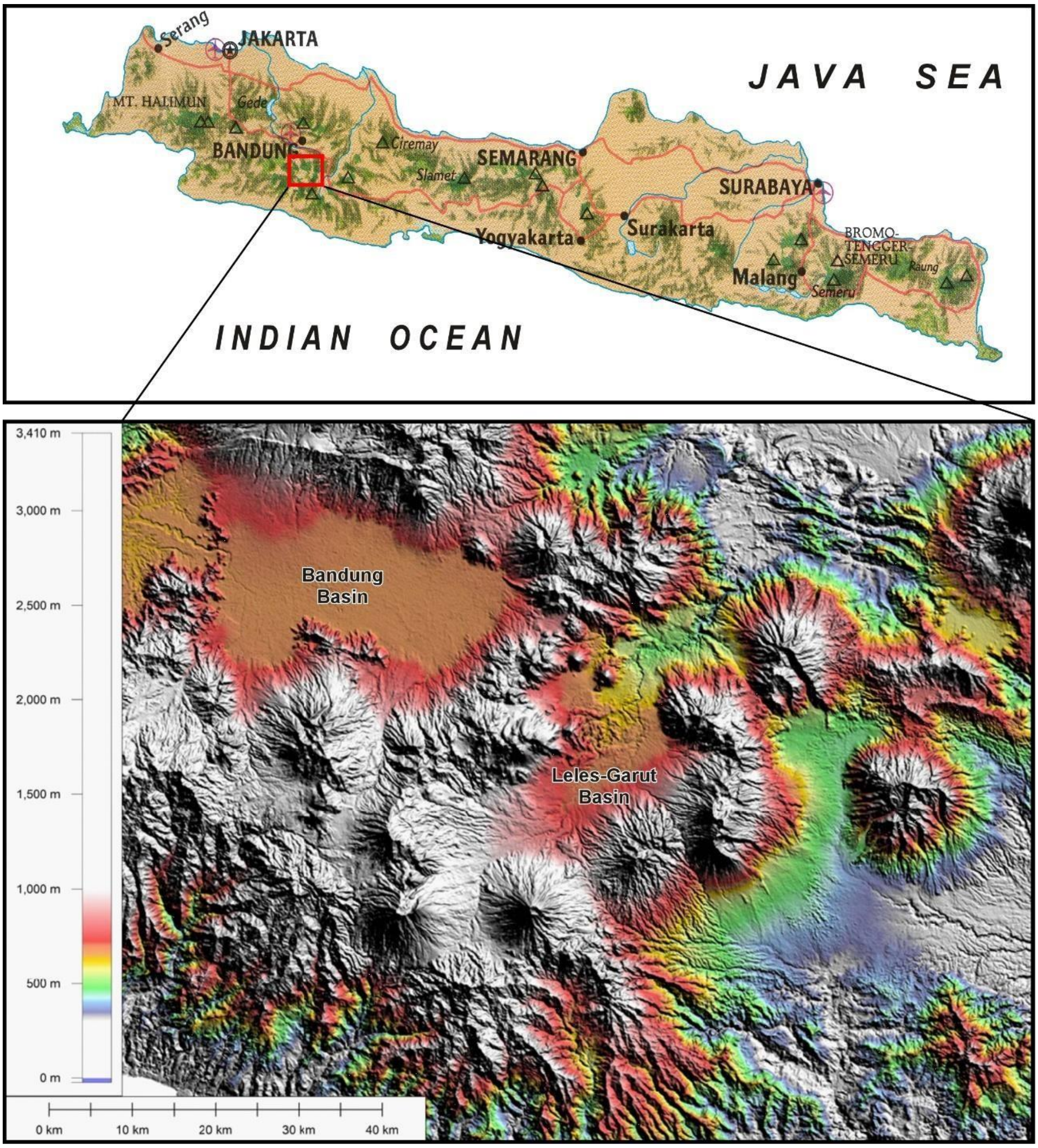

Figure 1. The Leles-Garut at its geological and geographical context.

