Landslides in Southeast Asia

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When we explain the causes of landslides, we are used to explain them by two factors. The first is the inducing factor caused, for example, by melting of accumulated snow, rainfall, variation of ground water levels, change of ground water way, earthquakes, leaching action, etc. The second is the basic factor of zones, i.e., the Tertiary zone, fractured zone, volcanic action zone, clay zone acted upon by hot springs, the marine clay zone, etc. In addition, we often account for these causes by use of geographic explanations.

These explanations are only qualitative not quantitative. We cannot estimate what percentage of these causes are governed by the basic factor or the inducing factor. Also, we cannot presume to know what percentage of these causes is controlled by one peculiar inducing factor when there are many inducing factors. Do landslides always break out due to the same combination of inducing and basic factors ? Can we estimate the percentage of occurrence at any combination of inducing and basic factors ? The problems mentioned above have yet to be answered. One way to answer these questions may be to carry out geophysically precise observations on numerous landslides and make clear the mechanisms of occurrence and statistically assess major factors. Another way to investigate the relation between the inducing factor and the basic one is to observe landslides of an entirely different climate region from Japan.

We designed a survey to investigate the distribution and character of landslides in Southeast Asia according to the above mentioned idea. Two famous tectonic lines run through Southeast Asia. One is the Thesis tectonic line which runs from northern Italy to Java Island, through Nepar. The other one is the circum-Pacific tectonic line which runs from Japan to the Philippines, through Formosa. There are many volcanoes and hot springs along these tectonic lines, which also pass through Tertiary zone rock. Accordingly we can compare landslides in Southeast Asia with those in Japan covering these three types, namely fractured zone type, hot spring type and Tertiary type.

The course chosen was to connect volcanoes and hot springs, because those places are easily researched and are usually connected with landslides. The places researched are as follows: Fang spring in northern Thailand, Srircha spring south of Bangkok, Kelud and Tangkubanprahu volcanoes on Java Island, Batur volcano, and the hot springs around it, on Bali Island, and Taar volcano south of Manila. Even the intermediate courses between these places were carefully surveyed. Surprisingly, this author could find fewer such landslides than in Japan. As this is only a preliminary survey, further investigation may yield other results. But it may well be correct to suggest that the landslides in these regions are much less than in Japan. In Thailand, we suggest that landslides are few with scales as small as the collapse of road fill which occurs when the ground water level is high, because in this country there are no volcanoes, tectonic line or Tertiary rocks. On the other hand, we cannot find any reason for the small number of landslides on Java Island. The officers of the Geological Survey in Bandung say that about five landslides per year occur.

We would like to discuss the reasons for these occurrences. First, let us consider the volcanic or hot spring types of landslides. The distribution map of landslides made by the Civil Engineering Institute of the Public Works Ministry is used here. On this map, the locations of hot and cold mineral springs have been plotted from the distribution map published in memory of the 75th anniversary of the founding of the Japan Geological Survey. The locations are marked as circles having 16 km diameters in real size. Table 1 was made by counting the number of landslides in these circles. It will be observed that there are great variations in occurrence and degree of landslide according to the kind of springs. It can be assumed that the mineral springs are not always responsible for the landslides contained in the circle. So, it is impossible to discuss quantitatively the occurrence percentage. But there is evidence that landslides are apt to break out in locations near H_2S or HCO_3 mineral springs. At present, it is not clear whether landslides are influenced directly by mineral water or whether they are apt to happen in geological sites having relationships with mineral springs. We can identify H_2S by its peculiar smell, but the odors at volcanoes and springs in Indonesia are not as strong as in Japan. There seems to be a very clear difference in the character of mineral springs in Japan and in Indonesia. Accordingly, we are greatly interested in the character of volcanoes and hot springs in Formosa and the Philippines as a transition region.

