速　報

Landslide Disaster at Mt. Bawakaraeng Caldera, South Sulawesi, Indonesia [*1]

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The magnitude and impact of a landslide disaster at Mt. Bawakaraeng, South Sulawesi, Indonesia was investigated. The landslide caused significant damage including loss of life, destruction of property, contamination of drinking water and blockage of water at a nearby dam. It also hampered the economic activities of the residents, affecting a large area of population-settlement. The landslide was caused by the collapse of the walls of the caldera leading to a flow of a large amount of debris. In this paper, certain preventive methods to lessen the degree of the damage are cited. In addition, controlling mechanisms to tackle the problem of landslides in the area are mentioned.

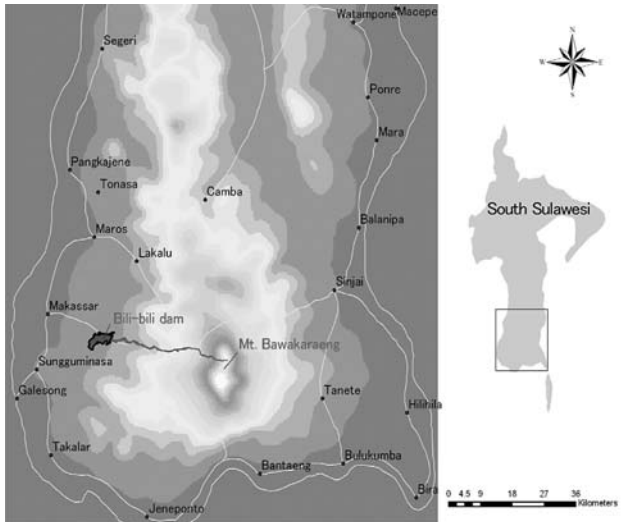
Key words: landslide, caldera, Mt. Bawakaraeng

Ⅰ. Introduction

Mt. Bawakaraeng, located 90 km from Makassar, South Sulawesi, Indonesia, has an elevation of 2,830 m above sea level (Fig - 1). This mountain is considered by some local people to be a holy place. It has beautiful scenery including pine forests and unique flowers such as edelweiss. Many rivers flow along the foot of the mountain to the Jeneberang River, where the Bili-bili dam is built downstream in Gowa district. On March 26, 2004, a landslide took place at Mt. Bawakaraeng and hundreds of residents were forced to evacuate from the surrounding area.

This landslide was one of the worst disasters in the history of Indonesia. It resulted in loss of life and damage to properties and infrastructures. Some research can be conducted to comprehend the phenomena related to the landslide and its effects. In this paper, the occurrence and general impacts of landslides on human life and economic activities are highlighted by considering the case study at Mt. Bawakaraeng.

Fig－1a.　Location map of South Sulawesi, Indonesia



Fig－1b.　Location map of Mt. Bawakaraeng, South Sulawesi

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Ⅱ. History and Mode of Occurrence of Landslides at Mt. Bawakaraeng

Parts of the caldera of Mt. Bawakaraeng started to collapse in 1974 by cracking. The cracks became progressively wider in 1977 and 1987 (Djabbar, *et al*., 2004). This gradually led to the big landslide that occurred on March 26, 2004, and caused serious damage of the mountain through vibration, eruption, landslide and mud floods.

On that day, the Geophysical station at Gowa noted 3 big vibrations at 13 : 46 WITA (local time) with a strength of 3 on the Richter scale.

An enormous amount of earth and debris ran down the slope and accumulated as much as 7 km along the valley (Fig - 2). Two collapsed areas are found at the source section of the landslide: one occurred near Mt. Bawakaraeng is a collapse with a width of 500 m (Collapse A); the other is a large collapse at the ridge of Mt. Sarongan, which occurred in a horseshoe shape with a horizontal length of about 1,300 m (Collapse B). The relative height of the failure slope in both collapses is about 700 m (Fig - 3).

There was no conspicuous rainfall on the three days preceding the landslide. Also, the occurrence of an earthquake is not confirmed. Some of the mechanical factors which enhanced the landslide are the tremendous height of the side wall of the caldera ; fragility of the bedrock of the side wall; and susceptibility to erosion of the accumulated sediment inside the caldera. The lack of resistance to erosion of accumulated sediment induced riverbed degradation of the Jeneberang River that flows inside the caldera, making the relative height of the side wall of the caldera taller and removing talus accumulation at the foot section. As a result of this phenomenon, the shear force working on the foot of the side wall increased gradually, enabling the development of a slip surface over a long time, which contributed substantially to the occurrence of the landslide.