Having a NNE-SSW orientation, the Leles-Garut Basin is surrounded by the Kendang – Guntur – Mandalawangi volcanic to the west and the Karacak – Galunggung – Sadakeling volcanic chain to the east. The northern side of the basin is bounded by Mt. Kaledong and Mt. Haruman, whereas its southern end is bounded by the Papandayan and Cikuray volcanoes. Those encircled volcanic centers rise to elevation of 1218-2820 meters above mean sea level and some of them, *i.e.*, the Papandayan, Guntur, and Galunggung, are belonging to the active volcanic arc of West Java. Handayani et al. (2013) suggest a possible extension force as the current stage of Garut Basin based on geophysical survey, *i.e.*, Magnetotelluric analysis. They concluded the extension process that developed horst-graben structures as the first stage and the horizontal layering as the second stage that indicates a stable regime of tectonic.

In general, the Leles-Garut has been constructed by the unconsolidated and undifferentiated Quaternary volcanic products, derived from the aforementioned encircled volcanic centre, that rest unconformably above the late Tertiary Beser and Jampang Formations (Alzwar et al., 1992). They were emplaced to their depositional sites by various volcanic and fluvial sedimentary processes.

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The sedimentary processes have been facilitated by the Cimanuk River and its distributaries that flow mainly in the axial area of the Garut sub-basin.

METHOD

The method used has been well summarized in Keller et al. (1996). Landscape shape forms as the main object. Quantifying such a landscape yield several parameter called geomorphic indices into certain classification. The classification divided into classes that having an implication to an active tectonic of the region. According to Keller et al. (1996), geomorphic indices consist of the hypsometric (Baker, 1986) integral (Baker, 1986), drainage basin asymmetry (Davis, 1899; Penck, 1953), stream length-gradient index (Hack, 1960), mountain front sinuosity and ratio of valley floor width to valley height (Balmino et al., 1973; Burchfiel, 1983).

The geomorphic indices have their own definition and uses. Distribution of elevation to an area of drainage basin is described through hypsometric curve. Stream-gradient index represents the channel profile and its ability to erode and transport sediment. The mountain slope of volcanic chain, stream-gradient would not have a significant difference. The stream channels flow to Cimanuk River as the main valley of Leles-Garut Basin. Therefore, all these three parameters, *i.e.*, hypsometric curve, stream length-gradient index, and ratio of valley floor width to height, are not included in this research. Mountain front sinuosity and drainage basin asymmetrical factor play an important role in defining an active tectonic of basin boundary.

Landscape quantification of the Leles-Garut Basin is measured along the mountain-front of volcanic chain. The coherent geomorphic indices are mountain front sinuosity (Smf) and asymmetry factor (AF). Figure 2 and 3 visualize the theoretical scheme of measuring mountain-front sinuosity (Smf) and asymmetry factor (AF).

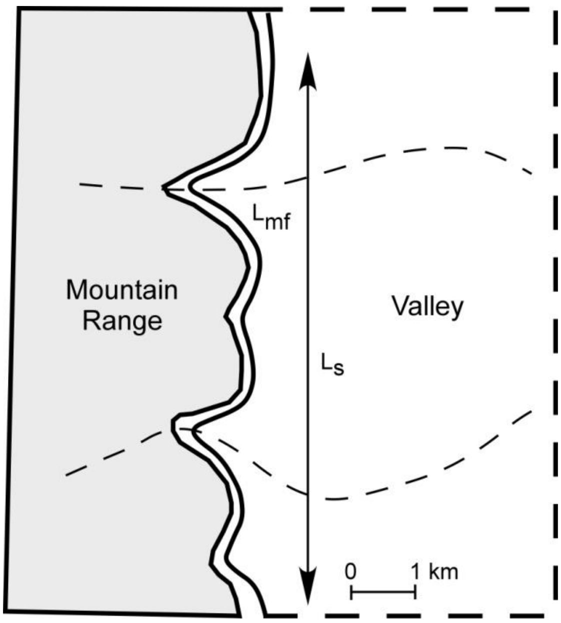

Figure 2. Mountain front sinuosity, Smf (Keller et al., 1996)