Table 1 The number of landslides per one mineral spring (From this author's calculations)

Kind	Hot mineral spring		Cold mineral spring	
Acid	17/27	63.0%	17/20	85.0%
Chloride	143/188	75.5	66/83	79.5
Sulphate	41/103	39.8	11/23	47.8
Bicarbonate	135/53	254.7	33/57	58.0
Alkali	8/22	36.4	1/6	16.7
Carbonate	6/9	66.7	0/27	0.0
Hydrogen-Sulfide	57/34	167.6	17/8	212.5
Radio-Active	2/22	9.5	13/17	76.5

The results of investigations in Formosa show that only two hot springs in Peito north of Taipei, contain chiefly H_2S as a component. This is a special clay region altered by hot spring chemical action, the aspect of which looks like the Owakudani landslide in the Hakone district of Japan. But there is no sign of landslide in this region. We may expect to find the main cause of hot spring type landslides as well as the local character of volcanoes, if we investigate the local variations of the main component of these mineral springs.

Next, we should like to discuss the Tertiary type landslides. We can find 4931 Tertiary type landslides out of 5716 landslides in Japan. Accordingly, we may assume that there are many landslides of the Tertiary type in Java.

The representative idea mentioned by Dr. Koide is as follows: "Java Island, which is very similar to Japan Islands in respect to its geological state and the agricultural aspects in its mountain region, is a slender island whose length is 1200 km in an east-west direction and 200 km in a north-south direction with many volcanoes centering around Slamet and Merapi, their heights about 3000 m, in a line from east to west. Ancient strata before the Cenozoic and the older Tertiary strata, appear scattered as small masses from the eastern part to the central part. These strata are considered to be the basic rock of Java Island, and younger Tertiary sediments thickly cover these rocks. The above mentioned volcanic group has erupted on the younger Tertiary. Quaternary strata are distributed chiefly in the northern part of the island and constitute the wet land which extends along the Java Sea. The Tertiary strata can be divided into several groups. There also exist strata which contain plenty of tuff, tuffaceous sandstone, shale, clay slate and volcanic rocks. Small scale and fresh granitic diorites belonging to the Miocene are interpenetrating into the younger Tertiary, and solfatara exist in scattered deposits in the volcanic belt zone. The highland agriculture in Java Island rapidly developed under the colonial policy of the Dutch from the 19 th century and has been practiced chiefly on the volcanic soil slopes. Rice agriculture has been practiced for a long time by the natives on fields of the younger Tertiary and the Quaternary strata. It should be noted that shelf-like fields are developing on the younger Tertiary which look very much like the shelf-like fields in Japan. The only difference in the shelf-like fields in Japan and Indonesia is that cedar are planted in Japan, for example in Niigata Prefecture, instead of the coconut which is planted in Indonesia. The farming scenery of the shelf-like fields is spreading to the slopes of the younger Tertiary of Java Island thus resembling Japanese agriculture to a great extent. As there are many solfatara in Java, mineral spring type landslides may exist on this island."

In spite of the above mentioned consideration, Tertiary type landslides do not often occur on Java Island. A member of the Geological Survey in Indonesia says, "About five landslides happen in Indonesia per year." What is the reason for this? Here, we may compare the relationships of rainfall, evaporation and displacement in Japan, in the Kamiya landslide area of Niigata Prefecture. It is commonly said that the displacement in one landslide location or the number of landslide occurrences in a region has close relationships with the level of ground water. If we take a monthly average, we can see that the amount of displacement has a close correlation with the difference between rainfall and evaporation, not the underground water level (see Fig. 1). How about in Indonesia? Monthly evaporation and rainfall are shown in Fig. 2. In the yearly average, evaporation predominates over rainfall with the exception of Padung in Sumatra Island. In contrast when the evaporation and rainfall in Japan are studied we find that rainfall predominates over evaporation, with few exceptions.

