THE VOLCANOES OF INDONESIA AND NATURAL DISASTER REDUCTION (with some examples) by Herman Th. Verspagen

ABSTRACT

Indonesian volcanoes is related to the subduction zones of the Indo-Australian and the Pacific-Philippine plates at the center with the Australo plate. Rates of vertical movement of the plate movement point to quenching of the subduction zone with time. String volcanoes and also ignimbrite plateaus associated with scorialed "volcaniclastic" deposits of deep-seated faults are major features.

Fluvo-volcanic fans and slopes are common due to the humid tropical climate. Large volcanic landscapes and debris flows causing rupture of crater or caldera visis and the collapse of slopes are important volcanic geomorphological features.

The role of geomorphological survey and the use of remote-sensing technology in volcanic hazard zoning is emphasized.

GENERAL CHARACTERISTICS

Indonesian volcanism is related to the subduction zones of major tectonic plates and its origin and nature visis are similar to those of the Circum-Pacific volcanic belt. The Indo-Australian (Indian Ocean) plate is instrumental in Southern Indonesia (Sumatra, Java, Nusa Tenggara Islands) while the Pacific Ocean plate, inclusive the Philippine (sub) plate plays a comparable part in Northern Indonesia. The N-S profile of Figure 1 illustrates the mechanism.

The actual intermediate (Andesitic-Basaltic) volcanism (Verspagen, 1963, 1964) is not evenly distributed over the volcanic belts as formed. On Sumatra for instance only 9 active volcanoes occur that together cause 128 eruptions in historical time while on the much smaller island of Java 23 active volcanoes occur with 470 historical eruptions on record. In fact almost half (473) of all historical eruptions have occurred on Java, the most densely populated island of the country. One may say that

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justification that volcanic hazards and population density in Indonesia are incompatible.

Sumatra stretched at an angle with the direction of the plate movement and a denser transcurrent fault, the Sembran zone handdeveloped. This zone and the adjacent areas are the main zone of volcanic activity. Apart of strato volcanoes also ignimbrite plateaus, mostly linked to localized "volcanotectonic" depressions, are important features. Lake Toba in northern Sumatra and Lake Batur in the South are examples.

Java stretches perpendicularly to the plate movement and here tectonic compartmentalization has occurred as is evidenced by several deep-seated N-S faults (The Thousand Islands ridge of the coast of West Java; the fault cutting off the Kendeng and Rembang hills in Central Java). A broad E-W stretching deformation is formed in most of the island and from it the strato volcanoes rise, with a somewhat regular spacing.

At places N-S stretching rows of volcanoes occur, the subterranean one usually being the most active one. This is most likely the result of a gradual steepening of the subduction zone that induces a southward displacement of the magma chambers. It may, at places also be related to the tectonic segmentation already mentioned: N-S faults occur in the top area of some strato volcanoes. It is not certain, however, that these faults reflect deep-seated segmentation faults.

The top area of the Arjoa-Welang twin volcano (Fig. 2, drawn from an air photo), is given as an example. Mt. Arjano (3540 m) forms the SSE end of an alignment of diversified volcanic features that ends in the NNW with the cone of the active Mt. Welang (3556 m) strato volcano. In this case, no volcanic or post-volcanic activity occurs at the southern end of the fault governing the location of the volcanic features. One short parallel fault and 2 or more transverse faults can be recognized. The top area of the Arjano strato volcano is situated on a narrow ridge separating two earlier horseshoe-shaped Calderas. To the South of the Welang the Old Welang occurs and between the two main volcanoes the craters of Mt. Kimber I and Iland a lava dome are dominant features. A range of other features, including smaller cones and crater pits, lava and lagoon forms, etc., also can easily be traced.

Among the major volcanic landforms of Indonesia consist of strato volcanoes, calderas, and "volcanotectonic" depressions with related ignimbrite/welded tuff plateaus rank high. Since, however, magnitude and frequency of volcanic eruptions are inversely correlated, the emphasis of volcanic disaster reduction is on the average-intensity eruptions of some strato volcanoes and on the activity at smaller eruption point, including also gas emissions, that put large populations at risk.

The humid tropical climate of Indonesia has an important effect on the development of volcanic slopes. The upper slopes of strato volcanoes are usually dominated by the gravity force on the volcanic debris and slope angle thus approximates the maximal angle of repose. Below this zone of "dry" transportation and often separated from it by a fairly distinct knack point the middle slopes stretch. These have been formed primarily by rain-fed lahars and this "wet" transportation has led to gradients in the order of 0.12. This phenomenon is least developed in the dryer areas of SE Indonesia. The lower, very gentle, slope of the volcanoes are of fluvial origin.

Summit or Semuwa calderas are common features and have been formed during Pleistocene eruptions of the past. If no shift in eruption centre occurred a nested crater may result but much more common is the collapse of part of the caldera/crater
rim and the corresponding slope was leading to the formation on of a horseshoe-shaped caldera. Also the large radial tectonic collapse baram撄en known from several of the stratovolcanoes (Staite) and calderas (Tengger) are noteworthy. Among the slope processes land slips affecting two layers with the underlying ash deposits acting as sliding planes, rank high. Huge volcanic landslides resulting in lahar formations on the affected collapsed slopes also are on record.

Large calderas resulting from major collapse following a paroxysmal Plinian eruption are common. In historical times the formation of the Tambora caldera on the island of Sumbawa (1815) destroyed an about 4000 m high stratovolcano. 10,000 people died in the process while another 82,000 died following months from starvation and disease even on the adjacent island of Lombok. The ill-fated Krakatau eruption (1883) in Sunda Strait was of much smaller magnitude but killed nevertheless about 30,000 people mainly by tsunami waves. Most existing calderas protect the population around them from new volcanic activity inside. As nature, however, is not there, the caldera bottom.