The compartmentalization of Smf is Lmf and Ls within the following equation:

$$S_{mf} = \frac{L_{mf}}{L_s} \quad \text{.................................} \quad (1)$$

$S_{mf} = mountain\ front\ sinuosity$
$L_{mf} = the\ length\ of\ the\ mountain\ front\ along\ the\ foot\ of\ the\ mountain$
$L_s\ = the\ stright - line\ length\ of\ the\ mountain\ front$

Mountain-front sinuosity is an index that reflects the balance between erosional forces that tend to cut embayments into a mountain front and tectonic forces that tend to produce a straight mountain front coincident with an active range-bounding fault (Keller et al., 1996). It is implicitly said that not all mountain goes into the measurement of Smf, there must be a straight mountain landform. In additional definition, a mountain-front is a topographic transition zone between mountains and plains

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with landscape assemblage includes the escarpment (Bull, 2007).

Another geomorphic index is asymmetry factor. The asymmetry factor (AF) is a way to evaluate the existence of tectonic tilting and transverse to the flow at the scale of a drainage basin (El Hamdouni et al., 2008; Özkaymak, 2015).

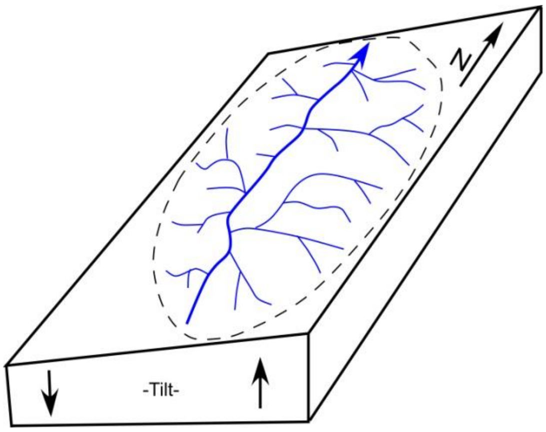

Figure 3. Block diagram of basin drainage asymmetry factor (Keller et al., 1996).

The following equation simply explaining the asymmetry factor:

$$AF = 100(A_r/A_t) \quad \text{.............................} \quad (2)$$

$AF = asymmetry\ factor$
$A_r = the\ area\ of\ the\ basin\ to\ the\ right$
$(facing\ downstream)$
$A_t = the\ total\ area\ of\ drainage\ basin$

From the equation above, the main channel must be defined firstly as the symmetrical axis. The equation (2) also has an explicit meaning. The wider the area on one side of the drainage basin, the greater the asymmetry factor. Then the subsequent tilting involved the genetic of drainage geometry.

The quantification produces a wide range of numerical result, either Smf or AF. To make it easier to read, some group interval class or classifications have been made. This is an alternative way to interpret in term of an active tectonic relative.

Drainage basin somehow reflects its self similarity. Fault and drainage basin is natural system, and has its self-similarity between individual to the gross system (Alam and Saputra, 2017). Dehbozorgi et al., (2010), has divided the Smf into Class 1 (Smf < 1.1), Class 2 (1.1 ≤ Smf < 1.5), and Class 3 (Smf ≥ 1.5). In simply, the landforms that are still influenced by an active tectonics will have a lower Smf index and vice versa. The same way goes to AF classification. The values of AF are classified into Class 1 (AF ≥ 65 or AF < 35), Class 2 (35 ≤ AF < 43 or 57 ≤ AF < 65), and Class 3 (43 ≤ AF < 57).

RESULT AND DISCUSSION

About 69 segments of mountain-fronts and 114 drainage basins were calculated for selected quantitative measurements. All Smf measurements were marked on the basin boundary around volcanic chain. The Smf segments encircles the entire circular volcanic chain (Kendang — Guntur — Mandalawangi volcanic to the west, Karacak — Galunggung — Sadakeling volcanic to the east, Mt. Kaledong and Mt. Haruman to the north, and Papandayan and Cikuray volcanoes to the south). The Smf values range from Class 1 up to Class 3. There are differences in segment length groups. In the east and south of volcanic chain, the Smf line segment is longer than in another.

