Recent landslides in Niigata Region, Japan

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ABSTRACT: The Niigata region is known in Japan for landsliding at high frequency. Recently, slope failures were taking place at different places in the region as a result of heavy rainfall, rapid snow melting and other factors. This paper introduces some of these landslides and gives a brief discussion on what has been done subsequently.

1. INTRODUCTION

Japanese islands are part of the island arcs, beneath which the Pacific Plate and the Philippine Sea are subducting. Therefore, the geological history is relatively young and many active volcanoes and earthquakes are dominant. This has led to the occurrence of many landslides in various regions as the earthquakes and volcanoes together with factors such as heavy rainfall, flooding and tsunami can easily affect the equilibrium of slopes and hills. In particular, the Niigata region has a history of being affected by landslides caused by intense rainfalls and snow melts compared to other places in Japan. It is therefore, on this basis that the region has been selected by many researchers for prototype studies and as a model area for the susceptible zoning according to a new law of management of debris disasters.

In this paper, we introduce the landslides taking place recently in Niigata region and deliver a short discussion on each. A detailed account on the causes and mechanisms of formation of these landslides is beyond the scope of this article since studies on most of these slope failures are still going on.

2. LANDSLIDES IN SADO ISLAND

Sado Island, located offshore of Niigata City, lies in the Japan Sea, isolated from the mainland by around 35 km Sado Strait (Fig. 1, point 1). It is one of the largest islands in Japan and consists of two visually distinct parts OhSado (big Sado) and Kosado (small Sado). Both of these parts of Sado are composed mostly of Neogene volcanics, and are continuously affected by landslides. Kosado in particular has not only ancient slope failures, but recent landslides are also quite common. Two examples of these latest activities are Shiidomari and Katanoo landslides.

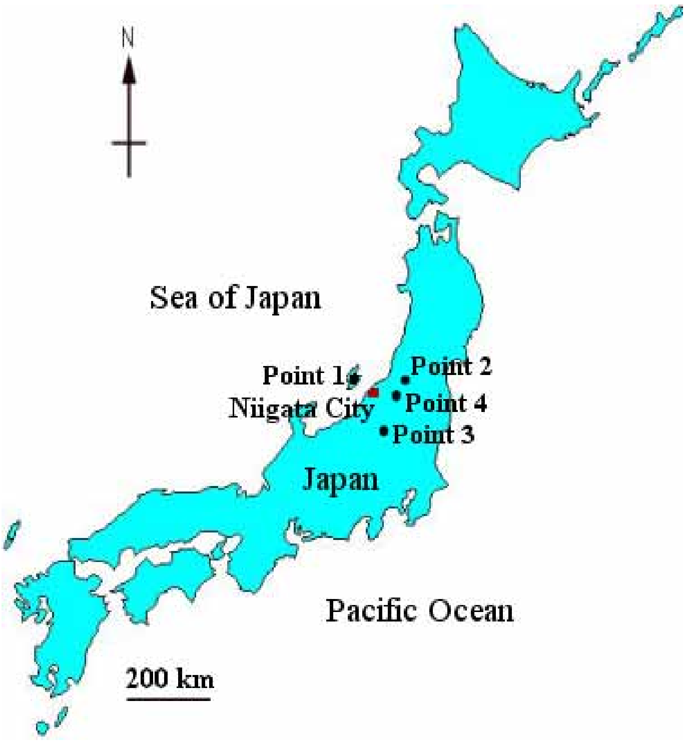

Figure 1. Location map of the landslides described.

2.1. *Shiidomari landslide(August 4, 1998)*

The northern Kosado ranges are composed of Neogene volcanics such as andesitic lavas and rhyolitic intrusives. The Shiidomari slide area consists of Miocene andesitic lavas. These volcanics are altered into green clay due to hyrothermal processes. The slide occurred probably on August 4, 1998 due to heavy rainfall. It was regarded as a reactivation of an old, large-scale landslide that has been eroded at the marginal toe. The Shiidomari slide has an adjusted volume of $1.7X10^7$ m^3, and is 800 m long and 400 m wide. Its maximum depth was roughly 100 m.