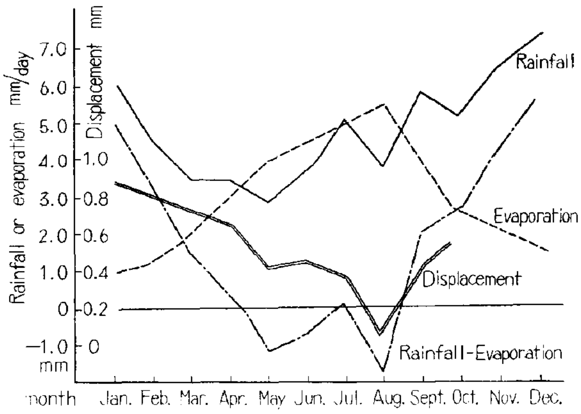


Fig. 1 Correlation between rainfall, evaporation and displacement in the Kamiya landslide area

* Evaporation is the mean value for 56 years observation at Niigata Weather Bureau.

(From a Research Report of the Sand Control Section in Niigata Prefecture)

Next, let us consider the fractured zone type landslide. We can construct Table 2 by counting the number of landslIdes near the fractured zone in Japan. One thousand, one hundred thirty-three are a significant portion of the 5716 landslides in Japan. Why are fractured type landslides so few in Indonesia with a famous tectonic zone running through Java? Is there any difference in the nature of the fractured zone in Japan and in Java? There are methods for detecting the fractured zone. For example, there are geological survey,

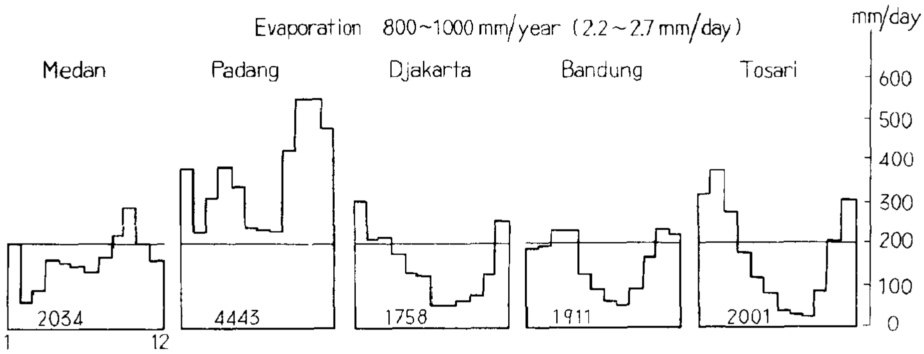


Fig. 2 Evaporation and rainfall in Indonesia

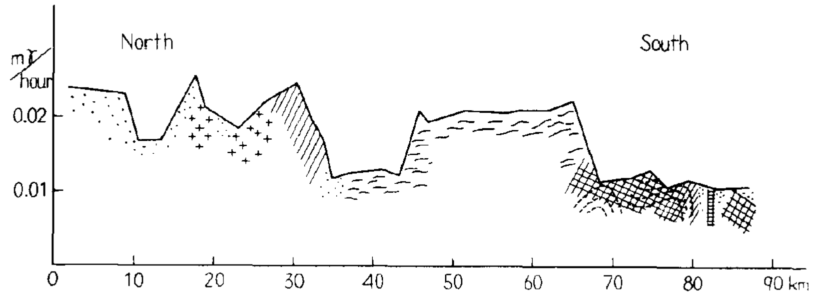


Fig. 3 Measured values across the Shikoku fractured zone (Results of my research)

Fig. 4-i Measured points around the Kelud Volcano

seismic prospecing, natural radio activity, etc. The most convenient method is the natural radio activity one. In Fig. 3, we show the result measured in a north-south direction across Shikoku Island where there is a famous fractured zone running in an east-west direction. We can clearly distinguish the Yoshinogawa Kinokawa fractured zone and the Mikabo fractured zone from