The drainage basin determination covered all the landscapes, including the Cimanuk river system and volcanic high. The Cimanuk river system forms a major drainage basin in NNE-SSW direction. The minor drainage basins compose the adjacent major basin separated by a series of volcanic chain.

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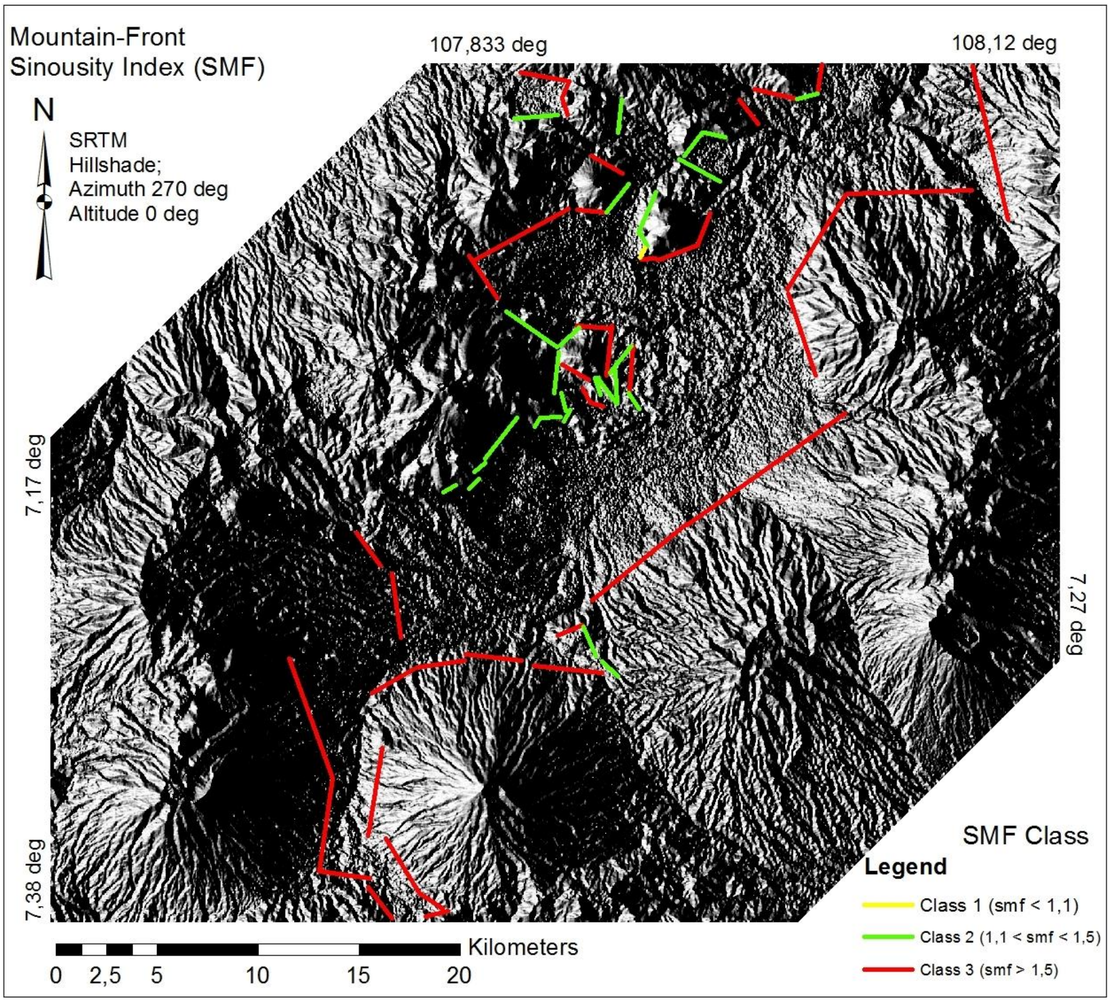

Figure 4. Mountain-front sinuosity (Smf) index map of Leles-Garut Basin.