On August 4, 1998, the northern Sado area was damaged by intensive flooding immediately after heavy rainstorms. There is a belief with little evidences that it might be on this day that Shiidomari landslide has started to occur. However, it was in May, 1999 that the slide was first recognized by the people living in the area. In September 1999, an amphitheater like scarp (Fig. 2) associated with cracks has appeared, and was followed by the deformation of river structures of the nearby Masara River. The marginal slip plane was presumed to be under the river. Finally a squeezed-up mound (Fig. 3) appeared at the opposite side of the marginal front (Kanno et al., 2002), most probably due to the fact that the margin of the slide pushed the opposite side of the stable wall of the river.

Figure 2. A crack appeared at the crown of the Shiidomari landslide.

Figure 3. A squeezed-up mound at the opposite side of the lower margin of Shiidomari landslide.

2.2. Katanoo landslide (January 28, 2003)

The other recent landslide in Sado Island was Katanoo, occurred on January 28, 2003 (Fig. 4). It is located at the north eastern part of Kosado where the geology is dominated by gravel, clay and the underlying Neogene tuffs. This landslide is 75 m wide, 250 m long and 11-18 m deep. The sliding block was divided into two, a lower one and an upper part. At the time of sliding, it was the upper block which was mobilized first. The stress on the lower one has increased instantly and the block failed entirely under gravitational pull. The immediate effect of the slide was that the main road which connects the Ohsado and Kosado parts was completely blocked.

Figure 4. Aerial view of the Katanoo landslide (Courtesy of Kowa Co. Ltd.).

Figure 5. A closer look into Katanoo landslide as the effort to prevent further sliding was underway.

The contribution of geology in the formation of Katanoo landslide was directly related to the type of materials lying underneath the sliding area. The bedrocks exposed on the main scarp were Neogene tuffs. These rocks are highly weathered and changed into brownish clay soil (Fig. 5). At some places, the extent of weathering deep into the mountain has reached 30 m. This encouraged the upper block mentioned above of the slide to make a crest and the lower block a hollow even before landsliding, which could be an indication for the presence of a repeated slope failures in earlier times, just because the material is weak.

The few weeks prior to the onset of Katanoo landslide were marked by abnormally high temperatures. Snowfall was registered from December 9 to 16, 2002, but then it started to melt immediately despite the fact that the season was still winter. One week before the sliding, the main scarp area (the rice field at the top) underwent cracking because of the surface water percolating in excess. The cracks continued to enlarge until the slope materials finally moved downward aided by gravity.

In Sado island, several other landslides were documented, such as the Akadama slide (August, 1998), the Akadomari slide (March, 2001), the Ohma slide (August, 2002) and the Koroku slide (August, 2002). Most of these landslides were destructive, but it was fortunate that no victims were known except for damages on properties. A study on these landslides is part of a regional analyses and susceptibility mapping and a detailed account will be given in another article.

3. TOZAWAGAWA SLIDE, KAMIKAWA

On January 5, 2000, a landslide occurred on the right-hand side of the Tozawa River, which is an upper tributary of Agano River in Niigata Prefecture. The area of landsliding was located approximately 56 km northeast of Niigata City (Fig. 1, point 2). The landslide affected mainly the less consolidated sediment at the top and the movement was concentrated along that part of the hill where an eroding gully was present. The type of materials involved were a mixture of soil debris and blocks of rocks that can reach 1-2 m in diameter (Fig. 6). At the time of landsliding and for sometime after, relatively hard and fresh varieties of these blocks rolled downstream for a distance of about 2 km along the river course. While there was no direct damage on humans or their properties, the main mass that was moving together downhill was able to dam the river and form a lake of up to 10 m deep.

Figure. 6. Front view of the Tozawagawa landslide.

Figure 7. Oblique aerial view of the Tozawagawa landslide (Photo taken in September, 2001 by Shin Engineering Consultant Co. Ltd.).

Figure 7 shows the aerial photograph taken on October 27, 2001 by Shin Engineering Consultant Co. Ltd. Post failure field investigations aided by the interpretation of this photograph allowed us to deduce that the landslide complex as a whole might have developed as a result of a series of relatively brief episodes of ground movement with intervening phases of general inactivity. Hence, as it is shown in Figure 7, we identified three progressive phases of ground displacements. Movement most probably started a little below the crown of the current slide, possibly influenced by the location of soil pipes and zones of higher permeability. The material further down was becoming completely unstable soon after the driving force from above was increasing. A transient rise in groundwater table in the hill following heavy rainfalls would have a greater contribution to transform the small scale slope movements into a landslide observed on January 5, 2000. What has been termed as a third phase of sliding in Figure 7 could simply be taken as a sign of a retrogressive action of the current landslide to encroach shoulders of slopes uphill before equilibrium is established.