As to the failure mode, judging from the fact that the collapsed sediment passed over the ridge having a relative height of 200 m existing in the caldera, it is considered that the landslide movement was not the toppling type in which the head section of a soil mass overturns largely, but the falling of a soil mass with buckling-like rotation after the bedrock had failed at the bottom of the slope (Koga, et al., 2004).

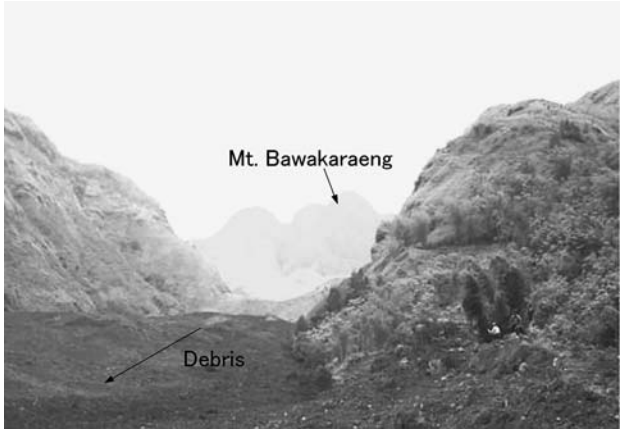

Fig - 2. The landslide-debris at Mt. Bawakaraeng

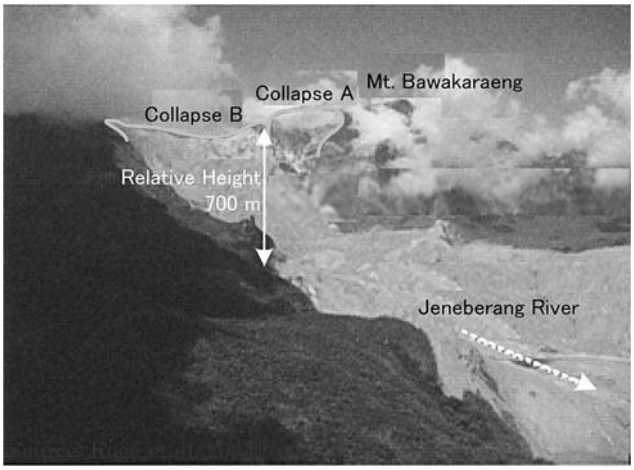

Fig - 3. Sites of collapse areas

Ⅲ. General Impacts of Landslide

On March 26, 2004 a gigantic caldera-wall collapse occurred at the northeastern part of the caldera of Mt. Bawakaraeng (hereafter the collapse). It was the headwaters of the Jeneberang River. The collapse area is identified as a ridge including Mt. Sarongan (elevation 2,514m above MSL). The volume of collapsed mass is estimated to be 200 to 300 million m^3.

The caldera-wall collapse brought tremendous damage to the area, accounting for dead and missing among the local people (32 people), the loss of 635 livestock, many houses, and an elementary school. Also, around 1500 ha of the agricultural land was buried. Both protected and productive forest areas were damaged as well. Total damage was estimated at about $2,315,000. After the collapse, several ponds and gullies developed on the debris. The debris flow occurred repetitively. Sabo dam No 4, which had been constructed 5 km down stream of the caldera in the year 2000, was completely buried. The debris flows had already reached downstream to Sabo Dam No 4 and a number of paddy fields were damaged in the vicinity. The river discharge containing a high density of the sediment has been flowing into Bili-bili reservoir and it is anticipated that its duration will be shortened and that the water quality of municipal water will deteriorate.

Ⅳ. Effects of the Landslide

After the landslide at Bawakaraeng mountain in March 2004, the headwaters of the Jeneberang River were covered by sediment. There was tremendous suspension of sediment in the

river water. More than 200 million m^3 of mud flow covered the headwaters of the Jeneberang River. It had width of about 1 - 3 km, not less than 30 km length and a depth of 40 - 200 m. During the dry season, the sediment does not disturb the river flow much. However, during the rainy season, when there is heavy rain, water erodes the sediment into the Jeneberang River until the entrance of Bili-bili Dam and the water treatment company Somba Opu. That company, belonging to the local government (PDAM), supplies water from the Jeneberang River to 2 districts (municipalities), Gowa and Makassar. This is the worst disaster ever to happen in the history of the drinking water company in Makassar. In January 2005, the company stopped the water supply for 10 days. Hence, 350,000 people experienced a water shortage. Before the landslide occurred, the turbidity of Jeneberang River that entered Sombu Opu reached only 0 - 50 NTU (Nephelometric Turbidity Units) with a maximum value of 100 NTU at times. But heavy rain from December 2004 to January 2005 filled the Jeneberang River with mud. Therefore, on January 22, the turbidity reached a peak value of 219.000 NTU. In fact, a value of 6000 NTU can be obtained by cleaning the water using screening and chemical additives. However, the level of turbidity can never be below 10.000 NTU. With an NTU value of 6,000, 1 out of 2 liters of a sample is mud. This result is obtained after adding double chemical additives, Poly aluminum chlorite (PAC), in order to clean the water from the mud (Taslim, A, and Nainggolan, R., 2005).