Figure 4 above is Mountain-front Sinuosity Index Map. The red line indicates Class 3, the green line indicates Class 2, and the yellow line indicates Class 1 of mountain-front sinuosity. The Class 3 consists of forty one line segments, Class 2 consists of twenty seven line segments, and one line segment for Class 1. From the Smf measurement, the minimum value is 1.04 and the maximum value is 3.94. The Class 3 (with Smf > 1.5) dominates surrounding volcanic chain of Leles-Garut Basin.

In Leles-Garut region, there are still several active volcanoes. The straight-lines of mountain front are not equally spread to the entire basinal edge. The erosional forces form an embayment dominantly emplaced the east to southwest with a minor tectonic force straight-line mountain front. The extremely different Smf values have an assemblage locating to the northwest-north of the Leles-Garut Basin. Class 1 and Class 2 of Smf dominate the northern part of the basin. This area is thought to be structurally faulted. The subsurface gravity modeling has presented a general idea of subsurface structure and indicates the possible existence of Haruman faults as the east boundary of Garut-Bandung Basins (Handayani et al., 2012). These classes represent ratio balance factor between eroded-embayed topographic fronts and lesser or associated with an active tectonic.

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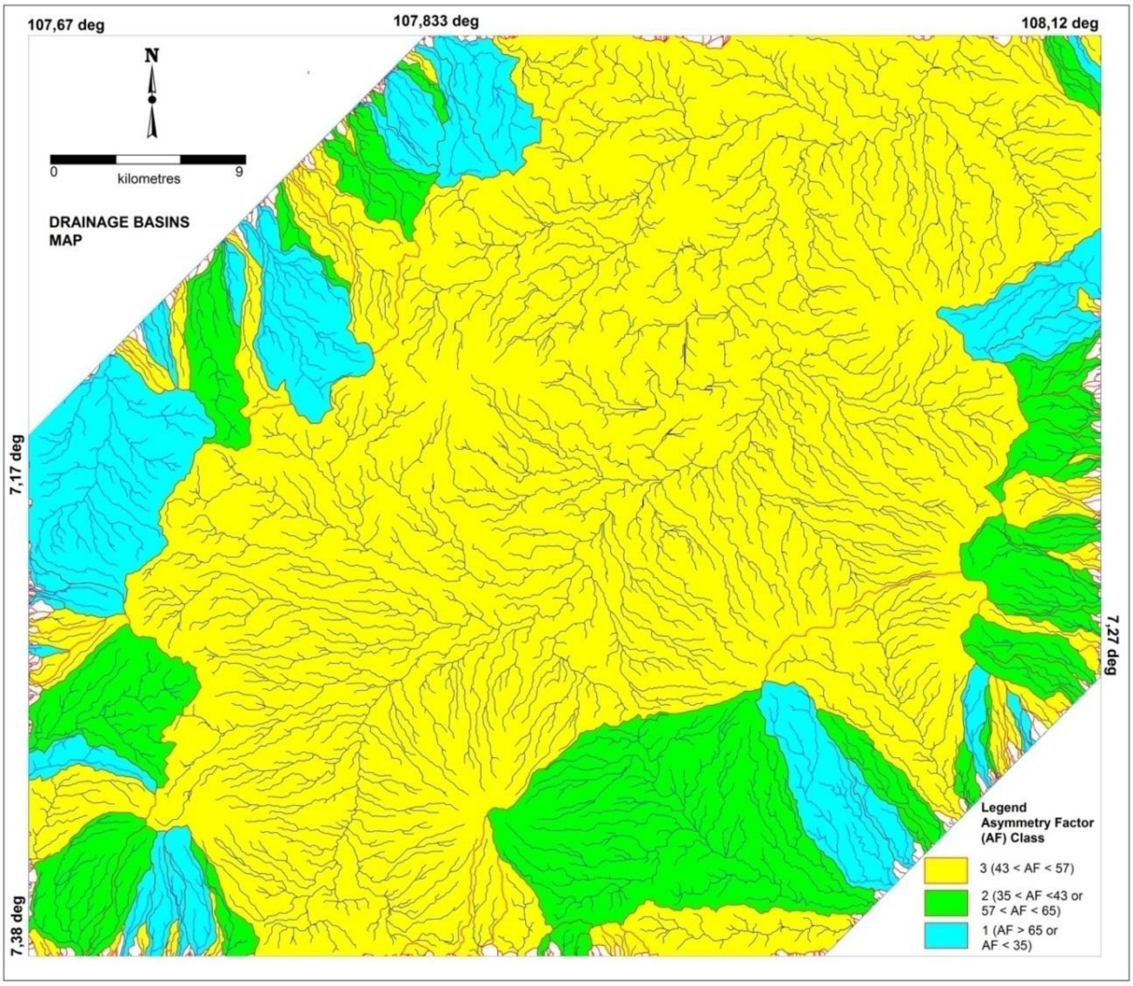