The ignimbritic eruptions that occurred in the so-called "volcanic-terrific" depressions and along the collapse zone of Sunda Strait are pre-historic. Fissure track (Nishiuma and Steffler, 1981) and E-Ar dating (Decharme et al., 1963) of Toba ashes deposited in Malaysia give a age of 77,000 B.P. and 80,000 B.P. for the youngest eruptions. Contrary to earlier views (Boeckmann, 1949) it is now generally agreed that the ignimbritic depression predates the eruptions although its subsequent development may be influenced by the eruptions activity. Vestappen (1961, 1973) observed two levels of warped lake terraces, related to these eruptions, in the eastern part of the Toba graben. The highest uplift of the South of the village of Parapat, is 130 and 250 m respectively. The average uplift rate there is thus about 5 mm/yr. The phenomenon is probably intermittent, however, and when unexplained changes of the lake level occur one should therefore be on the alert. Differential changes notably in the Sibuleng-Samori area would point to renewed (volcanic) tectonic activity. Subsidence near the outlet of the lake would result in all water fall of the lake level except near Peltara since the bench mark there would go down. The lake level lowering recorded in the 19 eighties do not seem to fit this picture and has been attributed to hydrological and some other causes.

**VOlCanIC G eOMorphOLOGIC aNd aEROSPace TECHNOLOGY**

It is obvious that geomorphological survey is an essential prerequisite for studies on volcanic geomorphology and for subsequent volcanic hazard zoning and assessment of volcanic hazards (Vestappen, 1988, 1992). The sequence of volcanic deposition as well as the detrital history of the volcanism have to be considered in this context. Aerial photography are a useful tool as is evident from the example of Fig. 2. Also data from satellite or manned orbits as well as the humid tropics notably radar imagery are important. Figure 3 gives a geomorphological interpretation of a Space Shuttle SIR-A radar image of part of the summit of Sungaiw. The spatial situation and temporal variations of diversified volcanic landforms are indicated, emphasizing Holocene volcanism. Erosional as well as depositional and structural...
Geomorphology and volcanic hazard mitigation in Indonesia

Volcanic hazard zoning is strongly related to geomorphologic mapping of active volcanoes and their surroundings. A dilemma always is how to incorporate the diversified hazard types in a limited number of hazard classes. The alternative solution, to make separate zoning maps for every hazard type lacks comprehensiveness and is not practiced in Indonesia. Monitoring volcanic activity is largely outside the realm of geomorphology but a part in hazard reduction through structural means (check dams, sediment traps, etc.) may be played by assessing the processes creating and the landforms evolved.

One may, for instance, question on geomorphological grounds whether the check dams and other structures erected in some high-river towns on the West slopes of the Merapi volcano, Central Java, are appropriate. They lead to a gradual rise of the beds of these rivers thus increasing the hazard for the nearby villages. Using a pyroclastic density current higher up-stops for spreading out the Merapi products here and thus reducing the chance of them reaching the densely populated lower area may be an alternate solution (Verstappen, 1988). It would require the step-by-step reduction of the incursions existing in the community.

The volcanic hazard zoning system applied in Indonesia is, generally speaking, well adapted to the static volcanoes and the eruption types occurring. It comprises three multi-hazard classes:

1. The forbidden zone where nobody is supposed to live, is close to the eruption point and subjected to pyroclastic density current, primary blast and fall.

The second hazard zone where no settlement should be founded, are parts destroyed by pyroclastic eruptions possibly subjected to pyroclastic flows, while paroxysms may lead to landslides overall.
The second hazard time includes: slopes in or near valleys and ravines radiating from the top areas. The main hazard here is formed by lava flows but also ash flows may occur. Because this zone stretches for downhill areas often densely populated areas of high vulnerability the quantified risk in this zone has a lower degree of hazard in comparison to many volcanoes.

Assumptions made in the classification are: (i) the eruptive occurs at the main active crater or craters of earlier activity, (ii) explosive eruptions are directed vertically upward, (iii) no collapse phenomena or caldera formation are included. Evidently a change in the morphological situation or a shift in activity center requires a adaptation of the zoning.

An example is the shift in activity of the Merapi volcano, Java (Indonesia), 1977 from the southern to the western side of the top area early this century: The lakes of the southern slopes are now inactive but still visible in the same category on the hazard zoning map as the active ones on the western side. The fact that they are more safely and differ essentially from the course covered lake in the west also is not indicated. The western slopes of the Old Merapi have collapsed as a result of a prehistoric pericentral eruption and the subsequent pyroclastic flows and lavas originating from the New Merapi thus were directed to the West, (Iwanhornum, F.1990). The southern slopes have been covered by ashes and thick fluvi-volcanic deposits some centuries ago when the Hindu-Javanese temples located there were burnt. The collapse of eruptions, previously thought to have caused the collapse of the Old Merapi (e. Bremmer, 1949), occurred between those two major eruption (periods). The inherent geomorphological characteristics of the Merapi resulting from its eruptive history affect the distribution of present volcanic hazards in the area.

Summarizing it can be said that the volcanic hazard zoning methodology applied in Indonesia is closely rooted in the geomorphology (NowamprPadiang, 1951, Kusumadhatma, 1979) and is well adapted to the area volcanoes occurring. The classification is less suitable, however, to eruption types such as gas emissions found e.g. in part of the Dieng Plateau in Central Java. One may also argue that, since emergency scenarios inevitably vary with the intensity and type of kind utilization the compilation of vulnerability maps of the endangered areas merits consideration in the context of disaster reduction policy.

REFERENCES