In addition, the fish habitat of the Jeneberang River was damaged; in general, the river ecosystem was destroyed. The landslide also caused intense sedimentation of the Bili-bili dam, reducing the lifetime and function of the dam.

Ⅴ. How Farmers and Fishermen Suffered Due to the Landslide

As a result of the catastrophy, the income of the community living in the Jeneberang watershed decreased. The debris-flow movement hampered the community from working in the paddy fields and inhibited the fishing activity in that area. In particular, one month after the landslide, the community ceased these activities completely. The result of monitoring carried out by Indonesian Forum for the environment (WALHI), an NGOs in Indonesia, showed that before the landslide the farmers had normally produced as much as 250 kg to 1 ton of rice during a single harvest, but during the year when the landslide occurred, they yielded nothing at all. Similarly, the fishermen averaged daily incomes of $10.50, but only earned as much as $1.20 after the disaster. As a result, they could not afford their household needs (AIS, and Taruna I., 2005).

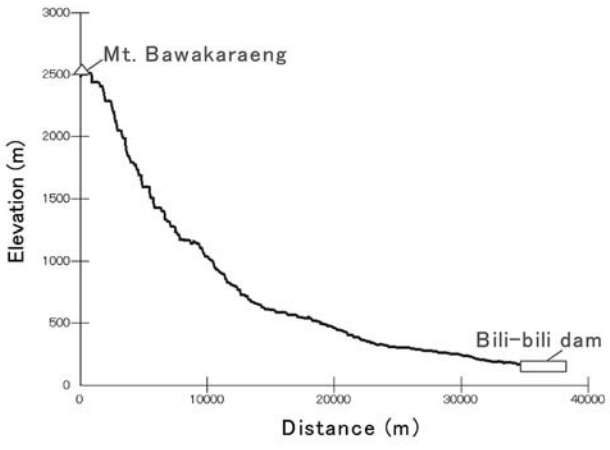

Fig - 4. Cross section of Jeneberang River

Fig - 5. The river water before the landslide (clear water)

Fig - 6. The river water after the landslide (muddy water)

Additionally, in January 2005, due to rainfall and subsequent erosion, about 350 ha of ricefield and 250 ha of maize farm were covered by mud. Eight localities in Parangloe and Manuju subdistricts in Gowa district were affected. Only two months were remaining for the rice and maize farms to be harvested. The loss is estimated to reach hundreds of millions of rupiah or hundreds of thousands of US dollars.

Ⅵ. Mitigative Measures

Some actions have been implemented in order to reduce the negative impacts of the landslide after its occurrence. These are:

1. Monitoring the location of the area.
2. Making society aware that similar disasters might occur in the future. Informing residents what to do before a landslide.

3. Identifying localities with a high susceptibility/ vulnerability to disaster, and preparing a hazard map showing potentially dangerous areas in order to avoid damage.
4. Monitoring the movement of debris, the frequency and amount of rainfall and setting up warning schemes around Mt. Bawakaraeng. Conduct scientific research and monitoring to understand indications that lead to an occurrence of landslide beforehand.
5. Controlling the course of the rivers in the area.
6. Dredging the river sedimentation.
7. Constructing of Sabo dam, sand pockets, and maintaining rehabilitation programmes.

Ⅶ. Conclusion

The landslide at Mt. Bawakaraeng, South Sulawesi, Indonesia shows:

1. The possibility that a large landslide affecting cast area can occur. Some of the problems due to the landslide include a scarcity of water at Gowa and Makassar regions, a suspension of huge amount of sediment in the Jeneberang River, a decline in incomes of the fishermen and farmers, and hampering of economic activity in the region in general.
2. The counter measures and mitigation measures are not enough.

Therefore, to formulate and implement proper mitigation plans, collaboration by various organizations like the local and central government, NGOs, universities, and research institutes is necessary.

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