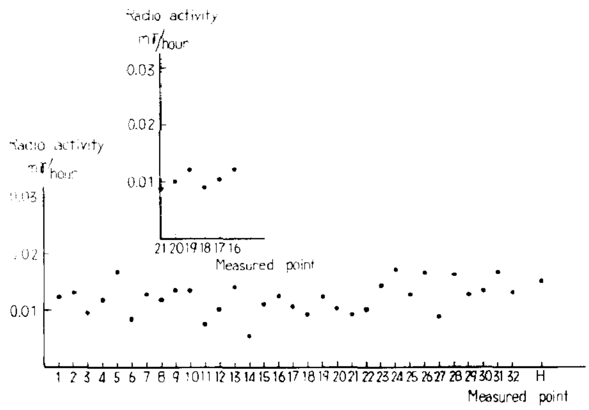


Fig. 4-ii Measured values around the Kelud Volcano

Table 2 Landslide numbers near various fractured zone in Japan (From this anthor's calculations)

Mikabo	412	Futaba	12
Yoshinogawa	123	Natsui	3
Fuzigawa	28	Minomata	2
Himekawa	418	Tokuyama	2
Nakatsugawa-Tsurukawa	11	Totsugawa	23
		Minamishikoku	4
Mineoka	62	Ōigawa	6
Hikawa	3	Ōeyama	6
Ogagawa	5		
Tanakura	13	Total	1133

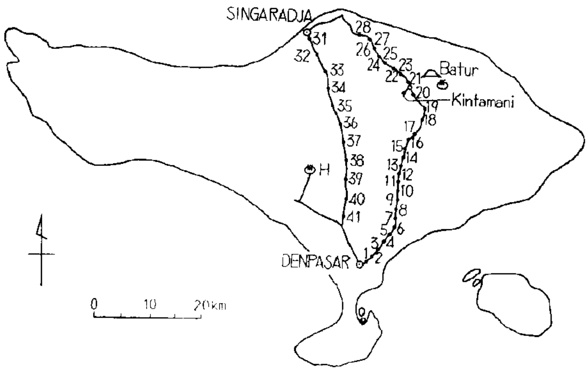
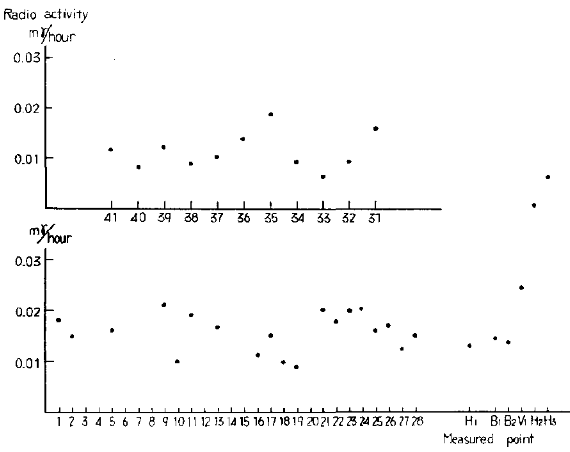


Fig. 5-i Measured points on Bali Island



H_1 : Hot spring in Bali
B_1, B_2 : Bogor
V : Tangkubaprahu Crater
H_2, H_3 : Hot spring near Tangkubanprahu

Fig. 5-ii Measured values on Bali Island

other regions. By this same method, we measured the fractured zone in Indonesia. The results measured around Kelud Volcano and across Bali Island are shown in Figs. 4i-4ii and Figs. 5i-5ii, respectively. We could not clearly determine the fractured zone although this may be attributable to the small number of observed points. The values observed seem to be small compared to the values in Japan. Considered from the viewpoint of landslides, the nature of fractured zones are not simple. Ground water is rising from the zone at the Kurumi landslide in Toyama Prefecture, is sinking into that zone at the Choja landslide in Kochi Prefecture and has an intercepted flow in the one at Kameno se in Osaka. As mentioned above, there are various kinds of fractured zones from the viewpoint of physical nature. Moreover, if we are able to investigate precisely, in a geological sense, we may postulate the kinds of fractured zones will increase. We must study fractured zones further. The natural radio activity along the road between Djakarta, Bogor and Bandung was also measured. High radio activity was found at the crater of Tangkubanprahu and the hot spring near it.

Although we found many interesting facts in this survey, we could not come to any definite conclusions. We are designing another to increase the observed data and to make a geophysically precise survey in specially selected locations.