In order to calculate the volume of material displaced from the hill, we considered aerial photographs developed by Geographic Survey Institute of Japan in 1976 (before landsliding) and those taken after sliding by Shin Engineering Consultant Ltd. in October, 2001 (Figs. 7 & 8). Calculation of the landslide volume was carried out by reconstructing the likely topography of the pre-landslide slope on which the slip surfaces occurred. We also considered the sabo dam located a little downstream as a limit of the moving mass.

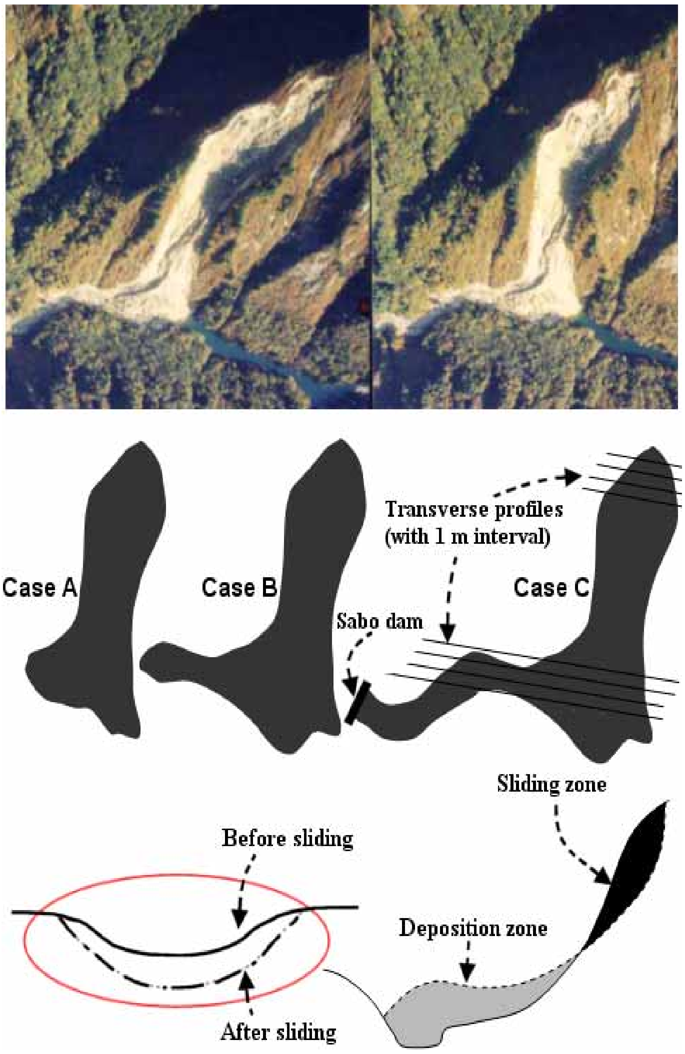

Figure 8. The system of computing the volume of Tozawagawa landslide based on photographic records.

The calculation procedure was performed in such a way that the landslide zone was included into the process in three phases, A, B and C. The middle part of Figure 8 shows a graphical sketch which illustrates how this has been carried out. Case A considered the straight section of the disturbed zone with an average length and width of 460 m. In case B, the area up to a curve on the river floor where most of the displaced materials were pushed at the time of landsliding was taken into account. The last case (C) covered the whole sliding zone up to the sabo dam. Then, a total of 611 transverse profiles, each with 1 m interval, were constructed across sliding zones in all three cases, as it is shown in the middle part of Figure 8 (Case C). Next, slip surfaces before and after landsliding were determined from photographic records of 1976 and 2001 (lower part of Figure 8). Finally, displaced and deposited volumes were calculated for each profile and summed up to give overall results which are summarized in Table 1. It is seen in this table that the difference between the two volumes (displaced and deposited) is higher in case A than in case B and C indicating that much material was coming from the top of the hill.

Table 1. The volume of materials displaced.