Figure 5. Asymmetry Factor (AF) index map of Leles-Garut Basin.

Figure 5 describes asymmetry factor (AF) of Leles-Garut Basin. The drainage basin shows a various type of geometry, *i.e.*, symmetrical and asymmetrical forms. With total area 1,106 km^2, the Cimanuk river system acts as major drainage basin. It reflects a symmetrical factor with Cimanuk axial channel flows to the NNE-SSW orientation. The AF value of this drainage basin is 44.59. This Cimanuk drainage basin is categorized as Class 3. It implies that Cimanuk river system is in a stable setting with no or little tilting. However, Leles-Garut Basin is covered by the unconsolidated and undifferentiated Quaternary products resulting from surrounding volcanic chain. This made a numerous possibilities the existence of other underlying strata to consider any dipping layer as an indication of tectonic tilting. Structural control of dipping layer plays a significant role in a further analysis of asymmetrical factor of drainage basin. This consideration is such a logical consequence that must be integrated. Inclination of dipping layer ought to be producing an asymmetric basin.

The various geometries of drainage basins are shown encircling the volcanic chain, mostly in the forms of asymmetrical factor. Class 1 and Class 2 are dominantly covering the basin boundary. Class 2 is more lying down in surrounding volcanic border than Class 1. It implies tilt down to the area of the basin to the right orientation in accordance with measurement of asymmetrical factor. Class 1 spread out in volcanic chain is inferred as under the control of active tectonics due to several structural lineaments along the basin boundary and also lithological control. Most of the major faults in the periphery of the Leles-Garut Basin shows trend northwest and northeast. The minor faults, however, evolves from northwest to nearly west and from northeast to north in the western and eastern boundaries of the basin.

The most interesting morphological feature is located around Haruman Mt. The Haruman Mt. is characterized by separated mount block and straight mountain front. The Smf and AF are not largely developed as well as in the Guntur – Papandayan – Galunggung volcanic constellation landform. The Smf segments of Haruman Mt. region, in the northern part, reflect a deformed landscape frequently more

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than in the eastern up to western part of the basin. A few straight mountain front of Guntur ─ Papandayan ─ Galunggugung side represents unbalance between stream erosion processes and active tectonic.

CONCLUSION

The quantitative geomorphology was applied to the Leles-Garut Basin, West Java. This method results mountain-front sinuosity (Smf) and asymmetry factor (AF) as the geomorphic indices. The geomorphic indices were assessed to identify an active tectonic and fault-bounded of Quaternary basin due to lacks proper works on intra-arc basin.

The values of Smf and AF were found in three types of the classes. The Smf classes indicate the active tectonic process dominates in the northern part than in the easter ─ southern ─ western part of the basin. The AF classes show different characteristics between basin-filled and basin-border. The AF classes in basin bounding inferred that the Leles-Garut Basin is under the effects of active tectonic and tilting down. Considering the spatial distribution between volcanic chain and geomorphic indices concluded that Leles-Garut Basin is a hybrid (both volcano- and fault-) bounded type of intra-arc basin.

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