Case	Volume (m^3)		
	Displaced	Deposited	Difference
A	195,863.975	138.207.145	57,656.830
B	196,151.882	172,229.328	23,922.554
C	196,391.568	192,308.570	4,082.998

As a part of an effort to determine the history of the Tozawagawa landslide prior to and after January 5, 2000, we have tried to collect various sources of information from old archives to current digital records. Accordingly, earlier topographic sheets and existing landslide scarps indicate that the slide might be a reactivation of a previous slope failure occurred in 1947. The January, 2000 activity simply covered a wider area. From January 10 to 19, further displacement has occurred in the right hand margin, resulting in a gully-aided debris flow. The landslide again was disturbed in August, 2000 at the left hand head due to heavy rainfalls. The natural dam slightly failed on August 10, 2001, allowing a reduction in water level, and hence, a stress level in the hills.

4. HIGASHIKAWA SLIDE, MATSUNOYAMA

This sliding phenomenon took place at the southern margin of Niigata sedimentary basin where mainly Neogene to Quaternary sediments are present. The exact place of the slide is close to Matsunoyama Hot Spring, at the east margin of the 300-700 m high Higashi-Kubiki Hills, approximately 90 km southeast of Niigata City (Fig. 1, point 3).

Figure 9. Aerial view of Higashikawa slide (April 28, 2001).

The geology of the area is dominated by black mudstones, which belongs to Late Miocene sediments, and overlying deeply weathered formations. The area in general corresponds to the southeastern wing of the Matsunoyama Dome Structure.

The Higashikawa landslide occurred in the early morning of April 28, 2001. The first person to witness the activity was a lady who was delivering newspapers. As it is shown in Figure 9, the landslide rode over the mountain for a considerable distance before it crossed a road and completely blocked it. The slide continued further moving downward and reached the floor of Higashikawa River. The entire debris accumulated along the hill was about 380 m long, 80 m wide and 5 m thick. From the crown down to the 200 m mark, the slope failed in the form of quasi-translational sliding. Toward the bottom, the slide was transformed into earth-flow because it was coming in contact with enough moisture（Fig. 10）. At the top of the slide, the slope gradient is around 22^{o}. The latter decreases to 12^{o} in the middle section and then to 10^{o} further downward, allowing the hill to accumulate a relatively high amount of groundwater with a near-surface static level at the bottom. There is a high probability that the moisture content of the materials displaced from top has increased dramatically because of a supply of excessive water from the ground and the immediate surroundings of the slide.

The velocity of the slide together with the earthflow was estimated to be 1 m/h on Apr 28, 2001 (Yamagishi et al, 2001). The displacement continued further at a lower speed and on May 15, 2001, the velocity has finally decreased to 2-3 mm/h.

Figure 10. Marginal toe of the Higashikawa Slide.

5. IWATSU SLIDE, AGANO RIVER

Landslides are common along Agano River, in Niigata Prefecture of Japan. Despite the presence of dense vegetation and little human interference, some areas are currently too sensitive for high precipitation and turned out to be zones of active landsliding.

Figure 11. New cracks appeared on the road in May 2003.

One of these areas is Tsugawa, located 37.5 km east of Niigata City (Fig. 1, point 4), where rhyolitic lava domes associated with mudstones that are interbedded with clayey tuffs are prone to landsliding (Yamagishi et al., 2003). In Tsugawa itself the Iwatsu area located along Agano River, is currently designated to be active. In this area, old landslide zones that were once thought to be relatively stable are changed to be active with an increase in rain fall. In October 2001, new cracks appeared on the nearby road (Fig. 11), marking the beginning of the formation of a scarp of probably a large landslide that can engulf a big area. The crack is still growing in size moving toward the right (river side). The road has already stopped services, and at the moment, there is a coordinated activity of ground monitoring in the area with an aim of acquiring a detailed knowledge on why the ground is unstable.

6. SUMMARY

The presence of heavy rainfalls and snow melting in Niigata region of Japan together with the Neogene clayey mudstones and deep weathered volcanics led to a frequent occurrence of landslides at different places. This paper reported data that has been compiled from six landslides located in five places. Numerous slips have occurred in the past, however, little is known about the intensity, cause and severity of these old landslides. What is common in all places of recent slope failures is that the structure and stratigraphy of the slopes create the conditions that allow them to retain water perennially, and landslides occur when additional moisture is induced during rainfall or snow melting. Currently geological investigations are being carried out at different areas and a number of surface survey stations are established to accurately determine the characteristics of the ground surface. At some places restoration works have already been started so as public safety can be reassured.

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